Technical Memorandum

Date:	Thursday, May 05, 2016
Project:	Stormwater Master Plan Update
To:	City of Cedar Rapids
From:	Mike Butterfield, PE/HDR, Mike Schubert, PE/HDR, Bryon Wood, PE/HDR, Brice Stafne PE/HDR, Wilson Wheeler/HDR, Robin Hegedus, PE/HDR
Subject:	TM 3.1 Macro Modeling

This Technical Memorandum presents the macro-scale stormwater model development, results from the model, and the conclusions based on this modeling study. The intent is to document model input data, modeling methodology, provide pertinent relevant information from the simulation results, and develop conclusions and general recommendations about improvements in the CIP in light of modeling results. The Technical Memorandum is organized as follows:

- Objective
- Summary
- Model Development
- Analysis
- Recommendations

Objective

The City of Cedar Rapids (City) is updating the City's Stormwater Master Plan. As part of this effort, the City is evaluating the stormwater collection and conveyance system using a city-wide hydraulic model. The modeling for the Stormwater Master Plan will be conducted in multiple steps: a system-wide macro-scale model and one more detailed basin-scale model. During the initial Master Plan a system-wide macro-scale model and one more detailed basin-scale model will be developed. The macro-scale effort focuses on modeling the large pipes (48" and larger), open channels, and major detention facilities of City's stormwater conveyance system. The results are intended to provide the city a broad overview of performance of major components of the stormwater system. This model is also the foundational level for individual basin models, one of which will also be developed during the initial Master Plan. Other basin models will be developed in subsequent years.

The basin models, which will simulate ponding, overland flow, and a much more extensive pipe network (12" and larger), will be developed to evaluate individual projects and mitigation alternatives both locally and in the context of the entire system. As individual basin models are developed and analyzed over multiple years, results will be used to inform and improve the capital improvement plan (CIP). This multi-year strategy will also allow for the model to be improved over time and updated as more data becomes available.

The objective of this Technical Memorandum is to summarize the development of the macro-scale model, report simulation results, and discuss the conclusions and recommendations

drawn from the macro-scale model. This document will become part of the Stormwater Master Plan.

Summary

HDR has developed a macro-scale model of the City's stormwater conveyance system. The model was developed based on GIS data provided by the City, including topography, soil type, land use, pipe network data and additional survey data. 239 catchments were delineated based on previously delineated boundaries and reconciled with LiDAR data and pipe network data. Time of concentration and runoff curve numbers were developed from the provided data. Based on these characteristics and rainfall, the model calculates runoff hydrographs at each catchment, which are applied to the one-dimensional (1D) network.

The 1D network was developed based on the GIS-data provided and additional pipe survey data collected and furnished by the City during the fall of 2015. Gaps in data (pipes without data and pipes that are apparently missing) were resolved by inferring geometric and attribute data based on upstream and downstream reaches. Some survey data was collected during the summer of 2015 and the model was updated with this information. Open channel sections connecting pipe sections were included as approximated trapezoidal channels with similar capacity to the bounding pipe sections.

The model was used to evaluate the 5-year and 100-year 24-hour nested storm events over the entire city. Results from these events indicated that several capacity limitations prevent the piped stormwater collection system from conveying a five-year rainfall event. Further basin-scale modeling should be conducted to confirm problem areas and assess improvement project alternatives.

Model Development

Software

InfoWorks ICM software was selected for the stormwater master plan modeling effort. InfoWorks ICM, from Innovyze, provides a comprehensive, GIS-integrated, computational engine that is both stable and efficient. The model capabilities and HDR's experience with this software make this selection a good and fitting platform to analyze the city's stormwater and sanitary collection systems both during this initial Master Plan and in the future as stormwater basin scale models are developed. The software selection process is documented in the "Model Software Selection" Technical Memorandum, Appendix A.

Catchment Characteristics

SUMMARY OF CATCHMENTS

In TM 1.0, 8 watersheds and 23 subwatersheds were identified and characterized (see Figure 1). Based on the subwatersheds, LiDAR data, and pipe data provided by the City, 239 catchments were identified and delineated. Catchments are used to characterize the areas that contribute runoff to reaches of the stormwater conveyance system. Catchment size varies based on the topography and pipe network. The average catchment size for the macro-scale model is approximately 75 acres. All of the catchments delineated for the macro-scale model

are shown by subwatershed (as appropriate) in Appendix B.

Figure 1: Watershed and Subwatershed Map

DATA SOURCES AND ASSUMPTIONS

GIS Watersheds

GIS data representing watersheds from the City's Envision CR study as well as watersheds from the USGS National Hydrography Dataset (HUC 12) were used as references when delineating catchment boundaries. These watershed boundary sources were updated and amalgamated for use in the macro-scale stormwater model.

Topography (LiDAR)

LiDAR data collected in October of 2012 was used to develop a digital elevation model (DEM) with a 3-foot grid cell size. The DEM, along with GIS data representing the City's storm pipe network and open channels, were used as input for the Arc Hydro GIS data model. Arc Hydro Tools were then used to delineate initial catchments for the model.

Soil Type (Hydrologic Soil Group)

The USDA Soil Survey Geographic (SSURGO) Database for Linn County, Iowa, published on August 19th, 2014, was used to characterize hydrologic soil group conditions for each catchment. The soil groups were used in establishing curve numbers for runoff calculations in the model. Table 1 summarizes hydrologic soil groups by area across the citywide catchments. These soils types are shown in Figure 2.

Table 1 - Hydrologic Soil Group Summary

HSG	% of Citywide Catchment Area
A	11
B	6
B/D	4
C	47
C/D	21
D	10
Water	1

Cover Type (Land Use)

Existing land use GIS data was provided by the City from the Envision CR report (Figure 3). The data is maintained at the parcel level and includes descriptions of the associated land use category and links to the Envision CR website. An aerial photo taken on September 18th, 2014 was used to verify existing land use GIS data. Based on this review, some existing land use types were modified to better represent existing conditions. Specifically, land use types such as civic and agricultural we revised to better match land use descriptions from the NRCS TR-55 manual. In addition, the parcel-based land use layer was "flattened" to remove duplicate and overlapping polygons. These instances typically occur at multifamily (condominium) locations. The updated existing land use data was used in establishing curve numbers for runoff calculations in the model.

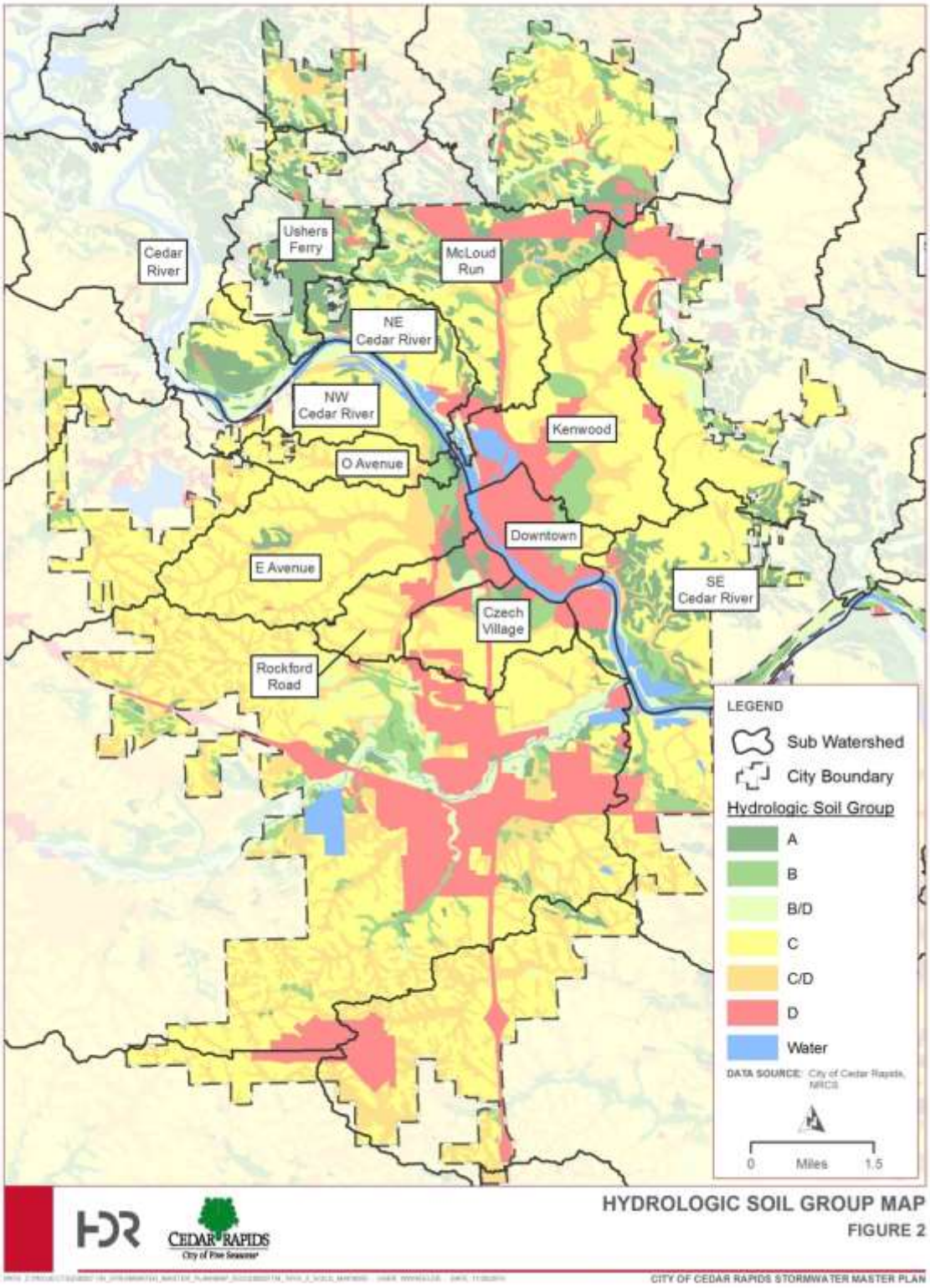


Figure 2: Hydrologic Soil Group Map

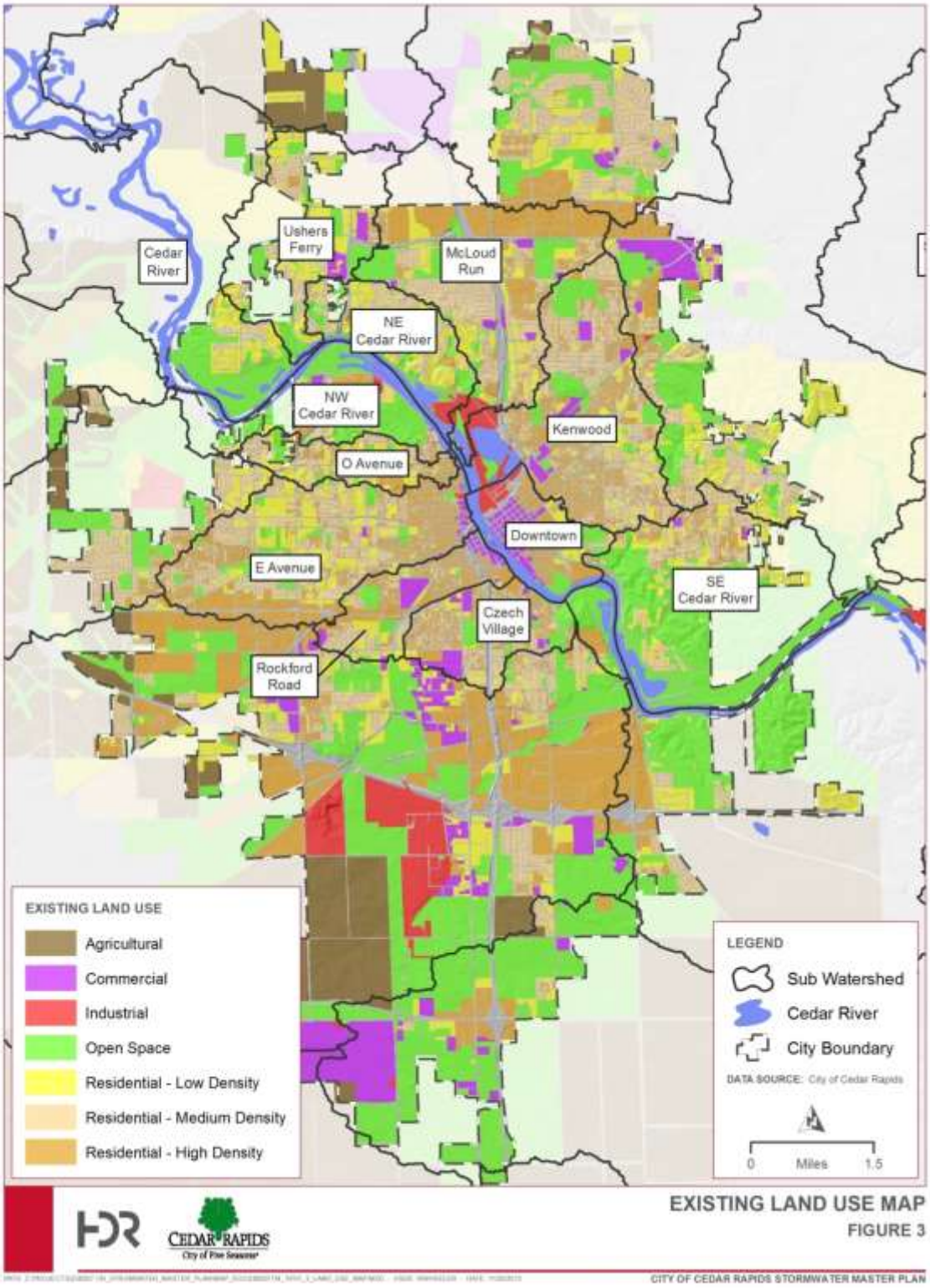


Figure 3: Land Use Map

Rivers, Creeks, and Channels

There are several miles of open channels within the City which ultimately drain to the Cedar River. The open channels, which include both constructed and natural channels, were used along with the City's pipe network data to delineate the watersheds and catchments and route flows in the model. Roughness values for the model were assigned to the open channels using aerial imagery (See Table 2).

Table 2: Manning's Roughness Coefficients

Classification	Manning's Roughness
Pipes	0.013
Grass Swale	0.03 to 0.04
Long grass, scattered brush	0.05
Wooded areas	0.08

CATCHMENT HYDROLOGY

Runoff Method

The Soil Conservation Service (SCS) runoff curve number transform method (NRCS TR-55) was used to develop hydrographs from each of the catchments. This method is commonly used across the United States when modeling urban hydrology, and is consistent with Iowa Department of Natural Resources (DNR) guidance for evaluating stormwater hydrology. The SCS method has been successfully used in a calibrated stormwater model in previous InfoWorks stormwater models in Cedar Rapids, and for this reason is used in this evaluation. This method generates the runoff hydrograph based on rainfall intensity and curve numbers. The following equations summarize the SCS runoff method:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \quad , \qquad I_a = 0.2S, \qquad S = \frac{1000}{CN} - 10$$

where

Q = runoff (in)

P = rainfall (in)

S = potential maximum retention after runoff begins (in) and

$\mathrm{I_a}$ = Initial abstraction (in)

CN = Curve number

The S and I_a variables are based on calculations from the curve number (CN) values from the catchments. Using the individual catchment information including area, curve number, time of concentration and time of travel from flow path lengths, the model software converts this SCS calculated runoff over the simulation time to flow hydrographs routed to the 1D model flow network.

Curve Numbers

Composite (area-weighted) curve numbers used in the SCS runoff method were calculated for each catchment by intersecting hydrologic soil group and existing land use GIS data with the developed catchment boundaries. The spatial distribution of curve numbers throughout the City is shown in Figure 4.

1D Model Flow Network

SUMMARY OF ELEMENTS

The 1D model flow network in the macro scale model includes 45.4 miles of pipe, 9.5 miles of open channel, 13 detention facilities, and 52 outfalls. The 1D model flow network is shown in Figure 5. Inflow hydrographs determined for each catchment are applied directly to the 1D model flow network at the appropriate location, known as a “pour point”. Downstream boundary conditions include both free outfall conditions and fixed water levels.

DATA SOURCES

Several data sources were used to develop the 1D model flow network for the macro scale hydraulic model. They include GIS data and survey data for the closed conduits, LiDAR and aerial photography for open channels, and GIS and LiDAR for lakes and large detention ponds. Survey data (from Anderson Bogert) and the draft XPSWMM model (from HR Green) for the Westside Flood Protection Project were utilized to fill in data gaps in the GIS. Design drawings provided by the City were also utilized where applicable.

City Stormwater Network GIS Data

The City’s GIS database of the storm sewer network was provided to HDR as the primary data source for development of the hydraulic model. The GIS data contain over 28,000 pipe elements and nearly 31,000 storm sewer structures or junctions. The most applicable information in the GIS data for the hydraulic model is the network connectivity, pipe invert elevations and pipe shapes and sizes. The GIS network including pipes 48-inches and larger, open channels, and detention ponds was extracted for use in the macro-scale model. A data gap analysis was completed and a prioritized survey request was sent to the City for collection. The resulting survey completed by Anderson Bogert in September 2015 was provided to HDR. This survey data along with design drawings where applicable were used to update the 1D model flow network.

To validate the network for modeling and to fill in remaining segment (pipes and open channels) data gaps in the 1D flow network after inclusion of all available data, the following steps were taken in the model software:

- To fill in remaining gaps with diameters, sections and inverts, the missing segment data not surveyed were inferred from upstream/downstream pipes
- To maintain positive slopes going downstream within the network, data issues (vertical datum and invalid inverts) were resolved by correcting by interpolating from upstream/downstream pipes

- To rectify pipe direction and connectivity, pipes were reversed direction from GIS so that they would flow downstream in the model and some pipes needed to be added to the model to maintain connectivity

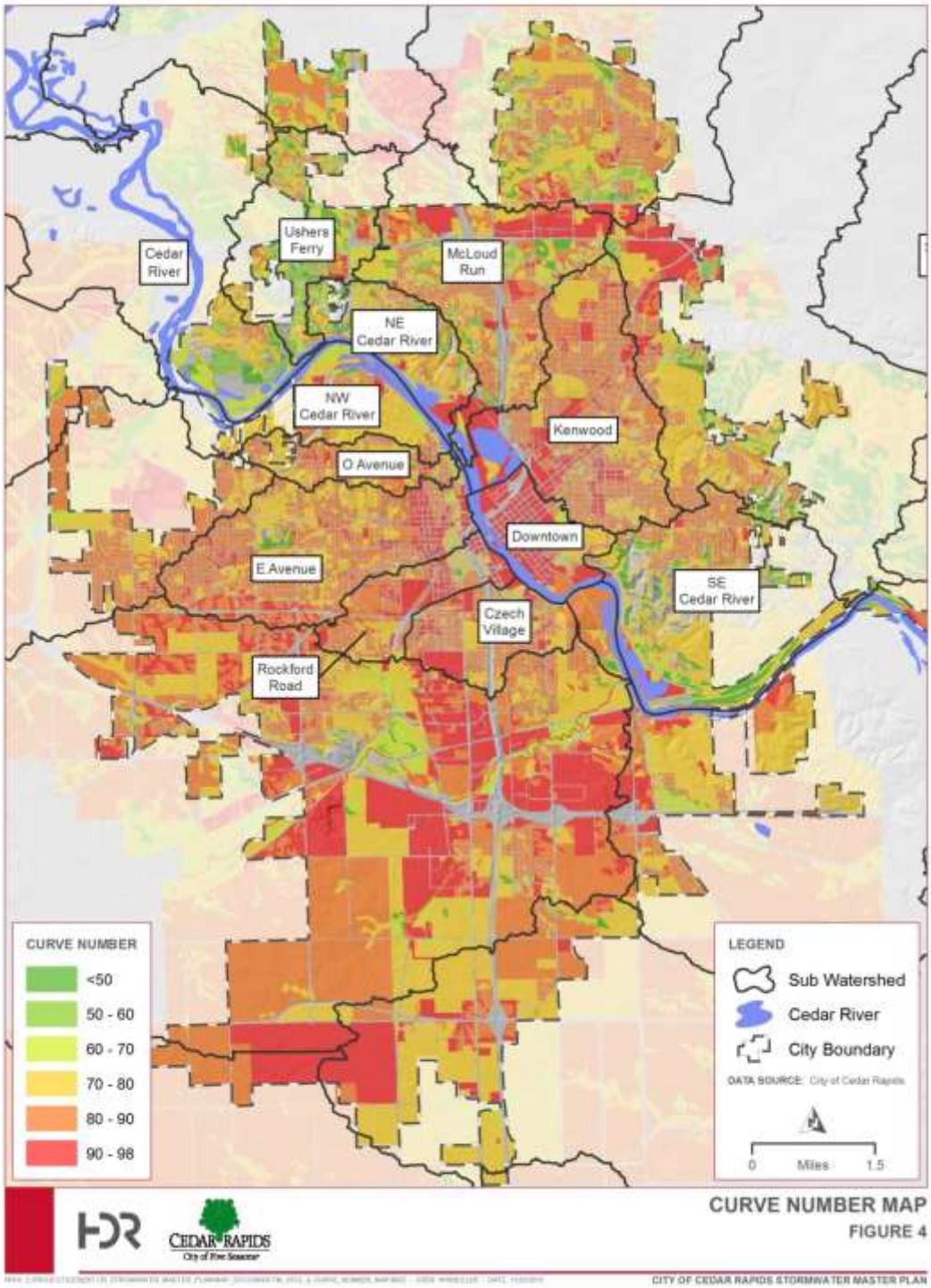


Figure 4: Curve Number Map

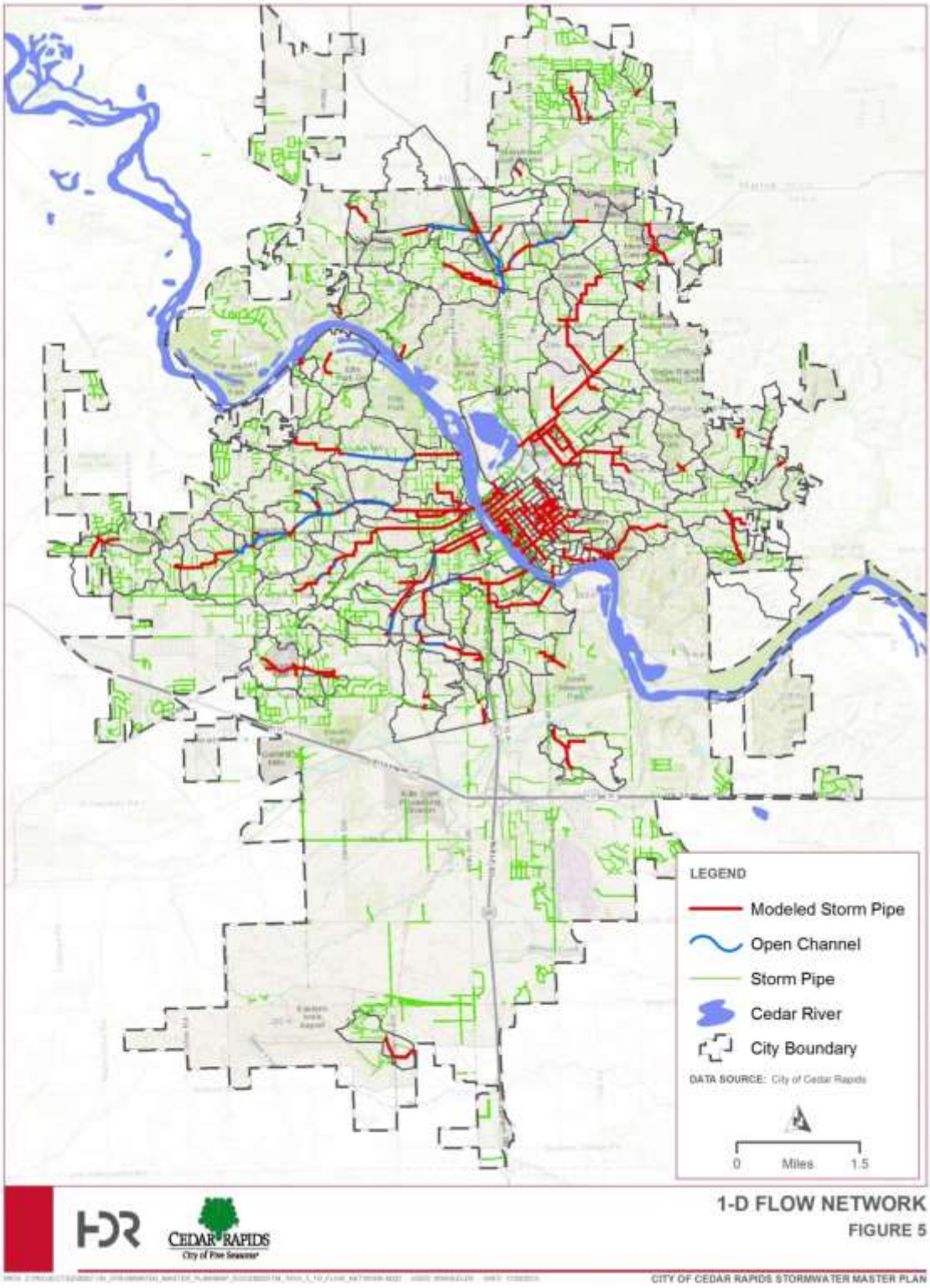


Figure 5: 1D Flow Network

Supplemental Survey Data

Supplemental survey data was collected for the current project to fill in gaps in the GIS data or replace the GIS data where applicable. The survey data included pipe invert elevations, pipe shapes and sizes, and notes describing unique pipe configurations or conflicts between field observations and the GIS data. Photographs were also taken of each structure that was accessed during the survey and provided to HDR for use in updating the model network.

Westside Flood Protection Project Survey Data and Draft Model

The survey data collected for development of the XPSWMM model as part of the Westside Flood Protection Project along with the draft model was provided to HDR by HR Green. The survey data included similar information as the supplemental survey data gathered for the current project except that no photographs were provided. The survey data and model were used to fill in gaps in the GIS data or to replace the GIS data where applicable in updating the model network in this area of the stormwater system.

Open Channel Data

Stormwater in the City is conveyed through a series of pipes and open channels, ultimately draining to the Cedar River. For the macro scale model, all of the open channels between closed conduits were included in the model. However, in areas where closed conduits discharge to a natural channel and flow is conveyed to the Cedar River without passing through any additional closed conduits, no open channels were modeled. In these cases, an outfall was used at the downstream end of the last modeled pipe and a free discharge was assumed.

The City's GIS database did not include dimensions or elevations associated with open channels. In the Westside Flood Protection Project area, open channel characteristics were taken from the draft XPSWMM model where available. In other key subwatersheds with many open channel segments (O Avenue, E Avenue, 4th Avenue, 13th Avenue, and McLoud Run), a typical channel cross section was determined using LiDAR data. In the remainder of the City, open channels were represented as trapezoidal channels with 4:1 side slopes and dimensions were approximated based on the upstream and downstream pipe sizes. Roughness characteristics were assigned based on aerial photography (see Table 2).

Detention Facilities

Thirteen inline or other major detention facilities were included in the macro scale hydraulic model. The detention facilities ranged in area from one half acre to nearly 12 acres and had total storage volumes ranging from 1.3 to 50 acre-feet at high water level. Detention facility characteristics were taken from design drawings where available and supplemented with LiDAR data when necessary. Outlet structure information was taken from GIS data and supplemented with design drawings or other hydraulic information provided by the City. A data request for the macro model detention facilities was prepared for the City to assist in filling gaps in pond geometry, depth, and outlet structures. The received data was updated in the macro scale model.

The in-line or other major detention facilities that were included in the macro scale model are shown in Table 3.

Table 3: Macro Scale Model Detention Facilities

Detention Facility	Basin ID	Subwatershed	Estimated Storage Volume (ac-ft)
WESTWIND CREEK 1ST	C-404	Prairie Creek	1.42
GREYSTONE 3RD	C-112	Indian Creek - Dry Creek	2.76
OAK RIDGE ESTATES 2ND	C-302	Cedar River	1.88
CEDAR HILLS	C-205	E Avenue	8.93
HARRISON ELEMENTARY SCHOOL	C-206	O Avenue	6.30
NOELRIDGE POND	C-113	Cedar River	21.71
HAGAN'S 2ND	C-209	E Avenue	6.76
CONCORDIA LUTHERAN CHURCH	C-211	E Avenue	3.37
16TH AVE SW #2	C-411	E Avenue	7.00
CHEROKEE PARK	C-208	E Avenue	5.34
EIA #7	C-442	Hoosier Creek	49.87
EIA #6	C-426	Hoosier Creek	30.54
CRESCENT VIEW 1ST - #2	C-127	Indian Creek - Dry Creek	17.69

An elevation-area table was defined for each detention facility to represent the basin storage. All detention facilities with the exception of C-127 were modeled as dry ponds based on the available information about the outlet structures. Basin C-127 was modeled with an initial water level based on the design normal water level of 783 ft. The influence of smaller detention facilities was not captured in the macro scale model but will be in the basin scale models.

ASSUMPTIONS

The 1D model flow network was developed using the best available information from GIS, survey data and other sources. In some cases, the survey data conflicted with the GIS data. The following procedures and assumptions were used to simplify the flow network.

- If a dimension, such as “48x72” was reported in notes within the GIS data, it was assumed that the height was reported first based on information from City GIS staff. Similarly, for supplemental survey data, it was assumed that height was recorded first, then width, based on information provided by the surveyor that gathered the data for the macro scale model. The same assumption was made for the survey data collected for the Westside Flood Protection Project model.
- If only one dimension was provided in City GIS data for pipes indicated to be arch, oval, or elliptical pipe, it was assumed that the size represented an equivalent circular pipe (e.g. a 36” arch pipe was assumed to be 43”W x 26”H). If one dimension was provided in the supplemental survey data, it was assumed that the dimension represented a height based on the method of survey (measuring the pipe size from ground level). This assumption was typically confirmed with the photographs that accompanied the survey when available.
- In some cases, conflicts existed between survey data and GIS data. Generally GIS data was given preference over survey data based on the rationale that in many cases it can be difficult to measure pipe diameters without entering the adjoining manhole. At pipe endwalls or for box culverts, preference was given to survey data as those locations are more readily accessible. Additionally, in areas where the GIS data seemed suspect and survey data made more sense, the survey data was used. For example, if a GIS shows

a 54” pipe flowing into a 48” pipe and survey data indicated the 54” should be a 48”, the 48” was used.

1D FLOW NETWORK HYDRAULICS

The 1D flow network is routed by the software with runoff from the catchments to the pipe network. Energy losses and boundary conditions are set up in the model to route the flow in a similar fashion as the actual stormwater collection system.

Energy Losses

Major energy losses in open channels and pipes were represented using Manning’s equation. Manning’s equation and these losses limit the amount of stormwater that can be conveyed by a certain model open channel and pipe segment based on its roughness, length, and slope. The roughness coefficients that were used are summarized in Table 2.

Boundary Conditions

Both free outfall and submerged gravity outfall conditions were used in the macro scale model. Table 4 summarizes the subwatersheds where submerged gravity outfall conditions were used. The remaining outfalls in the macro model were represented as free outfalls.

Table 4: Submerged Outfall Water Surface Elevations

Subwatershed	Water Surface Elevation (ft NAVD88)
Kenwood	720.0
O Avenue	717.0
Robbins Lake	717.0
Applewood Mesa	717.0
River Bluff	717.0

The Kenwood subwatershed discharges to Cedar Lake, which is hydraulically isolated from the Cedar River by a weir at low Cedar River discharges. The elevation was approximated using the Cedar Lake elevation shown in LiDAR data, with the assumption being that the water surface elevation was near the weir crest elevation at the time the LiDAR data was collected.

The remaining subwatersheds in Table 3 discharge upstream of the 5-in-1 dam on the Cedar River and are typically submerged as a result. The water surface elevations for these outfalls were determined using the City’s HEC-RAS model of the Cedar River for a discharge of 3,050 cfs, which represents the 50% duration exceedance (median) flow.

Rainfall

For applying rainfall to the macro scale model to generate runoff flows, the nested design storm hyetographs were developed from NOAA Atlas 14 rainfall depths for recurrence intervals of 5 and 100 years. A nested storm hyetograph embeds the rainfall totals for multiple durations, creating a storm with a single steep curve (that is, the most intense 1 hour in the nested storm would generate the rainfall depth entered for the 1-hour duration). The simulated 24-hour hyetographs were generated for both 5-year and 100-year storm reoccurrence intervals using HEC-HMS using NOAA Atlas 14 rainfall depths for durations of 5 minutes, 15 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, and 24 hours. The hyetograph for the 5- and 100-year, 24-hour storm is shown in Figure 6.

With a non-nested hydrograph, the maximum flowrates are generated when the storm duration matches the time of concentration for a location in the model based on upstream catchments and flow routing. A short-duration storm would be required to generate the high-intensity rainfall periods observed in the historical storms, but may not create the rainfall depths of a longer storm, which would create higher flowrates at some locations. Using a nested storm pattern eliminates the need to run multiple simulations of different durations, producing a short, high-intensity period with the appropriate 24-hour storm rainfall depth. For these reasons, the nested 24-hour distribution was used in this analysis.

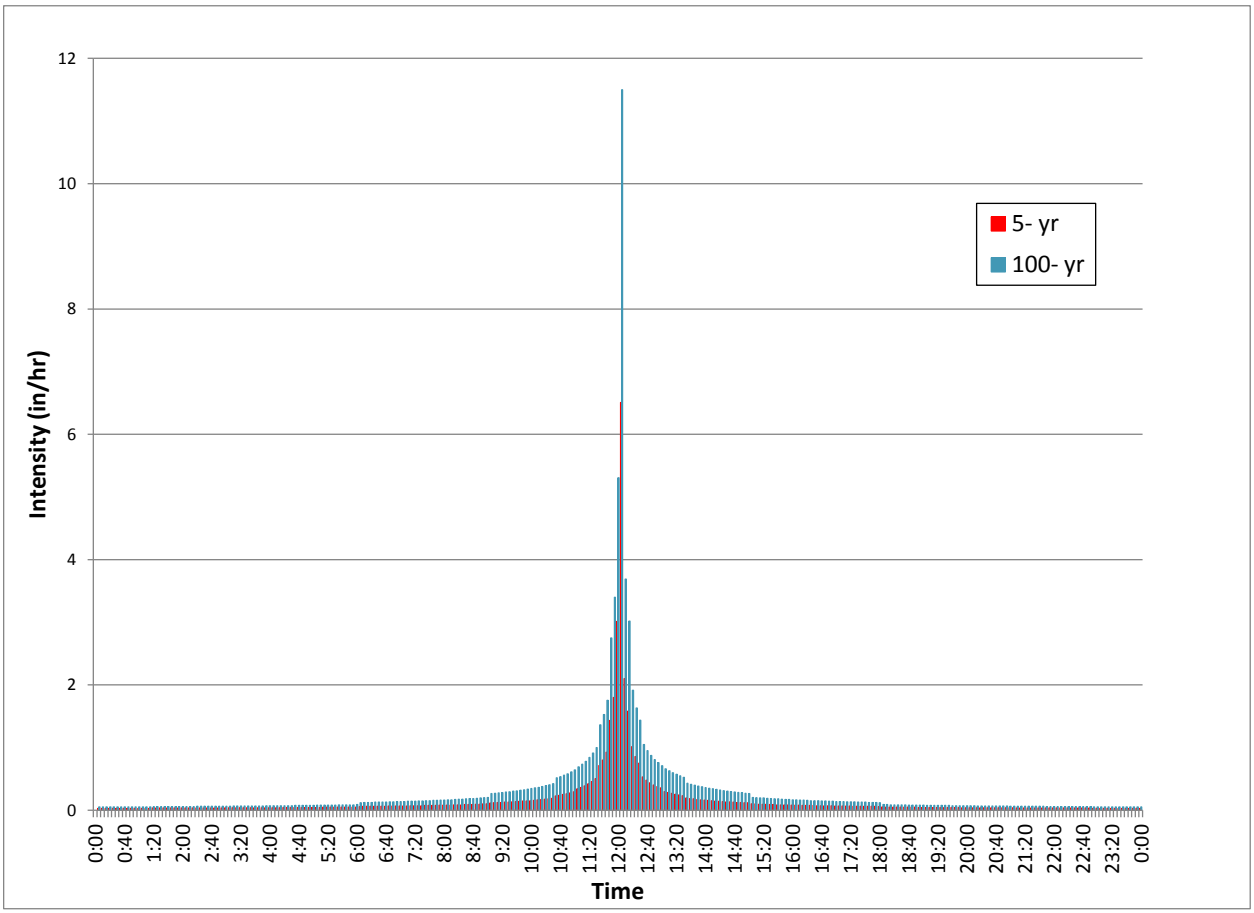


Figure 6: Rainfall Hyetographs for 5- and 100-year Nested Storms

An evaluation of the June 29 to June 30, 2014 rainfall event was completed to provide context to duration/intensity values used in the 5- and 100-year nested storms. The June 2014 event had average rainfall depths of around 4.5 inches in Cedar Rapids, most of which fell in a 1-hour period. The rainfall intensities peaked above 8 inches per hour in some areas. The rainfall intensities for a location within Cedar Rapids for the 2014 event are shown in Figure 7.

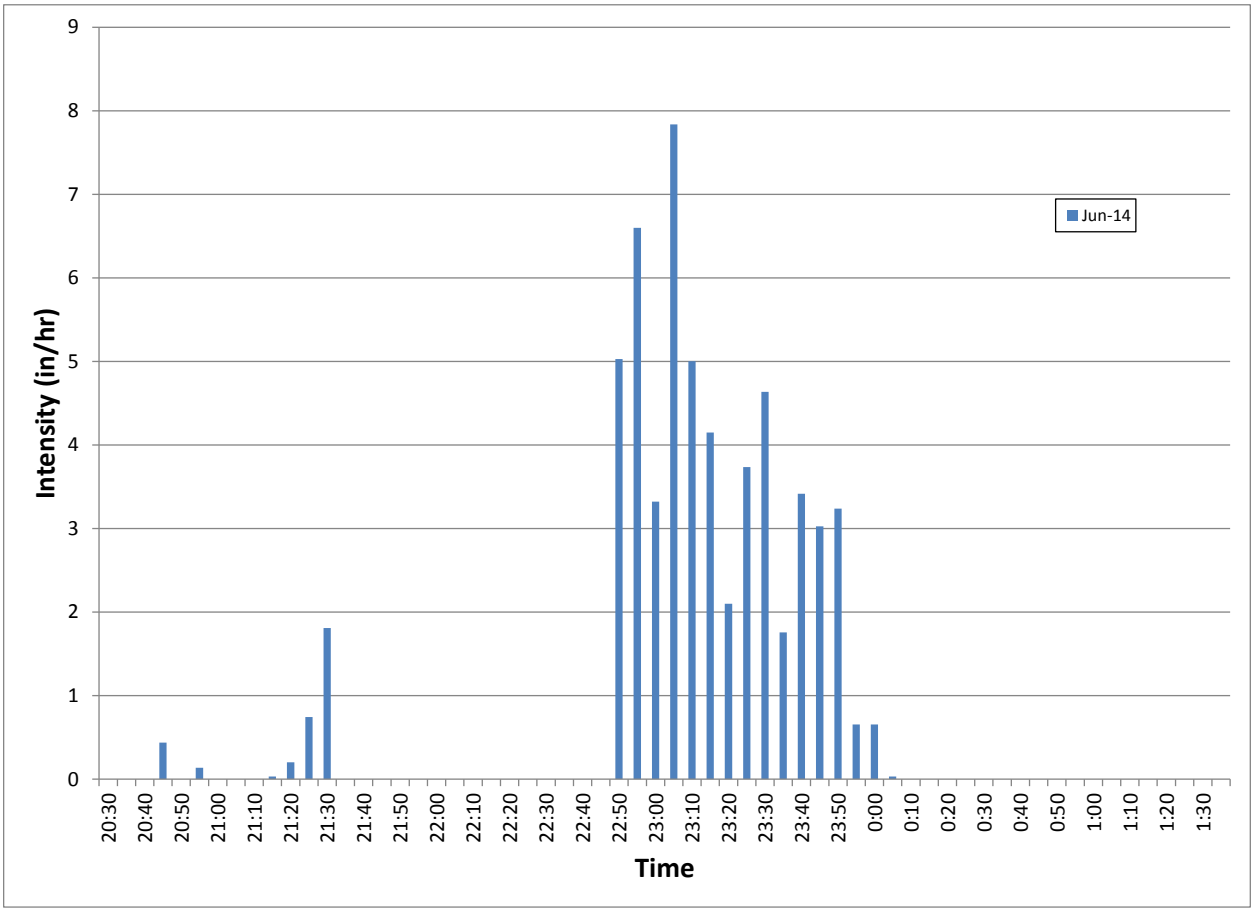


Figure 7: Rainfall Hyetographs for June 29-30, 2014 Event

Analysis

Results for the 5-year and 100-year rainfall event simulations are shown for the entire city in Figures 8 and 9. Map books of results by catchment and subcatchment are shown in Appendices C and D. Results figures show the maximum flow condition in each pipe and open channel section included in this model relative to the maximum conveyance capacity of the pipe. Pipes shown as limitations have a maximum flow equal to or greater than the conveyance capacity. Other pipes and channels may exhibit full pipe (or bank-full) flow but not be flowing at capacity. This is generally an indication of a downstream bottleneck. If the maximum flow condition in the simulation is less than full pipe or channel flow, that segment is shown in the results figures as either greater than half or less than half full.

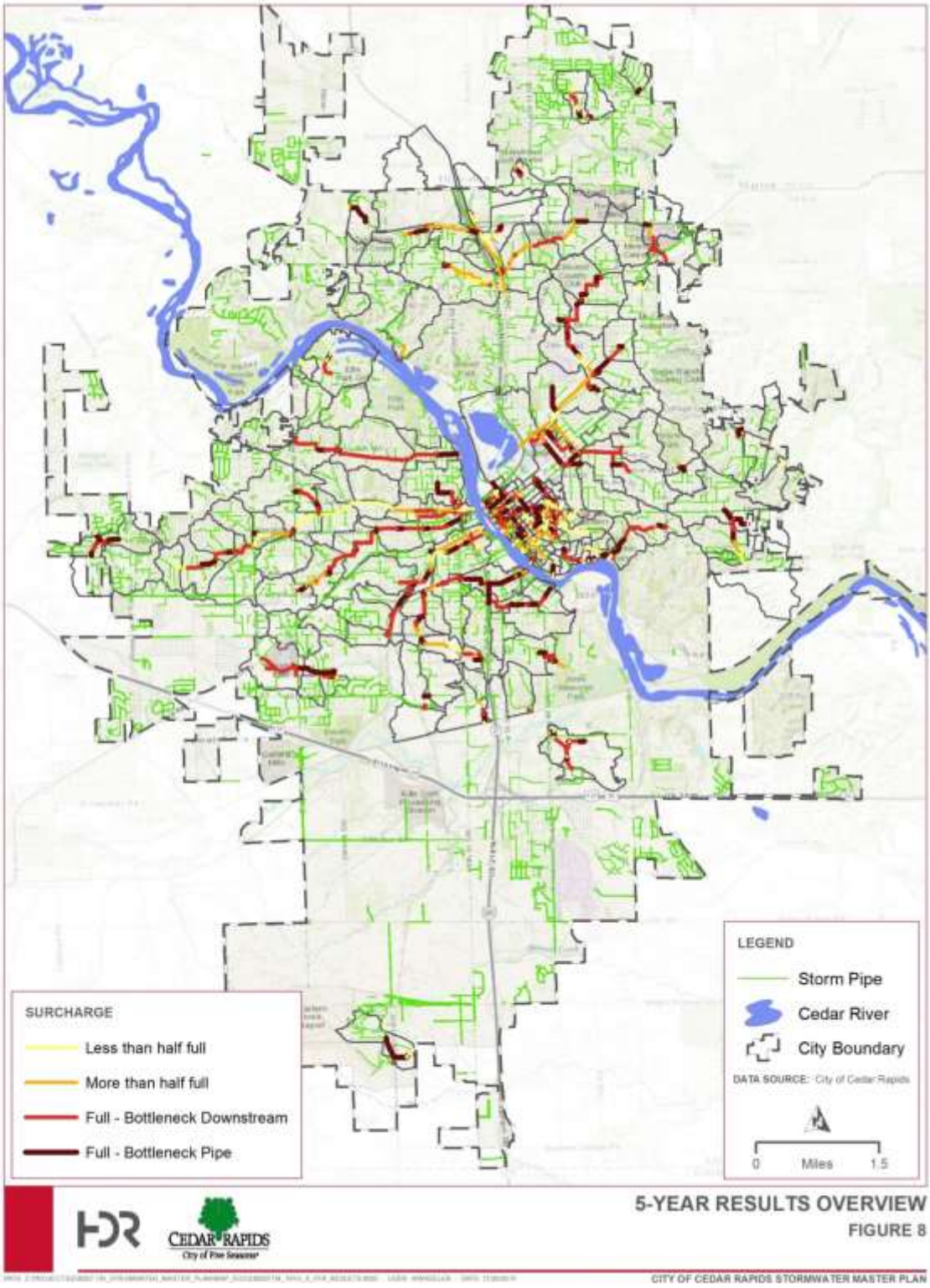


Figure 8: 5-Year Results Overview

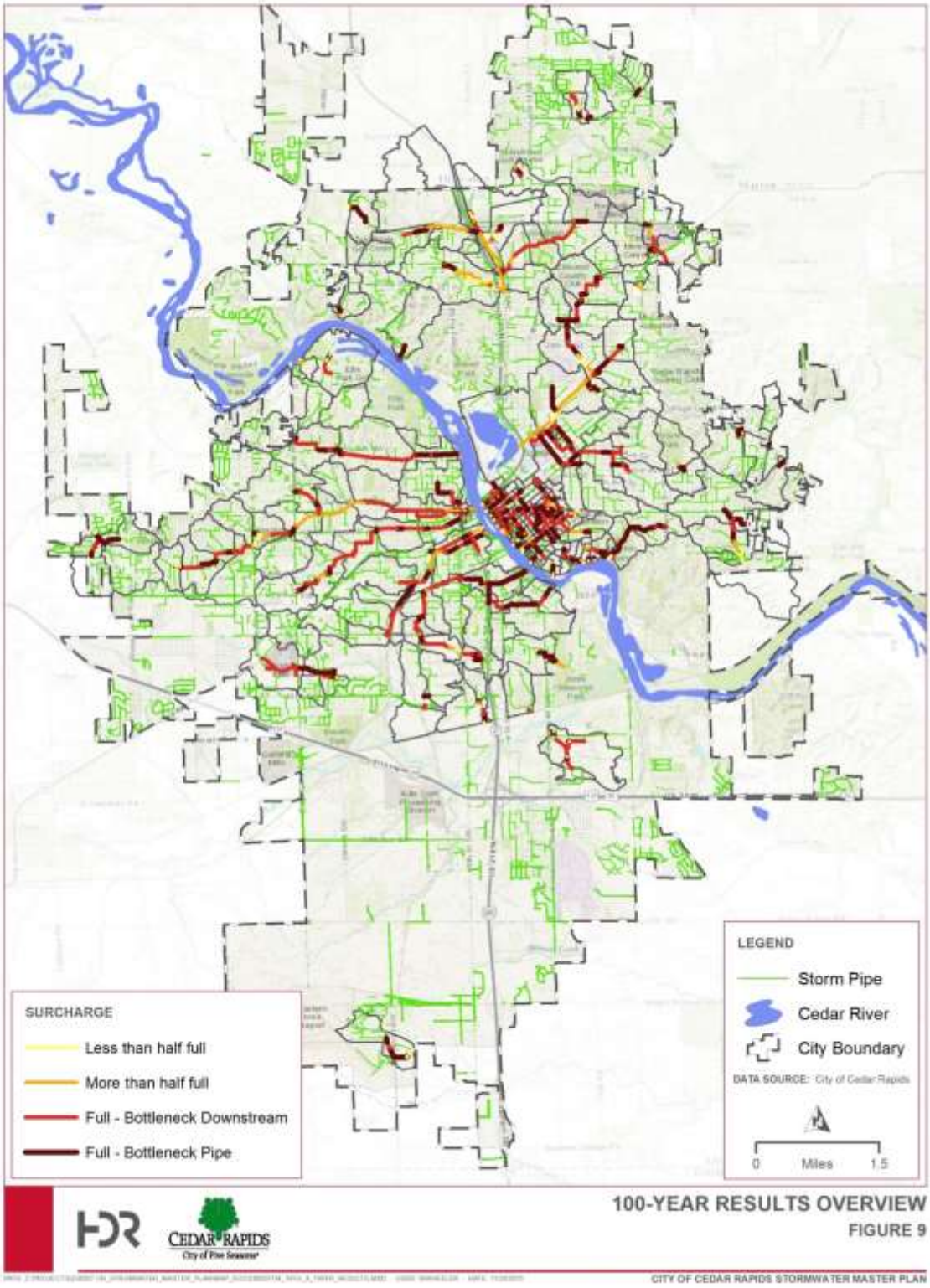


Figure 9: 100-Year Results Overview

5-year Rainfall Results

The 5-year rainfall event was simulated to evaluate the conveyance provided by the major conveyance structure and collection networks in comparison this level of service. An overview of results for the entire city is shown in Appendix C. The 5-year rainfall event results are discussed by subwatershed in greater detail below.

NW CEDAR RIVER

The NW Cedar River subwatershed was divided in 5 catchments. There are less than 2,000 feet of pipe in this subwatershed that are large enough to be considered in the macro-scale model. One 60 inch diameter segment of pipe north of Ellis Road is predicted to be at a bottleneck at the 5-year rainfall condition. Results are shown in Figure 10.

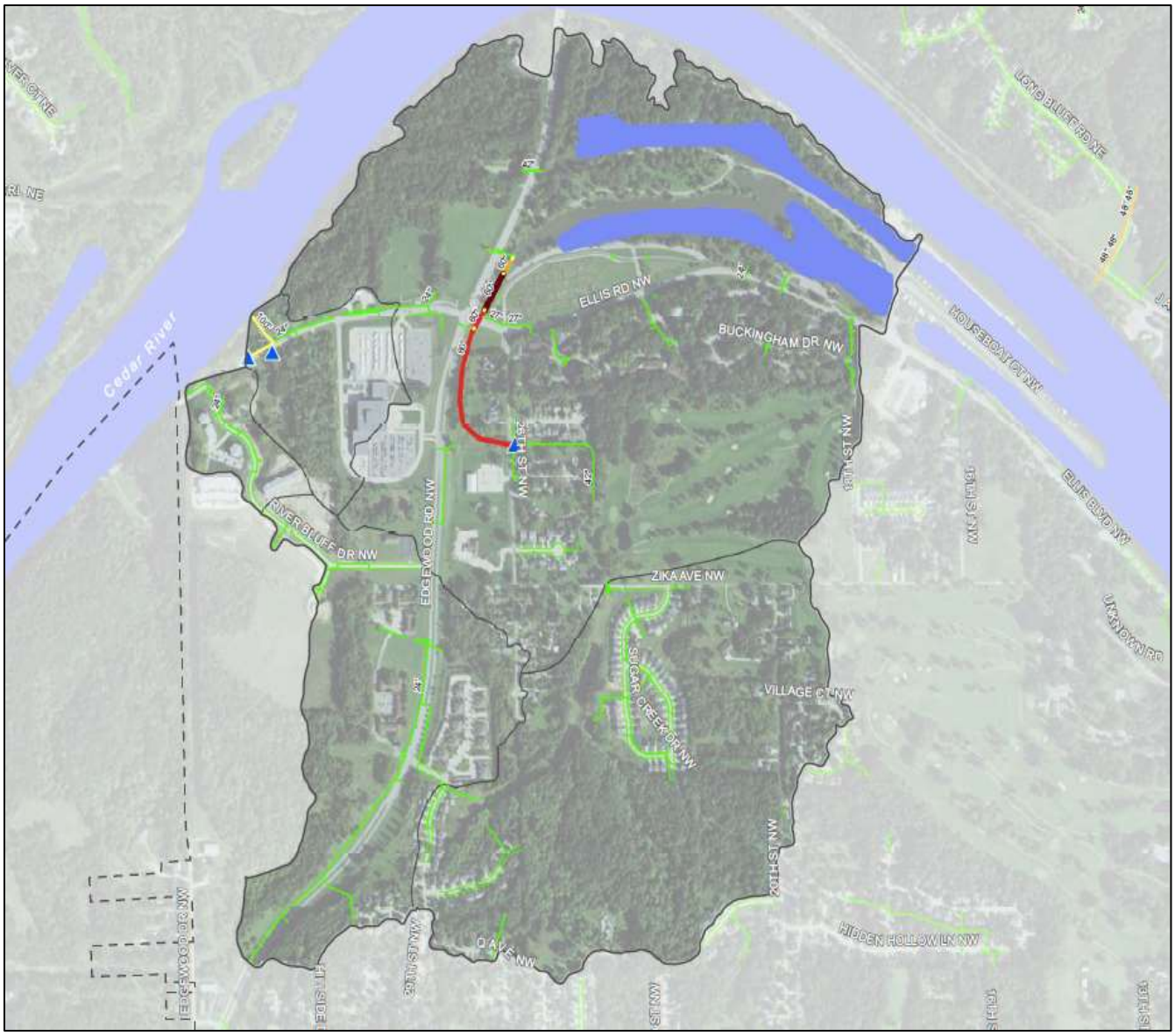


Figure 10: 5-year results, NW Cedar Subwatershed

Three subcatchments that contribute stormwater flow to pipes with diameters 48 inches and greater were identified in the Morgan Creek subwatershed. Capacity limitations are predicted in some of these downstream locations during a 5-year rainfall event. With little pipe larger than 48 inches, a more detailed evaluation of this subwatershed would confirm the level of service provided by these storm sewers. Results are shown in Figure 11.

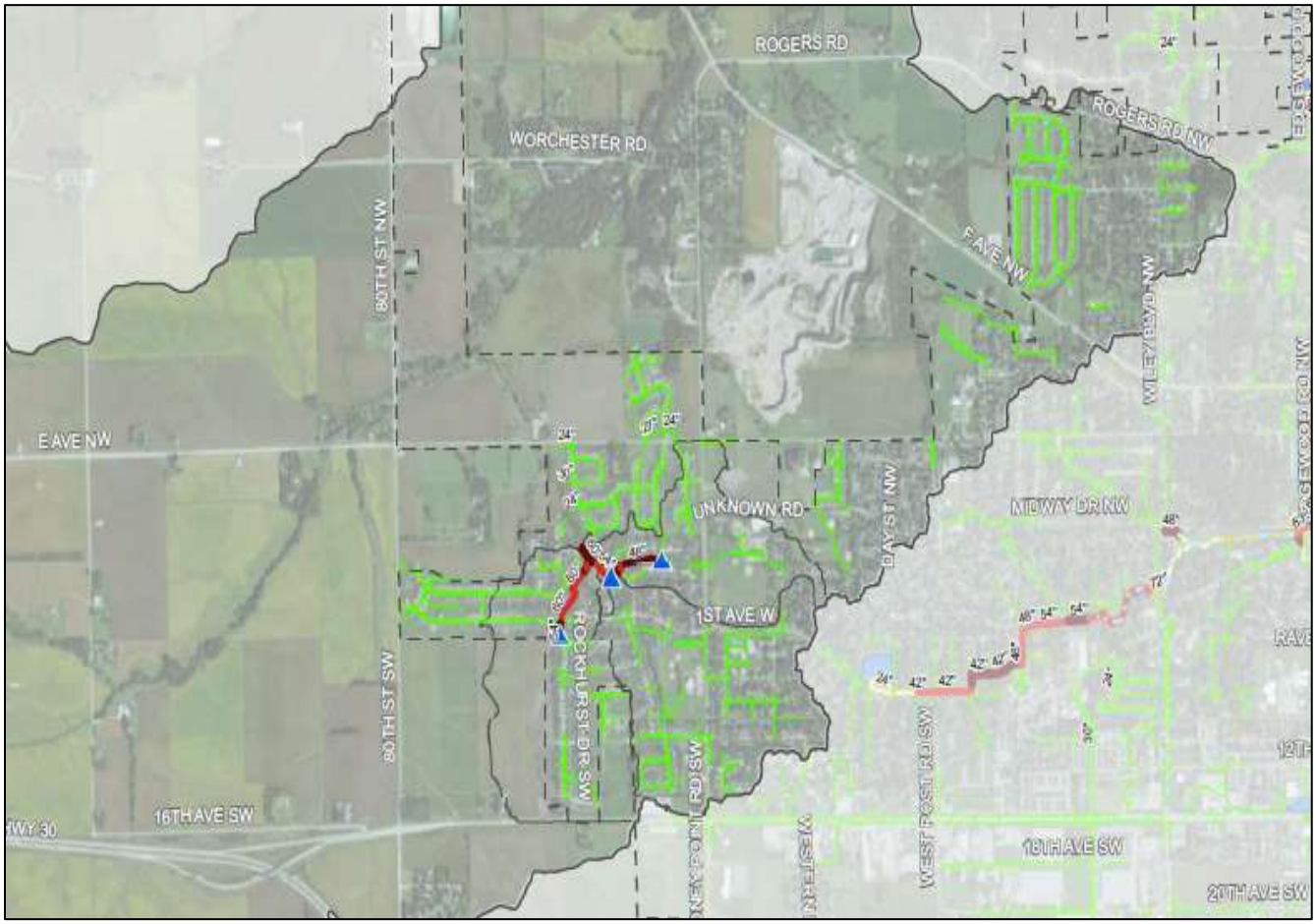


Figure 11: 5-year Results, Morgan Creek Subwatershed

O AVENUE

The O Avenue subwatershed was divided into four catchments. Based on this evaluation, two capacity limitations were observed in the system. One is at the 4'x12' RCB leading to the Cedar River outfall. Further upstream in the subwatershed, a there is a bottleneck shown at the 60" pipe along O Avenue near Blanche Road. Results are shown in Figure 12.

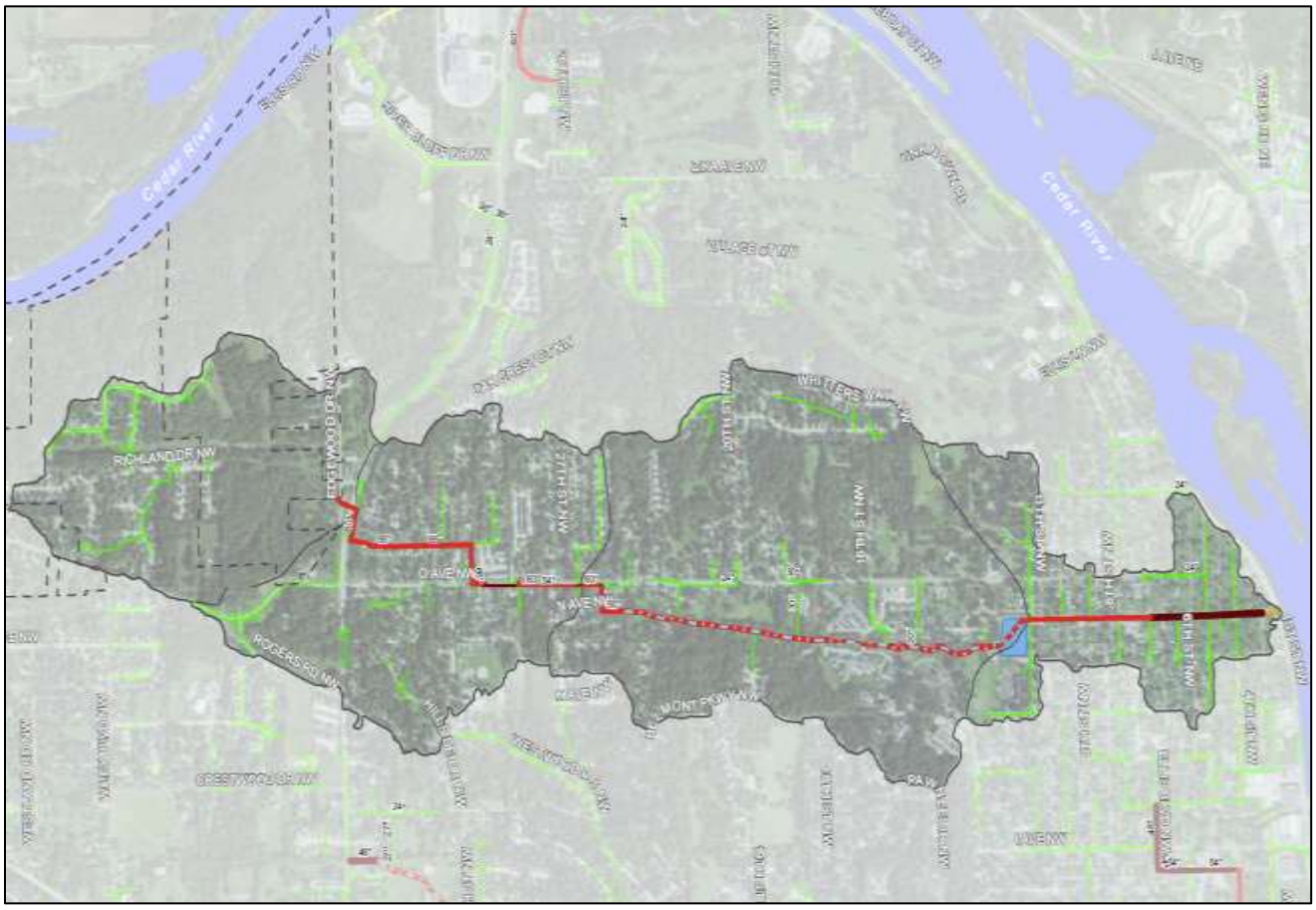


Figure 12: 5-year Results, O Avenue Subwatershed

E AVENUE

The E Avenue subwatershed was divided into 18 catchments. The E Avenue system has two main branches- Vinton Ditch (which primarily flows east) and a southern branch (which flows northeast from Edgewood Road And 16th Ave SW to 18th Street SW and Johnson Ave). The two branches join near the Cedar River Outfall. Several conveyance constrictions are shown in the results in the piped sections of both branches. During the October 14, 2015 workshop, City staff confirmed observed conveyance limitations at Johnson Avenue and Edgewood Road (Vinton Ditch branch), 16th Ave and Edgewood Road, and A Avenue and 4th Street NW (southern branch). Results are shown in Figure 13.

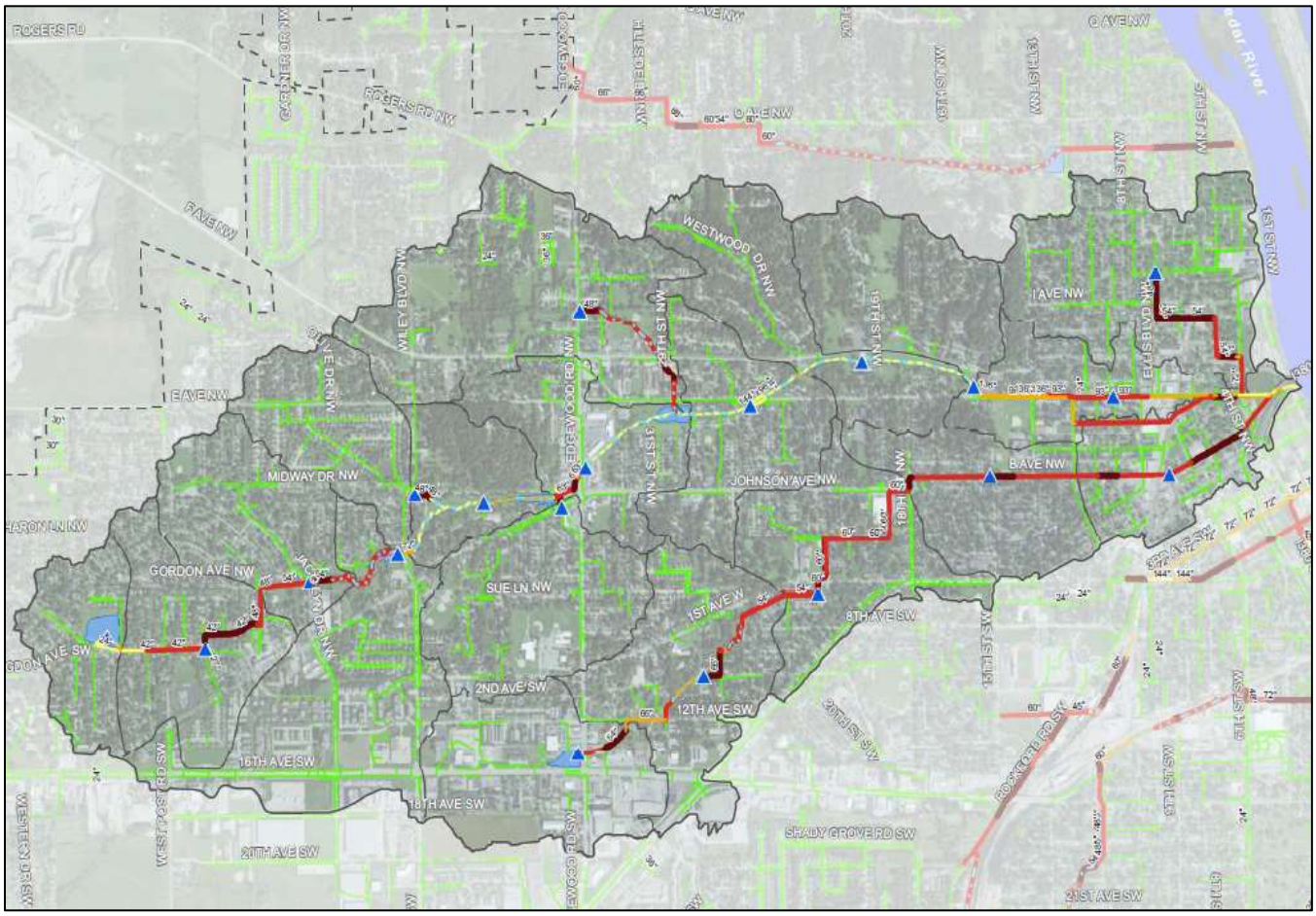


Figure 13: 5-year Results, E Avenue Subwatershed

Rockford Road subwatershed was divided into 7 catchments. Conveyance limitations are simulated along 4th Avenue SW and 3rd Avenue SW (between 6th Street SW and 9th Street SW), east of Rockford Road between 12th Ave and 8th Ave, and west of Rockford Road near the 15th/16th Avenue viaduct. During the October 14, 2015 workshop, City staff confirmed that the 15th/16th Avenue viaduct, and generally indicated that these results were similar to the results of study conducted for the west side interior drainage analysis. Results are shown in Figure 14.

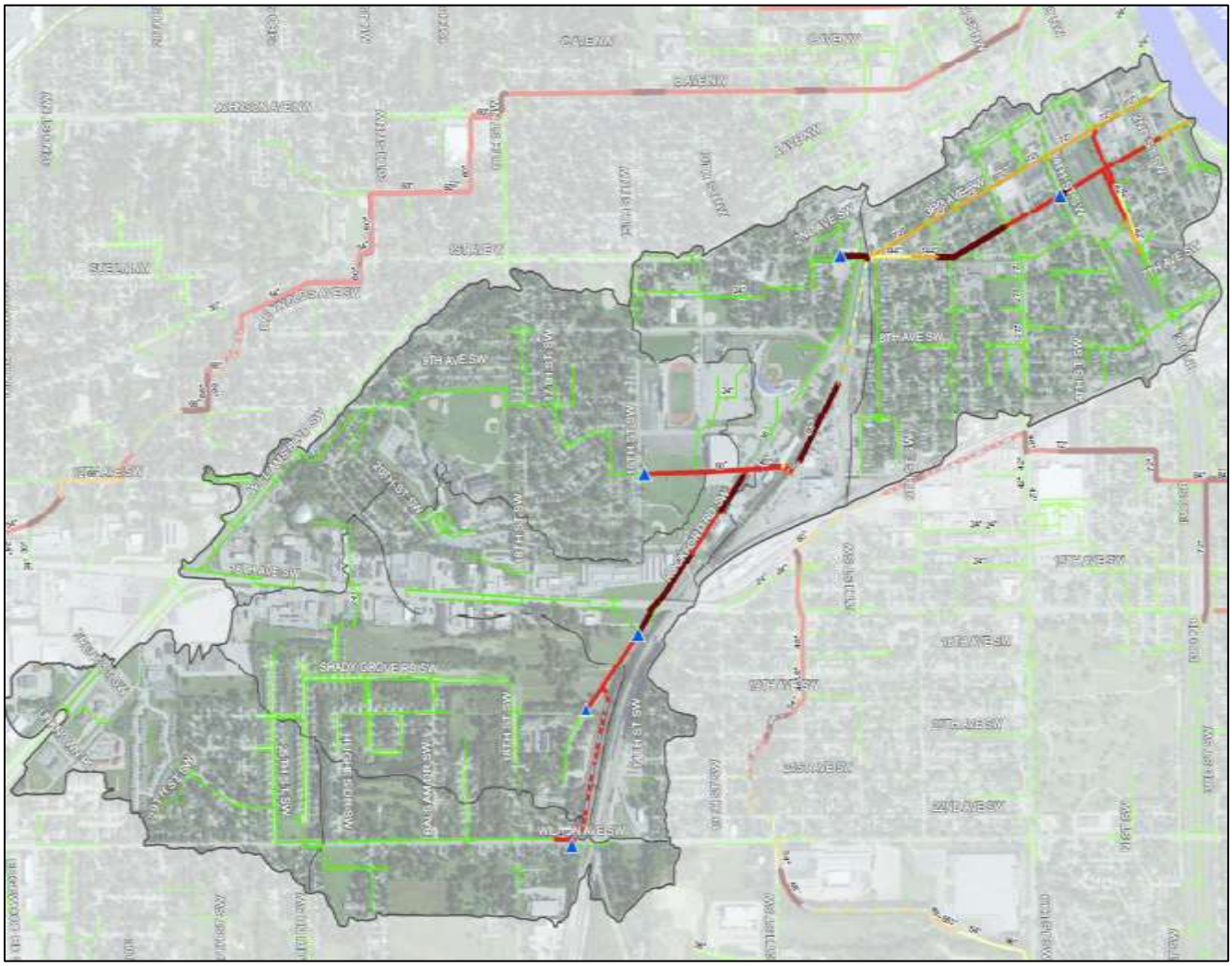


Figure 14: 5-year Results, Rockford Road Subwatershed

The Czech Village subwatershed was divided into 7 catchments with two main sewer lines with independent outfalls. One sewer line flows from 27th Ave SW and I-380 west and north to 12th Avenue SW and 14th Ave SW, then east along 13th Avenue SW to its outfall at the Cedar River. The second line starts at 16 Ave SW and I-380 and flows east to its outfall at 21st Avenue SW. The results indicate many conveyance limitations in this area. During the October 14, 2015 workshop, City staff confirmed the areas between 6th Street SW and I-380 along 12th Avenue and Mallory St SW and 19th Avenue SW are frequently problematic. Results are shown in Figure 15.

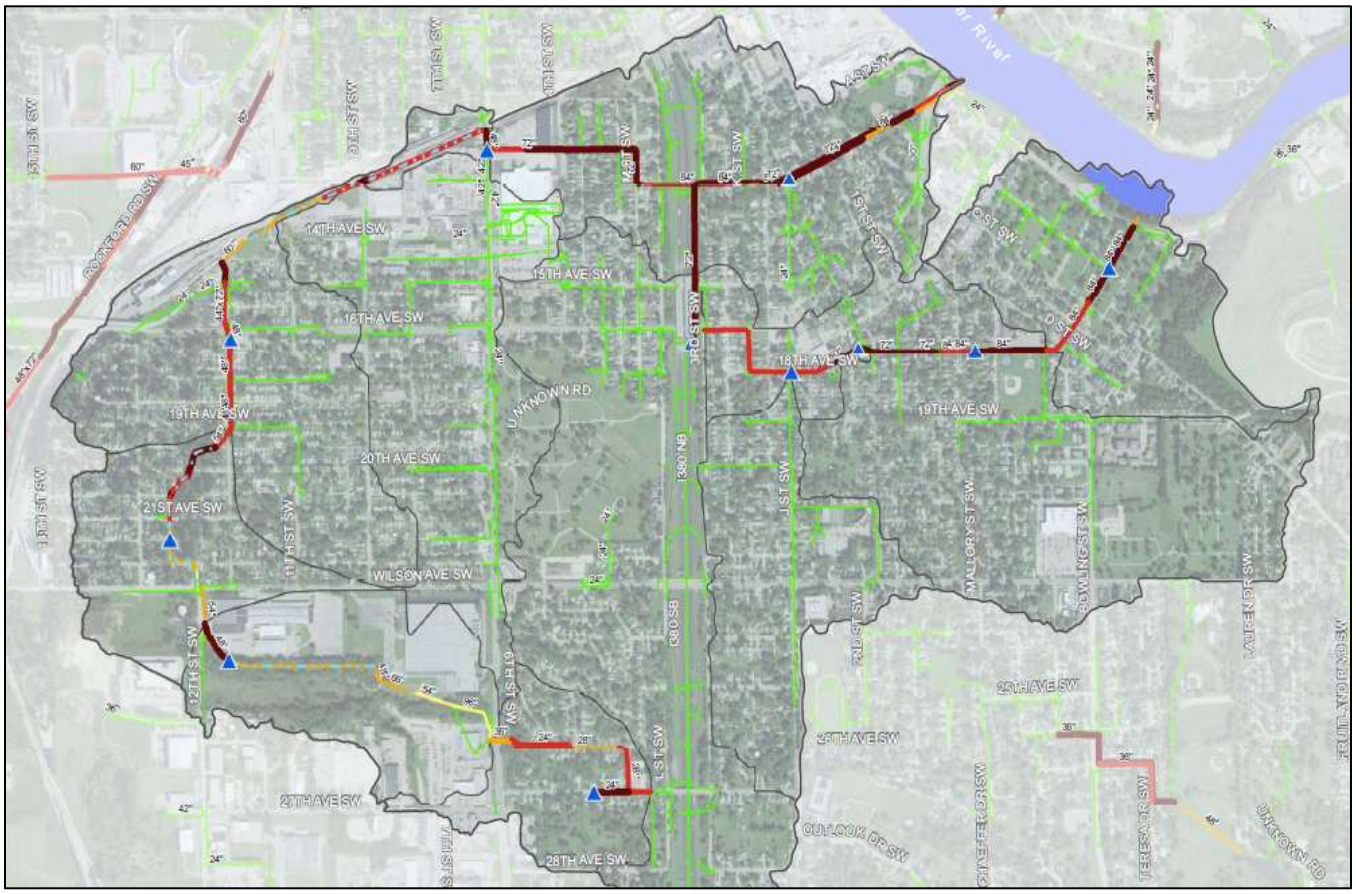


Figure 15: 5-year Results, Czech Village Subwatershed

The components of the macro-scale model in the Prairie Creek subwatershed include five separate piped collection systems with 13 catchments. Conveyance limitations are present in the model results in for each system. The longest bottleneck pipe section in the Prairie Creek subwatershed is located north of 29th Ave SW between Edgewood Rd and 27th St SW. Results are shown in Figure 16.

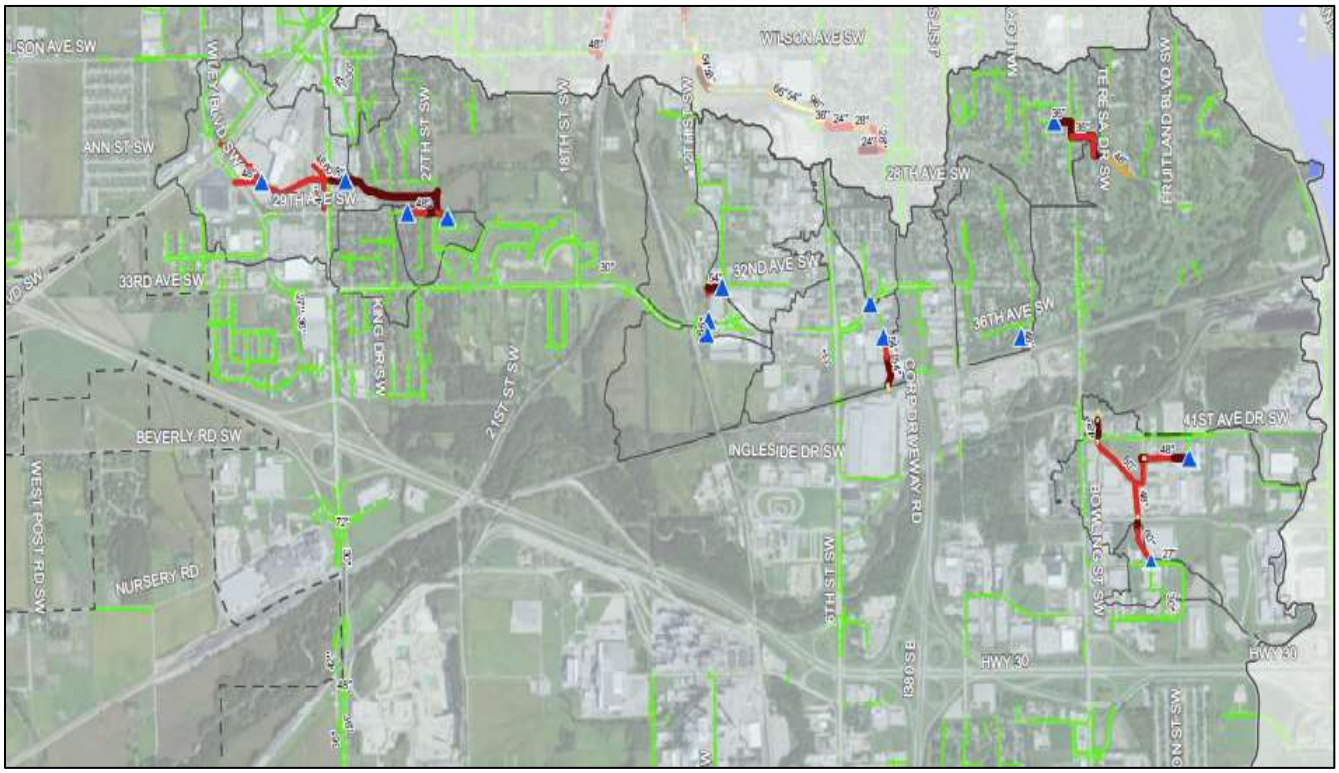


Figure 16: 5-year Results, Prairie Creek Subwatershed

Four small pipe networks in the Dry Creek subwatershed were simulated as part of the macro-scale model. Capacity limitations were predicted for the five year storm event in the pipe network and two of these pipe segments. With little pipe larger than 48 inches, more detailed modeling that considers storage volume in smaller pipes may influence these results. Results are shown in Figure 17.

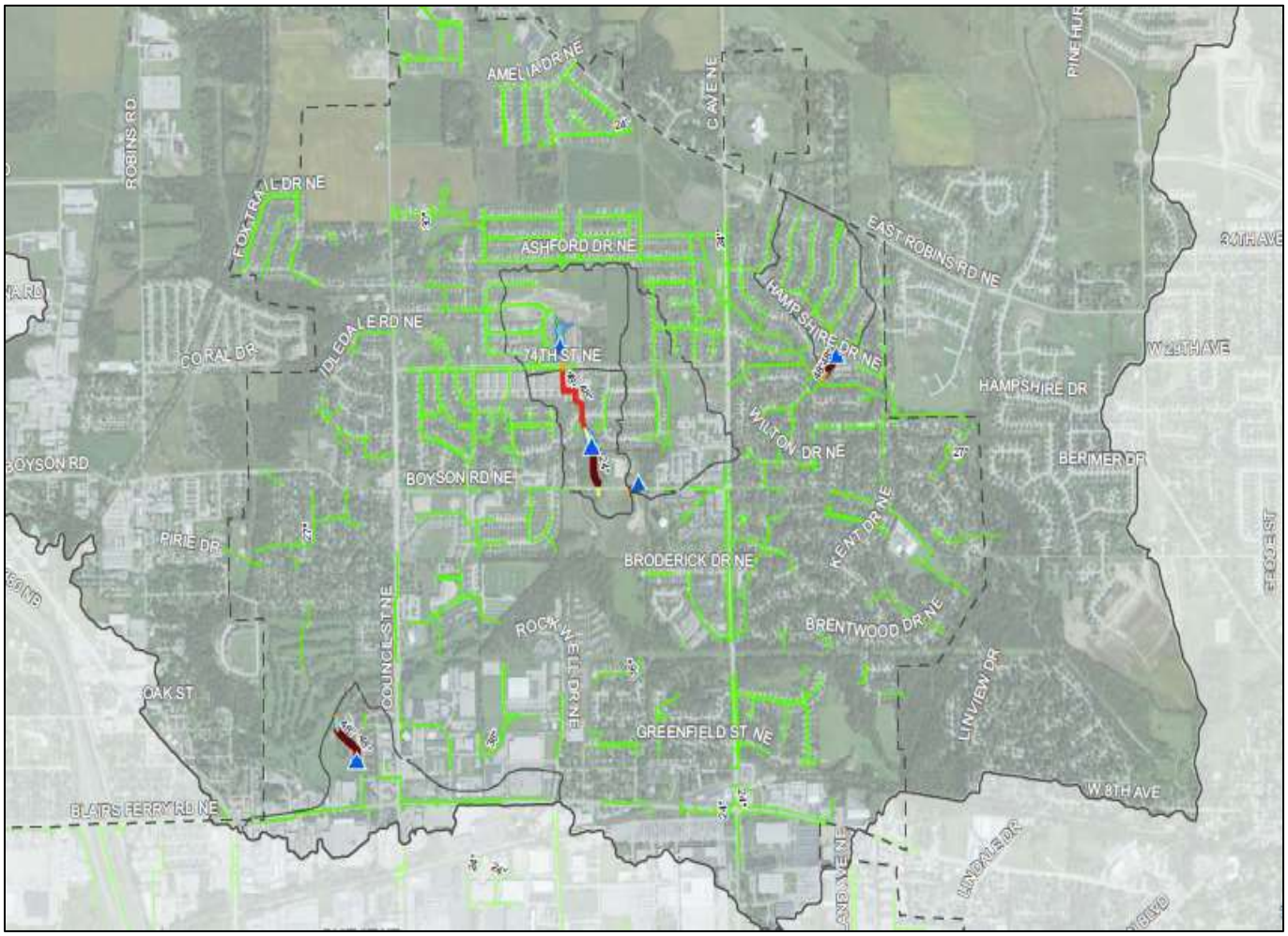


Figure 17: 5-year Results, Dry Creek Subwatershed

One pipe network from the Usher Ferry subwatershed was included in the macro model. This sewer, which is a 48 inch storm sewer north of Highway 100 and east of Edgewood Road, is shown as a capacity limitation in the model results. This may be a result of the loading point location in the subwatershed, which would be refined in a more detailed analysis. Results are shown in Figure 18.

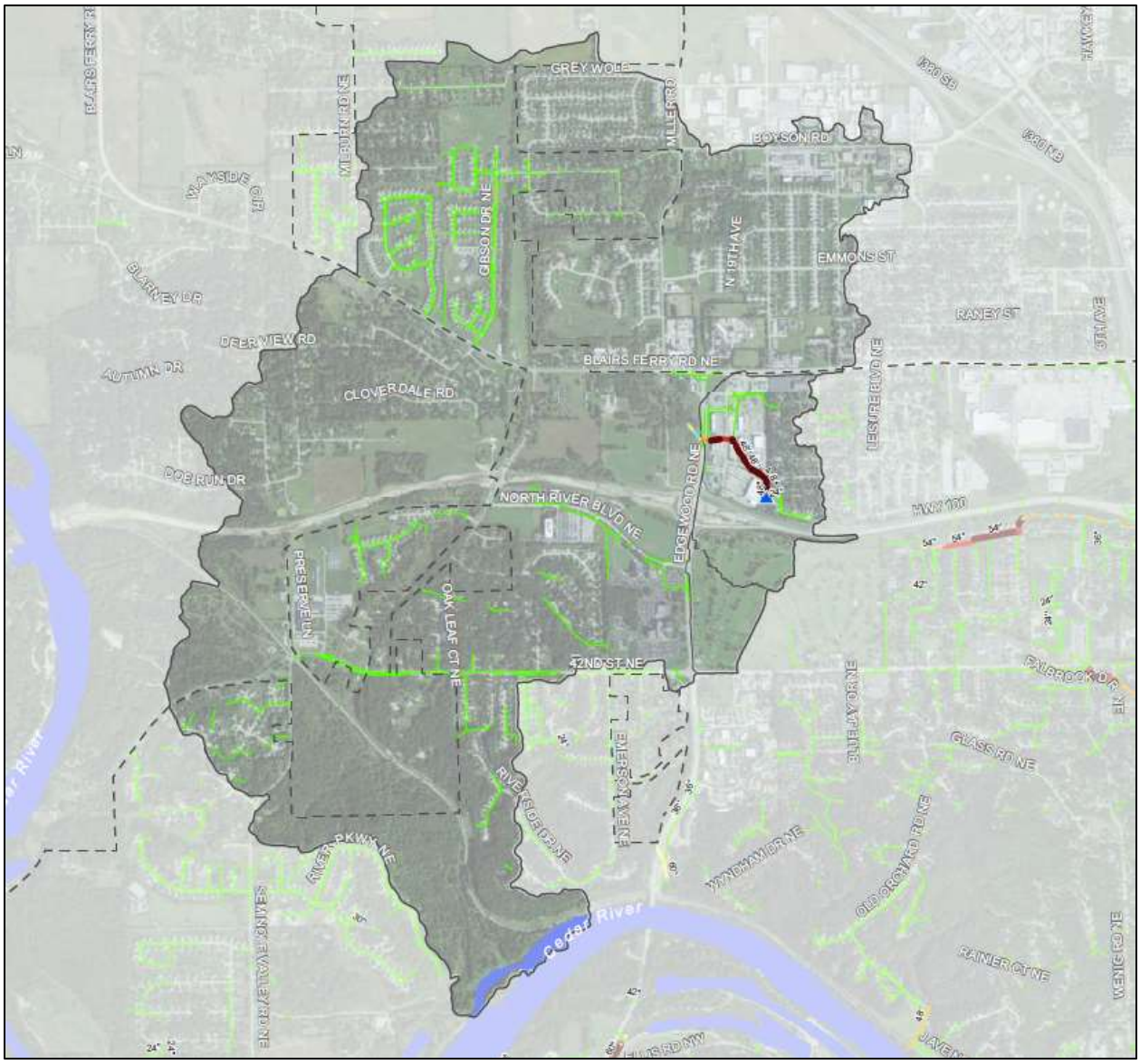


Figure 18: 5-year Results, Usher Ferry Subwatershed

The McLoud Run subwatershed was divided in 11 catchments. Model results indicate conveyance limitations in the under I-380 south of Collins Rd, along Towne House Drive NE, and near Centerpoint Road NE and Miami Drive NE. The results in this area, especially open channel and overland flow interactions, will be refined in the basin-scale model. Results are shown in Figure 19.

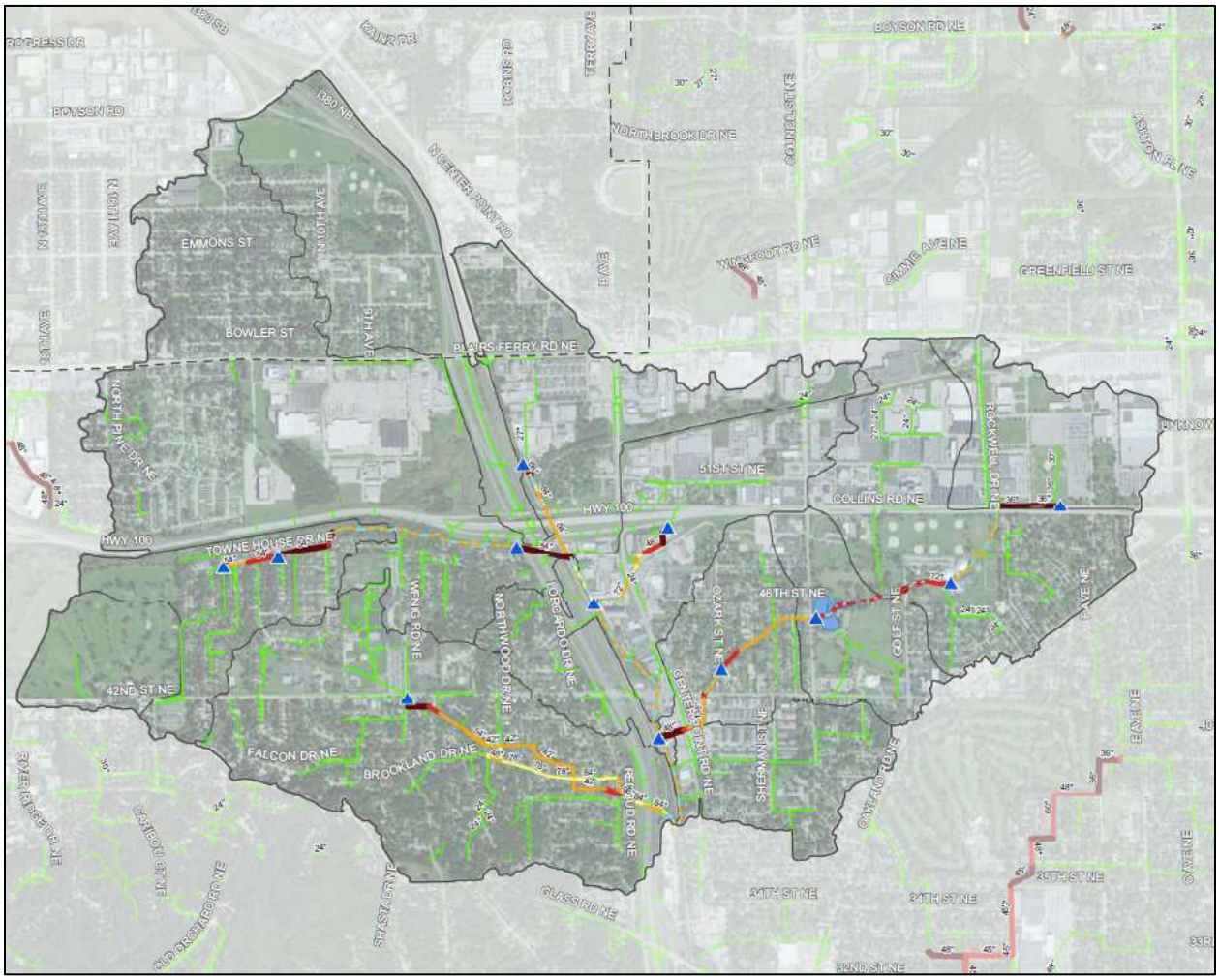


Figure 19: 5-year Results, McLoud Run Subwatershed

Two small pipe networks were included in the NE Cedar River subwatershed in the macro-scale model. Based on model results, both have adequate capacity to convey runoff from the 5-year rainfall event without creating a bottleneck. Results are shown in Figure 20.

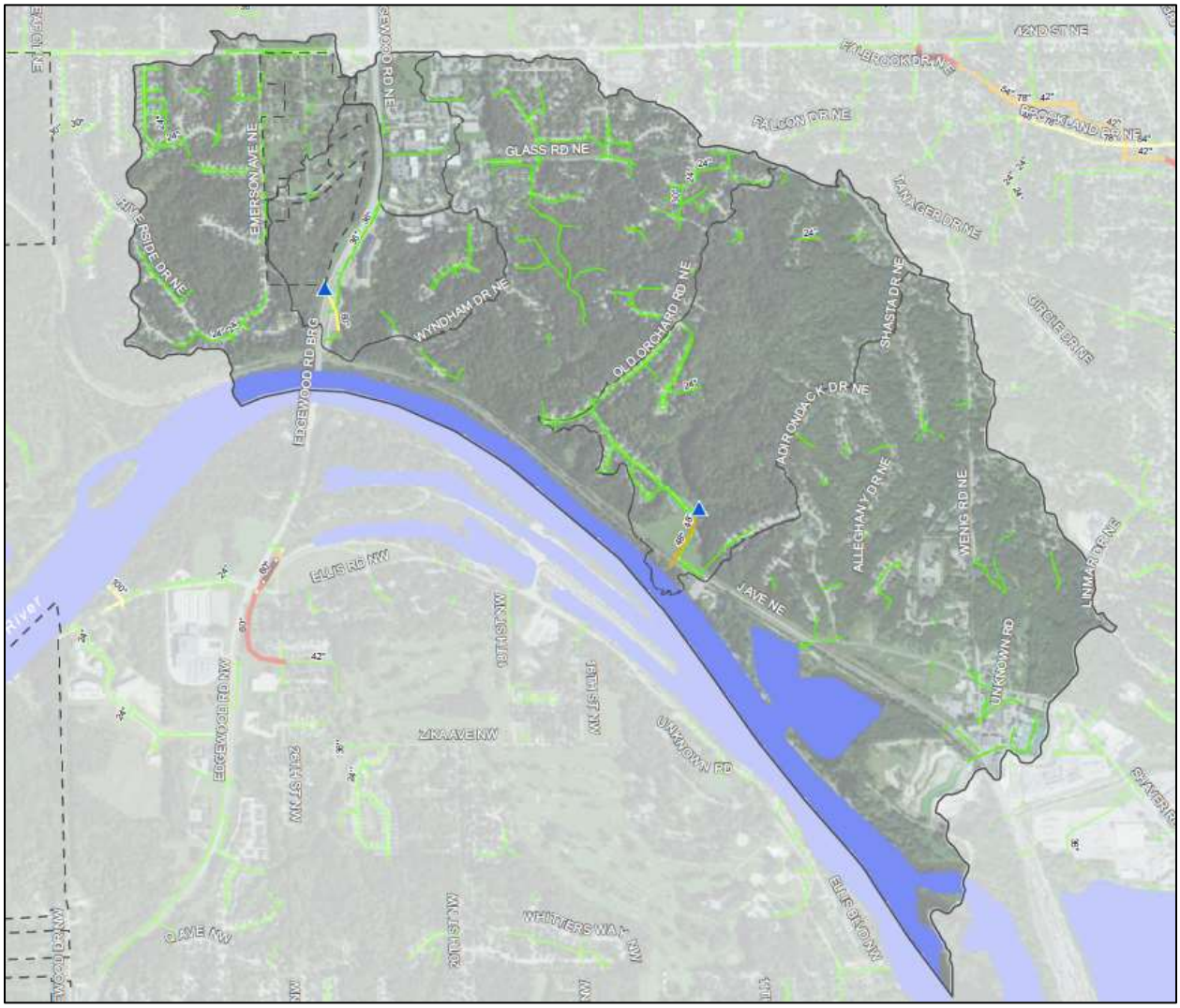


Figure 20: 5-year Results, NE Cedar River Subwatershed

The Kenwood subwatershed was divided in 17 catchments. Several conveyance limitations are shown the results in the northern portion of the subwatershed in addition to these, more bottlenecks occur between 14th and 16 Streets NE and 3rd Avenue SE and D Avenue NE. This is a subwateshed that City staff indicated many stormwater management issues have been observed. Results are shown in Figure 21.

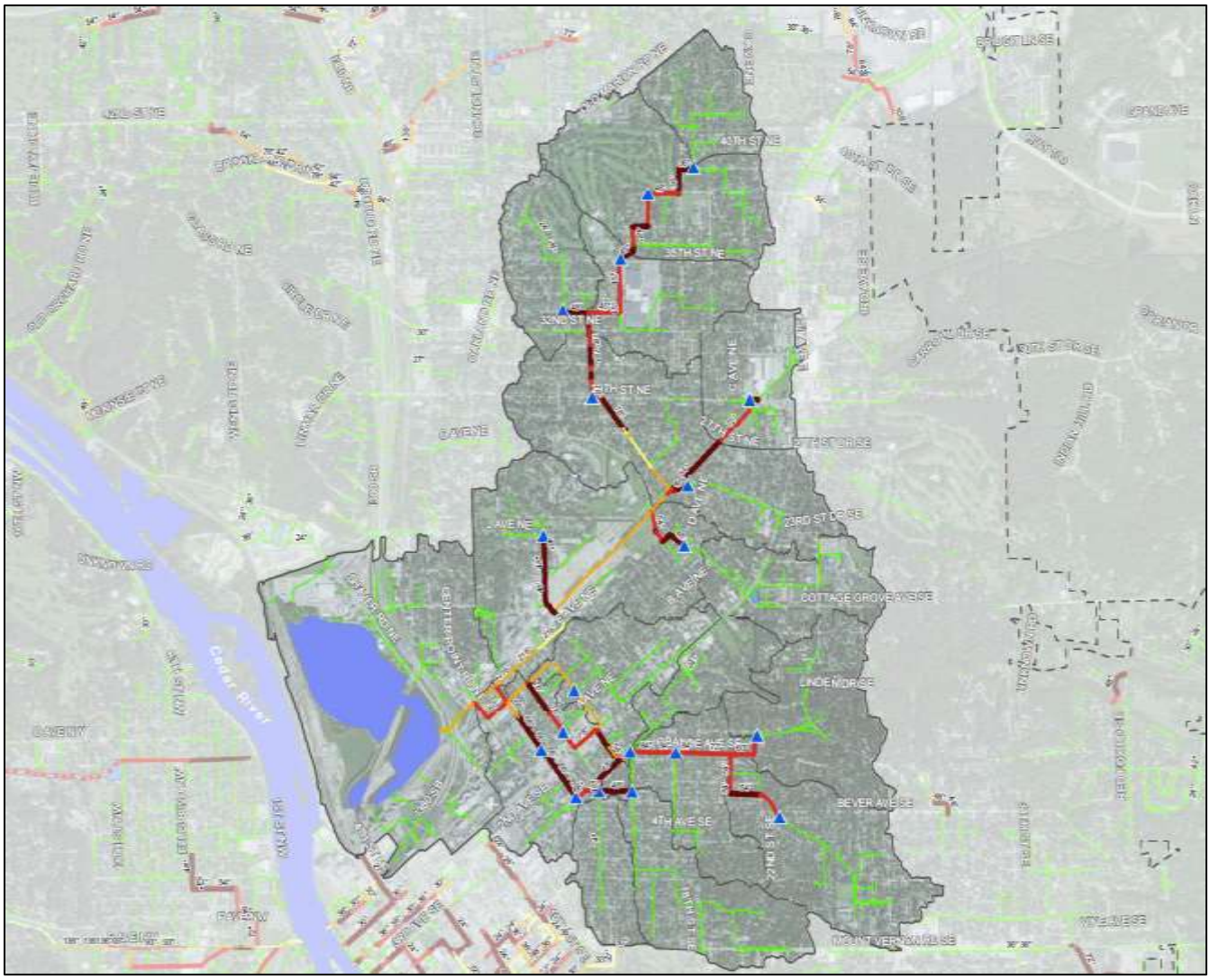


Figure 21: 5-year Results, Kenwood Subwatershed

Few large pipes exist in the Indian Creek subwatershed. Conveyance limitations in these were observed in the model results at Collins Road and Northland Avenue NE, at Beaver Avenue SE, and at Red Fox Road SE. With little pipe larger than 48 inches, a more detailed evaluation of this subwateshed would confirm the level of service provided by these storm sewers. Results are shown in Figure 22.

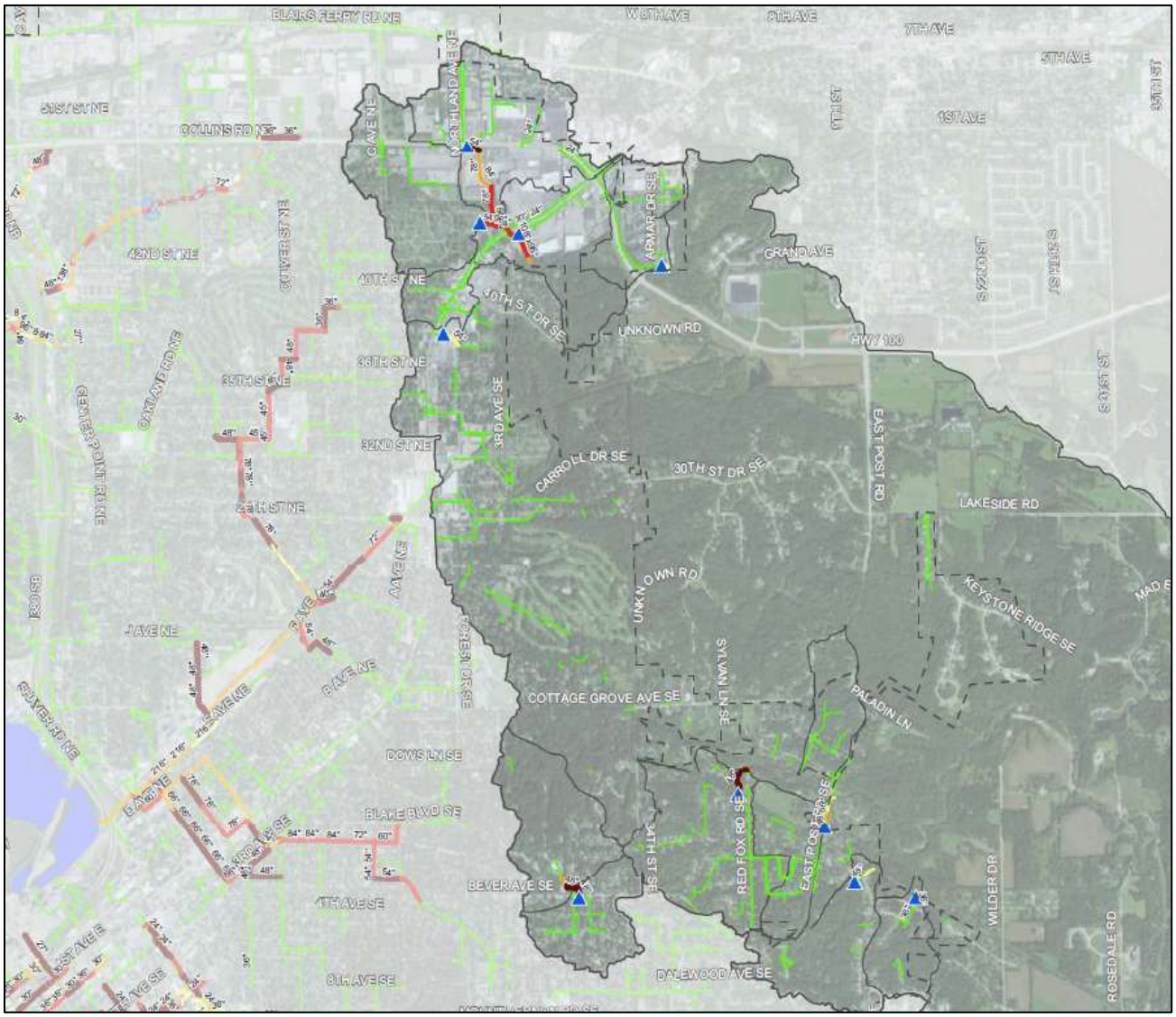


Figure 22: 5-year Results, Indian Creek Subwatershed

From the model results, several conveyance constrictions are revealed in the downtown area. Model results indicate capacity limitations in the systems upstream of 1st ,2nd, and 3rd Avenues SE. Additionally, more conveyance bottlenecks are shown between 5th and 8th Streets SE and 5th and 8th Avenues SE, and along 10th Street SE. Results are shown in Figure 23.

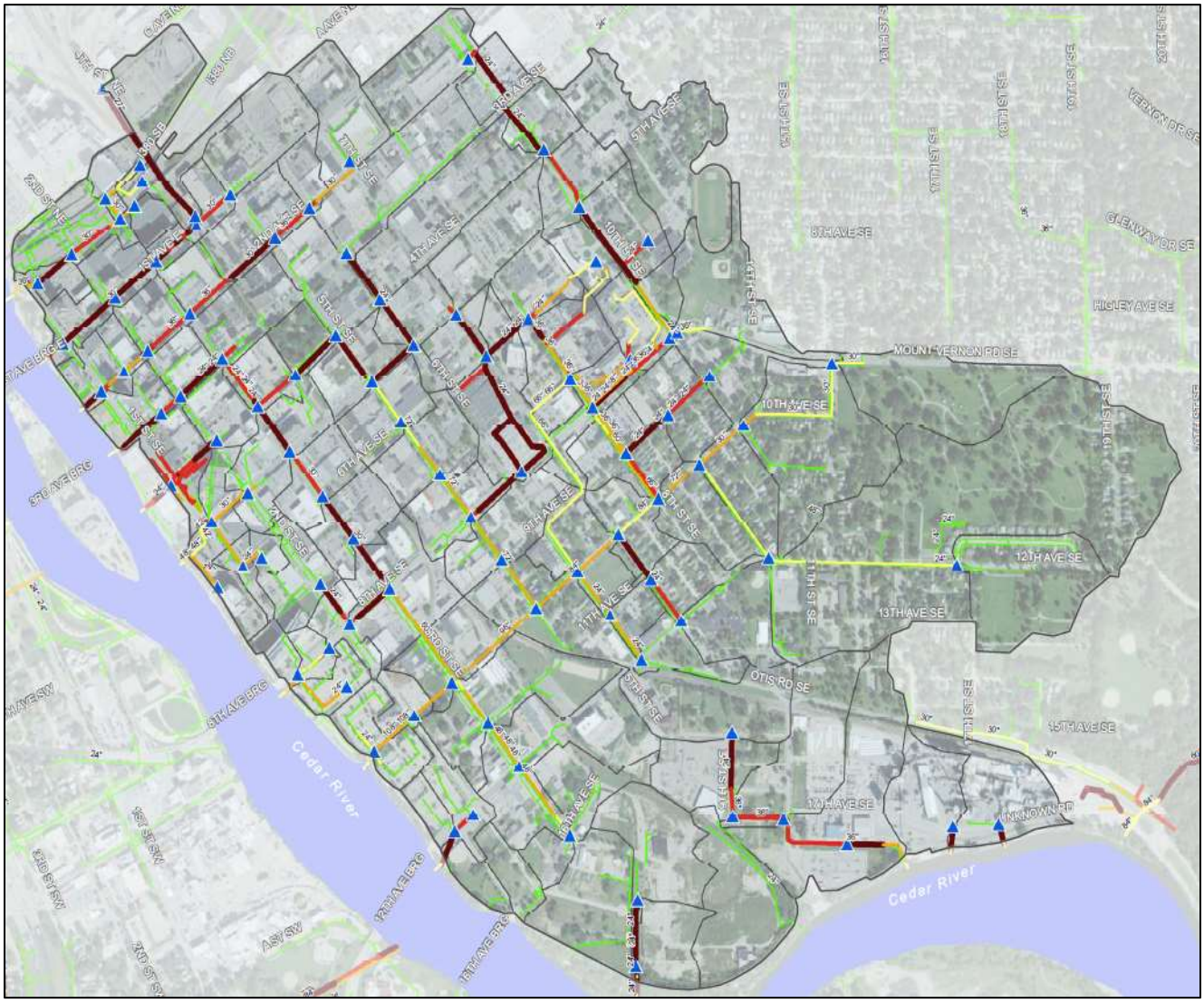


Figure 23: 5-year Results, Downtown Subwatershed

Two storm sewer systems were modeled in the SE Cedar River subwatershed area in the macro-scale model. One, which discharges to the Cedar River at Otis Road near Cargill Corn, may result in capacity limitations in two sections- west of Memorial Dr. SE and south west of McCarthy Rd. SE. The other storm sewer system is south of Mount Vernon Road, between 38th St SE and 42nd St SE. Model results indicate that bottlenecks may be present in the sewers upstream of the 200" sewer. Results are shown in Figure 24.

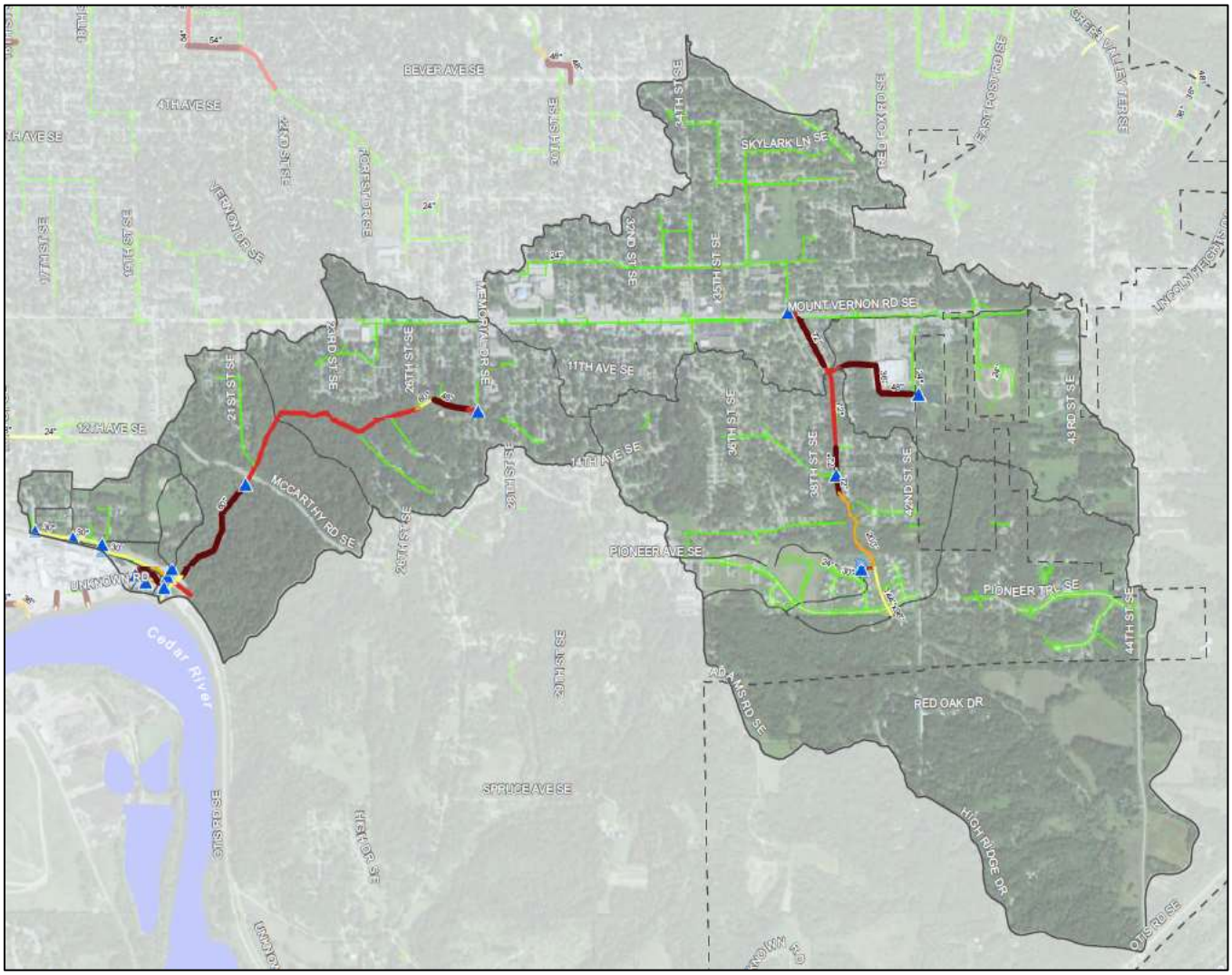


Figure 24: 5-year Results, SE Cedar River Subwatershed

100-year Rainfall Results

Results from the 100-year rainfall simulation are presented in Appendix D. These results were not interpreted in this TM. Significant overland conveyance would likely result during a 100-year rainfall event. Since the macro-scale model does not represent overland conveyance, the results for this model are not considered reasonable representations of predicted conditions. However, these 100-year rainfall results can be used as a general comparison to the 5-year rainfall results of where existing capacity limitations would likely increase in the system. Future basin scale models and their results will include overland conveyance and thus be better predicators of capacity limitations and flooding as well as the benefit of specific stormwater improvements than the macro scale 1D flow model.

Recommendations

Results from the macro-scale model indicate several areas for which the citywide storm water system does not have the capacity to convey the 5-year rainfall runoff. Two strategies can be used independently or interdependently to address conveyance limitations. One strategy would be to reduce the amount and intensity of runoff to the capacity-limited portions of the system. This can be achieved by detaining water upstream of the bottleneck through large-scale detention facilities or by the collective effect of best management practices at individual parcels. Best management practices include stormwater facility maintenance or the potential for green infrastructure retrofits. The other strategy is to increase conveyance capacity at the bottleneck portion of the system by replacing and upsizing existing pipes, paralleling existing pipes if there is space, and/or adding upstream to the existing storm water system. The effectiveness and impacts of implementing any of or combinations of these strategies can be evaluated best using a 1D-2D detailed basin model. Additionally, future land use should also be considered using the more-detailed basin-scale model.

Basin Scale Modeling

As discussed in the Objectives section, basin scale models will be developed progressively. As part of the current scope of work, the first critical basin-scale model will be developed as part of this contract. Additional basin-scale models will be developed in subsequent contracts.

A workshop with the City was conducted on October 14, 2015. Macro-scale model development and preliminary results were presented and discussed. Following this presentation, the group discussed which subwatershed would be most beneficial to evaluate with the initial basin-scale modeling effort. The Kenwood subwatershed was identified as the primary subwatershed of interest for several reasons:

- Following the June 2015 rainfall event, the Kenwood subwatershed had the highest reported density of issues.
- A loss-of-life event occurred during the June 29-30, 2014 event in the Kenwood subwatershed.
- Issues in the Kenwood subwatershed and plans to address them are not well understood at this time.
- Kenwood is among the older neighborhoods, which presents the greatest number of restrictions to making improvements (due to the fully-built nature of the area).

- Kenwood has many sanitary sewer inflow and infiltration sources, which when mitigated, would increase flow in the stormwater system. This condition could be modeled in anticipation of sanitary sewer inflow and infiltration source reductions.
- Kenwood has the largest contribution to Cedar Lake, and developing stormwater alternatives may influence any potential Cedar Lake restoration goals.

For these reasons, the Kenwood subwatershed was selected as a critical basin to be modeled in greater detail.

Appendix A – Software Selection Memorandum

Technical Memorandum

Date:	Wednesday, November 18, 2015
Project:	City of Cedar Rapids Storm Water and Sanitary Master Plan Updates
To:	City of Cedar Rapids Staff
From:	Dave Dechant, Mike Schubert, Bryon Wood, Robin Hegedus - HDR
Subject:	Model Software Comparison Memo

The purpose of this memorandum is to recommend an appropriate modeling software package for the Storm Water and Sanitary System Master Plan Updates (Master Plans) for the City of Cedar Rapids (City). Several software vendors that offer hydraulic modeling packages considered in the memorandum include Innovyze, Bentley Systems, DHI Group, and XP Solutions. The key to selecting the proper modeling software is a balance between software data management and graphical user interface (GUI) platform, methods used in the hydraulic and hydrologic solvers (flow routing, rainfall derived infiltration and inflow [RDII]), 2D modeling capabilities, applicable extensions and add-ons, and software, maintenance and use cost. The advantages and disadvantages to each depend on user needs and preferences, quality of data available for building and calibrating the model of the systems and available features required to complete the goals of the Master Plans.

To develop the Master Plan models, the software recommended in this memo will be used in conjunction with ArcGIS by Esri to build the model, assign loads and flows, calibrate the model, and run analysis for the existing and future flow scenarios. The Master Plan models can then be used as a tool to assess the existing and future hydraulic conditions, develop recommended system improvements, test improvement alternatives and assist in development of the Capital Improvement Plan (CIP) for the stormwater and sanitary sewer collection systems.

HDR will concurrently be performing the modeling for the Sanitary Sewer and Stormwater Master Plans for the City. Many of the model input data required for these Master Plans will be duplicate (soil type, land use, terrain, rainfall, etc.). Using the same modeling package for the Master Plans would allow for several efficiencies to be realized in setting up the respective models, for the modelers supporting these Master Plan projects, and long-term for the City's stormwater and sanitary planning and design efforts. Therefore, if possible, a single modeling platform is preferred to using different modeling platforms for each master plan.

1 Software Selection Considerations

The following sections discuss key items that affect software selection. These considerations have been presented to support discussions of the specific software packages (Section 2) available for the Master Plans projects.

1.1 Software Platform

Modeling software packages available for this project are available on three different software platforms. The software is either AutoCAD-based, ArcGIS-based or a standalone package.

AutoCAD-based and standalone packages can use GIS information for model building or as supporting background information. ArcGIS-based packages offer an added benefit of the full integration of modeling and GIS data, although import/export is still required between the model database and GIS databases.

Direct integration with the GIS platform allows for straightforward model result sharing between the model and the GIS information. The sewer system components and its attribute data such as elevations, diameters, slopes, roughness, etc., can be imported directly into the model in all platforms using GIS data. Land use, population, traffic analysis zones and flow monitoring data for load allocation can be processed with direct GIS routines and linked to appropriate data fields within the model across all platforms. **Since the City data is stored in a GIS Environment, a software package that is either GIS-based, GIS-integrated or standalone with GIS integration capabilities is recommended.**

1.2 Hydraulic Calculations

1.2.1 Collection System Hydraulics

One key consideration is the simulation of backwater conditions that result when a collection system has sufficient volume to store and thus attenuate peak flows. Some packages can simulate these conditions more accurately than others. The differentiation between how effectively they can handle backwater conditions are termed as “fully-dynamic” or “hydrologic, non-dynamic.”

Fully-dynamic calculations are both hydraulic and hydrologic wave models that can completely simulate backwater conditions caused by downstream conditions, free-surface flow (overflows), pressure or surcharge flow, flow reversals, flow transfer by weirs and orifices, and equalization basins in dendritic (branching) and looped sewer systems. The calculations develop either explicit or implicit solutions to the St. Venant equations. Because of its complexity, fully-dynamic calculations take longer to solve but are appropriate for complex systems involving surcharge, flooding and complex sewer appurtenances (weirs, siphons, equalization basins, etc.).

Non-dynamic calculations are less accurate and typically take less time to perform. Non-dynamic software packages are hydraulic wave models using the Manning’s equation that simulate partial hydraulic conditions using various methods such as standard-step gradually varied, modified standard step, and direct-step. However, these equations do not ensure conservation of momentum and continuity of flow, and non-dynamic calculations are limited in ability to simulate the full range of backwater conditions. Therefore, non-dynamic calculations are usually more appropriate for sanitary sewer collection systems that do not experience significant surcharging conditions. As stated above, explicit and implicit methods are approaches used in numerical analysis for obtaining solutions of time-dependent equations. Explicit methods calculate the state of a system at a later time from the state of the system at

the current time, while implicit methods find a solution by solving an equation involving both the current state of the system and the later one. Implicit methods, which are more accurate and require extra computation time, create a more robust hydraulic engine to complete analyses.

A dynamic modeling software package with implicit solutions is appropriate for the Master Plan models as the City does have a history of surcharged conditions, with the potential of complex hydraulic or sewer appurtenances within the system.

1.2.2 2D Overland Hydraulics

In stormwater models, a 2D simulation is required to model flow through complex geometries such as streets and buildings. This becomes critical in simulations with high-intensity rainfall, in which flow can both enter and exit sewers and cause overland flooding. This is not as critical for the sanitary sewer system model. **A modeling software package that links 1D/2D hydraulic solutions is recommended the Master Plan models to evaluate inundation and overland flow for rainfall events that exceed the capacity of the stormwater collection system.**

1.3 Steady-State vs. Extended Period Simulation

A majority of software packages support both steady-state and extended period simulations (EPS). The industry trend is for system models to be developed that allow for EPS to better simulate pulses and waves traveling through the collection system. An EPS model allows for a more precise routing of flows throughout the system and better understanding of flow conveyance and hydraulic conditions within the system under dry weather and wet weather conditions.

Software that is capable of EPS is recommended for these Master Plan projects. The City maintains a series of flow meters in the sanitary sewer system with data available to calibrate the model in an EPS scenario with respect to flow peak and volume.

1.3.1 Infiltration and Inflow (I&I)

To account for I&I across the system, all the industry-standard software packages can accept either fixed inflows or input hydrographs, or generate time-dependent flows based on rainfall data. This is done using built-in empirical hydrologic equations or externally using the RTK method or others. However, the software packages differ in how they generate RDII and options for developing I&I allocations.

As a result, **the selected software should allow a time-dependent simulation of I&I through the RTK or similar method** that will accommodate the results of the City's monitoring and analysis of sanitary sewer flow metering throughout the collection system.

1.4 Applicable Software Features

1.4.1 Scenario Management

Scenario Management is a convenient feature for model data management to make it possible to simulate varying system scenarios and efficiently compare results. Examples are different loading conditions such as dry weather and wet weather, design rainfall events, different alternatives to system improvements, or comparing system flow response under existing system

versus future conditions. **This feature is of high importance in order to efficiently complete the modeling goals of these Master Plans.**

1.4.2 Elevation Extraction

Elevation extraction is a feature that allows the modeler to interpolate and assign the elevations from an elevation source file to the nodal junctions in the models. Some packages have an elevation extraction tool for contour format only and others have it for both contour and raster formats. **This feature is recommended for these Master Plans.**

1.4.3 Load Allocation

Dry weather load allocation is a feature to allocate the wastewater and RDII loads to model nodes from a variety of sources, including, but not limited to, geocoded water meters, population data, land-use layer or user-created loading polygons. **This feature is recommended for these Master Plans.**

1.4.4 Data Analysis Tools

Several packages include tools to calculate or infer missing data such as pipe inverts and slopes. A few packages include a tool to evaluate invert data at manholes to locate out-of-tolerance drops. In addition, a few packages provide an automated tool to locate and correct adverse pipe slopes. **This feature varies between packages and is not a critical comparison feature, especially given the data-gaps identification and collection tasks that precede modeling in these Master Plans.**

1.4.5 Model Calibration

Model calibration is necessary to verify the extent to which a computer hydraulic model accurately represents physical conditions. Calibration hinges on having good field data (flow monitoring data) to calibrate against. There are modeling software packages that include an automatic calibrator that can aide in and simplify the calibration process. **Given the extent of calibration data and RDII analyses already completed, an automatic calibration feature is not required for these Master Plans.**

1.4.6 Pump Station and Forcemain Modeling

Most of the packages have full support for sewer pump station and forcemain modeling. **The City's collection system includes several pump stations and forcemains, and, as a result, the selected software package must be able to incorporate these system features.** Real time controls (RTC) are available in most packages for pump stations and other hydraulic structures to optimize system operation and control but is not necessary for the Master Plans.

1.4.7 Low-Impact Development (LID) Control Modeling

A common stormwater management practice is to install LID controls including rain barrels, vegetative swales infiltration basins, or porous pavement. Software packages have various methods to account for the impact on runoff from these improvements. **The ability to model the impact of LID improvements is not required for either of the Master Plan projects.**

1.4.8 System Analysis Tools

Most of the software packages offer sophisticated result reporting tools to analyze system capacity. However some offer better presentation and more comprehensive reports. Advanced symbology features available in the ArcGIS platform inherently increase available presentation options for analysis. Flow information is available in most packages in an EPS simulation. **The ability to report and analyze model results is a requirement for software selected for both Master Plans.**

1.5 Software Considerations

1.5.1 Long-Term Support

As software companies develop new software products, support for the older products is phased out. As a product is phased-out, less technical support is available and eventually, licenses are no longer maintained. The modeling efforts associated with the Master Plans are anticipated to be refined and added to for years to come as a key analysis and design-aid tool for the City. A software package with anticipated long-term support will allow for a smooth transition from year-to-year without having to convert model files from one software package to another. In anticipation of a multi-year modeling effort, **software with long-term support and availability is recommended for the Master Plan models**.

1.5.2 Cost

During preliminary discussions, the City expressed the desire to have HDR maintain the hydraulic models associated with the Master Plans. HDR furnishes licenses for all of the 1D/2D collection system models compared in Section 2. **Therefore, the cost of proprietary software is not a critical comparison for these Master Plan projects**.

2 Modeling Software

The primary, industry standard, sewer modeling software packages are described in the following sections. Table 1 compares the modeling software packages using the software selection considerations established in Section 1. Sections 2.1 through 2.7 provide additional discussion of software descriptions summarized in Table 1.

Based on the results of this comparison, InfoSewer, SewerGEMS and MikeURBAN do not have the minimum recommended features for this project. They will not be evaluated further. The next section conducts a more detailed comparison of InfoSWMM, InfoWorks ICM, MikeURBAN MOUSE, and XP SWMM.

Feature	Recommendation for Master Plan Models	Model Software Package						
		Innovyze			Bentley Systems	DHI Group		XP Solutions
		InfoSewer	InfoSWMM	InfoWorks ICM	SewerGEMS	MikeURBAN	MikeURBAN Mouse	XP-SWMM
Platform	ArcGIS or Standalone with ArcGIS Integration	ArcGIS	ArcGIS	Standalone with ArcGIS integration	Standalone, AutoCAD, and ArcGIS	Standalone on ArcEngine offering full GIS integration	Standalone on ArcEngine offering full GIS integration	Standalone with ArcGIS integration
Steady-State and Extended Period Simulation	Extended Period Simulation	Both	EPS	EPS	Both	Both	Both	EPS
Hydraulic Calculations	Full-dynamic , implicit solution, 1D/2D	Semi-dynamic (uses Manning equation and an explicit solution to Muskingum-Cunge equation) with limited surcharging, flow attenuation and backwater capabilities. 1D Only	Fully dynamic (Implicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities.1D/2D (2D is an extra module)	Fully dynamic (Implicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. 1D and 2D river drainage modeling capabilities. 1D/2D	Fully dynamic (Implicit and explicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. 1D	Fully dynamic (Implicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities.1D/2D	Fully dynamic (Implicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. 1D/2D	Fully dynamic (Implicit and explicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. 1D/2D (2D is an extra module)
Infiltration and Inflow (I&I)	Time-varying simulation of I&I	Standard version includes constant and time-varying inflow. InfoSewer includes rainfall generation, runoff routing, and an automatic RTK unit hydrograph method.	Constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, RTK unit hydrograph method and modeling of snow melt.	Constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, RTK unit hydrograph method and modeling of snow melt.	Constant and time-varying inflow, rainfall generator, runoff routing, and the RTK unit hydrograph method.	Constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, RTK unit hydrograph method and modeling of snow melt.	Constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, RTK unit hydrograph method and modeling of snow melt.	Constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, RTK unit hydrograph method and modeling of snow melt.
Scenario Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Automated Elevation Extractor	Yes	Yes (Raster and Contour)	Yes (Raster and Contour)	Yes (Contour and Raster)	Available through ArcGIS routine	Yes (Contour and Raster)	Yes (Contour and Raster)	Yes (Contour and Raster)
Automated Load Allocation	Yes	Yes (Suite version)	Yes (Suite version)	Yes	Yes	Yes	Yes	Yes
Pump Station and Forcemain	Yes	Limited	Yes	Yes	Yes	Limited	Yes	Yes
LID Controls Modeling Capabilities	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Long-term Support	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Relative Cost ($-$$$$$)	-	$$	$$$$	$$$$$	$$$$	$$$$	$$$$	$$$

2.1 InfoWorks ICM

InfoWorks ICM by Innovyze is a rainfall runoff, storm sewer, river and sanitary sewer system modeling package based on a standalone platform. InfoWorks ICM is effective in modeling complex networks including overflow with an integrated 1D/2D engine. The hydraulics and hydrology are sophisticated and fully dynamic (Implicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. InfoWorks ICM provides complete support for siphons, parallel pipes, and reverse flow. Modeling of looping systems and equalization basins is possible.

InfoWorks ICM handles I&I in a variety of ways including constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, including the RTK unit hydrograph method and modeling of snow melt. This package models pump stations and forcemains with a fully-integrated RTC module for most hydraulic structures.

Additional features InfoWorks ICM offers are load allocation tool, automated network data validation and tools to infer missing data such as invert, diameter and slope. InfoWorks ICM includes support for water quality analysis and sediment transport.

Another related software consideration that was made is that InfoWorks CS, which was being used to complete some local modeling within the City, will no longer be supported by Innovyze at the end of 2015. Eventually the licenses themselves will stop working sometime in the years ahead. Therefore, this software was not considered as a viable option going forward. However, the existing InfoWorks CS models will be converted to InfoWorks ICM to utilize that previous work during these Master Plan projects. In addition, InfoWorks ICM has a more robust and optimized calculation engine reducing run times for complex 2D calculations.

2.2 MikeURBAN (MOUSE)

MikeURBAN (MOUSE) by the DHI Group is a rainfall runoff, storm sewer, and sanitary sewer system modeling package based on a standalone platform. MikeURBAN is effective in modeling complex networks including overflow with an integrated 1D/2D engine. The hydraulics and hydrology are sophisticated and fully dynamic (Implicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. MikeURBAN provides complete support for siphons, parallel pipes, and reverse flow. Modeling of looping systems and equalization basins is possible.

MikeURBAN handles I&I in a variety of ways including constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, and modeling of snow melt. This package models pump stations and forcemains with a fully-integrated RTC module for most hydraulic structures.

Additional features of MikeURBAN offers tools to infer missing data such as invert and slope. MikeURBAN includes support for water quality analysis and sediment transport.

2.3 XP-SWMM

XP-SWMM by XP Software is a rainfall runoff, storm sewer, and sanitary sewer system modeling package based on a standalone platform. XP-SWMM is effective in modeling complex networks including overflow with a 1D/2D engine. The 2D engine is a separate module that has to be purchased separately. The hydraulics and hydrology are sophisticated and fully dynamic (Implicit and explicit solution to St. Venant equation) with full surcharging, flow attenuation and backwater capabilities. XP-SWMM provides complete support for siphons, parallel pipes, and reverse flow. Modeling of looping systems and equalization basins is possible.

XP-SWMM handles I&I in a variety of ways including constant and time-varying inflow, rainfall generator, runoff routing, groundwater infiltration, including the RTK unit hydrograph method. This package models pump stations and forcemains with a fully-integrated RTC module for most hydraulic structures.

XP-SWMM includes support for water quality analysis and sediment transport.

2.4 InfoSWMM

InfoSWMM by Innovyze is a rainfall runoff, storm sewer, and sanitary system modeling package based on the ArcGIS platform. InfoSWMM is effective in modeling complex sewer systems for steady-state and extended period simulation. The hydraulics and hydrology are sophisticated and fully-dynamic (uses an explicit solution to St. Venant equation with variable time step) with full surcharge, surface flow, and backwater capabilities. InfoSWMM includes looped network, equalization basin, reverse flow, and inverted siphon support. InfoSWMM's 2D engine is a separate module that has to be purchased separately.

InfoSWMM handles I&I with many input options including constant and time varying inflow, rainfall generator, groundwater infiltration, and modeling of snowmelt and evaporation of standing surface water. This package models pump stations and forcemains with fully integrated RTC module for most hydraulic structures.

Additional features InfoSWMM offers are sediment transport, water quality analysis, automated network data validation, missing invert, diameter and slope inference tools and elevation extraction from contour or raster data. Dry weather flow allocation, automated calibration and design, conduit storage analysis, and risk assessment are available in the Suite version of the software.

3 Modeling Software Recommendations

InfoWorks ICM, XP-SWMM, InfoSWMM and MikeURBAN are all suitable software with the recommended features for the Master Plans. Based on experience with these models, InfoWorks ICM features a significantly faster and more stable computational engine than XP-SWMM, InfoSWMM or MikeURBAN. Due to the number of simulations required for the Master Plans, a more-efficient computational engine would be greatly beneficial. InfoWorks ICM also allows for multiple simulations to be performed at the same time and the load from the simulations spread throughout a network. Additionally, the flexible-mesh capabilities within InfoWorks allow for overland hydraulic features to be represented both accurately and efficiently. Lastly, InfoWorks ICM has data management tools that will allow data to be tracked and updated as more data are available or changes are made to the system. The input data for both the stormwater and sanitary sewer system can be stored within the same project database, and can be flagged based on the original source data. Using the same software for both Master Plans will lead to efficiencies during this project as well as long-term for the City's use of the models. For these reasons, **HDR recommends the use of InfoWorks ICM for these Master Plan projects**, and additional information on InfoWorks ICM's benefits is included below.

InfoWorks ICM is a top-of-the-line hydraulic modeling platform. Since the City is not planning to purchase modeling software at this time and HDR maintains current licenses of InfoWorks ICM, the cost of the software was not the dominating factor. InfoWorks ICM fits the current modeling needs for the Master Plans and allows for future refinement of the model based on flow

monitoring data and operations/maintenance input. InfoWorks ICM is also used by Midwest utilities (Omaha, etc.) which facilitates expertise exchange and ensures that there will be available consultants to assist the City's with future modeling needs. This package uses ArcGIS-based platform ArcObjects and MapObjects components for data exchange and map display. This will facilitate complete integration of the City's GIS data and provide the way to cross-integrate the City's GIS, model components and simulation results under the same umbrella.

InfoWorks ICM has fully-dynamic hydraulic and hydrologic solutions that will benefit the City's complex systems including support for gravity and forcemain conveyance, I&I allowance, existing and future load allocation, and system calibration, along with a powerful interface and data management system.

I&I allowance can be handled by InfoWorks ICM solver using the RTK or similar methodology. InfoWorks ICM can break Rainfall Derived I&I into three components (initial losses, runoff volume and runoff routing) which can be individually calibrated to produce the best match for a range of rainfall events. Load allocation will be performed through GIS routines for both existing and future flows. The model data can then be validated and calibrated to extended period field data using InfoWorks ICM Validation and Inference tools to modify friction factors, manholes losses and other model parameters. The myriad of pump stations and associated forcemains can be accurately modeled with the gravity sewer system.

In conclusion, InfoWorks ICM by Innovyze provides a fitting platform to model the City's stormwater and sanitary sewer collection systems in developing system improvements and CIP plan. The resulting sewer collection model will be an indispensable tool in understanding the City's system dynamics and areas of interest in regards to existing conditions and future development.

Appendix B – Catchment Delineation Map Book

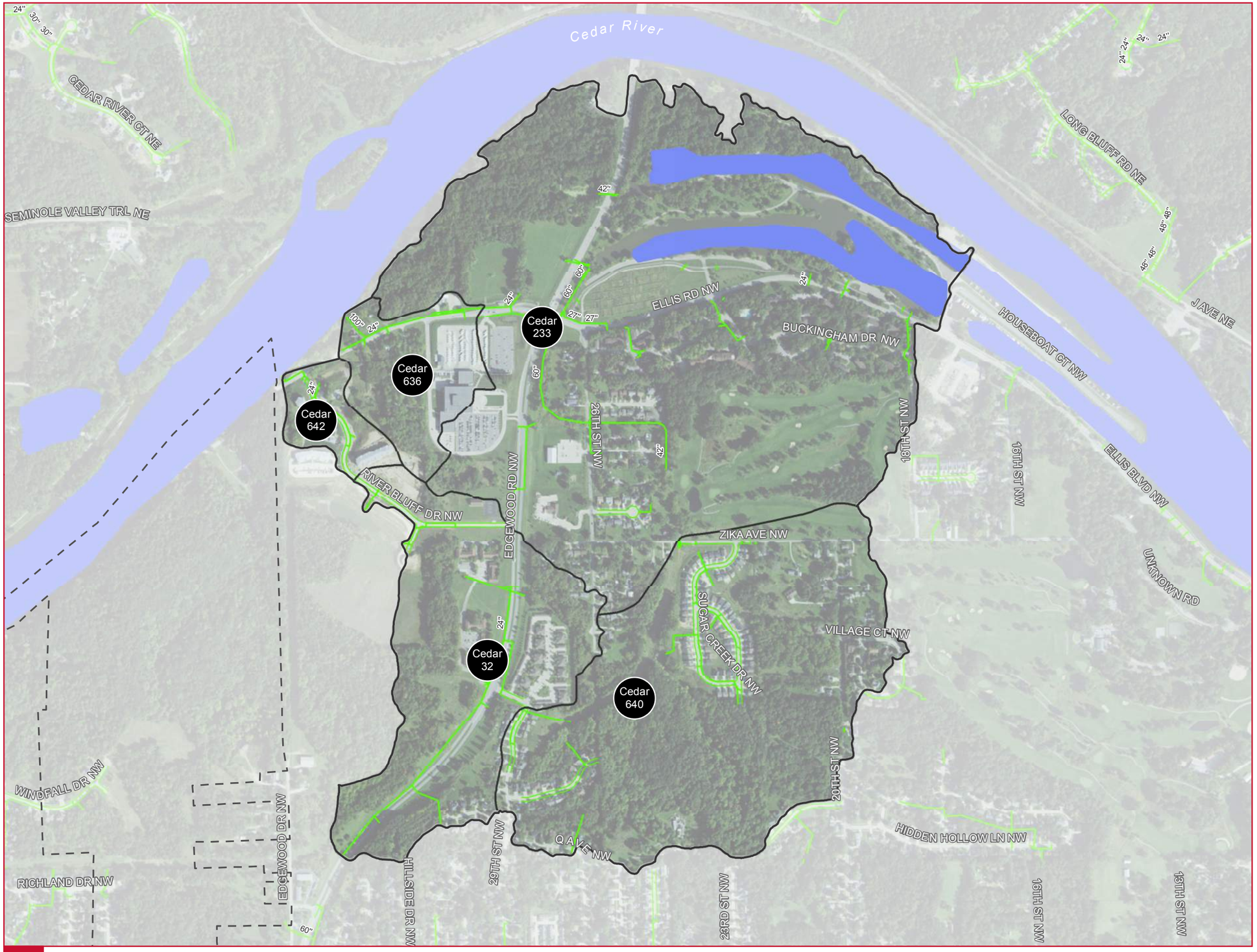


FIGURE 1
NW CEDAR RIVER MODELED CATCHMENTS

City Boundary

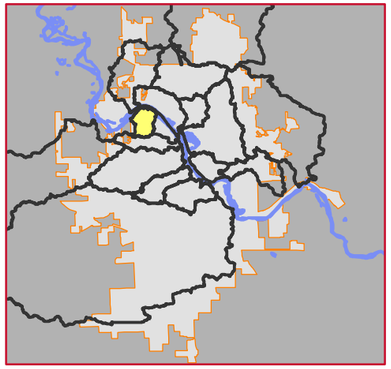
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 800

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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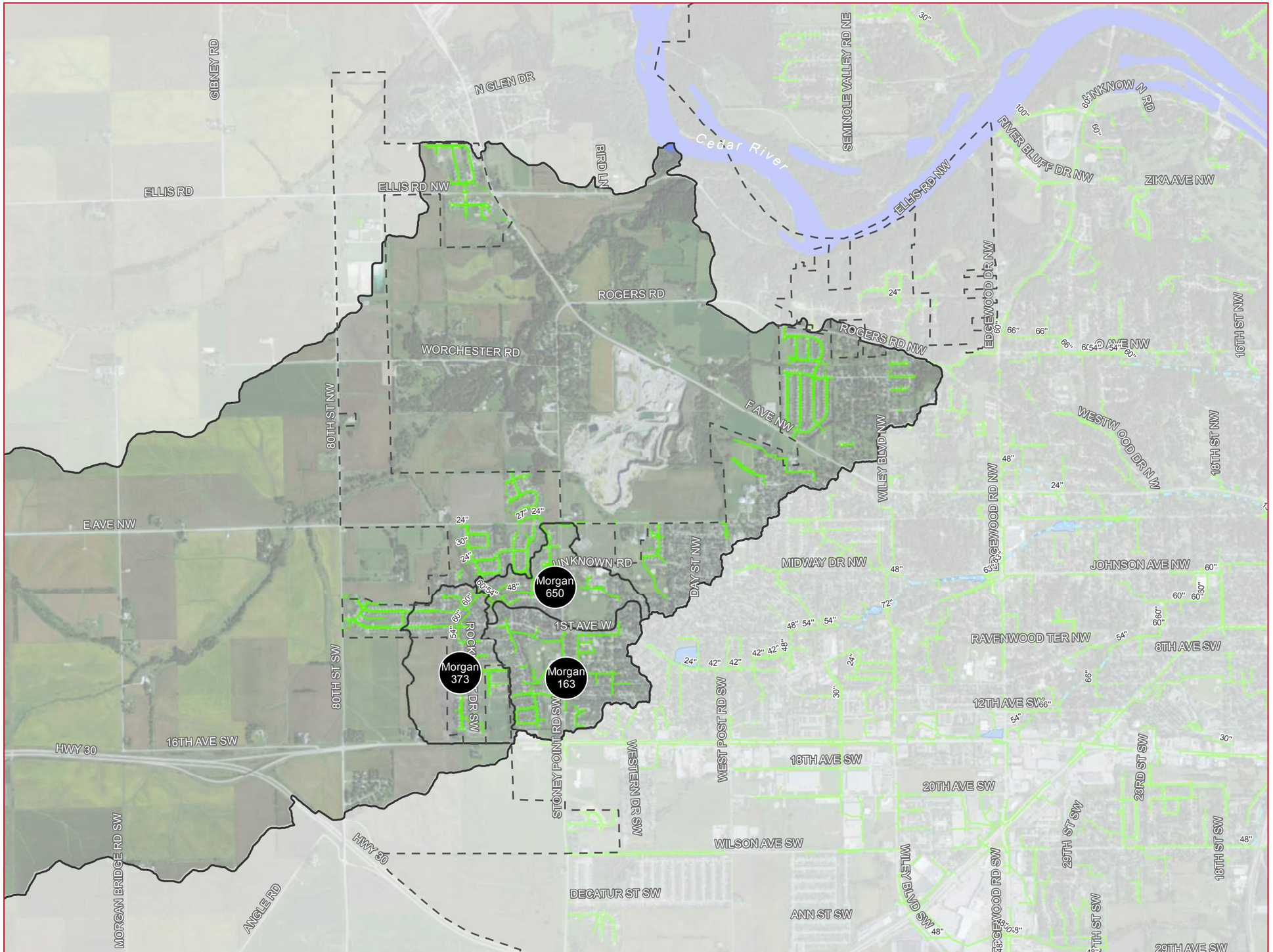
FIGURE 2
MORGAN CREEK
MODELED CATCHMENTS



City Boundary

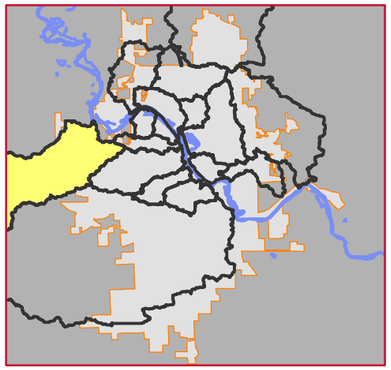
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



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DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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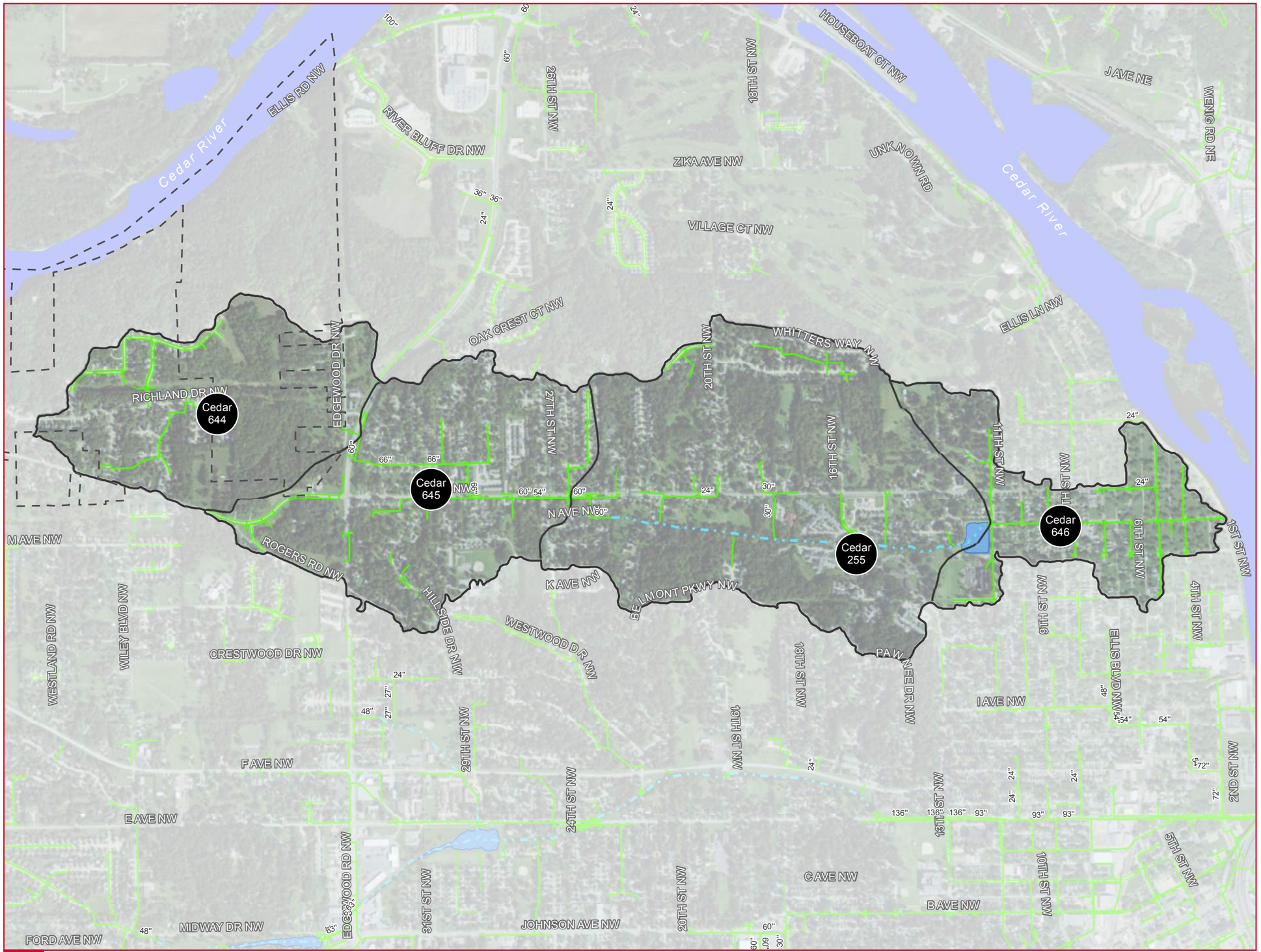
FIGURE 3
O AVENUE
MODELED CATCHMENTS



City Boundary

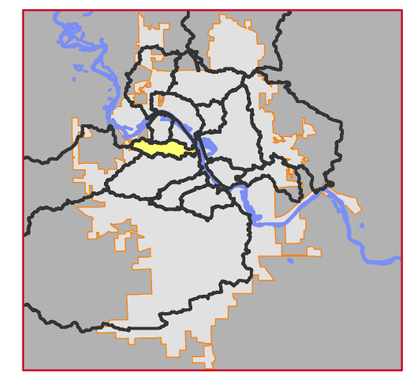
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



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DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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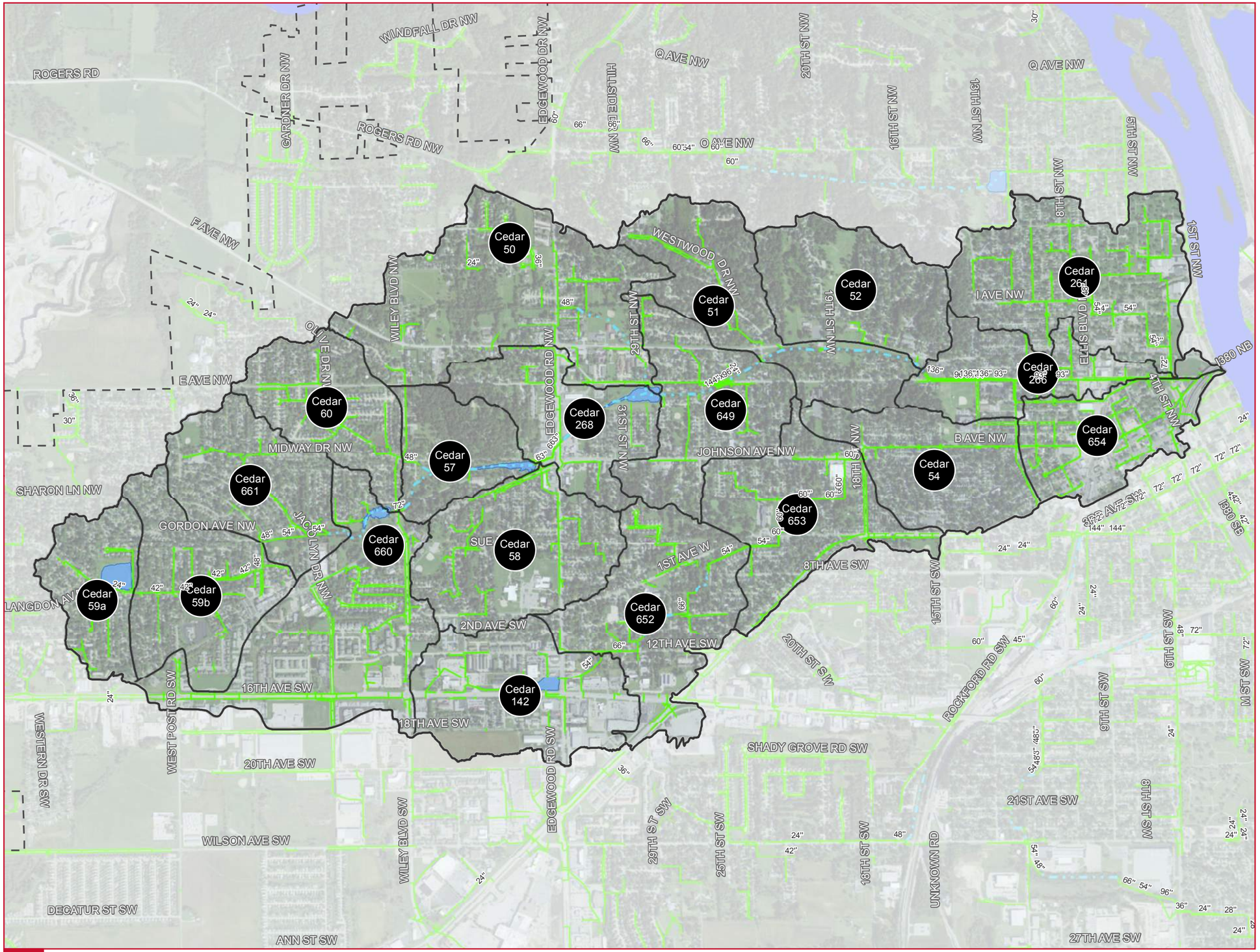


FIGURE 4
E AVENUE
MODELED CATCHMENTS

City Boundary

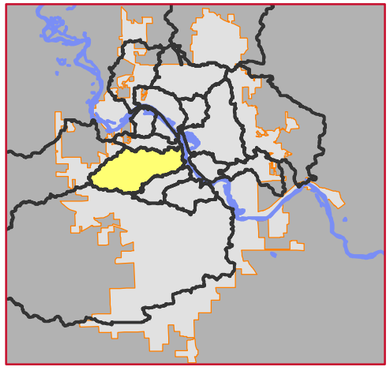
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



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DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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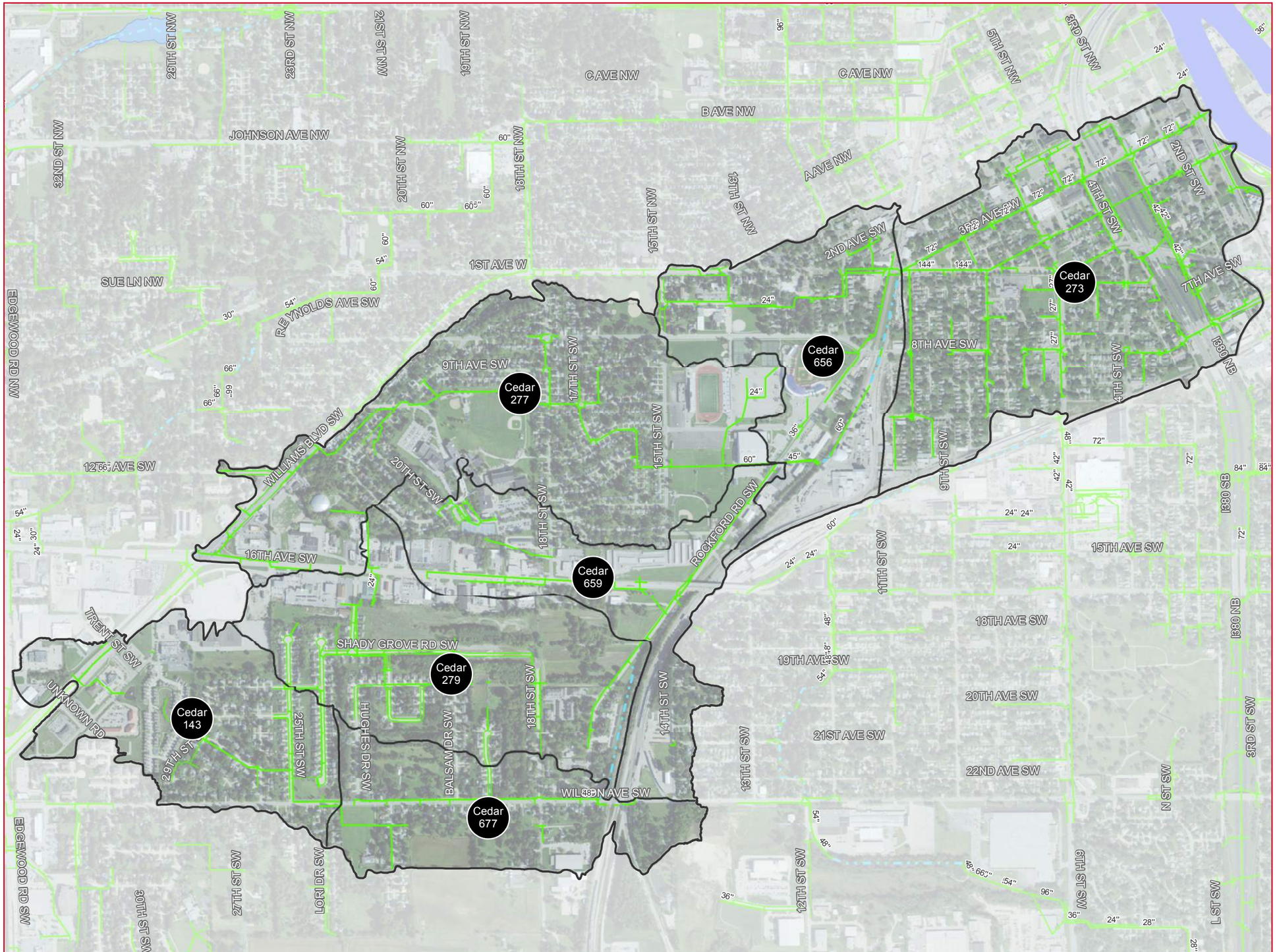
FIGURE 5
4TH AVENUE
MODELED CATCHMENTS



City Boundary

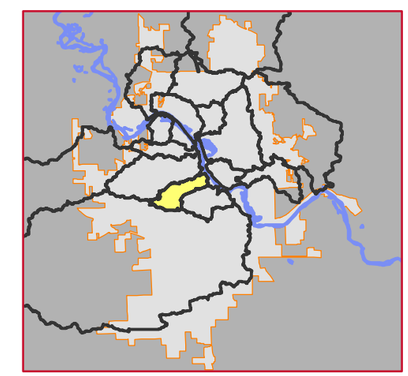
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 1,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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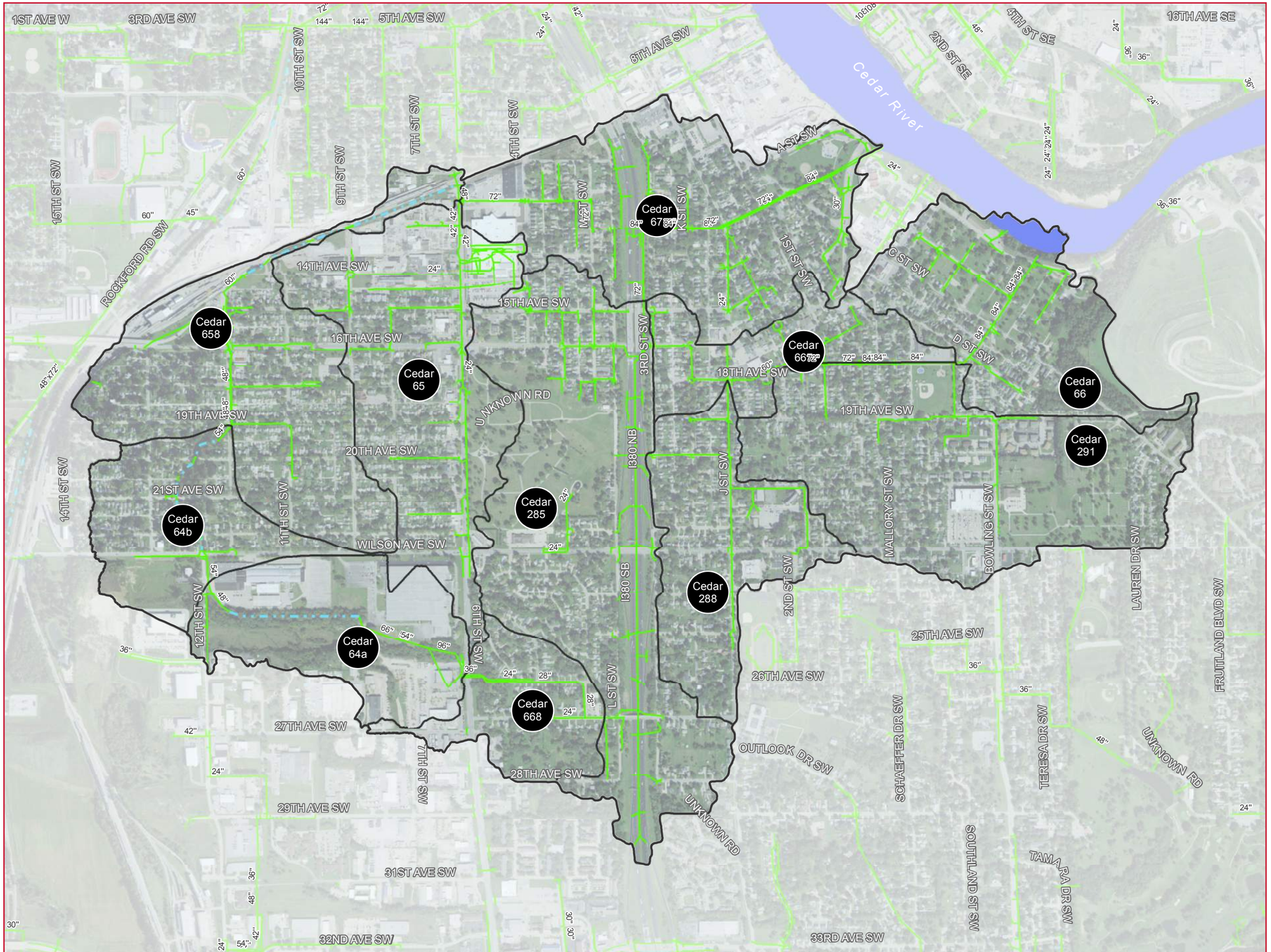
FIGURE 6
CZECH VILLAGE MODELED CATCHMENTS



City Boundary

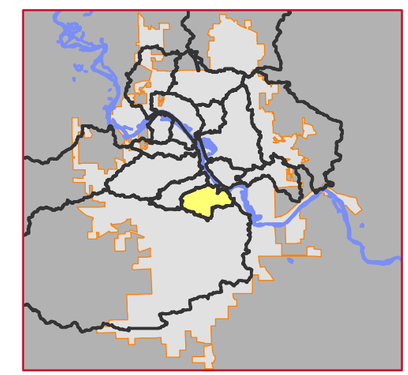
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 1,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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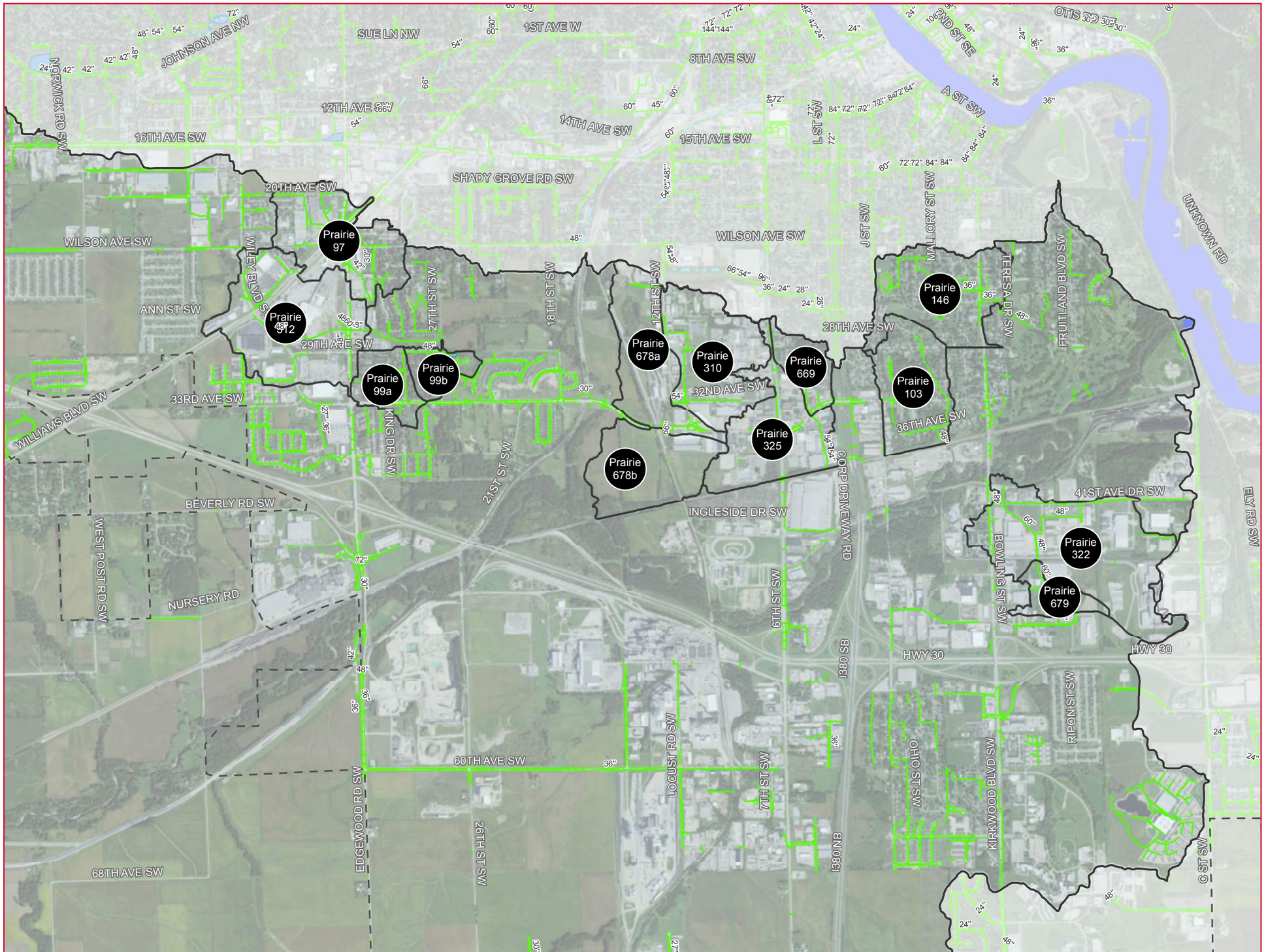
FIGURE 7
PRAIRIE CREEK
MODELED CATCHMENTS



City Boundary

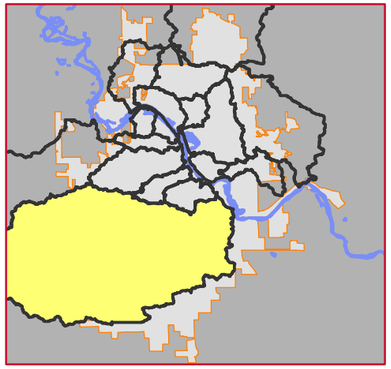
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 2,500

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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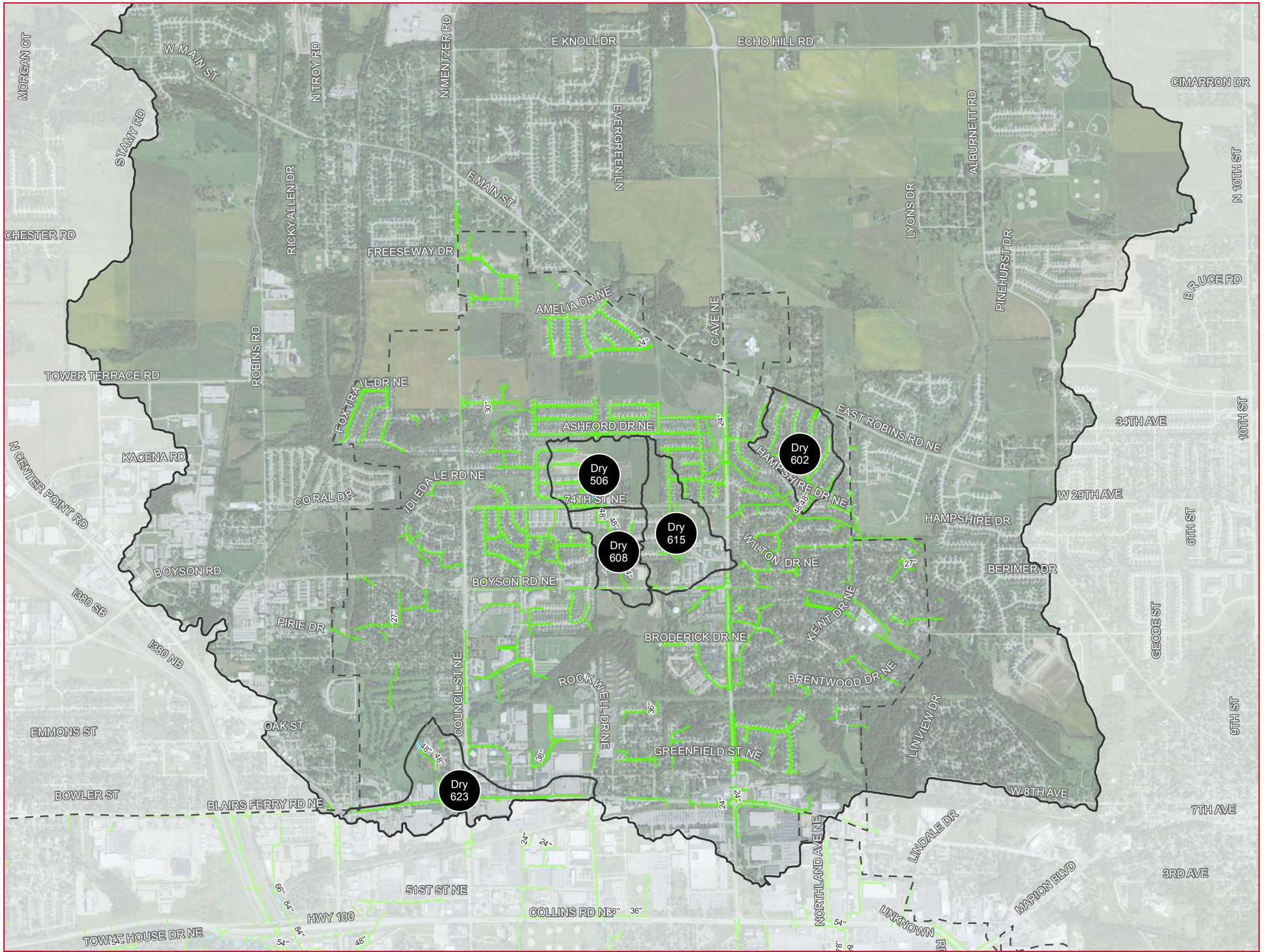
FIGURE 8
DRY CREEK
MODELED CATCHMENTS



City Boundary

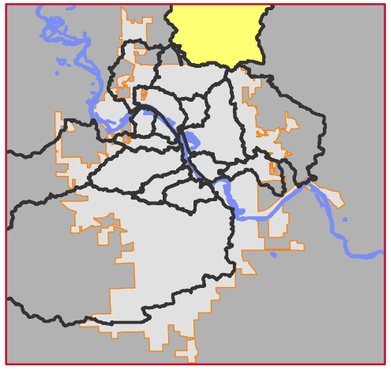
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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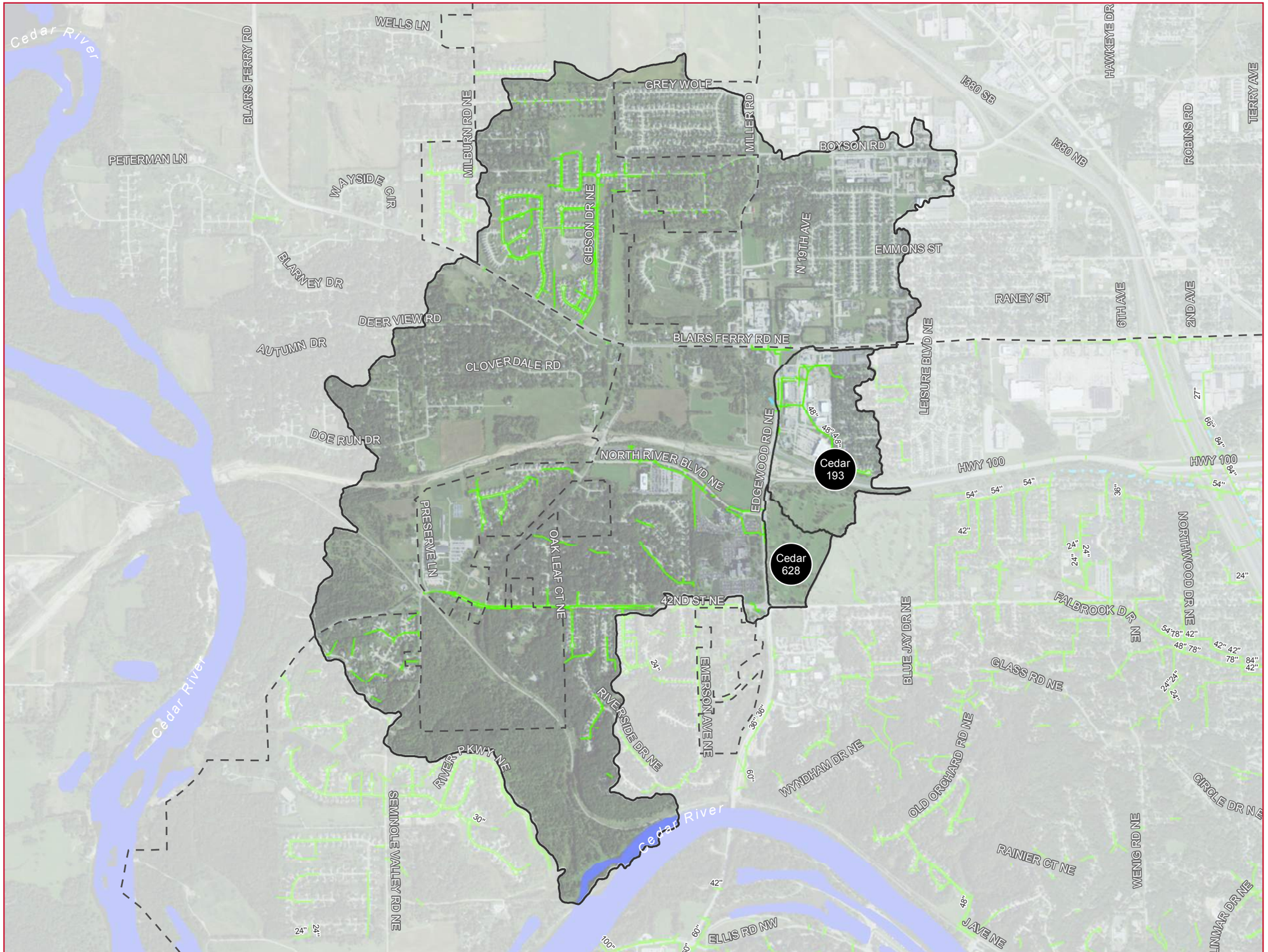
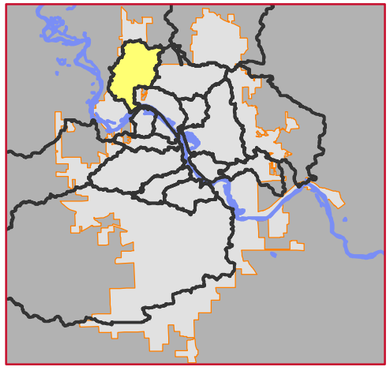
FIGURE 9
USHER FERRY
MODELED CATCHMENTS



- City Boundary
- Modeled Catchment
- Modeled Detention Pond
- Open Channel
- Storm Pipe
- Cedar River



0 Feet 1,800

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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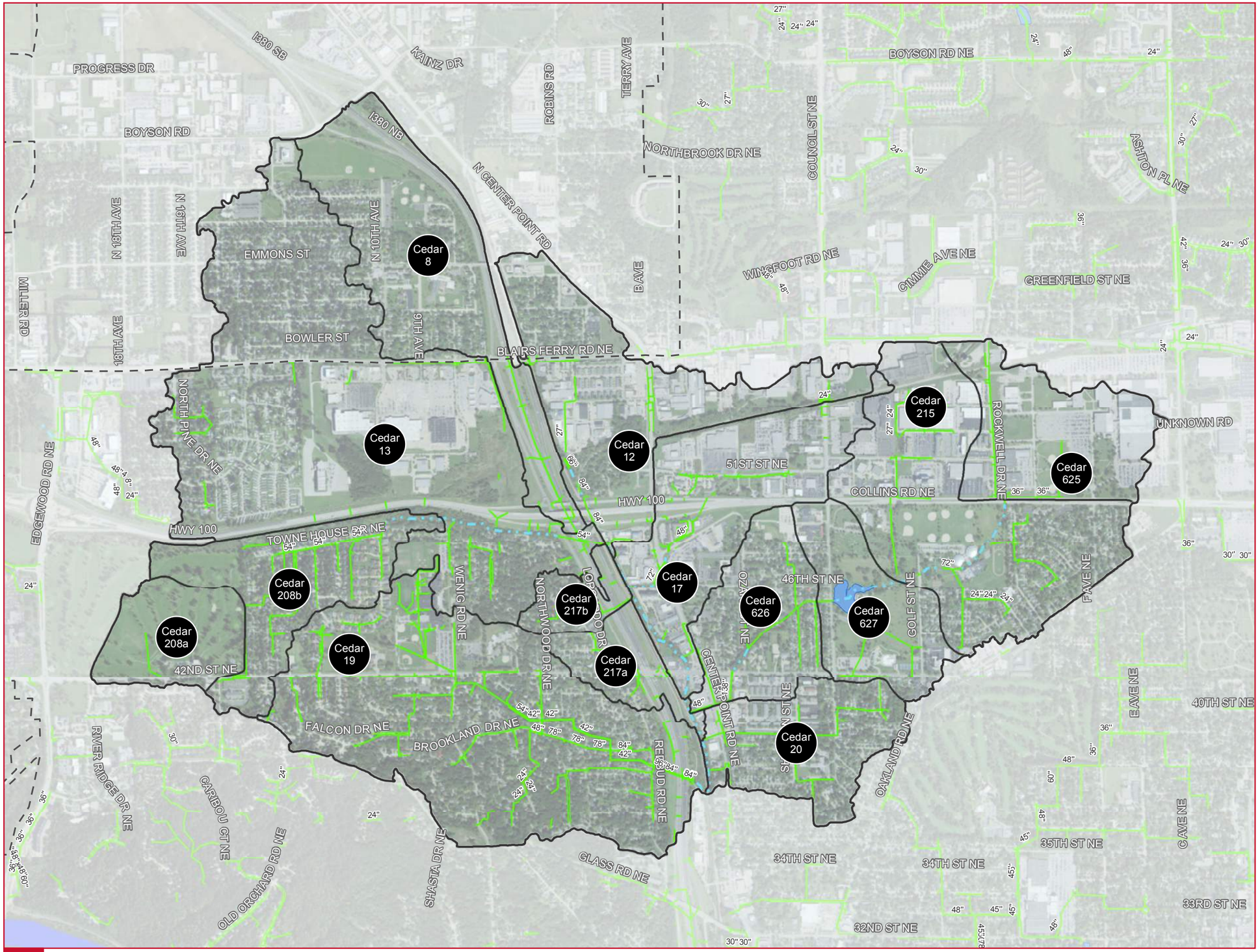
FIGURE 10
MCLOUD RUN
MODELED CATCHMENTS



City Boundary

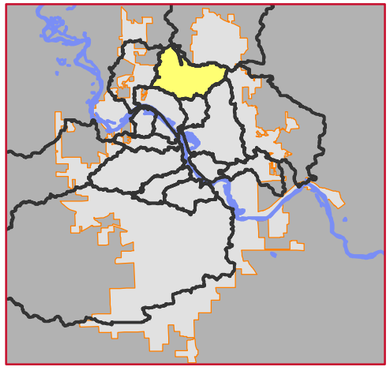
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 1,500

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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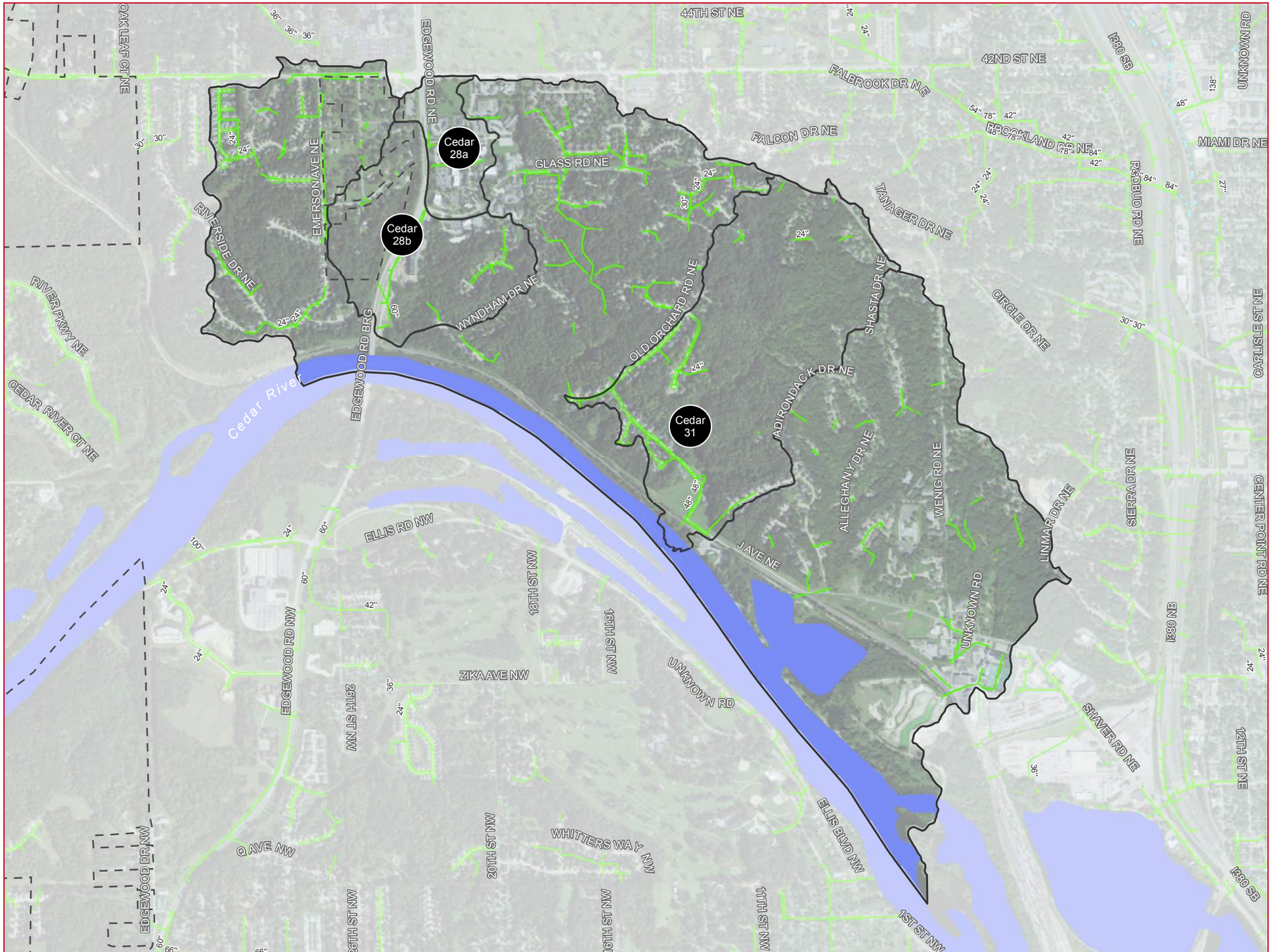
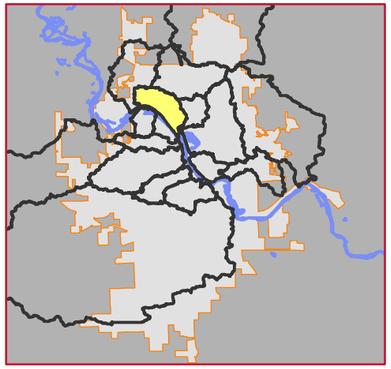
FIGURE 11
NE CEDAR RIVER MODELED CATCHMENTS



- City Boundary
- Modeled Catchment
- Modeled Detention Pond
- Open Channel
- Storm Pipe
- Cedar River



0 Feet 1,300

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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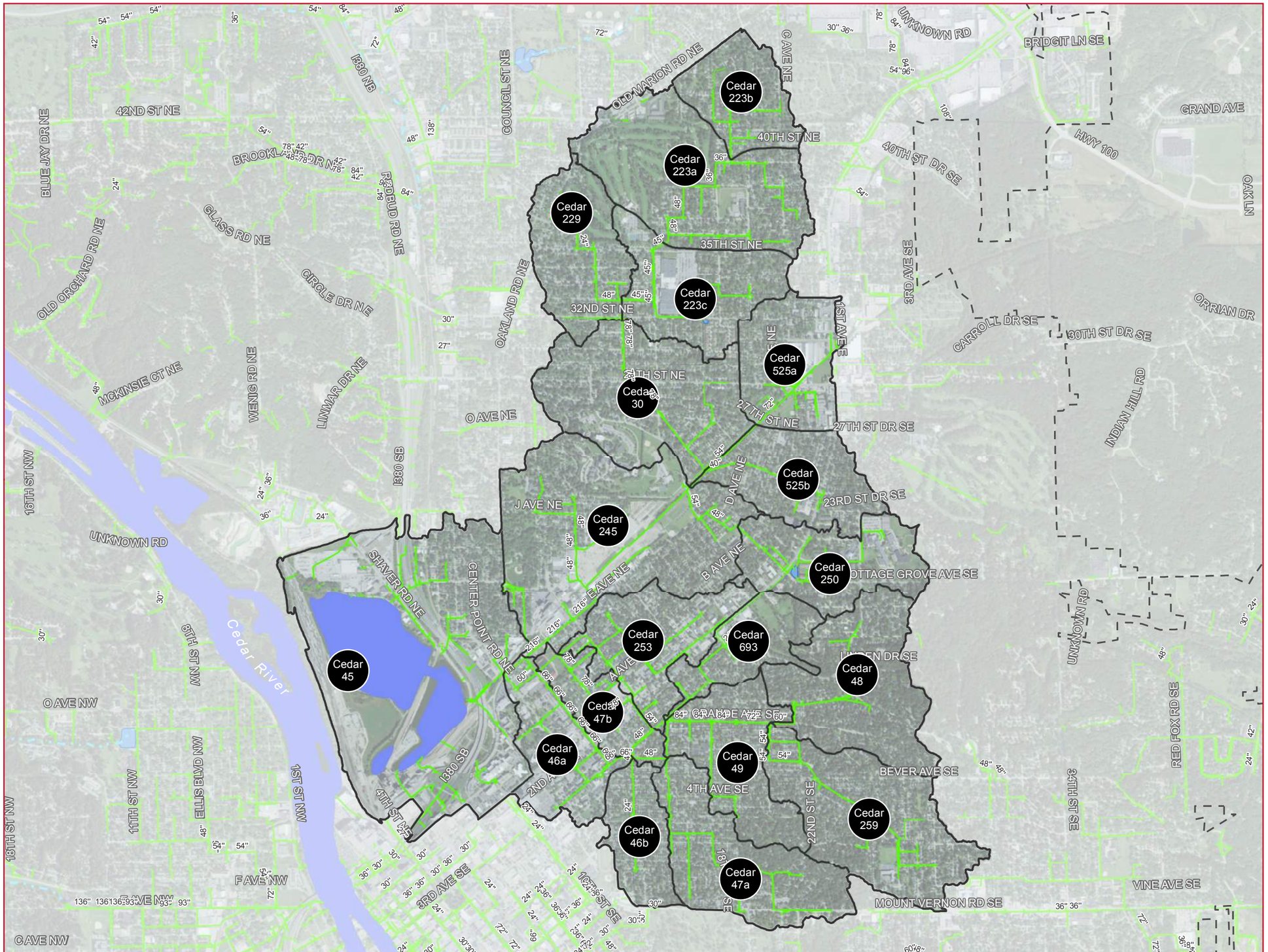


FIGURE 12
KENWOOD
MODELED CATCHMENTS

City Boundary

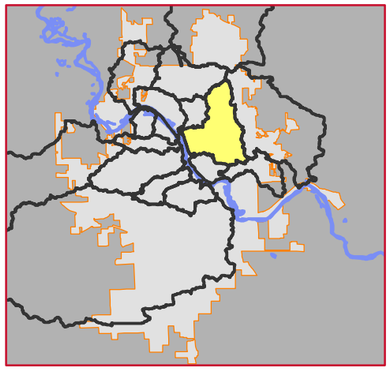
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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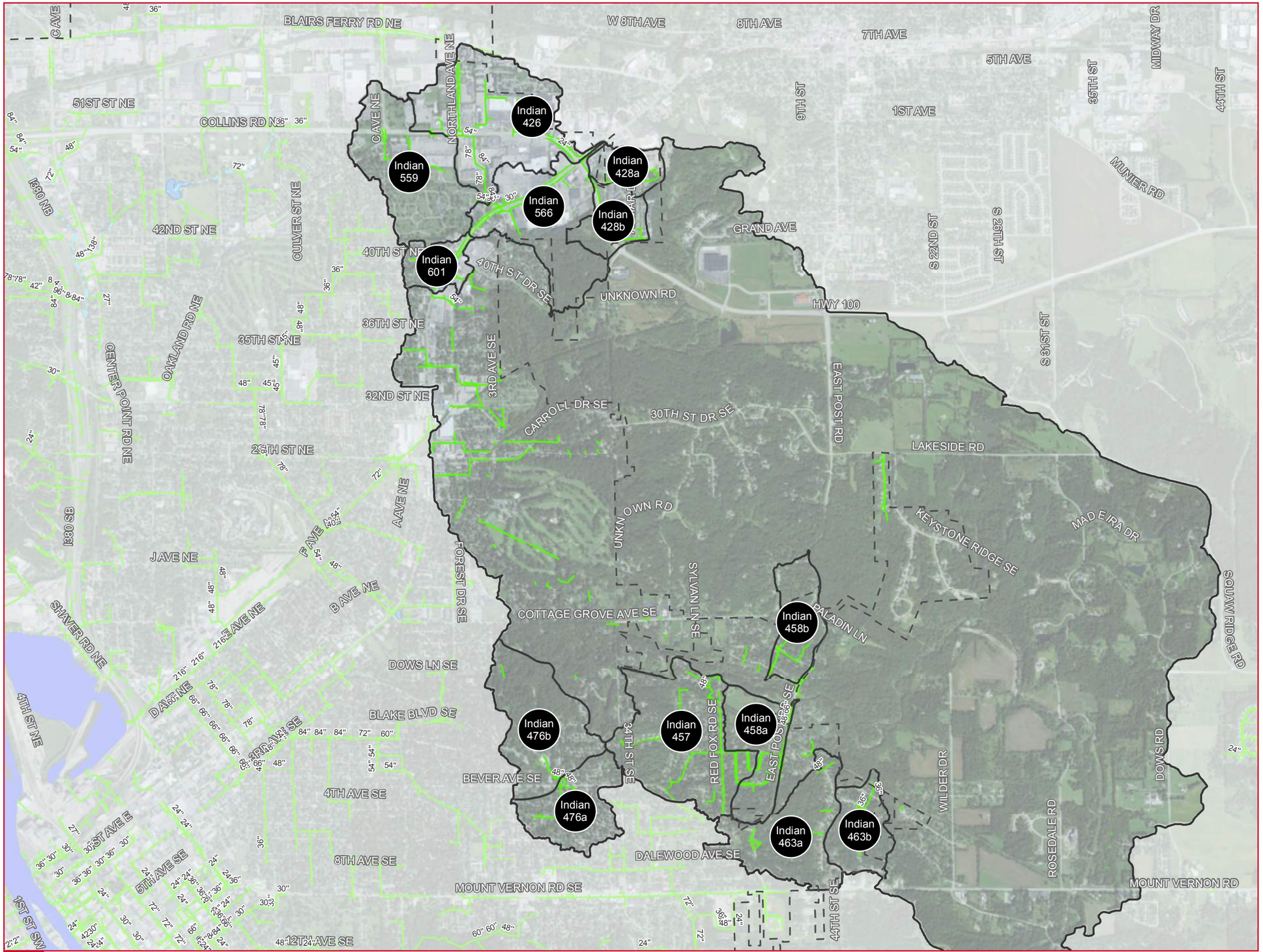
FIGURE 13
INDIAN CREEK MODELED CATCHMENTS



City Boundary

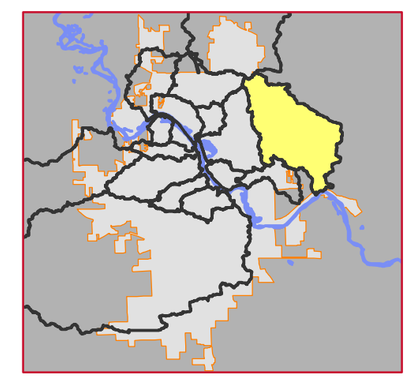
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 2,400

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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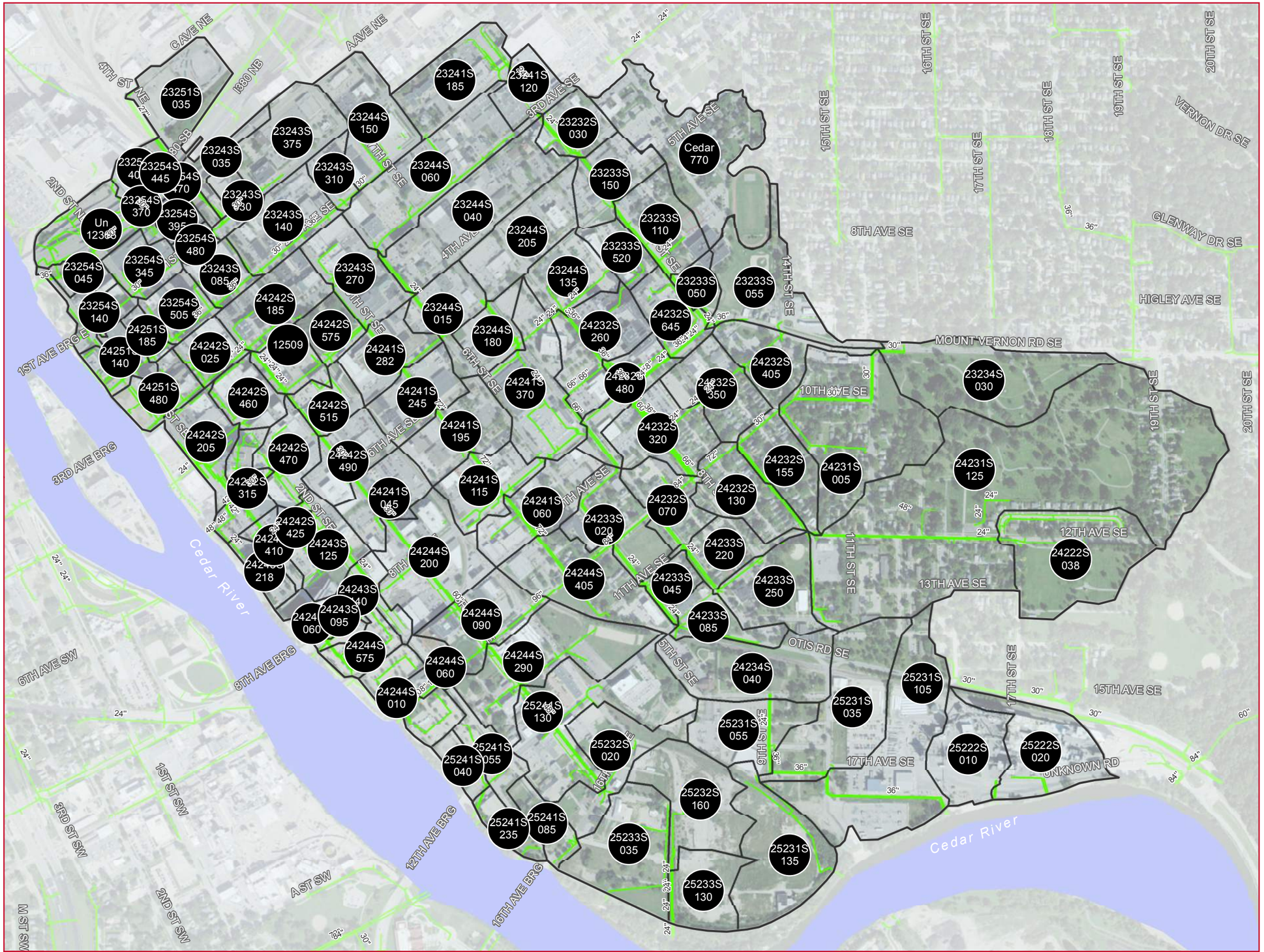


FIGURE 14
DOWNTOWN
MODELED CATCHMENTS

City Boundary

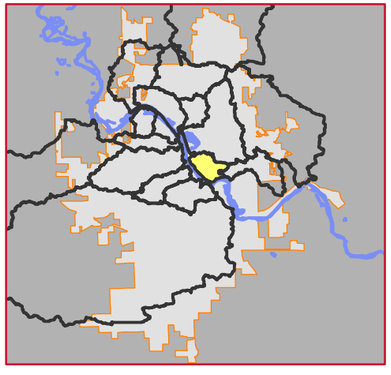
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 700

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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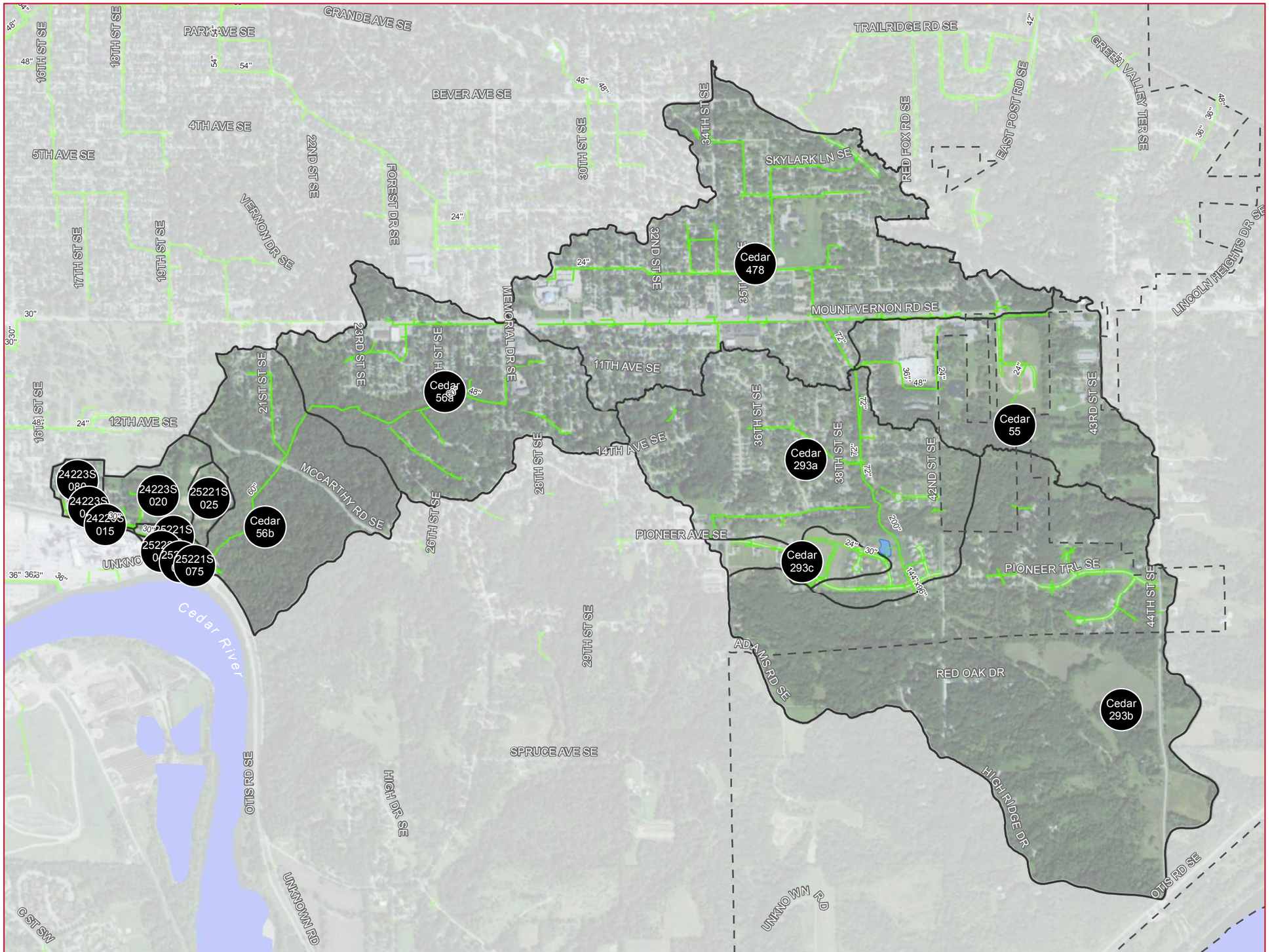
FIGURE 15
SE CEDAR RIVER MODELED CATCHMENTS



City Boundary

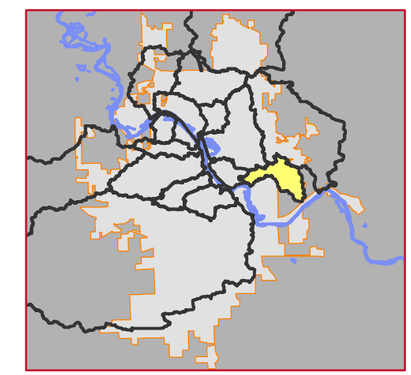
Modeled Catchment

Modeled Detention Pond

Open Channel

Storm Pipe

Cedar River



0 Feet 1,200

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Appendix C – 5-Year Rainfall Model Results Map Book

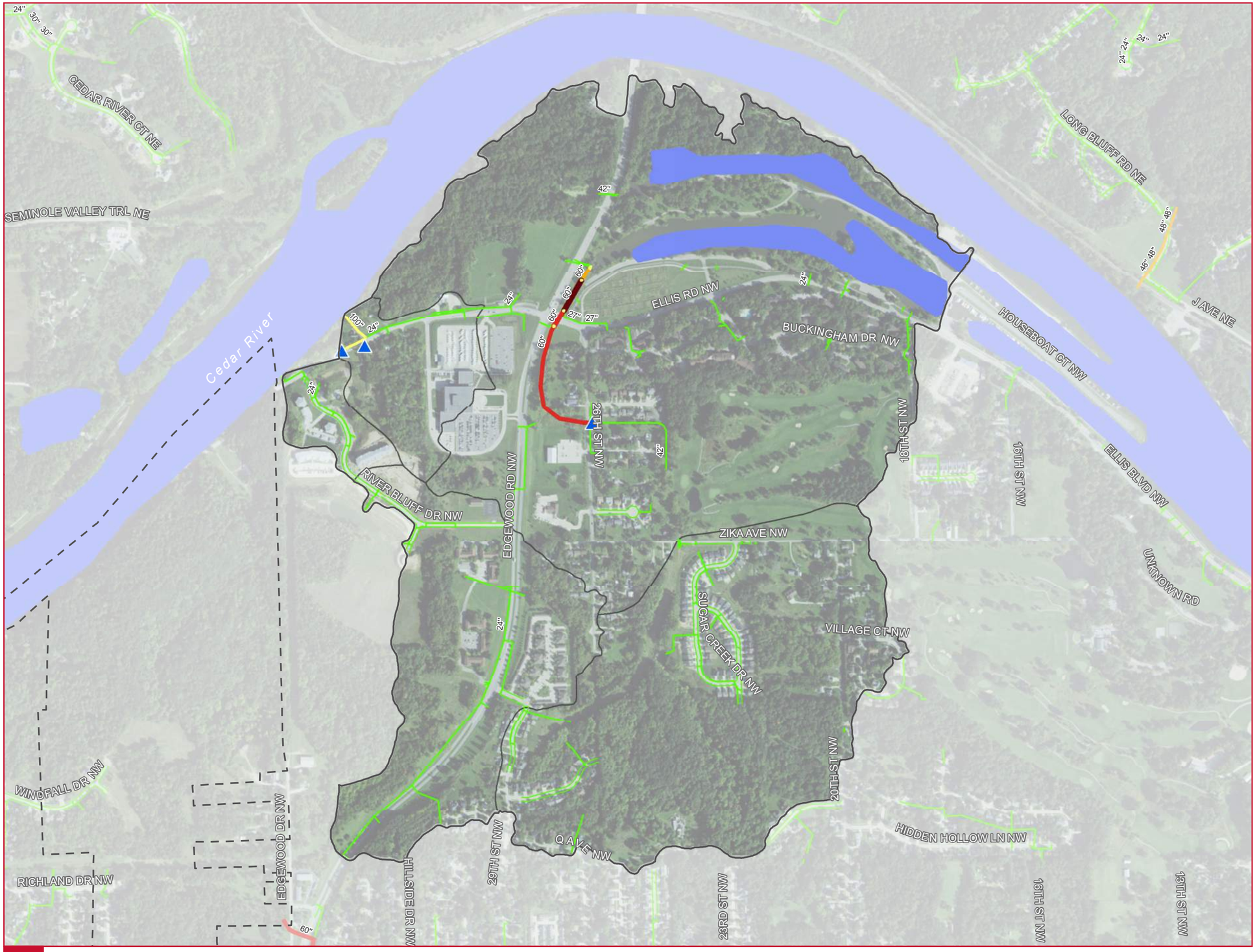


FIGURE 1
NW CEDAR RIVER
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

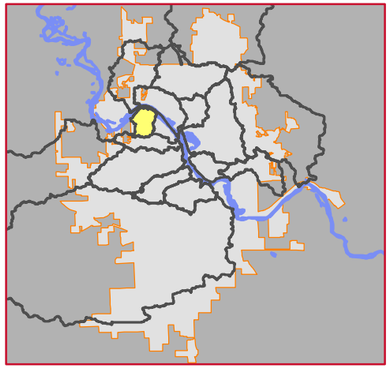
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



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DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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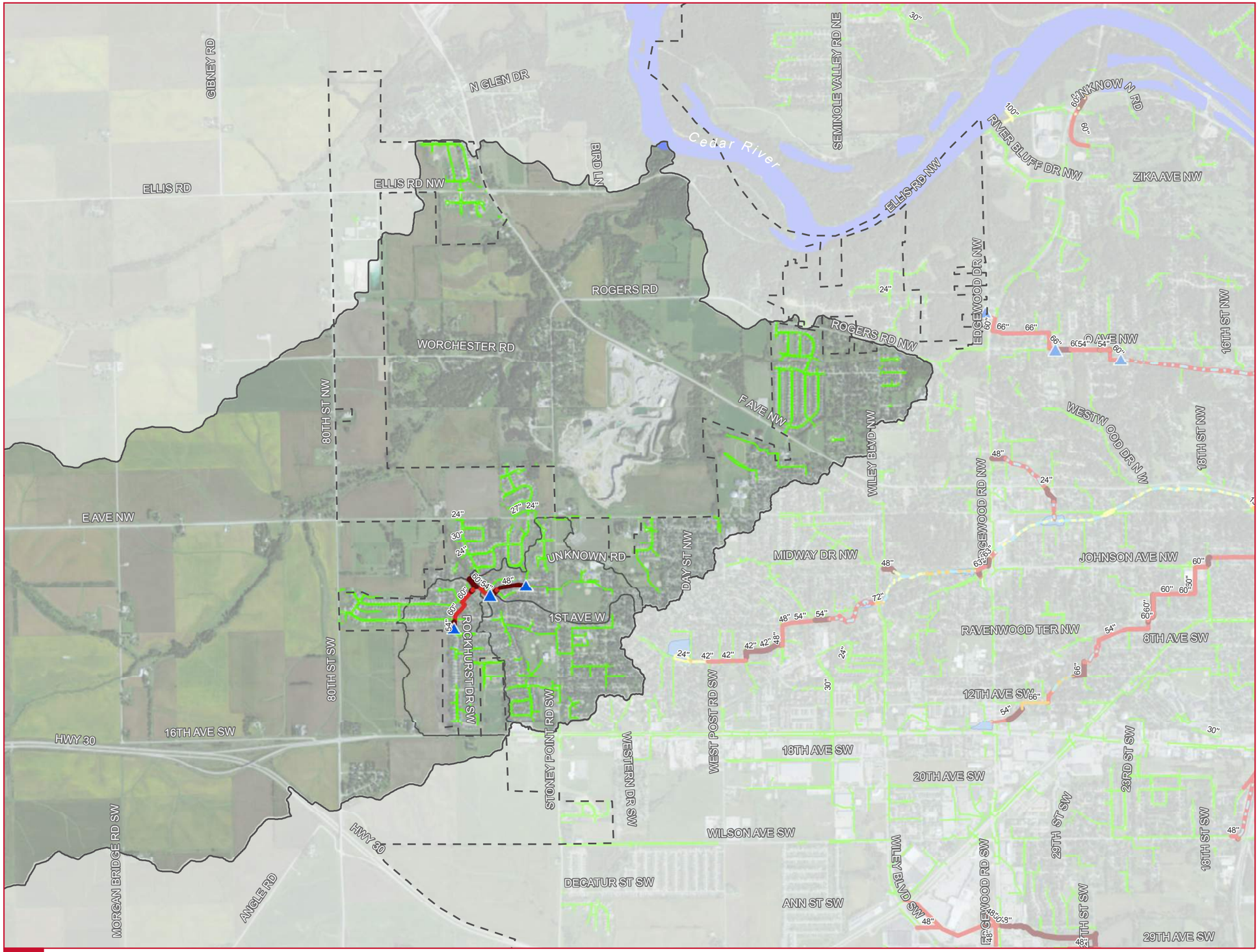


FIGURE 2
MORGAN CREEK
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

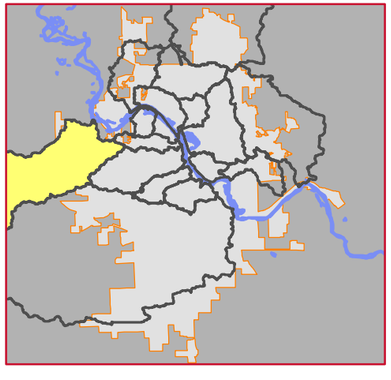
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,400

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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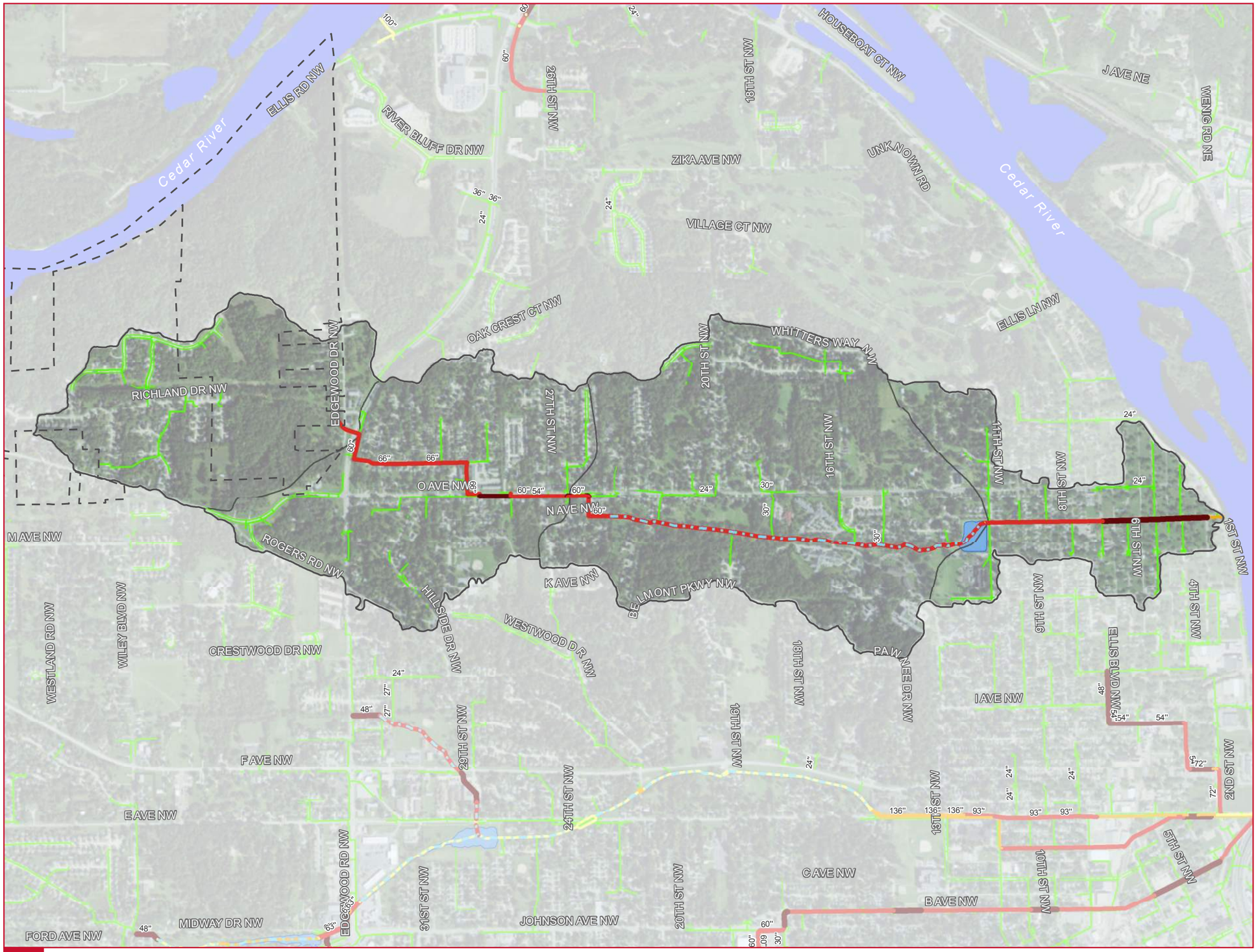
FIGURE 3
O AVENUE
MODEL RESULTS, 5-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

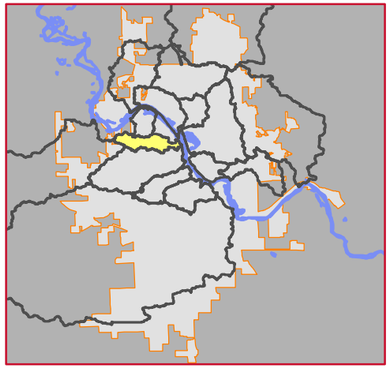
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



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DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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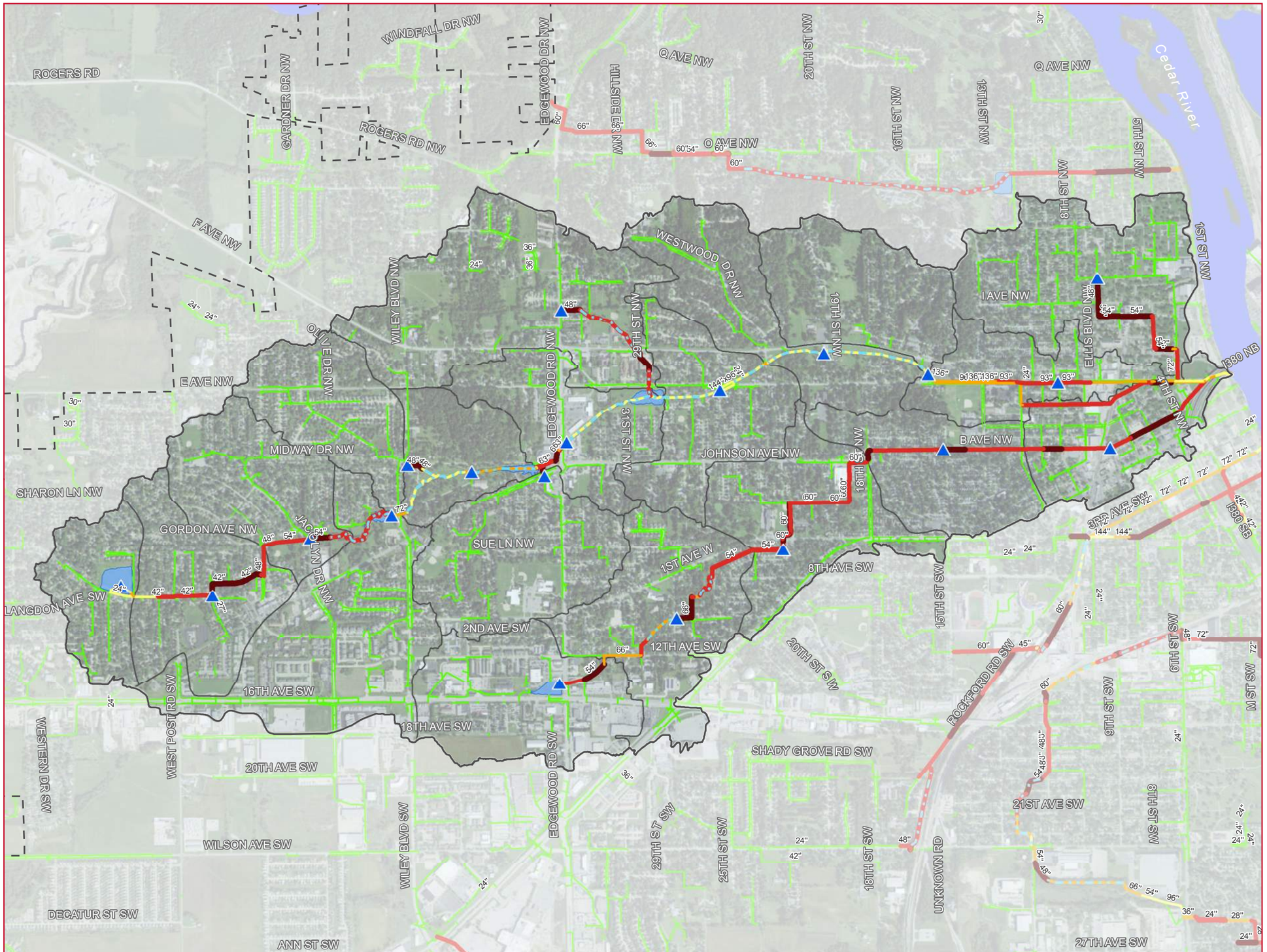
FIGURE 4
E AVENUE
MODEL RESULTS, 5-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

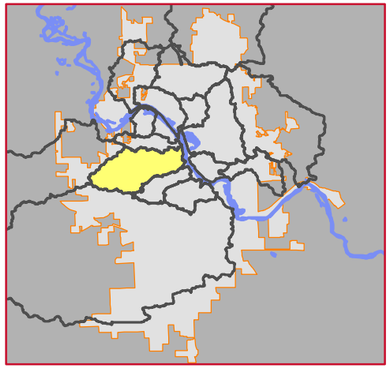
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



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DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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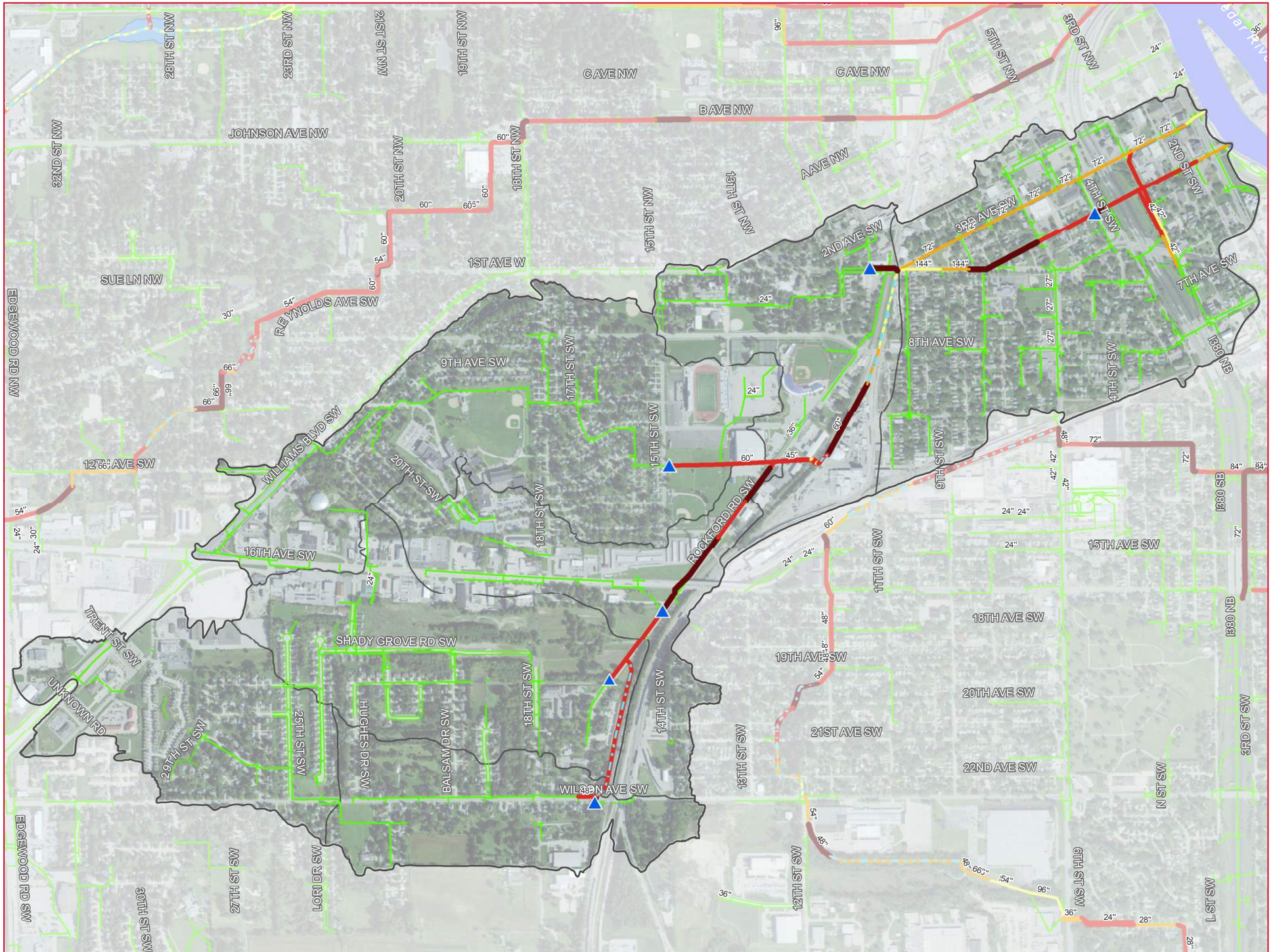


FIGURE 5
4TH AVENUE
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

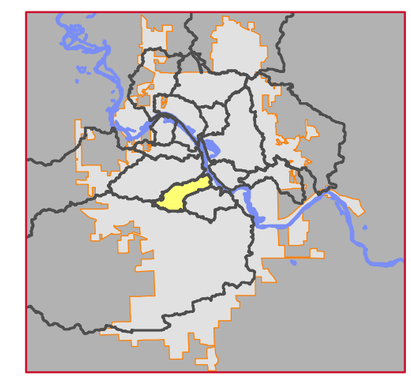
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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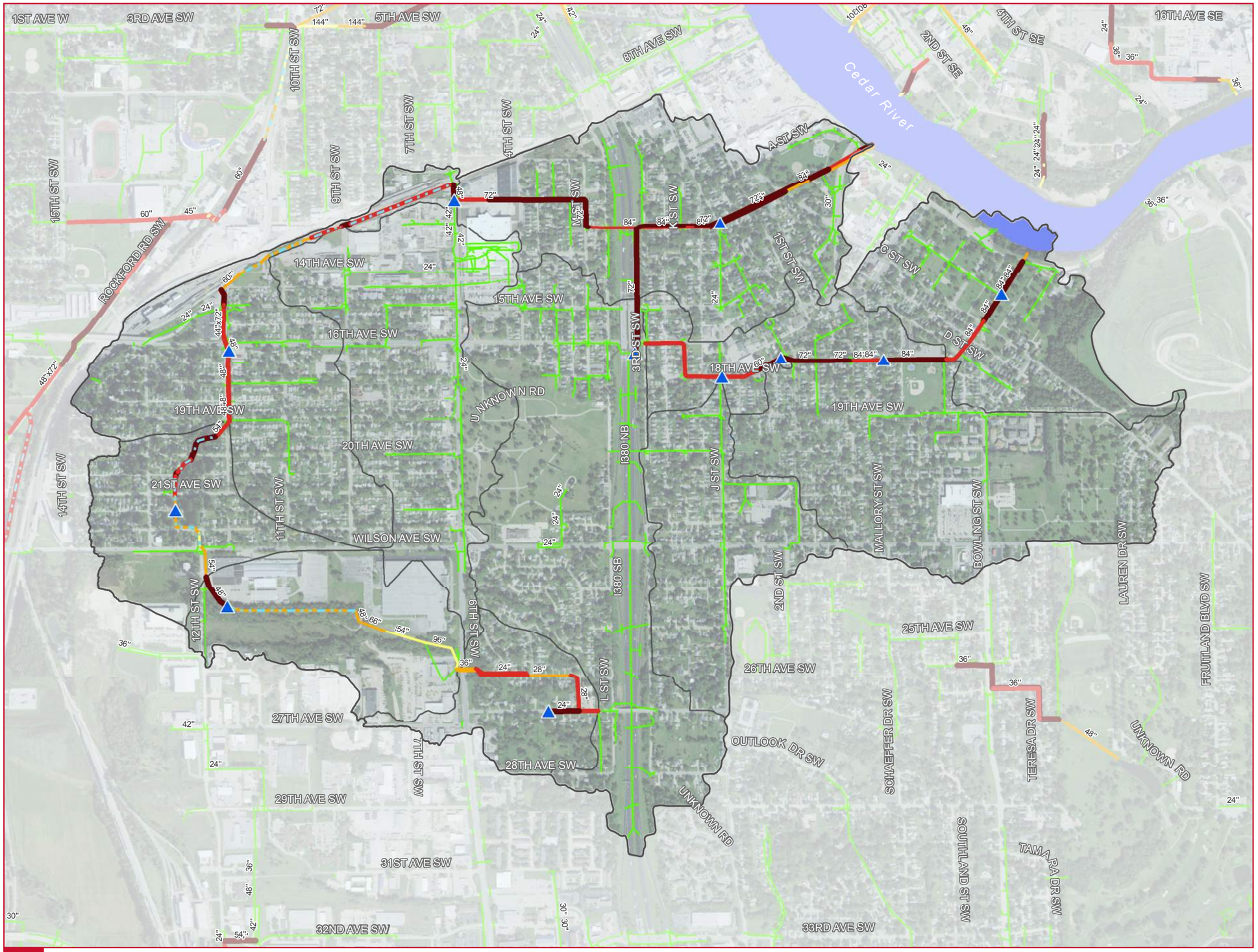


FIGURE 6
CZECH VILLAGE
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

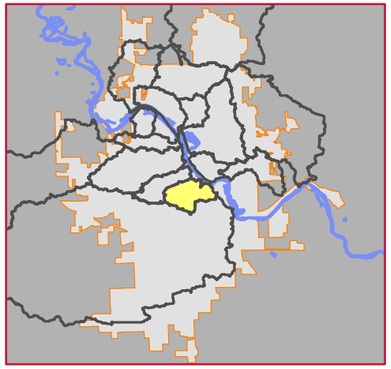
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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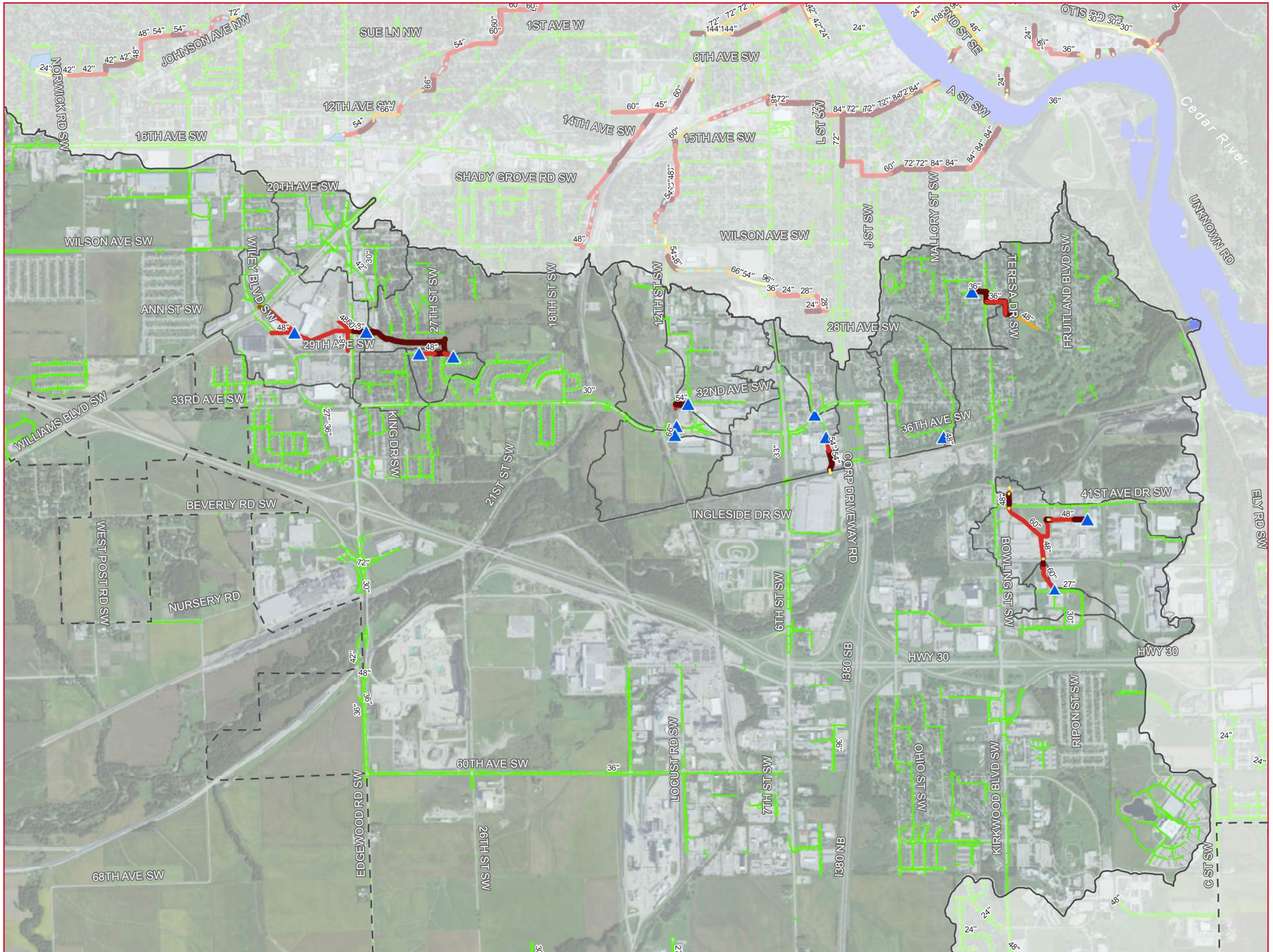
FIGURE 7
PRAIRIE CREEK
MODEL RESULTS, 5-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

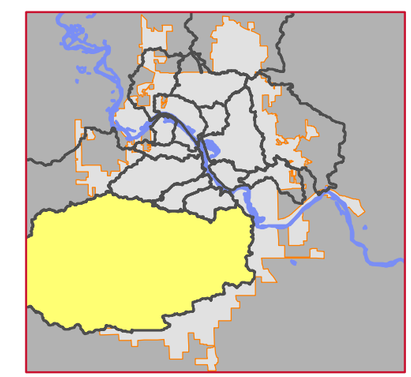
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,500

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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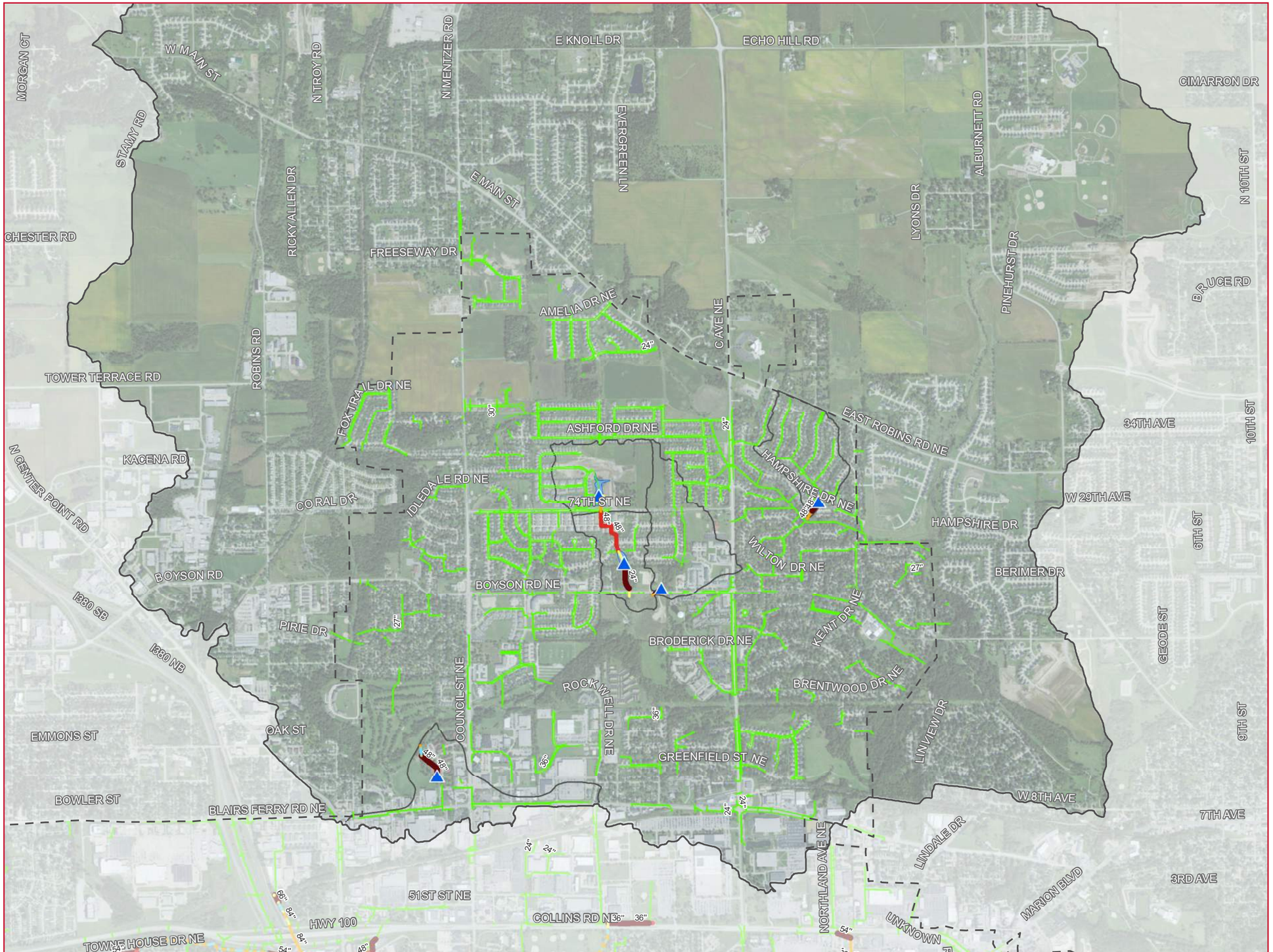


FIGURE 8
DRY CREEK
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

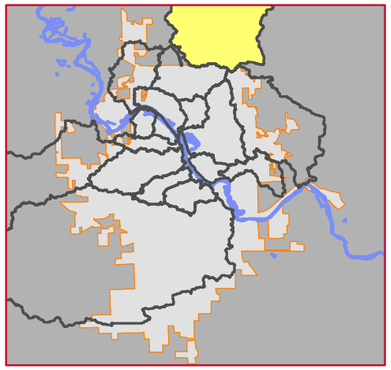
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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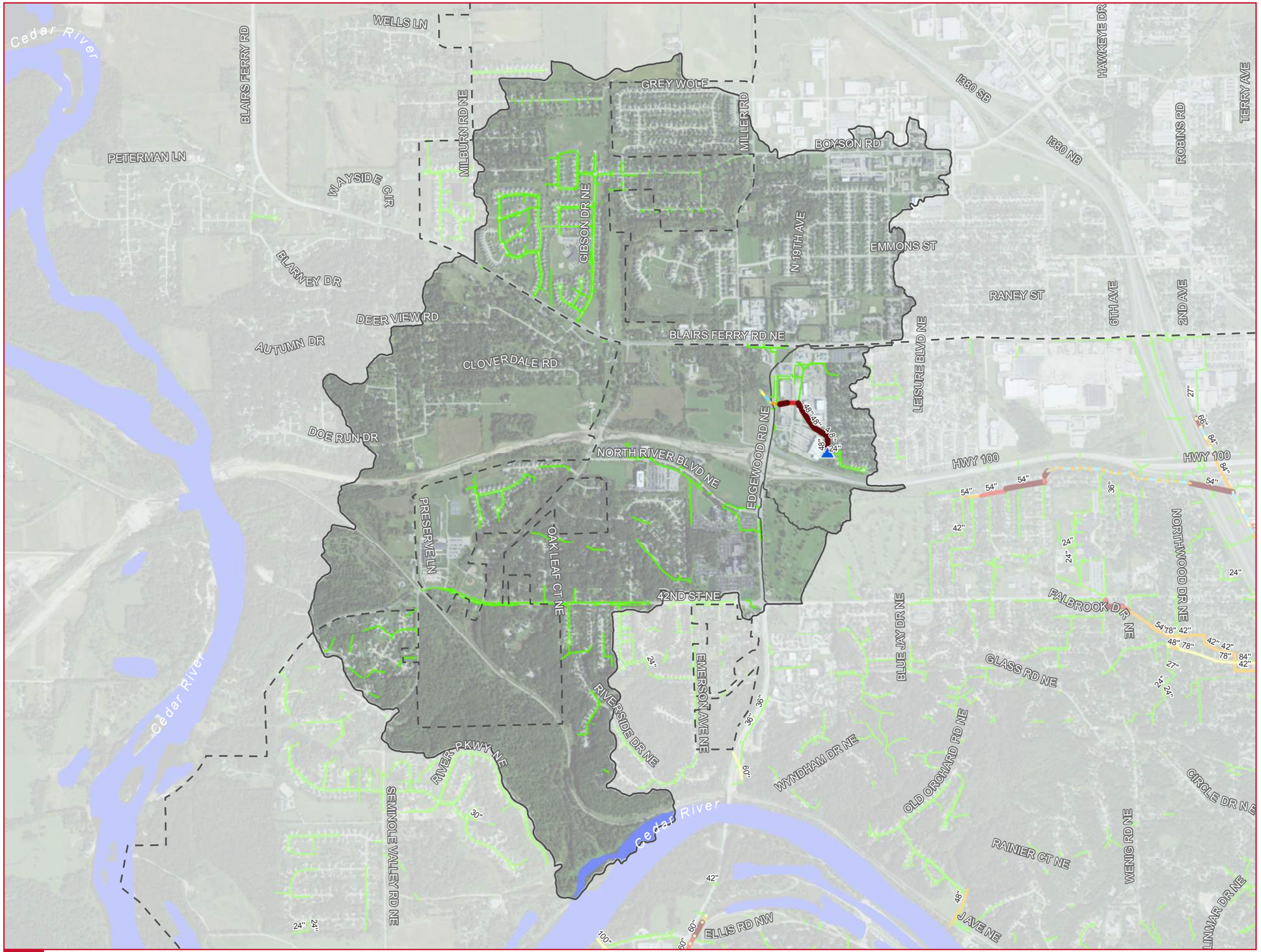


FIGURE 9
USHER FERRY
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

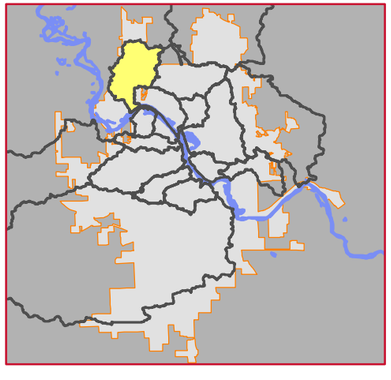
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,800

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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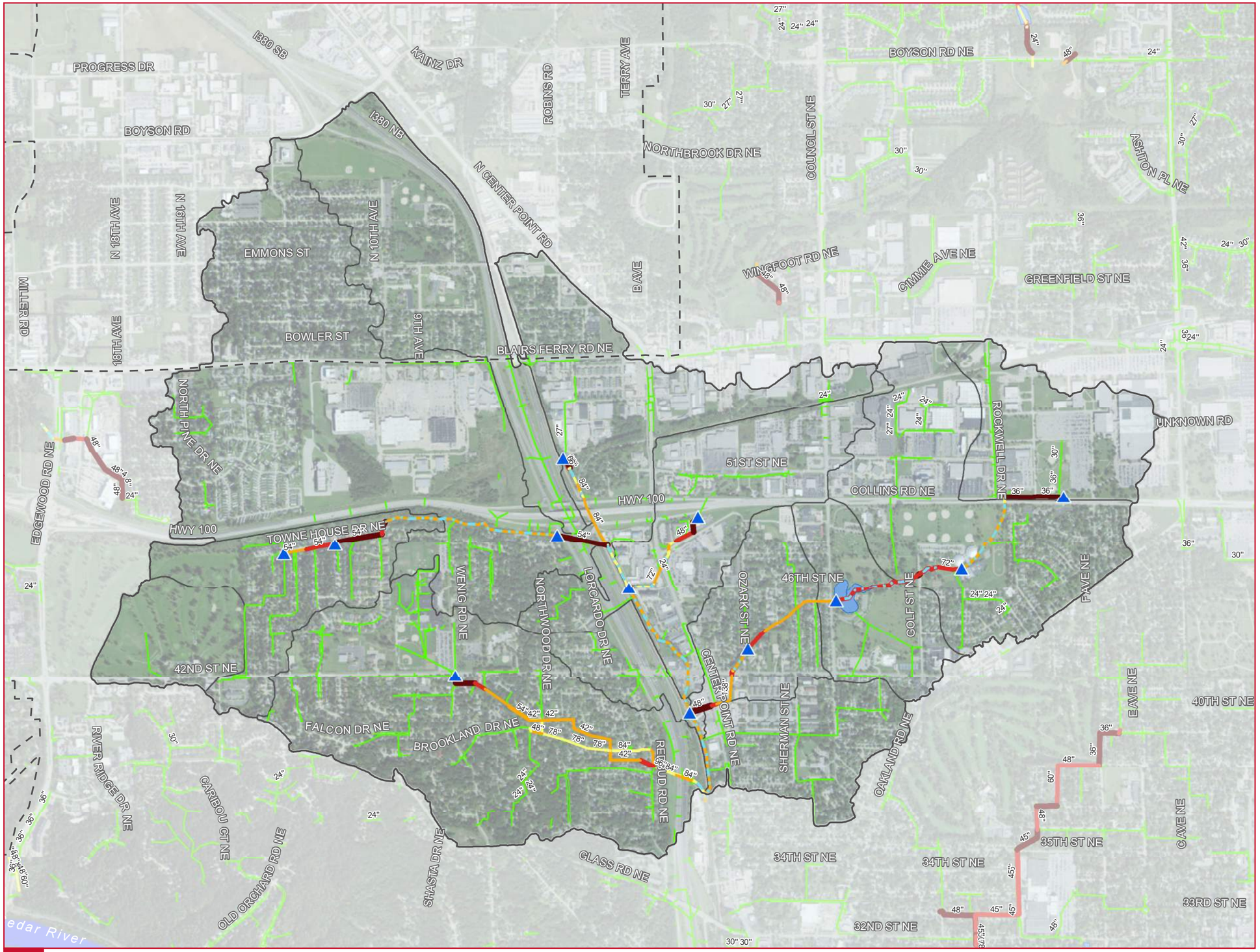
FIGURE 10
MCLOUD RUN
MODEL RESULTS, 5-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

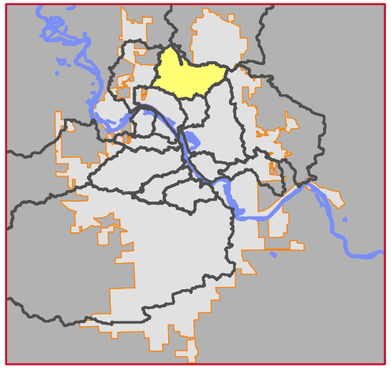
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,500

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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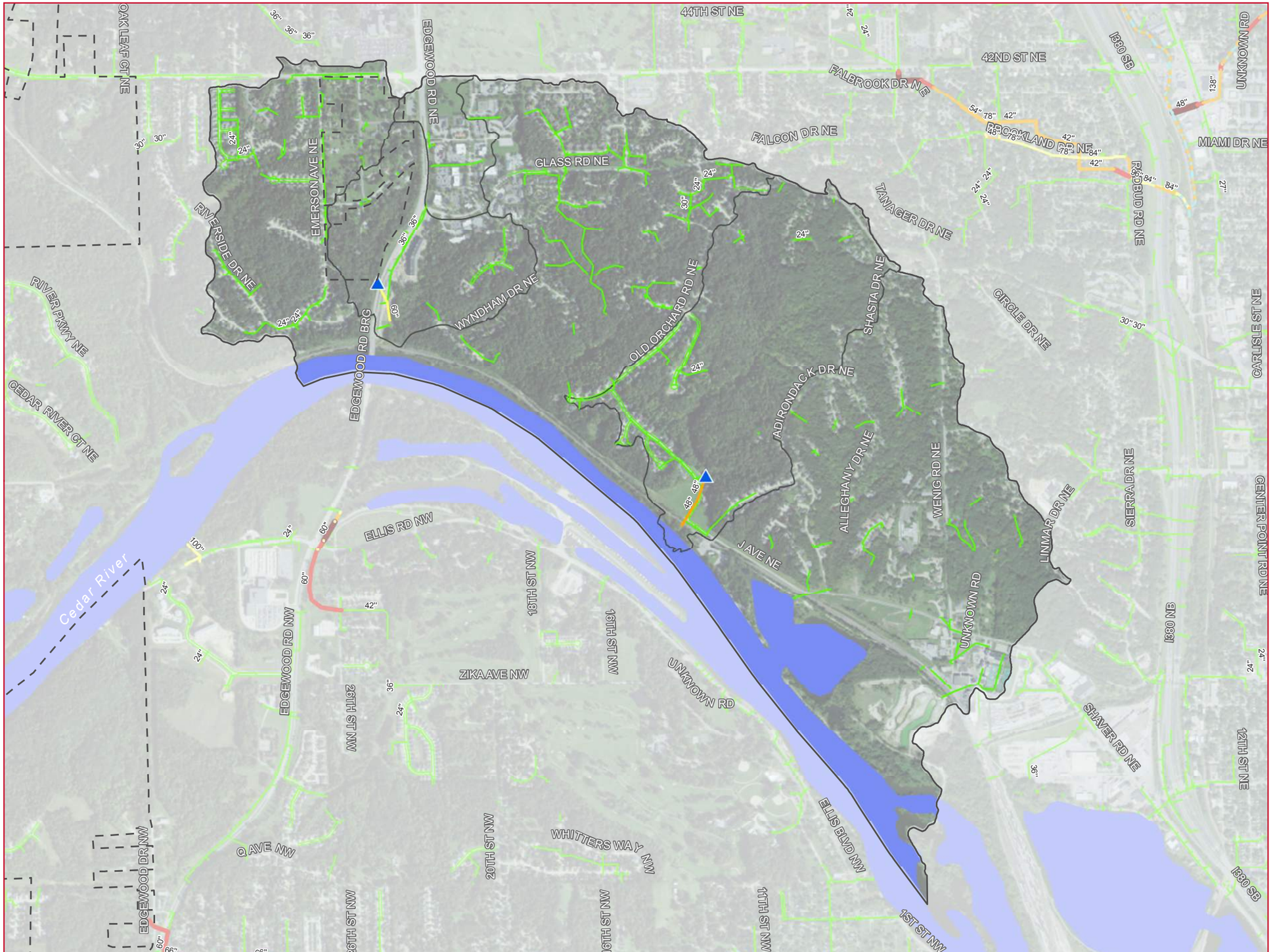


FIGURE 11
NE CEDAR RIVER
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

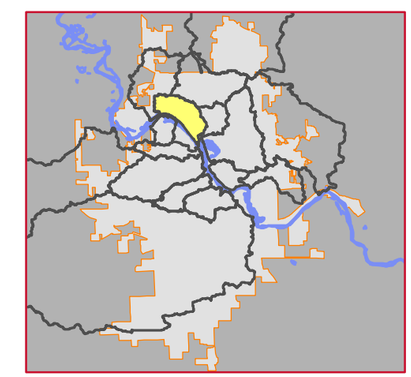
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,300

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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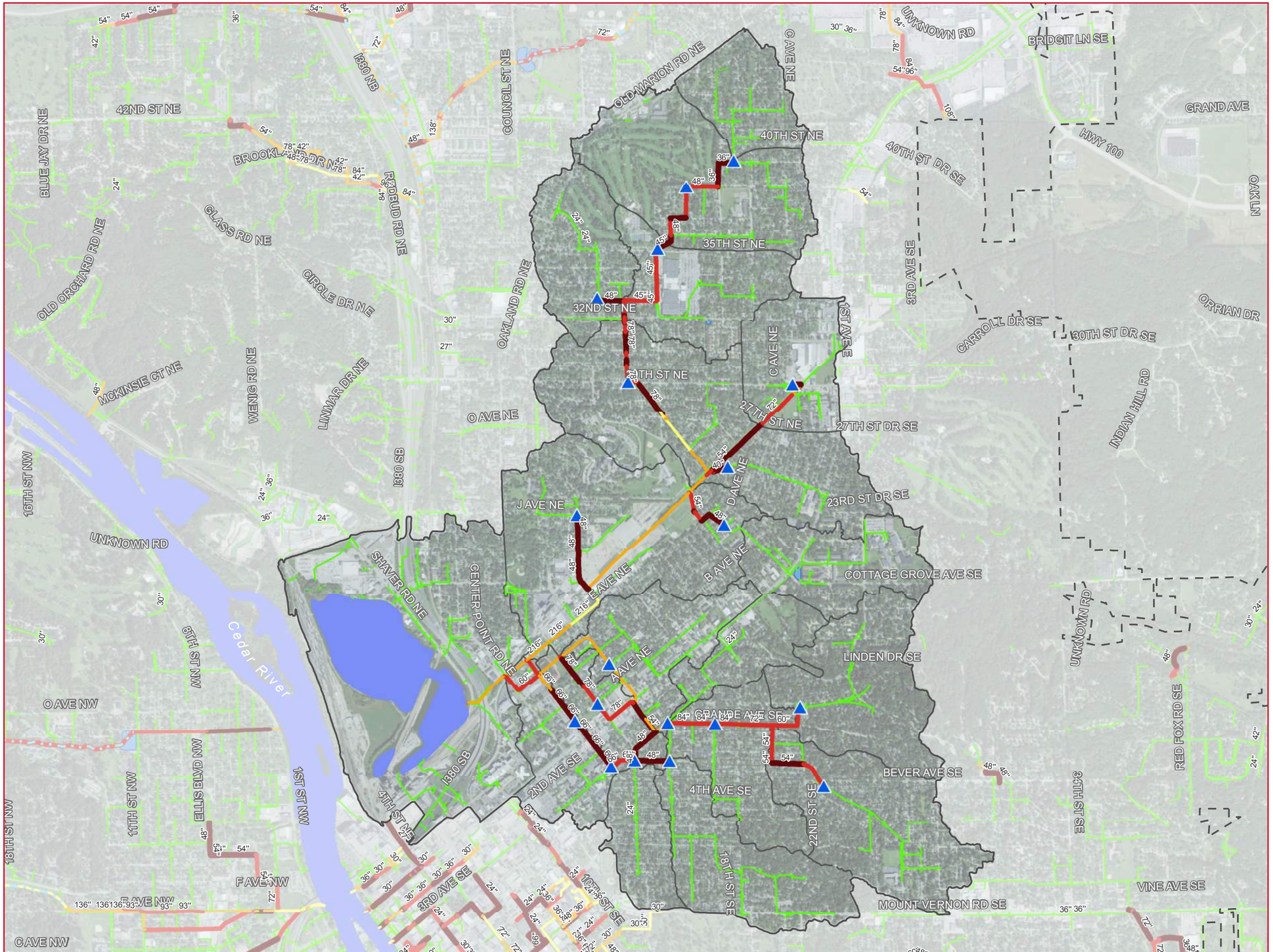


FIGURE 12
KENWOOD
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

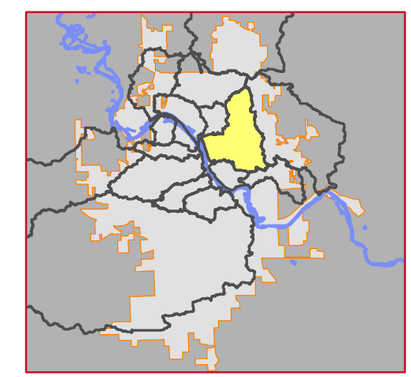
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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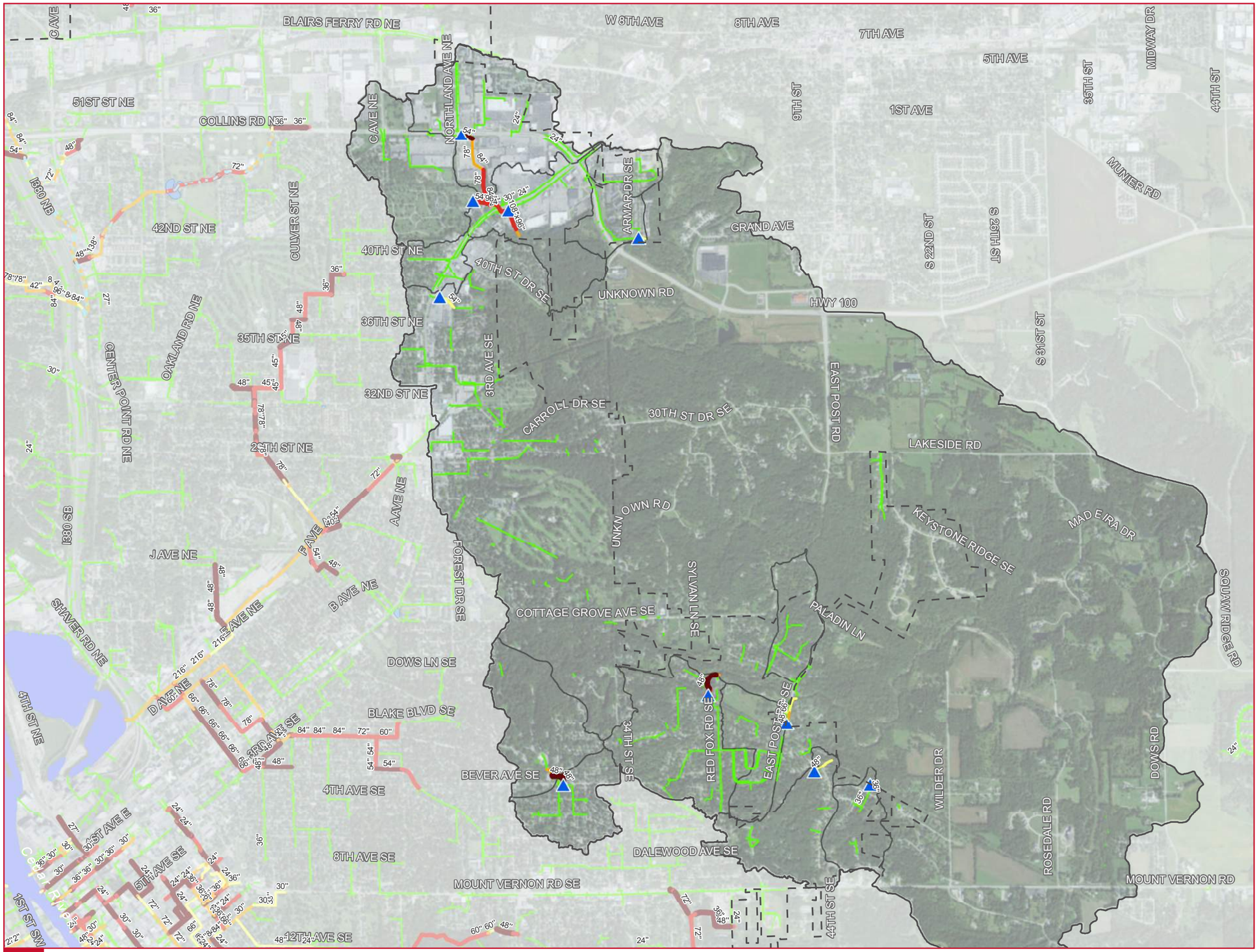


FIGURE 13
INDIAN CREEK
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

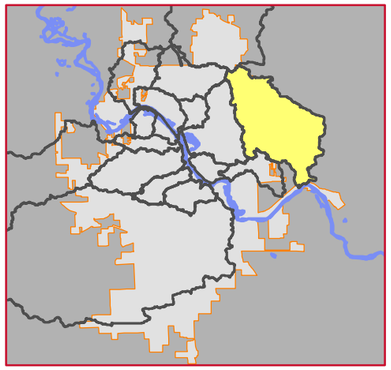
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,400

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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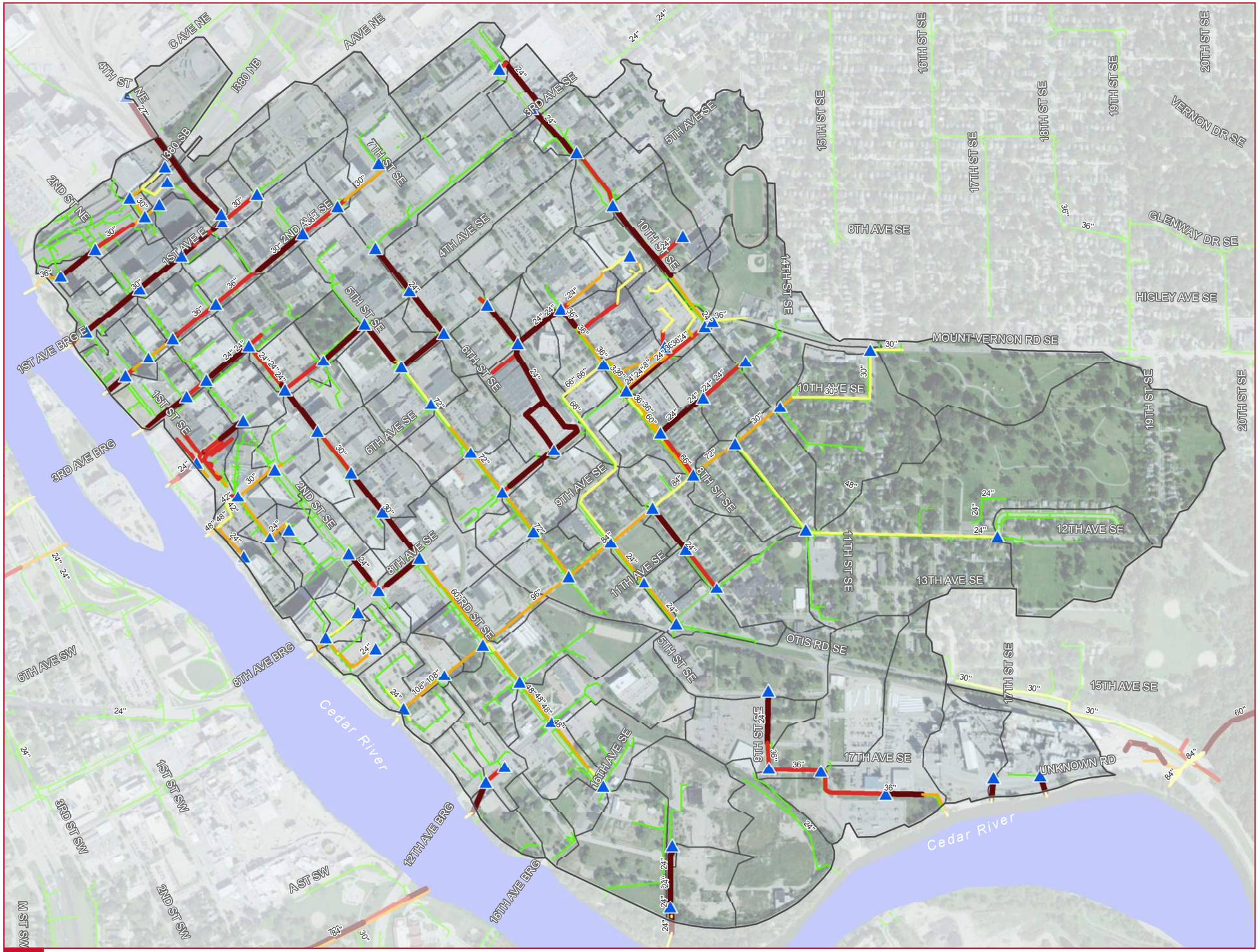


FIGURE 14
DOWNTOWN
MODEL RESULTS, 5-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

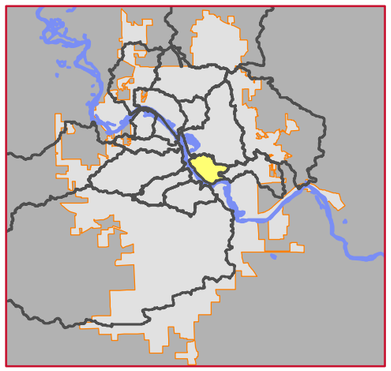
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 700

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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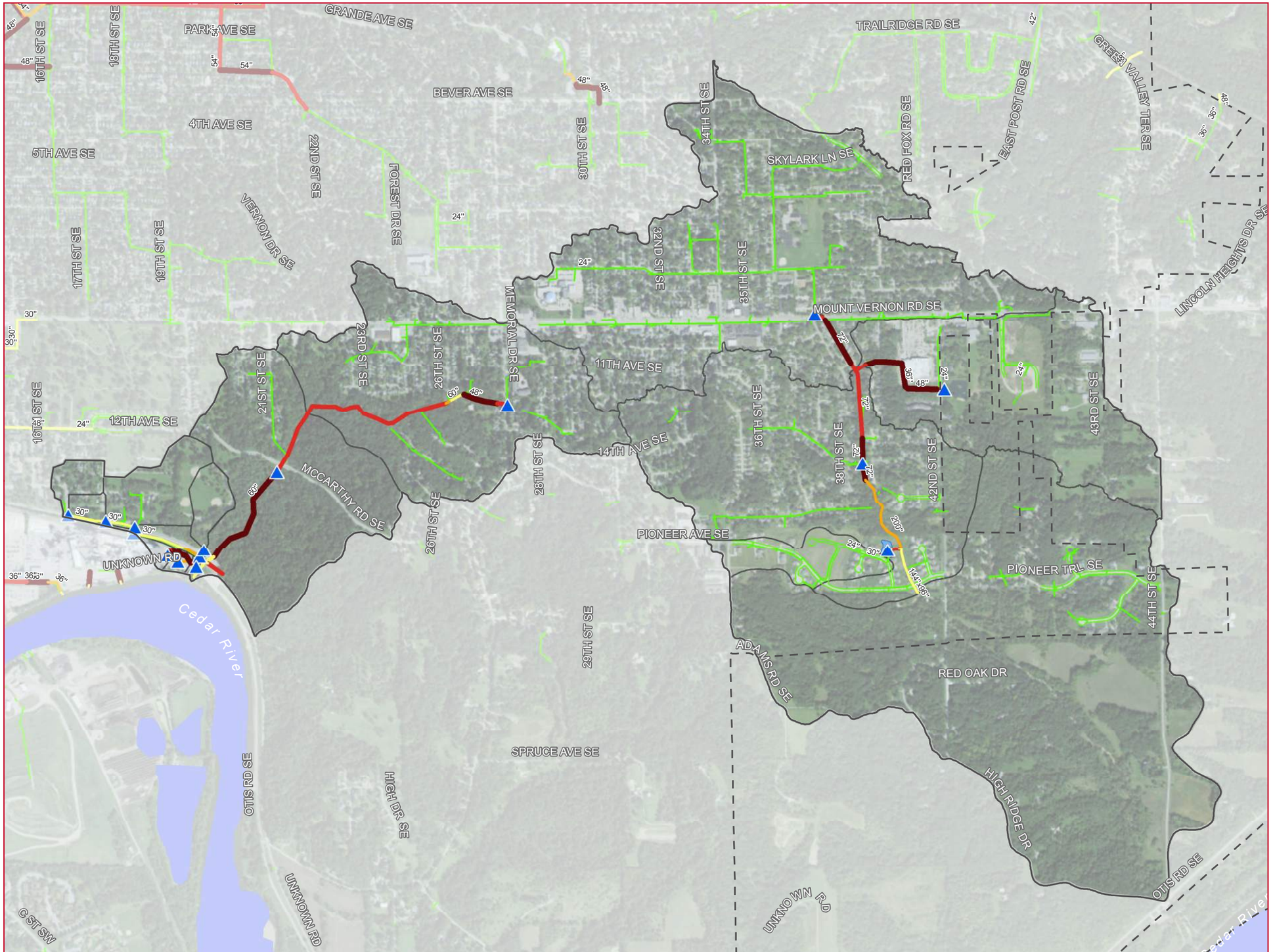
FIGURE 15
SE CEDAR RIVER
MODEL RESULTS, 5-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

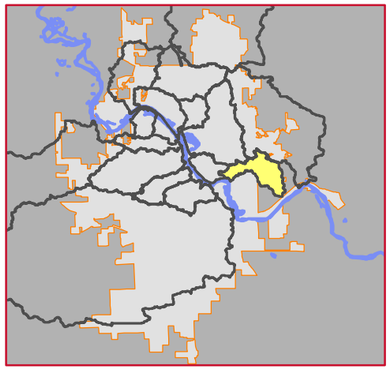
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,200

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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Appendix D – 100-Year Rainfall Model Results Map Book

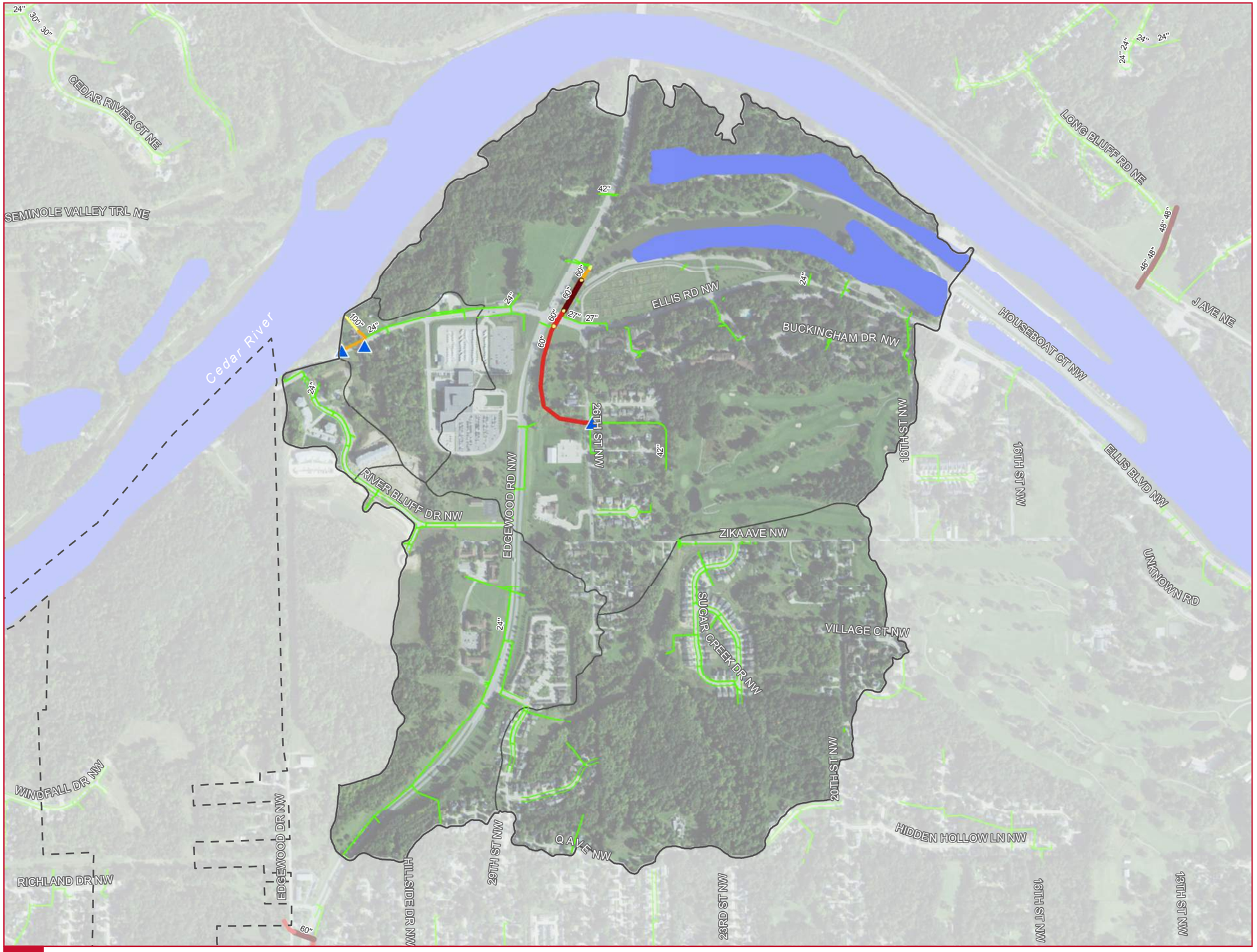


FIGURE 1
NW CEDAR RIVER
MODEL RESULTS, 100-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

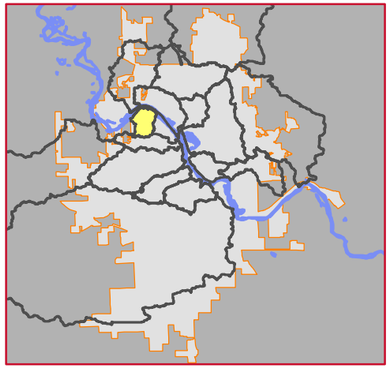
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 800

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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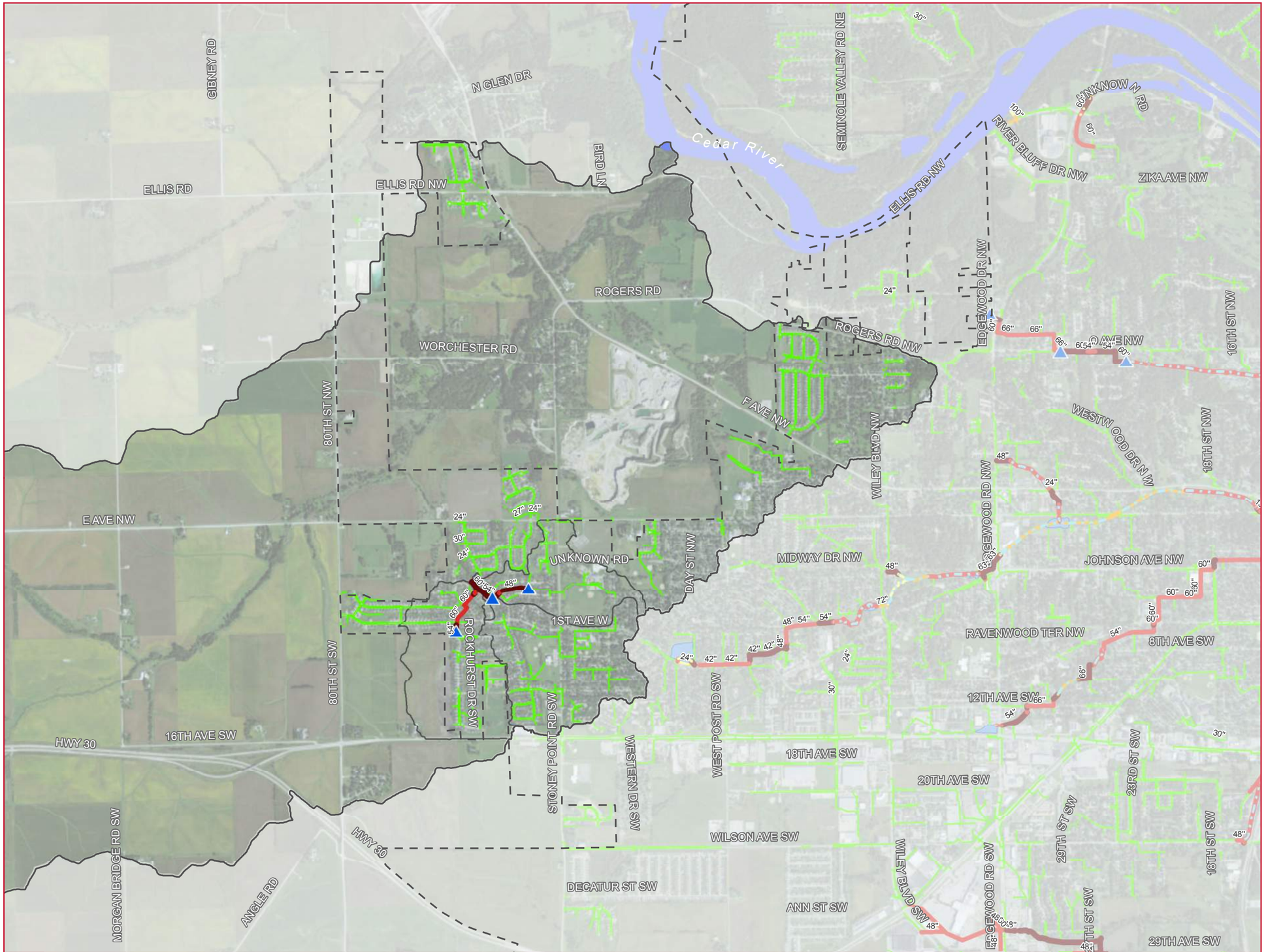
FIGURE 2
MORGAN CREEK
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

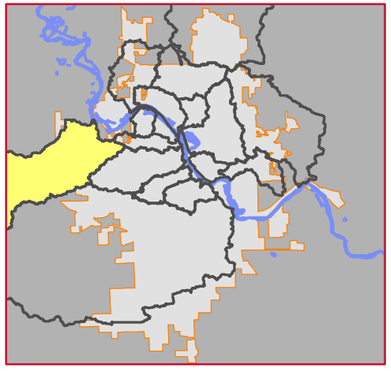
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,400

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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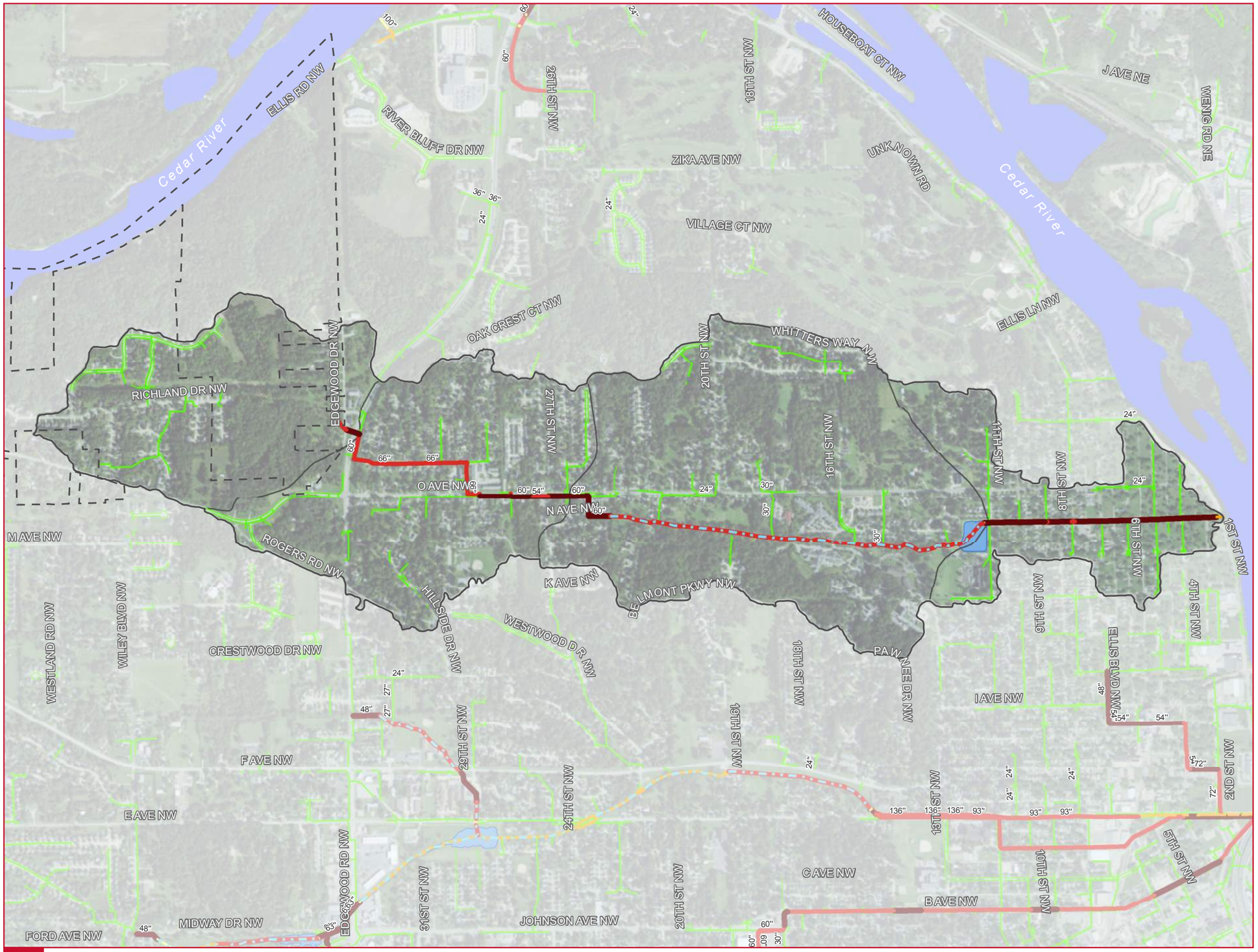
FIGURE 3
O AVENUE
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

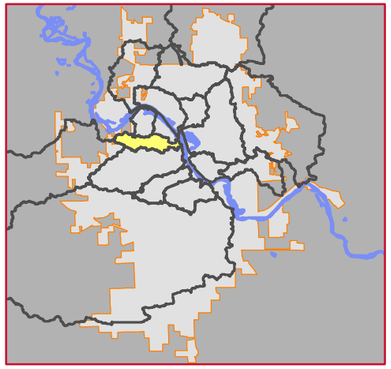
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,200

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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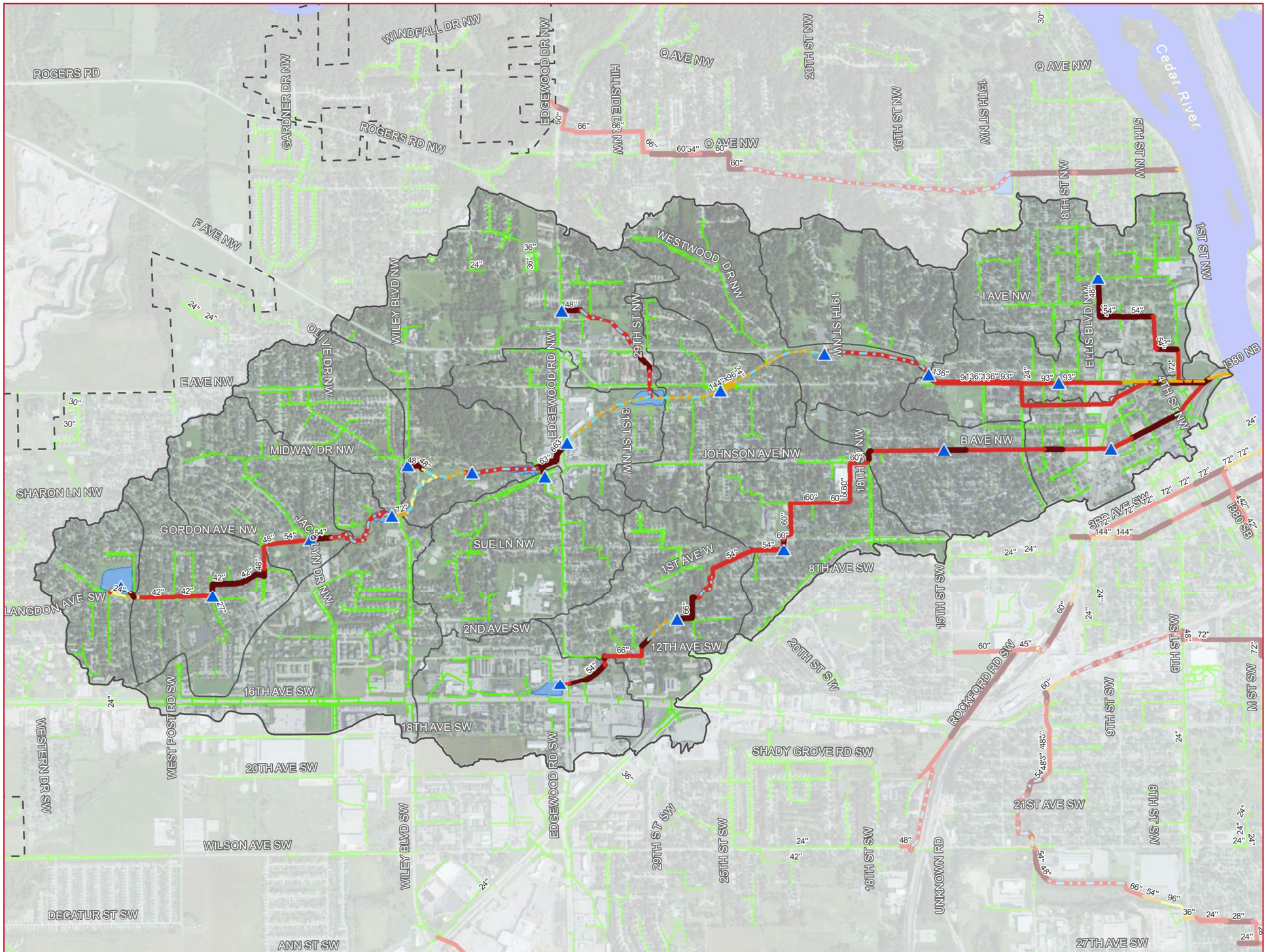


FIGURE 4
E AVENUE
MODEL RESULTS, 100-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

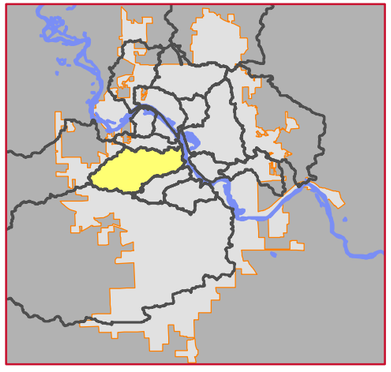
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,700

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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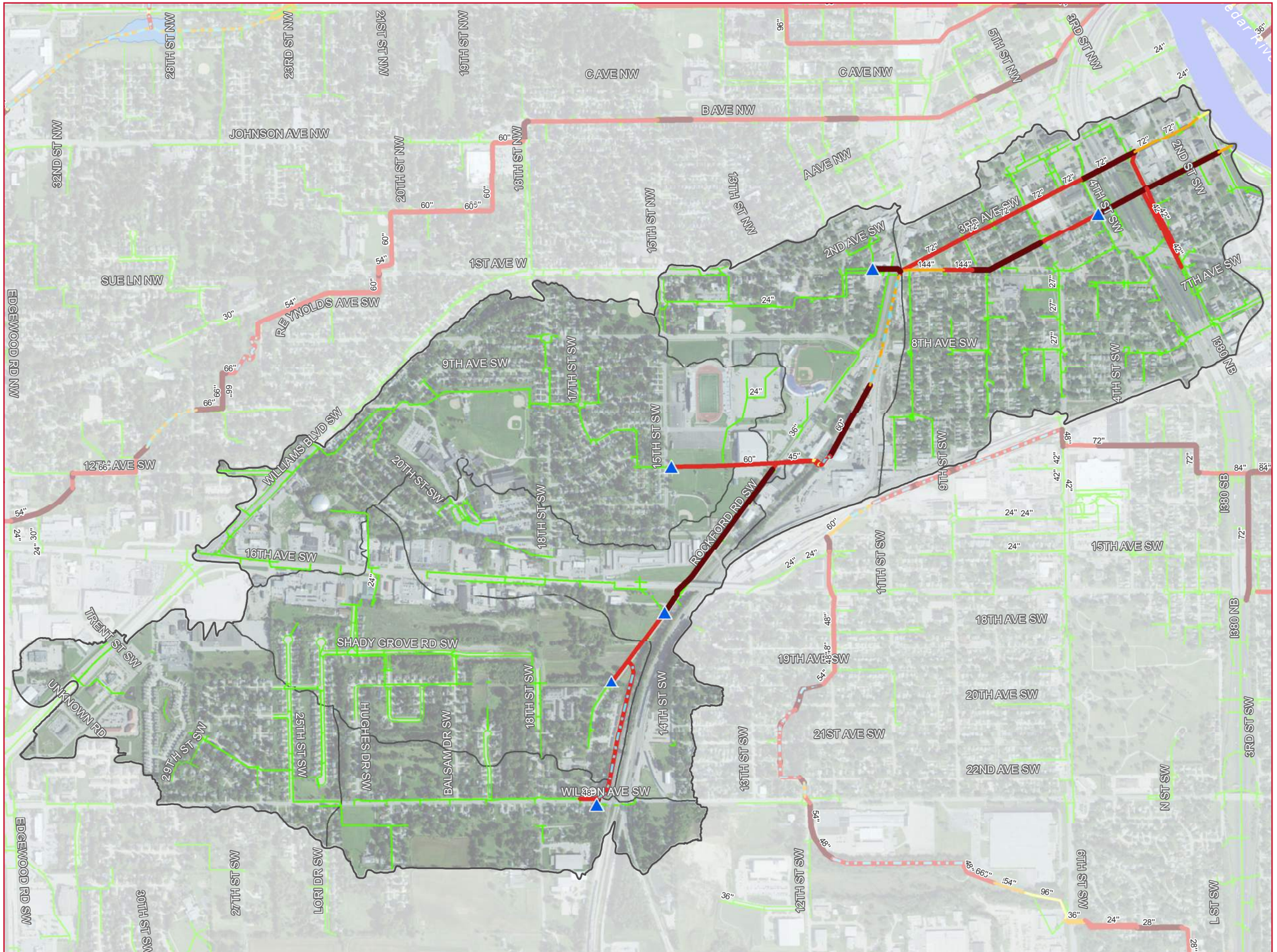
FIGURE 5
4TH AVENUE
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

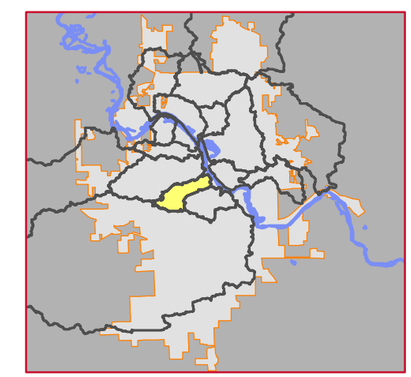
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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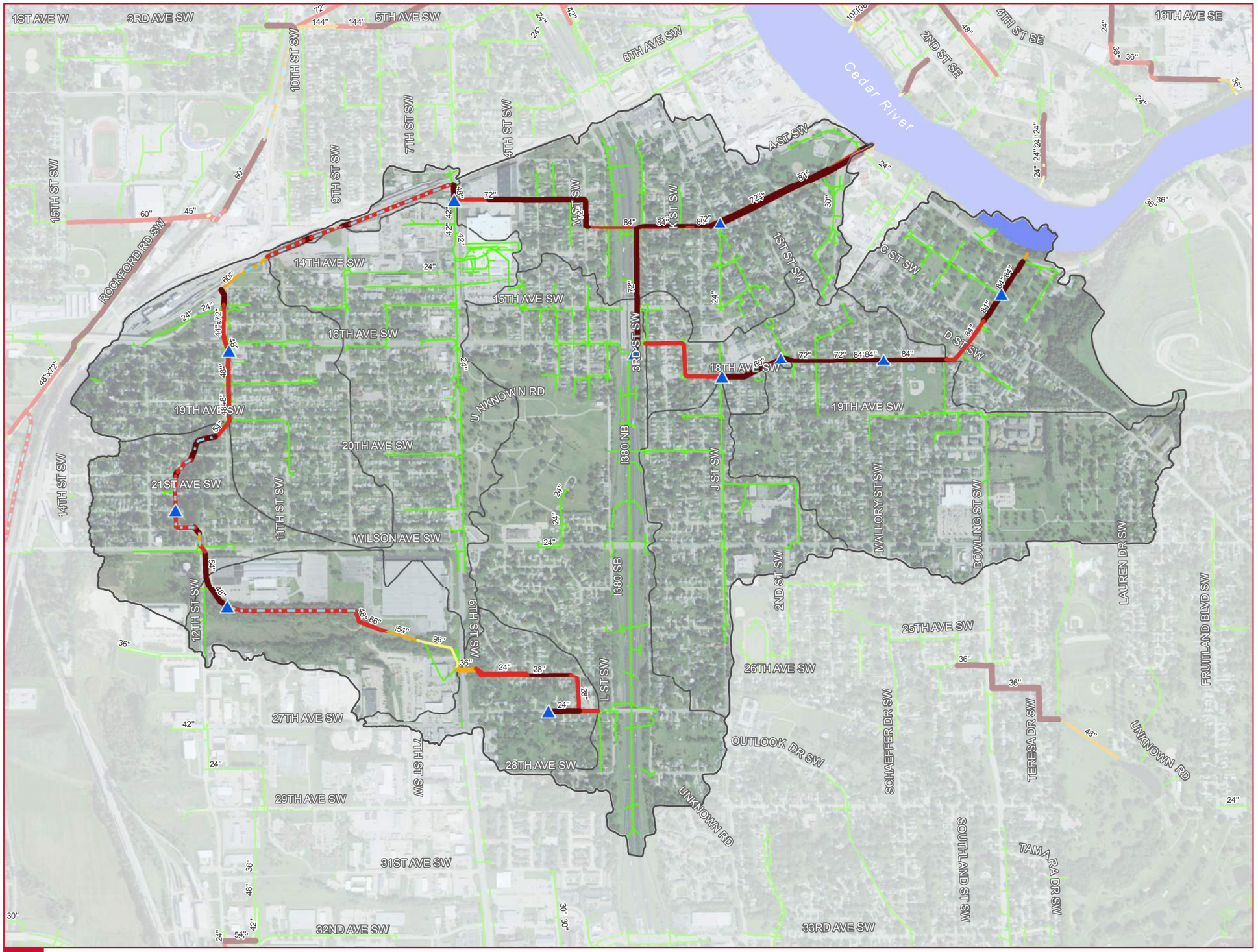
FIGURE 6
CZECH VILLAGE
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

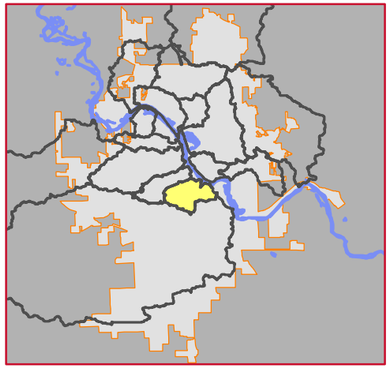
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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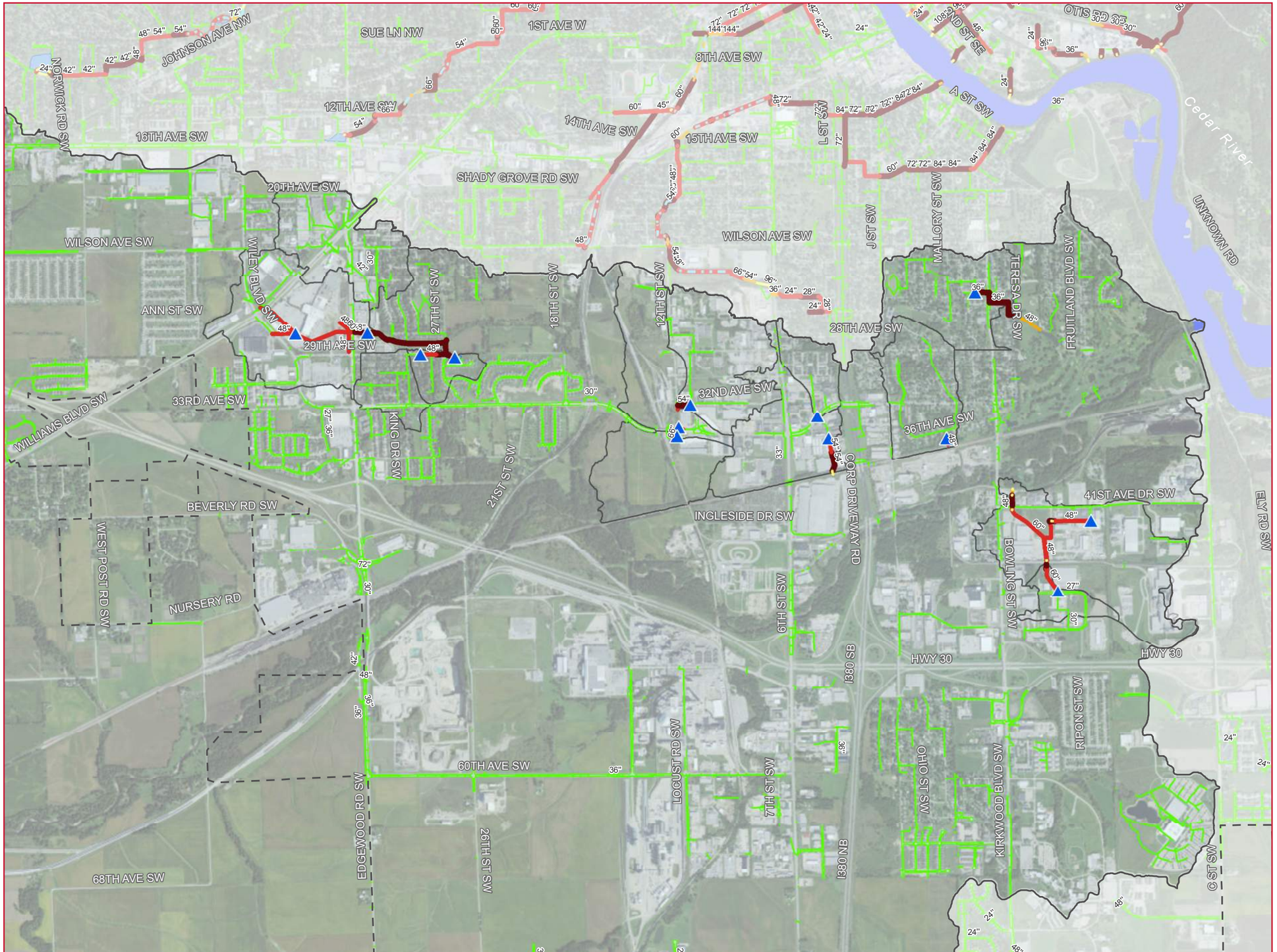
FIGURE 7
PRAIRIE CREEK
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

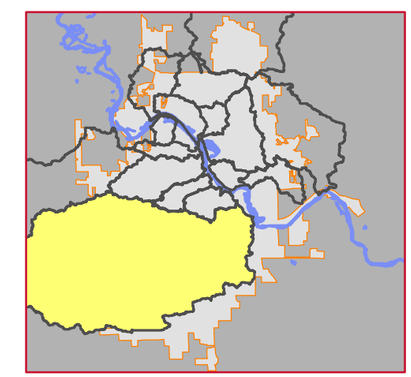
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,500

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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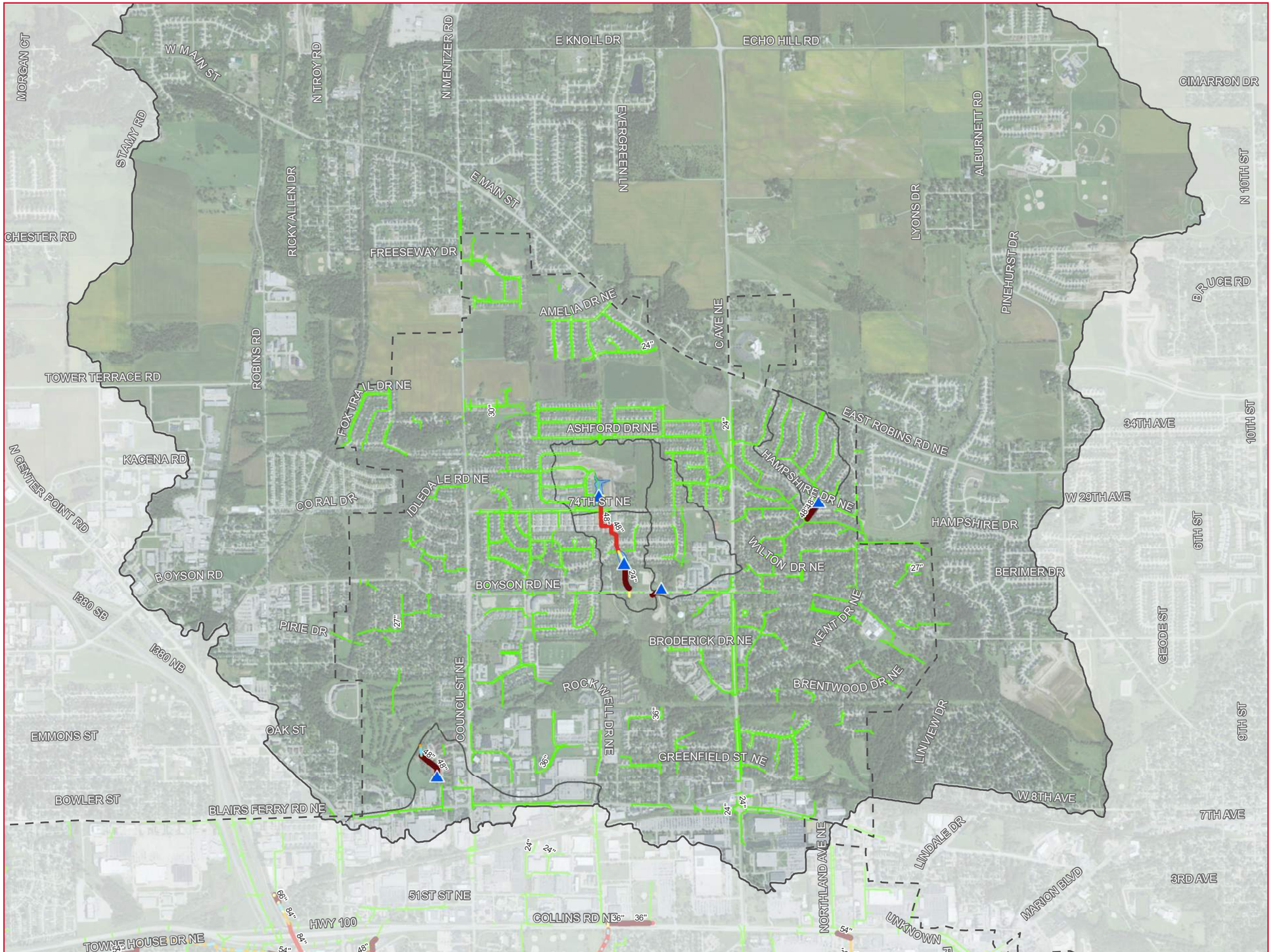


FIGURE 8
DRY CREEK
MODEL RESULTS, 100-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

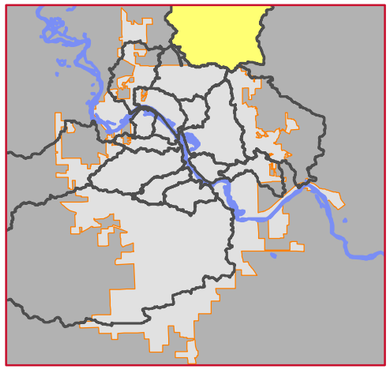
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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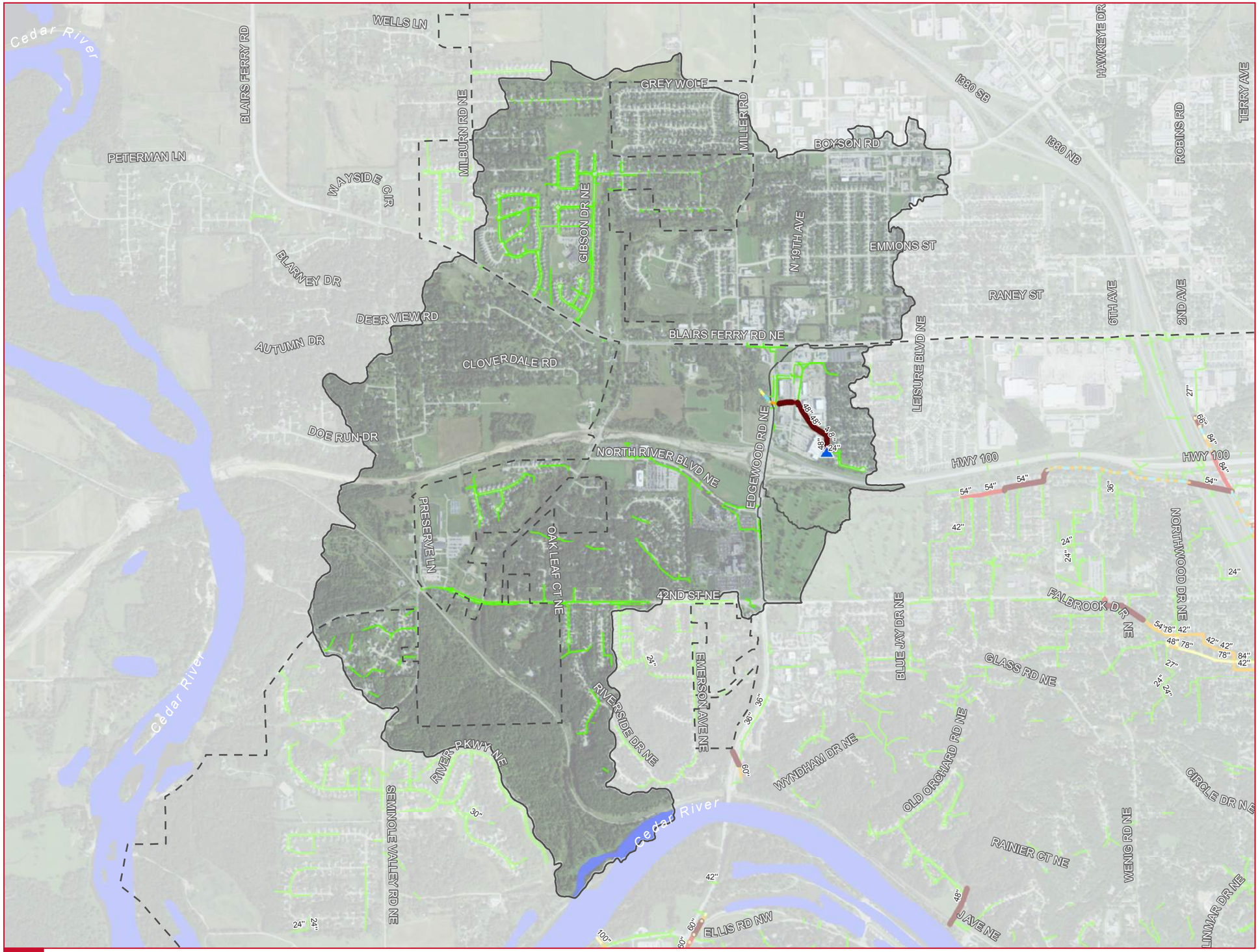
FIGURE 9
USHER FERRY
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

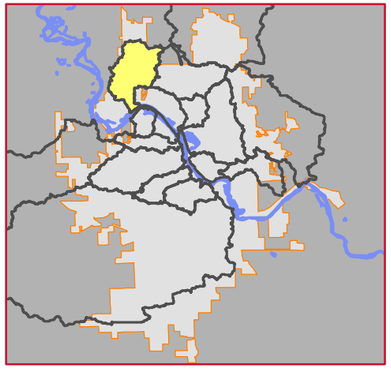
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,800

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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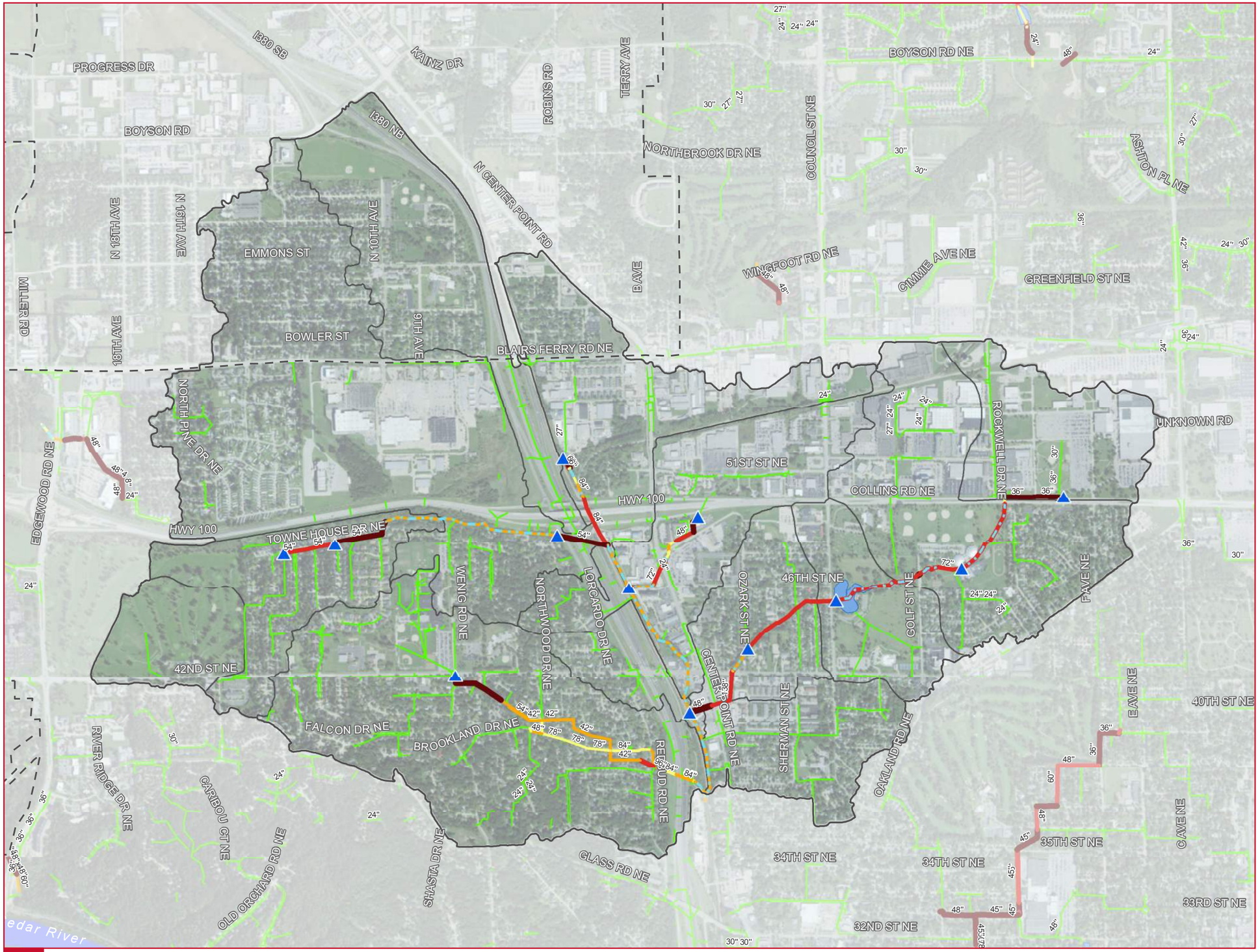
FIGURE 10
MCLOUD RUN
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

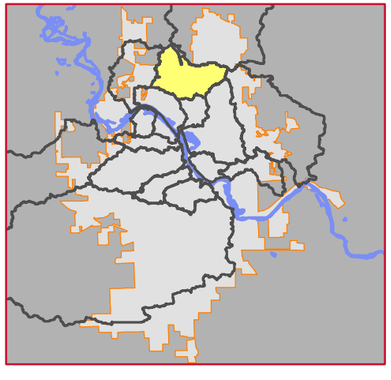
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,500

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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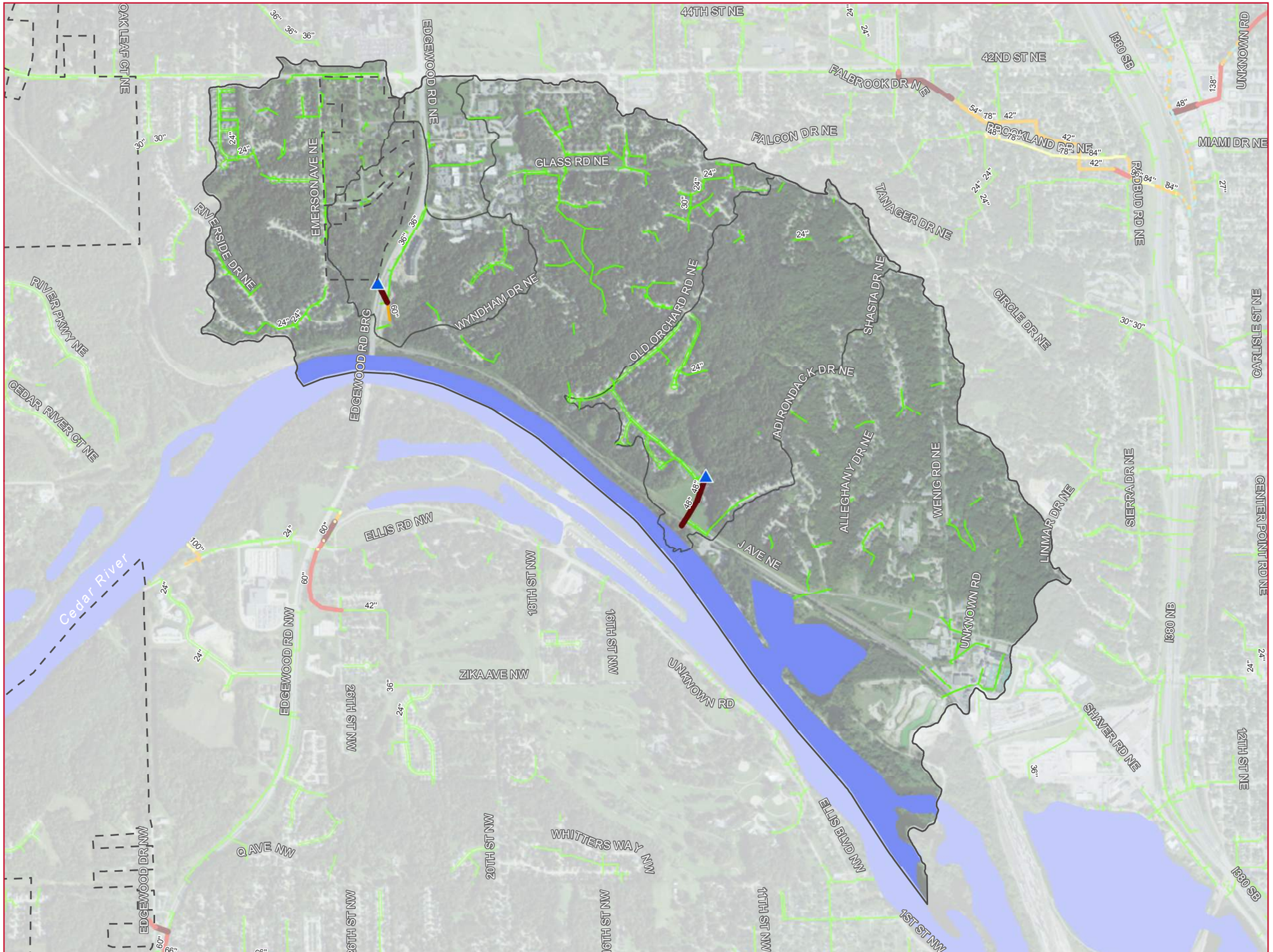


FIGURE 11
NE CEDAR RIVER
MODEL RESULTS, 100-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

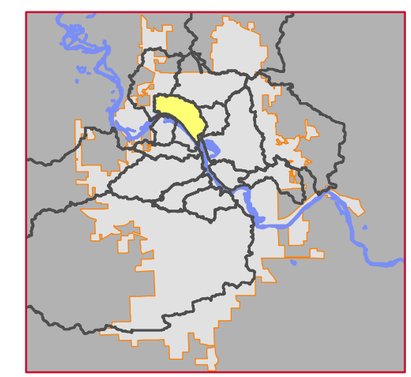
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,300

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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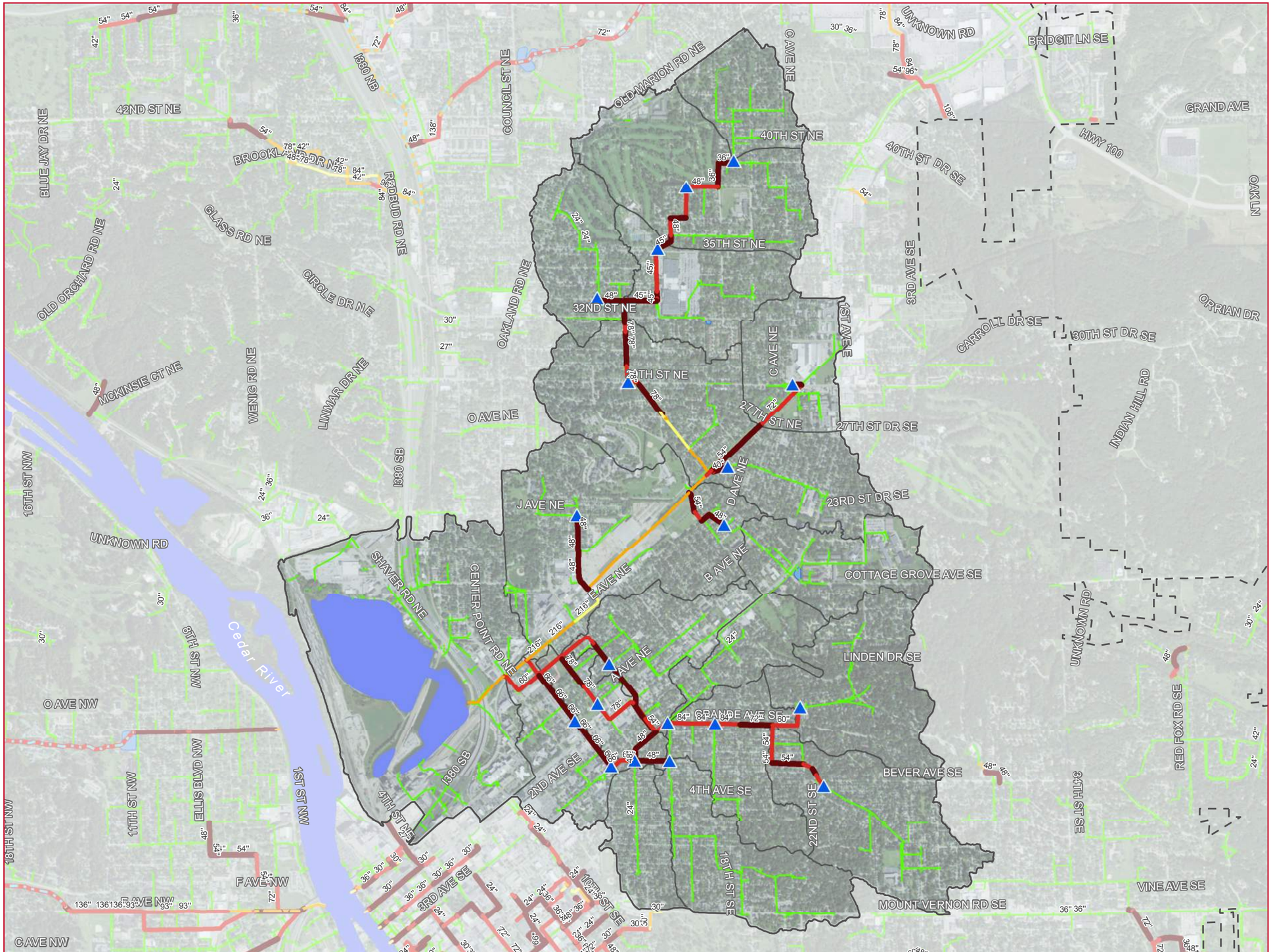


FIGURE 12
KENWOOD
MODEL RESULTS, 100-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

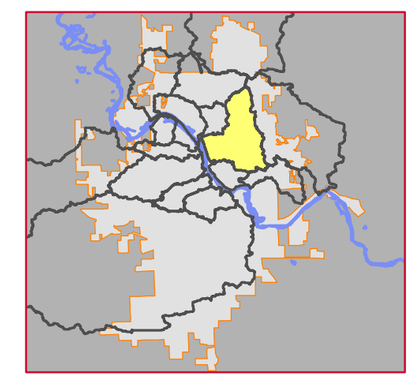
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,000

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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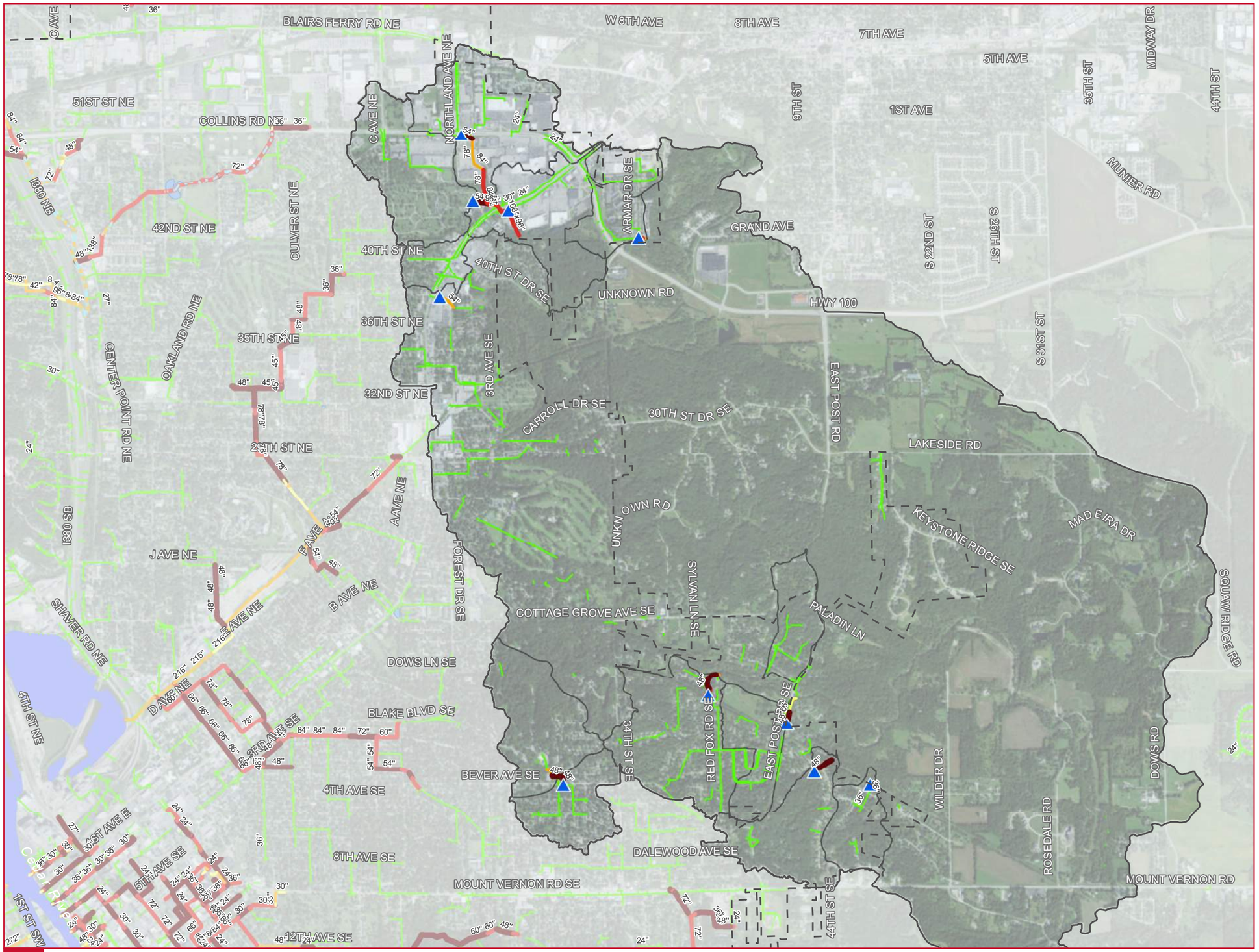


FIGURE 13
INDIAN CREEK
MODEL RESULTS, 100-YEAR EVENT

City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

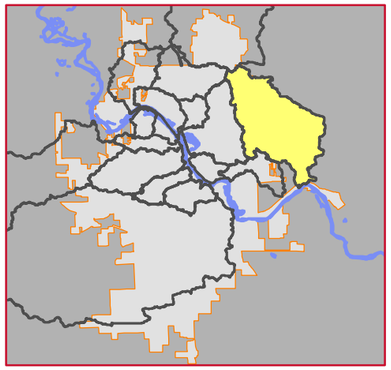
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 2,400

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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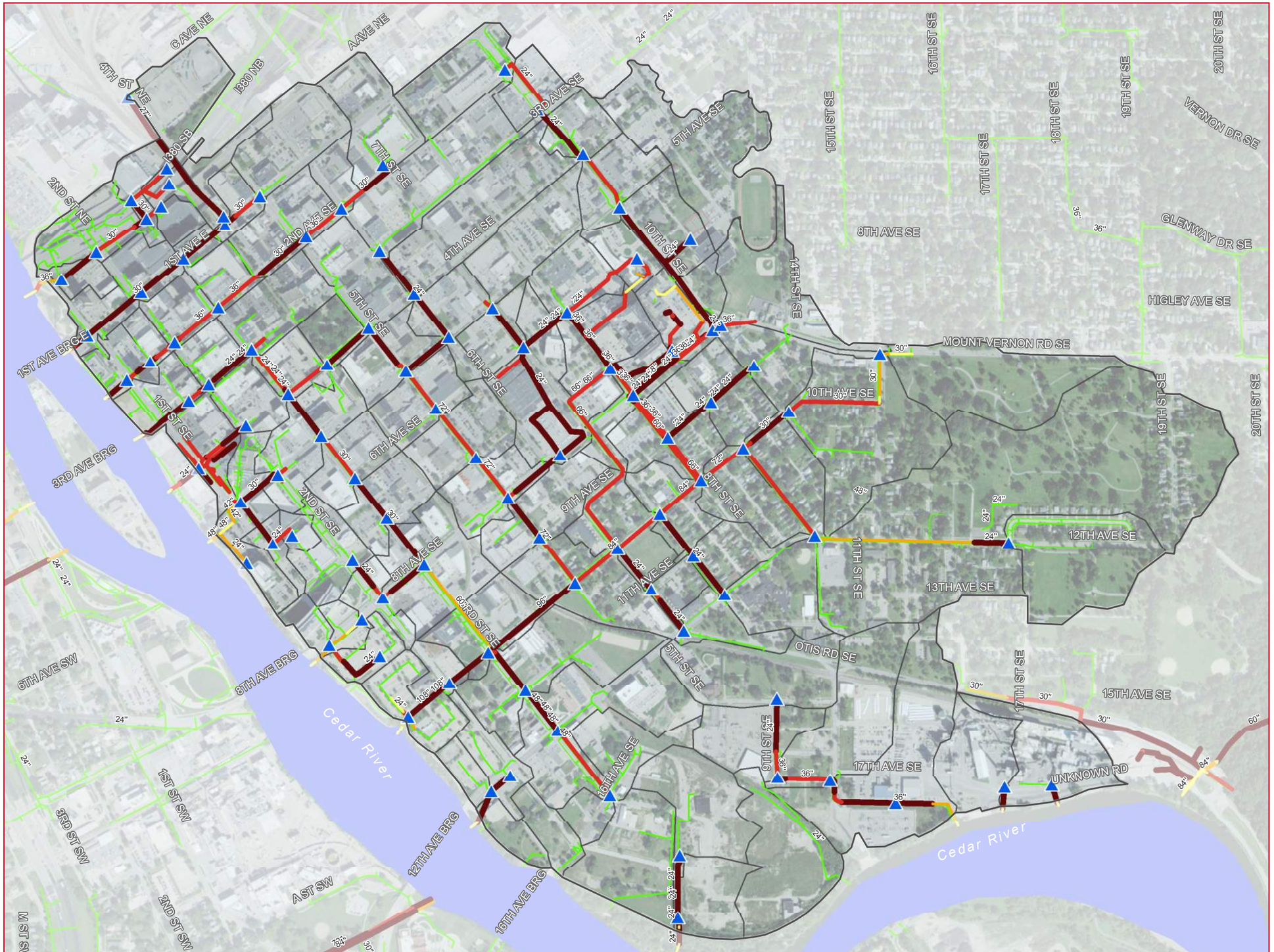
FIGURE 14
DOWNTOWN
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

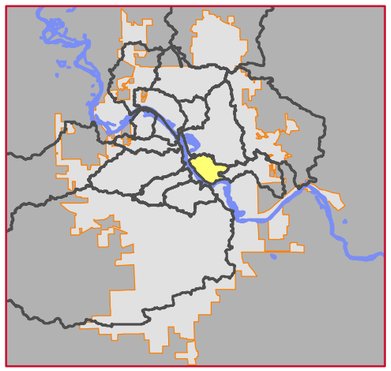
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 700

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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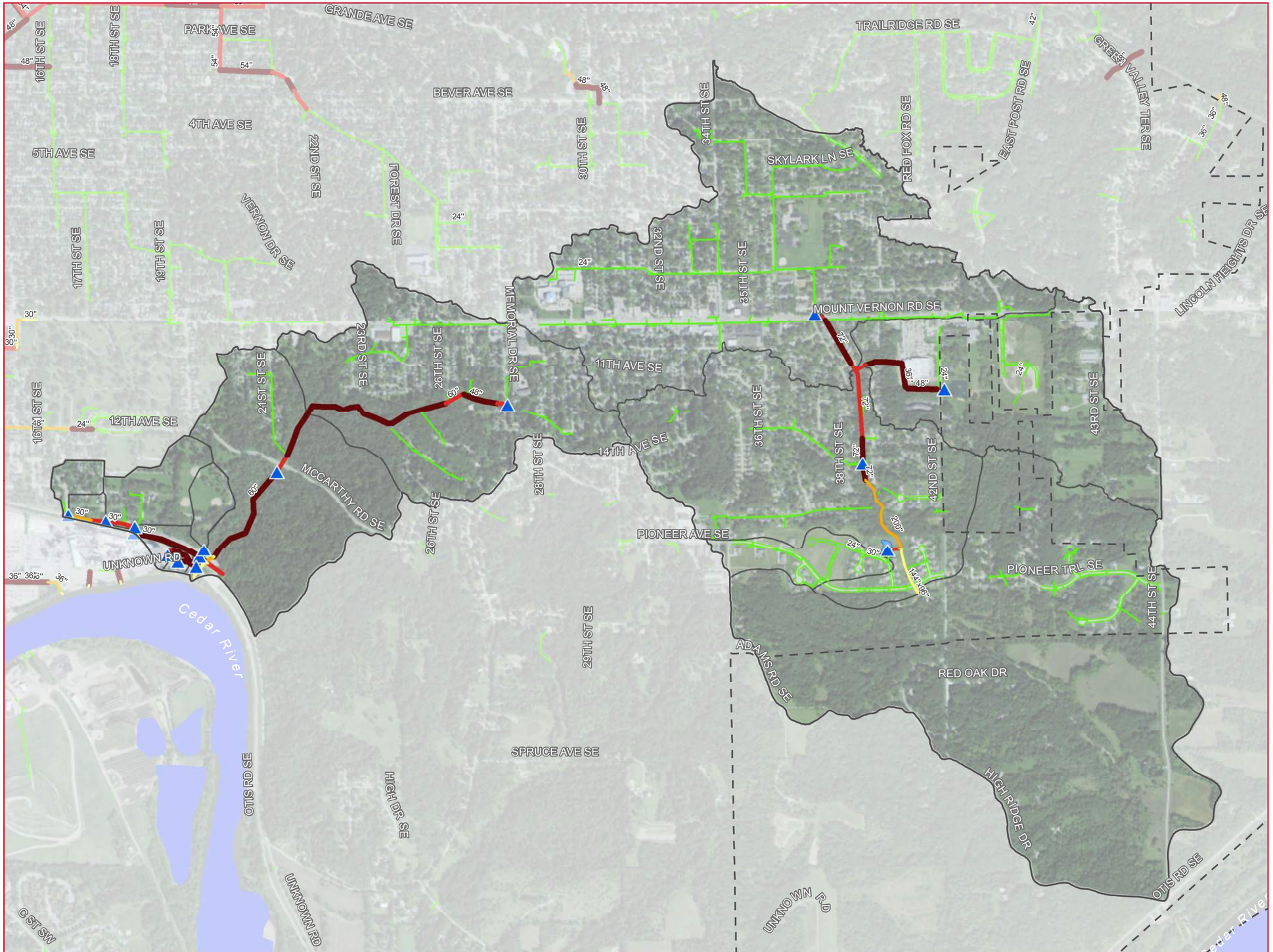
FIGURE 15
SE CEDAR RIVER
MODEL RESULTS, 100-YEAR EVENT



City Boundary

Catchment

Pour Point

Cedar River

Modeled Detention Pond

Open Channel

Storm Pipe

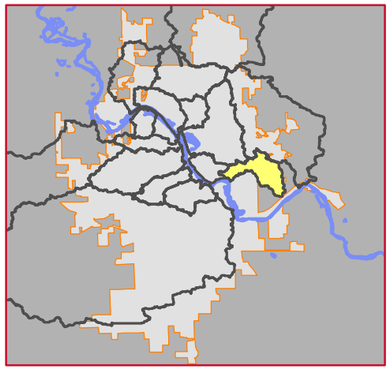
Surcharge

Less than half full

More than half full

Full - Bottleneck Downstream

Full - Bottleneck Pipe



0 Feet 1,200

DATA SOURCE: City of Cedar Rapids

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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