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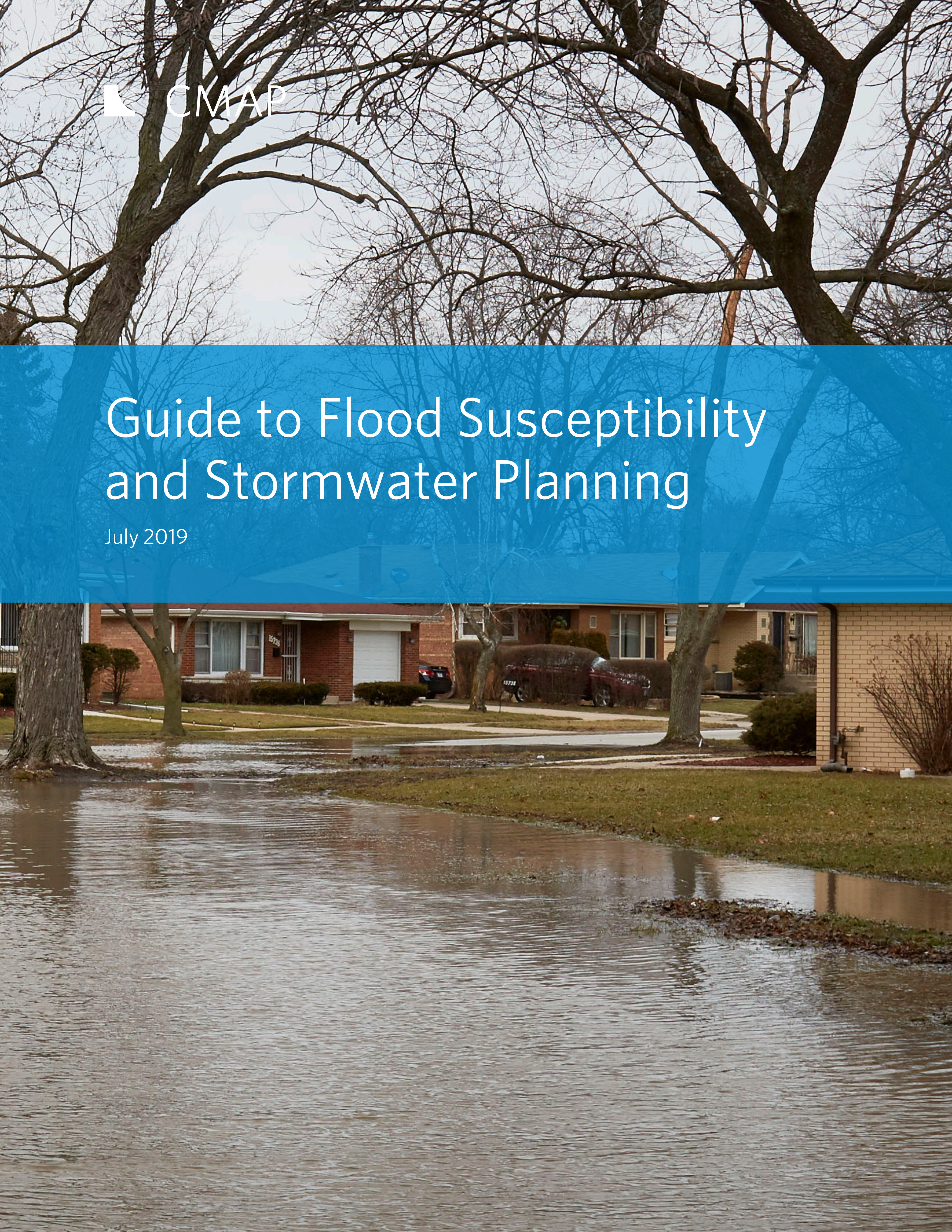

Guide to Flood Susceptibility and Stormwater Planning

July 2019

Funding Acknowledgement

This project was supported by the MacArthur Foundation, Cook County Community Development Block Grant Disaster Recovery (CDBG-DR), and through the Chicago Metropolitan Agency for Planning's (CMAP) Local Technical Assistance (LTA) program, which is funded by the Federal Highway Administration (FHWA), Federal Transit Administration (FTA), U.S. Department of Housing and Urban Development (HUD), Illinois Department of Transportation (IDOT), and the Chicago Community Trust. CMAP would like to thank these funders for their support for this project.

The Chicago Metropolitan Agency for Planning (CMAP) is the region's official comprehensive planning organization. Its GO TO 2040 planning campaign is helping the region's seven counties and 284 communities to implement strategies that address transportation, housing, economic development, open space, the environment, and other quality of life issues.

See www.cmap.illinois.gov for more information

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Introduction

Northeastern Illinois experiences both riverine and urban flooding. While flooding is a natural occurrence, continued urbanization and climate change are leading to more flooding. Development of impervious cover prevents the infiltration of rainwater and generates stormwater runoff, while climate change results in more frequent and intense storm events. Increased stormwater runoff can overwhelm local drainage systems and lead to urban flooding, such as ponding water in streets and yards, basement flooding, and sewer backups. Stormwater eventually flows to rivers and streams and can cause riverine flooding as water flows over riverbanks and into the floodplain.

Flooding presents significant economic, social, infrastructural, and environmental challenges and can make it difficult for communities to implement regional and local goals. Land use changes and transportation investments can increase the risk of flooding, but can also, when designed appropriately, contribute to stormwater solutions and reduced risk. Historically, planners have relied on mapped floodplains to protect people and assets from harm's way, yet the majority of recent flood damages in northeastern Illinois have occurred outside of the floodplain.[1]

Stormwater management issues, particularly urban flooding, may not be included in planning efforts due to a limited understanding of where flooding problems are located without expensive engineering studies. In response to this issue, the Chicago Metropolitan Agency for Planning (CMAP) developed a GIS-based, planning-level approach to identify areas with potential flooding issues and corresponding land use based solutions for communities in the Chicago region. The approach utilizes CMAP's Regional Flood Susceptibility Index (FSI), which helps prioritize areas susceptible to flooding for planning and mitigation investments. The approach does not replace or replicate the in-depth engineering that is often necessary to develop a detailed understanding of flooding causes and solutions, but it does provide a simpler, more cost-effective approach that can serve as an interim step for identifying areas needing further investigation.

This guide is intended for community planners and others interested in integrating more information about flooding conditions into future land use and transportation planning processes. It presents methods for utilizing the FSI and additional water resources data to assess flooding issues, inform stakeholders and decision makers about potential flood mitigation options, particularly green infrastructure (GI) and land use solutions, and to incorporate those solutions into land use and transportation decisions. The guide first introduces the FSI and steps through how it can be used to quickly identify areas that could be more susceptible to flooding and incorporate that information into any standard planning project.

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[1] Chicago Metropolitan Agency for Planning, "Stormwater and Flooding Strategy Paper," 2018, http://www.cmap.illinois.gov/onto2050/strategy-papers/stormwater.

This guide then outlines steps for conducting a more detailed review of hydrological conditions within the community and how to prioritize areas that would benefit from GI and land use intervention and identify potential locations for further analysis. This application could also fit within any standard planning process, but is more time intensive and the methodology relies on knowledge of ArcGIS software, including Arc Hydro tools and the Spatial Analyst extension. The methodology assumes the practitioner is conducting the analysis as part of an overall planning process and has access to community input on both flooding problem areas as well as the proposed solutions. Where available, CMAP has provided a list of stormwater planning datasets on the CMAP website to help assist planners in the Chicago region.[2]

Given the severity of urban flooding in Northeastern Illinois, and the watershed-scale challenges necessary to properly address overbank flooding using stormwater management practices as opposed to more straightforward floodplain restoration, this approach concentrates more on localized drainage problems and less on riverine flooding.[3] Land use interventions can mitigate many flooding issues; however, they are only a part of the total solution. Severe flooding problems are likely to require both grey and green infrastructure solutions, as well as policy and regulatory responses. Furthermore, GI solutions have implementation limitations in already developed areas due to site constraints, and may not provide sufficient capacity to manage stormwater generated from large storms. GI best management practices (BMPs) are typically sized to capture the first half-inch to inch and a half of rainfall, i.e., more frequent and smaller storm events, which in some cases may be sufficient to address localized urban flooding problems. GI provides an added benefit, however, in that it can significantly improve the quality of runoff into rivers and streams by capturing and filtering that first flush of runoff, where a majority of many non-point source pollutants are carried.

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[2] CMAP. 2017. Stormwater Planning Data Inventory. See http://www.cmap.illinois.gov/livability/water/stormwater/stormwater-data.

[3] Given the many causes for urban flooding and the changing urban environment, precise mapping of urban flood areas is not technically possible at this time. Instead, this approach identifies areas of the community that may be prone to urban flooding and then identifies opportunities to reduce the amount of runoff generated or flowing to the subsurface and overland drainage systems. It also recognizes that structural differences between properties can make a large difference in flood susceptibility.

Regional Flood Susceptibility Index

Given the different causes and contributing factors for riverine and urban flooding, CMAP developed two regional flood susceptibility indexes (FSI) to identify areas across the region that may require closer investigation for flood mitigation activities. The urban and riverine FSIs are spatially-depicted through raster grids and are available for the seven counties of northeastern Illinois. The two FSIs use slightly different flood-related factors.[4] The riverine FSI pertains to those areas of the region within the Federal Emergency Management Agency (FEMA) 100-year floodplain or Metropolitan Water Reclamation District (MWRD) 100-year inundation layer within Cook County (Figure 1), and the urban FSI includes all areas of the region outside of those 100-year zones (Figure 2).[5] Although existing floodplain maps already identify areas of riverine flood risk, the riverine FSI highlights areas within floodplains that have characteristics that may be at greater risk and therefore warrant closer investigation.

While riverine flood risk continues to be best identified through up-to-date floodplain modeling efforts, locations of urban flooding risk remain largely unknown outside of infrequent and individual local modeling efforts. These indexes are not intended to replace those more technical efforts; instead they are designed to identify priorities for mitigation activities at the regional scale, and help inform flood susceptibility in communities lacking more technical analysis.

The FSIs were constructed using a statistical method based on the observed relationship between the distribution of reported flood locations and a variety of flood-related factors. With data assistance from FEMA, counties, and the City of Chicago, CMAP created an address-level database of documented flood locations[6] to cross-reference with flooding-related factors. CMAP's database consists of over 165,000 unique locations. The majority of the reported flood locations occurred within the past ten years (2007-17), however, some of the data from the National Flood Insurance Program dates back to 1978. More information about the FSI methodology, as well as the FSI layers, are available for download on the CMAP Data Hub.[7]

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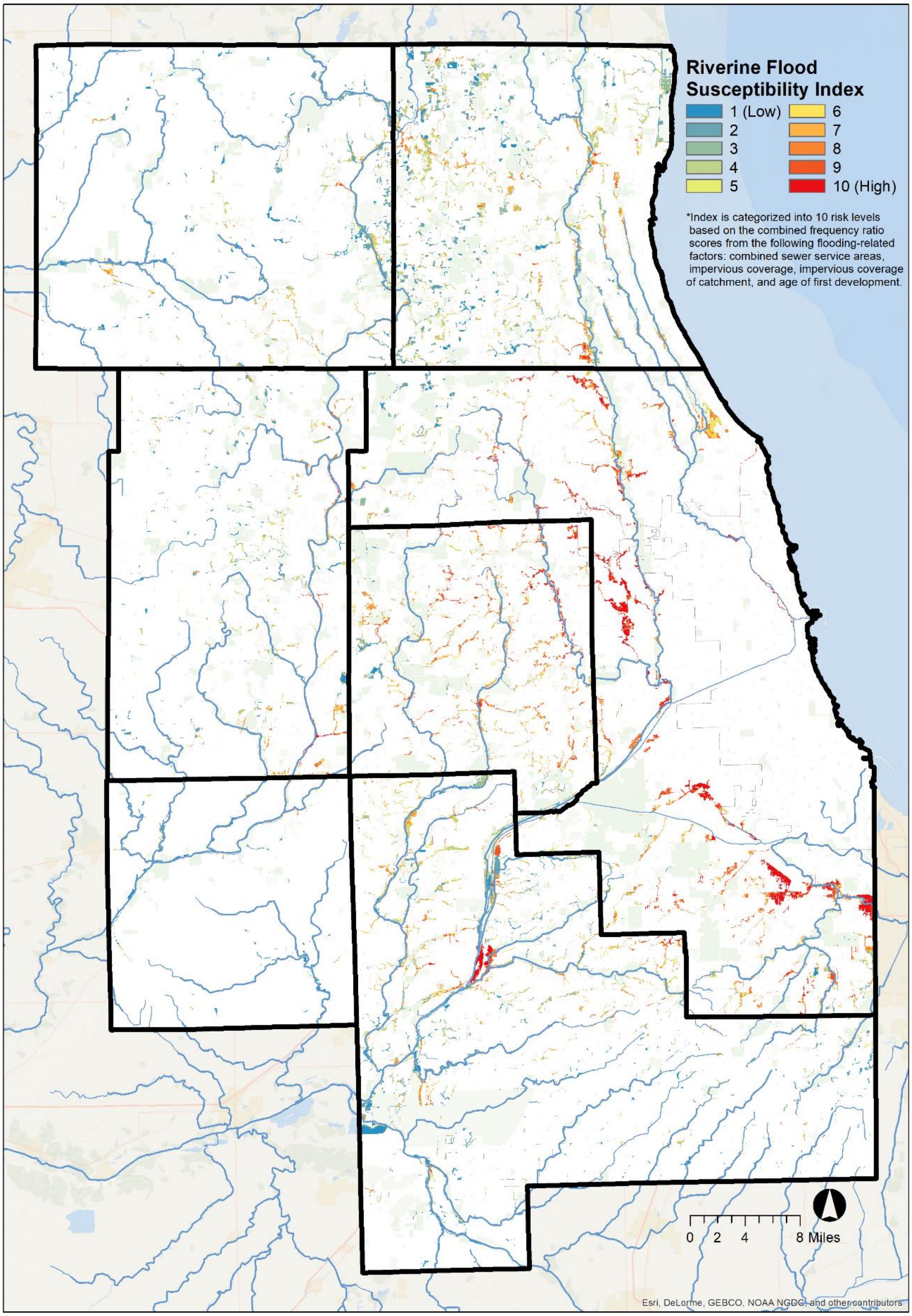
[4] CMAP, 2018, "Flood Susceptibility Index Appendix," https://datahub.cmap.illinois.gov/dataset/14e2d069-20b3-4c45-a8cc-e4ae31fb8e61/resource/9ec0ed5e-15ab-4c9c-a7b4-332e755ba872/download/FloodSusceptibilityIndexAppendix.pdf.

[5] The analysis focused on flooding of developed areas, so the geographies of both urban and riverine flooding have been further refined to exclude areas of water, open space, and agricultural production using data from the 2013 CMAP Land Use Inventory.

[6] Reported flood locations were identified through the following sources: FEMA National Flood Insurance Program claims, FEMA Individual Assistance Grants, FEMA Discovery Data, City of Chicago 311 Standing Water Locations, MWRD Detailed Watershed Plans, DuPage County, Kendall County Department of Planning, and the Lake County Stormwater Management Commission.

[7] CMAP, 2018, "ON TO 2050 Layer: Flood Susceptibility Index," https://datahub.cmap.illinois.gov/dataset/on-to-2050-layer-flood-susceptibility-index.

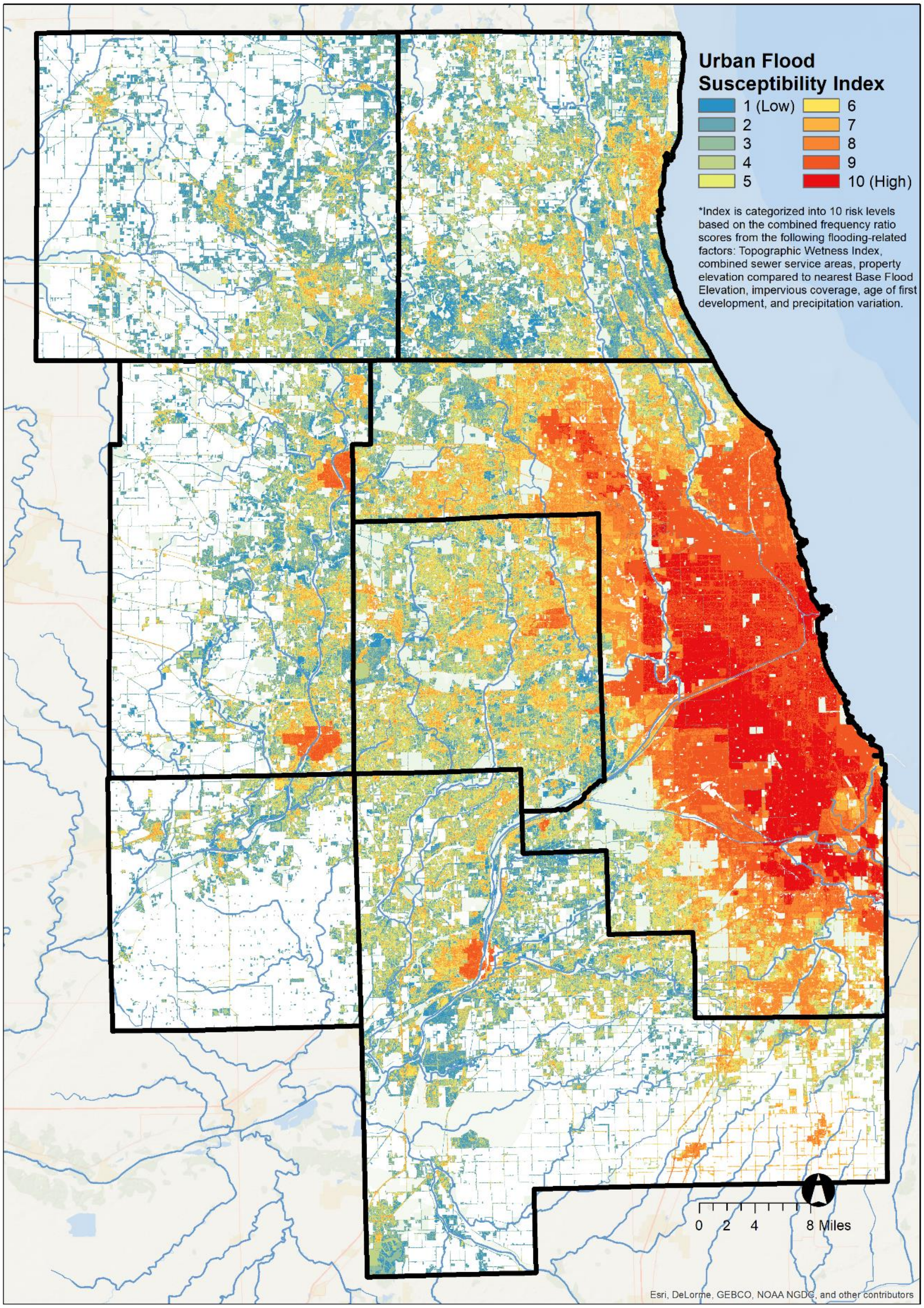
Figure 1. Regional Riverine Flood Susceptibility Index, CMAP region



*Index is categorized into 10 risk levels based on the combined frequency ratio scores from the following flooding-related factors: combined sewer service areas, impervious coverage, impervious coverage of catchment, and age of first development.

Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

Figure 2. Regional Urban Flood Susceptibility Index, CMAP region



*Index is categorized into 10 risk levels based on the combined frequency ratio scores from the following flooding-related factors: Topographic Wetness Index, combined sewer service areas, property elevation compared to nearest Base Flood Elevation, impervious coverage, age of first development, and precipitation variation.

Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

Table 1. Flooding-related factors used in the urban and riverine flood susceptibility indexes

Flooding-related factor	Description
Topographic Wetness Index (TWI) (urban FSI only)	The TWI identifies flat areas with high flow accumulation where water is likely to pond, especially if the existing storm sewer network has reached capacity. Streets and buildings within these areas could be more susceptible to surface ponding, overland flow, or water seepage. The TWI is calculated by evaluating the flow accumulation, slope, and various geometric functions through GIS
Combined sewer service areas	Combined sewers have long been recognized as more susceptible to flooding given the combination of flow from storm and sanitary sewers. When flows exceed sewer design capacities, areas of the region can experience basement backups and combined sewer overflows. CMAP identified those areas of the region currently being served by combined sewers with data assistance from MWRD and various communities.
Elevation differential between property and nearest Base Flood Elevation (BFE) (urban FSI only)	Development with a surface elevation within six feet of the BFE near a floodplain have been identified as higher urban flooding risk. The Cook County Hazard Mitigation Plan identified that the majority of repetitive loss properties located outside of the floodplain had basements below the base flood elevation. Using GIS, CMAP calculated the mean parcel elevation for properties within 1,500 feet of the nearest BFE and identified those whose elevation was within six feet.
Impervious cover	Impervious cover prevents infiltration of rainwater and generates stormwater runoff. Areas with higher impervious cover generate more runoff and are more reliant on sewer drainage capacity. Development in these areas could experience flooding in the form of basement backups, due to overloaded sewers, and surface ponding. CMAP relied on the National Land Cover Dataset to identify the percent of impervious cover.
Impervious cover of watershed catchment (riverine FSI only)	Riverine flooding is related to the imperviousness of the contributing watershed catchment. More developed catchments have the potential to generate more stormwater runoff that increases the risk of flooding. CMAP relied on the National land Cover Dataset to identify the percent of impervious cover within catchment boundaries from the National Hydrography Dataset Plus.
Age of first development	Nationally, development regulations began to recognize floodplains in 1968, and stormwater management ordinances were introduced in the region in 1972. However, large portions of the region were developed prior to these practices and may be more likely to experience flooding. In addition, older development may be more susceptible to flooding due to greater maintenance demands over time. CMAP utilized the USGS National Water-Quality Assessment (NAWQA) Wall-to-Wall Anthropogenic Land Use Trends (NWALT) 1974-2012 land cover datasets in order to conduct a comparison over time.

Interpreting the indexes

The flood susceptibility indexes identify locations that may be more susceptible to riverine or urban flooding than other parts of the region. Although specific locations identified in the FSIs may not currently flood, streets and buildings within these areas could be more susceptible to overbank flooding, surface ponding, overland flow, water seepage, and basement backups due to the presence of flood-related factors and physical conditions that are correlated with reported flood damages.

The high scoring areas of the index (scores 8 – 10) have a combination of physical factors that make them more susceptible to flooding.

> **High score – riverine index:** Areas receiving a high score have dense development in the floodplain that occurred prior to the early 1990s. In addition to developed floodplains, locations with dense upstream development have the potential to generate more stormwater runoff that increases the risk of riverine flooding. The presence of these conditions, particularly in areas served by combined sewers, can result in the highest scoring areas. It is important to remember that the riverine index is focused on locations within the 100-year floodplain, which has been delineated through floodplain modeling, but may be based on outdated data. While the index does not take into account the hydraulics and hydrology of these waterways, high scoring areas illustrate locations where development could be at a higher risk of flooding.
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> **High score – urban index:** High scoring locations tend to be older areas of the region that were not only developed without stormwater management systems, but are often served by combined sewers. These areas have a moderate to high percentage of impervious cover, where intense stormwater runoff can overwhelm the combined sewer system. Low-lying depressions in developed areas where water is likely to pond, especially if the sewer system has reached capacity, are also identified by the index and are associated with high flooding reports as well.

The moderate scoring areas of the index (scores 4 – 7) often have a combination of factors that can make them susceptible to flooding, but may also have other physical assets that help to reduce flooding risk.

> **Moderate score – riverine index:** Areas receiving a mid-range score have development in the floodplain; however, the development may have been built following floodplain management standards, development may be less dense, or there may be more open space upstream in the watershed to help absorb runoff and decrease the risk of riverine flooding. These areas are often served with separate sewers that experience a lower risk of flooding than combined sewer areas. It is important to remember that the riverine index is focused on locations within the 100-year floodplain, which has been delineated through floodplain modeling. While the index does not take into account the hydraulics

and hydrology of these waterways, moderate scores indicate locations where development could be at a moderate risk of flooding.

Moderate score – urban index: Areas receiving a mid-range score in the urban index are often served with separate sewers and may have been developed with floodplain and stormwater management practices. However, some development may still be located in low-lying areas where water is likely to pond, especially if the existing storm sewer network has reached capacity. While these areas typically have less impervious cover than high scoring locations, some areas may still have localized flooding due to stormwater runoff.

Riverine example: Fox River Corridor Plan[8]

Figure 3 shows riverine flood susceptibility for the Fox River Corridor. Areas at the highest end of the scale are highly susceptible compared to the region as a whole, not to the study area depicted in the map. The map shows that the riverine flood susceptibility of the corridor's developed areas is lower than in other areas throughout the region. The lower risk is partly due to the open space that buffers the river as well as the relatively little development in corridor floodplains compared to the rest of the region. This makes open space maintenance even more important to ensure these areas continue to perform floodplain management services.

The map does indicate that some developed portions of the study area are more susceptible to riverine flooding, likely due to the older age of development and higher density, as well as the extent of development and impervious cover upstream. All developed areas could potentially become more vulnerable to flooding if development in the floodplain expands, if the contributing watershed significantly increases its imperviousness, and if precipitation patterns continue to change.

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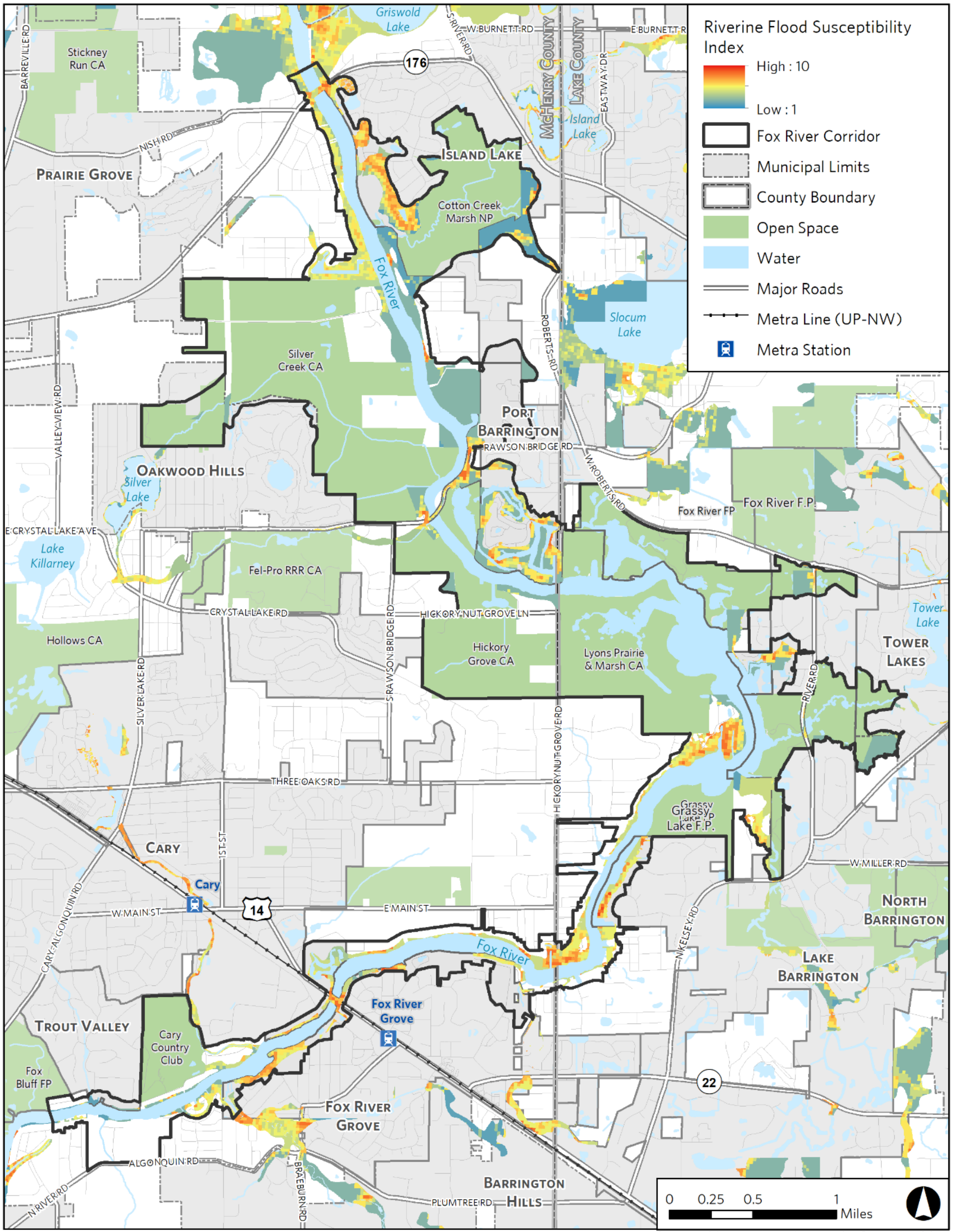
[8] Information about the Fox River Corridor Plan for McHenry and Lake Counties can be found here: http://www.cmap.illinois.gov/programs/lta/fox-river-mchenry-lake

Figure 3. Regional Riverine Flood Susceptibility Index, Fox River Corridor



Chicago Metropolitan Agency for Planning, 2017

Urban example: City of Wilmington Downtown Plan[9]

Figure 4 shows urban flood susceptibility for the Downtown area of the City of Wilmington. Areas at the highest end of the scale are highly susceptible compared to the region as a whole, not just to the community. The map shows that the urban flood susceptibility of Downtown Wilmington is one of several potential priority areas in the City. The mid-range scores reflect dense development with high impervious cover, older buildings constructed in areas prior to stormwater management practices, and low-lying areas on streets and private property that could experience ponding. While community outreach has indicated that urban flooding is not currently a concern in the City, the index results show that the downtown area has a higher relative susceptibility to urban flooding than other parts of the community, and could become vulnerable to localized flooding caused by stormwater runoff if precipitation patterns continue to change.

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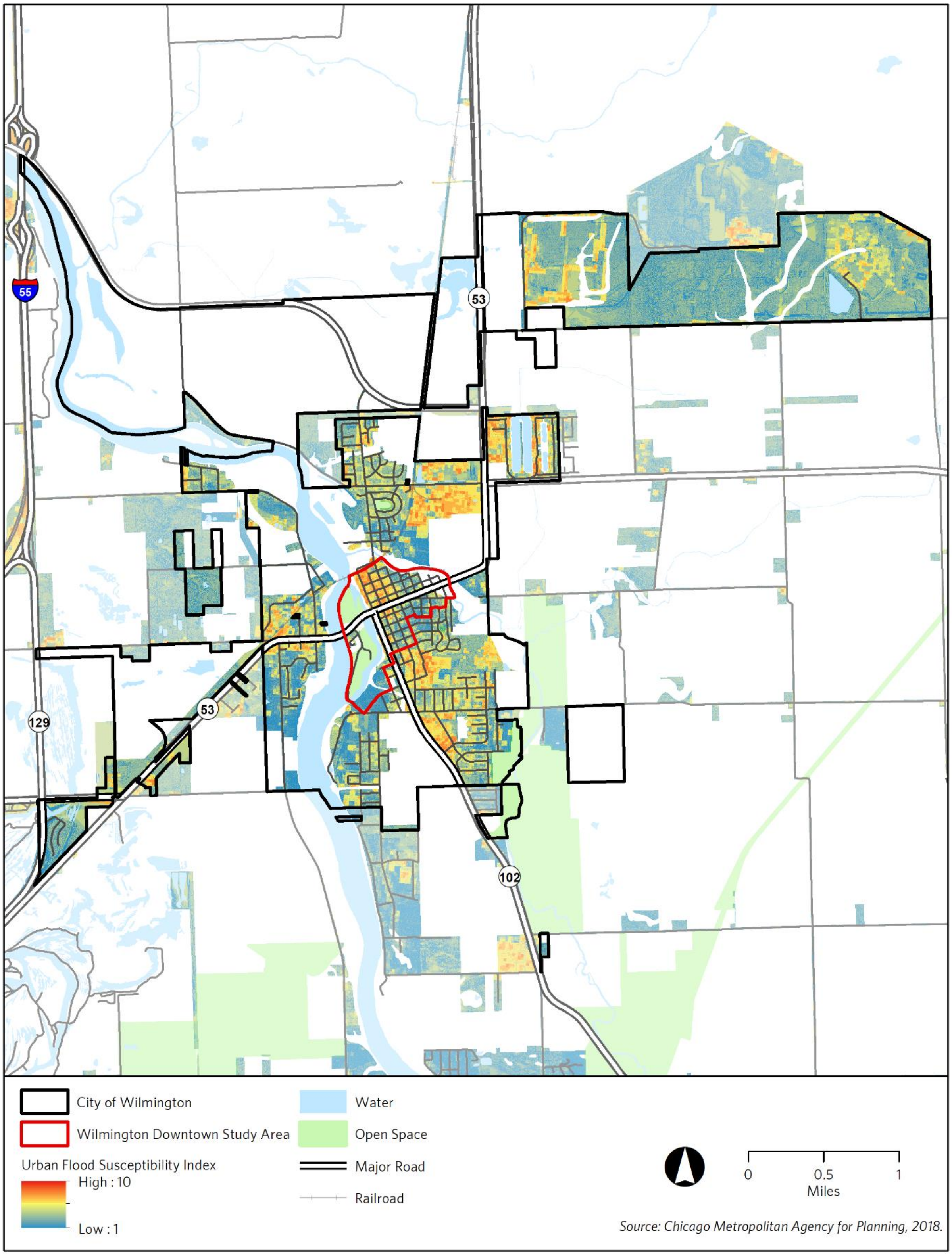
[9] Information about the Downtown Plan for Wilmington can be found here: http://www.cmap.illinois.gov/programs/lta/wilmington

Figure 4. Regional Urban Flood Susceptibility Index, Wilmington, Illinois



Source: Chicago Metropolitan Agency for Planning, 2018.

Urban example: City of Berwyn Stormwater Management Plan[10]

The urban FSI does not provide much distinction in risk across dense urban cities like Berwyn and the communities that surround it, as shown in Figure 45. The index illustrates that the City is at the highest end of the scale and is highly susceptible to urban flooding when compared to the rest of the Chicago region. These high scores are a result of dense and uniform development patterns, high imperviousness, older buildings constructed prior to stormwater management practices, and the presence of a combined sewer system. When communities or study areas score uniformly high on the urban FSI, it is recommended that a more detailed stormwater analysis is performed as described in the following section.

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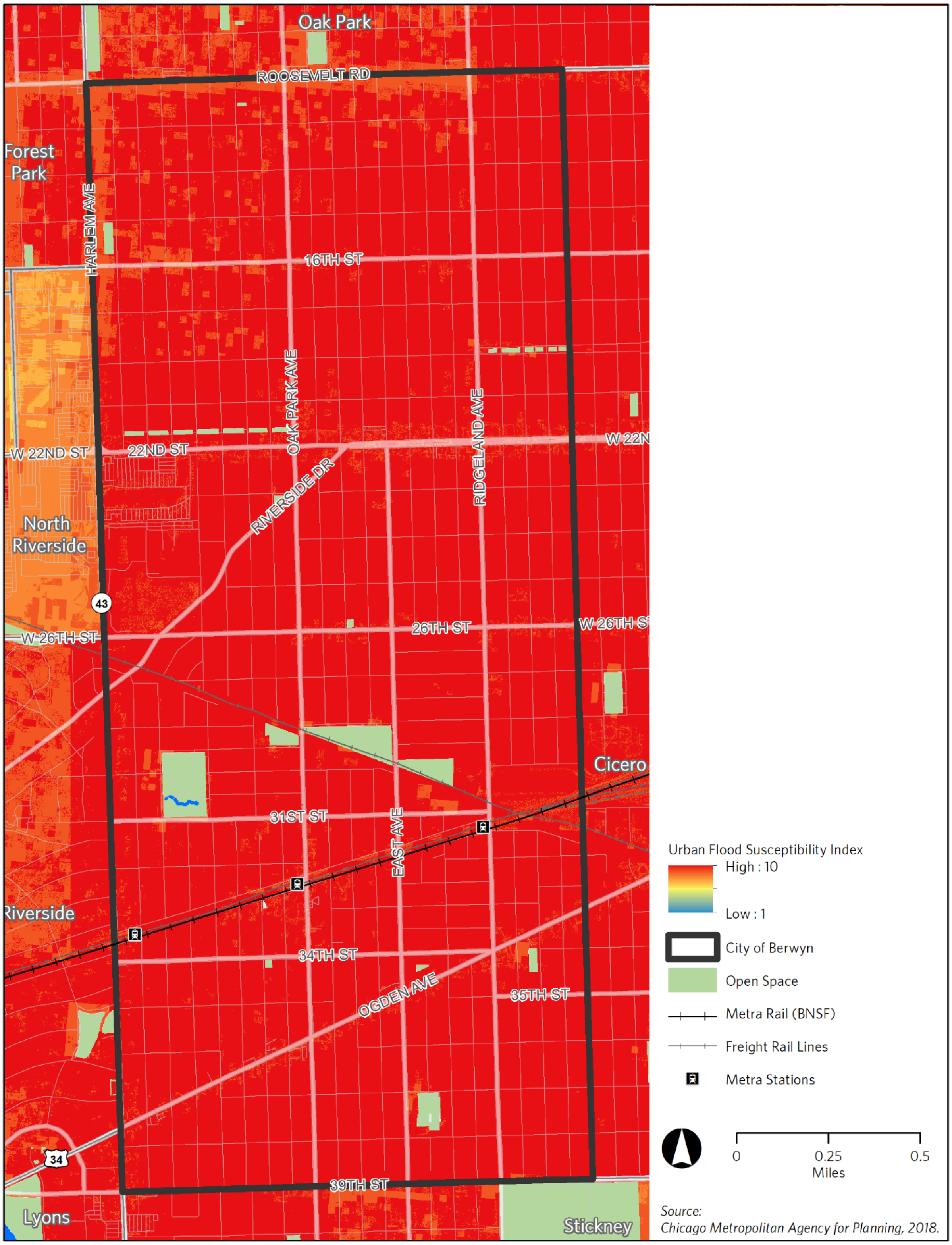
[10] Information about the Stormwater Management Plan for Berwyn can be found here: http://www.cmap.illinois.gov/programs/lta/berwyn-stormwater

Figure 5. Regional Urban Flood Susceptibility Index, Berwyn, Illinois



Source:
Chicago Metropolitan Agency for Planning, 2018.

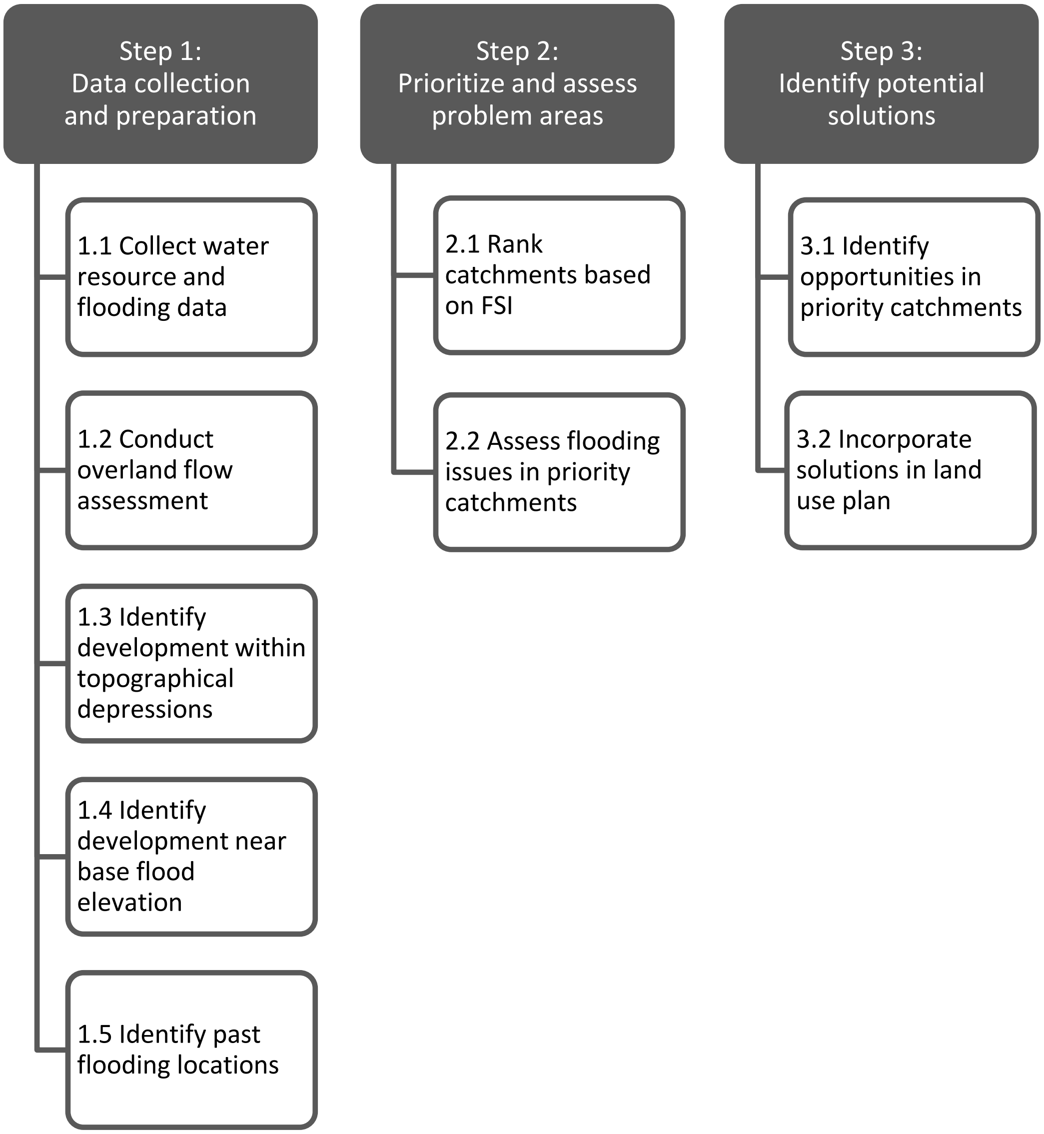
Using the Flood Susceptibility Index for stormwater planning

CMAP has designed a stormwater planning approach to complement comprehensive planning, stormwater planning, and other local planning processes. Table 2 provides an overview of the major steps of a standard planning process along with the additional stormwater management components. The rest of this guide focuses on key steps within the existing conditions analysis and vision development phase, highlighted in Figure 6. Within each step, it is critical to receive input from stakeholders and municipal staff who are familiar with the causes and characteristics of flooding in the community.

Table 2. Standard planning steps and suggested stormwater planning components

Plan phases	Standard planning steps	Enhanced stormwater planning steps
Community outreach and engagement *(Ongoing)*	Engage municipal staff, elected officials, residents, business owners, and others through public meetings, online surveys, focus groups, and stakeholder interviews.	Gather municipal, resident, and other stakeholder feedback on flooding locations within the community.
Existing conditions analysis *(Phase 1)*	Compile information on community existing conditions, including historical context, previous planning efforts, demographics, land use, housing, transportation, and natural resources.	*Step 1: Data collection and preparation* - Gather water resources and flooding data (for example, some communities have a flood reporting system such as 311 reports), overland flow assessment, and identify potential areas of vulnerability. *Step 2: Prioritize and assess problem areas* - Identify catchments with a higher potential for flooding problems. Confirm priority catchments with stakeholders and identify the likely causes of flooding in each priority catchment.
Vision development *(Phase 2)*	Develop a shared vision with the community informed by the existing conditions analysis and public engagement.	*Step 3: Identify potential solutions* - Identify land use and green infrastructure opportunities within high priority catchments to mitigate causes of flooding. Develop a menu of community-appropriate mitigation measures.
Draft plan *(Phase 3)*	Draft plan with recommendations on various topics, such as housing, land use, transportation, etc. The plan also outlines an implementation strategy.	*Step 3: Identify potential solutions* - Identify municipal-wide policies or more local strategies for stormwater management. Incorporate larger, already developed regional scale solutions to riverine flooding into land use plan and strategies. Develop list of potential improvement sites or focus areas and offer concept-level solutions. - Reflect opportunities in future land use plan. - Identify areas that may require engineered structural solutions. - Identify areas that require multi-jurisdictional collaboration. - Include stormwater projects in implementation strategy.

Figure 6. Enhanced stormwater planning steps



Step 1: Data collection and preparation

The first step in this process is to learn more about the conditions that can cause flooding, like water resources, topography, and stormwater infrastructure capacity, and to collect available information on past flooding events. In addition, several datasets should be prepared to better understand how water flows across the built environment/landscape in relation to community assets and facilities, residential neighborhoods, commercial districts, and other features. This step is comprised of five sub-tasks and includes modeling overland flow accumulation, mapping flood risk indicators, and performing spatial intersections of the data. The prepared datasets will be used to better understand existing conditions within the community and to inform Step 2. Mapped datasets may contain sensitive information and should only be used in internal conversations with municipal staff and leadership.

1.1 Collect spatial data and past flood locations

The initial step involves collection of spatial data, development of a GIS database, and compiling other background materials. Table 3 lists several data sets that can be analyzed to identify flooding problems and solutions, and which step uses or produces the data. This list includes the FSI, which is available for download on the CMAP Data Hub,[11] as well as a number of other datasets that are available or accessible from CMAP's Stormwater Planning Data Inventory, which provides links to regional and local data sources in northeastern Illinois.[12]

In addition to these datasets, general knowledge of the study area, such as whether the sewer system is combined or separated, should be included to strengthen the analysis and recommendations. Conversations with municipal engineering, planning, and public works staff will be essential to learn about the study area and gather relevant datasets. Local watershed and stormwater plans, particularly those that include modeling efforts, should also be referenced to understand conditions and potential solutions. Additional datasets to account for site-specific concerns and constraints may be added during Step 2.

Anecdotal information can be very helpful in identifying flood problem areas. Public meetings and other outreach activities, such as online surveys, provide an opportunity to collect additional information on current and past flooding problem areas using maps and other media. Ideally, information gained through the public outreach process would identify the type of flooding (basement backups, basement or foundation seepage, yard flooding, street flooding, or riverine flooding) as well as the frequency and severity of the flooding, such as the water depth or extent of flooded area. Determining flood locations is critical for the analysis, but because residents may be sensitive about sharing this information, CMAP recommends establishing processes to maintain confidentiality.

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[11] "ON TO 2050 Layer: Flood Susceptibility Index," Chicago Metropolitan Agency for Planning, January 2018, https://datahub.cmap.illinois.gov/dataset/on-to-2050-layer-flood-susceptibility-index.

[12] "Stormwater Planning Data Inventory," Chicago Metropolitan Agency for Planning, 2017, http://www.cmap.illinois.gov/livability/water/stormwater/stormwater-data.

Table 3. Data Needs

Data	Source	Steps Used
Hydrology	EPA National Hydrology Dataset (NHD) Plus, County	1.2
Known sinks[13]	Community, County Stormwater/MWRD	1.2
Watershed (HUC 12)	U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) or NHD	1.2
Digital Elevation Model (DEM)	Illinois Height Modernization (ILHMP)	1.2
Building footprints	Community, County	1.2, 2.2
Land use	CMAP Land Use Inventory	1.3, 2.2, 3.1
Regional Flood Susceptibility Indexes	CMAP	2.1
Catchments	Derived in overland flow assessment, step 1.2	2.1, 2.2, 3.1
Depressions	Derived in overland flow assessment, step 1.2	1.3, 2.2
Flowpath / flow accumulation grid	Derived in overland flow assessment, step 1.2	2.2, 3.1
Floodplains and Base Flood Elevation (BFE) (for 1% annual chance)	FEMA National Flood Hazard Layer or MWRD 100-yr inundation layer (Cook County only)	1.4, 2.2
National Flood Insurance Program claims	FEMA	1.5
Reported problem areas	Community,[14] FEMA Flood Risk Mapping,[15] outreach data	1.5, 2.2
Historic stream locations	U.S. Geological Survey (USGS) quads or other historic maps (digitize if historic streams are identified)	2.2
Combined sewer service area	Community, County	2.2
Age of first development	USGS Anthropogenic Land Use Trends (NWALT), 1974-2012	2.2
Impervious cover	National Land Cover Dataset	2.2
Potential wetland soil landscapes	NRCS	2.2
Sewer system, sewershed	Community, County Stormwater/MWRD	2.2
Stormwater facilities and BMPs	Community information	2.2, 3.1
Public right-of-way and land	CMAP, Illinois Department of Transportation, County Assessor	3.1
Land bank property	Cook County Land Bank Authority, South Suburban Land Band Development Authority	
Green infrastructure mapping	CMAP or local mapping efforts	3.1
Urban tree canopy and land cover	Urban Tree Canopy Assessment; University of Vermont	3.1
Recommended stormwater or flood control projects	U.S. Army Corps of Engineers, County Stormwater Departments, FEMA, Illinois Environmental Protection Agency, Watershed plans	3.1
Local pavement conditions	Community	3.1
Planned capital projects	Community, stakeholder interviews, CMAP Transportation Improvement Program, County Department of Transportation	3.1

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[13] "Sinks" are low-lying areas without a drainage point, which may or may not be overtopped during rain events depending on the volume of accumulated flow. ""Known sinks" are areas that can accommodate typical accumulated flow, such as quarries, large scale flood control facilities, and waterbodies with a high-capacity drainage system.

[14] Municipal flood records vary but may include direct flood reporting, flood rebate recipient locations, or other response data.

[15] FEMA Flood RISK Mapping has been recently conducted for the Chicago River Watershed and the Des Plaines River Watershed, see http://www.illinoisfloodmaps.org/discovery.aspx for more details.

1.2 Conduct overland flow assessment

This step builds an understanding of how water may be expected to pond and move across the landscape when the sewer system reaches capacity, and is based on topography. This information is also used to delineate local (small scale) drainage areas, or catchments. Conducting an overland flow assessment can be done using Arc Hydro tools and a digital elevation model (DEM). Several additional datasets from Table 3 are critical, including the HUC 12 watershed boundaries, hydrology, and known sinks. For best accuracy, the overland flow analysis should be performed for the entire HUC 12 watershed(s) that intersect the study area, in order to model flows within a hydrologically-relevant area. ESRI provides an online tutorial for using Arc Hydro tools; CMAP highly recommends using this guide to step through creating a hydrologically-corrected digital elevation model and then developing flow direction grids, flow accumulation grids, drainage lines, catchments, and depressions.[16] See the CMAP Data Hub for Arc Hydro output descriptions and downloadable data for a number of completed project areas.[17]

Outputs from the overland flow assessment are integral to completing the stormwater assessment. Flow accumulation, which identifies how water is flowing from one area to another, is used to identify the drainage network, or flowpaths, within an area. Depressions, or areas where surface ponding could occur, are used to identify potential vulnerable areas in the next step. Catchments, which identify the areas draining to a particular flowpath segment, are used as the scoring boundary in Step 2. Catchment delineation does not consider subsurface stormwater infrastructure or capacity and, thus, represents surface catchments, not sewersheds. Figure 77 illustrates catchments and flowpaths in a local plan study area.

1.3 Identify development within topographical depressions

Some community facilities or other assets may be more vulnerable to urban flooding due to their location within topographical depressions. First, review the community's existing land use and create a GIS layer that only includes developed areas. Using the depressional areas derived from the overland flow assessment in Step 1.2, create a filter to identify depressions with a depth greater than 1.5 feet, to exclude shallower depressions typically found in parking lots and along curb-lined streets. Then, overlay the filtered depressions with developed areasto identify locations that could be vulnerable to surface ponding, overland flow, or water seepage. These locations should be mapped and can be used to assess flooding issues in Step 2. Figure 8 illustrates the intersection of residential development with depressional areas for a local plan study area. For communities where building footprints are available, the location of the buildings in relation to depressional areas could also be evaluated.

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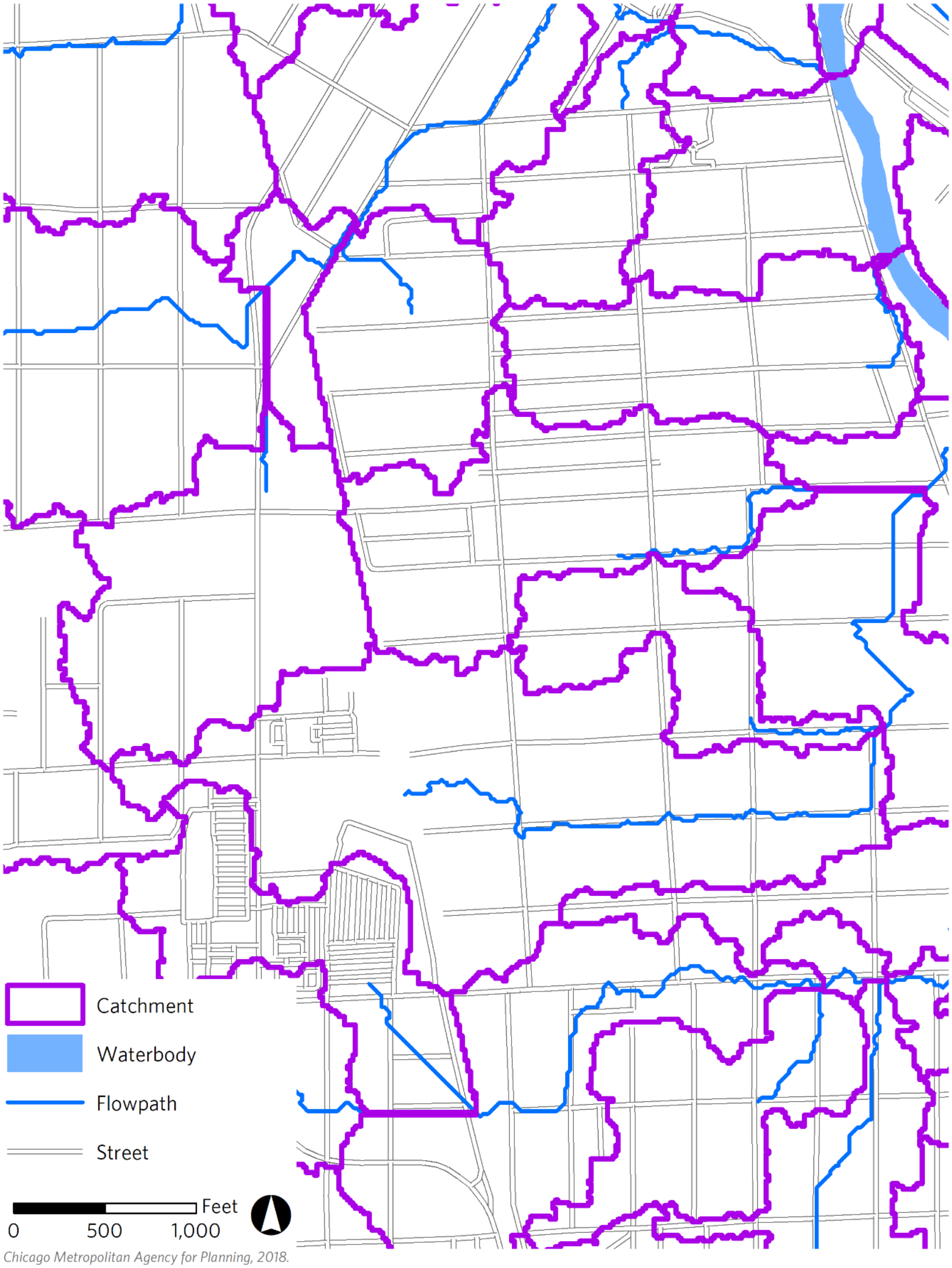
[16] ESRI. 2014, "Arc Hydro Tools – Tutorial. Version 2.0 – October 2011," http://downloads.esri.com/archydro/archydro/Tutorial/Doc/Arc%20Hydro%20Tools%202.0%20-%20Tutorial.pdf.

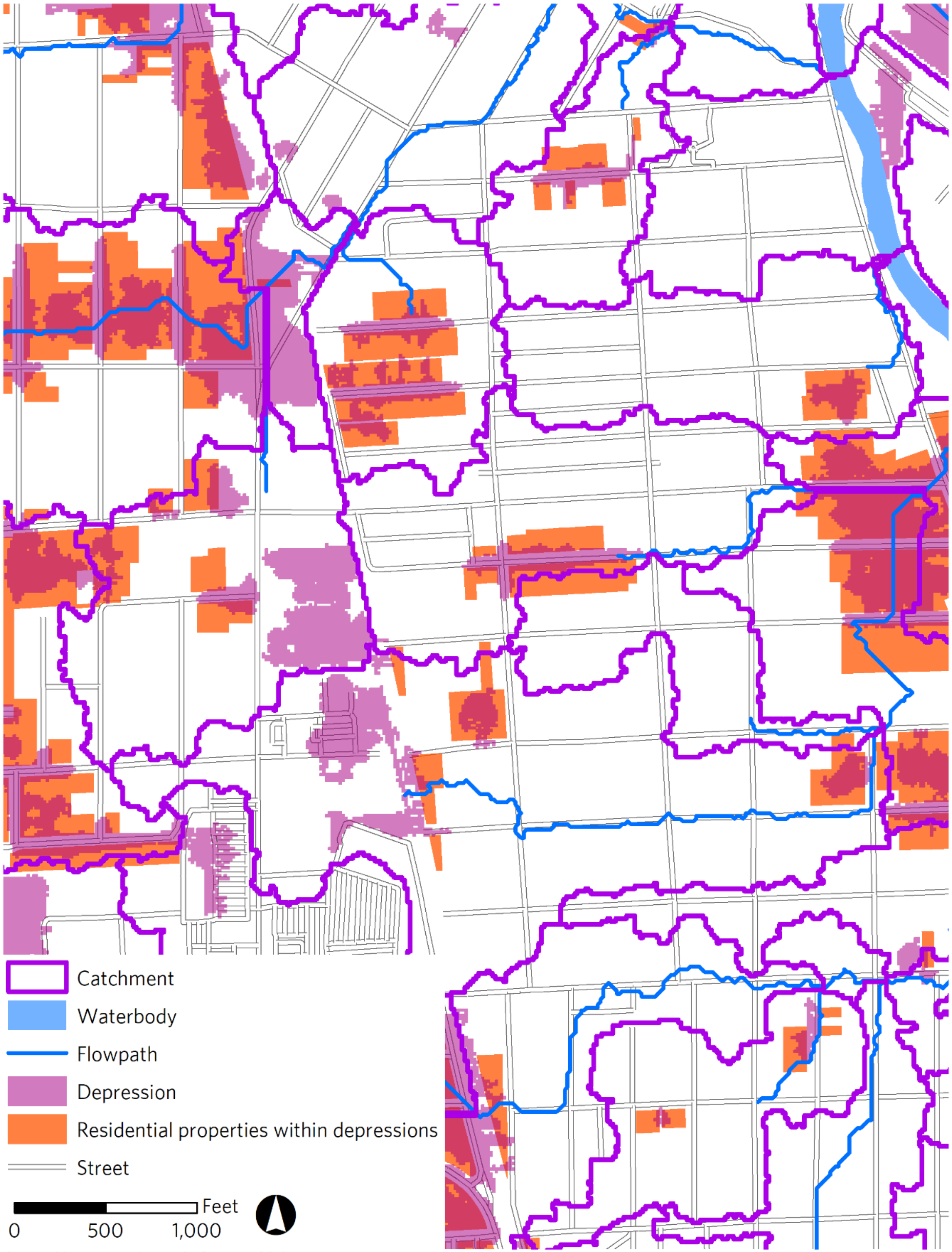
[17] Arc Hydro modeling outputs, CMAP Data Hub, see https://datahub.cmap.illinois.gov/dataset/archydro-modeling-outputs-2017.

Figure 7. Catchments delineated in a local plan study area



Chicago Metropolitan Agency for Planning, 2018.

Figure 8. Residential properties intersecting topographical depressions in a local plan study area



Chicago Metropolitan Agency for Planning, 2018.

1.4 Identify development near base flood elevation

Development near a floodplain with a surface elevation that is within six vertical feet of FEMA's 100-year Base Flood Elevation (BFE) has been identified as having higher flood risk. The Cook County Hazard Mitigation Plan states that the majority of repetitive loss properties located outside of the floodplain had basements below the BFE.[18] This step identifies properties that potentially contain structures with first floor or basement floor elevations at or below the nearest BFE and are, therefore, at greater risk of surface ponding, overland flow, or water seepage than structures which have the first floor or basement floor above the nearest BFE.[19]

To identify potentially vulnerable areas, the surface elevation and basement floor elevation[20] of properties is compared to the nearest FEMA BFE.[21] For communities where building footprints are available, the surface elevation should be calculated based on the building centroid elevation. For communities where building footprints are unavailable or for parcels without a structure, the mean surface elevation[22] of the property can be used.

The comparison yields two categories of parcels/buildings based on the surface elevation of the property: parcels or buildings with an elevation of one foot or less of the nearest FEMA BFE; and parcels or buildings with an elevation of six feet or less of the nearest FEMA BFE.[23] Figure 9 illustrates the position of a building (or parcel elevation) in relation to the BFE and describes the potential flooding risk. Figure 10 shows these areas mapped for a local plan.

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[18] The development of this flooding-related factor was also informed by FEMA Technical Bulletin 10: Ensuring that Structures Built on Fill in or Near Special Flood Hazard Areas are Reasonably Safe from Flooding, see https://www.fema.gov/media-library/assets/documents/3522.

[19] Based on guidance provided by FEMA Technical Bulletin 10: Ensuring that Structures Built on Fill in or Near Special Flood Hazard Areas are Reasonably Safe from Flooding, see https://www.fema.gov/media-library/assets/documents/3522.

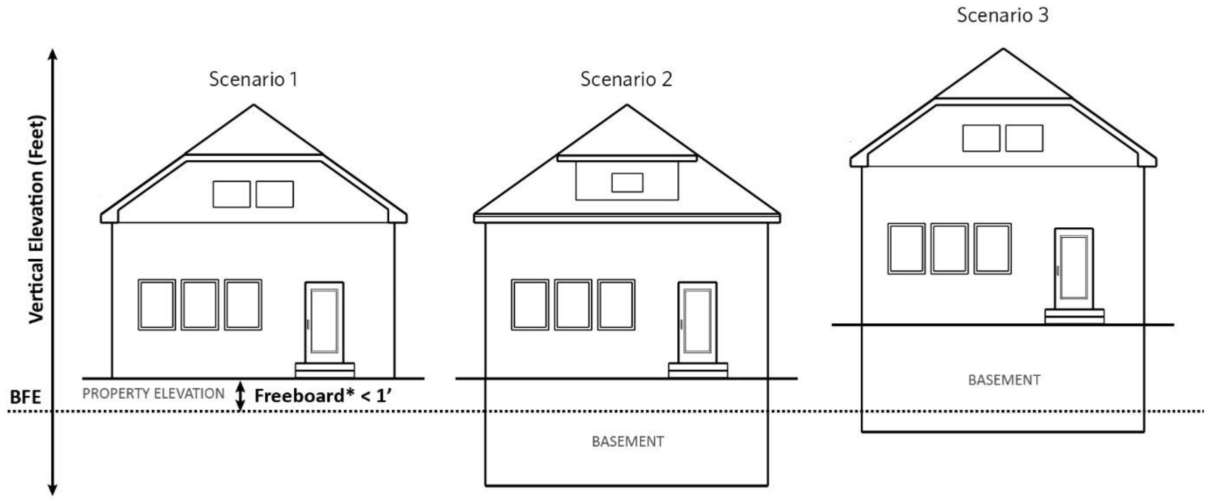
[20] Basement floor measured as six feet below mean surface elevation. Given high prevalence of basements in the region, residential parcels are assumed to have basements. Basement data may be available through county assessor.

[21] The nearest BFE should be limited by a horizontal distance; CMAP is currently using 1,500 feet. Distance and nearest BFE value can be computed using Generate Near Table tool. See http://desktop.arcgis.com/en/arcmap/10.3/tools/analysis-toolbox/generate-near-table.htm.

[22] Mean surface elevation can be computed using the Zonal Statistics tool, see http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/zonal-statistics.htm. The building centroid elevation can be computed using the Extract Values to Points tool, see http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/extract-values-to-points.htm.

[23] The comparison of parcels that have an elevation within six feet of the nearest BFE should be applied to properties with a basement; if unknown, only properties with residential land use.

Figure 9. Diagram of development near the base flood elevation (BFE)

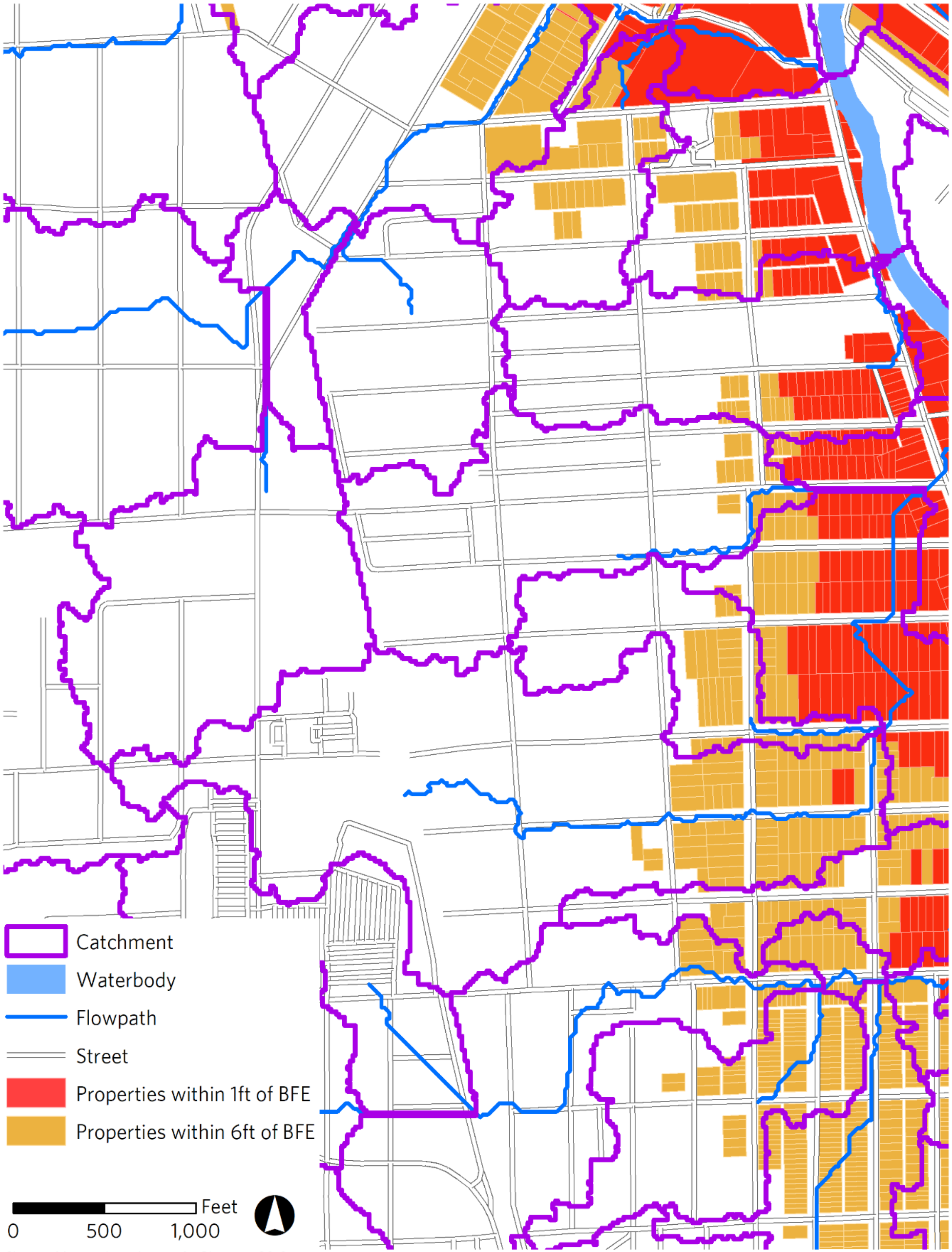


Scenarios 1 & 2:
Within 1 Foot of Nearest BFE
Insufficient freeboard from
first floor and basement

Scenario 3:
Within 6 Feet of Nearest BFE
Sufficient freeboard from first floor,
insufficient freeboard for basement

*FEMA defines freeboard as “a factor of safety usually expressed in feet above a flood level,” and encourages that communities adopt at least a one-foot freeboard.

Figure 10. Properties near the FEMA BFE in a local plan study area



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1.5 Identify past flooding locations

Maps of past flooding events are a valuable indicator of where future flooding could occur. This step maps clusters of reported flood damage by using point-based flood locations to create a Kernel Density visualization[24] (commonly referred to as a heat map) for the community. This visualization serves two purposes – first, it can be employed as a tool during discussions with the municipality and public; and second, it can be used internally to assess flooding issues in Step 2.

Figure 11 illustrates the Kernel Density visualization for a local study area based on locations of FEMA NFIP claims, local road closures, and locally reported drainage problem areas. Given the goal of identifying urban flooding locations, the visualization focuses on the location of the flooding event, not the frequency of its occurrence. In order to prevent the misuse of potentially sensitive information about individual properties, the visualization generates a generalized grid representation of point density. It is important to note that the resulting map illustrates the level of human response (i.e., reports and claims) to flooding and does not necessarily illustrate the entire scope of past flood events. In addition to confirming known flood-prone areas, the planning team should also inquire about flood occurrence in unreported areas of the community. For example, businesses along a commercial corridor could be impacted by flooding but might be reluctant to report for fear of revealing code violations.

While the damages documented through the NFIP, FEMA IA grant program, and other local datasets help provide a partial understanding of the cost and extent of flooding, it is not comprehensive of the damages experienced in the region. There are a variety of limitations and barriers to consider with damage payments, including economic barriers in obtaining insurance, underutilization of available resources, and flooding associated with smaller storm events that may not trigger presidentially declared disasters. Flooding is known to result in property damage under a range of different sized storms. For example, some neighborhoods experience basement backups during two- to five- year storm events which will not be captured by disaster relief programs. In addition, both the FSI and this step focus on property level damage and do not include disaster relief and hazard mitigation programs for local governments. For example, after the presidentially declared disaster DR-4116, the State of Illinois received $30 million in public assistance dollars to help with both emergency and permanent mitigation projects. At the same time, Cook County received $83 million of disaster relief funding to support the planning, design, and engineering costs related to identified stormwater issues.

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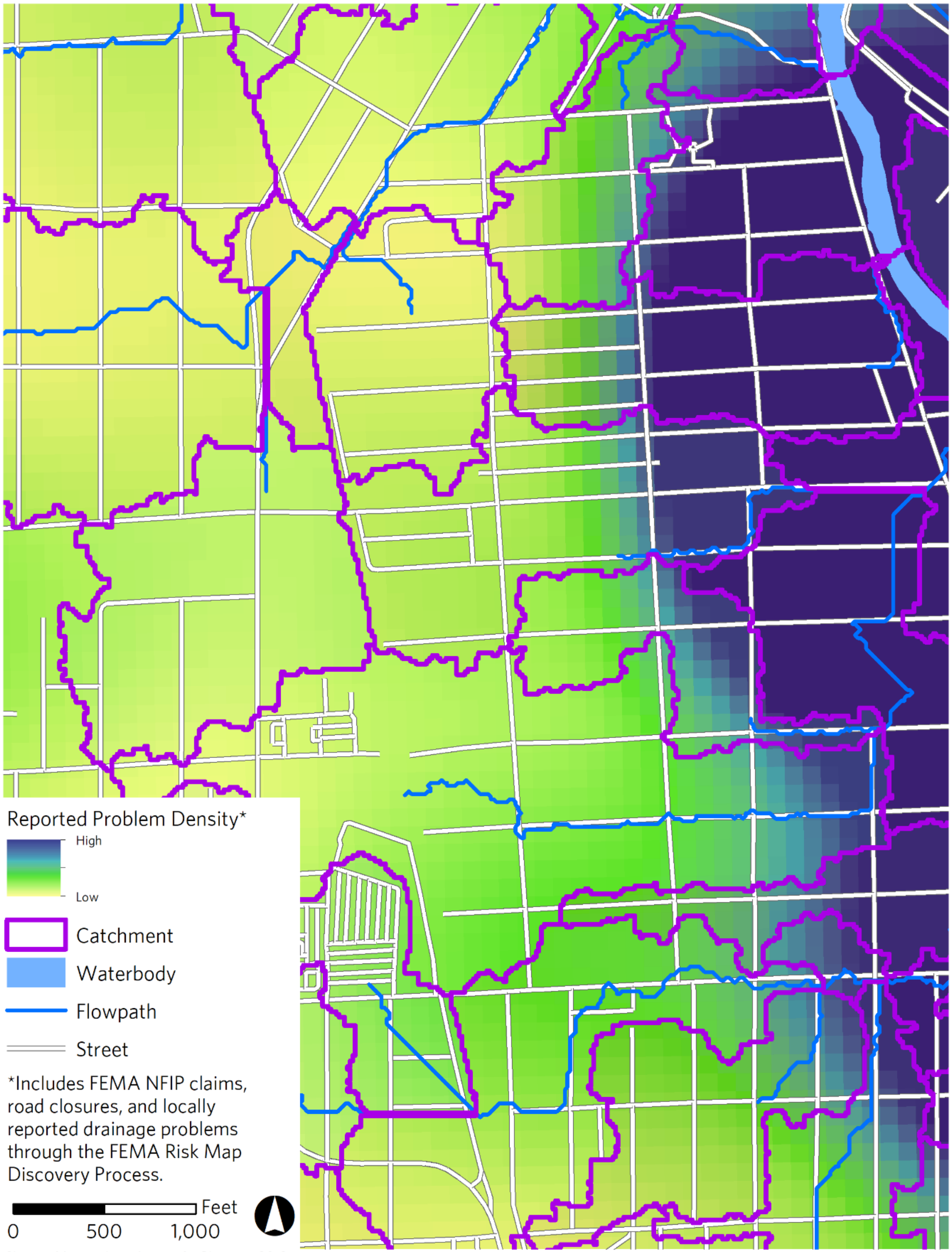
[24] This can be accomplished using the Kernel Density tool in ArcMap's Spatial Analyst toolbox. See http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/kernel-density.htm.

Figure 11. Density of past flooding locations



Chicago Metropolitan Agency for Planning, 2018.

Step 2: Prioritize and assess problem areas

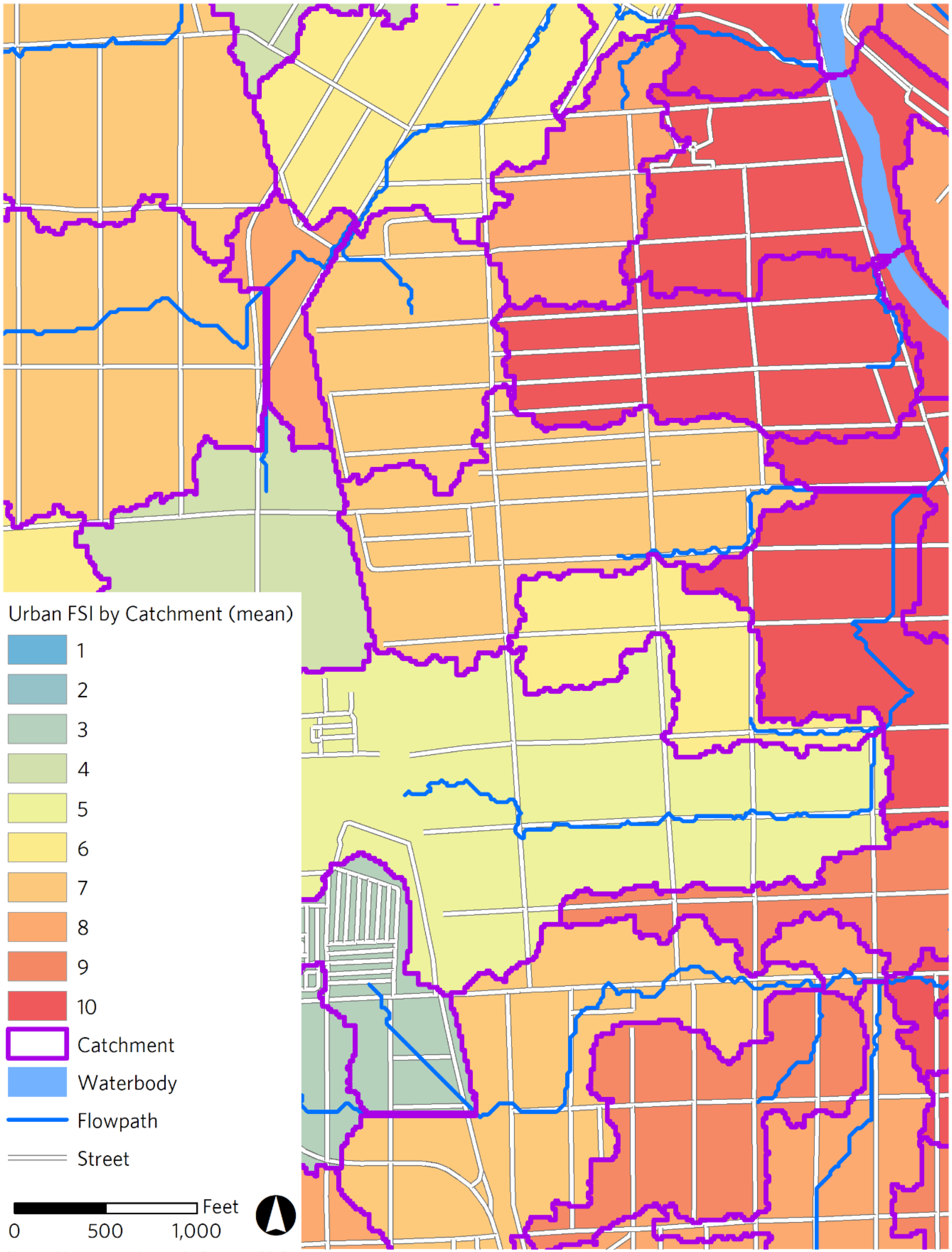
The second step attempts to identify implementation priorities for a community within the timeframe and context of the local plan, using CMAP's urban and riverine FSIs. Once areas are broadly identified as priorities, the locations are assessed using datasets prepared in Step 1 to gain a better understanding of the flooding potential.

2.1 Rank catchments based on the FSI

The catchments derived from the overland flow assessment (Step 1.2) are used to divide the community into different areas to conduct the prioritization. Only catchments that intersect the study area boundary should be used in this step, including those that are located within the 1.5 mile planning boundary. Catchments were summarized by their mean FSI value for riverine and urban flooding using ArcMap's Spatial Analyst tools. The mean FSI value for each of these were then translated into a ranking score of 1 through 10 and mapped by catchment. Figure 12 illustrates the urban FSI score, and Figure 13 shows the riverine FSI score for a community. To assess the accuracy of the score, compare the prioritization to the flooding variables derived in Step 1. Ideally, past flooding events should be captured in the prioritization, though additional areas could be identified as well.

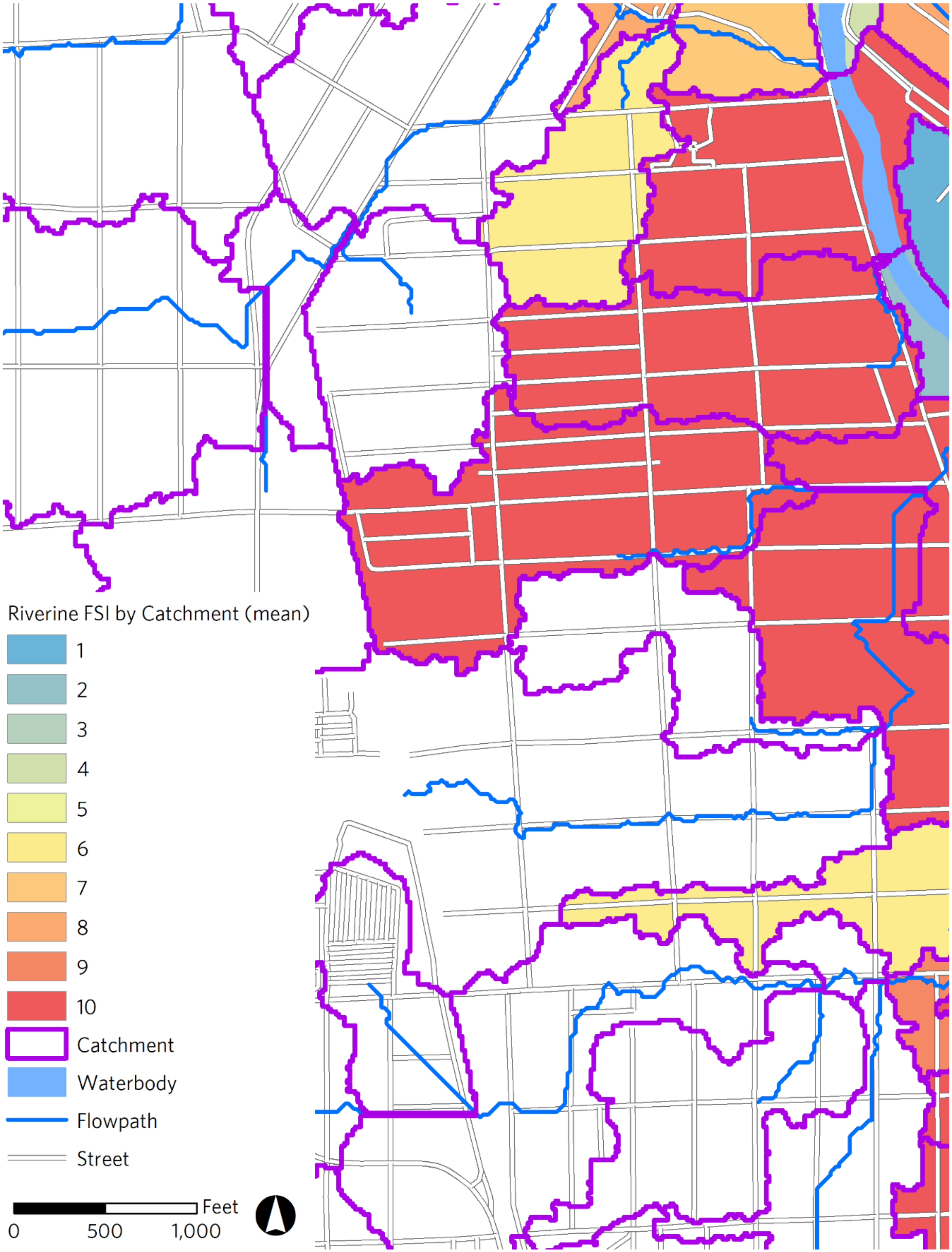
This approach allows one to compare catchments to identify those with the highest score, or greatest potential for flooding problems. Because catchments span multiple communities and do not align with municipal boundaries, development and stormwater drainage patterns in one community may impact flooding locations and contribute to problems in other communities. These locations should be identified as areas ripe for multi-jurisdictional collaboration.

Figure 12. Urban FSI summarized by catchment for a local plan study area



Chicago Metropolitan Agency for Planning, 2018.

Figure 13. Riverine FSI summarized by catchment for a local plan study area



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2.2 Assess flooding issues in priority catchments

This step analyzes priority catchments, identified in step 2.1, to identify potential cause(s) of, and solutions to, flooding. Using available datasets outlined in Table 3, the data is analyzed to identify possible locations where conditions could make different types of flooding, described below, more likely.

Riverine flooding

Riverine flooding occurs when large volumes of water cause a river or stream to overflow its banks. Indicators of riverine flooding may include locations that are within or near the 100-year or 500-year floodplains.

Urban flooding

Urban flooding occurs when rainfall overwhelms the capacity of the drainage system causing the inundation of property in a built environment. It includes situations in which stormwater enters buildings through structural openings such as windows or doors, backs up through sewer pipes, seeps in through walls or floors, or ponds on property or streets. There are two types of urban flooding that can be identified by the data:

> **Ponding and overland flow**: flooding that occurs when local drainage capacity is not adequate to convey stormwater runoff to the receiving stream or when the local topography causes runoff to collect and pool in streets, alleys, or yards.
>
> **Basement backup:** structure flooding caused by combined or separate sanitary sewers that have been overloaded by stormwater or groundwater seepage. In locations with separate sanitary sewers, basement backups can occur due to infiltration/inflow (I/I) of water from the surrounding soil into the pipes. Sources of I/I that restrict or reduce available pipe capacity and contribute to basement backups include illegal connections and blocked pipes.[25] Illegal connections occur when roof downspouts, sump pumps, or foundation drains are connected to the sanitary sewer. Blocked pipes can occur from tree roots, grease, and other obstructions. Flooding from basement backups typically occur through floor drains and toilets. The best indicators of excessive I/I are known locations where backups have occurred.
>
> **Other:** structure flooding that could be caused by water seeping through foundation walls or other structure specific issues. While these structure specific conditions could be the sole cause for flooding, they may also contribute to other types of urban flooding. Seepage indicators may include poorly draining or hydric soils or ponding on property close to the structure.

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[25] Connected downspouts, sump pumps, or foundation drains and blocked pipes are structure specific issues that cannot be identified based on the data collected to date; surveys could help in these cases.

To analyze each catchment, multiple data layers should be reviewed in a step-wise fashion as follows.

Depressions: Review this data layer for locations where:

- **Building structures are located within a depression.** These structures could be subject to ponding or overland flow that result in property damage, including basement seepage.
- **Sanitary or combined sewers intersect a depression.** Sewers beneath depressions could have a higher potential for stormwater inflow into deteriorated or cracked sewer pipes, which reduces sewer capacity and could cause basement backups when the sewer fills with water.

Flowpaths: Review this data layer for locations where:

- **Building structures that intersect a flowpath**: These structures could be subject to ponding or overland flow that result in property damage, including basement seepage.
- **Sanitary or combined sewers running parallel to a flowpath:** Sewers running beneath flowpaths could have a higher potential for stormwater inflow into deteriorated or cracked sewer pipes which reduces sewer capacity.

Sewer network: Review this data layer for locations where:

- **Sewers and surface flow in different directions**: Review the direction of flow of the sewer network in relation to the direction of the surface flowpaths. Locations where the sewer network and flowpaths flow in different directions could cause the stormwater to overwhelm the sewer system (Figure 14). This is particularly a challenge if the 'top' of the sewer system, where the smaller capacity pipes are located, overlaps with the 'bottom' of the catchment, where the flowpaths converge.
- **Flowpaths are underserved by sewers or swales:** Review flowpaths in relation to the sewer network to reveal locations where there are flowpaths, but no corresponding storm sewer or swale drainage system, which could put the area at risk for ponding and overland flow.
- **Storm sewers connect to a waterway**: Storm sewer outfalls into a waterway can cause the sewer system to backup with river water when water levels in the river rise above the level of the outfall and the outfall is not equipped with a backflow preventer.
- **Flooding has been documented at the top of a sewershed:** While locations near the top of a sewershed are less likely to experience flooding from overland flow or ponding, documented flooding reports in these locations could indicate excessive I/I into the sewer system.

Figure 14. Example of sewers and surface flow in different directions

Catchment boundary: Review this data layer for locations where:

- **Flooding has been documented at the top of a catchment:** While locations at the top of a catchment are less likely to experience flooding from overland flow or ponding, documented flooding reports in these locations could indicate excessive I/I into the sewer system.

Base Flood Elevation: Review this data layer for locations where:

- **Combined sewer areas intersect properties at elevations within a 6-foot range of the nearest BFE**: Low-lying areas of combined sewer service areas are at greater risk for basement backups. The elevation difference between the private sewer lateral at the property and the public sewer main in the street may be small, which makes it easier for water to backflow up the lateral and into basements.

100- and 500-year floodplain: Review this data layer for locations where:

- **Building structures are located within a floodplain.** These structures are at risk of riverine flooding that could result in significant property damage, particularly if they were constructed without floodplain management practices.
- **Critical facilities are located within a floodplain.** These structures are at risk of riverine flooding, which could result in their damage or closure during storm events, hindering the community's ability to respond to emergencies. Critical facilities include hospitals, fire stations, and police stations, as well as pumping stations, utility power stations, water and waterwater treatment plans, and similar facilities.

Evaluation based on other characteristics

In addition to flood-related factors, high priority catchments should also be evaluated based on capital improvements, social vulnerability, and climate vulnerability.

- **Capital improvements:** Completed capital improvements that were designed to reduce and convey stormwater volumes can reduce the need for additional stormwater investments. If the data is available, overlay recently completed and planned capital improvement projects with the urban and riverine FSIs. Given that the regional FSIs rely on past flooding reports, improved conditions in these areas may not be reflected in the indexes. However, the index does indicate that these areas could be at risk if stormwater facilities do not function as designed.
- **Social vulnerability:** It is important to consider socioeconomic factors given that flooding does not affect all populations equally. Vulnerability to flooding appears to be greater in communities and neighborhoods already facing social vulnerability due to socioeconomic, demographic, and health factors.[26] Consideration of flood risk in areas with lower median incomes, limited English proficiency, and higher minority populations can help identify areas that may have the greatest need of stormwater management and flood mitigation projects.
- **Climate vulnerability:** While this assessment is focused on known problem areas, some indicators may provide insight into future vulnerability to climate impacts elsewhere in the catchment.

Once analyzed, the prioritized catchments should be discussed with municipal staff, including floodplain managers, engineers, public works, community development, and planning. Aerial maps of each catchment with relevant spatial data, such as flowpaths, depressions, and the sewer system, can help verify conditions and potentially deprioritize catchments due to recently completed work or other nuances. Municipal staff may also pinpoint catchments that were not identified as high priority through the index but should be evaluated. Depending on the complexity of the flooding problem, catchment characteristics can be summarized to determine the predominant type(s) of flood risk in a community.[27]

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[26] Lowe, Dianne, Kristie L. Ebi, and Bertil Forsberg. "Factors Increasing Vulnerability to Health Effects before, during, and after Floods," International Journal of Public Health, 2013. 10, 7015-7067; doi:10.3390/ijerph10127015.

[27] Documenting information on flood types could also help the community determine priorities for post disaster flooding.

Step 3: Identify potential solutions

The third step is to identify potential solutions to flooding through the use of land-based approaches and coordination with planning priorities and policies. Recommendations to improve stormwater management should include community scale policies and programs, including ordinance updates, operations and maintenance practices, education and engagement, and capital planning and financing. In addition to these, the results of the stormwater analysis should provide the community with a more prioritized set of actions and locations for implementation.

3.1 Identify opportunities in priority catchments

This step uses land use, parcel, and land cover data (Table 3) to pinpoint parcel and street level locations for green infrastructure practices or other land use interventions. Within the priority catchments identified in step 2.1, identify and map land-based opportunities such as public rights-of-way, public property, and vacant property. When possible, coordinate opportunities with planned or recommended capital improvements, which may include streets with poor pavement conditions, sewer or water improvements, and redevelopment opportunities identified through the concurrent land use planning process. Once these areas are identified, the total acreage of land-based opportunities can be used to rank the catchments, which can help further prioritize opportunity areas.

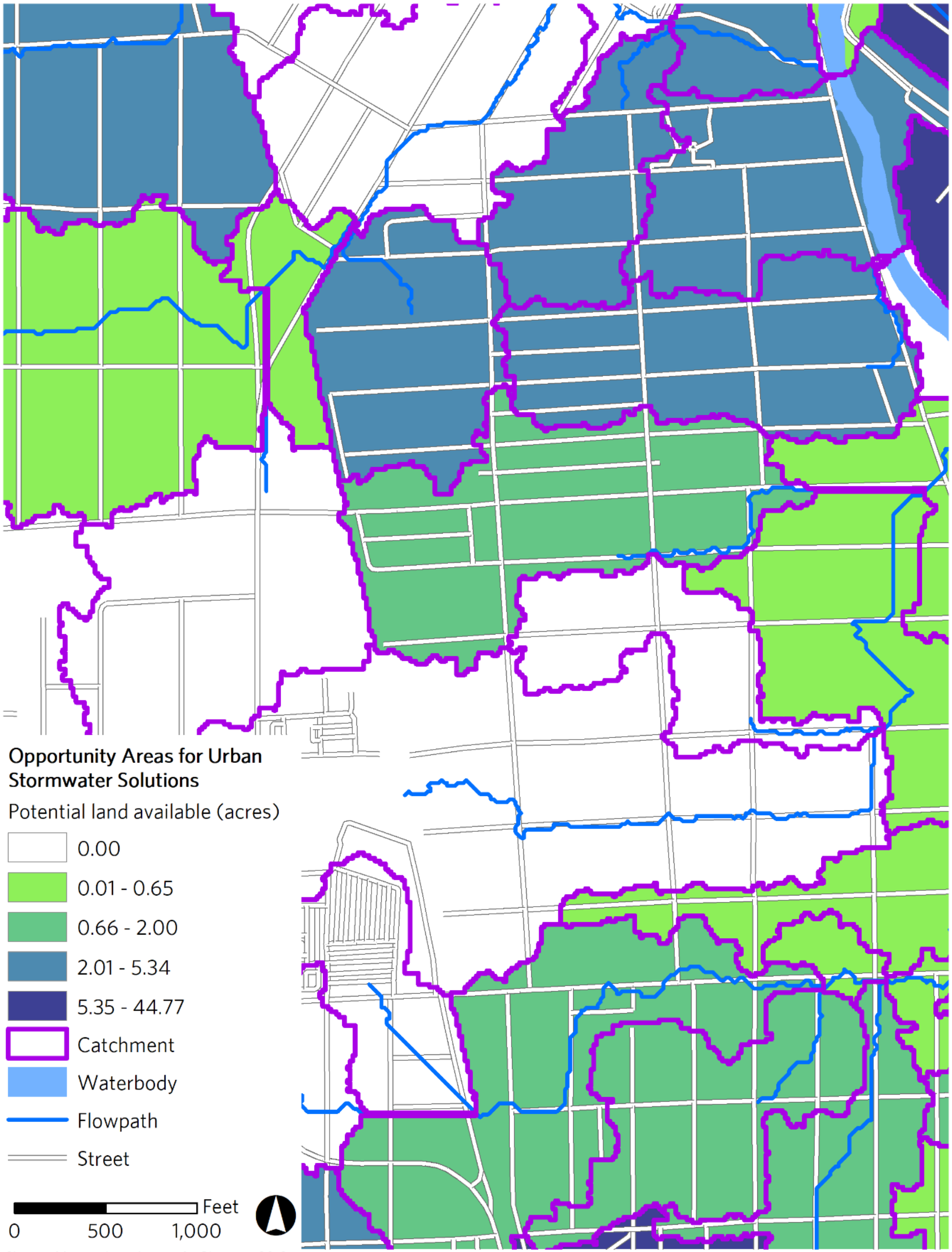
15 illustrates the land-based opportunity assessment for a local plan study area. Parcels with educational facilities, government facilities, vacant land, public buildings/grounds, or parks/open space, as well as local streets, were identified and quantified for each priority catchment.

Once opportunities have been identified, assess the priority catchments to provide a more refined evaluation of opportunities. Overlay key datasets, such as flowpaths and known flood locations, to pinpoint discrete opportunities within, upstream, or downstream of the catchment. Ensure that the opportunities correspond to the identified flood problems. For example, if excessive stormwater overwhelms the capacity of the sewer system, identify opportunities to reduce runoff volumes and the risk of flooding within or upstream of the catchment. Some areas will require property-specific improvements to reduce the occurrence of basement backups. While some of these improvements may be structural, such as installing an overhead sewer, others can be accomplished via GI, such as disconnecting downspouts and redirecting flow to a rain garden.

3.2 Incorporate solutions in future land use plan

Where appropriate, some of the opportunities identified above should be reflected in the future land use plan. This could result in additional areas of open space, specific overlay districts related to floodplain management, or other techniques highlighting increased focus on stormwater management.

Figure 15. Land-based opportunities assessment



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