REGIONAL DRAINAGE ANALYSIS

FOR

CITY OF MORA

Technical Report

October 3, 2019

Presented to:

City of Mora
Minnesota

05362-2018-000

REGIONAL DRAINAGE ANALYSIS

For

October 2019

Professional Certification

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

Name: ______________________

Company: Advanced Engineering and Environmental Services, Inc. (AE2S)

Date: October 3, 2019 Registration Number: 48701

Prepared By:

Advanced Engineering and Environmental Services, Inc. (AE2S)

Water Tower Place Business Center
6901 E Fish Lake Road, Suite 184
Maple Grove, MN 55369

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction and Background

1.1 Project Background

The City of Mora retained AE2S to complete a regional drainage analysis for three major watersheds located within the community: Downtown, Fairgrounds, and Mora Lake. Figure 1.1 shows the overall study area and highlights each watershed.

The purpose of this analysis is threefold:

1) Identify and assess key storm system deficiencies and risk areas within the Downtown and Fairground watersheds;
2) Determine the hydraulic interaction between Mora Lake and the City's storm system and design a gravity outlet system for Mora Lake; and
3) Evaluate alternative solutions to improve regional drainage and reduce the risk of flooding.

The hydraulic and hydrologic analysis methods, results, and recommendations are presented in this report.

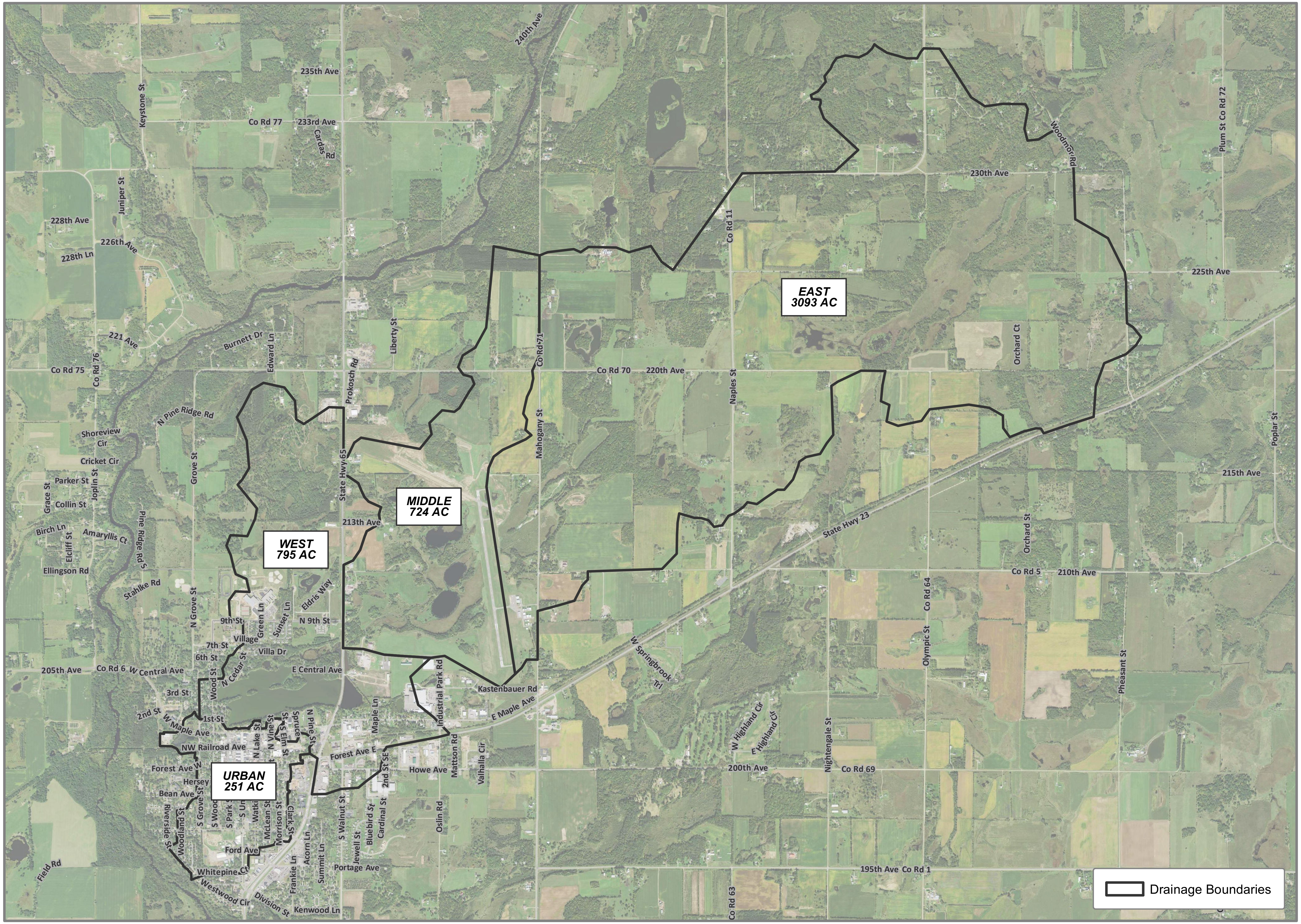
1.1 Data Used

The following is a list of data used in this analysis:

- Base storm sewer data (GIS Data provided by City of Mora, supplemental field survey collected by AE2S and City, 2019)
- LiDAR Elevation DEM (MnTOPO, 2011)
- Aerial imagery (MnGeo WMS service, 2017)
- Design storm precipitation data (NOAA Atlas 14)
- NRCS Web Soil Survey (NRCS)

Figure 1.1 Study Area Map

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.



N

0 1,250 2,500

Feet

1 inch = 2,500 feet

Locator Map Not to Scale

Mora, MN

Figure 1.1
STUDY AREA MAP

CITY OF MORA
STORMWATER
EVALUATION

Date: 9/17/2019

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 1 - Study Location Map.mxd

Chapter 2 Modeling Methodology

This hydrologic and hydraulic analysis was carried out using XPSTORM, a proprietary version of EPA-SWMM. Two-dimensional (2D) hydraulic simulation was used to quantify flooding depths and extents throughout the modeled area. The 2D approach provides more accurate and rapid analysis of surface flooding throughout complex urban watersheds. Additional details regarding the 2D methods are provided in Section 2.2.

2.1 Hydrologic Parameters

Subcatchment runoff was computed using SWMM hydrology and Horton infiltration. SWMM hydrology uses subcatchment average slope and width to compute peak runoff time of concentration. Horton infiltration parameters for each NRCS Hydrologic Soil Group are summarized below in Table 2.1 Horton Infiltration Soil Parameters.

Table 2.1 Horton Infiltration Soil Parameters

NRCS Hydrologic Soil Group	Maximum Infiltration Rate (in/hr)	Minimum Infiltration Rate (in/hr)	Drying Time (days)
A	4.0	1.0	3.1
B	2.0	0.5	4.4
C	1.0	0.2	7.0
D	0.5	0.1	9.9

Subcatchment imperviousness was determined based on land use. Commercial and industrial land use areas were set at a 90% impervious based on aerial imagery. Residential land use, which comprises most of the Downtown and Fairgrounds watersheds, was set to 30% impervious based on the typical lot size and impervious percentage within these watersheds. The Mora Lake drainage areas are predominantly pervious with the exception of water surface areas of the lake and upstream wetland complexes.

Subcatchment average surface slope was computed within ArcMap using the MnTOPO LiDAR data. Subcatchment width was calculated based on area using the following equation:

$$Width\ (ft) = 0.7 * \sqrt{Area\ (ft^2)}$$

NOAA Atlas-14 design storm depths with MSE-3 precipitation distribution were used in the model. Table 2.2 summarizes the design storm depths.

Table 2.2 NOAA Atlas 14 Design Storm Depth (inches)

2-Year	10-Year	100-Year
2.69	3.95	6.37

2.2 Hydraulic Parameters

Hydraulic computations were analyzed with the dynamic wave model within XPSTORM. The list below summarizes the key hydraulic methods / assumptions:

- Surface flow modeled with 2D methods
  - Surface roughness assumed a uniform value of 0.02
  - LiDAR elevation data were used to develop surface digital elevation model
  - 10 x 10 foot grid cells used
  - 2D Domain boundary condition assumes "dry" conditions (i.e., water can freely exit 2D domain)
  - Mora Lake assumed starting water surface elevation set based on OHWL established by the MnDNR (983.9, NAVD 88).
- Inlet capacity and interaction with 2D surface modeled using HEC-22 methods
  - All inlets assumed R-3076 grate type
- Storm sewer assigned roughness values of 0.013 for concrete pipe and 0.024 for corrugated metal pipe

Chapter 3 Existing Conditions Results

Figure 3.2 & Figure 3.3 show the 10- and 100-year modeling results. The figures display the estimated flooding extents and depths throughout the City. Generally, the greatest risk of flooding occurs in the vicinity of Grove St., Downtown, at the Fairgrounds and around Mora Lake. Please note that the flooding depth color ramp shown in these maps excludes flooding depths less than four inches, but the full flooding extents are shown with the hatched symbology. When using 2D modeling methods, areas on the surface that experience any amount of water, even very minimal, will be shown as flooding. It is more reasonable to visualize flooding greater than 4-inches as this provides a more realistic estimation of inundation during storm events.

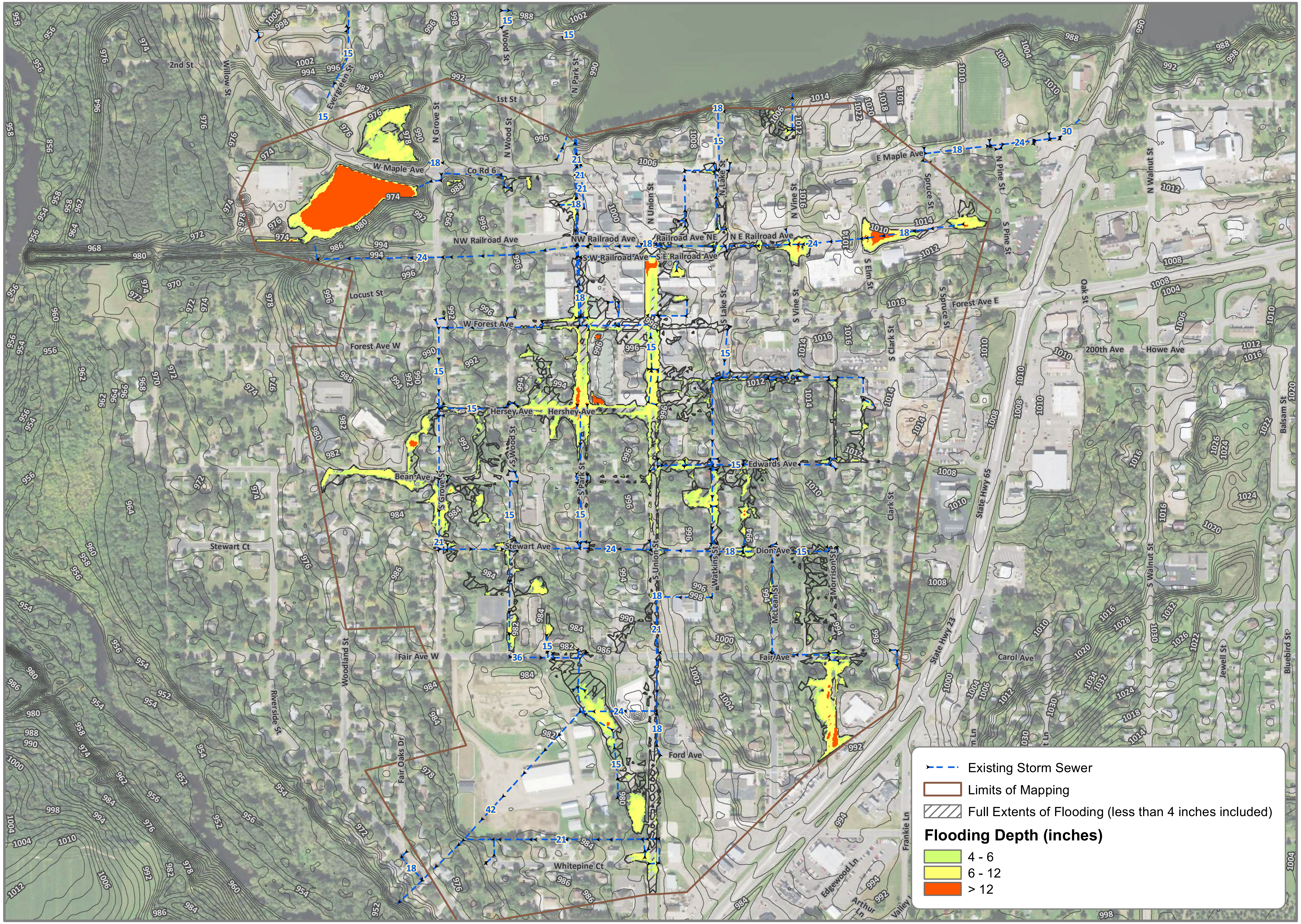
3.1 Grove St. Area

The major flooding along Grove St. occurs from Bean Ave. to Stewart Ave where a sag is located in Grove St. The City's natural topography slopes from the northeast to the southwest. As a result, any runoff from the Downtown area not collected by the storm sewer systems serving the streets in those areas, will flow down the streets (Figure 3.1) and eventually collect in this area along Grove St. If the water level in Grove St. is high enough, water will flow west on Bean Ave. and eventually get to the river.

Figure 3.1 Grove St. Flooding (Looking South from Bean Ave.)

Figure 3.2 Existing Conditions 10-Year Flooding

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.



N

0 250 500

Feet

1 inch = 500 feet

Locator Map Not to Scale

Mora, MN

Figure 3.2

EXISTING CONDITIONS 10-YEAR FLOODING

CITY OF MORA STORMWATER EVALUATION

Date: 10/2/2019

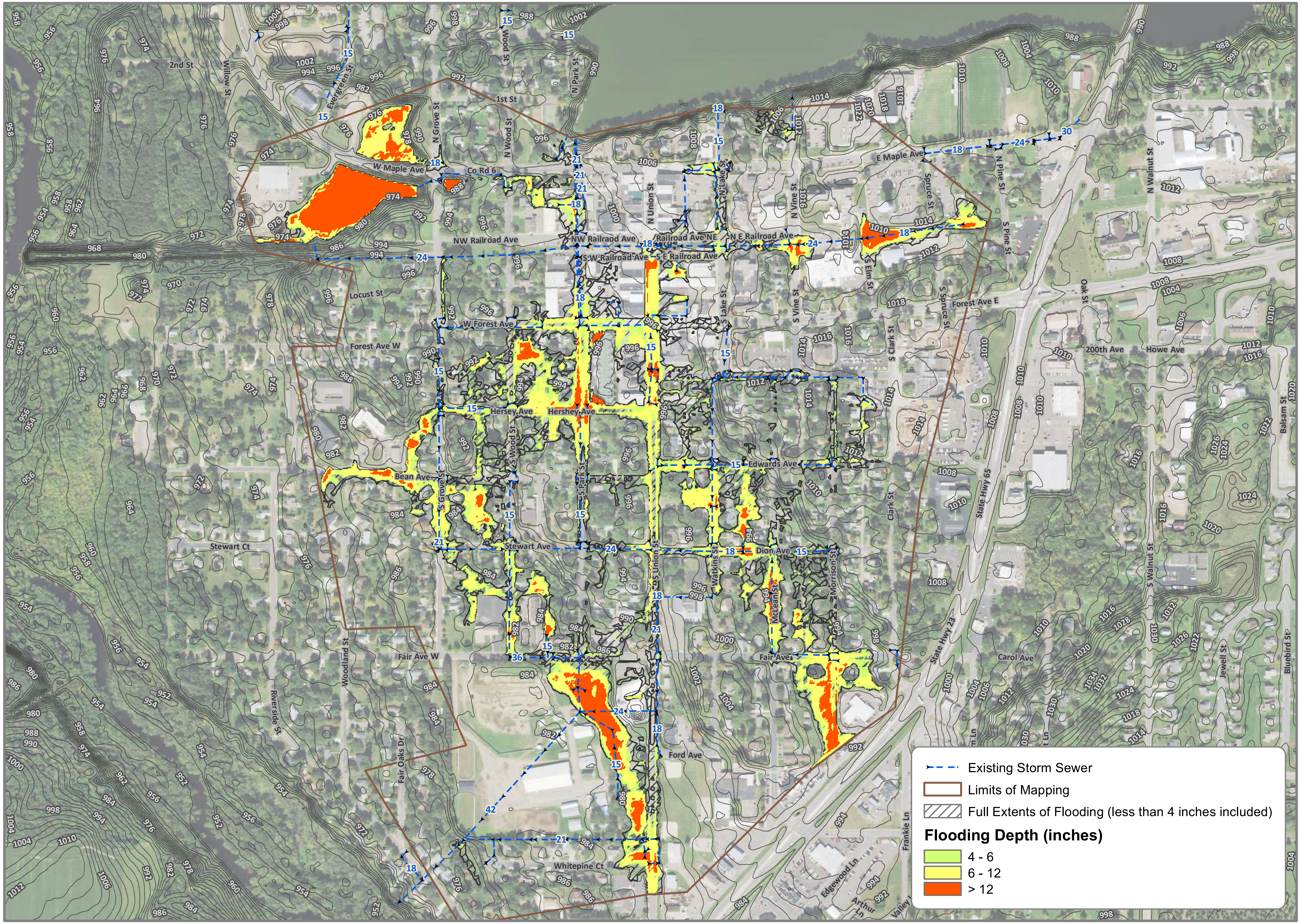
AE2S

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 3.2 - 10-Year Existing Inundation.mxd

Figure 3.3 Existing Conditions 100-Year Flooding

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.



N

0 250 500

Feet

1 inch = 500 feet

Locator Map Not to Scale

Mora, MN

Figure 3.3

EXISTING CONDITIONS 100-YEAR FLOODING

CITY OF MORA STORMWATER EVALUATION

Date: 10/2/2019

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 3.3 - 100-Year Existing Inundation.mxd

3.2 Downtown Area

During recent rain events, several locations throughout the downtown area have been observed to flood by City staff. These areas include Hersey Ave. from S. Park St. to S. Union St. near the Paradise Theater, the intersection of Railroad Ave. NE & S. Lake St. and Park St. north of Railroad Ave.

Nearly 30 acres of predominantly commercial area contributes runoff to Railroad Ave, east of Park Street. The storm sewer under Railroad Ave conveys runoff to Park Street and ultimately continues west along the bike path. This storm system is not sized to accommodate the recent large storm events experienced in Mora. Inadequate storm sewer and catch basins lead to greater surface ponding; the issue is compounded by highly impervious drainage area and relatively flat grades throughout this area.

The Downtown Area overflows to the south causing flooding along Hersey Ave and Union Street. The storm sewer system along Union Street feeds into the trunk line along Park Street as well and is similarly insufficient at conveying large storm events. Typical storm sewer is only sized for events less than the 10-year event, so anytime larger rainfall is experience, the roadway systems have to convey the excess runoff unable to be routed through the storm sewer systems.

3.3 Fairgrounds Area

The Fairgrounds Area is a naturally low area to the south of the Downtown and Grove St. areas. The Fairgrounds experienced significant flooding during the July 2016 and 2018 large storm events. This is due to overland flow coming from the north and to the storm trunk mains surcharging at their confluence within the Fairgrounds.

The majority of the developed portion of Mora is served by storm sewer ultimately conveying runoff south and west toward and then beyond the Fairgrounds. A 36-inch line from the north joins a 24-inch line from the east and transitions to a 42-inch line heading southwest away from the Fairgrounds. This system was likely designed to convey the 10-year storm event but cannot handle larger events. The two recent summer storm events were estimated to be greater than 6-inches of precipitation, approximately the 100-year event.

3.4 Mora Lake

Mora Lake has an overall drainage area of approximately 7.2 square miles, the vast majority of which is undeveloped agricultural land to the northeast of the City. The Lake has no natural gravity outlet; however, the City storm sewer system will allow the discharge from the Lake when the water level exceeds 985.36 by backing water up into the system and ultimately discharging into the pond located adjacent to public works via the urban storm sewer system. The Minnesota Department of Natural Resources (DNR) monitored Lake water levels periodically between 1959 and 2004 and has established the ordinary high-water level (OHWL) to be 983.9

(NAVD 88). More recently, the seasonally high-water level is estimated to be closer to 986.0; therefore, causing a constant flow through the City storm sewer.

Chapter 4 Drainage Improvements

4.1 Urban Improvements

A system-wide approach is required to minimize flooding in all identified urban problem areas given the interconnectivity of the surface conveyance (streets) and storm sewer systems. The improvement of storm sewer in one problem area will necessitate the improvement of downstream storm sewer to accommodate additional flows. In general, the storm sewer throughout Mora is undersized even for the 10-year event.

The system-wide approach proposes to increase storm sewer capacity conveying runoff west along Railroad Ave and the bike path as well as south to Fair Ave. At Fair Ave, a new storm trunk line would convey runoff west and discharge via a new outfall to Snake River. Figure 4.2 and Figure 4.3 show the 10- and 100-year inundation results assuming all of the proposed improvements are installed. These figures also show the inundation area that would be removed by these improvements.

The majority of the flooding along Grove Street is removed by the proposed improvements. It is possible to achieve this decreased flooding by upsizing and extending the storm sewer along Grove Street south to Fair Ave and then constructing new storm sewer and an outfall to Snake River along Fair Ave.

The flooding within the commercial Downtown area is more difficult to reduce given the relatively flat grades and high imperviousness. Increasing the capacity of the storm sewer along Railroad Ave and west along the bike path alone will not solve the flooding issues here. Increased capacity and additional storm sewer along Park Street heading south to Fair Ave is recommended as well.

The flooding within the Fairground area will only slightly improve in the 100-year event as a result of these improvements. However, during the 10-year event, the flooding in the Fairground will be substantially reduced.

For any of the proposed storm sewer pipe improvement areas, additional catch basins are necessary to collect runoff from the street and direct it into the storm sewer system.

4.2 Mora Lake Outlet Improvements

In order to manage the lake level of Mora Lake and reduce the flooding of upstream structures and roadways, the City requested an evaluation of a gravity outlet alternative for Mora Lake. In collaboration with City staff, the most economical alignment for the gravity outlet was determined to be along W. Maple Ave., with the lake intake structure in Library Park, and the pipe outlet discharging into the pond located adjacent to the City Public Works shop, which would ultimately discharge into the Snake River via the existing channel.

Mora Lake and the upstream contributing areas were modeled to estimate the peak water levels within the lake for the 50-, 100-, and 500-year storm events for existing and proposed conditions.

The starting water surface elevation used for the existing conditions analysis is based on the gravity outlet elevation within the existing storm sewer system (985.36). The Lake relies upon infiltration to lower the water level below 985.36 and based on field observations by City staff, it can take weeks and/or months for the lake level to drop to the OHWL. Therefore, utilizing this elevation as a starting water surface elevation is a conservative approach for the analysis.

The proposed conditions analysis utilized the OHWL as the starting water surface elevation of the lake. The reason for the change between existing to proposed conditions is that under proposed conditions, a gravity outlet would be installed which would control the lake level to the regulated OHWL established by the MnDNR.

A preliminary outfall design was developed to integrate into the analysis to determine how much bounce the lake could be expected to have for the three storm events listed above, with the goal to limit the bounce for each event. The outlet design will need to be further refined based on collaboration with the MnDNR and potentially integrating in an adjustable gate system, allowing the City to better manage the lake level prior to, during and after rainfall events.

The outfall included in the analysis consists of a multi-stage 4x6 foot concrete structure. The outfall low flow elevation was set at the DNR OHWL, 983.9. The top of the outfall structure was set at 985.36 to allow additional discharge into the structure under high water level conditions. The storm sewer pipe leaving the structure is proposed to be a 36-inch RCP, extending to the existing pond near the Public Works building.

Figure 4.1 below shows a conceptual detail of the outfall structure with Table 4.1 & Table 4.2 summarizing the water levels under each scenario.

Figure 4.1 Mora Lake Concept Outfall Structure

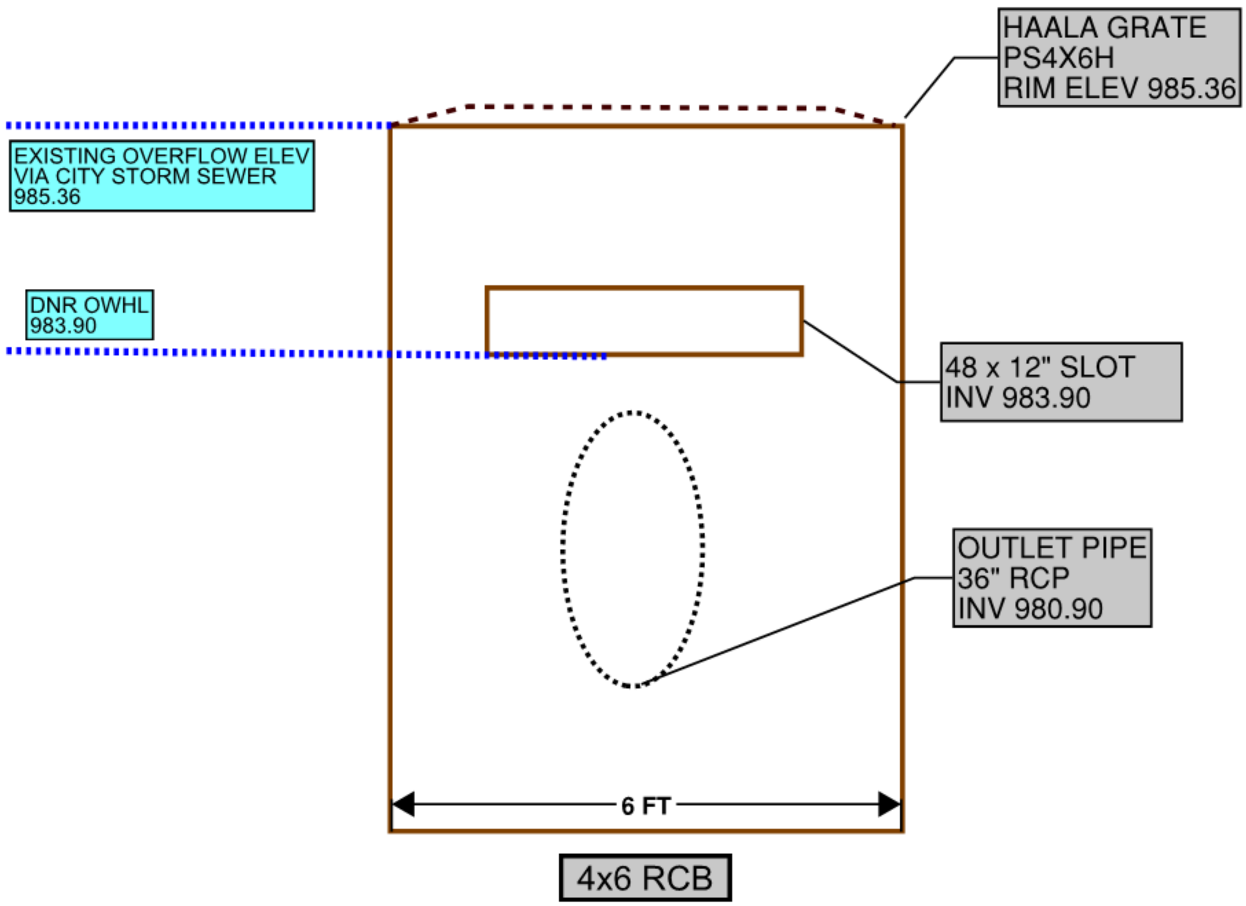


Table 4.1 Mora Lake Analysis w/36" Outlet Pipe (NAVD 88)

Location	50-Year			100-Year			500-Year		
	Existing	Proposed	Delta	Existing	Proposed	Delta	Existing	Proposed	Delta
Mora Lake	987.70	985.57	-2.13	988.42	985.93	-2.49	990.34	987.83	-2.51
PW Pond	974.42	974.48	+0.06	974.48	974.65	+0.17	974.6	974.88	+0.28

Table 4.2 Mora Lake Analysis w/48" Outlet Pipe (NAVD 88)

Location	50-Year			100-Year			500-Year		
	Existing	Proposed	Delta	Existing	Proposed	Delta	Existing	Proposed	Delta
Mora Lake	987.70	985.57	-2.13	988.42	985.93	-2.49	990.34	987.24	-3.10
PW Pond	974.42	974.48	+0.06	974.48	974.65	+0.17	974.6	974.88	+0.28

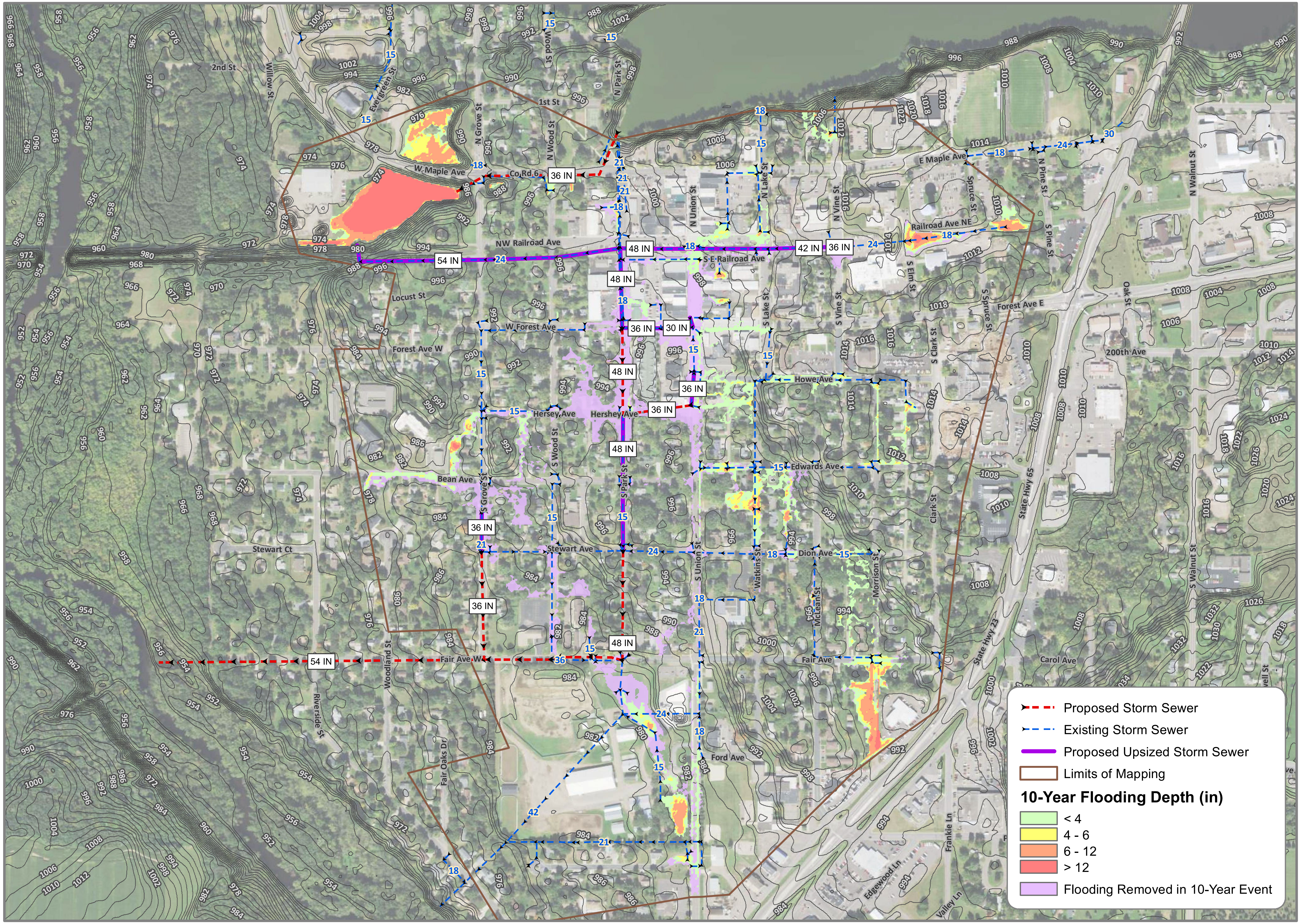
In addition to evaluating a 36-inch outlet option, a 48-inch option was evaluated to determine the incremental benefit it would have on the lake. Overall, based on the outlet configuration detailed in Figure 4.1, increasing the outlet pipe size doesn't provide any additional benefit for the 50- and 100-year events. However, it does reduce the high water level of the lake for the 500-year event by allowing additional water to discharge from the lake. If the City pursues Federal Emergency Management Agency (FEMA) grant dollars, the outlet design will need to be further refined to ensure the maximum benefit is being created by the outlet to obtain the highest Benefit-Cost-Ratio (BCR) to obtain federal funding.

4.3 Snake River FIS

Constructing a larger outlet for Mora Lake will increase the discharge to the Snake River. The Flood Insurance Study (FIS)(1977) for the Snake River was reviewed to determine what the flow rate at Mora is for the base flood elevation (BFE) condition. Based on the 1977 FIS, the flow rate used to calculate the 100-year BFE is 14,000 c.f.s. Streamstats was also reviewed to determine what the most current flow rate is for the Snake River and that analysis yielded a 100-year flow rate of 11,600 c.f.s. By comparision, the new outlet to the Snake River from Mora Lake is anticipated to discharge less than 70 c.f.s. for the 500-year event and less than 30 c.f.s. for the 50-year event. Therefore, the additional discharge from a new outlet from Mora Lake is anticipated to have a negligible impact to the BFE of the Snake River.

Figure 4.2 10-Year Improvement Flooding Comparison

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.

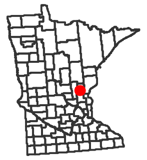


N

0 250 500

Feet

1 inch = 500 feet



Locator Map Not to Scale

Mora, MN

Figure 4.2

10-YEAR IMPROVEMENTS FLOODING COMPARISON

CITY OF MORA STORMWATER EVALUATION

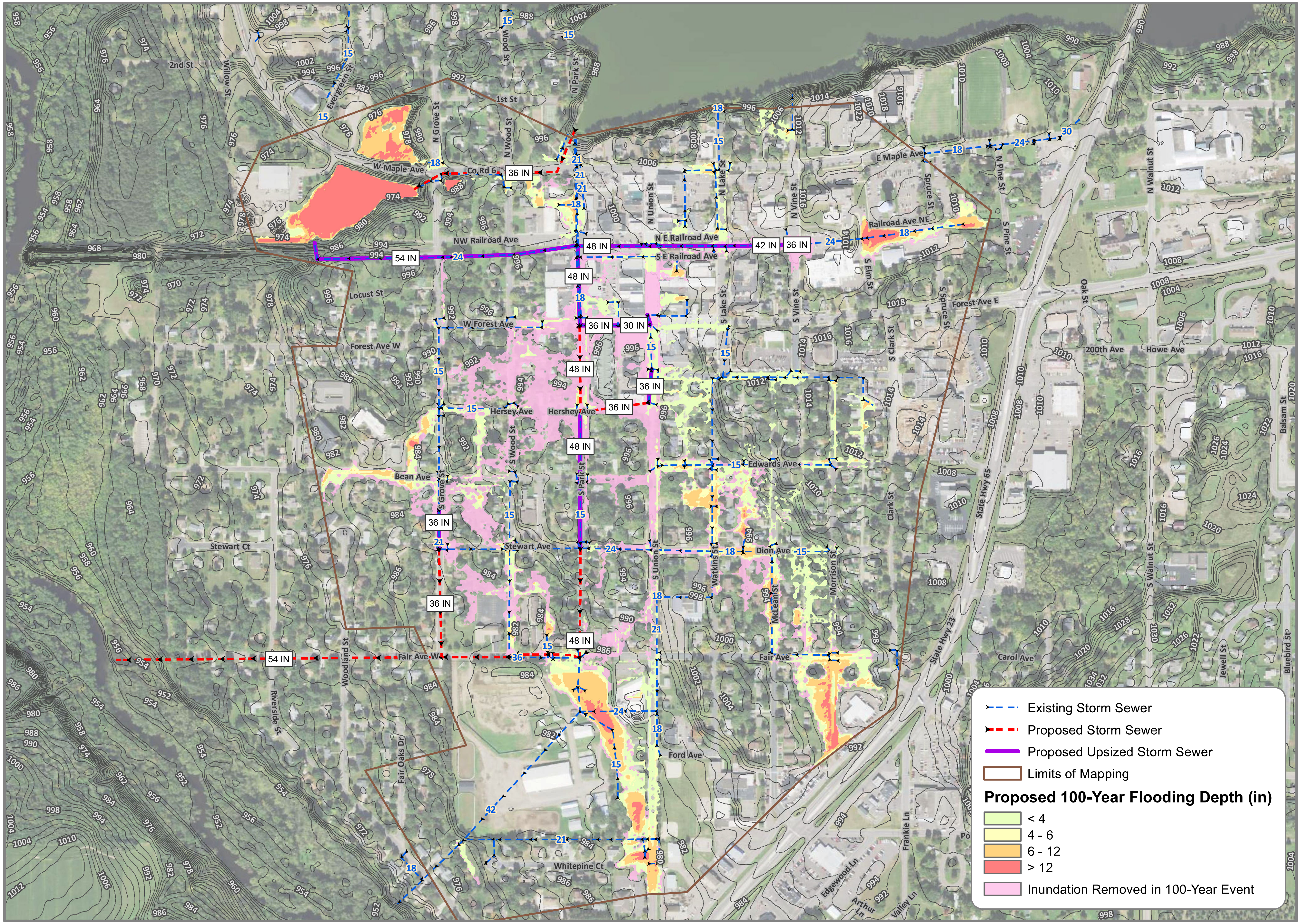
Date: 10/3/2019

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 4.2 - 10-Year Compare.mxd

Figure 4.3 100-Year Improvement Flooding Comparison

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.



N

0 250 500

Feet

1 inch = 500 feet

Locator Map Not to Scale

Mora, MN

Figure 4.3

100-YEAR IMPROVEMENTS FLOODING COMPARISON

CITY OF MORA STORMWATER EVALUATION

Date: 10/3/2019

AE2S

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 4.3 - 100-Year Compare.mxd

Chapter 5 Implementation & Prioritization

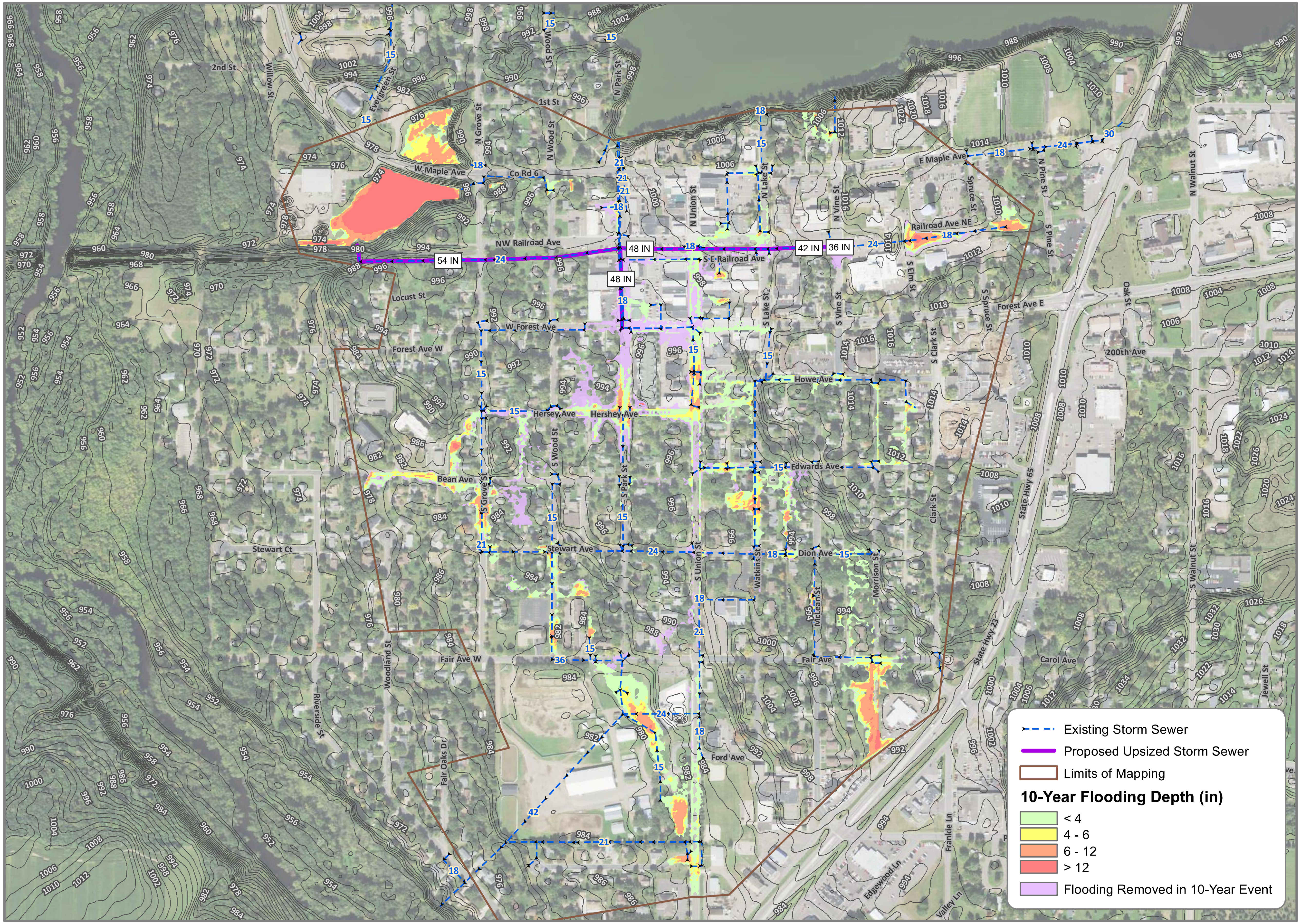
Constructing all of the storm sewer system improvements at once is not anticipated to be financially feasible by the City. It is anticipated the improvements will be phased and integrated into the street and utility improvement projects (if possible).

The northern or "Railroad" Improvements and the Southern Improvements were analyzed separately to evaluate the individual benefits of implementing one or the other improvement area alone. Figures 5.1 and 5.2 show the 10- and 100-year flood conditions if the Railroad Improvements are made only. Figures 5.3 and 5.4 show the flood conditions if only the Southern Improvements are constructed. Localized flooding will be reduced if the improvement areas are constructed in isolation, but the greatest impact will be achieved when both improvements are made.

Overall, when comparing the individual benefit of each improvement, the Southern improvement has the greatest reduction in flooding throughout the City. This improvement also has the largest quantity of storm sewer to be installed and the most street length to be impacted. The Southern improvement is recommended to be constructed first, because it benefits the most critical flooding areas within the City (i.e. Grove St. & Bean Ave. and Hersey Ave. & Union St.).

Figure 5.1 10-Year Railroad Improvements Flooding Comparison

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.

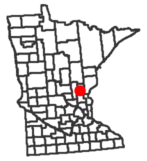


N

0 250 500

Feet

1 inch = 500 feet



Locator Map Not to Scale

Mora, MN

Figure 5.1

10-YEAR RAILROAD IMPROVEMENTS FLOODING COMPARISON

CITY OF MORA STORMWATER EVALUATION

Date: 10/3/2019

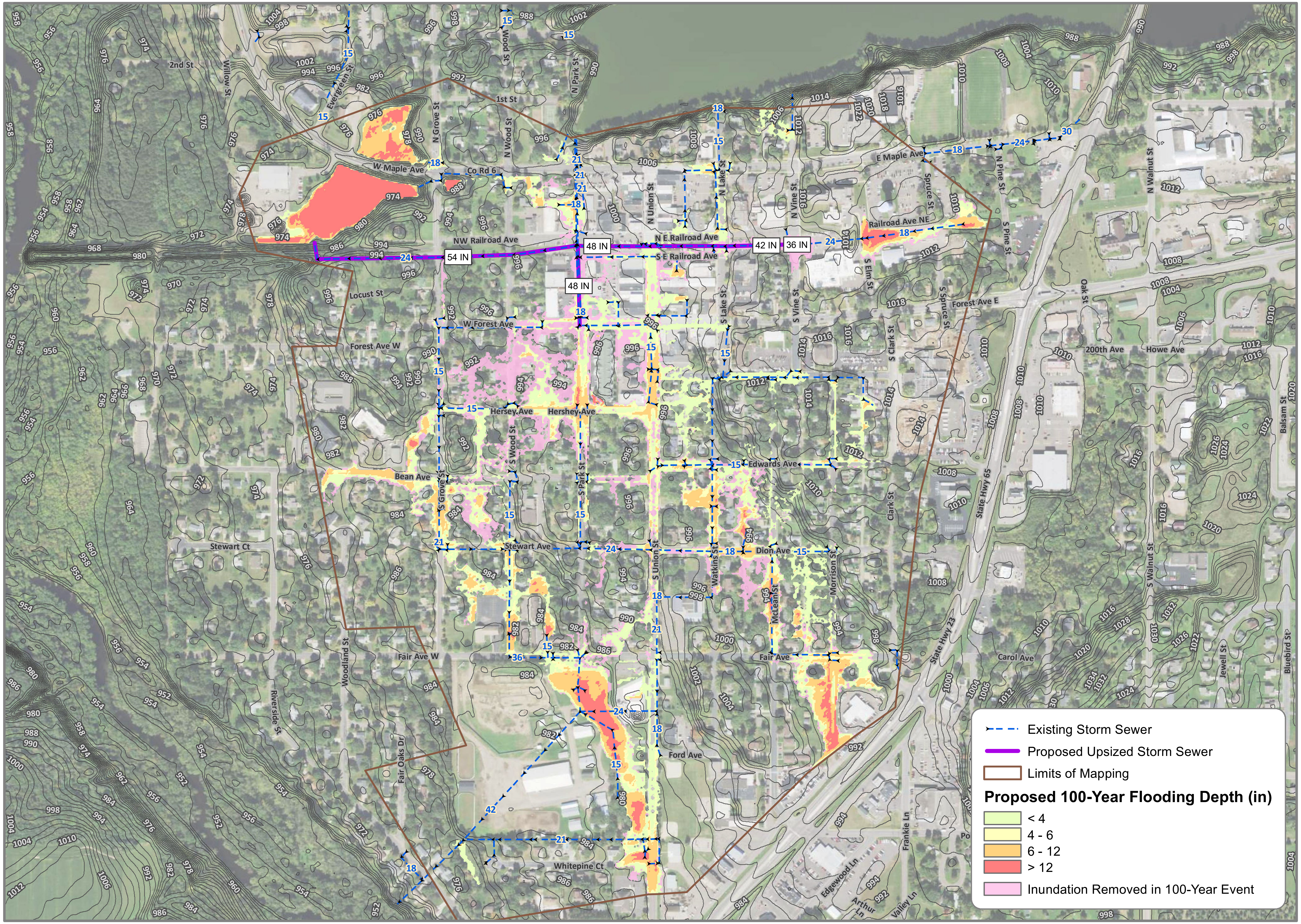
AE2S

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 5.1 - 10-Year Compare Railroad.mxd

Figure 5.2 100-Year Railroad Improvements Flooding Comparison

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.



N

0 250 500

Feet

1 inch = 500 feet

Locator Map Not to Scale

Mora, MN

Figure 5.2

100-YEAR RAILROAD IMPROVEMENTS FLOODING COMPARISON

CITY OF MORA
STORMWATER
EVALUATION

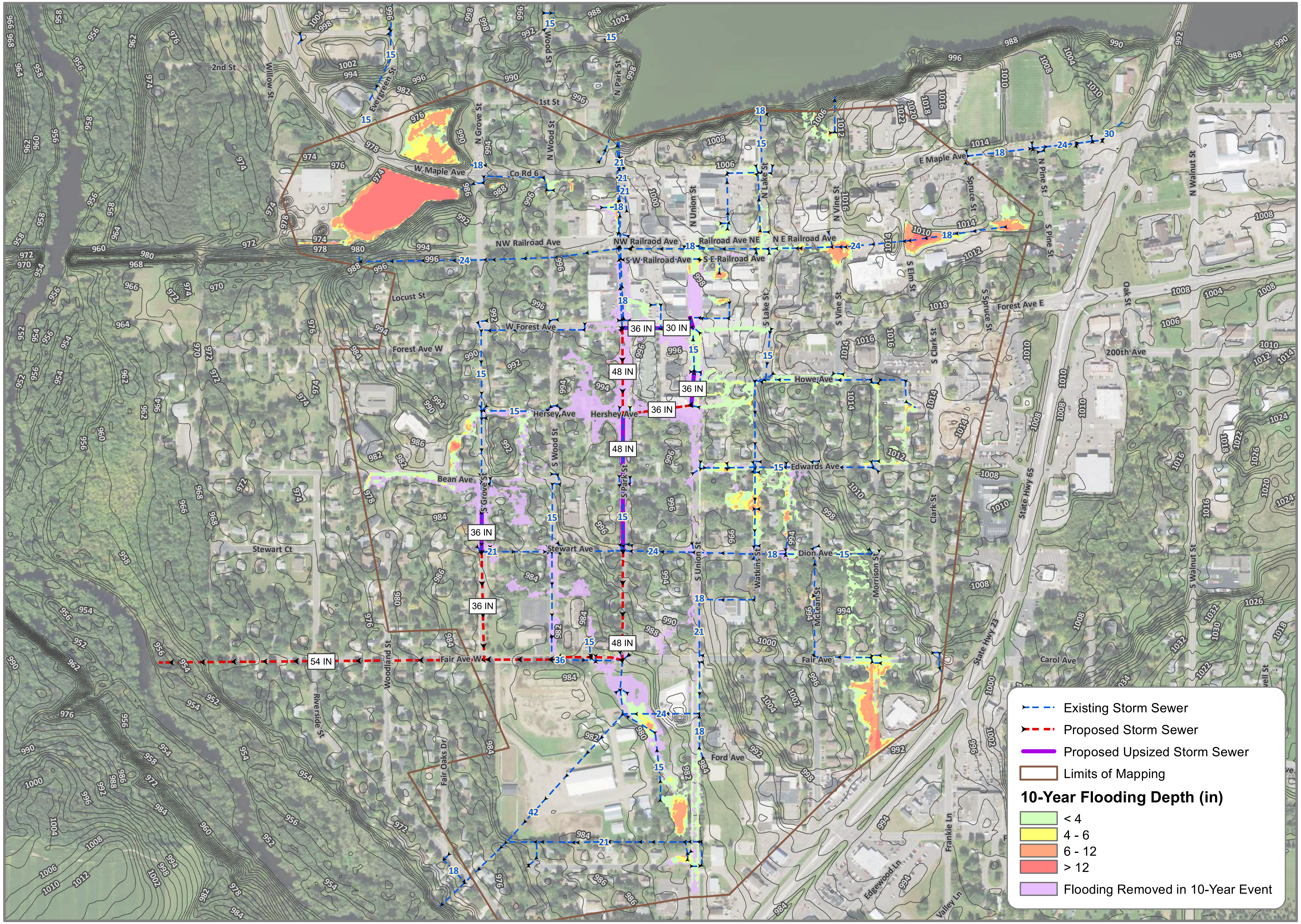
Date: 10/3/2019

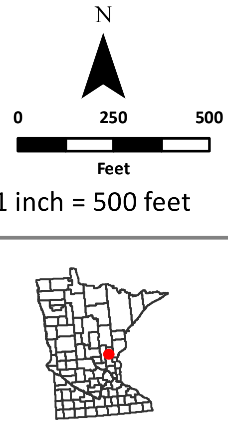
AE2S

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 5.2 - 100-Year Compare Railroad.mxd

Figure 5.3 10-Year Southern Improvements Flooding Comparison





1 inch = 500 feet

Locator Map Not to Scale

Mora, MN

Figure 5.3

10-YEAR SOUTHERN IMPROVEMENTS FLOODING COMPARISON

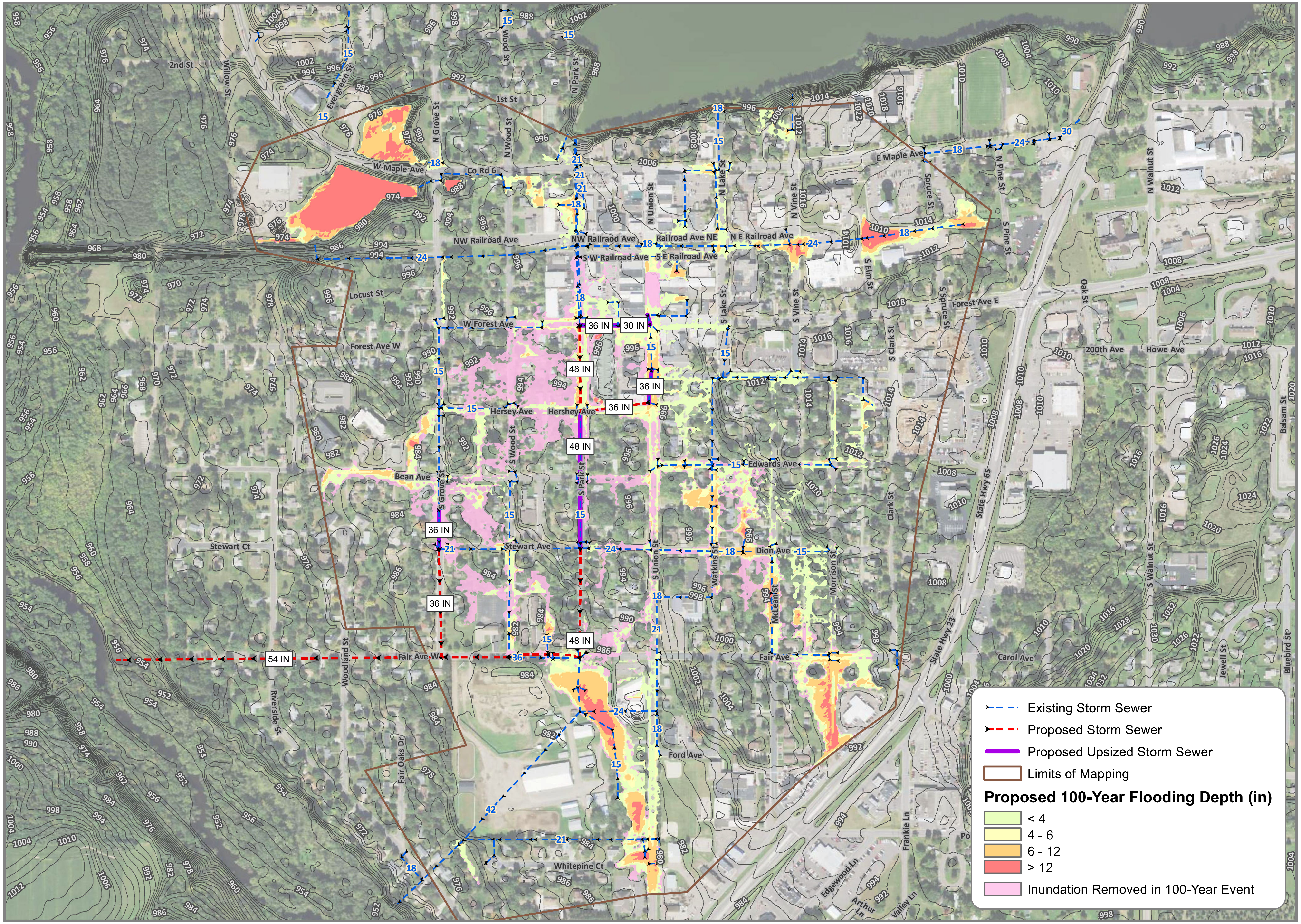
CITY OF MORA STORMWATER EVALUATION

Date: 10/3/2019

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 5.3 - 10-Year Compare South.mxd

Figure 5.4 100-Year Southern Improvements Flooding Comparison

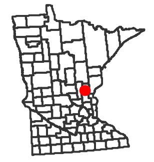


N

0 250 500

Feet

1 inch = 500 feet



Locator Map Not to Scale

Mora, MN

Figure 5.4

100-YEAR SOUTHERN IMPROVEMENTS FLOODING COMPARISON

CITY OF MORA STORMWATER EVALUATION

Date: 10/3/2019

AE2S

www.ae2s.com | Advanced Engineering and Environmental Services, Inc.

Information depicted may include data unverified by AE2S. Any reliance upon such data is at the user's own risk. AE2S does not warrant this map or its features are either spatially or temporally accurate.

Coordinate System: NAD 1983 HARN Adj MN Kanabec Feet | Edited by: zmagdol | C:_Projects\Mora - Stormwater Analysis\Maps\Figure 5.4 - 100-Year Compare South.mxd