

Technical Memorandum

To: Nathan Boerboom PE, CFM
City of Fargo

From: Gregory S. Thompson PE, CFM
Houston Engineering, Inc.

Subject: South Fargo - Hydraulic Impact Analysis

Date: May 19, 2016

Project: MS-14-20, Southwest Metro Storm Sewer Master Plan
HEI 6059-077

I hereby certify that the attached plan, specification, or 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 North Dakota.

DATE: 5/19/2016

GREGORY S. THOMPSON
PE 5959

NORTH DAKOTA

INTRODUCTION

The City of Fargo (city) is continuing to experience development pressure to expand the city to the south, and it is expected to continue into the future. Therefore, the city, through MS 14-20, enlisted Houston Engineering, Inc. to conduct a storm sewer master plan for undeveloped portions of the city and its Extra Territorial (ET) jurisdictional area south of 52nd Avenue S. This study has two primary components; the first is to develop a storm sewer master plan that presents various storm sewer infrastructure alternatives for future development, and the second part is to conduct a hydraulic impact analysis to determine the flooding effects a proposed levee system may have on adjacent lands. This Technical Memorandum is intended to provide a concise summary of the floodplain analysis for review by city officials.

STUDY AREA

The initial scope of the study defined the flood protection study area as extending from approximately 52nd Avenue S. to as far south as 100th Avenue S. However, after initial discussions with the city regarding realistic flood mitigation, the efforts honed in on an area generally extending between 52nd Avenue S. and 76th Avenue S. and as far west as Drain 27 and east to the Red River. The area defined is the area studied for future flood protection options, however for hydraulic analysis purposes, the overall study area extends from as far south as the Wild Rice River to as far north as approximately Interstate 94. The study area is shown in Exhibit 1.

BACKGROUND/MODELING APPROACH

The North Dakota State Water Commission (NDSWC) requires completion of a hydraulic impact analysis prior to issuing a construction permit for a flood protection project such as a levee or floodwall. Then, prior to issuing the construction permit, a property right must be obtained for lands incurring flooding impacts greater than 0.1 feet as a result of the project.

The hydraulic modeling that supports the Cass County Flood Insurance Study (FIS) utilized the Hydrologic Engineering Center – River Analysis System (HEC-RAS) in a steady-state environment. This is a relatively

simple yet widely accepted modeling approach that uses a constant flow to represent a flooding event, and it is currently the most common tool used for FIS efforts. Modeling for the FM Diversion project uses the same HEC-RAS program, but with an unsteady state approach that analyzes a river system with the entire flood hydrograph. Unsteady state models are capable of producing more realistic flooding results when compared to a steady state model, especially in areas where floodplain storage and hydrograph timing is critical, like it is in the Red River Valley. The city engineering staff recognizes that the unsteady state HEC-RAS model from the FM Diversion modeling is the best model available, therefore it has been chosen to be used for this study to analyze the impacts of future flood mitigation projects.

FLOOD CHARACTERISTICS

Flooding throughout the study area can be quite complex when breakout flows and reverse flows are observed. [Exhibit 2](#) and the following text further describe the flood patterns throughout the study area. Flood waters upstream of the study area originate in the Wild Rice River and Red River basins which converge upstream of the Fargo/Moorhead area. Floodwaters continue north through Fargo and Moorhead as displayed with white arrows on [Exhibit 2](#).

During large flood events, the Wild Rice River will break out into Drain 27 and/or Drain 53. This water then continues north and east until it enters Rose Coulee which outlets into the Red River between 40th Avenue S. and 52nd Avenue S. The breakout waters are shown with red arrows in [Exhibit 2](#).

Near the crest of a flood, Red River floodwaters will back up into Rose Coulee, Drain 27 and Drain 53 until flooding levels equalize between the Red River and the currently undeveloped land upstream along Drain 27 and Drain 53. This “reverse” flow effect was observed by sand bagging volunteers along Drain 27 just before the crest of the 2009 flood. The orange arrows on [Exhibit 2](#) show the reverse flow.

Without temporary and permanent flood protection measures (levees and floodwalls) along Drain 27 and Rose Coulee, flooding would break out of the north side of Drain 27 and Rose Coulee and flow through the developed portions of the city as displayed with blue arrows in [Exhibit 2](#).

FLOODPLAIN IMPACTS

EXISTING CONDITIONS FLOODING

An “existing conditions” floodplain assumes no permanent or temporary flood protection measures are in place. The communities have been fortunate to not have had to experience an “existing conditions” floodplain as described in the FEMA Flood Insurance Rate Map (FIRM), or as described in the FM Diversion modeling. This is attributed to the rigorous flood fighting efforts put forth by the local communities during the recent floods. As displayed in [Exhibit 3](#), the existing conditions floodplain would extend throughout the light blue and dark blue flooded areas.

FUTURE CONDITIONS FLOODING

For this analysis, it was assumed that future conditions would include flood protection down to approximately 76th Avenue S. Then, upon levee certification, it is expected that the remaining floodplain would more closely resemble the dark blue flooding shown on [Exhibit 3](#). However, eliminating the light blue floodplain would cause adverse flooding impacts on adjacent areas (dark blue).

Floodplain impacts are primarily caused by one or both of the following:

- 1) Reducing the conveyance in a river corridor (levees/floodwalls)
- 2) Removing natural storage from a floodplain (fill or levees on previously flooded land)

Within the study area, conveyance issues are typically identified along the Red River and Wild Rice River, whereas storage loss is more readily measured in the backwater flooding areas of Drain 27, Drain 53, and Rose Coulee.

HYDRAULIC MODELING

HEC-RAS – 1D MODEL

The unsteady state HEC-RAS model (Phase 8) from the FM Diversion project was used as a backbone for this analysis. The model uses cross sections to represent the rivers themselves and storage areas to represent sections of farmland and/or developed areas through town. The model has gone through several internal and external reviews through the FM Diversion project and it has been considered to be the best available large scale model of the Red River. Historic flood events from 1997, 2006, 2009, and 2011 have been used for calibration, and synthetic events such as 10-, 25-, 50-, 100-, and 500-year events have been created for FM Diversion design purposes. The synthetic events utilize the latest hydrology developed for the FM Diversion project. Since the primary objective of the “In-Town” flood mitigation work through Fargo has been to provide certifiable flood protection, the levees and floodwalls have been designed to protect against the regulatory FEMA floodplain which produces 29,300 cfs (39.3 feet) at the Fargo Gage. Therefore, for this analysis, the 50-year hydrology from the FM Diversion model was adjusted to closely match the FEMA 100-year flood elevation and discharge at the Fargo Gage.

The existing conditions unsteady model reflects the flooding that would exist through town if no flood protection measures were implemented. With this model, approximately 4,500 cfs would be expected to flow through the developed portion of town and approximately 24,800 cfs would flow in the channel portion of the Red River. When the flood protection measures are implemented, the north side of Drain 27 and Rose Coulee essentially become a wall that prevents floodwaters from flowing north. The floodwaters become restricted to the Red River channel which causes a stage increase, adversely affecting flooding in other areas (Exhibit 3, dark blue). Exhibit 4 further describes the flow distribution between the overland conveyance and the channel conveyance. The impacts are partially attributed to the encroachment along the Red River, but are also a result of removing the floodplain storage in the Drain 27, Drain 53, and Rose Coulee areas. Exhibit 5 displays five study areas referred to as “zones” with the associated floodplain volume removed by implementing the flood protection projects.

The proposed solution agreed upon during the planning process was to provide comparable floodplain storage in a condensed location such that the city could further expand south of 52nd Avenue S. in the remaining available land. The results of the preliminary analysis were presented to the City Commission on September 21, 2015.

The required mitigation from the preliminary 1D analysis was fairly conceptual, and consisted of the following:

30,000,000 CY of Pond Excavation
15 Miles of Levee
2,000 Acres of Land to be used for Flood Storage

Construction =	\$150M
Land =	\$30M
Total Cost =	\$180M

Exhibit 6 displays the potential storage requirements from the initial 1D modeling assuming mitigation ponds would be excavated 10 feet deep. The pond shape and locations were subjectively chosen as a concept. They could be placed almost anywhere along Drain 27 and Drain 53. However, the storage volume becomes less efficient as the distance increases from the existing conditions floodplain area (Rose Coulee area).

HEC-RAS – 2D MODEL

The unsteady state HEC-RAS model as described above uses 1 Dimensional calculations. However, as this study developed, a beta version of HEC-RAS 2D became available, and as of spring 2016, the first official release of HEC-RAS 2D was made available. The 2D model has the capability of accounting for more detail within the city such as building structures, building pads, and roughness of the ground (grass vs. pavement). This provides a more accurate representation of how flood waters would move through the city, potentially slowing down the “through town” hydrograph. If the hydrograph is slowed, it pushes more water to the channel for existing conditions, reducing the level of necessary mitigation. This would result in an overall savings in the cost of mitigation.

Since HEC-RAS 2D modeling is relatively new, several sensitivity analyses were conducted to validate assumptions and parameters used in the modeling. The final 2D modeling results showed that the 4,500 cfs flow through town identified in the 1D model was reduced to approximately 1,850 cfs. This reduced the required flood mitigation to the following:

20,000,000 CY of Pond Excavation
10 Miles of Levee
1,100 Acres of Land to be used for Flood Storage

Construction =	\$100M
Land =	\$16M
Total Cost =	\$116M

Exhibit 7 displays the area of the model that was evaluated with the 2D approach. 2D modeling utilizes a “grid” or a “mesh” that provides the additional detail. For this analysis, a mesh spacing of 50 feet was used to better define the buildings and obstructions through town. Each face of the mesh acts like a channel cross section in a 1D model. Exhibit 8 displays how the 2D mesh reflects the topography along a row of houses. The 2D mesh also utilized the city GIS impervious layer to account for the roughness of grass compared to impervious pavement surfaces.

CONCLUSION

The city recognizes that the flooding south of the city limits is real, regardless of if it was defined by FEMA or with the more detailed unsteady state modeling. The initial scope of the study was intended to provide a conceptual line of flood protection for areas south of 52nd Avenue, while still mitigating the adverse floodplain impacts. However, the study expanded beyond mitigating only for future levees. It also addressed the necessary mitigation for the levees that are currently being constructed along Drain 27, Drain 53, and Rose Coulee assuming that they would need a NDSWC construction permit and would become certified.

The initial analysis was conducted with the readily available FM Diversion unsteady HEC-RAS model. The model was originally developed for the larger scale diversion analysis, but was then revised with more detail (2D) specific to the south Fargo area. The initial analysis of this study suggested that significant flood mitigation would be required to offset the flooding impacts. After expanding the analysis with the 2D modeling, the mitigation still remains quite extensive.

ADDITIONAL CONSIDERATIONS

Flood Insurance Studies are hydrologic and hydraulic analyses conducted to provide a better understanding of the potential flood risk for a given area. The flood elevations are created using a hydraulic model and the flows are generated using historic gage records. The effective (regulatory) floodplain through the Fargo/Moorhead area (39.3 feet) was developed using hydrology from the 1970s. When the latest FIS was developed for Fargo (Effective, 2014), the process began before many of the larger floods were experienced (2006, 2009, 2010, 2011, etc.), so even the newer hydrology didn't prove to be much different than what was developed in the 1970s. However, the FM Diversion project hydrology was developed using many of the more recent large floods. This produced a 100-year discharge of 34,700 cfs, which equates to approximately 41 feet at the Fargo Gage as opposed to the previously defined 39.3 feet. If the Red River is encroached with levees on either side with the higher flows, the flood elevation is anticipated to exceed 42 feet. This shows that the real 1% chance flood risk is much higher than the in-town flood protection projects are being designed for. Due to bank stability concerns along the rivers and natural ground elevations, it is not likely that many of the existing levees would be capable of being raised to be certified to the revised floodplain.

Exhibit 1 Study Area

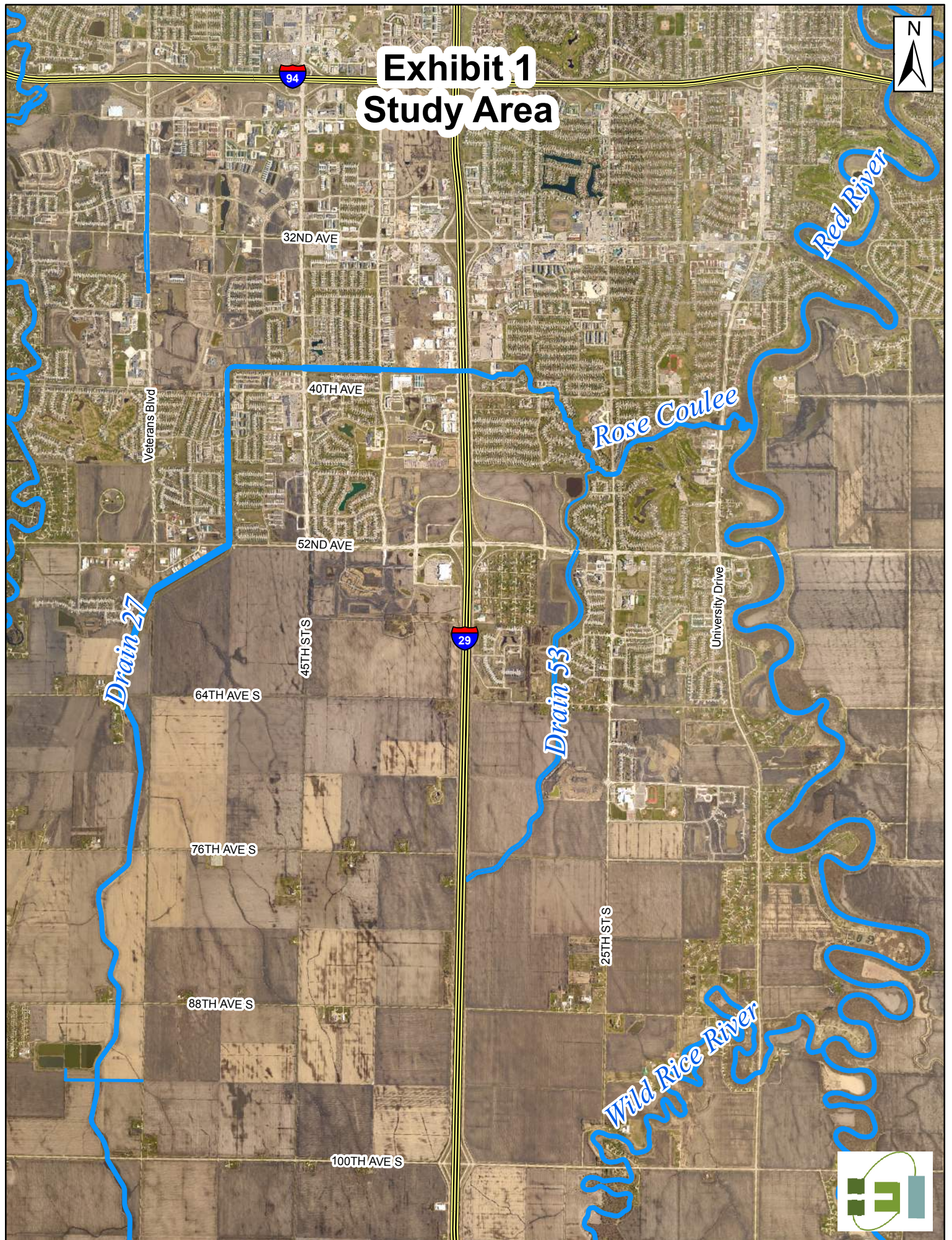


Exhibit 2 Flood Characteristics

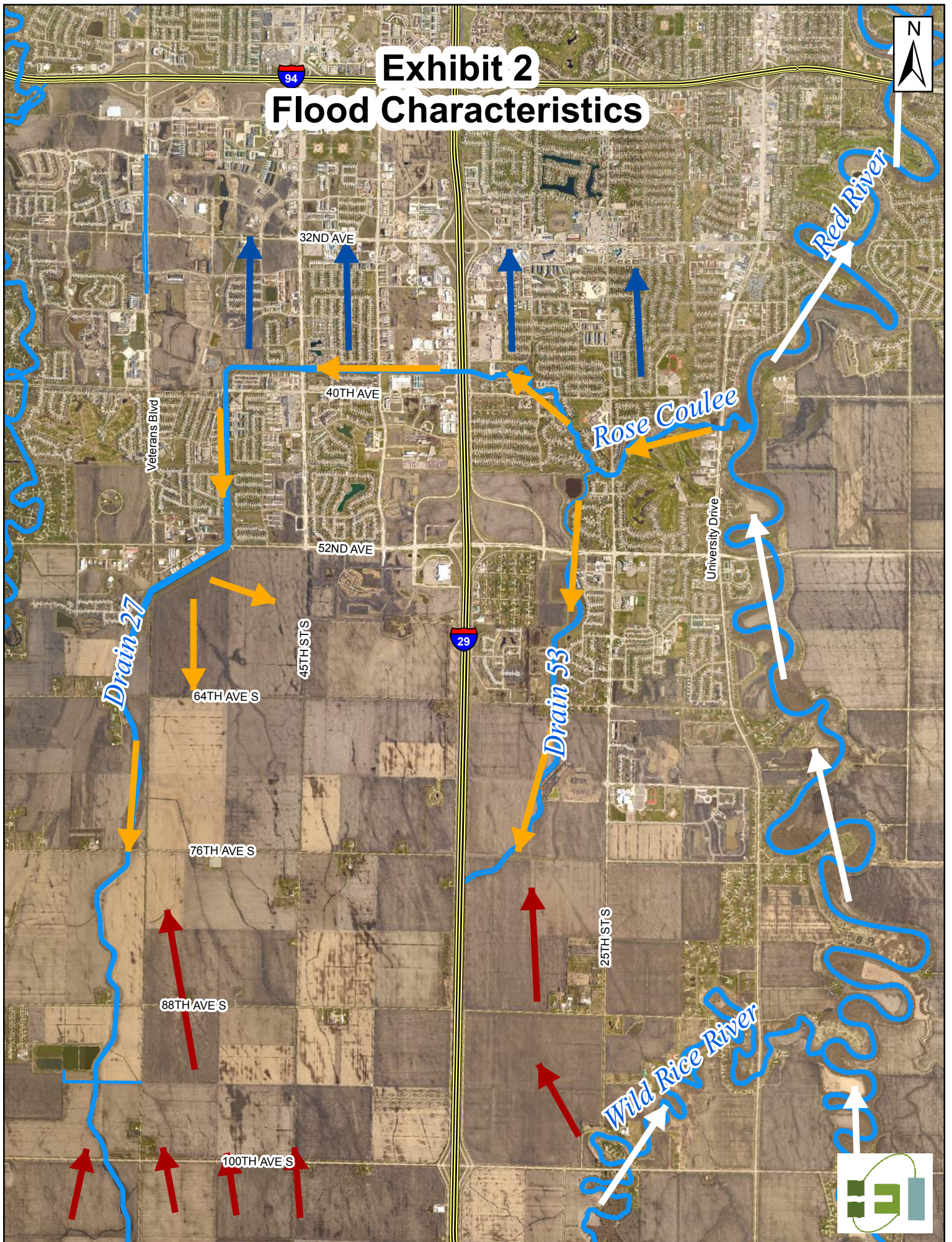
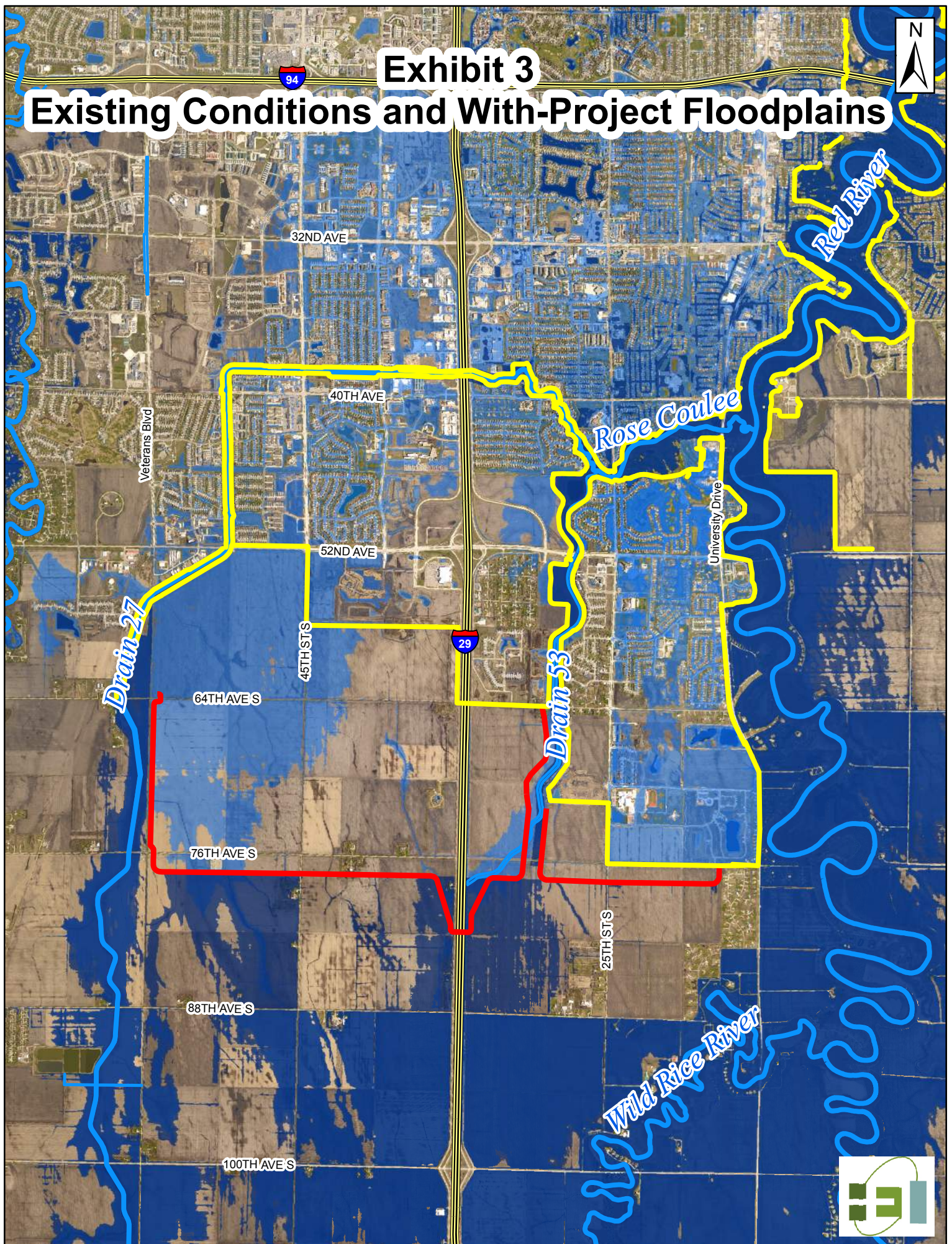
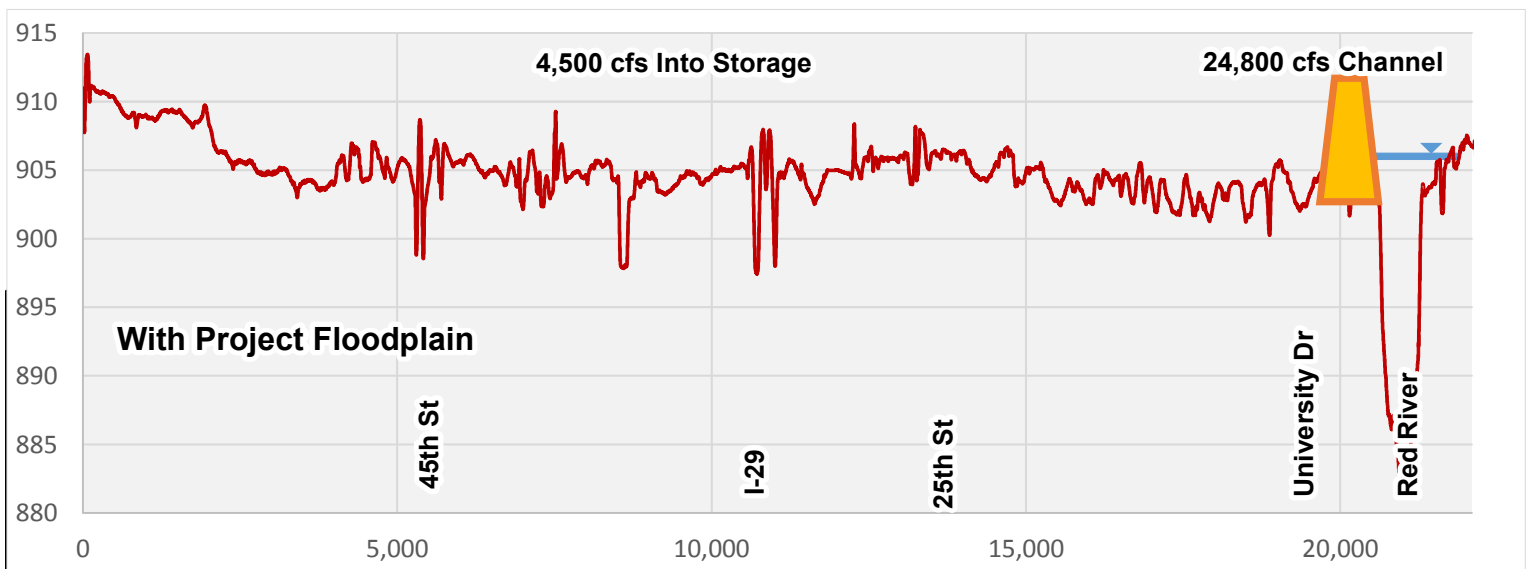
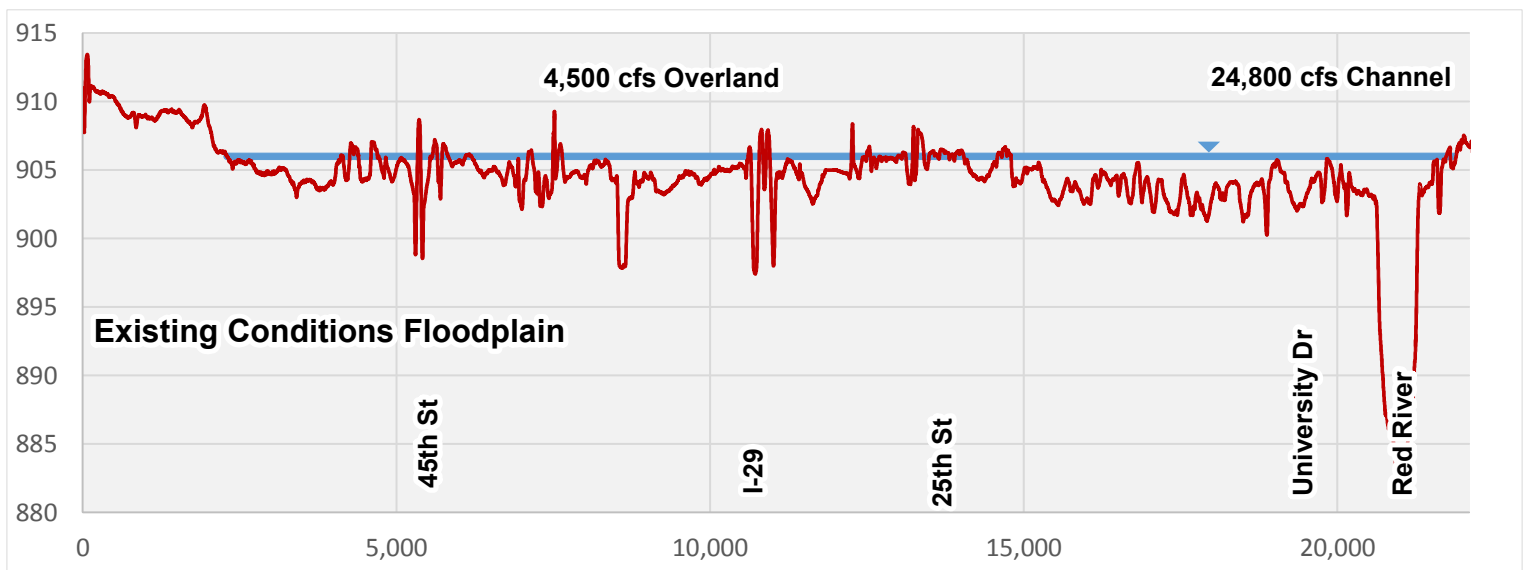
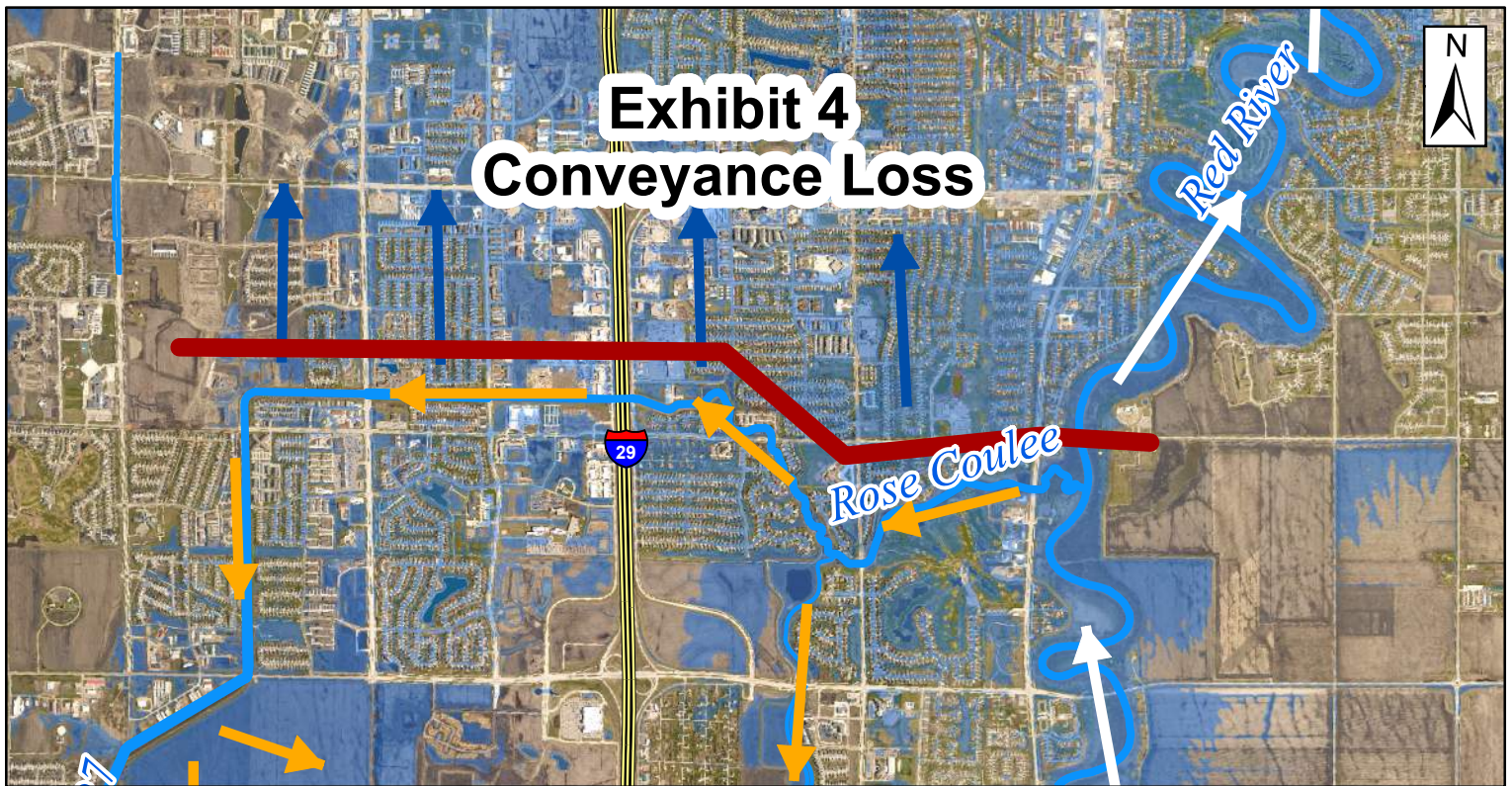


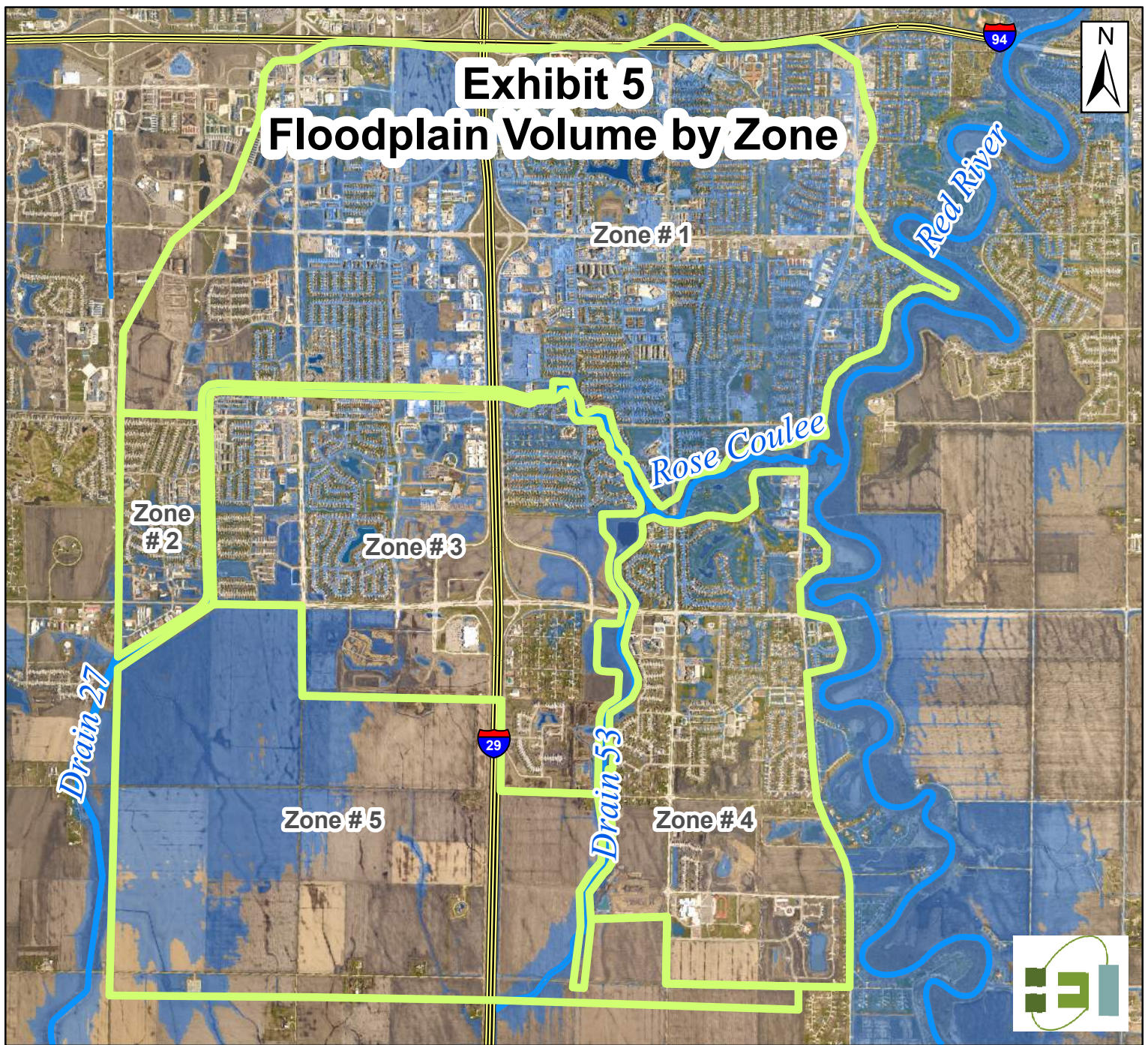


Exhibit 3

Existing Conditions and With-Project Floodplains







Zone 1 = 3,100 ac-ft

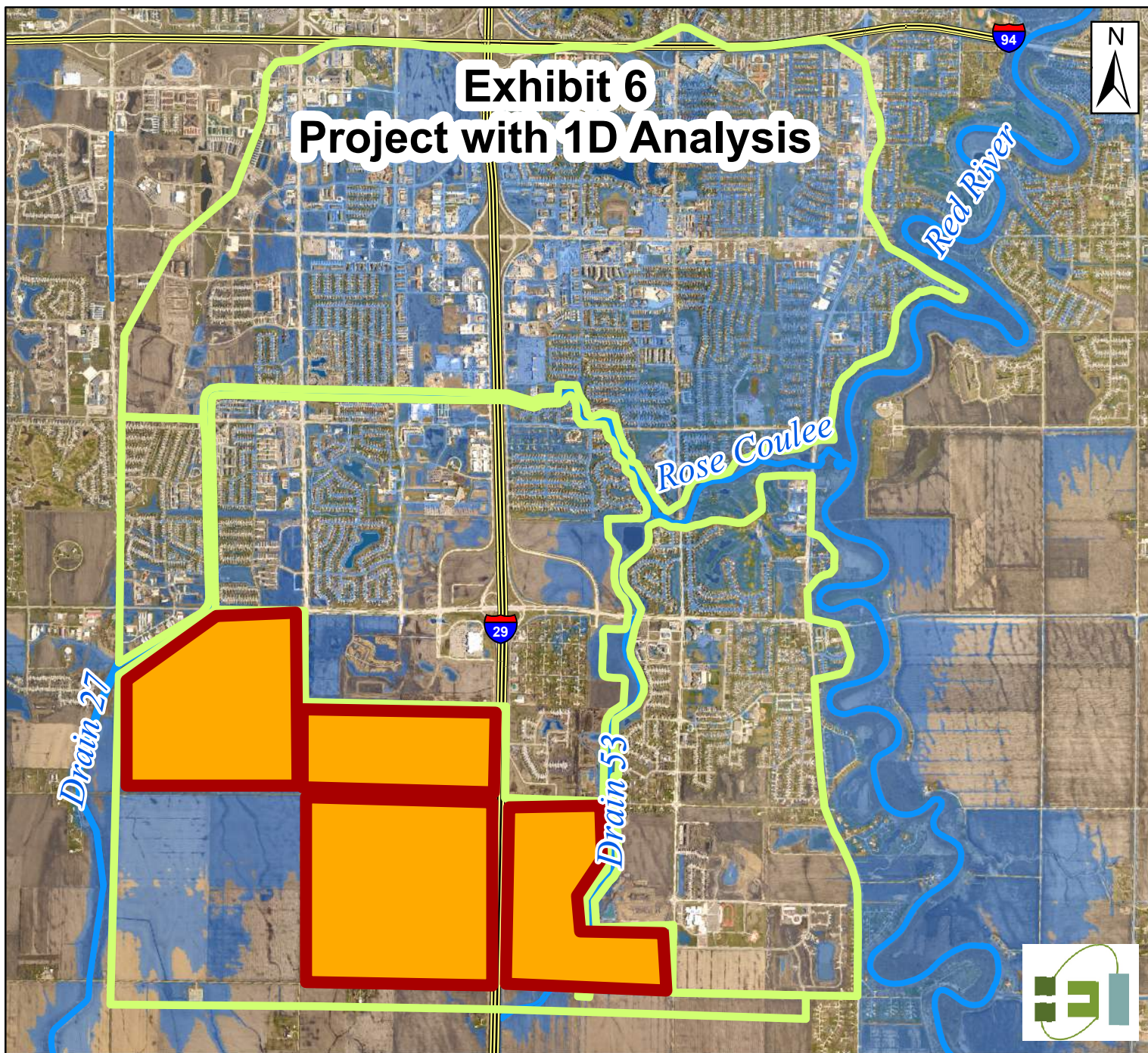
Zone 2 = 100 ac-ft

Zone 3 = 1,000 ac-ft

Zone 4 = 800 ac-ft

Zone 5 = 1,400 ac-ft

Total = 6,400 ac-ft



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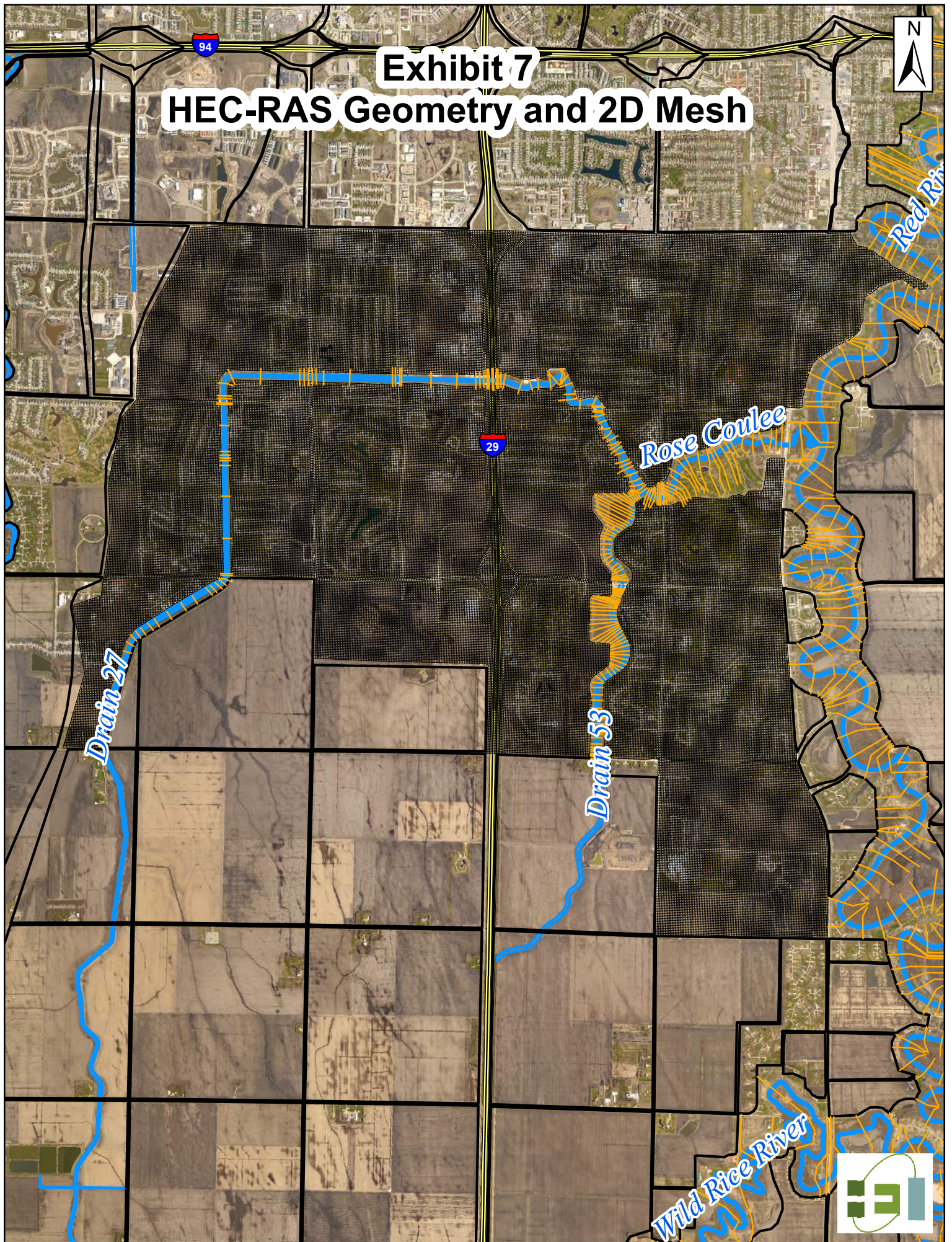
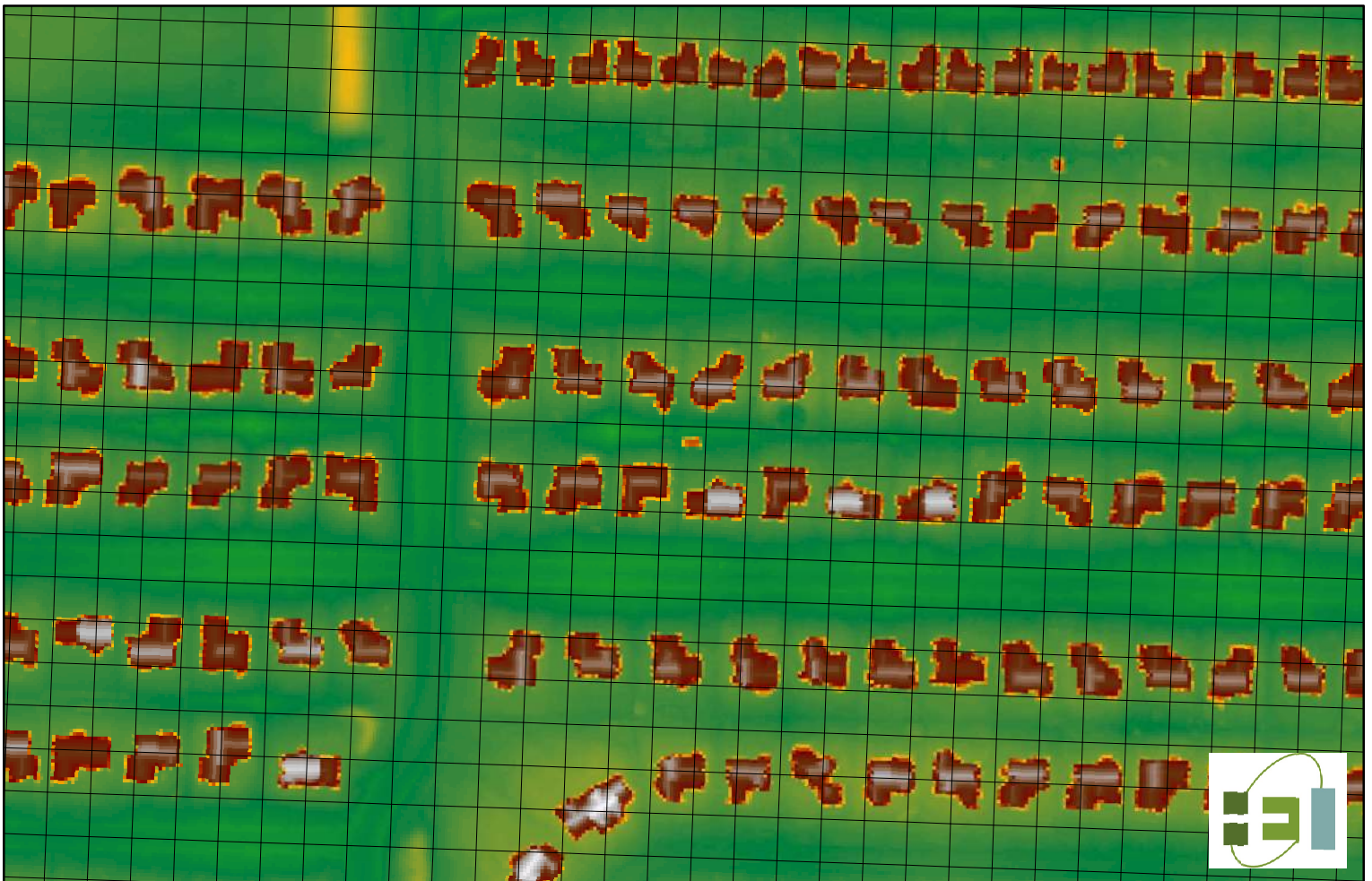
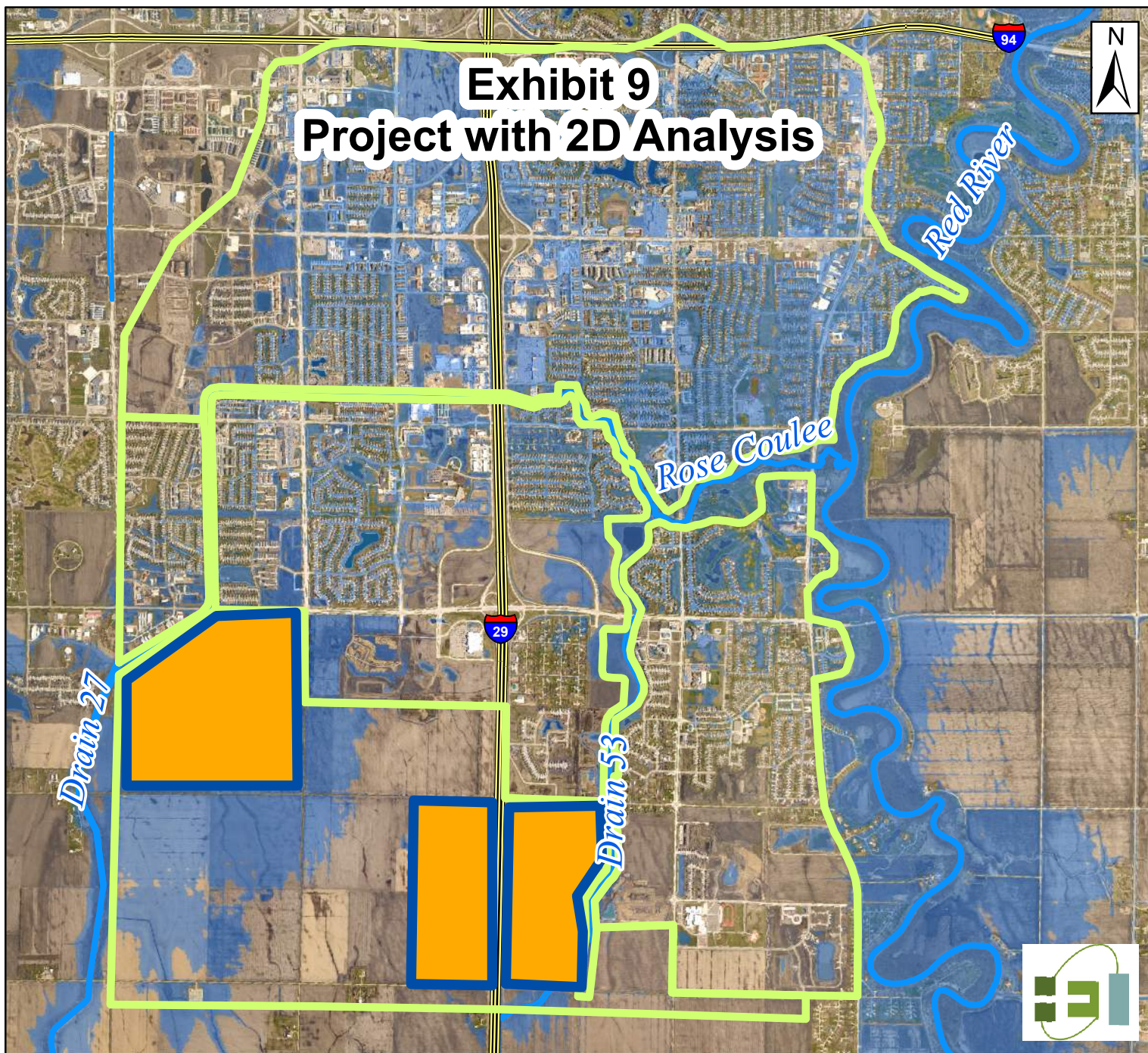


Exhibit 8 HEC-RAS 2D Mesh





20,000,000 CY Excavation
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1,100 Acres of Land

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Exhibit 10 - Red River and Wild Rice River Profile Impacts

