Flooding Resilience Plan for Bus Operations

Project Report

Prepared for the Regional Transportation Authority of Northeast Illinois

May 18, 2018

Prepared for:

The Regional Transportation Authority of Northeast Illinois (RTA)

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Distribution List

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Table of Contents

Appendices

Figures

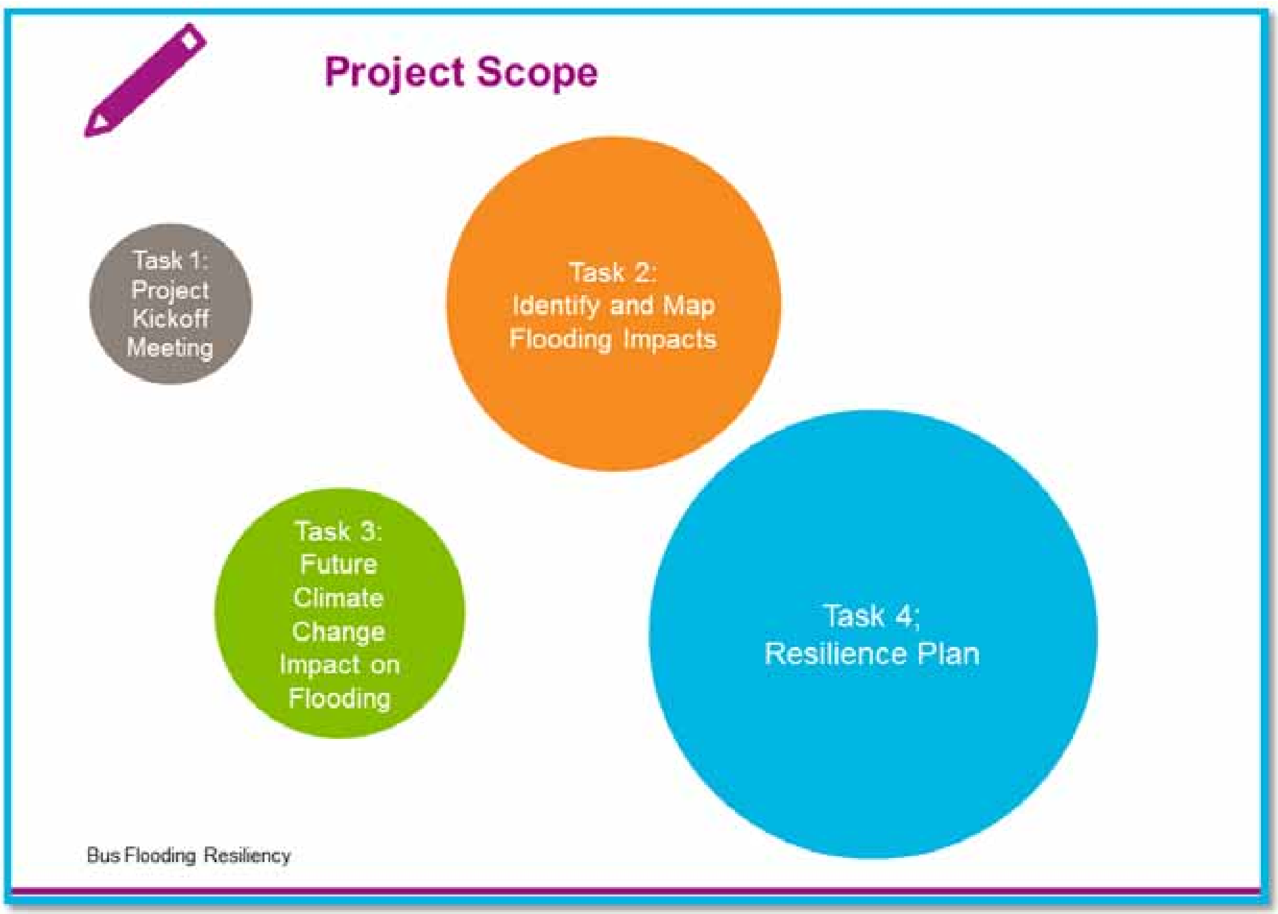
Tables

1. Introduction

In Fall 2015, as a continuation of its Green Transit program, the Regional Transportation Authority (RTA) initiated a project to prepare a bus route flooding resilience plan for the RTA service area composed of its six-county jurisdiction in northeastern Illinois, including Cook, DuPage, Kane, Lake, McHenry, and Will Counties. The objective of this project is to identify CTA and Pace bus routes that are prone to flooding during both average rain events and extreme weather events and to develop recommendations to address flooding issues and reroute service during flooding to minimize impacts and inconvenience to riders. Aside from hampering citizens' mobility, such flooding events can have negative impacts on operating costs and ridership revenues.

The scope of the study, which kicked off in Summer 2016, was organized into four major work tasks:

1. Initiate Project
2. Identify and Map Flooding Impacts
3. Assess Future Climate Change Impacts on Flooding
4. Prepare a Resilience Plan



Summary of Tasks and Themes

Based on our observations of significant flood events during the last five to 10 years, flood events in the RTA service area are a combination of water body overflows, as well as stormwater runoff and localized drainage issues. Bus transit is most obviously impacted when roads are wholly flooded and impassible, and viaducts and underpasses around the region's railroad and highway network are particularly vulnerable. As part of the Chicago Climate Action Plan—one of the key precursor studies to the RTA Flooding Resilience for Bus Operations plan—the CTA noted that their bus service is particularly vulnerable to flood events because of the more than 1,500 railway viaducts, of which more than 10 percent are troubled by frequent flooding. After a kickoff meeting in **Task 1**, the project team in **Task 2** identified and reviewed datasets describing the natural systems across the region—primarily the floodplains and floodways—as the starting point for identifying areas that present risk based on riverine and overbank flooding.

In addition to conclusions that can be inferred from an overlay of viaduct locations, conditions and bus routes, we supplemented our understanding of risk with anecdotal reports of flooding from the front lines—the CTA and Pace bus drivers who call in flooded roads and detours. Areas with recurring problems for boarding and alighting were provided by the drivers and operations management, as well as from passengers who make reports of access difficulty. Additionally, insight from emergency management stakeholders and local departments of stormwater management and transportation provided further insight into troubled areas, impact, and the status of mitigation work.

In **Task 3**, the project team examined the effects of changing climate patterns on the flood risk landscape in the region. Research conducted in 2008 for the Chicago Climate Action Plan indicated that increases in winter and spring precipitation are likely, with projected increases of about 10 percent by the year 2050, and of about 20 to 30 percent by 2099. At present, even minor storms are enough to overwhelm the stormwater system of some parts of the region, and these are expected to occur even more often. For example, today's two-year storm event is expected to occur every year by mid-century, or phrased differently, an event that has a 50 percent chance of being equaled or exceeded in any given year is expected to have a 100 percent chance by mid-century. Additionally, the intensity of heavy precipitation events (5-, 10-, and 25-year storms) is likely to continue to increase. Effects of these trends will vary across the region according to watershed and sub-watershed hydrological patterns. With input from county and local stormwater management departments, the project team assesses whether these forecasted increases are likely to worsen risk conditions for the bus routes identified in Task 2.

In **Task 4**, the project team prepared responses to the identified risks in three major categories:

- Reroute plans for impacted bus routes,
- Communications strategies for updating impacted stakeholders of service interruptions, and
- Inventories of potential mitigation projects and recommendations, with suggested next steps for items outside agencies' control.

The resilience strategies are composed of some projects that fall under the jurisdiction of CTA and Pace, but the majority are located in the public right-of-way or on private property. For these projects, the RTA, CTA, and Pace can influence other entities' actions but cannot control the outcome of these plans and may be able to participate from a funding or advocacy perspective.

The full Task 2 Technical Memorandum is included as Appendix A. The full Task 3 Technical Memorandum is included as Appendix B. A summary of national and local Best Practices is included as Appendix C, and Impact Analysis Workbooks for CTA and Pace are included as Appendix D and E, respectively.

2. Transit in the Chicago Region

The Chicago region has several agencies providing public transportation services that make connections within and between municipalities. Service providers include Chicago Transit Authority (CTA), Metra, Pace Suburban Bus, and Northern Indiana Commuter Transportation District (NICTD), commonly known as the South Shore Line.

Regional Transportation Authority (RTA)

The RTA serves as the governing body with financial oversight of the Chicago-area public transportation service providers of the Chicago Transit Authority (CTA), Metra, and Pace Suburban Bus. In addition to providing financial support for the transit agencies, RTA conducts long-range transportation studies and maintains several funding programs for planning transportation improvements. RTA has a jurisdiction that includes six of the seven counties that compose the Chicago region.

Chicago Transit Authority (CTA)

CTA manages the third-largest transit system in the United States, providing public transportation service to the City of Chicago and 35 surrounding suburban communities. CTA operates eight rapid transit rail lines covering 145 rail stations and 130 bus routes serving roughly 11,000 posted bus stops. In 2016, CTA systemwide ridership stood at nearly 500 million boardings. As of June 2017, CTA provided 42.6 million rides a month, roughly equally split between rail and bus.[1] On an average weekday, 1.6 million people board CTA trains or buses.[2]

Pace Suburban Bus

As one of the largest public bus service providers in the US, Pace operates approximately 200 fully accessible bus routes within the six-county area of Cook, DuPage, Kane, Lake, McHenry, and Will, serving more than 220 communities. Besides traditional fixed-route bus service, Pace provides paratransit service via roughly 450 vehicles, as well as vanpool service using a fleet of about 700 vehicles. In 2016, Pace fixed-route bus ridership stood at 28.4 million and other services (paratransit, vanpool, Dial-a-Ride, Taxi Access) added 6.9 million trips to total 35.3 million trips overall.[3] Monthly ridership as of June 2017 was 2.4 million on fixed-route bus service, and 0.6 million using other services.[4]

Commuter Rail

Metra's commuter passenger rail service spans 11 rail lines linking 241 stations.[5] In 2016 Metra provided about 80 million trips annually, many of which originated in collar counties, including those of DuPage, Kane, Lake, McHenry, and Will. As of June 2017, Metra provided just under seven million rides per month. Outside of the New York City metropolitan area, Metra is the busiest commuter rail system in the United States by ridership.

The last remaining interurban railroad—the South Shore Line—is operated by the Northern Indiana Commuter Transportation District (NICTD) and connects northern Indiana with downtown Chicago with 19 stations. This rail service provided 331,000 rides per month as of June 2017.

While commuter rail and CTA heavy rail transit are not the primary focus of this project's analysis, bus connections to the wider high-capacity network are an important factor in evaluating or prioritizing topics of focus.

[1] Chicago Transit Authority (CTA). June 2017 Monthly Ridership Report. http://www.transitchicago.com/performance/ (2017)
[2] http://www.transitchicago.com/about/facts.aspx (2017)
[3] RTA. 2016 Ridership report. www.rtachicago.org (2017)
[4] RTA Mapping and Statistics. Pace Bus Ridership Summary. www.rtams.org (2017)
[5] Metra, Frequently Asked Questions, metrarail.com/metra/en/home/utility_landing/riding_metra/faq.html#q2 (2014)

2.1 CTA Bus

Ridership

CTA accounts for the majority of public transportation ridership numbers in the Chicago metropolitan area. System-wide ridership from 2005 to 2012 increased more than 11 percent, or 1.5 percent each year. Since that 2012 peak, it has fallen to just below 500 million riders, similar to pre-2008 recession levels.

Buses are often cited as the workhorses of the CTA system, as they have historically provided more than half of all CTA transit trips. However, since CTA was forced to implement service cuts in 2010 to meet budgetary constraints, bus ridership fell by approximately 75 million between 2012 and 2016. Rail, on the other hand, has increased significantly nearly every year. Between 2012 to 2016, annual rail ridership increased by about 28 million rides, or 12 percent.

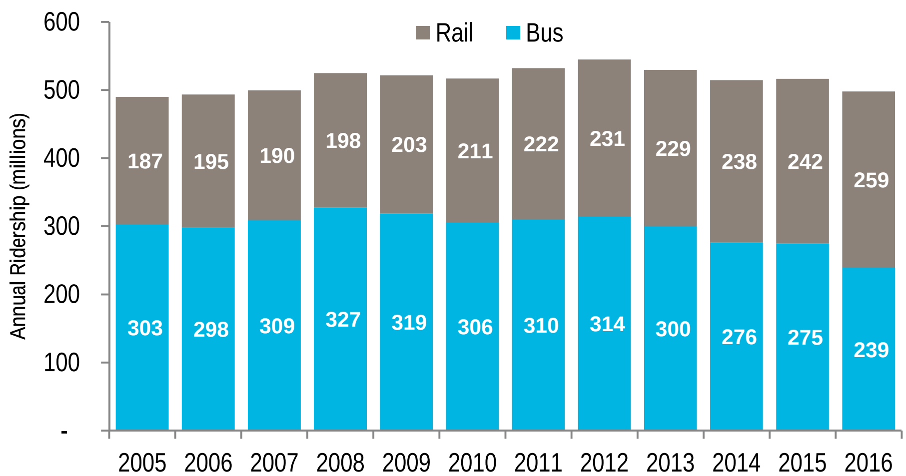
Table 1 and **Figure 1** display bus, rail, and total system ridership for each year between 2005 and 2016. Rail ridership has been increasing and bus ridership falling over this period. System ridership as of 2016 is 497 million rides per year, which is above the 2005 total of 490 million, but is down from the 2012 peak of 545 million.

Table 1: Annual CTA Ridership (in millions)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Bus	303.2	298.4	309.3	327.3	318.9	306.1	310.5	314.0	300.3	276.3	274.6	259.1
Rail	186.8	195.2	190.3	197.6	202.8	210.8	221.7	231.0	229.3	238.2	242.0	238.6
Systemwide	**490.0**	**493.6**	**499.6**	**524.9**	**521.7**	**516.9**	**532.2**	**545.0**	**529.6**	**514.5**	**512.6**	**497.7**

Source: CTA Annual Ridership report (2016).

Figure 1: Annual CTA Total System Ridership (in millions)



Source: CTA Annual Ridership report (2016).

Table 2 provides ridership figures for each of the top performing bus routes by ridership, highlighting those routes that had the most average weekday riders in 2015. Ashland and 79th Street routes are the highest performing routes, followed by Chicago and Western. Each of these routes carries about two to three percent of all CTA bus riders each year, and combined they comprise 25 percent of CTA bus ridership.

Table 2: Top CTA Routes by Ridership

Route #	Name	Avg. Weekday Riders	Annual Ridership (2015)
9	Ashland	27,499	8,856,955
79	79th	26,830	8,716,277
66	Chicago	23,506	7,399,957
49	Western	23,417	7,462,133
77	Belmont	22,150	7,008,072
8	Halsted	22,093	6,820,599
4	Cottage Grove	21,143	6,747,771
53	Pulaski	19,909	6,293,990
3	King Drive	19,235	6,132,991
82	Kimball-Homan	18,939	5,898,214

Source: RTAMS data

Alignments

The CTA operates an integrated transit system designed to provide both access to downtown Chicago (through direct service or connections to rail lines) and comprehensive crosstown local service throughout the service area. The bus system is generally aligned in a grid pattern to provide efficient transportation coverage and maximize connections, requiring most riders to walk less than a half-mile to reach transit. Main functions of bus routes are serving neighborhoods, providing access to downtown Chicago, feeding rapid transit stations, and providing service to major activity centers and local markets.

The #66 Chicago provides north side east-west local service from Chicago's western border to the lakefront at Navy Pier. It also provides feeder service to Blue, Brown, and Red Line trains at each line's respective Chicago Avenue stations, and provides service to the River North/ Magnificent Mile neighborhoods, extensions of downtown Chicago.

A heavily used south side east-west crosstown route, the #79 79th Street, also serves multiple purposes in that it serves neighborhoods throughout Chicago's south side from the city's western boundary to the lakefront. It also connects passengers with the Red Line rail station, from which one can directly access downtown Chicago and other north and south side neighborhoods along the corridor. The route also serves the Ford City Mall at Cicero Avenue and 76th Street, a major activity center at the west end.

Two key north-south crosstown routes include the #9 Ashland and the #49 Western. Both provide critical service to neighborhoods and access to east-west bus routes, as well as providing feeder connections to rail service. Both are also served by CTA and Pace routes at each terminal, which extends services farther into the northern and southern portions of Cook County. Given their length and absence of a parallel rail line in close proximity, both of these routes have limited-stop service (#X9 Ashland Express and #X49 Western Express), providing less on-board travel time for customers traveling longer distances. The heavy usage of these routes is a strong indicator of the demand for service that connects secondary employment and activity centers outside of Chicago's downtown. The high demand for service, connectivity to multiple rail lines, and access to existing and emerging activity centers outside of downtown was instrumental in recommending Ashland for Bus Rapid Transit investment.

Modal Technology

The CTA has a bus fleet of over 1,800 vehicles with modern and advanced passenger amenities and technologies to help track, diagnose, and monitor service in real-time. There are two main types of buses in operation; 40' standard bus, and 60' articulated buses. Vehicle types are assigned based on ridership demand, and different vehicles may be used along the same route.

All CTA buses are also equipped with technology that transmits real-time location data from an on-board computer system which is equipped with a Global Positioning System (GPS) to a CTA database called the Data Communications Controller (DCC). The DCC polls the on-board computer, the Intelligent Vehicle Network (IVN), every 30 seconds for location data. The DCC data in turn feeds into a real-time bus management (RTBM) database system used by CTA to monitor bus service. The DCC also passes data to the Bus Tracker prediction system for creating bus arrival predictions. The CTA control center uses an application called CleverCAD to communicate in real-time two-way with buses, and the DCC facilitates the communication between the Computer Aided Dispatch (CAD) system and the on-board IVN and operator screen.

In addition, all CTA buses are equipped with the Ventra fare collection equipment. The Ventra fare collection equipment is comprised of a Bus Mobile Validator (BMV) that connects via a separate cellular connection to the back office to operate the Open Standards Fare System. The bus also has a farebox used to collect cash fares with data physically probed from the bus once per day.

Currently, 97 percent of the CTA bus fleet has automatic passenger counting (APC) sensors at doorways to collect boarding and alighting data as passengers break an infrared beam. The APC data is collected on board the bus and sent to servers once per day and processed twice per day. Raw passenger load data is available in real-time via the CleverCAD application but is not as reliable since cleaning algorithms are not run on the data in real-time.

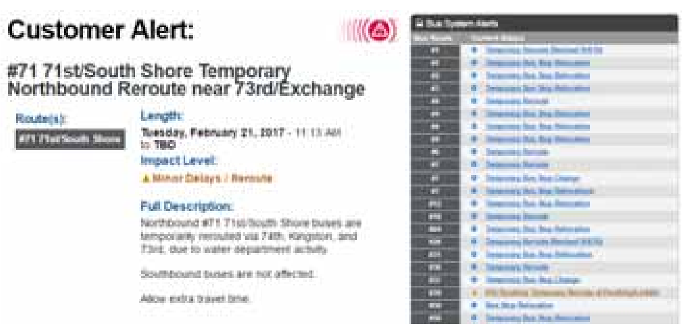
Bus drivers also have direct radio communication with dispatchers and supervisors, again via the CleverCAD system. Each bus is also equipped with several fixed-view cameras to provide video surveillance for security. Buses are also equipped with automated audio announcements of upcoming stop arrivals, also supported through the aforementioned IVN.

One technology of particular value to passengers is the CTA's Bus Tracker system. Bus arrival prediction information is distributed to users of computers, mobile phones, and other electronic devices. The CTA provides an application programming interface (API) so that developers can incorporate the real-time prediction data into smartphone apps and other uses. Users can then find the anticipated arrival times of buses for every stop in the CTA system. This capability has had a significant positive impact on the perceived and actual reliability of CTA services among passengers and the general public.

Communications

CTA communicates with passengers using customer alerts posted on the website. Spontaneous reroutes are highlighted with a different symbol and color, in comparison with planned temporary reroutes or bus stop changes/relocations that are in place for several weeks at a time (see **Figure 2**).

Figure 2: Sample CTA Website Bus System Alerts



Source: http://www.transitchicago.com/travel_information/systemalerts.aspx?source_quicklinks=1

Riders can sign up to receive CTA updates via email or text message. These updates can include weekly planned service change updates, unplanned events affecting service, and station accessibility updates, according to user preference. CTA also reports reroutes and other changes on its Twitter feed.

2.2 Pace Bus

Ridership

As one of the largest public bus service providers in the US, Pace operates 209 fully accessible fixed bus routes within the six-county area of Cook, DuPage, Kane, Lake, McHenry, and Will—a territory which covers 3,446 square miles and includes 284 municipalities. In addition to traditional fixed-route bus service, Pace provides paratransit service via 442 vehicles, as well as vanpool service via 784 vehicles. Ridership stood at 33.1 million in 2015, with Pace ADA ridership at 4.2 million that same year. Pace ADA ridership has been growing steadily since it was inaugurated, while Pace suburban service dropped dramatically in 2009 and has not fully recovered its pre-2009 ridership levels.

The paratransit services are a major distinguishing factor between Pace and the CTA, which only provides fixed-route services. Pace is the only provider of all demand-response service, which includes dial-a-ride, call-n-ride, accessible fixed-route (for elderly and disabilities), and ADA paratransit, filling the needs of Chicago and other CTA-served municipalities that are required by the FTA to provide such services. In this way, the RTA fulfills the metropolitan area's paratransit needs via its suburban bus division, Pace.

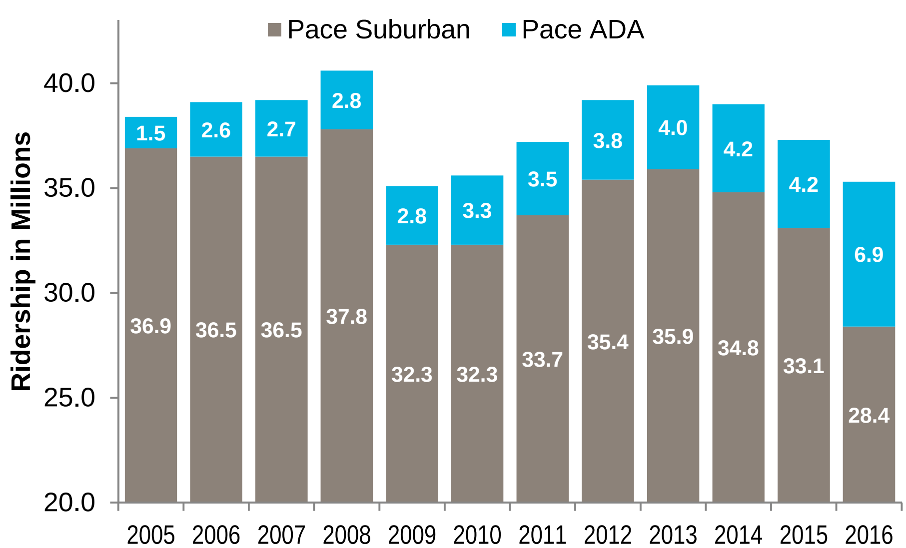
Table 3 and **Figure 3** display annual Pace ridership including both Pace fixed-route and ADA service.

Table 3: Annual Pace System Ridership (in millions)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Pace Suburban	36.9	36.5	36.5	37.8	32.3	32.3	33.7	35.4	35.9	34.8	33.1	28.4
Pace ADA	1.5	2.6	2.7	2.8	2.8	3.3	3.5	3.8	4.0	4.2	4.2	6.9
System	**38.4**	**39.1**	**39.2**	**40.6**	**35.1**	**35.6**	**37.2**	**39.2**	**39.9**	**39.0**	**37.3**	**35.3**

Source: RTA 2016 Ridership Report

Figure 3: Annual Pace System Ridership (2005-2015)



Source: RTA 2016 Ridership Report

Alignments

Pace fixed routes fall into four main categories: CTA Connector, Suburban Links, Intra-Community, and Commuter Links. Pace also operates other non-fixed or non-regular services, including Special Event routes. In terms of average daily ridership, the CTA Connector routes carry by far the greatest proportion of riders—71 percent in 2015. This is followed by Suburban Links with 14 percent, Intra-Community with 11 percent, and Commuter Links with four percent.

Table 4 shows the ten routes with the highest average daily ridership in 2015. Of these 10 routes, nine are designated as CTA Connectors, while the tenth, the 159th St Route, is a Suburban Links bus. They are located primarily within three Pace divisions: South, West, and Northwest, with one in the Southwest division.

Table 4: Top Pace Routes by Average Daily Ridership (2015)

Route #	Name	Route Type	Average Daily Riders
352	Halsted	CTA Connector	5,612
381	95th Street	CTA Connector	3,899
290	Touhy Avenue	CTA Connector	3,341
270	Milwaukee Avenue	CTA Connector	3,029
307	Harlem	CTA Connector	2,879
250	Dempster Street	CTA Connector	2,617
349	South Western	CTA Connector	2,558
322	Cermak Road - 22nd Street	CTA Connector	2,413
318	West North Avenue	CTA Connector	2,364
364	159th Street	Suburban Links	2,345

Source: Pace data

Many Pace routes operate within the framework of a “pulse” network; in this scenario, buses pick up passengers along the fixed routes and converge at a common location. The schedules of such routes are planned so that buses arrive at or around the same time, and similarly depart around the same time. This type of service scheduling provides passengers with increased opportunities to transfer to other services which can then transport them to their final destination. Pace buses pulse at several locations throughout the metropolitan area, such as the Schaumburg and Aurora transit centers in DuPage County, Elgin transit center in Kane County, and the Chicago Heights Transfer Center and the Harvey Transportation Center in Cook County.[6] Pace owns and operates 12 park & ride lots, some of which are located at transit centers, and also provides service to 17 park & ride lots that are not owned by Pace.

Other Pace alignments primarily serve the purpose of circulating passengers in loop-like routes that access various nodes, activity centers, and prominent land uses within communities. These may include shopping centers, schools, municipal centers, hospitals, sporting and entertainment venues, among others. Pace also operates several employment shuttle services that are subsidized by several major employers.

Finally, Pace has been implementing a number of strategies to provide better and faster service to riders. For example, in the “Bus On Shoulder” service, certain bus routes can utilize the shoulder of the I-55 / Stevenson Expressway—an allowance that was coordinated with the Illinois Legislature, IDOT, the Illinois State Police, and RTA. By allowing the bus to drive on a modified shoulder in order to by-pass slow traffic, this pilot program has proved to be an affordable way to keep buses on schedule and reduce customers’ travel time. Pace is expanding this program (implemented in 2011) to other services that currently or could potentially provide service along area expressways. Pace also offers “Pace Express” service, as well as “Express Service to Popular Destinations” to speed up travelers’ journeys. In 2018, Pace will

[6] Pace Suburban Bus. www.pacebus.com (2014)

launch its new rapid transit network, Pulse, to provide riders with fast, frequent, and reliable bus service along heavily traveled corridors. The first Pulse line is along Milwaukee Avenue and will include limited-stop express service, Wi-Fi enabled vehicles, weather-protected stations, and real-time bus arrival signage.

Bus Technologies

Pace has a fleet of over 440 40' standard buses, as well as over 300 shorter buses.[7] 100 percent of Pace vehicles are ADA-accessible. In total, Pace operates about 700 fixed-route vehicles and 1,800 smaller transit vehicles through its paratransit and vanpool programs.[8] Buses are also equipped with automated vehicle locator devices, boarding / alighting sensor counts, and onboard computers to record and transmit this data wirelessly.

Communications

On the Pace website, visitors can access the Passenger Notices page with information on temporary detours and permanent schedule adjustments to Pace routes (see **Figure 4**). Customers can sign up for email notifications on the website, specifying the type of information they'd like to receive, including service updates connected to particular Pace routes. Pace also communicates with passengers using customer alerts posted on its Twitter feed and Facebook page.

Figure 4: Sample Pace Website Passenger Notices

Route	Notice Type	End Date
223 Elk Grove - Rosemont CTA Station	Bus Stop Restriction	12/31/2017
226 Oakton Street	Bus Stop Restriction	12/31/2017
234 Wheeling - Des Plaines	Detour Alert	12/31/2017
332 River Road - York Road	Detour Alert	12/31/2017
348 Harvey - Riverdale - Blue Island	Detour Update	12/31/2017
352 Halsted	Temporary Bus Stop Relocation	8/9/2017
359 Robbins / South Kedzie Avenue	Detour Notice	3/1/2017
381 95th Street	Temporary Bus Stop Relocation	8/9/2017
384 Narragansett - Ridgeland	Service Change	3/30/2017
395 95th/Dan Ryan CTA Station - UPS Hodgkins	Temporary Bus Stop Relocation	8/9/2017
422 Linden CTA/Glenview/Northbrook Court	Service Clarification	3/1/2017
465 Belmont Station-Esplanade Shuttle Bug	Public Hearing	2/28/2017
504 South Joliet	Detour	12/31/2017
533 Northeast Aurora	Routing Change	3/26/2017
540 Farnsworth Avenue	Routing Change	3/26/2017
547 Wing Park	Detour Notice	12/31/2017
562 Gurnee via Sunset	Detour Update	3/5/2017
565 Grand Avenue	Pases Publicados Sólo	3/27/2017
565 Grand Avenue	Posted Stops Only	3/27/2017
569 Lewis	Detour Extended	12/31/2017
574 CLC - Hawthorn Mall	Service Change	3/27/2017
600 Rosemont - Schaumburg Express	Detour Notice	12/13/2017
606 Rosemont - Schaumburg Limited	Mejoramientos Al Horario	4/1/2017
606 Rosemont - Schaumburg Limited	Detour Notice	12/13/2017
606 Rosemont - Schaumburg Limited	Bus Stop Restrictions	12/31/2017
606 Rosemont - Schaumburg Limited	Weekend Schedule Improvements	4/1/2017

Source: https://www.pacebus.com/sub/schedules/route_notices.asp

[7] Regional Transportation Authority Mapping and Statistics (RTAMS). (2017).
[8] Regional Transportation Authority Mapping and Statistics (RTAMS). (2014).

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3. Climate and Flooding in Chicagoland

3.1 Chicago Climate

Historically, the City of Chicago receives about 34 inches of precipitation annually,[9] and localized small-scale flooding is frequent. Chicago was built on flat marshland, which makes it difficult for stormwater and runoff to drain from the land. In many areas of the region, urbanization occurred long before modern stormwater management rules were in place. For these reasons, Chicago's history has no shortage of flood events—NOAA reports 29 significant flood events between 1950 and 2005 in Cook County. In 1954, a foot of rain fell during one week, resulting in $25 million in damage. In 1987, nine inches fell in a day, affecting 15,000 buildings and leaving area roads and expressways under water. A rainy month and one large storm in July 1996 caused $45 million in direct damages. [10] Heavy downpours in 2002 shut down interstates and underpasses of Lake Shore Drive. The remnants of hurricane Ike in 2008 caused flash flooding in many waterways; many streets were closed and thousands were evacuated, not to mention the flooding of the Blue Line near the Des Plaines River and suspension of service between Rosemont and O'Hare. In 2010, interstates and hundreds of streets were flooded as a three-day storm covered the area; FEMA committed over $300 million in assistance in Cook County alone for this event. A 2011 storm event left roadways and basements flooded, water more than 10 feet deep on I-57, and rail tracks on CTA's Red, Blue, and Pink lines flooded.[11] In April 2013, Naperville, Elmhurst, and Aurora saw more than seven inches of rain in two days, and river crests along the Des Plaines, Vermilion, and North Branch of the Chicago River (among others) broke records.[12] The list goes on and on.

Source: Steve Miller/WBBM

To handle the precipitation, the City of Chicago and many older suburban Cook County communities / stormwater management districts have combined sewer systems that collect both wastewater and stormwater and are generally designed to accommodate a five-year storm event. This water is then conveyed to interceptor sewers and on to wastewater treatment plants. After treatment, the water is discharged into local waterways. During storms that exceed the sewer system's capacity, there is often localized flooding and combined sewer overflow that is discharged untreated into area waterways. Some communities have separate sewer systems for wastewater and stormwater, which may still be subject to overflow depending upon capacity and age.

3.2 Understanding Why, Where, and When Flooding Happens

Flooding is a regular, natural process that is nevertheless variable. Spring runoff is cyclical and thus reasonably predictable, while large rainwater events like hurricanes can cause unpredictable flooding. The floodplains adjacent to streams tend to be frequently inundated. Areas in the flood plain fringe are inundated by less frequent floods. The flood fringe is not always immediately recognizable.[13] The floodplain functions as a temporary storage space for floodwaters. In our analysis, we highlight as risk areas the FEMA 100- and 500-year floodplain based on the expectation that these areas are more likely to experience flood events that would impact bus transit operations. These events have a one percent and 0.2 percent chance of being equaled or exceeded in any given year, respectively.

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[9] http://www.usclimatedata.com/climate/chicago/illinois/united-states/usil0225
[10] National Weather Service, NOAA. http://www.weather.gov/lot/top20events_1900to1999.
[11] National Weather Service, NOAA. http://www.weather.gov/lot/science
[12] National Weather Service, NOAA. http://www.weather.gov/lot/2013Apr1718
[13] USDA, FISRWG, *Stream Corridor Restoration: Principles, Processes, and Practices*. (2001).

The frequency of floods along streams or rivers is estimated by completing statistical analysis of the historical maximum flood discharges in each year for which gage data is available. Where available river flow records are insufficient to estimate flood frequency for a given location, rainfall runoff models are used to estimate the amount and rate of flow generated by the watershed. The frequency of floods is estimated based on the rainfall frequency and duration of the storm. Regional statistical analysis methods are also available to complete these analyses when detailed historic flood discharge information is available from nearby similar watersheds.

The Federal Emergency Management Agency has available Flood Insurance Rate Maps (FIRM) that illustrate flood stage elevations and inundation limits for a variety of flood recurrence intervals and for selected streams within most urban communities. This agency has generated these maps by analyzing river geometry and flow characteristics in computer models. These models estimate flood levels based on river geometry obtained through land and bathymetric surveys and considering the unique characteristics of each stream that influence flood stage. For streams that have not been studied or mapped by FEMA, a stream specific computer model can be used to identify flood stage data once the flood discharges have been estimated. These maps are periodically updated; for example, the current City of Chicago FIRM is from 2008 and the first was produced in 1980. Local agencies, such as the MWRD and county stormwater departments or commissions, also create floodplain maps of different recurrence levels. The major floodplain locations in the Chicago area are chiefly along the Des Plaines River, DuPage River, Chicago River (North Branch watershed) and Salt Creek Watershed.

The Federal FIRM maps and regional flood studies are generally focused on river and stream system flooding. Local flood problems that are often not the focus of federal flood documentation and not always influenced by river or stream flooding is sometimes referred to as hot-spot flooding, This type of flooding can occur in places where the stormwater infrastructure no longer has the capacity to handle the amount of runoff generated by a rainstorm. Undersized storm sewers that are not directly influenced by a larger stream system studied by FEMA can often cause local flood problems.

Beyond the issue of riverine flooding, hot-spot flooding can occur in places where the stormwater infrastructure no longer has the capacity to handle the amount of runoff generated. As shown in **Figure 5**, the amount of impervious surface in an area significantly impacts the amount of water runoff generated. Urban areas like the Chicago region have more impervious surface, which can more than double the amount of runoff in comparison with less urbanized locations. This increased runoff can accumulate in low-lying areas such as viaducts, blocking buses and other vehicles from traversing the location. The City of Chicago alone has over 1,500 viaducts, of which nearly 200 have been identified as “troubled” by frequent flooding in prior CTA analysis (see **Figure 6**).

Local stormwater system capacity is normally designed to handle rain events that have a 10 to 20 percent chance of exceedance in any given year. System planning needs to compare the likelihood and frequency of flood risk against flood mitigation cost to inform decision making. Local stormwater systems put in place years ago were historically designed for five- or 10- year events. This was likely due to the high cost to build greater capacity and perhaps a lack of understanding of the impact of future urbanization on these flood conveyance systems. The cost to implement systems that could manage events with lesser recurrence intervals, such as 25-to 500-year events, would entail significantly higher costs. As existing stormwater systems age, the amount of runoff increases due to continuing urbanization, and the influences of urbanization on weather patterns and climate change make matters worse, the systems are more frequently overwhelmed. As well, areas that may not have flooded in the past are now experiencing problems.

Figure 5: The effects of urbanization on evapotranspiration, infiltration, and runoff

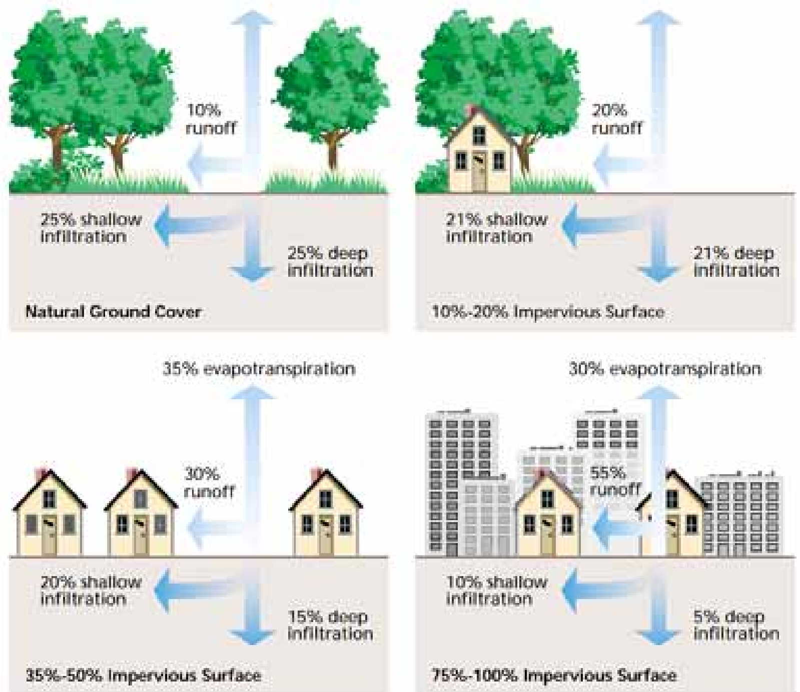
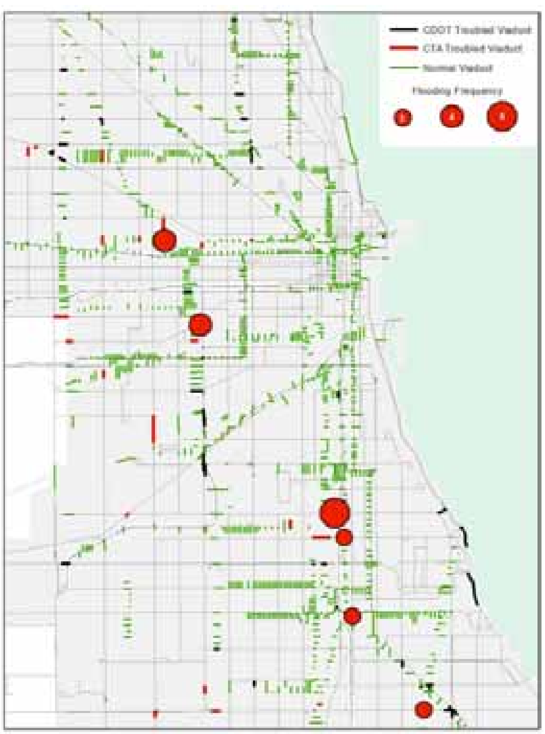


Image Source: USDA, FISRWG, *Stream Corridor Restoration: Principles, Processes, and Practices.* (2001).

Figure 6: Chicago Viaducts



According to the Chicago Office of Emergency Management's *All Hazard Mitigation Plan*, the probability of flood hazards is moderately high, the impact is moderately significant, and the risk assessment receives a rating verging on severe—the higher rating relative to other natural hazards due to the high frequency of occurrence.[14] The OEMC *All Hazard Mitigation Plan* recommends increasing the open space and natural features in high flood hazard areas in coordination with the MWRD, as well as completing the Tunnel and Reservoir Program (TARP)—aka "Deep Tunnel Project"—in order to mitigate flood risk. MWRD currently expects to complete TARP by 2029.

Image Source: FTA Report 0070 (2013), p. 96.

[14] The risk assessment framework is that risk rating is the probability multiplied by impact. A high probability is a hazard that would happen more than 50 times in 50 years, and a significant impact would have parameters such as 40% of population affected, direct damages over $100 million and/or economic damages over $1 billion, disruption of critical infrastructure for one week and of essential services for over two weeks, or some combination thereof. Ratings are given on a graphical scale which does not greater precision here, but flood hazards are midway between moderate and high probability, and closer to significant impact than moderate. They are based on historical data, and thus do not include the potential impacts of climate change.

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4. Analyzing Flooding Impacts in Chicago Area

4.1 Data

A robust set of quantitative data was collected for the project, much of it loaded into the project GIS database. The data are described and presented in tabular format in the Task 2 Technical Memorandum, along with a series of maps in that memorandum's Appendix A.

4.1.1 Contextual Data

Geospatial data on the location and characteristics of FEMA flood risk zones were gathered to overlay with bus transit route and stop locations. These were supplemented with locally updated maps from Cook County (MWRD), DuPage County, and Will County.

Figure 7 shows where these flood zones intersect bus routes in the RTA service area.

The Chicago Department of Transportation (CDOT) provided geospatial data on the location of viaducts. Viaduct flooding is a major issue for transit operations, as reported by CTA and OEMC. Cook County Department of Homeland Security and Emergency Management (CCDHSEM) also provided locations of road closures on County roads from the April 2013 flood event. Socio-economic geospatial data (including population, employment, and median household income) were gathered for the RTA service area from the US Census, CMAP and RTAMS.

4.1.2 CTA Data

Shapefiles with CTA bus routes and stops were used for mapping and analysis purposes. CTA provided data on average daily and total annual ridership by bus route, as well as boardings by stop. Data on revenue mile and hours by route, as well as existing daily estimated costs and revenue by route, were provided and are used in the reroute planning in **7.1**.

In terms of data on historic flooding incidents, data from CTA's CleverCAD (a computer-aided dispatch technology, in place after 2013) system and prior manual notation (2010-2012) provides information of the date, time, location, and type of event, along with additional notes from the operator, the route number, and the disposition of the event (e.g., whether and how the bus was able to reroute in the event of street or viaduct flooding). These data were plotted in the project team GIS and their density calculated to generate flooding incident hot spots (**Figure 8**).

4.1.3 Pace Data

GTFS data on Pace bus routes and stops were used for mapping and analysis purposes. Representatives from Pace operating divisions provided information on the location of recurrent flooding areas and typical reroutes, which were used to generate a shapefile with point data of flooding noted by Pace. Ridership information by route from the second quarter of 2016 was used in identifying and sorting bus routes for analysis. The Pace dataset also included information on revenue and costs for use in reroute impact analysis.

Figure 7: Intersection of Bus Routes with Flood Zones

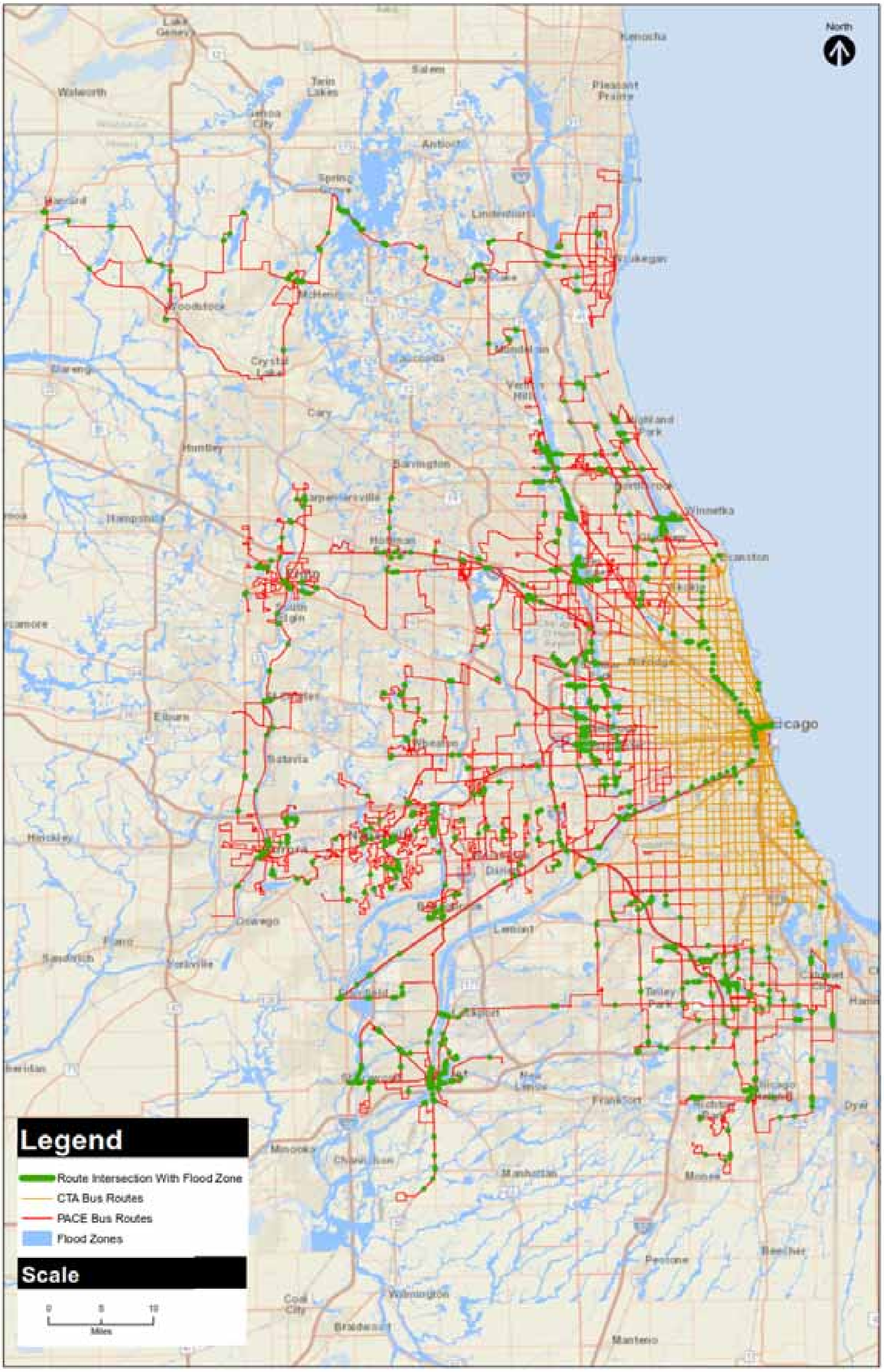
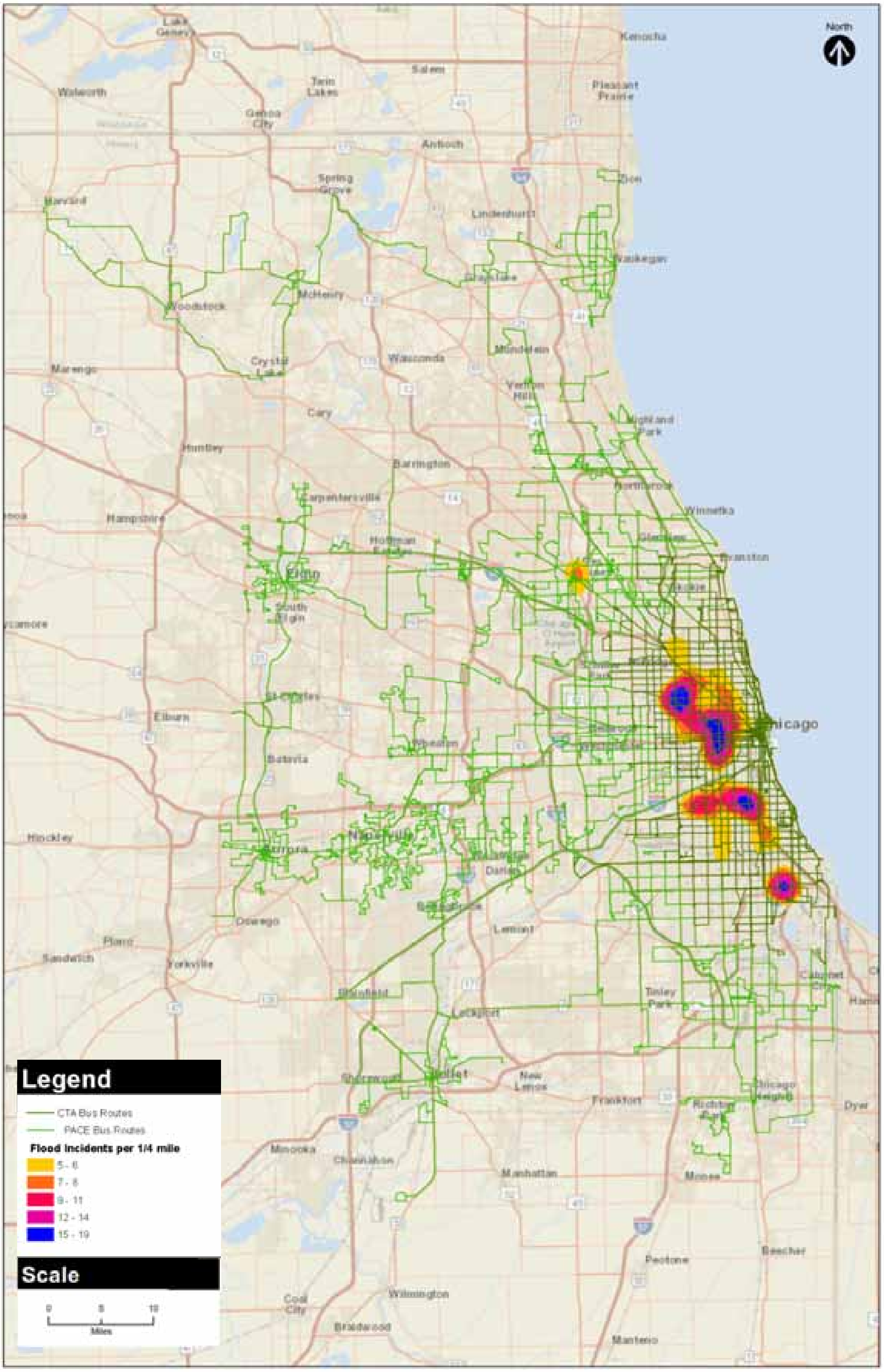


Figure 8: Bus Routes with CTA-reported Flood Incident Hotspots



4.2 Stakeholder Interviews

A series of stakeholder interviews were conducted with agencies or groups responsible for planning for stormwater management and/or transportation infrastructure for the purpose of identifying interesting data sources and providing insight into flood-prone areas and mitigation tactics in place or planned.

Organization	Contact
Chicago Department of Transportation (CDOT)	Joe Alonzo, Transportation Planner Mike Drake, General Superintendent, Division of In-House Construction Tony Rainey, Civil Engineer
Chicago Department of Water Management (CDM)	Sid Osakada, Coordinating Engineer Anupam Verma, PE, Managing Engineer - Water Management
Chicago Metropolitan Agency for Planning (CMAP)	Jason Navota, Director Nora Beck, Senior Planner
Chicago Office of Emergency Management and Communications (OEMC)	Chris Pettineo, Manager of Emergency Management Services Peter Raber, Senior Emergency Management Coordinator
Cook County Department of Transportation and Highways (CCDOTH)	Maria Choca-Urban, Director of Strategic Planning and Policy
Cook County Department of Homeland Security and Emergency Management (CCDHSEM)	Dana Curtiss, Operations Information Support Manager, Office of the President
DuPage County Stormwater Management	Christine Klepp, Senior Project Engineer, Stormwater Management Chris Vonnahme, Senior Project Engineer, Dept of Economic Development & Planning
DuPage County Department of Transportation (DCDOT)	John Loper, Director of Transportation Planning
Illinois Department of Transportation (IDOT)	Rick Wojcik, IDOT Hydraulics
Metropolitan Water Reclamation District (MWRD)	Joe Kratzer, PE, CFM, Managing Civil Engineer, Engineering Dept/Stormwater Management Greg Koch, PE, Principal Civil Engineer, Engineering Dept/Stormwater Management
US Army Corps of Engineers (USACE)	Sarah Brodcinski Sue Davis, Planning Division Chief
Will County Division of Transportation (WCDOT)	Christina Kupkowski, PE, Phase I Project Manager Raymond A. Semplinski, Maintenance Administrator

Key findings from these interviews include:

- Documentation of actual, historical flood events is inconsistent among agencies and across the RTA service area. Technology in many agencies for recording incidents is evolving, from paper-based notation and decentralized storage, to GIS records, to sophisticated operations systems that provide access to and collect data from a wide range of agency stakeholders. Understanding where flood incidents are located is a combination of data analysis and discussions with knowledgeable parties.
- In some instances, urban flooding is caused by adjacency or proximity to river and stream floodplains and floodways. However, within the boundaries of this study area, flooding is more often associated with stormwater infrastructure capacity deficiencies. The systems are not designed to accommodate significant storm event runoff without significant water backups and inundation. Low-lying areas, such as viaducts, are particularly problematic.
- Many stormwater management departments have projects underway across the region that will serve to either reduce flood risk area or increase stormwater capacity. Analysis presented in this study should be checked with these local experts to ensure changes to the project conclusions as local projects are implemented in the future The current perception of potential risk areas could change as progress is made on these initiatives. Some of these projects are locally/municipally-managed and funded, and some are conducted in coordination with county and state stormwater and transportation agencies.
- FEMA-compliant All-Hazard Mitigation Plans or Natural Hazard Mitigation Plans contain good sources of information on flood-prone areas and community-specific assessments of risk and priority. Since preparing its last regional comprehensive plan, GO TO 2040, CMAP has undertaken substantial consideration of climate change and stormwater management for inclusion in the ON TO 2050 plan.
- Many local and regional organizations, with both jurisdictional responsibility as well as advocacy missions, are preparing wide-area stormwater management programs and plans. RTA, CTA, Pace and CMAP project team members should keep informed of activities undertaken these groups to take advantage of their knowledge and analysis, and avoid duplication of work efforts.

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5. Risk Assessment of System Routes

5.1 Scenarios

The data described in the previous section does not provide a clear indication of which CTA and Pace routes should filter to the top of the list for more detailed analysis later in the project. In the interest of engaging input from the project's steering committee composed of representatives from RTA, CTA and Pace, the project team prepared five alternative selection scenarios to identify potentially vulnerable bus routes. These scenarios were applied to both the Pace and CTA bus networks and analyzed to the extent of availability of data.

The key criteria that appear in the scenario permutations outlined below include route ridership, presence of transit agency-reported flooding events, count of route segments in flood zones, and system connectivity (defined as the number of connections the route has with CTA and Metra rail stations). Detailed data related to primary filtering and sorting criteria, as well as contextual socio-economic factors about the selected routes were presented in Task 2 Technical Memorandum.

	Criteria and Ranking
Scenario A	Routes with reported flooding and located in flood zones, ranked by ridership
Scenario B	Routes with reported flooding, ranked by ridership
Scenario C	Routes in flood zones, ranked by ridership
Scenario D	Routes with reported flooding or located in flood zones, ranked by ridership
Scenario E	Routes with reported flooding, ranked by system connectivity and ridership

5.2 Top CTA and Pace Routes Affected by Flooding

The CTA and Pace bus routes were analyzed according to the criteria summarized above and ranked according to their performance within each scenario (see **Appendix A: Task 2 Technical Memorandum: Identification of Flooding Impacts**).

For the CTA bus routes, 56 of the 130 bus routes appeared as priorities according to Scenarios A through E. There are a varied numbers of routes within in each ranking (usually between 20 and 25) in order to ensure that the thresholds were not arbitrary—they were created at natural break points in the data. Four CTA routes (3, 8, 9, 20) appeared in all five scenarios, three CTA routes (4, 49, J14) appeared in four of five scenarios.

The same process was conducted for the Pace bus network, and of the 212 Pace bus routes, 54 appeared as priorities according to Scenarios A through E. One Pace route (208) appeared in all five scenarios, and nine Pace routes (234, 303, 318, 322, 330, 364, 381, 386, 626) appeared in four scenarios.

Bus routes that were prioritized were then analyzed according to the socioeconomic characteristics of the populations they traverse. Quarter-mile buffers were generated and intersected with CMAP 2014 data on population and employment counts per subzone in 2010 and projections for 2040. Proportional representations of population and employment counts were created for subzones that lay only partially within the quarter-mile radius. These same buffers were then intersected with ACS 2014 median household income data by tract. Using the proportional area of each tract that is located within the bus corridor, a weighted average median household income was created for each of the bus routes. The results of these analyses can be found in **Appendix A: Task 2 Technical Memorandum: Identification of Flooding Impacts**, with illustrative maps provided in that memorandum's appendix.

Figure 9: CTA Scenarios A-E

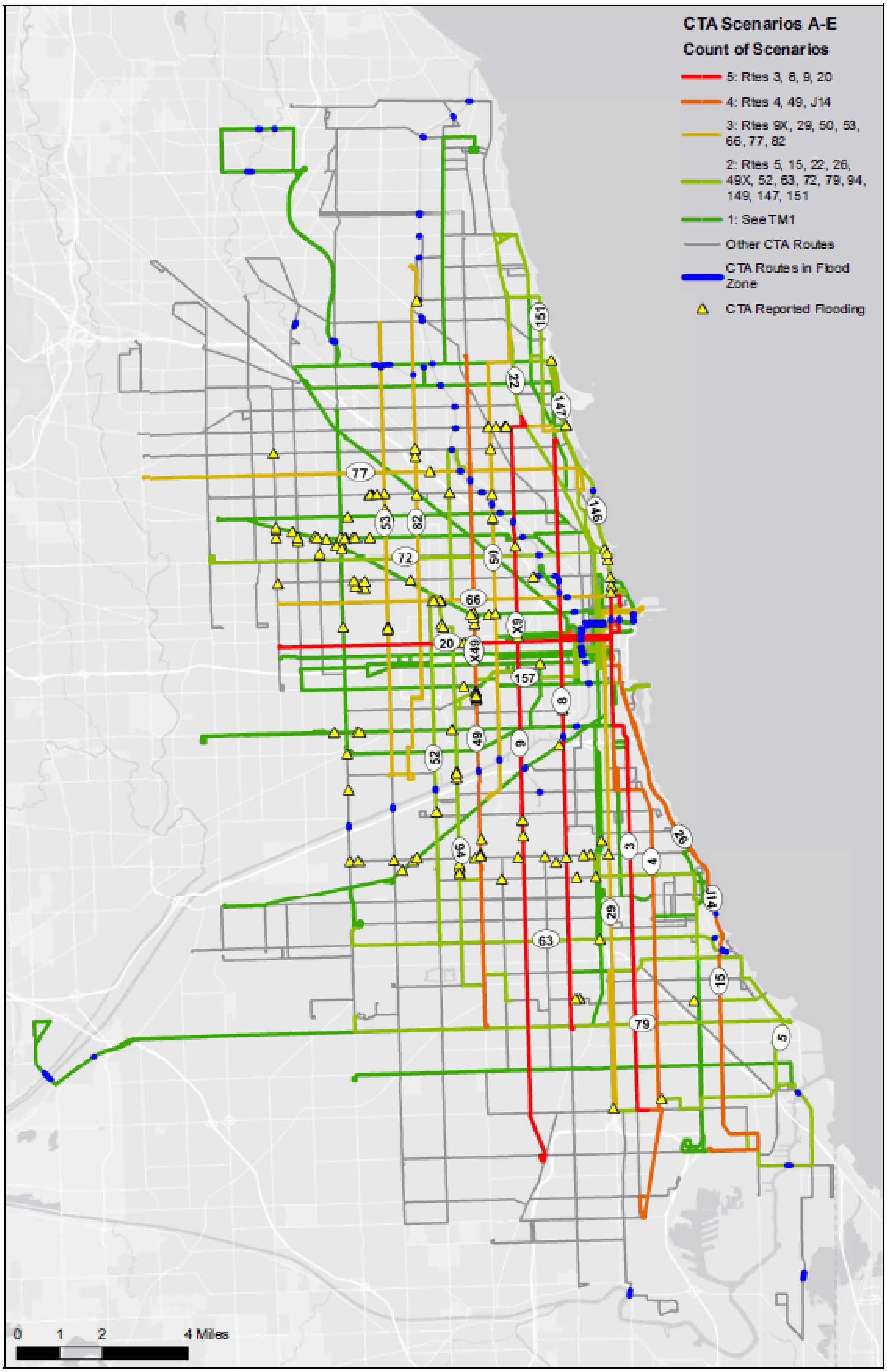
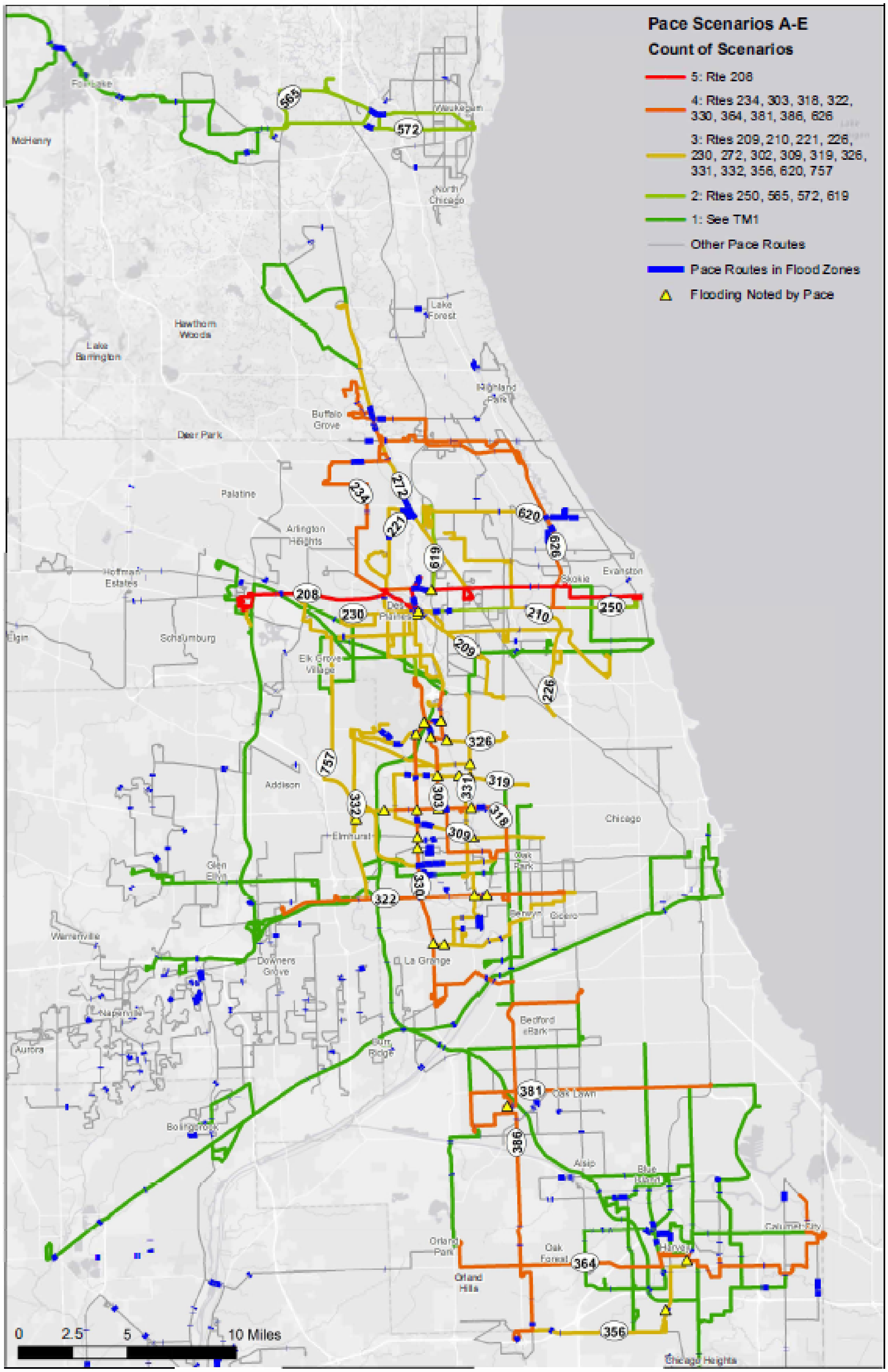


Figure 10: Pace Scenarios A-E



5.3 Scenario Selection

After discussion with CTA and Pace staff during the Task 2 Stakeholder Meeting in February 2017 and the Task 3 Stakeholder Meeting in May 2017, followed by further deliberation within each agency internally, final scenario selections were made. CTA decided to focus flooding impact analysis on the routes listed in **Table 5**, referred to as Scenario F. These routes were selected due to their role as the “workhorses” of the CTA network, moving large volumes of passengers across the city and making vital connections between transit modes, as well as connecting residential communities to downtown and other employment centers. Pace decided that they would most benefit from analysis of the routes in Scenario E.

Table 5: CTA and Pace Routes Selected for Reroute and Impact Analysis

CTA Scenario F Routes	
4	Cottage Grove
8	Halsted
9	Ashland
20	Madison
22	Clark
52	Kedzie/California
53	Pulaski
55	Garfield
62	Archer
66	Chicago
77	Belmont
79	79th
85	Central
92	Foster
147	Outer Drive Express
J14	Jeffery Jump
X49	Western Express

Pace Scenario E Routes	
208	Golf Road
209	Busse Highway
210	Lincoln Avenue
221	Wolf Road
226	Oakton Street
230	South Des Plaines
234	Wheeling - Des Plaines
272	Milwaukee Avenue North
302	Ogden - Stanley
303	Forest Park - Rosemont
309	Lake Street
318	West North Avenue
319	Grand Avenue
322	Cermak Road - 22nd Street
326	W Irving Park Road / Rosemont CTA to Norridge
330	Mannheim - LaGrange Roads
331	Cumberland - 5th Avenue
332	RT 83 / River Road - York Road
356	Harvey - Homewood - Tinley Park
364	159th Street
381	95th Street
386	South Harlem
565	Grand Avenue
572	Washington
619	Des Plaines Station - Willow Road Corridor
620	Yellow Line Dempster - Allstate
626	Skokie Valley Limited
757	Oak Park - Schaumburg Limited

6. Future Climate Change Impact on Flooding

6.1 Climate Studies in the Region

6.1.1 Chicago Climate Action Plan

The Chicago Climate Action Plan was an important precursor to the RTA's Green Transit and Resilience planning efforts. This comprehensive program looks to both the past and the future before laying out its action steps for a more resilient metropolis.

This study included extensive analysis (2008) by climate science experts and water resource engineers, who noted that climate change impacts—higher temperatures and greater precipitation in heavier rain events—will have a major impact on Chicago's infrastructure. Emissions levels will be significant here: under the high-emissions scenario, the projected costs of adaptation for government are nearly four times higher than the low-emissions scenario. Aside from the direct costs of increased maintenance and replacement of hard infrastructure like roadways, bridges, fleet vehicles, etc., there will be less tangible costs such public health problems arising from poor air quality and temperature extremes, more frequent disease outbreaks, crop damage from intense storm events or summer droughts, among other consequences of climate change.

The Chicago Climate Change Action Plan looks at the costs of adapting to more sustainable practices that would reduce emissions and thus climate impacts, and finds that sustainable practices (such as those that would result in resource efficiencies) could generate $400 million to $1.2 billion in savings each year by 2020. It also quantifies the increase in green jobs in order to achieve the plan's goals, as well as the jobs that would be created by achieving the goals. More detail on action steps for climate change resilience in the Chicago region can be found in **Appendix C: Best Practices**.

6.1.2 Center for Neighborhood Technology

In 2014, the Center for Neighborhood Technology examined the economic costs of urban flooding in Cook County. This report, "The Prevalence and Cost of Urban Flooding," found that between 2007 and 2011, 181,000 insurance claims added up to $773 million in damages, and there was no correlation between damage payouts and floodplains, either in number or value of claims. One pattern that was noticeable was that places that had flooded once were likely to flood again—and soon. Of the 115 survey respondents, 70 percent said they had been flooded three times or more in the last five years, and 20 percent had been flooded 10 times or more.

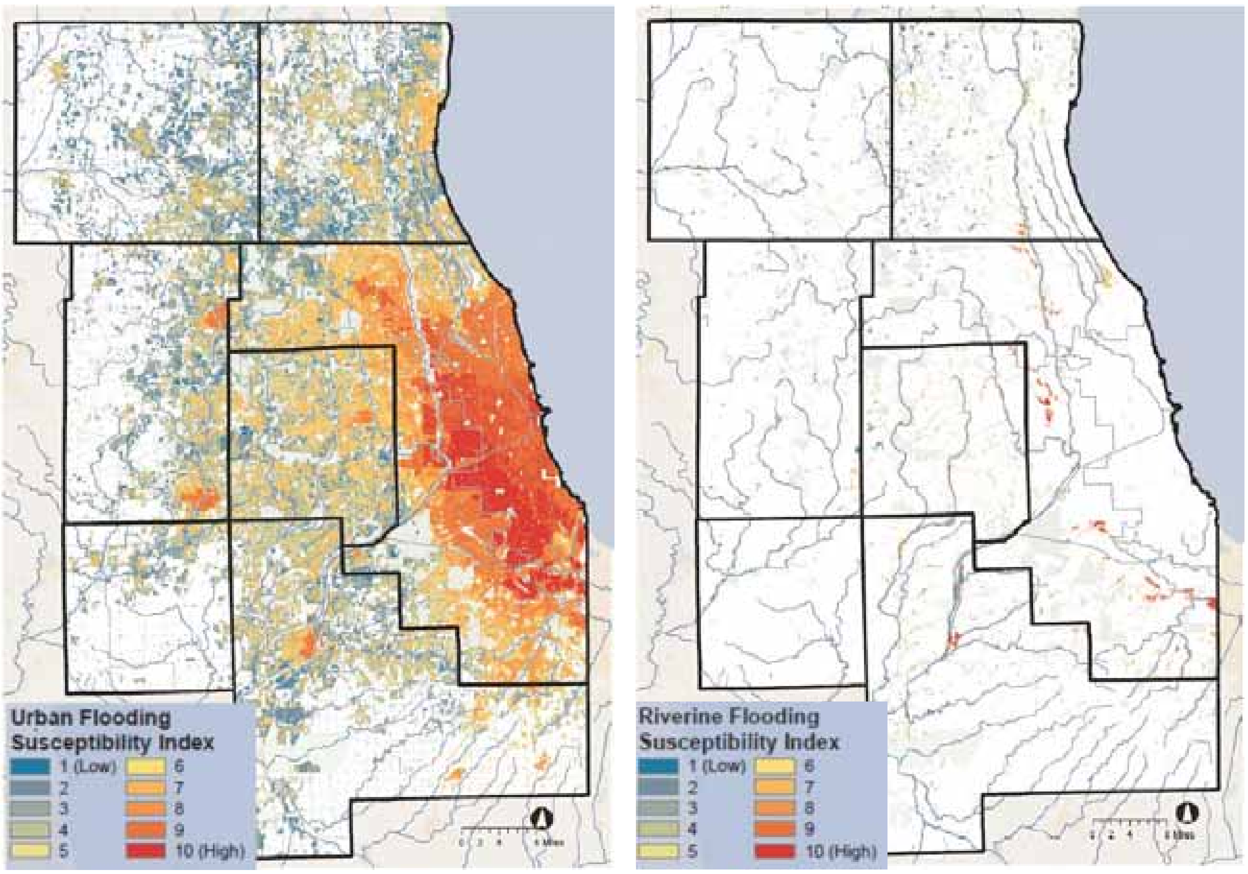
6.1.3 Illinois State Water Survey

A 2016 Illinois State Water Survey report, "Communicating the Impacts of Potential Future Climate Change on the Expected Frequency of Extreme Rainfall Events in Cook County, Illinois" sought to design a framework to translate future climate scenarios into something that local-level engineers and planners can use to quantify the impact of climate change. The output can then be used to inform and plan adaptive strategies for floodplain management. The research found that two of the three data sources (WCRP and ORNL) commonly used for climate change modeling considerably underestimated rainwater extremes in Cook County.

6.1.4 CMAP Stormwater Management Strategy Paper

While the Chicago Metropolitan Agency for Planning (CMAP) created regional indicators and targets related to greenhouse gas reduction in prior planning work, climate resilience is a new policy topic for the agency in the ON TO 2050 plan, not having been included in the GO TO 2040 plan. In support of ON TO 2050, the agency undertook detailed work to identify flooding risk areas across its seven-county region, illustrating the prevalence of flooding in the Chicago region and highlighting that climate change is anticipated to bring more flooding. Its December 2017 **Stormwater and Flooding** strategy paper notes other ongoing efforts to improve stormwater planning that are included in this document, such as MPC's effort to create a multi-jurisdictional modeling framework, updates to floodplain maps and CNT's urban flooding analysis. This paper also introduces CMAP's own urban and riverine flood susceptibility indices (**Figure 11**) which are complex multivariate algorithms that provide a GIS-driven calculation of risks based on features such as floodplain boundaries, elevation, soil types, drainage, combined sewer service areas, pervious cover, precipitation, development patterns, and other variables. Combining this index with the more vulnerable communities and economically disconnected areas (identified in by CMAP in its Inclusive Growth strategy paper) should serve as a useful prioritization structure moving forward.

Figure 11: CMAP Flooding Susceptibility Indices (Urban and Riverine Flooding)



Source: CMAP Stormwater and Flooding Strategy Paper. (2017)

6.2 Analysis of Future Areas of Risk for Bus Operations

As detailed in previous chapters, the process to identify bus routes of concern used a range of environmental, socio-economic and transit data to flag risks and areas of focus in the present period. In preparing mitigation strategies, it is prudent to look ahead to the extent possible to anticipate future conditions to avoid recommendations that might be short-lived or less relevant under future scenarios of climate change.

6.2.1 Input data

The analysis in this study to understand the potential implications of future climate change, and more-frequent, more severe storm events in the future was divided into two work streams to address the different root causes of flooding in urban vs. suburban / exurban contexts. A full presentation of this methodology, data, and illustrations is available in **Appendix B: Task 3 Technical Memorandum: Future Climate Change Impacts on Flooding**.

Analysis of urban flooding – with its origins typically in the built environment and ability of infrastructure to manage large amounts of stormwater – included the following base data:

- Locations of bus service interruption and route-level comments on typical flood problems reported by CTA staff
- Locations of bus service interruption and route-level comments on typical flood problems reported by Pace staff
- Road closures due to flooding reported by Cook County Department of Transportation and Highways
- Locations of viaducts (and annotation of “problematic” or “flood-prone” viaducts) by CDOT, CTA and Pace
- City of Chicago 311 reported flood calls, including water on pavement and flooded viaducts

Analysis of riverine flooding – with its origins typically in overbanking of water bodies (rivers, streams, reservoirs, etc.) from large amounts of stormwater – are more often located in suburban / exurban areas and included the following base data:

- Locations of bus service interruption and route-level comments on typical flood problems reported by CTA staff
- Locations of bus service interruption and route-level comments on typical flood problems reported by Pace staff
- FEMA 100-year and 500-year floodplain boundaries
- Local updates on floodplain boundaries / inundation areas from counties (Cook/MWRD, DuPage, Will)

Figure 12: OEMC Street Flood Calls, Density of CTA Flood Reports and CTA Scenario F Routes

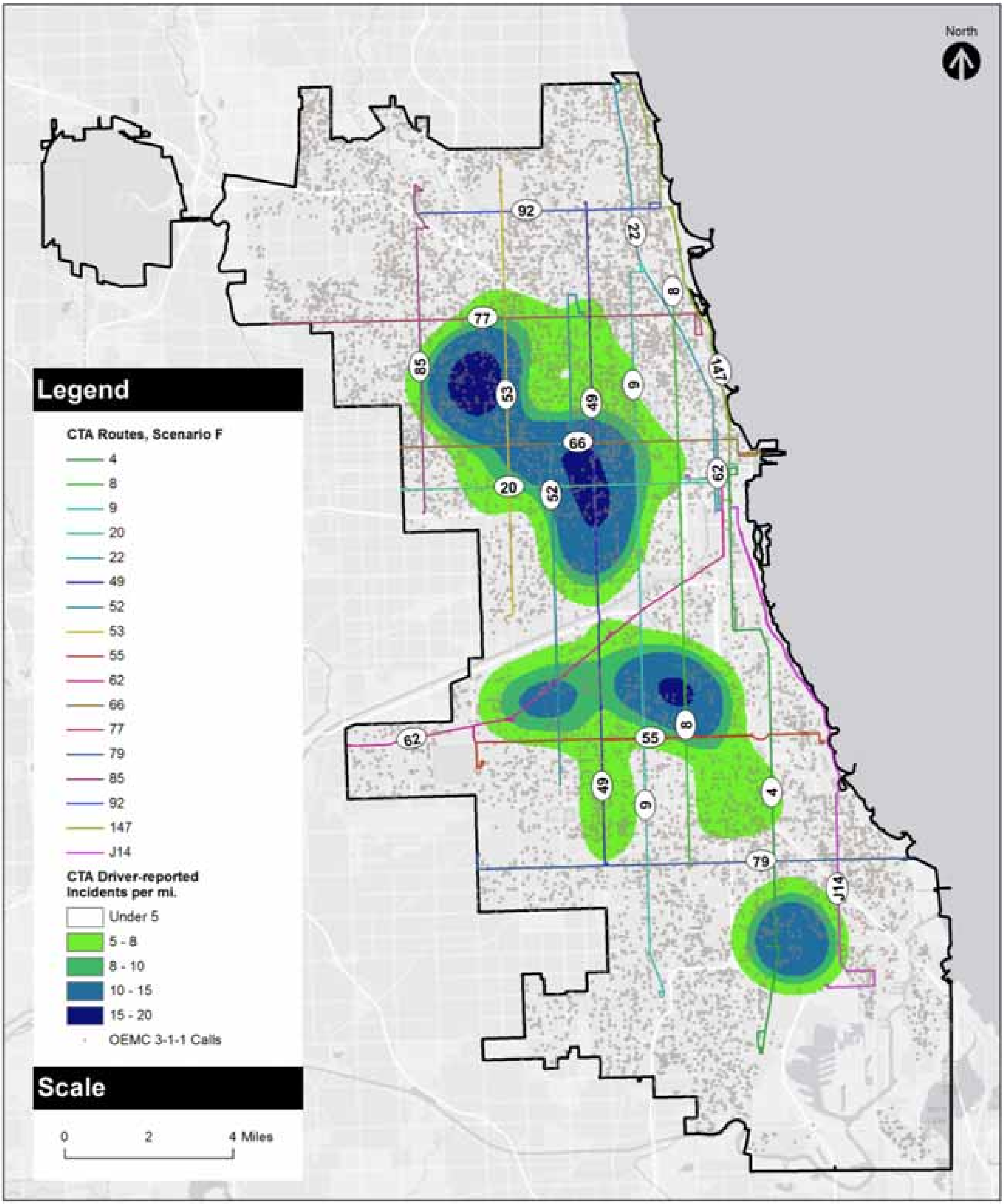


Figure 13: CDOT Viaducts, OEMC Viaduct Flood Calls, CTA Flood Reports, and CTA Scenario E Routes

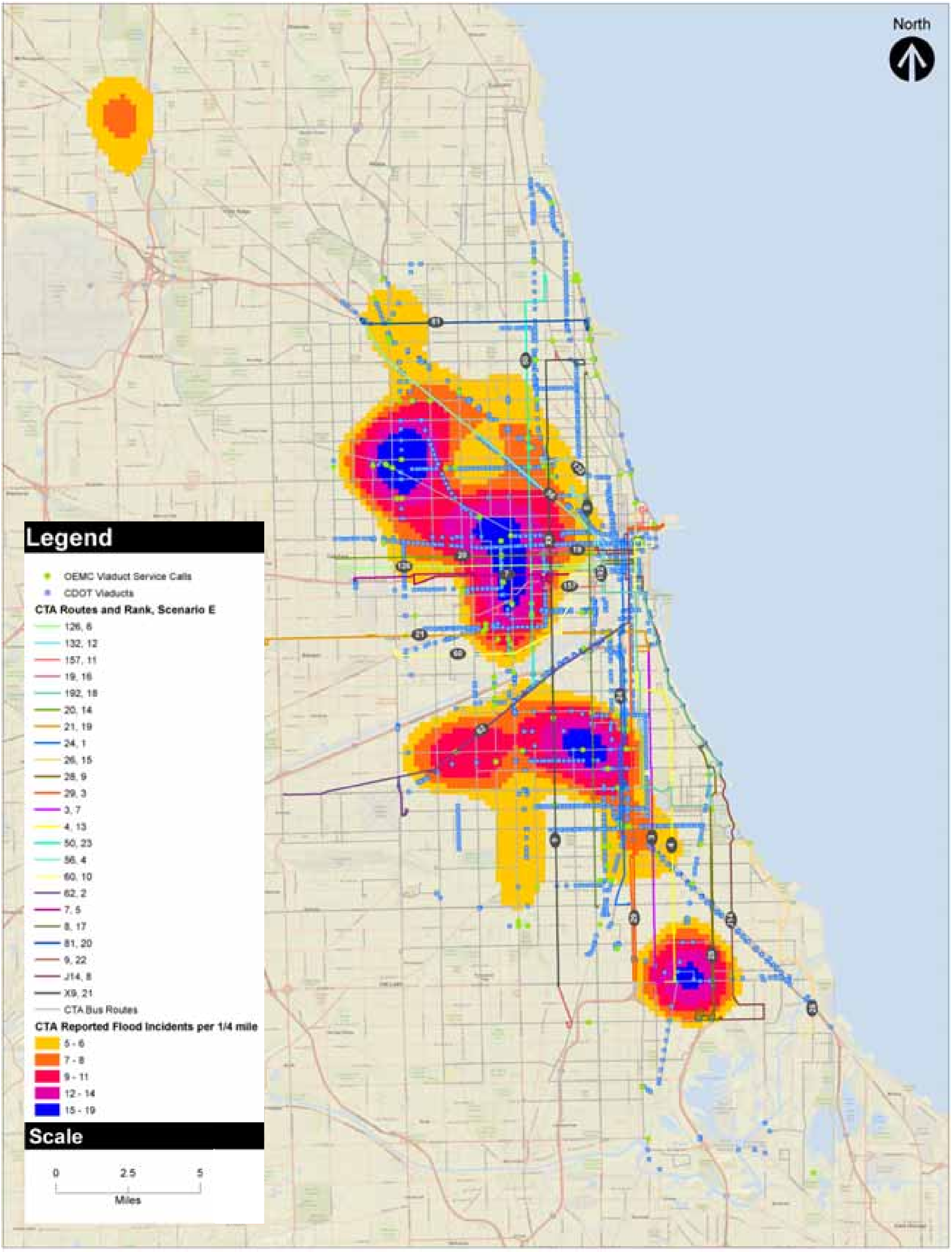


Figure 14: CTA Routes with Greatest OEMC 3-1-1 Calls on Street & Viaduct Flooding

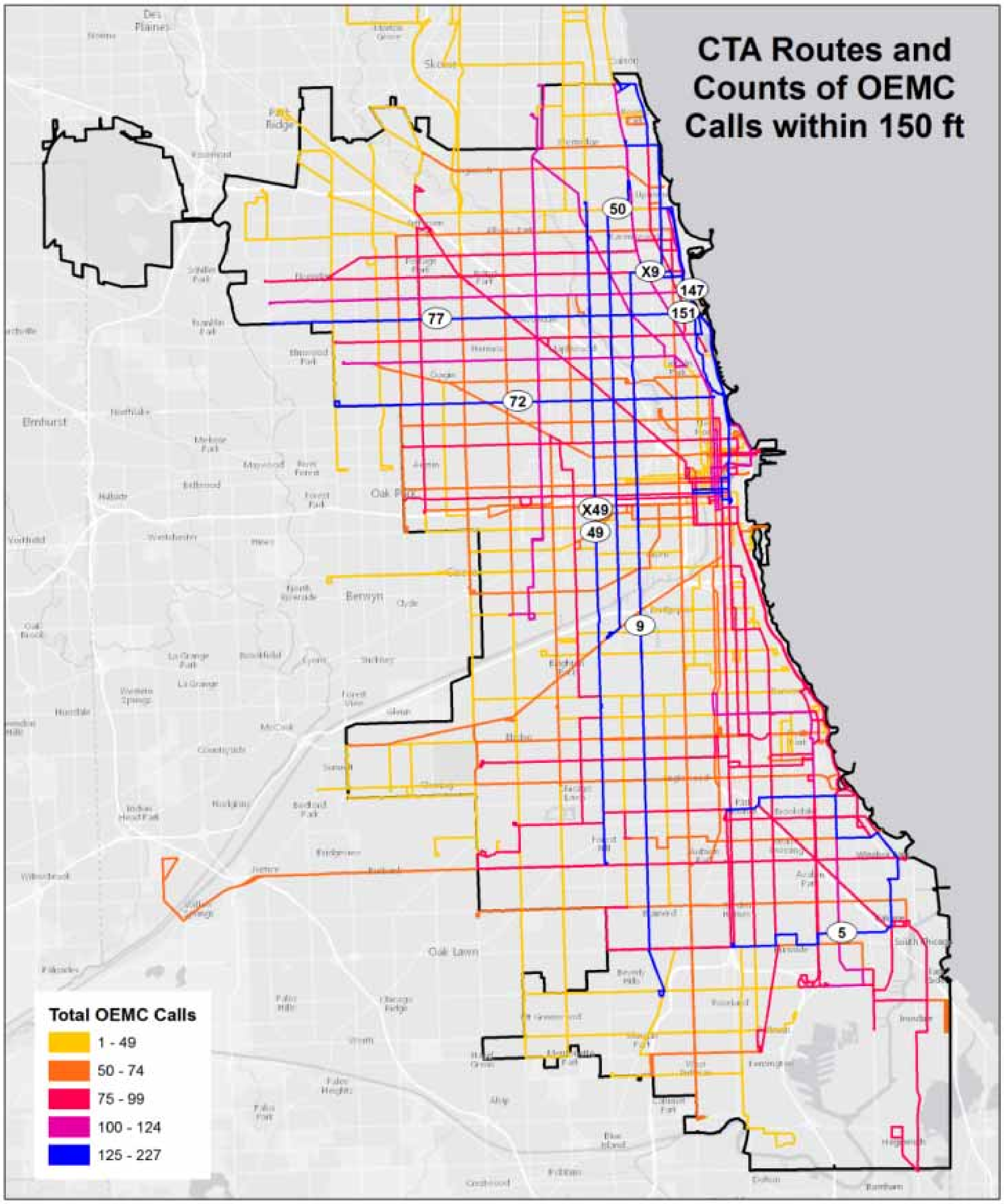
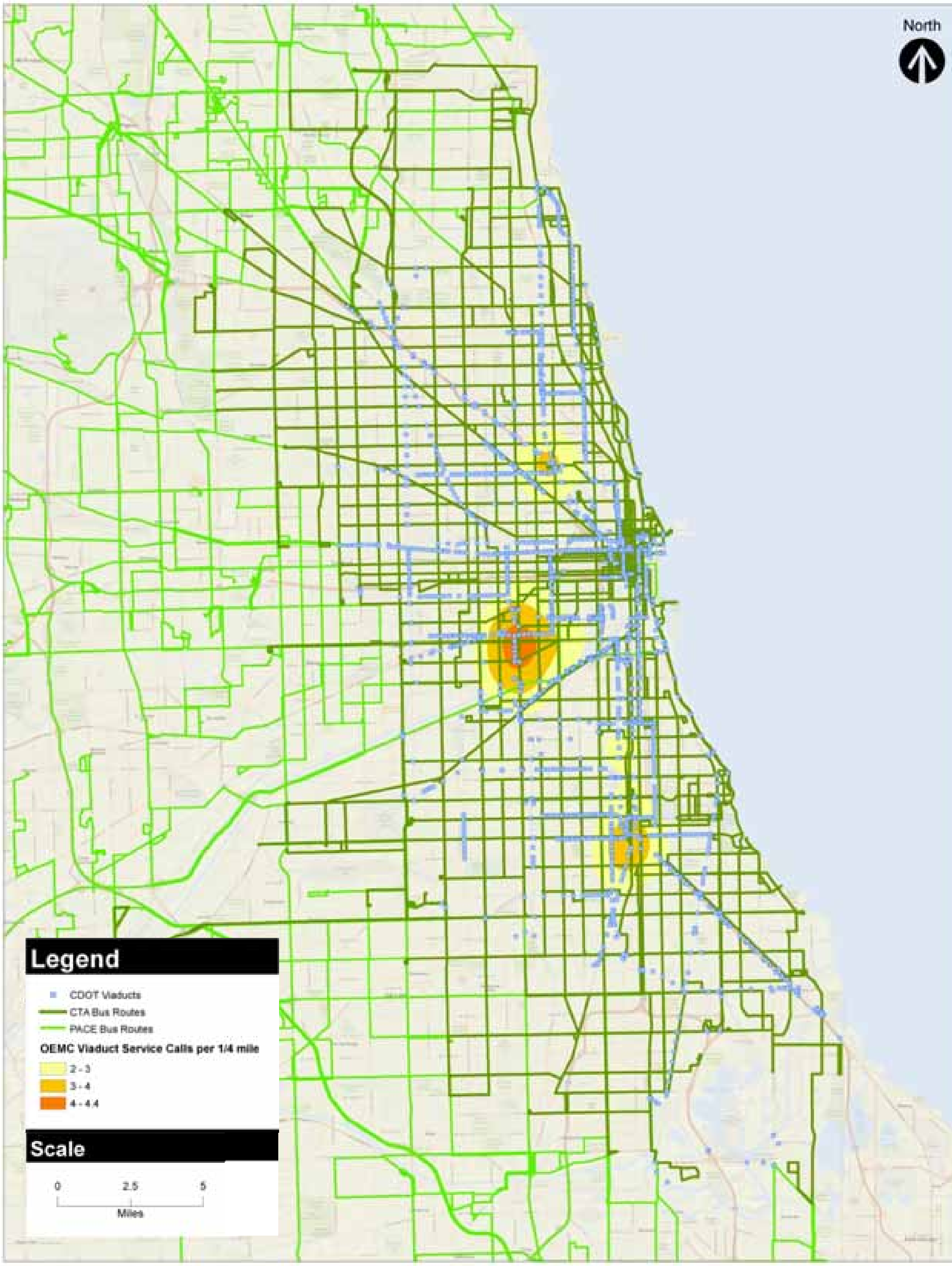


Figure 15: All Bus Routes, CDOT Viaducts and OEMC Viaduct Flood Calls



6.2.2 Methods for evaluating climate change data and potential future flooding patterns

6.2.2.1 Rainfall Frequency Adjustment for Climate Change

Stormwater and water resource engineers and scientists on this project team evaluated the potential increases in rainfall in the RTA service area by reviewing the climate change scenarios from the Chicago Area Climate Action Plan noted in the previous section and applying the increases for future climate change scenarios B1, A1B, and A2 to the Illinois State Water Survey's Bulletin 70 24-hr rainfall amounts. Team members interpolated existing and future rainfall frequency curves to identify the equivalent storm frequency for future rainfall events at mid-century 2017 and late-century 2017.

The term "Storm Recurrence Interval" refers to the chance or probability that a storm of a certain magnitude may occur or be exceeded in a given year. For example, a "100-year storm" has a 1 in 100 chance of occurring in any given year, or 1% chance (called the "Annual Exceedance Probability"). It does not mean that such a storm only occurs once every 100 years, and once happened, won't happen again in the same 100-year period.

Table 6: Mid-Century Adjusted Rainfall

Bulletin 70 Current Storm Recurrence Interval (Years)	Current Annual Exceedance Probability (%)	Bulletin 70 24-hr Rainfall	ISWS Contract Report 2016-05 Mid Century 24-hr Rainfall Adjustment (in)	Adjusted Rainfall (in)	Equivalent Bulletin 70 Future Storm Recurrence Interval (Years)
1	100%	2.51	0.46	2.97	1.9
2	50%	3.04	0.55	3.59	4.3
5	20%	3.80	0.70	4.50	11.0
10	10%	4.47	0.83	5.30	24.0
25	4%	5.51	0.83	6.34	44.0
50	2%	6.46	0.83	7.29	85.0
100	1%	7.58	0.83	8.41	150.0
500*	0.2%	11.10	0.83	11.93	620.0

*Extrapolated

Source: Illinois State Water Survey Contract Report 2016-05; ISWS Bulletin 70, AECOM and 2IM Group

Table 7: Late-Century Adjusted Rainfall

Bulletin 70 Current Storm Recurrence Interval (Years)	Current Annual Exceedance Probability (%)	Bulletin 70 24-hr Rainfall	ISWS Contract Report 2016-05 Mid Century 24-hr Rainfall Adjustment (in)	Adjusted Rainfall (in)	Equivalent Bulletin 70 Future Storm Recurrence Interval (Years)
1	100%	2.51	0.72	3.29	2.5
2	50%	3.04	0.83	3.87	5.4
5	20%	3.80	1.00	4.80	14
10	10%	4.47	1.15	5.62	28
25	4%	5.51	1.27	6.78	60
50	2%	6.46	1.38	7.84	110
100	1%	7.58	1.50	9.08	240
500*	0.2%	11.10	1.77	12.87	915

*Extrapolated

Source: Illinois State Water Survey Contract Report 2016-05; ISWS Bulletin 70, AECOM and 2IM Group

This generalized modeling of anticipated rainfall suggests storms of greater severity may occur more frequently in the future. That is….

For severe storms:

A 100-year storm mid-century could be like today's 150-year storm
A 100-year storm late-century could be like today's 240-year storm

For moderate storms:

A 5-year storm mid-century could be like today's 11-year storm
A 5-year storm late-century could be like today's 14-year storm

A 1-year storm mid-century could be like today's 1.9-year storm
A 1-year storm late-century could be like today's 2.5-year storm

6.2.2.2 Urban Flooding Methodology

To analyze the potential impact of future climate change and rainfall events of increasing severity and frequency over the next century on urban flooding patterns, water resource and stormwater specialists correlated rainfall data from recent storm events with recorded flood incidents from CTA and OEMC. A subset of recent storm events of varying frequencies were selected from the period 2013-2016 when CTA recorded flood incidents and OEMC 311 call data were available on the same dates.

CTA and OEMC flood complaint call data were correlated to the selected storms' rainfall data to identify spatial patterns and density of potentially recurring problems. It was noted that the density of OEMC 311 calls complaining about water on roadway and/or flooded viaducts increased with storm type, as shown in **Figure 16** and **Figure 17**. CTA drivers' reports of flood incidents generally found to correlate with moderate or more severe storms, that is, storms with 1-year recurrence intervals or greater.

This approach draws on a finite sample set of rainfall data *and* data documenting actual flood incidents reported by CTA staff or through OEMC via 311. While the available data is not particularly robust in terms of number of significant events and storm severity, the analysis provides valuable insight to areas of future risk for flooding that might impact CTA bus operations. The degree of severity of urban flooding can be subject to the human interventions by water departments to manage stormwater and sewer capacity across their networks and to discharge decisions at any given time. Therefore, this study cannot broadly draw spatial conclusions that areas currently prone to flooding will be larger or wider in the future – just that the intensity of flooding may be worse and/or more frequent. A more complex effort that models a greater base of rainfall, storm, and complaint data, together with dynamic sewer capacity management and/or hydraulic and hydrologic modeling may provide more precise conclusions but was beyond the schedule, scope and budget of this project.

Figure 16: OEMC 311 Calls in Minor to Major Storms

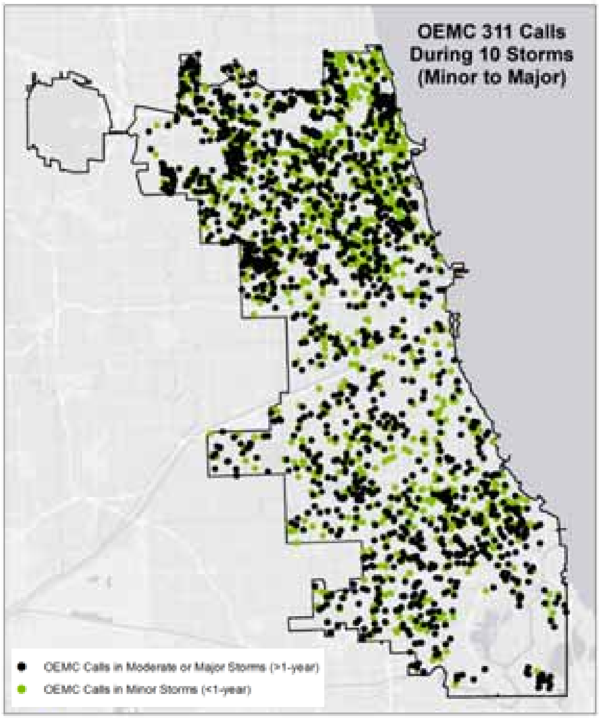
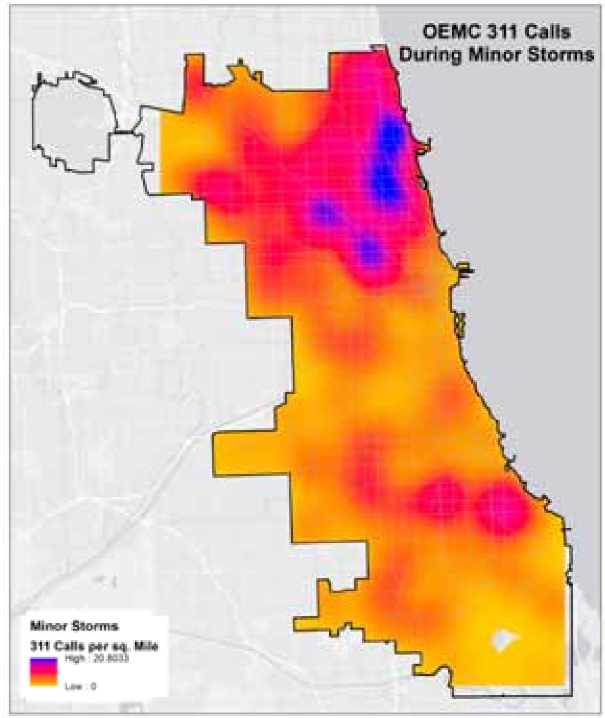


Figure 17: Density of Calls During Minor Storms (<1-Year Recurrence Interval)



6.2.2.3 Suburban/Exurban Flooding Methodology

The potential impact of future climate change over the next century on riverine and suburban/exurban flooding patterns and levels are available from a 2010 report by the US Army Corps of Engineers for several water bodies in the RTA service area. Water resource and stormwater specialists reviewed this information with a particular focus on the general areas through which Pace's Scenario E priority bus routes run. These include the Des Plaines River, Addison Creek, and Silver Creek. The storm profiles were reviewed to identify incremental surface elevation differences for various storm profiles. **Table 8** below presents these differences for the Des Plaines River.

Table 8: Des Plaines River Elevations

Flood Event Water Surface Profile	Elevation Increment (ft)
1- to 2-year	2
2- to 5-year	2
5- to 10-year	1
10- to 25-year	1
50- to 100-year	0.8
100- to 500-year	2.4

Source: USACE, August 2010

Based on these incremental differences and the storm frequency shift identified based on future rainfall amounts in Section 6.2.2.1, revised 100-year floodplain limits were drawn in GIS approximately halfway between the existing FEMA 100- and 500-year flood plain limits. In the absence of complex hydraulic and hydrologic modeling, this broad-brush approach is appropriate for identifying locations impacted by future conditions. This exercise concludes that there was very limited spatial expansion of floodplain areas impacting bus routes. This project's initial screening of Pace bus routes for risk of flood interruption was based on defining risk areas including both the 100- and 500-year floodplain limits, so adjustments for future conditions were already within the zones noted as potentially risk-prone. A sampling of the minor locations where the floodplain limits shifted are in **Figures 18** and **19** on the following pages, which appear to be very minor.

Across the RTA service region, there are few areas with 500-year floodplain concerns that intersect with bus routes. The conclusion from this exercise is similar to the conclusion for urban flooding: locations that are currently prone to flooding may have more frequent or severe flooding in the future. Due to the time and resource intensity of the processing required to model and truth-check these estimated boundaries, and the fact that a critical number of Pace routes impacted by flooding are in the Des Plaines River watershed, future 100-year floodplain limit adjustments were only made to that river system.

Figure 18: Pace Routes with Enhanced Flood Zones (Des Plaines)

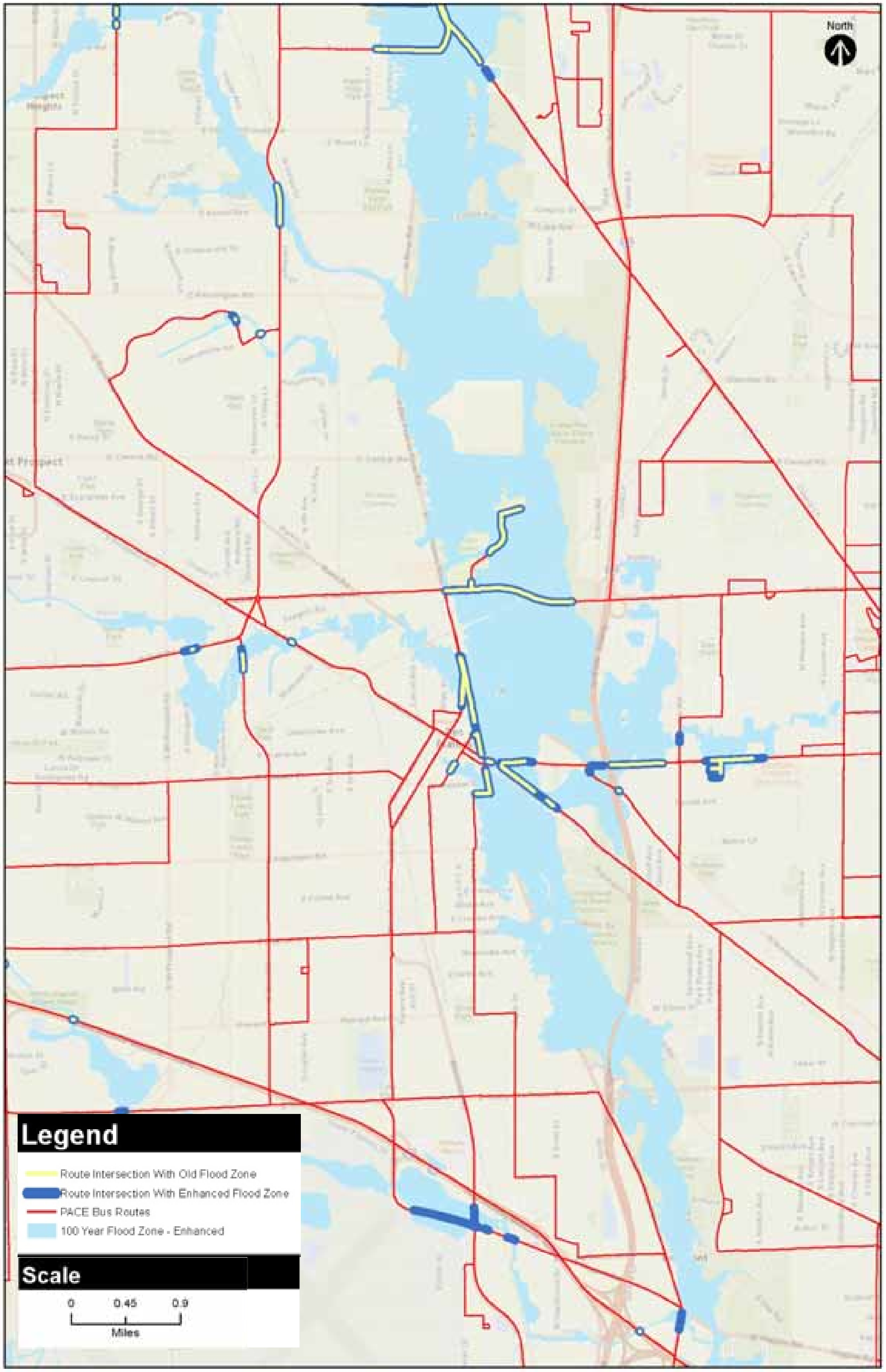
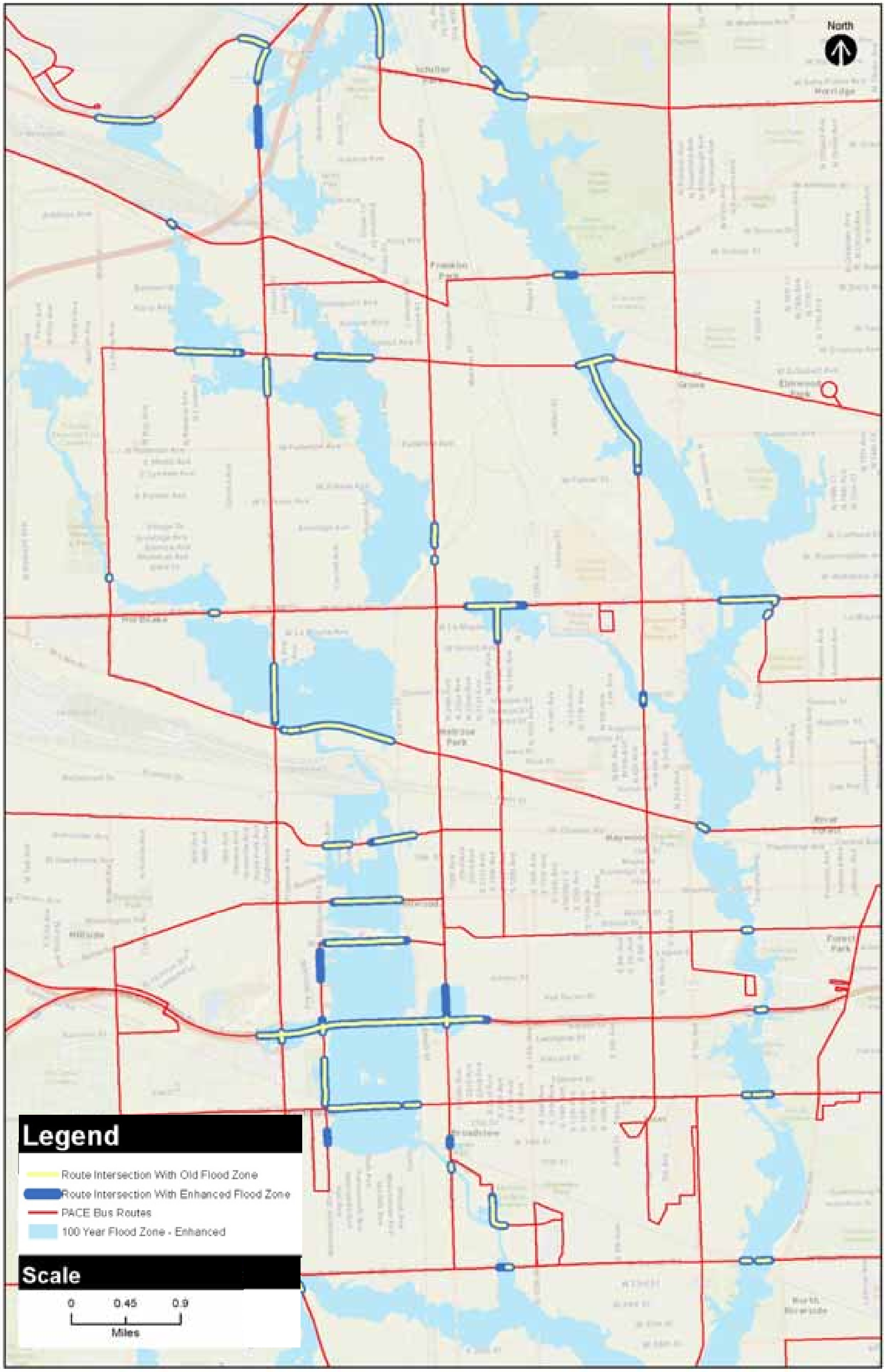


Figure 19: Pace Routes with Enhanced Flood Zones (Melrose Park)



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7. Resilience Planning: Transit Service

7.1 Reroute Plans for Impacted Bus Routes

7.1.1 Methodology

The objective of the impact analysis task is to quantify the potential impacts on CTA and Pace service and operations due to bus reroutes to avoid impassable flooding on street or under viaducts due to severe rain events. Quantifying the impacts of rain-related reroutes would provide additional arguments regarding the negative impacts of flooding on bus service, and potential benefits from the investment in infrastructure projects that would serve to mitigate/minimize/reduce flooding, now and in the future under expected climate change scenarios.

To understand the potential travel time, cost, and revenue implications of reroutes, AECOM collected a number of datasets to assist in the understanding of ridership and operations characteristics of the selected bus routes; operations characteristics of reroutes; and potential elasticities/ridership change factors under ordinary circumstances as well as actual ridership changes (as available). AECOM also developed a travel time factor that adds a certain percentage to the travel time and cost per trip based on three factors: congestion, storm severity, and operating delay. Each of these three factors can be adjusted from low, moderate, or high to represent a variety of external factors during storm incidents that further impact changes in travel time due strictly to the change in route alignment. A composite of these factors adjusts the Base reroute travel time up by an additional five percent (Low), 15 percent (Moderate), or 30 percent (High).

The presentation of impacts as "cost per trip" metrics allows a clean figure for analyzing the impact of storm activity on the financials of rerouting a bus trip. If CTA or Pace would want to assume a certain number of trips for each route as diverted, the agency could multiply that number of trips by the cost change to get an estimate of the total cost impact. For example, to quantify the impact of a short-duration storm, perhaps only three or fewer trips might be impacted. The agency could multiply each of the cost change metrics by three to derive a total cost per route for that particular storm. To calculate the cost per day, or half-day, this figure would be derived by calculating the per-trip cost by the number of route runs per day or half day; to estimate the cost for a given storm, the agency could then multiply the per-day cost by the number of days that a reroute was implemented.

7.1.2 CTA

As noted in **5.3**, a selection of bus routes ("Scenario F") was defined by CTA stakeholder committee members as a subset of all CTA routes to focus analysis.

Features of the analysis that are specific to CTA are outlined below. The full Excel workbook was provided to CTA staff for ongoing use and interactive scenario play, and will be included in Appendix B-1. Results from the analysis using the data collected during the course of this project are summarized below.

7.1.2.1 Reroutes

CTA has defined turn-by-turn reroute directions for numerous routes throughout the city in response to historic flood incidents that have consistently impeded regular operations (**Table 9**). About half of the Scenario F routes have reroutes in place already, defined by CTA, and used routinely during storm events. Some Scenario F routes are unlikely to need reroute plans due to low risk of intersection with identified flood risk areas. The AECOM team defined reroutes for other routes based on assessment of characteristics of the recent flood incidents as documented by CTA or OEMC. Reroute design principles included minimizing the distance off the main route, avoiding residential neighborhoods, utilizing collector or greater capacity roadways, and avoiding other flood-prone areas. These reroutes are depicted from a citywide perspective in **Figure 20**, and as enlarged segment views in **Figure 21**, **Figure 22**, and **Figure 23**.

Table 9: CTA Reroutes

Route	Location to Review		Turn-by-Turn Reroutes
4	Cottage Grove-61st	NB	No reroute needed
		SB	No reroute needed
4	Cottage Grove-71st	NB	Cottage Grove-73rd Street- St Lawrence- 71st Place- Cottage Grove
		SB	Reverse of northbound
4	Cottage Grove-93rd	NB	No reroute needed
		EB	No reroute needed
4	95th- St Lawrence	EB	No reroute needed
		WB	No reroute needed
4	Cottage Grove- 95th Street	NB	Cottage Grove-99th Street-ML King Dr- 95th Street-Cottage Grove
		SB	Reverse of northbound
8	Halsted-75th	NB	Halsted-76th-Morgan-74th-Halsted
		SB	Reverse of northbound
8	Halsted-51st thru 43rd Street	NB	Halsted-51st-Racine-Exchange-Halsted
		SB	Reverse of northbound
8	Halsted-75th	NB	Halsted-76th-Morgan-74th-Halsted
		SB	Reverse of northbound
8	Halsted-51st thru 43rd Street	NB	Halsted-51st-Racine-Exchange-Halsted
		SB	Reverse of northbound
8	Halsted-16th	NB	Halsted-18th-Morgan-14th-Halsted
		SB	Reverse of northbound
8	Halsted-Hubbard	NB	Halsted-Fulton-DesPlaines-Milwaukee-Halsted
		SB	Reverse of northbound
8	Halsted-Altgeld	NB	No reroute needed
		SB	No reroute needed
20	Madison-California	EB	Madison-California-Washington-Western-Madison
		WB	Madison-Western-Warren-California-Madison
22	Clark	NB	No reroute needed
		SB	No reroute needed
52	California-Diversey (I90)	NB	California-Logan-Sacramento-Belmont-California
		SB	Reverse of northbound
52	California Chicago	NB	Kedzie-Augusta-California
		SB	Reverse of northbound
52	Kedzie-Roosevelt Rd and Cermak Rd	NB	Kedzie-24th Street – Marshall/Sacramento-Roosevelt-Kedzie
		SB	Reverse of northbound
52	Kedzie-31st/Sanitary and Ship Canal/ 38th Street / 48th & 49th	NB	Begin northbound route from northernmost flooded viaduct – eg 31st street; that is, there will be no service south of 31st from Orange Line / 63rd; (customer alternate is Pink Line or California or Pulaski)
		SB	Only provide Service on Kedzie north of flooded viaduct – stop at 31st and do not go off route around the rail yard to avoid flooded viaducts in the 31st – 48th street range; provide no service south to Orange Line / typical terminus at 63rd (customer's alternate is Pink Line rail or California or Pulaski buses)
55	Garfield-Sacramento	EB	Garfield-Kedzie-59th Street-California-Garfield
		WB	No reroute needed
55	Garfield-Stewart	EB	Garfield-Halsted-59th Street-LaSalle-Garfield

Route	Location to Review		Turn-by-Turn Reroutes
		WB	Garfield-Wells-59th Street-Halsted-Garfield
77	Belmont-Kostner	EB	Belmont-Kostner-Roscoe-Milwaukee-Pulaski-Belmont
		SB	Reverse of northbound
77	Belmont-Kimball/Kedzie	EB	Belmont-Kimball-Diversity-Sacramento-Belmont
		WB	Reverse of northbound
85	Central-Grand (Prosser HS)	NB	Central-North Ave (west)-Narragansett Ave – Fullerton (east) – Central (alternates are closer but may also have flooded viaducts at Grand and rr) Central-North Ave (west) -Austin Blvd – Fullerton – Central Central-North Ave (east) - Laramie Ave – Fullerton – Central
		SB	Reverse of northbound
147	Michigan Ave – on/off ramp at Oak Street to Outer LSD	NB	Michigan to Inner Lake Shore (north) - enter Outer LSD at LaSalle/North If LaSalle/North entrance is impassible, west on LaSalle Parkway to Stockton (north) to Fullerton (east) to Outer LSD
		SB	Outer LSD-LaSalle/North-Inner Lake Shore (south) –Michigan
147	Michigan Ave-Chicago to Oak	NB	Michigan-Chicago (west) –State (north) –Division (east) – Inner Lake Shore (north) – enter Outer LSD at LaSalle/North If LaSalle/North entrance is impassible, west on LaSalle Parkway to Stockton (north) to Fullerton (east) to Outer LSD
		SB	Outer LSD-LaSalle-Chicago-Michigan
147	Outer LSD- Foster	NB	Outer LSD– Lawrence- Sheridan
		SB	Outer LSD- Lawrence- Outer LSD

Figure 20: CTA Scenario F Reroutes

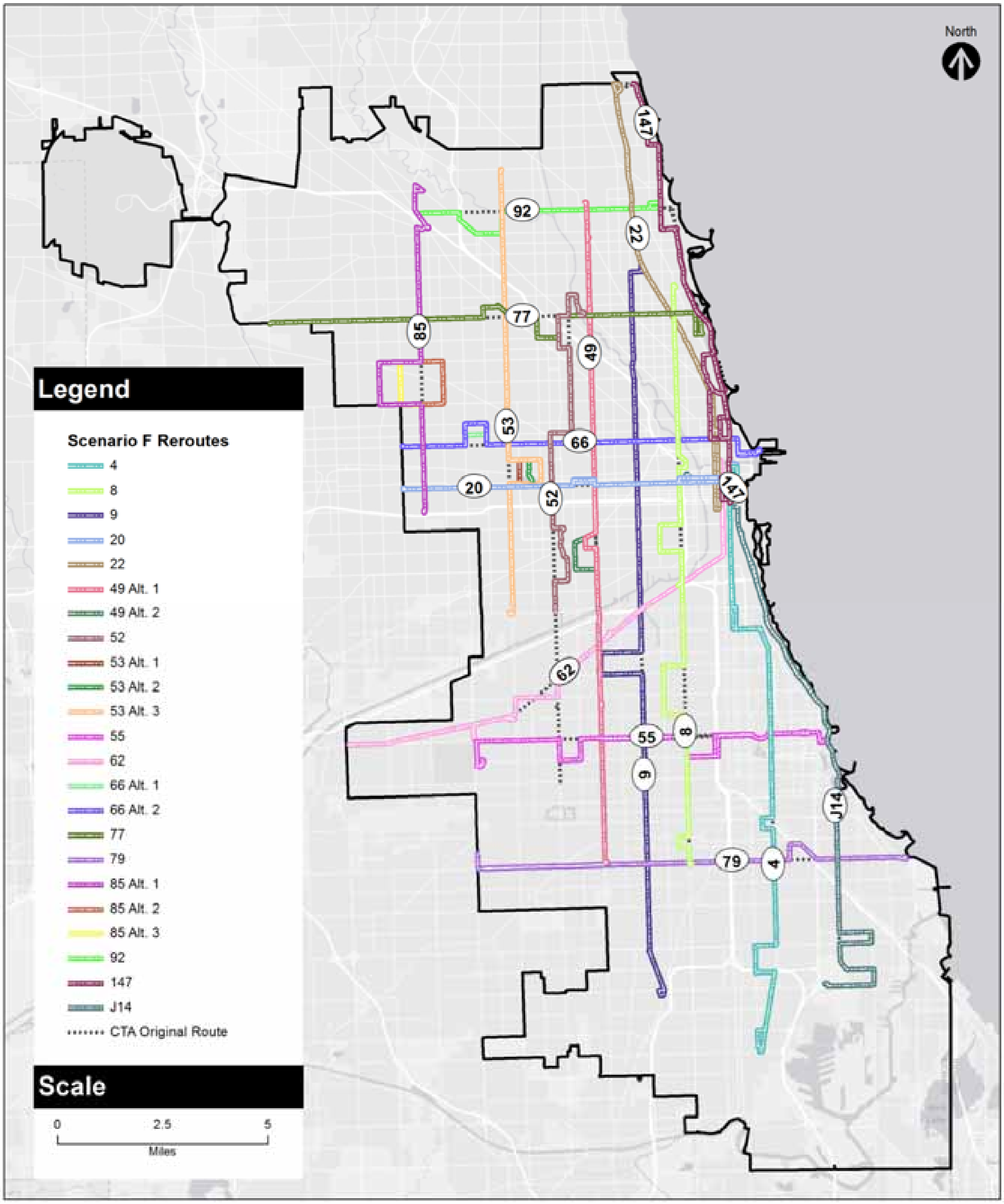


Figure 21: CTA Scenario F Reroutes (North)

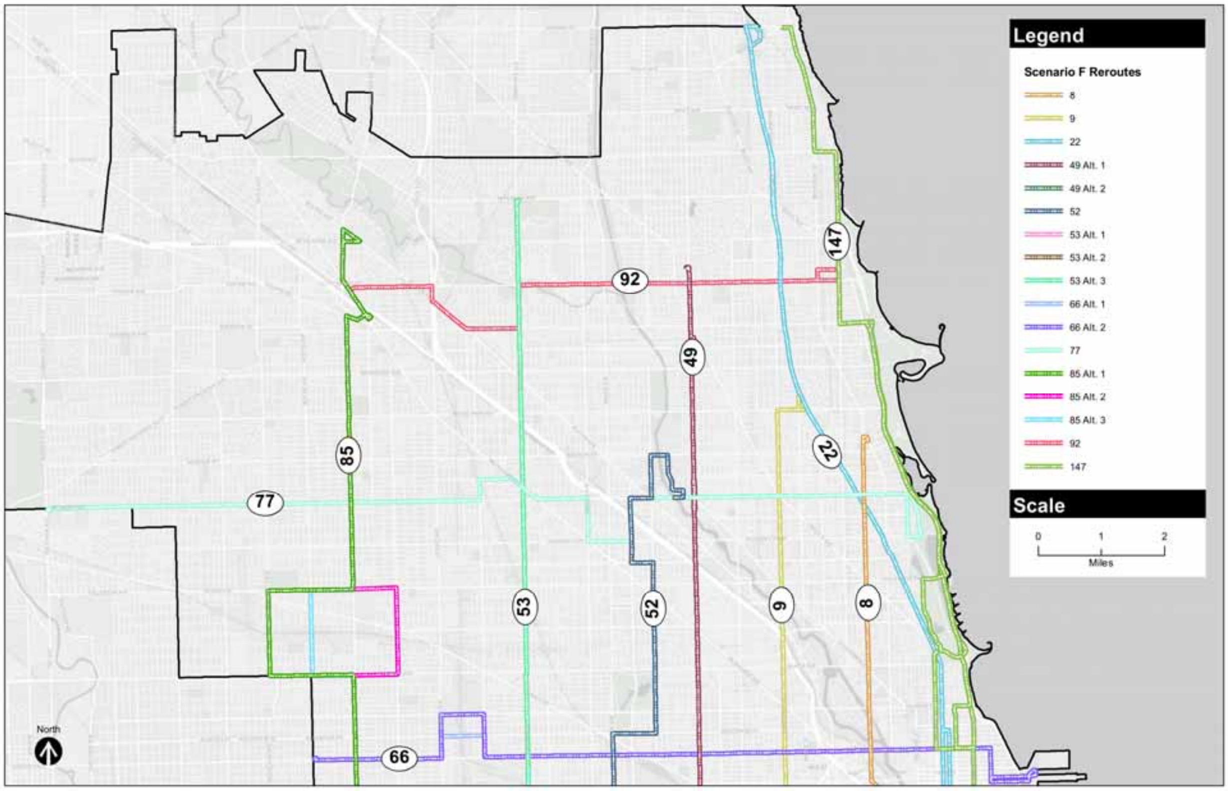


Figure 22: CTA Scenario F Reroutes (Central)

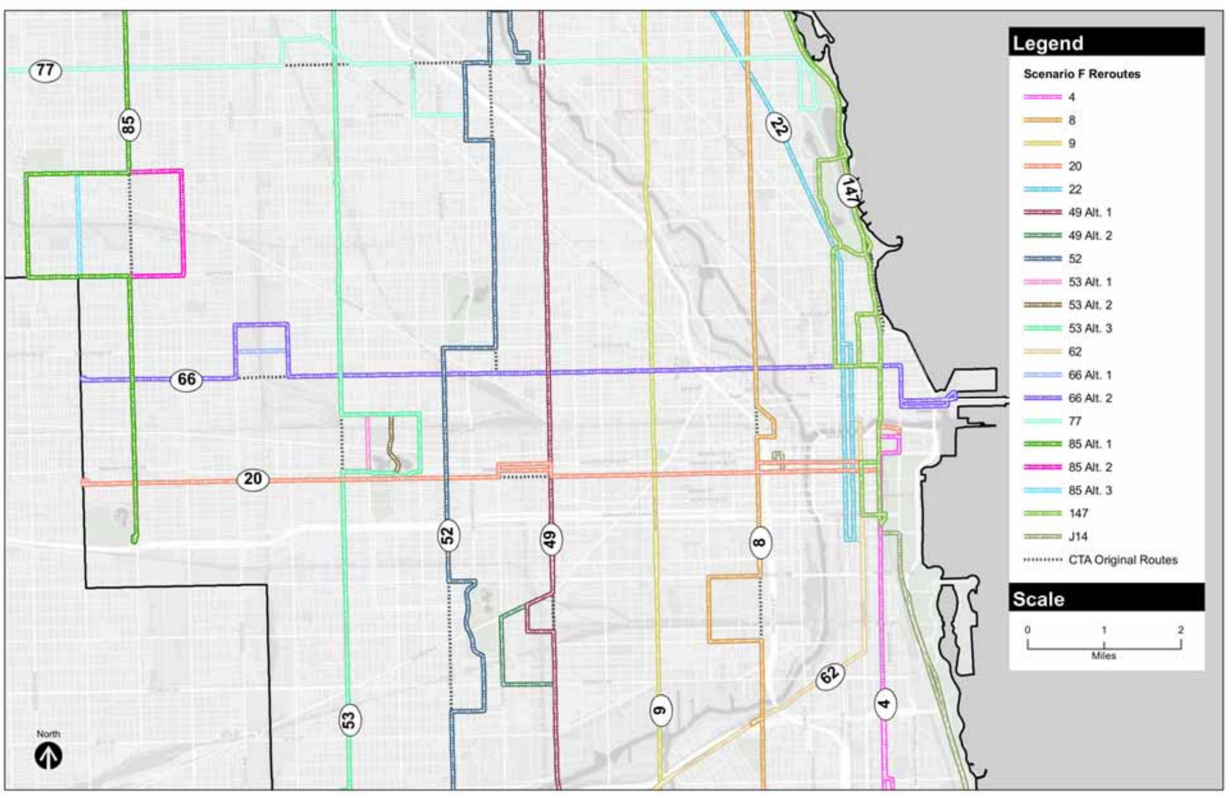
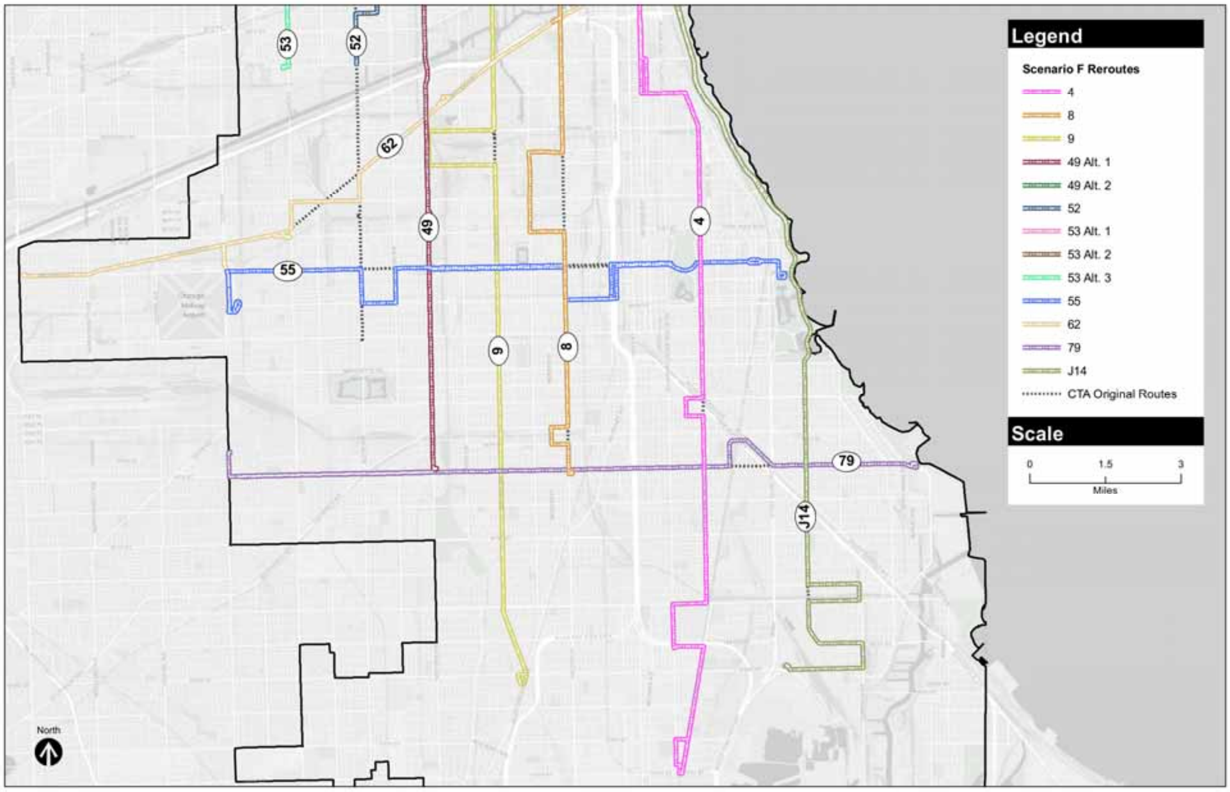


Figure 23: CTA Scenario F Reroutes (South)



7.1.2.2 Analysis

To understand the potential travel time, cost, and revenue implications of reroutes, AECOM collected a number of datasets to assist in the understanding of ridership and operations characteristics of the Scenario F routes; operations characteristics of reroutes; and potential elasticities/ridership change factors under ordinary circumstances as well as actual ridership changes during documented storm events for which we collected hourly rainfall data, 311 flood report data, and ridership by stop and hour.

A travel time factor was developed in order to add a percentage increase to the travel time and cost per trip based on three factors: congestion, storm severity, and operating delay. Each of these three factors can be adjusted from low, moderate, or high to represent a variety of storm incidents.

7.1.2.2.1 Datasets

All transit GIS data was provided by CTA, and processed by AECOM and its subconsultant UrbanGIS.

- Bus stop locations
- Location of OEMC/311 flood call complaints
- Driver-reported flooding hot spot locations
- Ventra boarding location

Flooding Resiliency Plan OPERATIONS 2016-08-31. This table provided annual daily ridership categorized by route and day type, annual revenue miles and hours by route, and estimated operating costs and revenue received by route.

Ventra boarding locations. The Ventra file provided GPS locations of boarding activity. The data was limited to the week prior to nine identified storm day incidents, as well as the nine storm day incidents. There are a few issues identified by CTA staff which may cause the exact GPS location to move away from the physical bus stop location. To address this issue, buffers were created around bus stops to capture the adjacent Ventra GPS points.

*Ridership summary***.** The ridership summary file provided ridership at the route level summarized at half-hour intervals. The data was limited to the week prior to nine identified storm day incidents, as well as the nine storm day incidents.

Rainfall data. Rainfall Data was obtained from the MRCC's online cli-MATE database. The rainfall gauge at three airports was used to obtain total rainfall on an hourly basis. These airports are Midway Airport, Chicago O'Hare International Airport, and Palwaukee Airport.

7.1.2.2.2 Analysis Workbook Features

7.1.2.2.2.1 Travel Time and Ridership Impacts

Metric	Description
# of Potential Incidents (OEMC)	Count of calls to the Office of Emergency Management and Communications (OEMC) (311) to report incidents of on-street and viaduct flooding.
Flooding noted within 400 ft	Flooding incidents identified by CTA operations staff within 400 feet of the specific route. This distance was used as the approximate distance of one city block.
Bus Stops Missed	Number of existing bus stops skipped due to a reroute.
Avg Riders Impacted per Day	Sourced from CTA provided Ventra boarding data. This number represents the average number of boardings missed or riders impacted if the bus were to be rerouted for an entire day.
Travel Time	Calculated using the route network on Google for a one-way trip, which is based on CTA published schedules. Reroutes were calculated using the same bus route on Google, but modifying the route to reflect adjustments to avoid areas of flooding.
Travel Time Change (Base)	The change in travel time for a one-way trip operating on a reroute.
Travel Time Change (Low)	The change in travel for a one-way trip operating on a reroute with a five percent time factor added to the base travel time.
Travel Time Change (Mod)	The change in travel for a one-way trip operating on a reroute with a 15 percent time factor added to the base travel time.
Travel Time Change (High)	The change in travel for a one-way trip operating on a reroute with a 30 percent time factor added to the base travel time.
Revenue Hour	Sourced from CTA-provided data for annual revenue hours by route.
Cost per trip	Sourced from CTA-provided data for annual revenue hours by route. Annual Cost for reroutes was calculated by adding a multiplier to the existing cost determined by the percentage change in travel time from existing route to reroute. The cost is based on an assumption of $100 per revenue hour. This assumption can be modified by the user on the *Existing Cost-Revenue* tab and costs will update automatically.
Cost per trip (Base)	Calculated by multiplying the assumption of $100 per revenue hour to the total one-way hours, which is the travel time divided by 60 minutes.
Cost per trip (Low/Mod/High)	Calculated by multiplying the cost per hour by the reroute travel time (one-trip) incremented by the selected time factor.
Cost Change per Trip (Base)	The change in cost per trip going into reroute using base travel time with no additional time factor multiplier.
Cost Change per Trip (Low/Mod/High)	The change in cost per trip for a reroute with additional congestion.
Custom Travel Time Adjustments	Three factors which compose the travel time factor. User selects "Low", "Moderate" or "High" additional Travel Time impact values to calculate a customized adjusted reroute time.
Congestion	Travel time factor reflecting additional roadway congestion resulting from a rain event.

Metric	Description
Storm Severity	Travel time factor reflecting storm severity which may contribute to traffic slowdowns resulting from a rain event.
Operating Delay	Travel time factor representing the difficulty for CTA dispatch or the CTA bus operator to respond to the storm incident.
Factor AVG	Represents the average score of the three factors
Time Factor	The percentage which is added to travel time and cost per trip to represent estimates of how the storm incident could impact travel time and operating costs.
Travel Time (Time Factor)	Represents the base reroute trip time incremented by the selected travel time factor (5%,15%, 30%).

7.1.2.2.2.2 Ridership Impacts: Storm Days Correlation

The storm days correlation worksheet provides the correlation summary for rainfall and ridership. The rainfall data comes from rainfall measurement stations at three locations, Midway Airport, O'Hare Airport, and Palwaukee Airport. Rainfall is measured in inches. The days selected are the same as those days in **Table 10** and **Table 11**. The numbers between the two datasets may not match because they come from two different sources.

Table 10: Moderate/Major Storms

Date	Day of the week	Previous day
April 17 – 18, 2013	Wednesday and Thursday	April 10 – 11, 2013
June 15 – 16, 2015	Monday and Tuesday	June 8 – 9, 2015
September 18 – 19, 2015	Friday and Saturday	September 11 – 12, 2015
July 23 – 24, 2016	Saturday and Sunday	July 16 – 17, 2016

Table 11: Minor Storms

Date	Day of the week	Previous day
April 9 – 10, 2015	Thursday and Friday	April 2 – 3, 2015
December 23, 2015	Wednesday	December 16, 2015
March 24 – 25, 2016	Thursday and Friday	March 17 – 18, 2016
January 16 – 17, 2016	Monday and Tuesday	January 9 – 10, 2016
February 7, 2017	Tuesday	January 31, 2017

As shown in **Figure 24** and **Figure 25**, a perhaps counterintuitive key takeaway—consistent with research from other organizations—is that larger ridership decreases are seen on minor storm days (i.e., less than one-year storm) rather than moderate or major storms. This is most likely because people are unwilling to risk driving themselves during moderate or major storms and thus are more likely to rely on transit if they cannot avoid traveling entirely. A direct comparison of changes in total boardings by route and storm type can be seen in **Figure 26**. Furthermore, analysis of the Ventra data shows that during moderate and major storms, ridership falls by an average of 7.8 percent on Scenario F routes on weekend storm days, but only 4.7 percent on weekday storms, reinforcing the role that discretionary travel plays.

Figure 24: Ridership Change on Moderate/Major Storm Days

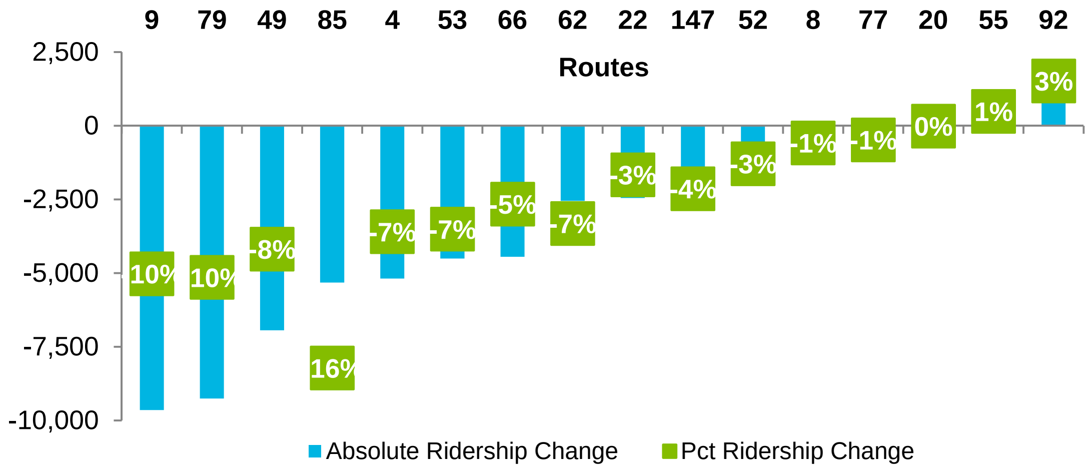


Figure 25: Ridership Change on Minor Storm Days

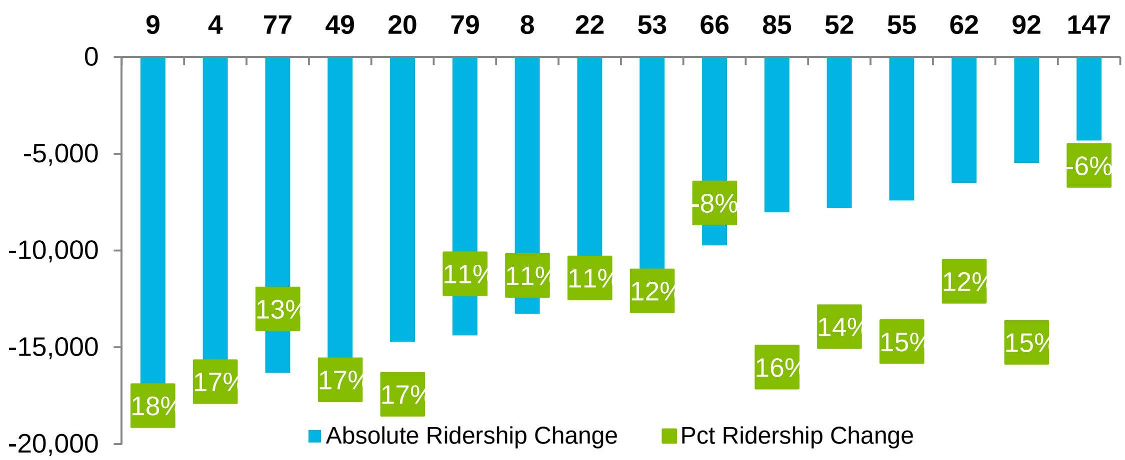
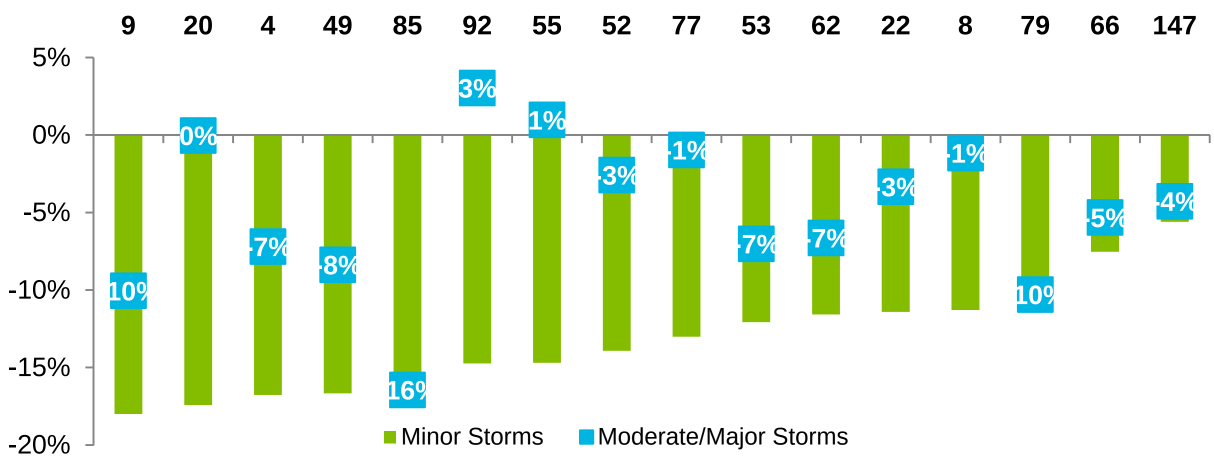


Figure 26: Percent Ridership Change by Storm Type



7.1.2.3 Summary of Findings

The tables below summarize the impact analysis of reroutes on the Scenario F routes, including estimates of changes in stops serviced based on the reroute alignment, associated changes in ridership, changes in travel time, and associated operating costs. The estimates presented assume full implementation of reroutes as documented, including situations where a route may have multiple diversions.

7.1.2.3.1 Alignment and Ridership Impacts

Table 12 presents the summary of physical and ridership characteristics of the CTA Scenario F routes with reroute alignments, as described in 7.1.2.1. In most cases, the reroute diversions reduce the number of locations where a route alignment encounters flood risk areas; however, there are situations where the reroute touches one or two additional areas. Due to the unpredictable nature of urban flooding and the influence of human design factors on the degree of flooding and speed of drainage or dispersal, this is a point to monitor rather than a concern.

The number of bus stops on the original routing missed by the reroute ranges from nominal to many; from this calculation, estimates of potential Average Daily Ridership (ADR) for the reroute are derived. Only a handful of routes experience substantial riders impacted (and potentially lost or diverted). These estimates do not take into account counteracting communications mechanisms (discussed later in this chapter) which would direct regular riders to alternate stop locations on the reroute or alternate transit routes, thus reducing the potential lost ridership.

Table 12: CTA Reroute Physical and Ridership Characteristics

Route	# of CTA-reported Flooding Incident Areas on Original Route	Change in # CTA Flooding Incident Areas with Reroute	Missed Bus Stops with Reroute	Avg Riders Impacted Per Day from Reroute
4	34	0	16	2
8	21	-7	36	336
9	47	-6	4	63
J14	7	0	0	0
20	8	+1	7	44
22	3	0	0	N/A
49	89	-23	3	11
49a	89	-29	8	98
52	113	-24	98	750
53	36	-9	9	155
53 Alt 1	36	-9	9	155
53 Alt 2	36	-3	9	155
55	10	-6	18	253
62	38	0	15	87
66 Alt 1	22	-1	5	21
66 Alt 2	22	+9	5	21
77	11	-3	14	224
79	24	-3	12	87
85 E	2	+4	14	72
85 W	2	+2	14	72
85 Nar	2	-2	14	72
92	9	+3	15	31
147 Alt 1	21	-3	5	78
147 Alt 2	21	-2	5	78
147 Alt 1& 3	21	-1	2	78
147 Alt 2 & 3	21	+1	2	78

7.1.2.3.2 Operational Impacts

Operational impacts to reroutes are estimated based on travel times for the altered routes. Changes in travel times on a per-trip basis between the standard route and the reroute vary substantially. In some cases, a reroute is longer than the standard route, and incurs greater travel time; in other cases, a reroute runs shorter and faster. Base travel time estimates for the reroutes are presented in **Table 13**, along with other travel time projections accounting for additional Low, Moderate and High travel delay factors.

Table 13: CTA Reroute Travel Time Estimates

	Travel Time per Trip (minutes)					Change in Travel Time per Trip (minutes)			
Route	Existing	Reroute (Base)	Reroute (+Low)	Reroute (+Mod)	Reroute (+High)	Reroute (Base)	Reroute (+Low)	Reroute (+Mod)	Reroute (+High)
4	91	97	102	112	126	6	11	21	35
8	93	105	110	120	136	12	17	28	43
9	113	119	125	137	155	7	12	24	42
J14	58	63	66	72	82	5	8	14	24
20	60	62	65	71	80	2	5	11	20
22	76	76	79	87	98	0	4	11	23
49	92	94	99	108	122	2	7	16	30
49a	92	96	100	110	124	4	8	18	32
52	81	71	74	81	92	-10	-6	1	11
53	72	75	78	86	97	3	6	14	25
53 Alt 1	72	77	80	88	99	5	8	16	27
53 Alt 2	72	78	82	90	101	6	10	18	29
55	51	58	61	67	75	8	10	16	25
62	73	76	80	87	99	4	7	15	26
66 Alt 1	65	67	70	76	86	2	5	12	22
66 Alt 2	65	69	72	79	89	4	7	14	25
77	68	78	82	90	101	10	14	22	33
79	71	73	76	83	94	2	5	12	23
85 E	52	56	58	64	72	4	7	12	21
85 W	52	56	58	64	72	4	7	12	21
85 Nar	52	59	61	67	76	7	10	16	25
92	39	43	45	49	55	4	6	10	16
147 Alt 1	60	73	76	83	94	13	16	23	34
147 Alt 2	60	78	81	89	101	18	21	29	41
147 Alt 1&3	60	71	74	81	92	11	14	21	32
147 Alt 2&3	60	76	79	87	98	16	19	27	38

Estimates of impacts to operating costs are calculated using each route's cost per-hour metric. Just as the changes in travel times vary substantially in both positive and negative directions, changes in trip cost likewise show positive and negative impacts, with increased costs projected to be incurred in some situations, and savings in other situations.

In **Table 14**: CTA Reroute Cost Estimates below, these cost projections are presented as Base costs, along with other scenarios which illustrate the additional Low, Moderate and High travel delay factors which would increase costs.

Table 14: CTA Reroute Cost Estimates

Route	Cost per Trip					Change in Cost per Trip			
	Existing	Reroute (Base)	Reroute (+Low)	Reroute (+Mod)	Reroute (+High)	Reroute (Base)	Reroute (+Low)	Reroute (+Mod)	Reroute (+High)
4	$152	$162	$170	$186	$210	$10	$18	$34	$59
8	$154	$174	$183	$200	$226	$20	$29	$46	$72
9	$188	$198	$208	$228	$258	$11	$21	$41	$70
J14	$97	$105	$110	$121	$137	$8	$14	$24	$40
20	$99	$70	$73	$80	$91	-$29	-$26	-$19	-$8
22	$126	$126	$132	$145	$164	$-	$6	$19	$38
49	$153	$157	$165	$180	$204	$3	$11	$27	$50
49a	$153	$159	$167	$183	$207	$6	$14	$30	$54
52	$134	$118	$123	$135	$153	-$17	-$11	$1	$19
53	$120	$124	$130	$143	$161	$4	$10	$23	$41
53 Alt 1	$120	$128	$134	$147	$166	$7	$14	$27	$46
53 Alt 2	$120	$130	$137	$150	$169	$10	$17	$30	$49
55	$84	$97	$102	$111	$126	$13	$17	$27	$42
62	$121	$127	$133	$146	$165	$6	$12	$25	$44
66 Alt 1	$108	$111	$116	$127	$144	$3	$9	$20	$37
66 Alt 2	$108	$114	$120	$131	$148	$7	$12	$24	$41
77	$113	$130	$137	$150	$169	$17	$23	$36	$56
79	$118	$121	$127	$139	$157	$3	$9	$21	$39
85 E	$86	$93	$97	$106	$120	$7	$11	$21	$34
85 W	$86	$93	$97	$106	$120	$7	$11	$21	$34
85 Nar	$86	$98	$102	$112	$127	$12	$17	$26	$41
92	$65	$71	$74	$81	$92	$6	$9	$16	$27
147 Alt 1	$100	$121	$127	$139	$157	$21	$27	$39	$57
147 Alt 2	$100	$129	$136	$149	$168	$29	$36	$49	$68
147 Alt 1&3	$100	$118	$123	$135	$153	$18	$23	$35	$53
147 Alt 2&3	$100	$126	$132	$145	$164	$26	$32	$45	$64

7.1.3 Pace

As noted in **5.3**, a selection of bus routes (Scenario E) was made by Pace stakeholder committee members as a subset of all Pace routes to focus analysis (**Figure 27**: Pace Scenario E Reroutes).

Features of the analysis that are specific to Pace are outlined below. The full Excel workbook was provided to Pace staff for ongoing use and interactive scenario play, and will be included in Appendix B-2. Results from the analysis using the data collected during the course of this project are summarized below.

7.1.3.1 Reroutes

Pace has defined turn-by-turn reroute directions for numerous routes throughout the region in response to historic flood incidents that have impeded regular operations. Most Scenario E routes have reroutes in place already, defined by Pace, and used routinely during storm events. Notably, these reroutes have not required further diversion, even during severe storms experienced in 2013, 2016 and 2017.

7.1.3.1.1 North Division

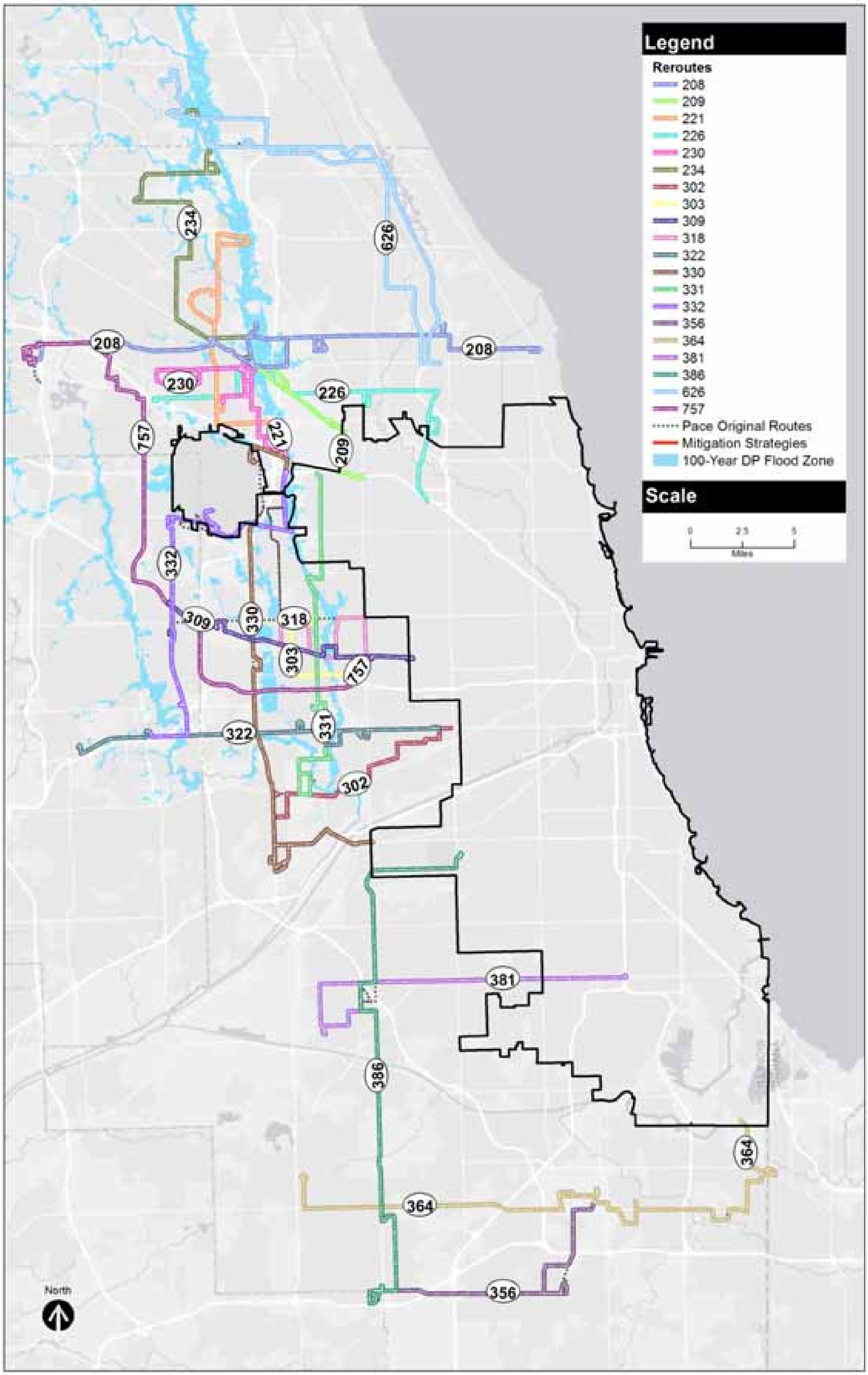
North Division reports that three routes are impacted when the Des Plaines River floods: routes 272, 565 and 572. Des Plaines River flooding occurs occasionally. The detours listed below are used when the Des Plaines River floods.

Route			Turn-by-turn Reroute
272	Milwaukee Ave	NB	R-Willow/Palatine, L-Sanders, L-Dundee, R-Milwaukee and resume route
		SB	R-Dundee, L-Wolf, L-Willow/Palatine, R-Milwaukee and resume route
565	Grand Ave	EB	R-Riverside/Milwaukee, L-Washington, L-O'Plaine, R-Grand and resume route
		WB	L-O'Plaine, R-Washington, R-Milwaukee/Riverside, L-Grand and resume route
572	Washington Street	EB	L-Milwaukee/Riverside, R-Grand, R-O'Plaine, L-Washington and resume route
		WB	R-O'Plaine, L-Grand, L-Milwaukee/Riverside, R-Washington and resume route

The detours listed below are used when the Des Plaines River floods, and both Grand Avenue and Washington Street are closed simultaneously.

Route			Turn-by-turn Reroute
565	Grand Ave	EB	R-Riverside/Milwaukee, R-to ramp to Belvidere, L-O'Plaine, R-Grand and resume route
		WB	L-O'Plaine, R-Belvidere, R-to ramp to Milwaukee, L-Milwaukee/Riverside, L-Grand and resume route
572	Washington Street	EB	R-Milwaukee, R-to ramp to Belvidere, L-O'Plaine, R-Washington and resume route
		WB	L-O'Plaine, R-Belvidere, R-to ramp to Milwaukee, L-Milwaukee, L-Washington and resume route

Figure 27: Pace Scenario E Reroutes



7.1.3.1.2 North Shore Division

The North Shore reports rare flooding along four routes. Des Plaines in downtown on Route 619 floods very rarely (there has not been a detour for flooding in the last few years). The detour usually involves using River Road instead of Golf Rd to Sanders; otherwise buses can take NW Hwy past NW garage to Broadway to Wolf to Palatine, etc. The flooding along Edens Expressway in Winnetka on Routes 620, 626 is also very rare and can affect deadheads. Skokie Blvd between Lincoln and Oakton on Route 210 rarely floods Blizzards are also an issue, but even more rare than flooding; when this occurs, Green Bay Road is a very reliable roadway to use. Turn by turn reroutes include:

Route			Turn-by-turn Reroute
210	Skokie Blvd between Lincoln & Oakton	NB	Detour from Lincoln/Skokie Blvd: continue north on Lincoln Av., R-Niles Center Rd., cross Oakton St, regular route
		SB	Detour from Niles Center/Oakton St: continue south on Niles Center Rd., L-Lincoln Av, resume regular route at Skokie Blvd
619	Des Plaines Downtown	NB	Detour from Des Plaines Metra Station: EB on Miner, L-River RD., continue past Golf Rd., R-Euclid/West Lake, L-Milwaukee, R-Sanders, R-Allstate/Astellas. Alternate detour: from Des Plaines Metra Station, NB on Miner/Northwest Hwy, R-Broadway, traffic circle to Wolf Rd, NB on Wolf Rd., R-Palatine Rd./Willow Rd. to Allstate/Astellas.
		SB	Detour from Allstate/Astellas: Leaving from Astellas, R-Willow Rd., L-Sanders, L-Milwaukee, R-West Lake/Euclid, L-River Rd., R-Lee St., R-Jefferson, L-Graceland, L-Miner St. to Des Plaines Metra Station. alternate detour: from Allstate/Astellas, WB on Willow/Palatine Rds., L-Wolf Rd, traffic circle, R-State, L-Northwest Hwy/Miner S.t to Des Plaines Metra Station.
620	Edens Expressway in Winnetka	NB	Detour from Skokie Swift Station: WB Dempster St, continue to Harms Rd., R-Harms Rd, L-Lake Ave., R-Sunset Ridge Rd., L-Willow Rd to Allstate.
		SB	Detour: EB Willow Rd., R-Sunset ridge Rd., L-Lake Ave., R-Harms Rd., L-Dempster, R-Skokie Swift station
626	Edens Expressway in Winnetka	SB	From Skokie Blvd/Dundee Rd: continue south on Skokie Blvd, R-Sunset ridge Rd, L-Lake Av, R-Harms Rd., L-Dempster St.to Skokie Swift Station

7.1.3.1.3 Northwest Division

Northwest Division reports that six routes are impacted when the Des Plaines River floods: Routes 230, 208, 226, 209, 221 and 234. Des Plaines River flooding occurs about every three years, sometimes it lasts one to five days and worst case scenario, it can last one to three weeks (happened twice in 25 years). There has also been some short-term local flooding (water standing on roadway) on portions of Route 606 and 616 during heavy rain storms.

The detours used when the Des Plaines River floods are listed below:

Route			Turn-by-turn Reroute
208	River Rd/Golf/OCC blocked	EB	EB Miner/Dempster, L-Potter, R-Golf. Regular Route
		WB	Golf/River/OCC blocked) WB Golf, L-Potter, R-Dempster, to Des Plaines to Regular Route
209	Busse Hwy closed at Dempster	EB	Dempster , R-Rand, R-Potter, L-Busse Hwy to regular route (all trips doing "B" trips follow this detour)
		WB	R- Potter, L- NWHY, L- Dempster to regular route (all trips doing "B" trips follow this detour)
221	Trips begin/end at Prospect Heights Metra	NB	Regular Route to Prospect Heights Metra
		SB	From Prospect Height Metra Regular Route
226	Busse Hwy closed at Dempster	EB	Dempster , R-Rand, R-Potter, L-Busse Hwy to regular route
		WB	R- Potter, L- NWHY, L- Dempster to regular route
230	River Road closed	SB	R- Pearson R-Thacker L-Center L- Algonquin R- White Regular route

Route			Turn-by-turn Reroute
264	River Road / Golf Road closed	NB	WB Miner/NWHY, R-Broadway (circle) R-state , regular route
		SB	L –State thru Cumberland Circle, R-State L- NWHY to Des Plaines

7.1.3.1.4 West Division

West Division reports flooding-related reroutes for 10 routes, with several of the routes having detours in more than one segment due to multiple instances of street flooding. Turn-by-turn reroutes are provided below.

Route			Turn-by-turn Reroute
302	Ogden between LaGrange/East Ave	WB	Westbound on Ogden, left East Ave, right 47th, right LaGrange, LaGrange/Hillgrove end of line
		EB	Eastbound on Ogden, left Ashland, left Hillgrove, right LaGrange, left 47th, left East Ave, right Ogden, regular route
303	25th near Irving Park	NB	Northbound on 25th, right Belmont, left Des Plaines River Rd to Roasemont CTA
		SB	Reverse route
309	1st Ave to Thatcher	EB	Eastbound on Lake, left 1st Ave, right Chicago Ave, right Thatcher, left Lake St, regular route
		WB	Reverse route
309	North Ave at Railroad Ave	WB	Westbound on North Ave, left Hillside Ave, Northlake Wal-Mart service drive to reverse
		EB	Eastbound on North Ave, right North Ave, right Lake St, Lake westbound I-290, right York Rd, exit left York Rd, right 2nd Ave, regular route.
318	North Ave near 1st	WB	North Ave to Thatcher, left Thatcher, right Lake, right 9th Ave, left North Ave, regular route
		EB	Reverse route
318	25th Ave	WB	North Ave to 25th Ave, left 25th, right Lake, right Wolf Rd, left North Ave, regular route
		EB	Reverse route
319	Flooding near Grand/Belmont	WB	Grand Ave, left Thatcher/1st Ave, right North Ave, right 25th, left Grand Ave, regular route
		EB	Reverse route
322	1st Ave/Des Plaines	WB	Cermak, left Des Plaines Ave, right 26th, right 1st Ave, left Cermak, regular route
		EB	Reverse route
330	Washington to St. Charles	NB	Mannheim, right Washington, left Bellwood Ave, left St. Charles, right Mannheim, regular route
		SB	Reverse route
330	Irving Park to Lawrence	NB	Mannheim, right Irving Park, left Des Plaines River Road, left Higgens Road, left Mannheim, right Zemke Blvd, regular route
		SB	Reverse route
331	River Rd to Grand	NB	Departing Triton College , right 5th Ave, left North Ave, left 1st Ave, regular route
		SB	Reverse route
332	Irving Park to Rosemont CTA	NB	Irving Park to River Rd, left Des Plaines River Rd, right Rosemont CTA station
		SB	Reverse route
757	Standing water on 290 during a downpour.		

7.1.3.1.5 Southwest Division

The Southwest Division reports occasional flooding on two routes along the same stretch of W 100th Pl. The reroutes are listed below for both routes, though the turn-by-turn directions are identical.

Route			Turn-by-turn Reroute
381	100th/Industrial Drive to 100th/76th Ave	WB	95th St, to 76th Ave, to 103rd, to regular route
		EB	Reverse route
386	100th/Industrial Drive to 100th/76th Ave	WB	95th St, to 76th Ave, to 103rd, to regular route
		EB	Reverse route

7.1.3.1.6 South Division

South Division reports flooding along two routes in Harvey and Homewood, as described below.

Route			Turn-by-turn Reroute
356	Viaduct on Dixie Hwy/Park in Homewood (s. of 175th)	EB	At Ridge/Dixie, left on Ridge, left on Harwood, right on 183rd St, right on Governors Hwy, right on 175th, regular route
		WB	At 175th/Dixie Hwy continue straight, left on Governors Hwy, left on 183rd St, left on Harwood, right on Ridge, regular route
364	159th / Park in Harvey	NB	Left on 157th, right on Park
		SB	Left on 157th, right on Halsted

7.1.3.2 Analysis

7.1.3.2.1 Datasets

All transit GIS data was provided by Pace, and processed by AECOM and its subconsultant UrbanGIS. It included the following:

- Bus stop locations
- Driver-reported routes with flood problems
- Stop-level ridership

Costs and Operating Stats Q2 sent 20161012. This table provided annual daily ridership categorized by route and day type, annual revenue miles and hours by route, and estimated operating costs, estimated hourly operating costs and revenue received by route.

RSM_APC_Spring 2016. Three Excel files were included for weekday, Saturday, and Sunday ridership by stop. The data provided average boardings and alightings at each stop. For our analysis, we only included boarding averages. All boarding averages were rounded to the next whole number.

7.1.3.2.2 Analysis Workbook Features

7.1.3.2.2.1 Travel Time Impacts

Routes are characterized by their service pattern. Existing conditions represent normal operating patterns, while reroute represents the operating pattern when inclement weather requires adjustments to the route alignment.

Metric	Description
Travel Time	Calculated using the route network on Google for a one-way trip, which is based on Pace published schedules. Reroutes were calculated using the same bus route on Google, but modifying the route alignment to reflect adjustments to avoid areas of flooding.
Travel Time (Time Factor)	Represents the trip time with the travel time factor added to the existing time.
Hours	Represents the one-way trip time in total hours.
Congestion	One of the three factors which compose the travel time factor. The factor can be adjusted from low, moderate, or high. Select a factor impact through the drop down arrow, or type the degree of factor impact.

Metric	Description
Storm Severity	Same as above.
Operating Delay	Same as above. This factor represents the ability for Pace dispatch or the Pace bus operator to respond to the storm incident.
Factor AVG	Represents the average score of the three factors
Time Factor	The percentage which is added to travel time and cost per trip to represent estimates of how the storm incident could impact travel time and operating costs.
Cost per hour	For existing routes, provided by Pace in the Cost and Operating Stats excel. Costs per hour for reroutes were assumed to be the same as the existing route.
Cost per trip (Base)	For existing routes and reroutes, calculated by multiplying the cost per hour by the travel time (one-trip). This cost does not include any time factor multiplier and assumes route time using Google – a change in travel time due strictly to the change in route alignment.
Cost per trip (Low)	Calculated by multiplying the cost per hour by the travel time (one-trip) and then multiplying by the "Low" time factor (5 percent).
Cost per trip (Mod)	Calculated by multiplying the cost per hour by the travel time (one-trip) and then multiplying by the "Moderate" time factor (15 percent).
Cost per trip (High)	Calculated by multiplying the cost per hour by the travel time (one-trip) and then multiplying by the "High" time factor (30 percent).
Cost Change per Trip (Base)	The change in cost per trip going into reroute using base travel time with no time factor multiplier.
Cost Change per Trip (Low)	The change in cost per trip going into reroute using the base travel time incremented by 5 percent.
Cost Change per Trip (Mod)	The change in cost per trip going into reroute using the base travel time incremented by 15 percent.
Cost Change per Trip (High)	The change in cost per trip going into reroute using the base travel time incremented by 30 percent.
Average Missed Passengers per Trip	The estimated average missed passengers due to the reroute pattern. This number represents the average daily ridership for the week prior to one of the nine storm incidents. Although all passengers may not be missed, this data provides a conservative estimate of the potential number of passengers missed.
Segment Data	Consists of three columns for each reroute segment of the existing route. *Total Ridership* represents the total number of boardings for the segment, and the *Non Incident Days* column provides the total number of regular service days surveyed in the data. The *Average missed* column provides an average daily ridership missed for the segment.
Custom Travel Time Adjustments	User selects "Low", "Moderate" or "High" additional Travel Time impact values in "Congestion", "Storm Severity" and "Operating Delay" categories to calculate a customized adjusted reroute time.

7.1.3.2.2.2 Ridership Impacts

The *Pace Ridership Impacts* worksheet provides a summary of 2016 ridership data and impact analysis.

Metric	Description
Average Daily Ridership	Sourced from Pace data in the Costs and Operating Stats spreadsheet. The average daily ridership number for reroutes was calculated by subtracting the estimated impacted (potentially missed) ridership from the existing route's average daily ridership.
Ridership Change	Represents the change in ridership between a normal operating day and ridership on a day operating around flooded areas (with potentially lost or diverted customers).
Missed Ridership	Four columns representing boardings for total, weekday, Saturday, and Sunday.
# Flooding Incidents	Represent locations of flooding hot spots based on intersections with floodplain risk areas, current and enhanced for future climate change
Bus Stops Missed	Number of existing bus stops skipped due to a reroute.

7.1.3.3 Summary of Findings

The tables below summarize the impact analysis of reroutes on the Scenario E routes, including estimates of changes in stops serviced based on the reroute alignment, associated changes in ridership changes in travel time, and associated operating costs. The estimates presented assume full implementation of reroutes as documented, including situations where a route may have multiple diversions.

7.1.3.3.1 Alignment and Ridership Impacts

Table 15 presents the summary of physical and ridership characteristics of the Pace reroutes. In most cases, the reroute diversions reduce the number of locations where a route alignment encounters a flood risk area; however, there are a pair of instances where the reroute touches one or two additional areas; feedback from Pace staff on the reliability of their defined reroutes even through severe storm events suggests this is a point to monitor rather than a concern. The number of bus stops on the original routing missed by the reroute ranges from nominal to many; from this calculation, estimates of potential ADR for the reroute. Similarly, changes in ridership for most routes is less than 10 percent, with only four routes experiencing substantial numbers of riders impacted (potentially lost or diverted) due to skipped stops. These estimates do not take into account counteracting communications mechanisms (discussed later in this chapter) which would direct impacted riders to alternate stop locations on the reroute or alternate transit routes, thus reducing the potential lost system ridership.

Table 15: Pace Route Change

Route Change							
Route	# of Flooding Incidents	Change # of Flooding Incidents with Reroute	Missed Bus Stops with Reroute	Existing ADR	ADR with Reroute	% Change	Net Riders Impacted by Reroute
208	1	-1	34	1,847	1,687	-8.7%	160
209	1	0	6	369	368	-0.3%	1
221	0	0	34	726	683	-5.9%	43
226	1	0	17	696	694	-0.3%	2
230	1	0	7	370	365	-1.4%	5
234	0	0	30	266	248	-6.8%	18
302	2	0	2	551	546	-0.9%	5
303	5	-5	138	1,130	515	-54.4%	615
309	2	0	25	881	820	-6.9%	61
318	3	-1	32	2,402	926	-61.5%	1476
322	2	0	2	2,243	2,175	-3.0%	68
330	6	+2	16	1,223	948	-22.5%	275
331	4	-1	33	1,142	1,080	-5.4%	62
332	4	+1	19	629	477	-24.2%	152
356	2	0	7	581	567	-2.4%	14
364	1	0	0	2,043	2,043	0.0%	0
381	1	-1	7	3,669	3,631	-1.0%	38
386	1	-1	10	1,423	1,344	-5.6%	79
626	0	0	0	346	346	0.0%	0
757	0	0	0	210	210	0.0%	0

7.1.3.3.2 Operational Impacts

Operational impacts to reroutes are estimated based on travel times for the altered routes. Changes in travel times on a per-trip basis between the standard route and the reroute vary substantially. In some cases, a reroute is longer than the standard route, and incurs greater travel time; in other cases, a reroute runs shorter and faster. Base travel time estimates for the reroutes are presented in **Table 16**, along with other travel time projections accounting for additional Low, Moderate and High travel delay factors.

Table 16: Pace Reroute Travel Time Estimates

	Travel Time per Trip (Minutes)					Change in Travel Time per Trip			
	Existing	Reroute	+ Low	+ Mod	+High	Reroute	+Low	+Mod	+High
208	95	73	77	84	95	-22	-18	-11	0
209	30	28	29	32	36	-2	-1	2	6
221	55	45	47	52	59	-10	-8	-3	4
226	56	44	46	50	57	-12	-10	-5	1
230	40	33	35	38	43	-7	-5	-2	3
234	46	34	35	39	44	-13	-11	-7	-2
302	34	36	38	41	47	3	4	8	13
303	45	40	42	46	52	-5	-3	1	7
309	45	48	50	55	62	3	5	10	17
318	31	39	41	45	51	9	10	14	20
322	60	67	70	76	86	7	10	16	26
330	64	70	74	81	91	6	10	17	27
331	55	60	63	69	78	5	8	14	23
332	69	63	66	72	81	-6	-3	3	13
356	33	35	37	40	46	3	4	8	13
364	90	90	95	104	117	0	5	14	27
381	54	53	55	60	68	-2	1	6	14
386	67	70	74	81	91	3	7	14	24
626	70	75	79	86	98	5	9	16	28
757	63	64	67	74	83	2	5	11	21

Estimates of impacts to operating costs are calculated using each route's cost per-hour metric. As with the changes in travel times vary substantially in both positive and negative directions, changes in trip cost likewise show as positive and negative, with increased costs projected to be incurred in some situations, and savings in other situations. These cost projections are presented in **Table 17**, as Base costs, along with other scenarios accounting for additional Low, Moderate and High travel delay factors which would increase costs.

Table 17: Pace Reroute Cost Estimates

Route	Cost per Trip					Change in Cost per Trip			
	Existing	Reroute (Base)	Low	Mod	High	Reroute (Base)	Low	Mod	High
208	$119.78	$92.53	$97.15	$106.41	$120.29	-$27.25	-$22.63	-$13.37	$0.51
209	$38.03	$35.49	$37.26	$40.81	$46.14	-$2.54	-$0.76	$2.79	$8.11
221	$69.71	$57.04	$59.89	$65.59	$74.15	-$12.68	-$9.82	-$4.12	$4.44
226	$70.35	$55.14	$57.89	$63.41	$71.68	-$15.21	-$12.45	-$6.94	$1.33
230	$50.70	$41.83	$43.92	$48.10	$54.38	-$8.87	-$6.78	-$2.60	$3.68
234	$58.31	$42.46	$44.58	$48.83	$55.20	-$15.84	-$13.72	-$9.47	-$3.11
302	$40.84	$43.88	$46.08	$50.46	$57.05	$3.05	$5.24	$9.63	$16.21
303	$54.85	$48.76	$51.20	$56.07	$63.39	-$6.09	-$3.66	$1.22	$8.53
309	$54.85	$58.51	$61.44	$67.29	$76.06	$3.66	$6.58	$12.43	$21.21
318	$37.18	$47.54	$49.92	$54.67	$61.80	$10.36	$12.74	$17.49	$24.62
322	$73.14	$81.06	$85.11	$93.22	$105.38	$7.92	$11.98	$20.08	$32.24
330	$78.01	$85.33	$89.59	$98.13	$110.93	$7.31	$11.58	$20.11	$32.91
331	$67.04	$73.14	$76.79	$84.11	$95.08	$6.09	$9.75	$17.07	$28.04
332	$83.50	$76.18	$79.99	$87.61	$99.04	-$7.31	-$3.50	$4.11	$15.54
356	$47.86	$51.54	$54.12	$59.27	$67.01	$3.68	$6.26	$11.41	$19.14
364	$132.54	$132.54	$139.17	$152.42	$172.30	$0.00	$6.63	$19.88	$39.76
381	$59.96	$58.30	$61.21	$67.04	$75.79	-$1.67	$1.25	$7.08	$15.82
386	$74.40	$77.73	$81.62	$89.39	$101.05	$3.33	$7.22	$14.99	$26.65
626	$81.60	$87.42	$91.80	$100.54	$113.65	$5.83	$10.20	$18.94	$32.06
757	$76.18	$78.01	$81.91	$89.72	$101.42	$1.83	$5.73	$13.53	$25.23

7.2 Communications and Coordination Plans

In the event that severe rain events disrupt regular bus service, communications and coordination plans are critical for notifying the public about service changes, including reroutes. The project team developed the plans below through interviews with interested departments within CTA and Pace, as well as partner agencies such as OEMC with responsibility for public safety, to document current protocols and procedures. Both CTA and Pace have well-established procedures tested and refined over the course of numerous severe rain events as well as other types of service interruptions, weather-related and not. Recommendations from this project include identification for areas of new or deeper collaboration among interested agencies, as well as suggestions for consideration of additional technological resources; both of which are subject to available financial and human resources.

7.2.1 CTA

This CTA Bus Flood Reroute Operations Communications and Coordination Plan outlines internal and external coordination steps to support timely and efficient responses to anticipated and actual flooding along bus routes. Key activities include:

- Communications/Power Control Center[15] (C/PC) preparedness coordination with the Chicago Office of Emergency Management & Communications (OEMC) prior to and during forecasted heavy rainfall and flooding;

[15] The heart of bus service operations management and oversight is in CTA's Communications/Power Control Center department. This department supervises all bus operations activities, communicating with drivers and field supervisors and connecting as needed to other CTA departments.

– CTA internal communications and implementation of diversions to respond to route locations that are experiencing flood conditions; and
– Disseminating public information messages through online, television, radio and other means.

Pre-Flooding Preparedness Operations

C/PC will:

– Monitor weather forecast for rainfall that may produce flood water impediments to bus operations;
– Regularly coordinate with OEMC and monitor OEMC push notification traffic to evaluate the potential for flooding along city streets and viaducts;
– As deemed necessary, Safety Department will dispatch a CTA bus operations representative to sit at the OEMC, and notify Operations that someone is there;
– Participate in multi-agency conference calls to monitor weather conditions and identify the need for Streets and Sanitation to clean sewer grates and culverts and for Water Management to pre-check at-risk drains and pumps;
– Coordinate with Customer Information and Media Relations as necessary and in a timely fashion to convey the potential for bus re-routes; and

Example reroute text, NEC 18th & Michigan, northbound stop, July 29, 2017

CTA Safety will:

– As deemed necessary, deploy a representative to sit at the OEMC to participate in city-wide planning efforts and coordinate with CTA C/PC, Dispatch.

Flood Event Operations

C/PC will:

– Receive notification from CTA field supervisors and OEMC on flood conditions;
– Re-route bus operations as necessary and practical along routes that experience flooding;
– Inform operators of route changes who, in turn, will provide such information to patrons, as necessary;
– Provide updates to CTA website and bus shelter variable messaging sign updates to direct passengers to temporary alternate stop locations.
– If dispatched to OEMC, the CTA representative will monitor the WebEOC interface for city-wide flooding incidents and occurrences that may impact CTA services;

- CC/Dispatch will coordinate with field supervisors and OEMC to respond to route flood conditions that are not historically typical; and
- Coordinate with Customer Information and Media Relations to publish and relay bus service updates to the public.

CTA Safety will:

- For major rain events, coordinate with city-wide storm/rainfall operations with OEMC; and
- As deemed necessary, dispatch a representative to sit at OEMC, maintaining coordination with CC/Dispatch;

CTA Customer Information will:

- Provide supplemental information beyond standard Customer Alert information on CTA's website, Twitter, digital signage and other online communication outlets as deemed necessary; and
- Provide information to RTA, for its Travel Info Center.

CTA Media Relations will:

- Convey news about CTA implementing service reroutes as flooding circumstances require, to television, radio and other media outlets as deemed necessary.

7.2.2 Pace

This Pace Bus (Pace) Flood Re-Route Operations Communications and Coordination Plan (FCCP) outlines internal and external coordinative steps to ensure timely and efficient responses to anticipated flooding public along bus routes. Such activities include:

- Preparedness coordination with municipalities prior to the commencement of and during forecasted heavy rainfall and flooding;
- Pace internal communications and implementation and of diversions to respond to route locations that are experiencing flood conditions; and
- Disseminating public information messages through online, television, radio and other means.

Pre-Flooding Preparedness Operations

Operations will:

- Monitor weather forecast for rainfall that may produce flood water impediments to bus operations;
- Coordinate with local partners in anticipation of potential reroutes to confirm the decision-making process; these partners may include municipal, township, county, state, water management, police, and emergency management contacts, among others; and
- Communicate potential detour recommendations to Service Planning via detour@pace.com email to Garages.

Service Planning will:

- Obtain management approvals for service detours;
- Prepare passenger detour notifications; and
- Inform Communications about impending service detours to provide patrons with detour notifications.

Communications will:

- As informed by Service Planning, prepare to communicate potential service reroutes.

Flood Operations

Operations will:

- Garages will re-route bus operations based on information that route sections are impassible, from drivers, supervisors, or other external sources.
- Supervisors will coordinate with Dispatch to respond to route flood conditions that are not historically typical; and
- Communicate re-route activations to Service Planning via detour@pace.com
- Coordinate with Communications to publish and relay bus service updates to the public.

Service Planning will:

- Obtain management approvals for service detours;
- Prepare passenger detour notifications; and
- Send Communications a reroute notice to approve.

Communications will:

- Approve Service Planning's reroute notification and relay bus service updates to various parties.
  - RTA, for its Travel Info Center
  - Pace Customer Relations, for phone line and phone inquiries
  - Pace IT team, to post to website on relevant route's web page.
  - Social media detour posts have been discontinued, but some service change notices and "extreme" detours – a major last-minute one, or a weather- or safety-related one – will still be posted. This would happen right away if needed.

Doe, Jane

Attention Passengers

WINTER STORM WARNING:

Doe, Jane

Attention Passengers

WINTER STORM WARNING: UPDATE

Pace service is operating today, but running 20-30 minutes behind schedule in most cases. Paratransit trips may be up to an hour late. There are a few canceled trips in our South region. For the latest update on your bus route, call Pace customer service at (847) 364-7223, option 3.

Thank you and stay safe today!

Example GovDelivery email warnings about storm-related service interruptions, February 9, 2018

- Send out a GovDelivery blast to passengers who have signed up for updates on a specific route. This could be 400 to 2,000 people, via email and/or text message; this update happens after the online web page post goes live.

   - In an extreme event, Communications can put an emergency bulletin on the front page of the Pace website. Communications can then alert people via GovDelivery who have signed up for “What’s New” alerts—a wider group of subscribers than route-specific recipients. In theory, Communications could send an alert out to all subscribers, but Pace does not anticipate using such wide blasts.

Pace Garages will:

- Either print or receive a shipment of notices to post on the actual buses. This usually happens surprisingly quickly. A detour for one route will be posted on all buses in that route’s division garage, so there are usually several notices in each bus, not all of which will always be relevant to all riders.
   - If there is sufficient time and Pace believes the detour warrants it, laminated copies will be posted on location. The Garage may also put the notices up at terminals.

Innovations

Pace Communications suggests innovations to enhance communications to the public in a number of areas.

- Use of real-time information signs up at Transit Centers to display notice text. Some Transit Centers feature these signs, the remainder will have these installed in 2018. There is currently no regular practice to post service notifications, although other information (e.g., annual budget hearing notifications) is posted.
- Use of real-time web-connected monitors on board buses would be an effective alternative to posting paper notices about planned future detours as well as active reroutes. Electronic media would allow Pace to publicize notices faster, update them frequently, enjoy flexibility in how long the notices are posted, and filter them to only show notices for selected routes (such as current route or intersecting or nearby routes). There are screens on the new Pulse buses but Pace is not quite using the screens to their full potential yet
- Pace does not submit real-time detour information to Google Maps, Pace’s own mapping engine, or other mapping or trip-planning applications at this time, although this may be desirable in the future for Pace staff or customers to be able to see route changes real-time, if such an effort were not time-intensive or technically burdensome.

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8. Resilience Strategies: Action Plan

8.1 General Strategies and Projects

8.1.1 Viaducts and Street Flooding

As documented earlier in this report, flooding under road and rail viaducts or underpasses is a common source of storm event blockage. In many situations over the course of time, roads have been lowered to allow clearance under bridge and viaduct structures to allow sufficient height for vehicles to pass. Gravity naturally can cause water to collect in these low-lying areas, which can accumulate and build if drainage technologies and systems are insufficient or not operating as needed to drain the stormwater. While every situation for blocked viaducts needs to be investigated individually to determine root causes and corrective actions, there are general commonalities that are useful to understand.

Viaduct flooding generally falls under the jurisdiction of a municipal or county water management department or agency, such as the City of Chicago's Department of Water Management (CDWM). A water department tracks local areas that are prone to flooding, particularly during storm events, and takes steps to minimize the impacts of rain events. They also receive messages from sources such as 311 / emergency services or local government resident service hotlines. Ideally, call services (like the City of Chicago / OEMC's Open311 service) maintain a history of infrastructure performance and facilitate communication that is open and accountable.

In order for the drainage to properly occur, from the lightest rainfall to the heaviest storm event, the infrastructure must be sized properly, and in good working condition. The elements of street and parkway drainage in the public right-of-way include:

- Street surface (pavement): The pavement must grade toward the drainage structures. If the street is in disrepair or the drainage structures are not located at the low points of the surface grade, flooding will occur.
- Drainage structures: The drainage structures collect surface runoff and route the water to underground storm sewer pipes. The structures are mostly inlets and catch basins, but other types of structures may be utilized, such as French drains. It is imperative that these structures be kept clear of debris and be vacuumed regularly and as necessary.
- Storm sewer: Underground pipe may be composed of masonry or metal. Typically, a water department will investigate a poorly performing drain system by televising the pipe. The video capture will show if and where a pipe collapse or blockage has occurred.
- Pump stations: In some cases low-lying areas require a mechanical means of pumping the water up, out, and into the existing storm sewer system, which lies higher than the viaduct elevation.

Viaduct and street flooding occurs most dramatically following storm events. In most flooding cases, the water will take time to drain completely because the drain system capacity (size of sewer) is insufficient to facilitate the amount of water discharged during a storm event. In cases where one of the elements as described above are in need of repair, a water department may not be able to make the necessary repairs with a local fix, but will require extensive reconstruction. These larger capital improvements require funding, design, inter-agency coordination and time to construct.

If a flood-prone area requires a construction project to repair or replace a sewer system or street, a water department will typically reach out to a sister department of transportation or engineering and all affected utilities to coordinate construction.

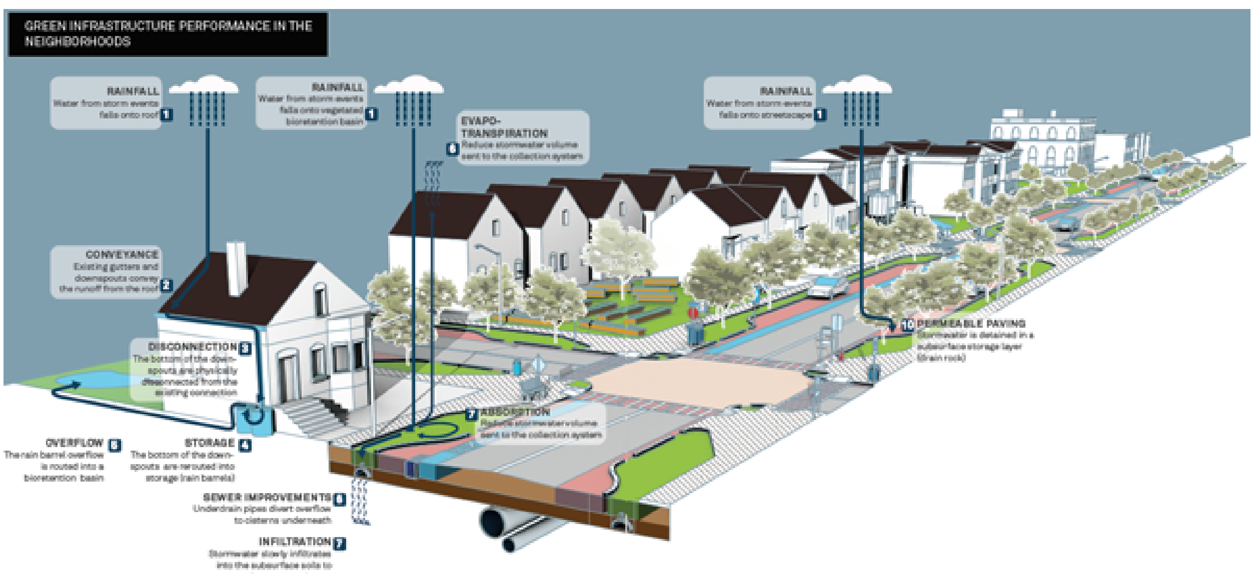
8.1.2 Green Infrastructure

Green infrastructure systems are technologies installed to minimize points of overflow into the sewer system, mitigate localized flooding, and allow for infiltration, storage or evapotranspiration of water such as stormwater runoff. Reducing the volume of runoff entering the sewer system avoids overtaxing current infrastructure capacity and offers numerous community livability benefits. Illustrations of how green infrastructure systems behave during storm events and interact with traditional grey infrastructure are provided in **Figure 28** for neighborhood environments and in **Figure 29** for commercial areas.

In addition to helping address flooding problems, investment in green infrastructure in Chicago's public right-of-way and vacant land can be used to improve community livability and neighborhood development. Repurposing vacant lots, parkways, and underutilized spaces improves community safety, health, and wellbeing. These co-benefits can be realized through coordinated planning and investments. Determining how to best coordinate these investments with initiatives to create more livable, sustainable communities requires collaboration across agencies and a clear articulation of the value of such coordinated investments.

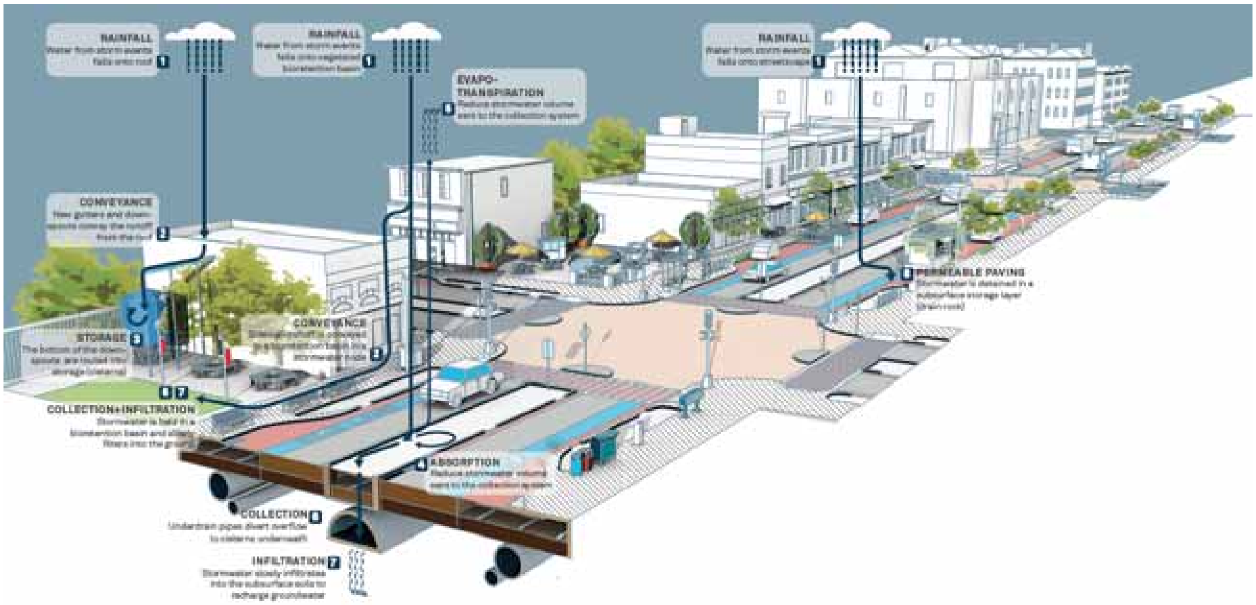
Green infrastructure is most effective in mitigating flooding in a particular area if a comprehensive program of components is implemented in the area, as opposed to installation of a few "spot fix" elements in the immediate flood-prone location. That is, the investment in a larger, coordinated set of elements will have a larger positive impact (although at higher cost) than a smaller investment would be able to achieve. However, the mix of technologies should be customized to the different land uses of the subject area to assure that the improved stormwater capture capacity is well distributed and integrates into the fabric of the neighborhood or community. Individual examples of green infrastructure elements are provided in **Table 18**, along with images and rough cost indicators.

Figure 28: Prototypical Green Infrastructure System - Neighborhood



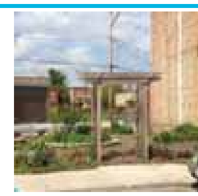
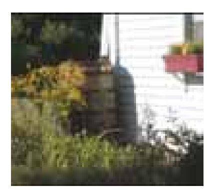
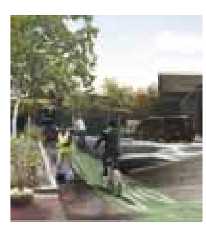
Source: AECOM. "City of Chicago West Side Resilience Project." (2016)

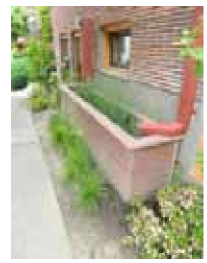
Figure 29: Prototypical Green Infrastructure System - Commercial



Source: AECOM. "City of Chicago West Side Resilience Project." (2016)

Table 18: Green Infrastructure Elements

Element	Description / What it Accomplishes	Image
Rain gardens and urban agriculture	A landscaped, man-made depression that both improves water quality and reduces flooding by promoting infiltration. Can be used to grow local foodstuffs.	
Bioretention basins	Stormwater is held in a bioretention basin and slowly filters into the ground	
Downspout Disconnection and Rainwater Harvesting / Rain Barrels	New gutters and down-spouts convey the runoff from the roof; down-spouts are routed into storage (cisterns or barrels) rather than stormwater system	
Permeable Pavement	Stormwater is detained in a subsurface storage layer (drain rock) or slowly infiltrates into the subsurface soils to recharge groundwater	

Element	Description / What it Accomplishes	Image
Bioswale	Open vegetated channels designed to detain and promote filtration of stormwater runoff	
Trees / Street planting	Aside from reducing air pollution and heating & cooling costs, trees also absorb excess water from storm events	
Flow through planters	Placed at or above ground level, flow-through planters do not infiltrate the ground but can help in constrained sites with poorly draining soils, steep slopes, or contaminated areas	
Stormwater conveyance	Sidewalk or street runoff is conveyed to a bioretention basin in a stormwater node	

Sources: AECOM, West Side Resilience. Cape Cod Green Guide. Connecticut Dept of Energy. City of Plattsburgh Stormwater Conveyance System

Green infrastructure is a good opportunity because multiple transformative investments in green space and green infrastructure are underway in the RTA service area. In the City of Chicago, notable initiatives include the Resilient Corridors work through the Department of Planning and Development, and the L-Evated Chicago project through Strong, Prosperous, And Resilient Communities Challenge (SPARCC) and the Chicago Community Trust. The MWRD is one of the biggest implementers of green stormwater infrastructure in the region and is in the midst of a comprehensive program to study all of the watersheds in its jurisdiction to create detailed action plans. A number of agencies increasingly recognize and encourage investment in a range of co-benefits that can be produced by integrated strategies capable of producing a resilience dividend.

8.1.3 Data Collection and Forecasting

This project has represented an interesting opportunity to collect and synthesize transit operations and flooding / climate datasets for the purpose of defining meaningful and implementable resilience strategies and recommendations. Funding permitting, it would be valuable to continue collecting actual flood incident data (from source such as OEMC or consortia of jurisdictions sharing 311/911 service) and reports from CTA and Pace operations, actual traffic delays, and sewer capacity performance measures together with rainfall and storm date-specific data to further correlate complaints and actual incidents of bus operations interruption with location-specific problem areas will help to further understand and prioritize flood mitigation priority areas.

8.1.4 Smart Cities Implementations

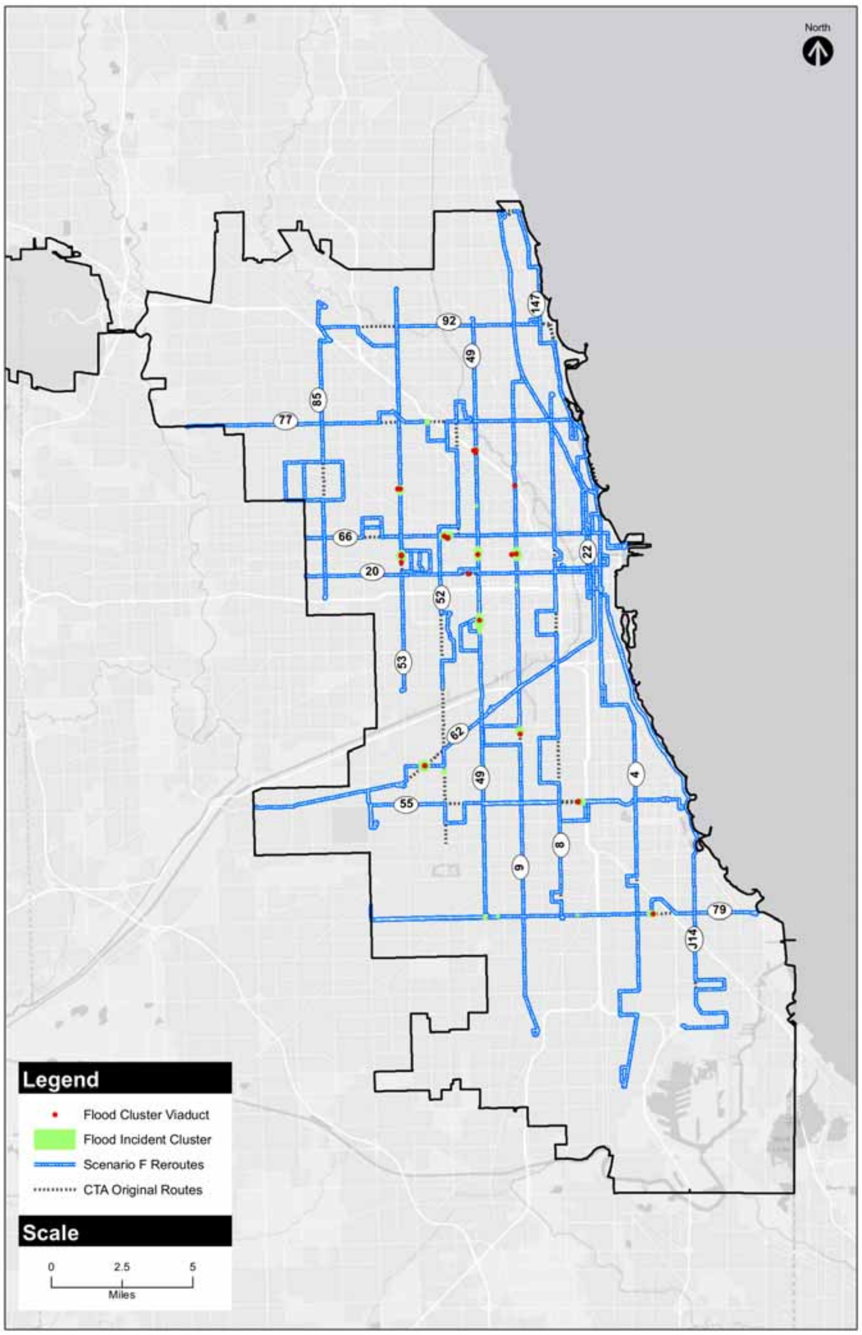
As cities and regions' infrastructure ages, an increasing trend is the introduction of technological solutions to manage the increasingly scarce infrastructure resources with strained financial resources, growing populations and increased development, and weak political will to impose new funding sources. Advancing technologies, particularly the networked "internet of things" (IoT) offer techniques for improving the resource management of many assets related to city life, the flow of goods, people, and vehicles, and the perception of improved quality of life. This "Smart City" approach coordinates investment and innovation to improve the function of an area through the use of technology and data. As pertains to flooding that disrupts bus service, Smart Cities investments can include technologies that monitor water levels (especially where there should be little-to-none under regular conditions), traffic congestion, drain system blockages, and transmit such data to a monitoring hub that alerts CTA, Pace and local stakeholders to problems requiring immediate attention.

8.2 CTA Resilience Strategies

8.2.1 Projects

By analyzing CTA-reported flooding events that were within 100 feet of a Scenario F route, the project team was able to generate a map of dense flood incident clusters in the City of Chicago. In most cases the larger clusters with a higher density of flooding reports (depicted in green in **Figure 30**) also have a viaduct (red dot) in the vicinity. This information, along with the acreage of the cluster and the number of reported flooding incidents is shown in **Table 19.**

Figure 30: CTA Flood Incident Clusters and Flood Cluster Viaducts



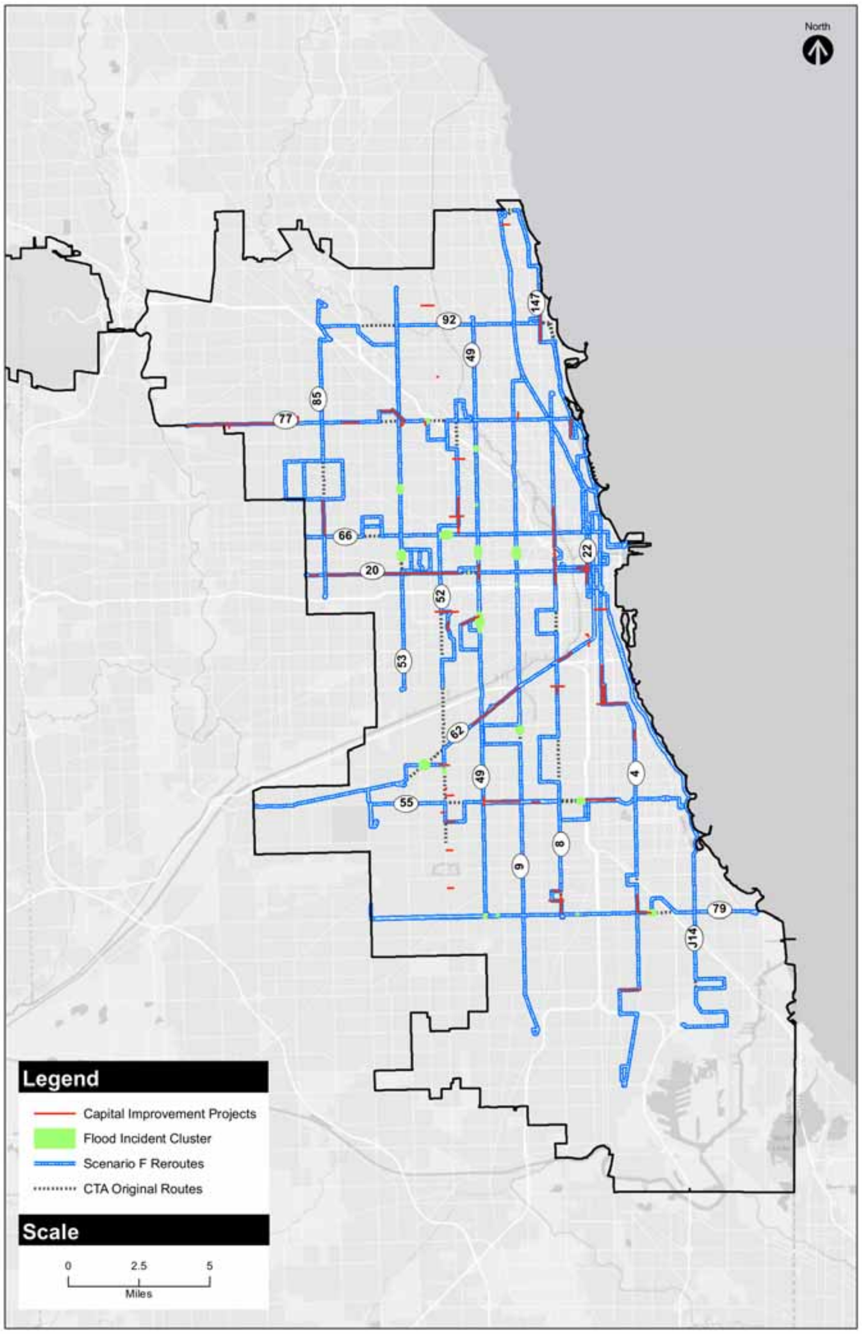
As demonstrated in Table 19, all of the largest flooding clusters (more than five CTA-reported incidents) have a rail crossing or facility nearby. They also have 86 percent of the OEMC 311 calls reporting flooding or water on street, and 25 of the 30 viaducts in the sample set. It would be difficult to fully remediate these pervasive problems areas via green infrastructure mitigation—construction projects to address stormwater infrastructure or roadway design are probably needed. Consultation with CDOT planners and engineers suggests that for many of these rail-adjacent and viaduct-adjacent flooding problems, an effective avenue for pursuing mitigation projects is to coordinate such improvements with projects in the Chicago Region Environmental and Transportation Efficiency Program (CREATE). This public-private partnership has completed 29 of its planned 71 freight and passenger rail improvement projects to date, focusing mainly on eliminating at-grade rail crossings, but also including viaduct improvements. For more details on the 50+ viaducts improved between 2005 and 2015, see http://www.createprogram.org/factsheets/viaduct_2015.pdf.

Table 19: Properties of CTA Scenario F Flooding Clusters

Cluster ID	Location	Rail nearby	Acres	CTA Flood Incidents Count	OEMC Flood Incidents Count	Capital Improvement Projects Nearby	Viaducts Count
1	Belmont @ Kimball		166	4	6	Yes (Dec 2013, Water)	0
2	Western @ I-90/94		163	4	4	No	3
3	Ashland @ I-90/94		28	0	0	No	1
4	Pulaski @ Cortland	Yes	346	8	4	No	2
5	Western @ Hirsch		64	3	6	No	0
6	Sacramento @ Chicago	Yes	559	16	6	Yes (Sep 2013, Arterial Surfacing)	7
7	Western @ Kinzie	Yes	516	12	7	Yes (Dec 2015, Water)	1
8	Ashland @ Kinzie	Yes	590	17	5	No	2
9	Pulaski @ Kinzie	Yes	481	12	7	No	6
10	Madison @ Rockwell	Yes	40	2	1	No	1
11	Ashland @ I-290		69	3	0	No	0
12	Western @ Ogden	Yes	752	18	2	Yes (Dec 2013, Arterial Surfacing)	1
13	Pulaski @ Ogden	Yes	45	2	0	No	0
14	Ashland @ W 41st	Yes	344	8	2	No	1
15	Archer @ W 48th	Yes	549	24	3	No	2
16	Kedzie @ W 48th	Yes	136	3	0	Yes (Mar 2015, Water)	0
17	Garfield @ Shields	Yes	316	7	3	Yes (Aug 2014, Arterial Surfacing)	2
18	W 79th @ Eggleston		65	1	0	No	0
19	E 79th @ Greenwood	Yes	330	8	21	Yes (Dec 2013, Water)	1
20	W 79th @ Hamilton	Yes	71	3	0	No	0
21	w 79th @ Western		130	3	0	No	0

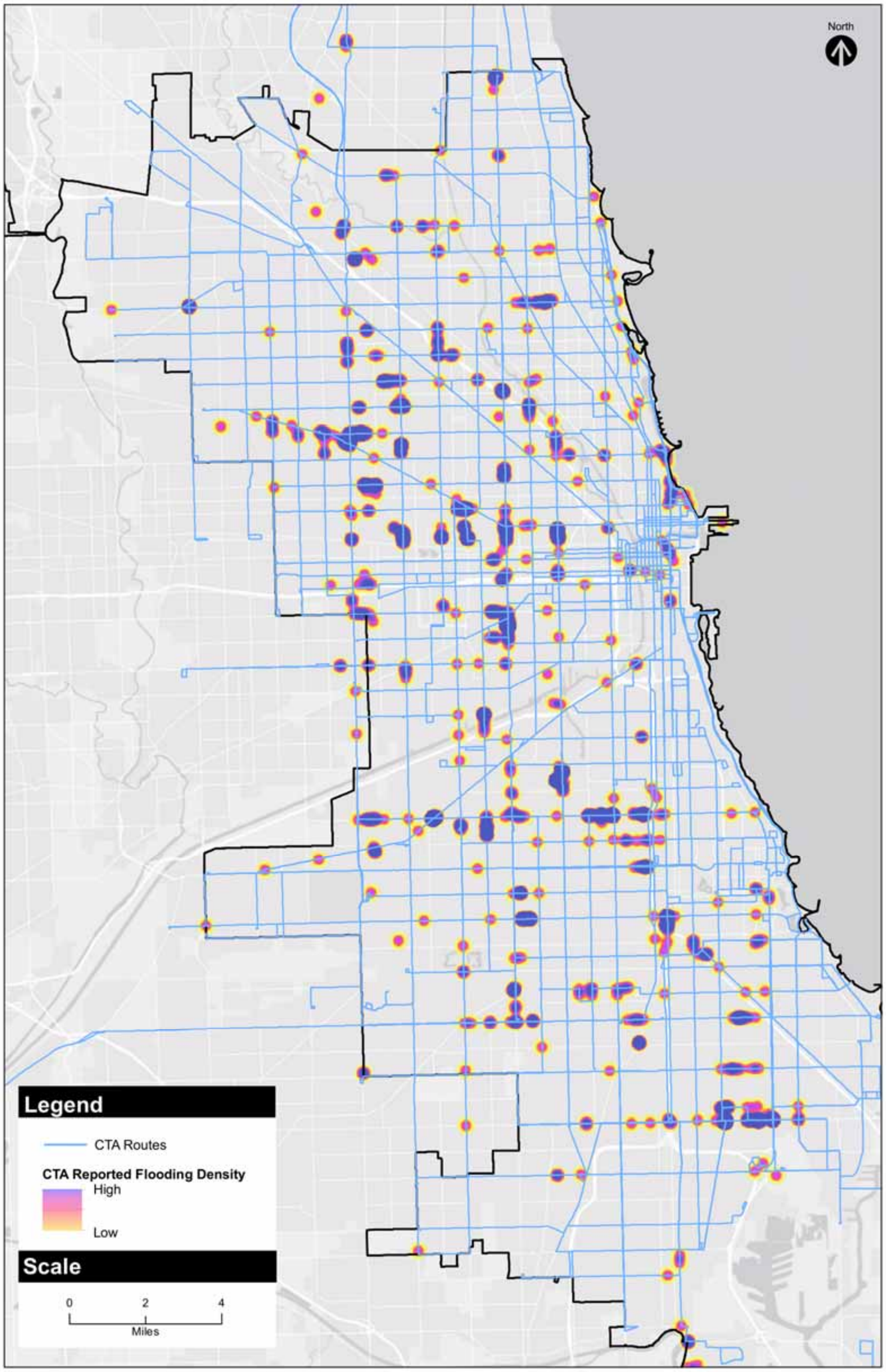
Comparing these cluster locations with the 2014-2018 Capital Improvement Plan shows that seven clusters are in proximity of a project completed since 2013 (Figure 31). These projects either involved water infrastructure or arterial surfacing, as noted in the table. There are no future projects nearby at this time, but it is possible that completed projects may already be resolving some of the historical flooding problems in the area (CTA flood incident data from 2011-2016 was used in this analysis). These areas should be monitored for ongoing problems that would be scheduled for future capital projects.

Figure 31: CTA Flood Incident Clusters and Capital Improvement Projects



Aside from the Scenario F routes selected for risk analysis and mitigation recommendations, there are many other areas of the city that experience repeated flooding. **Figure 32** shows the city-wide expanse of highly clustered CTA-reported flooding. This GIS layer can be overlaid with other agency data layers to determine opportunities for co-benefits in capital investment programming (supporting or supplementary to 8.2.2.1 below).

Figure 32: Density of CTA-Reported Flooding (All Routes)



Underground construction projects to resolve typical urban flooding points of failure—as defined in section 9.1.1 above—are numerous and ongoing within the City of Chicago. The projects may be initiated through Mayoral, Aldermanic, sister-agency and/or public (311) requests. However, CDWM actively tracks the sewer system and prioritizes projects in a multi-year look-ahead based on their plan. Ideally, the existing sewer system would facilitate all storm events and run-off; however, due to the age of the infrastructure, or the condition of adjacent areas producing the runoff, it is an ongoing challenge for CDWM to comprehensively correct the flooding issues at once.

8.2.2 Policies and Procedures

8.2.2.1 Construction Coordination

The City of Chicago Department of Transportation's Division of Infrastructure Management (CDOT's DOIM) directs the Office of Underground Coordination (OUC). The OUC is composed of members who review new construction and installation work in the public way. As stated in the City of Chicago's website, "The OUC is responsible for the protection of the City's surface and subsurface infrastructure from damage due to planned and programmed construction, installation and maintenance projects."

The OUC process contains two parts: Information Retrieval (IR) and Existing Facilities Protection (EFP). Typically, an agency or developer proposing a new project will engage the OUC for IR in the beginning of a project in order to obtain existing utility and facility maps, atlases, and other information. The intent is for the proposed plan to work around the existing infrastructure if possible. The next engagement with OUC occurs with an EFP submittal, once the plans are far enough along—typically varying from 60 percent to 90 percent complete. This step will allow the OUC to negotiate as necessary with the permit applicants to determine how conflicts may be resolved.

The applicant and OUC member may resolve a conflict by moving existing facilities out of the way of new construction, which may require reimbursement to the OUC member. An OUC member may also reject the proposed impact and not approve the construction permit. This would force the designer to make changes to the plans to clear the existing utility. If possible, the proposed design clears existing utilities, and the EFP review produces no conflict from most if not all members, and the OUC construction permit is issued.

The CDOT OUC members include:

- CDOT Project Development
- Comcast
- CTA – Traffic (Dean Pallanti)
- ComEd
- RCN
- Chicago Park District
- Bureau of Forestry
- MDE/Thermal Chicago Corporation
- ComEd Distribution
- Department of Water Management
- JC Decaux
- Chicago Water Partners
- CTA – Facilities
- People's Energy
- MCI
- CDOT Infrastructure Management
- Looking Glass Network
- CDOT Engineering
- AT&T – Illinois/SBC
- Metropolitan Water Reclamation District
- AT&T Local Network Services
- Level 3 Communications
- Bureau of Electricity

The CDOT OUC has developed a GIS-based system, dotMaps, which tracks on-going projects city-wide. The members meet weekly to address outstanding conflicts that are not easily resolved through the above process. Any developer or agency that is not on the above OUC member list is able to submit its project(s) through the IR and EFP process, but is also able to request a special section to the weekly OUC meeting. For example, the CTA presented the Red and Purple Modernization Program to the OUC members to provide insight for impending extensive coordination, and to discuss critical potential conflicts. Increasing the coordination of infrastructure investments in the public right-of-way has helped the city save $108 million in duplicative work since 2012, according to CDOT Division of Infrastructure Management.

Office of Underground Coordination Policy Recommendation

Infrastructure agencies traditionally consider only the resilience of their own individual systems. However, true infrastructure resilience requires thinking about infrastructure outside of traditional water, sewer, road, energy, and communications silos. By considering the cascading impacts of one infrastructure system on another, targeted and coordinated investments create greater system-wide benefits.

Key to enabling targeted and coordinated investments that benefit multiple infrastructure systems is developing a mutual understanding of infrastructure agencies' priorities, issues, and opportunities. As demonstrated in this report, in order for CTA and Pace to improve the resilience of their bus systems, region-wide flooding issues need to be addressed. Identifying solutions to these flooding issues is only the first step in creating a more resilient regional bus system. These transit agencies must also communicate their priorities to necessary partner agencies and coordinate with them to capture resilience benefits.

This communication of CTA/Pace priorities can occur through different channels. The first is through DOIM's use of "hot lists" - DOIM may accept "hot lists" from members and sister agencies for future planned projects or project areas. They will track any potential project against the list to ensure coordination.[16] CTA/Pace may be able to negotiate with the OUC to incorporate the Implementation Action Plan zones into dotMaps, and facilitate coordination between any potential construction impact within the zones with CTA or Pace.

Ideally, the coordination will lead to extensive synergy. Opportunities may arise, as the OUC considers the hot list, to prioritize work to address flooding issues with severe impact to CTA/Pace operations. The coordination that may occur by attending occasional weekly OUC meetings, as well as encouraging flooding concern areas to be mapped on dotMaps, the CTA/Pace teams will be better able to review potential projects by anyone on the above OUC member list, as well as any developer or new construction. If the Implementation Plan assists in incorporating the hot list of flooding zones into OUC review and coordination, the flooding zones may be improved either by determining priority project by the utilities (such as DWM), or by OUC review to determine whether a proposed project may address an ongoing issue that negatively impacts CTA/Pace operations.

CTA/Pace can also align directly with organizations not involved in the DOIM coordination efforts. Groups such as Chicago's Department of Planning and Development (DPD) have a stated interested in accelerating the implementation of green infrastructure solutions, but do not participate in dotMaps or DOIM's "hot lists". Through its Resilient Corridors project, DPD aims to construct stormwater landscapes (i.e., Green Infrastructure) that not only reduce flooding but also create additional co-benefits. As the City of Chicago considers the expansion of this project to additional corridors, CTA's priority routes can be considered. Reducing flooding on these priority routes creates added co-benefits for DPD's projects by reducing negative impact on riders and CTA revenues from reroutes.

8.2.2.2 Communication Coordination

As noted in section 7.2.1, CTA participates in some communications and planning activities with OEMC to monitor activity during severe weather and other special events. To the extent that staffing resources and budgets allow, CTA may want to explore access to OEMC data and contact/workflow systems and regular participation in all event monitoring activities.

[16] An example of this would be the Street Resurfacing program. If an underground utility proposes a project within a potential street-resurfacing area, the OUC will strive to assist either party with a benefit of restoration. Either the underground utility may restore the street if the schedule dictates, and the Resurfacing program may skip the project site; or the utility may leave behind a restored utility trench for the Resurfacing program to resurface shortly thereafter.

8.3 Pace Resilience Strategies

8.3.1 Projects

Pace needs to coordinate with 3 primary agencies (MWRDGC, IDOT, and US Army Corps of Engineers) to deal with most of the flood problems identified in Scenario E.

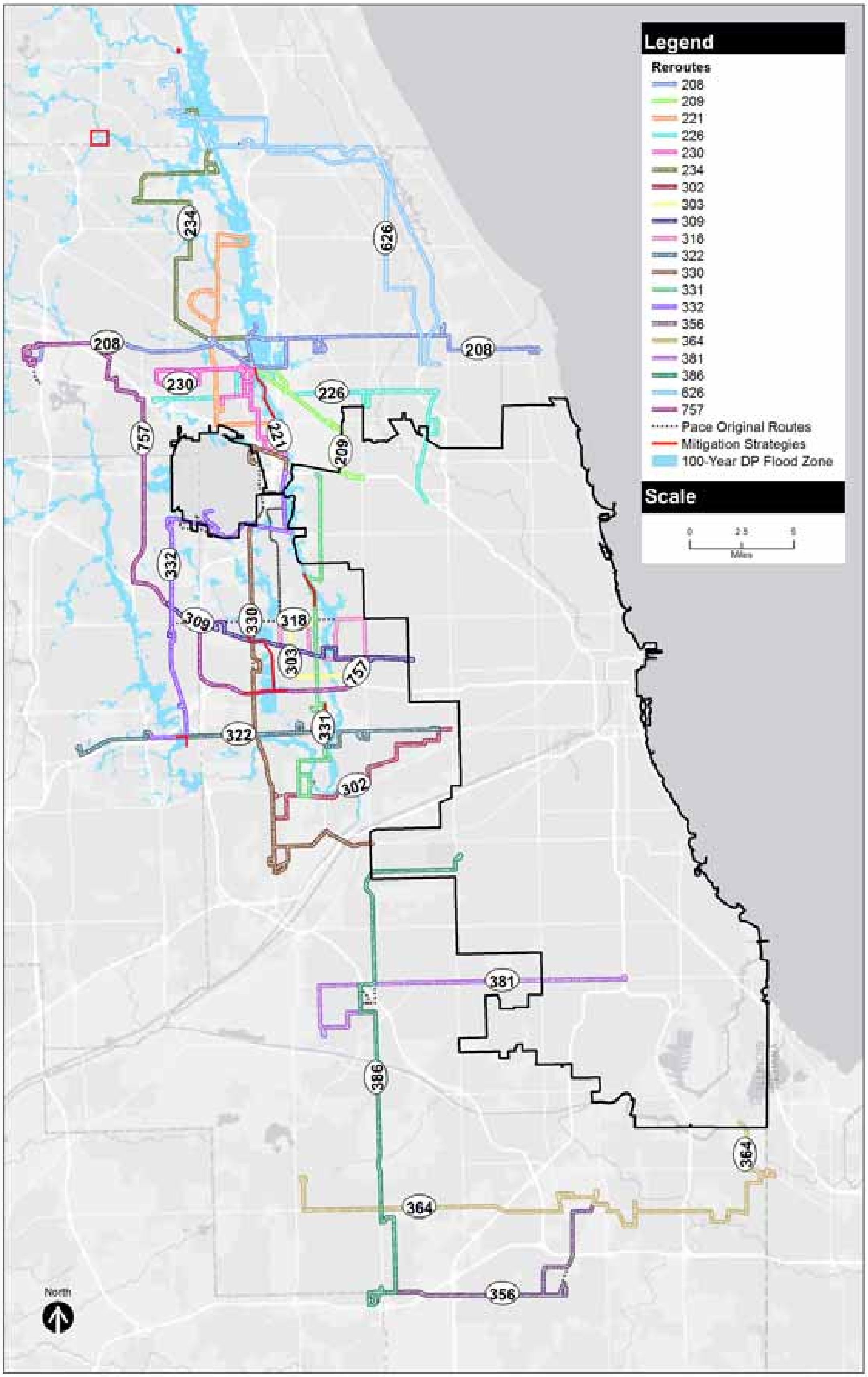
In terms of prioritizing projects to mitigate flooding issues, if Pace is having a problem, the County DOTs, County or municipal stakeholders, and stormwater agencies would be best groups to approach first, as they are probably having a problem at that same location. Cost- sharing for studying solutions with these groups may be the most effective approach.

Mitigation strategies that have already been brought forward are described in **Table 20** and depicted in **Figure 33**.

Table 20: Pace Scenario E Mitigation Projects

Route	Mitigation Strategy
209, 226	IDNR-OWR has built two flood control projects in this area in the last decade that should solve most of the flooding problems shown. It is uncertain whether floodplain maps were ever updated with the results of these projects; it might be the method of handling the enhanced flood plain in this area that flags these areas as potential problems. These routes should experience infrequent flooding at the worst.
230	Pace needs to lobby Congress regarding funding for the Corps Des Plaines River Levee 9. The Des Plaines River project was authorized by Congress in the Water Resources Development Act of 2016. Now Congress has to include funding for the project in budget.
234	MWRDGC is studying reservoir expansion on Buffalo Creek upstream of this flooding problem. Need to coordinate with MWRDGC to move this project forward.
303, 309, 330	MWRDGC's Addison Creek project that is moving into the design phase should reduce the flood frequency for these routes.
318	MWRDGC's Addison Creek project and a study by IDOT on North Avenue at Silver Creek should reduce the flooding frequency along this route.
331	The Corps Des Plaines River Levee 4 with two closure structures should reduce the flood frequency for this route. The Grand Avenue closure structure would close Grand Avenue but will allow Des Plaines River Road to remain open, and generally would be closed between the 10 and 50-yr flood event. The closure structure at Des Plaines River Road and 5th Avenue would close Des Plaines River Road here during the 100-yr events.
332	DuPage County Stormwater did not show the portion of this route on 22nd Street flooding. They will need to coordinate with Elmhurst regarding solutions for the York Road underpass flooding. The portion of the route along Irving Park Road and Bensenville Ditch may have been addressed when Irving Park and Bensenville Ditch were relocated for the O'Hare Airport Expansion.
626	The Aptakisic Creek flooding along a portion of this route should be coordinated with the Lake County Stormwater Management Commission. The roads are IDOT's jurisdiction at this location and talks about any flooding problems here should also be discussed with IDOT.
757	The flooding shown along I-290 portion of this route should be addressed when IDOT reconstructs I-290. PACE needs to work with IDOT on scheduling this reconstruction.

Figure 33: Pace Scenario E Reroutes and Mitigation Projects



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8.4 Action Plan Matrix

8.4.1 CTA

CTA can coordinate with a broad range of partners to pursue short and long term flood mitigation actions.

Project/Policy	Agency/ Organization	Cost	Notes
Viaduct improvement projects	CREATE public and private partners; Metra; railroads; CDOT; CDWM	$$$	CREATE Viaduct Improvement Program completed in 2015. Negotiate additional funding for expansion of that program along with remaining CREATE projects.
Underground construction projects	CDWM, sister water departments	$$$	Such projects may be initiated through Mayoral, Aldermanic, sister-agency and/or public (311) requests.
Clearance of drains of debris prior/during storm	OEMC; Chicago Streets & Sanitation	$	Proactive pre-storm preparation
Coordination with other development/ utility/ roadwork projects	CDOT DOIM	$	Potential participation in dotMaps system. Submittal of a project “hot list” for consideration by the Office of Underground Coordination. The benefit would be potential remediation of infrastructure-induced flooding while other capital projects are being carried out, thus minimizing costs and potential conflicts.
Green infrastructure	Chicago DPD and CDOT (Resilient Corridors Program)	$$	As the Resilient Corridors program is expanded to additional corridors, CTA’s priority routes can be considered.
Ongoing monitoring and data collection	CTA (CleverCAD); OEMC 311 data	$	Use of flood report data to identify and monitor problem areas can be used to generate hot list for participation in OUC meetings (above) or to provide to Streets and Sanitation for debris clearance (above)
	CMAP; CDWM; CDOT; OEMC; MWRD; IDNR; FEMA; CNT; MPC	$$	Develop and enhance/maintain City and/or regional database of flood incidents, forecasts, risk factors, and mitigation measures

Decode of Agency / Organization Abbreviations

CDOT – Chicago Department of Transportation
CDPD – Chicago Department of Planning and Development
CDWM – Chicago Department of Water Management
CMAP – Chicago Metropolitan Agency for Planning
CNT – Center for Neighborhood Technology
CREATE - Chicago Region Environmental and Transportation Efficiency Program
DOIM – Division of Infrastructure Management within CDOT
FEMA – Federal Emergency Management Agency
IDNR – Illinois Department of Natural Resources
IDOT – Illinois Department of Transportation
MPC – Metropolitan Planning Council
MWRDGC – Metropolitan Water Reclamation District of Greater Chicago
OEMC – Chicago Office of Emergency Management & Communications
OUC – Office of Underground Coordination managed by CDOT DOIM

8.4.2 Pace

Pace can coordinate with a broad range of partners to pursue short and long term flood mitigation actions. .

Project/Policy	Agency/ Organization	Cost	Notes
Viaduct improvement projects	CREATE public and private partners; Metra; railroads; local DOT	$$$	CREATE Viaduct Improvement Program completed in 2015. Negotiate additional funding for expansion of that program along with remaining CREATE projects.
Underground construction projects	Local and county departments of water management and transportation	$$$	Such projects may be initiated through municipal, sister-agency and/or public (311) requests.
Clearance of drains of debris prior/during storm	Local DOT and Departments of Streets & Sanitation	$	Proactive pre-storm preparation
Coordination with other development/ utility/ roadwork projects	Local Councils of Governments	$	Participate in TIP planning process to reinforce priority hotlist
Watershed planning councils	MWRD, local departments of planning, water and transportation	$	Identify risk areas and problems, with corresponding mitigation projects and policies
		$$	Prepare stormwater master plans to address urban flooding; five pilot studies under way or complete; expand to other high-priority / high-flood risk areas
Green infrastructure	Local departments of planning, water and transportation, MWRD	$$	Implement carefully curated palettes of green infrastructure for maximum benefit
Ongoing monitoring and data collection	Pace operating systems; local 311/911 services; smart cities service providers	$	Use of flood report data to identify and monitor problem areas can be used to generate hot list for participation in infrastructure planning meetings (above); provide to streets and sanitation departments for debris clearance (above)
	County and municipal stormwater departments; CMAP; IDNR; FEMA; CNT	$$	Develop and enhance/maintain county and/or regional database of flood incidents; rainfall, water level, and flood forecasts; risk factors; and mitigation measures
Cost-sharing for local capital improvement projects to alleviate flooding issues	County DOTs, County, municipality, stormwater agencies	$$	Coordinate problem diagnosis and solution planning among agencies
Cost-sharing on major capital improvement projects pertaining to riverine flooding	County and municipal stormwater departments; MWRDGS, IDOT, US Army Corps of Engineers	$$$	Projects include reconstruction of a segment of I-290 (IDOT), Des Plaines River Levee 9 (US ACE), Buffalo Creek reservoir expansion (MWRDGC), Addison Creek (in design phase, MWRDGC), Silver Creek (IDOT), among others

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Flooding Resilience Plan for Bus Operations

Appendix A.1: Task 2 Technical Memorandum: Maps Identifying Flooding Impacts

Prepared for the Regional Transportation Authority of Northeast Illinois

March 30, 2018

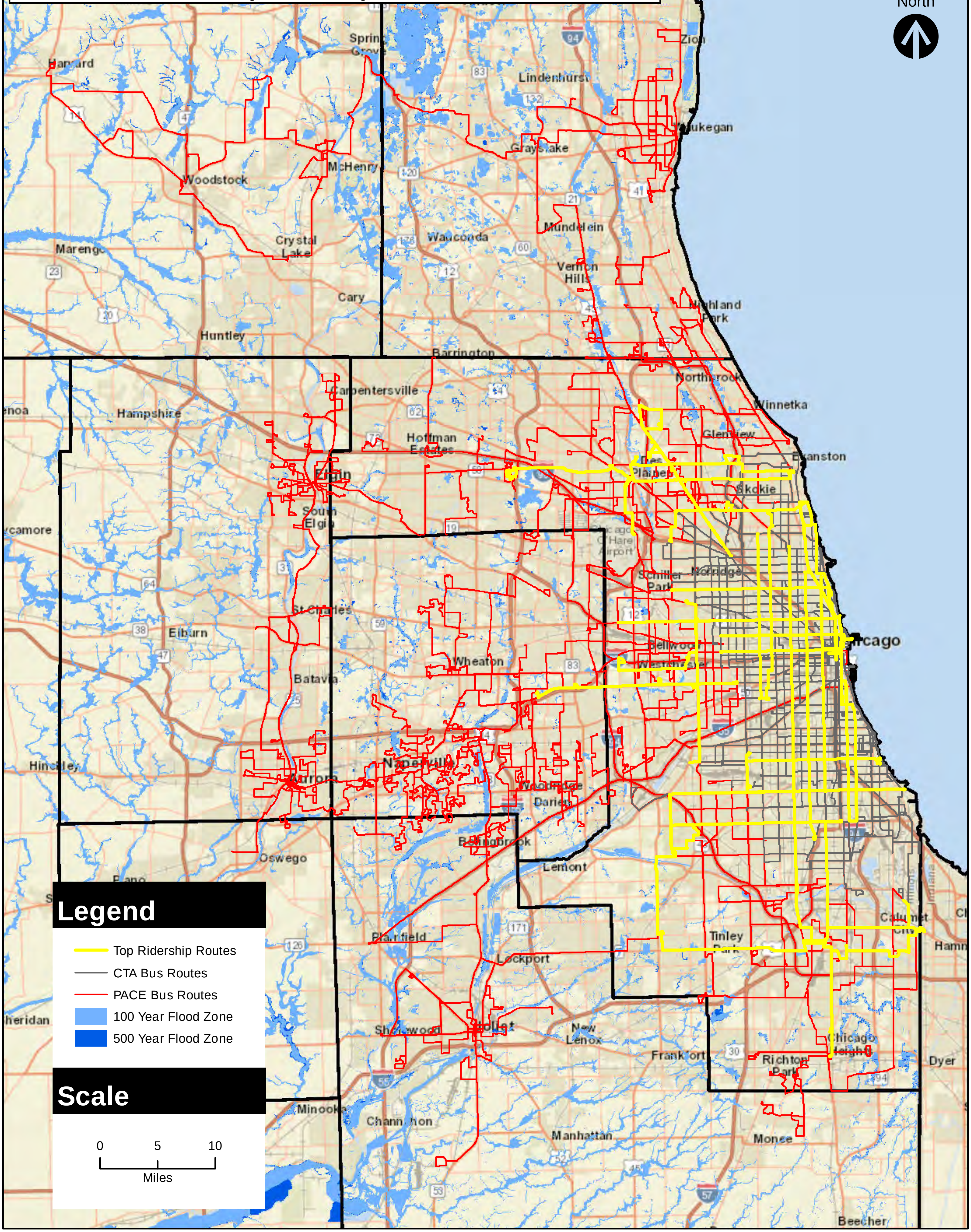
Appendix A.1 Contents

Regional Contextual Maps

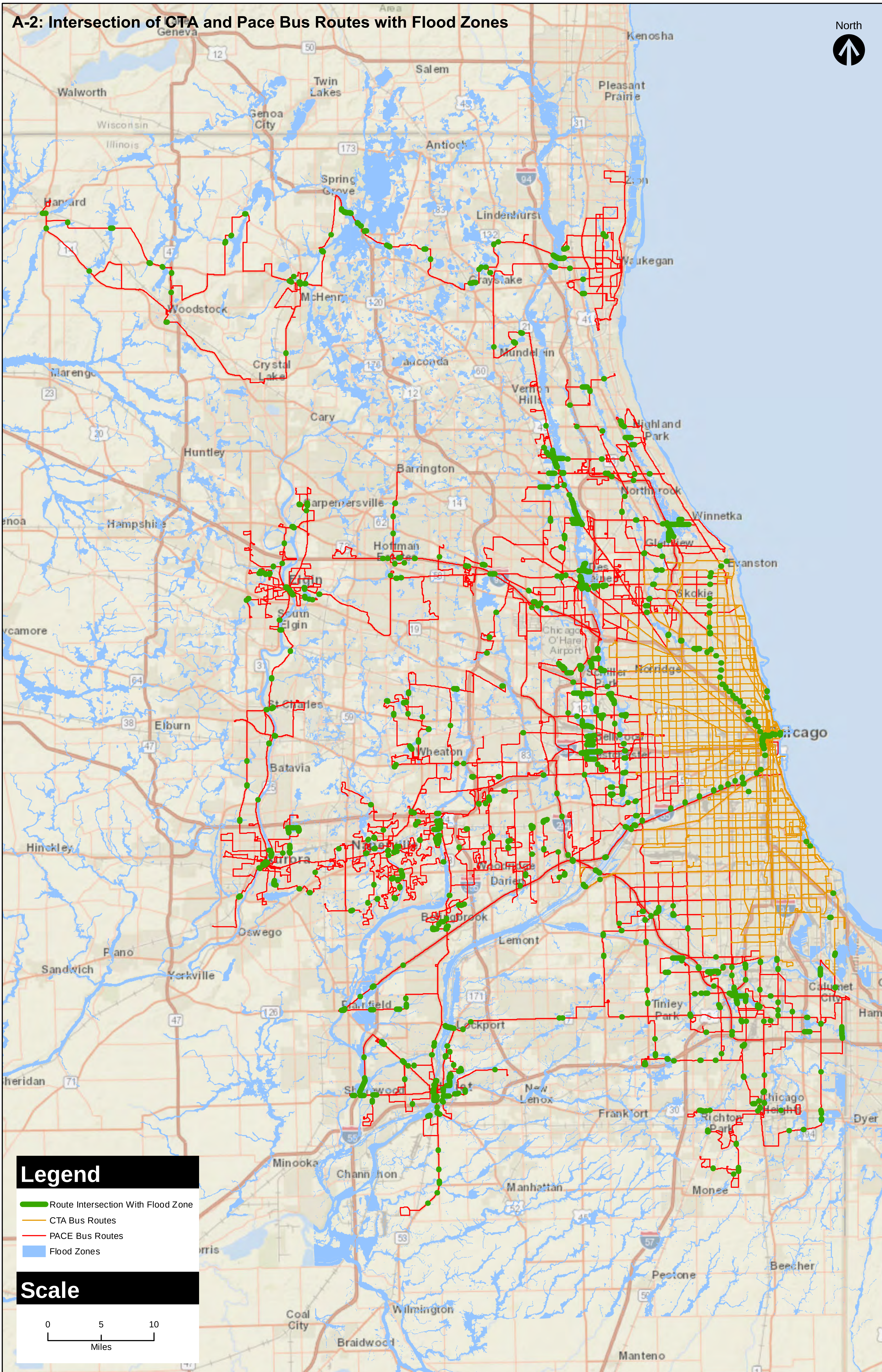
CTA Scenario Maps

Pace Scenario Maps

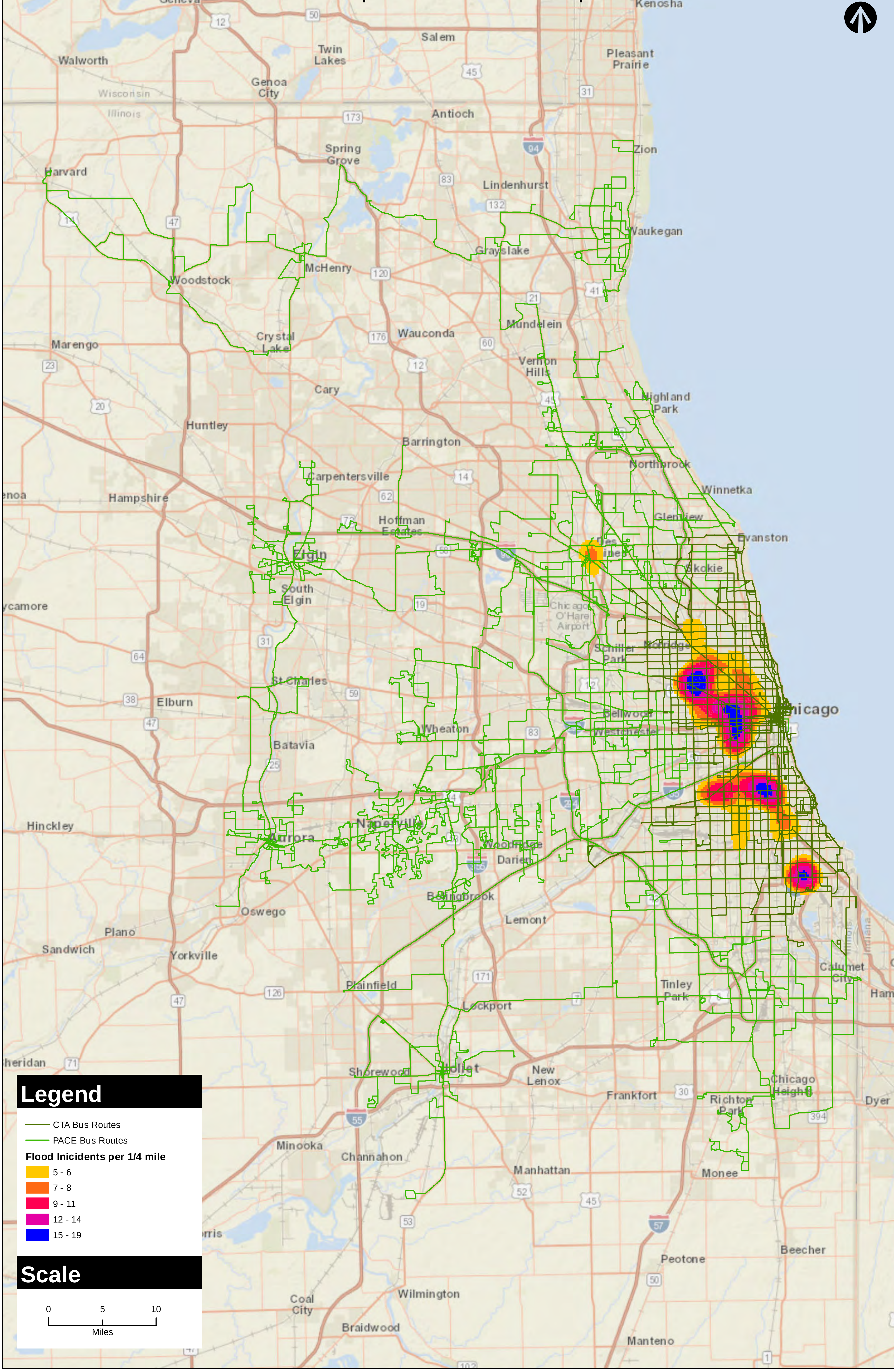
A-1: CTA and Pace Top Ridership Routes and Flood Zones



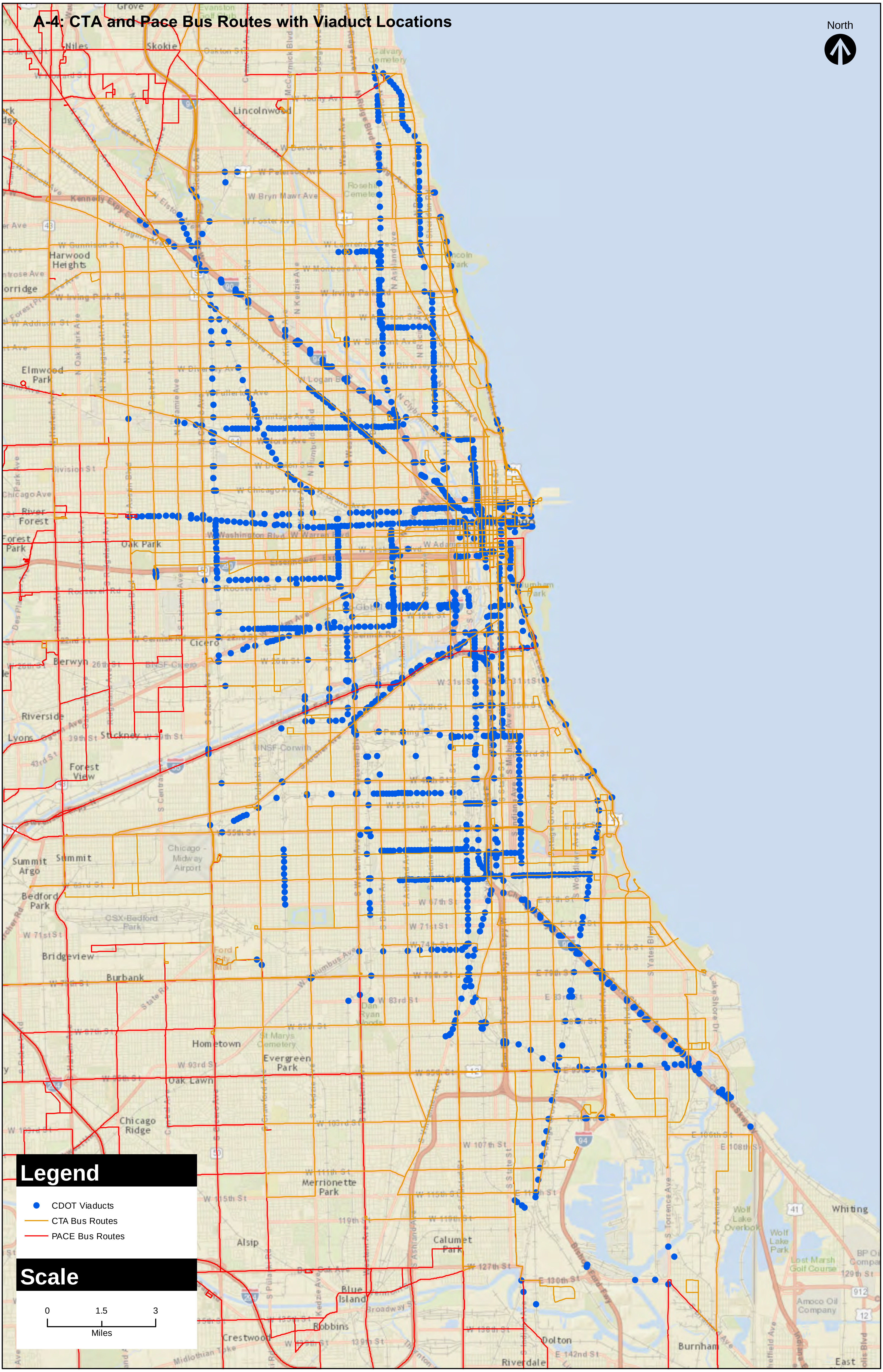
A-2: Intersection of CTA and Pace Bus Routes with Flood Zones



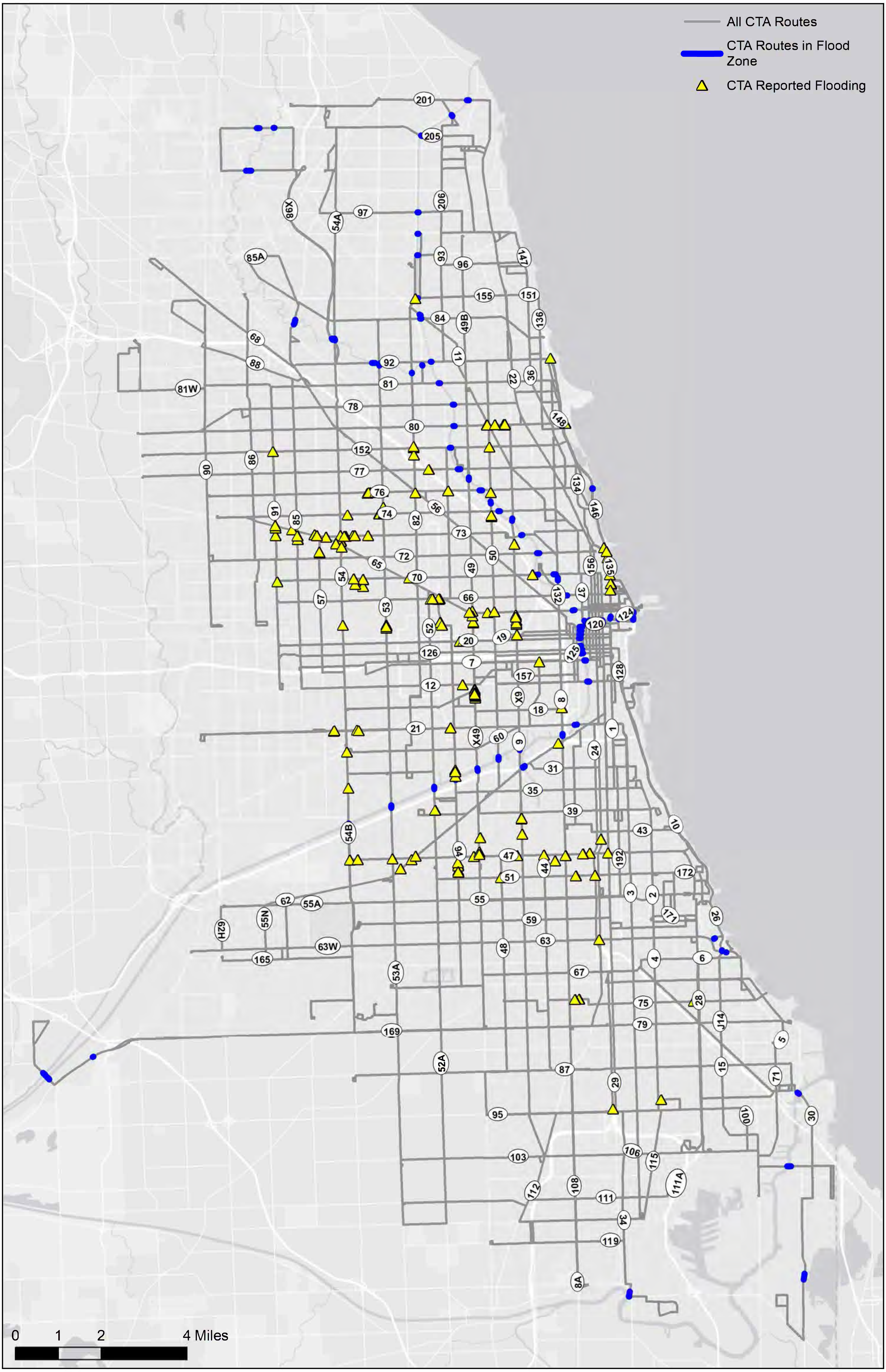
A-3: CTA and Pace Bus Routes with CTA-Reported Flood Incident Hot Spots



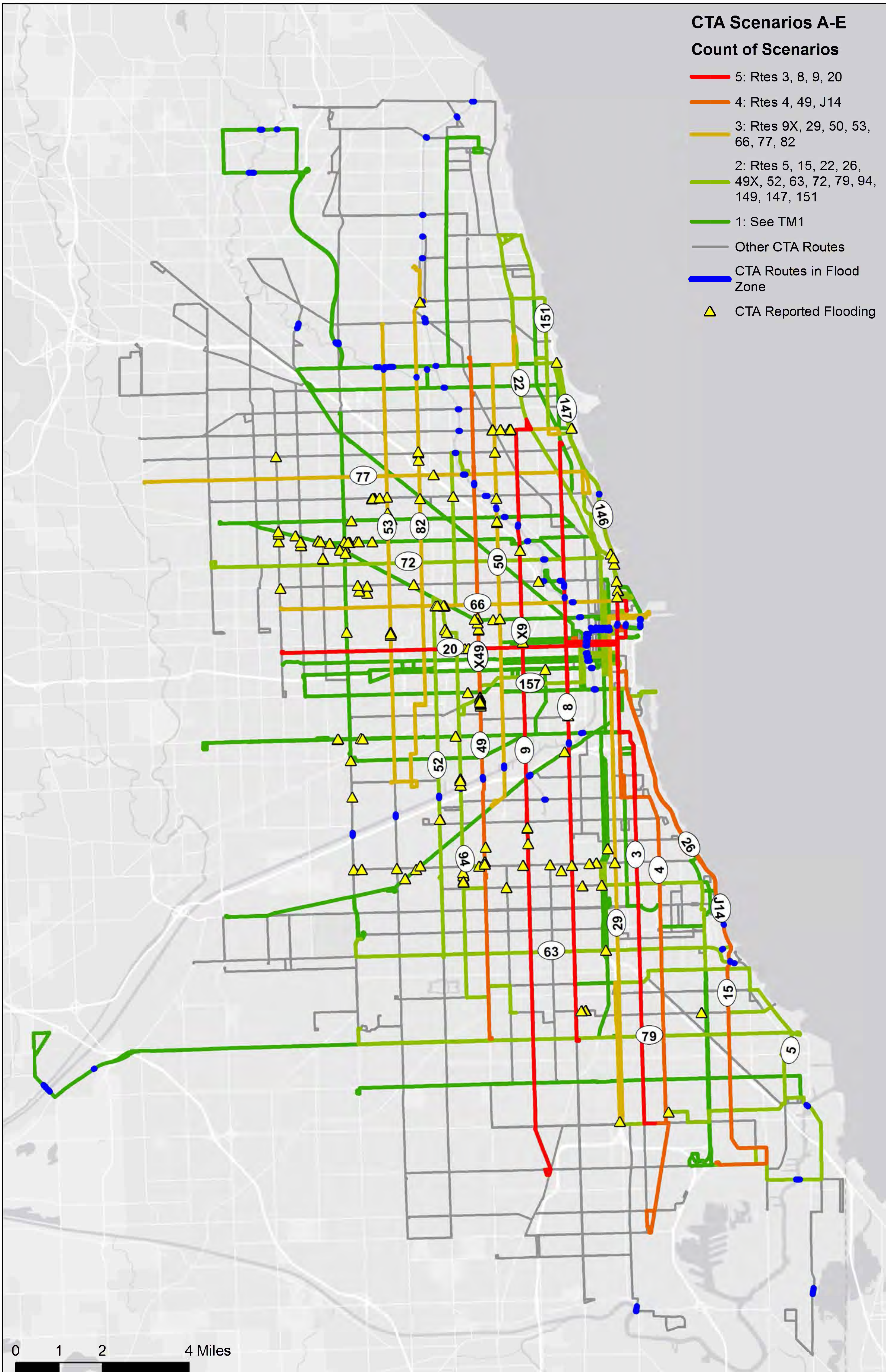
A-4: CTA and Pace Bus Routes with Viaduct Locations



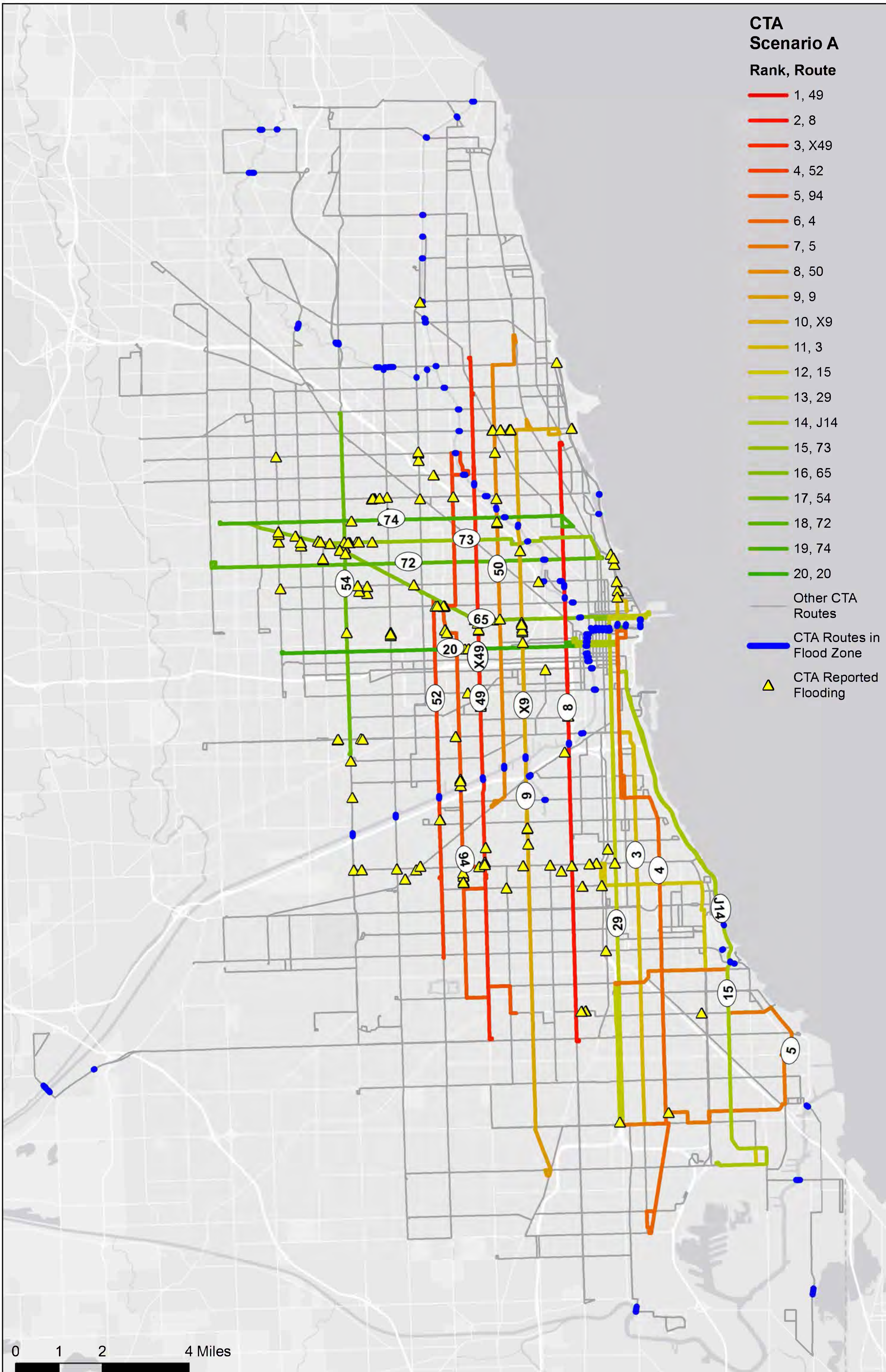
B-1: CTA Route Network with Flood Zone Intersections and Reported Flood Incidents



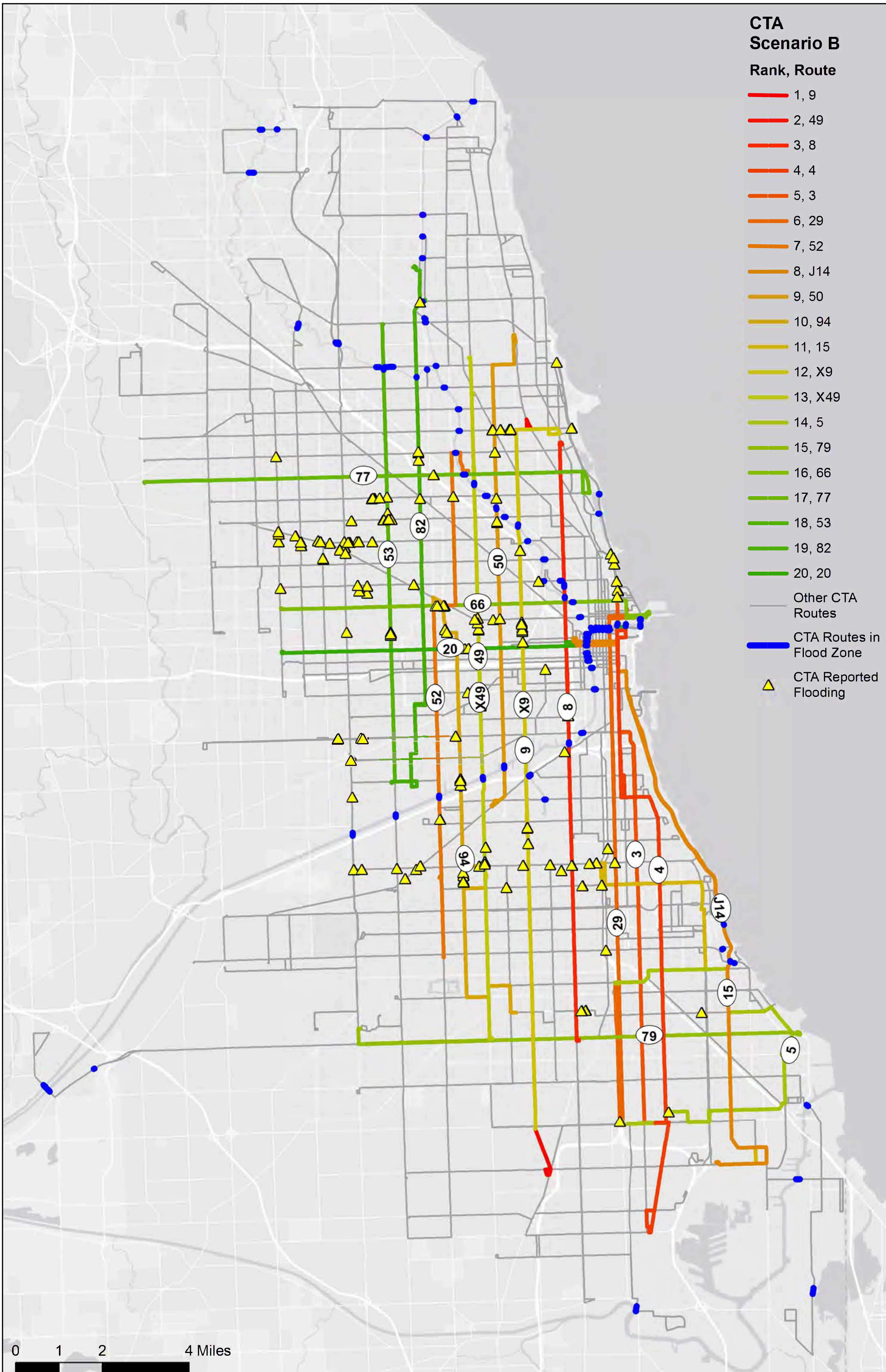
B-2: CTA Scenarios A-E with Flooding Data



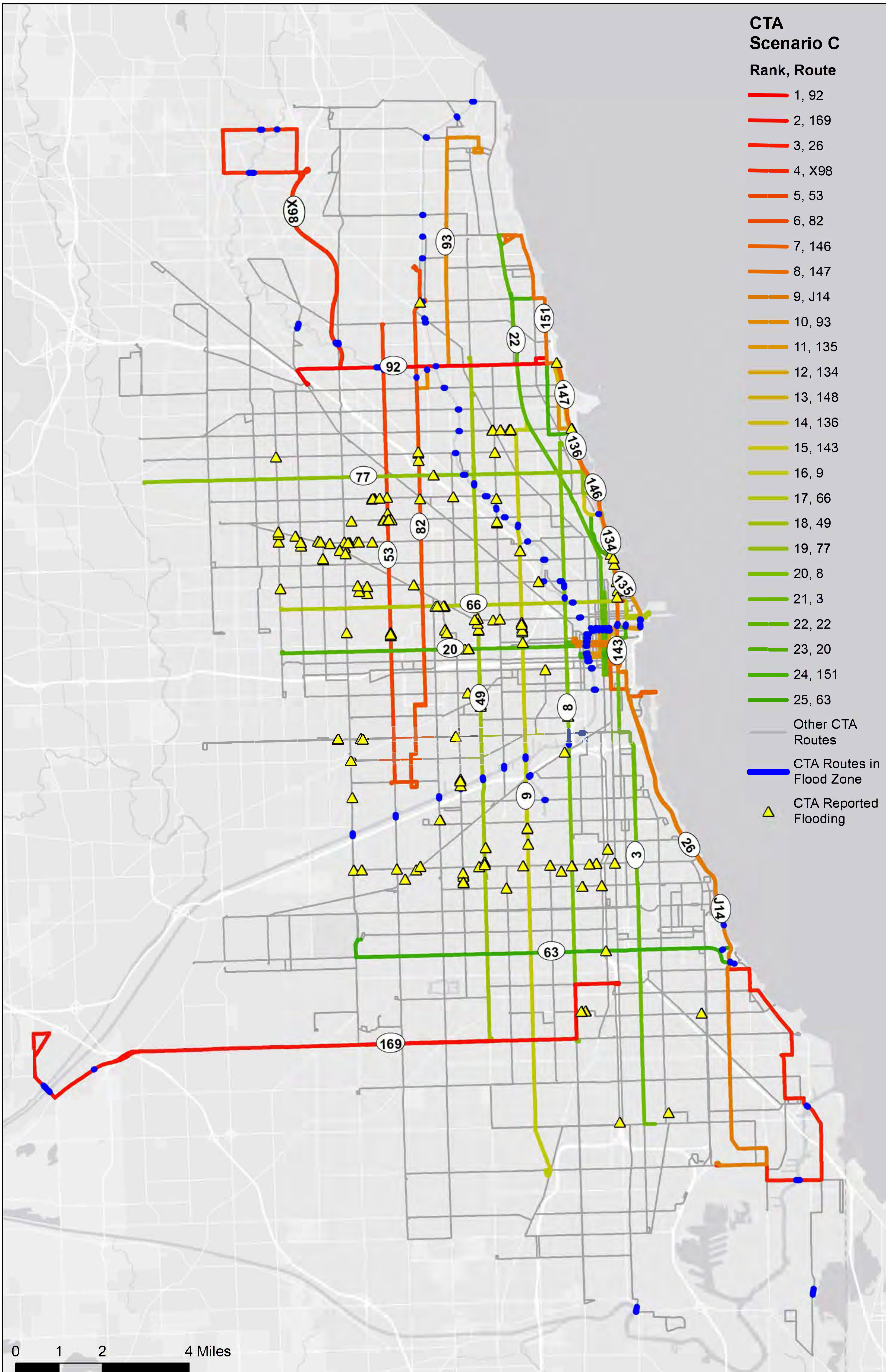
B-3: CTA Scenario A with Flooding Data



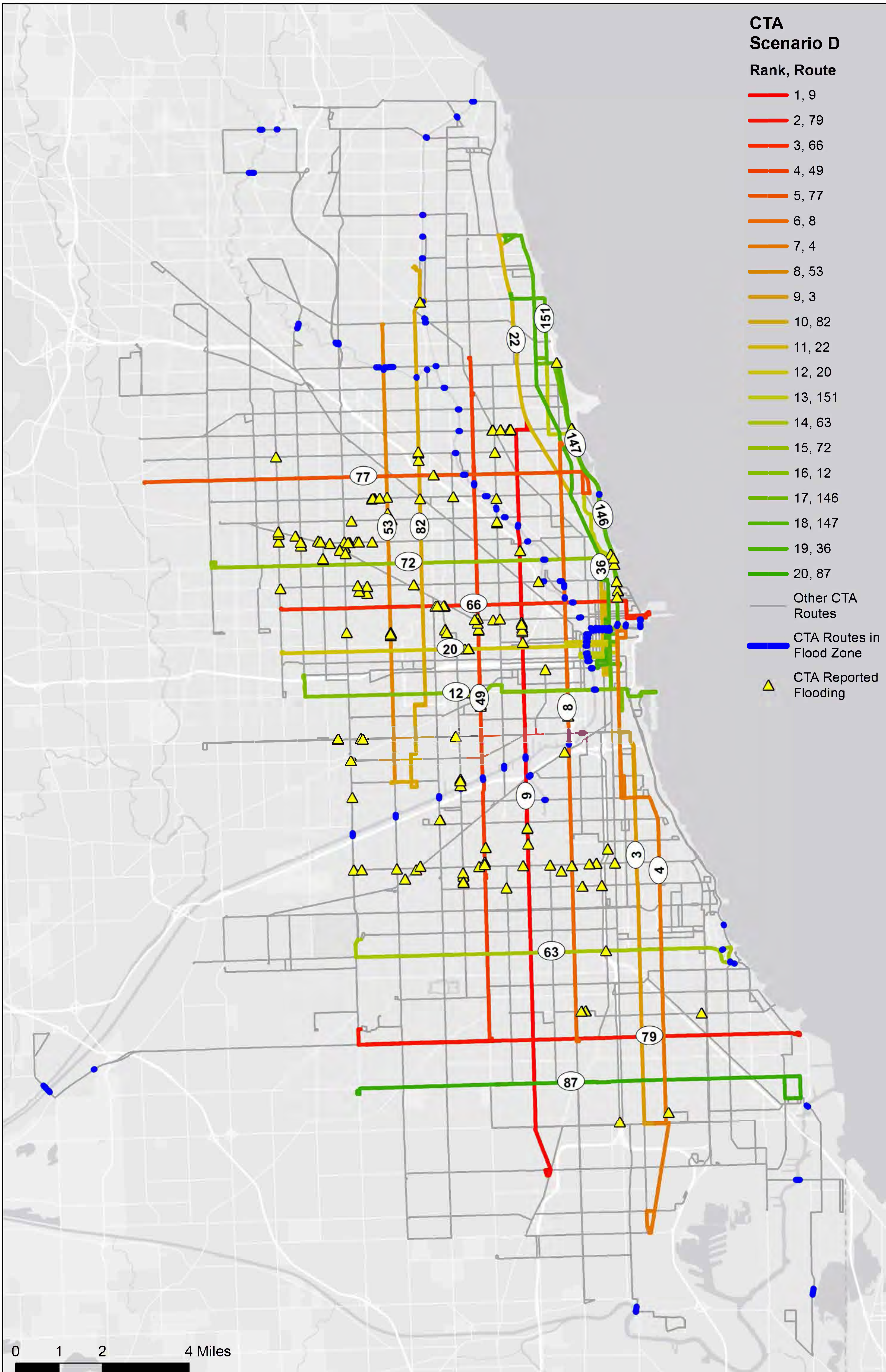
B-4: CTA Scenario B with Flooding Data



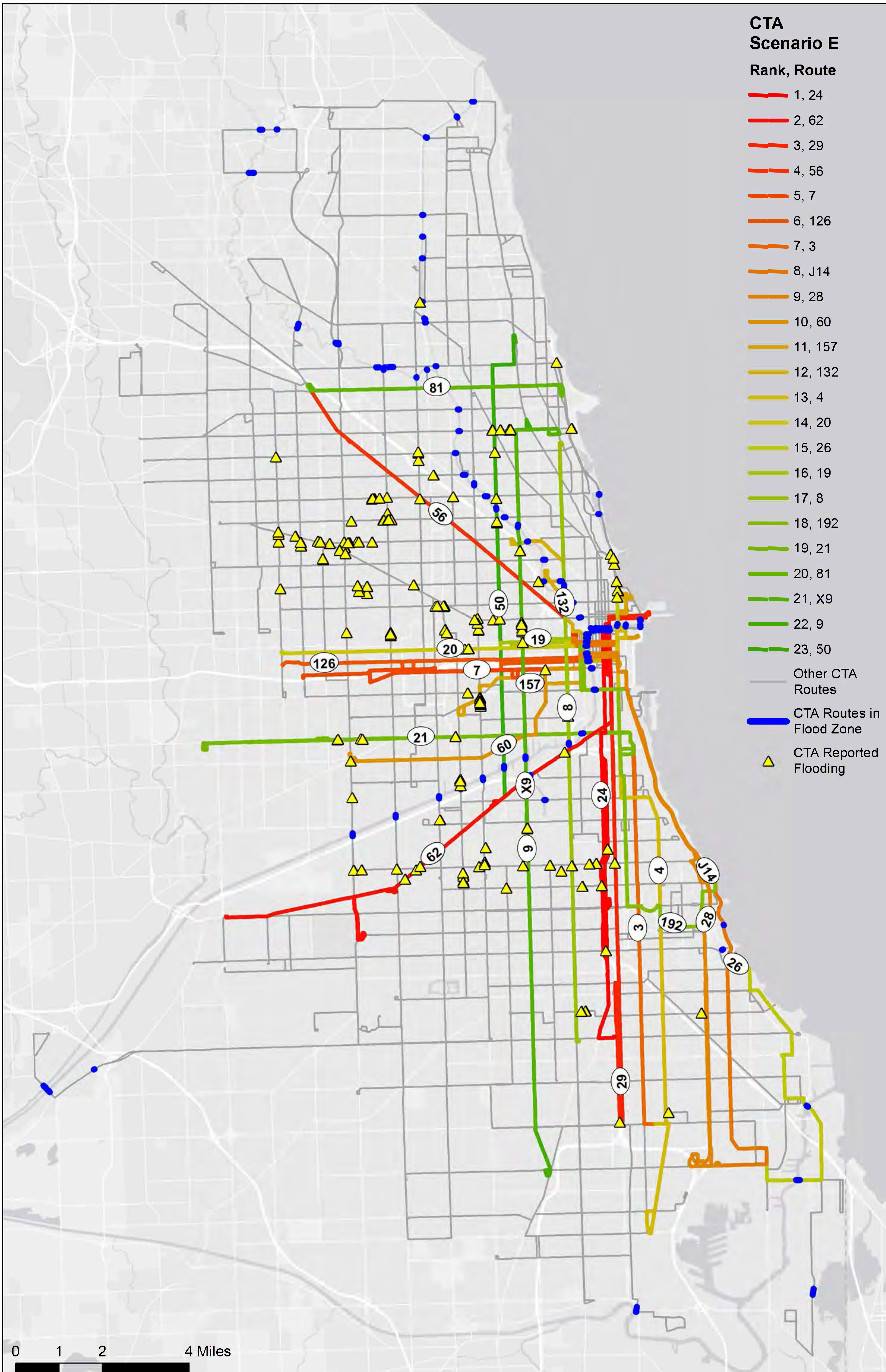
B-5: CTA Scenario C with Flooding Data



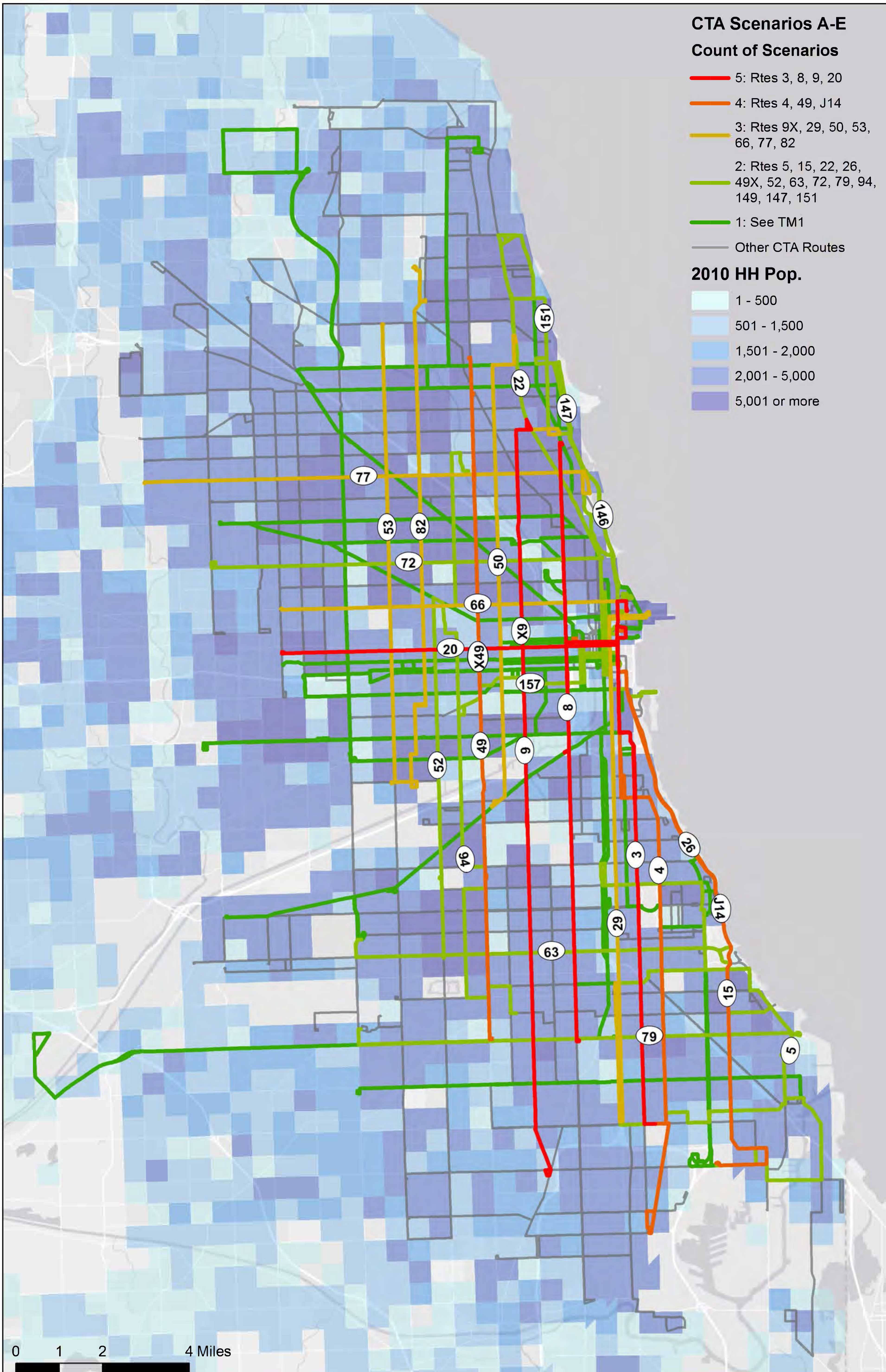
B-6: CTA Scenario D with Flooding Data



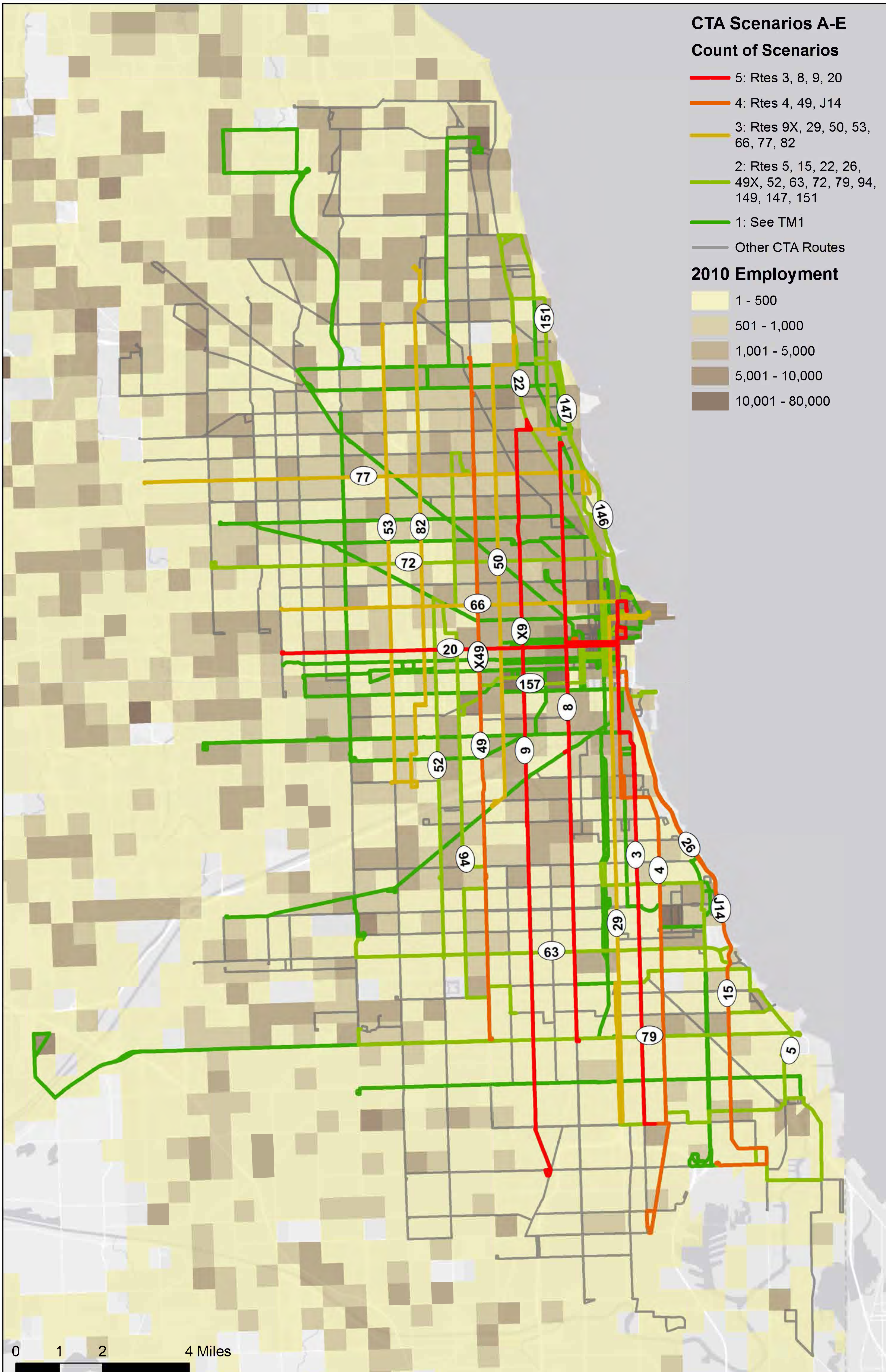
B-7: CTA Scenario E with Flooding Data



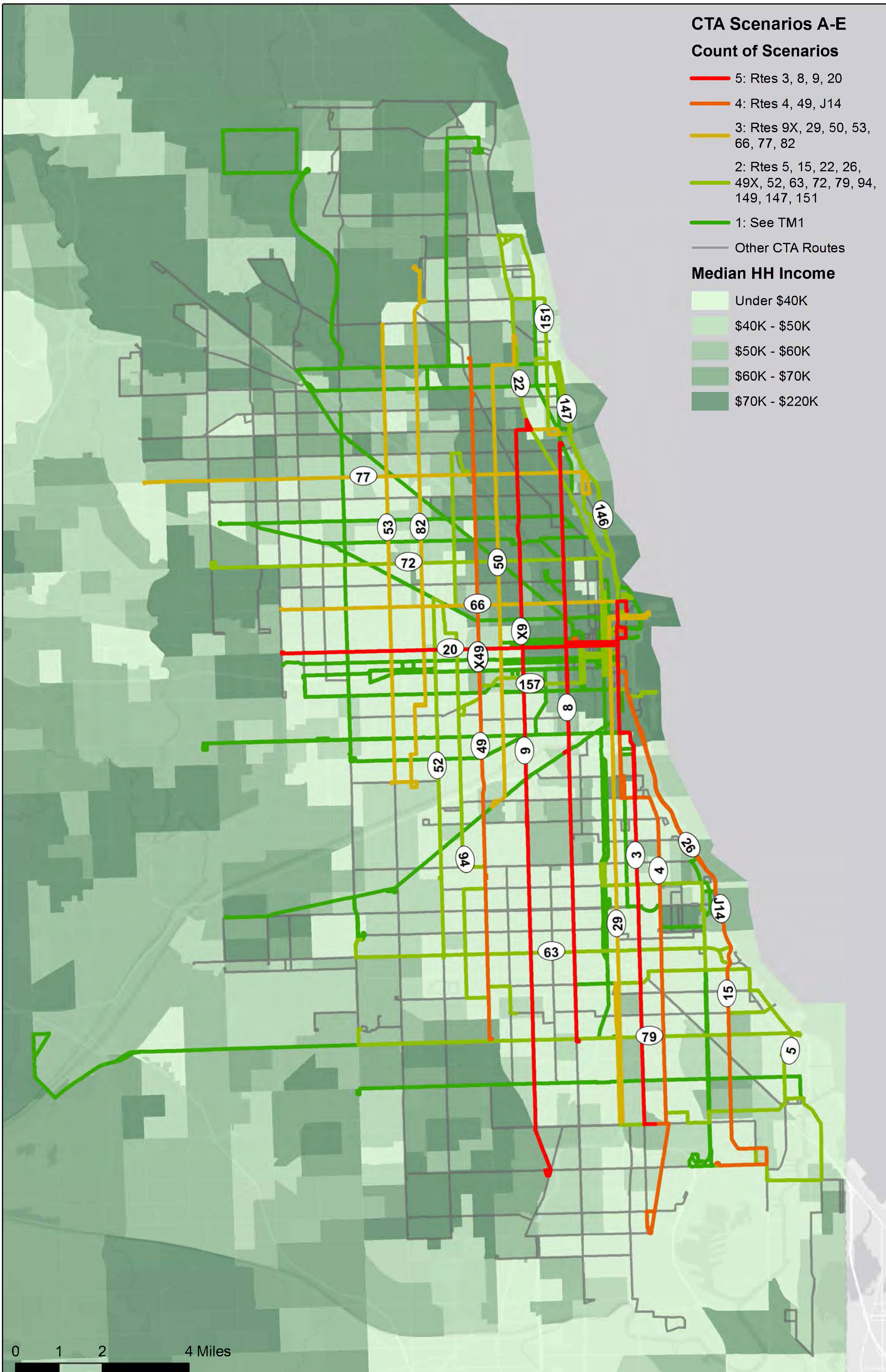
B-8: CTA Scenarios A-E with 2010 Population Subzones



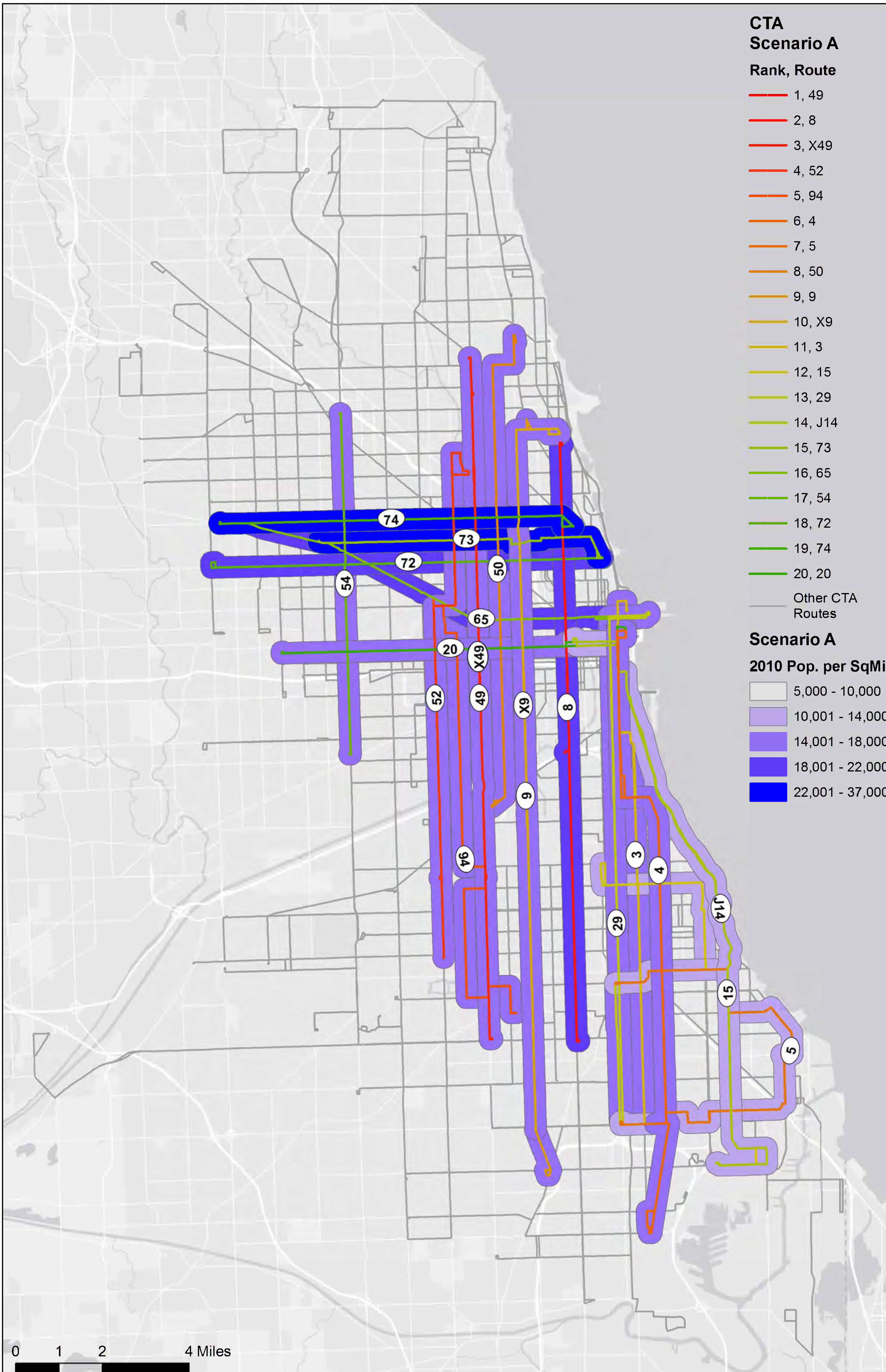
B-9: CTA Scenarios A-E with 2010 Employment Subzones



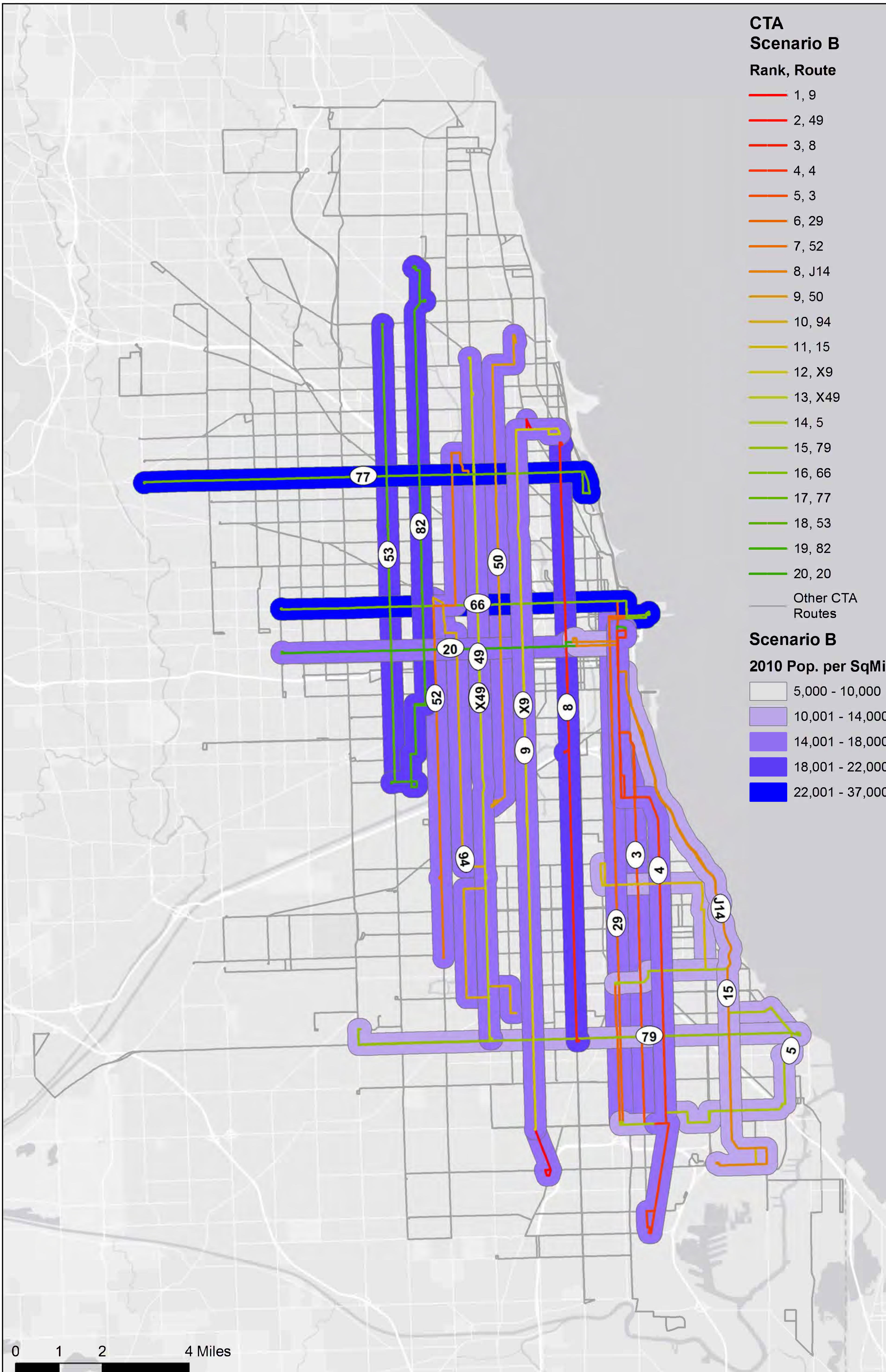
B-10: CTA Scenarios A-E with 2014 Median Household Income Tracts



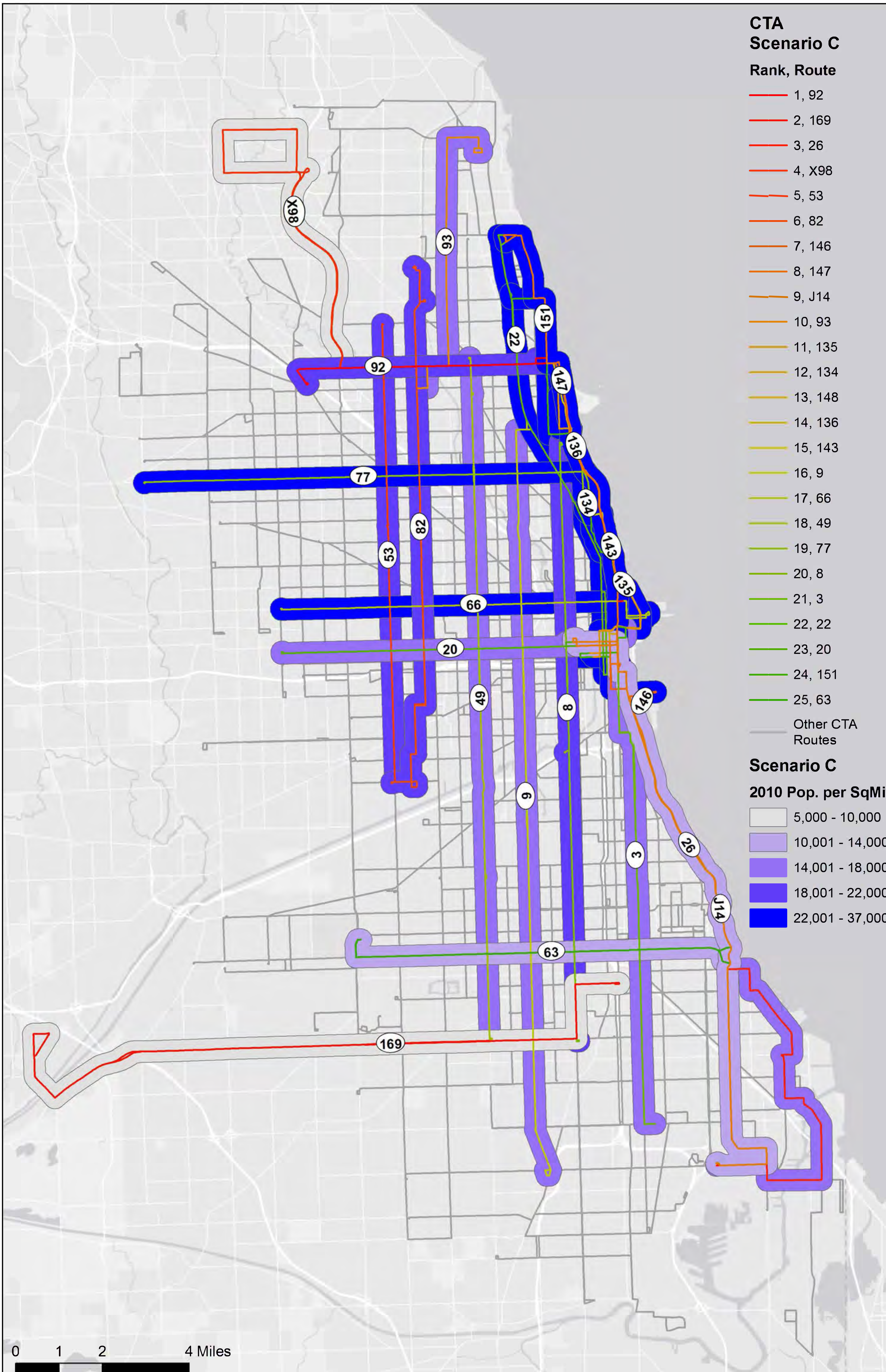
B-11: CTA Scenario A with 2010 Population Density Buffers



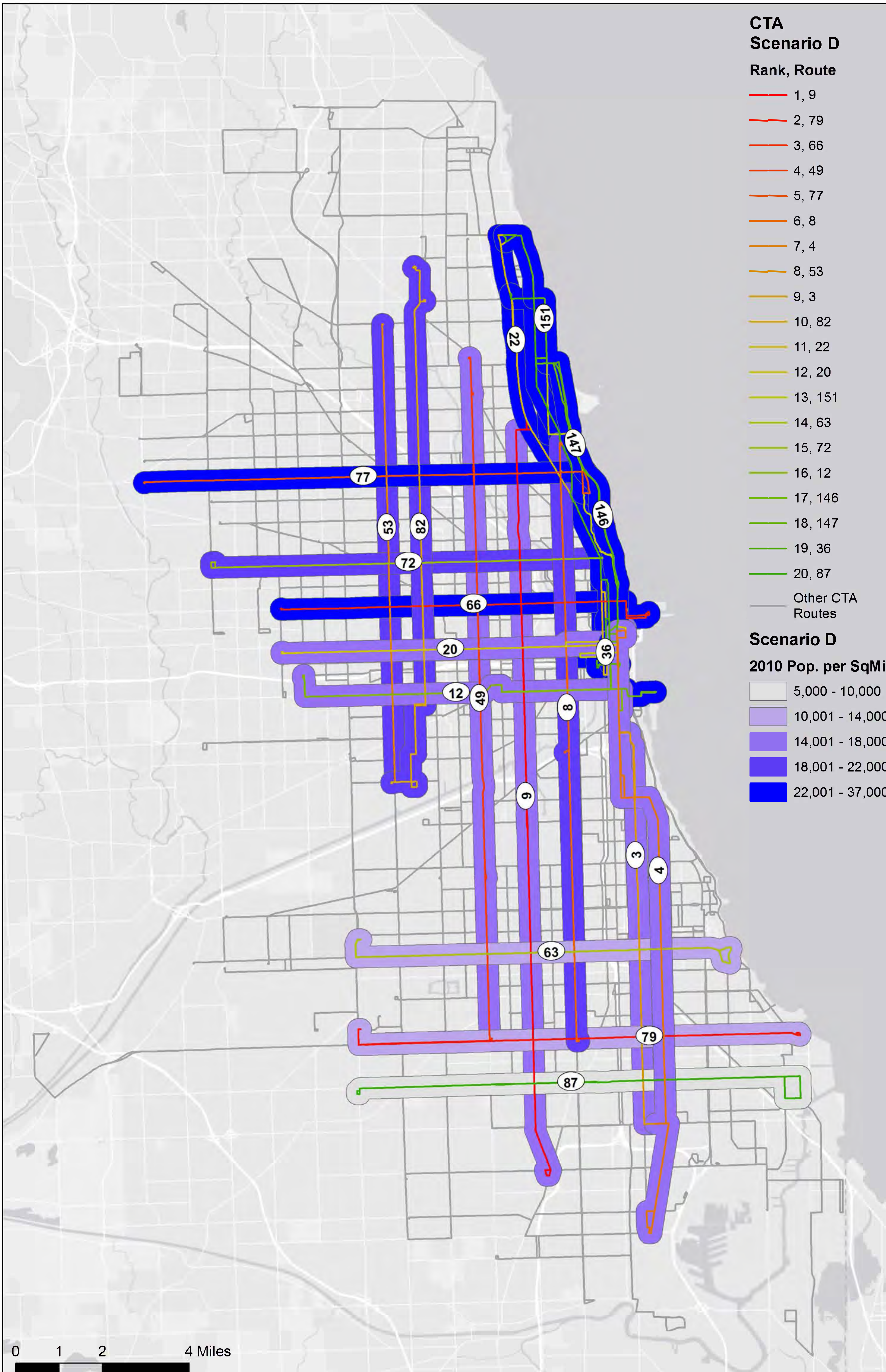
B-12: CTA Scenario B with 2010 Population Density Buffers



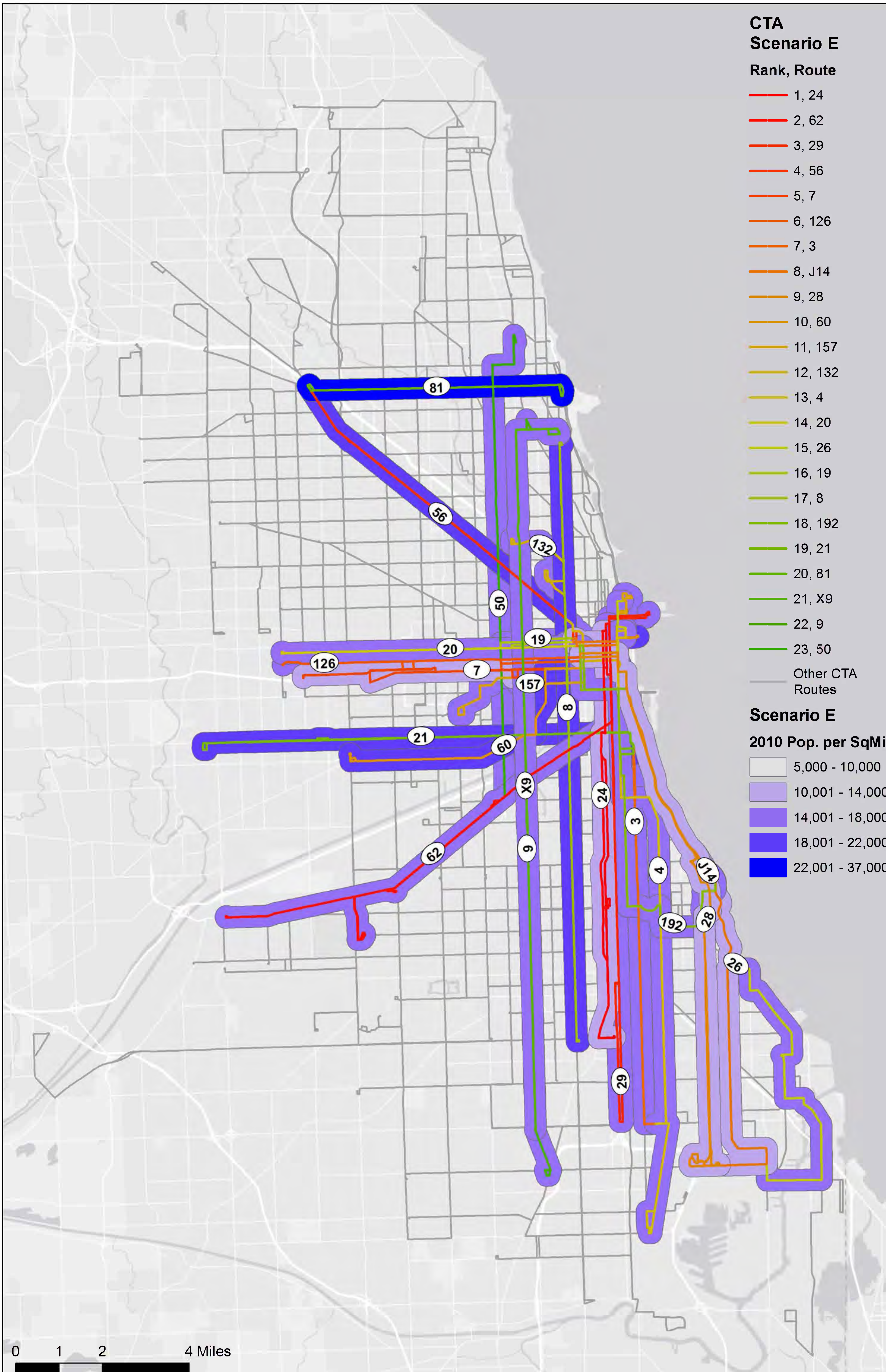
B-13: CTA Scenario C with 2010 Population Density Buffers



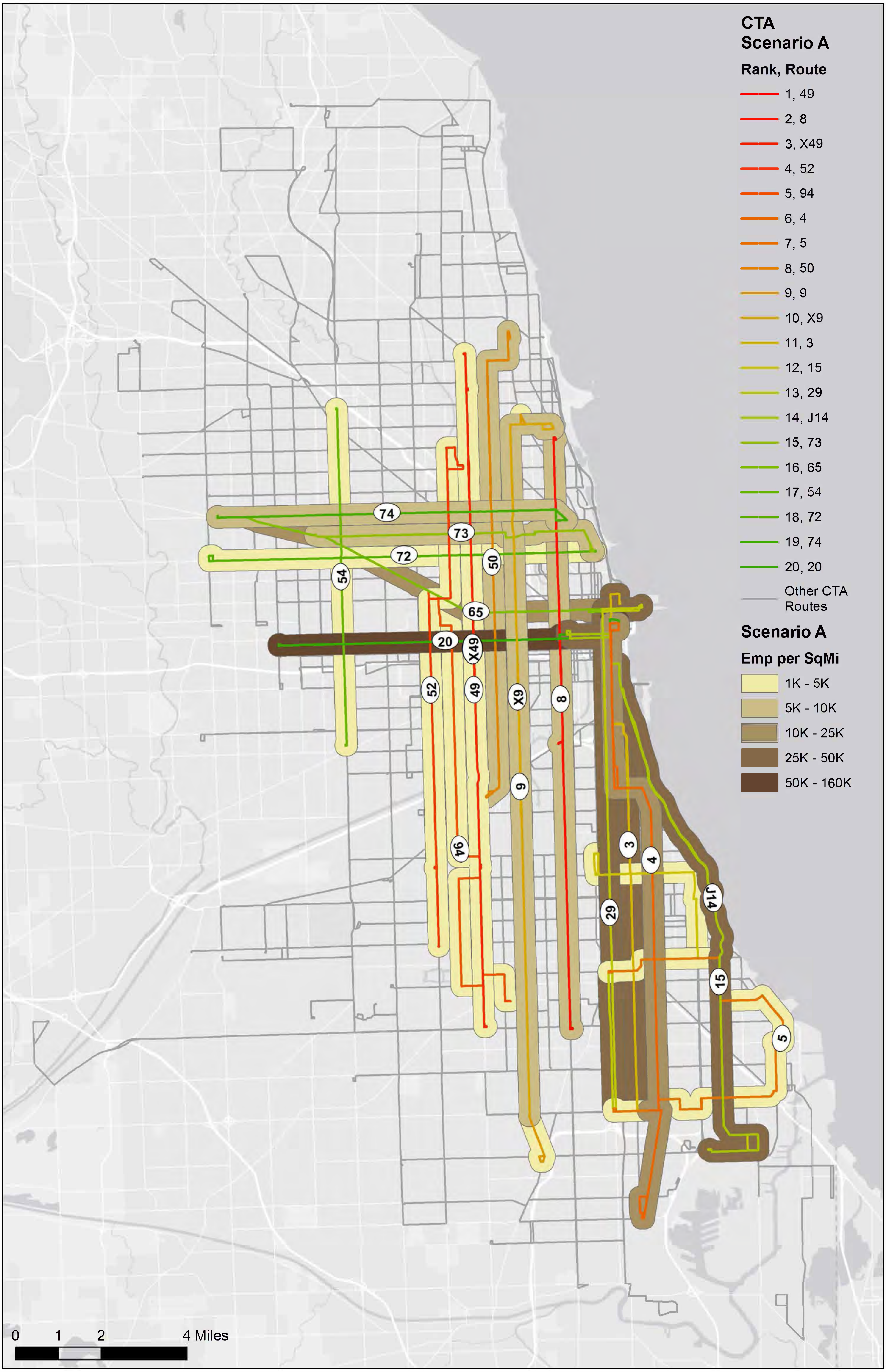
B-14: CTA Scenario D with 2010 Population Density Buffers



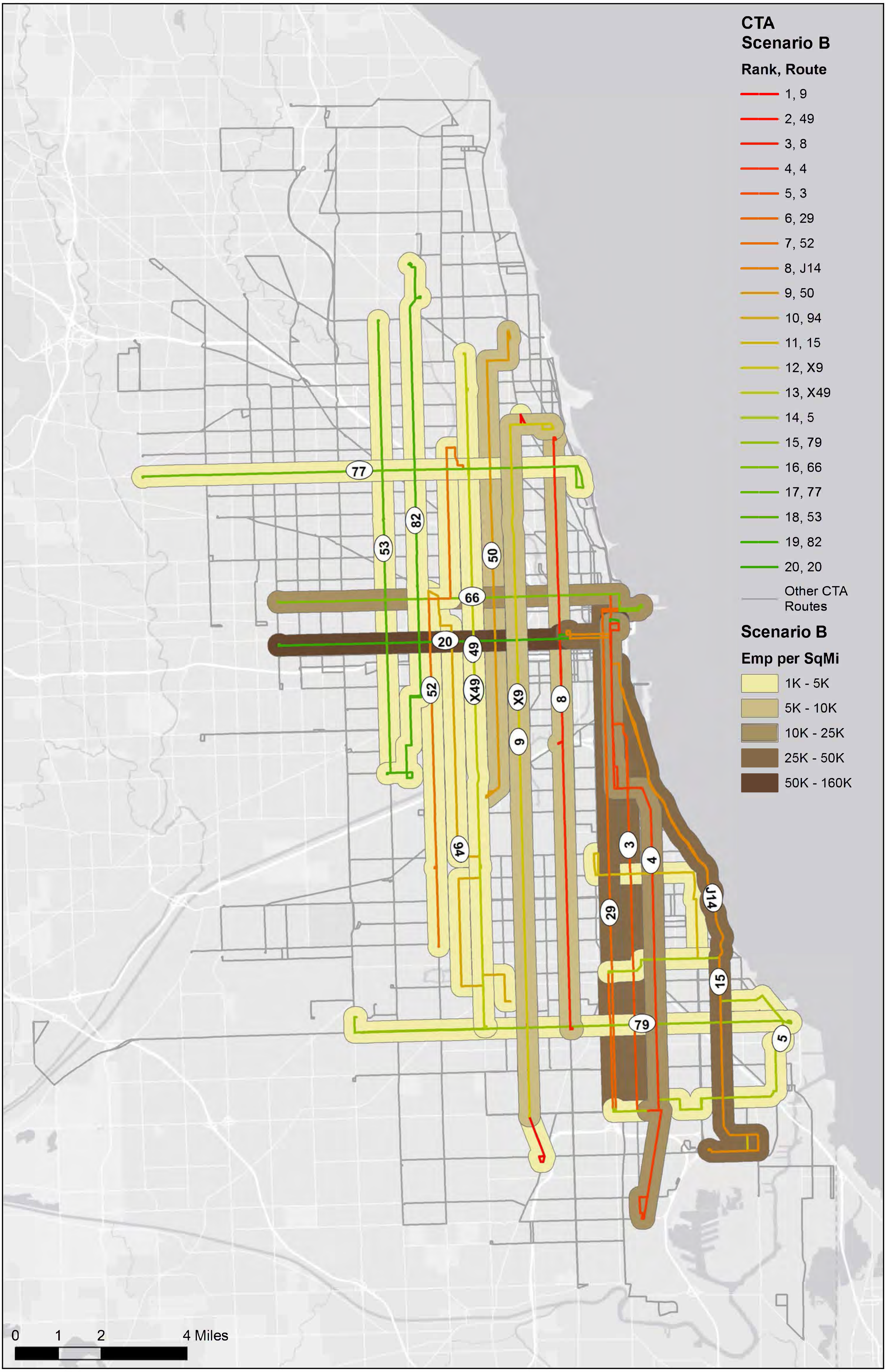
B-15: CTA Scenario E with 2010 Population Density Buffers



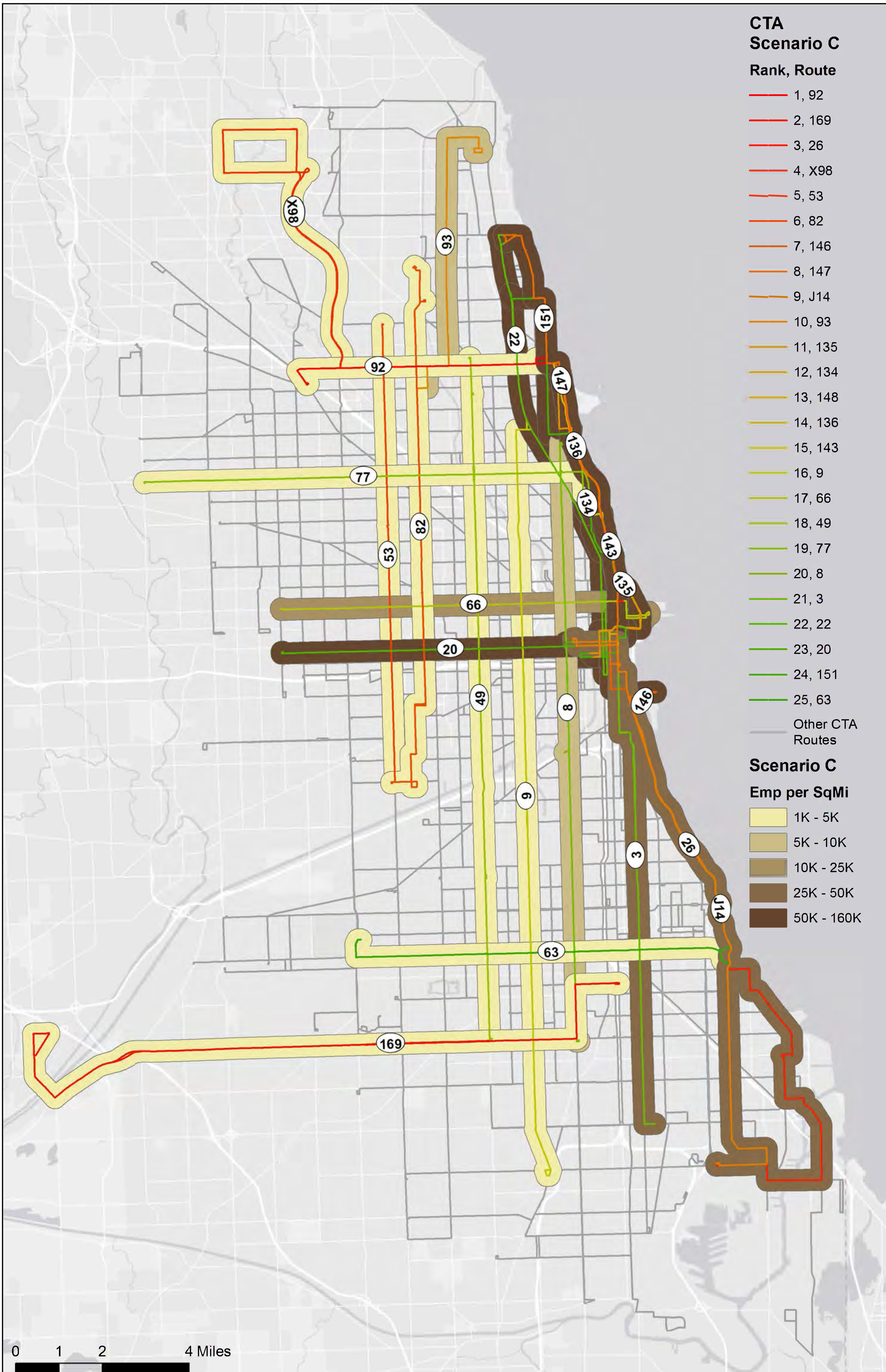
B-16: CTA Scenario A with 2010 Employment Density Buffers



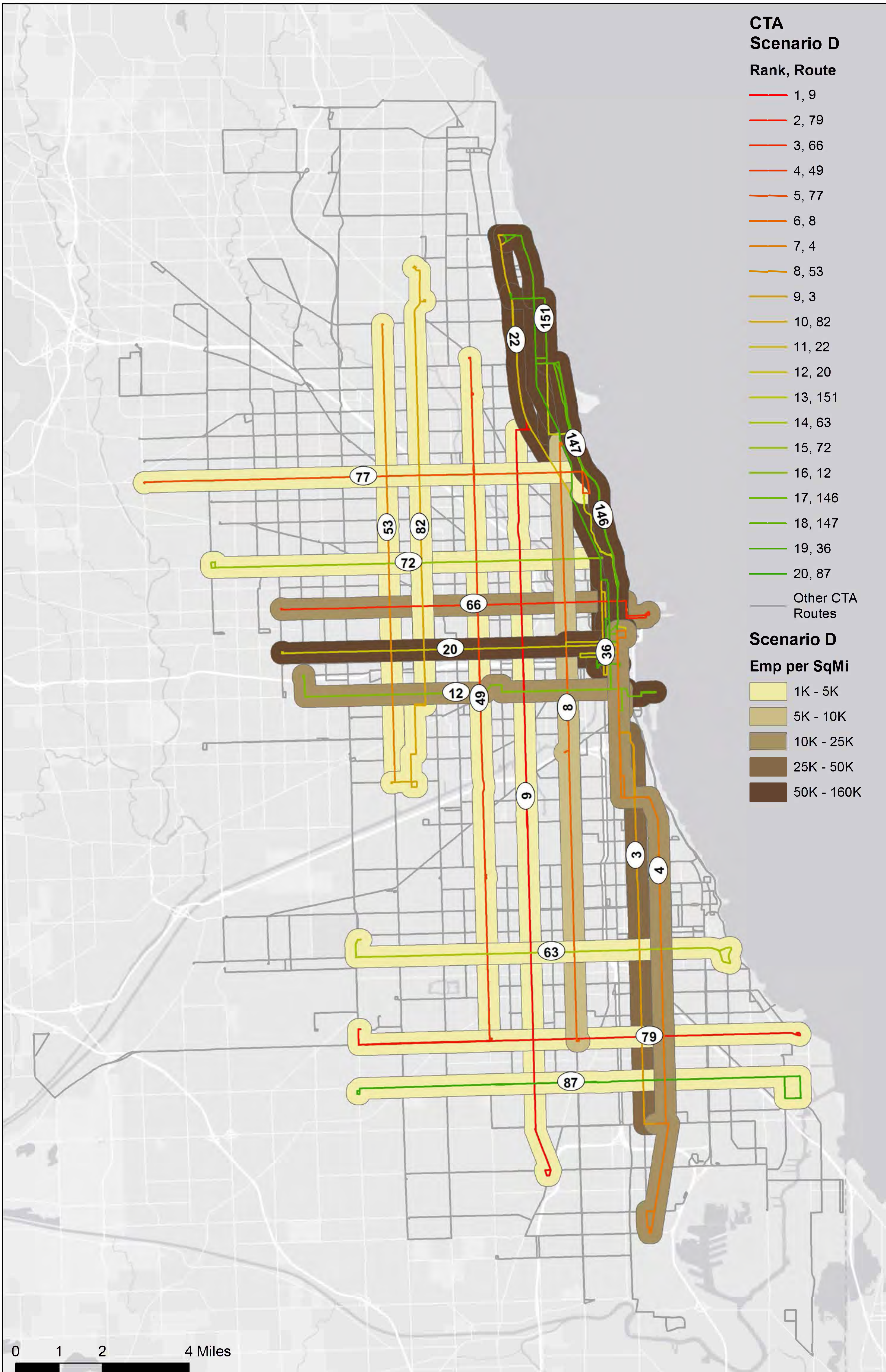
B-17: CTA Scenario B with 2010 Employment Density Buffers



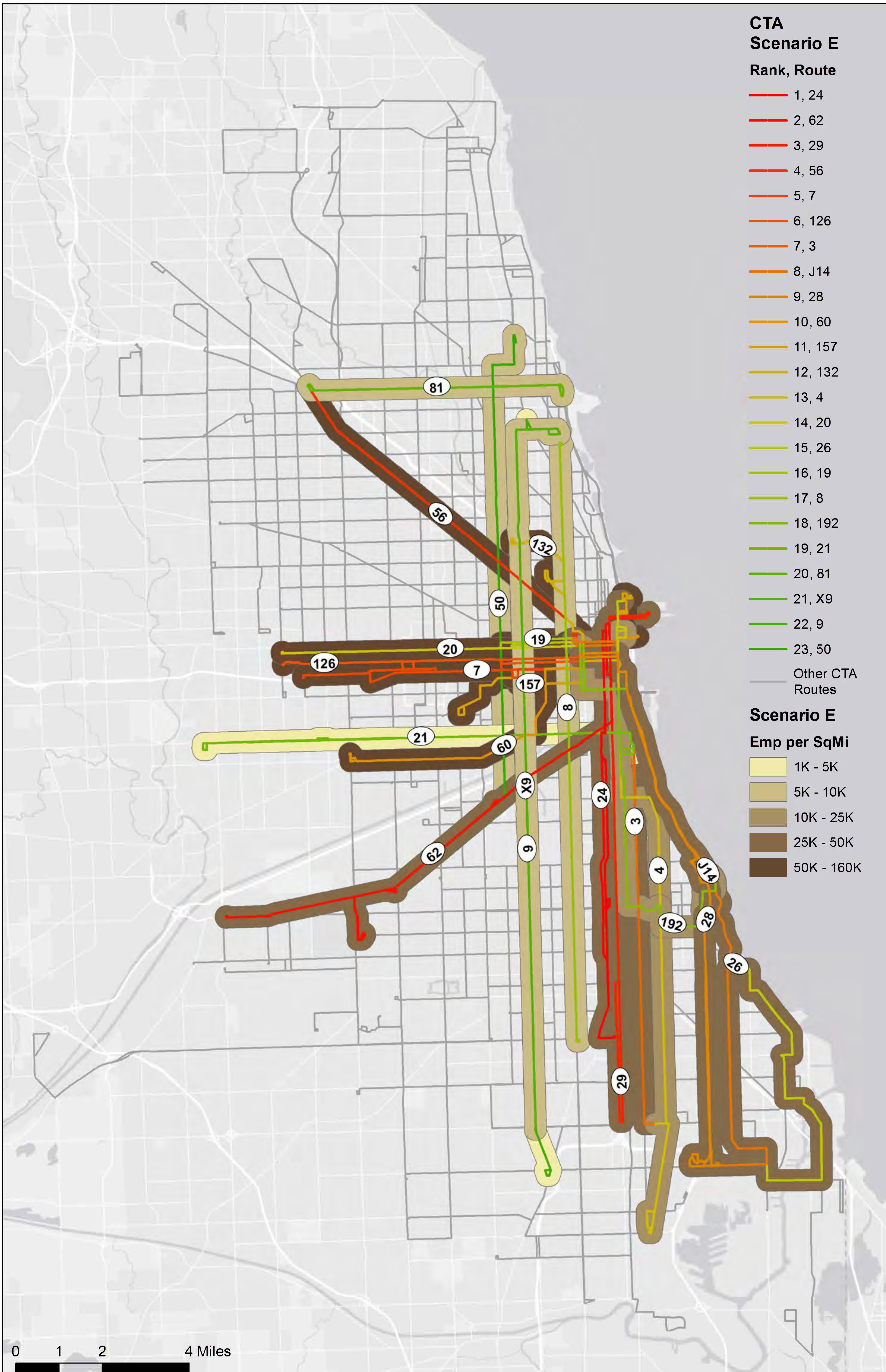
B-18: CTA Scenario C with 2010 Employment Density Buffers



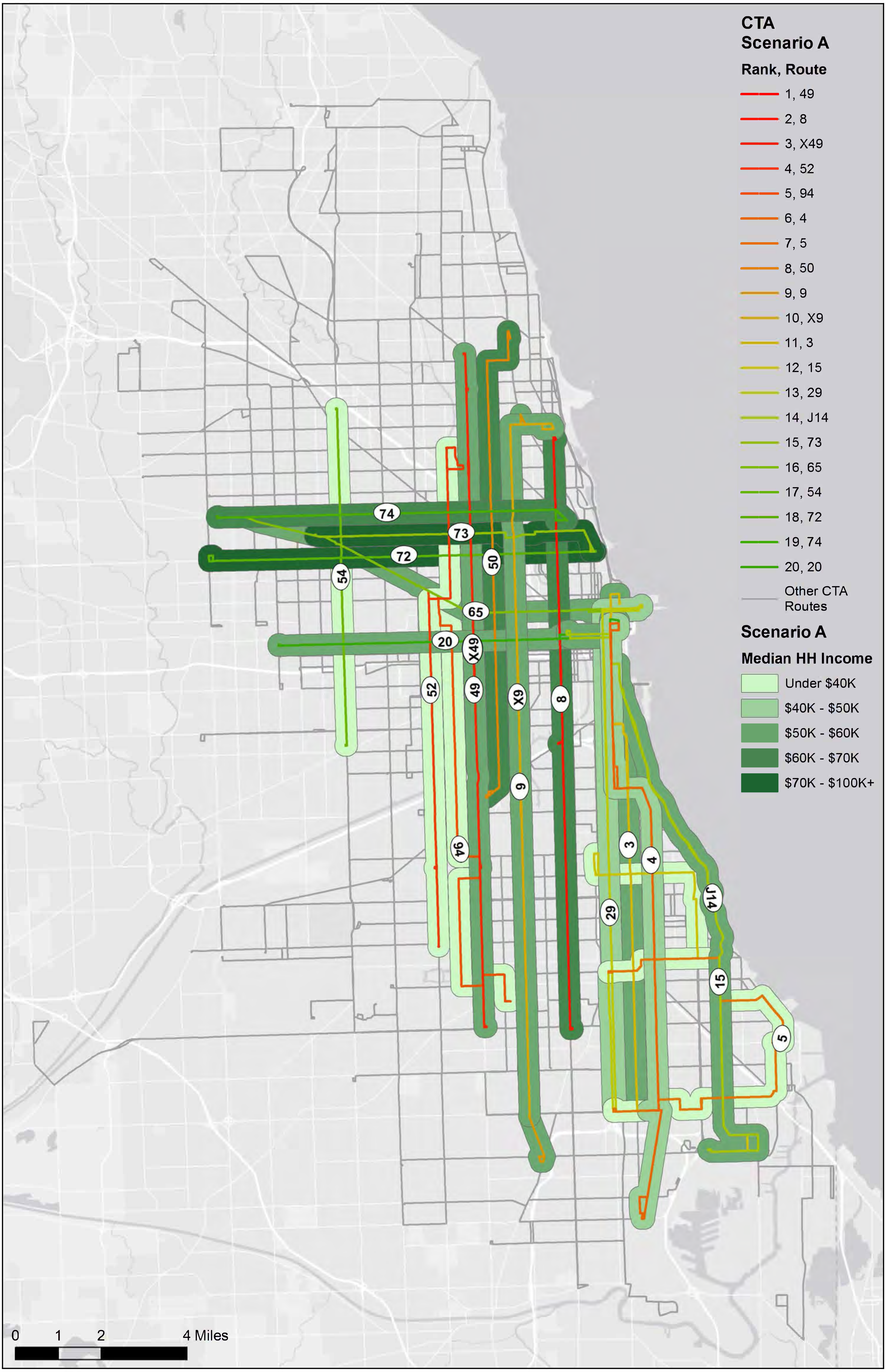
B-19: CTA Scenario D with 2010 Employment Density Buffers



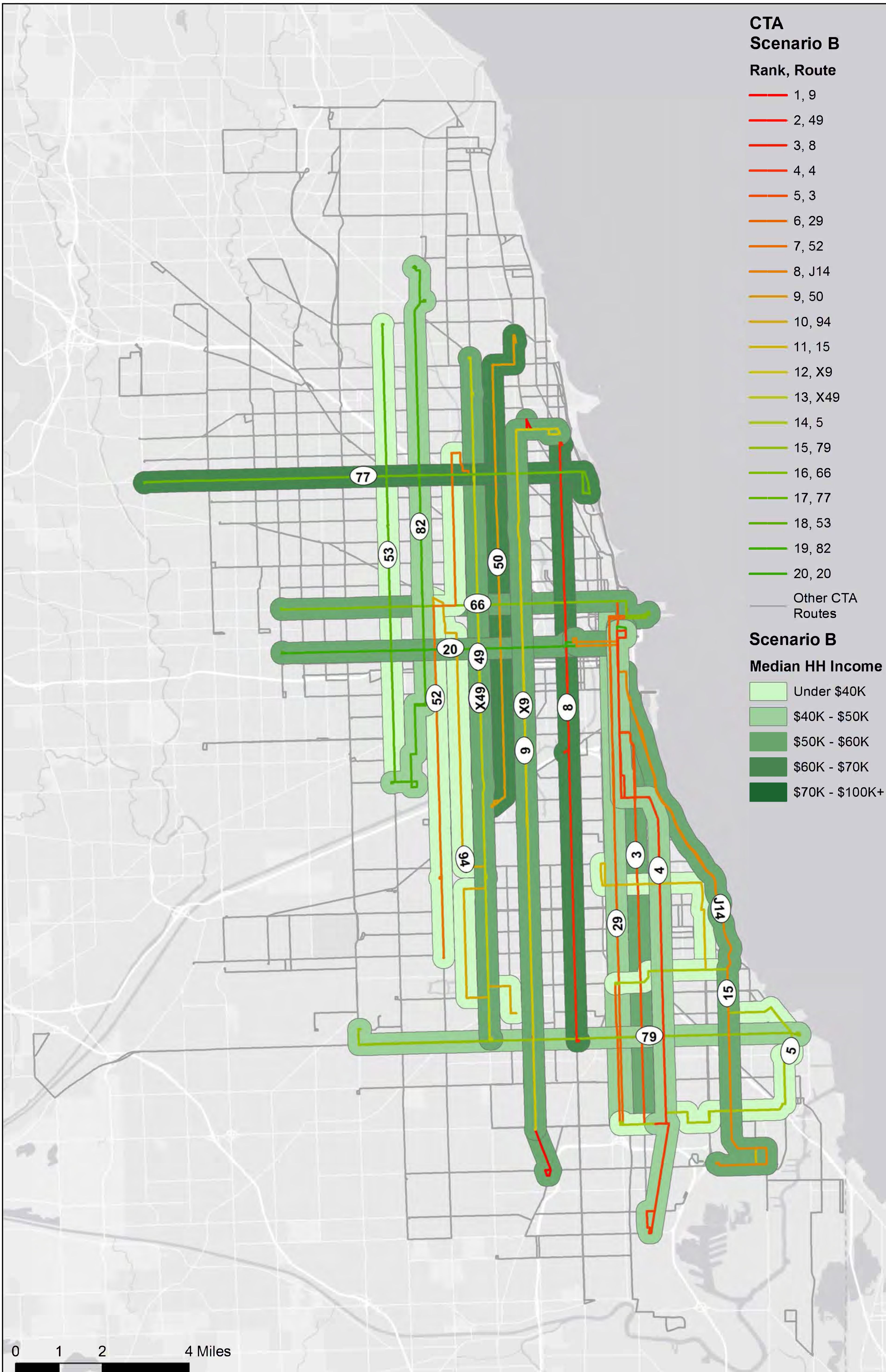
B-20: CTA Scenario E with 2010 Employment Density Buffers



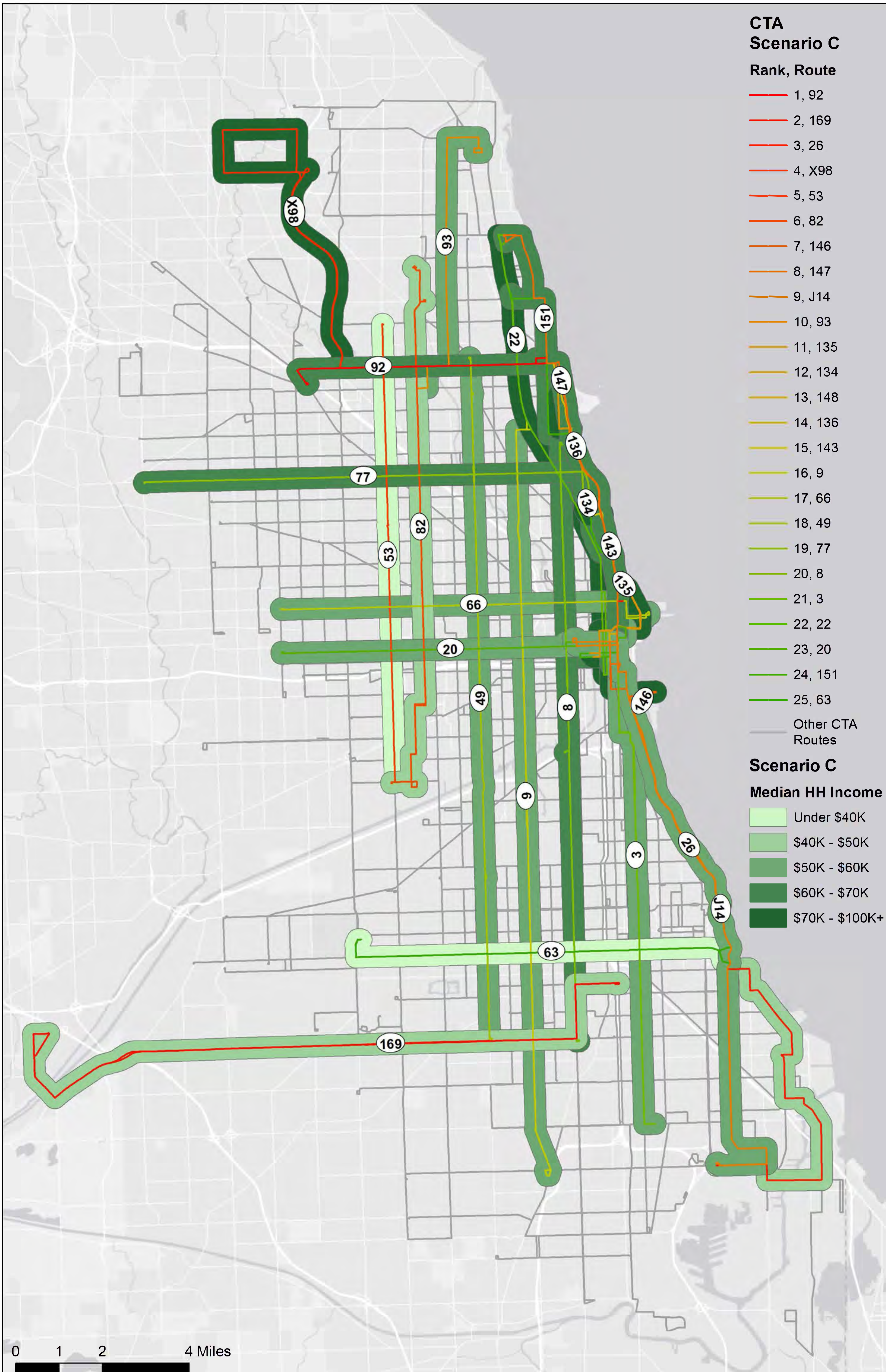
B-21: CTA Scenario A with 2014 Median Household Income Buffers



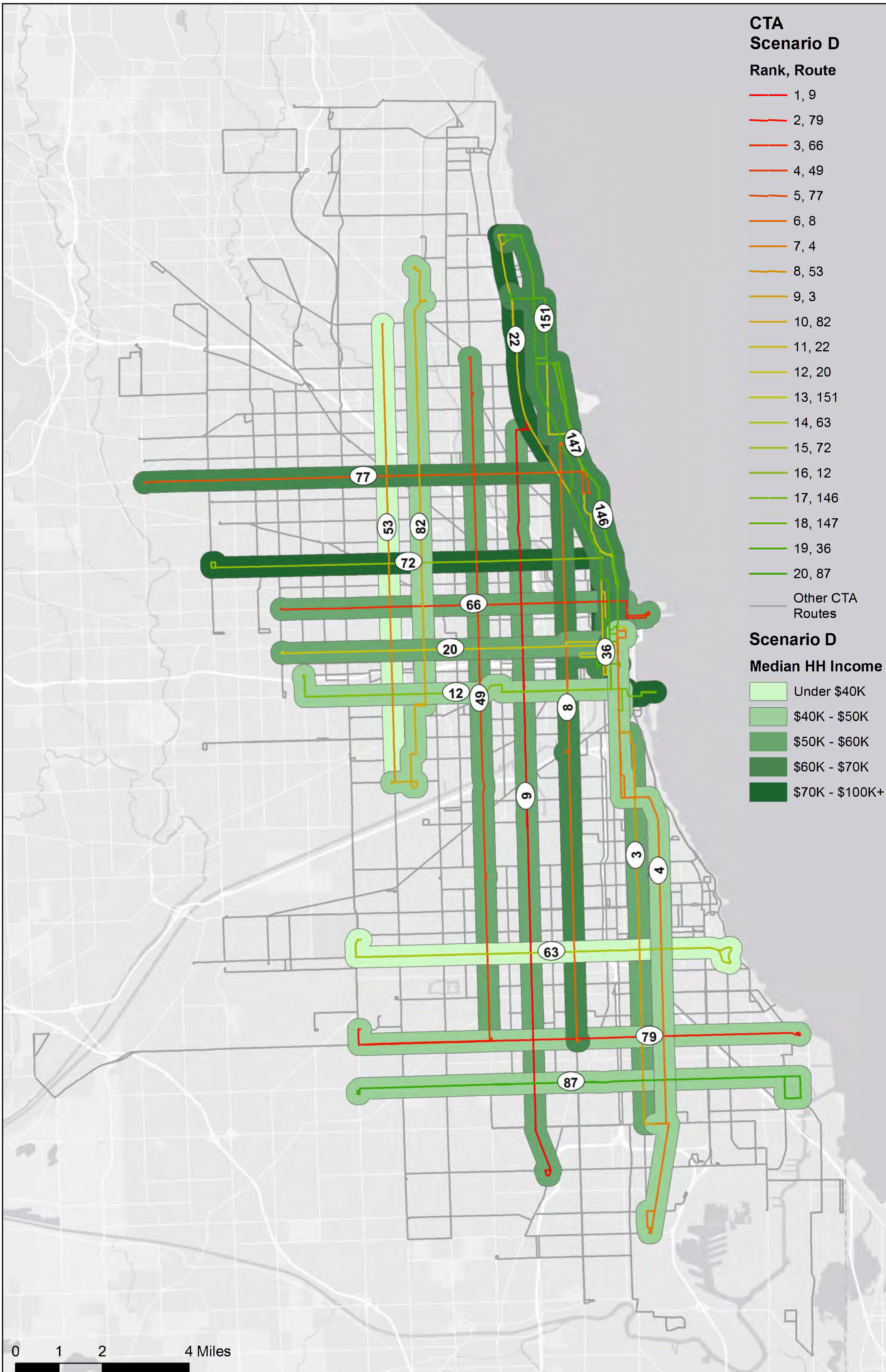
B-22: CTA Scenario B with 2014 Median Household Income Buffers



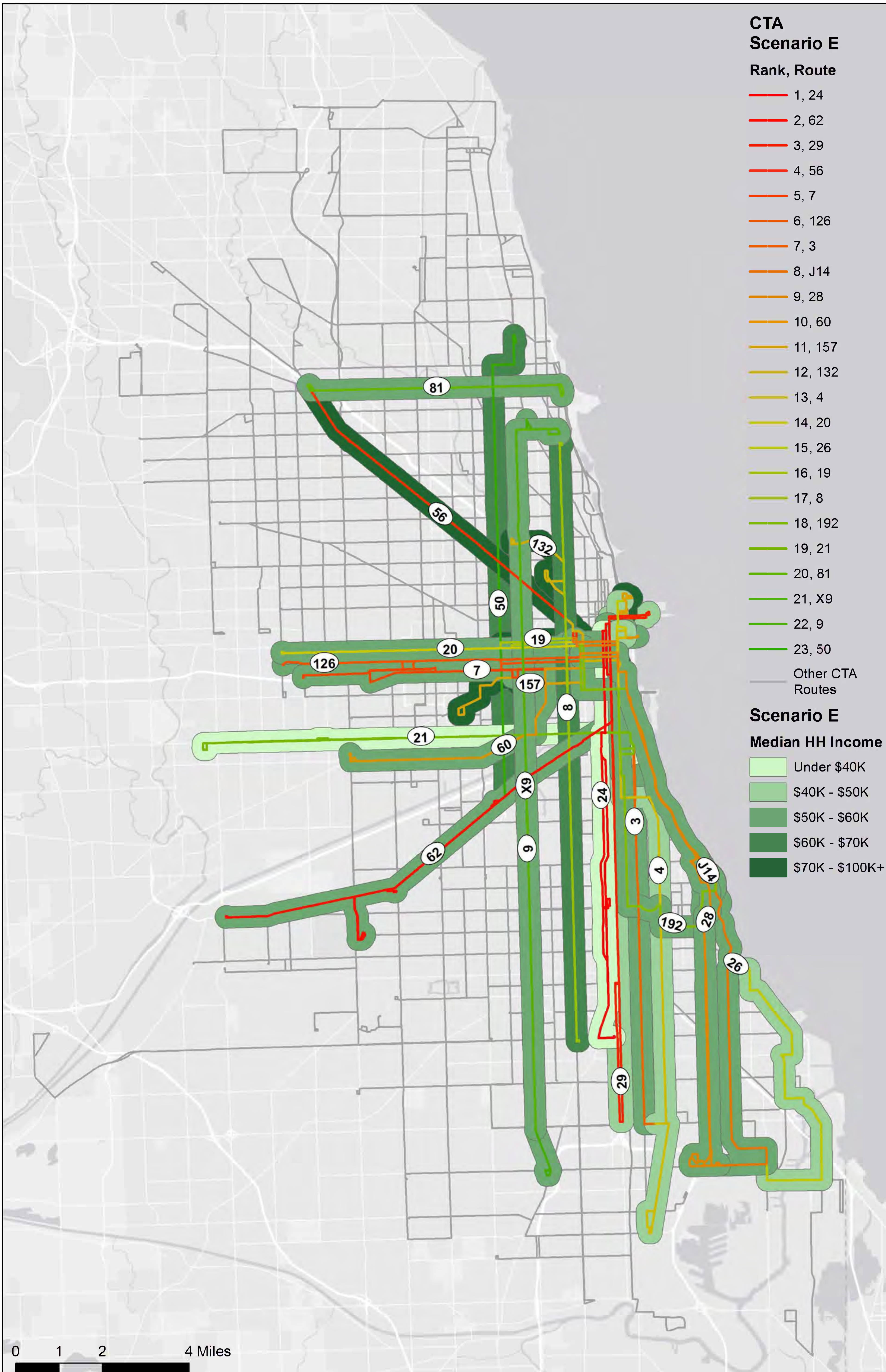
B-23: CTA Scenario C with 2014 Median Household Income Buffers



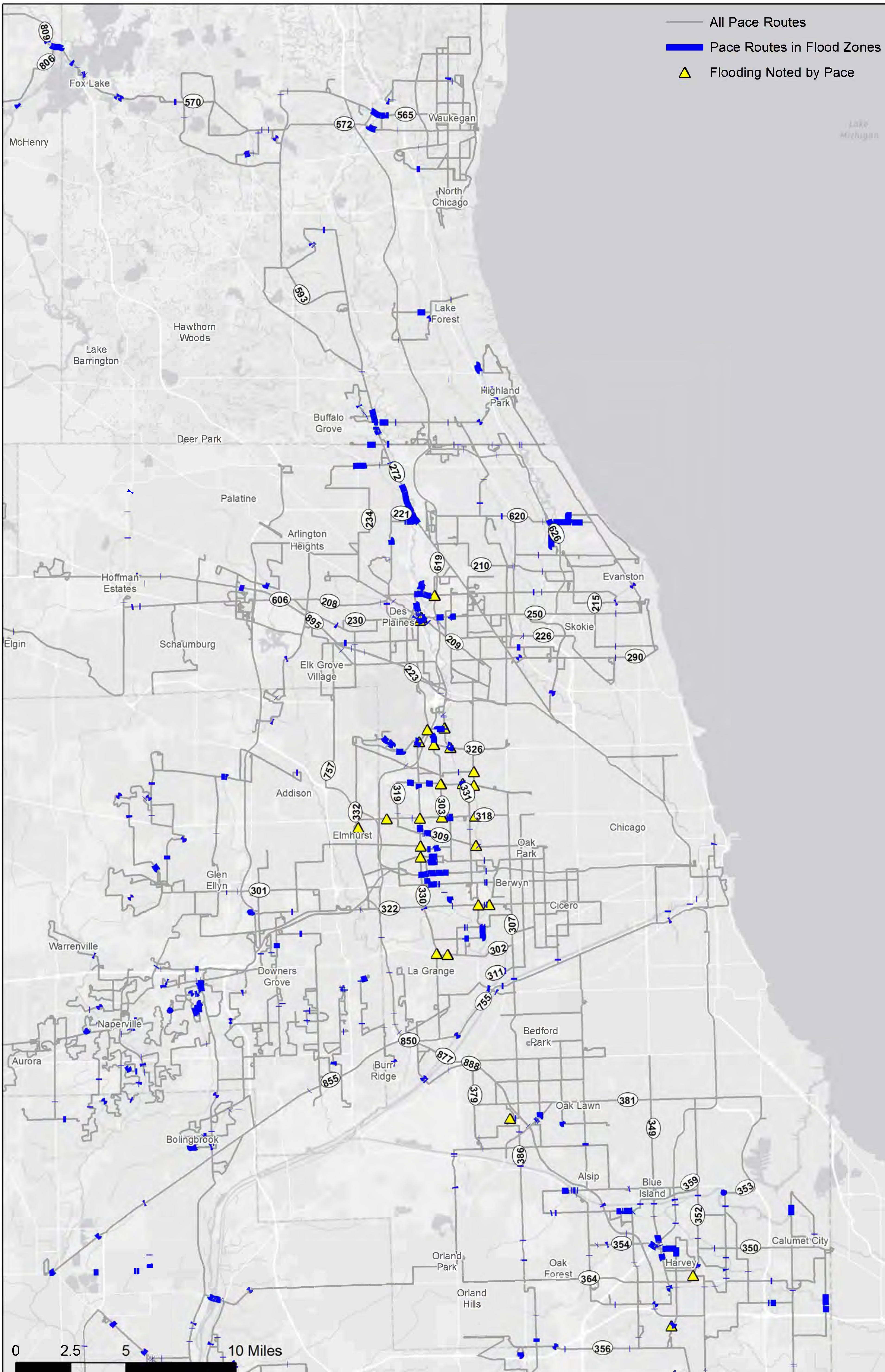
B-24: CTA Scenario D with 2014 Median Household Income Buffers



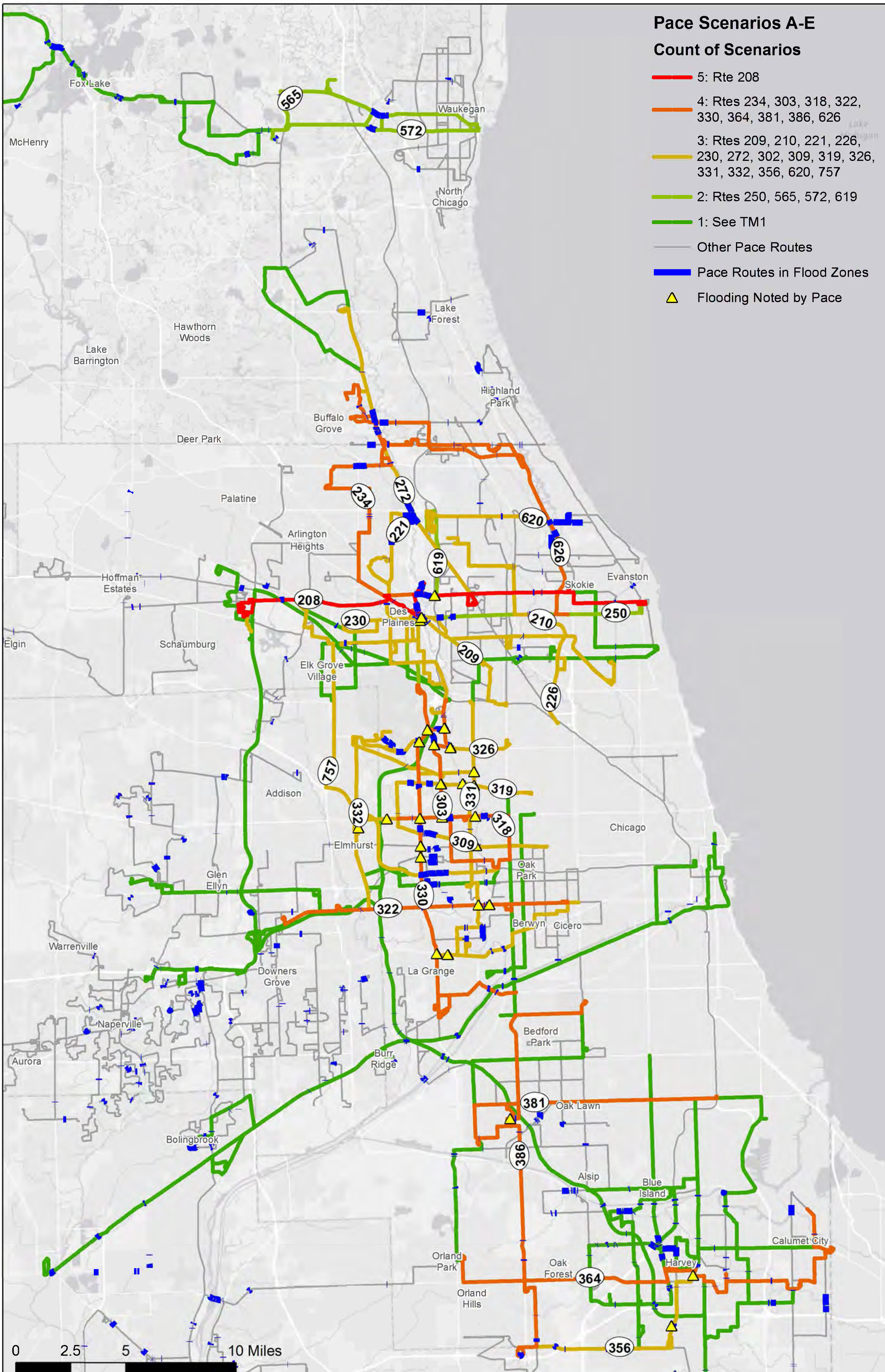
B-25: CTA Scenario E with 2014 Median Household Income Buffers



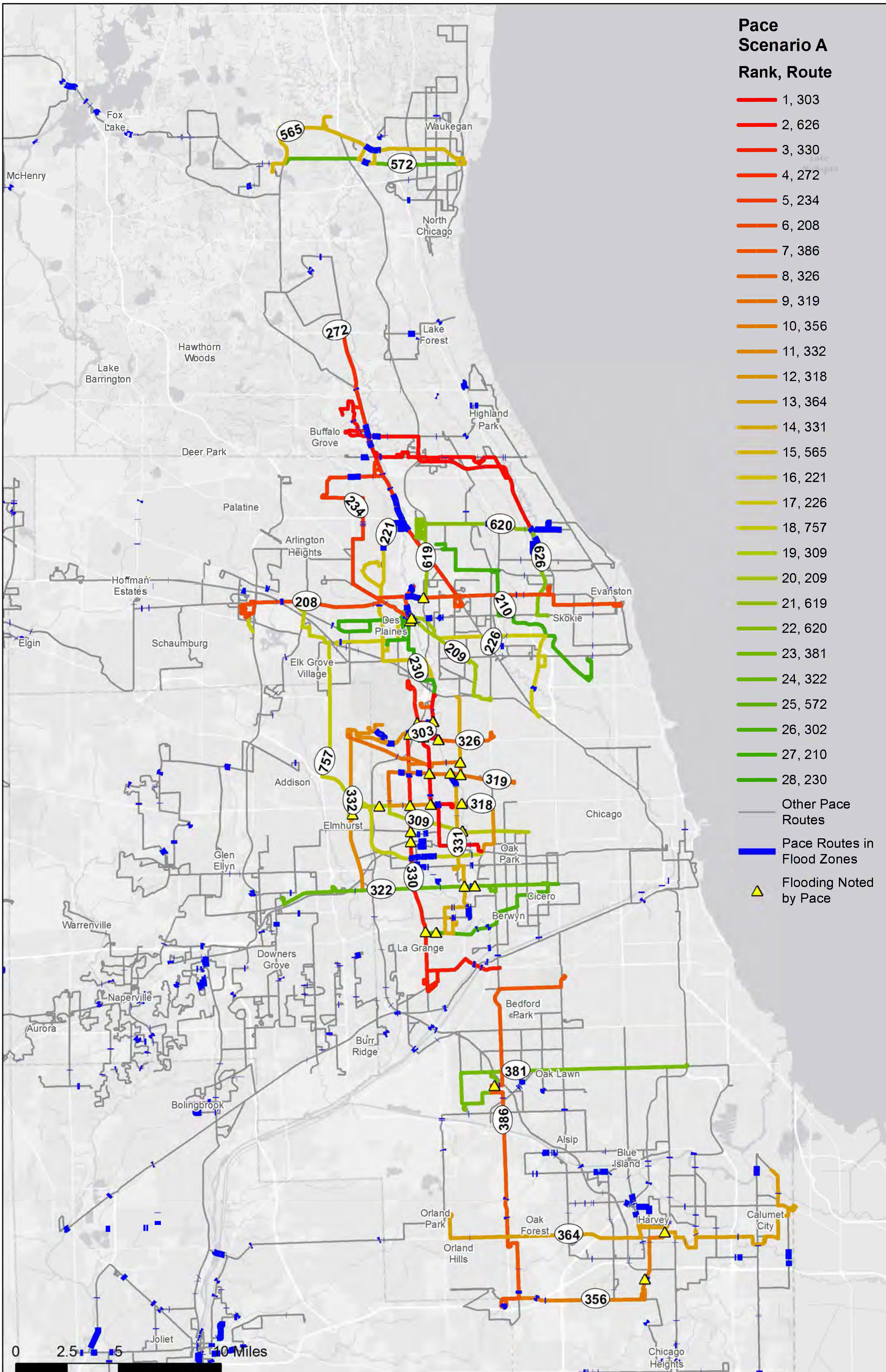
C-1: Pace Route Network with Flood Zone Intersections and Flooding Noted by Pace



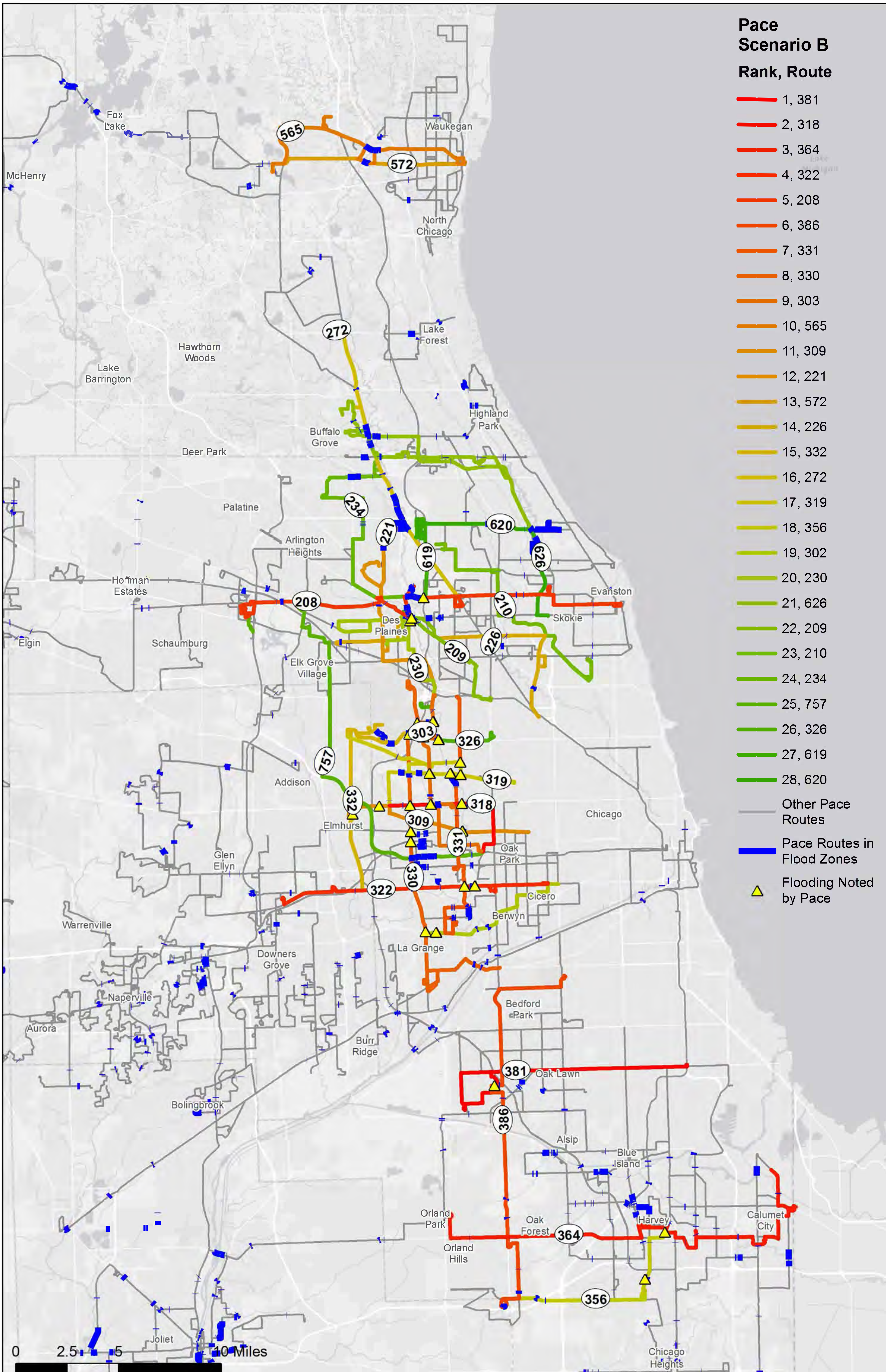
C-2: Pace Scenarios A-E with Flooding Data



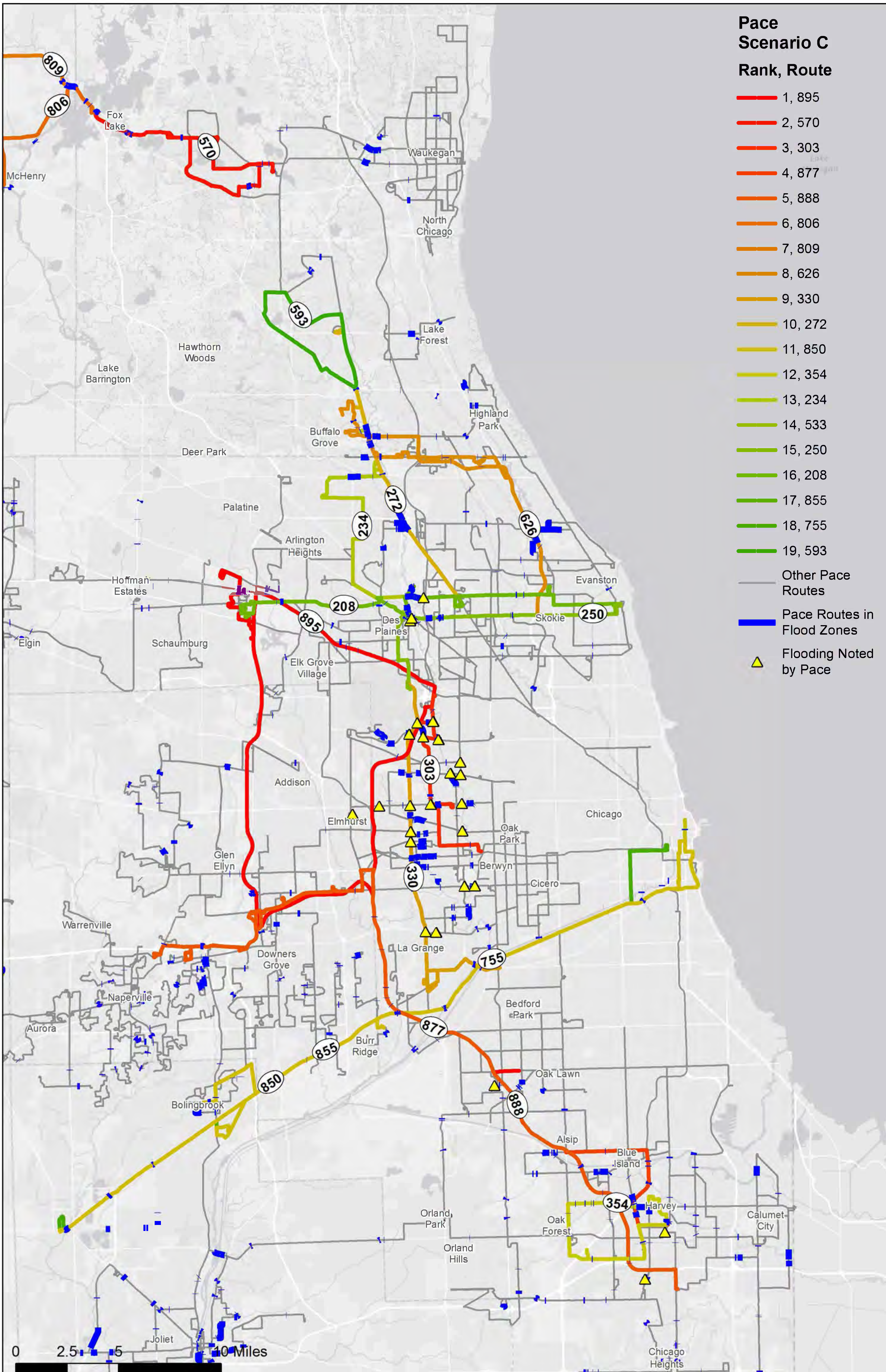
C-3: Pace Scenario A with Flooding Data



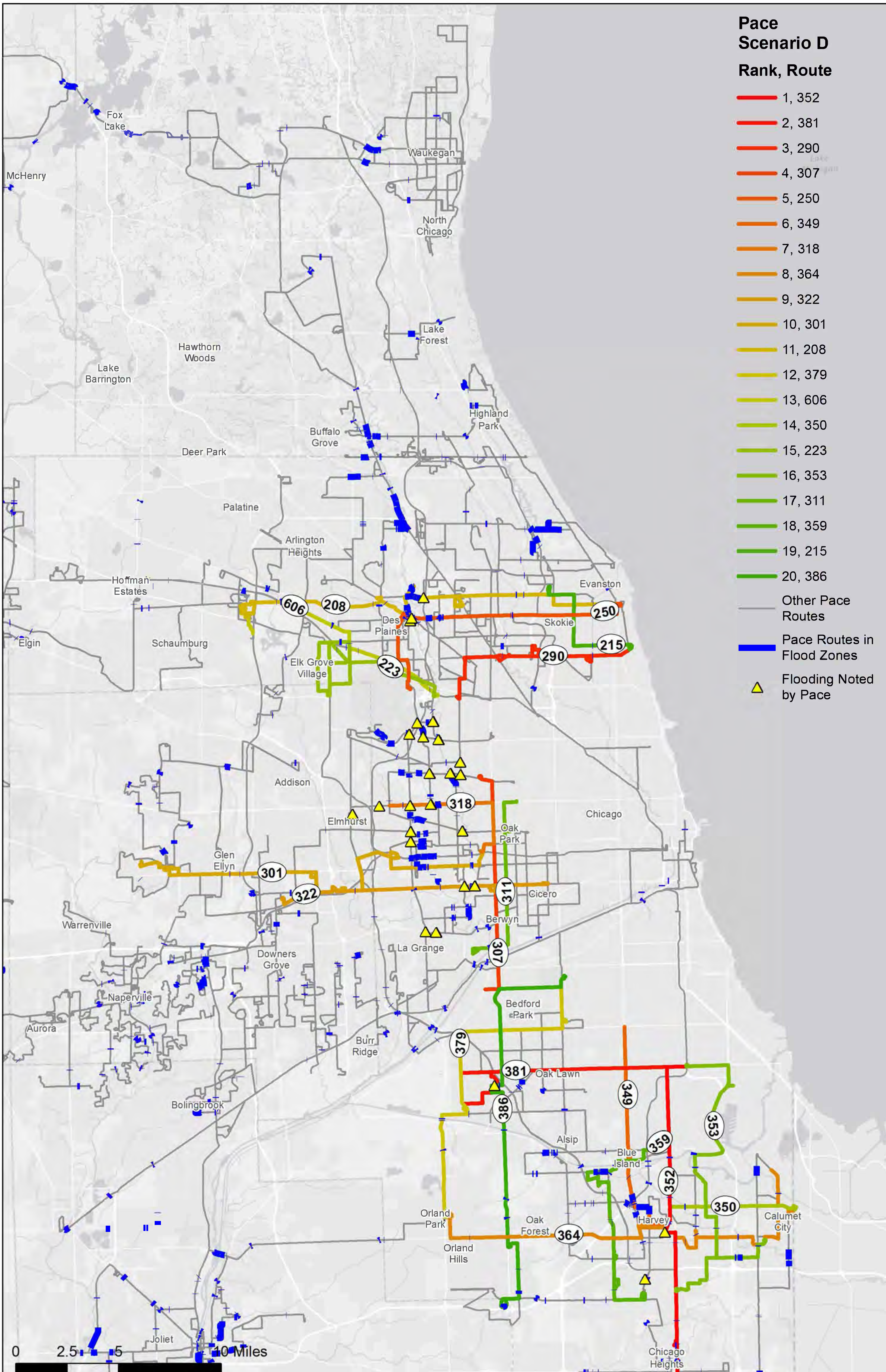
C-4: Pace Scenario B with Flooding Data



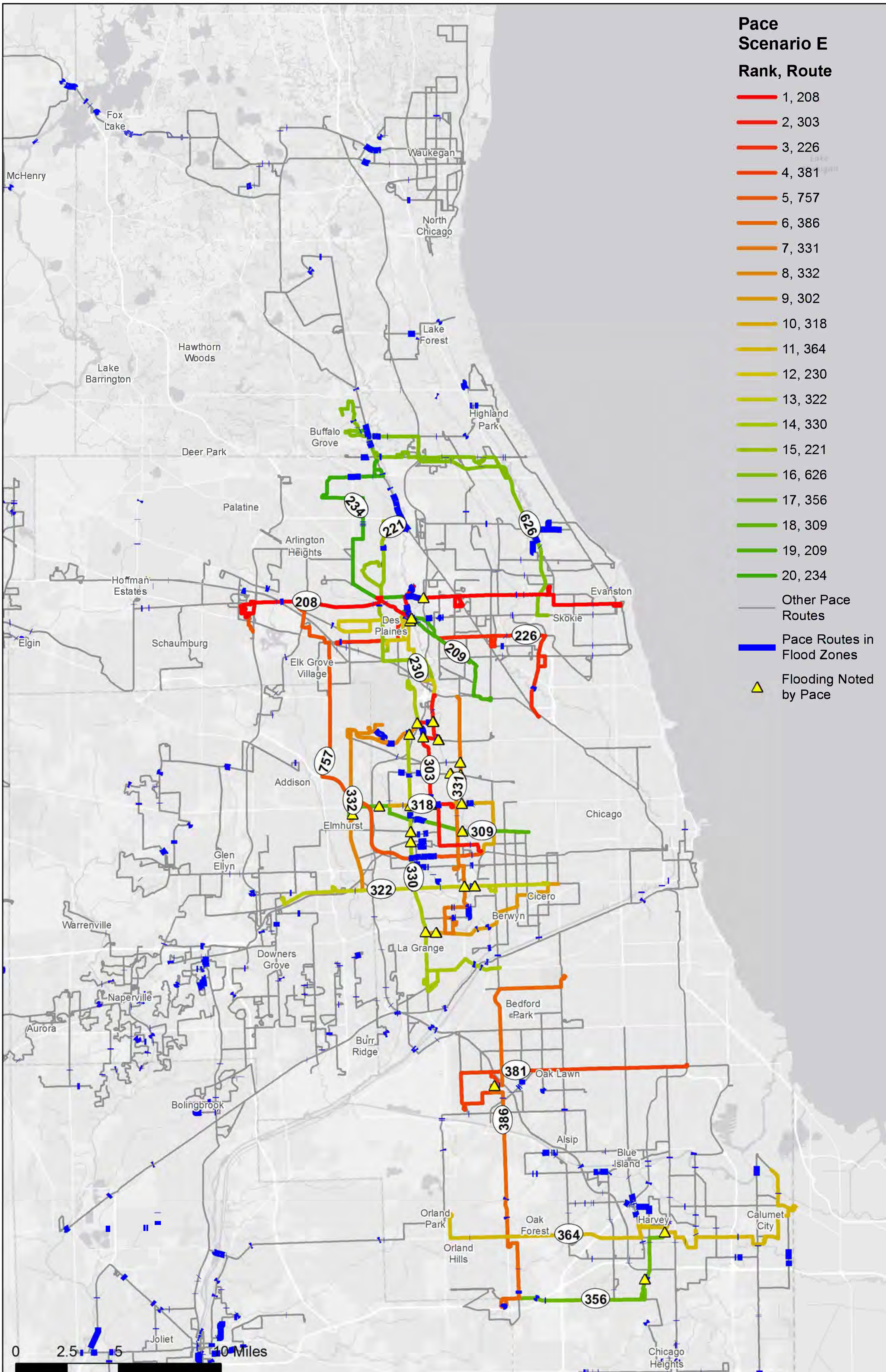
C-5: Pace Scenario C with Flooding Data



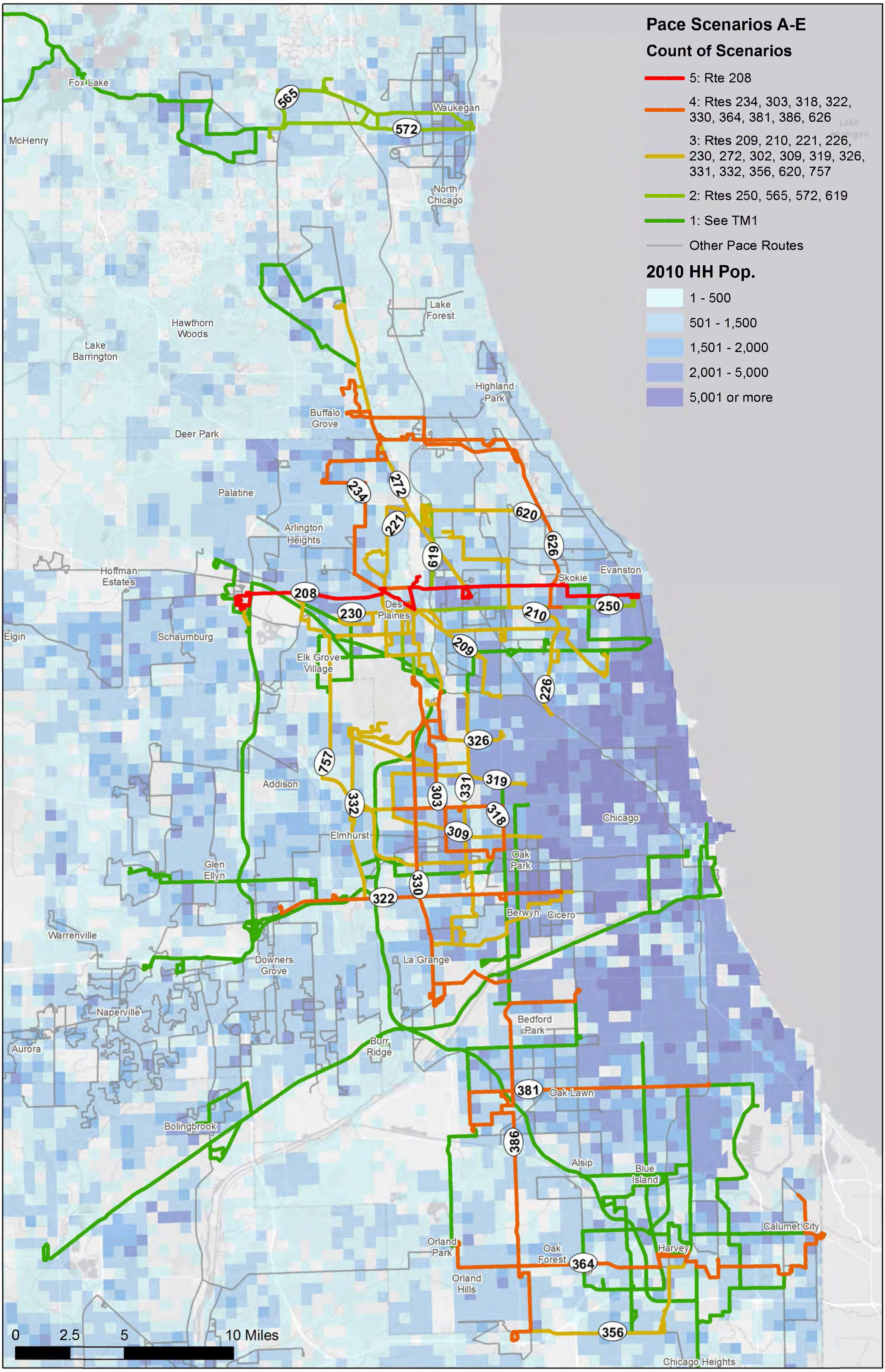
C-6: Pace Scenario D with Flooding Data



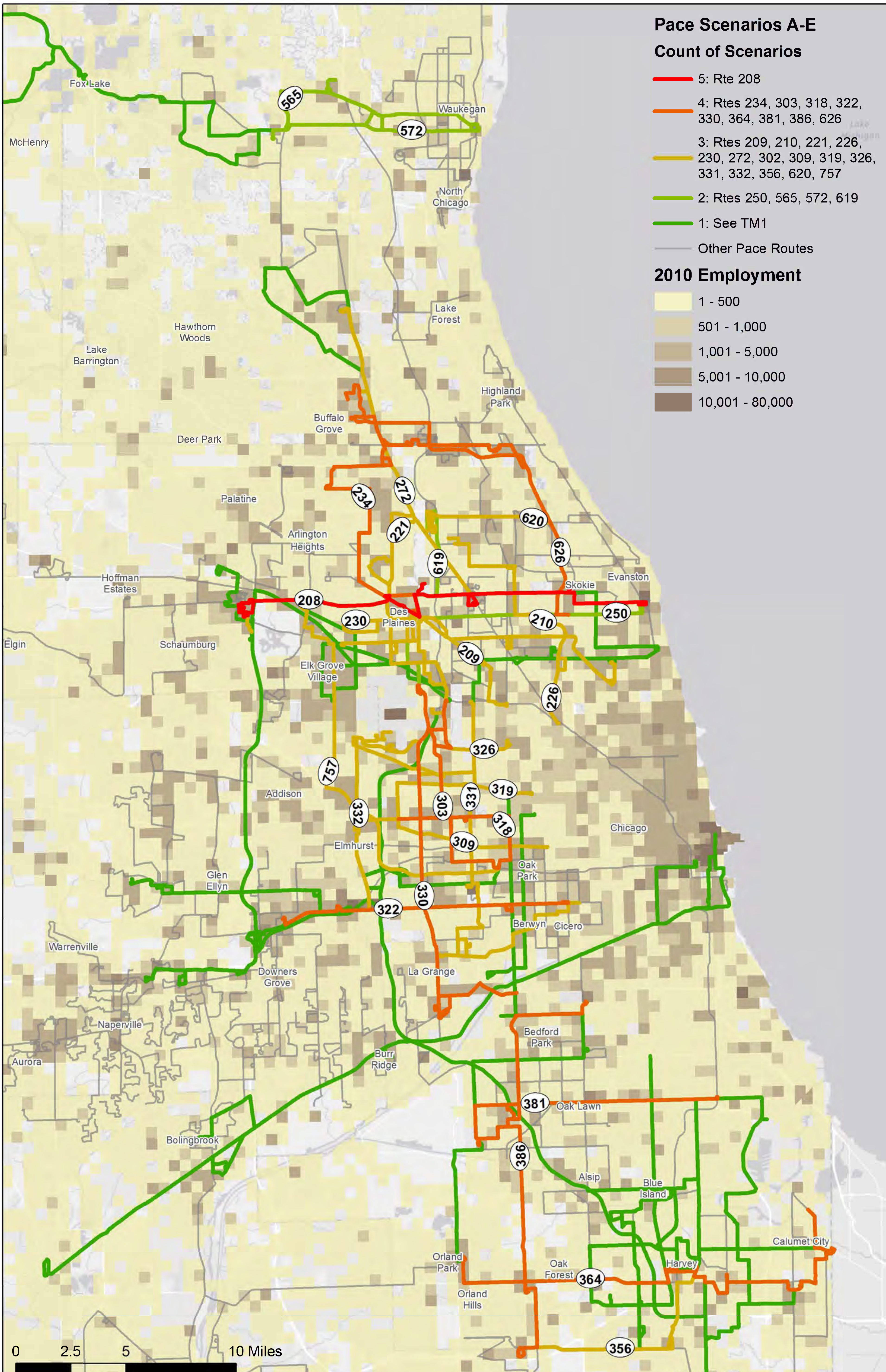
C-7: Pace Scenario E with Flooding Data



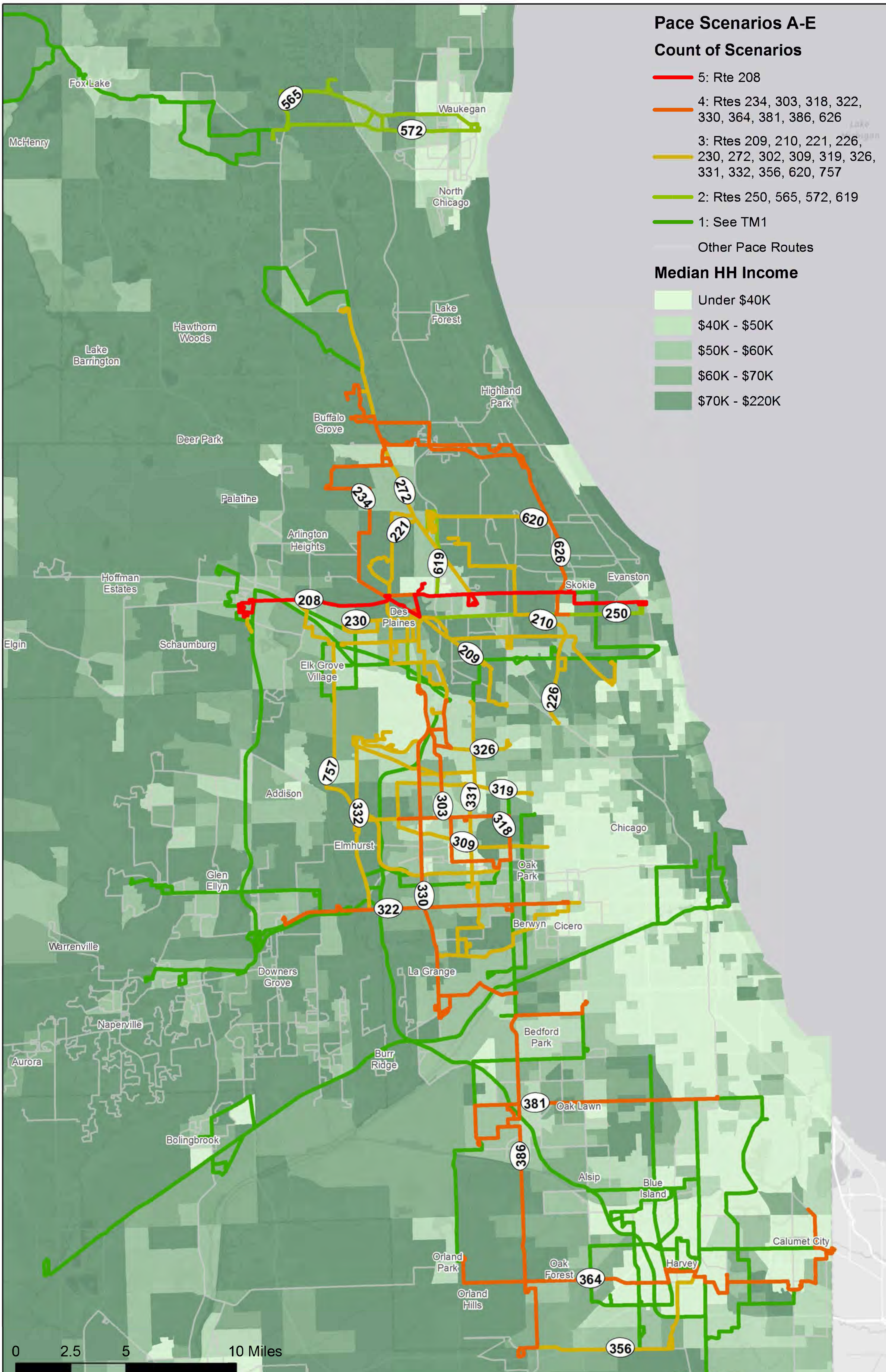
C-8: Pace Scenarios A-E with 2010 Population Subzones



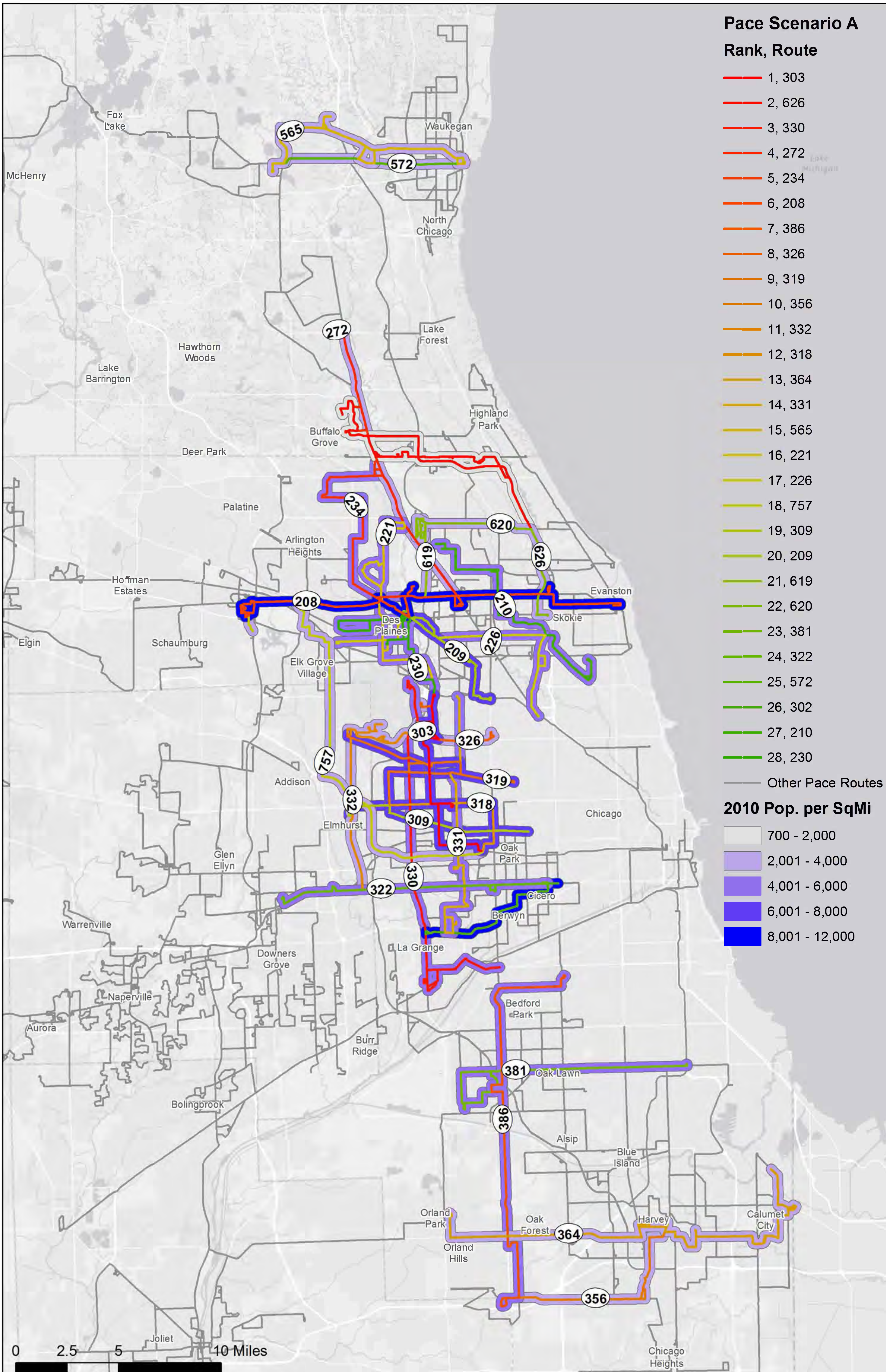
C-9: Pace Scenarios A-E with 2010 Employment Subzones



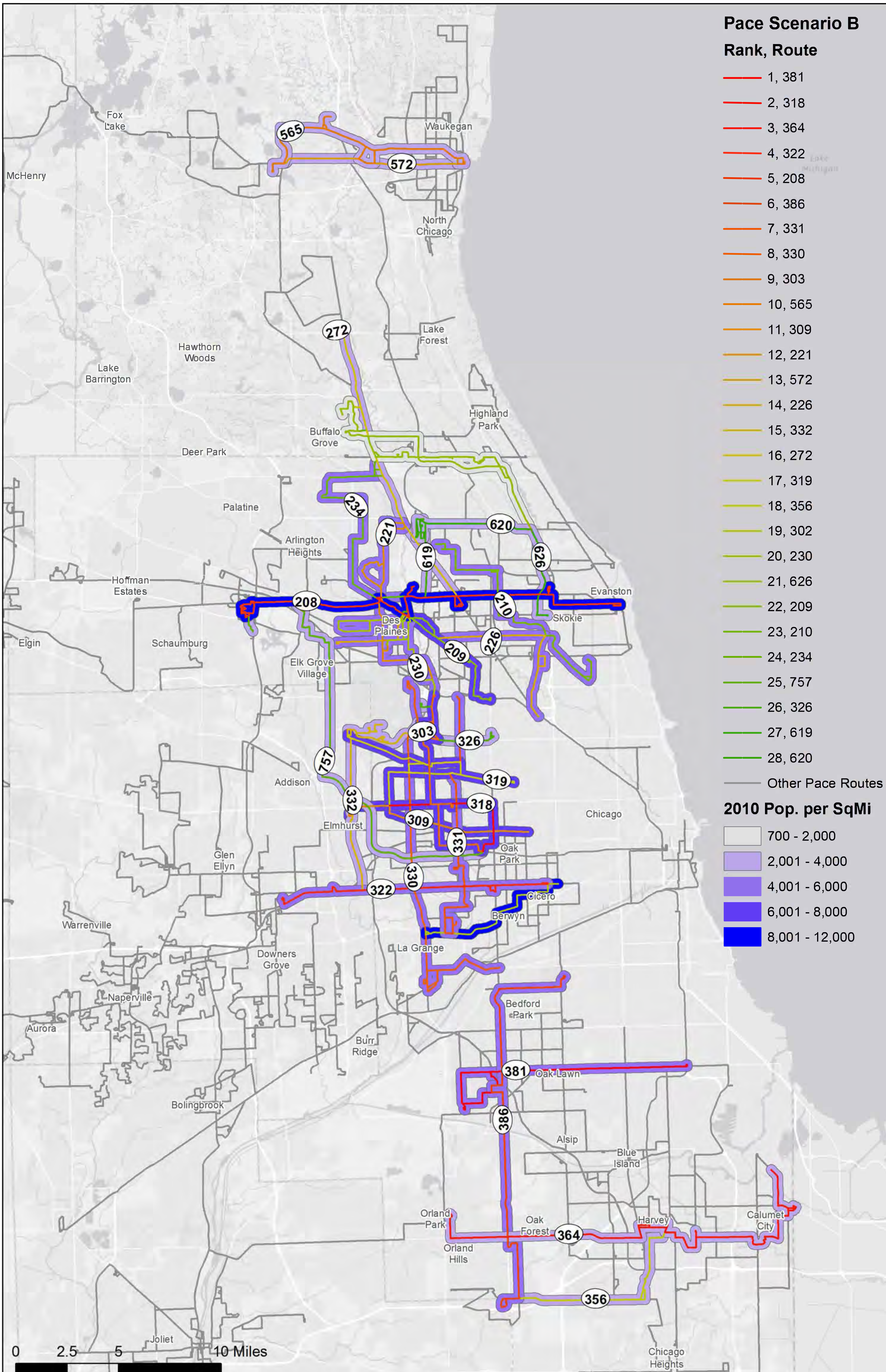
C-10: Pace Scenarios A-E with 2014 Median Household Income Tracts



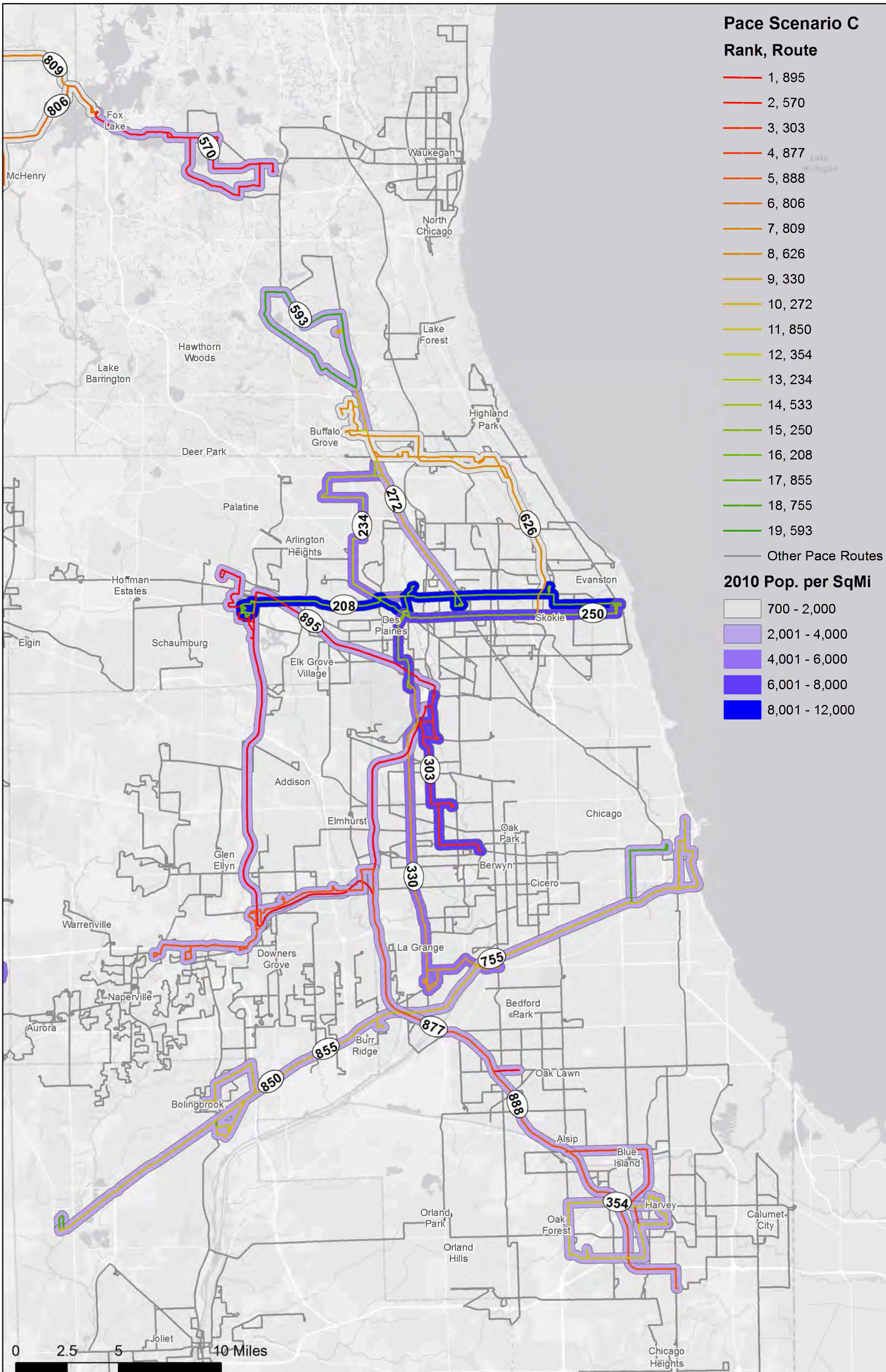
C-11: Pace Scenario A with 2010 Population Density Buffers



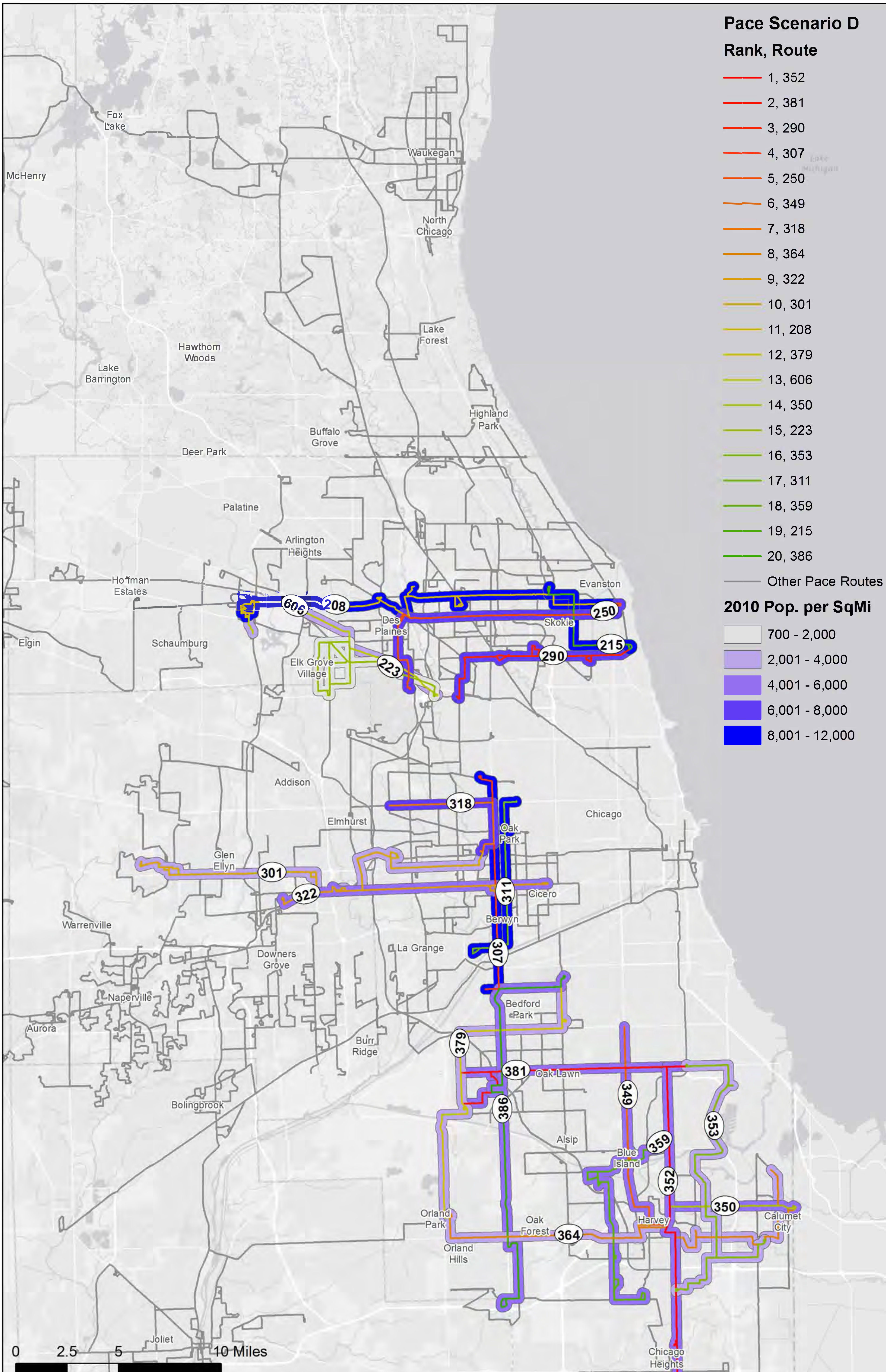
C-12: Pace Scenario B with 2010 Population Density Buffers



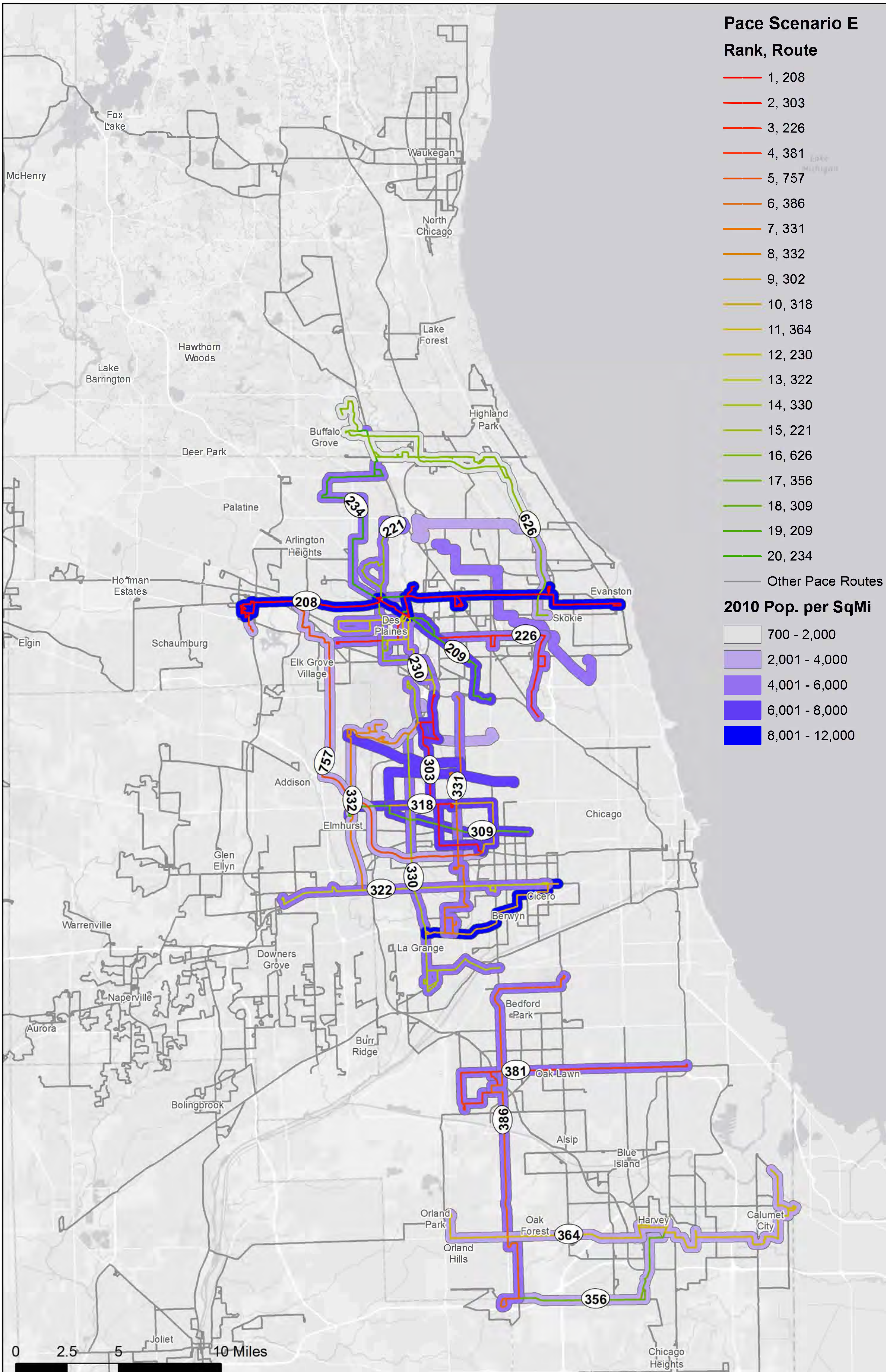
C-13: Pace Scenario C with 2010 Population Density Buffers



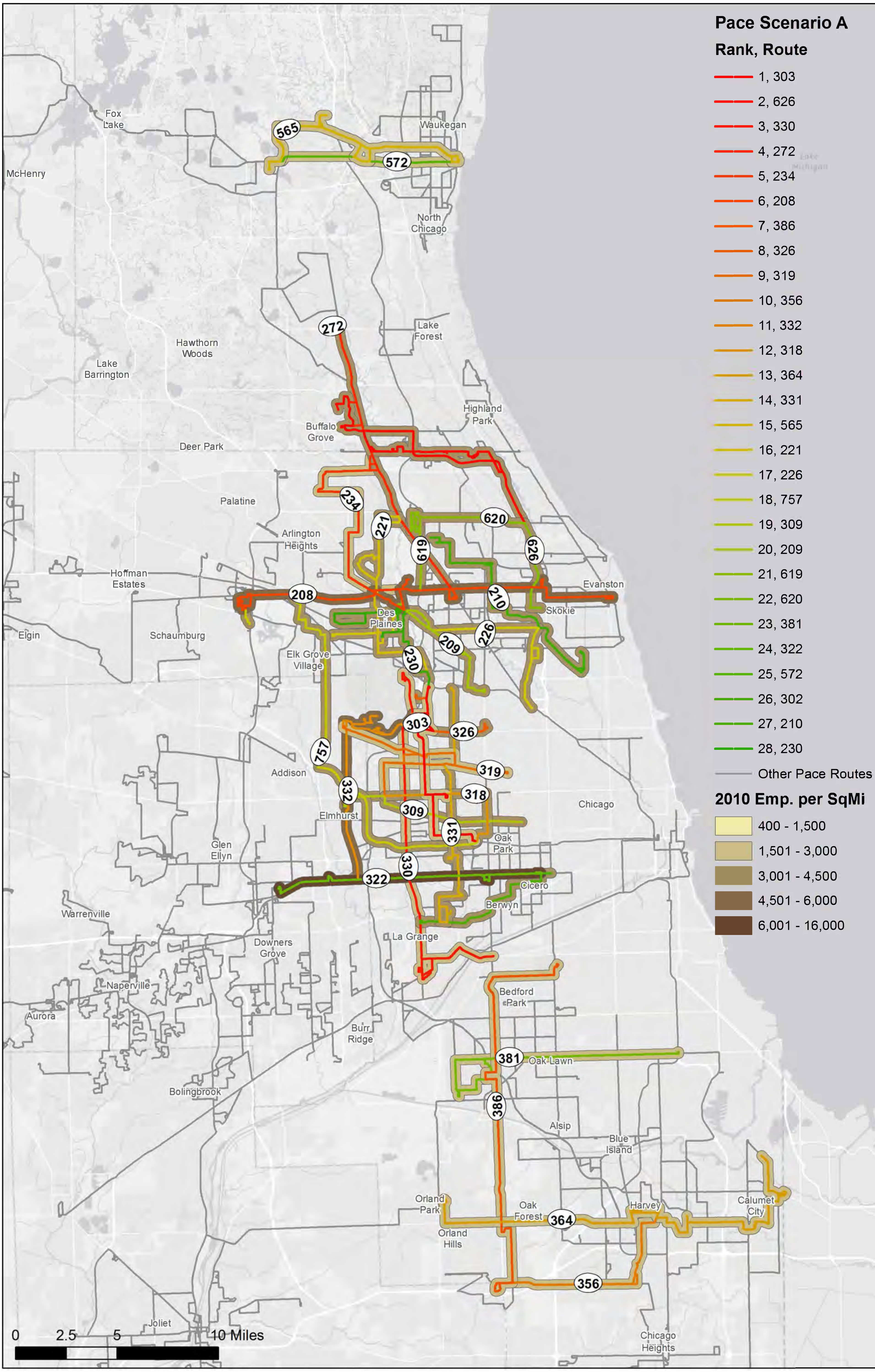
C-14: Pace Scenario D with 2010 Population Density Buffers



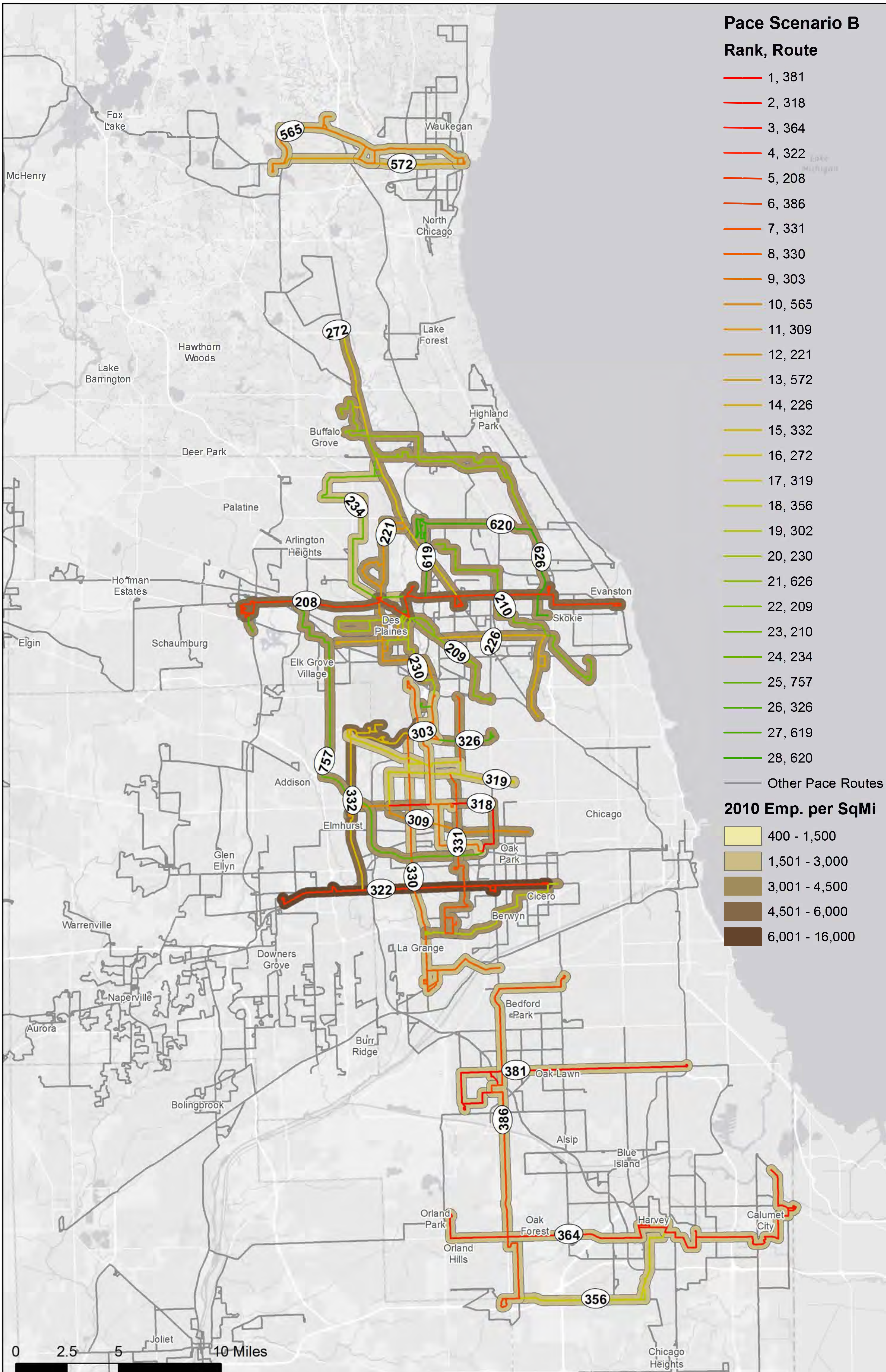
C-15: Pace Scenario E with 2010 Population Density Buffers



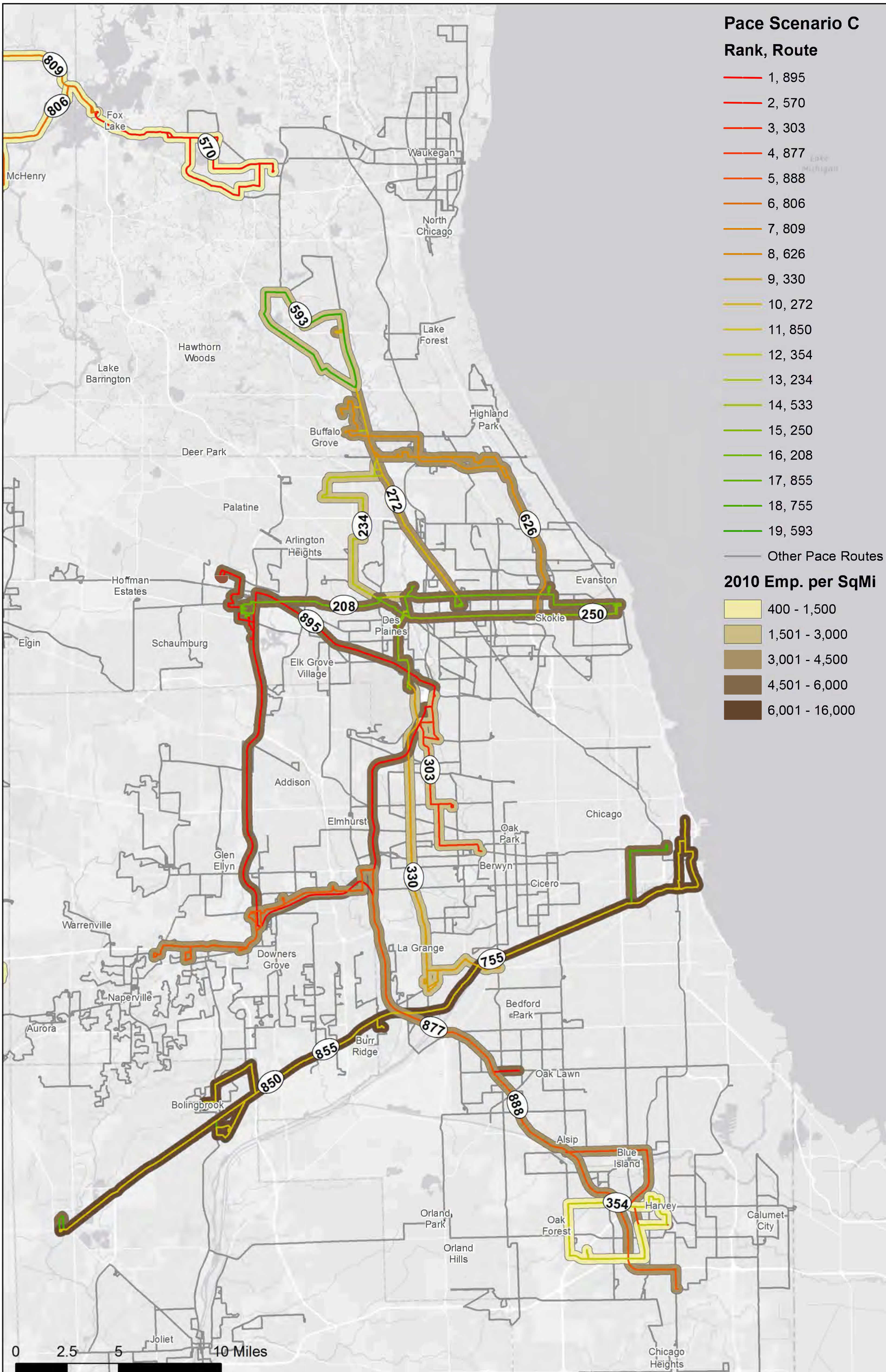
C-16: Pace Scenario A with 2010 Employment Density Buffers



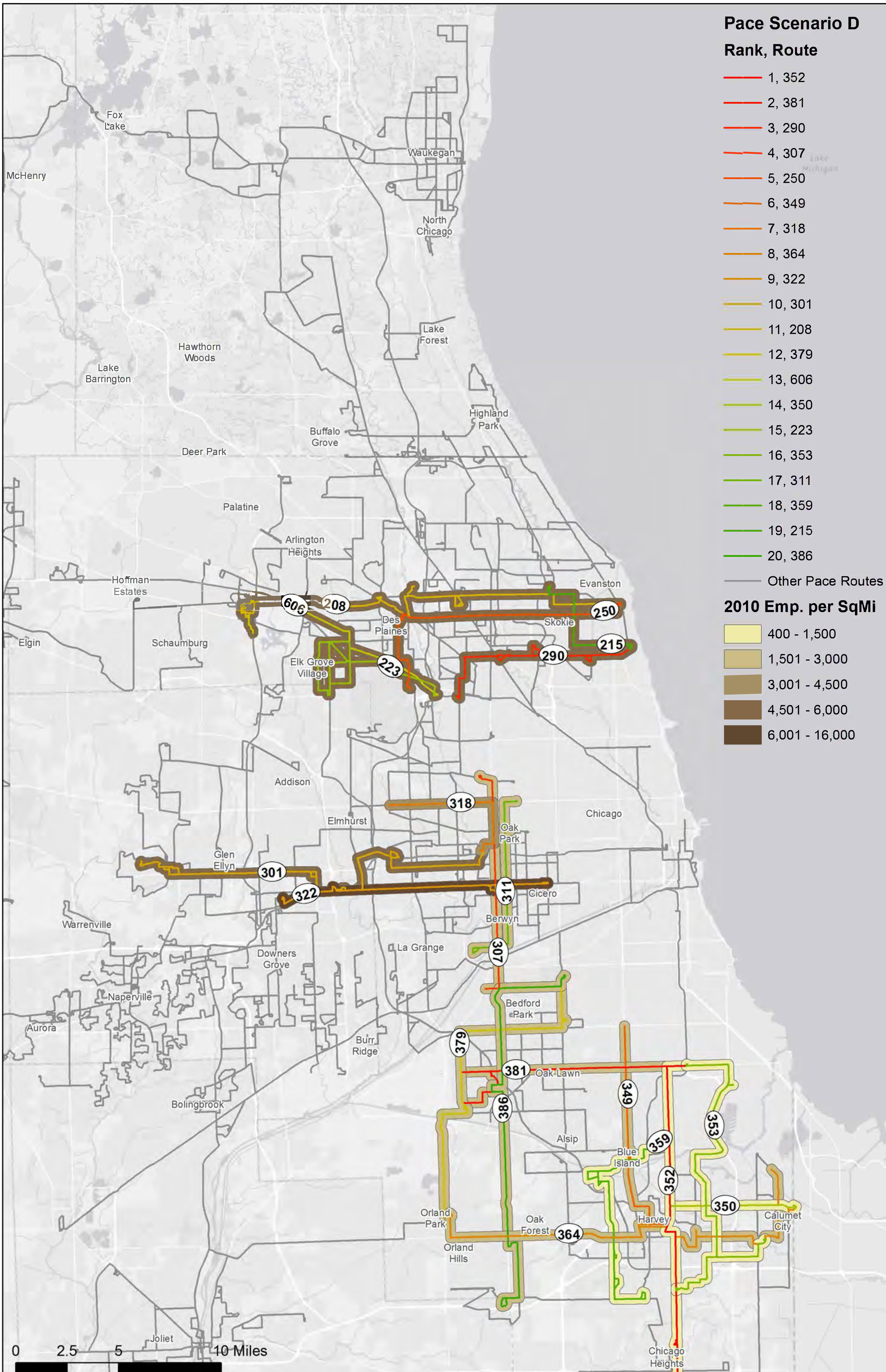
C-17: Pace Scenario B with 2010 Employment Density Buffers



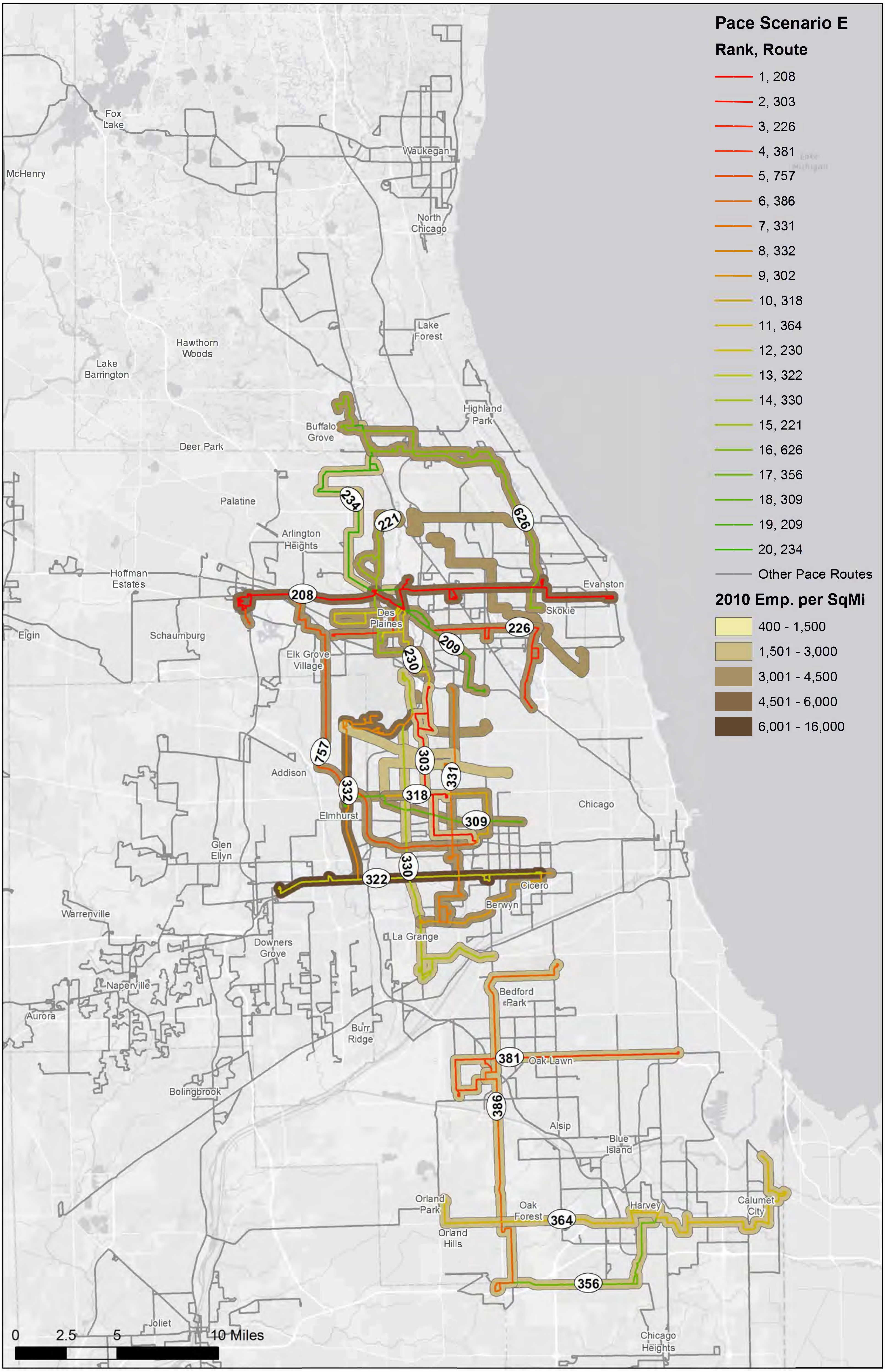
C-18: Pace Scenario C with 2010 Employment Density Buffers



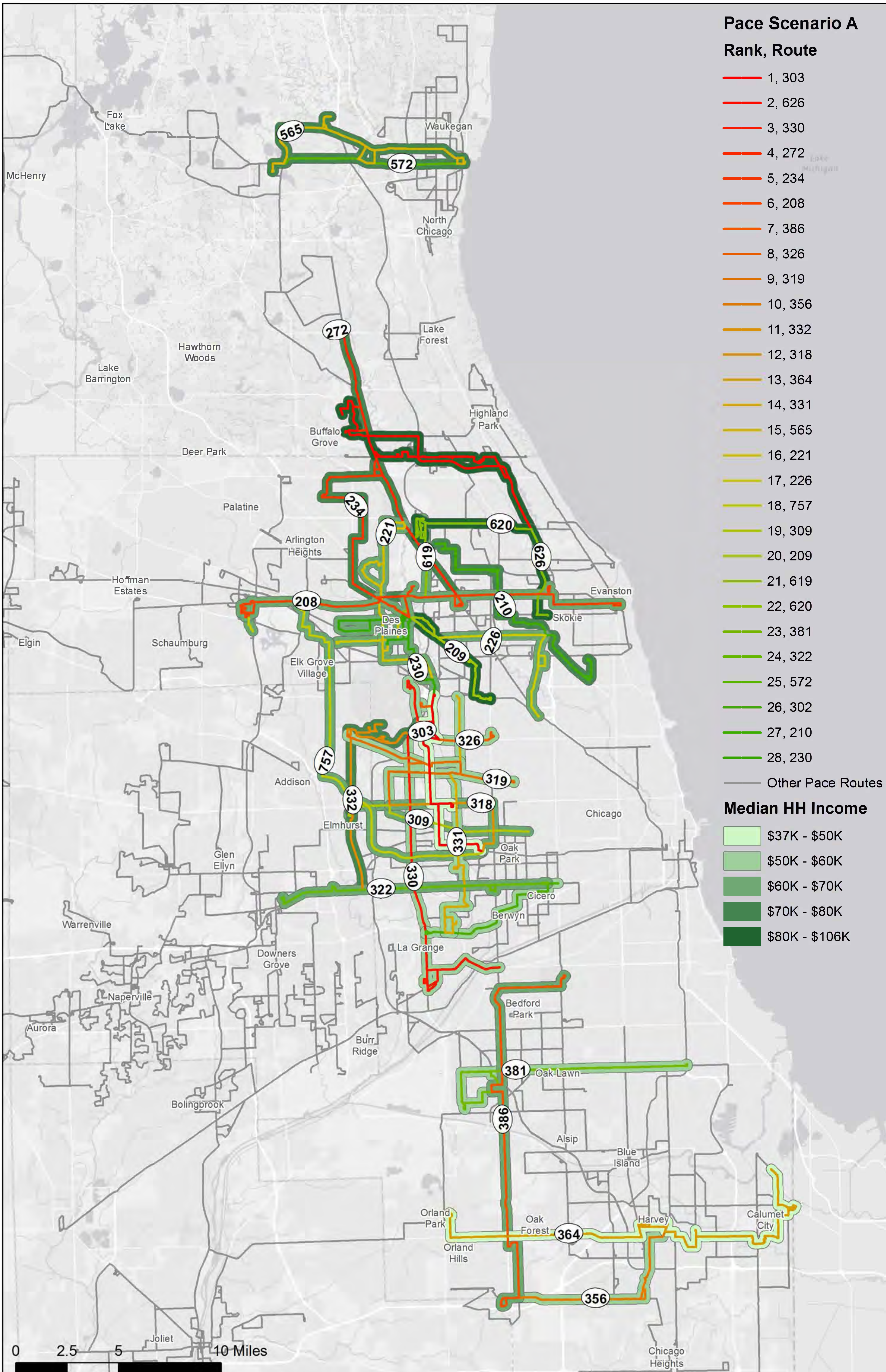
C-19: Pace Scenario D with 2010 Employment Density Buffers



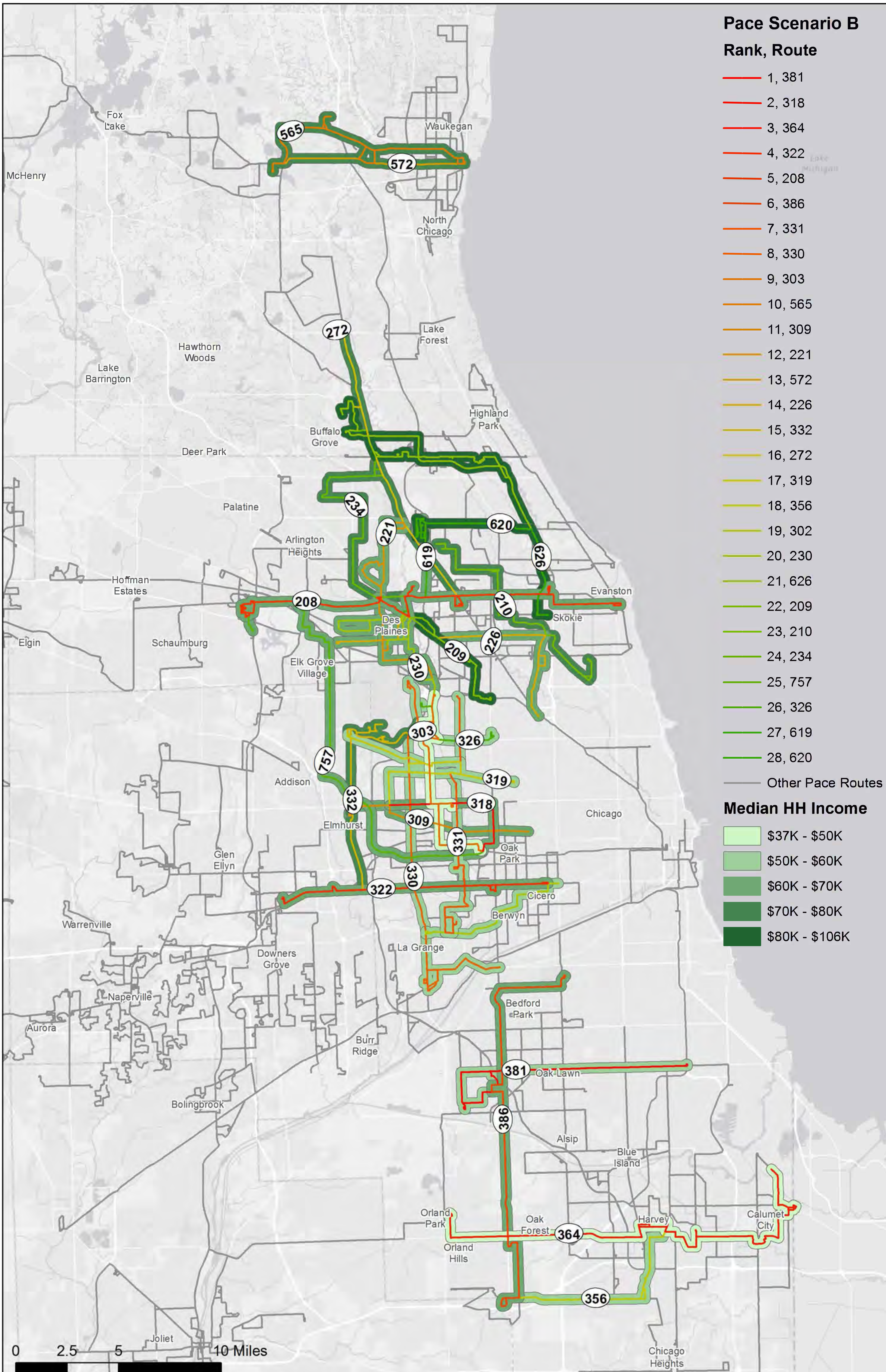
C-20: Pace Scenario E with 2010 Employment Density Buffers



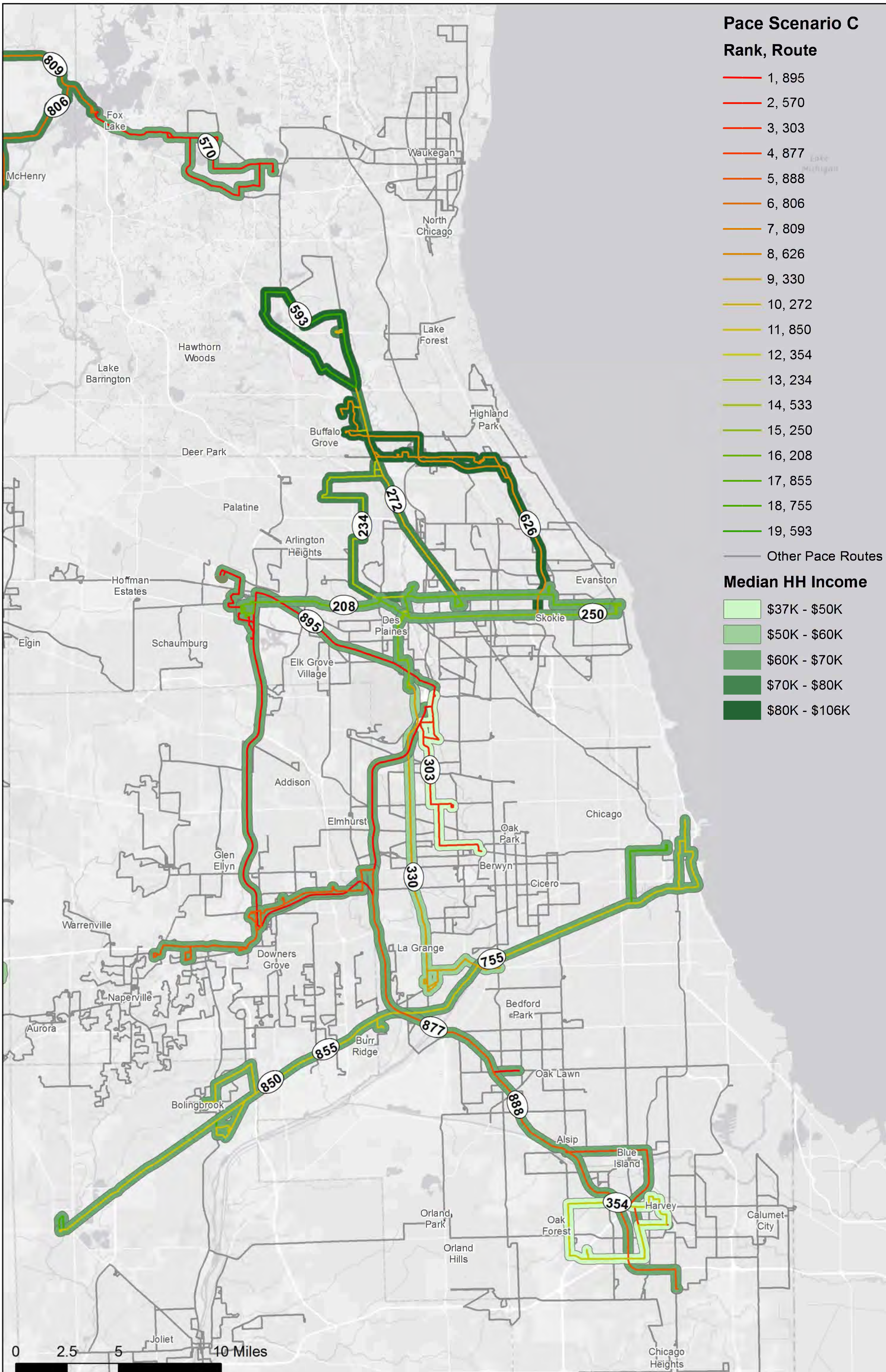
C-21: Pace Scenario A with 201 Median Household Income Buffers



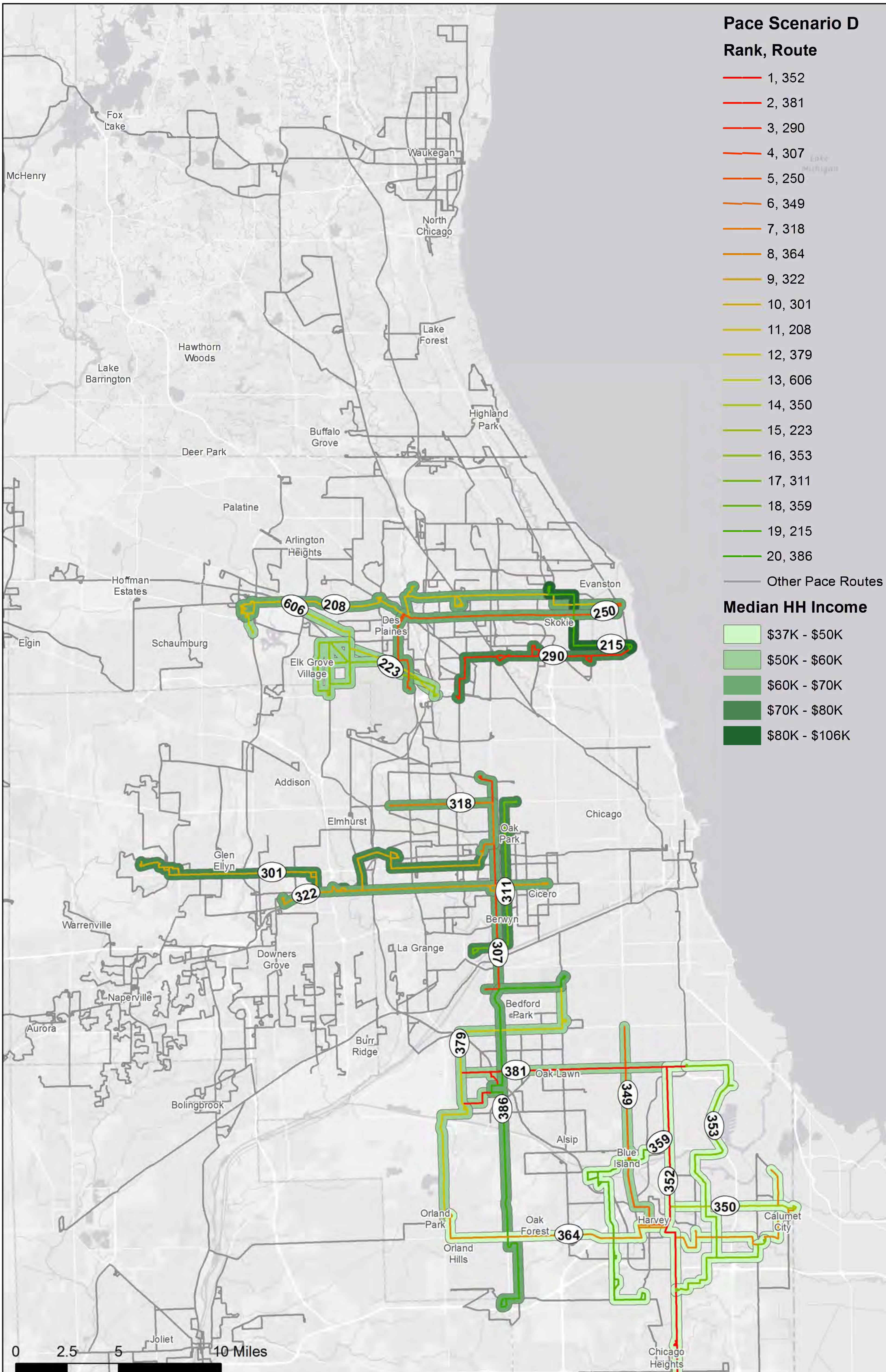
C-22: Pace Scenario B with 2014 Median Household Income Buffers



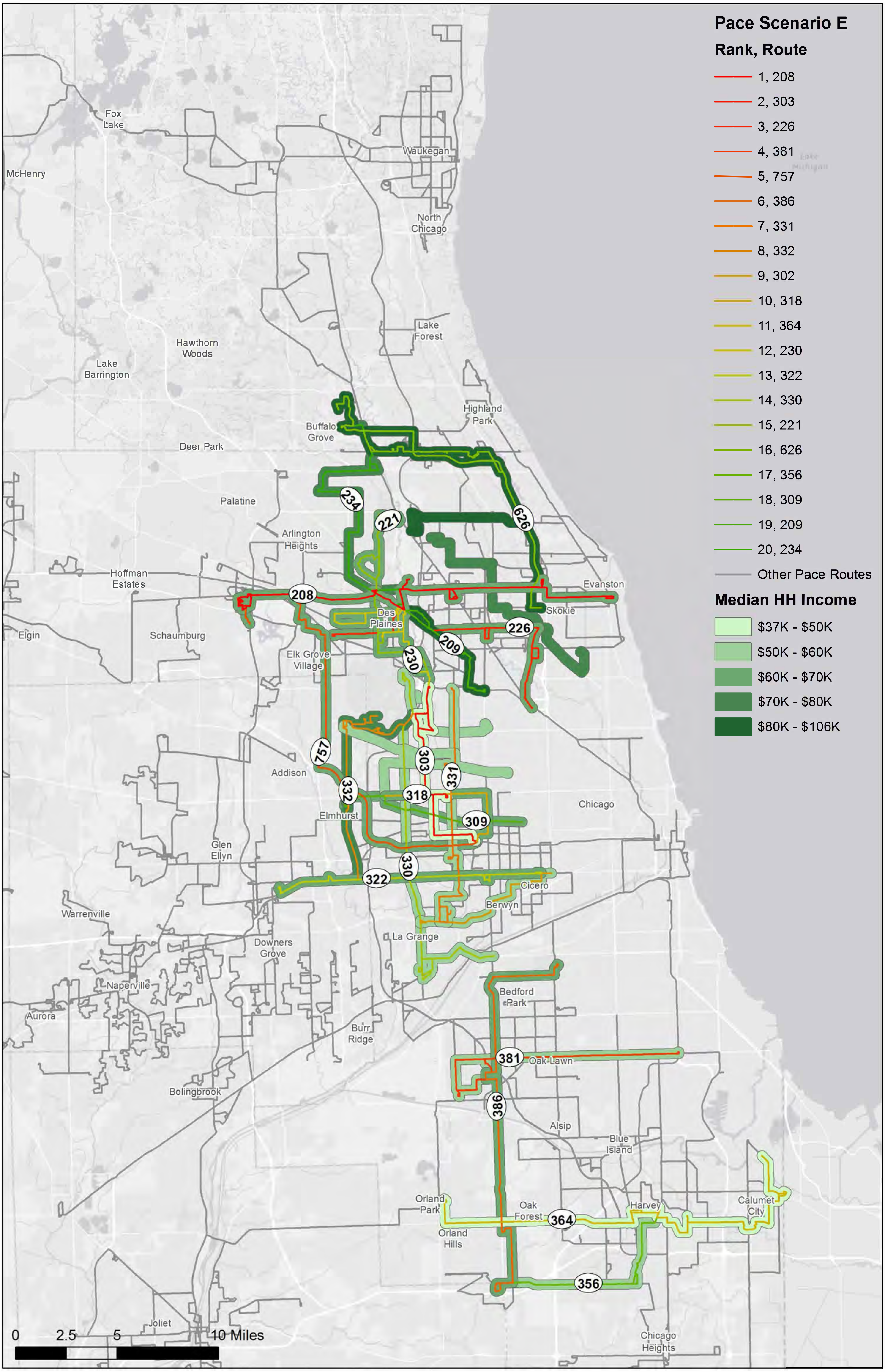
C-23: Pace Scenario C with 2014 Median Household Income Buffers



C-24: Pace Scenario D with 2014 Median Household Income Buffers



C-25: Pace Scenario E with 2014 Median Household Income Buffers



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Flooding Resilience Plan for Bus Operations

Appendix A: Task 2 Technical Memorandum: Identification of Flooding Impacts

Prepared for the Regional Transportation Authority of Northeast Illinois

rta

March 30, 2018

Quality information

Prepared by	Checked by	Approved by
Hilary Page (AECOM), Jen McNeil Dhadwal (AECOM), Julia Suprock (AECOM), Bill Weaver (AECOM), Chris Nimmo (UG), John Morgan (2IM Group)	Jen McNeil Dhadwal	Jen McNeil Dhadwal

Revision History

Version	Revision Date	Details
1	March 20, 2017	Comments from RTA
2	April 27, 2017	Comments from CTA
3	March 30, 2018	Best Practices section moved to Appendices B and C; Finalized

Distribution List

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Brian Hacker	RTA
Heather Tabbert	RTA
Heather Ferguson	CTA
Patricia Thomas-Miller	CTA
Bill Lynch	Pace
AECOM Project Team	AECOM, 2IM Group, Urban GIS

Prepared for:

The Regional Transportation Authority of Northeast Illinois (RTA)

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Table of Contents

Figures

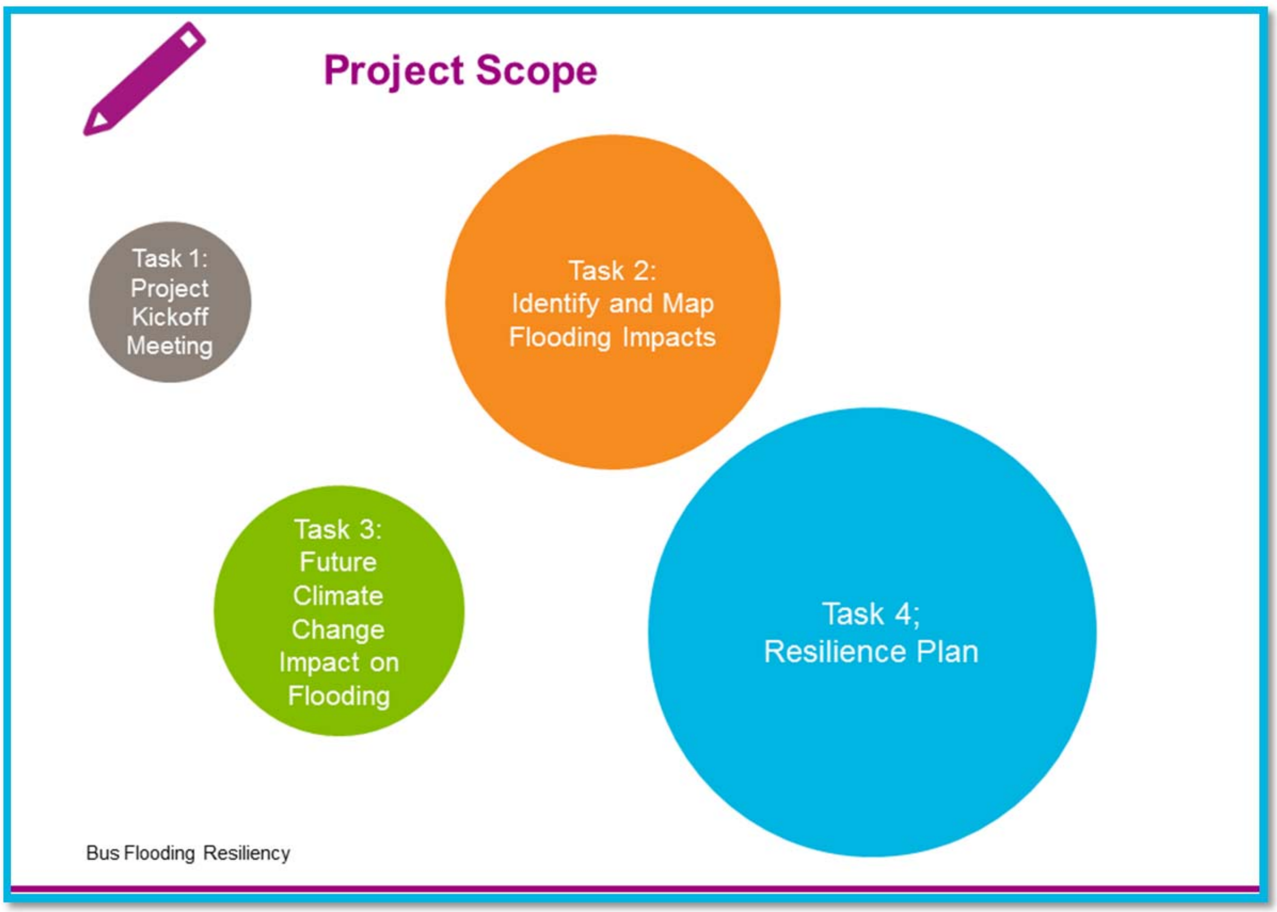
Tables

1. Introduction

In Fall 2015, as a continuation of its Green Transit program, the Regional Transportation Authority (RTA), initiated a project to prepare a bus route flooding resilience plan for the RTA region composed of its six-county jurisdiction in northeastern Illinois, including Cook, DuPage, Kane, Lake, McHenry, and Will Counties. The objective of this project is to identify CTA and Pace bus routes prone to flooding during average rain events and extreme weather events. Such flooding events can have negative impacts on operating costs and ridership revenues. The project is intended to develop recommendations to address flooding issues and reroute service during flooding.

The scope of the study, which kicked off in Summer 2016, is organized into four major work tasks:

1. Initiate Project
2. Identify and Map Flooding Impacts
3. Assess Future Climate Change Impacts on Flooding
4. Prepare a Resilience Plan



This technical memorandum presents draft findings from Task 2 work for consideration by the steering committee.

Summary of Tasks and Themes

Based on our observations of significant flood events during the last 5-10 years, flood events in the RTA region are a combination of water body overflows, as well as stormwater runoff and localized drainage issues. Bus transit is most obviously impacted when roads are wholly flooded and impassible, and viaducts and underpasses around the region's railroad and highway network are particularly vulnerable. As part of the Chicago Climate Action Plan—one of the key precursor studies to the RTA Flooding Resilience for Bus Operations plan—the CTA noted that their bus service is particularly vulnerable to flood events because of the over 1,500 railway viaducts, of which more than 10 percent are troubled by frequent flooding. Starting in **Task 2**, the project team identifies and reviews datasets describing the natural systems across the region – primarily the floodplains and floodways – as the starting point for identifying areas that present risk based on riverine and overbank flooding.

In addition to the conclusions that can be inferred from an overlay of viaduct locations, conditions and the bus routes, we are supplementing our understanding of risk with anecdotal reports of flooding from the front lines—the CTA and Pace bus drivers who call in flooded roads and detours. Areas with recurring problems for boarding and alighting are provided by the drivers and operations management, as well as from passengers who make reports of access difficulty. Additionally, insight from emergency management stakeholders and local departments of stormwater management and transportation provide further insight into troubled areas, impact, and the status of mitigation work.

As we turn next to **Task 3**, the project team will examine the effects of changing climate patterns on the flood risk landscape in the region. Research conducted in 2008 for the Chicago Climate Action Plan indicates that increases in winter and spring precipitation are likely, with projected increases of about 10 percent by the year 2050, and of about 20 to 30 percent by 2099. Additionally, the intensity of heavy precipitation events is likely to continue to increase. Effects of these trends will vary across the region according to watershed and sub-watershed hydrological patterns. In addition to input from county and local stormwater management departments, the project team will determine how to apply these forecasted increases to determine if the bus routes identified as likely at risk in Task 2 in the current state are still the routes

In **Task 4**, the project team will prepare responses to the identified risks in three major categories:

- Reroute plans for impacted bus routes,
- Communications strategy(ies) for updating impacted stakeholders of service interruptions, and
- Inventory potential mitigation projects and recommendations, with suggested next steps for items outside agencies' control

The resiliency strategies that we expect to propose during Task 4 will be composed of some projects that fall under the jurisdiction of CTA and Pace, but the majority are likely to be located in the public right-of-way or on private property. For these projects, the RTA, CTA, and Pace can influence other entities' actions but cannot control the outcome of these plans and may be able to participate from a funding or advocacy perspective.

2. Transit in the Chicago Region

The Chicago region has several agencies providing public transportation services that make connections within and between municipalities. Service providers include Chicago Transit Authority (CTA), Metra, Pace Suburban Bus, Amtrak, and Northern Indiana Commuter Transportation District (NICTD), commonly known as South Shore.

Regional Transportation Authority (RTA)

The RTA serves as the governing body which manages the Chicago-area public transportation service providers of the Chicago Transit Authority (CTA), Metra, and Pace Suburban Bus. Besides providing financial and management support for the transit agencies, RTA conducts long-range transportation studies and maintains several funding programs for planning transportation improvements. RTA has a jurisdiction that includes six of the seven counties that compose the Chicago region.

Chicago Transit Authority (CTA)

Providing public transportation service to the City of Chicago and 35 surrounding suburban communities, CTA manages the third-largest transit system in the United States. CTA operates eight rapid transit rail lines covering 145 rail stations and 130 bus routes serving roughly 11,000 posted bus stops. As of June 2016, CTA was providing 42.6 million rides each month, roughly equally split between rail and bus.[1] On an average weekday, 1.6 million people board CTA trains or buses.[2]

Pace Suburban Bus

As one of the largest public bus service providers in the US, Pace operates 209 fully accessible bus routes within the six-county area of Cook, DuPage, Kane, Lake, McHenry, and Will, which includes 284 municipalities. Besides traditional fixed-route bus service, Pace provides paratransit service via 454 vehicles as well as vanpool service via 694 vehicles. Ridership stood at 40 million in 2014, and monthly ridership as of June 2016 was 2.3 million.

Commuter Rail

Metra's commuter passenger rail service spans 11 rail lines linking 241 stations.[3] In 2015 Metra provided more than 81 million trips annually, many of which originated in collar counties, including those of DuPage, Kane, Lake, McHenry, and Will. As of June 2016, Metra provided 7 million rides per month. Outside of the New York City metropolitan area, Metra is the busiest commuter rail system in the United States by ridership.

The last remaining interurban railroad—the South Shore Line—is operated by the Northern Indiana Commuter Transportation District (NICTD) and connects northern Indiana with downtown Chicago with 19 stations. This rail service was providing 325,000 rides per month as of June 2016.

While commuter rail and CTA heavy rail transit are not the primary focus of this project's analysis, bus connections to the wider high-capacity network are an important factor in evaluating or prioritizing topics of focus.

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[1] Chicago Transit Authority (CTA). Performance Metrics. http://www.transitchicago.com/performance/ (2016)
[2] http://www.transitchicago.com/about/facts.aspx (2016)
[3] Metra, Frequently Asked Questions, metrarail.com/metra/en/home/utility_landing/riding_metra/faq.html#q2 (2014)

2.1 CTA Bus

Ridership

CTA accounts for the majority of public transportation ridership numbers in the Chicago metropolitan area. System-wide ridership from 2005 to 2015 has increased more than 5%.

Buses are often cited as the workhorses of the CTA system as they have historically provided more than half of all CTA transit trips. However, since CTA was forced to implement service cuts in 2010 to meet budgetary constraints, bus ridership fell by approximately 45 million between 2009 and 2015. Rail, on the other hand, has increased significantly every year. From 2005 to 2015, annual rail ridership has increased by about 55 million rides, or 30%.

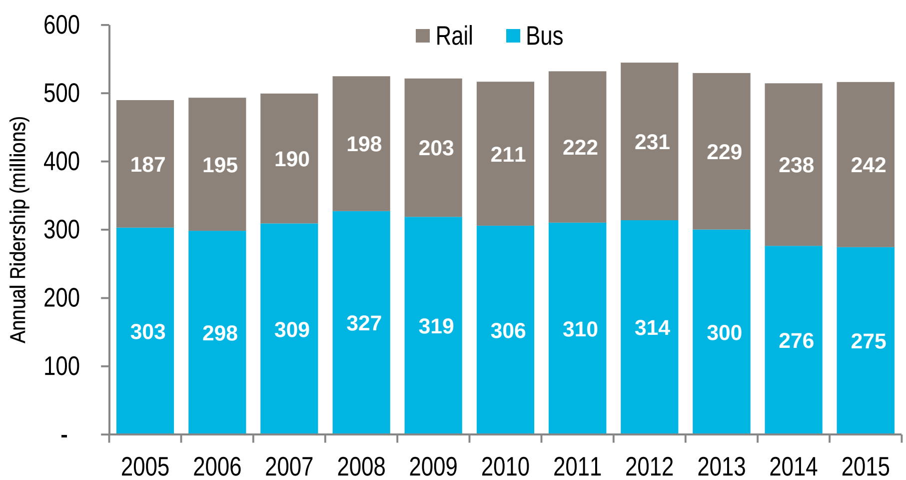
Table 2-1 and Figure 2-1 display bus, rail, and total system ridership for each year between 2005 and 2015. Rail ridership has been increasing and bus ridership falling over this period. System ridership as of 2015 is 517 million rides per year, which is above the 2005 total of 490 million, but is down from the 2012 peak of 545 million.

Table 2-1: Annual CTA Ridership (in millions)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bus	303.2	298.4	309.3	327.3	318.9	306.1	310.5	314.0	300.3	276.3	274.6
Rail	186.8	195.2	190.3	197.6	202.8	210.8	221.7	231.0	229.3	238.2	242.0
Systemwide	490.0	493.6	499.6	524.9	521.7	516.9	532.2	545.0	529.6	514.5	516.6

Source: RTAMS (2016).

Figure 2-1: Annual CTA Total System Ridership (in millions)



Source: RTAMS (2016).

Table 2-2 provides ridership figures for each of the top performing bus routes by ridership, highlighting those routes that had the most average weekday riders in 2015. Ashland and 79th Street routes are the highest performing routes, followed by Chicago and Western. Each of these routes carries about 2-3% of all CTA bus riders each year, and combined they comprise one quarter of CTA bus ridership.

Table 2-2: Top CTA Routes by Ridership

Route #	Name	Avg. Weekday Riders	Annual Ridership (2015)
9	Ashland	27,499	8,856,955
79	79th	26,830	8,716,277
66	Chicago	23,506	7,399,957
49	Western	23,417	7,462,133
77	Belmont	22,150	7,008,072
8	Halsted	22,093	6,820,599
4	Cottage Grove	21,143	6,747,771
53	Pulaski	19,909	6,293,990
3	King Drive	19,235	6,132,991
82	Kimball-Homan	18,939	5,898,214

Source: CTA data

Alignments

The CTA operates an integrated transit system designed to provide both maximum access to downtown Chicago and comprehensive local service throughout the service area. The bus system is generally aligned in a grid pattern to provide efficient transportation coverage and maximize connections, requiring most riders to walk less than a half-mile to reach transit. Main functions of bus routes are serving neighborhoods, providing access to downtown Chicago, feeding rapid transit stations, and providing service to major activity centers and niche markets.

Most routes serve multiple purposes in that they provide both maximum access to downtown and comprehensive crosstown local service throughout the service area. The #66 Chicago provides north side east-west local service from Chicago's western border to the lakefront at Navy Pier. It also provides feeder service to Blue, Brown, and Red Line trains at each line's respective Chicago Avenue stations, and provides service to the River North/ Magnificent Mile neighborhoods, extensions of downtown Chicago.

A south side heavily used east-west crosstown route, the #79 79th, also serves multiple purposes in that it serves neighborhoods throughout Chicago's south side from the western boundary to the lakefront. It also connects passengers with the Red Line rail station, from which one can directly access downtown Chicago and other north and south side neighborhoods along the corridor. The route also serves a major activity center at the west end, the Ford City Mall at Cicero Avenue and 76th Street.

Two key north-south crosstown routes include the #9 Ashland and the #49 Western. Both provide critical service to neighborhoods and access to east-west bus routes, as well as providing feeder connections to downtown rail. Both are also served by auxiliary CTA and Pace routes at each terminal, to extend services farther into the northern and southern portions of Cook County. Given their length and lack of a rail line in close proximity, both of these routes have limited-stop service (#X9 Ashland Express and #X49 Western Express), providing less on-board travel time for customers traveling longer distances. The heavy usage of these routes is a strong indicator of the demand for service that connects smaller employment and activity centers, without having to pass through Chicago's downtown. The high demand for service along these routes was instrumental in choosing Ashland for the Ashland Bus Rapid Transit study.

Modal Technology

The CTA has a bus fleet of over 1,800 vehicles with highly modern and advanced buses passenger amenities and technologies to help track, diagnose, and monitor service in real-time. There are two main types of buses in operation; 40’ heavy duty “standard bus,” and 60’ articulated buses. Vehicle types are assigned based on ridership demand and different vehicles may be used along the same route.

All CTA buses are also equipped with with technology that transmits location data from an on board computer system which is equipped with a Global Positioning System (GPS) to a CTA database called the Data Communications Controller (DCC) in real-time. The DCC polls the on-board computer, the Intelligent Vehicle Network (IVN), every 30 seconds for location data. The DCC data in turn feeds into a real-time bus management (RTBM) database system used by CTA to monitor bus service. The DCC also passes data to the BusTracker prediction system for creating bus arrival predictions. The CTA control center uses an application called CleverCAD to communicate in real-time two-way with buses and the DCC facilitates the communication between the Computer Aided Dispatch (CAD) system and the on-board IVN and operator screen. In addition, all CTA buses are equipped with the Ventra fare collection equipment. The Ventra fare collection equipment is comprised of a Bus Mobile Validator (BMV) that connects via a separate cellular connection to the back office to operate the Open Standards Fare System. The bus also has a farebox used to collect cash fares with data physically probed from the bus once per day.

Currently, 97% of the CTA bus fleet has automatic passenger counting (APC) sensors at doorways to collect boarding and alighting data as passengers break an infrared beam. The APC data is collected on board the bus and sent to servers once per day and processed twice per day.

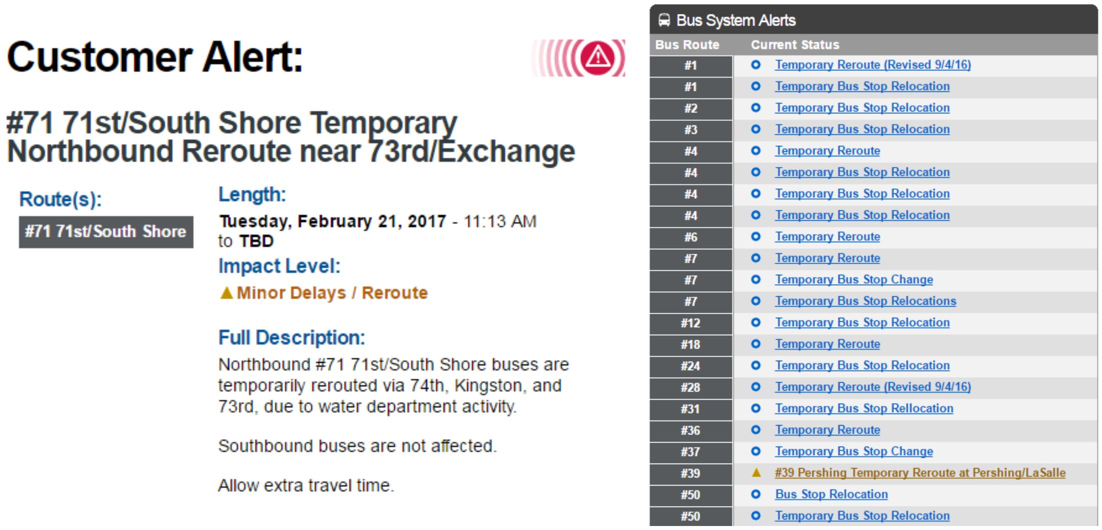
Bus drivers also have direct radio communication with dispatchers and supervisors, again via the CleverCAD system. Each bus is also equipped with several fixed-view cameras to provide video surveillance for security. Buses are also equipped with automated audio announcements of upcoming stop arrivals, also supported through the aforementioned IVN.

One technology of particular value to passengers is the CTA’s Bus Tracker system. Bus prediction information is distributed to users of computers, mobile phones, and other electronic devices. The CTA provides an application programming interface (API) so that developers can incorporate the real-time prediction data into smartphone apps and other uses. Users can then find the anticipated arrival times of buses for every stop in the CTA system. This capability has had a significant positive impact on the perceived and actual reliability of CTA services among passengers and the general public.

Communications

CTA communicates with passengers using customer alerts posted on the website. Spontaneous reroutes are highlighted with a different symbol and color, in comparison with planned temporary reroutes or bus stop changes/relocations that are in place for several weeks at a time (see Figure 2-2).

Figure 2-2: Sample CTA Website Bus System Alerts



Customer Alert:

#71 71st/South Shore Temporary Northbound Reroute near 73rd/Exchange

Route(s):
#71 71st/South Shore

Length:
Tuesday, February 21, 2017 - 11:13 AM
to **TBD**

Impact Level:
▲Minor Delays / Reroute

Full Description:
Northbound #71 71st/South Shore buses are temporarily rerouted via 74th, Kingston, and 73rd, due to water department activity.

Southbound buses are not affected.

Allow extra travel time.

Bus System Alerts

Bus Route	Current Status
#1	Temporary Reroute (Revised 9/4/16)
#1	Temporary Bus Stop Relocation
#2	Temporary Bus Stop Relocation
#3	Temporary Bus Stop Relocation
#4	Temporary Reroute
#4	Temporary Bus Stop Relocation
#4	Temporary Bus Stop Relocation
#4	Temporary Bus Stop Relocation
#6	Temporary Reroute
#7	Temporary Reroute
#7	Temporary Bus Stop Change
#7	Temporary Bus Stop Relocations
#12	Temporary Bus Stop Relocation
#18	Temporary Reroute
#24	Temporary Bus Stop Relocation
#28	Temporary Reroute (Revised 9/4/16)
#31	Temporary Bus Stop Rellocation
#36	Temporary Reroute
#37	Temporary Bus Stop Change
#39	▲ #39 Pershing Temporary Reroute at Pershing/LaSalle
#50	Bus Stop Relocation
#50	Temporary Bus Stop Relocation

Source: http://www.transitchicago.com/travel_information/systemalerts.aspx?source_quicklinks=1

Riders can sign up to receive CTA updates via email or text message. These updates can include weekly planned service change updates, unplanned events affecting service, and station accessibility updates, according to user preference. CTA also reports reroutes and other changes on its Twitter feed.

2.2 Pace Bus

Ridership

As one of the largest public bus service providers in the US, Pace operates 209 fully accessible fixed bus routes within the six-county area of Cook, DuPage, Kane, Lake, McHenry, and Will—a territory which covers 3,446 square miles and includes 284 municipalities. In addition to traditional fixed-route bus service, Pace provides paratransit service via 442 vehicles as well as vanpool service via 784 vehicles. Ridership stood at 33.1 million in 2015, with Pace ADA ridership at 4.2 million that same year. Pace ADA ridership has been growing steadily since it was inaugurated, while Pace suburban service dropped dramatically in 2009 and has not fully recovered its pre-2009 ridership levels.

The paratransit services are a major distinguishing factor between Pace and the CTA, which only provides fixed-route services. Pace is the only provider of all demand-response service, which includes dial-a-ride, call-n-ride, accessible fixed-route (for elderly and disabilities), and ADA paratransit, filling the needs of Chicago and other CTA-served municipalities who are required by the FTA to provide such services. In this way, the RTA fulfills the metropolitan area's paratransit needs via its suburban bus division, Pace.

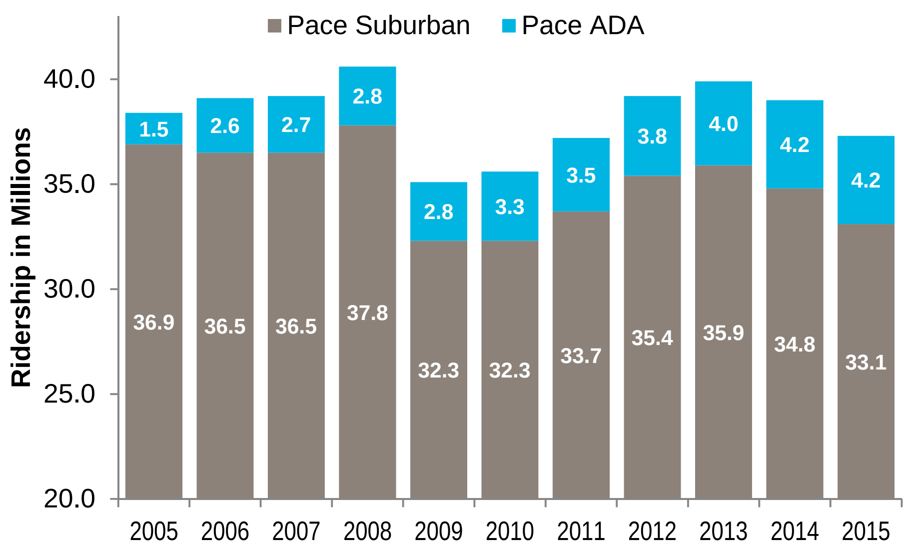
Table 2-3 and Figure 2-3 display annual Pace ridership including both Pace fixed-route and ADA service.

Table 2-3: Annual Pace System Ridership (in millions)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Pace Suburban	36.9	36.5	36.5	37.8	32.3	32.3	33.7	35.4	35.9	34.8	33.1
Pace ADA	1.5	2.6	2.7	2.8	2.8	3.3	3.5	3.8	4.0	4.2	4.2
System	**38.4**	**39.1**	**39.2**	**40.6**	**35.1**	**35.6**	**37.2**	**39.2**	**39.9**	**39.0**	**37.3**

Source: Pace 2015 Annual Financial Report

Figure 2-3: Annual Pace System Ridership (2005-2015)



Source: Pace 2015 Annual Financial Report

Alignments

Pace fixed routes fall into several main categories: CTA Connector, Suburban Links, Intra-Community, and Commuter Links. Pace also operates other non-fixed or non-regular services, including Special Event routes. In terms of average daily ridership, the CTA Connector routes carry by far the greatest proportion of riders—71% in 2015. This is followed by Suburban Links with 14%, Intra-Community with 11%, and Commuter Links with 4%.

Table 2-4 shows the ten routes with the highest average daily ridership in 2015. Of these 10 routes, nine are designated as CTA Connectors, while the tenth, the 159th St Route, is a Suburban Links bus. They are located primarily within three Pace divisions: South, West, and Northwest, with one in the Southwest division.

Table 2-4: Top Pace Routes by Average Daily Ridership (2015)

Route #	Name	Route Type	Average Daily Riders
352	Halsted	CTA Connector	5,612
381	95th Street	CTA Connector	3,899
290	Touhy Avenue	CTA Connector	3,341
270	Milwaukee Avenue	CTA Connector	3,029
307	Harlem	CTA Connector	2,879
250	Dempster Street	CTA Connector	2,617
349	South Western	CTA Connector	2,558
322	Cermak Road - 22nd Street	CTA Connector	2,413
318	West North Avenue	CTA Connector	2,364
364	159th Street	Suburban Links	2,345

Source: Pace data

Many Pace routes operate within the framework of a "pulse" network; in this scenario, buses pick up passengers along the fixed routes and converge at a common location. The schedules of such routes are planned so that buses arrive at or around the same time, and similarly depart around the same time. This type of service scheduling provides passengers with increased opportunities to transfer to other services which can then transport them to their final destination. Pace buses pulse at several locations throughout the metropolitan area, such as the Schaumburg and Aurora transit centers in DuPage County, Elgin transit center in Kane County, and the Chicago Heights Transfer Center and the Harvey Transportation Center in Cook County.[4] Pace owns and operates 12 park & ride lots, some of which are located at transit centers, and also provides service to 17 park & ride lots that are not owned by Pace.

Other Pace alignments primarily serve the purpose of circulating passengers in loop-like routes that access various nodes, activity centers, and prominent land uses within communities. These may include shopping centers, schools, municipal centers, hospitals, sporting and entertainment venues, among others. Pace also operates several employment shuttle services, subsidized by several major employers.

Finally, Pace has been implementing a number of strategies to provide better and faster service to riders. For example, in the "Bus On Shoulder" service, certain bus routes can utilize the shoulder of the I-55 / Stevenson Expressway—an allowance that was coordinated with the Illinois Legislature, IDOT, the Illinois State Police, and RTA. By allowing the bus to drive on a modified shoulder in order to by-pass slow traffic, this pilot program has proved to be an affordable way to keep buses on schedule and reduce customers' travel time. Pace is expanding this program (implemented in 2011) to other services that currently or could potentially provide service along area expressways. Pace also offers "Pace Express" service, as well as "Express Service to Popular Destinations" to speed up travelers' journeys. In 2018, Pace will launch its new rapid transit network, Pulse, to provide riders with fast, frequent, and reliable bus service along heavily traveled corridors. The first Pulse line is along Milwaukee Avenue and will include limited-

[4] Pace Suburban Bus. www.pacebus.com (2014)

stop express service, Wi-Fi enabled vehicles, weather-protected stations, and real-time bus arrival signage.

Bus Technologies

Pace has a fleet of over 440 40 foot buses, as well as over 300 shorter buses.[5] One-hundred percent of Pace vehicles are ADA-accessible. In total, Pace operates about 700 fixed-route vehicles and 1,800 smaller transit vehicles through its paratransit and vanpool programs.[6] Buses are also equipped with automated vehicle locator devices, boarding / alighting sensor counts, and onboard computers to record and transmit this data wirelessly.

Communications

On the Pace website, visitors can access the Passenger Notices page with information on temporary detours and permanent schedule adjustments to Pace routes (see Figure 2-4). Customers can sign up for email notifications on the website, specifying the type of information they'd like to receive, including service updates connected to particular Pace routes. Pace also communicates with passengers using customer alerts posted on its Twitter feed and Facebook page.

Figure 2-4: Sample Pace Website Passenger Notices

Route	Notice Type	End Date
223 Elk Grove - Rosemont CTA Station	Bus Stop Restriction	12/31/2017
226 Oakton Street	Bus Stop Restriction	12/31/2017
234 Wheeling - Des Plaines	Detour Alert	12/31/2017
332 River Road - York Road	Detour Alert	12/31/2017
348 Harvey - Riverdale - Blue Island	Detour Update	12/31/2017
352 Halsted	Temporary Bus Stop Relocation	8/9/2017
359 Robbins / South Kedzie Avenue	Detour Notice	3/1/2017
381 95th Street	Temporary Bus Stop Relocation	8/9/2017
384 Narragansett - Ridgeland	Service Change	3/30/2017
395 95th/Dan Ryan CTA Station - UPS Hodgkins	Temporary Bus Stop Relocation	8/9/2017
422 Linden CTA/Glenview/Northbrook Court	Service Clarification	3/1/2017
465 Belmont Station-Esplanade Shuttle Bug	Public Hearing	2/28/2017
504 South Joliet	Detour	12/31/2017
533 Northeast Aurora	Routing Change	3/26/2017
540 Farnsworth Avenue	Routing Change	3/26/2017
547 Wing Park	Detour Notice	12/31/2017
562 Gurnee via Sunset	Detour Update	3/5/2017
565 Grand Avenue	Pases Publicados Sólo	3/27/2017
565 Grand Avenue	Posted Stops Only	3/27/2017
569 Lewis	Detour Extended	12/31/2017
574 CLC - Hawthorn Mall	Service Change	3/27/2017
600 Rosemont - Schaumburg Express	Detour Notice	12/13/2017
606 Rosemont - Schaumburg Limited	Mejoramientos Al Horario	4/1/2017
606 Rosemont - Schaumburg Limited	Detour Notice	12/13/2017
606 Rosemont - Schaumburg Limited	Bus Stop Restrictions	12/31/2017
606 Rosemont - Schaumburg Limited	Weekend Schedule Improvements	4/1/2017

Source: https://www.pacebus.com/sub/schedules/route_notices.asp

[5] Regional Transportation Authority Mapping and Statistics (RTAMS). (2017).
[6] Regional Transportation Authority Mapping and Statistics (RTAMS). (2014).

3. Climate Change and Resilience Planning

3.1 Chicago Climate

Historically, the City of Chicago receives 34 inches of precipitation annually,[7] and localized small-scale flooding is frequent. Chicago was built on flat marshland, which makes it difficult for stormwater and runoff to drain from the land. For this reason, Chicago's history has no shortage of flood events—NOAA reports 29 significant flood events between 1950 and 2005 in Cook County. In 1954, a foot of rain fell during one week, resulting in $25 million in damage. In 1987, 9 inches fell in a day, affecting 15,000 buildings and leaving area roads and expressways under water. A rainy month and one large storm in July 1996 caused $45 million in direct damages. [8] Heavy downpours in 2002 shut down interstates and underpasses of Lake Shore Drive. The remnants of hurricane Ike in 2008 caused flash flooding in many waterways; many streets were closed and thousands were evacuated, not to mention the flooding of the Blue Line near the Des Plaines River and suspension of service between Rosemont and O'Hare. In 2010, interstates and hundreds of streets were flooded as a 3-day storm covered the area; FEMA committed over $300 million in assistance in Cook County alone for this event. A 2011 storm event left roadways and basements flooded, water more than 10 feet deep on I-57, and rail tracks on CTA's Red, Blue, and Pink lines flooded.[9] In April 2013, Naperville, Elmhurst, and Aurora saw over 7 inches of rain in 2 days, and river crests along the Des Plaines, Vermilion, and North Branch of the Chicago River (among others) broke records.[10] The list goes on and on.

To handle the precipitation, the City of Chicago and many suburban communities / stormwater management districts have combined sewer systems that collect both wastewater and stormwater and are generally designed to accommodate a 5-year storm event. This water is then conveyed to interceptor sewers and on to wastewater treatment plants. After treatment, the water is discharged into local waterways. During storms that exceed the sewer system's capacity, there is often localized flooding and combined sewer overflow that is discharged untreated into area waterways. Some communities have separate sewer systems for wastewater and stormwater, which may still be subject to overflow depending upon capacity and age.

3.2 Understanding Why, Where, and When Flooding Happens

Flooding is a regular, natural process that is nevertheless variable. Spring runoff is cyclical and thus reasonably predictable, while large rainwater events like hurricanes can cause unpredictable flooding. The floodplains adjacent to streams are typically defined as either hydrologic (directly adjacent to the stream, this land between the riverbanks is typically inundated two years out of every three) or topographic (the land elevation reached by a flood peak of a given frequency, such as a 100-year flood; unlike the hydrologic floodplain, it is not immediately visible).[11] The floodplain functions as a temporary storage space for floodwaters. In our analysis, we highlight as risk areas the FEMA 100- and 500-year topographic floodplain (also known as the 1% or 0.2% annual flood area) based on the expectation that these areas are more likely to experience flood events that would impact bus transit operations

The frequency of floods along streams or rivers is determined by looking at the historical data of maximum and minimum flow values for the waterway to gauge recurrence intervals at which the waterway's flow will be exceeded. This is then correlated with results from hydrologic and hydraulic modeling as well as survey elevation data to set the Flood Insurance Rate Map (FIRM), which identifies areas of different risk type. These maps are periodically updated; for example, the current City of Chicago FIRM is from 2008 and the first was produced in 1980. Local agencies, such as the MWRD and county stormwater departments or commissions, also create floodplain maps of different recurrence levels. The

[7] http://www.usclimatedata.com/climate/chicago/illinois/united-states/usil0225
[8] National Weather Service, NOAA. http://www.weather.gov/lot/top20events_1900to1999.
[9] National Weather Service, NOAA. http://www.weather.gov/lot/science
[10] National Weather Service, NOAA. http://www.weather.gov/lot/2013Apr1718
[11] USDA, FISRWG, *Stream Corridor Restoration: Principles, Processes, and Practices*. (2001).

major floodplain locations in the Chicago area are chiefly along the Des Plaines River, DuPage River, Chicago River (North Branch watershed) and Salt Creek Watershed.

Beyond the issue of riverine flooding, hot-spot flooding can occur in places where the stormwater infrastructure no longer has the capacity to handle the amount of runoff generated. As shown in Figure 3-1, the amount of impervious surface in an area significantly impacts the amount of water runoff generated. Urban areas like the Chicago region have more impervious surface, which can more than double the amount of runoff in comparison with less urbanized locations. This increased runoff then accumulates in low-lying areas such as viaducts, blocking buses and other vehicles from traversing the location. Chicago alone has over 1,500 viaducts, of which nearly two hundred have been identified as "troubled" by frequent flooding in prior CTA analysis (see Figure 3-2). (Typically, stormwater systems are usually designed to have the capacity for rain events that happen once every five to ten years. System planning needs to take cost versus the likelihood and frequency of flood risk into account to develop a reasonable cost-benefit assessment to inform decision making; due to drastically higher costs, systems are not often designed for 25-year events, and infrequently for 50-year, 100-year or 500-year, events, which would entail even higher costs.) However, as current systems age and major 25-year events occur more frequently, the stormwater system is more frequently overwhelmed and flooding occurs.

Figure 3-1: The effects of urbanization on evapotranspiration, infiltration, and runoff

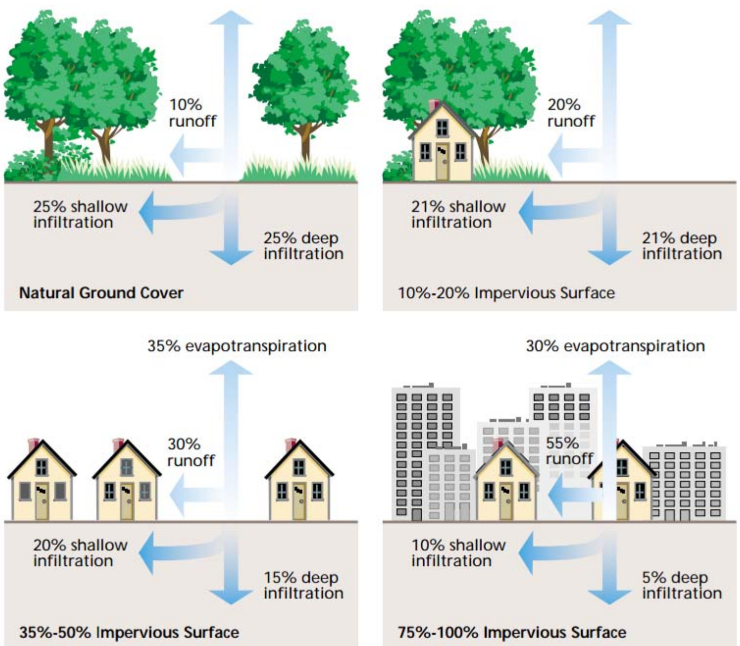


Image Source: USDA, FISRWG, *Stream Corridor Restoration: Principles, Processes, and Practices*. (2001).

According to the Chicago Office of Emergency Management's *All Hazard Mitigation Plan*, the probability of flood hazards is moderately high, the impact is moderately significant, and the risk assessment receives a rating verging on severe—the higher rating relative to other natural hazards due to the high frequency of occurrence.[12] The OEMC *All Hazard Mitigation Plan* recommends increasing the open space and natural features in high flood hazard areas in coordination with the MWRD, as well as completing the TARP system, in order to mitigate flood risk.

[12] The risk assessment framework is that risk rating is the probability multiplied by impact. A high probability is a hazard that would happen more than 50 times in 50 years, and a significant impact would have parameters such as 40% of population affected, direct damages over $100 million and/or economic damages over $1 billion, disruption of critical infrastructure for one week and of essential services for over two weeks, or some combination thereof. Ratings are given on a graphical scale which does not greater precision here, but flood hazards are midway between moderate and high probability, and closer to significant impact than moderate. They are based on historical data, and thus do not include the potential impacts of climate change.

Figure 3-2: Chicago Viaducts

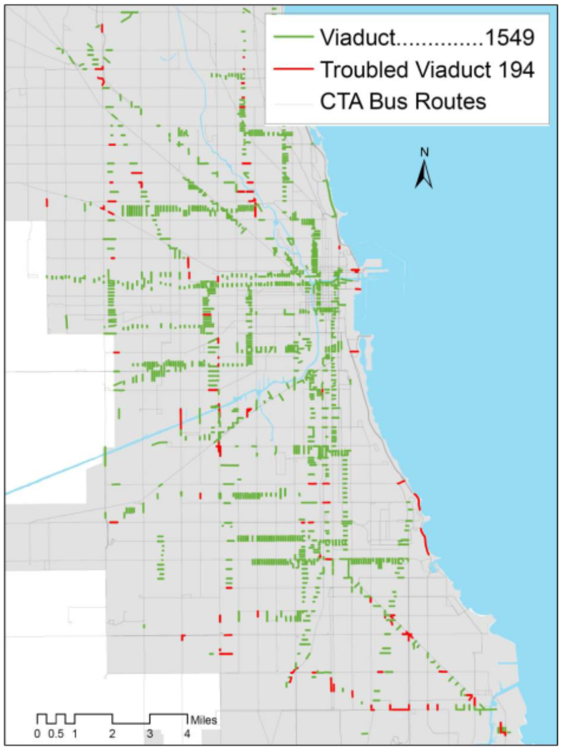


Image Source: CTA CCAP Presentation by Karl Peet, Strategic Planning and Policy Department (2012).

3.3 Chicago Climate Studies

3.3.1 Chicago Climate Action Plan

The Chicago Climate Action Plan looks to both the past and the future before laying out its action steps for a more resilient metropolis.

According to historical records, the frequency of heavy storms has doubled since the 1970s, with more of the precipitation falling as rain rather than snow. There is less ice coverage on Lake Michigan and area lakes and less snowpack in the winter. Temperatures have risen by 2.6°F since 1980—especially winters, which are on average are almost 4°F warmer.

The projections used in the Chicago Climate Action Plan come from three different global climate models (GDFL, HadCM3, and PCM), which are then downscaled to the Chicago region using long-term historical records and advanced statistical techniques. These models are run using two different emissions scenarios—low and high—to reflect different potential futures based on the climate change mitigation policies espoused and undertaken in the coming years. The resulting six simulations generate climate projections through 2100.

These temperature and precipitation rates are then input into hydrological models to simulate how much of the water will be absorbed into the earth, evaporated into the sky, or runoff into waterways (e.g., evapotranspiration, runoff generation, soil infiltration and drainage, snowpack accumulation, snowmelt). These results, in turn, are then routed through stream networks using a hydraulic model to determine where that water will go and where it will accumulate.

According to this analysis by climate science experts and water resource engineers, the Chicago region can expect:

- Average annual temperatures 3-4°F (low emissions) or 7-8°F (high emissions) warmer, and up to 10°F warmer during the summers
- Summers that feel similar to current Mobile, AL, with heat indexes averaging 105°F (high emissions scenario); under low emissions, more like Atlanta, GA, with heat indexes around 94°F
- More heatwaves, higher heat indexes due to increased humidity, fewer cold spells, decreased air quality, more frequent vector- and water-borne diseases
- 10% more winter and spring precipitation by 2050, and 20-30% more by 2100 (both high and low emissions)
- More heavy rainfall events of 2.5 inches or more in 24-hour period—i.e., those associated with flooding
- Increased evapotranspiration, increased runoff, and an increase in peak flow in Illinois River

A comparison with previous climate change impact projects conducted for the Midwest and Great Lakes region from 2000 and 2003 shows that this analysis confirms these earlier projections.

These types of impacts—higher temperatures, greater precipitation in heavier rain events—will have a major impact on Chicago's infrastructure. Emissions levels will be significant here: under the high-emissions scenario, the projected costs of adaptation for government are nearly four times higher than the low-emissions scenario. Aside from the direct costs of increased maintenance and replacement of hard infrastructure like roadways, bridges, fleet vehicles, etc., there will be less tangible costs such public health problems arising from poor air quality and temperature extremes, more frequent disease outbreaks, crop damage from intense storm events or summer droughts, among other consequences of climate change.

The Chicago Climate Change Action Plan looks at the costs of adapting to more sustainable practices that would reduce emissions and thus climate impacts, and finds that sustainable practices (such as those that would result in resource efficiencies) could generate $400 million to $1.2 billion in savings each year by 2020. It also quantifies the increase in green jobs in order to achieve the plan's goals, as well as the jobs that would be created by achieving the goals.

3.3.1.1 Chicago Climate Action Plan Strategies

Five strategies were identified for the Action Plan: energy-efficient buildings, renewable energy sources, improved transportation options, reduce waste and pollution, and adaptation. To address the issue of adaptation, CTA identified the need to better understand the projected change in frequency and intensity of storm events in current CTA flood-vulnerable locations, and what assets and locations are projected to become more vulnerable as climate change impacts make themselves felt. On the point of ridership, they also wish to know how CTA customers can be better protected from extreme precipitation currently, and what long-term measures need to be taken in order to ensure that ridership does not erode as temperatures and storms escalate.[13]

3.3.2 Green Transit Plan

The material originally presented in this section has been updated in **Appendix C**.

3.3.3 Metropolitan Planning Council

The material originally presented in this section has been updated in **Appendix C**.

[13] CTA CCAP Presentation by Karl Peet, Strategic Planning and Policy Department (2012).

3.3.4 Illinois State Water Survey

An Illinois State Water Survey report, “Communicating the Impacts of Potential Future Climate Change on the Expected Frequency of Extreme Rainfall Events in Cook County, Illinois” sought to design a framework to translate future climate scenarios into something that local-level engineers and planners can use to quantify the impact of climate change. The output can then be used to inform and plan adaptive strategies for floodplain management. The research found that two of the three data sources (WCRP and ORNL) commonly used for climate change modeling considerably underestimated rainwater extremes in Cook County.

3.3.5 Center for Neighborhood Technology

In 2014, the Center for Neighborhood Technology examined the economic costs of urban flooding in Cook County. This report, “The Prevalence and Cost of Urban Flooding,” found that between 2007 and 2011, 181,000 insurance claims added up to $773 million in damages, and there was no correlation between damage payouts and floodplains, either in number or value of claims. One pattern that was noticeable was that places that had flooded once were likely to flood again—and soon. Of the 115 survey respondents, 70% said they had been flooded three times or more in the last five years, and 20% had been flooded ten times or more.

3.4 Climate Change National Best Practices

3.4.1 Climate Change Projections Methodology Overview

The material originally presented in this section has been updated in **Appendix B**.

3.4.2 FTA Climate Change and Adaptation Strategies

The material originally presented in this section has been updated in **Appendix C**.

4. Analyzing Flooding Impacts in Chicago Area

4.1 Data

A robust set of quantitative data was collected for the project, much of it loaded into the project GIS database. Data is described and presented in tabular format in this document, and illustrated on a series of maps included as Appendix A.1 due to the file size of large-layout maps.

4.1.1 Contextual Data

Geospatial data on the location and characteristics of FEMA flood risk zones were gathered to overlay with bus transit route and stop locations. These were supplemented with locally-updated maps from Cook County (MWRD), DuPage County and Will County. See Appendix A.1 to this document for a representation of where these flood zones intersect bus routes in the RTA service area.

The Chicago Department of Transportation (CDOT) provided geospatial data on the location of viaducts. Viaduct flooding is a major issue for transit operations, as reported by CTA and OEMC. See Appendix A.1 for the location of viaducts in relation to bus routes. Cook County Department of Homeland Security and Emergency Management (CCDHSEM) also provided locations of road closures on County roads from the April 2013 flood event.

Socio-economic geospatial data (including population, employment, and median household income) were gathered for the RTA service area from the US Census, CMAP and RTAMS.

4.1.2 CTA Data

Shapefiles with CTA bus routes and stops were used for mapping and analysis purposes.

CTA provided data on average daily and total annual ridership by bus route, as well as boardings by stop. Data on revenue mile and hours by route as well as existing daily estimated costs and revenue by route were provided that will be included in Task 4 analysis.

In terms of data on historic flooding incidents, data from CTA's CleverCAD (a computer-aided dispatch technology, in place after 2013) system and prior manual notation (2010-2012) provides information of the date, time, location, and type of event, along with additional notes from the operator, the route number, and the disposition of the event (e.g., whether and how the bus was able to reroute in the event of street or viaduct flooding). These data were plotted in the project team GIS and their density calculated to generate flooding incident hot spots.

4.1.3 Pace Data

GTFS data on Pace bus routes and stops were used for mapping and analysis purposes. Representatives from Pace operating divisions provided information on the location of recurrent flooding areas and typical reroutes, which were used to generate a shapefile with point data of flooding noted by Pace. Ridership information by route from the second quarter of 2016 for use in identifying and sorting bus routes for analysis.

The dataset also included information on revenue and costs for use in Task 4 analysis.

4.2 Stakeholder Interviews

A series of stakeholder interviews were conducted with agencies or groups responsible for planning for stormwater management and/or transportation infrastructure for the purpose of identifying interesting data sources and providing insight into flood-prone areas and mitigation tactics in place or planned.

Organization	Contact	Status
Chicago Department of Water Management (CDM)	Sid Osakada, Coordinating Engineer Anupam Verma, PE, Managing Engineer - Water Management	Ongoing
Chicago Office of Emergency Management and Communications (OEMC)	Rich Guidice, Managing Director of Operations Chris Pettineo, Manager of Emergency Management Services Peter Raber, Senior Emergency Management Coordinator	Complete, February 21
Cook County Department of Transportation and Highways (CCDOTH)	Maria Choca-Urban, Director of Strategic Planning and Policy	Complete, February 9
Cook County Department of Homeland Security and Emergency Management (CCDHSEM)	Dana Curtiss, Operations Information Support Manager, Office of the President	Complete, February 22
DuPage County Stormwater Management	Christine Klepp Chris Vonnahme	Scheduled, March 1
DuPage County Department of Transportation (DCDOT)	John Loper, Director of Transportation Planning Sidney Kenyon, Senior Transportation Planner	Scheduled, March 1
Metropolitan Water Reclamation District (MWRD)	Joe Kratzer, PE, CFM, Principal Civil Engineer, Engineering Dept/Stormwater Management Greg Koch, PE, Principal Civil Engineer, Engineering Dept/Stormwater Management	Complete, February 23
Will County Division of Transportation (WCDOT)	Christina Kupkowski, PE, Phase I Project Manager Raymond A. Semplinski, Maintenance Administrator	Complete, February Complete, February 17

Key findings from these interviews include:

- Documentation of actual, historical flood events is inconsistent within agencies and across the RTA region. Technology in many agencies for recording incidents is evolving, from paper-based notation and decentralized storage, to GIS records, to sophisticated operations systems that provide access to and collect data from a wide range of agency stakeholders. Understanding where flood incidents are located is a combination of data analysis and talking to knowledgeable parties.
- Urban flooding is not generally correlated to location relative to floodplains and floodways. Urban flooding is more often associated with infrastructure failures to accommodate situations of high water levels and rapid precipitation or water movement. Low-lying areas such as viaducts are particularly problematic.
- Many stormwater management departments have projects underway across the region that will serve to either reduce flood risk area or increase stormwater capacity and improved drainage. Analysis that the project performs should be checked with these local experts to ensure that conclusions the project reaches are still relevant given the progress of their project implementation (i.e., what we perceive as a potential risk area may already be in repair!). Some of these projects are locally/municipally-managed and funded, and some are conducted in coordination with county and state stormwater and transportation agencies.
- FEMA-compliant All-Hazard Mitigation Plans or Natural Hazard Mitigation Plans may also generally contain good sources of information on flood-prone areas and community-specific assessments of risk and priority.
- Many local and regional organizations, with both jurisdictional responsibility as well as advocacy missions, are preparing wide-area stormwater management programs and plans. It will be important to the project team throughout this study, not just during Task 2, to keep abreast of activities undertaken by many groups to take advantage of their knowledge and analysis, and avoid duplication of work efforts.

5. Risk Assessment of System Routes

5.1 Scenarios

In review of the data described in the previous section, it was not immediately obvious which CTA and Pace routes filtered to the top of the list for more detailed analysis in Task 3 and Task 4. In the interest of engaging input from the project's steering committee composed of representatives from RTA, CTA and Pace, the project team prepared five scenarios alternative selection scenarios to identify potentially vulnerable bus routes. These scenarios were applied to both the Pace and CTA bus networks and analyzed to the extent of availability of data. Their criteria are summarized below. Detailed data related to primary filtering and sorting criteria, as well as contextual socio-economic factors about the selected routes, are presented in tables in Section 5.2 and in Appendix A.1 maps.

Scenario A
Routes with reported flooding *and* located in flood zones, sorted by ridership

Pace:

- Only routes with flooding noted by Pace
- Routes then sorted by number of flood zones they traverse, and then by average monthly weekday ridership

CTA:

- Only routes with flooding incidents recorded by CTA
- Routes then sorted by number of recorded flood incidents they intersect, number of flood zones they traverse, and then by average daily weekday ridership

Scenario B
Routes with reported flooding, sorted by ridership

Pace:

- Only routes with flooding noted by Pace
- Routes then sorted by average monthly weekday ridership

CTA:

- Only routes with flooding incidents recorded by CTA
- Routes then sorted by number of recorded flood incidents they intersect, and then by average daily weekday ridership

Scenario C
Routes in flood zones, sorted by ridership

Pace:

- Only routes that traverse flood zones
- Routes then sorted by number of flood zones they traverse, then by average monthly weekday ridership

CTA:

- Only routes that traverse flood zones
- Routes then sorted by number of flood zones they traverse, then by average daily weekday ridership

Scenario D
Routes with reported flooding *or* located in flood zones, sorted by ridership

Pace:

- Only routes with flooding noted by Pace *or* that traverse flood zones
- Routes then sorted by average monthly weekday ridership

CTA:

- Only routes with flooding incidents recorded by CTA *or* that traverse flood zones
- Routes then sorted by average daily weekday ridership

Scenario E
Routes with reported flooding, sorted by system connectivity and ridership

Pace:

- Only routes with flooding noted by Pace
- Routes then sorted by number the number of connections they have with CTA rail or Metra rail stations, then by average monthly weekday ridership

CTA:

- Only routes with flooding incidents recorded by CTA
- Routes then sorted by number the number of connections they have with CTA rail or Metra rail stations, then by average daily weekday ridership

5.2 Top CTA and Pace Routes Affected by Flooding

The CTA and Pace bus routes were analyzed according to the criteria summarized above and ranked according to their performance within each scenario. In addition to the primary sort and filter criteria of flood risk, ridership and connectivity to the transit network, demographic information about the routes is also presented to provide more color about the communities that each route serves, in terms of population (numbers and density), employment (numbers and density) and median household income. The results are all summarized in the tables below, and illustrated on a variety of maps as noted in Appendix A.1.

For the CTA bus routes, all routes that appeared in scenario rankings are included Table 5-1. Fifty-six of the 130 bus routes appeared as priorities according to Scenarios A-E. The value in the Scenario columns indicates its level of priority, with “1” as highest priority. There are a varied numbers of routes within in each ranking (usually around 20-25) in order to ensure that the thresholds were not arbitrary—they were created at natural break points in the data. This same data is included in Table 5-2, but it is sorted by the count of scenarios in which the given route is considered a priority. Four CTA routes (3, 8, 9, 20) appeared in all five scenarios, three CTA routes (4, 49, J14) appeared in four of five scenarios, etc. Note that the Number of Scenarios Featured does not take into consideration where these routes appeared in terms of priority within each scenario (e.g., 1 as top priority, or 25 as a much lower priority), which is a factor that must be considered.

The same process was conducted for the Pace bus network, and the results are summarized in Table 5-3 and Table 5-4. Of the 212 Pace bus routes, 54 appeared as priorities according to Scenarios A-E. One Pace route (208) appeared in all five scenarios, and 9 Pace routes (234, 303, 318, 322, 330, 364, 381, 386, 626) appeared in four scenarios. As with the CTA routes, the Number of Scenarios Featured does not take into consideration where these routes appeared in terms of priority within each scenario (e.g., 1 as top priority, or 25 as a much lower priority).

Bus routes that were prioritized were then analyzed according to the socioeconomic characteristics of the populations they traverse. Quarter-mile buffers were generated and intersected with CMAP 2014 data on population and employment counts per subzone in 2010 and projections for 2040. Proportional representations of population and employment counts were created for subzones that lay only partially within the ¼-mile radius. These same buffers were then intersected with ACS 2014 median household income data by tract. Using the proportional area of each tract that is located within the bus corridor, a weighted average median household income was created for each of the bus routes. The results of these analyses, along with the average daily ridership of the route, are included in Table 5-5, Table 5-6, Table 5-7, Table 5-8, and Table 5-9 for CTA, and Table 5-10, Table 5-11, Table 5-12, Table 5-13, and Table 5-14 for Pace.

Table 5-1: CTA Routes with Scenario Rankings, Sorted by Route Number

Route	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Number of Scenarios Featured
3	11	5	21	9	7	**5**
4	6	4		7	13	**4**
5	7	14				**2**
7					5	**1**
8	2	3	20	6	17	**5**
9	9	1	16	1	22	**5**
9X	10	12			21	**3**
12				16		**1**
15	12	11				**2**
19					16	**1**
20	20	20	23	12	14	**5**
21					19	**1**
22			22	11		**2**
24					1	**1**
26			3		15	**2**
28					9	**1**
29	13	6			3	**3**
36				19		**1**
49	1	2	18	4		**4**
49X	3	13				**2**
50	8	9			23	**3**
52	4	7				**2**
53		18	5	8		**3**
54	17					**1**
56					4	**1**
60					10	**1**
62					2	**1**
63			25	14		**2**
65	16					**1**
66		16	17	3		**3**
72	18			15		**2**
73	15					**1**
74	19					**1**
77		17	19	5		**3**
79		15		2		**2**
81					20	**1**
82		19	6	10		**3**
87				20		**1**
92			1			**1**
93			10			**1**
94	5	10				**2**
98X			4			**1**
126					6	**1**
132					12	**1**
134			12			**1**
135			11			**1**
136			14			**1**
143			15			**1**
146			7	17		**2**
147			8	18		**2**
148			13			**1**
151			24	13		**2**
157					11	**1**
169			2			**1**
192					18	**1**
J14	14	8	9		8	**4**

Table 5-2: CTA Routes with Scenario Rankings, Sorted by Count of Scenarios

Route	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Number of Scenarios Featured
3	11	5	21	9	7	**5**
8	2	3	20	6	17	**5**
9	9	1	16	1	22	**5**
20	20	20	23	12	14	**5**
4	6	4		7	13	**4**
49	1	2	18	4		**4**
J14	14	8	9		8	**4**
9X	10	12			21	**3**
29	13	6			3	**3**
50	8	9			23	**3**
53		18	5	8		**3**
66		16	17	3		**3**
77		17	19	5		**3**
82		19	6	10		**3**
5	7	14				**2**
15	12	11				**2**
22			22	11		**2**
26			3		15	**2**
49X	3	13				**2**
52	4	7				**2**
63			25	14		**2**
72	18			15		**2**
79		15		2		**2**
94	5	10				**2**
146			7	17		**2**
147			8	18		**2**
151			24	13		**2**
7					5	**1**
12				16		**1**
19					16	**1**
21					19	**1**
24					1	**1**
28					9	**1**
36				19		**1**
54	17					**1**
56					4	**1**
60					10	**1**
62					2	**1**
65	16					**1**
73	15					**1**
74	19					**1**
81					20	**1**
87				20		**1**
92			1			**1**
93			10			**1**
98X			4			**1**
126					6	**1**
132					12	**1**
134			12			**1**
135			11			**1**
136			14			**1**
143			15			**1**
148			13			**1**
157					11	**1**
169			2			**1**
192					18	**1**

Table 5-3: Pace Routes with Scenario Rankings, Sorted by Route Number

Route	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Scenario E*	Number of Scenarios Featured
208	6	5	16	11	6	**5**
209	20	22			9	**3**
210	27	23			22	**3**
215				19		**1**
221	16	12			15	**3**
223				15		**1**
226	17	14			7	**3**
230	28	20			21	**3**
234	5	24	13		13	**4**
250			15	5		**2**
272	4	16	10			**3**
290				3		**1**
301				10		**1**
302	26	19			2	**3**
303	1	9	3		3	**4**
307				4		**1**
309	19	11			1	**3**
311				17		**1**
318	12	2		7	5	**4**
319	9	17			8	**3**
322	24	4		9	20	**4**
326	8	26			23	**3**
330	3	8	9		12	**4**
331	14	7			11	**3**
332	11	15			16	**3**
349				6		**1**
350				14		**1**
352				1		**1**
353				16		**1**
354			12			**1**
356	10	18			17	**3**
359				18		**1**
364	13	3		8	19	**4**
379				12		**1**
381	23	1		2	10	**4**
386	7	6		20	14	**4**
533			14			**1**
565	15	10				**2**
570			2			**1**
572	25	13				**2**
593			19			**1**
606				13		**1**
619	21	27				**2**
620	22	28			24	**3**
626	2	21	8		18	**4**
755			18			**1**
757	18	25			4	**3**
806			6			**1**
809			7			**1**
850			11			**1**
855			17			**1**
877			4			**1**
888			5			**1**
895			1			**1**

Table 5-4: Pace Routes with Scenario Rankings, Sorted by Count of Scenarios

Route	*Scenario A*	*Scenario B*	*Scenario C*	*Scenario D*	*Scenario E*	Number of Scenarios Featured
208	6	5	16	11	6	**5**
234	5	24	13		13	**4**
303	1	9	3		3	**4**
318	12	2		7	5	**4**
322	24	4		9	20	**4**
330	3	8	9		12	**4**
364	13	3		8	19	**4**
381	23	1		2	10	**4**
386	7	6		20	14	**4**
626	2	21	8		18	**4**
209	20	22			9	**3**
210	27	23			22	**3**
221	16	12			15	**3**
226	17	14			7	**3**
230	28	20			21	**3**
272	4	16	10			**3**
302	26	19			2	**3**
309	19	11			1	**3**
319	9	17			8	**3**
326	8	26			23	**3**
331	14	7			11	**3**
332	11	15			16	**3**
356	10	18			17	**3**
620	22	28			24	**3**
757	18	25			4	**3**
250			15	5		**2**
565	15	10				**2**
572	25	13				**2**
619	21	27				**2**
215				19		**1**
223				15		**1**
290				3		**1**
301				10		**1**
307				4		**1**
311				17		**1**
349				6		**1**
350				14		**1**
352				1		**1**
353				16		**1**
354			12			**1**
359				18		**1**
379				12		**1**
533			14			**1**
570			2			**1**
593			19			**1**
606				13		**1**
755			18			**1**
806			6			**1**
809			7			**1**
850			11			**1**
855			17			**1**
877			4			**1**
888			5			**1**
895			1			**1**

Table 5-5: CTA Scenario A Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Weekday Ridership	Scenario Ranking
049	128,305	31,829	128,305	34,858	15,797	3,919	15,797	4,292	$50,683	23,417	**1**
008	137,491	62,672	137,491	77,764	19,160	8,734	19,160	10,837	$61,899	22,093	**2**
049X	128,305	31,829	128,305	34,858	15,797	3,919	15,797	4,292	$81,155	3,459	**3**
052	113,927	19,796	113,927	22,065	17,447	3,032	17,447	3,379	$39,015	12,231	**4**
094	101,604	19,057	101,604	21,109	15,820	2,967	15,820	3,287	$31,484	9,571	**5**
004	120,386	185,397	120,386	213,054	15,277	23,526	15,277	27,036	$44,808	21,143	**6**
005	75,149	8,874	75,149	11,631	12,580	1,486	12,580	1,947	$34,061	497	**7**
050	106,161	46,998	106,161	53,346	17,782	7,872	17,782	8,936	$64,658	9,860	**8**
009	143,170	44,847	143,170	52,609	15,655	4,904	15,655	5,753	$53,590	27,499	**9**
009X	151,573	46,773	151,573	54,579	17,135	5,287	17,135	6,170	$50,683	4,606	**10**
003	117,407	219,015	117,407	249,537	17,736	33,086	17,736	37,697	$50,955	19,235	**11**
015	71,214	10,528	71,214	11,628	12,388	1,831	12,388	2,023	$36,789	7,519	**12**
029	107,930	310,959	107,930	357,553	15,867	45,715	15,867	52,565	$47,281	13,245	**13**
J014	94,848	316,649	94,848	387,363	13,008	43,429	13,008	53,127	$51,932	11,449	**14**
073	89,498	23,586	89,498	24,567	24,220	6,383	24,220	6,648	$70,543	4,392	**15**
065	115,345	119,353	115,345	131,654	20,962	21,690	20,962	23,925	$57,458	8,593	**16**
054	68,216	14,736	68,216	16,955	16,439	3,551	16,439	4,086	$38,757	11,425	**17**
072	93,184	21,132	93,184	23,467	19,518	4,426	19,518	4,915	$71,786	15,765	**18**
074	101,346	23,681	101,346	24,484	23,047	5,385	23,047	5,568	$60,624	12,743	**19**
020	75,723	332,567	75,723	406,884	16,817	73,860	16,817	90,365	$52,534	17,767	**20**

Table 5-6: CTA Scenario B Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Weekday Ridership	Scenario Ranking
009	143,170	44,847	143,170	52,609	15,655	4,904	15,655	5,753	$53,590	27,499	**1**
049	128,305	31,829	128,305	34,858	15,797	3,919	15,797	4,292	$50,683	23,417	**2**
008	137,491	62,672	137,491	77,764	19,160	8,734	19,160	10,837	$61,899	22,093	**3**
004	120,386	185,397	120,386	213,054	15,277	23,526	15,277	27,036	$44,808	21,143	**4**
003	117,407	219,015	117,407	249,537	17,736	33,086	17,736	37,697	$50,955	19,235	**5**
029	107,930	310,959	107,930	357,553	15,867	45,715	15,867	52,565	$47,281	13,245	**6**
052	113,927	19,796	113,927	22,065	17,447	3,032	17,447	3,379	$39,015	12,231	**7**
J014	94,848	316,649	94,848	387,363	13,008	43,429	13,008	53,127	$51,932	11,449	**8**
050	106,161	46,998	106,161	53,346	17,782	7,872	17,782	8,936	$64,658	9,860	**9**
094	101,604	19,057	101,604	21,109	15,820	2,967	15,820	3,287	$31,484	9,571	**10**
015	71,214	10,528	71,214	11,628	12,388	1,831	12,388	2,023	$36,789	7,519	**11**
009X	151,573	46,773	151,573	54,579	17,135	5,287	17,135	6,170	$50,683	4,606	**12**
049X	128,305	31,829	128,305	34,858	15,797	3,919	15,797	4,292	$81,155	3,459	**13**
005	75,149	8,874	75,149	11,631	12,580	1,486	12,580	1,947	$34,061	497	**14**
079	69,759	7,976	69,759	10,662	12,864	1,471	12,864	1,966	$43,363	26,830	**15**
066	105,458	91,685	105,458	102,527	22,712	19,746	22,712	22,081	$58,897	23,506	**16**
077	124,609	21,263	124,609	22,636	22,205	3,789	22,205	4,034	$61,234	22,150	**17**
053	108,598	12,975	108,598	14,638	19,643	2,347	19,643	2,648	$38,829	19,909	**18**
082	147,241	21,790	147,241	23,783	21,849	3,233	21,849	3,529	$41,407	18,939	**19**
020	75,723	332,567	75,723	406,884	16,817	73,860	16,817	90,365	$52,534	17,767	**20**

Table 5-7: CTA Scenario C Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Weekday Ridership	Scenario Ranking
092	64,047	16,642	64,047	17,674	19,213	4,992	19,213	5,302	$62,069	6,953	**1**
169	67,786	17,158	67,786	19,944	7,906	2,001	7,906	2,326	$49,712	219	**2**
026	120,808	210,187	120,808	242,195	14,570	25,349	14,570	29,209	$45,517	3,222	**3**
098X	39,028	16,999	39,028	20,287	6,510	2,836	6,510	3,384	$53,732	17	**4**
053	108,598	12,975	108,598	14,638	19,643	2,347	19,643	2,648	$38,829	19,909	**5**
082	147,241	21,790	147,241	23,783	21,849	3,233	21,849	3,529	$41,407	18,939	**6**
146	124,188	330,759	124,188	376,481	27,788	74,010	27,788	84,240	$71,115	13,838	**7**
147	151,687	316,505	151,687	358,828	28,595	59,665	28,595	67,644	$62,090	13,372	**8**
J014	94,848	316,649	94,848	387,363	13,008	43,429	13,008	53,127	$51,932	11,449	**9**
093	71,503	35,854	71,503	36,641	17,278	8,664	17,278	8,854	$59,918	3,466	**10**
135	97,506	347,762	97,506	413,803	27,269	97,256	27,269	115,725	$73,756	3,332	**11**
134	74,444	343,534	74,444	409,414	27,019	124,684	27,019	148,595	$78,944	3,014	**12**
148	102,067	320,831	102,067	363,455	28,326	89,039	28,326	100,868	$70,406	2,416	**13**
136	135,972	352,659	135,972	418,827	28,991	75,192	28,991	89,300	$65,335	1,910	**14**
143	66,694	211,421	66,694	237,878	28,174	89,311	28,174	100,487	$83,324	1,876	**15**
009	143,170	44,847	143,170	52,609	15,655	4,904	15,655	5,753	$53,590	27,499	**16**
066	105,458	91,685	105,458	102,527	22,712	19,746	22,712	22,081	$58,897	23,506	**17**
049	128,305	31,829	128,305	34,858	15,797	3,919	15,797	4,292	$50,683	23,417	**18**
077	124,609	21,263	124,609	22,636	22,205	3,789	22,205	4,034	$61,234	22,150	**19**
008	137,491	62,672	137,491	77,764	19,160	8,734	19,160	10,837	$61,899	22,093	**20**
003	117,407	219,015	117,407	249,537	17,736	33,086	17,736	37,697	갌50,955	19,235	**21**
022	179,829	345,096	179,829	400,743	31,174	59,823	31,174	69,469	$70,060	18,188	**22**
020	75,723	332,567	75,723	406,884	16,817	73,860	16,817	90,365	$52,534	17,767	**23**
151	214,716	398,364	214,716	460,570	33,297	61,776	33,297	71,423	$61,252	16,947	**24**
063	67,186	8,894	67,186	9,942	13,685	1,812	13,685	2,025	$29,018	16,794	**25**

Table 5-8: CTA Scenario D Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Weekday Ridership	Scenario Ranking
009	143,170	44,847	143,170	52,609	15,655	4,904	15,655	5,753	$53,590	27,499	**1**
079	69,759	7,976	69,759	10,662	12,864	1,471	12,864	1,966	$43,363	26,830	**2**
066	105,458	91,685	105,458	102,527	22,712	19,746	22,712	22,081	$58,897	23,506	**3**
049	128,305	31,829	128,305	34,858	15,797	3,919	15,797	4,292	$50,683	23,417	**4**
077	124,609	21,263	124,609	22,636	22,205	3,789	22,205	4,034	$61,234	22,150	**5**
008	137,491	62,672	137,491	77,764	19,160	8,734	19,160	10,837	$61,899	22,093	**6**
004	120,386	185,397	120,386	213,054	15,277	23,526	15,277	27,036	$44,808	21,143	**7**
053	108,598	12,975	108,598	14,638	19,643	2,347	19,643	2,648	$38,829	19,909	**8**
003	117,407	219,015	117,407	249,537	17,736	33,086	17,736	37,697	$50,955	19,235	**9**
082	147,241	21,790	147,241	23,783	21,849	3,233	21,849	3,529	$41,407	18,939	**10**
022	179,829	345,096	179,829	400,743	31,174	59,823	31,174	69,469	$70,060	18,188	**11**
020	75,723	332,567	75,723	406,884	16,817	73,860	16,817	90,365	$52,534	17,767	**12**
151	214,716	398,364	214,716	460,570	33,297	61,776	33,297	71,423	$61,252	16,947	**13**
063	67,186	8,894	67,186	9,942	13,685	1,812	13,685	2,025	$29,018	16,794	**14**
072	93,184	21,132	93,184	23,467	19,518	4,426	19,518	4,915	$71,786	15,765	**15**
012	69,713	44,756	69,713	55,671	15,578	10,001	15,578	12,441	$45,122	14,160	**16**
146	124,188	330,759	124,188	376,481	27,788	74,010	27,788	84,240	$71,115	13,838	**17**
147	151,687	316,505	151,687	358,828	28,595	59,665	28,595	67,644	$62,090	13,372	**18**
036	187,295	368,842	187,295	424,819	36,038	70,970	36,038	81,741	$67,157	13,254	**19**
087	53,865	5,775	53,865	7,997	9,307	998	9,307	1,382	$46,897	13,247	**20**

Table 5-9: CTA Scenario E Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Weekday Ridership	Scenario Ranking
024	72,343	279,552	72,343	334,483	12,797	49,450	12,797	59,167	$37,838	2,933	**1**
062	110,313	311,180	110,313	363,831	15,263	43,055	15,263	50,340	$54,563	10,764	**2**
029	107,930	310,959	107,930	357,553	15,867	45,715	15,867	52,565	$47,281	13,245	**3**
056	111,447	302,432	111,447	370,909	21,467	58,255	21,467	71,446	$73,861	9,138	**4**
007	60,510	255,438	60,510	306,929	13,326	56,254	13,326	67,594	$51,024	5,747	**5**
126	73,085	245,704	73,085	294,084	15,369	51,670	15,369	61,844	$50,474	6,124	**6**
003	117,407	219,015	117,407	249,537	17,736	33,086	17,736	37,697	$50,955	19,235	**7**
J014	94,848	316,649	94,848	387,363	13,008	43,429	13,008	53,127	$51,932	11,449	**8**
028	86,767	228,058	86,767	274,477	12,302	32,334	12,302	38,916	$51,366	7,027	**9**
060	96,782	331,249	96,782	408,481	20,821	71,264	20,821	87,879	$54,121	10,126	**10**
157	61,808	410,889	61,808	497,668	17,212	114,424	17,212	138,590	$70,306	5,443	**11**
132	51,551	244,656	51,551	306,809	16,033	76,093	16,033	95,424	$101,056	241	**12**
004	120,386	185,397	120,386	213,054	15,277	23,526	15,277	27,036	$44,808	21,143	**13**
020	75,723	332,567	75,723	406,884	16,817	73,860	16,817	90,365	$52,534	17,767	**14**
026	120,808	210,187	120,808	242,195	14,570	25,349	14,570	29,209	$45,517	3,222	**15**
019	29,765	297,702	29,765	366,773	15,693	156,963	15,693	193,380	$82,043	332	**16**
008	137,491	62,672	137,491	77,764	19,160	8,734	19,160	10,837	$61,899	22,093	**17**
192	112,222	112,249	112,222	145,790	15,872	15,876	15,872	20,620	$53,611	859	**18**
021	103,077	26,427	103,077	30,197	18,245	4,678	18,245	5,345	$39,678	9,464	**19**
081	75,119	19,217	75,119	20,325	22,768	5,824	22,768	6,160	$55,693	12,160	**20**
009X	151,573	46,773	151,573	54,579	17,135	5,287	17,135	6,170	$50,683	4,606	**21**
009	143,170	44,847	143,170	52,609	15,655	4,904	15,655	5,753	$53,590	27,499	**22**
050	106,161	46,998	106,161	53,346	17,782	7,872	17,782	8,936	$64,658	9,860	**23**

Table 5-10: Pace Scenario A Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Mth. Wkd Ridership	Scenario Ranking
303	38,893	19,206	44,431	21,416	6,008	2,967	6,863	3,308	$48,114	25,802	**1**
626	24,737	58,842	33,187	67,807	1,887	4,489	2,532	5,173	$105,816	7,867	**2**
330	41,745	27,375	46,554	31,367	4,010	2,630	4,472	3,013	$58,679	25,856	**3**
272	25,948	29,968	32,447	33,002	2,847	3,288	3,560	3,621	$78,480	12,971	**4**
234	40,481	24,521	49,145	27,557	4,461	2,702	5,416	3,037	$73,860	6,011	**5**
208	60,063	55,307	68,628	60,241	11,963	4,574	5,676	4,982	$66,703	40,598	**6**
386	44,064	24,218	49,408	28,343	4,008	2,203	4,494	2,578	$63,132	29,999	**7**
326	14,106	13,161	16,125	16,528	3,786	3,533	4,328	4,436	$50,787	3,846	**8**
319	44,627	18,132	52,178	20,301	6,018	2,445	7,036	2,738	$52,428	12,923	**9**
356	20,312	9,648	24,544	12,050	3,278	1,557	3,961	1,945	$58,867	12,804	**10**
332	21,866	45,167	27,342	54,734	2,490	5,144	3,114	6,234	$73,146	13,878	**11**
318	29,356	15,070	32,282	16,584	7,081	3,635	7,787	4,000	$69,598	50,416	**12**
364	42,748	21,990	50,807	26,582	3,395	1,746	4,035	2,111	$49,509	50,173	**13**
331	45,760	29,769	50,970	30,769	5,985	3,894	6,667	4,025	$56,677	26,868	**14**
565	23,799	17,436	27,711	21,037	3,068	2,248	3,573	2,712	$74,513	22,675	**15**
221	31,551	25,475	36,023	29,778	4,064	3,282	4,640	3,836	$68,475	16,937	**16**
226	47,655	30,490	53,815	35,469	5,451	3,488	6,156	4,057	$69,335	15,022	**17**
757	41,469	55,912	48,085	63,003	3,174	4,280	3,680	4,822	$61,949	4,729	**18**
309	36,478	19,253	43,071	21,793	7,265	3,835	8,578	4,340	$67,984	19,176	**19**
209	24,257	17,184	28,455	18,602	6,130	4,343	7,191	4,701	$81,658	7,774	**20**
619	13,325	15,745	15,859	17,150	3,479	4,111	4,140	4,477	$62,932	1,352	**21**
620	21,034	20,763	25,566	24,359	3,385	3,341	4,114	3,920	$87,595	1,336	**22**
381	44,598	20,877	49,777	22,056	5,583	2,613	6,231	2,761	$58,375	82,494	**23**
322	39,467	48,406	45,206	52,380	5,509	6,757	6,310	7,312	$63,949	49,549	**24**
572	18,325	13,107	22,612	15,320	3,518	2,517	4,341	2,941	$76,491	16,470	**25**
302	45,219	15,399	51,406	17,993	10,499	3,575	11,935	4,178	$59,002	12,405	**26**
210	38,054	26,502	46,445	32,085	5,337	3,717	6,514	4,500	$71,273	7,666	**27**
230	33,549	24,085	37,943	28,009	5,471	3,927	6,187	4,567	$61,869	8,346	**28**

Table 5-11: Pace Scenario B Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Mth. Wkd Ridership	Scenario Ranking
381	44,598	20,877	49,777	22,056	5,583	2,613	6,231	2,761	$58,375	82,494	**1**
318	29,356	15,070	32,282	16,584	7,081	3,635	7,787	4,000	$69,598	50,416	**2**
364	42,748	21,990	50,807	26,582	3,395	1,746	4,035	2,111	$49,509	50,173	**3**
322	39,467	48,406	45,206	52,380	5,509	6,757	6,310	7,312	$63,949	49,549	**4**
208	60,063	55,307	68,628	60,241	11,963	4,574	5,676	4,982	$66,703	40,598	**5**
386	44,064	24,218	49,408	28,343	4,008	2,203	4,494	2,578	$63,132	29,999	**6**
331	45,760	29,769	50,970	30,769	5,985	3,894	6,667	4,025	$56,677	26,868	**7**
330	41,745	27,375	46,554	31,367	4,010	2,630	4,472	3,013	$58,679	25,856	**8**
303	38,893	19,206	44,431	21,416	6,008	2,967	6,863	3,308	$48,114	25,802	**9**
565	23,799	17,436	27,711	21,037	3,068	2,248	3,573	2,712	$74,513	22,675	**10**
309	36,478	19,253	43,071	21,793	7,265	3,835	8,578	4,340	$67,984	19,176	**11**
221	31,551	25,475	36,023	29,778	4,064	3,282	4,640	3,836	$68,475	16,937	**12**
572	18,325	13,107	22,612	15,320	3,518	2,517	4,341	2,941	$76,491	16,470	**13**
226	47,655	30,490	53,815	35,469	5,451	3,488	6,156	4,057	$69,335	15,022	**14**
332	21,866	45,167	27,342	54,734	2,490	5,144	3,114	6,234	$73,146	13,878	**15**
272	25,948	29,968	32,447	33,002	2,847	3,288	3,560	3,621	$78,480	12,971	**16**
319	44,627	18,132	52,178	20,301	6,018	2,445	7,036	2,738	$52,428	12,923	**17**
356	20,312	9,648	24,544	12,050	3,278	1,557	3,961	1,945	$58,867	12,804	**18**
302	45,219	15,399	51,406	17,993	10,499	3,575	11,935	4,178	$59,002	12,405	**19**
230	33,549	24,085	37,943	28,009	5,471	3,927	6,187	4,567	$61,869	8,346	**20**
626	24,737	58,842	33,187	67,807	1,887	4,489	2,532	5,173	$105,816	7,867	**21**
209	24,257	17,184	28,455	18,602	6,130	4,343	7,191	4,701	$81,658	7,774	**22**
210	38,054	26,502	46,445	32,085	5,337	3,717	6,514	4,500	$71,273	7,666	**23**
234	40,481	24,521	49,145	27,557	4,461	2,702	5,416	3,037	$73,860	6,011	**24**
757	41,469	55,912	48,085	63,003	3,174	4,280	3,680	4,822	$61,949	4,729	**25**
326	14,106	13,161	16,125	16,528	3,786	3,533	4,328	4,436	$50,787	3,846	**26**
619	13,325	15,745	15,859	17,150	3,479	4,111	4,140	4,477	$62,932	1,352	**27**
620	21,034	20,763	25,566	24,359	3,385	3,341	4,114	3,920	$87,595	1,336	**28**

Table 5-12: Pace Scenario C Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Mth. Wkd Ridership	Scenario Ranking
895	65,537	142,559	78,756	164,020	2,075	4,515	2,494	5,194	$68,129	4,350	**1**
570	31,475	8,256	41,494	12,592	3,402	892	4,485	1,361	$67,753	4,797	**2**
303	38,893	19,206	44,431	21,416	6,008	2,967	6,863	3,308	$48,114	25,802	**3**
877	51,809	76,904	62,292	86,029	2,753	4,086	3,310	4,571	$66,361	3,033	**4**
888	49,026	91,841	62,452	109,055	2,156	4,039	2,747	4,796	$66,712	1,675	**5**
806	19,312	13,935	29,215	19,602	1,739	1,255	2,631	1,765	$74,968	596	**6**
809	3,835	2,169	5,551	3,684	712	403	1,031	684	$71,304	49	**7**
626	24,737	58,842	33,187	67,807	1,887	4,489	2,532	5,173	$105,816	7,867	**8**
330	41,745	27,375	46,554	31,367	4,010	2,630	4,472	3,013	$58,679	25,856	**9**
272	25,948	29,968	32,447	33,002	2,847	3,288	3,560	3,621	$78,480	12,971	**10**
850	95,816	329,079	119,661	391,091	3,834	13,167	4,788	15,648	$69,083	11,458	**11**
354	30,321	8,110	38,701	10,914	3,806	1,018	4,858	1,370	$41,176	8,702	**12**
234	40,481	24,521	49,145	27,557	4,461	2,702	5,416	3,037	$73,860	6,011	**13**
533	28,515	7,531	39,828	15,470	5,422	1,432	7,574	2,942	$50,903	3,510	**14**
250	55,114	37,887	63,134	39,714	6,945	4,774	7,955	5,004	$68,250	54,066	**15**
208	60,063	55,307	68,628	60,241	11,963	4,574	5,676	4,982	$66,703	40,598	**16**
855	85,021	322,537	106,921	381,523	3,994	15,153	5,023	17,924	$70,779	8,011	**17**
755	49,450	90,101	61,974	116,070	2,538	4,624	3,180	5,956	$69,367	7,396	**18**
593	20,942	14,432	27,050	16,773	2,730	1,881	3,526	2,186	$99,706	Call-n-Ride	**19**

Table 5-13: Pace Scenario D Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Mth. Wkd Ridership	Scenario Ranking
352	41,770	12,431	49,472	15,420	4,838	1,440	5,730	1,786	$39,482	119,298	**1**
381	44,598	20,877	49,777	22,056	5,583	2,613	6,231	2,761	$58,375	82,494	**2**
290	47,800	33,602	55,869	38,663	7,696	5,410	8,996	6,225	$73,124	69,449	**3**
307	53,531	17,267	59,072	18,510	9,001	2,903	9,932	3,112	$68,868	60,484	**4**
250	55,114	37,887	63,134	39,714	6,945	4,774	7,955	5,004	$68,250	54,066	**5**
349	34,015	11,246	39,116	12,609	5,752	1,902	6,615	2,132	$55,495	53,100	**6**
318	29,356	15,070	32,282	16,584	7,081	3,635	7,787	4,000	$69,598	50,416	**7**
364	42,748	21,990	50,807	26,582	3,395	1,746	4,035	2,111	$49,509	50,173	**8**
322	39,467	48,406	45,206	52,380	5,509	6,757	6,310	7,312	$63,949	49,549	**9**
301	43,063	58,955	50,987	65,174	3,762	5,150	4,454	5,693	$72,624	45,749	**10**
208	60,063	55,307	68,628	60,241	11,963	4,574	5,676	4,982	$66,703	40,598	**11**
379	36,148	18,481	42,268	22,276	3,811	1,948	4,456	2,348	$58,404	40,235	**12**
606	16,542	37,848	19,359	45,511	2,345	5,366	2,745	6,453	$54,628	39,047	**13**
350	19,737	3,790	24,290	4,974	5,489	1,054	6,755	1,383	$37,556	36,688	**14**
223	10,645	41,469	12,450	50,550	1,367	5,327	1,599	6,493	$54,451	36,135	**15**
353	31,747	12,029	37,560	14,688	3,046	1,154	3,604	1,409	$43,670	35,471	**16**
311	48,106	14,671	53,064	16,559	9,501	2,898	10,481	3,271	$79,138	32,392	**17**
359	51,443	12,361	61,570	15,500	5,262	1,264	6,298	1,586	$44,677	31,219	**18**
215	32,072	17,265	35,467	19,232	8,475	4,563	9,372	5,082	$83,442	30,403	**19**
386	44,064	24,218	49,408	28,343	4,008	2,203	4,494	2,578	$63,132	29,999	**20**

Table 5-14: Pace Scenario E Socioeconomic and Ridership Characteristics

Route	Pop. in HH 2010	Emp. 2010	Pop. in HH 2040	Emp. 2040	Pop. per sqmi 2010	Emp. per sqmi 2010	Pop. per sqmi 2040	Emp. per sqmi 2040	Median HH Income	Avg. Mth. Wkd Ridership	Scenario Ranking
309	36,478	19,253	43,071	21,793	7,265	3,835	8,578	4,340	$67,984	19,176	**1**
302	45,219	15,399	51,406	17,993	10,499	3,575	11,935	4,178	$59,002	12,405	**2**
303	38,893	19,206	44,431	21,416	6,008	2,967	6,863	3,308	$48,114	25,802	**3**
757	41,469	55,912	48,085	63,003	3,174	4,280	3,680	4,822	$61,949	4,729	**4**
318	29,356	15,070	32,282	16,584	7,081	3,635	7,787	4,000	$69,598	50,416	**5**
208	60,063	55,307	68,628	60,241	11,963	4,574	5,676	4,982	$66,703	40,598	**6**
226	47,655	30,490	53,815	35,469	5,451	3,488	6,156	4,057	$69,335	15,022	**7**
319	44,627	18,132	52,178	20,301	6,018	2,445	7,036	2,738	$52,428	12,923	**8**
209	24,257	17,184	28,455	18,602	6,130	4,343	7,191	4,701	$81,658	7,774	**9**
381	44,598	20,877	49,777	22,056	5,583	2,613	6,231	2,761	$58,375	82,494	**10**
331	45,760	29,769	50,970	30,769	5,985	3,894	6,667	4,025	$56,677	26,868	**11**
330	41,745	27,375	46,554	31,367	4,010	2,630	4,472	3,013	$58,679	25,856	**12**
234	40,481	24,521	49,145	27,557	4,461	2,702	5,416	3,037	$73,860	6,011	**13**
386	44,064	24,218	49,408	28,343	4,008	2,203	4,494	2,578	$63,132	29,999	**14**
221	31,551	25,475	36,023	29,778	4,064	3,282	4,640	3,836	$68,475	16,937	**15**
332	21,866	45,167	27,342	54,734	2,490	5,144	3,114	6,234	$73,146	13,878	**16**
356	20,312	9,648	24,544	12,050	3,278	1,557	3,961	1,945	$58,867	12,804	**17**
626	24,737	58,842	33,187	67,807	1,887	4,489	2,532	5,173	$105,816	7,867	**18**
364	42,748	21,990	50,807	26,582	3,395	1,746	4,035	2,111	$49,509	50,173	**19**
322	39,467	48,406	45,206	52,380	5,509	6,757	6,310	7,312	$63,949	49,549	**20**
230	33,549	24,085	37,943	28,009	5,471	3,927	6,187	4,567	$61,869	8,346	**21**
210	38,054	26,502	46,445	32,085	5,337	3,717	6,514	4,500	$71,273	7,666	**22**
326	14,106	13,161	16,125	16,528	3,786	3,533	4,328	4,436	$50,787	3,846	**23**
620	21,034	20,763	25,566	24,359	3,385	3,341	4,114	3,920	$87,595	1,336	**24**

6. Next Steps

Task 2

The initial draft of this technical memorandum will be presented at a meeting of the project's technical advisory committee for discussion of methodology and data findings. This meeting will include not only a review of the static data and maps presented in this delivery, but will also include interactive use of the project GIS system for the technical advisory committee to review and "play with" data in real time. At the end of this meeting, a desirable outcome would be agreement on route selection scenario and initial prioritization of routes of concern. CTA and Pace may wish to use different selection scenarios based on their own priorities, and through the realization that data sources for each agency's service area vary based on contributing parties, as well as the differing origins of flooding between urban and suburban contexts. The project team will continue to refine selection results as additional data on actual incidents or localized changes to floodplain/floodplain understanding evolve.

Task 3

The project team has collected a variety of projection methodologies through literature review and conversation with regional stakeholders on forecasting future flooding conditions, risks, frequency and likelihood. As the project team wraps up Task 2, we beginning assessment of approach for modeling and applying data to identify whether current risk areas are the same, improved, or potentially more severe in the future.

Task 4

Through the collection of background information for project initiation and Task 2, the project team uncovered a variety of datasets and commentary useful for Task 4. So far, the team has undertaken the following activities toward Task 4 work.

- Researched best practices nationally on transit-related flood mitigation and resilience work.
- Inventoried local/regional initiatives on stormwater programs. Discussed tactical projects under way or programmed by interviewed agencies or documented in plans.
- Initiated discussions with CTA and Pace staff on internal communications protocols related to service interruption and known flooding problems. In the process of collecting documented reroute procedures that may exist.
- Initiated discussions with CTA and Pace staff on service planning tools (e.g., Remix), approaches and practices related planning for route updates and restructuring.

These activities are expected to continue in parallel with remaining Task 2 and imminent Task 3 activities.

Appendix A.1 Contents

Regional Contextual Maps

CTA Scenario Maps

Pace Scenario Maps

- C-1: Pace Route Network with Flood Zone Intersections Flooding Noted by Pace
- C-2: Pace Scenarios A-E with Flooding Data
- C-3: Pace Scenario A with Flooding Data
- C-4: Pace Scenario B with Flooding Data
- C-5: Pace Scenario C with Flooding Data
- C-6: Pace Scenario D with Flooding Data
- C-7: Pace Scenario E with Flooding Data
- C-8: Pace Scenarios A-E with 2010 Population Subzones
- C-9: Pace Scenarios A-E with 2010 Employment Subzones
- C-10: Pace Scenarios A-E with 2014 Median Household Income Tracts
- C-11: Pace Scenario A with 2010 Population Density Buffers
- C-12: Pace Scenario B with 2010 Population Density Buffers
- C-13: Pace Scenario C with 2010 Population Density Buffers
- C-14: Pace Scenario D with 2010 Population Density Buffers
- C-15: Pace Scenario E with 2010 Population Density Buffers
- C-16: Pace Scenario A with 2010 Employment Density Buffers
- C-17: Pace Scenario B with 2010 Employment Density Buffers
- C-18: Pace Scenario C with 2010 Employment Density Buffers
- C-19: Pace Scenario D with 2010 Employment Density Buffers
- C-20: Pace Scenario E with 2010 Employment Density Buffers
- C-21: Pace Scenario A with 2014 Median Household Income Buffers
- C-22: Pace Scenario B with 2014 Median Household Income Buffers
- C-23: Pace Scenario C with 2014 Median Household Income Buffers
- C-24: Pace Scenario D with 2014 Median Household Income Buffers

Flooding Resilience Plan for Bus Operations

Appendix B: Task 3 Technical Memorandum: Future Climate Change Impacts on Flooding

Prepared for the Regional Transportation Authority of Northeast Illinois

March 30, 2018

March 2018

Table of Contents

Figures

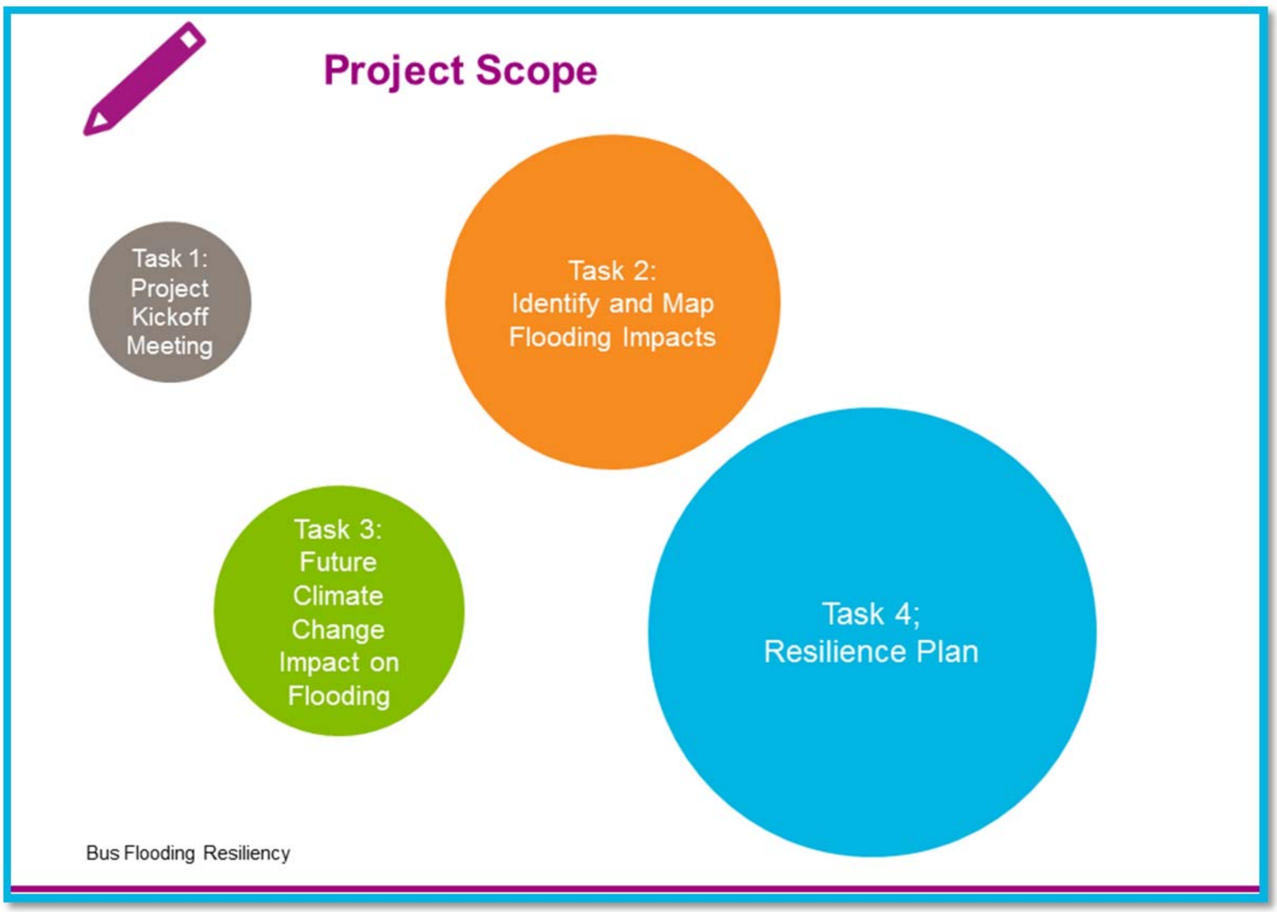
Tables

1. Introduction

In Fall 2015, as a continuation of its Green Transit program, the Regional Transportation Authority (RTA), initiated a project to prepare a bus route flooding resilience plan for the RTA region composed of its six-county jurisdiction in northeastern Illinois, including Cook, DuPage, Kane, Lake, McHenry, and Will Counties. The objective of this project is to identify CTA and Pace bus routes prone to flooding during both average rain events and extreme weather events. Aside from hampering citizens' mobility, such flooding events can have negative impacts on operating costs and ridership revenues. The project is intended to develop recommendations to address flooding issues and reroute service during flooding.

The scope of the study, which kicked off in Summer 2016, is organized into four major work tasks:

1. Initiate Project
2. Identify and Map Flooding Impacts
3. Assess Future Climate Change Impacts on Flooding
4. Prepare a Resilience Plan



March 2018

This Technical Memorandum summarizes the work of **Task 3**, during which the project team examined the effects of changing climate patterns on the flood risk landscape in the region. Research conducted in 2008 for the Chicago Climate Action Plan indicates that increases in winter and spring precipitation are likely, with projected increases of about 10 percent by the year 2050, and of about 20 to 30 percent by 2099. At present, even minor storms are enough to overwhelm the stormwater system of some parts of the region, and these are expected to occur even more often. For example, today's 2-year storm event is expected to occur every year by mid-century, or phrased differently, an event that has a 50% chance of being equaled or exceeded in any given year is expected to have a 100% chance by mid-century. Additionally, the intensity of heavy precipitation events (5-, 10-, and 25-year storms) is likely to continue to increase. Effects of these trends will vary across the region according to watershed and sub-watershed hydrological patterns. With input from county and local stormwater management departments, the project team assesses whether these forecasted increases are likely to worsen risk conditions for the bus routes identified in Task 2.

2. Future Climate Change Impact on Flooding

2.1 Climate Studies in the Region

2.1.1 Chicago Climate Action Plan

The Chicago Climate Action Plan was an important precursor to the RTA's Green Transit and Resilience planning efforts. It looks to both the past and the future before laying out its action steps for a more resilient metropolis.

According to historical records, the frequency of heavy storms has doubled since the 1970s, with more of the precipitation falling as rain rather than snow. There is less ice coverage on Lake Michigan and area lakes and less snowpack in the winter. Temperatures have risen by 2.6°F since 1980—especially winters, which are on average are almost 4°F warmer.

To understand how a local area will be affected by climate change in the future, climate scientists take global circulation models (GCM) and downscale them to a finer resolution at the regional level to predict temperature and precipitation levels before running that data through hydrological and hydraulic models to determine where the water is likely to go. An example of this downscaling is shown in **Figure 1**. Given the uncertainty of the field, several datasets and models (e.g., GDFL, PCM, CCSM3) engineered by different research agencies across the world are used and their results compared to find the more likely outcome. To reflect the different possible futures in terms of emission reduction policies, population growth, economic growth, etc., it is important to run the models under high and low emissions scenarios (e.g., A1 and B1). By combining this forecasting of future climate conditions with current data on severe weather events, it is possible to gain a more realistic understanding on what kind of weather to expect and where.

Figure 1: Sample Downscaled Climate Projections

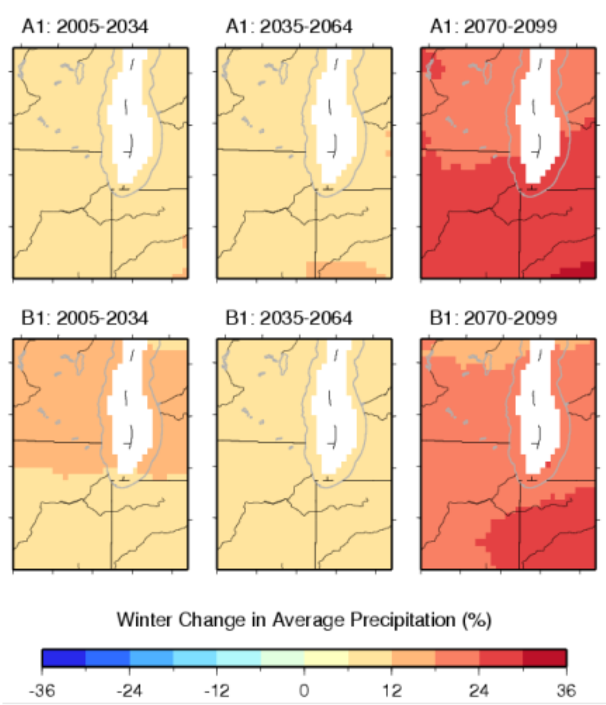


Image source: Chicago Climate Change Action Plan, p. 4.

The federal government and research organizations like the World Climate Research Programme provide data and tools to assist transportation agencies in generating local climate change projections and interpreting their effects. For example, the US DOT provides the Coupled Model Intercomparison Project (CMIP) Climate Data Processing Tool and the Vulnerability Assessment Scoring Tool, which translate downscaled climate model data into more relatable terms for non-experts and helps them to assess vulnerability to extreme weather events. Local and regional agencies like the Illinois State Water Survey also do their own analyses. In their analysis that agency found that some of the global climate change data sources underestimated precipitation extremes when downscaled to the regional level (see below). The U.S. Global Change Research Program has developed climate information that is relevant at broad geographical scales and can be used by local agencies or project teams. Federal agencies like NOAA, USGS, and USACE have data, modeling, historical weather data, and future climate predictions that local agencies can draw from.[1]

The climate forecast projections used in the Chicago Climate Action Plan come from three different global climate models (GDFL, HadCM3, and PCM), which are then downscaled to the Chicago region using long-term historical records and advanced statistical techniques. These models are run using two different emissions scenarios—low and high—to reflect different potential futures based on the climate change mitigation policies espoused and undertaken in the coming years. The resulting six simulations generate climate projections through 2100.

These temperature and precipitation rates are then input into hydrological models to simulate how much of the water will be absorbed into the earth, evaporated into the sky, or runoff into waterways (e.g., evapotranspiration, runoff generation, soil infiltration and drainage, snowpack accumulation, snowmelt). These results, in turn, are then routed through stream networks using a hydraulic model to determine where that water will go and where it will accumulate.

According to this analysis by climate science experts and water resource engineers, the Chicago region can expect:

– Average annual temperatures 3-4°F (low emissions) or 7-8°F (high emissions) warmer, and up to 10°F warmer during the summers
– Summers that feel similar to current Mobile, AL, with heat indexes averaging 105°F (high emissions scenario); under low emissions, more like Atlanta, GA, with heat indexes around 94°F
– More heatwaves, higher heat indexes due to increased humidity, fewer cold spells, decreased air quality, more frequent vector- and water-borne diseases
– 10% more winter and spring precipitation by 2050, and 20-30% more by 2100 (both high and low emissions)
– More heavy rainfall events of 2.5 inches or more in 24-hour period—i.e., those associated with flooding
– Increased evapotranspiration, increased runoff, and an increase in peak flow in Illinois River

A comparison with previous climate change impact projects conducted for the Midwest and Great Lakes region from 2000 and 2003 shows that this analysis confirms these earlier projections.

These types of impacts—higher temperatures, greater precipitation in heavier rain events—will have a major impact on Chicago's infrastructure. Emissions levels will be significant here: under the high-emissions scenario, the projected costs of adaptation for government are nearly four times higher than the low-emissions scenario. Aside from the direct costs of increased maintenance and replacement of hard infrastructure like roadways, bridges, fleet vehicles, etc., there will be less tangible costs such public health problems arising from poor air quality and temperature extremes, more frequent disease outbreaks, crop damage from intense storm events or summer droughts, among other consequences of climate change.

The Chicago Climate Change Action Plan looks at the costs of adapting to more sustainable practices that would reduce emissions and thus climate impacts, and finds that sustainable practices (such as those that would result in resource efficiencies) could generate $400 million to $1.2 billion in savings each year by 2020. It also quantifies the increase in green jobs in order to achieve the plan's goals, as well as the jobs that would be created by achieving the goals. More detail on action steps for climate change resilience in the Chicago region can be found in **Appendix C: Best Practices**.

[1] As a primer to the subject, the FHWA published *Regional Climate Change Effects: Useful Information for Transportation Agencies* (2010), which provides basic information on climate change effects in the near, medium, and long term by region, as well as how this information can be applied to transportation planning, operations, and asset management. The analysis relies on USGCRP climate impact data and projections using the CMIP tool. For further discussion of climate change data, analyses, and applications, see the 2011 FHWA report, *The Use of Climate Information in Vulnerability Assessments.*

2.1.2 Illinois State Water Survey

A 2016 Illinois State Water Survey report, “Communicating the Impacts of Potential Future Climate Change on the Expected Frequency of Extreme Rainfall Events in Cook County, Illinois” sought to design a framework to translate future climate scenarios into something that local-level engineers and planners can use to quantify the impact of climate change. The output can then be used to inform and plan adaptive strategies for floodplain management. The research found that two of the three data sources (WCRP and ORNL) commonly used for climate change modeling considerably underestimated rainwater extremes in Cook County.

2.1.3 Center for Neighborhood Technology

In 2014, the Center for Neighborhood Technology examined the economic costs of urban flooding in Cook County. This report, “The Prevalence and Cost of Urban Flooding,” found that between 2007 and 2011, 181,000 insurance claims added up to $773 million in damages, and there was no correlation between damage payouts and floodplains, either in number or value of claims. One pattern that was noticeable was that places that had flooded once were likely to flood again—and soon. Of the 115 survey respondents, 70% said they had been flooded three times or more in the last five years, and 20% had been flooded ten times or more.

2.2 Analysis of Future Areas of Risk for Bus Operations

As detailed in previous chapters, the process to identify bus routes of concern used a range of environmental, socio-economic and transit data to flag risks and areas of focus in the present period. In preparing mitigation strategies, it is prudent to look ahead to the extent possible to anticipate future conditions to avoid recommendations that might be short-lived or less relevant under future scenarios of climate change.

2.2.1 Input data

The analysis in this study to understand the potential implications of future climate change, and more-frequent, more severe storm events in the future was divided into two work streams to address the different root causes of flooding in urban vs. suburban / exurban contexts.

Analysis of urban flooding – with its origins typically in the built environment and ability of infrastructure to manage large amounts of stormwater – included the following base data:

- Locations of bus service interruption and route-level comments on typical flood problems reported by CTA staff
- Locations of bus service interruption and route-level comments on typical flood problems reported by Pace staff
- Road closures due to flooding reported by Cook County Department of Transportation and Highways
- Locations of viaducts (and annotation of “problematic” or “flood-prone” viaducts) by CDOT, CTA and Pace
- City of Chicago 311 reported flood calls, including water on pavement and flooded viaducts

March 2018

Figure 2: OEMC Street Flood Calls, Density of CTA Flood Reports, CDOT Viaducts, and CTA Scenario E Routes

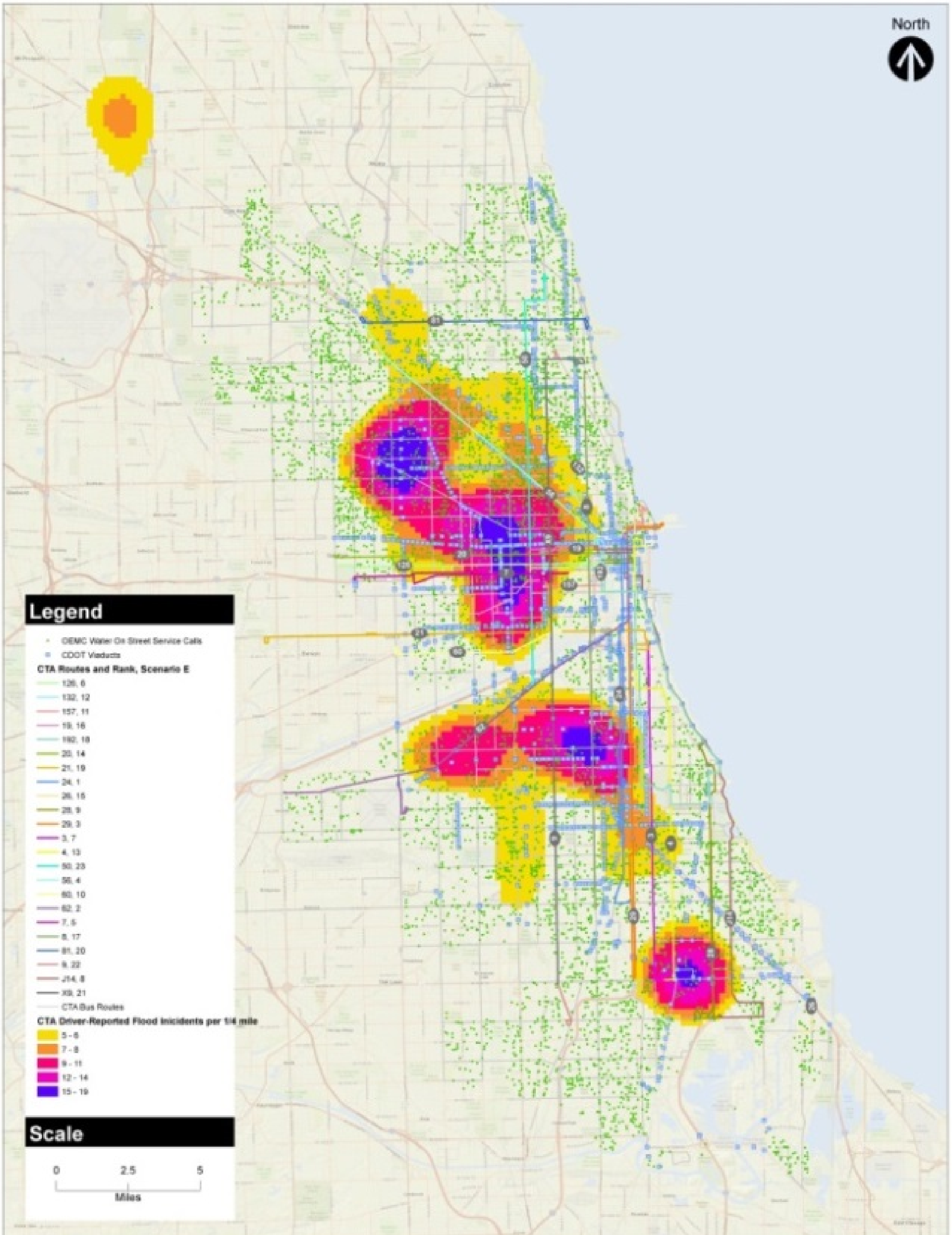
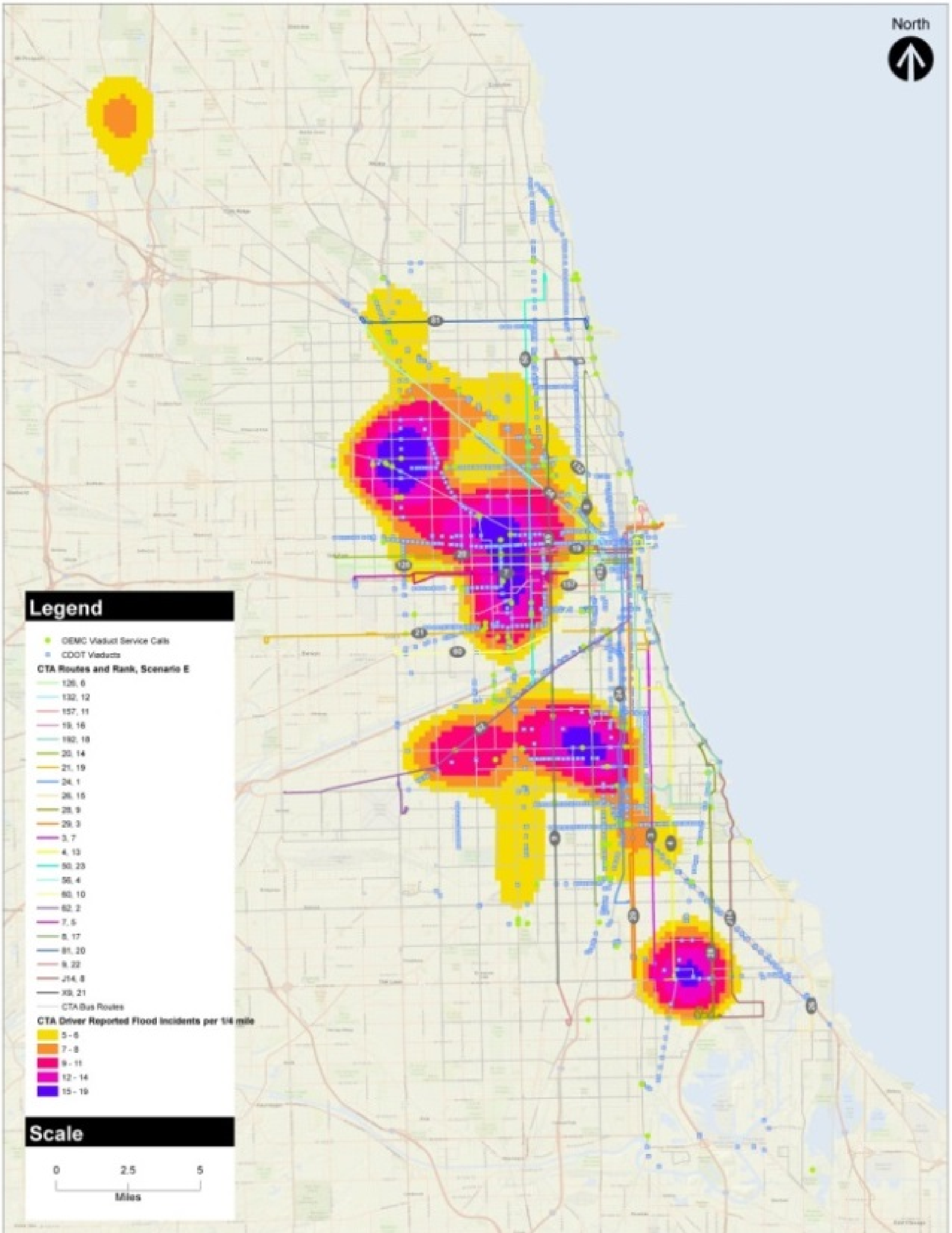


Figure 3: CDOT Viaducts, OEMC Viaduct Flood Calls, CTA Flood Reports, and CTA Scenario E Routes



March 2018

Figure 4: CTA Routes with Greatest OEMC 3-1-1 Calls on Street & Viaduct Flooding

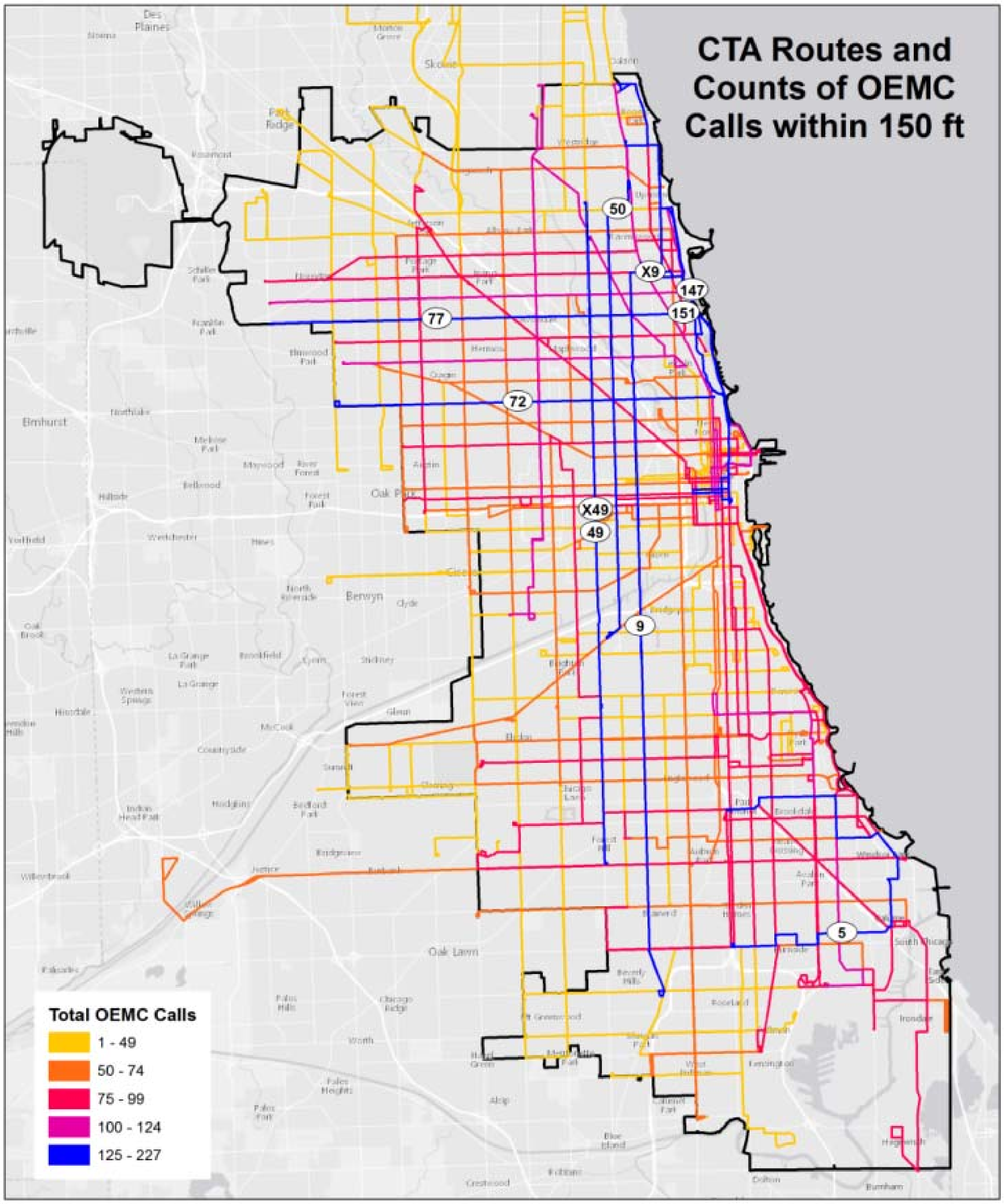
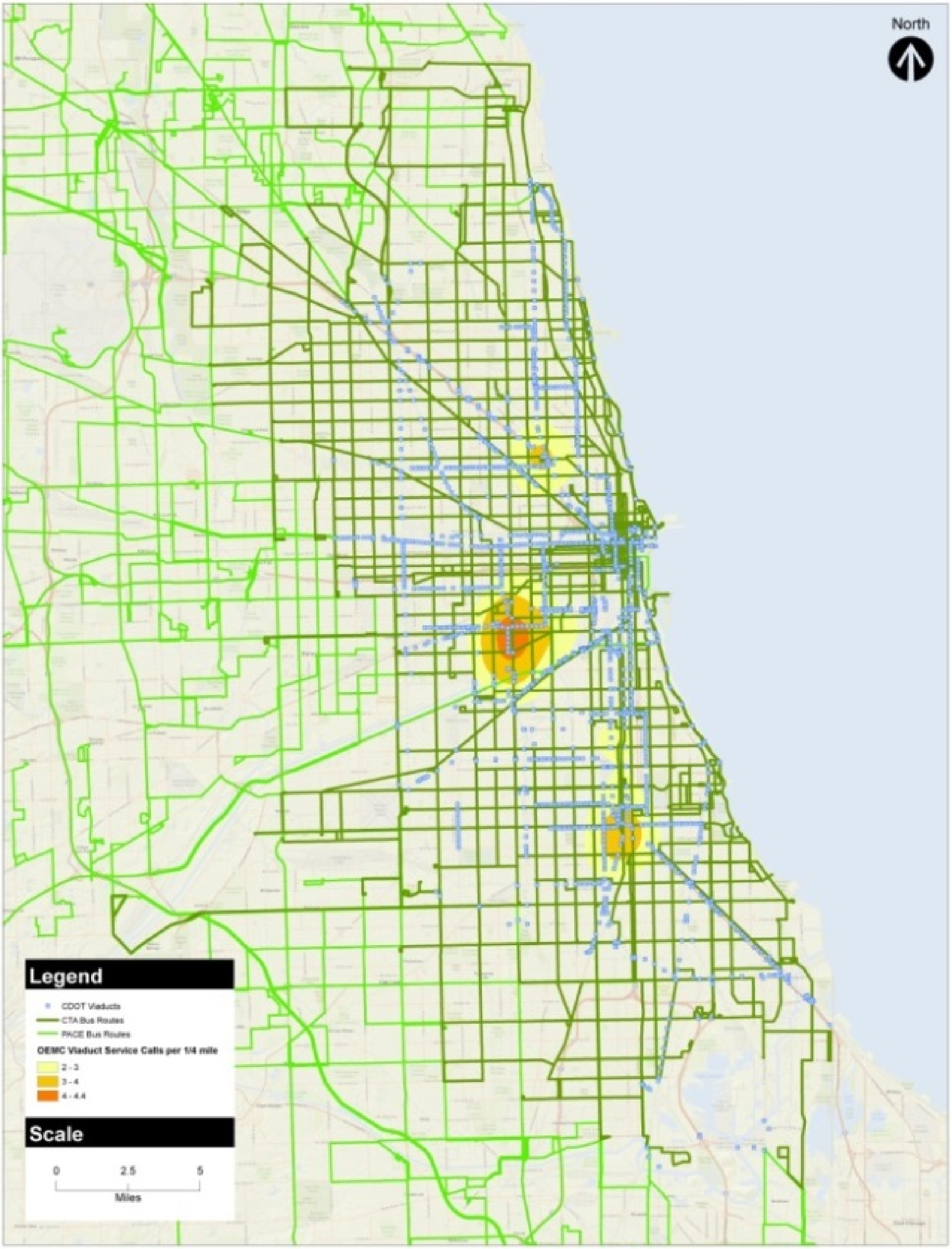


Figure 5: All Bus Routes, CDOT Viaducts and OEMC Viaduct Flood Calls



Analysis of riverine flooding – with its origins typically in overbanking of water bodies (rivers, streams, reservoirs, etc.) from large amounts of stormwater – are more often located in suburban / exurban areas and included the following base data:

- Locations of bus service interruption and route-level comments on typical flood problems reported by CTA staff
- Locations of bus service interruption and route-level comments on typical flood problems reported by Pace staff
- FEMA 100-year and 500-year floodplain boundaries
- Local updates on floodplain boundaries / inundation areas from counties (Cook/MWRD, DuPage, Will)

2.2.2 Methods for evaluating climate change data and potential future flooding patterns

2.2.2.1 Rainfall Frequency Adjustment for Climate Change

Stormwater and water resource engineers and scientists on this project team evaluated the potential increases in rainfall in the RTA service area by reviewing the climate change scenarios from the Chicago Area Climate Action Plan defined in the previous section. The increases for future climate change scenarios B1, A1B, and A2 were averaged and plotted as 2-, 10-, and 100-year adjustments on log-log paper to determine adjustments for other types of storms. These adjustments were then added to the Illinois State Water Survey's Bulletin 70 24-hr rainfall amounts, which likewise were plotted on log-log paper. Team members then interpolated existing and future rainfall frequency curves to identify the equivalent storm frequency for future rainfall events at mid-century 2017 and late-century 2017.

The term "Storm Recurrence Interval" refers to the chance or probability that a storm of a certain magnitude may occur or be exceeded in a given year. For example, a "100-year storm" has a 1 in 100 chance of occurring in any given year, or 1% chance (called the "Annual Exceedance Probability"). It does not mean that such a storm only occurs once every 100 years, and once happened, won't happen again in the same 100-year period.

Table 1: Mid-Century Adjusted Rainfall

Bulletin 70 Current Storm Recurrence Interval (Years)	Current Annual Exceedance Probability† (%)	Bulletin 70 24-hr Rainfall	ISWS Contract Report 2016-05 Mid Century 24-hr Rainfall Adjustment (in)	Adjusted Rainfall (in)	Equivalent Bulletin 70 Future Storm Recurrence Interval (Years)
1	100%	2.51	0.46	2.97	1.9
2	50%	3.04	0.55	3.59	4.3
5	20%	3.80	0.70	4.50	11.0
10	10%	4.47	0.83	5.30	24.0
25	4%	5.51	0.83	6.34	44.0
50	2%	6.46	0.83	7.29	85.0
100	1%	7.58	0.83	8.41	150.0
500*	0.2%	11.10	0.83	11.93	620.0

*Extrapolated

†Percent chance of occurrence in any given year; also called Annual Exceedance Probability (AEP) the percent chance storm is equaled or exceeded in any given year
*** Extrapolated*
Source: Illinois State Water Survey Contract Report 2016-05; ISWS Bulletin 70, AECOM and 2IM Group

Table 2: Late-Century Adjusted Rainfall

Bulletin 70 Current Storm Recurrence Interval (Years)	Current Annual Exceedance Probability (%)	Bulletin 70 24-hr Rainfall	ISWS Contract Report 2016-05 Mid Century 24-hr Rainfall Adjustment (in)	Adjusted Rainfall (in)	Equivalent Bulletin 70 Future Storm Recurrence Interval (Years)
1	100%	2.51	0.72	3.29	2.5
2	50%	3.04	0.83	3.87	5.4
5	20%	3.80	1.00	4.80	14
10	10%	4.47	1.15	5.62	28
25	4%	5.51	1.27	6.78	60
50	2%	6.46	1.38	7.84	110
100	1%	7.58	1.50	9.08	240
500*	0.2%	11.10	1.77	12.87	915

*Extrapolated

Source: Illinois State Water Survey Contract Report 2016-05; ISWS Bulletin 70, AECOM and 2IM Group

This generalized modeling of anticipated rainfall suggests storms of greater severity may occur more frequently in the future. That is….

For severe storms:

A 100-year storm mid-century could be like today's 150-year storm
A 100-year storm late-century could be like today's 240-year storm

For moderate storms:

A 5-year storm mid-century could be like today's 11-year storm
A 5-year storm late-century could be like today's 14-year storm

A 1-year storm mid-century could be like today's 1.9-year storm
A 1-year storm late-century could be like today's 2.5-year storm

2.2.2.2 Urban Flooding Methodology

To analyze the potential impact of future climate change and rainfall events of increasing severity and frequency over the next century on urban flooding patterns, water resource and stormwater specialists correlated rainfall data from recent storm events with recorded flood incidents from CTA and OEMC. A subset of recent storm events of varying frequencies were selected from the period 2013-2016 when CTA recorded flood incidents and OEMC 311 call data were available on the same dates. This data is presented in **Table 3** and **Table 4** below.

Table 3: Rain Storm Frequency – Analysis of Subset of Storms

Rain Storm Frequency									
	Storm Gage								
Storm Event	Midway			O'Hare			Palwaukee		
	Rain (in)	Duration (hrs)	Rec Interval	Rain (in)	Duration (hrs)	Rec Interval	Rain (in)	Duration (hrs)	Rec Interval
Minor Storms (100% to 500% chance in any given year)									
April 18, 2013	1	4	2 mo					nm	
April 19, 2015		nm		1.28	6	3.5 mo			
December 23, 2015	0.7	1	2.5 mo	0.7	1	3.25 mo	0.7	1	2.5 mo
February 2, 2016	2	10	2 mo	0.8	3	2 mo	0.8	3	2 mo
March 24, 2016	0.9	7	2 mo	0.9	7	2 mo	0.9	7	2 mo
January 17, 2017	1.2	24	2 mo	1.2	24	2 mo	1.2	24	2 mo
February 7, 2017	0.5	1	2 mo	0.5	1	2 mo		nm	
Moderate Storms (e.g., 1 Year Event (50% to 100% chance in any given year))									
April 19, 2015		nm					1.7	6	9 mo
June 15, 2015	1.47	5	1	2.5	12	2 yr		nm	
Severe Storms (e.g., 25 Year Event (5% chance in any given year))									
April 18, 2013				5.5	2.4	25 yr			

Table 4: Urban Rainfall Data Analysis - Selection of Storms

Storm Date	Frequency	Duration	Gauge Level	311 Calls	311 Call Density
Feb 7, 2017	<2-month	1hr	0.5"	249	1.1
January 16-17, 2017	<2-month	24hr	1.2"	374	1.6
March 24, 2016	<2-month	25hr	1.0"	241	1.0
June 15-16, 2015	2-month	11hr	1.2"	252	1.8
December 23, 2015	2.5-month	1hr	0.7"	213	0.9
Feb 7, 2017	2- to 6-month	1hr		50	3.7
April 9, 2015	4-month	6hr	1.3"	254	1.2
Feb 2-3, 2016	6- to 9-month	10hr	2"	149	2.8
July 23-24, 2016	1-yr	7hr	2.0"	166	0.8
Sept 17-19, 2015	2-yr	24hr	3.0"	202	0.9
June 15-16, 2015	2-yr	11hr	2.5"	297	3.1
July 23-24, 2016	5-yr	7hr	2.5"	5	0.9
April 17-18, 2013	5-yr	20hr	3.5"	179	2.0
April 17-18, 2013	15-yr	16hr	4.0"	381	4.0
April 17-18, 2013	25-yr	24hr	5.5"	257	4.9

Rainfall levels and durations of storm at three regional gages were analyzed to identify storm type. Data from the three regional gages at O'Hare, Midway, and Palwaukee airports were used because these gages provide hourly measurements, whereas other gages across the region may provide geographic breadth but do not generate data on an hourly basis. Hourly measurements are necessary to align rainfall severity with flood complaint calls. It is important to note that storm patterns are not always uniform; for any given storm, the rainfall levels and storm severity often varies across region and during the duration of the storm**.** **Figure 6** , **Figure 7**, and **Figure 8** illustrate such storm patterns for a selection of storm dates.

Figure 6: Sample Minor Storms (Radar Precipitation and Storm Recurrence Interval Extent)

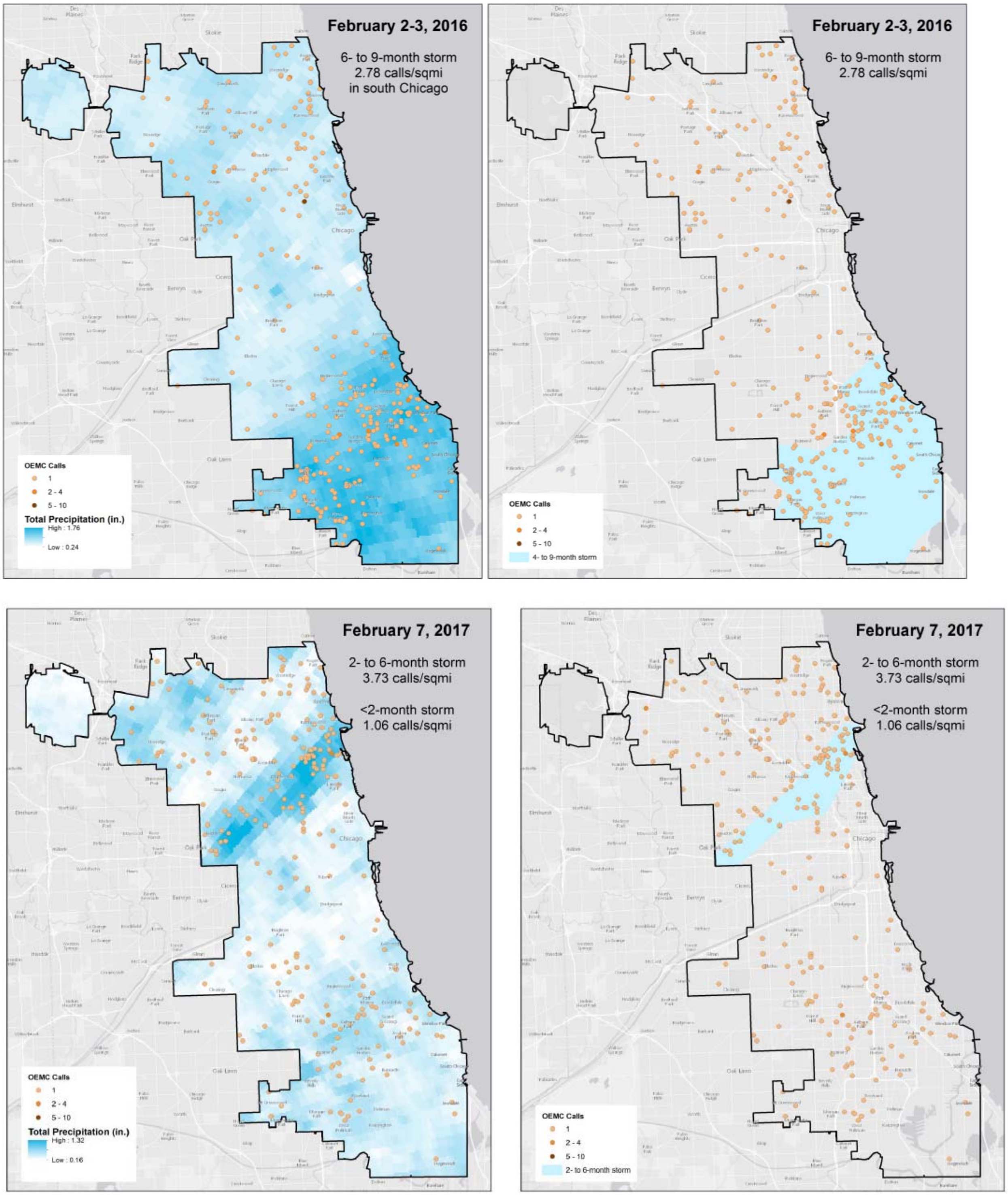


Figure 7: Sample Moderate Storms (Radar Precipitation and Storm Recurrence Interval Extent)

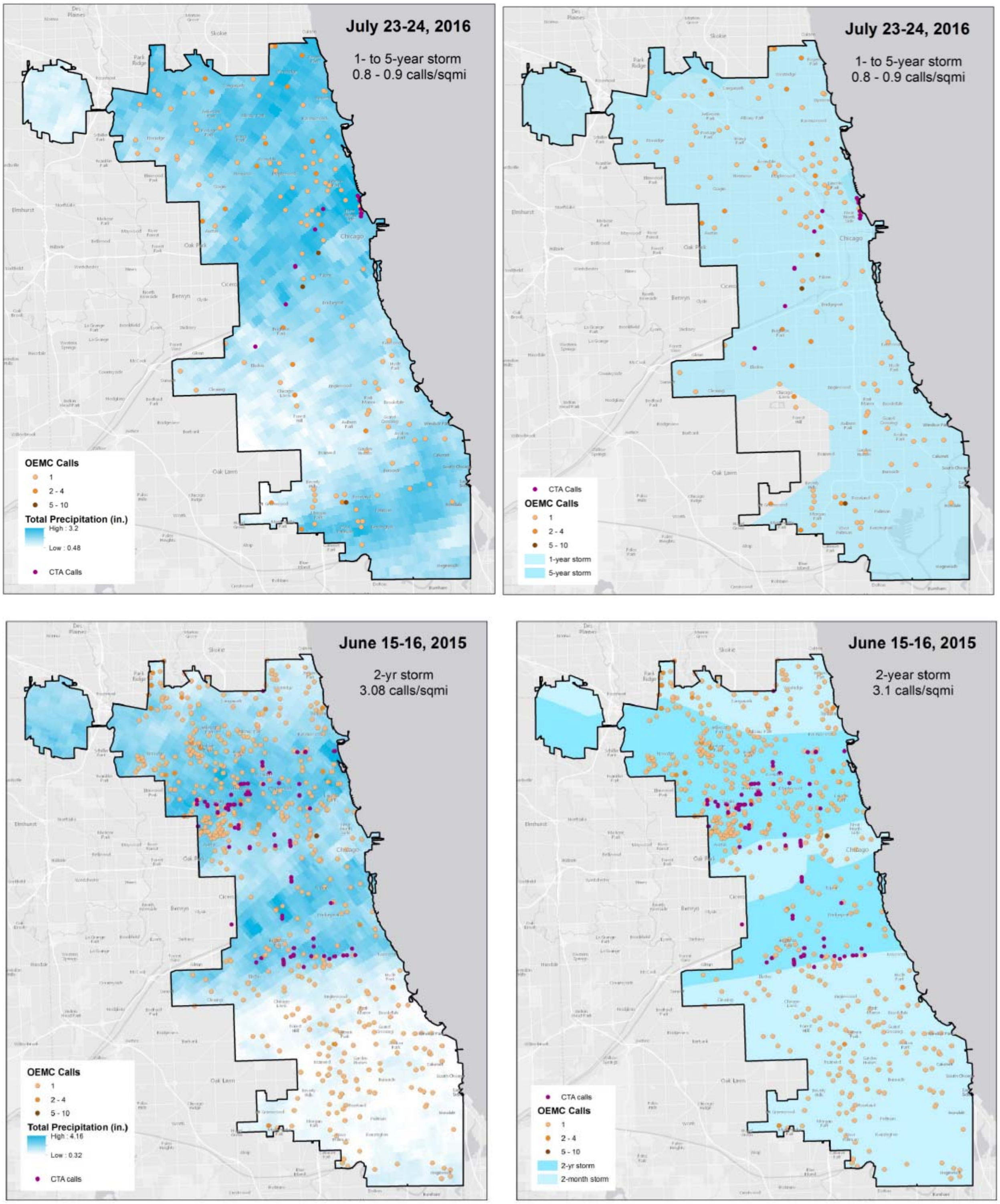
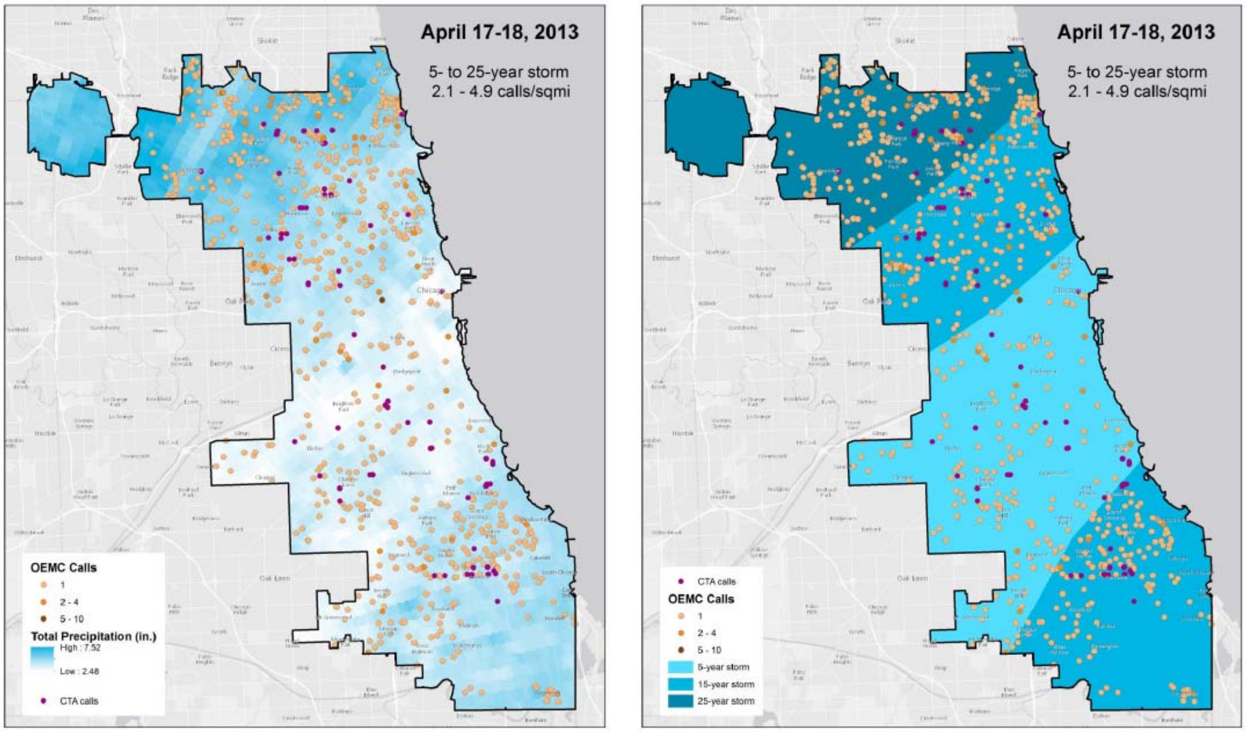


Figure 8: Sample Severe Storm (Radar Precipitation and Storm Recurrence Interval Extent)



CTA and OEMC flood complaint call data were correlated to the selected storms' rainfall data to identify spatial patterns and density of potentially recurring problems. It was noted that the density of OEMC 311 calls complaining about water on roadway and/or flooded viaducts increased with storm type, as shown in **Figure 9** and **Figure 10**. CTA drivers' reports of flood incidents generally found to correlate with moderate or more severe storms, that is, storms with 1-year recurrence intervals or greater.

This approach draws on a finite sample set of rainfall data *and* data documenting actual flood incidents reported by CTA staff or through OEMC via 311. While the available data is not particularly robust in terms of number of significant events and storm severity, the analysis provides valuable insight to areas of future risk for flooding that might impact CTA bus operations. The degree of severity of urban flooding can be subject to the human interventions by water departments to manage stormwater and sewer capacity across their networks and to discharge decisions at any given time. Therefore, this study cannot broadly draw spatial conclusions that areas currently prone to flooding will be larger or wider in the future – just that the intensity of flooding may be worse and/or more frequent. A more complex effort that models a greater base of rainfall, storm, and complaint data, together with dynamic sewer capacity management and/or hydraulic and hydrologic modeling may provide more precise conclusions but was beyond the schedule, scope and budget of this project.

Figure 9: OEMC 311 Calls in Minor to Major Storms

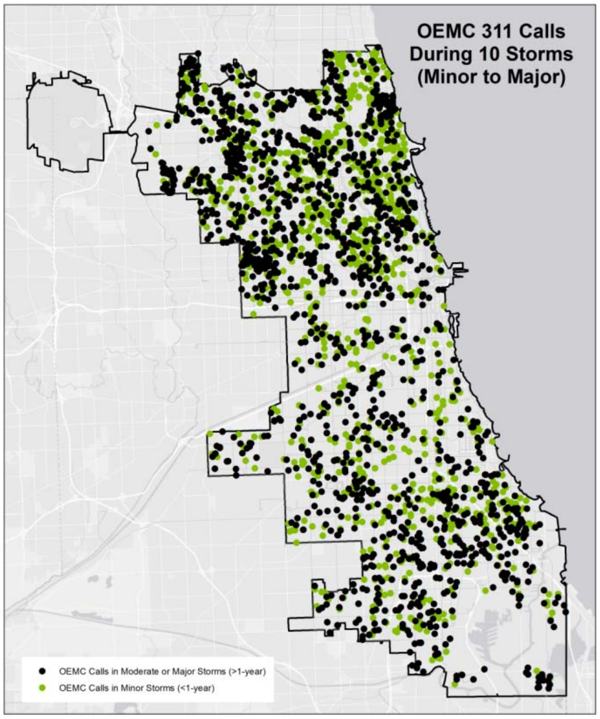
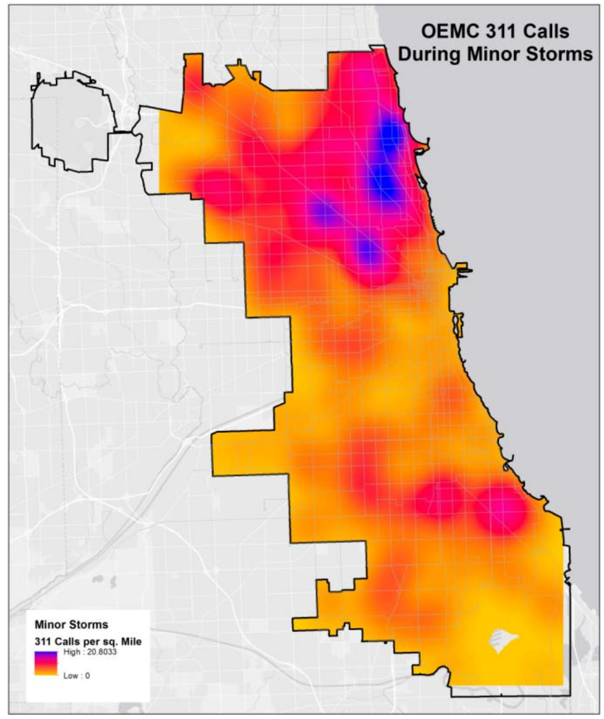


Figure 10: Density of Storms During Minor Storms (<1-Year Recurrence Interval)



2.2.2.3 Suburban/Exurban Flooding Methodology

The potential impact of future climate change over the next century on riverine and suburban/exurban flooding patterns and levels are available from a 2010 report by the US Army Corps of Engineers for several water bodies in the RTA service area. Water resource and stormwater specialists reviewed this information with a particular focus on the general areas through which Pace's Scenario E priority bus routes run. These include the Des Plaines River, Addison Creek, and Silver Creek. The storm profiles were reviewed to identify incremental surface elevation differences for various storm profiles. Table 5 below presents these differences for the Des Plaines River.

Table 5: Des Plaines River Elevations

Flood Event Water Surface Profile	Elevation Increment (ft)
1- to 2-year	2
2- to 5-year	2
5- to 10-year	1
10- to 25-year	1
50- to 100-year	0.8
100- to 500-year	2.4

Source: USACE, August 2010

Based on these incremental differences and the storm frequency shift identified based on future rainfall amounts in Section 6.2.2.1, revised 100-year floodplain limits were drawn in GIS approximately half way between the existing FEMA 100- and 500-yr flood plain limits. In the absence of complex hydraulic and hydrologic modeling, this broad-brush approach is appropriate for identifying locations impacted by future conditions. This exercise concludes that there was very limited spatial expansion of floodplain areas impacting bus routes. This project's initial screening of Pace bus routes for risk of flood interruption was based on defining risk areas including both the 100 and 500 year floodplain limits, so adjustments for future conditions were already within the zones noted as potentially risk-prone. A sampling of the minor locations where the floodplain limits shifted are in **Figures 11** and **12** below, which appear to be very minor.

Across the RTA service region, there are few areas with 500 year floodplain concerns that intersect with bus routes. The conclusion from this exercise is similar to the conclusion for urban flooding: locations that are currently prone to flooding may have more frequent or severe flooding in the future. Due to the time and resource intensity of the processing required to model and truth-check these estimated boundaries, and the fact that a critical number of Pace routes impacted by flooding are in the Des Plaines River watershed, future 100-year floodplain limit adjustments were only made to that river system.

Figure 11: Pace Routes with Enhanced Flood Zones (Des Plaines)

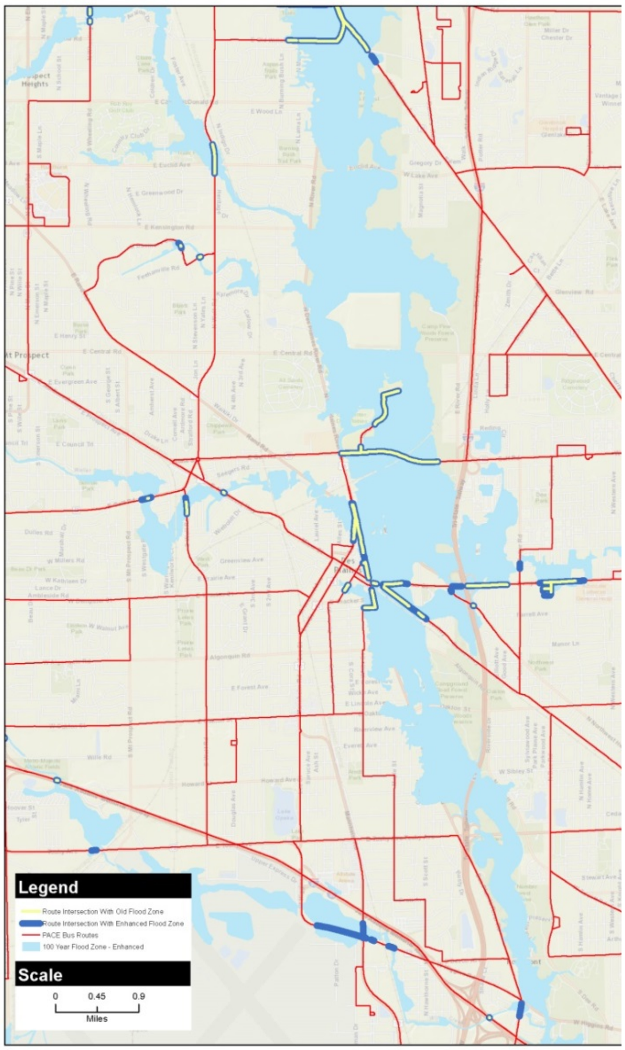
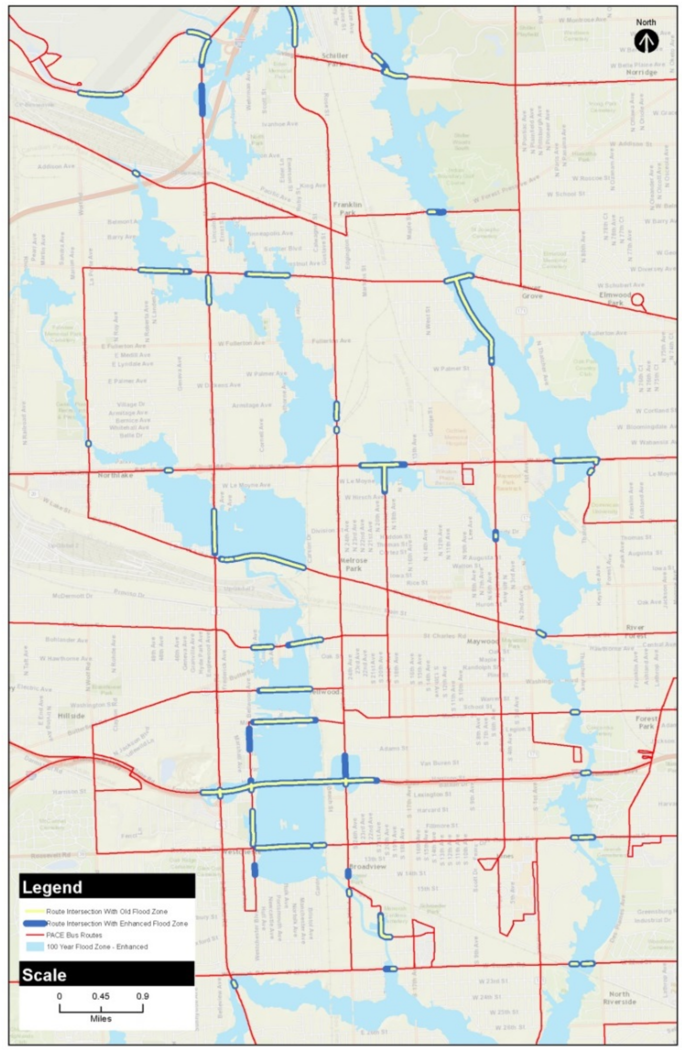


Figure 12: Pace Routes with Enhanced Flood Zones (Melrose Park)



Flooding Resilience Plan for Bus Operations

Appendix C: Best Practices

Prepared for the Regional Transportation Authority of Northeast Illinois

March 30, 2018

March 2018

Prepared for:

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March 2018

Table of Contents

Figures

Tables

Resilience Planning: Research and Active Programs

This technical appendix represents a summary of best practices in resilience planning and current local and national research.

1. Climate Change Resilience National Best Practices

1.1.1 FTA Climate Change and Adaptation Strategies

FTA's analysis and guidance on climate change preparedness for transit agencies has focused largely on asset management due to the high capital costs to repair or replace transportation assets after severe weather events. This research still holds relevance to transit operation strategy.

1.1.1.1 FTA Report 0001

Flooded Bus Barns and Buckled Rails: Public Transportation and Climate Change Adaptation (FTA Report No. 0001, August 2011) addresses climate change and resiliency planning. The report offers an overview of climate change impacts to transit and industry practices in climate change adaptation. As shown in **Figure 1**, the report finds that intense participation with resulting flooding of track, bus ways, tunnels, lots, and facilities are among the most likely transit-related impacts of climate change.

Figure 1: Four Main Transit Impacts of Climate Change

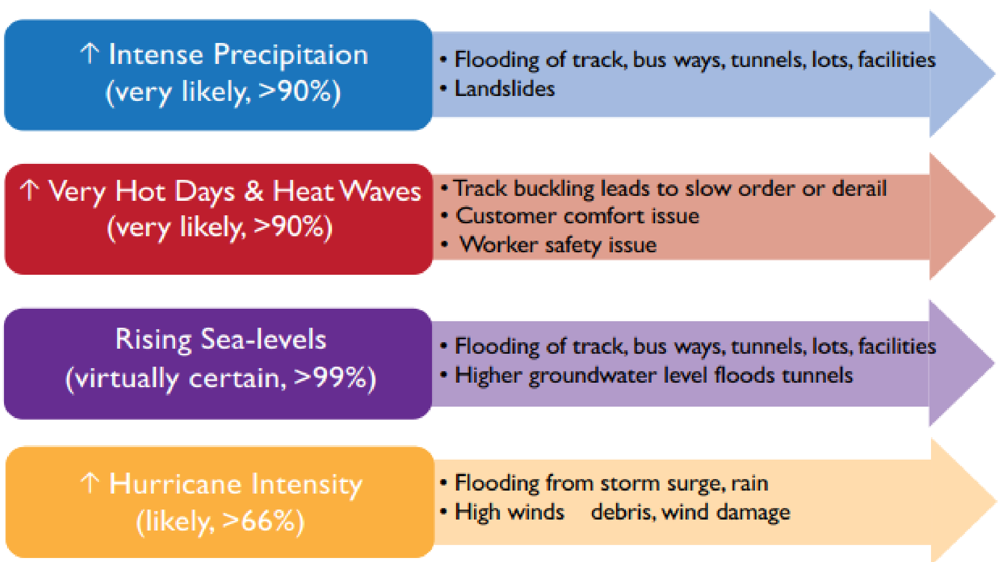


Image source: FTA Report 0001 (2011), p. 13.

The report looks at case studies of transit agencies' resilience projects across the country (for example, Nashville, shown in **Figure 2** and identifies commonalities and best practices. Several key elements of successful adaptation of resilience efforts include:

- Flexibility to deal with multiple layers of uncertainty (e.g., future greenhouse gas emissions, magnitude of climate change, how climate change will impact infrastructure and operations, future transit ridership levels)
- Broad involvement and buy-in
- Embedding climate change adaptation into existing work streams (e.g., state of good repair efforts, asset management systems, standard operating procedures)
- Prioritize "no regrets" strategies with multiple benefits even without climate impacts

- Plan for communication with customers
- Top-level external push
- Central point of coordination, including coordination with other infrastructure and service providers

In terms of adaptation strategies, the FTA groups them into four broad categories: maintain and manage, strengthen and protect, enhance redundancy, and retreat.

Looking at flooding in particular, the FTA advises moving assets out of harm's way, as they frequently occupy low-lying inexpensive land that is subject to flooding. Transit agencies should also ensure that major transportation facilities cannot be built in flood risk zones in future. Clearing debris from drainage systems is critical to prevent flooding; this can and should be done both before and during storm events to prevent flooding. Green infrastructure stormwater management features like rain gardens, stormwater ponds, pervious pavement, and native vegetation buffers along waterways can help to prevent localized flooding by reducing runoff from assets like park and ride lots, maintenance facilities, and paved roadway networks. However, while green infrastructure is helpful in mitigating future increases in stormwater runoff, such measures are normally not sufficient by themselves to resolve existing flood problems. More intensive measures such as capacity improvements, flood storage facility construction, or other types of physical system improvements are generally required.

In terms of emergency preparedness, response and recovery, the FTA report emphasizes the importance of Standard Operating Procedures (SOPs) for extreme weather events in light of their increasing frequency. As an example, the London Undergrounds has SOP for the various operations personnel and managers for varying thresholds of precipitation (0.6 inches, 1.4 inches, etc.) during a twenty-four hour period, and also identifies stations and track sections and circuits most vulnerable to flooding with the location of pumps and floodplains.

For bus operations, SOP relevant to storm events can include moving buses out of flood-prone areas, fueling fleet and staff vehicles prior to an emergency event, splitting a fleet between two or more locations to maximize the survival of vehicles, ensuring that hard copies of reroutes are available in case of communication system disruptions, etc.

In the case of transit-based evacuation, best practices include establishing evacuation routes and bus assignments in advance and communicating this to transit-dependent populations, coordinating with local school bus fleets to expand the pool of resources, and setting a maximum threshold at which operations are ceased to avoid jeopardizing transit personnel, passengers, and vehicles.

Figure 2: Nashville MTA Property (2010)

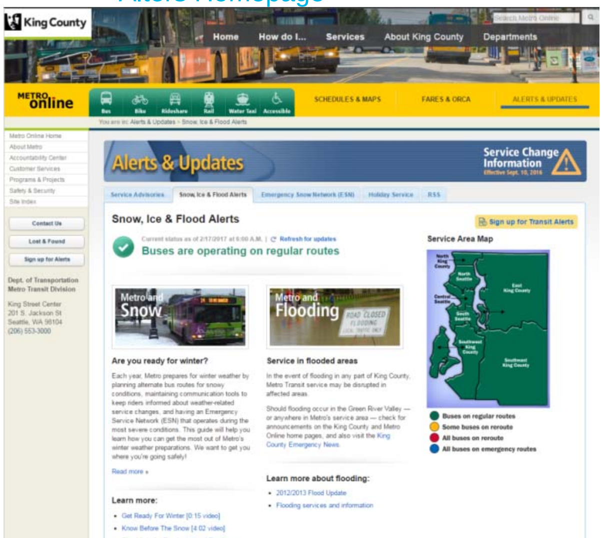
Image source: FTA Report 0001 (2011), p. 18.

Recommended Emergency Preparedness Guidelines for Urban, Rural, and Specialized Transit Systems (FTA, 1991) offers valuable information on vehicle operating and maintenance practices, but is not a source for current practices in information management and communications systems.

Case Study in Severe Weather Rerouting

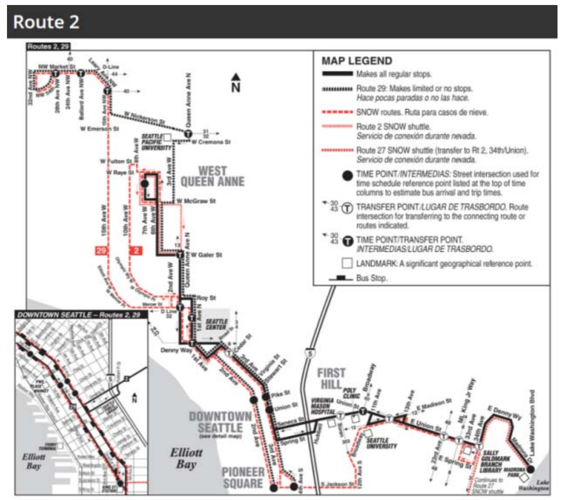
King County Metro Transit (KCMT) in metropolitan Seattle, WA, is considered at the forefront of the field in FTA Report 0001.[1] KCMT offers several helpful resources during severe weather events which represent industry best practices for severe weather transit network routing and customer service, though not necessarily system design for weather event resiliency. The KCMT website resources include:

- Specific snow, ice and flood alerts on the agency webpage (
-
- Figure 3: KCMT Snow, Ice and Flood Alters Homepage



Source: http://metro.kingcounty.gov/alerts/adverse-weather.html

Figure 4: Example of a KCMT route-specific snow routing map



Source: KCMT website

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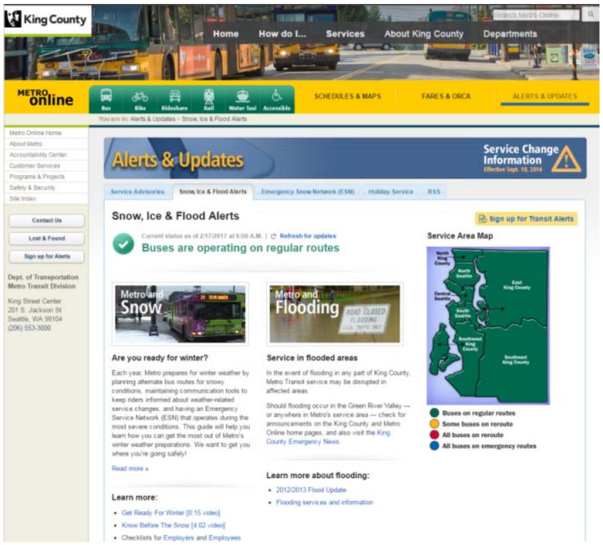
- Advance information on how to navigate the transit system during weather events
- Updated service advisories with reroute information
- A link to enroll in email or text message service alerts (general and route-specific) for a variety of conditions, including snow, ice and flooding
- A regional service map of the standard Emergency Snow Network (ESN), as well as individual ESN route maps (**Figure 4**)
- Coding symbols indicating the current level of system rerouting due to weather.

During its snow alerts, KCMT notifies customers by placing alert banners and other notification tools on the agency website, sending alerts via email and/or text message to those who have registered, and referring customers to routing information on the agency website, at major transportation centers, at transit stop information signage, and vehicle electronic display.

[1] Federal Transit Administration (2011). FTA Report No. 0001, page 53, Table 3-1.

Figure 3: KCMT Snow, Ice and Flood Alters Homepage



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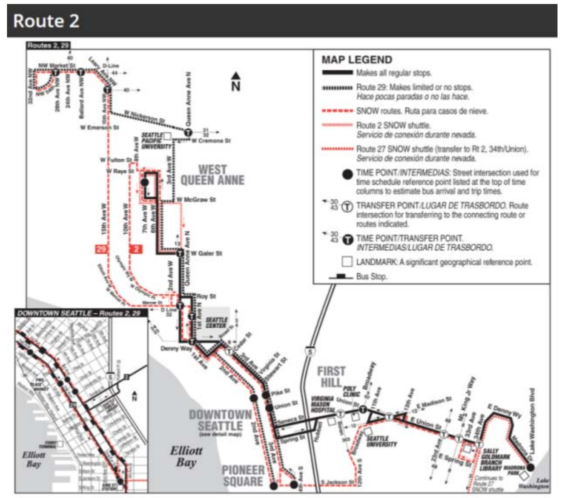


Source: KCMT website

1.1.1.2 FTA Report 0069

Transit and Climate Change Adaptation: Synthesis of FTA-Funded Pilot Projects (FTA Report No. 0069, August 2014) examines asset management in the face of increasing weather severity as part of a $1 million research effort announced in 2011. Pilot resiliency plans at seven transit agencies are described; locations include San Francisco, Chicago, Houston, Los Angeles, Atlanta, Philadelphia, and Seattle.

As an example, the Gulf Coast study (Houston, Galveston, and Tampa), identified the following strategies for dealing with flooding:

- Ensure new facilities are build outside the 100-year floodplain or elevated above it
- Coordinate with public works departments to ensure that debris is cleared from storm sewers
- Use agency operations experience to identify flood-prone route segments and preferred alternatives
- Educate riders about typical reroutes and procedures in case of flooding
- Identify SOP to reduce the impact of flooding on vehicle maintenance and other assets
- Establish data-gathering methods to better quantify the incidence and impacts of street flooding

FTA Gulf Coast Pilot Project

The Gulf Coast pilot project report also includes guidance on how to use GIS to assess vulnerability of transit assets to climate change. For the rainfall dimension of climate change, they use the following spatial data layers:

- Distance to 100-year floodplains (FEMA)
- Distance to any wetland type (NOAA 2006 land cover)
- Projected rate of change in precipitation, 2012-2050 (NCAR)
- Soil Porosity (SSURGO soil hydraulic conductivity field)
- Impervious Surfaces (NOAA 2006 land cover)
- Distance to streams (National Hydrological Dataset)
- Property Damage (FEMA-insured losses 1998-2009)

These data layers were scored on a scale of 0 to 100 for each climate change dimension and then normalized by the number of layers in that dimension and summed for all dimensions to derive a Climate Change Vulnerability Index to prioritize transit asset adaptation efforts. For example, in the Tampa area case study, this analysis showed the bus barn to have the highest degree of vulnerability due to exposure to hurricanes and sea-level rise.

Aside from the GIS analysis noted above, the report also researched more qualitative analysis of transit asset vulnerability, such as questionnaires. The report also included sample questions to better understand transit agency practices for service delivery, maintenance, operations, facilities, communications, etc., such as:

- What is maintenance staff role in the recovery effort (during and after) flooding?
- How are assets tracked or monitored (e.g., with vehicles being moved to different locations)?
- How are activities/expenses documented and reported for FEMA reimbursement?
- Historically, what level of maintenance (both in terms of cost and time) has been needed after flooding?
- Advance announcement of a reroute vs. unanticipated street flooding where normal route is underwater—who, how, what happens, and who communicates with whom? What are the policies for determining when drivers should reroute during street flooding events?
- Who assesses conditions and determines when and how services area restored to partial and then normal operations?
- What are policies/practices for Americans with Disabilities (ADA) passengers whose home or location is not accessible due to high water?
- Does your agency have contingency funds for costs due to unexpected impacts?
- What are the formal criteria or informal guidelines for when your agency decides to announce service disruption?
- What is the chain of command when communicating to the public on changes in service schedules as a result of flooding?
- For customer service lines, what is the call volume during flooding?
- What are some of the known barriers for communicating to passengers during changes in service, especially during flooding or other weather events?
- Have any facilities sustained damage during the last few floods? How and when were damages reported and later on repaired?
- What is the organizational structure for police/security forces and the risk management staff? What is the police department and risk management staff's role in the preparation and recovery process?
- Does the police department communicate or act as the liaison to emergency management services on behalf of the transit agency?

Relevant in particular to bus operations during flood events, this report makes specific recommendations to identify standard re-routes for routes frequently affected by flooding and make sure that the public is aware of alternative alignments. To ensure better planning and operations in the future, there should be a standard procedure to record flooding impacts to maintenance, facilities, and service delivery, as well as to use operators as "eyes on the street," reporting drainage issues like debris blocking stormwater drains.

In the case study of bus service provided by Hillsborough Area Regional Transit (HART) in the Tampa area, the agency handles street flooding by having the operators radio Dispatch with location and description of flooding. HART then sends a supervisor to observe the flooding and determines a necessary reroute onsite, which he/she conveys to Dispatch, which passes the information on to affected operators. The supervisor waits until the reroute is active to make a sweep of the affected bus stops to ensure that no riders are left at the stops (**Figure 5**). This procedure is similar to CTA's current SOP.

Figure 5: Flooding in HART Service Area, Tampa, FL

Image source: FTA Report 0072 (2013), p. 58.

1.1.1.3 FTA Report 0070

Climate change preparedness in terms of asset management at the Chicago Transit Authority (CTA) is the focus of FTA Report No. 0070, dated August 2013. The study concluded that climate change in terms of both extreme heat and precipitation events are likely to significantly impact CTA assets and operations. Historically, heavy rain results in higher bus transit ridership on weekdays and lower ridership on weekends. Potential disruptions include flooding in the right-of-way and particularly at viaducts and subway portals, as well as rail buckling, signal equipment failure, and increased energy consumption from extreme heat. The adaptation strategies focused on rail infrastructure. A life-cycle cost analysis (LCCA) model was developed to evaluate the return on investment of proposed solutions for right-of-way flooding, rail heat kinks, and signal house overheating. A positive return on investment was found only at higher severe event frequencies than baseline climate models predicted, but the study recommended that additional factors be considered beyond solely the LCCA analysis. Finally, the study made recommendations on how to integrate the adaptation strategies into standard business practices.

For bus service, the study identifies troubled viaducts and their impact on high-ridership routes as a key concern and recommends ongoing analysis to define more proactive and cost-effective approaches to this problem. However, for implementation strategies, the topic of roadway flooding impacts to bus operations was explored but not advanced in that study, but rather was deferred to the current study.

1.1.2 FHWA Climate Change and Resilience Initiatives

The FHWA 2012 *Climate Change and Extreme Weather Vulnerability Assessment Framework* is a guide to help transportation agencies assess their vulnerability to climate change and extreme weather events. The document identifies three primary components of the Vulnerability Assessment Framework:

Applicability of FHWA Vulnerability Assessment Framework to RTA Flooding Resilience Plan

The FHWA study defines vulnerability as “a function of a transportation asset or system’s sensitivity to climate effects, exposure to climate effects, and adaptive capacity.” In other words, to assess the vulnerability of the bus operations, we need to know how easily it is impacted by flooding, how often it does (or will) flood, and what resources it has available to respond to flooding. To do so, data is gathered on the existing bus system as well historical weather events and projected climate change, and then they are considered together to identify vulnerability.

Given that it is cost-inefficient to totally eliminate all vulnerabilities to climate change impacts, it is also important to consider the criticality of the potential impact and prioritize accordingly. For example, flood-prone routes that affect a larger number of people score higher in criticality than low-ridership routes or those with low levels of system connectivity.

1.1.2.1 Resilience Pilot Strategies and Results

The FHWA began the Climate Resilience Program in coordination with state DOTs and MPOs to carry out 19 assessments of extreme weather vulnerability and adaptation alternatives for their transit systems, building on the Climate Change and Extreme Weather Vulnerability Assessment Framework.

At the front end of the project, the study recommends a cross-disciplinary project team, including transportation planners familiar with the area's long-range planning and scenario planning, GIS specialists who can analyze and display transportation assets and analysis, asset managers with valuable datasets and expert knowledge, state climatologists and NOAA or university climate change research centers, maintenance or operations personnel with on-the-ground knowledge of current weather impacts, and design engineers for adaptation solutions.

Once the vulnerability assessment is completed, incorporating the results into standard decision-making processes is key. Examples of how pilot study areas have incorporated their results into transportation programs and practices include:

- WSDOT created a guidance tool that calls for project teams to review vulnerability assessment results and maps as part of their project plans.
- Virginia developed a decision support tool to prioritize projects in plans based on how they would address various issues, including climate change vulnerability.
- Boston MPO undertook a hazard mapping project that resulted in an interactive web tool that links TIP projects, the transportation network, areas exposed to flooding, storm surge, and sea-level rise.
- Los Angeles County MTA specifies that construction contractors must consider projected climate impacts in the design and construction of the project.
- MARTA in Atlanta is incorporating climate change data, impacts, and extreme weather vulnerability into its asset management system and software, as is Maryland State Highway Administration.

1.1.2.2 Pilot Project Findings for Transit

The Resilience Pilot Studies included transit assets in their assessment of the resilience of transportation network and potential adaptation strategies. For example, the New Jersey project looked at how changes in the 100-year floodplain would affect transit service. The study used climate models to project, temperature and precipitation and estimated the size of the 100-year floodplain to grow by 17%, 80%, or 178% in width under low, medium, and high emissions scenarios by 2100. This means that 1,120 transit bus route miles and 26 NJ Transit track miles will fall within the 100-year floodplain by 2100 under the medium emissions scenarios. By statistically adjusting the top width of the floodplain, the project team was able to conduct a high-level assessment of large study areas in such a way that only required a small fraction of the resources that would be required to run hydrological models.

The Oahu pilot study assessed the vulnerability of a transit facility which houses 1,800 employees, 531 buses, and 166 vehicles and is located near a bend in the Kalihi Stream, making it more prone to flooding. The facility was determined to have a high socioeconomic valuation under the climate change variables of storm surge, sea level rise, and heavy rain events, largely because the vehicles are needed for evacuations and to provide mobility to the community. This is addressed by redundancy at the Pearl City/Manana Baseyard, and by the fact that the assets are mobile and can be relocated in case of emergency. The largest issue was determined to be getting drivers and employees to report back to work after an emergency event.

While many of the projects focused on transportation asset management in the areas of highway, rail, and freight infrastructure, the Gulf Coast Study area included analysis of transit operations and infrastructure in the context of increasingly severe rain events. Phase II focusing on Mobile, AL, and its transit agency, Wave Transit, is especially useful for organizations wishing to carry out in-depth analysis of local climate change. They use very detailed and robust downscaling of climate models, hydrologic impacts, including sea level rise and storm surge and wave analysis. Wave Transit has two facilities—the downtown transfer center and Beltline facility that houses administrative, operations, and maintenance functions. The study examined the impact of sea level rise and heavy rain events on facilities, bus stops, and bus routes.

In this Mobile study, the project team created a framework to assess each transportation asset's criticality using mode-specific criteria related to (1) socioeconomic importance, (2) use and operational characteristics, and (3) health and safety role in the community. The scores were generated using quantified metrics like ridership, traffic modeling, cargo volumes, and qualitative expert judgment. Criteria for defining criticality in transit assets include:

- Serves economic centers (assets that provide access to important economic activity and employment centers may be critical for maintaining functioning of local and regional economies)
- Multi-modal linkages (whether an asset provides access to other modes of transportation. Multi-modal linkages help to maintain the functioning of the entire network)
- Ability to serve transit dependent populations (including low-income, elderly, or physically disabled persons. These individuals would be unable to get to their jobs, medical appointments, grocery stores, or other important facilities without transit)
- Ability to serve environmental justice populations (can include low-income and minority groups. Serving these populations helps to ensure that communities are treated equally and fairly with respect to access to transportation resources)
- Type/variety of services and fleet size (e.g., fixed-route, demand-response, and others, which, together with fleet size, can give a sense of the demographics of the population that may be solely reliant on transit and the size of the population that could be served during critical events)
- Facilities (location could be critical for storing or deploying vehicles, as well as supporting first responders)
- Role in evacuation (either identified as an evacuation route or fulfilling a role during weather emergencies and evacuations)
- Access to medical, health, and safety facilities (whether an asset provides direct access or materials to hospitals or other health and safety facilities that are vital for health and human services)

The assets identified as critical using this framework were then screened for vulnerability to extreme weather events. Vulnerability was scored based on three indicators: exposure, sensitivity, and adaptive capacity. The 11 critical transportation assets deemed vulnerable were then the subject of detailed engineering assessments, demonstrating unique methodologies and results.

1.1.2.3 Best Practices Based on Participant Feedback and Exchange

Summary comments from the peer exchange, based on the 2012 FHWA publication, *Adaptation Peer Exchanges Final Report,* include the following:

- Climate change data can be overwhelming, and there are not yet established best practices for the field. Strong leadership is critical, as well as guidance from the State on which data sources and climate scenarios to consider.
- Resources are limited, and it can be challenging to devote them to this area when maintaining a state of good repair and the status quo tends to take precedence. Integrating climate change vulnerability assessment and adaptation into asset management and emergency management decision-making processes is considered a best practice among participants. Long-range

planning can also be an appropriate process in which to incorporate climate change consideration.

– Collaboration and engagement with stakeholders were cited as key strategies to help facilitate information-sharing and coordinated planning processes at different geographic scales. It is also helpful in communicating the need for climate change adaptation, in which case different terms are recommended, such as “extreme events,” “event management,” multi-hazard management,” and “resilience.” Adaptation can also be framed as better planning, responsible risk management, saving money by preventing impacts rather than cleaning up after them. It can be helpful to use past events to help communicate the meaning, as well as explaining about how the climate is already changing in the local area.

Best practices from the 2013-2015 pilot projects include:

– Defining the scope and project scale at the outset, using existing studies and stakeholder expertise
– Working closely with maintenance and operation staff during the vulnerability assessment to take advantage of institutional knowledge
– Screening assets qualitatively to avoid wasting resources if local knowledge is easily obtainable
– Using existing data and vulnerability assessment tools and indicators (e.g., exposure, sensitivity, adaptive capacity, and criticality). Indicator libraries have been developed in previous FHWA studies, including things like AADT, detour length, pavement condition, and evacuation route status (**Figure 6**).
– Using maps and other visualization tools to engage stakeholders
– Leveraging existing adaptation tools, processes, and datasets when evaluating adaptation alternatives. Examples include the General Process for Transportation Facility Adaptation Assessments developed by the Gulf Coast Study Phase II, REMI economic model, travel demand models, cost-benefit analysis, triple bottom line analysis, T-COAST model, etc.

Figure 6: Sample Vulnerability Indicators

Vulnerability Component	Indicator	Asset Type: Roads	Bridges	Culverts	Pipes	Pumps	Rail	Climate Stressor(s)
Exposure	Demonstrated past exposure	X	X	X	X		X	Heavy Precipitation
Exposure	Whether asset is located in FEMA 100-year flood plain	X	X				X	Coastal Flooding, Heavy Precipitation
Exposure	Elevation relative to nearest FEMA flood zone	X	X				X	Coastal Flooding, Heavy Precipitation
Exposure	Depth of inundation in FEMA 100-year floodplain	X	X				X	Coastal Flooding, Heavy Precipitation
Exposure	Percent of segment inundated under given scenario	X	X				X	Coastal Flooding, Heavy Precipitation
Exposure	Distance to nearest FEMA flood zone	X	X				X	Coastal Flooding, Heavy Precipitation
Exposure	Segment within identified chronic drainage issue areas*	X						Heavy Precipitation, Coastal Flooding
Exposure	Modeled SLR Inundation Depth	X	X					Coastal Flooding
Exposure	Modeled Surge Inundation Depth	X	X					Coastal Flooding
Exposure	Proximity to Coastline		X					Coastal Flooding
Exposure	Whether asset is located within annual high tide due to sea level rise*	X						Coastal Flooding
Exposure	Whether asset is located within daily high tide due to sea level rise*	X						Coastal Flooding
Exposure	Segment intersects with existing daily high tide*	X						Coastal Flooding
Exposure	Segment within identified chronic sea level issue areas*	X						Coastal Flooding
Exposure	Located at low elevation in a coastal area*	X	X	X				Coastal Flooding
Exposure	Change in Total Annual Precipitation		X					Heavy Precipitation
Exposure	Percent change in precipitation quantity constituting 24-hour 100-year event	X						Heavy Precipitation
Exposure	Percent change in precipitation quantity constituting 24-hour 30-year event			X				Heavy Precipitation
Exposure	Percent change in precipitation quantity					X		Heavy Precipitation

Source: FHWA 2013-2015 Climate Resilience Pilot Program: Outcomes, Lessons Learned, and Recommendations (2016), p. 25.

1.1.3 Other Climate Change Research

The Transportation Cooperative Research Program (TCRP) is has completed a synthesis on the subect of severe weather event re-routing. *TCRP A-41: Improving the Resiliency of Transit Systems Threatened by Natural Disasters* was completed in May 2017. The findings and a database and handbook of guidelines and tools for practitioners are to be published as *TCRP Web-Only Document 70* (publication pending as of December 2017).

The American Public Transportation Association (APTA) developed a white paper in November 2012 titled “Acts of Nature & Public Transportation.” This paper builds on FTA Report 0001 and responds to dramatic recent events, including Super Storm Sandy of October 2012. It notes the importance of conducting risk assessments and pursuing adaptation strategies and that these adaptation strategies should include a mix of maintaining a state of good repair in response to acts of nature, as well as hardening the assets to withstand extremes and enhancing redundancy to avoid loss of service for transit users. Infrastructure that cannot be adapted should be relocated or abandoned. The paper highlights that as of 2012, transit agencies in the U.S. already face over $77 billion in deferred maintenance needs, and that severe weather events will further stress infrastructure that is already in need of investment. It identifies the need for additional federal support to protect the safe and reliable provision of public transportation.

2. Existing Local Climate Change Resilience Studies and Policies

2.1 RTA

2.1.1 Green Transit Plan

In 2012 RTA published the *Green Transit Plan*, which quantifies the environmental benefits of transit and develops strategies and action steps to improve the sustainability of the Chicago region. It builds on *Chicago Climate Action Plan* and *GO TO 2040* goals to reduce citywide and regional greenhouse gas emissions to 25% below 1990 levels by 2020, and 80% below by 2050.

According to the study, by removing over one million cars from the road each weekday, transit saves more than 750 million gallons of gas each year and prevents 6.7 million metric tons of greenhouse gases from being released (the transit network itself produces only 1.4 million metric tons of greenhouse gases). Furthermore, without transit, we'd need an additional 30 highway lanes to accommodate all of the additional VMT by private automobile.

Green Transit Plan identifies three strategies to improve the sustainability of the Chicago region: grow ridership and market share, promote transit-oriented development, and improve operational efficiency. Growing ridership can be achieved by making targeted improvements to technology (trip-planning apps, seamless regional fare payment platforms), and upgrading the infrastructure and enhancing the service to attract new riders and keep the existing ones. This could include upgraded bus stops, new rail cars, rail transit extensions and bus rapid transit service.

To promote TOD, providing information and technical assistance to local governments is of critical importance, as they are the ones to put the zoning ordinances and TOD entitlement processes in place. RTA and CMAP have supported this by sponsoring or lending expertise to the development of local plans, as well as by engaging developers to vet the plans to ensure that the real estate conditions are right for TOD at a given location.

For operational efficiency, the plan highlights new initiatives or strategies to increase fuel economy in service and support vehicles, conserve electricity and natural gas in agency assets, and identify new opportunities to incorporate renewable energy in the agency's operations.

Measures to adapt to a changing climate get special recognition in this plan. As part of sustaining long-term transit ridership and growth, the transit agencies "should continue to develop and implement plans to lower the risk of service disruptions due to climate change."

2.2 Chicago Metropolitan Agency for Planning

2.2.1 Climate Resilience Strategy Paper

While the Chicago Metropolitan Agency for Planning (CMAP) created regional indicators and targets related to greenhouse gas reduction in prior planning work, climate resilience is a new policy topic for CMAP in the ON TO 2050 plan, not having been included in the GO TO 2040 plan. This strategy paper develops the agency's first recommendations of building climate resilience through land use and infrastructure planning, economic development, capacity building, and natural resource management. Other agency efforts to combat climate change include the creation of emissions inventories, influencing transportation programming to reduce emissions, providing local technical assistance to develop sustainability plans and guidelines, developing a stormwater analysis methodology to address urban flooding, among others.

The report notes that climate change is having increasingly significant impacts on transportation infrastructure, e.g. bridge deterioration, buckled rails, outage in road and rail networks, and increasing maintenance costs. Other areas of impact described include land use, natural resources, the regional economy, and climate-vulnerable populations.

The Climate Resilience Resource Group identified 3 overarching principles guiding the strategies:

1. Responsive and robust infrastructure
2. Participatory and integrated processes
3. Equitable reduction of vulnerability

The main themes and strategies include:

Themes	Strategies
Planning for Climate Change	• Achieve greater livability through resilience planning • Integrate resilience policies into existing planning processes Update development regulations to prepare for a changing climate
Promoting Climate-Resilient Infrastructure	• Update infrastructure design standards • Encourage infrastructure that provides multiple benefits • Protect critical assets
Building Resilient Transportation Networks	• Strengthen transportation infrastructure to withstand climate changes • Ensure multiple transportation options • Adopt smarter transportation infrastructure management
Addressing Climate Change through Natural Resource Management	• Increase biodiverse ecosystems • Support adaptive management of water resources • Build climate resilience through green infrastructure
Building Resilience in the Energy Sector	• Increase low- and zero-emissions generation • Strengthen energy infrastructure for a changing climate • Support decentralized energy generation and distribution
Fostering Economic Resilience	• Reduce community vulnerability to climate change • Increase the resilience of freight networks • Build resilience for the region's economic clusters • Prepare agricultural resources for climate change
Building Capacity for Resilience Planning	• Building community capacity • Provide data to build climate literacy and facilitate informed decisions • Explore a platform for coordinating regional resilience initiatives

Source: CMAP. Climate Resilience Strategy Paper, p. 36. (2017)

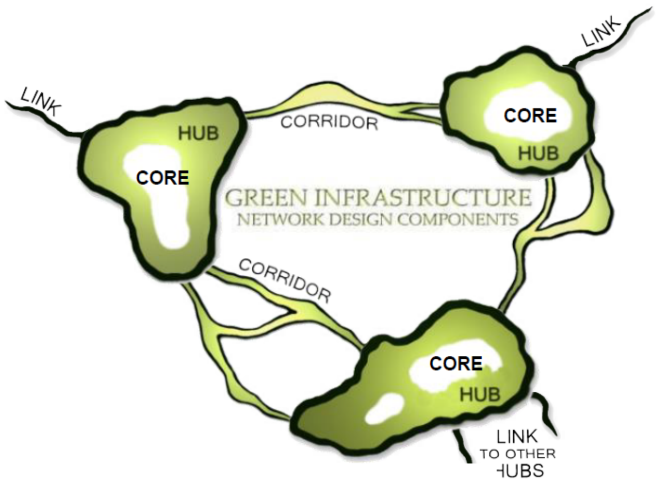
2.2.2 Integrating Green Infrastructure Strategy Paper

This paper builds on the green infrastructure analysis and planning included in GO TO 2040. GO TO 2040 set several green infrastructure goals at different scales:

- Increase acres of conservation open space from 250,000 to 400,000
- Provide 4 acres of park land per 1,000 people for all residents
- Provide 10 acres of park land per 1,000 residents for 70% of residents
- Linking open space areas and local parks via functional connections like greenways & trails by adding 1,348 miles of new greenways
- Emphasize the importance of green infrastructure best management practices in stormwater management and site planning.

The policy refinement framework proposed in this strategy paper is based on GO TO 2040's core-hub-corridor model, depicted in **Figure 7**, along with four key themes: protecting ecological cores, encouraging green infrastructure in community-scale green spaces, greening hardscapes, and accounting for co-benefits.

Figure 7: Green Infrastructure Network Design Components



Source: CMAP. GO TO 2040.

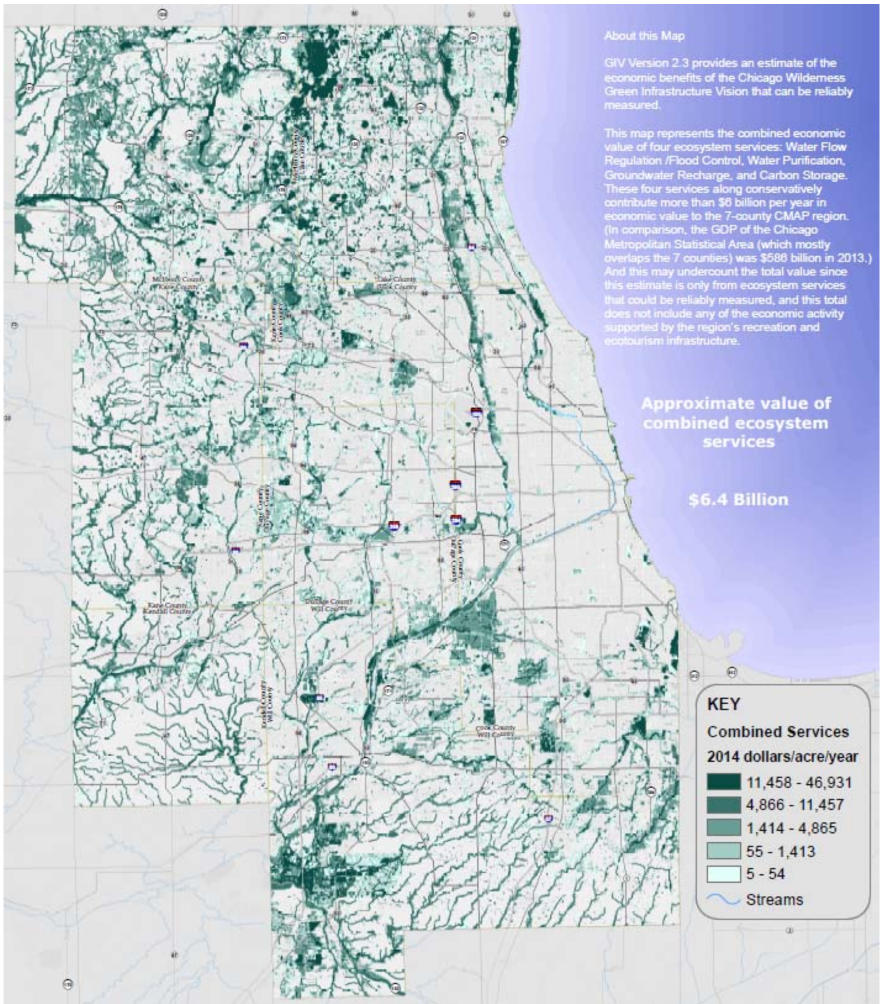
Regarding ecological cores, CMAP has updated the data underlying the Green Infrastructure Vision 2.0, which can be used to identify and assess the ecological characteristics of important natural assets. This, in turn, can be used to prioritize community- and site-scale strategies to support ecological processes and thus strengthen natural assets. The strategic placement of community- and site-scale green infrastructure is highlighted as a mean to bolster hubs, and the study recommends targeting areas by identifying the ecological characteristics, such as soil types, that make them suitable for green infrastructure.

In community-scale green spaces, CMAP recommends increasing the co-benefits of parks, for example, using recreation-friendly stormwater management techniques (i.e., a sunken ball field that can effectively absorb stormwater, or designing a naturalized wetland rather than detention ditch). Aside from community parkland green spaces, communities can implement green infrastructure on private land or rights-of-way, with community programs like Space to Grow providing incentive programs and partnerships to build awareness and capacity. Furthermore, municipalities can require than new developments or significant redevelopments include green infrastructure designs.

Chicago had 556,000 acres of impervious cover as of 2012, and greening these impervious surfaces and rooftops with green roofs, permeable paving in parking lots, bioswales and other measures in transportation rights-of-way—which have a shorter design life and thus are more easily renewed and updated. In terms of reducing the rate of imperviousness, this will depend largely on denser and more compact development (especially in the suburbs, which have much higher rates of imperviousness creation), as well as revitalization of existing communities that are shrinking and thus have underutilized infrastructure and development.

Finally, due to financial constraints that limit enthusiasm for environmental priorities, it’s important to emphasize the economic value of conserving natural resources. Recent research by The Conservation Fund shows that over 800,000 acres of land in the Green Infrastructure Vision contribute about $6.4 billion of economic value in the form of flood control, water purification, groundwater recharge, and carbon storage (**Figure 8**). Being able to quantify the benefits in this way can help with messaging the importance of green infrastructure policies. For example, CNT provides a Green Values Stormwater Calculator that estimates the value for site-scale green infrastructure best management practices, and the McHenry County Consolidated Economic Development Strategy showed that the value of the green infrastructure was equal to 18% of the total equalized assessed value of the county in 2014. For quality of life benefits, research by CMAP and the Chicago Regional Trees Initiative on unban heat island effect, climate resilience, and urban forestry are underway and may be included in future projects.

Figure 8: Ecosystem Services Aggregated Value



Source: *CMAP Green Infrastructure Vision 2.3 (2014)*

2.2.3 Water Resources Strategy Paper

As noted in this strategy paper, CMPA is involved in wastewater planning, watershed-based planning, nonpoint source pollution reduction, the Illinois Volunteer Lake Monitoring Program, as well as technical assistance and guidance documentation. Specific policy areas in this study include water quality; water service, infrastructure, and facilities; water source availability and quality constraints; water withdrawal management and source protection, and waterways, water bodies, recreation, and habitat.

Several of the action items are of relevance to the issue of flooding and its impact on bus operations. CMAP recommends adopting an integrated water resource management, such as One Water, in order to integrate the planning and management of water supply, wastewater, and stormwater as a single integrated system. One Water also seeks to minimize or avoid impact on the environment. Collaborative and stakeholder-based planning is key, in addition to innovative and best practices.

CMAP also recommends improving data collection availability. Funding for the agencies that gather, process, and publish data has been inconsistent, hampering the maintenance of high-quality datasets. Of relevance to this project, CMAP also supports expanded research into the impacts of urbanization and water use.

In terms of coordinating land use planning and water resource planning, this strategy paper prioritizes assistance to communities that would benefit from best practices such as green infrastructure, urban retrofit, compact and water-efficient development patterns that minimize runoff and maximize infiltration, integrated planning to avoid damaging water resources, and enhanced local stormwater requirements, among others. Emphasizing the connection between open space conservation and protecting water supply has also proved a viable means of achieving water resources goals.

Finally, establishing consistent funding to maintain or expand water system infrastructure is key to implementing the action items included in this strategy paper. In particular, green infrastructure can be carried out at many different levels of governance and additionally has cross-jurisdictional benefits (i.e., one community may have many opportunities that may help multiple neighboring communities). Coordination and sharing of resources is important to achieving these co-benefits. Other steps to improving fiscal management and efficiency include asset management, full cost pricing that incorporate life cycle costs, shared services across municipalities, innovative financing such as public-private partnerships, tax increment financing, and greater application of state revolving loan funds. Private capital investment could also be applied to green infrastructure practices.

2.2.4 Highway Operations Strategy Paper

In a 2017 strategy paper addressing needs and opportunities for improved highway operations, CMAP acknowledges that climate change is already causing more frequent road flooding and heat- and cold-related pavement failures. The agency recommends that operating agencies such as IDOT, the Tollway, county and municipal departments of transportation perform an analysis of road performance under severe weather conditions to highlight critical locations for management and operations changes and to plan for detours and traffic management needed to support them. It will be important to collect and analyze information about how facilities perform under various weather scenarios so agencies (primarily highway departments, but also bus transit operators) can develop planned responses to weather events, such as focusing incident management resources on locations that are known to be especially impacted by severe rainfall to reduce congestion and avoid diversions.

CMAP notes that pavement flooding information has not been collected on a regional basis, and there is no standard pavement flooding reporting system. Consequently, from a regional perspective, the impact of flooding on roadway operations is unknown; negative incidents impact not only the flow and performance of the roadways for passenger and freight vehicles but also for transit vehicles that use the region's highways, freeways, tollways and arterials. In this strategy paper, CMAP recommends that it develop a regional pavement flooding reporting system to help plan for flood events.

2.2.5 Stormwater Management Strategy Paper

After illustrating the prevalence of flooding in the Chicago region and highlighting that climate change is anticipated to bring yet more flooding, this strategy paper outlines a policy framework to address flooding problems. The framework includes 5 themes:

Recommended actions	Implementation strategies
Identify and communicate flooding risk and exposure	• Update precipitation data and floodplain maps • Continue advancing watershed and sewer modeling efforts • Enhance understanding of urban flooding risk • Assess impacts to vulnerable populations, communities, and critical assets • Communicate risk and exposure to residents, businesses
Advance planning efforts to reduce current and future risk	• Continue advancing stormwater management ordinances • Update municipal plans and ordinances to better manage stormwater • Coordinate flood reduction and water quality improvement efforts • Enhance floodplain management compliance • Prepare for future floods
Invest and maintain grey and green infrastructure	• Enhance maintenance of grey and green infrastructure • Protect and expand open spaces to enhance stormwater management • Encourage coordinated investments with green infrastructure • Establish dedicated revenue streams for stormwater management

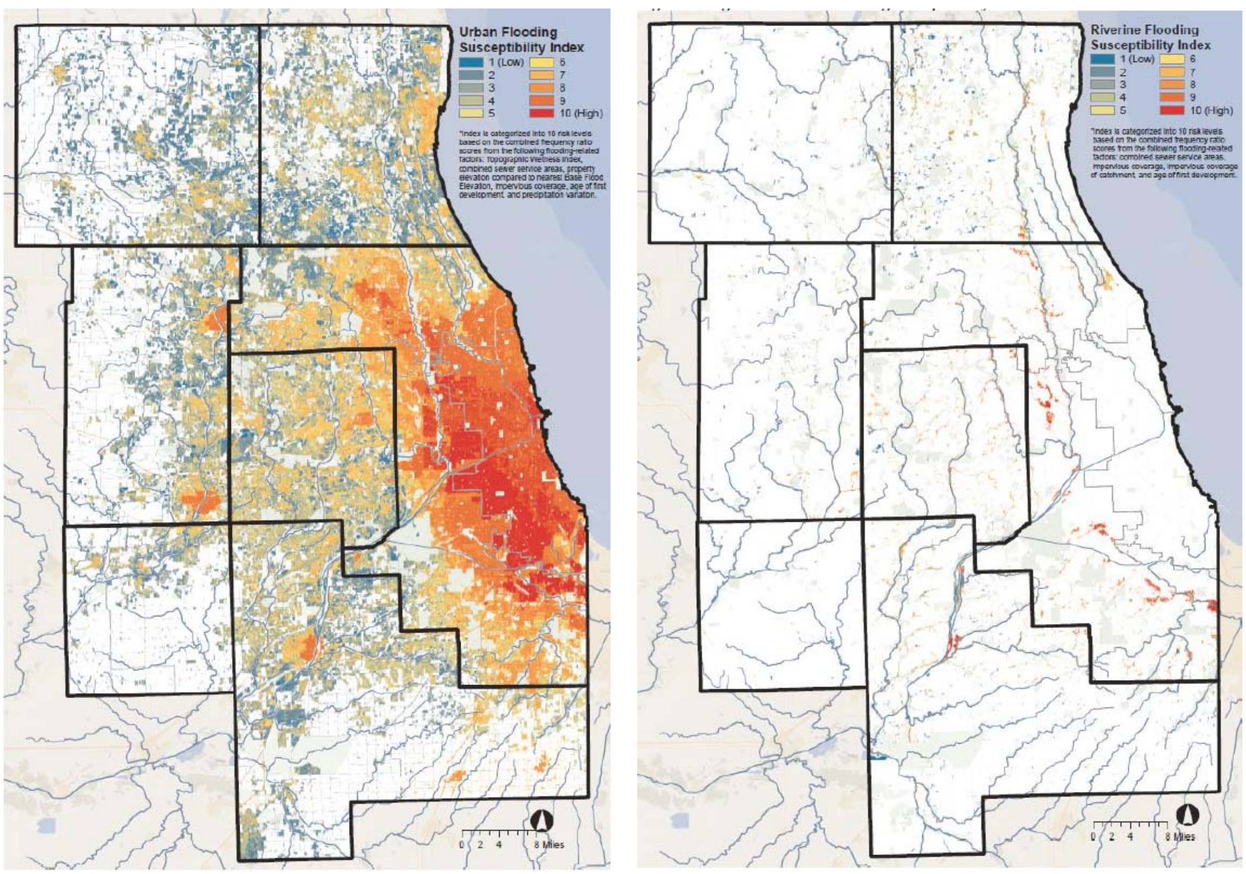
Recommended actions	Implementation strategies
Increase resiliency of the transportation system	• Conduct vulnerability assessments to transportation planning • Integrate stormwater management in transportation planning and investments • Develop and enhance operational strategies to maintain performance
Improve state and regional coordination	• Enhance regional coordination and information sharing • Review state agency coordination

Direct source: CMAP Stormwater and Flooding Strategy Paper. December 2017

Functions to support stormwater management that CMAP assigns itself include transportation planning, the Local Technical Assistance program, local ordinances and toolkits, policy research and development, and ON TO 2050.

The strategy paper notes other ongoing efforts to improve stormwater planning that are included in this document, such as MPC's effort to create a multi-jurisdictional modeling framework, updates to floodplain maps, CNT's urban flooding analysis, as well as CMAP's own urban and riverine flood susceptibility index (**Figure 9**). Combining this index with the more vulnerable communities and economically disconnected areas (identified in by CMAP in Inclusive Growth strategy paper) should serve as a useful prioritization structure moving forward.

Figure 9: CMAP Flooding Susceptibility Index (Urban and Riverine Flooding)



Source: CMAP Stormwater and Flooding Strategy Paper. (2017)

In terms of action items to address future flooding, CMAP notes the importance of coordinated stormwater ordinances and standards adapted to current and future precipitation and specific to watersheds, green infrastructure improvements (including standards in MWRD's recently updated technical reference manual), and transfer of benefits programs as a market-based way to improve stormwater management by setting up mechanisms for stormwater credit trading, for example, and increasing flexibility. Enhancing floodplain management compliance is another area of improvement, as CMAP found that nearly 12,000 acres of greenfield were developed in the floodplain between 2001 and 2015. Keeping hazard mitigation plans up-to-date is vital to ensuring eligibility for federal recovery funding after a disaster storm event.

Ongoing work in the areas of grey and green infrastructure is summarized in the document, providing specific case studies of activities in different counties and municipalities across the Chicago region. The strategy paper emphasizes the importance of dedicated revenue streams (e.g., a stormwater user fee) for stormwater management, echoing the analysis completed by MPC in its 2016 “Steady Streams” white paper.

One of CMAP’s strategies directly addresses increasing the resiliency of the transportation system, both to ensure mobility and to reduce maintenance costs as infrastructure ages and storms increase in frequency. The FAST Act requires that MPO’s integrate resilience into the planning process, and thus should now assess the vulnerability of capital assets and coordinate with emergency and disaster risk management officials when carrying out long-range transportation plans and transportation improvement programs. The FAST Act also requires that MPOs and states include the reduction or mitigation of stormwater impacts in surface transportation plans. Currently, IDOT design guidelines call for projects have capacity to handle 10-year or 5-year storm frequencies, without retention requirements. Such guidelines could be updated to include green infrastructure and other local best practices.

To address operations, CMAP has recommended ITS approaches, such as enhancements to weather-responsive traffic management—stormwater monitoring technology, a regional pavement flooding reporting system, and vulnerability assessments to plan for needed detours and traffic management activities.

2.2.6 CMAP Stormwater Management Opportunity Planning

Concurrently with this project, CMAP carried out an analysis of stormwater solutions and created a cost-efficient planning tool that uses GIS data to assess, analyze, and mitigate flooding problems in the Chicago region. Similar to the findings of this report, CMAP has separate methodologies for urban and riverine flooding. However, its focus leans toward flooding impacts on structures (especially homes) rather than on transportation.

According to the study, key factors that correlate with flooding incidents fall within several categories: environmental conditions, climate change, development extent and location, stormwater system design and maintenance, and regulatory structure. GIS analysis to quantify these factors and assess the correlation involved gathering GIS data on water resources (hydrology, watersheds, digital elevation model, etc.), reported flooding (NFIP claims, locally reported problem areas), built environment (especially age and extent of developed areas), infrastructure (gray and green), and soil types, among others.

The team then conducted an overland flow assessment to ensure that water systems were not viewed in isolation and to generate catchments that would be used to define the areas to be prioritized for mitigation measures. The catchments were ranked based on flooding factors outlined above to determine which had the greatest potential for either urban or riverine flooding. The priority catchments were then analyzed to determine the relationship between their potential and actual reported flooding using a frequency ratio. This Flooding Susceptibility Index can then be used to pinpoint problem areas within catchments.

To identify mitigation opportunities in priority locations to reduce these impacts, the team uses land use and parcel data to find ideal location for green infrastructure or other projects. It is then recommended that these solutions be incorporated in future land use plans.

Upon reviewing project activities, CMAP Environment and Natural Resources Committee members have advised integrating stormwater management strategies with other modeling tools and capitalizing on opportunities to include stormwater management or green infrastructure improvements into basic roadway improvement projects, as well as advocating for green infrastructure solutions and connectivity during the development review process.

2.2.7 CMAP Climate Adaptation Guidebook for Municipalities in the Chicago Region

Published in 2013, this toolkit aids municipalities interested in adapting their communities to a changing climate. It provides guidance on how to conduct local vulnerability assessments based on local conditions and the regional climate studies available, as well as how to prioritize impacts and develop an overarching adaptation strategy.

The second portion of the guide highlights specific adaptation measures for different kinds of climate impacts and local assets. For example, in the area of drainage and flood protection, the guidebook highlights that Chicago municipalities can expect more frequent heavy rainfall, and thus increased flood damage locally and downstream. Sample adaptation measures include elevating structures above the base flood elevation, applying floodplain management requirements to broader areas (due to out-of-date Flood Insurance Rate Maps), expanding outreach to local property owners, developing stormwater master plans, and implementing green infrastructure.

2.3 Metropolitan Planning Council

In November 2016 the Metropolitan Planning Council (MPC) held “A Flood of Ideas: Emerging Best Practices in Stormwater Planning.” During this event, nearly 100 participants focused on two key themes for stormwater planning: 1) the need for dedicated revenue streams, and 2) the need for interjurisdictional collaboration.

2.3.1 Steady Streams

Steady Streams is an online guide to help community leaders allocate money to alleviate flooding impacts and to develop dedicated funding sources for stormwater management. The purpose of the guide is to identify and evaluate the different avenues available to municipalities to generate money for stormwater management. Such avenues include:

- dedicated taxes
- stormwater fees (typically user fees assessed to property owners based on the amount of impervious surface area or stormwater runoff generated
- special assessments attached to new infrastructure projects or improvements to existing ones

These dedicated funding streams give the municipalities the option to leverage them to finance capital projects via funding mechanisms like bond issue, state revolving funds, public-private partnerships, etc.

The Steady Streams guide acknowledges municipalities are facing a triple threat in stormwater management: increasing impervious surface as development grows, stormwater infrastructure that is deteriorating and/or reaching the end of its useful life, and the likely increase in the frequency and intensity of rain events. It also cites a federal study that found that municipalities in the Chicago region had a stormwater management funding backlog of $233 per household as of 2012. Meanwhile, a National Research Council found that putting off maintenance and repairs doesn’t work—each $1 “saved” leads to a long-term capital liability of $4 to $5.

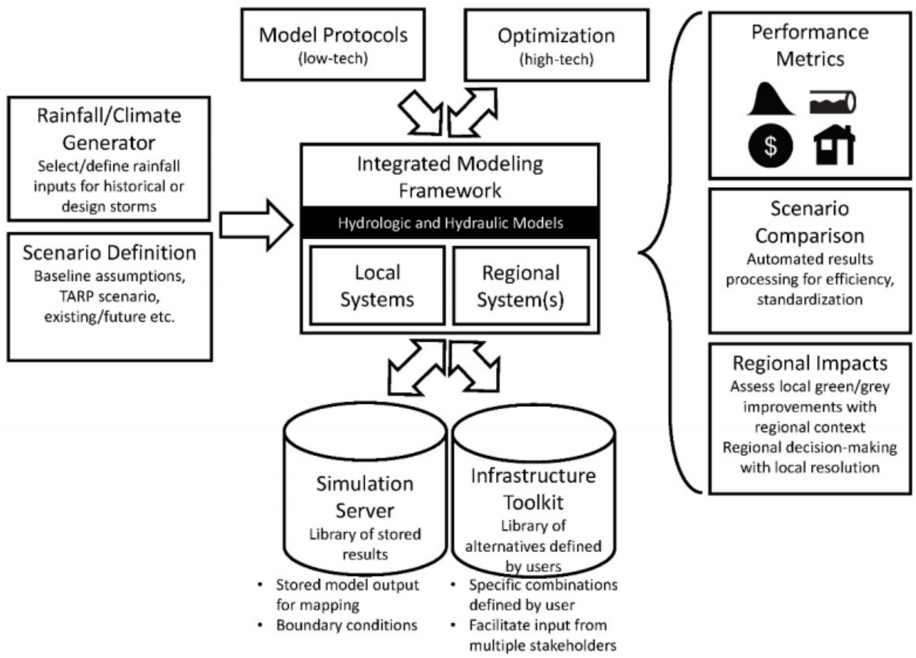
To help municipalities get started, the guide provides a questionnaire to assess local conditions and remind officials of factors to consider, such as statutory authority, public input, equity issues, etc.

The includes case studies from various municipalities, including 5 in Illinois, highlighting the dedicated funding stream they selected and the lessons learned. The 2013 CMAP report, “The Value of Stormwater Utilities for Local Governments in the Chicago Region,” is cited in this guide and includes further case studies for consideration.

2.3.2 Model Behavior

In 2016 MPC published “Model Behavior: A Framework for Regional, Inter-Jurisdictional, and Multi-level Stormwater Planning.” This document outlines the Regional Planning Framework created to coordinate hydrologic to hydraulic models across jurisdictions and extend these models to smaller communities that do not have the resources to carry out such modeling themselves. By coordinating and extending coverage, planners can prioritize projects and understand the aggregate impact of these projects on regional performance. This coordinated model would also show flood risk for stakeholders in a visual, intuitive way that would help communicate the lack of respect water has for jurisdictional boundaries, and how each municipality’s projects can affect their neighbors and vice versa. The framework also identifies key performance metrics and calculates rough order of magnitude project costs. **Figure 10** shows the concept of the proposed framework, with inputs from various climate models and defined scenarios created by planners and other stakeholders, and output in the form of performance metrics, scenario comparisons, and regional impacts.

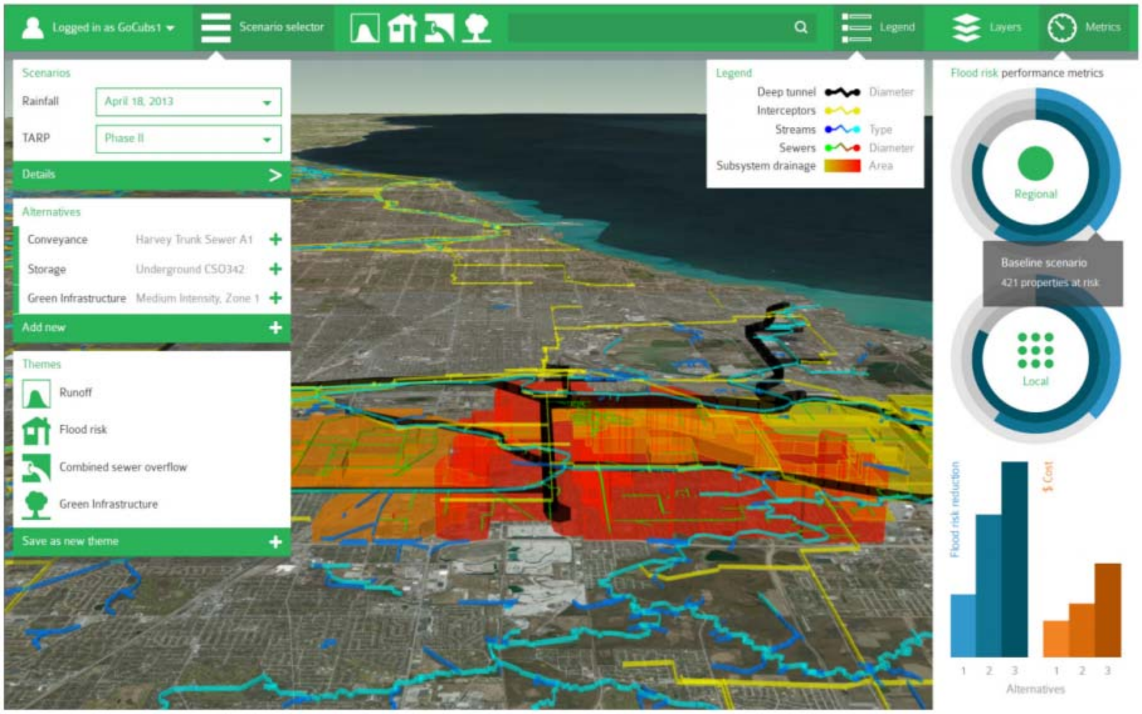
Figure 10: Coordinated Regional Stormwater Planning Framework Concept



Source: MPC “Model Behavior” (2016)

The framework also outlines the procedure for creating an interactive mapping application to visualize the model results and graphically indicate the costs and benefits of stormwater projects on key performance indicators (**Figure 11**). This type of coordination could be expanded to include impacts on transit networks in an interactive way. By cooperating with the hydrological and hydraulic modeling efforts of stormwater management agencies, the incremental costs of proactively planning for flooding resiliency in bus operation could be reduced.

Figure 11: Mock-up of Interactive Flood Modeling Application



Source: MPC "Model Behavior" (2016)

The Calumet region is included as a case study. For such a region, stakeholder agencies include the City of Chicago (Water Department and Planning Department), CMAP, Cook County Forest Preserve, and MWRDGC. Data input for the models should be sourced from all of these agencies, in addition to GIS data from the non-profit Center for Neighborhood Technology. Performance metrics would include reduction in runoff and flood risk reduction (e.g., "the number of individuals predicted to experience flooding for a 5-year recurrence interval, 2-hour duration storm event"), and should be scaled to cost.

2.4 City of Chicago

2.4.1 Chicago and 100 Resilient Cities

Chicago is currently participating in the Rockefeller Foundation's 100 Resilient Cities program. 100RC helps cities around the world become more resilient to social, economic, and physical challenges. Engagement with diverse stakeholders has taken place through workshops, online surveys, focus groups, meetings, and panels, beginning in late 2014 and continuing through the present. These outreach events identified Chicago's shocks, stresses, strengths, weaknesses, and priorities as the foundation on which to develop an action plan. Among the top 4 shocks identified in workshops were: storms, economic crash, flooding, and infrastructure failure—3 of which are addressed in this study.

The forthcoming Resilience Strategy will build on existing actions and propose new initiatives to make Chicago more resilient, focusing on three main areas: strong neighborhoods, robust infrastructure, and prepared communities. It will place specific emphasis on building on sustainability initiatives like the Chicago Climate Action Plan and Sustainable Chicago 2015. The project is currently in the process of defining and acting on recommendations and strategies.

2.4.2 Chicago Climate Action Plan

Five strategies were identified for the 2008 Chicago Climate Action Plan: energy-efficient buildings, renewable energy sources, improved transportation options, reduce waste and pollution, and adaptation. To address the issue of adaptation, CTA identified the need to better understand the projected change in frequency and intensity of storm events in current CTA flood-vulnerable locations, and what assets and locations are projected to become more vulnerable as climate change impacts make themselves felt. On the point of ridership, they also wish to know how CTA customers can be better protected from extreme precipitation currently, and what long-term measures need to be taken in order to ensure that ridership does not erode as temperatures and storms escalate.[2]

2.4.3 City of Chicago Green Stormwater Infrastructure Strategy Plan

This City of Chicago plan notes that Chicago is experiencing and increasing number of severe storms and that these are consistent with climate change projections. The plan places itself as the next step in environmental stewardship and economic development, building on the Chicago Climate Action Plan.

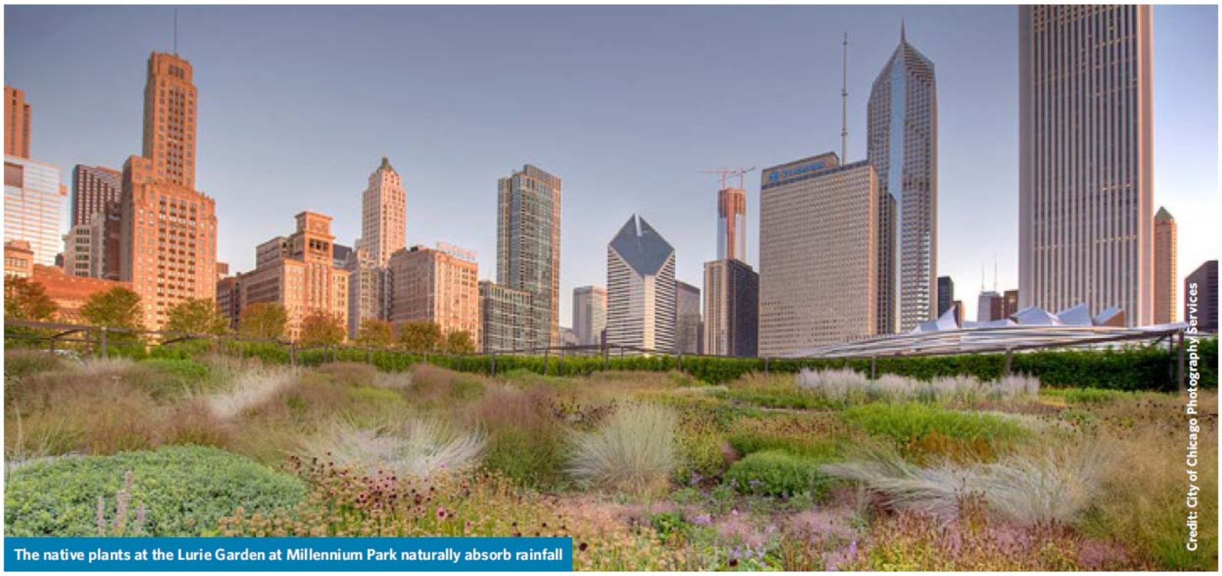
As the plan states, the city's stormwater system must manage 4 billion gallons of stormwater for each inch of rain that falls, and that without adequate green space or infrastructure to absorb that rainfall, the sewer system is overwhelmed and can lead to the necessity of combined sewer overflows during larger storms, contaminating area waterways. To combat this and related concerns, major issues highlighted in the plan include:

- That major long-term investment in stormwater infrastructure is necessary
- The completion of TARP is a vital part of both ensuring and improving water quality, as well as mitigating flooding problems
- Both green and grey stormwater infrastructure will be necessary to prevent or mitigate flooding
- Collaboration between City departments, sister government agencies, MWRD, non-governmental organizations, and citizens will be vital

Green stormwater infrastructure strategies have been implemented in Chicago for a least a decade, but not in a city-wide, organized program. Since implementation has been so fragmented, there is relatively little information about the actual costs and benefits of an integrated green infrastructure networks. Collaboration between public agencies, non-profits, and private landowners is vital to ensuring a comprehensive green stormwater infrastructure program, supported by proper maintenance.

As green stormwater projects can take up a large amount of physical space, it's important to maximize publicly available land for such uses. Chicago's right-of-way covers 23% of the city's land area (and even more of its impervious surfaces), which makes it the key location for green infrastructure in the form of tree pits, bioswales, rain gardens, filter strips, and stormwater planters—all with high-infiltration soil layers and plants that can help to filter pollutants and salt that drain into these areas. Futhermore, permeable pavements can be used to promote soil infiltration in places with pedestrian, bicycle, and low-impact vehicular traffic—alleys, sidewalks, parking lots, plazas, bike lanes, etc. Larger green stormwater infrastructure (such as detention ponds) can be sited in parks and open spaces, such as schoolyards and vacant lots.

[2] CTA CCAP Presentation by Karl Peet, Strategic Planning and Policy Department (2012).



Source: City of Chicago Green Stormwater Infrastructure Strategy (2014)

Chicago's Stormwater Ordinance of 2008 states that buildings with footprints over 15,000 square feet and parking lot's over 7,500 square feet must either detain at least the first half inch of rain on-site, or reducing the prior imperviousness by 15%. The Ordinance specifically promotes the use of green stormwater infrastructure and has helped to achieve the elimination of over 3 million square feet of impervious surfaces between 2008 and 2014.

Other policies and guidelines include the Sustainable Development Policy, updated in 2008, requiring green stormwater on new buildings that receive certain special land use approvals or public financing. Adding Green to Urban Design, published in 2008 by the Chicago Plan Commission, provides guidance to Chicago City Council on regulating urban design, including green stormwater infrastructure. Sustainable Urban Infrastructure Guidelines, released by CDOT in 2013, formalizes standards and policies for implementing innovative techniques like green infrastructure into transportation projects city-wide. City programs including Green Roofs, Green Alleys, Green Streets, Downspout Disconnections, Sustainable Backyard, and MeterSave are key for implementing green infrastructure programs across the city.

To achieve the plan's goals of minimizing basement flooding, reducing pollution to Chicago waterways, enhancing environmental quality, and boosting resilience to extreme rain events and climate change, the plan seeks to build more green stormwater infrastructure by incorporating it in future public capital projects, using permeable pavement during appropriate sewer main replacement projects, increasing green stormwater infrastructure in streetscape projects, and undertaking studies to better understand the costs and benefits of using green infrastructure and to develop a better understanding of rainfall frequency and climate change in the Chicago region. Additionally, it will create a comprehensive plan for managing stormwater with green and grey stormwater infrastructure.

2.5 Center for Neighborhood Technology

2.5.1 RainReady

This CNT initiative is intended to help people manage flooding & drought in a time of change. It has two programs, one for individual homeowners to address problems like basement flooding, and another for communities which seek to develop cost-effective strategies to mitigate the impact of major rainstorm events on both public and private land by conducting a community-wide risk assessment, performing public outreach, and creating a multi-year action plan to improve stormwater management via such means as landscaping, downspout disconnection and drywells, rain gardens, tree planting and bioswales, among others.

A case study plan has already been completed in the Calumet Corridor.[3] The plan specifically addresses the issue of financing stormwater infrastructure improvements and maintenance. One example of innovative financing options include mini-bonds sold to the community itself in denominations lower than the typically $5,000+, such as the $500 bonds sold in Denver, CO. Special Service Areas can help to raise the necessary funding by ensuring that those who benefit will also be the ones who pay, thus more easily gaining public buy in. On-bill financing allows municipalities to borrow on behalf of local property owners and receive payment through the water bill or property tax bill. Fifty-fifty financing shares sidewalk repair costs between property owners and municipalities, and is often combined with other programs like on-bill financing. Finally, "Tree Increment"—a version of tax increment financing—can help municipalities to carry out green infrastructure stormwater management projects.

Broader financing and investment mechanisms, along with the potential returns, are described in **Table 1**. They are sorted by investor type, be it individual property owners, municipalities, private entities, etc., based on the suitability for the project site or context.

[3] http://rainready.org/calumet-corridor/

Table 1: Stormwater Investment Funding

Investor	Investment Mechanism	Return
Property owner	• Pays for RainReady property upgrades (coordinated through the municipality)	• Improves landscape and aesthetics • Increases property value • Reduces financial, health, and time burdens of repeat flood damage
Municipality	• Sets up a Rain Fund to provide financial assistance for the upfront costs of home upgrades and the full cost of upgrades in the public rights-of-way[37] • Uses related public works projects, such as road repairs, to help pay for RainReady improvements • Establishes private-sector partnerships on behalf of residents, such as insurance discounts for private building sewer repair and replacement • Sets up a performance-based contract with a private-sector partner • Offers developers incentives for RainReady upgrades, such as reducing impervious surfaces by establishing parking space maximums instead of minimums • Matches job training/employment opportunities to RainReady upgrades	• Improves neighborhood aesthetics, water quality in local waterways, and recreational opportunities • Increases property values • Maintains the tax base by enhancing neighborhood appeal • Reduces municipal insurance premiums by reducing flooding risk • Stimulates housing market/economic development • Increases low- and semi-skilled employment opportunities • Reduces impact of flooding on roads and other public infrastructure
Insurance sector	• Provides premium discounts for customers adopting RainReady practices, like the RainReady Alert system • Offers new, income-generating insurance policies, such as partnering with cities to offer building sewer insurance riders • Establishes promotional partnerships with RainReady services	• Improves the economic health of existing customer base, making it more likely for people to renew their policies • Reduces damage claims from sewer backup policies and reduces risk of legal disputes • Diversifies insurance portfolio
Private-sector service, system suppliers + contractors	• Establishes promotional partnerships with RainReady services	• Directs sales by providing RainReady upgrades like technology platforms, sensors, plumbing, and landscaping supplies • Increases sales of indirectly related services, like interior design for RainReady basements
Banks + mortgage companies	• Establish promotional partnerships with RainReady services • Offer RainReady Home upgrade loans and/or lower mortgage interest rates for RainReady homes	• Improves economic health of existing customer base • Provides entry point for new customers and related policies • Reduces the risk of default/foreclosure
Real estate sector*	• Establishes partnerships with RainReady service providers to design certifications and rating programs for RainReady Homes • Establishes promotional partnerships with RainReady service providers	• Enhances value of home property, particularly if the Residential Real Property Disclosure Reports and/or C.L.U.E. reports reveal previous flooding • Drives consumer demand for related services like urban flooding risk assessments
County/state government	• Establishes loans for municipalities to support RainReady services, repaid via Rain Funds • Supports the assembly of RainReady services, financing partners, and certification/rating programs • Establishes land banks and enhanced protection for critical natural defenses like wetlands	• Brings regional aesthetic and recreational benefits, like when RainReady upgrades can be linked to parks and trails • Creates new low- and semi-skilled employment opportunities • Stimulates housing market and economic development • Reduces legal/statutory costs associated with Clean Water Act • Reduces disaster mitigation planning costs
Federal government	• Gives the legal authority to FEMA, U.S. Army Corps of Engineers, and EPA to tackle urban flooding • Makes FEMA's existing National Flood Insurance Program and its mitigation programs (such as the Community Rating System) more relevant to all communities • Establishes loans for municipalities to support RainReady services, repaid via Rain Funds	• Brings national aesthetic and recreational benefits, like when RainReady upgrades can be linked to national parks and trails • Reduces economic and social impacts of federal disasters on U.S. towns and cities • Stimulates housing market and economic development, including employment opportunities • Reduces costs associated with Clean Water Act violations

CNT. *RainReady Nation*. p.23

AECOM

Flooding Resilience Plan for Bus Operations

Appendix D: CTA Reroute Impact Analysis

Prepared for the Regional Transportation Authority of Northeast Illinois

March 30, 2018

March 2018

Quality Management

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4	February 25, 2018	Final draft
5	March 30, 2018	Final

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CTA-Impact Matrix Worksheet
Routes are characterized by their service pattern. Existing conditions represent normal operating patterns, while reroute represents the operating pattern when inclement weather requires adjustments to the route alignment.
Estimates of impacts to operating costs are calculated using each route's cost per-hour metric. As with the changes in travel times vary substantially in both positive and negative directions, changes in trip cost likewise show as positive and negative, with increased costs projected to be incurred in some situations, and savings in other situations. These cost projections are presented as Base costs, along with other scenarios accounting for additional Low, Moderate and High travel delay factors which would increase costs.

Metric	Description
# of Potential Incidents (OEMC)	Count of calls to the Office of Emergency Management and Communications (OEMC) (311) to report incidents of on-street and viaduct flooding.
Flooding noted within 400 ft	Flooding incidents identified by CTA operations staff within 400 feet of the specific route. This distance was used as the approximate distance of one city block.
Bus Stops Missed	Number of existing bus stops skipped due to a reroute.
Avg Riders Impacted per Day	Sourced from CTA provided Ventra boarding data. This number represents the average number of boardings missed or riders impacted if the bus were to be rerouted for an entire day.
Travel Time	Calculated using the route network on Google for a one-way trip, which is based on CTA published schedules. Reroutes were calculated using the same bus route on Google, but modifying the route to reflect adjustments to avoid areas of flooding.
Travel Time Change (Base)	The change in travel time for a one-way trip operating on a reroute.
Travel Time Change (Low)	The change in travel for a one-way trip operating on a reroute with a 5 percent time factor added to the base travel time.
Travel Time Change (Mod)	The change in travel for a one-way trip operating on a reroute with a 15 percent time factor added to the base travel time.
Travel Time Change (High)	The change in travel for a one-way trip operating on a reroute with a 30 percent time factor added to the base travel time.
Revenue Hour	Sourced from CTA-provided data for annual revenue hours by route.
Cost per trip	Sourced from CTA-provided data for annual revenue hours by route. Annual Cost for reroutes was calculated by adding a multiplier to the existing cost determined by the percentage change in travel time from existing route to reroute. The cost is based on an assumption of $100 per revenue hour. This assumption can be modified by the user on the *Existing Cost-Revenue* tab and costs will update automatically.
Cost per trip (Base)	Calculated by multiplying the assumption of $100 per revenue hour to the total one-way hours, which is the travel time divided by 60 minutes.
Cost per trip (Low/Mod/High)	Calculated by multiplying the cost per hour by the reroute travel time (one-trip) incremented by the selected time factor.
Cost Change per Trip (Base)	The change in cost per trip going into reroute using base travel time with no additional time factor multiplier.
Cost Change per Trip (Low/Mod/High)	The change in cost per trip for a reroute with additional congestion.
Custom Travel Time Adjustments	Three factors which compose the travel time factor. User selects "Low", "Moderate" or "High" additional Travel Time impact values to calculate a customized adjusted reroute time.
Congestion	Travel time factor reflecting additional roadway congestion resulting from a rain event.
Storm Severity	Travel time factor reflecting storm severity which may contribute to traffic slowdowns resulting from a rain event.
Operating Delay	Travel time factor representing the difficulty for CTA dispatch or the CTA bus operator to respond to the storm incident.
Factor AVG	Represents the average score of the three factors
Time Factor	The percentage which is added to travel time and cost per trip to represent estimates of how the storm incident could impact travel time and operating costs.

All transit GIS data was provided by CTA, and processed by AECOM and its subconsultant UrbanGIS.
- Bus stop locations
- Location of OEMC/311 flood call complaints
- Driver-reported flooding hot spot locations
- Ventra boarding location

Flooding Resiliency Plan OPERATIONS 2016-08-31. This table provided annual daily ridership categorized by route and day type, annual revenue miles and hours by route, and estimated operating costs and revenue received by route. Shown on the *Existing Cost-Revenue* tab and *Revenue Mile and Hours by Route* tab.

Ventra boarding locations. The Ventra file provided GPS locations of boarding activity. The data was limited to the week prior to nine identified storm day incidents, as well as the nine storm day incidents. There are a few issues identified by CTA staff which may cause the exact GPS location to move away from the physical bus stop location. To address this issue, buffers were created around bus stops to capture the adjacent Ventra GPS points. Shown on the *Dly Rider by Rt and Day* tab.

Ridership summary. The ridership summary file provided ridership at the route level summarized at half-hour intervals. The data was limited to the week prior to nine identified storm day incidents, as well as the nine storm day incidents. Shown on the *Ridership* tab.

Rainfall data. Rainfall Data was obtained from the MRCC's online cli-MATE database. The rainfall gauge at three airports was used to obtain total rainfall on an hourly basis. These airports are Midway Airport, Chicago O'Hare International Airport, and Palwaukee Airport. Shown on the *Storm Days Correlation* tab.

		Risk Areas			Ridership		Travel Time (Minutes)								Travel Time (Hours)						
Route	Route Type	# of Potential Incidents (OEMC)	Flooding Noted within 400ft	Change in Flood Areas	Bus Stops Missed	Avg Riders Impacted per Day	Travel Time (Base)	Travel Time (Low)	Travel Time (Mod)	Travel Time (High)	Travel Time Change (Base)	Travel Time Change (Low)	Travel Time Change (Mod)	Travel Time Change (High)	Hours (Base)	Hours (Low)	Hours (Mod)	Hours (High)	Revenue Hour	Cost	Cost per trip (Base)
4	Existing	139	34				91								1.52				124,579	$ 12,457,940.83	$ 152
8	Existing	154	21				93								1.54				130,401	$ 13,040,070.00	$ 154
9	Existing	356	47				113								1.88				185,329	$ 18,532,925.00	$ 188
J14	Existing	183	7				58								0.97				72,031	$ 7,203,098.33	$ 97
20	Existing	88	8				60								0.99				99,581	$ 9,958,073.33	$ 99
22	Existing	161	3				76								1.26				111,424	$ 11,142,421.67	$ 126
49	Existing	297	89				92								1.53				165,379	$ 16,537,850.83	$ 153
52	Existing	151	29				81								1.34				83,977	$ 8,397,655.83	$ 134
53	Existing	149	36				72								1.20				113,663	$ 11,366,315.83	$ 120
55	Existing	108	10				51								0.84				76,366	$ 7,636,570.00	$ 84
62	Existing	99	38				73								1.21				88,649	$ 8,864,887.50	$ 121
66	Existing	156	22				65								1.08				123,139	$ 12,313,887.50	$ 108
77	Existing	295	11				68								1.13				126,327	$ 12,632,654.17	$ 113
79	Existing	189	24				71								1.18				166,935	$ 16,693,537.50	$ 118
85	Existing	163	2				52								0.86				58,756	$ 5,875,565.00	$ 86
92	Existing	69	9				39								0.65				37,047	$ 3,704,691.67	$ 65
147	Existing	193	21				60								1.00				78,320	$ 7,831,969.17	$ 100
4	Reroute	179	34	0	16	2	97	102	112	126	6	11	21	35	1.62	1.70	1.86	2.10	124,579	$ 12,457,940.83	$ 162
8	Reroute	189	14	-7	36	336	105	110	120	136	12	17	28	43	1.74	1.83	2.00	2.26	130,401	$ 13,040,070.00	$ 174
9	Reroute	368	41	-6	4	63	119	125	137	155	7	12	24	42	1.98	2.08	2.28	2.58	185,329	$ 18,532,925.00	$ 198
J14	Reroute	189	7	0	0	0	63	66	72	82	5	8	14	24	1.05	1.10	1.21	1.37	72,031	$ 7,203,098.33	$ 105
20	Reroute	92	9	1	7	44	62	65	71	80	2	5	11	20	1.03	1.08	1.18	1.33	99,581	$ 6,786,466.67	$ 70
22	Reroute	161	3	0	0	0	76	79	87	98	0	4	11	23	1.26	1.32	1.45	1.64	111,424	$ 11,142,421.67	$ 126
49	Reroute	298	66	-23	3	11	94	99	108	122	2	7	16	30	1.57	1.65	1.80	2.04	165,379	$ 16,537,850.83	$ 157
49a	Reroute	305	60	-29	8	98	96	100	110	124	4	8	18	32	1.59	1.67	1.83	2.07	165,379	$ 16,537,850.83	$ 159
52	Reroute	113	5	-24	98	750	71	74	81	92	-10	-6	1	11	1.18	1.23	1.35	1.53	83,977	$ 8,397,655.83	$ 118
53	Reroute	148	27	-9	9	155	75	78	86	97	3	6	14	25	1.24	1.30	1.43	1.61	113,663	$ 11,366,315.83	$ 124
53a	Reroute	151	27	-9	9	155	77	80	88	99	5	8	16	27	1.28	1.34	1.47	1.66	113,663	$ 11,366,315.83	$ 128
53b	Reroute	163	33	-3	9	155	78	82	90	101	6	10	18	29	1.30	1.37	1.50	1.69	113,663	$ 11,366,315.83	$ 130
55	Reroute	132	4	-6	18	253	58	61	67	75	8	10	16	25	0.97	1.02	1.11	1.26	76,366	$ 7,636,570.00	$ 97
62	Reroute	100	38	0	15	87	76	80	87	99	4	7	15	26	1.27	1.33	1.46	1.65	88,649	$ 8,864,887.50	$ 127
66	Reroute	162	21	-1	5	21	67	70	76	86	2	5	12	22	1.11	1.16	1.27	1.44	123,139	$ 12,313,887.50	$ 111
66a	Reroute	178	31	9	5	21	69	72	79	89	4	7	14	25	1.14	1.20	1.31	1.48	123,139	$ 12,313,887.50	$ 114
77	Reroute	327	8	-3	14	224	78	82	90	101	10	14	22	33	1.30	1.37	1.50	1.69	126,327	$ 12,632,654.17	$ 130
79	Reroute	190	21	-3	12	87	73	76	83	94	2	5	12	23	1.21	1.27	1.39	1.57	166,935	$ 16,693,537.50	$ 121
85 E	Reroute	205	6	4	14	72	56	58	64	72	4	7	12	21	0.93	0.97	1.06	1.20	58,756	$ 5,875,565.00	$ 93
85 W	Reroute	197	4	2	14	72	56	58	64	72	4	7	12	21	0.93	0.97	1.06	1.20	58,756	$ 5,875,565.00	$ 93
85 Nar	Reroute	201	0	-2	14	72	59	61	67	76	7	10	16	25	0.98	1.02	1.12	1.27	58,756	$ 5,875,565.00	$ 98
92	Reroute	104	12	3	15	31	43	45	49	55	4	6	10	16	0.71	0.74	0.81	0.92	37,047	$ 3,704,691.67	$ 71
147 A	Reroute	229	18	-3	5	78	73	76	83	94	13	16	23	34	1.21	1.27	1.39	1.57	78,320	$ 7,831,969.17	$ 121
147 B	Reroute	233	19	-2	5	78	78	81	89	101	18	21	29	41	1.29	1.36	1.49	1.68	78,320	$ 7,831,969.17	$ 129
147 AC	Reroute	207	20	-1	2	78	71	74	81	92	11	14	21	32	1.18	1.23	1.35	1.53	78,320	$ 7,831,969.17	$ 118
147 BC	Reroute	220	22	1	2	78	76	79	87	98	16	19	27	38	1.26	1.32	1.45	1.64	78,320	$ 7,831,969.17	$ 126

		Cost per Trip			Cost Change per Trip				Custom Travel Time Adjustments									
Route	Route Type	Cost per trip (Low)	Cost per trip (Mod)	Cost per trip (High)	Cost Change (Base)	Cost Change (Low)	Cost Change (Mod)	Cost Change (High)	Congestion (choose)	Storm Severity (choose)	Operating Delay (choose)	Factor AVG	Time Factor	Travel Time (Min, with Time Factor)	Travel Time Change (Min, with Time Factor)	Travel Time (Hours, with Time Factor)	Cost per Trip (with Time Factor)	Cost Change per Trip (with Time Factor)
4	Existing																	
8	Existing																	
9	Existing																	
J14	Existing																	
20	Existing																	
22	Existing																	
49	Existing																	
52	Existing																	
53	Existing																	
55	Existing																	
62	Existing																	
66	Existing																	
77	Existing																	
79	Existing																	
85	Existing																	
92	Existing																	
147	Existing																	
4	Reroute	$ 170	$ 186	$ 210	$ 10	$ 18	$ 34	$ 59	Low	Low	Low	1.0000	5%	101.9	11	1.70	$ 169.75	$ 18.08
8	Reroute	$ 183	$ 200	$ 226	$ 20	$ 29	$ 46	$ 72	Low	Low	Low	1.0000	5%	109.7	17	1.83	$ 182.88	$ 28.71
9	Reroute	$ 208	$ 228	$ 258	$ 11	$ 21	$ 41	$ 70	Low	Low	Low	1.0000	5%	125.0	12	2.08	$ 208.25	$ 20.75
J14	Reroute	$ 110	$ 121	$ 137	$ 8	$ 14	$ 24	$ 40	Low	Low	Low	1.0000	5%	66.2	8	1.10	$ 110.25	$ 13.58
20	Reroute	$ 73	$ 80	$ 91	$ (29)	$ (26)	$ (19)	$ (8)	Low	Low	Low	1.0000	5%	64.6	5	1.08	$ 73.35	$ (25.82)
22	Reroute	$ 132	$ 145	$ 164	$ -	$ 6	$ 19	$ 38	Low	Low	Low	1.0000	5%	79.3	4	1.32	$ 132.13	$ 6.29
49	Reroute	$ 165	$ 180	$ 204	$ 3	$ 11	$ 27	$ 50	Low	Low	Low	1.0000	5%	98.7	7	1.65	$ 164.50	$ 11.17
49a	Reroute	$ 167	$ 183	$ 207	$ 6	$ 14	$ 30	$ 54	Low	Low	Low	1.0000	5%	100.3	8	1.67	$ 167.13	$ 13.79
52	Reroute	$ 123	$ 135	$ 153	$ (17)	$ (11)	$ 1	$ 19	Low	Low	Low	1.0000	5%	74.0	-6	1.23	$ 123.38	$ (10.79)
53	Reroute	$ 130	$ 143	$ 161	$ 4	$ 10	$ 23	$ 41	Low	Low	Low	1.0000	5%	78.2	6	1.30	$ 130.38	$ 10.38
53a	Reroute	$ 134	$ 147	$ 166	$ 7	$ 14	$ 27	$ 46	Low	Low	Low	1.0000	5%	80.3	8	1.34	$ 133.88	$ 13.88
53b	Reroute	$ 137	$ 150	$ 169	$ 10	$ 17	$ 30	$ 49	Low	Low	Low	1.0000	5%	81.9	10	1.37	$ 136.50	$ 16.50
55	Reroute	$ 102	$ 111	$ 126	$ 13	$ 17	$ 27	$ 42	Low	Low	Low	1.0000	5%	60.9	10	1.02	$ 101.50	$ 17.33
62	Reroute	$ 133	$ 146	$ 165	$ 6	$ 12	$ 25	$ 44	Low	Low	Low	1.0000	5%	79.8	7	1.33	$ 133.00	$ 12.17
66	Reroute	$ 116	$ 127	$ 144	$ 3	$ 9	$ 20	$ 37	Low	Low	Low	1.0000	5%	69.8	5	1.16	$ 116.38	$ 8.88
66a	Reroute	$ 120	$ 131	$ 148	$ 7	$ 12	$ 24	$ 41	Low	Low	Low	1.0000	5%	71.9	7	1.20	$ 119.88	$ 12.38
77	Reroute	$ 137	$ 150	$ 169	$ 17	$ 23	$ 36	$ 56	Low	Low	Low	1.0000	5%	81.9	14	1.37	$ 136.50	$ 23.17
79	Reroute	$ 127	$ 139	$ 157	$ 3	$ 9	$ 21	$ 39	Low	Low	Low	1.0000	5%	76.1	5	1.27	$ 126.88	$ 8.54
85 E	Reroute	$ 97	$ 106	$ 120	$ 7	$ 11	$ 21	$ 34	Low	Low	Low	1.0000	5%	58.3	7	0.97	$ 97.13	$ 11.29
85 W	Reroute	$ 97	$ 106	$ 120	$ 7	$ 11	$ 21	$ 34	Low	Low	Low	1.0000	5%	58.3	7	0.97	$ 97.13	$ 11.29
85 Nar	Reroute	$ 102	$ 112	$ 127	$ 12	$ 17	$ 26	$ 41	Low	Low	Low	1.0000	5%	61.4	10	1.02	$ 102.38	$ 16.54
92	Reroute	$ 74	$ 81	$ 92	$ 6	$ 9	$ 16	$ 27	Low	Low	Low	1.0000	5%	44.6	6	0.74	$ 74.38	$ 9.38
147 A	Reroute	$ 127	$ 139	$ 157	$ 21	$ 27	$ 39	$ 57	Low	Low	Low	1.0000	5%	76.1	16	1.27	$ 126.88	$ 26.88
147 B	Reroute	$ 136	$ 149	$ 168	$ 29	$ 36	$ 49	$ 68	Low	Low	Low	1.0000	5%	81.4	21	1.36	$ 135.63	$ 35.63
147 AC	Reroute	$ 123	$ 135	$ 153	$ 18	$ 23	$ 35	$ 53	Low	Low	Low	1.0000	5%	74.0	14	1.23	$ 123.38	$ 23.38
147 BC	Reroute	$ 132	$ 145	$ 164	$ 26	$ 32	$ 45	$ 64	Low	Low	Low	1.0000	5%	79.3	19	1.32	$ 132.13	$ 32.13

Route	Route Type	New TT	Travel Time (Google)	NB/EB 1	SB/WB 1	NB/EB 2	SB/WB 2	NB/EB 3	SB/WB 3	NB/EB 4	SB/WB 4
4	Existing		91	92	90	182					
8	Existing		92.5	94	91	185					
9	Existing		112.5	112	113	225					
J14	Existing		58	57	59	116					
20	Existing		59.5	60	59	119					
22	Existing		75.5	76	75	151					
49	Existing		92	90	94	184					
52	Existing		80.5	80	81	161					
53	Existing		72	68	76	144					
55	Existing		50.5	50	51	101					
62	Existing		72.5	70	75	145					
66	Existing		64.5	66	63	129					
77	Existing		68	65	71	136					
79	Existing		71	72	70	142					
85	Existing		51.5	49	54	103					
92	Existing		39	36	42	78					
147	Existing		60	61	59	120					
4	Reroute	97	6	4	2	extra					
8	Reroute	104.5	12	2	5	3	2	extra			
9	Reroute	119	6.5	6.5	extra						
J14	Reroute	63	5	5	extra						
20	Reroute	61.5	2	2	extra						
22	Reroute	75.5	0		no reroute						
49	Reroute	94	2	2							
49a	Reroute	95.5	3.5	3.5							
52	Reroute	70.5	10	2.5	0	2.5	extra	15	less	10 less minutes total	
53	Reroute	74.5	2.5	2.5	extra						
53a	Reroute	76.5	4.5	4.5	extra						
53b	Reroute	78	6	6	extra						
55	Reroute	58	7.5	3.5	4	extra					
62	Reroute	76	3.5	3.5							
66	Reroute	66.5	2	2	extra						
66a	Reroute	68.5	4	4	extra						
77	Reroute	78	10	5	5	extra					
79	Reroute	72.5	1.5	1.5	extra						
85 E	Reroute	55.5	4	4	extra						
85 W	Reroute	55.5	4	4							
85 Nar	Reroute	58.5	7	7							
92	Reroute	42.5	3.5	3.5							
147 A	Reroute	72.5	12.5	5	3.5	4					
147 B	Reroute	77.5	17.5	10	3.5	4					
147 AC	Reroute	70.5	10.5	5	3.5	2					
147 BC	Reroute	75.5	15.5	10	3.5	2					

A; NB to Oak	5
Sheridan NB all	3.5
B; NB	10
SB AB	4
SB C	2

Access Database -- All Routes - All Storm Days

Selected Days*	Description	Total Ridership for Select Days	Average Daily Ridership	
2015/06/15-16; 2015/09/18-19; 2016/07/23-24; 2015/04/9-10; 2015/12/23; 2016/03/24-25; 2017/01/16-17; 2017/02/07	Total Ridership for Storm Days	2,406,711	401,119	Riders/day
2015/06/8-9; 2015/09/11-12; 2016/07/16-17; 2015/04/2-3; 2015/12/16; 2016/03/17-18; 2017/01/9-10; 2017/01/31	Total Ridership for Previous Days (Non-Storm)	2,642,546	440,424	Riders/day
	Average Daily Ridership Difference		39,306	
	Percent change		**-8.92%**	

Access Database -- All Routes - Moderate/Major Storm Days

Selected Days*	Description	Total Ridership for Select Days	Average Daily Ridership	
2015/06/15-16; 2015/09/18-19; 2016/07/23-24	Total Ridership for Storm Days	1,003,038	167,173	Riders/day
2015/06/8-9; 2015/09/11-12; 2016/07/16-17	Total Ridership for Previous Days (Non-Storm)	1,056,995	176,166	Riders/day
	Average Daily Ridership Difference		8,993	
	Percent change		**-5.10%**	

*no Ventra data for 2013. We can amend with APC summary data.

Minor Storm Days

Selected Days	Description	Total Ridership for Select Days	Average Daily Ridership	
2015/04/9-10; 2015/12/23; 2016/03/24-25; 2017/01/16-17; 2017/02/07	Total Ridership for Storm Days	1,403,673	233,946	Riders/day
2015/04/2-3; 2015/12/16; 2016/03/17-18; 2017/01/9-10; 2017/01/31	Total Ridership for Previous Days (Non-Storm)	1,585,551	264,259	Riders/day
	Average Daily Ridership Difference		30,313.00	
	Percent change		**-11.47%**	

Weekday vs Weekend Breakdown - Moderate/Major Storm Days

Selected Days*	Description	Total Ridership for Select Days	Average Daily Ridership	
2015/06/15-16; 2015/09/18-19	Weekday Storm Days Total	777,090	194,273	Riders/day
2015/06/8-9; 2015/09/11-12	Weekday Previous Days Total (Non-Storm)	813,414	203,354	Riders/day
	Percent change		**-4.47%**	
2016/07/23-24	Weekend Storm Days Total	225,948	112,974	Riders/day
2016/07/16-17	Weekend Previous Days Total (Non-Storm)	243,581	121,791	Riders/day
	Percent change		**-7.24%**	

*no Ventra data for 2013. We can amend with APC summary data.

Breakdown by Route Moderate/Major Storm Days

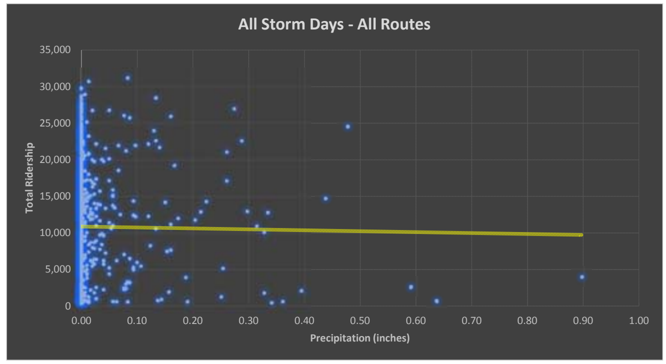
Route	Total Ridership for Storm Days	Total Ridership for Previous Days (Non-Storm)	Total Ridership Difference	Weekday Storm Days Total	Weekday Previous Days Total (Non-Storm)	Total Ridership Difference	Weekend Storm Days Total	Weekend Previous Days Total (Non-Storm)	Total Ridership Difference
4	72,136	77,318	**-7.18%**	56,546	59,419	**-5.08%**	15,590	17,899	**-14.81%**
8	73,955	74,812	**-1.16%**	58,482	59,664	**-2.02%**	15,473	15,148	**2.10%**
9	96,063	105,708	**-10.04%**	74,084	78,939	**-6.55%**	21,979	26,769	**-21.79%**
20	56,377	56,387	**-0.02%**	44,347	45,203	**-1.93%**	12,030	11,184	**7.03%**
22	73,866	76,318	**-3.32%**	54,859	55,748	**-1.62%**	19,007	20,570	**-8.22%**
49	82,970	89,909	**-8.36%**	65,427	71,188	**-8.81%**	17,543	18,721	**-6.71%**
52	38,779	39,774	**-2.57%**	31,176	30,823	**1.13%**	7,603	8,951	**-17.73%**
53	64,283	68,789	**-7.01%**	50,438	53,539	**-6.15%**	13,845	15,250	**-10.15%**
55	39,051	38,666	**0.99%**	29,199	29,738	**-1.85%**	9,852	8,928	**9.38%**
62	38,471	41,019	**-6.62%**	29,916	31,196	**-4.28%**	8,555	9,823	**-14.82%**
66	83,661	88,105	**-5.31%**	65,456	67,600	**-3.28%**	18,205	20,505	**-12.63%**
77	84,893	85,701	**-0.95%**	65,929	66,995	**-1.62%**	18,964	18,706	**1.36%**
79	90,005	99,259	**-10.28%**	68,182	76,264	**-11.85%**	21,823	22,995	**-5.37%**
85	32,371	37,691	**-16.43%**	24,350	28,947	**-18.88%**	8,021	8,744	**-9.01%**
92	25,475	24,698	**3.05%**	20,189	19,254	**4.63%**	5,286	5,444	**-2.99%**
147	50,682	52,841	**-4.26%**	38,510	38,897	**-1.00%**	12,172	13,944	**-14.56%**
Total	**1,003,038**	**1,056,995**	**-5.38%**	**777,090**	**813,414**	**-4.67%**	**225,948**	**243,581**	**-7.80%**

Minor Storm Days

Route	Total Ridership for Storm Days	Total Ridership for Previous Days (Non-Storm)	Total Ridership Difference
4	102,602	119,810	**-16.77%**
8	117,584	130,853	**-11.28%**
9	103,583	122,233	**-18.00%**
20	84,531	99,256	**-17.42%**
22	100,805	112,307	**-11.41%**
49	93,264	108,810	**-16.67%**
52	55,985	63,781	**-13.93%**
53	90,928	101,908	**-12.08%**
55	50,465	57,883	**-14.70%**
62	56,189	62,695	**-11.58%**
66	129,223	138,958	**-7.53%**
77	125,517	141,847	**-13.01%**
79	128,564	142,954	**-11.19%**
85	50,124	58,154	**-16.02%**
92	37,158	42,633	**-14.73%**
147	77,151	81,469	**-5.60%**
Total	1,403,673	1,585,551	**-12.96%**

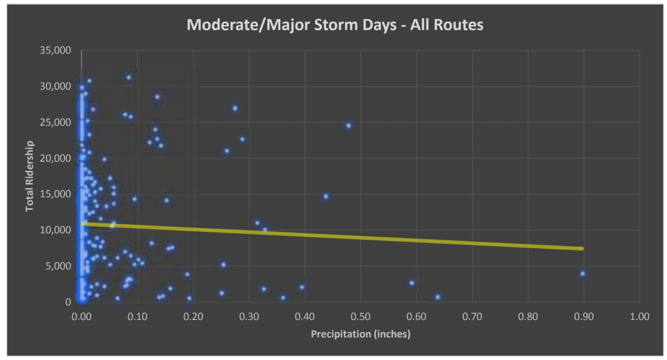
Nine Storm Days Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.708	1			
Palwkee_Precp	0.414	0.427	1		
AVG_Precp	0.874	0.888	0.702	1	
ALL_Routes	-0.030	0.002	-0.001	-0.012	1



Moderate/Major Storm Days Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.718	1			
Palwkee_Precp	0.396	0.363	1		
AVG_Precp	0.883	0.885	0.664	1	
ALL_Routes	-0.062	-0.019	-0.026	-0.044	1



Minor Storm Days Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.640	1			
Palwkee_Precp	0.488	0.750	1		
AVG_Precp	0.826	0.915	0.858	1	
ALL_Routes	0.044	0.070	0.049	0.063	1

February 7, 2017 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.547	1			
Palwkee_Precp	0.273	0.367	1		
AVG_Precp	0.864	0.887	0.451	1	
ALL_Routes	0.041	0.011	0.113	0.039	1

January 16-17, 2017 Correlation

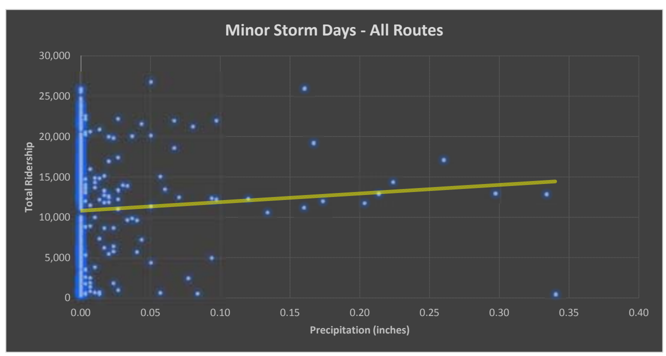
	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.897	1			
Palwkee_Precp	0.795	0.937	1		
AVG_Precp	0.937	0.989	0.947	1	
ALL_Routes	-0.080	-0.082	-0.057	-0.077	1

July 23-24, 2016 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.883	1			
Palwkee_Precp	0.586	0.646	1		
AVG_Precp	0.894	0.913	0.872	1	
ALL_Routes	-0.106	-0.059	-0.014	-0.062	1

March 24-25, 2016 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.473	1			
Palwkee_Precp	0.603	0.575	1		
AVG_Precp	0.876	0.747	0.870	1	
ALL_Routes	0.061	0.156	-0.051	0.052	1



December 23, 2015 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.713	1			
Palwkee_Precp	0.785	0.983	1		
AVG_Precp	0.944	0.904	0.944	1	
ALL_Routes	0.069	0.135	0.095	0.098	1

September 18-19, 2015 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.895	1			
Palwkee_Precp	0.506	0.670	1		
AVG_Precp	0.940	0.969	0.747	1	
ALL_Routes	-0.150	-0.226	-0.078	-0.175	1

June 15-16, 2015 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.644	1			
Palwkee_Precp	0.244	0.408	1		
AVG_Precp	0.815	0.922	0.604	1	
ALL_Routes	0.075	0.184	0.145	0.173	1

April 9-10, 2015 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.698	1			
Palwkee_Precp	0.403	0.766	1		
AVG_Precp	0.744	0.948	0.889	1	
ALL_Routes	0.118	0.165	0.131	0.160	1

April 17-18, 2013 Correlation

	Midway_Precp	Ohare_Precp	Palwkee_Precp	AVG_Precp	ALL_Routes
Midway_Precp	1				
Ohare_Precp	0.639	1			
Palwkee_Precp	-0.051	-0.038	1		
AVG_Precp	0.854	0.946	-0.039	1	
ALL_Routes	-0.150	-0.140	0.048	-0.158	1

Estimated $Cost/Rev-Hr	Estimated $Revenue/Rider
$ 100.00	$ 1.13

Route	Estimated Cost	Estimated Revenue	Est. Rev: Weekday	Est. Rev: Sat	Est. Rev: Sun
1	$ 984,629.17	$ 568,530.12	$ 2,212.54	$ -	$ -
2	$ 1,787,808.33	$ 963,056.06	$ 3,776.46	$ -	$ -
3	$ 12,141,531.67	$ 6,930,279.83	$ 21,735.55	$ 15,172.51	$ 10,321.42
4	$ 12,457,940.83	$ 7,624,981.23	$ 23,891.59	$ 16,094.59	$ 11,993.82
5	$ 842,893.33	$ 206,965.15	$ 561.61	$ 586.47	$ 575.17
6	$ 8,047,588.33	$ 4,008,484.03	$ 11,696.63	$ 10,732.74	$ 8,063.68
7	$ 3,576,763.33	$ 1,656,099.75	$ 6,494.11	$ -	$ -
8	$ 13,040,070.00	$ 7,707,276.87	$ 24,965.09	$ 14,384.90	$ 10,226.50
8A	$ 2,538,112.50	$ 1,188,865.09	$ 3,686.06	$ 2,712.00	$ 1,862.24
9	$ 18,532,925.00	$ 10,008,359.15	$ 31,073.87	$ 22,210.15	$ 16,029.05
X9	$ 159,186.67	$ 41,716.21	$ 5,204.78	$ 73.45	$ -
10	$ 381,146.67	$ 173,596.25	$ 759.36	$ 883.66	$ 693.82
11	$ 1,560,526.67	$ 585,010.04	$ 1,888.23	$ 1,114.18	$ 786.48
12	$ 7,900,445.83	$ 5,029,413.04	$ 16,000.80	$ 9,643.42	$ 7,721.29
J14	$ 7,203,098.33	$ 3,905,121.80	$ 12,937.37	$ 6,804.86	$ 4,348.24
15	$ 5,471,848.33	$ 2,732,481.25	$ 8,496.47	$ 5,864.70	$ 4,498.53
18	$ 2,847,706.67	$ 1,258,548.80	$ 3,924.49	$ 2,554.93	$ 2,152.65
19	$ -	$ 51,808.24	$ 375.16	$ 326.57	$ 305.10
20	$ 9,958,073.33	$ 6,246,476.15	$ 20,076.71	$ 11,844.66	$ 8,810.61
21	$ 6,786,466.67	$ 3,491,744.07	$ 10,694.32	$ 8,442.23	$ 5,614.97
22	$ 11,142,421.67	$ 6,875,549.41	$ 20,552.44	$ 16,772.59	$ 13,146.42
24	$ 2,839,278.33	$ 845,276.16	$ 3,314.29	$ -	$ -
26	$ 1,633,661.67	$ 928,440.77	$ 3,640.86	$ -	$ -
28	$ 5,261,448.33	$ 2,388,514.90	$ 7,940.51	$ 3,882.68	$ 2,789.97
29	$ 8,512,285.00	$ 4,866,629.76	$ 14,966.85	$ 11,171.18	$ 8,087.41
30	$ 3,882,132.50	$ 1,222,754.92	$ 4,065.74	$ 2,484.87	$ 980.84
34	$ 3,549,498.33	$ 1,867,366.81	$ 5,814.98	$ 3,898.50	$ 3,136.88
35	$ 4,690,035.00	$ 1,926,726.84	$ 6,198.05	$ 3,562.89	$ 2,775.28
36	$ 9,484,533.33	$ 5,304,439.22	$ 14,977.02	$ 15,371.39	$ 11,827.71
37	$ 1,472,122.50	$ 484,366.59	$ 1,899.53	$ -	$ -
39	$ 2,135,030.00	$ 639,066.98	$ 2,326.67	$ -	$ -
43	$ 1,500,880.00	$ 593,403.68	$ 1,978.63	$ 998.92	$ 636.19
44	$ 3,517,495.83	$ 1,293,220.59	$ 4,339.20	$ 2,020.44	$ 1,407.98
47	$ 6,597,173.33	$ 3,755,458.95	$ 11,609.62	$ 8,610.60	$ 5,985.61
48	$ 1,068,929.17	$ 332,525.10	$ 1,304.02	$ -	$ -
49	$ 16,537,850.83	$ 8,432,210.29	$ 26,461.21	$ 17,921.80	$ 12,975.79
49B	$ 2,619,403.33	$ 1,951,973.30	$ 6,096.35	$ 4,032.97	$ 3,236.32
X49	$ 132,106.67	$ 31,423.04	$ 3,908.67	$ 107.35	$ 45.20
50	$ 7,209,178.33	$ 3,404,224.44	$ 11,141.80	$ 6,105.39	$ 4,236.37
51	$ 1,770,977.50	$ 524,399.10	$ 1,657.71	$ 1,066.72	$ 800.04
52	$ 8,397,655.83	$ 4,329,520.42	$ 13,821.03	$ 8,628.68	$ 6,144.94
52A	$ 3,971,966.67	$ 1,472,587.75	$ 4,887.25	$ 2,507.47	$ 1,652.06
53	$ 11,366,315.83	$ 7,112,208.70	$ 22,497.17	$ 14,693.39	$ 10,539.51
53A	$ 6,401,025.83	$ 2,716,073.65	$ 9,199.33	$ 4,164.05	$ 2,652.11
54	$ 6,861,575.83	$ 4,205,507.44	$ 12,910.25	$ 9,779.02	$ 6,978.88
54A	$ 956,250.00	$ 241,195.11	$ 945.81	$ -	$ -
54B	$ 2,937,444.17	$ 1,297,218.53	$ 3,906.41	$ 3,356.10	$ 2,183.16
55	$ 7,636,570.00	$ 4,152,815.54	$ 12,770.13	$ 9,045.65	$ 7,347.26
55A	$ 330,012.50	$ 81,817.65	$ 320.92	$ -	$ -
55N	$ 834,445.00	$ 175,468.66	$ 642.97	$ 219.22	$ -
56	$ 6,875,140.00	$ 3,208,451.94	$ 10,325.94	$ 6,240.99	$ 4,326.77
57	$ 1,717,644.17	$ 1,581,168.32	$ 5,191.22	$ 2,767.37	$ 1,958.29
59	$ 2,946,737.50	$ 1,238,722.95	$ 4,374.23	$ 2,366.22	$ -
60	$ 7,941,492.50	$ 3,527,125.50	$ 11,442.38	$ 6,323.48	$ 4,837.53
62	$ 8,864,887.50	$ 3,806,887.51	$ 12,163.32	$ 7,341.61	$ 5,575.42
62H	$ 1,164,728.33	$ 298,006.99	$ 1,066.72	$ 498.33	$ -
63	$ 9,749,923.33	$ 6,079,239.54	$ 18,977.22	$ 12,666.17	$ 10,023.10
63W	$ 1,476,775.83	$ 459,686.26	$ 1,553.75	$ 667.83	$ 497.20
65	$ 5,920,128.33	$ 3,005,486.99	$ 9,710.09	$ 5,848.88	$ 3,884.94
66	$ 12,313,887.50	$ 8,361,951.41	$ 26,561.78	$ 17,039.27	$ 12,112.47
67	$ 7,393,507.50	$ 4,477,712.01	$ 13,795.04	$ 10,115.76	$ 7,482.86
68	$ 1,265,101.67	$ 438,572.21	$ 1,499.51	$ 613.59	$ 421.49

Route	Estimated Cost	Estimated Revenue	Est. Rev: Weekday	Est. Rev: Sat	Est. Rev: Sun
70	$ 5,720,508.33	$ 3,397,081.71	$ 10,746.30	$ 6,862.49	$ 5,172.01
71	$ 5,470,955.00	$ 3,222,571.29	$ 9,783.54	$ 7,410.54	$ 5,905.38
72	$ 9,549,948.33	$ 5,889,390.50	$ 17,817.84	$ 14,362.30	$ 10,329.33
73	$ 4,287,685.00	$ 1,447,369.54	$ 4,962.96	$ 1,963.94	$ 1,372.95
74	$ 7,781,376.67	$ 4,648,165.73	$ 14,399.59	$ 10,442.33	$ 7,470.43
75	$ 4,535,885.83	$ 2,737,940.28	$ 8,462.57	$ 6,071.49	$ 4,557.29
76	$ 6,970,852.50	$ 4,207,646.53	$ 13,601.81	$ 8,251.26	$ 5,349.42
77	$ 12,632,654.17	$ 7,919,121.36	$ 25,029.50	$ 16,261.83	$ 11,913.59
78	$ 5,634,602.50	$ 2,894,794.45	$ 9,223.06	$ 5,809.33	$ 4,151.62
79	$ 16,693,537.50	$ 9,849,393.01	$ 30,317.90	$ 22,106.19	$ 16,701.40
80	$ 8,293,834.17	$ 4,626,132.99	$ 14,372.47	$ 10,193.73	$ 7,433.14
81	$ 6,376,748.33	$ 4,536,442.63	$ 13,740.80	$ 10,663.81	$ 8,242.22
81W	$ 1,457,136.67	$ 559,890.14	$ 1,824.95	$ 1,100.62	$ 640.71
82	$ 10,612,298.33	$ 6,664,981.82	$ 21,401.07	$ 12,882.00	$ 9,271.65
84	$ 2,589,416.67	$ 1,369,015.34	$ 4,525.65	$ 2,342.49	$ 1,606.86
85	$ 5,875,565.00	$ 3,704,229.27	$ 11,721.49	$ 7,569.87	$ 5,542.65
85A	$ 671,680.00	$ 226,644.10	$ 813.60	$ 367.25	$ -
86	$ 2,144,570.83	$ 756,810.72	$ 2,967.38	$ -	$ -
87	$ 9,100,098.33	$ 4,779,962.15	$ 14,969.11	$ 10,182.43	$ 7,470.43
88	$ 1,134,833.33	$ 427,593.13	$ 1,424.93	$ 687.04	$ 493.81
90	$ 3,375,205.00	$ 1,782,381.77	$ 5,594.63	$ 3,919.97	$ 2,618.21
91	$ 4,155,783.33	$ 2,434,212.10	$ 7,911.13	$ 4,539.21	$ 3,116.54
92	$ 3,704,691.67	$ 2,427,307.80	$ 7,856.89	$ 4,489.49	$ 3,282.65
93	$ 2,313,041.67	$ 1,087,751.56	$ 3,916.58	$ 1,713.08	$ -
94	$ 7,366,231.67	$ 3,280,915.45	$ 10,815.23	$ 5,384.45	$ 4,190.04
95E	$ 2,614,353.33	$ 1,368,583.68	$ 4,286.09	$ 2,831.78	$ 2,210.28
95W	$ 1,919,242.50	$ 915,001.68	$ 2,669.06	$ 2,239.66	$ 2,032.87
96	$ 803,887.50	$ 252,992.31	$ 992.14	$ -	$ -
97	$ 2,787,693.33	$ 1,150,028.12	$ 3,632.95	$ 2,314.24	$ 1,782.01
X98	$ 10,625.00	$ 4,444.29	$ 19.21	$ -	$ -
100	$ 771,523.33	$ 208,253.35	$ 816.99	$ -	$ -
103	$ 2,714,483.33	$ 946,420.20	$ 3,097.33	$ 1,577.48	$ 1,285.94
106	$ 1,744,660.83	$ 529,459.24	$ 1,862.24	$ 650.88	$ 359.34
108	$ 920,994.17	$ 382,865.47	$ 1,501.77	$ -	$ -
111	$ 3,003,442.50	$ 1,367,387.01	$ 4,366.32	$ 2,649.85	$ 2,002.36
111A	$ 586,800.00	$ 81,085.41	$ 240.69	$ 206.79	$ 154.81
112	$ 2,373,920.00	$ 822,708.93	$ 2,749.29	$ 1,333.40	$ 900.61
115	$ 3,205,675.83	$ 1,438,966.86	$ 4,629.61	$ 2,615.95	$ 2,111.97
119	$ 3,649,146.67	$ 1,700,819.50	$ 5,198.00	$ 3,995.68	$ 2,889.41
120	$ 429,037.50	$ 279,135.99	$ 1,094.97	$ -	$ -
121	$ 591,387.50	$ 400,382.73	$ 1,569.57	$ -	$ -
124	$ 1,349,845.83	$ 389,014.93	$ 1,062.20	$ 1,314.19	$ 858.80
125	$ 809,576.67	$ 396,165.57	$ 1,553.75	$ -	$ -
126	$ 4,695,905.83	$ 2,096,429.11	$ 6,920.12	$ 3,464.58	$ 2,612.56
128	$ -	$ 7,786.83	$ 789.87	$ -	$ 887.05
132	$ 518,075.00	$ 69,566.19	$ 272.33	$ -	$ -
134	$ 970,112.50	$ 868,488.62	$ 3,405.82	$ -	$ -
135	$ 1,333,160.83	$ 960,248.01	$ 3,765.16	$ -	$ -
136	$ 1,012,904.17	$ 550,291.92	$ 2,158.30	$ -	$ -
143	$ 585,225.00	$ 540,610.08	$ 2,119.88	$ -	$ -
146	$ 8,708,675.00	$ 5,260,874.33	$ 15,636.94	$ 13,244.73	$ 10,081.86
147	$ 7,831,969.17	$ 4,976,055.57	$ 15,110.36	$ 12,173.49	$ 8,447.88
148	$ 1,046,085.83	$ 696,212.21	$ 2,730.08	$ -	$ -
151	$ 11,952,943.33	$ 6,595,404.33	$ 19,150.11	$ 17,783.94	$ 13,575.82
152	$ 6,388,048.33	$ 3,415,767.39	$ 11,397.18	$ 5,504.23	$ 3,849.91
155	$ 3,523,080.00	$ 2,722,812.97	$ 8,156.34	$ 6,595.81	$ 5,173.14
156	$ 3,611,881.67	$ 2,172,932.37	$ 8,521.33	$ -	$ -
157	$ 2,993,945.00	$ 1,568,463.73	$ 6,150.59	$ -	$ -
165	$ 156,187.50	$ 35,267.30	$ 137.86	$ -	$ -
169	$ 141,845.83	$ 65,149.02	$ 247.47	$ 35.03	$ -
170	$ 338,725.00	$ 94,550.49	$ 370.64	$ -	$ -
171	$ 696,250.00	$ 402,472.10	$ 1,418.15	$ 479.12	$ 462.17
172	$ 1,171,827.50	$ 596,614.01	$ 2,157.17	$ 550.31	$ 519.80
192	$ 259,462.50	$ 247,641.76	$ 970.67	$ -	$ -
201	$ 1,779,105.83	$ 638,872.62	$ 2,231.75	$ 1,339.05	$ -
205	$ 974,652.50	$ 265,075.40	$ 1,039.60	$ -	$ -
206	$ 547,604.17	$ 218,531.83	$ 856.54	$ -	$ -

Chicago Transit Authority
Daily Ridership by Route and Day Type - Annual

ROUTE #	ROUTE NAME	AVERAGE WEEKDAY	AVERAGE SATURDAY	AVERAGE SUNDAY	TOTAL ANNUAL
1	Bronzeville/Union Station	1,958			503,124
2	Hyde Park Express	3,342			852,262
3	King Drive	19,235	13,427	9,134	6,132,991
4	Cottage Grove	21,143	14,243	10,614	6,747,771
5	South Shore Night Bus	497	519	509	183,155
6	Jackson Park Express	10,351	9,498	7,136	3,547,331
7	Harrison	5,747			1,465,575
8	Halsted	22,093	12,730	9,050	6,820,599
8A	South Halsted	3,262	2,400	1,648	1,052,093
9	Ashland	27,499	19,655	14,185	8,856,955
X9	Ashland Express	4,606	65		36,917
10	Museum of S & I	672	782	614	153,625
11	Lincoln	1,671	986	696	517,708
12	Roosevelt	14,160	8,534	6,833	4,450,808
J14	Jeffery Jump	11,449	6,022	3,848	3,455,860
15	Jeffery Local	7,519	5,190	3,981	2,418,125
18	16th/18th	3,473	2,261	1,905	1,113,760
19	United Center Express	332	289	270	45,848
20	Madison	17,767	10,482	7,797	5,527,855
21	Cermak	9,464	7,471	4,969	3,090,039
22	Clark	18,188	14,843	11,634	6,084,557
24	Wentworth	2,933			748,032
26	South Shore Express	3,222			821,629
28	Stony Island	7,027	3,436	2,469	2,113,730
29	State	13,245	9,886	7,157	4,306,752
30	South Chicago	3,598	2,199	868	1,082,084
34	South Michigan	5,146	3,450	2,776	1,652,537
35	31st/35th	5,485	3,153	2,456	1,705,068
36	Broadway	13,254	13,603	10,467	4,694,194
37	Sedgwick	1,681			428,643
39	Pershing	2,059			565,546
43	43rd	1,751	884	563	525,136
44	Wallace-Racine	3,840	1,788	1,246	1,144,443
47	47th	10,274	7,620	5,297	3,323,415
48	South Damen	1,154			294,270
49	Western	23,417	15,860	11,483	7,462,133
49B	North Western	5,395	3,569	2,864	1,727,410
X49	Western Express	3,459	95	40	27,808
50	Damen	9,860	5,403	3,749	3,012,588
51	51st	1,467	944	708	464,070
52	Kedzie/California	12,231	7,636	5,438	3,831,434
52A	South Kedzie	4,325	2,219	1,462	1,303,175
53	Pulaski	19,909	13,003	9,327	6,293,990
53A	South Pulaski	8,141	3,685	2,347	2,403,605
54	Cicero	11,425	8,654	6,176	3,721,688
54A	North Cicero/Skokie Blvd.	837			213,447
54B	South Cicero	3,457	2,970	1,932	1,147,981
55	Garfield	11,301	8,005	6,502	3,675,058
55A	55th/Austin	284			72,405
55N	55th/Narragansett	569	194		155,282
56	Milwaukee	9,138	5,523	3,829	2,839,338
57	Laramie	4,594	2,449	1,733	1,399,264
59	59th/61st	3,871	2,094		1,096,215
60	Blue Island/26th	10,126	5,596	4,281	3,121,350
62	Archer	10,764	6,497	4,934	3,368,927
62H	Archer/Harlem	944	441		263,723
63	63rd	16,794	11,209	8,870	5,379,858
63W	West 63rd	1,375	591	440	406,802
65	Grand	8,593	5,176	3,438	2,659,723
66	Chicago	23,506	15,079	10,719	7,399,957
67	67th-69th-71st	12,208	8,952	6,622	3,962,577
68	Northwest Highway	1,327	543	373	388,117
70	Division	9,510	6,073	4,577	3,006,267
71	71st/South Shore	8,658	6,558	5,226	2,851,833
72	North	15,768	12,710	9,141	5,211,850

ROUTE #	ROUTE NAME	AVERAGE WEEKDAY	SATURDAY	SUNDAY	TOTAL ANNUAL
73	Armitage	4,392	1,738	1,215	1,280,858
74	Fullerton	12,743	9,241	6,611	4,113,421
75	74th-75th	7,489	5,373	4,033	2,422,956
76	Diversey	12,037	7,302	4,734	3,723,581
77	Belmont	22,150	14,391	10,543	7,008,072
78	Montrose	8,162	5,141	3,674	2,561,765
79	79th	26,830	19,563	14,780	8,716,277
80	Irving Park	12,719	9,021	6,578	4,093,923
81	Lawrence	12,160	9,437	7,294	4,014,551
81W	West Lawrence	1,615	974	567	495,478
82	Kimball-Homan	18,939	11,400	8,205	5,898,214
84	Peterson	4,005	2,073	1,422	1,211,518
85	Central	10,373	6,699	4,905	3,278,079
85A	North Central	720	325		200,570
86	Narragansett/Ridgeland	2,626			669,744
87	87th	13,247	9,011	6,611	4,230,055
88	Higgins	1,261	608	437	378,401
90	Harlem	4,951	3,469	2,317	1,577,329
91	Austin	7,001	4,017	2,758	2,154,170
92	Foster	6,953	3,973	2,905	2,148,060
93	California/Dodge	3,466	1,516		962,612
94	South California	9,571	4,765	3,708	2,903,465
95E	93rd-95th	3,793	2,506	1,956	1,211,136
95W	West 95th	2,362	1,982	1,799	809,736
96	Lunt	878			223,887
97	Skokie	3,215	2,048	1,577	1,017,724
X98	Avon Express	17			3,933
100	Jeffery Manor Express	723			184,295
103	West 103rd	2,741	1,396	1,138	837,540
106	East 103rd	1,648	576	318	468,548
108	Halsted/95th	1,329			338,819
111	111th/King Drive	3,864	2,345	1,772	1,210,077
111A	Pullman Shuttle	213	183	137	71,757
112	Vincennes/111th	2,433	1,180	797	728,061
115	Pullman/115th	4,097	2,315	1,869	1,273,422
119	Michigan/119th	4,600	3,536	2,557	1,505,150
120	Ogilvie/Streeterville Express	969			247,023
121	Union/Streeterville Express	1,389			354,321
124	Navy Pier	940	1,163	760	344,261
125	Water Tower Express	1,375			350,589
126	Jackson	6,124	3,066	2,312	1,855,247
128	Soldier Field Express	699		785	6,891
132	Goose Island Express	241			61,563
134	Stockton/LaSalle Express	3,014			768,574
135	Clarendon/LaSalle Express	3,332			849,777
136	Sheridan/LaSalle Express	1,910			486,984
143	Stockton/Michigan Express	1,876			478,416
146	Inner Drive/Michigan Express	13,838	11,721	8,922	4,655,641
147	Outer Drive Express	13,372	10,773	7,476	4,403,589
148	Clarendon/Michigan Express	2,416			616,117
151	Sheridan	16,947	15,738	12,014	5,836,641
152	Addison	10,086	4,871	3,407	3,022,803
155	Devon	7,218	5,837	4,578	2,409,569
156	LaSalle	7,541			1,922,949
157	Streeterville/Taylor	5,443			1,388,021
165	West 65th	122			31,210
169	69th-UPS Express	219	31		57,654
170	U. of Chicago/Midway	328			83,673
171	U. of Chicago/Hyde Park	1,255	424	409	356,170
172	U. of Chicago/Kenwood	1,909	487	460	527,977
192	U. of Chicago Hospitals Express	859			219,152
201	Central/Ridge	1,975	1,185		565,374
205	Chicago/Golf	920			234,580
206	Evanston Circulator	758			193,391

* Source 2015 Annual Reort

ROUTE	NAME	SORT	REVHR	REVMIL
1	Bronzeville/Union Station	10	9,846	69,828
2	Hyde Park Express	20	17,878	192,696
3	King Drive	30	121,415	1,051,769
4	Cottage Grove	40	124,579	1,093,297
5	South Shore Night Bus	45	8,429	101,353
6	Jackson Park Express	50	80,476	923,519
7	Harrison	60	35,768	307,163
8	Halsted	70	130,401	1,105,178
8A	South Halsted	80	25,381	256,492
9	Ashland	90	185,329	1,655,782
X9	Ashland Express	91	1,592	16,278
10	Museum of S & I	95	3,811	45,370
11	Lincoln	100	15,605	136,141
12	Roosevelt	110	79,004	673,067
J14	Jeffery Jump	121	72,031	1,021,345
15	Jeffery Local	125	54,718	578,404
18	16th/18th	150	28,477	242,175
20	Madison	160	99,581	808,689
21	Cermak	170	67,865	581,466
22	Clark	180	111,424	889,898
24	Wentworth	195	28,393	280,920
26	South Shore Express	205	16,337	228,439
28	Stony Island	220	52,614	586,521
29	State	230	85,123	827,145
30	South Chicago	240	38,821	506,352
34	South Michigan	261	35,495	400,529
35	31st/35th	270	46,900	418,854
36	Broadway	280	94,845	661,554
37	Sedgwick	290	14,721	97,335
39	Pershing	300	21,350	223,767
43	43rd	330	15,009	128,020
44	Wallace-Racine	340	35,175	367,398
47	47th	360	65,972	585,415
48	South Damen	370	10,689	131,539
49	Western	380	165,379	1,521,660
49B	North Western	400	26,194	235,484
X49	Western Express	405	1,321	13,007
50	Damen	410	72,092	614,982
51	51st	420	17,710	183,023
52	Kedzie/California	430	83,977	770,850
52A	South Kedzie	440	39,720	428,480
53	Pulaski	450	113,663	934,520
53A	South Pulaski	460	64,010	683,520
54	Cicero	470	68,616	588,859
54A	North Cicero/Skokie Blvd.	480	9,563	102,421
54B	South Cicero	490	29,374	331,848
55	Garfield	500	76,366	730,197
55A	55th/Austin	502	3,300	33,664
55N	55th/Narragansett	505	8,344	83,308
56	Milwaukee	510	68,751	554,376
57	Laramie	530	17,176	146,744
59	59th/61st	540	29,467	292,345
60	Blue Island/26th	550	79,415	639,292
62	Archer	570	88,649	869,140
62H	Archer/Harlem	575	11,647	135,044
63	63rd	580	97,499	865,309
63W	West 63rd	585	14,768	146,287
65	Grand	600	59,201	573,472
66	Chicago	610	123,139	967,645
67	67th-69th-71st	620	73,935	730,576
68	Northwest Highway	630	12,651	143,730
70	Division	650	57,205	484,951
71	71st/South Shore	660	54,710	495,666
72	North	670	95,499	770,230
73	Armitage	680	42,877	364,732
74	Fullerton	690	77,814	643,527
75	74th-75th	700	45,359	406,581
76	Diversey	710	69,709	581,530

ROUTE	NAME	SORT	REVHR	REVMIL
77	Belmont	720	126,327	1,116,319
78	Montrose	730	56,346	488,506
79	79th	740	166,935	1,446,592
80	Irving Park	750	82,938	731,582
81	Lawrence	760	63,767	503,990
81W	West Lawrence	770	14,571	162,134
82	Kimball-Homan	780	106,123	947,404
84	Peterson	790	25,894	245,392
85	Central	800	58,756	531,087
85A	North Central	810	6,717	86,879
86	Narragansett/Ridgeland	820	21,446	232,525
87	87th	830	91,001	817,211
88	Higgins	840	11,348	130,633
90	Harlem	860	33,752	326,860
91	Austin	880	41,558	416,797
92	Foster	890	37,047	321,431
93	California/Dodge	900	23,130	223,130
94	South California	910	73,662	726,539
95E	93rd-95th	925	26,144	270,776
95W	West 95th	930	19,192	159,984
96	Lunt	940	8,039	73,292
97	Skokie	950	27,877	344,046
X98	Avon Express	960	106	2,941
100	Jeffery Manor Express	980	7,715	90,297
103	West 103rd	990	27,145	306,097
106	East 103rd	1010	17,447	182,405
108	Halsted/95th	1020	9,210	101,760
111	111th/King Drive	1040	30,034	322,536
111A	Pullman Shuttle	1042	5,868	50,320
112	Vincennes/111th	1050	23,739	270,442
115	Pullman/115th	1053	32,057	343,169
119	Michigan/119th	1055	36,491	376,883
120	Ogilvie/Streeterville Express	1070	4,290	25,229
121	Union/Streeterville Express	1080	5,914	35,485
124	Navy Pier	1105	13,498	80,602
125	Water Tower Express	1110	8,096	47,200
126	Jackson	1120	46,959	424,124
130	Museum Campus	1145	2,654	15,387
132	Goose Island Express	1152	5,181	47,205
134	Stockton/LaSalle Express	1155	9,701	87,841
135	Clarendon/LaSalle Express	1160	13,332	130,498
136	Sheridan/LaSalle Express	1170	10,129	107,708
143	Stockton/Michigan Express	1175	5,852	50,028
146	Inner Drive/Michigan Express	1190	87,087	689,699
147	Outer Drive Express	1200	78,320	808,894
148	Clarendon/Michigan Express	1205	10,461	100,382
151	Sheridan	1210	119,529	825,430
152	Addison	1220	63,880	589,933
155	Devon	1230	35,231	248,298
156	LaSalle	1240	36,119	241,196
157	Streeterville/Taylor	1250	29,939	193,752
165	West 65th	1270	1,562	16,358
169	69th-UPS Express	1275	1,418	37,145
170	U. of Chicago/Midway	1276	3,387	29,670
171	U. of Chicago/Hyde Park	1277	6,963	64,083
172	U. of Chicago/Kenwood	1278	11,718	78,091
192	U. of Chicago Hospitals Express	1281	2,595	38,997
201	Central/Ridge	1286	17,791	230,433
205	Chicago/Golf	1311	9,747	104,960
206	Evanston Circulator	1312	5,476	70,745

```
select t.route, b.name, b.sort, sum(t.revbushr) RevHr, sum(t.revbusmile) RevMil
from SCHD_BUS_ROUTE_MONTH t, planningadmin.routes@CPC2.AVAS b
where t.month between '01jan15' and '01Dec15'
and t.route = b.routenum
group by t.route, b.name, b.sort
order by b.sort
```

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Flooding Resilience Plan for Bus Operations

Appendix E: Pace Reroute Impact Analysis

Prepared for the Regional Transportation Authority of Northeast Illinois

March 30, 2018

March 2018

Quality Management

Prepared by	Checked by	Approved by
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Revision History

Version	Revision Date	Details
1	August 10, 2017	Discussion draft
2	December 05, 2017	Draft Report for Review
3	December 14, 2017	Comments from Steering Committee
4	February 25, 2018	Final draft
5	March 30, 2018	Final

Distribution List

Name	Association / Company Name
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Kate Tomford, Heather Ferguson, Christina Arthur, Beverly Carey, Raymond Chan, Michael Connelly, Tony Coppoletta, Jonathan Czerwinski, Elsa Gutierrez, Marvin Hicks, Jamil Houston, Derrick McFarland, Patricia Thomas-Miller	CTA
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March 2018

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Pace Travel Time Impacts Worksheet

Routes are characterized by their service pattern. Existing conditions represent normal operating patterns, while reroute represents the operating pattern when inclement weather requires adjustments to the route alignment.

Estimates of impacts to operating costs are calculated using each route's cost per-hour metric. As with the changes in travel times vary substantially in both positive and negative directions, changes in trip cost likewise show as positive and negative, with increased costs projected to be incurred in some situations, and savings in other situations. These cost projections are presented as Base costs, along with other scenarios accounting for additional Low, Moderate and High travel delay factors which would increase costs.

Metric	Description
Travel Time	Calculated using the route network on Google for a one-way trip, which is based on Pace published schedules. Reroutes were calculated using the same bus route on Google, but modifying the route alignment to reflect adjustments to avoid areas of flooding.
Travel Time (Time Factor)	Represents the trip time with the travel time factor added to the existing time.
Hours	Represents the one-way trip time in total hours.
Congestion	One of the three factors which compose the travel time factor. The factor can be adjusted from low, moderate, or high. Select a factor impact through the drop down arrow, or type the degree of factor impact.
Storm Severity	Same as above.
Operating Delay	Same as above. This factor represents the ability for Pace dispatch or the Pace bus operator to respond to the storm incident.
Factor AVG	Represents the average score of the three factors
Time Factor	The percentage which is added to travel time and cost per trip to represent estimates of how the storm incident could impact travel time and operating costs.
Cost per hour	For existing routes, provided by Pace in the Cost and Operating Stats excel. Costs per hour for reroutes were assumed to be the same as the existing route.
Cost per trip (Base)	For existing routes and reroutes, calculated by multiplying the cost per hour by the travel time (one-trip). This cost does not include any time factor multiplier and assumes route time using Google – a change in travel time due strictly to the change in route alignment.
Cost per trip (Low)	Calculated by multiplying the cost per hour by the travel time (one-trip) and then multiplying by the "Low" time factor (5 percent).
Cost per trip (Mod)	Calculated by multiplying the cost per hour by the travel time (one-trip) and then multiplying by the "Moderate" time factor (15 percent).
Cost per trip (High)	Calculated by multiplying the cost per hour by the travel time (one-trip) and then multiplying by the "High" time factor (30 percent).
Cost Change per Trip (Base)	The change in cost per trip going into reroute using base travel time with no time factor multiplier.
Cost Change per Trip (Low)	The change in cost per trip going into reroute using the base travel time incremented by 5 percent.
Cost Change per Trip (Mod)	The change in cost per trip going into reroute using the base travel time incremented by 15 percent.
Cost Change per Trip (High)	The change in cost per trip going into reroute using the base travel time incremented by 30 percent.
Average Missed Passengers per Trip	The estimated average missed passengers due to the reroute pattern. This number represents the average daily ridership for the week prior to one of the nine storm incidents. Although all passengers may not be missed, this data provides a conservative estimate of the potential number of passengers missed.
Segment Data	Consists of three columns for each reroute segment of the existing route. *Total Ridership* represents the total number of boardings for the segment, and the *Non Incident Days* column provides the total number of regular service days surveyed in the data. The *Average missed* column provides an average daily ridership missed for the segment.
Custom Travel Time Adjustments	User selects "Low", "Moderate" or "High" additional Travel Time impact values in "Congestion", "Storm Severity" and "Operating Delay" categories to calculate a customized adjusted reroute time.

Pace Ridership Impacts Worksheet

The *Pace Ridership Impacts* worksheet provides a summary of 2016 ridership data and impact analysis. The tables summarize the impact analysis of reroutes on the Scenario E routes, including estimates of changes in stops serviced based on the reroute alignment, associated changes in ridership changes in travel time, and associated operating costs. The estimates presented assume full implementation of reroutes as documented, including situations where a route may have multiple diversions.

Metric	Description
Average Daily Ridership	Sourced from Pace data in the Costs and Operating Stats spreadsheet. The average daily ridership number for reroutes was calculated by subtracting the estimated impacted (potentially missed) ridership from the existing route's average daily ridership.
Ridership Change	Represents the change in ridership between a normal operating day and ridership on a day operating around flooded areas (with potentially lost or diverted customers).
Impacted Ridership	Four columns representing boardings for total, weekday, Saturday, and Sunday.
# Flooding Incidents	Represent locations of flooding hot spots based on intersections with floodplain risk areas, current and enhanced for future climate change
Bus Stops Missed	Number of existing bus stops skipped due to a reroute.

Pace Ops Data Worksheet

All transit GIS data was provided by Pace, and processed by AECOM and its subconsultant UrbanGIS. It included the following:

- Bus stop locations
- Driver-reported routes with flood problems
- Stop-level ridership

Costs and Operating Stats Q2 sent 20161012. This table provided annual daily ridership categorized by route and day type, annual revenue miles and hours by route, and estimated operating costs, estimated hourly operating costs and revenue received by route.

RSM_APC_Spring 2016. Three Excel files were included for weekday, Saturday, and Sunday ridership by stop. The data provided average boardings and alightings at each stop. For our analysis, we only included boarding averages. All boarding averages were rounded to the next whole number.

Reroute turn-by-turn directions were provided by Pace and coded in GIS by AECOM and Urban GIS.

Route		Travel Time				Travel Time (Hours)				Cost				
Number	Type	Travel Time	Travel Time (Low)	Travel Time (Mod)	Travel Time (High)	Hours (one-way, Base)	Hours (one-way, Low)	Hours (one-way, Mod)	Hours (one-way, High)	Cost per hour	Cost per Trip (Base)	Cost per Trip (Low)	Cost per Trip (Mod)	Cost Per Trip (High)
208	Existing	95				1.58				$ 76.05	$ 119.78			
209	Existing	30				0.50				$ 76.05	$ 38.03			
221	Existing	55				0.92				$ 76.05	$ 69.71			
226	Existing	56				0.93				$ 76.05	$ 70.35			
230	Existing	40				0.67				$ 76.05	$ 50.70			
234	Existing	46				0.77				$ 76.05	$ 58.31			
302	Existing	34				0.56				$ 73.14	$ 40.84			
303	Existing	45				0.75				$ 73.14	$ 54.85			
309	Existing	45				0.75				$ 73.14	$ 54.85			
318	Existing	31				0.51				$ 73.14	$ 37.18			
322	Existing	60				1.00				$ 73.14	$ 73.14			
330	Existing	64				1.07				$ 73.14	$ 78.01			
331	Existing	55				0.92				$ 73.14	$ 67.04			
332	Existing	69				1.14				$ 73.14	$ 83.50			
356	Existing	33				0.54				$ 88.36	$ 47.86			
364	Existing	90				1.50				$ 88.36	$ 132.54			
381	Existing	54				0.90				$ 66.63	$ 59.96			
386	Existing	67				1.12				$ 66.63	$ 74.40			
626	Existing	70				1.17				$ 69.94	$ 81.60			
757	Existing	63				1.04				$ 73.14	$ 76.18			
208	Reroute	73	77	84	95	1.22	1.28	1.40	1.58	$ 76.05	$ 92.53	$ 97.15	$ 106.41	$ 120.29
209	Reroute	28	29	32	36	0.47	0.49	0.54	0.61	$ 76.05	$ 35.49	$ 37.26	$ 40.81	$ 46.14
221	Reroute	45	47	52	59	0.75	0.79	0.86	0.98	$ 76.05	$ 57.04	$ 59.89	$ 65.59	$ 74.15
226	Reroute	44	46	50	57	0.73	0.76	0.83	0.94	$ 76.05	$ 55.14	$ 57.89	$ 63.41	$ 71.68
230	Reroute	33	35	38	43	0.55	0.58	0.63	0.72	$ 76.05	$ 41.83	$ 43.92	$ 48.10	$ 54.38
234	Reroute	34	35	39	44	0.56	0.59	0.64	0.73	$ 76.05	$ 42.46	$ 44.58	$ 48.83	$ 55.20
302	Reroute	36	38	41	47	0.60	0.63	0.69	0.78	$ 73.14	$ 43.88	$ 46.08	$ 50.46	$ 57.05
303	Reroute	40	42	46	52	0.67	0.70	0.77	0.87	$ 73.14	$ 48.76	$ 51.20	$ 56.07	$ 63.39
309	Reroute	48	50	55	62	0.80	0.84	0.92	1.04	$ 73.14	$ 58.51	$ 61.44	$ 67.29	$ 76.06
318	Reroute	39	41	45	51	0.65	0.68	0.75	0.85	$ 73.14	$ 47.54	$ 49.92	$ 54.67	$ 61.80
322	Reroute	67	70	76	86	1.11	1.16	1.27	1.44	$ 73.14	$ 81.06	$ 85.11	$ 93.22	$ 105.38
330	Reroute	70	74	81	91	1.17	1.23	1.34	1.52	$ 73.14	$ 85.33	$ 89.59	$ 98.13	$ 110.93
331	Reroute	60	63	69	78	1.00	1.05	1.15	1.30	$ 73.14	$ 73.14	$ 76.79	$ 84.11	$ 95.08
332	Reroute	63	66	72	81	1.04	1.09	1.20	1.35	$ 73.14	$ 76.18	$ 79.99	$ 87.61	$ 99.04
356	Reroute	35	37	40	46	0.58	0.61	0.67	0.76	$ 88.36	$ 51.54	$ 54.12	$ 59.27	$ 67.01
364	Reroute	90	95	104	117	1.50	1.58	1.73	1.95	$ 88.36	$ 132.54	$ 139.17	$ 152.42	$ 172.30
381	Reroute	53	55	60	68	0.88	0.92	1.01	1.14	$ 66.63	$ 58.30	$ 61.21	$ 67.04	$ 75.79
386	Reroute	70	74	81	91	1.17	1.23	1.34	1.52	$ 66.63	$ 77.73	$ 81.62	$ 89.39	$ 101.05
626	Reroute	75	79	86	98	1.25	1.31	1.44	1.63	$ 69.94	$ 87.42	$ 91.80	$ 100.54	$ 113.65
757	Reroute	64	67	74	83	1.07	1.12	1.23	1.39	$ 73.14	$ 78.01	$ 81.91	$ 89.72	$ 101.42

Route		Cost Change per Trip				Custom Travel Time Adjustments								
Number	Type	Cost Change per Trip (Base)	Cost Change per Trip (Low)	Cost Change per Trip (Mod)	Cost Change per Trip (High)	Congestion	Storm Severity	Operating Delay	Factor AVG	Time Factor	Travel Time (with time factor)	Hours (one-way, with time factor)	Cost Per Trip (Time Factor)	Cost Change per Trip (Time Factor)
208	Existing													
209	Existing													
221	Existing													
226	Existing													
230	Existing													
234	Existing													
302	Existing													
303	Existing													
309	Existing													
318	Existing													
322	Existing													
330	Existing													
331	Existing													
332	Existing													
356	Existing													
364	Existing													
381	Existing													
386	Existing													
626	Existing													
757	Existing													
208	Reroute	$ (27.25)	$ (22.63)	$ (13.37)	$ 0.51	Low	Low	Low	1.0000	5%	76.7	1.28	$ 97.15	$ (22.63)
209	Reroute	$ (2.54)	$ (0.76)	$ 2.79	$ 8.11	Low	Low	Low	1.0000	5%	29.4	0.49	$ 37.26	$ (0.76)
221	Reroute	$ (12.68)	$ (9.82)	$ (4.12)	$ 4.44	Low	Low	Low	1.0000	5%	47.3	0.79	$ 59.89	$ (9.82)
226	Reroute	$ (15.21)	$ (12.45)	$ (6.94)	$ 1.33	Low	Low	Low	1.0000	5%	45.7	0.76	$ 57.89	$ (12.45)
230	Reroute	$ (8.87)	$ (6.78)	$ (2.60)	$ 3.68	Low	Low	Low	1.0000	5%	34.7	0.58	$ 43.92	$ (6.78)
234	Reroute	$ (15.84)	$ (13.72)	$ (9.47)	$ (3.11)	Low	Low	Low	1.0000	5%	35.2	0.59	$ 44.58	$ (13.72)
302	Reroute	$ 3.05	$ 5.24	$ 9.63	$ 16.21	Low	Low	Low	1.0000	5%	37.8	0.63	$ 46.08	$ 5.24
303	Reroute	$ (6.09)	$ (3.66)	$ 1.22	$ 8.53	Low	Low	Low	1.0000	5%	42.0	0.70	$ 51.20	$ (3.66)
309	Reroute	$ 3.66	$ 6.58	$ 12.43	$ 21.21	Low	Low	Low	1.0000	5%	50.4	0.84	$ 61.44	$ 6.58
318	Reroute	$ 10.36	$ 12.74	$ 17.49	$ 24.62	Low	Low	Low	1.0000	5%	41.0	0.68	$ 49.92	$ 12.74
322	Reroute	$ 7.92	$ 11.98	$ 20.08	$ 32.24	Low	Low	Low	1.0000	5%	69.8	1.16	$ 85.11	$ 11.98
330	Reroute	$ 7.31	$ 11.58	$ 20.11	$ 32.91	Low	Low	Low	1.0000	5%	73.5	1.23	$ 89.59	$ 11.58
331	Reroute	$ 6.09	$ 9.75	$ 17.07	$ 28.04	Low	Low	Low	1.0000	5%	63.0	1.05	$ 76.79	$ 9.75
332	Reroute	$ (7.31)	$ (3.50)	$ 4.11	$ 15.54	Low	Low	Low	1.0000	5%	65.6	1.09	$ 79.99	$ (3.50)
356	Reroute	$ 3.68	$ 6.26	$ 11.41	$ 19.14	Low	Low	Low	1.0000	5%	36.8	0.61	$ 54.12	$ 6.26
364	Reroute	$ -	$ 6.63	$ 19.88	$ 39.76	Low	Low	Low	1.0000	5%	94.5	1.58	$ 139.17	$ 6.63
381	Reroute	$ (1.67)	$ 1.25	$ 7.08	$ 15.82	Low	Low	Low	1.0000	5%	55.1	0.92	$ 61.21	$ 1.25
386	Reroute	$ 3.33	$ 7.22	$ 14.99	$ 26.65	Low	Low	Low	1.0000	5%	73.5	1.23	$ 81.62	$ 7.22
626	Reroute	$ 5.83	$ 10.20	$ 18.94	$ 32.06	Low	Low	Low	1.0000	5%	78.8	1.31	$ 91.80	$ 10.20
757	Reroute	$ 1.83	$ 5.73	$ 13.53	$ 25.23	Low	Low	Low	1.0000	5%	67.2	1.12	$ 81.91	$ 5.73

				Impacted Ridership (ADR)				Segment 1 Ridership				Segment 2 Ridership						
Route	Route Type	Average Daily Ridership	Ridership Change	Total	Weekday	Saturday	Sunday	Total	Weekday	Saturday	Sunday	Total	Weekday	Saturday	Sunday	# of Flooding Incidents	Missed Bus Stops	Change in Flood Incidents
208	Existing	1,847														1		
209	Existing	369														1		
221	Existing	726														0		
226	Existing	696														1		
230	Existing	370														1		
234	Existing	266														0		
302	Existing	551														2		
303	Existing	1,130														5		
309	Existing	881														2		
318	Existing	2,402														3		
322	Existing	2,243														2		
330	Existing	1,223														6		
331	Existing	1,142														4		
332	Existing	629														4		
356	Existing	581														2		
364	Existing	2,043														1		
381	Existing	3,669														1		
386	Existing	1,423														1		
626	Existing	346														0		
757	Existing	210														0		
208	Reroute	1,687	-9%	160	160	55	35	160	149	55	35					0	34	-1
209	Reroute	368	0%	1	1	0	0	1	1	0	0					1	6	0
221	Reroute	683	-6%	43	43	NA	NA	43	43	NA	NA					0	34	0
226	Reroute	694	0%	2	2	NA	NA	2	2	NA	NA					1	17	0
230	Reroute	365	-1%	5	5	NA	NA	5	5	NA	NA					1	7	0
234	Reroute	248	-7%	18	18	NA	NA	18	18	NA	NA					0	30	0
302	Reroute	546	-1%	5	3	2	NA	5	3	2	NA					2	2	0
303	Reroute	515	-54%	615	615	NA	NA	615	615	NA	NA					0	138	-5
309	Reroute	820	-7%	61	35	20	6	8	5	2	1	53	30	18	5	2	25	0
318	Reroute	926	-61%	1476	716	426	334	280	181	62	37	1196	535	364	297	2	32	-1
322	Reroute	2,175	-3%	68	38	21	9	68	38	21	9					2	2	0
330	Reroute	948	-22%	275	150	74	51	200	115	52	33	75	35	22	18	8	16	2
331	Reroute	1,080	-5%	62	50	12	NA	62	50	12	NA					3	33	-1
332	Reroute	477	-24%	152	65	39	48	152	65	39	48					5	19	1
356	Reroute	567	-2%	14	6	5	3	14	6	5	3					2	7	0
364	Reroute	2,043	0%	0	0	0	0	0								1	0	0
381	Reroute	3,631	-1%	38	28	1	9	38	28	1	9					0	7	-1
386	Reroute	1,344	-6%	79	57	19	3	79	57	19	3					0	10	-1
626	Reroute	346	0%	0	NA	0	0	0	No ridership data was provided							0	0	0
757	Reroute	210	0%	0	NA	0	0	0	No reroute was suggested							0	0	0

**Note: The numbers represent average boardings and average ridership for September 2016.*

Route Number	Service Day	Division	Route Name	Service Type	Minority Service	Counties Served	2015 Average Daily Ridership	2016 Average Daily Ridership	Percent Change	Vehicle Miles
208	Wkd	Northwest	Golf Road	CTA Connector	*	Cook (Chicago), Cook (Suburbs)	1,943	1,847	-4.92%	1,743.83
209	Wkd	Northwest	Busse Highway	CTA Connector		Cook (Chicago), Cook (Suburbs)	368	369	0.39%	371.53
221	Wkd	Northwest	Wolf Road	CTA Connector	*	Cook (Chicago), Cook (Suburbs)	780	726	-6.90%	605.78
226	Wkd	Northwest	Oakton Street	CTA Connector		Cook (Chicago), Cook (Suburbs), Kane	726	696	-4.02%	763.51
230	Wkd	Northwest	South Des Plaines	CTA Connector	*	Cook (Suburbs), DuPage	396	370	-6.69%	382.95
234	Wkd	Northwest	Wheeling - Des Plaines	Suburban Links	*	Cook (Suburbs), Lake	301	266	-11.71%	581.85
302	Wkd	West	Ogden - Stanley	CTA Connector	*	Cook (Chicago), Cook (Suburbs)	620	551	-11.12%	437.98
303	Wkd	West	Forest Park - Rosemont	CTA Connector	*	Cook (Chicago), Cook (Suburbs)	1,216	1,130	-7.09%	723.36
309	Wkd	West	Lake Street	CTA Connector	*	Cook (Chicago), Cook (Suburbs), DuPage	890	881	-0.92%	521.31
318	Wkd	West	West North Avenue	CTA Connector	*	Cook (Chicago), Cook (Suburbs), DuPage	2,364	2,402	1.58%	851.63
322	Wkd	West	Cermak Road - 22nd Street	CTA Connector	*	Cook (Chicago), Cook (Suburbs), DuPage	2,413	2,243	-7.04%	1,676.09
330	Wkd	West	Mannheim - LaGrange Roads	CTA Connector	*	Cook (Chicago), Cook (Suburbs), DuPage	1,261	1,223	-3.00%	1,535.78
331	Wkd	West	Cumberland - 5th Avenue	CTA Connector		Cook (Chicago), Cook (Suburbs)	1,255	1,142	-9.01%	920.26
332	Wkd	West	River - York Roads	CTA Connector		Cook (Chicago), Cook (Suburbs), DuPage	530	629	18.53%	605.34
356	Wkd	South	Harvey - Homewood - Tinley Park	Suburban Links	*	Cook (Chicago), Cook (Suburbs), DuPage, Will	629	581	-7.59%	703.99
364	Wkd	South	159th Street	Suburban Links	*	Cook (Chicago), Cook (Suburbs), Lake (Indiana)	2,345	2,043	-12.89%	1,627.70
381	Wkd	Southwest	95th Street	CTA Connector		Cook (Chicago), Cook (Suburbs), Lake (Indiana), Will	3,899	3,669	-5.91%	1,350.33
386	Wkd	Southwest	South Harlem	CTA Connector		Cook (Chicago), Cook (Suburbs), DuPage, Will	1,402	1,423	1.45%	1,420.21
626	Wkd	North Shore	Skokie Valley Limited	CTA Connector		Cook (Suburbs), Lake	388	346	-10.70%	869.54
757	Wkd	West	Northwest Connection	CTA Connector	*	Cook (Suburbs), DuPage	210	210	-0.13%	476.62

Route Number	Revenue Miles	Vehicle Hours	Revenue Hours	Total Estimated Daily Operating Cost	Estimated Revenue	Passengers per Revenue Hour	Operating Subsidy per Rider	Farebox Recovery Ratio	Operating Subsidy per Vehicle Mile	Miles per Passenger	Cost per Revenue Hour	Passengers per Revenue Mile	Other External Block Funding	Revenue per Rider	Total Hourly Operating Cost
208	1,620.50	108.25	87.02	$8,232.26	$1,993.29	21	$3.38	24%	$3.58	0.94	$94.61	1.14		$1.08	$76.05
209	333.30	28.66	20.03	$2,179.65	$340.50	18	$4.98	16%	$4.95	1.01	$108.80	1.11		$0.92	$76.05
221	524.44	40.63	32.60	$3,090.00	$794.85	22	$3.16	26%	$3.79	0.83	$94.78	1.38		$1.09	$76.05
226	656.40	51.85	39.18	$3,942.88	$697.29	18	$4.66	18%	$4.25	1.10	$100.63	1.06		$1.00	$76.05
230	327.32	30.31	24.01	$2,305.29	$400.63	15	$5.15	17%	$4.97	1.04	$96.02	1.13		$1.08	$76.05
234	511.95	39.42	32.98	$2,997.67	$309.84	8	$10.11	10%	$4.62	2.19	$90.88	0.52		$1.16	$76.05
302	376.61	37.18	26.35	$2,719.34	$565.77	21	$3.91	21%	$4.92	0.79	$103.20	1.46		$1.03	$73.14
303	661.54	55.40	40.72	$4,051.47	$1,142.16	28	$2.57	28%	$4.02	0.64	$99.50	1.71		$1.01	$73.14
309	475.21	43.95	31.17	$3,214.66	$861.78	28	$2.67	27%	$4.51	0.59	$103.14	1.85		$0.98	$73.14
318	771.39	75.82	52.78	$5,545.34	$2,284.48	45	$1.36	41%	$3.83	0.35	$105.06	3.11		$0.95	$73.14
322	1,479.20	125.83	98.93	$9,202.94	$2,479.48	23	$3.00	27%	$4.01	0.75	$93.02	1.52		$1.11	$73.14
330	1,376.47	96.16	70.92	$7,032.81	$1,476.81	17	$4.54	21%	$3.62	1.26	$99.17	0.89		$1.21	$73.14
331	870.55	71.12	57.83	$5,201.25	$1,221.51	20	$3.48	23%	$4.32	0.81	$89.94	1.31		$1.07	$73.14
332	502.04	37.70	26.65	$2,757.51	$635.39	24	$3.38	23%	$3.51	0.96	$103.47	1.25		$1.01	$73.14
356	687.04	44.53	31.92	$3,934.94	$590.29	18	$5.75	15%	$4.75	1.21	$123.29	0.85		$1.02	$88.36
364	1,485.70	113.75	89.68	$10,050.90	$2,280.14	23	$3.80	23%	$4.77	0.80	$112.07	1.37		$1.12	$88.36
381	1,290.93	112.78	89.93	$7,514.29	$3,455.22	41	$1.11	46%	$3.01	0.37	$83.55	2.84		$0.94	$66.63
386	1,265.49	82.87	61.93	$5,521.07	$1,571.86	23	$2.78	28%	$2.78	1.00	$89.15	1.12		$1.10	$66.63
626	537.40	39.79	25.87	$2,783.14	$407.64	13	$6.86	15%	$2.73	2.51	$107.60	0.64		$1.18	$69.94
757	253.90	21.36	12.33	$1,562.09	$232.53	17	$6.33	15%	$2.79	2.27	$126.66	0.83		$1.11	$73.14

	Travel Time per Trip (Minutes)					Change in Travel Time per Trip (Minutes)				Cost per Trip					Change in Cost per Trip			
Route	Existing	Reroute (Base)	Low	Mod	High	Reroute (Base)	Low	Mod	High	Existing	Reroute (Base)	Low	Mod	High	Reroute (Base)	Low	Mod	High
208	95	73	77	84	95	-22	-18	-11	0	$ 119.78	$ 92.53	$ 97.15	$ 106.41	$ 120.29	$ (27.25)	$ (22.63)	$ (13.37)	$ 0.51
209	30	28	29	32	36	-2	-1	2	6	$ 38.03	$ 35.49	$ 37.26	$ 40.81	$ 46.14	$ (2.54)	$ (0.76)	$ 2.79	$ 8.11
221	55	45	47	52	59	-10	-8	-3	4	$ 69.71	$ 57.04	$ 59.89	$ 65.59	$ 74.15	$ (12.68)	$ (9.82)	$ (4.12)	$ 4.44
226	56	44	46	50	57	-12	-10	-5	1	$ 70.35	$ 55.14	$ 57.89	$ 63.41	$ 71.68	$ (15.21)	$ (12.45)	$ (6.94)	$ 1.33
230	40	33	35	38	43	-7	-5	-2	3	$ 50.70	$ 41.83	$ 43.92	$ 48.10	$ 54.38	$ (8.87)	$ (6.78)	$ (2.60)	$ 3.68
234	46	34	35	39	44	-13	-11	-7	-2	$ 58.31	$ 42.46	$ 44.58	$ 48.83	$ 55.20	$ (15.84)	$ (13.72)	$ (9.47)	$ (3.11)
302	34	36	38	41	47	3	4	8	13	$ 40.84	$ 43.88	$ 46.08	$ 50.46	$ 57.05	$ 3.05	$ 5.24	$ 9.63	$ 16.21
303	45	40	42	46	52	-5	-3	1	7	$ 54.85	$ 48.76	$ 51.20	$ 56.07	$ 63.39	$ (6.09)	$ (3.66)	$ 1.22	$ 8.53
309	45	48	50	55	62	3	5	10	17	$ 54.85	$ 58.51	$ 61.44	$ 67.29	$ 76.06	$ 3.66	$ 6.58	$ 12.43	$ 21.21
318	31	39	41	45	51	9	10	14	20	$ 37.18	$ 47.54	$ 49.92	$ 54.67	$ 61.80	$ 10.36	$ 12.74	$ 17.49	$ 24.62
322	60	67	70	76	86	7	10	16	26	$ 73.14	$ 81.06	$ 85.11	$ 93.22	$ 105.38	$ 7.92	$ 11.98	$ 20.08	$ 32.24
330	64	70	74	81	91	6	10	17	27	$ 78.01	$ 85.33	$ 89.59	$ 98.13	$ 110.93	$ 7.31	$ 11.58	$ 20.11	$ 32.91
331	55	60	63	69	78	5	8	14	23	$ 67.04	$ 73.14	$ 76.79	$ 84.11	$ 95.08	$ 6.09	$ 9.75	$ 17.07	$ 28.04
332	69	63	66	72	81	-6	-3	3	13	$ 83.50	$ 76.18	$ 79.99	$ 87.61	$ 99.04	$ (7.31)	$ (3.50)	$ 4.11	$ 15.54
356	33	35	37	40	46	3	4	8	13	$ 47.86	$ 51.54	$ 54.12	$ 59.27	$ 67.01	$ 3.68	$ 6.26	$ 11.41	$ 19.14
364	90	90	95	104	117	0	5	14	27	$ 132.54	$ 132.54	$ 139.17	$ 152.42	$ 172.30	$ -	$ 6.63	$ 19.88	$ 39.76
381	54	53	55	60	68	-2	1	6	14	$ 59.96	$ 58.30	$ 61.21	$ 67.04	$ 75.79	$ (1.67)	$ 1.25	$ 7.08	$ 15.82
386	67	70	74	81	91	3	7	14	24	$ 74.40	$ 77.73	$ 81.62	$ 89.39	$ 101.05	$ 3.33	$ 7.22	$ 14.99	$ 26.65
626	70	75	79	86	98	5	9	16	28	$ 81.60	$ 87.42	$ 91.80	$ 100.54	$ 113.65	$ 5.83	$ 10.20	$ 18.94	$ 32.06
757	63	64	67	74	83	2	5	11	21	$ 76.18	$ 78.01	$ 81.91	$ 89.72	$ 101.42	$ 1.83	$ 5.73	$ 13.53	$ 25.23

Route Change						
# of Flooding Incidents	Change # of Flooding Incidents	Missed Bus Stops	Existing ADR	ADR with Reroute	% Change	Net Impacted Riders
1	-1	34	1,847	1,687	-8.7%	160
1	0	6	369	368	-0.3%	1
0	0	34	726	683	-5.9%	43
1	0	17	696	694	-0.3%	2
1	0	7	370	365	-1.4%	5
0	0	30	266	248	-6.8%	18
2	0	2	551	546	-0.9%	5
5	-5	138	1,130	515	-54.4%	615
2	0	25	881	820	-6.9%	61
3	-1	32	2,402	926	-61.5%	1476
2	0	2	2,243	2,175	-3.0%	68
6	2	16	1,223	948	-22.5%	275
4	-1	33	1,142	1,080	-5.4%	62
4	1	19	629	477	-24.2%	152
2	0	7	581	567	-2.4%	14
1	0	0	2,043	2,043	0.0%	0
1	-1	7	3,669	3,631	-1.0%	38
1	-1	10	1,423	1,344	-5.6%	79
0	0	0	346	346	0.0%	0
0	0	0	210	210	0.0%	0

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Flooding Resilience Plan for Bus Operations

IDENTIFY – ASSESS – MITIGATE

Project Summary Presentation

March 2018

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Project Scope

Task 1:
Project
Kickoff
Meeting

Task 2:
Identify and Map
Flooding Impacts

Task 3:
Future
Climate
Change
Impact on
Flooding

Task 4;
Resilience Plan

current **risks** and areas of **concern**

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Task 2: Identify and Map Flood Impacts

2

Scope / Tasks

- Identify flood risk areas through mapping exercises
- Obtain stakeholder input
- Map bus routes and facilities
- Develop prioritization and risk assessment matrix
- Select highest risk routes for reroute planning

Deliverables

- Tech memo summarizing findings, including maps and route selection
- Stakeholder interview plan and notes

Meetings

- Steering Committee meeting
- Stakeholder Interviews

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Stakeholder Interviews

Organization	Contact
Chicago Department of Transportation (CDOT)	Joe Alonzo, Transportation Planner Mike Drake, General Superintendent, Division of In-House Construction Tony Rainey, Civil Engineer
Chicago Department of Water Management (CDM)	Sid Osakada, Coordinating Engineer Anupam Verma, PE, Managing Engineer - Water Management
Chicago Metropolitan Agency for Planning (CMAP)	Jason Navota, Director Nora Beck, Senior Planner
Chicago Office of Emergency Management and Communications (OEMC)	Chris Pettineo, Manager of Emergency Management Services Peter Raber, Senior Emergency Management Coordinator
Cook County Department of Transportation and Highways (CCDOTH)	Maria Choca-Urban, Director of Strategic Planning and Policy
Cook County Department of Homeland Security and Emergency Management (CCDHSEM)	Dana Curtiss, Operations Information Support Manager, Office of the President
DuPage County Stormwater Management	Christine Klepp, Senior Project Engineer, Stormwater Management Chris Vonnahme, Senior Project Engineer, Dept of Econ. Dev. & Planning
DuPage County Department of Transportation (DCDOT)	John Loper, Director of Transportation Planning
Illinois Department of Transportation (IDOT)	Rick Wojcik, IDOT Hydraulics
Metropolitan Water Reclamation District (MWRD)	Joe Kratzer, PE, CFM, Managing Civil Engineer, Engineering Dept/SW Mgmt Greg Koch, PE, Principal Civil Engineer, Engineering Dept/SW Mgmt
US Army Corps of Engineers (USACE)	Sarah Brodcinski Sue Davis, Planning Division Chief
Will County Division of Transportation (WCDOT)	Christina Kupkowski, PE, Phase I Project Manager Raymond A. Semplinski, Maintenance Administrator

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Stakeholder Interviews

- Inconsistent documentation of actual / historical flood incidents
  - Technology / format varies; ownership varies
  - Datasets dependent upon what others report, not a regular sampling / survey
  - Timeframes also dependent on what is reported
- Flooding has different root causes
  - Urban flooding not predicted by location relative to floodplains and floodways
- Lots of activity across the region
  - Active stormwater management projects in process – changing the boundaries of flood risk areas
  - Need to keep open communication
  - Wide-area stormwater management programs and plans
    - FEMA-compliant All-Hazard Mitigation Plans or Natural Hazard Mitigation Plans
    - Focus area in CMAP's ON TO 2050
  - Forecasting & application innovations

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Scenarios for identifying routes

Pace	CTA
Scenario A - Routes with reported flooding *and* located in flood zones, sorted by ridership	
Only routes with flooding noted by Pace Routes then sorted by number of flood zones they traverse, and then by average monthly weekday ridership	Only routes with flooding incidents recorded by CTA Routes then sorted by number of recorded flood incidents they intersect, number of flood zones they traverse, and then by average daily weekday ridership
Scenario B - Routes with reported flooding, sorted by ridership	
Only routes with flooding noted by Pace Routes then sorted by average monthly weekday ridership	Only routes with flooding incidents recorded by CTA Routes then sorted by number of recorded flood incidents they intersect, and then by average daily weekday ridership
Scenario C - Routes in flood zones, sorted by ridership	
Only routes that traverse flood zones Routes then sorted by number of flood zones they traverse, then by average monthly weekday ridership	Only routes that traverse flood zones Routes then sorted by number of flood zones they traverse, then by average daily weekday ridership
Scenario D - Routes with reported flooding or located in flood zones, sorted by ridership	
Only routes with flooding noted by Pace or that traverse flood zones Routes then sorted by average monthly weekday ridership	Only routes with flooding incidents recorded by CTA or that traverse flood zones Routes then sorted by average daily weekday ridership
Scenario E - Routes with reported flooding, sorted by system connectivity and ridership	
Only routes with flooding noted by Pace Routes then sorted by number the number of connections they have with CTA rail or Metra rail stations, then by average monthly weekday ridership	Only routes with flooding incidents recorded by CTA Routes then sorted by number the number of connections they have with CTA rail or Metra rail stations, then by average daily weekday ridership
Scenario F – Trunk Service Routes	
N/A	“Workhorses” of the CTA network, moving large volumes of passengers across the city and making vital connections between transit modes, as well as connecting residential communities to central business district and other employment centers.

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Scenarios for identifying routes

CTA Scenario F

Scenario Selection	Route	Route Name	Flood Zones	Reported Incident Zones	Incident Value	Weekday	Saturday	Sunday	Total Annual	Weekday Ridership Rank	Annual Ridership Rank	Within 1/4 - CTA Station	Within 1/4 - METRA Station	Within 1/4 - Both
X	4	Cottage Grove	0	2	15	21,143	14,243	10,614	6,747,771	7	7	38	9	47
X	8	Halsted	1	2	16	22,093	12,730	9,050	6,820,599	6	6	37	1	38
X	9	Ashland	1	2	13	27,499	19,655	14,185	8,856,955	1	1	21	4	25
X	20	Madison	1	1	16	17,767	10,482	7,797	5,527,855	12	13	44	3	47
X	22	Clark	1	0	0	18,188	14,843	11,634	6,084,557	11	10	84	2	86
X	52	Kedzie/California	1	2	15	12,231	7,636	5,438	3,831,434	24	26	15	1	16
X	53	Pulaski	2	1	14	19,909	13,003	9,327	6,293,990	8	8	12	2	14
X	55	Garfield	0	1	10	11,301	8,005	6,502	3,675,058	30	29	9	1	10
X	62	Archer	1	1	11	10,764	6,497	4,934	3,368,927	31	32	82	3	85
X	66	Chicago	1	1	14	23,506	15,079	10,719	7,399,957	3	4	9	1	10
X	77	Belmont	1	1	9	22,150	14,391	10,543	7,008,072	5	5	8	1	9
X	79	79th	0	1	5	26,830	19,563	14,780	8,716,277	2	2	3	3	6
X	85	Central	0	1	8	10,373	6,699	4,905	3,278,079	32	34	6	2	8
X	92	Foster	6	1	6	6,953	3,973	2,905	2,148,060	52	50	9	1	10
X	147	Outer Drive Express	2	0	0	13,372	10,773	7,476	4,403,589	18	19	79	3	82
X	J14	Jeffery Jump	2	2	6	11,449	6,022	3,848	3,455,860	28	31	47	10	57
X	X49	Western Express	1	2	16	3,459	95	40	27,808	74	127	18	2	20

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Scenarios for identifying routes

Pace Scenario E

Scenario Rank	Route	Route Name	No. of Flood Zones Intersected	No. of Enhanced DesPlaines R Incident Zones Intersected	Average Monthly Ridership (Weekday)	Ridership Rank	*Flooding Noted by Pace*	*Reroute Plan in Place*	*Division*	*Within 1/4 - CTA Station*	*Within 1/4 - METRA Station*	*Within 1/4 - Both*
1	309	Lake Street	4	2	19,176.08	34	X	X	West	12	5	17
2	302	Ogden - Stanley	2	1	12,404.58	54	X	X	West	6	5	11
3	303	Forest Park - Rosemont	16	3	25,801.50	27	X		West	6	2	8
4	757	Oak Park - Schaumburg Limited	6	3	4,729.33	93	X	X	West	6	2	8
5	318	West North Avenue	6	2	50,416.17	8	X	X	West	6	1	7
6	208	Golf Road	10	6	40,597.75	12	X	X	Northwest	3	4	7
7	226	Oakton Street	6	4	15,022.00	43	X	X	Northwest	3	4	7
8	319	Grand Avenue	8	2	12,923.08	49	X	X	West	1	6	7
9	209	Busse Highway	4	4	7,774.33	71	X	X	Northwest	3	4	7
10	381	95th Street	2	n/a	82,494.33	2	X	X	Southwest	3	3	6
11	331	Cumberland - 5th Avenue	6	2	26,867.83	24	X	X	West	3	3	6
12	330	Mannheim - LaGrange Roads	11	1	25,856.08	26	X	X	West	1	5	6
13	234	Wheeling - Des Plaines	11	6	6,010.75	83	X	X	Northwest	1	5	6
14	386	South Harlem	9	0	29,998.75	21	X	X	Southwest	3	2	5
15	221	Wolf Road	6	3	16,936.58	36	X	X	Northwest	3	2	5
16	332	RT 83 / River Road - York Road	7	4	13,878.08	45	X	X	West	3	2	5
17	356	Harvey - Homewood - Tinley Park	8	0	12,804.00	50	X	X	South	1	4	5
18	626	Skokie Valley Limited	12	n/a	7,866.58	70	X	X	North Shore	3	2	5
19	364	159th Street	6	0	50,173.25	9	X	X	South	1	3	4
20	322	Cermak Road - 22nd Street	2	n/a	49,549.17	10	X	X	West	3	1	4
21	230	South Des Plaines	1	5	8,346.00	66	X	X	Northwest	3	1	4
22	210	Lincoln Avenue	2	n/a	7,666.17	73	X	X	North Shore	1	3	4
23	326	W Irving Park Road / Rosemont CTA to Norridge	9	4	3,846.17	111	X		Northwest	3	1	4
24	620	Yellow Line Dempster - Allstate	4	n/a	1,335.67	159	X	X	North Shore	3	1	4
25	565	Grand Avenue	6	n/a	22,675.17	28	X	X	North	1	1	2
26	572	Washington	2	n/a	16,470.08	37	X	X	North	1	1	2
27	272	Milwaukee Avenue North	11	n/a	12,971.25	47	X	X	North	1	1	2
28	619	Des Plaines Station - Willow Road Corridor	4	4	1,351.67	157	X	X	North Shore	1	1	2

future **climate change**

risk analysis

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Task 3: Future Climate Change Impact on Flooding

3

Scope / Tasks

– Analyze existing climate change data and apply the data to develop a revised footprint for potential flooding

– Update the vulnerability risk matrix

– Confirm or revise selection of bus routes for re-route planning

Deliverables

– Tech memo / presentation summarizing climate impact projections, analysis findings, including revised maps and route recommendations

Meetings

– Steering Committee meeting

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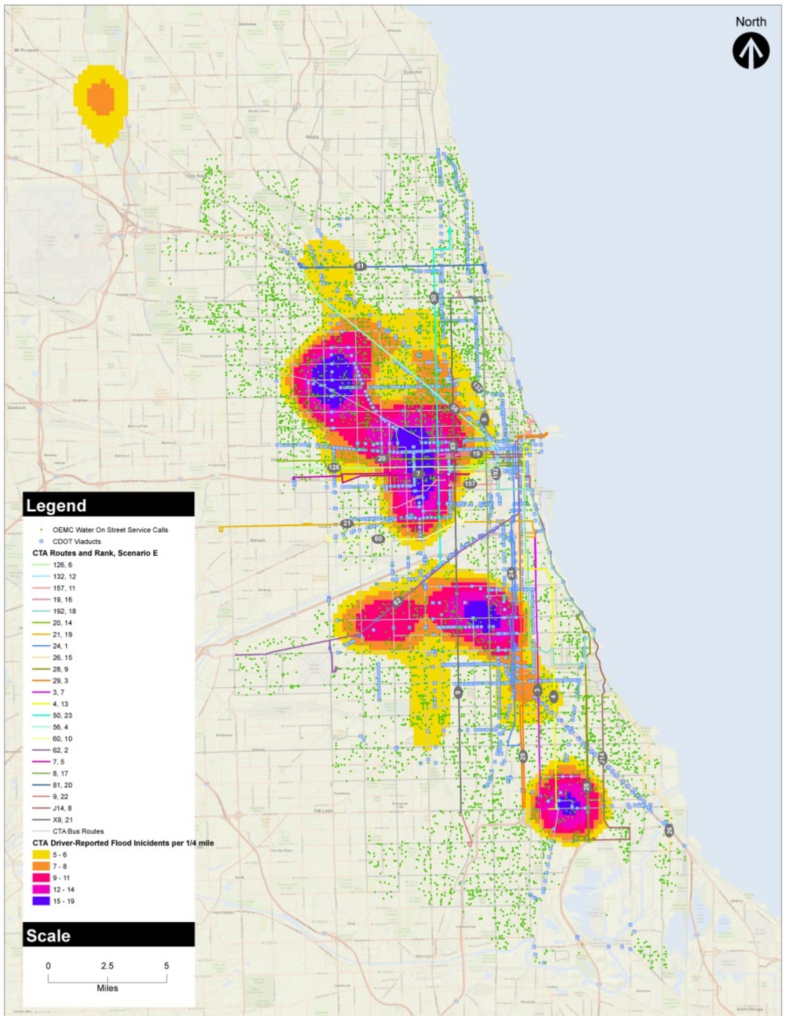
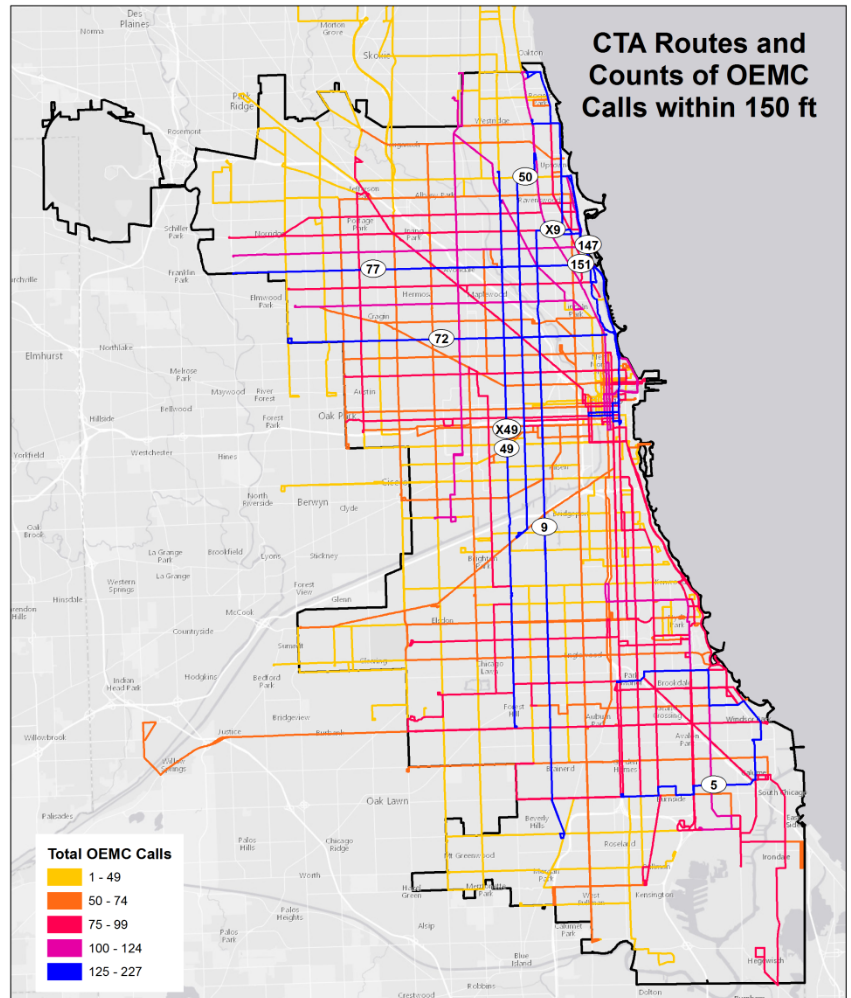
Urban Flooding Data Analysis

OEMC Street Flood Calls, CTA Driver Flood Reports, CDOT Viaducts, and CTA Top Routes (Scenario E)



CTA Routes by proximity of OEMC Street & Viaduct Flood Calls



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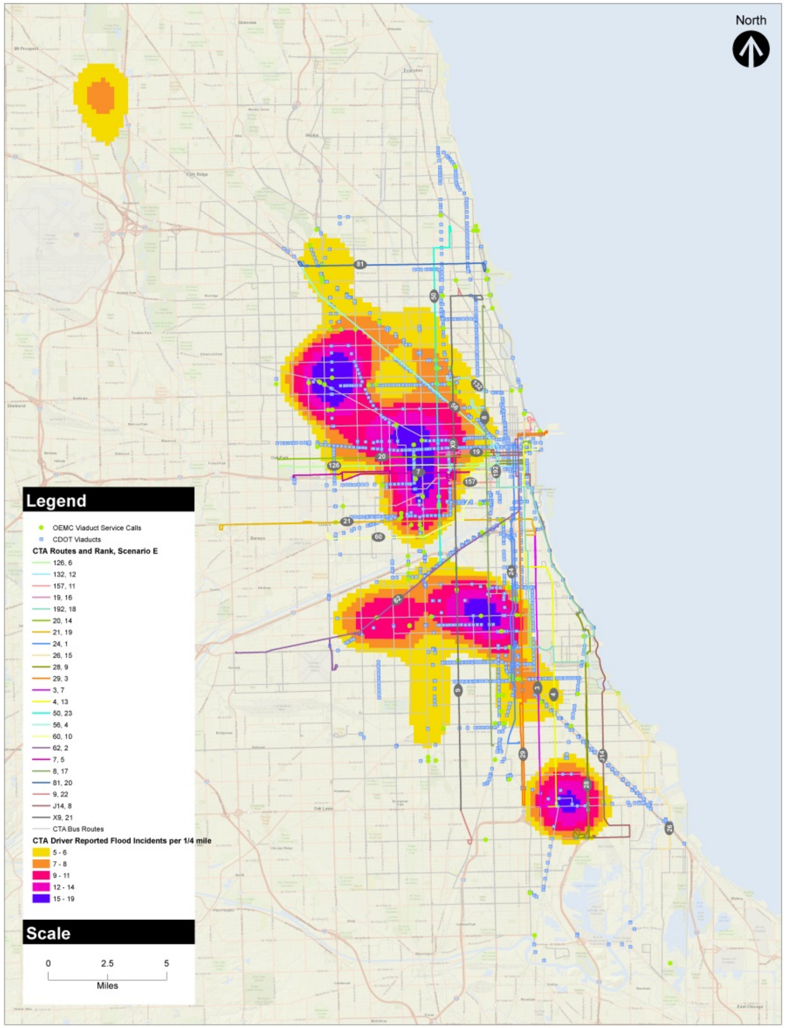
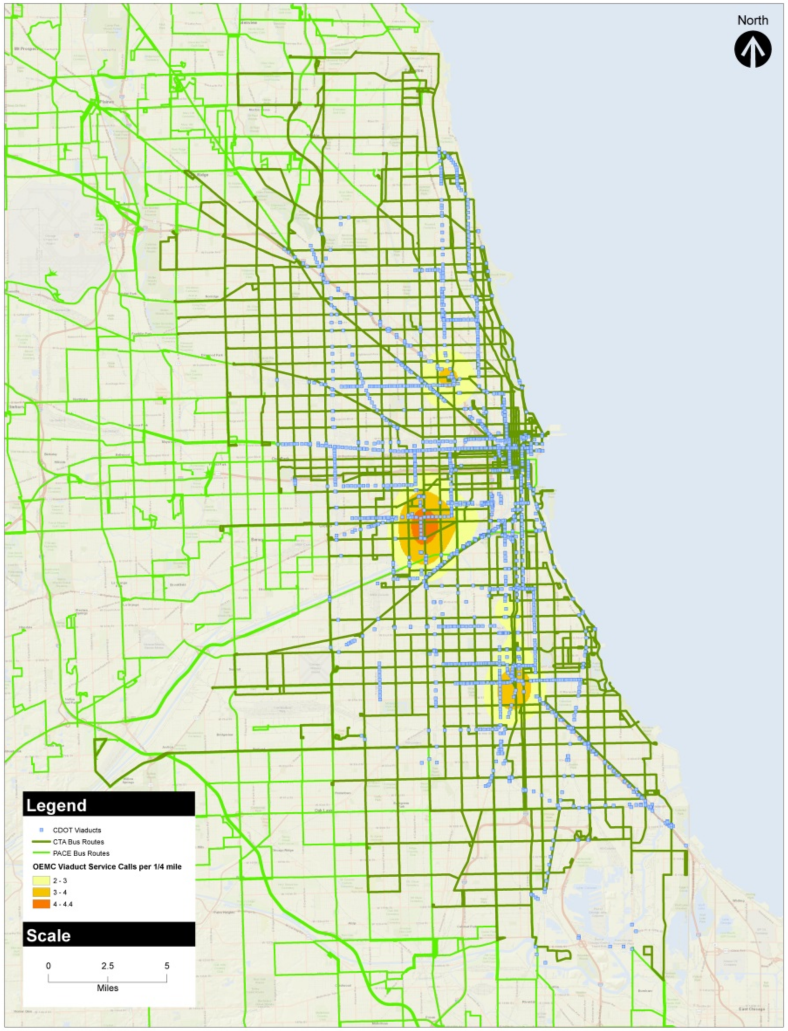
Urban Flooding Data Analysis

CDOT Viaducts, OEMC Viaduct Flood Calls and CTA Driver Flood Reports



Bus Routes, CDOT Viaducts and OEMC Viaduct Flood Calls



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Data and areas of concern: a Tale of Two floods

River Systems Data Sets

– FEMA 100-year and 500-year floodplain boundaries

– Local updates on floodplain boundaries / inundation areas from counties (Cook/MWRD, DuPage, Will)

Infrastructure / Incidents Data

– CTA reported flood locations

– Pace reported reroute / flood locations

– CCDOTH road closures

– CDOT viaducts

– City of Chicago 311 reported flood calls

Less developed / built
Suburban/exurban
Root: natural systems overflow

More developed / built
Urban
Root: infrastructure capacity, local drainage

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Methods for evaluating climate change data and potential future flooding patterns

Rainfall Frequency Adjustment for Climate Change

– Generalized modeling of anticipated rainfall suggests storms of greater severity may occur more frequently in the future. That is….

For severe storms:

100-year storm mid-century could be like today's 150-year storm

100-year storm end-century could be like today's 240-year storm

For moderate storms:

5-year storm mid-century could be like today's 11-year storm

5-year storm end-century could be like today's 14-year storm

1-year storm mid-century could be like today's 2-year storm

1-year storm end-century could be like today's 2.5-year storm

The term **Storm Recurrence Interval** refers to the chance or probability that a storm of a certain magnitude may occur or be exceeded in a given year.

For example, a **100-year storm** has a 1 in 100 chance of occurring in any given year, or 1% chance (called the **Annual Exceedance Probability**).

It does not mean that such a storm only occurs once every 100 years, and once happened, won't happen again in the same 100-year period.

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Methods for evaluating climate change data and potential future flooding patterns

Rainfall Frequency Adjustment for Climate Change

Mid-Century Adjusted Rainfall

Bulletin 70 Current Storm Recurrence Interval (Years)	Current Annual Exceedance Probability (%)	Bulletin 70 24-hr Rainfall	ISWS Contract Report 2016-05 Mid Century 24-hr Rainfall Adjustment (in)	Adjusted Rainfall (in)	Equivalent Bulletin 70 Future Storm Recurrence Interval (Years)
1	100%	2.51	0.46	2.97	1.9
2	50%	3.04	0.55	3.59	4.3
5	20%	3.80	0.70	4.50	11.0
10	10%	4.47	0.83	5.30	24.0
25	4%	5.51	0.83	6.34	44.0
50	2%	6.46	0.83	7.29	85.0
100	1%	7.58	0.83	8.41	150.0
500*	0.2%	11.10	0.83	11.93	620.0

*Extrapolated

Late-Century Adjusted Rainfall

Bulletin 70 Current Storm Recurrence Interval (Years)	Current Annual Exceedance Probability (%)	Bulletin 70 24-hr Rainfall	ISWS Contract Report 2016-05 Mid Century 24-hr Rainfall Adjustment (in)	Adjusted Rainfall (in)	Equivalent Bulletin 70 Future Storm Recurrence Interval (Years)
1	100%	2.51	0.72	3.29	2.5
2	50%	3.04	0.83	3.87	5.4
5	20%	3.80	1.00	4.80	14
10	10%	4.47	1.15	5.62	28
25	4%	5.51	1.27	6.78	60
50	2%	6.46	1.38	7.84	110
100	1%	7.58	1.50	9.08	240
500*	0.2%	11.10	1.77	12.87	915

*Extrapolated

- Averaged the increases for future climate change scenarios (B1, A1B, and A2)
- Plotted the 2-, 10-, and 100-yr adjustments on log-log paper to determine adjustments for other storms
- Added adjustments to the Bulletin 70 24-hr rainfall amounts
- Plotted these values on log-log paper
- Interpolated existing and future rainfall frequency curves to identify the equivalent storm frequency for the future rainfall events

Sources: Illinois State Water Survey Contract Report 2016-05; ISWS Bulletin 70

Methods for evaluating climate change data and potential future flooding patterns

*Urban Flooding Methodology **

– Sampled subset of recent storm events during last 4 years when CTA recorded flood incidents and OEMC 311 call data were available

– Analyzed rainfall levels and duration of storm at 3 regional gages to identify storm type

- O'Hare, Midway, Palwaukee provide hourly measurements (other gages less frequent)
- Storms patterns are not always uniform – depth and severity vary across region
- Correlated flood complaint data to event to identify spatial patterns and density

** Based on available data, selected sampling of recent storm events during period when reported call incidents & 311 data were available, at conceptual level analysis; no sewer system modeling w current or future volumes or hydraulic/hydrologic modeling*

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Methods for evaluating climate change data and potential future flooding patterns

*Urban Flooding Key Findings **

– Density of 311 calls complaining about water on roadway and/or flooded viaducts increases with storm type

– CTA drivers’ reports of flood incidents generally found with moderate or more severe storms (1-year storms or higher)

– In the future: storms of greater severity may occur more frequently. Cannot draw spatial conclusions that areas currently prone to flooding will be larger/wider – just that intensity may be worse.

– VARIABLE: Impacts for any given storm are affected by sewer capacity and/or water release actions.

** Based on available data, selected sampling of recent storm events during period when reported call incidents & 311 data were available, at conceptual level analysis; no sewer system modeling w current or future volumes or hydraulic/hydrologic modeling*

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Urban Rainfall Data Analysis

Rain Storm Frequency									
	Storm Gage								
Storm Event	Midway			O'Hare			Palwaukee		
	Rain (in)	Duration (hrs)	Recurrence Interval	Rain (in)	Duration (hrs)	Rec Interval	Rain (in)	Duration (hrs)	Rec Interval
Minor Storms (100% to 500% chance in any given year)									
April 18, 2013	1	4	2 mo					nm	
April 19, 2015		nm		1.28	6	3.5 mo			
December 23, 2015	0.7	1	2.5 mo	0.7	1	3.25 mo	0.7	1	2.5 mo
February 2, 2016	2	10	2 mo	0.8	3	2 mo	0.8	3	2 mo
March 24, 2016	0.9	7	2 mo	0.9	7	2 mo	0.9	7	2 mo
January 17, 2017	1.2	24	2 mo	1.2	24	2 mo	1.2	24	2 mo
February 7, 2017	0.5	1	2 mo	0.5	1	2 mo		nm	
Moderate Storms (e.g., 1 Year Event (50% to 100% chance in any given year))									
April 19, 2015		nm					1.7	6	9 mo
June 15, 2015	1.47	5	1	2.5	12	2 yr		nm	
Severe Storms (e.g., 25 Year Event (5% chance in any given year))									
April 18, 2013				5.5	2.4	25 yr			

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Urban Rainfall Data Analysis

Storm Date	Recurrence Interval	Duration	Gauge Level	311 Calls	311 Call Density
Feb 7, 2017	<2-month	1hr	0.5"	249	1.1
January 16-17, 2017	<2-month	24hr	1.2"	374	1.6
March 24, 2016	<2-month	25hr	1.0"	241	1.0
June 15-16, 2015	2-month	11hr	1.2"	252	1.8
December 23, 2015	2.5-month	1hr	0.7"	213	0.9
Feb 7, 2017	2- to 6-month	1hr		50	3.7
April 9, 2015	4-month	6hr	1.3"	254	1.2
Feb 2-3, 2016	6- to 9-month	10hr	2"	149	2.8
July 23-24, 2016	1-yr	7hr	2.0"	166	0.8
Sept 17-19, 2015	2-yr	24hr	3.0"	202	0.9
June 15-16, 2015	2-yr	11hr	2.5"	297	3.1
July 23-24, 2016	5-yr	7hr	2.5"	5	0.9
April 17-18, 2013	5-yr	20hr	3.5"	179	2.0
April 17-18, 2013	15-yr	16hr	4.0"	381	4.0
April 17-18, 2013	25-yr	24hr	5.5"	257	4.9

– Density of 311-reported flooding increases with identified storm recurrence interval

– CTA-reported flooding generally starts appearing at the 1-year storm recurrence interval

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Methods for evaluating climate change data and potential future flooding patterns

*Suburban/Exurban Flooding Methodology**

- Base of current flood plain limits as currently mapped
- Simple proration of rate of flood stage increase against current floodplain limits. Example:
  - Expected increase in the 100 year flood stage by 1’ at a given location.
  - Observe that the 500 year flood elevation is 2’ above the 100 year at this location
  - Estimate that future 100 year flood plain level is 50% of the way between the existing 100 and 500 year flood plain limits.
  - Plot a line that is 50% of the way between the two existing lines without modeling it as an elevation. (If modeled it as an elevation, the line would be clearly in error in places where the base DTM topo is inaccurate.)
- Manual adjustment / spot checking in certain locations where elevations are less uniform
- Tested on Des Plaines River and Silver Creek, Addison Creek

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Methods for evaluating climate change data and potential future flooding patterns

*Suburban/Exurban Flooding Methodology**

– Reviewed water surface profiles (Des Plaines River, Addison Creek, Silver Creek - Aug 2010 USACE report) to identify incremental elevation differences between the various storm profiles

– Based on these incremental differences and frequency shift identified based on future rainfall amounts, drawing a *future 100-yr flood plain limit* approximately half way between the existing FEMA 100- and 500-yr flood plain limits would be appropriate for identifying routes impacted along the Des Plaines River & creeks for future conditions.

Des Plaines River Elevations

Profiles	Elevation Increment (ft)
1- to 2-yr	2
2- to 5-yr	2
5- t0 10-yr	1
10- to 25-yr	1
25- to 50-yr	1
50- to 100-yr	0.8
100- to 500-yr	2.4

Sources: USACE, 2010

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Methods for evaluating climate change data and potential future flooding patterns

*Suburban/Exurban Flooding Key Findings **

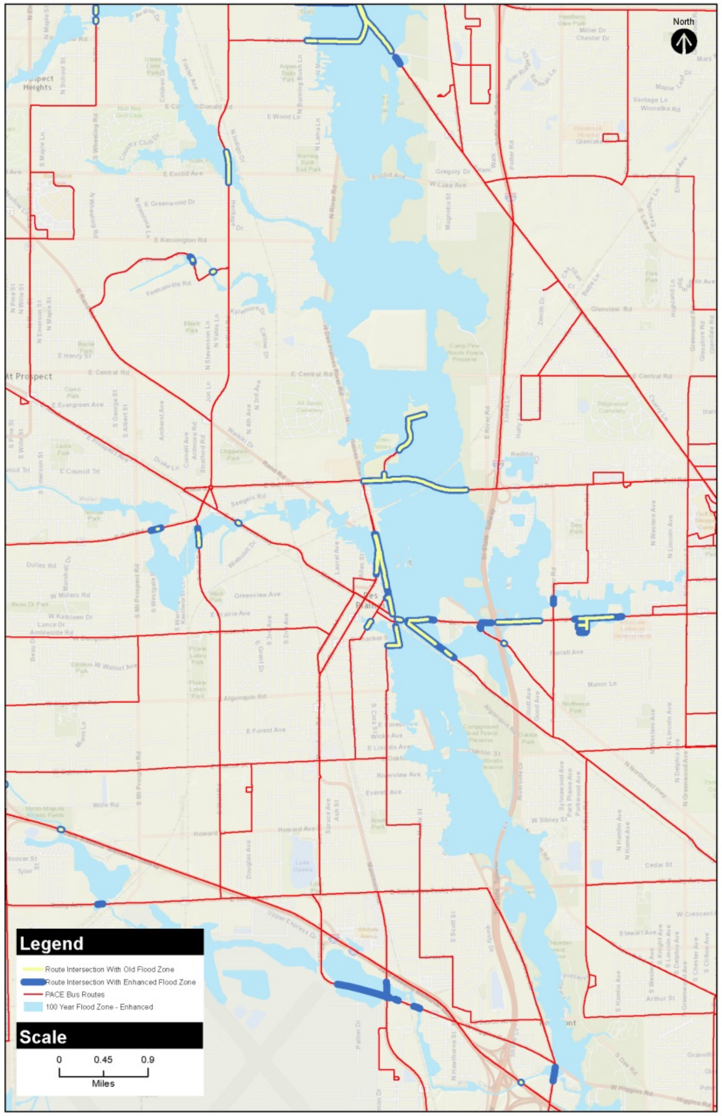
– Limited expansion of floodplain areas impacting bus routes

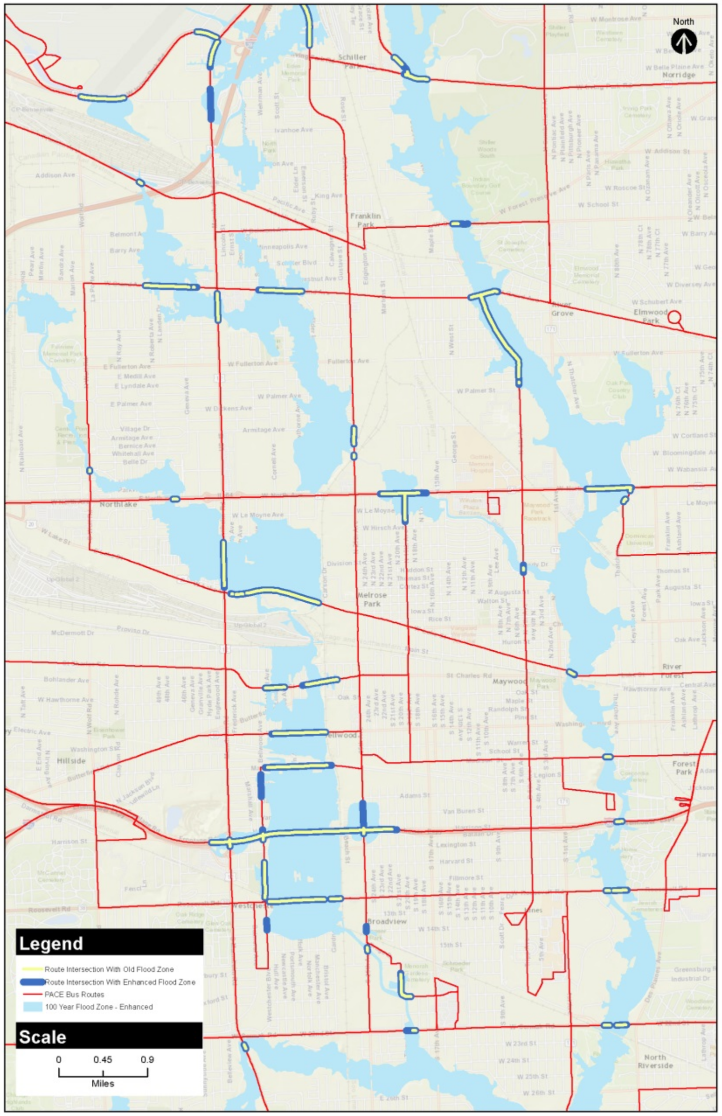
- Across region, few areas with 500 year floodplain concerns with collocation with bus routes
- Initial screen of routes already included 100 + 500 year floodplain limits
- Some spots may have more frequent / severe flooding

– LIMITATION: Approach is VERY broad brush, does not account for mitigation projects under way that are altering floodplain limits.

** Based on available data, no local or regional hydraulic/hydrologic modeling; significant manual correction/review of proposed lines required.*

Suburban Flooding Data Analysis





reroute **impact** analysis

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Task 4: Resilience Plan

4

Scope / Tasks

- Documented reroutes for prioritized CTA and Pace routes
- Estimated cost and revenue impacts
- Documented customer communication strategies
- Inventoried potential mitigation projects and recommendations, with suggested next steps for items outside agencies' control
- Summarized findings in project reports

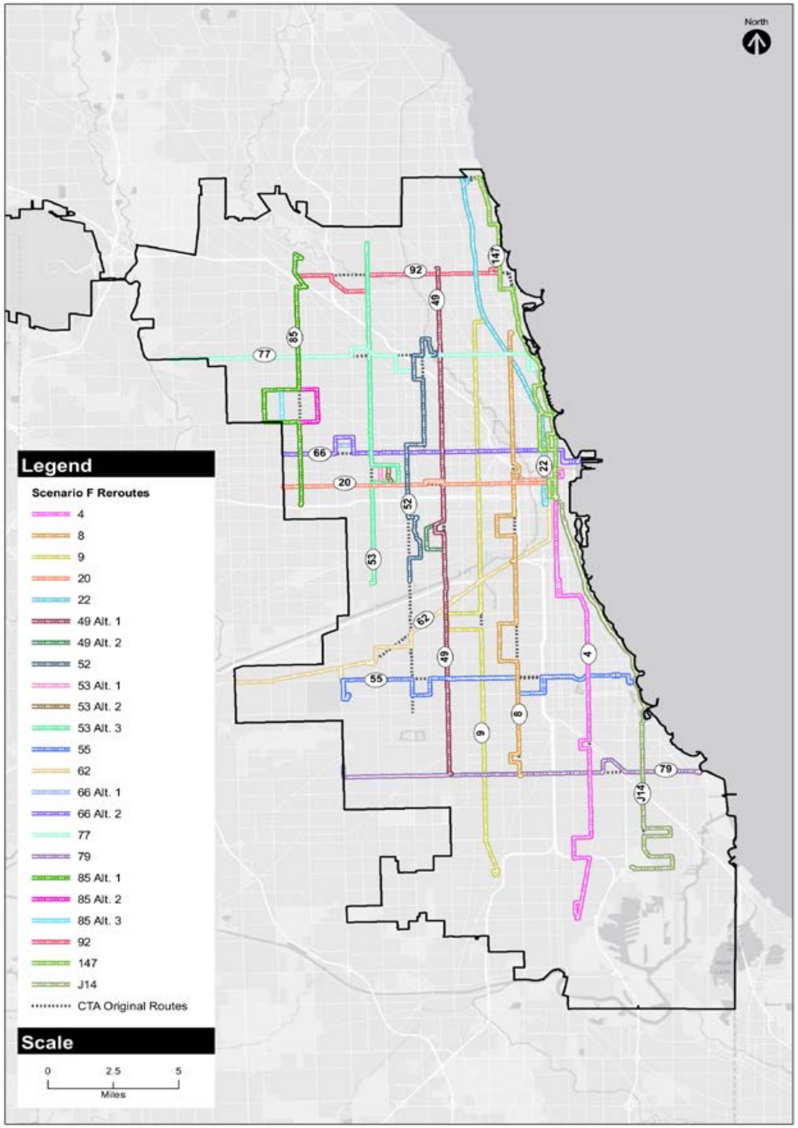
Deliverables

- Reroute recommendations with maps and impact assessment
- Reroute communication plans
- Flood mitigation strategies plan
- Draft and final project reports

Meetings

- Working meetings with operations and service planning staff
- Working meetings with communications staff
- Steering Committee meetings

Final Reroutes



CTA Reroutes Scenario F Routes	
4	53
8	55
9	62
J14	66
20	77
22	79
X49	85
52	92
	147

Final Reroutes – Impact Analysis

Route	# of CTA-reported Flooding Incident Areas	Change in # CTA Flooding Incident Areas with Reroute	Missed Bus Stops with Reroute	Avg Riders Impacted Per Day from Reroute
4	34	0	16	2
8	14	-7	36	336
9	41	-6	4	63
J14	7	0	0	0
20	9	+1	7	44
22	3	0	0	N/A
49	66	-23	3	11
49a	60	-29	8	98
52	5	-24	98	750
53	27	-9	9	155
53 Alt 1	27	-9	9	155
53 Alt 2	33	-3	9	155
55	4	-6	18	253
62	38	0	15	87
66	21	-1	5	21
66 Alt 1	31	+9	5	21
77	8	-3	14	224
79	21	-3	12	87
85 E	6	+4	14	72
85 W	4	+2	14	72
85 Nar	0	-2	14	72
92	12	+3	15	31
147 Alt 1	18	-3	5	78
147 Alt 2	19	-2	5	78
147 Alt 1&3	20	-1	2	78
147 Alt 2&3	22	+1	2	78

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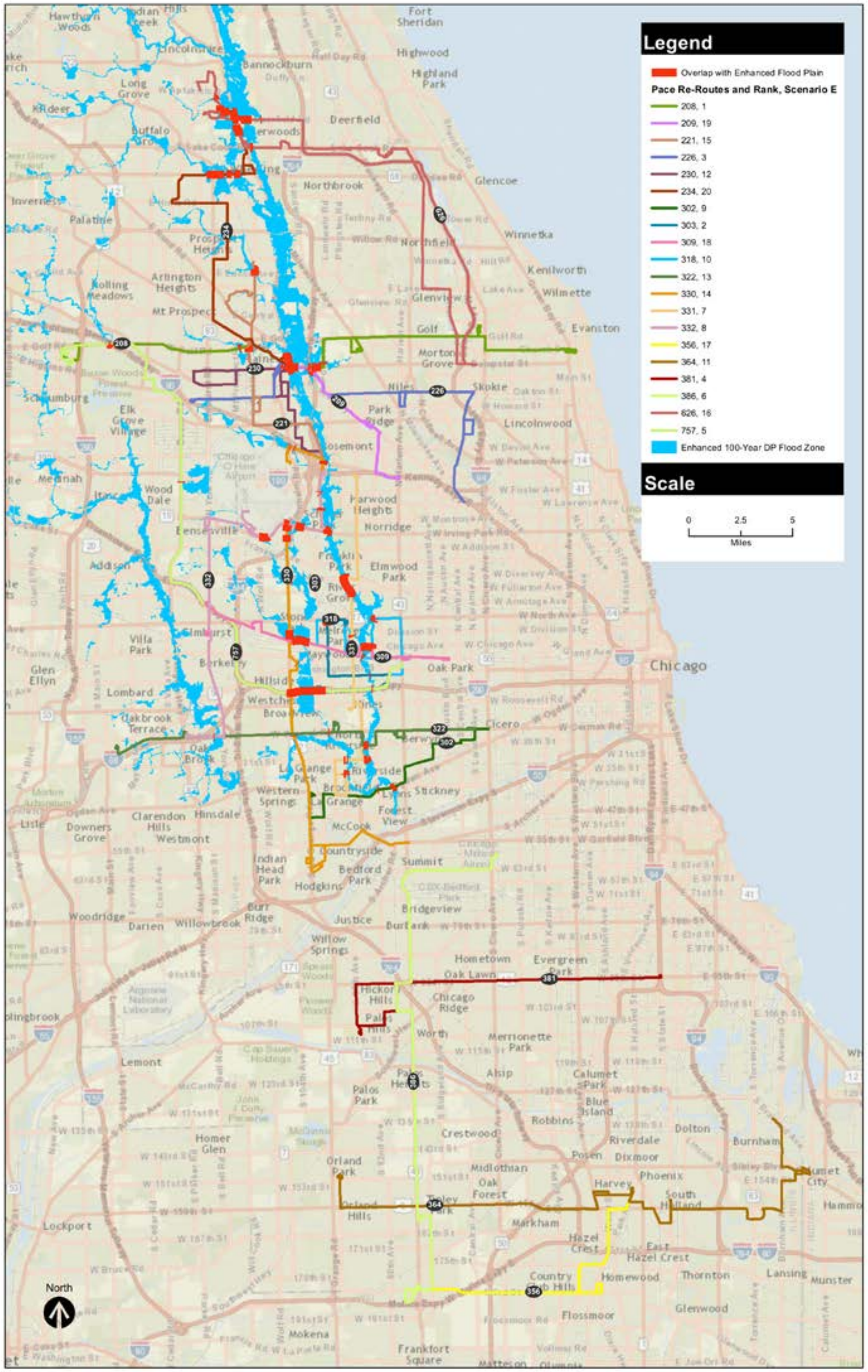
Final Reroutes – Impact Analysis

	Travel Time per Trip (minutes)					Change in Travel Time per Trip (minutes)			
Route	Existing	Reroute (Base)	Reroute (+Low)	Reroute (+Mod)	Reroute (+High)	Reroute (Base)	Reroute (+Low)	Reroute (+Mod)	Reroute (+High)
4	91	97	102	112	126	6	11	21	35
8	93	105	110	120	136	12	17	28	43
9	113	119	125	137	155	7	12	24	42
J14	58	63	66	72	82	5	8	14	24
20	60	62	65	71	80	2	5	11	20
22	76	76	79	87	98	0	4	11	23
49	92	94	99	108	122	2	7	16	30
49a	92	96	100	110	124	4	8	18	32
52	81	71	74	81	92	-10	-6	1	11
53	72	75	78	86	97	3	6	14	25
53 Alt 1	72	77	80	88	99	5	8	16	27
53 Alt 2	72	78	82	90	101	6	10	18	29
55	51	58	61	67	75	8	10	16	25
62	73	76	80	87	99	4	7	15	26
66	65	67	70	76	86	2	5	12	22
66 Alt 1	65	69	72	79	89	4	7	14	25
77	68	78	82	90	101	10	14	22	33
79	71	73	76	83	94	2	5	12	23
85 E	52	56	58	64	72	4	7	12	21
85 W	52	56	58	64	72	4	7	12	21
85 Nar	52	59	61	67	76	7	10	16	25
92	39	43	45	49	55	4	6	10	16
147 Alt 1	60	73	76	83	94	13	16	23	34
147 Alt 1	60	78	81	89	101	18	21	29	41
147 Alt 1&3	60	71	74	81	92	11	14	21	32
147 Alt 2&3	60	76	79	87	98	16	19	27	38

Pace Final Reroutes



Pace Final Reroutes – Impact Analysis

Route Change							
Route	# of Flooding Incident Areas	Change # of Flooding Incident Areas	Missed Bus Stops	Existing ADR	ADR with Reroute	% Change	Impacted Riders
208	1	-1	34	1,847	1,687	-8.7%	160
209	1	0	6	369	368	-0.3%	1
221	0	0	34	726	683	-5.9%	43
226	1	0	17	696	694	-0.3%	2
230	1	0	7	370	365	-1.4%	5
234	0	0	30	266	248	-6.8%	18
302	2	0	2	551	546	-0.9%	5
303	5	-5	138	1,130	515	-54.4%	615
309	2	0	25	881	820	-6.9%	61
318	3	-1	32	2,402	926	-61.5%	1476
322	2	0	2	2,243	2,175	-3.0%	68
330	6	2	16	1,223	948	-22.5%	275
331	4	-1	33	1,142	1,080	-5.4%	62
332	4	1	19	629	477	-24.2%	152
356	2	0	7	581	567	-2.4%	14
364	1	0	0	2,043	2,043	0.0%	0
381	1	-1	7	3,669	3,631	-1.0%	38
386	1	-1	10	1,423	1,344	-5.6%	79
626	0	0	0	346	346	0.0%	0
757	0	0	0	210	210	0.0%	0

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Pace Final Reroutes – Impact Analysis

	Travel Time per Trip (Minutes)					Change in Travel Time per Trip			
	Existing	Reroute (Base)	Reroute (+ Low)	Reroute (+ Mod)	Reroute (+ High)	Reroute (Base)	Reroute (+ Low)	Reroute (+ Mod)	Reroute (+ High)
208	95	73	77	84	95	-22	-18	-11	0
209	30	28	29	32	36	-2	-1	2	6
221	55	45	47	52	59	-10	-8	-3	4
226	56	44	46	50	57	-12	-10	-5	1
230	40	33	35	38	43	-7	-5	-2	3
234	46	34	35	39	44	-13	-11	-7	-2
302	34	36	38	41	47	3	4	8	13
303	45	40	42	46	52	-5	-3	1	7
309	45	48	50	55	62	3	5	10	17
318	31	39	41	45	51	9	10	14	20
322	60	67	70	76	86	7	10	16	26
330	64	70	74	81	91	6	10	17	27
331	55	60	63	69	78	5	8	14	23
332	69	63	66	72	81	-6	-3	3	13
356	33	35	37	40	46	3	4	8	13
364	90	90	95	104	117	0	5	14	27
381	54	53	55	60	68	-2	1	6	14
386	67	70	74	81	91	3	7	14	24
626	70	75	79	86	98	5	9	16	28
757	63	64	67	74	83	2	5	11	21

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Pace Final Reroutes – Impact Analysis

	Cost per Trip					Change in Cost per Trip			
Route	Existing	Reroute (Base)	Reroute (+ Low)	Reroute (+ Mod)	Reroute (+ High)	Reroute (Base)	Reroute (+ Low)	Reroute (+ Mod)	Reroute (+ High)
208	$119.78	$92.53	$97.15	$106.41	$120.29	-$27.25	-$22.63	-$13.37	$0.51
209	$38.03	$35.49	$37.26	$40.81	$46.14	-$2.54	-$0.76	$2.79	$8.11
221	$69.71	$57.04	$59.89	$65.59	$74.15	-$12.68	-$9.82	-$4.12	$4.44
226	$70.35	$55.14	$57.89	$63.41	$71.68	-$15.21	-$12.45	-$6.94	$1.33
230	$50.70	$41.83	$43.92	$48.10	$54.38	-$8.87	-$6.78	-$2.60	$3.68
234	$58.31	$42.46	$44.58	$48.83	$55.20	-$15.84	-$13.72	-$9.47	-$3.11
302	$40.84	$43.88	$46.08	$50.46	$57.05	$3.05	$5.24	$9.63	$16.21
303	$54.85	$48.76	$51.20	$56.07	$63.39	-$6.09	-$3.66	$1.22	$8.53
309	$54.85	$58.51	$61.44	$67.29	$76.06	$3.66	$6.58	$12.43	$21.21
318	$37.18	$47.54	$49.92	$54.67	$61.80	$10.36	$12.74	$17.49	$24.62
322	$73.14	$81.06	$85.11	$93.22	$105.38	$7.92	$11.98	$20.08	$32.24
330	$78.01	$85.33	$89.59	$98.13	$110.93	$7.31	$11.58	$20.11	$32.91
331	$67.04	$73.14	$76.79	$84.11	$95.08	$6.09	$9.75	$17.07	$28.04
332	$83.50	$76.18	$79.99	$87.61	$99.04	-$7.31	-$3.50	$4.11	$15.54
356	$47.86	$51.54	$54.12	$59.27	$67.01	$3.68	$6.26	$11.41	$19.14
364	$132.54	$132.54	$139.17	$152.42	$172.30	$0.00	$6.63	$19.88	$39.76
381	$59.96	$58.30	$61.21	$67.04	$75.79	-$1.67	$1.25	$7.08	$15.82
386	$74.40	$77.73	$81.62	$89.39	$101.05	$3.33	$7.22	$14.99	$26.65
626	$81.60	$87.42	$91.80	$100.54	$113.65	$5.83	$10.20	$18.94	$32.06
757	$76.18	$78.01	$81.91	$89.72	$101.42	$1.83	$5.73	$13.53	$25.23

resilience **strategies**

Current Regional Work

– CMAP ON TO 2050 Strategies

– Metropolitan Planning Council

– Center for Neighborhood Technology

– City of Chicago / Rockefeller Foundation 100 RC

General Recommendations

Street Flooding and Viaducts

– Street surface (pavement): The pavement must grade toward the drainage structures. If the street is in disrepair or the drainage structures are not located at the low points of the surface grade, flooding will occur.

– Drainage structures: The drainage structures collect surface runoff and route the water to underground storm sewer pipes. The structures are mostly inlets and catch basins, but other types of structures may be utilized, such as French drains. It is imperative that these structures be kept clear of debris and be vacuumed regularly and as necessary.

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General Recommendations

Street Flooding and Viaducts

– Storm sewer: Underground pipe may be composed of masonry or metal. Typically, a water department will investigate a poorly performing drain system by televising the pipe. The video capture will show if and where a pipe collapse or blockage has occurred.

– Pump stations: In some cases low-lying areas require a mechanical means of pumping the water up, out, and into the existing storm sewer system, which lies higher than the viaduct elevation.

General Recommendations

Green Infrastructure

Element	Description / What it Accomplishes
Rain gardens and urban agriculture	A landscaped, man-made depression that both improves water quality and reduces flooding by promoting infiltration. Can be used to grow local foodstuffs.
Bioretention basins	Stormwater is held in a bioretention basin and slowly filters into the ground
Downspout Disconnection and Rainwater Harvesting / Rain Barrels	New gutters and down-spouts convey the runoff from the roof; down-spouts are routed into storage (cisterns or barrels) rather than stormwater system
Permeable Pavement	Stormwater is detained in a subsurface storage layer (drain rock) or slowly infiltrates into the subsurface soils to recharge groundwater
Bioswale	Open vegetated channels designed to detain and promote filtration of stormwater runoff
Trees / Street planting	Aside from reducing air pollution and heating & cooling costs, trees also absorb excess water from storm events
Flow through planters	Placed at or above ground level, flow-through planters do not infiltrate the ground but can help in constrained sites with poorly draining soils, steep slopes, or contaminated areas
Stormwater conveyance	Sidewalk or street runoff is conveyed to a bioretention basin in a stormwater node

General Recommendations

Data and Technology

– Regional data collection and forecasting

– Collaboration on Smart Cities initiatives

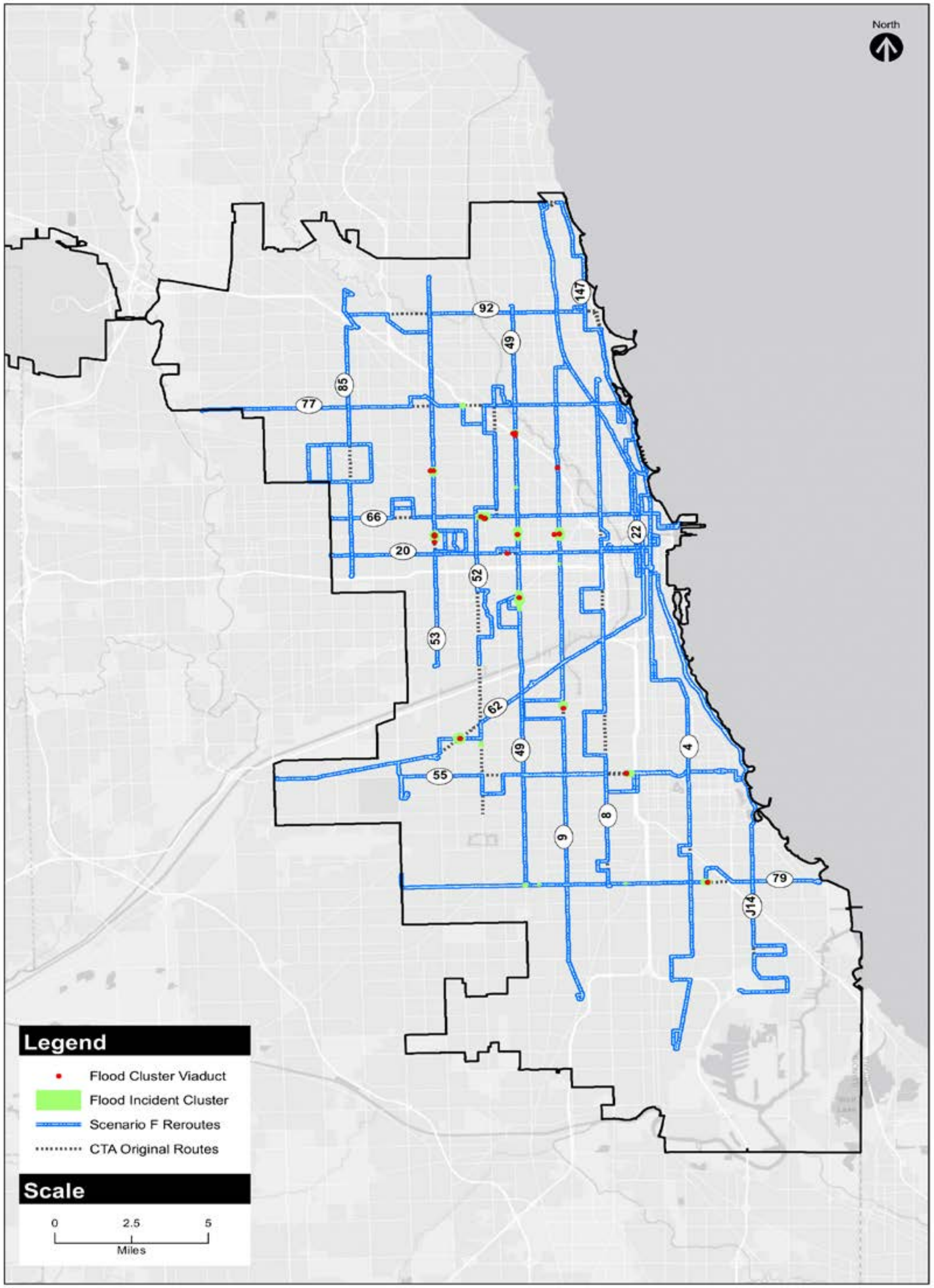
Policies

– CTA participation in City of Chicago Department of Transportation’s Division of Infrastructure Management (CDOT’s DOIM) - Office of Underground Coordination (OUC)

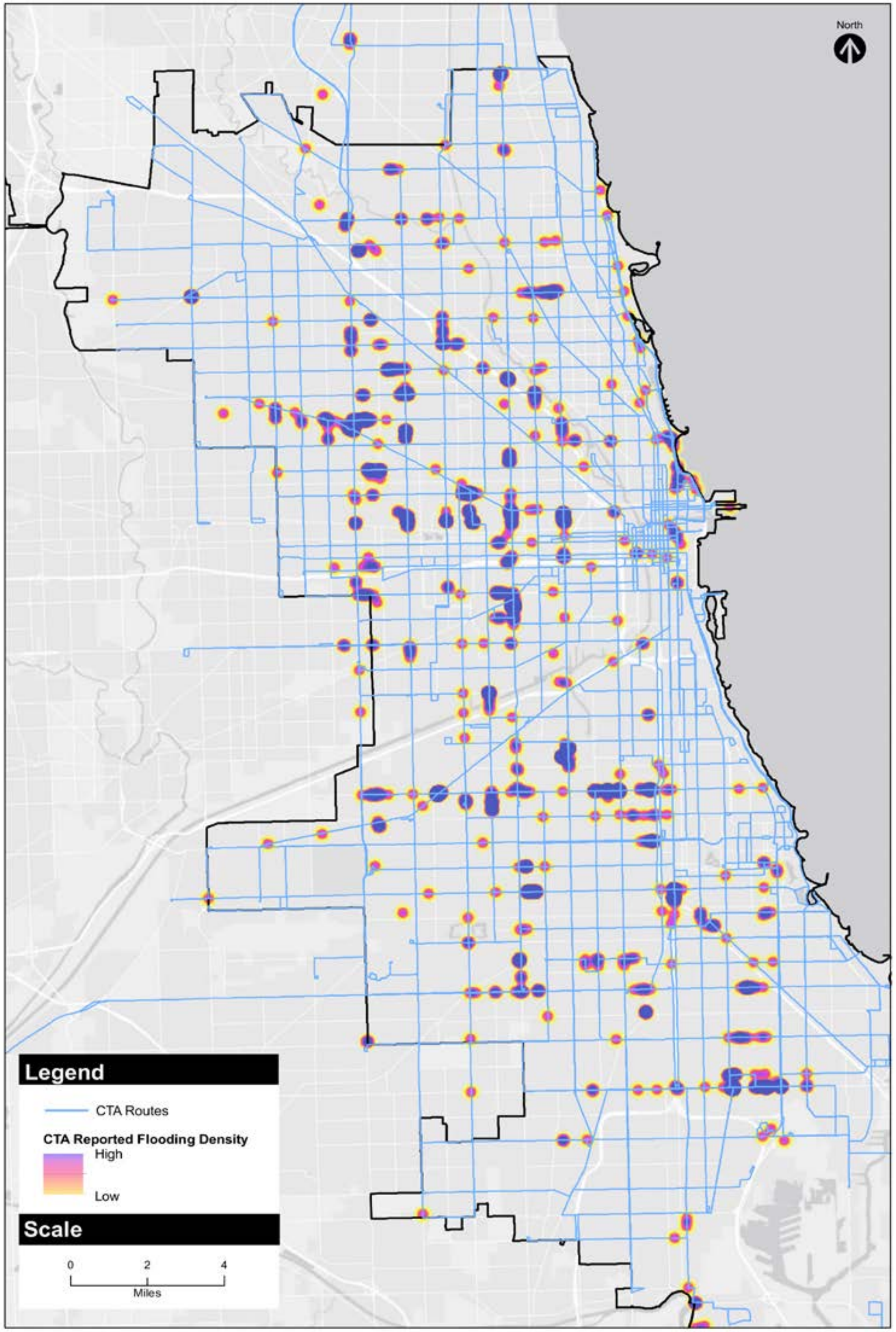
– CTA participation in OEMC Event Management center

– Pace participation in COG / coalition emergency response centers

CTA Specific Recommendations



CTA Specific Recommendations



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CTA Specific Recommendations

Street Flooding and Viaducts

Cluster ID	Scenario F Location	Rail nearby	Acres	CTA Flood Incidents Count	OEMC Flood Incidents Count	Capital Improvement Projects Nearby	Viaducts Count
1	Belmont @ Kimball		166	4	6	Yes (Dec 2013, Water)	0
2	Western @ I-90/94		163	4	4	No	3
3	Ashland @ I-90/94		28	0	0	No	1
4	Pulaski @ Cortland	Yes	346	8	4	No	2
5	Western @ Hirsch		64	3	6	No	0
6	Sacramento @ Chicago	Yes	559	16	6	Yes (Sep 2013, Arterial Surfacing)	7
7	Western @ Kinzie	Yes	516	12	7	Yes (Dec 2015, Water)	1
8	Ashland @ Kinzie	Yes	590	17	5	No	2
9	Pulaski @ Kinzie	Yes	481	12	7	No	6
10	Madison @ Rockwell	Yes	40	2	1	No	1
11	Ashland @ I-290		69	3	0	No	0
12	Western @ Ogden	Yes	752	18	2	Yes (Dec 2013, Arterial Surfacing)	1
13	Pulaski @ Ogden	Yes	45	2	0	No	0
14	Ashland @ W 41st	Yes	344	8	2	No	1
15	Archer @ W 48th	Yes	549	24	3	No	2
16	Kedzie @ W 48th	Yes	136	3	0	Yes (Mar 2015, Water)	0
17	Garfield @ Shields	Yes	316	7	3	Yes (Aug 2014, Arterial Surfacing)	2
18	W 79th @ Eggleston		65	1	0	No	0
19	E 79th @ Greenwood	Yes	330	8	21	Yes (Dec 2013, Water)	1
20	W 79th @ Hamilton	Yes	71	3	0	No	0
21	w 79th @ Western		130	3	0	No	0

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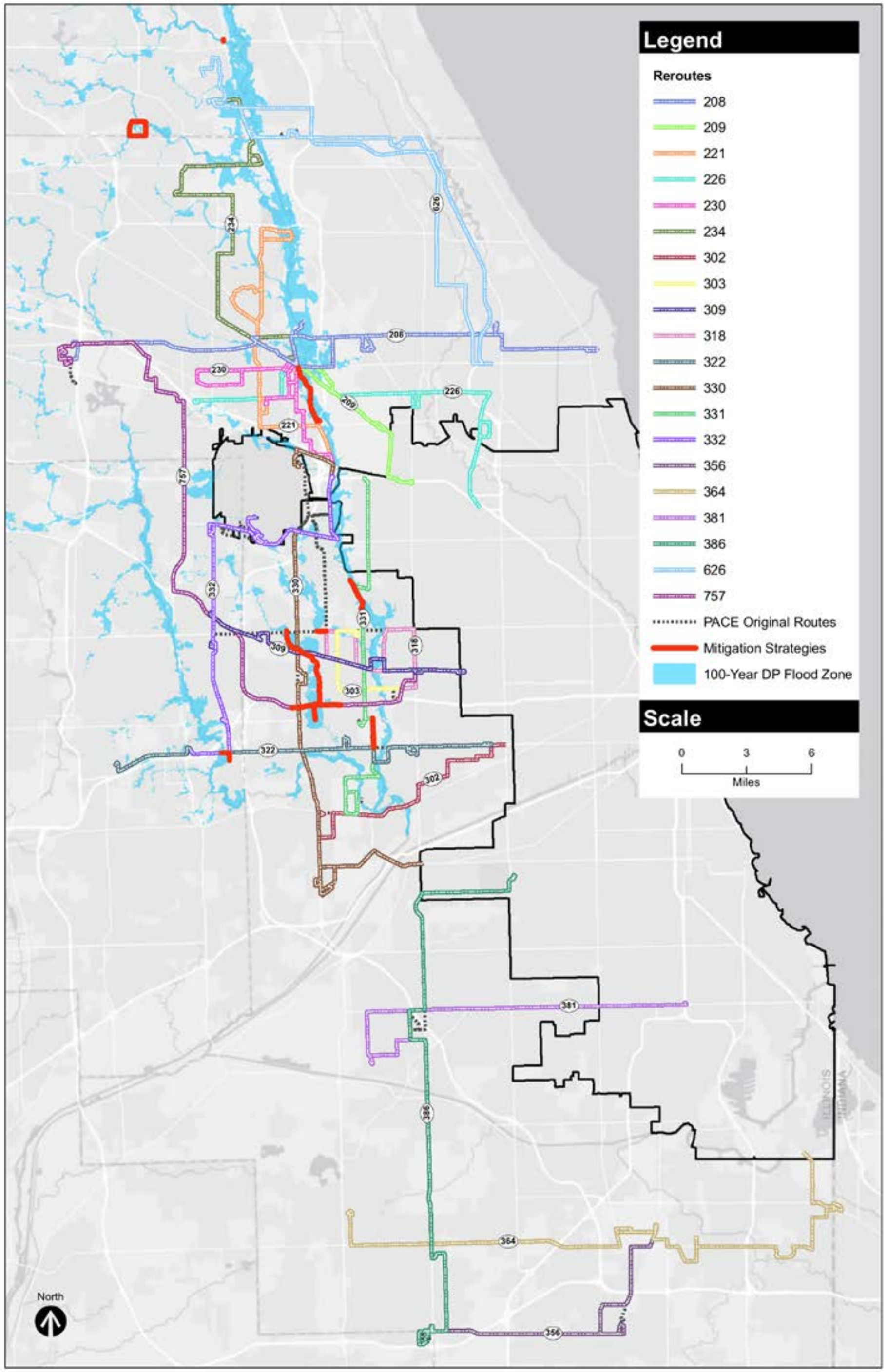
CTA Action Matrix

Project/Policy	Agency/ Organization	Cost	Notes
Viaduct improvement projects	CREATE public and private partners; Metra; railroads; CDOT; CDWM	$$$	CREATE Viaduct Improvement Program completed in 2015. Negotiate additional funding for expansion of that program along with remaining CREATE projects.
Underground construction projects	CDWM, sister water departments	$$$	Such projects may be initiated through Mayoral, Aldermanic, sister-agency and/or public (311) requests.
Clearance of drains of debris prior/during storm	OEMC; Chicago Streets & Sanitation	$	Proactive pre-storm preparation
Coordination with other development/ utility/ roadwork projects	CDOT DOIM	$	Potential participation in dotMaps system. Submittal of a project “hot list” for consideration by the Office of Underground Coordination. The benefit would be potential remediation of infrastructure-induced flooding while other capital projects are being carried out, thus minimizing costs and potential conflicts.
Green infrastructure	Chicago DPD and CDOT (Resilient Corridors Program)	$$	As the Resilient Corridors program is expanded to additional corridors, CTA’s priority routes can be considered.
Ongoing monitoring and data collection	CTA (CleverCAD); OEMC 311 data CMAP; CDWM; CDOT; OEMC; MWRD; IDNR; FEMA; CNT; MPC	$ $$	Use of flood report data to identify and monitor problem areas can be used to generate hot list for participation in OUC meetings (above) or to provide to Streets and Sanitation for debris clearance (above) Develop and enhance/maintain City and/or regional database of flood incidents, forecasts, risk factors, and mitigation measures

Pace Specific Recommendations



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Pace Specific Recommendations

Route	Mitigation Strategy
209, 226	IDNR-OWR has built two flood control projects in this area in the last decade that should solve most of the flooding problems shown. It is uncertain whether floodplain maps were ever updated with the results of these projects; it might be the method of handling the enhanced flood plain in this area that flags these areas as potential problems. These routes should experience infrequent flooding at the worst.
230	PACE needs to lobby Congress regarding funding for the Corps Des Plaines River Levee 9. The Des Plaines River project was authorized by Congress in the Water Resources Development Act of 2016. Now Congress has to include funding for the project in budget.
234	MWRDGC is studying reservoir expansion on Buffalo Creek upstream of this flooding problem. Need to coordinate with MWRDGC to move this project forward.
303, 309, 330	MWRDGC's Addison Creek project that is moving into the design phase should reduce the flood frequency for these routes.
318	MWRDGC's Addison Creek project and a study by IDOT on North Avenue at Silver Creek should reduce the flooding frequency along this route.
331	The Corps Des Plaines River Levee 4 with two closure structures should reduce the flood frequency for this route. The Grand Avenue closure structure would close Grand Avenue but will allow Des Plaines River Road to remain open, and generally would be closed between the 10 and 50-yr flood event. The closure structure at Des Plaines River Road and 5th Avenue would close Des Plaines River Road here during the 100-yr events.
332	DuPage County Stormwater did not show the portion of this route on 22nd Street flooding. They will need to coordinate with Elmhurst regarding solutions for the York Road underpass flooding. The portion of the route along Irving Park Road and Bensenville Ditch may have been addressed when Irving Park and Bensenville Ditch were relocated for the O'Hare Airport Expansion.
626	The Aptakisic Creek flooding along a portion of this route should be coordinated with the Lake County Stormwater Management Commission. The roads are IDOT's jurisdiction at this location and talks about any flooding problems here should also be discussed IDOT.
757	The flooding shown along I-290 portion of this route should be addressed when IDOT reconstructs I-290. PACE needs to work with IDOT on scheduling this reconstruction.

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Pace Action Matrix

Project/Policy	Agency/ Organization	Cost	Notes
Clearance of drains of debris prior/during storm	Local DOT and Departments of Streets & Sanitation	$	Proactive pre-storm preparation
Coordination with other development/ utility/ roadwork projects	Local Councils of Governments	$	Participate in TIP planning process to reinforce priority hotlist
Watershed planning councils	MWRD, local departments of planning, water and transportation	$ $$	Identify risk areas and problems, with corresponding mitigation projects and policies Prepare stormwater master plans to address urban flooding; five pilot studies under way or complete; expand to other high-priority / high-flood risk areas
Ongoing monitoring and data collection	Pace operating systems; local 311/911 services; smart cities service providers County and municipal stormwater departments; CMAP; IDNR; FEMA; CNT	$ $$	Use of flood report data to identify and monitor problem areas can be used to generate hot list for participation in infrastructure planning meetings (above); provide to streets and sanitation departments for debris clearance (above) Develop and enhance/maintain county and/or regional database of flood incidents; rainfall, water level, and flood forecasts; risk factors; and mitigation measures
Cost-sharing for local capital improvement projects to alleviate flooding issues	County DOTs, County, municipality, stormwater agencies	$$	Coordinate problem diagnosis and solution planning among agencies
Cost-sharing on major capital improvement projects pertaining to riverine flooding	County and municipal stormwater departments; MWRDGS, IDOT, US Army Corps of Engineers	$$$	Projects include reconstruction of a segment of I-290 (IDOT), Des Plaines River Levee 9 (US ACE), Buffalo Creek reservoir expansion (MWRDGC), Addison Creek (in design phase, MWRDGC), Silver Creek (IDOT), among others

Pace Action Matrix, continued

Project/Policy	Agency/ Organization	Cost	Notes
Viaduct improvement projects	CREATE public and private partners; Metra; railroads; local DOT	$$$	Funding of CREATE projects is pending.
Underground construction projects	Local and county departments of water management and transportation	$$$	Such projects may be initiated through Mayoral, Aldermanic, sister-agency and/or public (311) requests.
Green infrastructure	local departments of planning, water and transportation	$$	Implement carefully curated palettes of green infrastructure for maximum benefit

Flooding Resilience Plan for Bus Operations

AECOM March 2018

AECOM

Flooding Resilience Plan for Bus Operations

Project Executive Summary for the Chicago Transit Authority

Prepared for the Regional Transportation Authority of Northeast Illinois

rta

May 18, 2018

Project Background and Summary

In Fall 2015, as a continuation of its Green Transit program, the Regional Transportation Authority (RTA) initiated a project to prepare a bus route flooding resilience plan for the RTA service area composed of its six-county jurisdiction in northeastern Illinois, including Cook, DuPage, Kane, Lake, McHenry, and Will Counties. The objective of this project was to identify CTA and Pace bus routes that are prone to flooding during both average rain events and extreme weather events and to develop recommendations to address flooding issues and reroute service during flooding to minimize impacts and inconvenience to riders. Aside from hampering citizens' mobility, flood-driven service interruptions can also have negative impacts on operating costs and ridership revenues.

Summary of Tasks and Themes

Based on observations of significant flood events during the last five to 10 years, flood events in the RTA service area are a combination of water body overflows, as well as stormwater runoff and localized drainage issues. Bus transit is most obviously impacted when roads are wholly flooded and impassible, and viaducts and underpasses around the region's railroad and highway network are particularly vulnerable. As part of the Chicago Climate Action Plan—one of the key precursor studies to the RTA Flooding Resilience Plan for Bus Operations—the CTA noted that their bus service is particularly vulnerable to flood events because of the more than 1,500 railway viaducts, of which more than 10 percent are troubled by frequent flooding. After a kickoff meeting in **Task 1**, in **Task 2**, the project team identified and reviewed datasets describing the natural systems across the region—primarily the floodplains and floodways—as the starting point for identifying areas that present risk based on riverine and overbank flooding.

In addition to conclusions that can be inferred from an overlay of viaduct locations, conditions and bus routes, the project team supplemented its understanding of risk with anecdotal reports of flooding from the front lines—the CTA and Pace bus drivers who call in flooded roads and detours. Areas with recurring problems for boarding and alighting were provided by the drivers and operations management, as well as from passengers who make reports of access difficulties. Additionally, insight from emergency management stakeholders and local departments of stormwater management and transportation provided further insight into troubled areas, impact, and the status of mitigation work.

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Flood Risk Areas and Hotspots

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This plan's analysis of current and future flood risk areas categorized two types of flooding: **urban**, with origins in the built environment and ability of infrastructure to manage large amounts of stormwater; and **riverine**, resulting from overbanking of water bodies (rivers, streams, reservoirs, etc.) from large amounts of stormwater. To identify flood risk areas and hotspots across the RTA service area, the project team collected a variety of data:

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Specific to Urban Flooding

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Stormwater and water resource engineers on the project team evaluated the potential increases in rainfall using the climate change scenarios from the Chicago Area Climate Action Plan and applying the increases for future climate change scenarios to the Illinois State Water Survey's Bulletin 70 24-hr rainfall amounts. The project team interpolated existing and future rainfall frequency curves to identify the equivalent storm frequency for future rainfall events at mid-century 2017 and late-century 2017. This generalized modeling of anticipated rainfall suggests storms of greater severity may occur more frequently in the future. That is….

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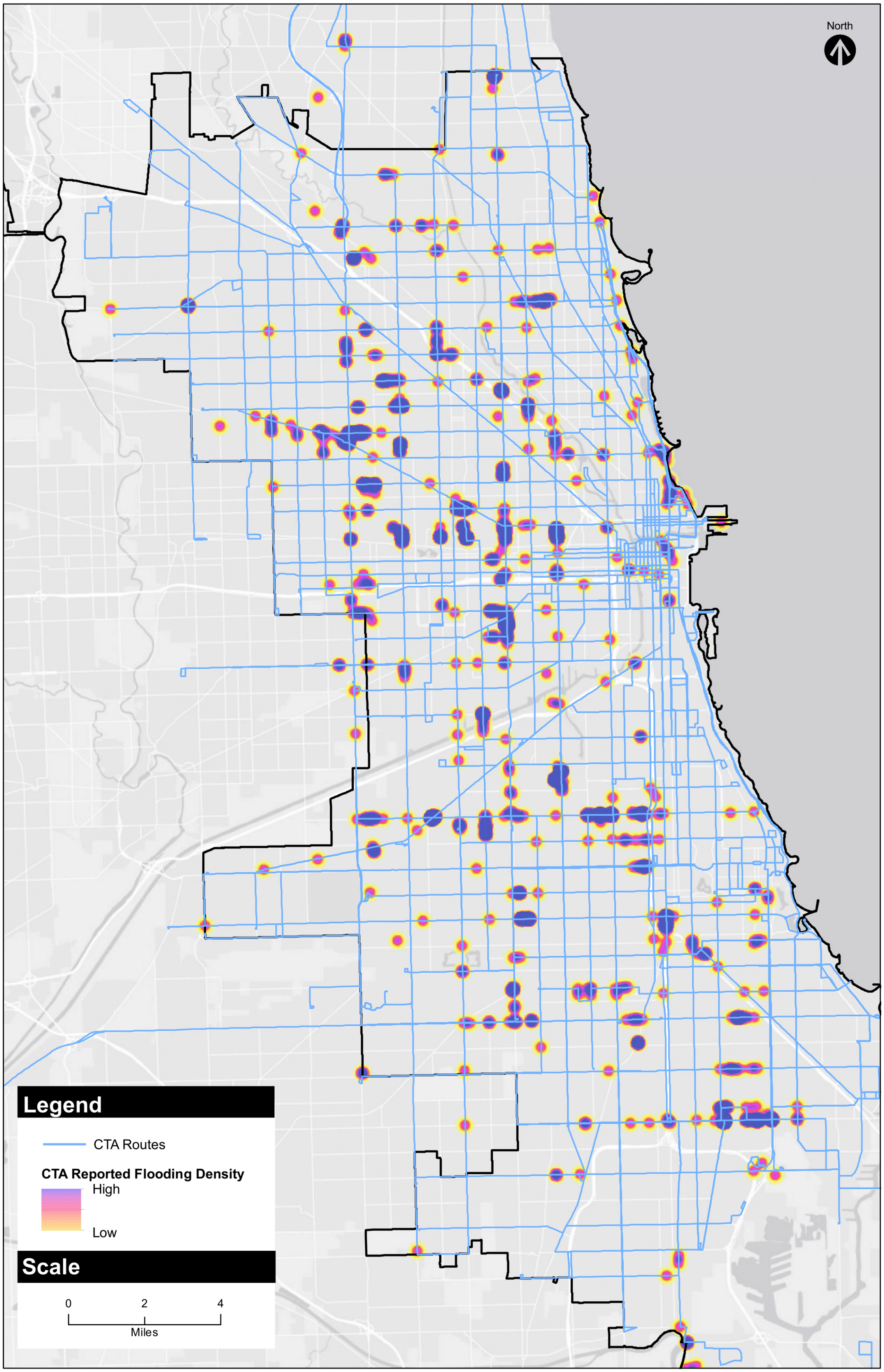
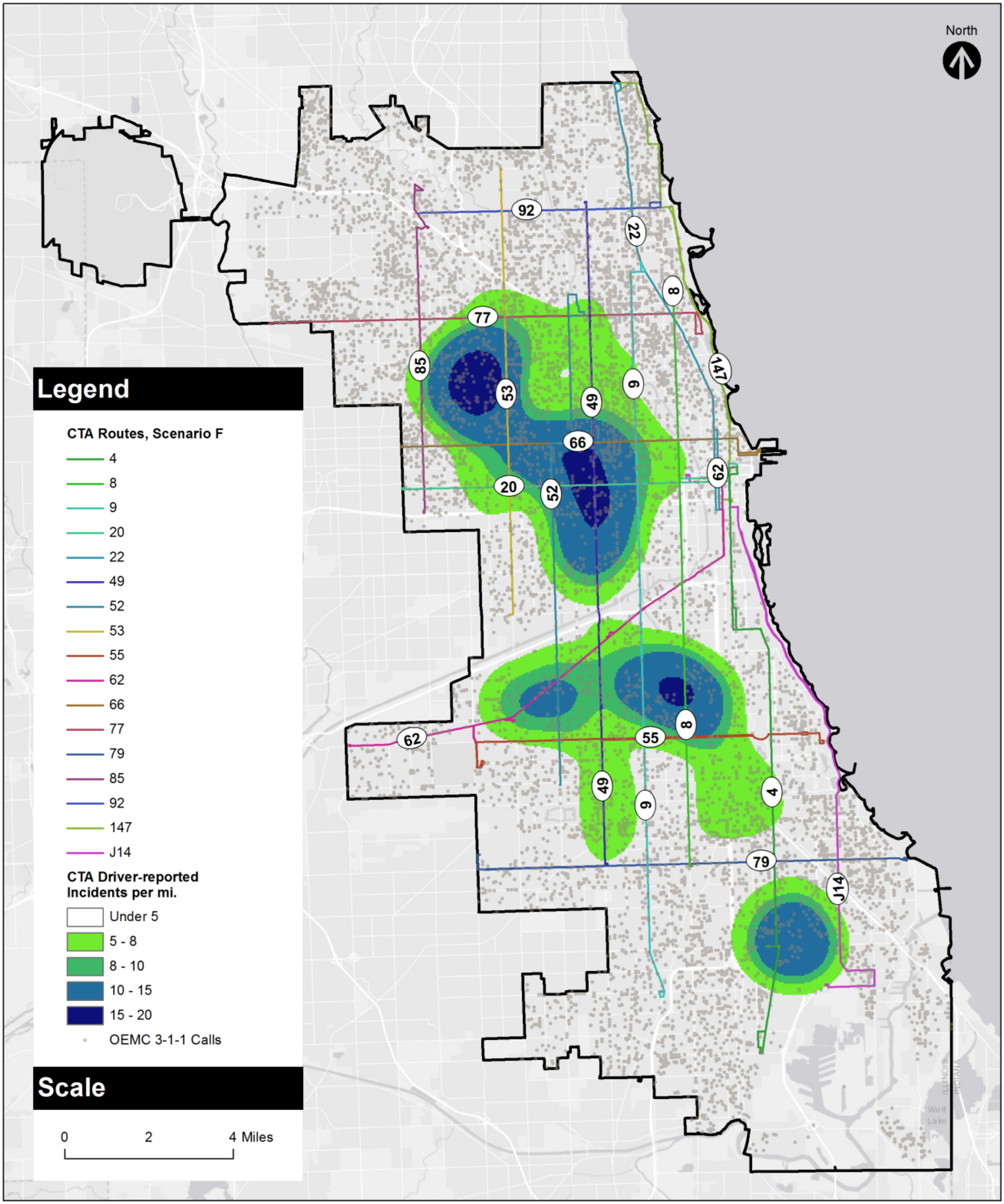
To analyze the potential impact of future climate change and rainfall events of increasing severity and frequency on urban flooding patterns, the project team correlated rainfall data from recent storm events with recorded flood incidents from the CTA and the City of Chicago's Office of Emergency Management & Communications (OEMC), using a subset of recent storm events of varying frequencies from the period 2013-2016 when CTA recorded flood incidents and OEMC 311 call data were available on the same dates. The project team observed that the density of OEMC 311 calls complaining about water on roadway and/or flooded viaducts increased with storm type. CTA drivers' reports of flood incidents were generally found to correlate with moderate or more severe storms, that is, storms with 1-year recurrence intervals or greater. While drawing on a finite sample set of rainfall data *and* data documenting actual flood incidents reported by CTA staff or through OEMC via 311, the analysis provides valuable insight to areas of future risk for flooding that might impact CTA bus operations. Although this study cannot draw broad spatial conclusions that areas currently prone to flooding will be larger or wider in the future – it appears that the intensity of flooding may become worse and/or more frequent. The degree of severity of urban flooding is subject to interventions by water departments to manage stormwater and sewer capacity across their networks and discharge decisions at any given time.

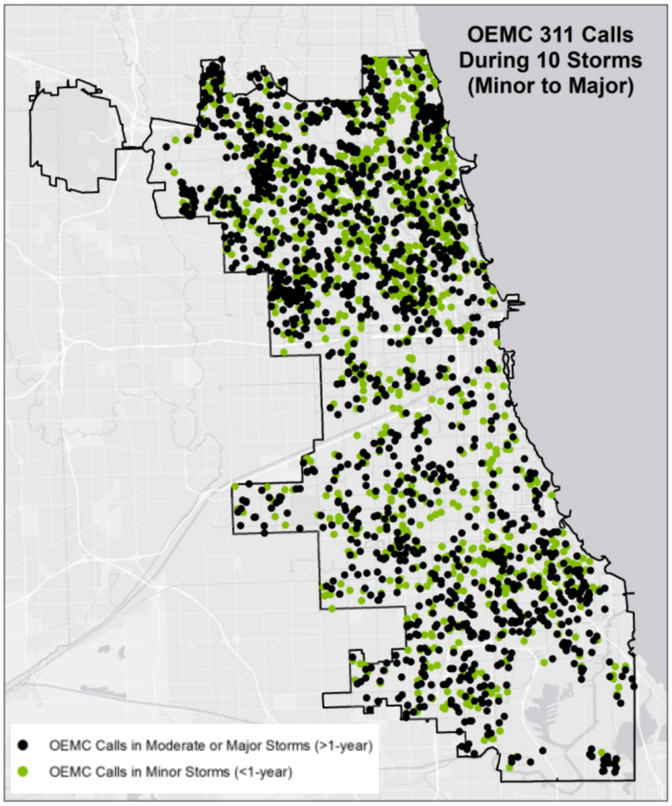
Density of CTA-Reported Flooding Incidents, 2011-2016



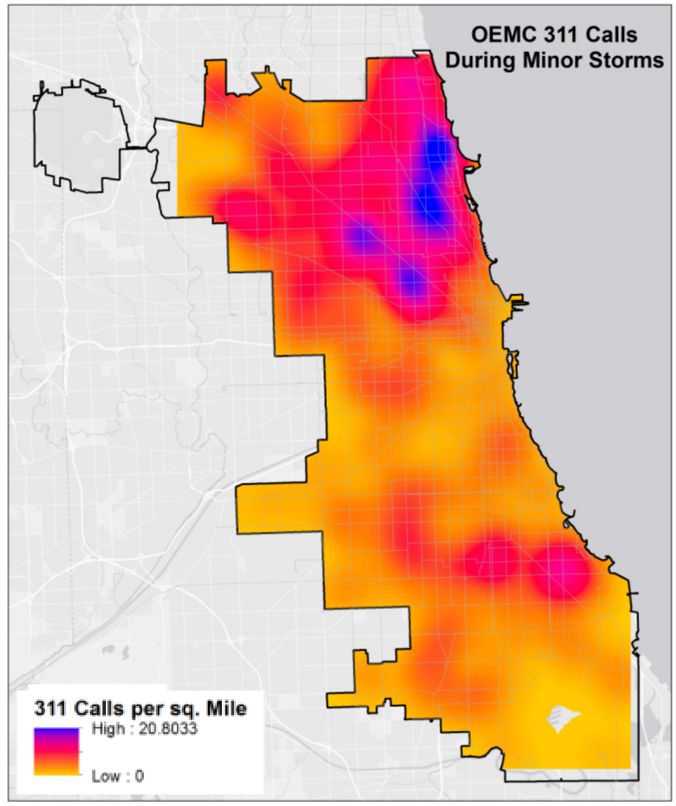
OEMC Calls, Density of CTA Flood Reports, and Selected CTA Routes



OEMC 311 Calls By Storm Type

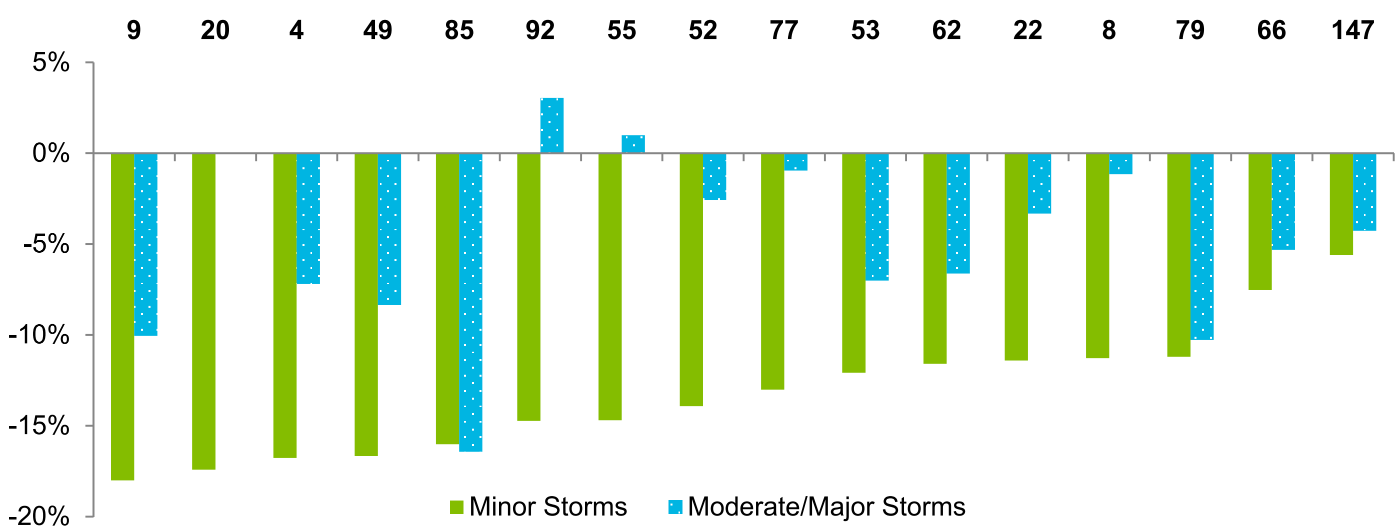


Density of Calls During Minor Storms (<1-Year Storm Recurrence Interval)



As shown below, larger decreases in ridership are seen on minor storm days (recurrence intervals of one year or less) than during moderate or major storms. This is most likely because people are unwilling to risk driving themselves during moderate or major storms and thus are more likely to rely on transit if they cannot avoid traveling entirely. Furthermore, analysis of Ventra data for selected routes shows that during moderate and major storms, ridership falls by an average of 7.8 percent on weekend storm days, but only 4.7 percent on weekday storms, illustrating the elasticity of discretionary travel.

Percent Ridership Change by Storm Type on Selected Routes, 2013-2017



Reroutes and Impact Analysis

Due to the size of the RTA service area and breadth of CTA's service area, this project was unable to analyze each and every bus route for flood impacts and plan for reroutes. The project team provided a variety of prioritization criteria to CTA and Pace to select a subset of routes for further analysis. Routes were filtered and sorted based on criteria such as: actual reports of flooding by drivers, number of intersections with flood zones (based on the 100- and 500-year flood plains), ridership, and number of connections with the regional transit network. CTA decided to apply a different selection mechanism, focusing flooding impact analysis on the routes they consider to be the "workhorses" of the CTA network, which move large volumes of passengers across the city, make vital connections between transit modes, and connect residential communities to downtown and other employment centers. This selected group of routes has been named Scenario F.

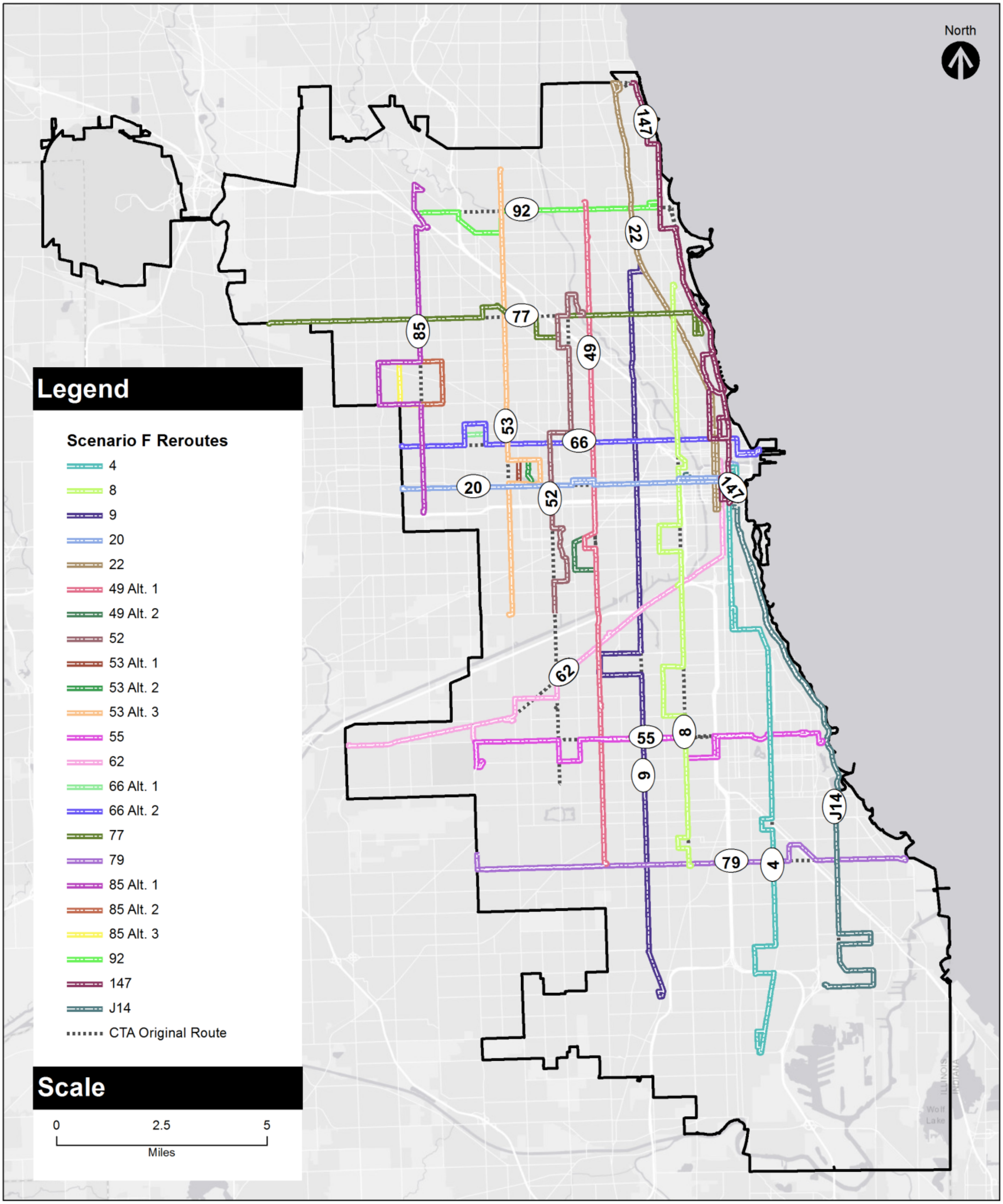
CTA Scenario F Routes

4	Cottage Grove	66	Chicago
8	Halsted	77	Belmont
9	Ashland	79	79th
20	Madison	85	Central
22	Clark	92	Foster
52	Kedzie/California	147	Outer Drive Express
53	Pulaski	J14	Jeffery Jump
55	Garfield	X49	Western Express
62	Archer		

The project team estimated quantitative impacts of the Scenario F reroutes, including changes in stops serviced based on the reroute alignment, associated changes in ridership, travel time, and operating costs. The estimates presented assume full implementation of reroutes as documented, including situations where a route may have multiple diversions.

- The number of bus stops on the original routing skipped by the reroute ranges from nominal to many; a few routes are truncated instead of rerouted due to major barriers that would require a significant diversion.
- In most cases, the reroute diversions reduce the number of locations where a route alignment encounters a flood risk area. However, there are a few instances where the reroute touches one or two additional areas. Because stormwater management is very dynamic, this is a point to monitor rather than a concern; in some cases, multiple reroute options were sketched and modeled.
- The change in estimated ridership for most reroutes is less than 1 percent of average weekday ridership on the standard routes, with only one line (52) experiencing substantial numbers of riders potentially impacted (diverted or potentially lost) due to a significant route truncation. These estimates do not take into account counteracting communications mechanisms that would direct impacted riders to alternate stop locations on the reroute or alternate transit routes, thus reducing the potential lost system ridership.
- Operational impacts to reroutes are estimated based on travel times for the altered routes. Changes in per-trip travel times between the standard route and the reroute vary substantially. In some cases, a reroute is longer than the standard route, and incurs greater travel time; in other cases, a reroute runs shorter and faster. Estimates of impacts to operating costs are calculated using each route's cost per-hour metric.
- As with the changes in travel times, increased costs may be incurred in some situations, and savings in other situations. Impacts from the base reroutes are presented here, with more travel time and cost projections accounting for additional low, moderate or high travel delay factors on top of the base reroute included in the full project report.

CTA Scenario F Reroutes



Estimated Key Performance Indicators for Reroutes

Route	# of CTA-reported Flooding Incident Areas on Original Route	Change in # CTA Flooding Incident Areas with Reroute	Missed Bus Stops with Reroute	Riders Impacted by Reroute	Change in Travel Time in Minutes (Base Reroute)	Change in Cost per Trip (Base Reroute)
4	34	0	16	2	6	$10
8	21	-7	36	336	12	$20
9	47	-6	4	63	7	$11
J14	7	0	0	0	5	$8
20	8	+1	7	44	2	-$29
22	3	0	0	N/A	0	$-
49	89	-23	3	11	2	$3
49a	89	-29	8	98	4	$6
52	113	-24	98	750	-10	-$17
53	36	-9	9	155	3	$4
53 Alt 1	36	-9	9	155	5	$7
53 Alt 2	36	-3	9	155	6	$10
55	10	-6	18	253	8	$13
62	38	0	15	87	4	$6
66	22	-1	5	21	2	$3
66 Alt 1	22	+9	5	21	4	$7
77	11	-3	14	224	10	$17
79	24	-3	12	87	2	$3
85 E	2	+4	14	72	4	$7
85 W	2	+2	14	72	4	$7
85 Nar	2	-2	14	72	7	$12
92	9	+3	15	31	4	$6
147 Alt 1	21	-3	5	78	13	$21
147 Alt 2	21	-2	5	78	18	$29
147 Alt 1 & 3	21	-1	2	78	11	$18
147 Alt 2 & 3	21	+1	2	78	16	$26

Interesting Comments about Certain Routes

22 Clark – Identified by CTA as a route of interest; no reroute was designed due to the low-risk nature of the potential flood-prone areas that it intersects and lack of historic reports of flood-diversion

52 Kedzie/California – Numerous flood-prone viaducts and intersections exist between 31st Street and 48th Street; reroute significantly truncates service in lieu of trying to drive a wide berth around potential flood spots and the Corwith Rail Yard

53 Pulaski, 66 Chicago, 85 Central, 147 Outer Drive Express — Several reroute alternatives were modeled to reflect different options available to the driver, due to the presence of potential flood spots on the diversion(s) as well

Communications and Coordination Plans

In the event that severe rain events disrupt regular bus service, communications and coordination plans are critical for notifying the public about service changes, including reroutes. CTA has well-established procedures tested and refined over the course of numerous severe rain events as well as other types of service interruptions, weather-related and not. Recommendations from this project include identification of areas for new or deeper collaboration among interested agencies, as well as suggestions for consideration of additional technological resources; both of which are subject to available financial and human resources. Key activities include:

Pre-Flooding Preparedness Operations

CTA Communications/Power Control Center will:

– Monitor weather forecast for rainfall that may produce flood water impediments to bus operations.

– Regularly coordinate with OEMC and monitor OEMC push notification traffic to evaluate the potential for flooding along city streets and viaducts.

– Participate in multi-agency conference calls to monitor weather conditions and identify the need for Streets and Sanitation to clean sewer grates and culverts and for Water Management to pre-check at-risk drains and pumps.

– Coordinate with Customer Information and Media Relations as necessary and in a timely fashion to convey the potential for bus re-routes.

CTA Safety will:

– As deemed necessary, deploy a representative to sit at the OEMC to participate in city-wide planning efforts and coordinate with CTA C/PC, Dispatch.

Flood Operations

CTA Communications/Power Control Center will:

– Receive notification from CTA field supervisors and OEMC on flood conditions.

– Re-route bus operations as necessary and practical along routes that experience flooding.

– Inform operators of route changes who, in turn, will provide such information to patrons, as necessary.

– Provide updates to CTA website and bus shelter variable messaging sign updates to direct passengers to temporary alternate stop locations.

– Coordinate with staff deployed to OEMC.

– Dispatch will coordinate with field supervisors and OEMC to respond to route flood conditions that are not historically typical.

– Coordinate with CTA Customer Information and Media Relations to publish and relay bus service updates to the public.

CTA Safety will:

– For major rain events, coordinate with city-wide storm/rainfall operations with OEMC.

– As deemed necessary, deploy a representative to sit at OEMC to monitor the WebEOC interface for city-wide flooding incidents and occurrences and coordinate with CTA C/PC, Dispatch.

CTA Customer Information will:

– Provide supplemental information beyond standard Customer Alert information on CTA's website, Twitter, digital signage and other online communication outlets as deemed necessary.

– Provide information to RTA, for its Travel Info Center.

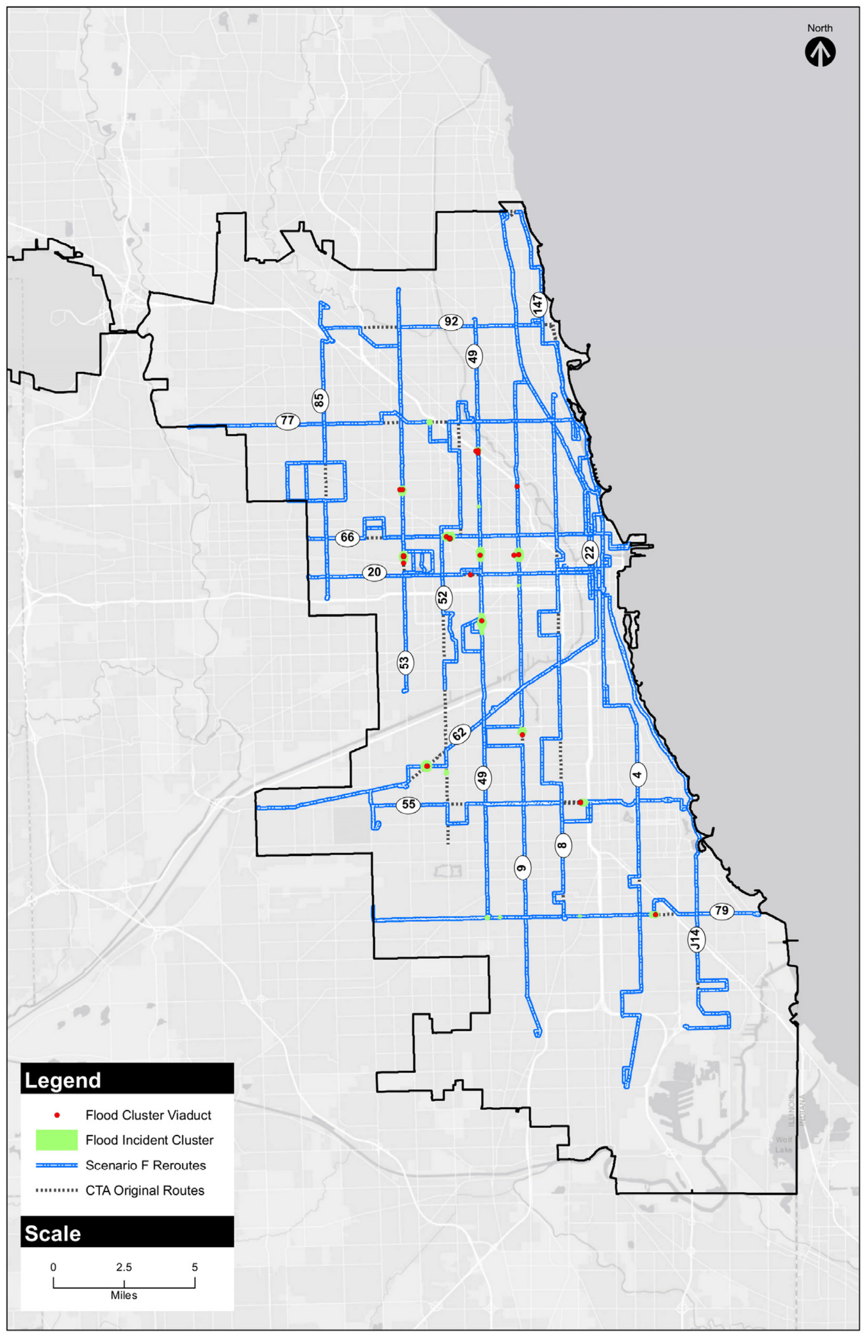
CTA Media Relations will:

– Convey news about CTA implementing service reroutes as flooding circumstances require, to television, radio and other media outlets as deemed necessary.

Mitigation Projects

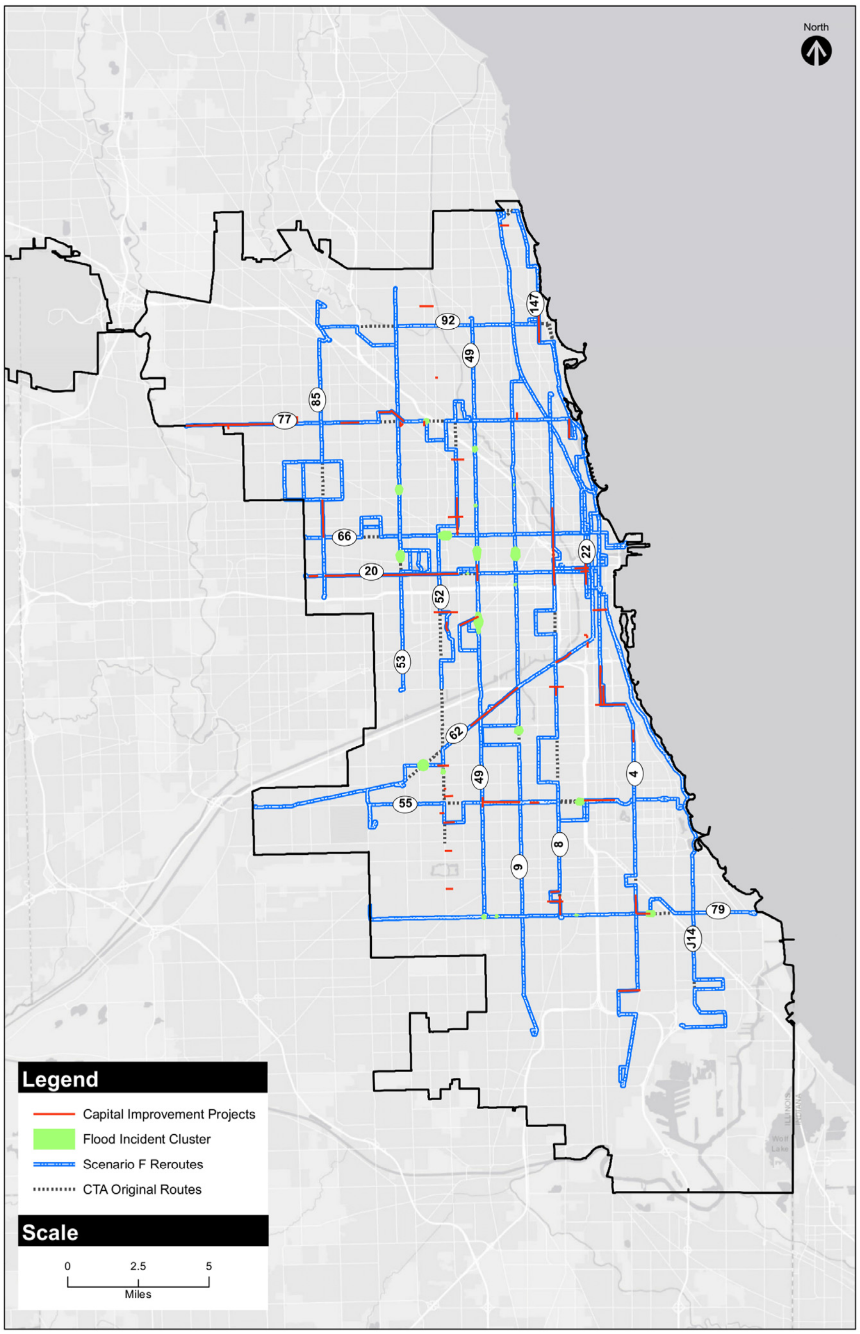
By analyzing CTA-reported flooding events that were within 100 feet of a Scenario F route, the project team was able to generate a map of dense flood incident clusters in the City of Chicago (below left). In most cases the larger clusters with a higher density of flooding reports (depicted below in green) also have a viaduct (red dot) in the vicinity. All of the largest flooding clusters (more than five CTA-reported incidents) studied here have a rail crossing or facility nearby. They also have 86 percent of the OEMC 311 calls reporting flooding or water on street, and 25 of the 30 viaducts in the sample set. It would be difficult to fully remediate these pervasive problems areas via green infrastructure mitigation—construction projects to address stormwater infrastructure or roadway design are probably needed. Consultation with CDOT planners and engineers suggests that for many of these rail-adjacent and viaduct-adjacent flooding problems, an effective avenue for pursuing mitigation projects is to coordinate such improvements through CDOT's Office of Underground Coordination (OUC) or in conjunction with larger projects in the Chicago Region Environmental and Transportation Efficiency Program (CREATE).

CTA Flood Incident Clusters and Flood Cluster Viaducts



Comparing these cluster locations with the 2014-2018 Capital Improvement Plan shows that seven clusters are in proximity of a project completed since 2013 (below right). These projects either involved water infrastructure or arterial surfacing, as noted in the table. There are no future projects nearby at this time, but it is possible that completed projects may already be resolving some of the historical flooding problems in the area (CTA flood incident data from 2011-2016 was used in this analysis). These areas should be monitored for ongoing problems that would be scheduled for future capital projects.

CTA Flood Incident Clusters and Capital Improvement Projects



Action Plan Matrix

CTA can coordinate with a broad range of partners to pursue short and long term flood mitigation actions.

Project/Policy	Agency/ Organization	Cost	Notes
Viaduct improvement projects	CREATE public and private partners; Metra; railroads; CDOT; CDWM	$$$	CREATE Viaduct Improvement Program completed in 2015. Negotiate additional funding for expansion of that program along with remaining CREATE projects.
Underground construction projects	CDWM, sister water departments	$$$	Such projects may be initiated through Mayoral, Aldermanic, sister-agency and/or public (311) requests.
Clearance of drains of debris prior/during storm	OEMC; Chicago Streets & Sanitation	$	Proactive pre-storm preparation.
Coordination with other development/ utility/ roadwork projects	CDOT DOIM	$	Potential participation in dotMaps system. Submittal of a project "hot list" for consideration by the Office of Underground Coordination (OUC). The benefit would be potential remediation of infrastructure-induced flooding while other capital projects are being carried out, thus minimizing costs and potential conflicts.
Green infrastructure	Chicago DPD and CDOT (Resilient Corridors Program)	$$	As the Resilient Corridors program is expanded to additional corridors, CTA's priority routes can be considered.
Ongoing monitoring and data collection	CTA (CleverCAD); OEMC 311 data	$	Use of flood report data to identify and monitor problem areas can be used to generate hot list for participation in OUC meetings (above) or to provide to Streets and Sanitation for debris clearance (above).
	CMAP; CDWM; CDOT; OEMC; MWRDGC; IDNR; FEMA; CNT; MPC	$$	Develop and enhance/maintain City and/or regional database of flood incidents, forecasts, risk factors, and mitigation measures.

Decode of Agency / Organization Abbreviations

CDOT – Chicago Department of Transportation
CDPD – Chicago Department of Planning and Development
CDWM – Chicago Department of Water Management
CMAP – Chicago Metropolitan Agency for Planning
CNT – Center for Neighborhood Technology
CREATE - Chicago Region Environmental and Transportation Efficiency Program
DOIM – Division of Infrastructure Management within CDOT
FEMA – Federal Emergency Management Agency
IDNR – Illinois Department of Natural Resources
MPC – Metropolitan Planning Council
MWRDGC – Metropolitan Water Reclamation District of Greater Chicago
OEMC – Chicago Office of Emergency Management & Communications
OUC – Office of Underground Coordination managed by CDOT DOIM
RTA – Regional Transportation Authority

Flooding Resilience Plan for Bus Operations

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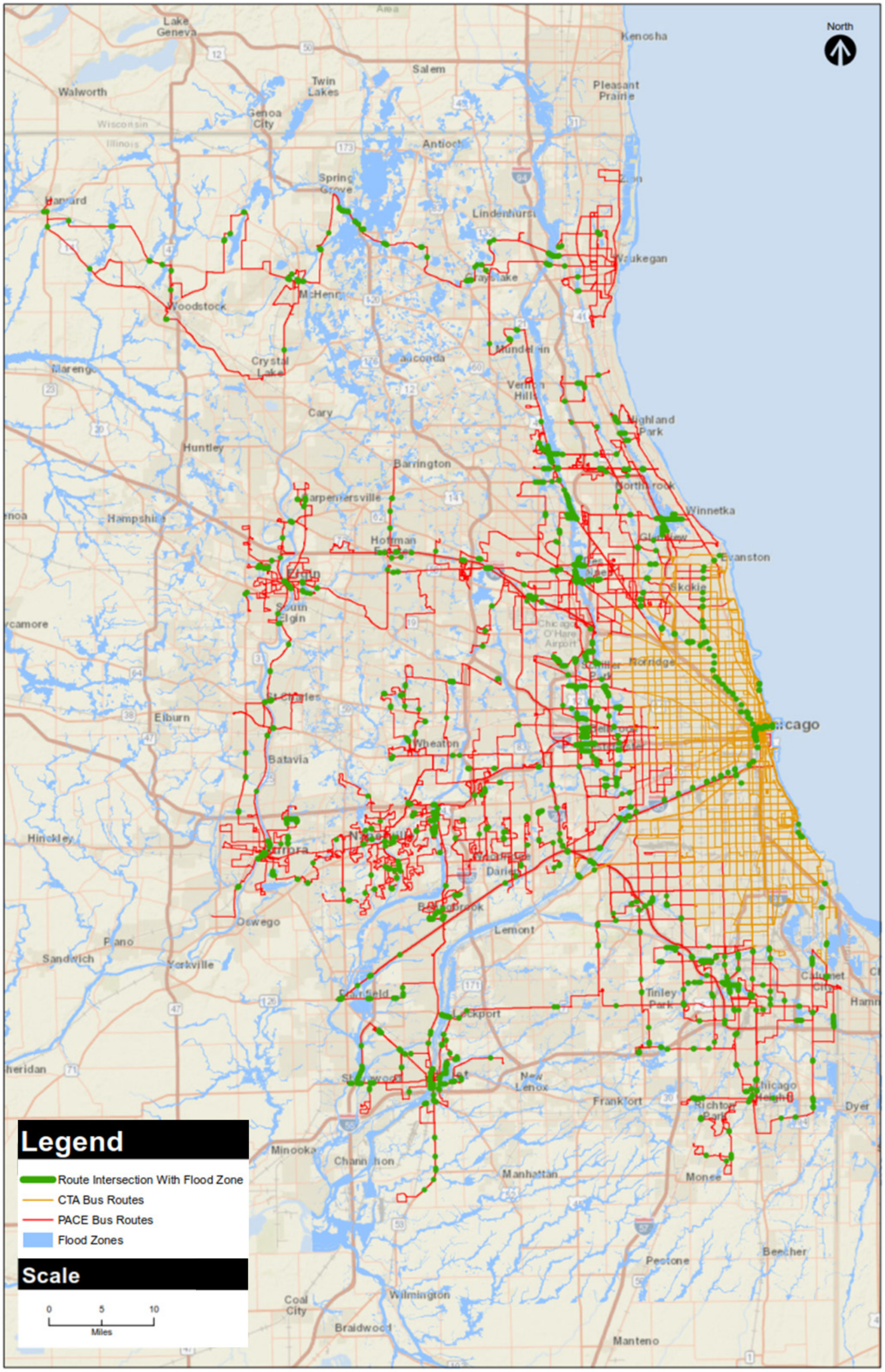
A 1-year storm mid-century could be like today's 2-year storm
A 1-year storm late-century could be like today's 2.5-year storm

The potential impact of future climate change on riverine and suburban/exurban flooding patterns and levels are available from a 2010 report by the US Army Corps of Engineers for several water bodies in the RTA service area, include the Des Plaines River, Addison Creek, and Silver Creek. Storm profiles were reviewed to identify incremental surface elevation differences, which range from 0.8 to 2.4 feet, and were used to project potential future 100-year floodplain limits as located approximately halfway between the existing FEMA 100- and 500-year flood plain limits. In the absence of complex hydraulic and hydrologic modeling, this broad-brush approach is appropriate for identifying locations impacted by future conditions. This exercise concludes that there was very limited spatial expansion of floodplain areas impacting bus routes. This project's initial screening of Pace bus routes for risk of flood interruption was based on defining risk areas including both the 100- and 500-year floodplain limits, so adjustments for future conditions were already within the zones noted as potentially risk-prone. Across the RTA service area, there are few areas with 500-year floodplain concerns that intersect with bus routes. The conclusion from this exercise is similar to the project team's conclusion for urban flooding: locations that are currently prone to flooding may have more frequent or severe flooding in the future.

Intersection of Bus Routes with Current 100-Year and 500-Year Flood Zones



Reroutes and Impact Analysis

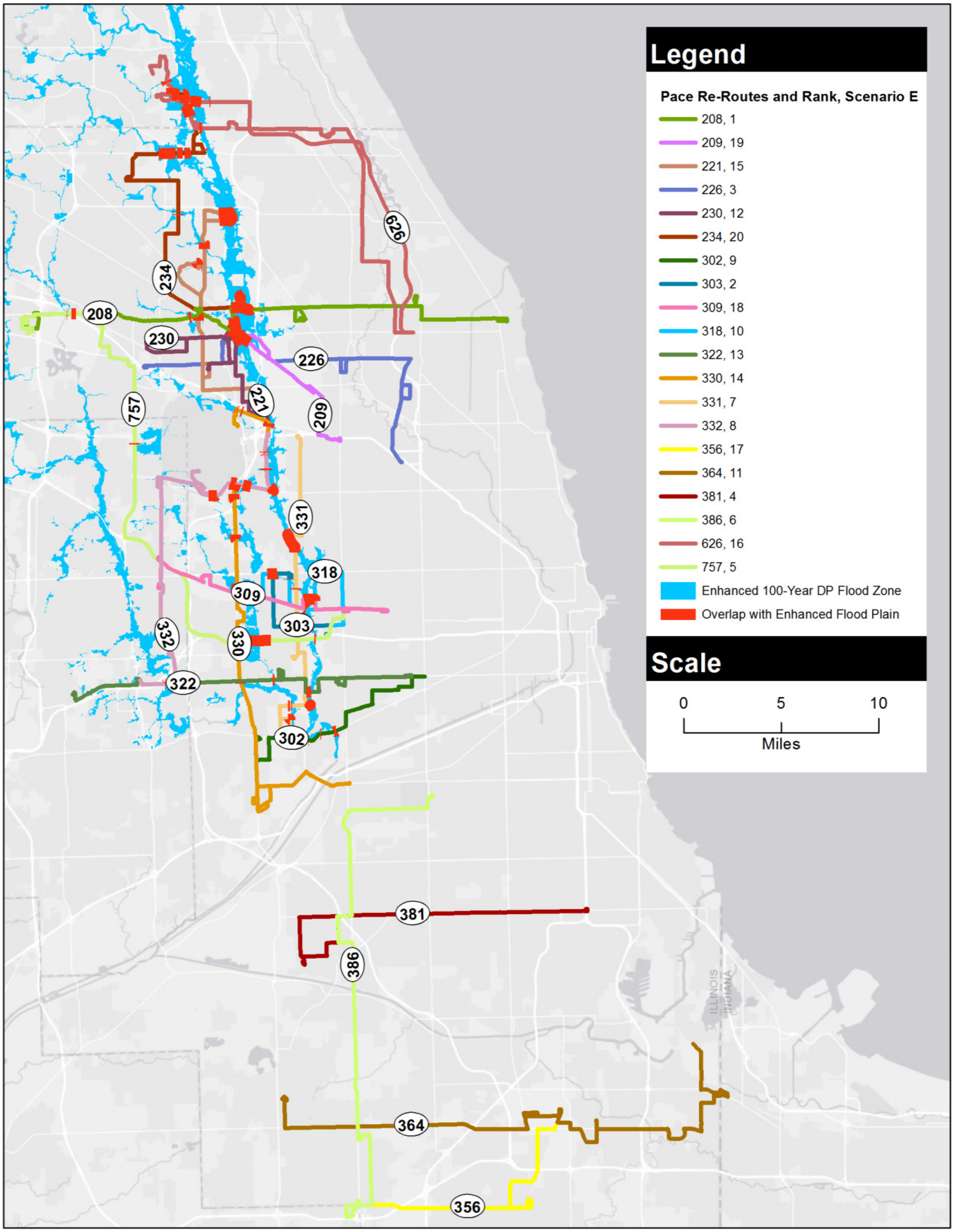
Due to the size of the RTA service region and breadth of Pace's service area, this project was unable to analyze each and every bus route for flood impacts and plan for reroutes. The project team provided a variety of prioritization criteria to CTA and Pace to select a subset of routes for further analysis. Routes were filtered and sorted based on criteria such as: actual reports of flooding by drivers, number of intersections with flood zones (based on the 100- and 500-year flood plains), ridership, and number of connections with the regional transit network. Pace representatives decided that they would most benefit from analysis of the routes in Scenario E, which filtered routes by actual flood reports, and sorted by transit network connectivity and ridership.

Pace Scenario E Routes

208	Golf Road
209	Busse Highway
210	Lincoln Avenue
221	Wolf Road
226	Oakton Street
230	South Des Plaines
234	Wheeling - Des Plaines
272	Milwaukee Avenue North
302	Ogden - Stanley
303	Forest Park - Rosemont
309	Lake Street
318	West North Avenue
319	Grand Avenue
322	Cermak Road - 22nd Street
326	W Irving Park Road / Rosemont CTA to Norridge
330	Mannheim - LaGrange Roads
331	Cumberland - 5th Avenue
332	RT 83 / River Road - York Road
356	Harvey - Homewood - Tinley Park
364	159th Street
381	95th Street
386	South Harlem
565	Grand Avenue
572	Washington
619	Des Plaines Station - Willow Road Corridor
620	Yellow Line Dempster - Allstate
626	Skokie Valley Limited
757	Oak Park - Schaumburg Limited

Pace had already defined turn-by-turn reroute directions for numerous routes throughout the region in response to historic flood incidents that have impeded regular operations. Most Scenario E routes have reroutes in place already, defined by Pace, and used routinely during storm events. Notably, these reroutes have not required further diversion, even during severe storms experienced in 2013, 2016 and 2017. These reroutes formed the basis of analysis during this project, although may need to be adjusted in the future by Pace as actual situations may warrant.

Pace Scenario E Reroutes



The project team estimated quantitative impacts of the Scenario E reroutes, including changes in stops serviced based on the reroute alignment, associated changes in ridership, travel time, and operating costs. The estimates presented assume full implementation of reroutes as documented, including situations where a route may have multiple diversions.

- In most cases, the reroute diversions reduce the number of locations where a route alignment encounters a flood risk areas; however, there are a pair of instances (330 and 332) where the reroute touches one or two additional areas; feedback from Pace staff on the reliability of their defined reroutes even through severe storm events suggests this is a point to monitor rather than a concern.
- The number of bus stops on the original routing skipped by the reroute ranges from nominal to many; while in some situations this metric may appear high, it reflects designating stops at every intersection while Pace transitions to fixed stops from flag stops.
- From the recalculation of bus stops serviced, the project team re-estimated potential ridership on the reroute. Changes in ridership for most routes is less than 10 percent, with only four routes experiencing substantial numbers of riders impacted (potentially lost or diverted) due to skipped stops. These estimates do not take into account counteracting communications mechanisms which would direct impacted riders to alternate stop locations on the reroute or alternate transit routes, thus reducing the potential lost system ridership.
- Operational impacts to reroutes are estimated based on travel times for the altered routes. Changes in travel times on a per-trip basis between the standard route and the reroute vary substantially. In some cases, a reroute is longer than the standard route, and incurs greater travel time; in other cases, a reroute runs shorter and faster. Base travel time estimates for the reroutes are presented. Estimates of impacts to operating costs are calculated using each route's cost per-hour metric. As with the changes in travel times, changes in trip cost likewise show as positive and negative, with increased costs projected to be incurred in some situations, and savings in other situations.

Estimated Key Performance Indicators for Selected Reroutes

Route	# of Flooding Incidents on Original Route	Change # of Flooding Incidents with Reroute	Missed Bus Stops with Reroute	Existing Average Daily Ridership (ADR)	Estimated ADR with Reroute	Net Riders Impacted by Reroute	Change in Travel Time in Minutes (Base Reroute)	Change in Cost per Trip (Base Reroute)
208	1	-1	34	1,847	1,687	160	-22	-$27.25
209	1	0	6	369	368	1	-2	-$2.54
221	0	0	34	726	683	43	-10	-$12.68
226	1	0	17	696	694	2	-12	-$15.21
230	1	0	7	370	365	5	-7	-$8.87
234	0	0	30	266	248	18	-13	-$15.84
302	2	0	2	551	546	5	3	$3.05
303	5	-5	138	1,130	515	615	-5	-$6.09
309	2	0	25	881	820	61	3	$3.66
318	3	-1	32	2,402	926	1476	9	$10.36
322	2	0	2	2,243	2,175	68	7	$7.92
330	6	+2	16	1,223	948	275	6	$7.31
331	4	-1	33	1,142	1,080	62	5	$6.09
332	4	+1	19	629	477	152	-6	-$7.31
356	2	0	7	581	567	14	3	$3.68
364	1	0	0	2,043	2,043	0	0	$0.00
381	1	-1	7	3,669	3,631	38	-2	-$1.67
386	1	-1	10	1,423	1,344	79	3	$3.33
626	0	0	0	346	346	0	5	$5.83
757	0	0	0	210	210	0	2	$1.83

Communications and Coordination Plans

In the event that severe rain events disrupt regular bus service, communications and coordination plans are critical for notifying the public about service changes, including reroutes. Pace has well-established procedures tested and refined over the course of numerous severe rain events as well as other types of service interruptions, weather-related and not. Recommendations from this project include identification for areas of new or deeper collaboration among interested agencies, as well as suggestions for consideration of additional technological resources; both of which are subject to available financial and human resources. Key activities and potential innovations include:

Pre-Flooding Preparedness Operations

Operations will:

- Monitor weather forecast for rainfall that may produce flood water impediments to bus operations.
- Coordinate with local partners in anticipation of potential reroutes to confirm the decision-making process.
- Communicate potential detour recommendations to Service Planning via detour@pace.com email to Garages.

Service Planning will:

- Obtain management approvals for service detours.
- Prepare passenger detour notifications.
- Inform Communications about impending service detours to provide patrons with detour notifications.

Communications will:

- Prepare to communicate potential service reroutes.

Flood Operations

Operations will:

- Garages will re-route bus operations based on information that route sections are impassible, from drivers, supervisors, or other external sources.
- Supervisors will coordinate with Dispatch to respond to route flood conditions that are not historically typical.
- Communicate re-route activations to Service Planning via detour@pace.com.
- Coordinate with Communications to publish and relay bus service updates to the public.

Service Planning will:

- Obtain management approvals for service detours.
- Prepare passenger detour notifications.
- Send Communications a reroute notice to approve.

Communications will:

- Approve Service Planning's reroute notification and relay bus service updates to various parties.
- Send out a GovDelivery blast to passengers who have signed up for updates on a specific route. This could be 400 to 2,000 people, via email and/or text message; this update happens after the online web page post goes live.
- In an extreme event, Communications can put an emergency bulletin on the front page of the Pace website and alert subscribers to "What's New" alerts via GovDelivery.

Pace Garages will:

- Post notices on the actual buses (printed at the garage or received from headquarters).
- Post each route's detour notice on every bus in that division garage, sometimes with multiple notices in each bus.
- If there is sufficient time and Pace believes the detour warrants it, laminated copies will be posted on location. The Garage may also put the notices up at terminals.

Potential Innovations

- Using real-time information signs at Transit Centers to display notice text.
- Using real-time web-connected onboard monitors as an alternative to paper notices.
- Submitting real-time detour information to Pace's own mapping engine, Google Maps, or other mapping or trip-planning applications.

Action Plan Matrix

Pace can coordinate with a broad range of partners to pursue general short and long term flood mitigation actions.

Project/Policy	Agency/ Organization	Cost	Notes
Viaduct improvement projects	CREATE public and private partners; Metra; railroads; local departments of transportation and water management	$$$	CREATE Viaduct Improvement Program completed in 2015. Negotiate additional funding for expansion of that program along with remaining CREATE projects.
Underground construction projects	Local and county departments of transportation and water management	$$$	Such projects may be initiated through municipal, sister-agency and/or public (311) requests.
Clearance of drains of debris prior/during storm	Local departments of transportation, streets & sanitation	$	Proactive pre-storm preparation
Coordination with other development/ utility/ roadwork projects	Local Councils of Governments	$	Participate in Transportation Improvement Program (TIP) planning process to reinforce priority hotlist
Watershed planning councils	MWRDGC, local departments of planning, transportation, and water management	$ $$	Identify risk areas and problems, with corresponding mitigation projects and policies Prepare stormwater master plans to address urban flooding; five pilot studies under way or complete; expand to other high-priority / high-flood risk areas
Green infrastructure	MWRDGC, local departments of planning, transportation, and water management	$$	Implement carefully curated palettes of green infrastructure for maximum benefit
Ongoing monitoring and data collection	Pace operating systems; local 311/911 services; smart cities service providers County and municipal water management departments; CMAP; IDNR; FEMA; CNT	$ $$	Use of flood report data to identify and monitor problem areas can be used to generate hot list for participation in infrastructure planning meetings (above); provide to streets and sanitation departments for debris clearance (above) Develop and enhance/maintain county and/or regional database of flood incidents; rainfall, water level, and flood forecasts; risk factors; and mitigation measures
Cost-sharing for local capital improvement projects to alleviate flooding issues	County DOTs, County, municipality, stormwater agencies	$$	Coordinate problem diagnosis and solution planning among agencies
Cost-sharing on major capital improvement projects pertaining to riverine flooding	County and municipal stormwater departments; MWRDGC, IDOT, US Army Corps of Engineers	$$$	Projects include reconstruction of a segment of I-290 (IDOT), Des Plaines River Levee 9 (US ACE), Buffalo Creek reservoir expansion (MWRDGC), Addison Creek (in design phase, MWRDGC), Silver Creek (IDOT), among others

Flood Mitigation Projects

As noted above, Pace needs to coordinate primarily with three agencies (MWRDGC, IDOT, and US Army Corps of Engineers) to deal with most of the flood problems identified for the Scenario E routes studied. In terms of prioritizing projects to mitigate flooding issues, the County DOTs, County or municipal stakeholders and stormwater agencies are good partners, as these agencies may be dealing with additional local impacts from the same problems or locations, and may offer cost- sharing arrangements for studying solutions. A number of mitigation strategies have already been brought forward and are described below:

Route	Mitigation Strategy
209, 226	IDNR-OWR has built two flood control projects in this area in the last decade that should solve most of the flooding problems shown. It is uncertain whether floodplain maps were ever updated with the results of these projects; it might be the method of handling the enhanced flood plain in this area that flags these areas as potential problems. These routes should experience infrequent flooding at the worst.
230	Pace needs to lobby Congress regarding funding for the Corps Des Plaines River Levee 9. The Des Plaines River project was authorized by Congress in the Water Resources Development Act of 2016. As of this report, Congress has to include funding for the project in budget.
234	MWRDGC is studying reservoir expansion on Buffalo Creek upstream of this flooding problem. Need to coordinate with MWRDGC to move this project forward.
303, 309, 330	MWRDGC's Addison Creek project that is moving into the design phase should reduce the flood frequency for these routes.
318	MWRDGC's Addison Creek project and a study by IDOT on North Avenue at Silver Creek should reduce the flooding frequency along this route.
331	The Corps Des Plaines River Levee 4 with two closure structures should reduce the flood frequency for this route. The Grand Avenue closure structure would close Grand Avenue but will allow Des Plaines River Road to remain open, and generally would be closed between the 10 and 50-yr flood event. The closure structure at Des Plaines River Road and 5th Avenue would close Des Plaines River Road here during the 100-yr events.
332	DuPage County Stormwater did not show the portion of this route on 22nd Street flooding. They will need to coordinate with Elmhurst regarding solutions for the York Road underpass flooding. The portion of the route along Irving Park Road and Bensenville Ditch may have been addressed when Irving Park and Bensenville Ditch were relocated for the O'Hare Airport Expansion.
626	The Aptakisic Creek flooding along a portion of this route should be coordinated with the Lake County Stormwater Management Commission. The roads are IDOT's jurisdiction at this location and talks about any flooding problems here should also be discussed with IDOT.
757	The flooding shown along I-290 portion of this route should be addressed when IDOT reconstructs I-290. Pace needs to work with IDOT on scheduling this reconstruction.

Decode of Agency / Organization Abbreviations

CMAP – Chicago Metropolitan Agency for Planning
CNT – Center for Neighborhood Technology
CREATE - Chicago Region Environmental and Transportation Efficiency Program
CTA – Chicago Transit Authority
DOT – Department of Transportation
FEMA – Federal Emergency Management Agency
IDNR – Illinois Department of Natural Resources
IDOT – Illinois Department of Transportation
MPC – Metropolitan Planning Council
MWRDGC – Metropolitan Water Reclamation District of Greater Chicago
RTA – Regional Transportation Authority
USACE – United States Army Corps of Engineers

Pace Scenario E Reroutes and Mitigation Projects