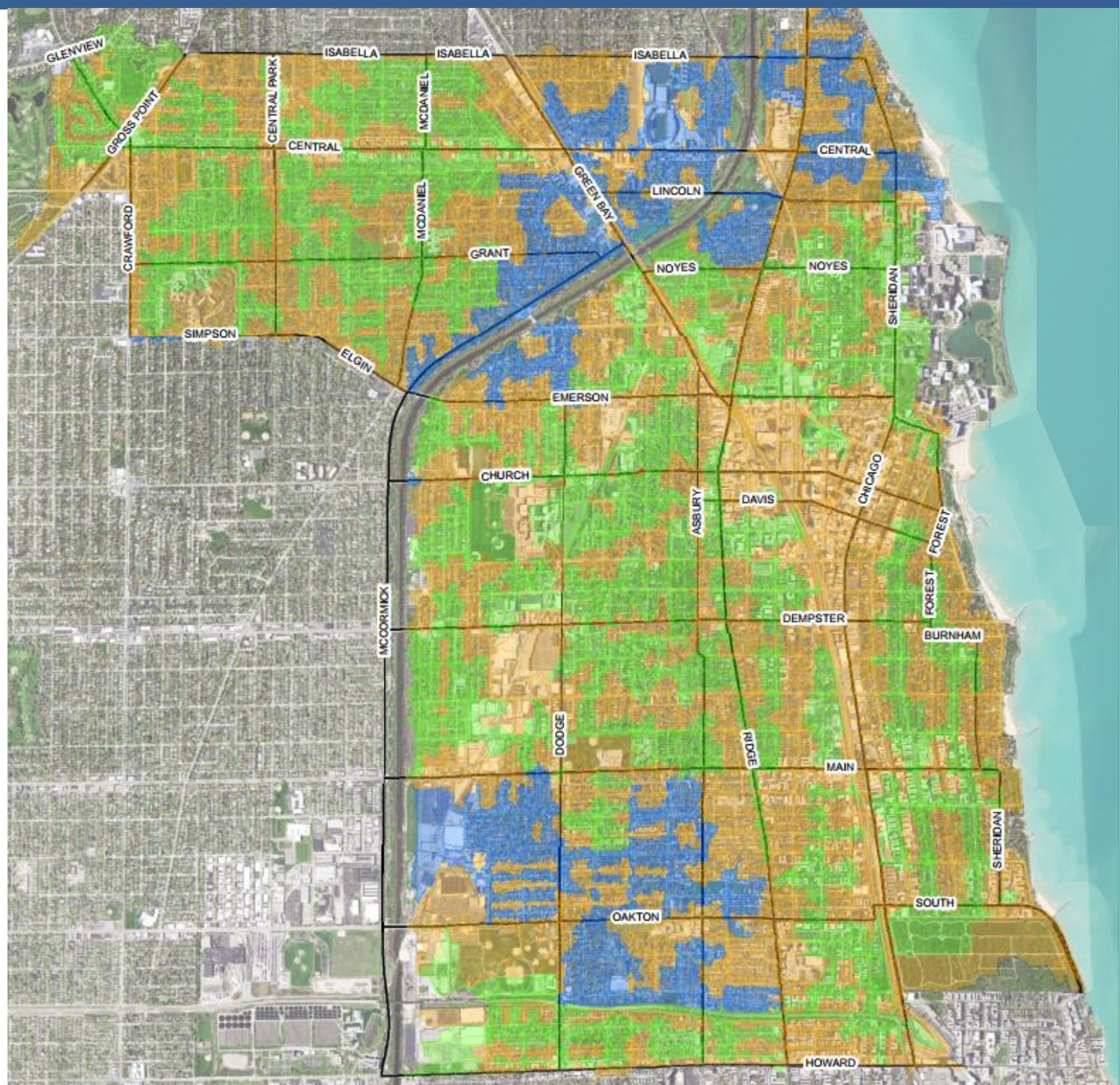
CITY OF EVANSTON
STORMWATER MANAGEMENT PLAN



City of Evanston™

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1. Executive Summary

1.1. Introduction

In 2019, Evanston prepared a Stormwater Management Guide (Guide) to identify the goals and approaches for managing the City's future stormwater needs. A key recommended action in the Guide was to prepare a Stormwater Management Plan based on detailed hydrologic and hydraulic modeling.

The main tasks involved in this study include:

- Data collection
- Model build
- Flow monitoring
- Model Calibration
- System Evaluation
- Improvement Development and Evaluation

The foundational task of this Stormwater Master Plan was to develop a detailed hydrologic and hydraulic model of the sewer system. The models prepared for this study include all public sewers and select private sewers when data was available. The existing system performance was evaluated, and identification and development of specific project capital improvements will be addressed using the information and tools developed by this study.

1.2. System Overview

The City of Evanston's sewers are a complex system of interconnected components comprised of private infrastructure and public infrastructure. While the City is responsible for a majority of the drainage system, private landowners control or own the sewers that discharge into the system, and the MWRD operates and can partially control the interceptor sewers, deep tunnel and North Shore Channel, which is downstream of the sewers operated by the City. There are parts of the system that are over a century old, while new components are continuously added through redevelopment and public infrastructure improvements.

The original combined sewer system consists of a series of street sewers and trunk sewers that are sub-divided into 15 drainage basins. Each combined sewer basin includes a separate trunk sewer and an independent connection to MWRD facilities, which directly discharge to the MWRD TARP deep tunnel system or are indirectly connected to TARP through the MWRD North Shore Intercepting sewer.

As part of the City's Long Range Sewer Program, the City supplemented the combined sewer system capacity with a series of relief sewers and storm sewers installed between 1991-2008. Restrictors are utilized in combined sewer drainage inlets/catch basins to reduce the risk of surcharging and basement back-ups during heavy rains. The relief sewer system is divided into seven drainage basins that have direct connections to TARP through drop shafts. The storm sewer system is divided into 10 drainage basins that discharge to the North Shore Channel or Lake Michigan.

1.3. Modeling

XPSWMM 2D was the modeling software selected for the Evanston Stormwater Master Plan. This model performs both hydrologic (rainfall and runoff) and hydraulic (flow overland and through sewers) computations. The City of Evanston was divided into three model areas, “Northwest”, “Southwest,” and “Main.”

The hydrology and hydraulic portions of the model were updated using 2017 Cook County LIDAR (Light Detection and Ranging) elevation data, City of Evanston sewer GIS database, as-built plans from the City and MWRD, and field verification. Design storm rainfall depths were based on the values provided in Bulletin 75 (*Precipitation Frequency Study for Illinois, Illinois State Water Survey, 2020*). Two historical storms were included, September 13, 2008 and April 17, 2013. According to Intergovernmental Panel on Climate Change (IPCC) 2013 Summary for Policymakers, the frequency of large rainfall events may nearly double by the end of the 21st century.

1.4 System Evaluation

Flow monitors, level monitors, and rain gages were installed to calibrate the sewer system models. The monitoring duration was from May 15, 2021 – August 18, 2021. The two most significant rainfall events during the monitoring period occurred on June 20, 2021 and August 10, 2021 and these were used for calibration.

The calibration process revealed that there are significant discharges to the existing sewer system that are not limited by the inlet restrictors. Without detailed monitoring throughout the interior of the drainage system (not just the outfalls), there is no way to know at this time if the additional flow into the combined sewer system occurs from widespread inflow and infiltration, or from a number of historical developments that discharge unrestricted into the system. Using the calibrated model setup to evaluate the design storm events could result in overestimating stages and flows in neighborhoods that are well protected by inlet restrictors. Because the source of the additional flow is currently unknown, the inlet capacities were restored to their designed maximum flow rates when evaluating the system to determine system performance under design storms.

The XPSWMM models were used to analyze two historically significant storms. These events include the September 14, 2008 storm and the April 17, 2013 storm.

The three models for the City of Evanston were used to evaluate the system response to a variety of rainfall depths and durations. The design storms were based on Bulletin 75 and were evaluated using the 2-, 5-, 10-, 50- and 100-year storm events. In general, the drainage system is critical for the 2-hour duration. The 2-hour storm should be used to evaluate flooding that results from the portion of the system owned and controlled by Evanston, as these facilities will be overwhelmed by a shorter duration event. The 12-hour storm was evaluated in conjunction with a high tailwater condition in the MWRD interceptors, MWRD TARP, and the North Shore Channel to represent a longer, more regional storm event where the capacity of those outfalls to receive discharge from Evanston is very limited.

Sewer surcharge risk was assessed using the hydraulic grade line elevation of the local sewer compared to a typical depth at which basement flooding would be expected to occur. The sewer surcharge performance criterion used was four feet below the rim of the sewer structure. The level of service for sewer surcharging varies across Evanston and is summarized in Table 1.1.

Table 1.1. Sewer Surcharge Risk Results Summary Table

Model Area	% Nodes with Hydraulic Grade Line within 4' of Street Surface				
	2-year Storm	5-year Storm	10-year Storm	50-year Storm	100-year Storm
Main	36%	54%	66%	75%	77%
Northwest	0%	14%	21%	37%	49%
Southwest	7%	10%	11%	21%	23%

Surface flooding risk is predicted when inundation for flood surface areas would threaten a structure. A depth of six inches or greater intersected with the limits of a building was identified as a structure with potential surface flooding risk. It is summarized in Table 1.2.

Table 1.2. Surface Flooding Risk Results Summary Table

Model Area	Buildings with Surface Flooding Risk	
	10-year Storm	100-year Storm
Main	32	138
Northwest	3	13
Southwest	6	16

There are two general conditions that can cause basement flooding in Evanston. The first is a lack of capacity in Evanston's local sewer system. This occurs during short duration, intense rainfall events that exceed the capacity of the system to convey the flows to the MWRD interceptors, TARP, and the CSOs. This condition was represented by the 2-hour duration.

The second scenario is a longer, more regional storm event where the capacity of MWRD outfalls is limited and the North Shore Channel elevations are high. While the overall system is better than for the short duration storm, there are several areas of the City that experience higher sewer surcharging risk in the longer duration storm.

1.5 Stormwater Management Recommendations

Stormwater management program recommendations have been prepared in three categories: Regulatory Program, Private System, and Public System. Table 1.3 summaries the recommendations in each category.

Table 1.3. Stormwater Management Recommendations

City of Evanston Stormwater Management Program Recommendations		
Regulatory	**Private System**	**Public System**
• Detention requirements • Private property plumbing code requirements • Property Transfer Inspections	• Overhead sewers • Sanitary sewer backup prevention • Sump pumps • Lot drainage • Floodproofing	• Capital Improvements • Combined Basin 07 Sewer Improvement Concept • Southwest Surface Flooding Concept • Green Infrastructure Program • Sewer System Monitoring

Evanston has adopted a number of regulations that govern stormwater management and drainage in the city. Updates to various regulations pertaining to stormwater can be strengthened to provide short- and long-term improvements.

The City could update their regulations to include the following for detention regulation:

- Consider stormwater performance criteria for single residential lots;
- Require detention for buildings smaller than 5,000 square feet;
- Require detention for parking lot resurfacing;
- Modify fee-in-lieu program to include residential lots;
- Update stormwater control fact sheet.

The City could update their private property plumbing code to include the following requirements:

- Require backflow preventers or overhead sewers for building additions or improvements;
- Require downspout and sump pump disconnection for building additions or improvements;

The City could investigate the ability to create and enforce the necessary procedures or forms to implement the following recommendations.

- Require backflow preventers/overhead sewers for sales of homes.
- Require basement flooding inspection/remediation at point of sale for homes.
- Require downspout disconnection at point of sale for homes.
- Require inspection of lateral sewer at sales of homes.
- Required inspection of sump pump.

There are multiple options available for property owners to improve their level of protection against flooding of their home. These can include the following:

- Overhead sewers
- Sanitary sewer backup prevention

- Sump pumps and roof drains
- Lot Drainage
- Floodproofing/waterproofing

Recommendations and future improvements to the public sewer system include capital improvements, green infrastructure, and sewer monitoring. Several policies could be considered with regard to the public system.

Capital improvement projects will be needed to improve system performance in areas that experience repeated flooding or for areas where surface flooding inundation risk has been identified. Types of improvements could include:

- Sewer capacity improvements
- Outlet improvements or modifications
- Detention or flood storage basins
- Green infrastructure

Combined Sewer Basin 07 was analyzed for opportunities to reduce sewer surcharging risk, specifically along Darrow Ave. A conceptual solution for this area included increasing the sewer capacity along Darrow Ave. and Emerson St. and reconfiguring the outfall to TARP. This conceptual improvement represents the types of solutions that should be possible to identify and implement for areas of localized flooding or underperforming sewers.

The southwest area of Evanston was analyzed for opportunities to reduce surface flooding. In order to alleviate the surface flooding in this area, the stormwater infrastructure will need to provide the 100-year, overland flow capacity in a pipe system since an overland flow path is not available. In order to reduce the flood risk in the 100-year storm the conceptual improvement would require approximately 8,000 feet of trunk sewer, 2,000 feet of local sewer, and a high capacity inlets into the system.

Green infrastructure is a way of managing stormwater that filters and absorbs stormwater where it falls, instead of using grey infrastructure to move the stormwater away. Green infrastructure is one way to provide resilience to the stormwater system as well as having environmental, social, and economic benefits. Evanston currently has a green building ordinance that provides credit for installation of BMPs, but standards could be developed for public projects. Accounting for additional stormwater capture in green infrastructure can help alleviate the impact of future potential increases in rainfall. Providing and promoting stormwater runoff volume capture can provide a cumulative benefit over time to the City's overall stormwater peak runoff while improving water quality.

The City should acquire and install additional water level meters at locations of interest or in priority project areas. These meters are low cost, battery operated, relatively simple to install, and can be deployed for months at a time. They can also be easily moved and operated at new locations of interest.

2. Introduction

2.1. Background

The origins of the City of Evanston's sewer system can be traced back to the 1880's. It is no wonder that after more than 140 years, the sewer system is now a complex system of interconnected components that work to manage both sewage and stormwater. It is not surprising that over this time, the goals and objectives for operating the sewer system have also evolved. The earliest sewers were designed and intended primarily to improve public health. We now expect the sewer system to protect public health, protect water quality and the environment, and prevent property damage caused by flooding.

Almost since its founding, there have been ongoing efforts to improve and expand the drainage system in Evanston. Some of these undertakings were very significant projects such as the construction of the North Shore Channel in the early 1900's, the Metropolitan Water Reclamation District's (MWRD's) Tunnel and Reservoir Plan (TARP or "Deep Tunnel") started in the 1970's, and Evanston's relief sewer program started in the 1980's. While these projects represent the largest investments made in the system, countless smaller street projects completed as the City developed and redeveloped are responsible for the majority of today's sewer system.

Typical approaches to drainage design in the mid-20th century did not result in a system capable of providing the desired level of service. As a result, many communities have needed to reinvest in their drainage systems over the last 30 years. However, climate change is now posing new challenges. The intensity and frequency of severe storm events are increasing compared to just several decades ago.

2.2. Purpose

In 2019, Evanston prepared a Stormwater Management Guide (Guide) to identify the goals and approaches for managing the City's future stormwater needs. A key recommended action in the Guide was to prepare a Stormwater Management Plan based on detailed hydrologic and hydraulic modeling. A detailed understanding of the system is needed in order identify recommendations to meet the desired performance goals now and into the future.

2.3. Scope and Approach

The main tasks involved in this study include:

- Data collection
- Model build
- Flow monitoring
- Model Calibration
- System Evaluation
- Improvement Development and Evaluation

The foundational task of this Stormwater Master Plan was to develop a detailed hydrologic and hydraulic model of the sewer system. While there were some modeling efforts completed in the early 1990's in support of the relief sewer program, there had never been a comprehensive system modeling effort. The models prepared for this study include all public sewers. When data was available, select private sewers, particularly for larger developments were also included in the model. The existing system performance was evaluated. This Stormwater Management Plan concludes with identification of conceptual improvements and recommendations for the stormwater management program. Identification and development of specific project capital improvements will be addressed using the information and tools developed by this study.

2.4. Evanston Drainage System Overview

The City of Evanston's sewers are a complex system of interconnected components comprised of private infrastructure and public infrastructure. While the City is responsible for a majority of the drainage system, private landowners control or own the sewers that discharge into the system, and the MWRD operates and can partially control the interceptor sewers, deep tunnel and North Shore Channel, which is downstream of the sewers operated by the City. There are parts of the system that are over a century old, while new components are continuously added through redevelopment and public infrastructure improvements.

The City Code defines the City Sewer System as:

> "The networks of closed pipes, conduits, and drainage structures within the city which consists of three (3) operational parts: the storm sewer system, which conveys storm water only; the combined sewer system, which conveys a combination of storm water and wastewater; and the relief combined sewer system, which conveys storm water during most ordinary rainfall events, until the combined sewer system capacity is reached, at which point the combined sewer system discharges into the relief combined sewer system."

The original combined sewer system consists of a series of street sewers and trunk sewers that are sub-divided into 15 drainage basins. Each combined sewer basin includes a separate trunk sewer and an independent connection to MWRD facilities. Some of these basins directly discharge to the MWRD TARP deep tunnel system through drop shafts, while others are indirectly connected to TARP through the MWRD North Shore Intercepting sewer.

The newer relief and storm sewer systems relieve the combined sewers by providing additional hydraulic capacity during wet weather. Restrictors are utilized in combined sewer drainage inlets/catch basins to reduce the risk of surcharging and basement back-ups during heavy rains. Excess runoff reaches relief and storm sewer inlets by overland flow, and any runoff that is beyond the capacity of the relief and storm sewer systems is temporarily stored within the curb line of the streets.

As part of the City's Long Range Sewer Program, the City supplemented the combined sewer system capacity with a series of relief sewers and storm sewers installed between 1991-2008. The relief sewer system is divided into seven drainage basins that have direct connections to TARP through drop shafts. The storm sewer system is divided into 10 drainage basins that discharge to the North Shore Channel or Lake Michigan.

A summary of pipe lengths and sizes in the City's sewer systems include:

- Combined Sewer System – 144 miles of pipe ranging from 6" to 72" diameter
- Relief Sewer System – 55 miles of pipe ranging from 6" to 120" diameter
- Storm Sewer System – 16 miles of pipe ranging from 8" to 60" diameter

3. Modeling Approach and Methodology

3.1. Introduction

XPSWMM 2D was the modeling software selected for the Evanston Stormwater Master Plan. XPSWMM 2D is a comprehensive software package for dynamic modeling of stormwater, sanitary or combined systems, and river systems. This model performs both hydrologic (rainfall and runoff) and hydraulic (flow overland and through sewers) computations. Evanston has a large number of restricted inlets that are intended to reduce the flow of water into the combined sewer system and instead create surface flow to relief sewer inlets. Due to the high degree of interaction between the surface flow and the underground sewer system, the modeling software for this project needed both 1D and 2D hydraulic analysis capabilities. For the hydraulics component, the program utilizes a traditional 1D (one-dimensional) pipe network to represent sewers and a digital elevation model (DEM) to represent surface flow and surface storage. The 2D (two-dimensional) portion of the model greatly simplifies the construction of the model while vastly improving the level of detail included in the model. Also, instead of simply depicting the limits of flooding or ponding, the model animates the movement of stormwater runoff and overland flow across the ground surface to allow for greater detail and understanding of how and why certain areas flood. Other benefits of XPSWMM include that it based on EPA SWMM as developed by the United States Environmental Protection Agency (USEPA) and is approved for use by the Federal Emergency Management Agency (FEMA), having met the minimum requirements of the National Flood Insurance Program (NFIP).

3.2. Hydrology

3.2.1. Catchment Delineation

The model uses catchments or subbasins to define the area that drains to each node that is represented in the drainage system. Each node in the model represents a point where runoff may enter a combined sewer, storm sewer or relief sewer. The sources of data used for the delineation of catchments included the 2017 Cook County LIDAR (Light Detection and Ranging) elevation data and the City of Evanston sewer GIS database. The Environmental Systems Research Institute's (ESRI's) ArcHydro toolbox was used to automatically process the delineation to each city-owned open sewer structure in the Evanston GIS database. Approximately 9,500 catchments were delineated. Refinements were made to the automatically delineated basins using aerial imagery, the Village of Wilmette sewer GIS data, detention information provided by Evanston, and as-built plans for private developments and the City of Evanston's sewer projects. The Village of Wilmette sewer GIS data was used to represent structures and pipes that are near the border of the two communities. The catchment delineations are shown in Exhibit 3.1. Catchments are depicted based on the type of sewer they drain to – combined (orange), storm (blue), or relief (green).

3.2.2. Hydrologic Parameters

The Soil Conservation Service (SCS) Runoff Curve Number method was selected as the method for estimating rainfall excess (runoff) from rainfall. The SCS method is a common method for estimating excess rainfall runoff, and input parameters are time of concentration, runoff curve numbers, and watershed drainage areas. The SCS method allows the use of different rainfall distributions for different storm durations. The SCS method was chosen because it is suited to generating hydrographs for individual sub-areas, combining them, and then routing them through conduits and storage facilities. This method is also by far the most commonly used approach in northeastern Illinois, with practitioners and regulators both having strong familiarity with it. The sections below describe how the input parameters needed for this method were calculated.

3.2.2.1. Curve Number

The Runoff Curve Number (CN) is a coefficient that can be used to estimate runoff potential based on land use and the hydrologic characteristics of the underlying soil. The Curve Number was calculated for each catchment using land use and soil classification data. The City of Evanston provided GIS data for the impervious area in the city (including buildings, garages, decks/patios, street outlines, and parking lots). The overall imperviousness of the city was estimated to be 33%. All impervious areas were assigned a curve number of 98. For pervious areas of the city, the curve number was assigned based on the hydrologic soil group, and ranged from 74 to 80 depending on surface type and soil group. The source of the soil classification data was the Natural Resources Conservation Service (NRCS) Web Soil Survey as accessed on January 21, 2021. Adjustments to the initial CN values were later made during the model calibration process.

3.2.2.2. Initial Abstraction

The initial abstraction (I_a) represents all losses before runoff begins including water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. The commonly used default value for the I_a parameter is 0.20. We have found that this value can overestimate retained water, particularly in urban systems with high amounts of directly connected impervious area. This parameter was reduced to 0.05 during the calibration process.

3.2.2.3. Dry Weather Flow

Dry weather flow represents flow in the system that results from human activity and is defined as the flow that exists during rainless periods. The flow can be composed of domestic, commercial, industrial, or institutional waste. Dry weather flow was assigned to the combined sewer basins based on an average flow rate derived from the monitoring data. The measured dry weather flow was prorated to constant flow inputs to all combined sewer mainline nodes. Flow loadings ranged from 0.003 to 0.007 cfs per node.

3.2.2.4. Time of Concentration

The Time of concentration (Tc) represents the total travel time of water from the most remote point in a sub-basin to the sub-basin outlet. Tc can include overland flow, shallow concentrated flow, and channel flow. To calculate the Tc, the ESRI ArcHydro toolbox was used to calculate the length of the longest flow path and the slope. Assumptions were made for the minimum slope, the sheet flow length, the sheet flow Manning's roughness coefficient, and the shallow concentrated length. With this data, the Tc was calculated for each of the catchments. Tc ranges from 5 minutes to 42 minutes.

3.2.3. Precipitation

Precipitation depths are a key input parameter used in the model to evaluate the stormwater management system. For the historical storms and the calibration storms, hourly rainfall records were used to create precipitation input files. Design storm rainfall depths were based on the values provided in Bulletin 75 (*Precipitation Frequency Study for Illinois, Illinois State Water Survey, 2020*).

3.2.3.1. Historical Storms

In addition to storms that occurred during the monitoring effort, two notable historical storm events were modeled to compare results to historical observations. Hourly rainfall records were provided by MWRD from the Wilmette-Lake Gage and the O'Brien plant gage. These two storms are:

September 13, 2008 – This is a regionally significant storm that occurred as a result of Hurricane Ike. The most intense period of rain started at 1:00 am on September 13 when 7.66 inches of rain fell over 38 hours. The rainfall total represents a 25-year to 50-year, 48-hour storm. The maximum 24-hour rainfall in Evanston during this storm was 6.29 inches, which is between a 10-year and 25-year storm. Peak rainfall totals for durations less than 6 hours that occurred during this event are below the 25-year design storm.

April 17, 2013 – This storm event started at 10:00 am on April 17 and lasted until 12:00 pm on April 18. A total of 4.83 inches fell during this event. The maximum 24-hour rainfall was 4.75 inches, which is between a 5-year and 10-year storm. Peak rainfall totals for durations less than 6 hours that occurred during this event are below the 5-year design storm.

3.2.3.2. Design Storms

Rainfall depths, durations and distributions were based on Bulletin 75. The drainage system existing conditions were evaluated using the 2-, 5-, 10-, 50- and 100-year storm events. The 1-hour through 24-hour storm durations were used to determine the critical duration of the system. The 1-hour through 6-hour storms used the Huff distribution, Quartile 1 for less than 10 square miles. The 12-hour storms used the Huff distribution, Quartile 2 for less than 10 square miles. The 18-hour to 24-hour storms used the Huff distribution, Quartile 3 for less than 10 square miles. In general, the drainage system is critical for the 2-hour duration. This means the system produces the highest flows and stages for a storm duration of 2 hours. While the 1-hour storm is slightly more intense than the 2-hour storm, it does not produce as much runoff as the 2-hour storm. The total rainfall depths increase as the design event durations get longer, but the rainfall intensities become lower and the urban system is more capable of handling the rate of runoff. For some areas that may be sensitive to higher volumes, such as depressional flooding areas, the 12- or 24-hour storms may be critical. When system improvements are designed, the full range of durations is checked again to ensure that the performance objectives are achieved across all event durations.

In order to provide historical context for the Bulletin 75 rainfall depths, an historical hourly rainfall record was evaluated for each depth and duration used in the study. The final column of the precipitation summary table identifies the number of times the design storm depth was exceeded during 20 years of recorded rainfall at O'Hare Airport.

Table 3.1. Summary of Design Storms

Return Period	Duration (hours)	Depth (inches)	Number of times exceeded at O'Hare gauge in last 20 years
2-year	2	1.94	9
5-year	2	2.49	2
10-year	2	2.99	1
50-year	2	4.35	1
100-year	2	4.97	1
10-year	12	4.48	3
100-year	12	7.46	0

3.2.3.3. Future Rainfall Projections

The Bulletin 75 Precipitation Frequency Study for Illinois was published in 2020. This document provided updated design storm guidance that was adopted in May 2020 by the MWRD for use in Cook County. Bulletin 75 rainfall depths increased by 8% to 17% with an average increase of 14%. When applied in a hydrology and hydraulics study of an urban drainage system, a 14% increase in rainfall can generate a 20% increase in runoff. When the total precipitation in larger rainfall events increases, the incremental precipitation is almost all converted to runoff. This explains why the increase in runoff is higher than the increase in precipitation for those events.

As shown in Figure 3.1, the predicted frequency of Bulletin 70 rainfall depths has approximately doubled under Bulletin 75. For example, the Bulletin 70 100-year, 24-hour rainfall depth now corresponds to the Bulletin 75 50-year, 24-hour rainfall depth. A system that was designed for Bulletin 70 rainfall data can now be assumed to be inadequate to handle the runoff for Bulletin 75 rainfall.

The Bulletin 75 rainfall values represent the best available information to determine flood risk as of today. When looking at the frequency of actual rainfall over the last 20 years in Table 3.1, they appear quite close to what might be expected. Many agencies expect heavy rainfall depths and frequencies to continue increasing in the Midwest.

The Intergovernmental Panel on Climate Change (IPCC) 2013 Summary for Policymakers reports that "The frequency or intensity of heavy precipitation events has likely increased in North America and Europe," and predicts that "Extreme precipitation events over most of the mid-latitude land masses and over wet tropical regions will very likely become more intense and more frequent by the end of this century, as global mean surface temperature increases." The IPCC report forecasts that "Based on a range of emissions scenarios, a 1-in-20-year annual maximum daily precipitation amount is likely to become a 1-in-5 to 1-in-15-year event by the end of the 21st century in many regions, and in most regions the higher emissions scenarios lead to a stronger projected decrease in return period."

The primary results of this study have been prepared using a range of return periods and rainfall depths as provided by Bulletin 75. As stated above, the frequency of large rainfall events may nearly double by the end of the 21st century. A future scenario 5-year event may be closer to the current 10-year event. If this approach is applied to the Bulletin 75 rainfall depths, rainfall depths do in fact increase about 15% to 20% for each doubling of the event frequency. As study results are evaluated, future scenarios representing the end of the 21st century can be estimated by considering the full range of results.

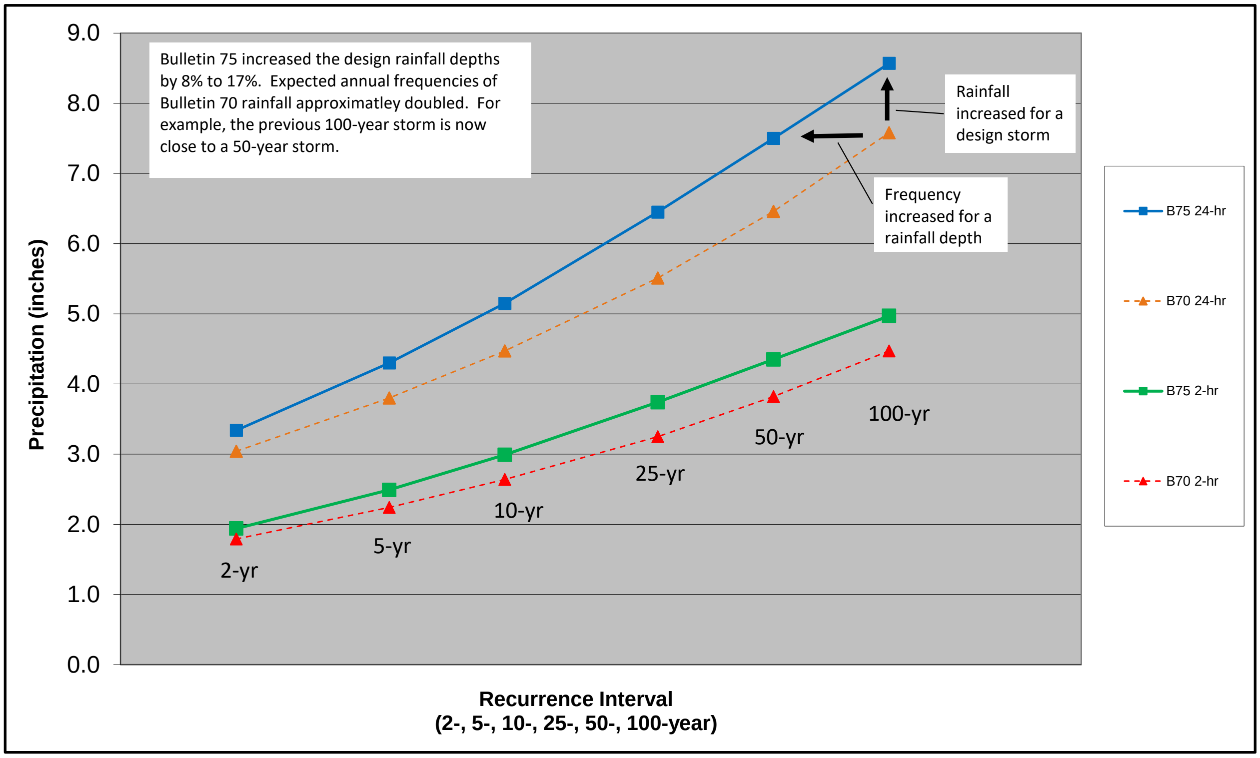


Figure 3.1. Bulletin 70 and Bulletin 75 Design Rainfall Depths.

3.3. Hydraulics

The City of Evanston was divided into three model areas as shown in Exhibit 3.2. The dividing lines for the models were selected so that there would be minimal exchange of flow between models. The "Northwest" model is bounded by the city limits on the north, west, and south and the North Shore Channel is the boundary for the southeast edge of the polygon. The "Southwest" model is bounded by the North Shore Channel to the west, roughly along Lee St to the north, Ridge Ave to the east, and Howard St to the south (the southern border of Evanston). The "Main" model included the rest of Evanston and is the largest of the three models.

3.3.1. 1D/2D Model Build

The 1D component of the model explicitly includes all pipes in the Evanston GIS database that are categorized as main line pipes (approximately 7,000 pipe segments). This information was imported to the XPSWWM model from Evanston's GIS data. After the information was imported, the model was reviewed and missing data was filled in either using appropriate assumptions or through obtaining additional data (field data, as-built plans, etc.). The connecting pipes (referred to as outfall pipes in the Evanston GIS database) are the generally short segments of smaller diameter pipe that connect the inlets and catch basins to the main line sewer. All connecting pipes are represented in the model, but not as individual pipes. Instead, connecting pipes located in close proximity to each other were grouped together and represented as a single, composited conduit. The process for grouping the inlets and connecting pipes is described in further detail in the Representation of Inlets section below.

The datasets necessary to execute the 2D portion of the XPSWMM model were prepared from Evanston's existing GIS data. The source of the elevation data for the 2D grid was the 2017 Cook County LIDAR. The surface elevation data was converted to the City of Evanston Datum (ECD). The at-grade land cover data in the Evanston GIS database was used to assign the Manning's Roughness coefficient for the overland surface flow.

3.3.2. Data Collection

The primary data source for the model hydraulics was the Evanston GIS database. This dataset was supplemented with additional sources, such as the Evanston as-builts and MWRD plans, when the values in GIS were missing or seemed unreasonable. The Village of Wilmette and Northwestern University also provided GIS databases that were used as a source of data for the hydraulic model inputs.

3.3.2.1. Evanston As-builts

Evanston as-built plans were an additional source of information that was used to supplement the Evanston GIS database. As-built plans were primarily reviewed for the long-range sewer projects previously implemented to construct Evanston's relief sewer system. Additional plans included smaller sewer projects that have been completed by Evanston (Figure 3.2).

Figure 3-2. Typical as-built plan for relief sewer system.

3.3.2.2. MWRD

The Metropolitan Water Reclamation District of Greater Chicago (MWRD) was contacted to obtain plans and information for MWRD sewers and facilities in Evanston. Plans for the Tunnel and Reservoir Plan (TARP), MWRD interceptor sewers, the North Shore Channel, and the Evanston Pumping Station were received from MWRD. For select larger development sites, MWRD was also able to provide the permit submittal and approved development plans. In some cases, these archived permits provided key information such as the location and type of connections to the sewer system and detention facilities.

The MWRD plans were particularly valuable for representing the more complicated special structures that connect to TARP and the MWRD interceptors. Exhibit 3.3 shows the location of MWRD interceptor sewers and TARP in Evanston.

3.3.2.3. Field Data

While the existing city GIS system contained extensive information on the existing sewer, it was known that this information was incomplete. The study approach included a planned field investigation effort to collect information at key locations. During the initial review of the GIS data, key locations in the system with missing data were identified for the field investigation. Field data was collected at these locations including measure-downs, pipe sizes, and pipe materials.

Figure 3.3. Typical manhole field inspection location.

3.3.2.4 Detention Storage and Private Development As-builts

As the modeling phase of the project progressed, it became clear that it would be important to obtain more information about the larger detention facilities and the drainage design for private developments. Evanston provided a list of sites that included the address, site area, and detention volume for developments where detention had been required. A limited number of private development as-built plans were obtained for larger or complex sites from both Evanston and the MWRD.

3.3.3. Representation of Inlets

Inlets and catch basins in close proximity, such as across the street from each other, or clustered around an intersection, were grouped together as one "inlet group." This group was then represented in the model as a single node and link. Inlets were grouped to decrease the total number of nodes in the model as a way of improving the computation time while still maintaining a high level of detail. Spreadsheet documentation on how the inlets were grouped is available. This backup will allow inlet groups to be easily separated in future studies if explicit structure representation is needed for an detailed area of interest.

The connecting pipes (referred to as outfall pipes in the Evanston GIS database) are the generally short segments of smaller diameter pipe that connect the inlets and catch basins to the main line sewer. The connecting pipes are all represented in the model, but not explicitly represented as individual pipes.

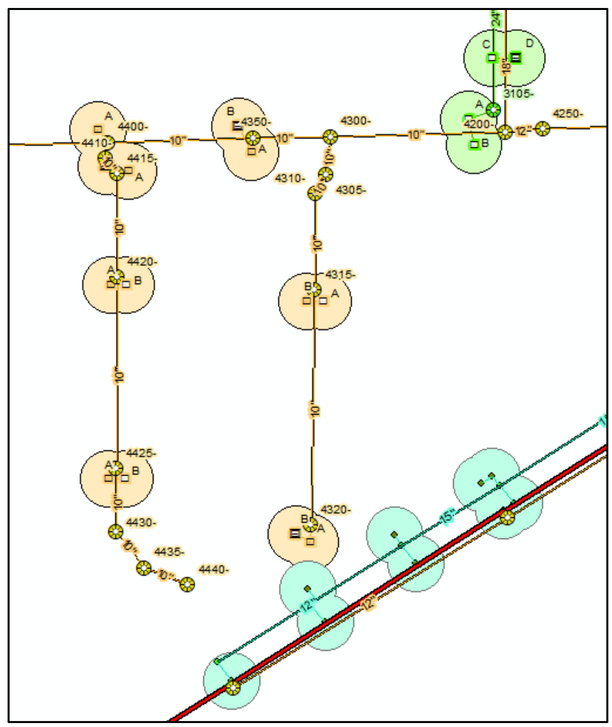


Figure 3.4. Representative Inlet groupings.

The node that represents each inlet group was selected by identifying the inlet that had the lowest rim elevation in the group. The inlet with the lowest rim was chosen so that water could move between the 2D surface and the 1D pipe network at the appropriate minimum elevation. The inlet capacity for the node was determined based on the number of restricted structures that were in the inlet group. The 2D inflow capture coefficient was updated based on the number of structures in the inlet group.

Each inlet group link was sized based on the combined conveyance capability of the inlets in the group. The two most common configurations of the inlets were a "z" shape (a pipe connects from one inlet to an inlet on the other side of the street which then connects to the main line) or a "v" shape that also has one inlet on each side of the street but both inlets connect directly to the main line. The "z" shape inlet group was represented with a link that was the equivalent of the pipe that connects directly to the main line. The "v" shape inlet group was represented with a link that had the equivalent diameter of the two pipes that both connected directly to the main line. A similar theory was applied to the other inlet group configurations to calculate the correct link inputs to represent the connection between the set of inlets in the group and the main line.

3.3.4. Boundary Conditions

For the XPSWMM 2D model, two types of boundary conditions were needed – one for the 1D component and another for the 2D component. For the 1D component of the model, an appropriate outfall condition was required for the most downstream nodes in the model. For the 2D component, at locations where overland flow reaches the edge of the 2D active area grid, a head/flow boundary condition was established.

Two different boundary condition scenarios were analyzed. The first condition assumed that elevations in the North Shore Channel and MWRD interceptors and TARP were low and those systems could receive free flow from Evanston. This condition was appropriate for smaller intensity events and events with short duration that stress the local sewer system before the larger diameter receiving sewers and river reach capacity. The second condition assumed that the elevations in the North Shore Channel were high and that the interceptors and TARP were full. This condition was used to evaluate how the local sewer system is impacted by high tailwater conditions.

3.3.4.1. 1D Boundary Conditions

The Evanston sewer systems discharge either to the Lake, an MWRD interceptor, TARP, or the North Shore Channel. There are a small number of locations where a storm sewer discharges to the Lake. At these locations, the outfall condition is set on the last segment of pipe or open channel (the Lake is not represented in the model). The MWRD interceptors, TARP, and the North Shore Channel were all represented in the 1D part of the model and were cut off just south of Evanston's southern border. Tailwater conditions were set for each of the three links in the model that represented the MWRD interceptor, TARP, and the North Shore Channel, respectively. The North Shore Channel was modeled as a trapezoidal conduit in the 1D model, and excluded from the 2D model surface. A 1D/2D interface boundary at the top of bank was provided for the excluded area.

The outfalls for the Northwest model included the MWRD interceptor, TARP, or the North Shore Channel. The Southwest and Main models had those three types of outfalls, but also had special boundary conditions along Lee St. and Main St. where the two models shared a border. An overlap area was included in each of the two models. The pipe outfall conditions were specified at the locations where there was a connection between the Southwest and Main models. There is one location that has significant flow from the Southwest Model into the Main model, located at the intersection of Cleveland Street and Dewey Avenue. Node C_S10_01080- in the Main model has the hydrograph from C_S10_01080-.2 in the Southwest model loaded as a user inflow.

In the scenario where the North Shore Channel and MWRD interceptors and TARP have available capacity the following tailwater assumptions were made:

- Sluice gates to MWRD are fully open and free flowing
- Unrestricted drop shafts to MWRD TARP are free flowing
- North Shore Channel elevation is at normal water level

In the scenario where the North Shore Channel and MWRD interceptors and TARP have limited capacity to receive water the following tailwater assumptions were made:

- Sluice gates to MWRD are closed
- Unrestricted drop shafts to MWRD TARP are unable to receive discharge due to high tailwater
- North Shore Channel elevation is at peak elevation

3.3.4.2 2D Boundary Conditions

For the 2D component, at locations where there is overland flow that reaches the edge of the 2D active area grid, a head/flow boundary condition was established. The head-flow boundary conditions were set with a slope representative of downstream conditions and extended the minimum distance beyond the community boundary. The limits of the 2D active grid area were set to ensure that the grid extended far enough so that it did not have a large impact on the inundation results within the study area. The North Shore Channel was excluded from the 2D model. A 1D/2D interface boundary was provided for the excluded area to allow it to overflow its banks.

3.3.5. Detention Facilities

Significant detention facilities were incorporated into the model. The locations of the storage were based on data received from MWRD and Evanston. Where the detention was above ground, the topography was used to represent the provided detention volume. For each detention basin that was added to the model, manual adjustments were made to one or more delineated catchments to create a new catchment for the permitted development. Forty-two detention facilities were included in the model, which represented over 80% of the detention storage that has been constructed in the city. There are approximately 85 additional smaller detention basins with an average storage volume of 0.15 acre-feet that were not included in the model because they would individually be less significant for the overall model representation of the system. Table 3.2 summarizes the detention facilities included in each model.

Table 3.2. Summary of modeled detention facilities.

Model	# Detention Facilities
Main	28
SW	7
NW	7

4. System Evaluation

4.1. System Monitoring, Model Calibration and Verification

4.1.1. System Monitoring

Monitoring was performed by ADS Environmental Services to collect data to calibrate the sewer system models developed for the Evanston Stormwater Master Plan. Three types of devices were installed: rain gauges, flow monitors, and level meters.

For the flow monitors, it was necessary to strike a balance between the duration that the flow monitors were installed (to increase the chance that a significant storm event would be captured) and the number of locations that could be monitored. When selecting the locations for the flow monitors, there were a number of factors considered, including drainage area, the size of the pipe, and the interaction/overlap between the combined, relief and storm sewer systems. Increasing the duration of the monitoring period was prioritized. However, the selected locations (generally near the downstream discharge point for a sewer basin area) still covered a high percentage of the total area of the city.

Twenty-three flow monitors were installed. With 23 monitoring locations, nearly all basin discharge locations with a drainage of area of 60 acres or more were monitored. One flow monitor was placed in a small drainage area (approximately 10 acres) to allow for analysis of hydrologic parameters at a smaller scale. The small drainage area was selected to represent the largest area possible that is drained by a single sewer type (combined) to a single monitoring location while also having a fairly typical residential land use.

The overflow pipes and summit manholes were not good candidates for locations for the flow monitoring devices, however in order better understand how these locations perform, two structures upstream of overflow pipes and two summit manholes were selected to have level monitors installed during the monitoring time period.

Exhibit 4.1 shows the locations of the monitoring equipment.

4.1.1.1 Monitoring Locations

4.1.1.1.1 Rain Gauges

Two rain gauges were installed during the monitoring period. One rain gauge was in northwest Evanston at 2700 Hurd Avenue. The other rain gauge was in southeast Evanston at 910 Forest Avenue. These rain gauges were used to augment data from the rain gauge at the Evanston water plant (located in northeast Evanston at 555 Lincoln St) as well as the Oakton College gauge in Skokie (to the southwest). Two MWRD-operated gauges at the O'Brien Plant and the Wilmette Pumping Station were referred to for additional insights into rainfall patterns during the monitoring period.

Exhibit 4.2 shows the location of all six rain gauges that were available for use in the study.

4.1.1.1.2 Flow Monitors

There were 23 locations selected for flow monitoring. These locations were selected so that monitors would be deployed at basin discharge locations that have a large area of drainage (60 acres or more). The 23 flow monitoring locations provide coverage for 86% of the combined sewer basins and 93% of the storm and relief sewer basins. In general, outfalls serving small areas were not monitored because of the favorable coverage achieved by the larger basins. However, one flow monitor was placed in a small drainage area (B13130000, approximately 10 acres) to allow for analysis of hydrologic parameters at a smaller scale. The small drainage area was selected to represent the largest area possible that is drained by a single sewer type (combined sewer) to a single monitoring location while also having a typical residential land use. The flow monitoring locations are shown on Exhibit 4.1.

During installation, a number of slight adjustments to the location of the flow monitors were made in the field. This step is regarded as a flow monitoring best practice and occurs after field personnel assess the field conditions of the selected locations. In some cases, the flow monitor was installed upstream or downstream of the originally selected location due to issues with accessing the structure or because of potential interference that could be caused by nearby hydraulic structures (a weir is one example). These adjustments were made with care to ensure that the flow monitor would still capture the flow from as much of the original drainage area as possible. There was one location (ADS gauge Evanston_S0901000) where the flow monitor could not be installed on the pipe that was originally selected because the pipe had conditions that would affect the accuracy of the readings - the downstream end transitioned from concrete pipe to corrugated metal and at the upstream end there was a weir. Upstream of the pipe that had been selected, the flow came into the structure from two pipes. In order to capture the entire flow at that location, there was one monitor installed in each of the two incoming pipes. This made it so that there were 24 pipe segments being monitored, representing 23 flow monitoring locations.

4.1.1.1.3 Level Monitors

Four level meters were installed in the B06 combined sewer drainage basin, which is overlapped by the S06 relief sewer drainage basin. Two of the level meters (Level 03 and Level 05) were installed at manholes where there was an overflow pipe that connects a combined sewer drainage basin to a relief sewer drainage basin. The water level at these locations determines when it is possible for there to be overflow from the combined to the relief system. Two of the level meters (Level 06 and Level 09) were installed in summit manholes (a manhole that is on the border between two sewer drainage basins – Level 06 was on the border of B06 and B04 and Level 09 was on the border of B06 and B05) to determine when the water level is high enough that it would be possible for water to be exchanged between the two drainage basins.

4.1.1.1.4 Demonstration Level Monitor

A demonstration level meter was installed to monitor possible surface flooding in the parking lot behind the businesses at 710 Main Street. It should be noted that this was an experimental installation that was included pro bono by ADS. This type of level meter is not intended to be installed in an exposed location where the temperature fluctuates due to the heat of the sun during the day and the cooler temperatures at night. The results show a few measured responses during rain events, but the dry weather data could be suspect due to the environmental conditions where the meter was installed.

4.1.1.2 Monitoring Period Duration

The monitoring duration was from May 15, 2021 – August 18, 2021. For the first part of the monitoring duration, the 5 monitors with locations in Metropolitan Water Reclamation District (MWRD) pipes were not yet installed. All of the monitors were installed during the time period from July 8, 2021 through August 18, 2021.

An overview of the data that was collected and an exhibit that shows the locations of the monitoring devices and the combined, relief, and storm basins that were monitored can be found in the ADS report that is included as Appendix 1. The report provides additional details and information about the monitors including the equipment, methodology, installation, and quality assurance. The ADS report includes graphs of the data collected at each location during the monitoring period.

4.1.1.3 Significant Rainfall Events

The two most significant rainfall events during the monitoring period occurred on June 20, 2021 and August 10, 2021.

June 20, 2021 – The rain started at 10:40pm on June 20, 2021 and continued until 12:35am on June 21, 2021. The rainfall totals from the different gauges employed at the time ranged from 1.45” to 2.05” over approximately two hours. The flood frequency for this event was a 1-year to 2-year storm. This was the largest rainfall event captured during the entire monitoring period. However, there were five flow monitors that were not yet installed when this event occurred.

August 10, 2021 – Rainfall started at 7:05pm and continued until 9:45pm on August 10, 2021. The rainfall totals from the different gauges employed at the time ranged from 0.91” to 1.14” over approximately three hours. The flood frequency for this event was a 3-month to 4-month storm. This was the largest rainfall that occurred with flow monitors installed at all 23 locations.

Data from these two events was used to calibrate the XPSWMM model developed for the study.

4.1.2. Model Calibration

The purpose of preparing the XPSWMM model for the city was to develop a tool that can be used for planning purposes, system evaluation and problem investigation. With such a complex stormwater management system, there is a range of uncertainty relative to various aspects of the modeling. Flow monitoring allows for the evaluation of this uncertainty. However, it does not always reveal exactly where the causes of the uncertainty lie. There are many thousands of data inputs and complex calculations required to represent physical processes as a numerical model. Several decades of modeling experience have led practitioners to develop standardized approaches for preparing the data sets used to construct a complex stormwater management model. Collecting monitoring data to calibrate the model is a key step in order to understand the model’s performance and ability to accurately simulate the drainage system.

In many stormwater studies, calibration may be performed at one or more locations that are primarily independent of one another. For this study, the monitoring location results are affected by both hydrologic and hydraulic model parameters, which can affect the routing of runoff over the surface and which sewer system ultimately collects or receives the stormwater runoff. Not only do the 23 flow monitoring locations cover many different outfalls in the city, the drainage systems leading to these outfalls are also interconnected in multiple ways.

In order to visualize the approach used to calibrate the models, a calibration flow chart was prepared as shown in Figure 4.1. Calibration data and calibration measures shown in the Figure 4.1 were evaluated, tested and utilized from top to bottom, following the path of runoff. The goal of the calibration effort was to make adjustments to the model parameters to generate the best possible results to match the flow monitoring data. There is no universal standard for this type of model calibration. Frequently used targets range from +/- 10% to /-25% and are highly specific to the model and modeling purpose. In order to evaluate performance for the Evanston models, target ranges of +/-20% for peak flow rate and runoff volume were selected. Calibrating an urban stormwater model with interconnected systems to multiple targets is much more complex than calibrating a watershed to a single gauge. With 23 locations and two storm events, it was almost a certainty that the best possible outcome with this level of modeling detail and effort would involve some locations falling outside the target range. Further changes that would be applied to the models on a uniform basis would push one location or another into or out of the target range. Specific outfalls that didn't meet the target represent locations where there is higher uncertainty in the model. Discussion of the calibration and implications for the use of the model to evaluate the system are included below.

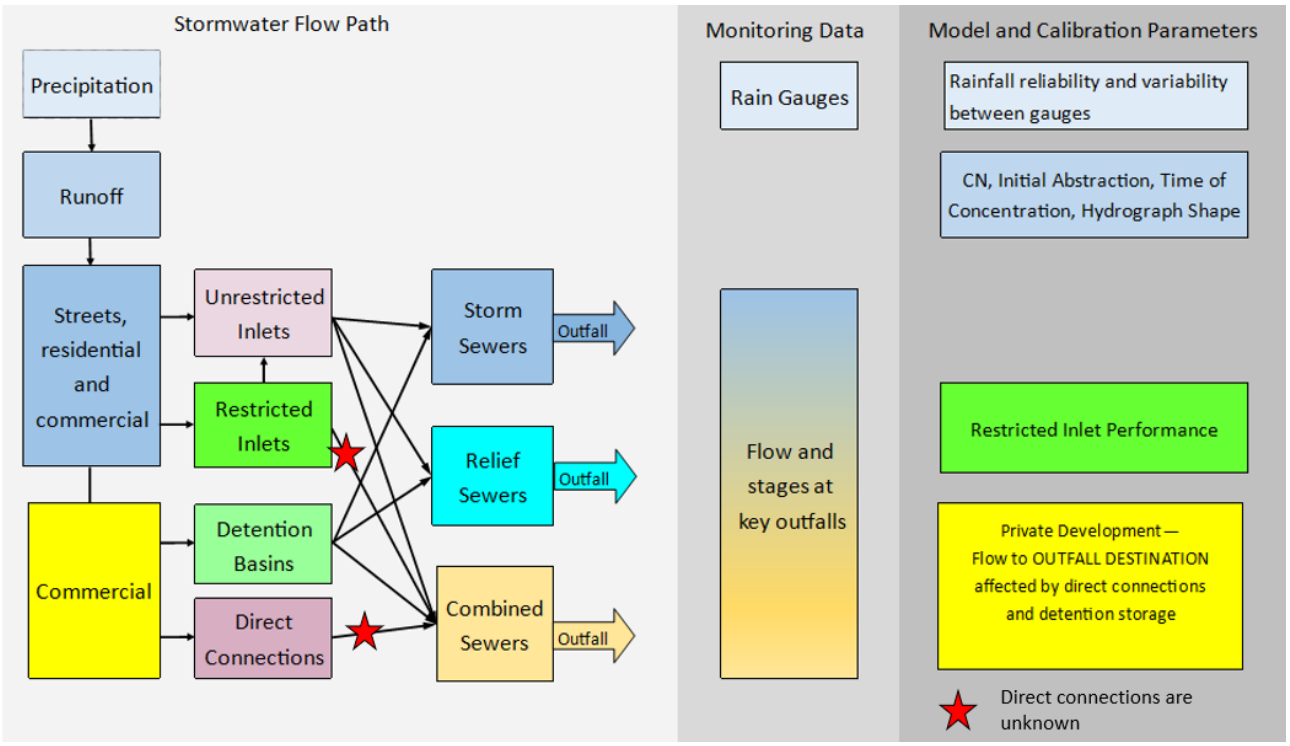


Figure 4.1. Calibration Flowchart

Prior to model calibration, the flowing monitoring data was reviewed and processed. Peak flows and levels were processed in a spreadsheet so the flow hydrograph, stage hydrograph and volume of runoff from each monitoring location could be plotted and tabulated.

Following Figure 4.1, the first calibration step was to evaluate Evanston rain gauge data and compare it to results from nearby gauges for consistency. Data from the two most significant events that occurred during the monitoring period was used to calibrate the three models (northwest, main and southwest). Rainfall data was prepared from the rain gauges and Thiessen polygons were drawn and used to assign rainfall from the gauges to the model catchment areas.

The models were run for each storm event and output hydrographs were loaded into the spreadsheet to compare the results. The results of the level meters were also evaluated. Model results from the initial calibration runs were generally low on flows and volumes from the combined sewer basins and high for the relief and storm sewer basins.

The time to peak in the initial model runs was generally slow compared to the monitoring data. The initial abstraction parameter (Ia) was reduced from 0.2 to 0.05 to increase the initial responsiveness of the model. Time of concentration and hydrograph shape were also tested for their sensitivity, but these factors were found to be less important for the time to peak. These parameters were not changed from their initial computed values. Finally, partially due to increases from the lowered initial abstraction parameter, the Curve Number was reduced to better match the measured runoff volumes. The curve number was reduced to 94.6% of the original in the Main and Southwest models, and reduced to 92.4% of the original in the Northwest Model.

After completing the calibration step of adjusting hydrologic parameters, total runoff volume (combined outfalls) for each of the three models and two different events was +/-15% (six different results). However, when the results were averaged for each model setup across both events, the difference was only +/- 7%. At this point, the total runoff volumes being produced by the models was considered very good and the attention shifted to evaluating individual basin outputs.

Model results for individual basins, particularly the combined sewer basins, were still low compared to the monitoring data. It was assumed that the differences were most likely coming from unknown or unquantified hydraulic connections in the drainage system, primarily on private properties. Potential additional model adjustments were identified and investigated. A number of large private developments were identified that were represented in the models with limited detail. In order to increase the detail and confirm drainage connections, historical plans were recovered from Evanston and the MWRD for these developments. In some cases, the private sewer outfalls were found to be connected to the wrong sewer system in the model, which was then corrected. In other cases, additional detail on detention and surface drainage was added based on information in the plans. These changes were incrementally helpful, but low peak flows and volumes predicted for many combined sewer basins persisted.

It was suspected that there were still potential avenues for flow to reach the combined sewer system that were unknown and not represented in the model. The initial model setup had created a combined sewer system that was almost fully protected (as documented in the city's GIS system) by the flow restrictors in the system. Flow restrictors have been installed in the vast majority of catchbasins connected to the combined sewer system. Although the delineation of catchments to nearly ever publicly owned inlet was incredibly detailed, it did not account for additional loading points that may exist on private properties. On residential properties, flow could enter the system through foundation drains, leaking private laterals, and/or illegally connected sump pumps or downspouts. On older commercial properties, many direct and unrestricted connections to the sewer system still exist from downspouts and loading docks. In order to represent the combined effect of these potential inflow points, the maximum restrictor capacity at inlets was increased to allow a higher rate of flow into the combined sewer system. Adjustments were made to the maximum flow rate allowed at the restricted inlets. This adjustment was effective in increasing the flow at the combined sewer outfalls to better match the calibration targets. The final calibration results are shown in Table 4.1.

This calibration effort involved dozens of locations and multiple storms. Such an endeavor was bound to have a range of results at individual locations, with some areas not meeting the established calibration targets. Between the two storms, the June 21st storm is considered more important because it produced approximately twice as much rain as the August 10 storm. Unfortunately, not all of the gauges were operational for that storm. When looking at the results for each basin, the performance under both storms should be taken into account. When a basin shows conflicting results in the two storms (above target for one storm and below target in the other), these results are most likely due to environmental variability such as minor in the actual versus measured rainfall or other system complexities that are not yet understood. When a basin underperformed in the same way for both events (under or over targets), there are likely hydraulic connections or other physical system complexities (likely on private properties) that are not fully represented in the model. As the model is used to conduct more detailed studies and evaluate designs for specific areas in the city, the calibration results should be closely reviewed. When conducting future work, the modeler should be aware of and looking for potential unknowns and uncertainties that could improve model performance in those areas.

Table 4.1. Calibration Results Summary Table

			June 20, 2021 Storm							August 10, 2021 Storm						
			Monitored		Modeled		% change		Total	Monitored		Modeled		% change		Total
Model	Type	Location	Peak	Vol	Peak	Vol	Peak	Vol	Volume	Peak	Vol	Peak	Vol	Peak	Vol	Volume
Northwest	Comb	C_B05_02000-.1	10.4	1.8	9.3	1.3	-10%	-23%	2%	7.2	0.7	8.2	0.7	14%	4%	13%
	Comb	C_B06_03570-.1	83.5	7.7	93.3	9.0	12%	18%		60.1	5.0	67.9	4.8	13%	-5%	
	Comb	C_B04_03000-.1	40.0	5.2	31.9	3.8	-20%	-28%		32.3	3.0	25.5	2.2	-21%	-26%	
	Comb	C_B04_02025-.1	8.7	1.4	8.0	1.3	-8%	-5%		6.4	0.6	7.0	0.7	10%	10%	
	Storm	C_S06_00115-.1	40.4	2.3	39.9	2.1	-1%	-10%		12.8	0.7	21.6	1.1	69%	44%	
	Relief	C_S06_02500-.1	270.2	15.7	291.8	17.1	8%	9%		98.5	5.7	155.9	8.4	58%	47%	
Southwest	Comb	C_B13_02500-.1	53.8	5.7	52.2	4.8	-3%	-17%	-14%	28.4	2.2	34.3	2.3	21%	5%	1%
	Relief	C_S13_00210-.1	132.3	6.6	129.1	7.2	-2%	9%		29.7	1.7	45.8	2.3	54%	34%	
	Storm	C_S11_00130-.1	107.6	7.5	101.8	6.7	-5%	-11%		35.9	2.4	38.0	2.4	6%	-2%	
	Comb	C_B11_01500-.1	74.5	8.3	50.1	5.4	-33%	-35%		31.0	3.3	32.6	2.7	5%	-17%	
Main	Relief	C_S10_00900-.1	341.0	22.6	443.6	28.7	30%	27%	11%	154.6	9.6	135.3	10.0	-13%	4%	-1%
	Comb	C_B81_05000-.1								76.1	6.6	62.8	5.9	-18%	-10%	
	Comb	C_B07_03000-.1								47.0	5.0	32.1	3.8	-32%	-22%	
	Comb	C_B82_01500-.1								103.6	9.6	72.1	9.8	-30%	2%	
	Comb	C_B09_03000-.1	78.6	8.7	64.0	5.8	-19%	-33%		45.0	3.5	33.7	2.9	-25%	-18%	
	Comb	C_B84_05100-.1								53.9	4.0	28.8	2.8	-47%	-30%	
	Relief	C_S82_07000-.1	363.8	13.5	236.9	13.5	-35%	0%		96.5	4.1	106.8	5.7	11%	38%	
	Relief	C_S07_02000-.1	191.1	11.2	260.0	14.9	36%	33%		85.3	4.6	88.1	5.6	3%	20%	
	Storm	C_S82_01015-.1	32.4	1.3	25.1	1.1	-23%	-13%		14.0	0.5	13.0	0.6	-7%	25%	
	Storm	C_S81_00175-.1	85.5	3.4	92.9	4.1	9%	21%		28.5	1.1	34.4	1.6	20%	45%	
	Relief	C_S09_01020-.1	11.5	1.0	6.8	0.7	-41%	-32%		6.8	0.4	5.8	0.4	-14%	-9%	
	Relief	C_S09_01080-.1	25.6	2.3	15.9	2.3	-38%	1%		18.6	0.9	16.2	1.1	-13%	25%	
	Comb	C_B83_05575-.1								57.4	5.5	41.1	4.9	-28%	-12%	

The calibration process revealed that there are significant discharges to the existing sewer system that are not limited by the inlet restrictors. This unexpected flow could be the result of localized point discharges from pre-ordinance commercial facilities that have direct connections to the sewer system, or from more universal issues such as inflow and infiltration from cracked pipes, private sewer laterals and/or foundation drains. Without detailed monitoring throughout the interior of the drainage system (not just the outfalls), there is no way to know at this time if the additional flow into the combined sewer system occurs from widespread inflow and infiltration, or from a number of historical developments that discharge unrestricted into the system. While the calibrated model was used to match peak flows and volumes at the basin outfalls, using this model setup to evaluate the design storm events could result in overestimating stages and flows in neighborhoods that are well protected by inlet restrictors. Because the source of the additional flow is currently unknown, the inlet capacities were restored to their designed maximum flow rates when evaluating the system to determine system performance under design storms.

4.1.3. Historical Storm Verification

The XPSWMM models were used to analyze two historically significant storms. These events include the September 14, 2008 storm and the April 17, 2013 storm.

Exhibit 4.3 shows the sewer surcharging risk and surface inundation areas for the September 14, 2008 storm. The September 2008 storm event was a heavy rainfall event from the remnants of Hurricane Ike. The storm event lasted over 3 days with a total rainfall of over seven inches. Water surface elevations in TARP in Evanston were not available for this storm event, however, it was assumed that the MWRD relief systems were at capacity. Therefore, this storm event was modeled with a high tailwater at elevation 5, based on a drop shaft water surface elevation at Howard Street from the April 17, 2013 storm event.

Exhibit 4.4 shows the sewer surcharging risk and surface inundation areas for April 17, 2013 storm. The April 2013 storm event was a heavy rainfall event. The storm event lasted approximately 2 days with a total rainfall of 4.75 inches. It was assumed that the MWRD relief systems were at capacity and this storm event was modeled with a high tailwater at elevation 5, based on a drop shaft water surface elevation at Howard Street provided by MWRD.

4.2. Critical Duration Analysis

The three models for the City of Evanston were used to evaluate the system response to a variety of rainfall depths and durations. The design storms were based on Bulletin 75 and were evaluated using the 2-, 5-, 10-, 50- and 100-year storm events. The 1-hour through 24-hour storm durations were used to determine the critical duration of the system. In general, the drainage system is critical for the 2-hour duration. This means the system produces the highest flows and stages for a storm duration of 2 hours. While the 1-hour storm is slightly more intense than the 2-hour storm, it does not produce as much runoff as the 2-hour storm. The total rainfall depths increase as the design event durations get longer, but the rainfall intensities become lower and the urban system is more capable of handling the rate of runoff. In some cases, longer duration events must still be run to verify results for areas that may be sensitive to larger volumes, such as depressional flooding areas.

The 2-hour storm should be used to evaluate flooding that results from the portion of the system owned and controlled by Evanston, as these facilities will be overwhelmed by a shorter duration event. The 12-hour storm was evaluated in conjunction with a high tailwater condition in the MWRD interceptors, MWRD TARP, and the North Shore Channel to represent a longer, more regional storm event where the capacity of those outfalls to receive discharge from Evanston is very limited.

4.3. Existing System Performance

The City of Evanston has a system that is combined sewer, relief sewer, and storm sewer. Large storm events can lead to sewer surcharging and surface flooding. Sewer surcharging can lead to basement backups for structures that are not protected by overhead sewers or a flood control system. The sewer level of service provided by the sewer system was determined by evaluating hydraulic grade lines in the sewer under a range of storm events. Surface flooding can lead to flood damage at structures. Flood risk was determined by identifying the most frequent storm that exceeds a flooding criterion.

4.3.1 Critical Duration Sewer Surcharge Risk

Sewer surcharge risk was assessed using the hydraulic grade line elevation of the local sewer compared to a typical depth at which basement flooding would be expected to occur. Evanston includes a wide range of home styles and types of construction. After reviewing a number of different structure types in various neighborhoods, it was determined that potential basement flood risk could be associated with a hydraulic grade line of four feet below the rim of the sewer structures. The sewer surcharge performance criterion used was four feet below the rim of the sewer structure. Level of protection refers to the largest modeled storm where there is no sewer surcharging.

The risk of flooding for basements may vary due to site-specific factors including installation of overhead sewer/backflow preventers or damaged service laterals. Since the presence of protective plumbing or the condition of privately owned sewer laterals has not been inventoried, sewer hydraulic grade line results only provide an indication of one type of risk of basement flooding, which is associated with the public sewer system. Sewer surcharging risk was identified for the 2-, 5-, 10-, 50- and 100-year storms.

In general, the majority of Evanston that is east of the North Shore Channel is drained from east to west. For areas east of Ridge Road, this drainage pattern is man-made. Sewers flowing east to west must pass under the topographical ridge that is generally represented by Ridge Road. The ground surface for much of this area of eastern Evanston is only several feet higher than the crown of the large diameter sewers serving this area. This limited range of elevations would appear to increase the sewer surcharging in these areas. However, as oldest areas of the city, it is highly likely that a combination of construction type and the use of overhead sewers or backflow prevention systems has decreased the actual backup risk to structures in these areas.

The level of service for sewer surcharging varies across Evanston. It is summarized in Table 4.2 and is shown on Exhibit 4.5. Only the northwest model area had no locations with sewer surcharging up to and including the 2-year event.

Table 4.2. Sewer Surcharge Risk Results Summary Table

Model Area	% Nodes with Hydraulic Grade Line within 4' of Street Surface				
	2-year Storm	5-year Storm	10-year Storm	50-year Storm	100-year Storm
Main	36%	54%	66%	75%	77%
Northwest	0%	14%	21%	37%	49%
Southwest	7%	10%	11%	21%	23%

4.3.2 Surface Flooding Risk

Surface flooding risk is predicted when inundation for flood surface areas would threaten a structure. Surface flooding risk was assessed by intersecting the predicted flood inundation areas with the building limits. A depth of six inches or greater intersected with the limits of a building was identified as a structure with potential surface flooding risk. Surface flooding risk was evaluated for the 10-year, 2-hour storm and the 100-year, 2-hour storm.

The level of service for surface flooding varies across Evanston. It is summarized in Table 4.3 and is shown on Exhibits 4.6 and 4.7.

Table 4.3. Surface Flooding Risk Results Summary Table

Model Area	Buildings with Surface Flooding Risk	
	10-year Storm	100-year Storm
Main	32	138
Northwest	3	13
Southwest	6	16

4.3.3 Long Duration System Performance (High Tailwater)

The critical duration event is the 2-hour event, however, a longer duration event (12-hour) with a high tailwater was evaluated to determine the impact of that type of storm event. In the long duration scenario, TARP is full and the North Shore Channel is allowed to rise with the assumption that the gates at Wilmette are not opened to provide relief to the system. As such, the model was modified to generate a high tailwater in the MWRD TARP and interceptor systems, as well as the North Shore Channel.

The MWRD DWP for the North Shore Channel shows the modeled channel elevation at a range of 9.4 at Howard to 7.6 at Green Bay Road for the 100-year storm event. The Green Bay Road tailwater was used as representative for the Northwest model, the Howard elevation was used as representative for the Southwest model, and an average of 8.5 was used for the Main model.

Sewer surcharging risk was identified for the 100-year, 12-hour storm and is shown in Exhibit 4.8. Surface flooding risk was identified for the 100-year, 12-hour storm and shown in Exhibit 4.9.

4.4. Existing System Performance

There are two general conditions that can cause basement flooding in Evanston. The first is a lack of capacity in Evanston's local sewer system. This occurs during short duration, intense rainfall events that exceed the capacity of the system to convey the flows to the MWRD interceptors, TARP, and the CSOs. This condition was represented by the 2-hour duration. The results of this scenario storm are shown in Exhibits 4.5 to 4.7. As shown in Figure 4.5, there are locations in the city that were found to have less than a 2-year level of service for the sewer surcharging criterion of four feet below structure rims. As discussed above, this doesn't necessarily directly result in basement flooding, but is indicative of locations where this may be a risk. Surface flooding was assessed for both the 10-year, 2-hour storm and the 100-year, 2-hour storm. Up to 167 structures were identified as being at risk of surface flooding in the 100-year, 2-hour storm.

The second scenario is a longer, more regional storm event where the capacity of MWRD outfalls is limited and the North Shore Channel elevations are high. The results of this scenario storm are shown in Exhibits 4.8 to 4.9. While the overall system is better than for the short duration storm, there are several areas of the city that experience higher sewer surcharging risk in the longer duration storm.

5. Stormwater Management Recommendations

Since the early 1990's, the City of Evanston has made a number of large investments to improve the publicly owned drainage infrastructure. These projects have resulted in a drainage system that has managed intense storm events without widespread catastrophic flood damages. Other communities in Cook County have fared significantly worse during these events. There have been very few reports flood damages caused by surface floodwaters. Basement backups caused by sewer surcharging have been reported, but the locations have tended to vary from storm to storm.

The analysis of the existing system performance also showed that the publicly owned system is not performing quite as expected. There are significant areas, mostly east of Ridge Ave., that have been identified as subject to potential sewer surcharging at storm events well below the 100-year event. Although sewer surcharging risk was found to be higher than expected, these areas have not reported widespread damages during large storm events. A combination of factors including the typical building height and protective plumbing systems are likely responsible for the lack of widespread damages. Going forward, the stormwater model will allow for detailed analysis and evaluation of the system as drainage projects are contemplated and areas of concern are further investigated.

The City's comprehensive stormwater management program will include a range of activities and services that go beyond future capital improvement projects. Stormwater management program recommendations have been prepared in three categories: Regulatory Program, Private System, and Public System. Table 5.1 summaries the recommendations in each category.

Table 5.1. Stormwater Management Recommendations

City of Evanston Stormwater Management Program Recommendations		
Regulatory	**Private System**	**Public System**
• Detention requirements • Private property plumbing code requirements • Property Transfer Inspections	• Overhead sewers • Sanitary sewer backup prevention • Sump pumps • Lot drainage • Floodproofing	• Capital Improvements • Combined Basin 07 Sewer Improvement Concept • Southwest Surface Flooding Concept • Green Infrastructure Program • Sewer System Monitoring

5.1. Regulatory Program

Regulations are an opportunity to implement baseline standards for stormwater management based on the infrastructure and needs of the community. The Cook County Watershed Management Ordinance (WMO) regulates stormwater across the county, but communities, including Evanston, can enact additional regulations that amend or extend coverage.

The WMO includes provisions for stormwater management that include runoff control, volume control and detention storage. The MWRD enforces this ordinance and has been proactive in making updates since the WMO's initial adoption in 2013. The biggest issue with implementing the WMO in Evanston is that the minimum parcel size requirements are 0.5 acres before volume control is required and 3.0 acres before detention storage is required. Many developments in a community like Evanston would fall below these thresholds, which is why more protective measures have been adopted.

Evanston has adopted a number of regulations that govern stormwater management and drainage in the City, including:

- Storm Water Control – City Code Title 4, Chapter 20
  - Requires detention for all new developments with exceptions for certain residential structures and paved parking lots.
- Plumbing Code
  - 4-5-3.M Subsoil Drain Pipe can discharge to storm sewer upon approval of Public Works Director, but not combined sewer.
  - 4-5-3.N Roof Drains of residential buildings can discharge directly to the storm sewer system, but not combined sewer.
- Property Maintenance Code
  - 304.7.1 Downspouts are required and shall terminate at grade. Footing drains connected to the sump pump shall terminate at grade.
- Floodplain Regulations
  - Comply with National Flood Insurance Program (NFIP)
- Green Building Ordinance
  - Applies to new construction and additions 10,000 sq ft or higher.
  - Applies to interior renovation 5,000 sq ft or higher.
  - Requires BMP measures based on square footage.

Updates to various regulations pertaining to stormwater can be strengthened to provide short- and long-term improvements. Additional analysis and work may be necessary in order to further consider and implement these recommendations. Below are recommended strategies to strengthen the regulatory requirements in order improve stormwater management and performance of the drainage system in Evanston.

5.1.1 Detention Requirements

The City of Evanston currently does not require detention for buildings smaller than 5,000 square feet and a construction cost greater than of 100% of the assessed property value. The City also does not require detention for residential buildings of 1-3 structures on 1-2 lots less than 1 acre each. The City could consider stormwater performance criteria for single residential lots. The majority of the single family homes in Evanston have a square footage of less than 5,000 square feet and would not be subject to the current regulation. These guidelines could be developed by the City of Evanston to provide consistent calculations and methodology among the systems and provide for an easier permit review process. It is recommended that the permit calculations be performed by a licensed engineer / architect. The City should review several different types of residential lots throughout the City to investigate what could be an adequate detention volume and footprint while allowing for some type of connection to the municipal sewer system. Review of some typical lots will help provide a possible range of detention volume that could be required and would lead to the development of permit guidelines for residential lot detention.

There is currently a fee-in-lieu program for stormwater control. This could be modified specifically for residential lots where site constraints may not allow for installation of detention systems.

The City has currently exempted the resurfacing of parking lots from stormwater control requirements. This exemption could be reconsidered, particularly for sites with no stormwater control or that exceed a certain size threshold.

The Stormwater control fact sheet should be clarified and updated. All stormwater ordinances should be updated to change references to Bulletin 70 to Bulletin 75. Bulletin 75 is the most up-to-date design storm guidance and is the standard used in the WMO.

5.1.2 Private Property Plumbing Code

The challenge for implementing improvements to the privately owned drainage system is identifying the best opportunity or trigger for the City to require the upgrades. Typically, improvements of this nature are only required when the property owner is applying for a building permit or upon sale of the property. The City could also consider encouraging these types of upgrades through a cost sharing program.

The plumbing code could be modified to require installation of backflow preventers or overhead sewers as part of home additions or improvements. Triggers could be based on the percent increase of square footage, or the cost of improvements relative to the assessed structure value. To protect their investments and to provide a reduced risk of future basement flooding, it would be beneficial to require installation of these plumbing measures.

The City currently allows for drain tiles, sump pumps, and roof drains to discharge to the storm sewer system. The plumbing code could be modified to require downspout and sump pump disconnection for building additions. Redirecting stormwater runoff from roofs to the ground will reduce the peak discharge to the sewer systems which could in turn reduce the risk of sewer backups.

5.1.3 Property Transfer Inspections

The sale of property is also an opportunity for the City to require inspections, ensure that the existing system meets certain provisions of the code, and require repairs or code compliance measures to the private system.

The City should investigate the ability to create and enforce the necessary procedures or forms to implement the following recommendations.

- Require backflow preventers/overhead sewers for sales of homes.
- Require basement flooding inspection/remediation at point of sale for homes.
- Require downspout disconnection at point of sale for homes.
- Require inspection of lateral sewer at sales of homes.
- Required inspection of sump pump.

5.2 Private System

There are multiple options available for property owners to improve their level of protection against flooding of their home. These can include the following:

- Overhead sewers
- Sanitary sewer backup prevention
- Sump pumps and roof drains
- Lot Drainage
- Floodproofing/waterproofing

5.2.1 Overhead Sewers

An overhead sewer system is one of the most reliable measures to prevent flooding due to basement backups. In an overhead sewer system, sewage leaves the home just below the first floor and backups into the home caused by the public system are extremely rare. A diagram of an overhead sewer is shown in Figure 5.1. If the home has existing drain tiles and no sump pump, a new sump pit and pump should also be installed.

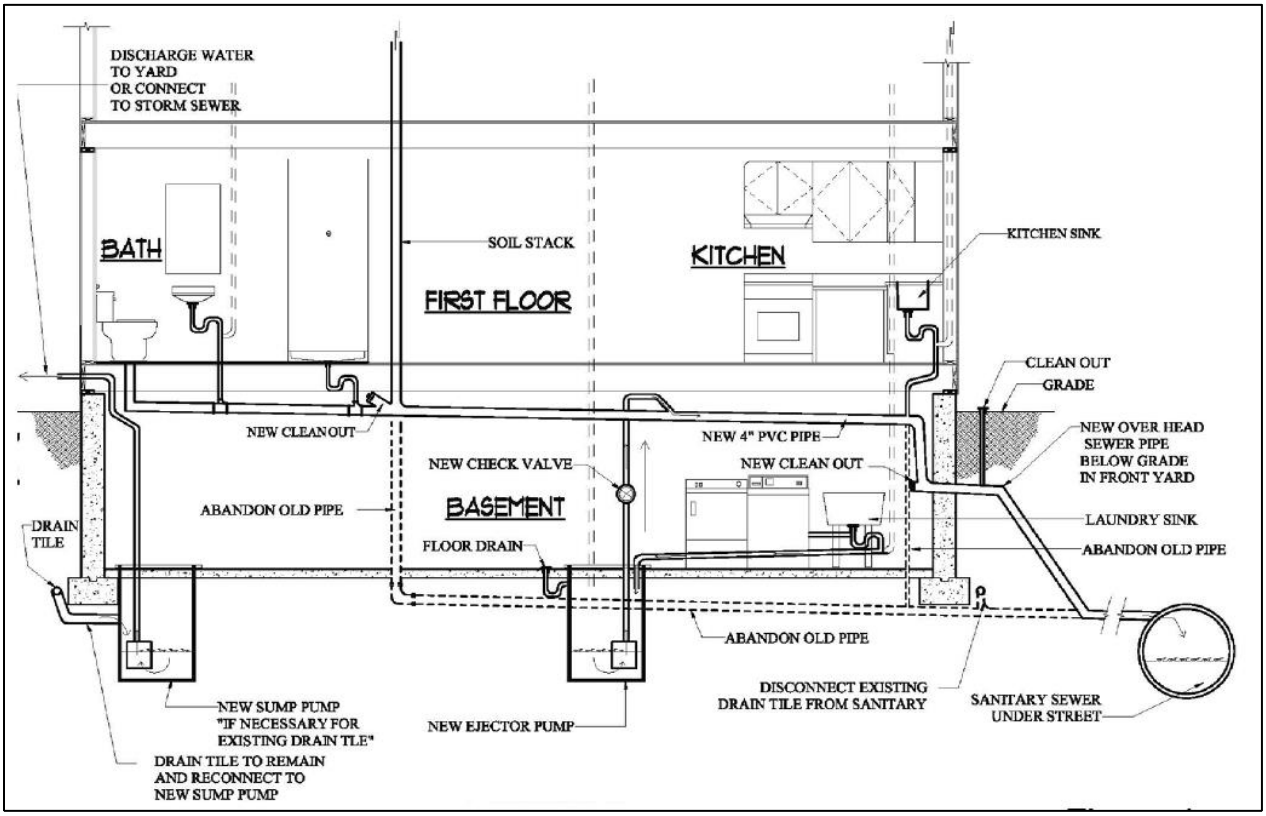


Figure 5.1. Overhead sewer diagram

5.2.2 Sanitary Sewer Backflow Prevention

A backflow preventer installed in a sewer service line is designed to allow water or sewage flow only out of the structure, providing protection from basement backups during storm events. Backflow preventers should be inspected yearly, and homeowners need to understand that during rain events where the valve is closed, sewage will not be able to discharge to the street and they should minimize their water usage in their home to avoid backups. See Figure 5.2 for a diagram.

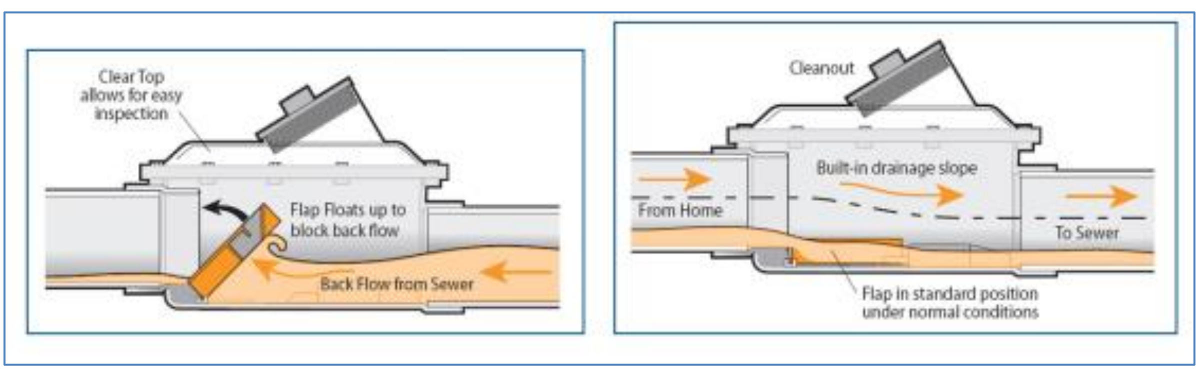


Figure 5.2. Backflow Preventer Diagram

5.2.3 Sump Pumps and Roof Drains

A sump pump and drain tile system around a structure's foundation serves to collect the groundwater and pump it away before it leads to seepage. Drain tile can be installed around the outside of a foundation on the outside walls or along the inside walls beneath the slab.

Gutters and downspouts collect water from the roof and direct it away from the structure. An improperly functioning roof drain system can allow excess water to collect near the exterior walls, which then flows down along the foundation wall, leading to seepage.

A best practice is to have sump pumps and downspouts discharge at grade, and not to the storm sewer system. Redirecting stormwater runoff from sump pumps and downspouts will reduce the peak discharge to the sewer systems, which could in turn reduce the risk of sewer backups.

5.2.4 Lot Drainage

Earth should always be graded to direct water away from all structures. Another common problem are sidewalks, slabs, or driveways that may heave or tilt over time and direct water toward the foundation of a structure with a basement or crawlspace. Lot issues that direct runoff toward the structure should be corrected to the extent possible. New drainage features or even an exterior sump pump system may be needed to correct difficult drainage situations.

If there are drainage swales on the property, those should be checked and kept free of obstructions.

5.2.5 Floodproofing

Floodproofing ranges from simple coatings and barriers to intensive structure retrofitting measures. Applicable floodproofing measures in Evanston would primarily include waterproofing of walls or foundation and simple adjustments to windows or doors of structures in commercial or industrial areas that might be at risk of flooding. A summary of the most applicable measures includes:

- Protective coating or membranes around basement wall to prevent seepage.
- Elevating utilities or appliances in the basement to prevent damage from seepage.
- Retrofitting low lying windows to glass block systems.
- Retrofitting or eliminating exterior doors to lower levels.

5.3 Public System

Recommendations and future improvements to the public sewer system include capital improvements, green infrastructure, and sewer monitoring. Several policies could be considered with regard to the public system. These include improving the stormwater system whenever a roadway is being reconstructed or other utility work is occurring. Another policy could be to incorporate green infrastructure into all public system projects, particularly for projects occurring in areas with sandy soil.

5.3.1. Capital Improvements

Capital improvement projects will be needed to improve system performance in areas that experience repeated flooding or for areas where surface flooding inundation risk has been identified. The sewer performance findings of this study will be used with areas where drainage problems are reported to identify future project areas.

Previously implemented public sewer projects have greatly improved the performance of Evanston's drainage system. While these systems have functioned well over the last two decades to prevent flood damages during intense storm events, updated rainfall data and the current stormwater analysis shows that the system does not provide 100-year level of performance for surface flooding and sewer surcharging.

The city should strive to reduce the risk of surface flooding structure in the 100-year storm. Property owners have little control over this situation. Floodproofing or structure alterations may reduce or prevent damage during flood events. However, the city is in the best position to design and implement project that would reduce the risk of flooding to these structures.

Regarding sewer performance, it would not be feasible for the city to achieve no sewer surcharging in the 100-year storm system wide. Simply put, property owners should not expect or rely on this level of service from the public combined sewer system. For decades, the building code requires overhead plumbing for all new construction. While the city may wish to improve the sewer system in some locations where sewer surcharging is particularly problematic or is causing property damage, the most robust and resilient way for properties to be protected is by having the private drainage system meet the current standards for new construction.

There are a number of potential stormwater improvements that could be implemented by the city to improve the system performance. These include:

- Sewer capacity improvements
- Outlet improvements or modifications
- Detention or flood storage basins
- Green infrastructure

The most feasible capital Improvement projects in Evanston will generally involve conveyance improvements. Because Evanston is fully developed, there are limited opportunities to implement above ground storage basins. In some locations, where the drainage problem is isolated or minor, then storage may play a role in the solution. As discussed below, green infrastructure will improve or prevent degradation of system performance over time.

The stormwater modeling tool will be used to analyze potential project areas to develop an appropriate suite of solutions. Site conditions such as soil permeability type, distance from a relief/storm sewer, and flooding type and depth should be considered when choosing appropriate solutions.

5.3.1.1 Refined Conceptual Improvements for Combined Sewer Basin 07

Combined Sewer Basin 07 is generally bounded by the North Shore Channel to the north and west, Church Ave. to the south, and the C&NW Railroad to the east, and approximately Simpson Ave. to the northeast. There are multiple reports of basement backups in this area, as well as several areas of 100-year surface flooding risk as identified by the model.

Combined Sewer Basin 07 discharges to the west along Emerson St. There is an outfall to TARP that has a weir to force dry weather/low flow across the North Shore Channel, and into MWRD interceptors. At high flow, the weir will overtop and allow flow into TARP.

The combined sewers on the side streets ranges from 9-inches to 15-inches in diameter. The combined sewers generally drain towards Emerson St., where a 54-inch diameter sewer drains towards the MWRD interceptor and TARP. There are relief sewers for this area along Lyons St., portions of Hartrey Ave., Foster St., portions of Dodge Ave., and portions of Church Ave.

Several of the basement backup reports overlap with areas in the model shown to only have a 2-year level of protection, which is along Darrow Ave. from Church Ave. to the south to the sewer ridge line to the north between Simpson St. and Payne St., see Figure 5.3. Below is a list of potential contributing factors to this flood risk area:

- The mainline sewer on Darrow Ave. is 9-inches to 12-inches, which is undersized for its drainage area.
- Darrow Ave. sewer drains toward the sewer along Emerson St., which experiences a high tailwater from the TARP outfall configuration.
- There are some relief sewers in Combined Sewer Basin 07, but no relief sewer along Darrow Ave. or Emerson St.

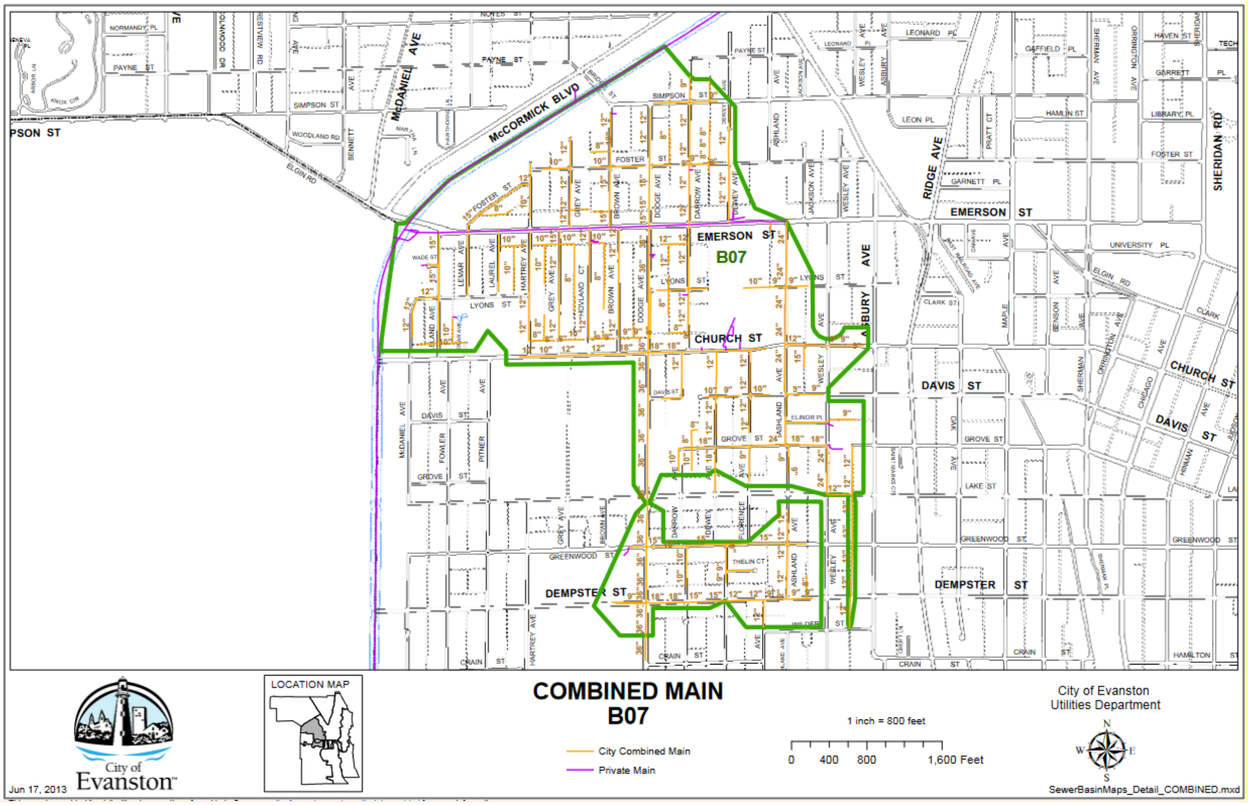


Figure 5.3 Combined Sewer Basin 07

The drainage system for this area was analyzed to develop solutions to improve the combined sewer performance and reduce the surface flooding risk. Increasing the local sewer capacity was able to provide the necessary conveyance capacity at the location of the problems. However, a downstream improvement was also needed to reduce tailwater on the problem area as well as ensuring that the flood risk wasn't translated downstream.

A conceptual solution for this area included the following improvements.

- Increase sewer capacity along Darrow Ave.
- Increase sewer capacity along Emerson St.
- Reconfigure outfall to TARP to decrease tailwater created by the outfall structure. This could help provide relief to other neighborhood streets in addition to Darrow Ave.

This conceptual improvement represents the types of solutions that should be possible to identify and implement for areas of localized flooding or underperforming sewers.

5.3.1.2 Refined Conceptual Improvements for Southwest Model Surface Flooding

The southwest area of Evanston is somewhat unique within Evanston. Pre-regulatory development along the North Shore Channel was built several feet above natural ground and cut off the overland flowpaths from the residential area between Oakton St. and Main St. This residential area is low lying and flat and has very few well-defined overland flowpaths, within the area itself, or leading from the area. Even if an overland flowpath between the neighborhood and the channel could be restored, it would still be problematic to direct surface floodwaters to the channel. Further improving the subsurface drainage system was found to be the most feasible strategy. Surface flooding risk for the area can be seen in Exhibits 4.6, 4.7 and 4.9.

The area is currently served by a combined sewer system and a separate storm sewer system. The combined sewer system discharges to the MWRD interceptor with an overflow to TARP. The combined sewer system serves the area from Main St. to the north, Ridge Ave. to the east, and Oakton St. to the south. There are local streets where there is no separate storm sewer and these are served only by the combined sewer system. The system is generally undersized for its service area.

The separate storm sewer system discharges directly to the North Shore Channel. The storm sewer serves the area from Main St. to the North, Ridge Ave. to the east, and Case St./Railroad to the south. The sewer does not reach all streets and is undersized for its service area. Both of these systems leave the neighborhood along Cleveland St. and pass through the commercial properties before reaching their outfalls.

In order to alleviate the surface flooding in this area, the stormwater infrastructure will need to provide the 100-year, overland flow capacity in a pipe system since an overland flow path is not available. In order to reduce the flood risk in the 100-year storm the conceptual improvement would require approximately 8,000 feet of trunk sewer, 2,000 feet of local sewer, and a high capacity inlets into the system.

This conceptual solution would address flooding issues in a specific area of the southwest model. The drainage configuration in this area is fairly unique within Evanston. In general, Evanston does not have many significant areas that lack overland flowpaths. Because of the this, the overall surface flooding risk was found to be rather low relative to other nearby communities. Most other potential projects to address surface flooding risk in Evanston are expected to be significantly smaller in scope than this concept.

5.3.2. Green Infrastructure

Green infrastructure is a way of managing stormwater that filters and absorbs stormwater where it falls, instead of using grey infrastructure to move the stormwater away. Green infrastructure solutions are varied and can be used at a small scale such as a rain barrel or rain garden for a home, or green alley or wetland at a neighborhood scale. Other examples include permeable pavement, green roofs, dry wells, stormwater trees, and bioswales. Green infrastructure is one way to provide resilience to the stormwater system as well as having environmental, social, and economic benefits, typically known as the Triple Bottom Line Analysis.

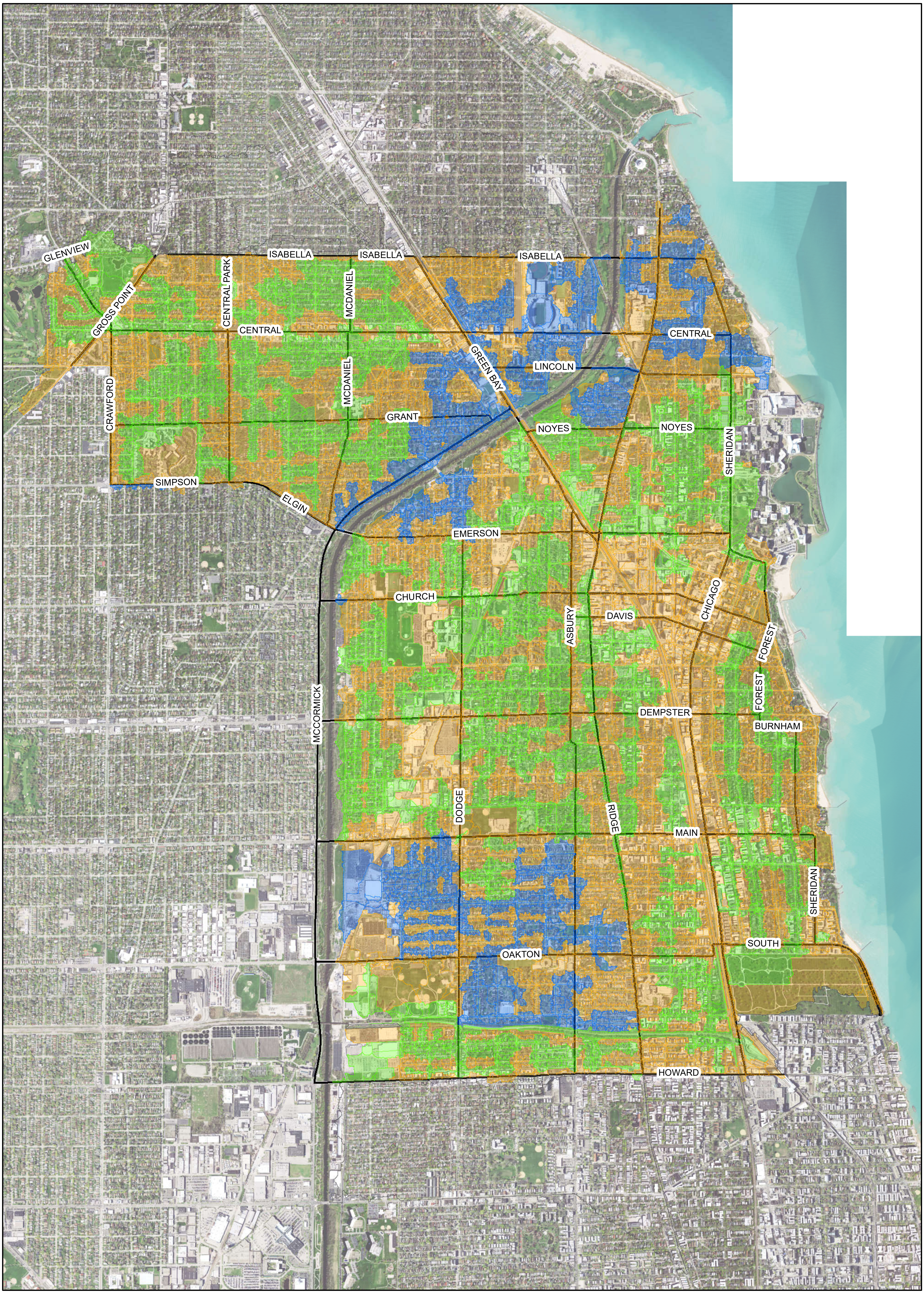
During the last several decades the impacts of increased rainfall and development have resulted in impacts to the City of Evanston, not unlike the majority of urban and suburban areas in the Midwest. City regulations and stormwater design standards have attempted to keep up with these ever-growing issues. The most recent update to local rainfall data showed an increase of one inch of rainfall in the 100-year, 24 storm event. Accounting for additional stormwater capture in green infrastructure can help alleviate the impact of future potential increases in rainfall. Providing and promoting stormwater runoff volume capture can provide a cumulative benefit over time to the City's overall stormwater peak runoff while improving water quality.

Evanston currently has a green building ordinance that provides credit for installation of BMPs has developed standard engineering details for Green Infrastructure to be used on their public projects. The City could enhance the policy and develop green infrastructure/sustainability goals and standards for all City-funded projects. Any related conveyance improvements should be a minimum 10-year design standard. Evanston currently evaluates capital improvement projects for their ability to support green infrastructure, considering site layout, infiltration rate, ground water level, environmental factors, and maintenance.

Evanston previously had a program called Livable Landscapes that supported raingardens. The City could consider providing homeowners with the ability to create their own BMPs at a reduced cost to promote green infrastructure on private property.

5.3.6 Sewer System Monitoring

Flow and water level monitoring was included in the development of the model and stormwater management plan as a way to calibrate and verify the model. Water level meters are significantly less complicated and less expensive to operate than flow monitoring equipment. In order to build out and calibrate the city-wide stormwater model, this project focused on flow metering of the basin outfalls to maximize coverage of the city. Information the performance at key locations throughout the interior of the drainage system was not collected. The calibration effort discovered that there is uncertainty in how a portion of the measured flow is entering the combined sewer system. The City should acquire and install additional water level meters at locations of interest or in priority project areas. These meters are low cost, battery operated, relatively simple to install, and can be deployed for months at a time. They can also be easily moved and operated at new locations of interest.



Scale:

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Project Number: 19-0420

Orientation:

Date: 2/7/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Legend:

Catchment Delineations

- Other
- Combined
- Relief
- Storm

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

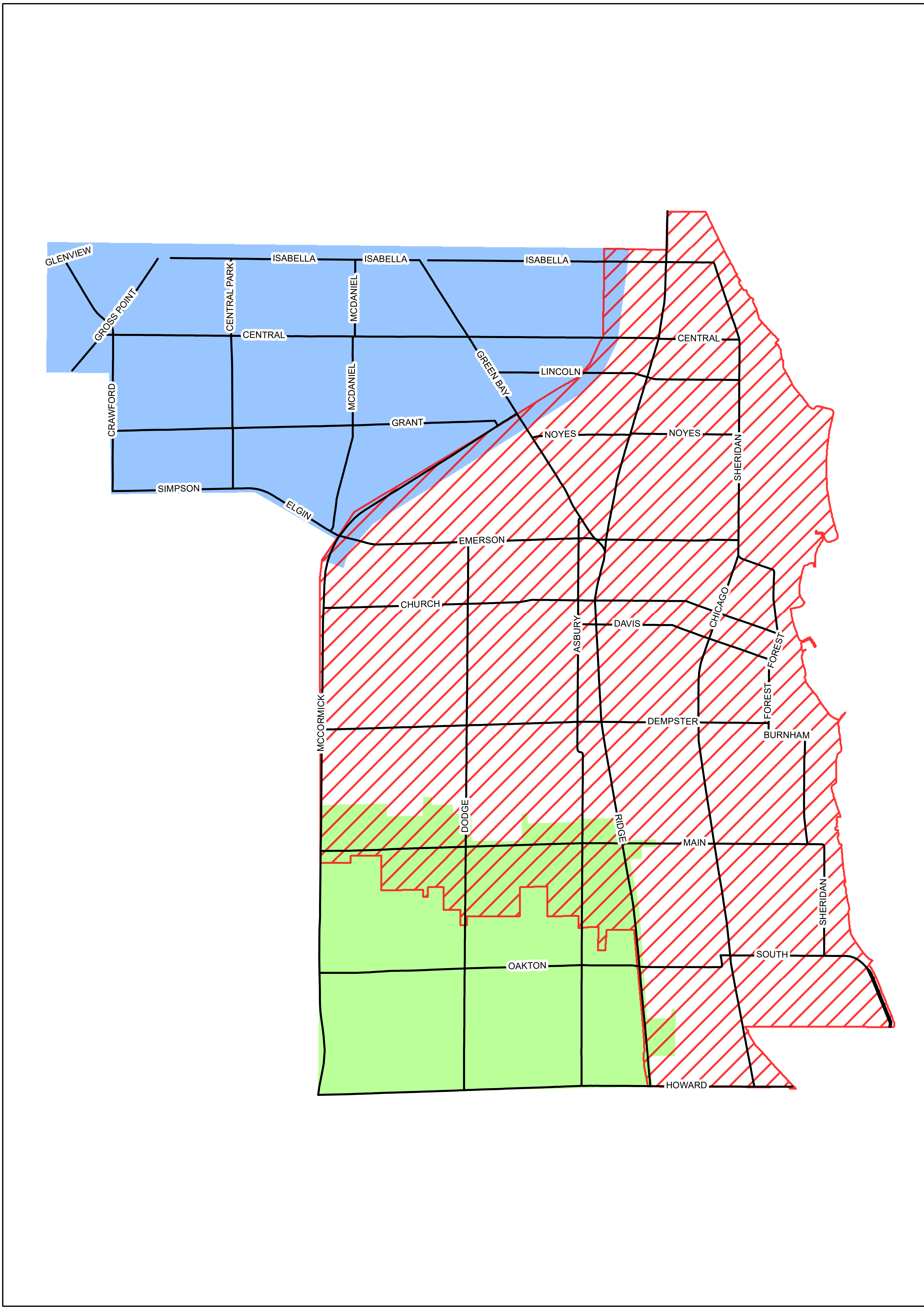
2017 Aerial

Exhibit Title:

Catchment Delineations

Exhibit:

3.1



Scale:

0 1,000 Feet

Orientation:

Project Number: 19-0420

Date: 2/7/2023

Legend:

Model Boundaries

- Main
- Northwest
- Southwest

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

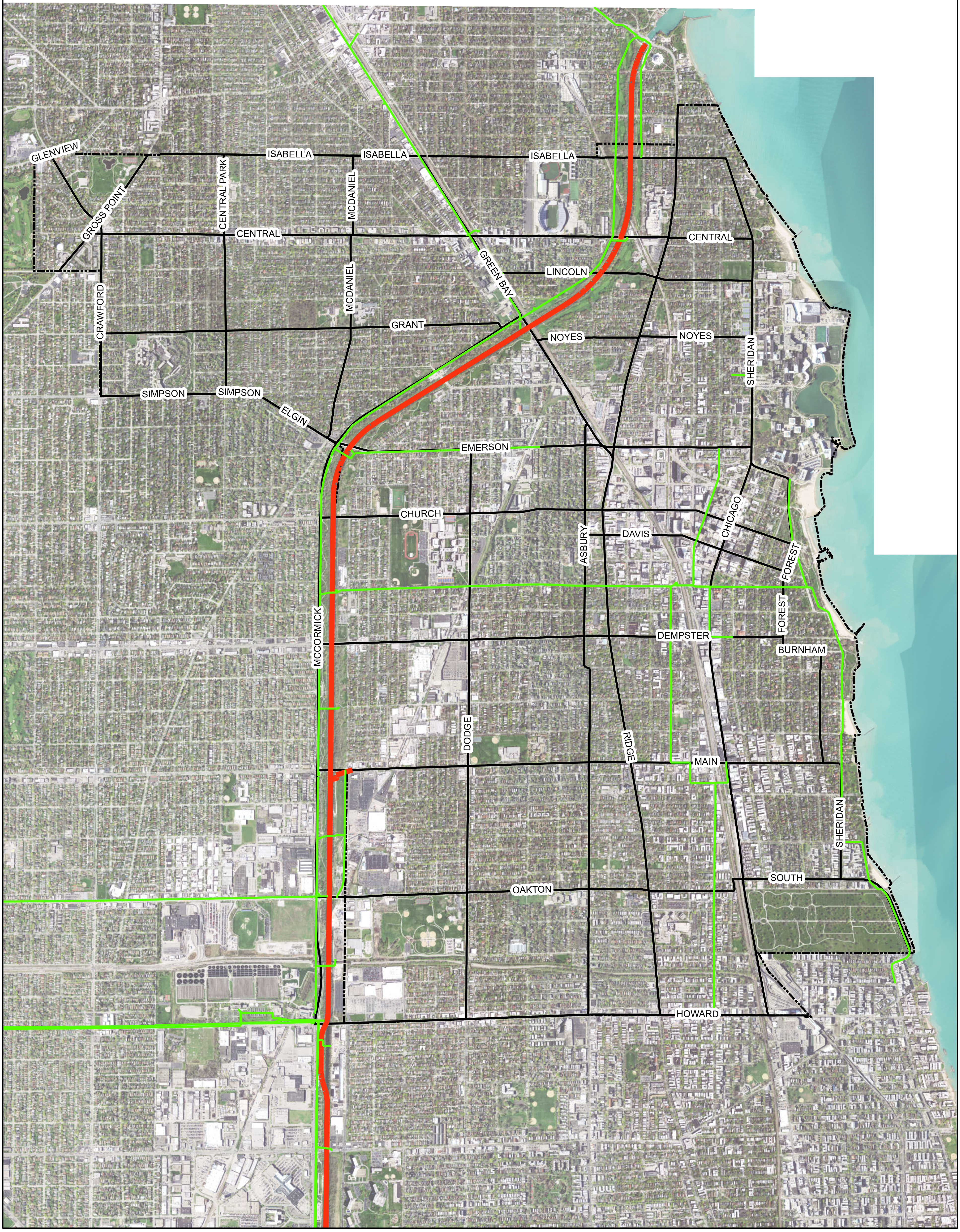
City of Evanston

Exhibit Title:

Model Boundaries

Exhibit:

3.2



Scale:

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Project Number: 19-0420

Orientation:

Date: 2/7/2023

Legend:

Tunnel and Reservoir Plan (TARP)

MWRD Interceptor

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

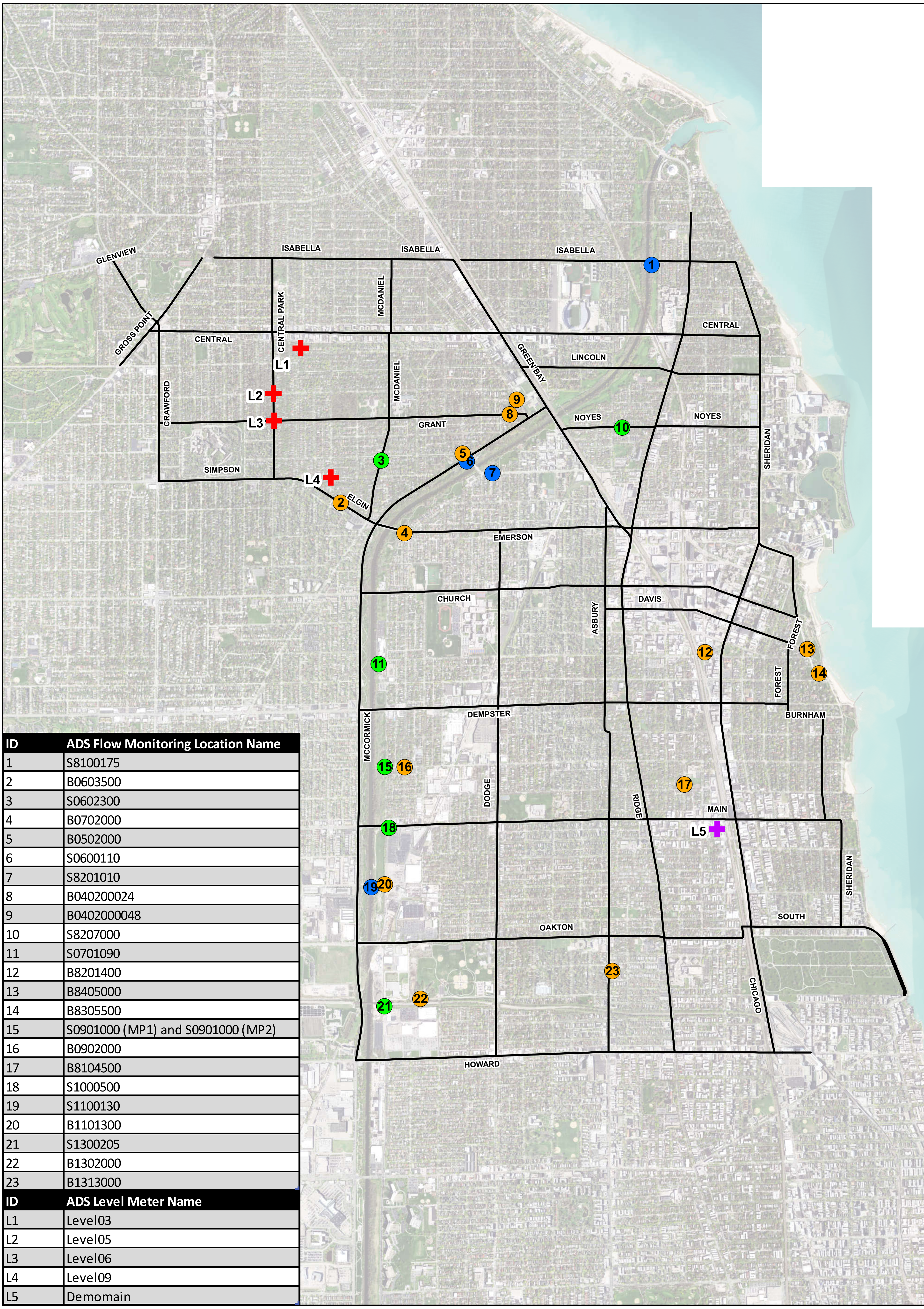
2017 Aerial

Exhibit Title:

MWRD Interceptors and TARP

Exhibit:

3.3



ID	ADS Flow Monitoring Location Name
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2	B0603500
3	S0602300
4	B0702000
5	B0502000
6	S0600110
7	S8201010
8	B040200024
9	B0402000048
10	S8207000
11	S0701090
12	B8201400
13	B8405000
14	B8305500
15	S0901000 (MP1) and S0901000 (MP2)
16	B0902000
17	B8104500
18	S1000500
19	S1100130
20	B1101300
21	S1300205
22	B1302000
23	B1313000
ID	**ADS Level Meter Name**
L1	Level03
L2	Level05
L3	Level06
L4	Level09
L5	Demomain

Scale:

0 1,000 Feet

Orientation:

Legend:

- Level Meter
- Experimental Level Meter
- Combined Sewer Monitoring Location
- Relief Sewer Monitoring Location
- Storm Sewer Monitoring Location

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

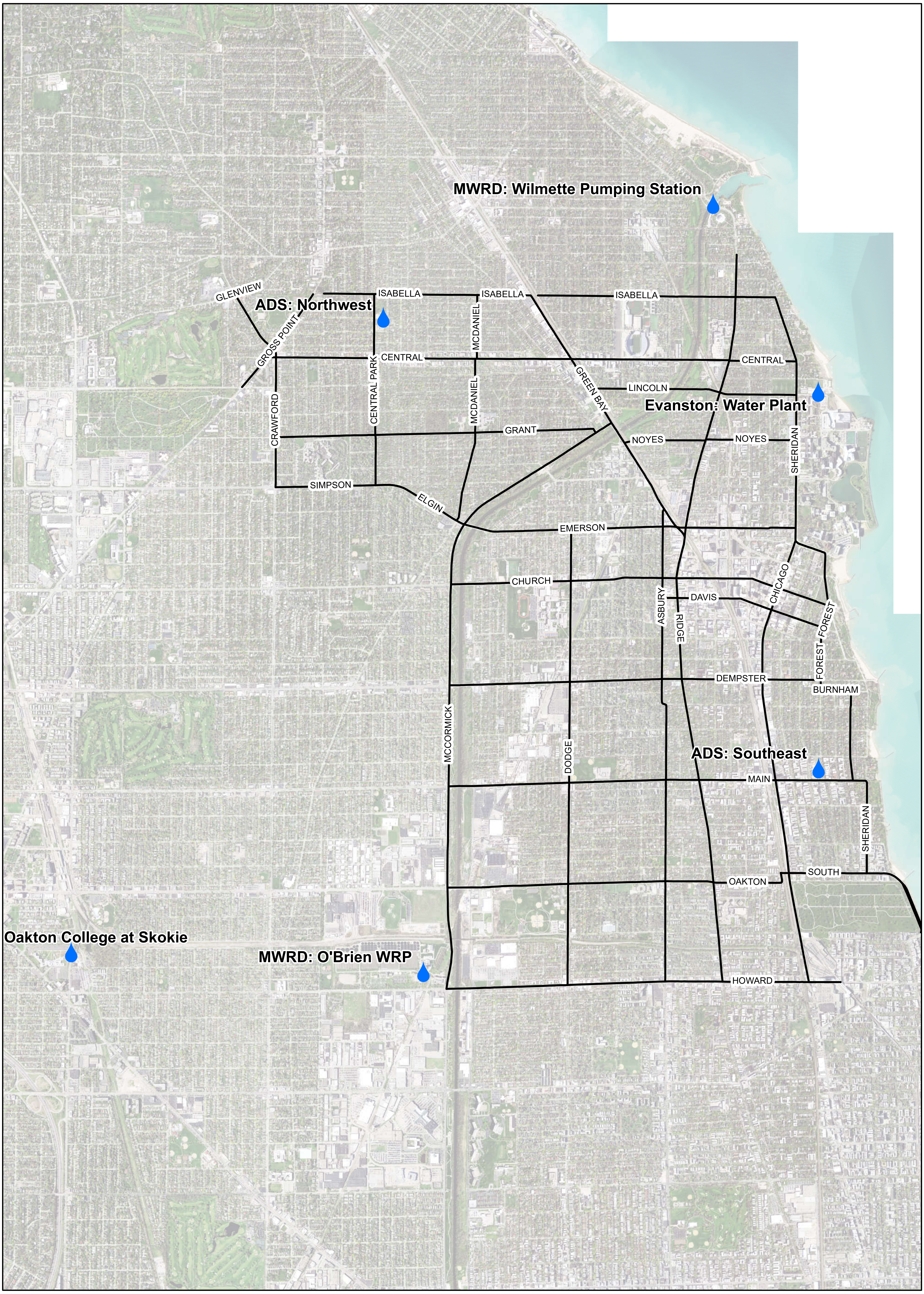
Project Name:
Stormwater Master Plan

Prepared for:
City of Evanston

Information about exhibit:
2017 Aerial

Exhibit Title:
Monitoring Locations

Exhibit:
4.1



Scale:

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Orientation:

Legend:

Rain Gauge

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

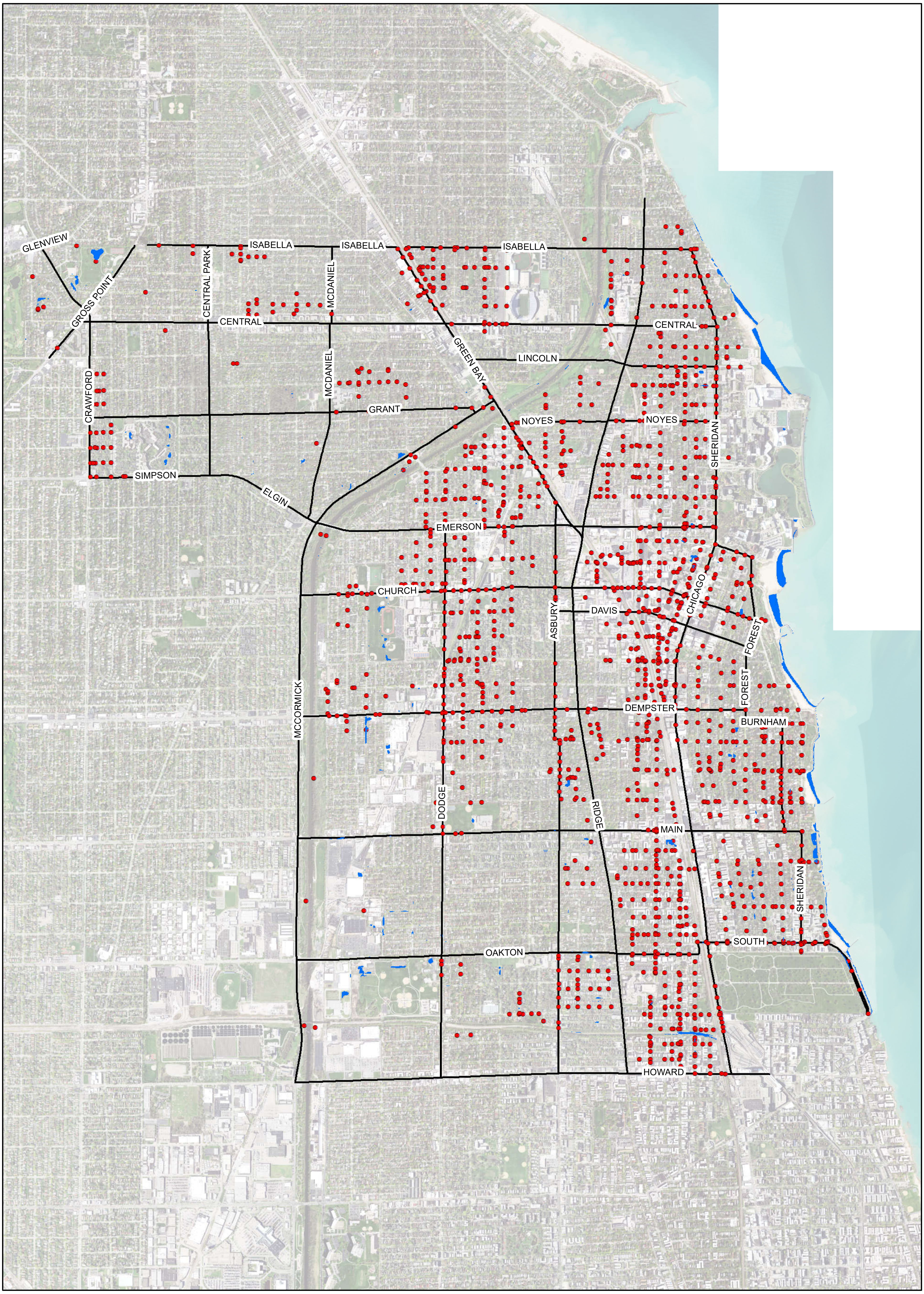
2017 Aerial

Exhibit Title:

Rain Gauge Locations

Exhibit:

4.2



Scale:

0 1,000 Feet

Orientation:

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Legend:

Sewer Surcharge Risk

Surface Flooding Risk Area

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

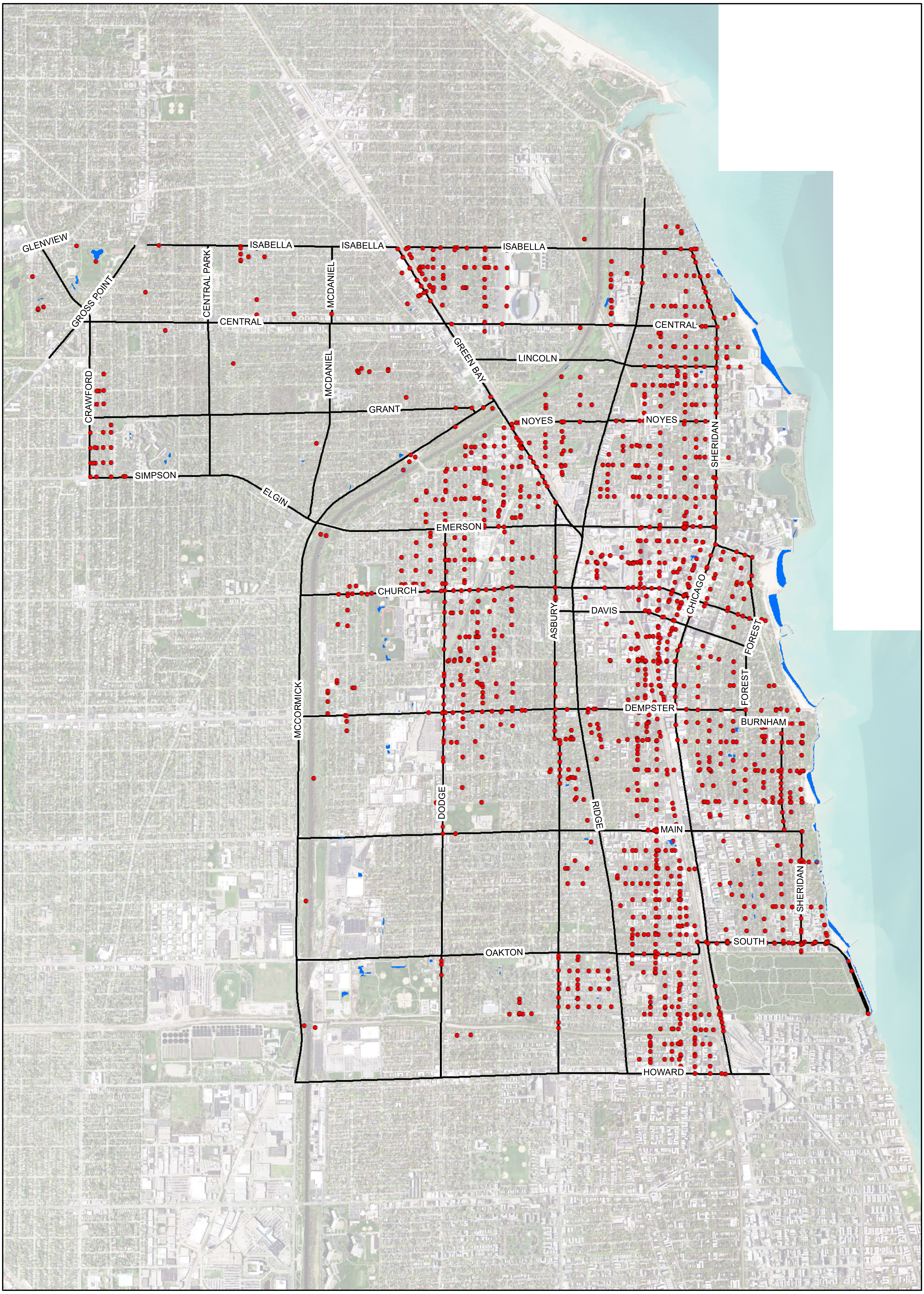
2017 Aerial

Exhibit Title:

Historic Storm: September 14, 2008

Exhibit:

4.3



Scale:

0 1,000 Feet

Orientation:

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Legend:

Sewer Surcharge Risk

Surface Flooding Risk Area

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

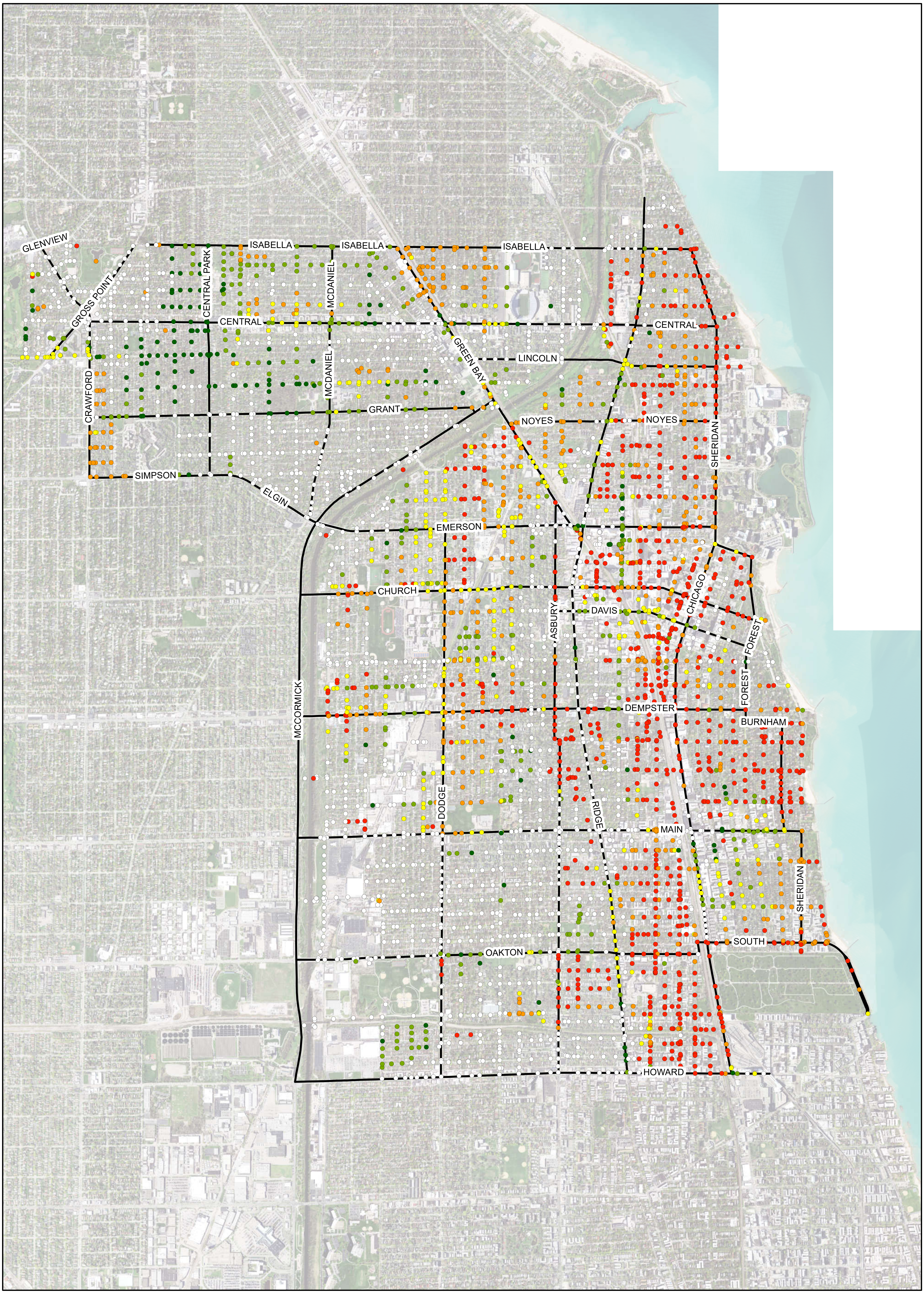
2017 Aerial

Exhibit Title:

Historic Storm: April 17, 2013

Exhibit:

4.4



Scale:

0 1,000 Feet

Orientation:

Project Number: 19-0420

Date: 2/28/2023

Legend:

Sewer Surcharge Risk for 2hr event

- 2yr Flood Risk
- 5yr Flood Risk
- 10yr Flood Risk
- 50yr Flood Risk
- 100yr Flood Risk
- >100yr Flood Risk

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

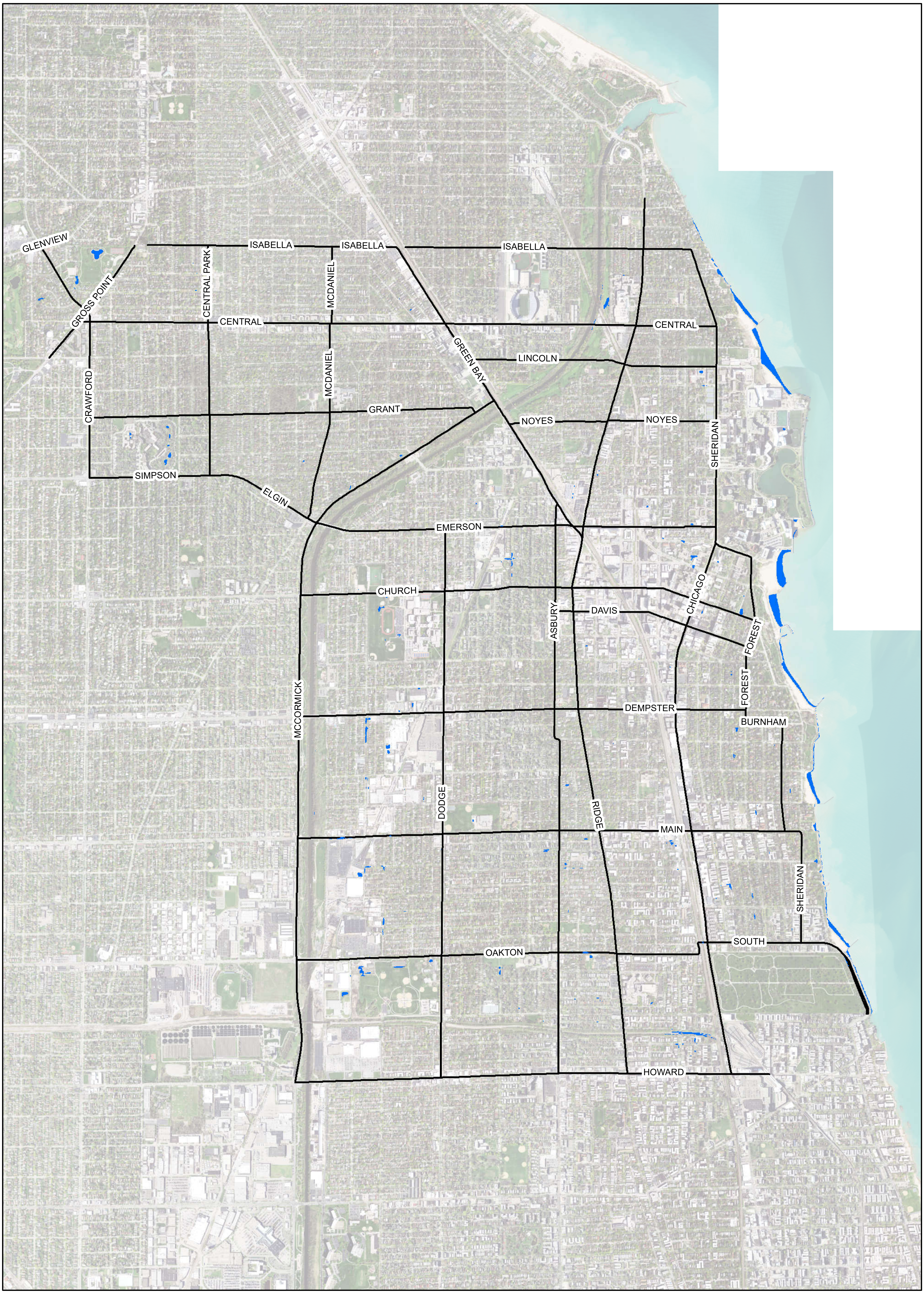
2017 Aerial

Exhibit Title:

Sewer Surcharge Risk

Exhibit:

4.5



Scale:

0 1,000 Feet

Orientation:

Legend:

Surface Flooding Risk Area

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

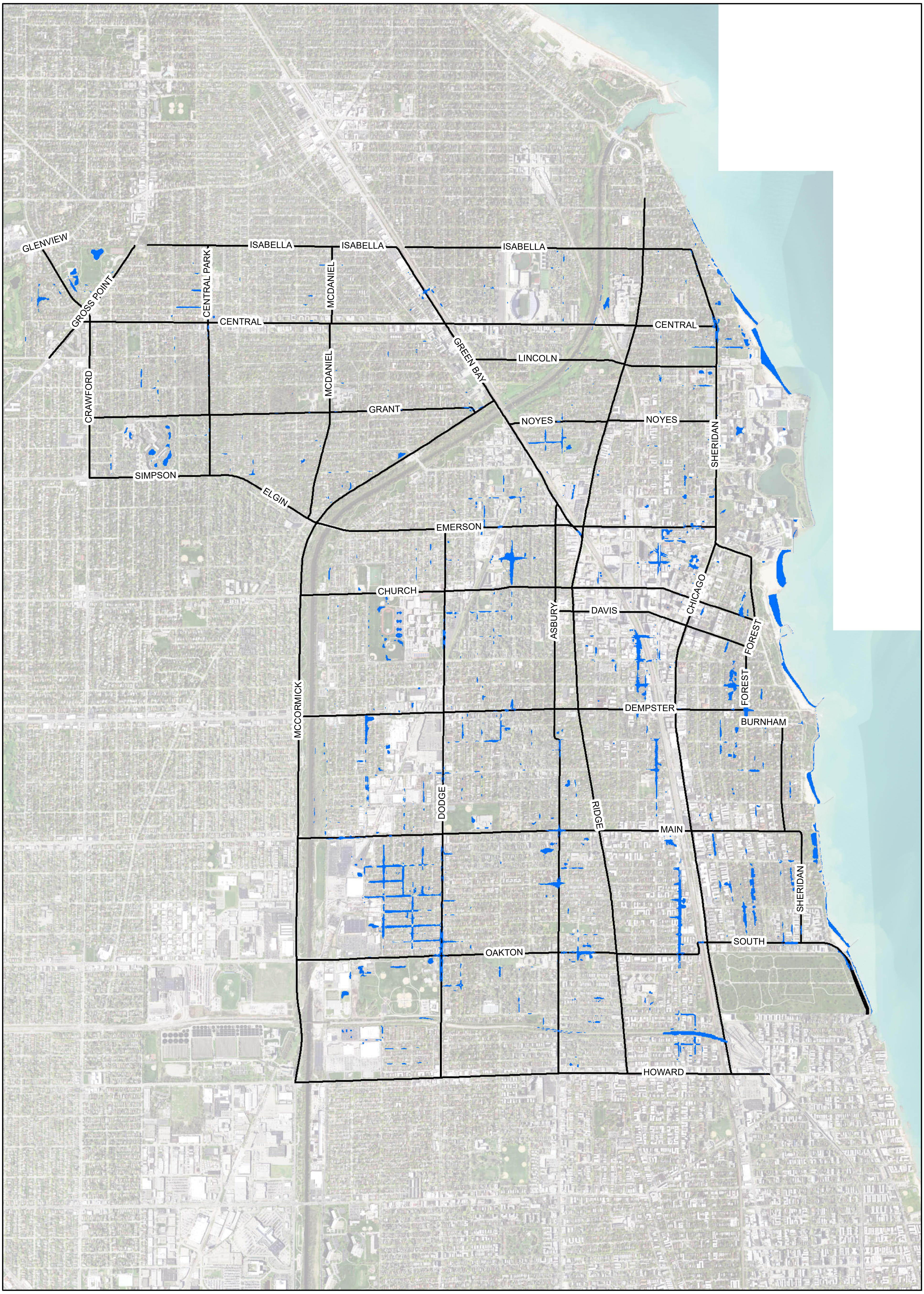
2017 Aerial

Exhibit Title:

Surface Flooding Risk 10yr 2hr

Exhibit:

4.6



Scale:

0 1,000 Feet

Orientation:

Legend:

Surface Flooding Risk Area

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

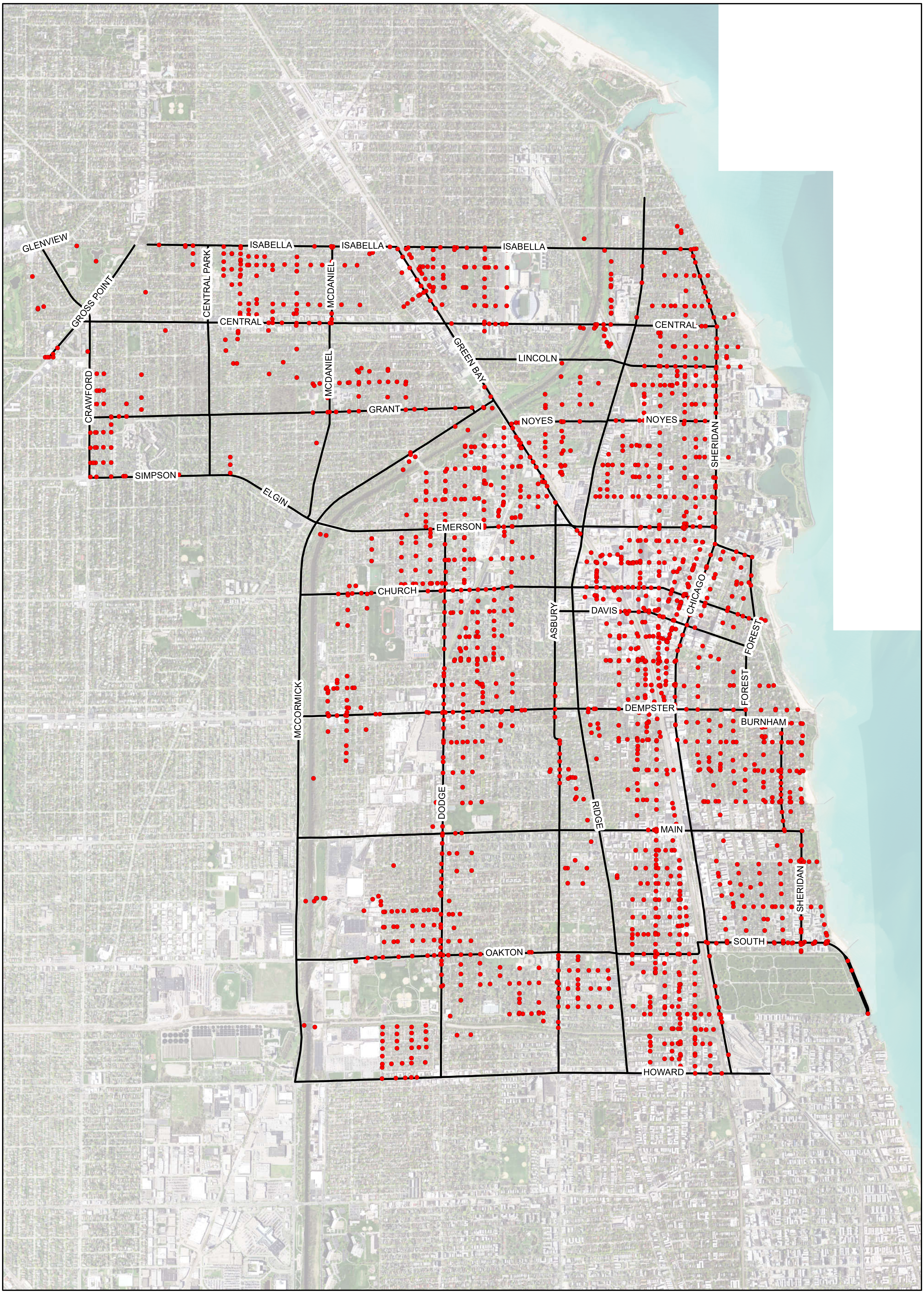
2017 Aerial

Exhibit Title:

Surface Flooding Risk 100yr 2hr

Exhibit:

4.7



Scale:

0 1,000 Feet

Orientation:

Legend:

Sewer Surcharge Risk

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

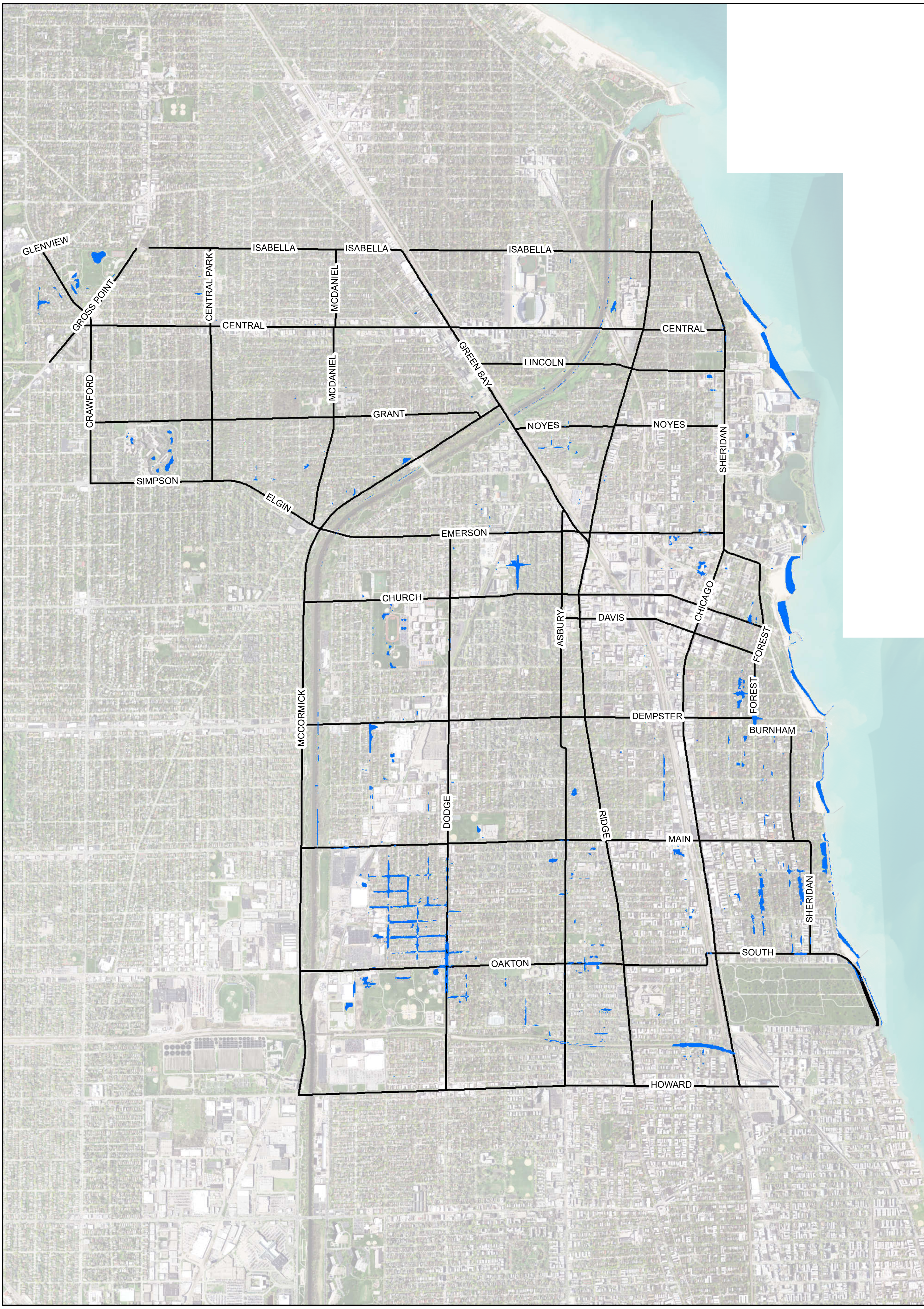
2017 Aerial

Exhibit Title:

Sewer Surcharge Risk 100yr 12hr

Exhibit:

4.8



Scale:

0 1,000 Feet

Orientation:

Legend:

Surface Flooding Risk Area

Project Number: 19-0420

Date: 2/28/2023

Prepared by:

Hey and Associates, Inc.

Engineering, Ecology and Landscape Architecture

Project Name:

Stormwater Master Plan

Prepared for:

City of Evanston

Information about exhibit:

2017 Aerial

Exhibit Title:

Surface Flooding Risk
100yr 12hr

Exhibit:

4.9