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Sustainable and Resilient Solid Waste Infrastructure: Davenport, Iowa Case Study

Office of Research and Development

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Sustainable and Resilient Solid Waste Infrastructure: Davenport, Iowa Case Study

Center for Environmental Measurement and Modeling &
Center for Environmental Solutions and Emergency Response
Office of Research & Development
U.S. Environmental Protection Agency
1200 Pennsylvania Ave, NW
Washington, DC 20460

Disclaimer

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Acronyms

ADT	American Discover Trail
CII	commercial, institutional, and industrial
CP	Canadian Pacific
DAT	dilution-attenuation factors
DDRT	Disaster Debris Recovery Tool
DOT	Department of Transportation
DRAS	Region 5 Delisting Risk Assessment Software
DVN	Davenport Airport
EJ	environmental justice
EPA	Environmental Protection Agency
FRAMES	Framework for Risk Analysis in Multimedia Environmental Systems
FSF-FM	First Street Foundation Flood Model
GHG	greenhouse gas
HE^2RMES	Human and Ecological Exposure & Risk in Multimedia Systems
IDF	intensity, depth, and frequency
IFIS	Iowa Flood Information System
IWFoS	Iowa Well Forecasting System
IPCC	Intergovernmental Panel on Climate Change
IWEM	Industrial Waste Management Evaluation Model
kwh	kilowatt hour
LCA	life cycle assessment
LCIA	life cycle impact assessment
MJ	megajoules
mph	miles per hour
MRF	materials recovery facility
MRT	Mississippi River Trail
MSW	municipal solid waste
MSW DST	Municipal Solid Waste Decision Support Tool
$MTCO_2$-eq	metric tons of CO_2 equivalent
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OLEM	Office of Land and Emergency Management
ORD	Office of Research and Development
PM	particulate matter
QAPP	Quality Assurance Project Plan
RBT	River Bend Transit
TRACI	Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts
USGS	United States Geological Service
WTE	waste-to-energy

Authors, Contributors and Reviewers

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AUTHORS:

Ozge Kaplan, U.S. EPA, Office of Research and Development

Susan Thorneloe, U.S. EPA, Office of Research and Development

Keith Weitz, RTI International

COLLABORATORS AND PARTNERS:

Gayle Hubert, U.S. EPA Region 7

Robbin Dunn, City of Davenport, IA

Kathy Morris, Waste Commission of Scott County

Brian Payne, Scott County Emergency management Agency

INTERNAL REVIEWERS:

Max Krause, U.S. EPA Office of Research and Development

Gayle Hubert, U.S. EPA Region 7

Timonie Hood, U.S. EPA Region 9

Melissa Kaps, U.S. EPA Office of Land and Emergency Management

Pricilla Halloran, U.S. EPA Office of Land and Emergency Management

Lawrence Doppelt, U.S. EPA Office of Land and Emergency Management

EXTERNAL REVIEWERS:

Bryan Staley, Environmental Research and Education Foundation

Michael Van Brunt, Covanta Energy

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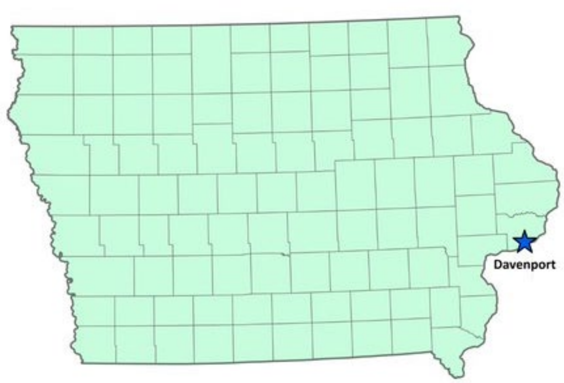
Executive Summary

The International Panel on Climate Change (IPCC) estimated that by 2100 global warming will cause sea levels to rise by approximately 0.5 to 3 feet (IPCC, 2001). The 2001 IPCC estimates have since been updated and the 2100 predictions now range from 0.66 to 6.6 feet (U.S. Global Climate Change Research Program, 2014). Projected sea level rise coupled with other climate events such as more frequent and intense storms may increase recurring damage to municipal infrastructure, including waste sector facilities. The potential for impacts from climate events thus creates an immediate concern for the security and resiliency of communities.

The goal for this report was to examine current municipal solid waste (MSW) management infrastructure of Davenport, Iowa and provide scenarios with resilience, sustainability, and equity considerations in mind. Scenarios will explore vulnerabilities to climate impacts (e.g., flooding) and sustainability of management practices—including reporting on cost, environmental impacts and environmental justice aspects of facility siting. For purposes of this study, infrastructure includes not only MSW collection and management infrastructure but also supporting urban infrastructure such roads, bridges, electricity and water utilities. Existing tools and data resources created by the State of Iowa (e.g., Iowa Flood Information System) were used to characterize potential climate events and associated impacts. Tools from the U.S. Environmental Protection Agency (EPA) including the Disaster Debris Recovery Tool (DDRT) was used to identify regional waste management infrastructure and the Municipal Solid Waste Decision Support Tool (MSW DST) was used to characterize the cost and life-cycle environmental impacts of MSW management and infrastructure options. EPA's Environmental Justice tool, EJScreen, was also used to evaluate social aspects of waste facility locations.

The results from this project are intended for use to: 1) gain a better understanding of the nature of potential climate events in communities and how those events can impact waste management infrastructure and planning needs, and 2) evaluate the current MSW management system and options to enhance its sustainability from cost and life-cycle environmental perspectives.

The City of Davenport, Iowa was selected as the project site through discussions among the project team based on its proximity to a major river, availability of data, and a varied set of waste facilities. The City of Davenport is part of the Quad Cities Region in Iowa and Illinois. The Mississippi River separates the Iowa cities of Davenport and Bettendorf from the Illinois Quad cities of Rock Island and Moline.



Population: 101,009

EPA Region 7

MSW Management System

The City collects and manages 80,000 metric tons per year from 40,400 households, commercial and institutional generators. The City also operates drop-off sites for recyclables and yard waste. The fraction of different materials in the waste stream is important to understanding the potential for recycling, composting and other potential waste management alternatives. The composition of MSW generated by Davenport is shown in **Figure ES-1**.

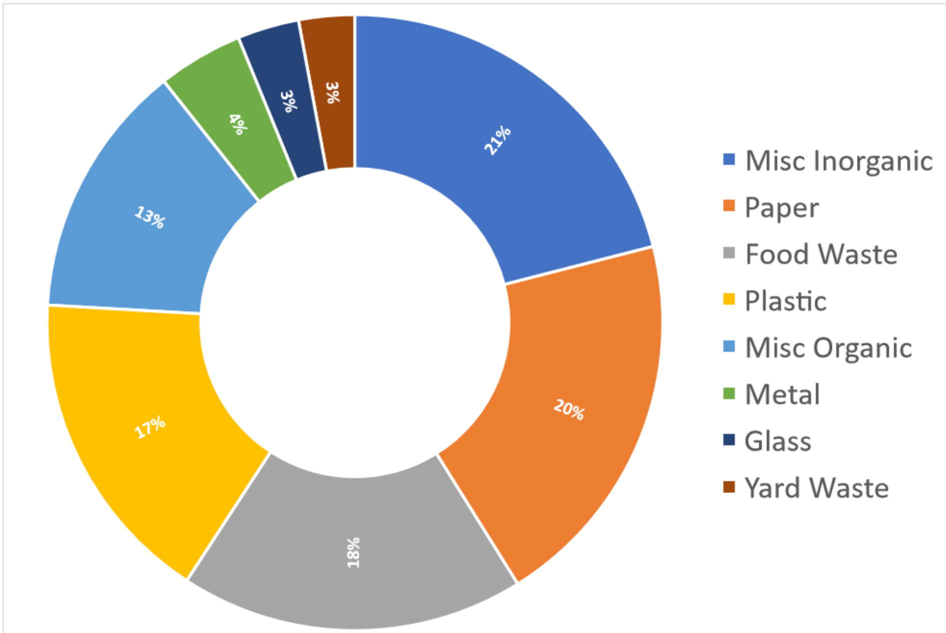


Figure ES-1. Davenport MSW Percent Composition (as generated)

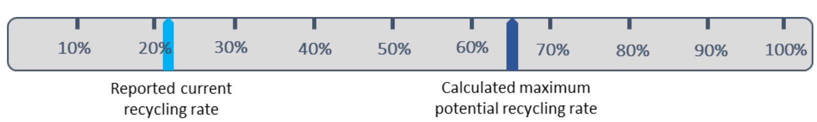
Davenport region waste management facilities are mapped in **Figure ES-2**. The current solid waste management system includes recycling, yard waste composting, and landfill disposal facilities. The Waste Commission of Scott County operates the following regional solid waste management facilities:

- Scott Area Regional Landfill
- Scott Area Recycling Center (i.e., materials recovery facility [MRF])
- Electronics Recovery and Household Hazardous Material Center

The City of Davenport operates one solid waste management facility:

- Davenport Compost Facility

At present, a total of 21% of the materials and organics generated are currently recovered for recycling or composting. Based on the composition of materials in the MSW stream, it was estimated that 45% of the materials in the MSW stream are potentially recoverable recyclables and 20% are potentially compostable organics (yard and food waste), equaling a total maximum potential recycling rate of 65%. **Figure ES-3** illustrates the flow of the 80,000 metric tons of MSW generated per year from the point to collection to ultimate disposition.



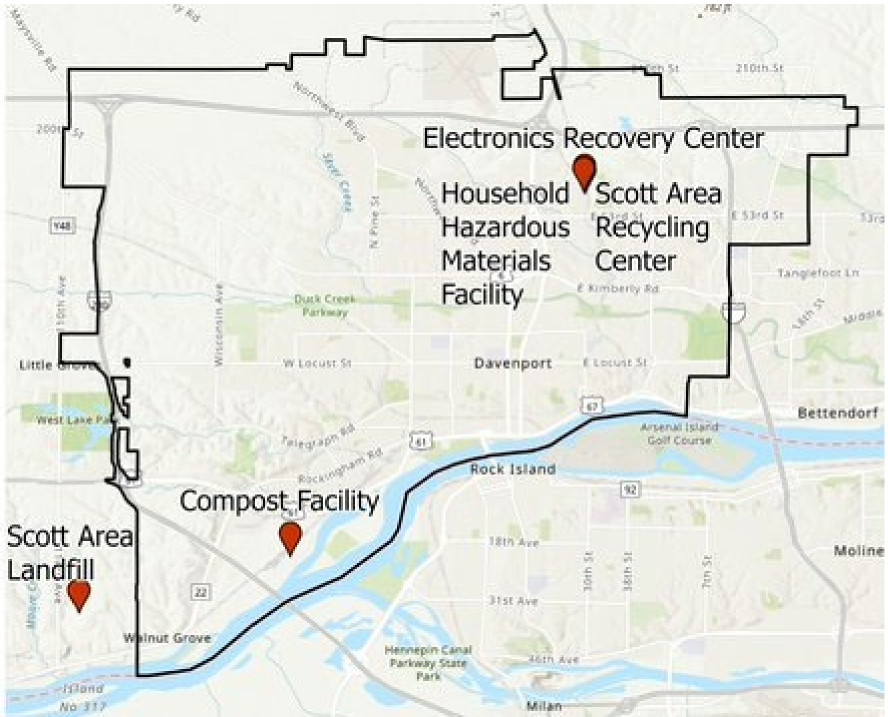


Figure ES-2. Davenport Area Waste Management Facilities

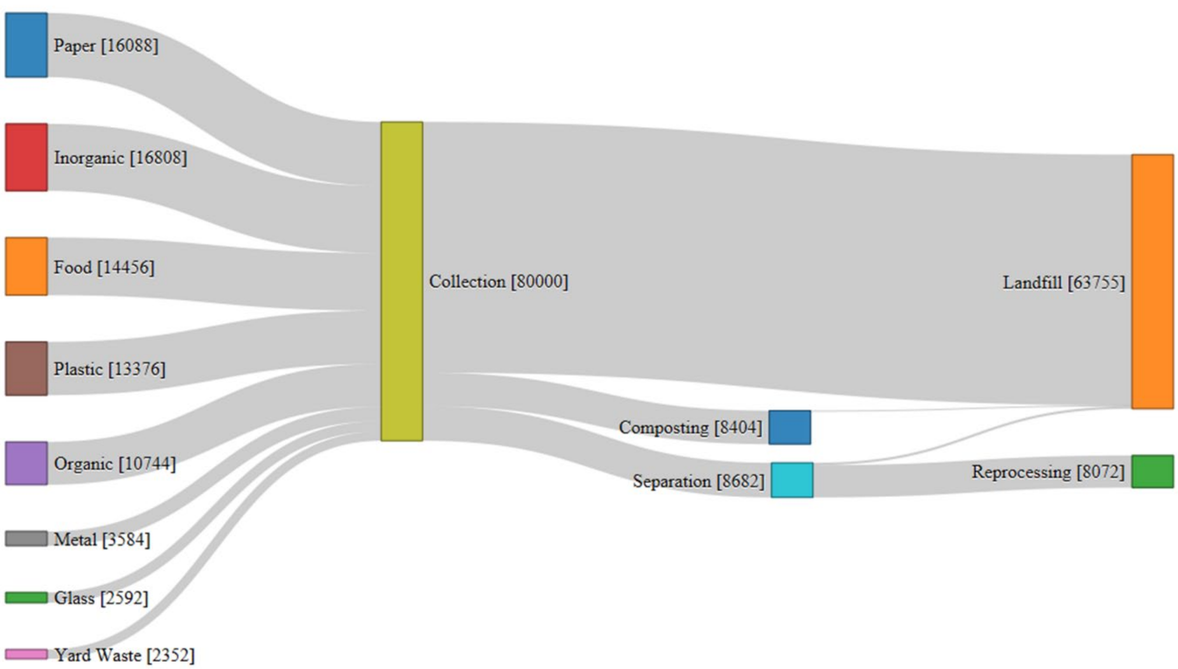


Figure ES-3. Davenport Flow of MSW Materials Through End-of-Life Pathways
(Values represent metric tons as generated, collected, and sent to management endpoints. Not corrected for significant figures.)

Climate Events and Waste Infrastructure Vulnerability

Climate events that affect the Davenport area primarily include Mississippi River and secondary river and stream flood events. As shown in **Figure ES-4**, none of the Waste Commission of County facilities are located immediately within flood impact boundaries. However, the City of Davenport Compost Facility is vulnerable due to its location adjacent to the Mississippi River and situated within the Mississippi flood hazard zone. The facility has closed or could not be accessed during April, May, and June 2019 flood events (City of Davenport, 2019). Overall, the facility has been inaccessible for 75 days during the past 25 years due to flooding. During closure, yard waste drop-off service is relocated to the landfill until it can be transport to the compost facility. The City received a grant in 2019 from the Department of Commerce's Economic Development Administration to improve flood protection measures at the facility. Specific measures implemented include construction of an earthen berm system to the height of three feet over a 500-year flood event (river stage 28.5) and installation of interior pumping systems that ensure the plant continues to operate efficiently and effectively during high water events from the Mississippi River.

In addition to flooding of the Mississippi River, severe creek flooding such as Duck Creek have occurred. Per the Waste Commission of Scott County, Duck Creek flooding in 1990 had a significant impact on the landfill due to the significant amount of debris generation that required disposal. Also prevalent in Davenport are hail and thunderstorms and high-wind events. A severe derecho storm in the summer of 2020, for example, resulted in significant debris generation that took the City weeks to collect and manage. As detailed in Chapter 3, such weather events have demonstrated an increasing trend over time.

Waste Management Scenario Analyses

To investigate the sustainability aspects of MSW management in the City of Davenport, the cost, life-cycle environmental impacts, and environmental justice aspects MSW management were analyzed. To characterize cost and life-cycle environmental impacts, the US EPA's Municipal Solid Waste Decision Support Tool[1] (MSW DST) was tailored to reflect City-specific conditions using available data and information about local waste generation and composition, waste collection and hauling, existing management infrastructure, and regional energy and market factors. Specific scenarios were then analyzed including:

- current and maximum potential recycling (including organics composting) rates,
- switching from diesel powered to electric waste collection vehicles, and
- adding a new compost facility to enhance organics management capacity.

Additional details about the scenarios analyzed and key assumptions employed are included in Chapter 4 of this report.

[1] Available at: https://mswdst.rti.org/

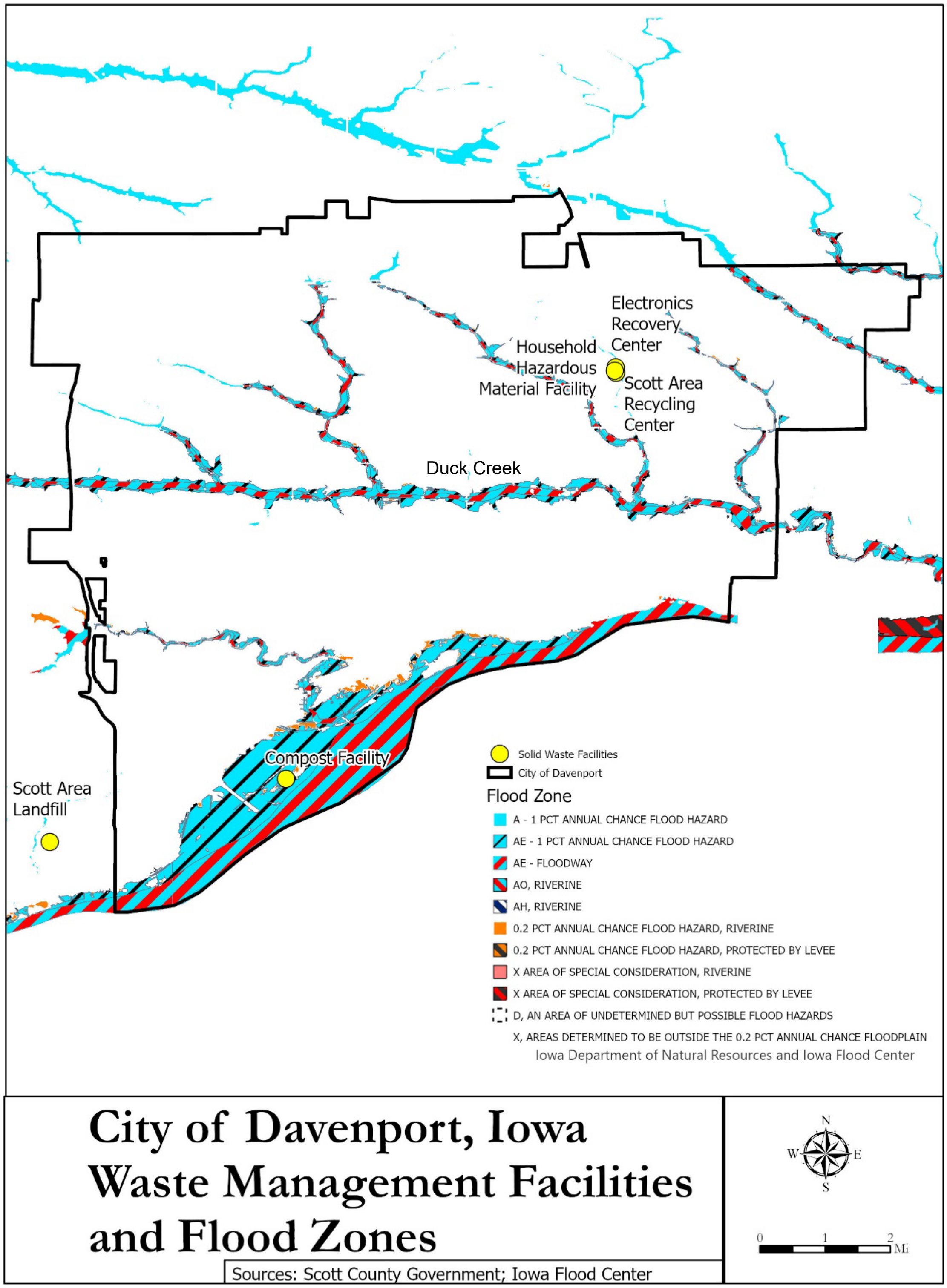


Figure ES-4. Davenport Region Flood Risk and Waste Infrastructure Locations

The MSW DST provides net total results for annual cost, life-cycle inventory (LCI) flows, and life-cycle impact assessment (LCIA). The tool also allows integration with EPA's EJ Screen[2] maps. The methods used in the MSW DST to calculate cost are consistent with "full cost accounting" principles and includes capital, operating and maintenance, and labor costs for waste collection and transportation, recycling, treatment, and disposal activities. Revenue from the sale of recyclables, compost product, and energy products are also captured and netted out of cost. The calculated cost is not representative of a tipping or gate fee charged by any facility.

Cost results for the recycling scenarios (**Figure ES-5)** show that landfill disposal of all waste would be the cheapest option. By increasing its recycling and composting rate, Davenport could reduce its overall net total cost by virtue of increasing revenues from the sale of recovered materials and compost product. Recycling and composting could be increased through implementation of measures such as education and outreach to waste generators, expanding recycling and organics collection, adding recycling and composting capacity, and/or enhancing end markets for recyclable material and compost product. Additional analyses would be needed to determine the cost for specific measures to increase materials recovery. Likewise, the potential revenue associated with increased materials recovery will be dependent on material market prices, which can fluctuate significantly over time.

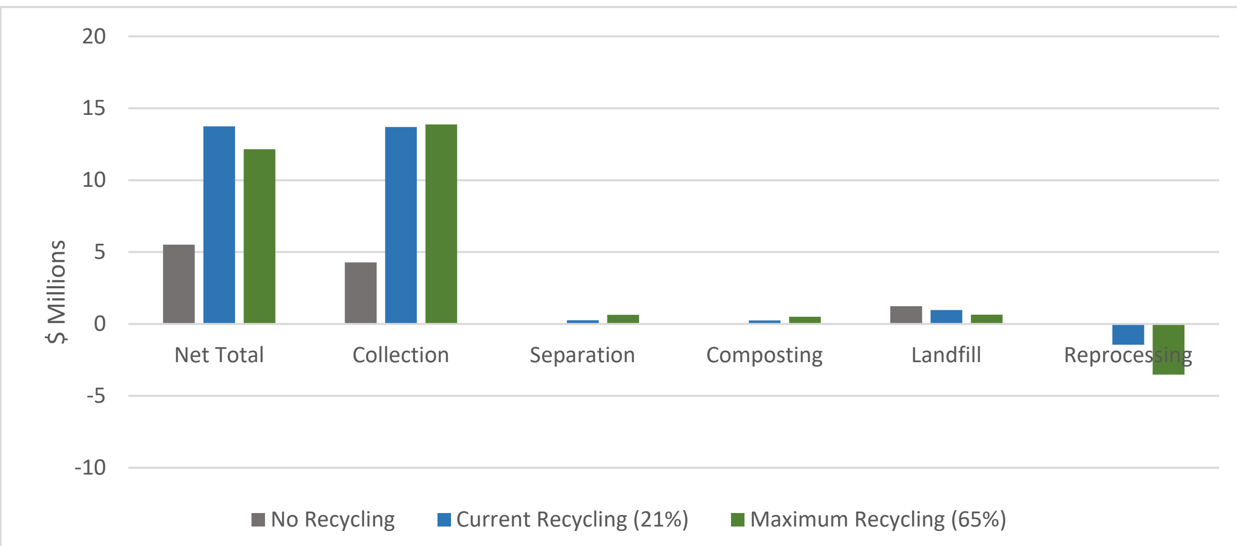


Figure ES-5. Net Total Annual Cost for Recycling Scenarios Analyzed
(Note: collection includes transportation from the collection route to the next facility)

Greenhouse gas (GHG) emissions contribute to the greenhouse effect and can lead to climate change and its associated impacts. From the waste sector, GHG emissions result from the combustion of fossil fuels in the collection and transportation of waste from curbside processing at recycling, composting, and disposal facilities. GHG emission reductions or offsets can result from the displacement of fossil fuels electricity generation, materials recycling, and diversion of organic wastes from landfills where they would produce methane (CH_4) emissions. Net annual GHG emissions estimated by the MSW DST includes emissions from collection and transportation, recycling, treatment and disposal processes less GHG emission reductions or savings from recycling and/or energy recovery. GHG emissions are reported

[2] Available at: EJScreen: Environmental Justice Screening and Mapping Tool | US EPA

by the MSW DST in units of metric tons of CO_2 equivalent emissions ($MTCO_2$-eq), and derived as follows:

*(metric tons CO_2*1) + (metric tons CH_4* CH_4 GWP)*

The 100-year CH_4 global warming potential (GWP) of 28 and the 20-year CH_4 GWP of 84 are based on IPCC's Sixth Assessment Report (2021) and used to show the impact that different GWP time scales have on landfill carbon emissions.

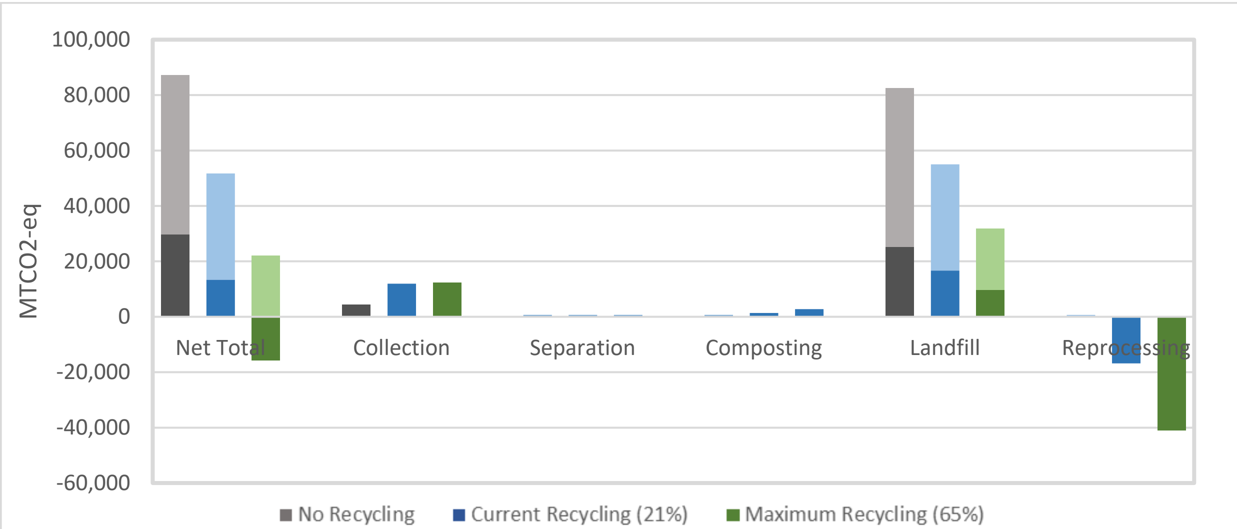


Figure ES-6. Net Total Annual GHG Emissions for Recycling Scenarios Analyzed
(note: darker areas represent results using 100-year methane GWP; lighter area are results if the 20-year methane GWP is used)

As shown in **Figure ES-6**, Davenport is currently saving approximately 18,000 (using 100-year CH_4 GWP) to 36,000 (using 20-year CH_4 GWP) $MTCO_2$-eq per year through its recycling and composting programs. If the City were to maximize its recycling and composting rates, approximately 47,000 (100-year CH_4 GWP) to 82,000 (20-year CH_4 GWP) $MTCO_2$-eq in savings could be realized. As noted in the cost analysis, this may also be a more cost-effective scenario.

LCA impact assessment (LCIA) results comparing each Davenport scenario can help city and waste infrastructure and program decision makers better understand and balance environmental, economic, and social factors. The LCIA results generated by the MSW DST use EPA's Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI). TRACI relies on characterization factors to quantify the potential impacts that inputs and releases (i.e., emissions) have on specific impact categories in common equivalence units. For example, a commonly known equivalency unit for various GHG pollutants is CO_2-eq emissions.

As shown in **Figure ES-7**, Davenport's current recycling (including composting) rate provides lower levels of impact than if all waste were landfilled. The City can implement measures to maximize recycling and further reduce waste management related impacts.

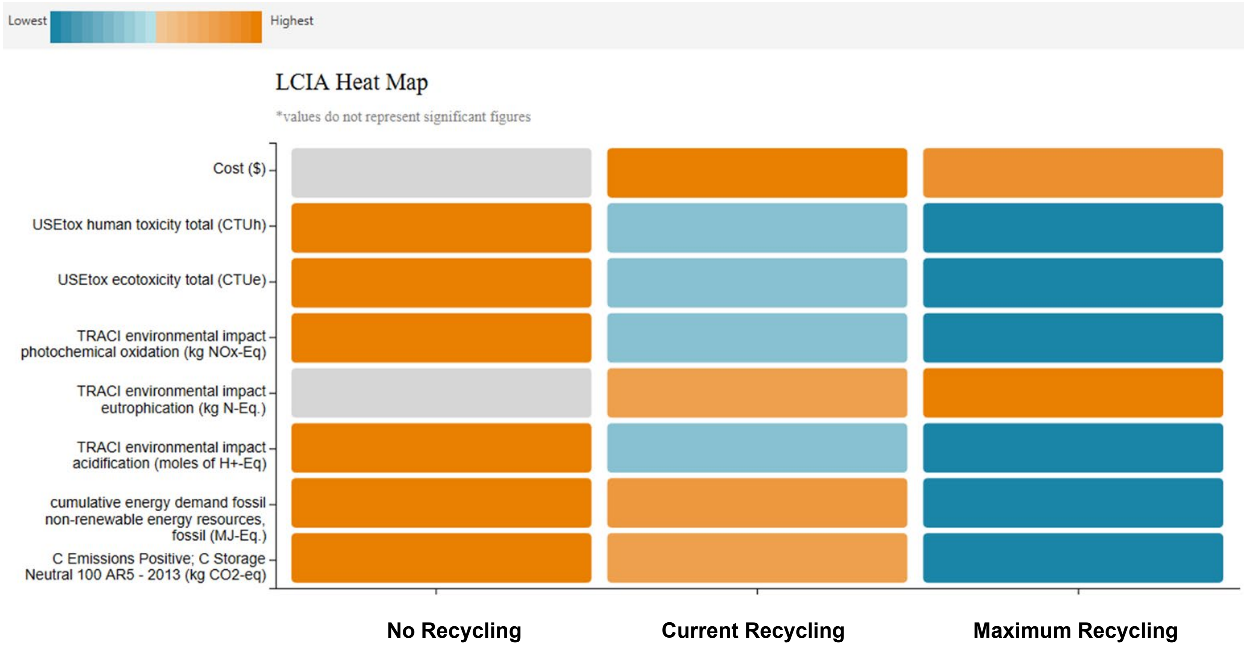


Figure ES-7. LCIA Results for Recycling Scenarios Analyzed

Switch to Electric Collection Trucks

The City of Davenport, Scott County, and private haulers use diesel collection vehicles. Based on MSW DST output, an equivalent of 68 collection vehicles and almost four million gallons of diesel fuel are needed per year to collect and transport waste. An analysis was done to estimate the potential cost and environmental benefits of switching to electric collection vehicles. Based on the annual tonnage of MSW collected and hauling distances to local management facilities, along with average diesel and electric vehicle prices and current regional diesel and electricity prices, the cost and environmental differential of switching to electric vehicles was calculated. As shown in **Figure ES-8**, and over the lifetime of a vehicle, the capital cost for electric collection vehicles is higher than diesel vehicles. However, the operational cost, driven by the price of diesel fuel ($3/gallon) versus electricity (11.2 cents/kilowatt hour), is significantly lower for electric vehicles.

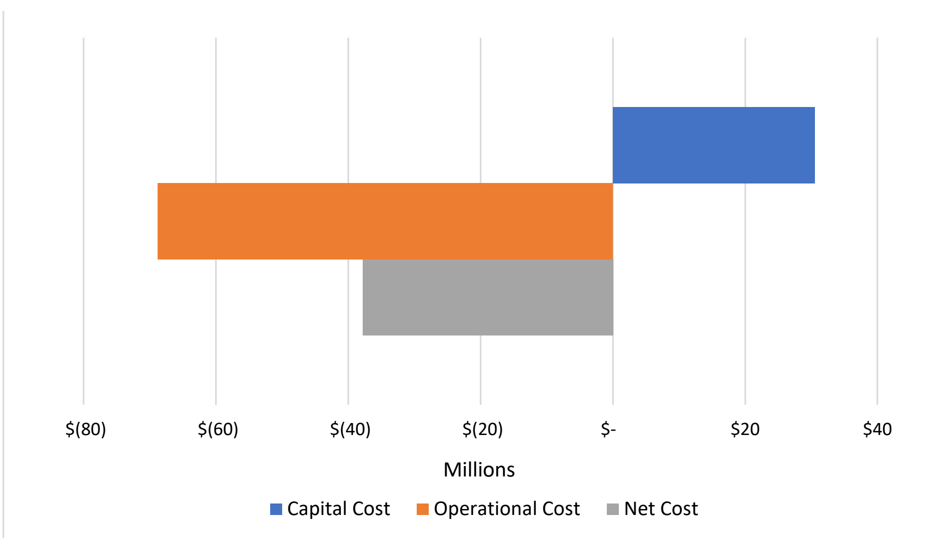


Figure ES-8. Total Cost (savings) for Switching to Electric Waste Collection Vehicles

Thus, the overall net cost favors electric collection vehicles. The capital cost for electric collection vehicles and current and future forecasted prices for diesel and electricity are important assumptions that should be reviewed carefully.

The emissions differential between electric and diesel collection vehicles is driven by carbon emissions with electric vehicles providing an estimated 255,000 $MTCO_2$ of carbon emissions savings per year. Davenport and the State of Iowa have a significant portion of wind power on their electricity grid and thus a relatively low carbon intensity per kilowatt hour (kwh) of electricity produced as compared to other states that rely more heavily on fossil fuels. As shown in **Figure ES-9**, electric vehicles can also provide significant reduction of local criteria air pollutants. This reduction will need to be viewed in context of potential increased emission of pollutants from regional electric utilities.

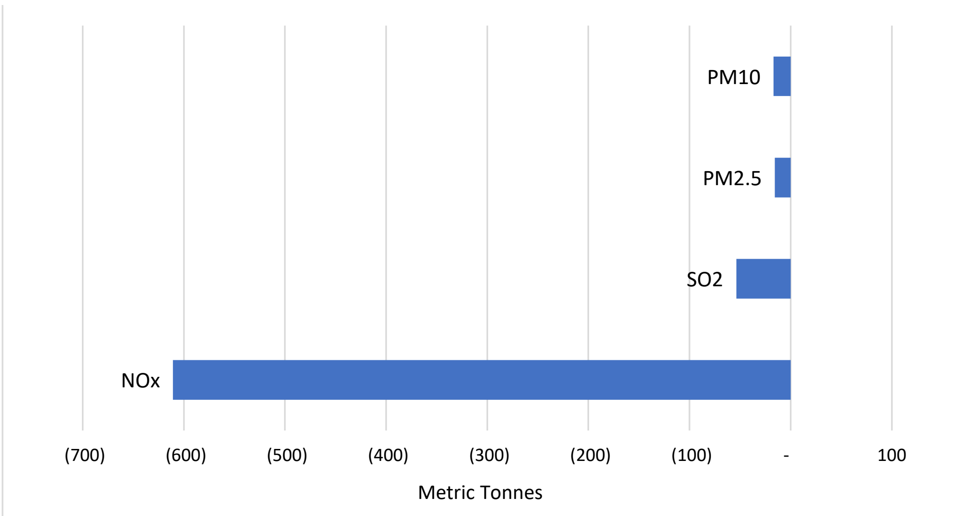


Figure ES-9. Annual Criteria Pollutant Emissions Reduction of Switching to Electric Vehicles

Switching to electric collection vehicles also results in savings of particulate matter (PM) and sulfur dioxide (SO_2) emissions. Note that PM10 represents inhalable particles with diameters that are generally 10 micrometers and smaller; PM2.5 includes fine inhalable particles with diameters that are generally 2.5 micrometers and smaller.

Expansion of Compost Capacity

Due to the current location of the Davenport Compost Facility in the Mississippi River floodplain and hazard plain and vulnerability to frequent river flood events, expansion of compost capacity via a new facility was analyzed. A likely location for a new compost facility would be at the Scott Regional Landfill, which would be approximately ten miles further from the current facility location and result in:

- an annual increase of $142,000 in transportation cost
- an annual increase of 1,110 $MTCO_2$-eq emissions

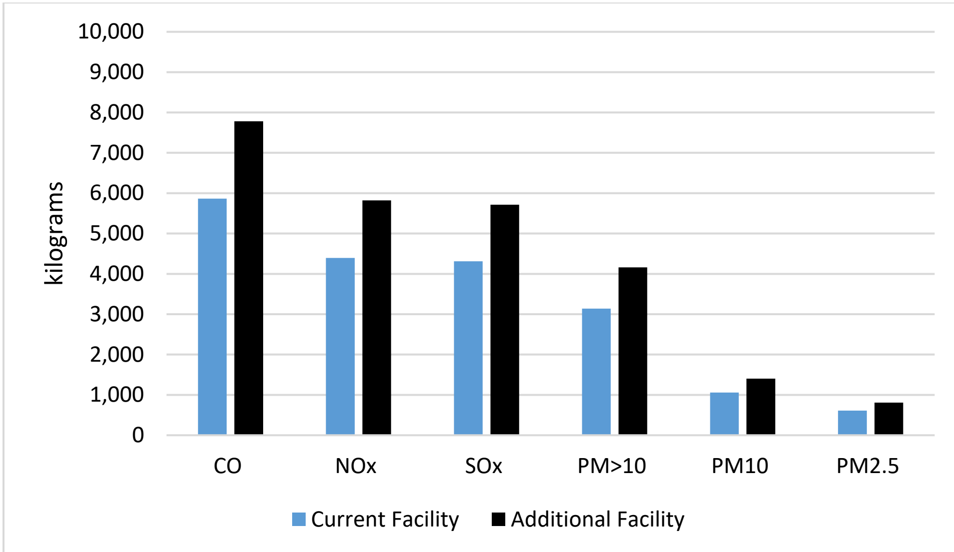


Figure ES-10. Annual Transportation Emissions for the Current and Additional New Compost Facility

Since the primary difference associated with a new additional facility is assumed to only include the transportation distance from the collection route(s) to the compost facility, potential increases in local emissions of criteria air pollutants, as shown in **Figure ES-10**, associated with this increased transportation distance should also be considered. One option to reduce the increase in emissions due to a new facility location could be to employ electric collection vehicles for organics.

Environmental Justice (EJ)

Environmental justice is an element of sustainability and critical to EPA's mission to protect human health and the environment. The evaluate potential environmental justice concerns, EPA's EJScreen[3] was used to map select environmental and demographic socioeconomic indices in relation to Davenport region waste facility locations. Sharing EJ data and information can enhance the sustainability of waste infrastructure by helping communities like Davenport to identify and address potential environmental justice concerns.

In **Figure ES-11**, EJScreen Air Toxics Respiratory Hazard Index was layered with Davenport area waste management infrastructure to provide a map of potential local air respiratory hazard in relation to waste management facilities. Respiratory pollutants and related impacts are a common health concern associated with waste management activities and facilities. The Air Toxics Respiratory Hazard Index indicates the ratio of exposure concentration to health-based reference concentration. Similarly, **Figures ES-12** and **ES-13** provide demographic socioeconomic indicators including low-income and people of color indices.

[3]Available at: EJScreen: Environmental Justice Screening and Mapping Tool | US EPA:

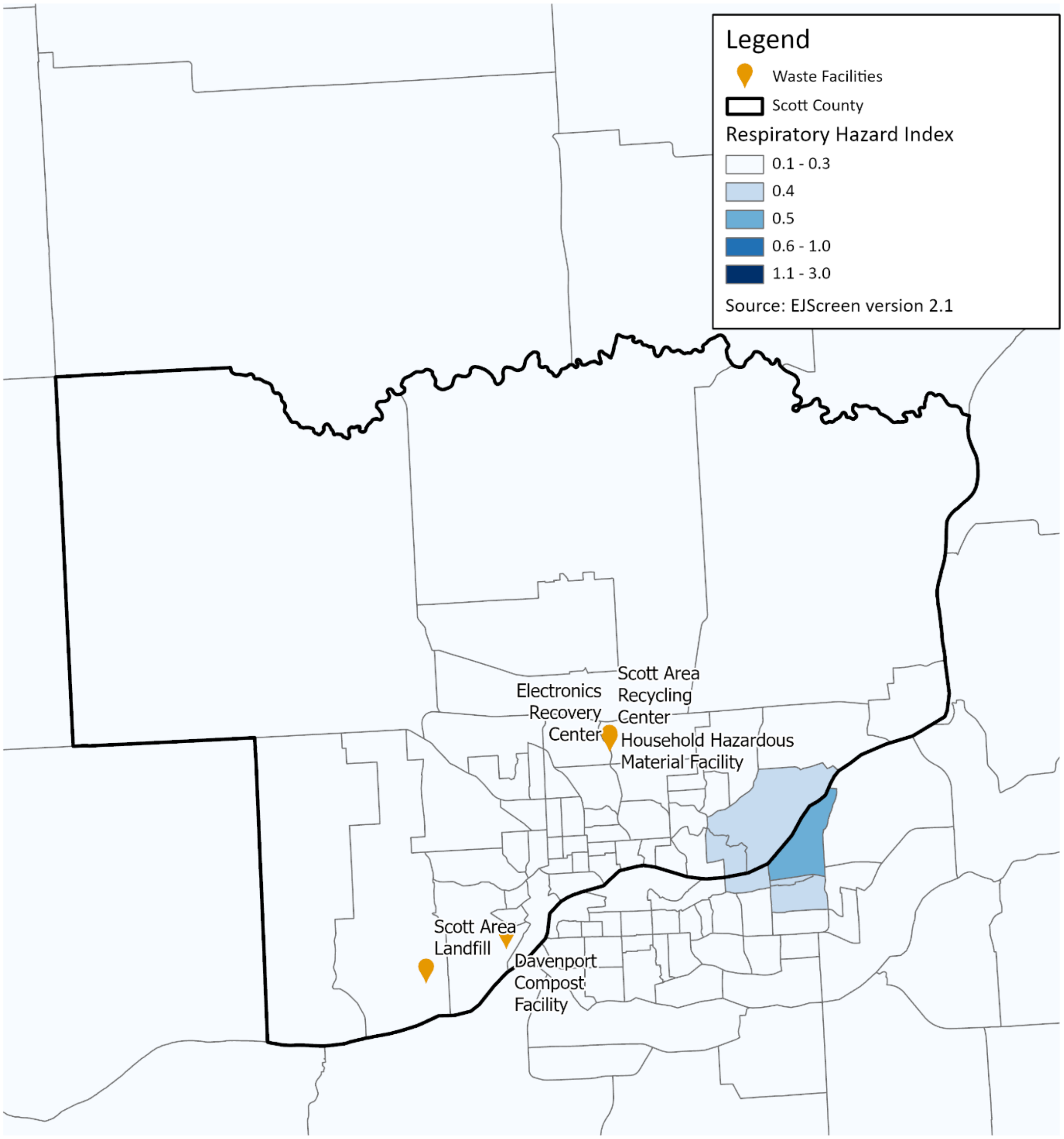


Figure ES-11. EJ Screen Air Toxics Respiratory Hazard Indicator and Waste Management Facilities in the Davenport Region

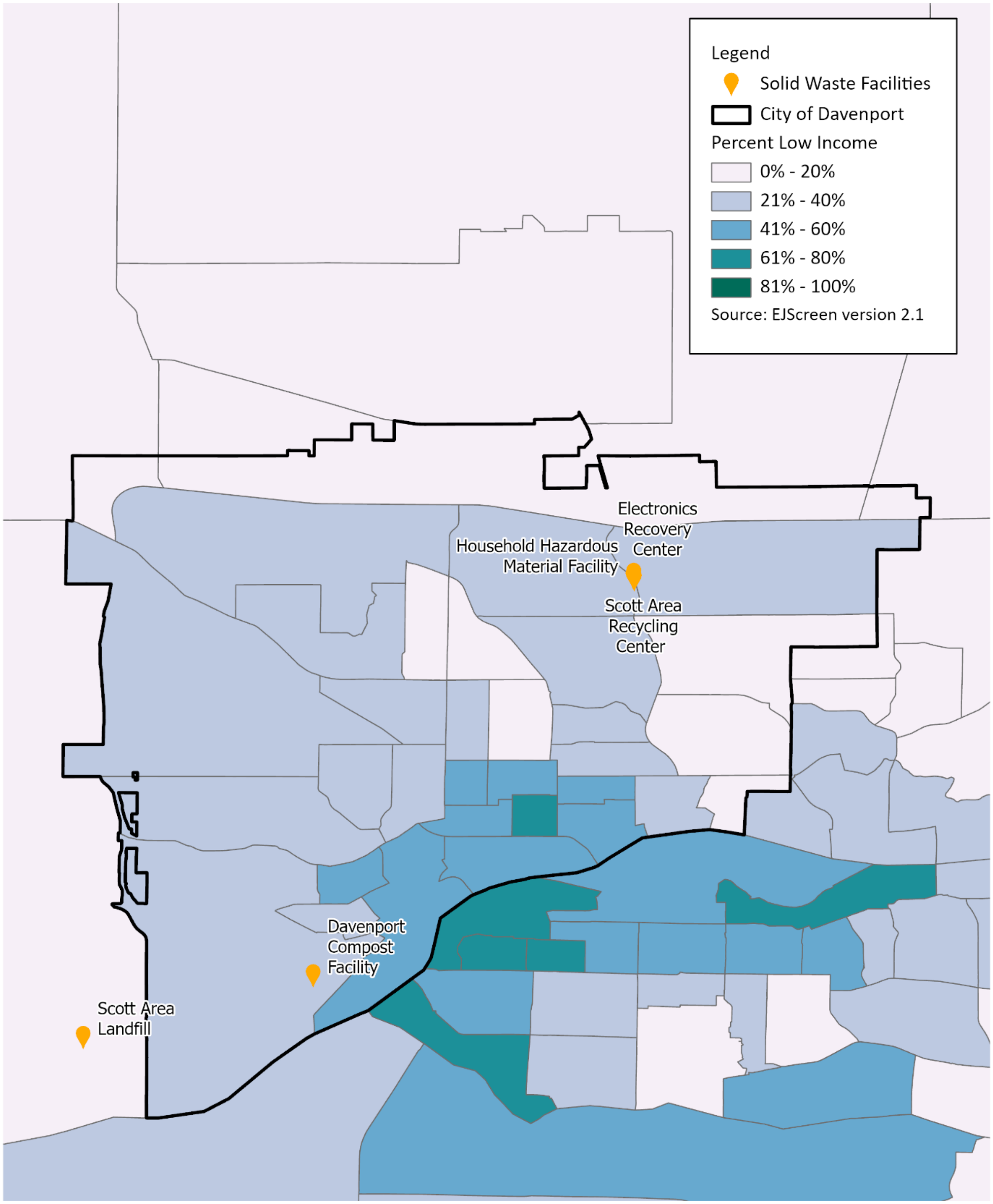


Figure ES-12. EJ Screen Low Income Indicator and Waste Management Facilities in the Davenport Region

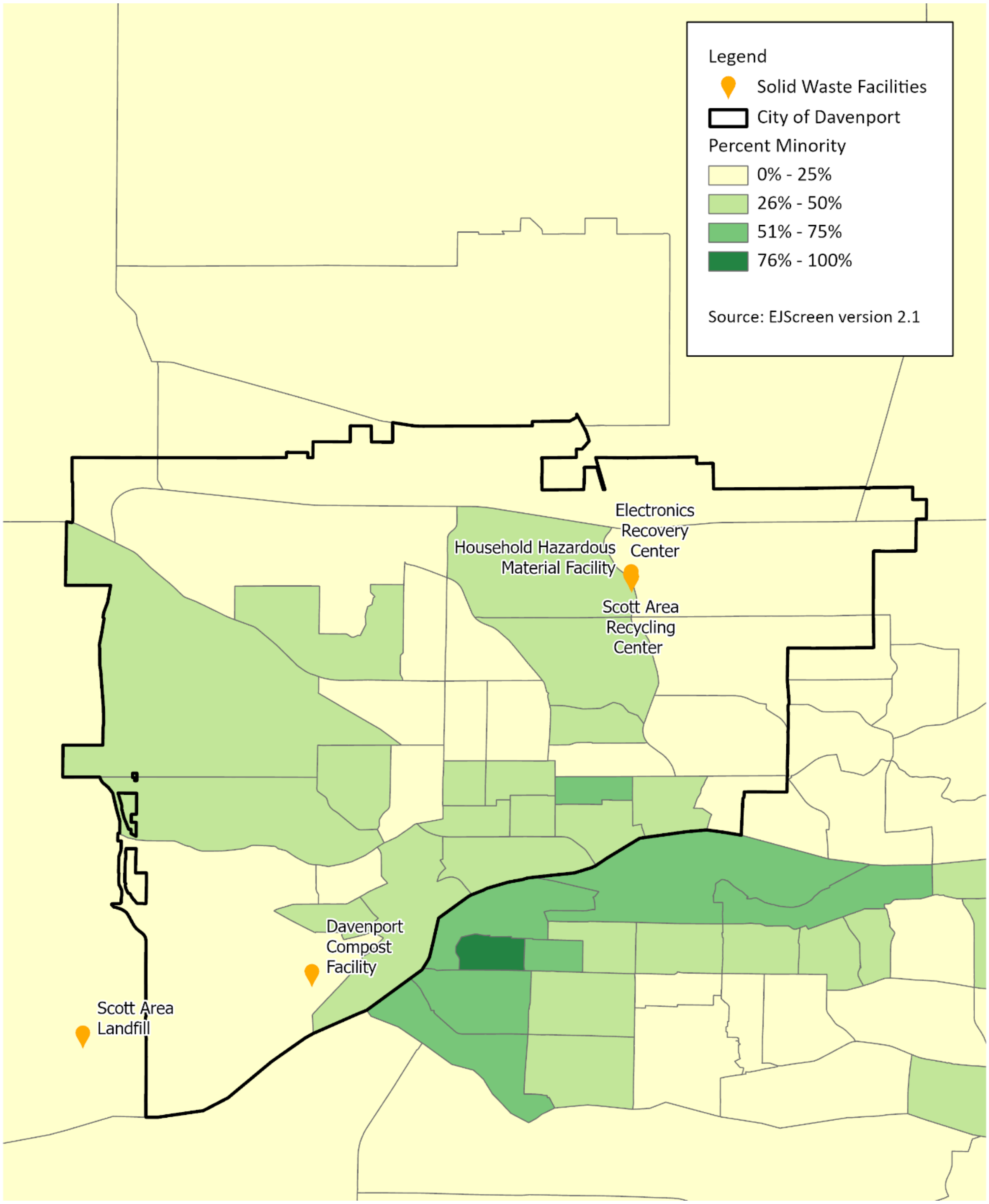


Figure ES-13. EJ Screen People of Color Indicator and Waste Management Facilities in the Davenport Region

Key Findings

The results from this case study are intended for use in gaining a better understanding of the nature of climate-induced impacts on communities, and how those impacts can affect waste management infrastructure and long-term planning needs. This study presents options available for minimizing impacts and potential cost and environmental implications for Davenport. The insights gathered from scenario analysis revealed that there can be opportunities to be leveraged if intensity and frequency of precipitation events continue to increase for the region. Planners could utilize these opportunities to better design the system to be more resilient and responsive at lower cost, and in some cases resulting in better environmental outcomes (e.g., reduced air emissions).

There are some caveats to this analysis. For example, the analysis looked at individual facility flooding however, other factors might influence the availability of waste management facilities such as inundation of access roads, or worker availability in the event of a storm. These aspects of waste management could be covered under emergency management planning process. The study is not intended for emergency management or analysis of options during an event.

The insights gathered from scenario analysis revealed that there can be opportunities to be leveraged if intensity and frequency of precipitation events continue to increase for the region. Planners could utilize these opportunities to better design the system to be more resilient and responsive at cheaper costs, and in some cases resulting in better environmental outcomes (e.g., reduced air emissions). These opportunities include:

- enhancing facility flood resiliency (or relocating vulnerable facilities) such as the current efforts by Davenport to construct berms and install pumping systems at their compost facility;
- expanding recycling and composting through measures such as education and outreach to waste generators, expansion of recycling and organics collection, recycling and composting capacity, and/or enhancing end markets for recyclable material and compost product; and
- switching the waste collection vehicle fleet (or part of the fleet) to electric vehicles.

Additional analyses would be needed to determine which options would be a best-fit and benefit the City most.

Chapter 1:
Introduction

Changing climate, evident in numerous scientific data records, creates an immense challenge to the security and resiliency of communities across the U.S. More frequent and intense disruptive events can increase the frequency and extent of damage to municipal infrastructure, including waste sector facilities. Impacts to supporting municipal solid waste (MSW) collection and management infrastructure such as transportation routes, energy supplies, and water supply and treatment can also significantly affect waste facility operations. Potentially large amounts of debris from disaster events and the release of pollutants and contaminants to the environment can have cascading effects such as the failure of additional facilities triggered by the failure of the initial one. The impacts of changing climate on waste management and other municipal infrastructure are immediate concerns for communities.

1.1 Project Goal

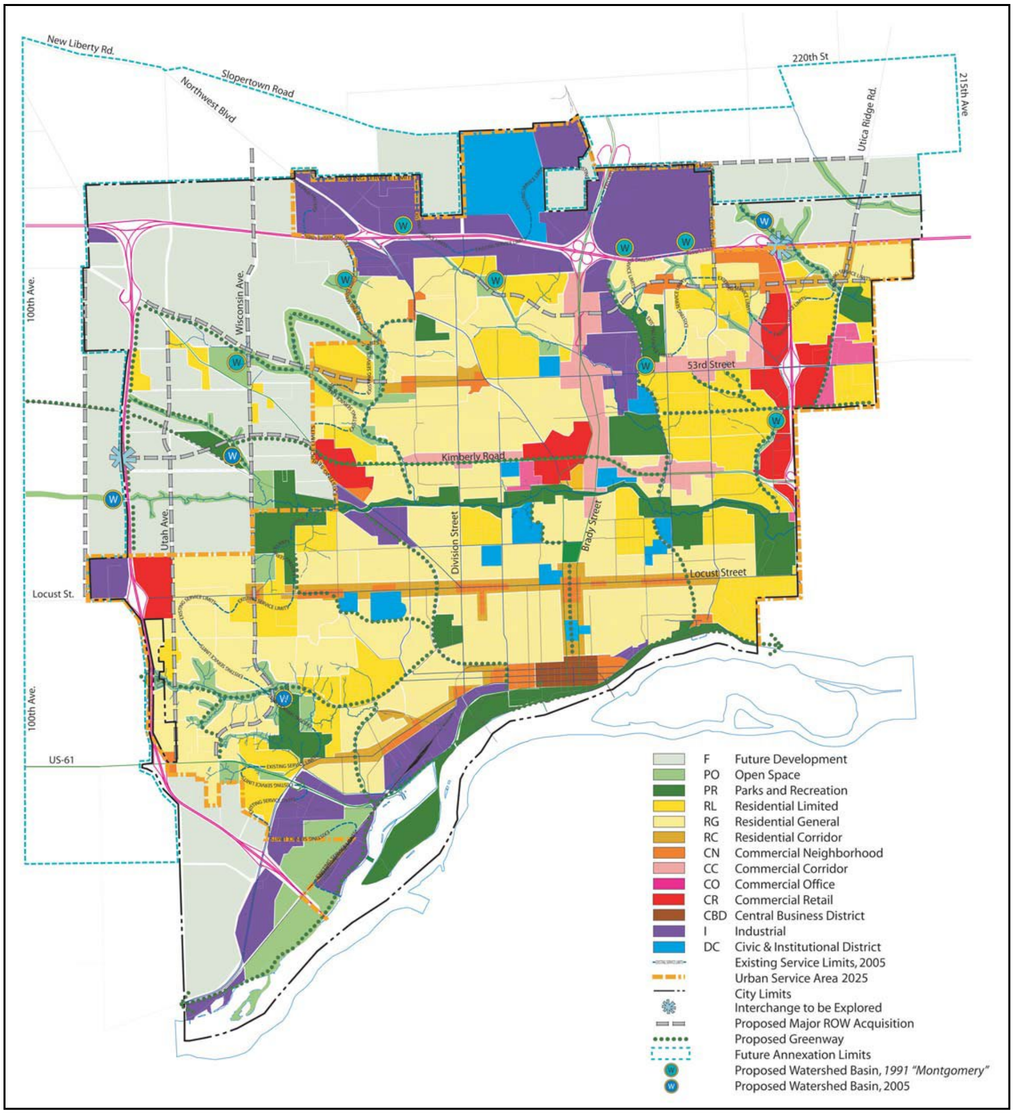
The goal for this report was to examine current municipal solid waste (MSW) management infrastructure of Davenport, Iowa and provide scenarios with resilience, sustainability, and equity considerations in mind. Scenarios will explore vulnerabilities to climate impacts (e.g., flooding) and sustainability of management practices—including reporting on cost, environmental impacts and environmental justice aspects of facility siting. For purposes of this study, infrastructure includes not only MSW collection and management infrastructure but also supporting urban infrastructure such roads, bridges, electricity and water utilities. Existing tools and data resources created by the State of Iowa (e.g., Iowa Flood Information System) were used to characterize potential climate events and associated impacts. Tools from the U.S. Environmental Protection Agency (EPA) including the Disaster Debris Recovery Tool (DDRT) was used to identify regional waste management infrastructure and the Municipal Solid Waste Decision Support Tool (MSW DST) was used to characterize the cost and life-cycle environmental impacts of MSW management and infrastructure options. EPA's Environmental Justice tool, EJScreen, was also used to evaluate social aspects of waste facility locations.

The results from this project are intended for use to: 1) gain a better understanding of the nature of potential climate events in communities and how those events can impact waste management infrastructure and planning needs, and 2) evaluate the current MSW management system and options to enhance its sustainability from cost and life-cycle environmental perspectives.

1.2 Case Study Site

The City of Davenport, Iowa was selected as a project case study through discussions with city representatives and based on its location along the Mississippi River floodplain, availability of data, and proximity to a varied set of waste facilities. The city, Scott County, and private entities are responsible for the collection and management of MSW. The primary boundary is the city's annual MSW that is collected and taken to management facilities in the city and county (Scott County). Contact was made with key agencies and organizations in Davenport and Scott County to understand the local context with respect to solid waste management and climate resiliency issues and initiatives.

Davenport is part of the Quad Cities Region in Iowa and Illinois. The Mississippi River separates the Iowa cities of Davenport and Bettendorf from the Illinois Quad cities of Rock Island and Moline. Per the Davenport 2025 Comprehensive Plan for the City (City of Davenport, 2005), the City's service area will expand significantly by 2025 as indicated by the gray areas on the Proposed Land Use Map – 2025 (**Figure 1**). Part of that expansion will occur adjacent to the Mississippi River.



Source: City of Davenport, 2005

Figure 1. Proposed Land Use Map – 2025

1.3 Report Structure

Data and information compiled is structured by topic matter areas and includes the follow:

- Davenport, IA background and historical weather events (Chapter 2)
- Vulnerability of solid waste and urban infrastructure to climate impacts (Chapter 3)
- Cost and life cycle environmental analysis of targeted resiliency measures (Chapter 4)

1.4 Quality Assurance and Data Limitations

This project involved collecting and analyzing secondary data to determine the potential impact of climate change on waste and urban infrastructure. Secondary data and information were collected via a formal literature search. Reports, data, and information detailing MSW generation and composition, waste management activities and facilities, historical weather events and flooding were provided by participating community representatives. This work was conducted under an approved Quality Assurance

Project Plan (QAPP, J-AESMD-QP-1-0), which was developed in accordance with guidance provided in EPA ORD's quality assurance requirements for secondary data projects. The QAPP was approved by EPA prior to the initiation of data gathering. The primary focus of the QAPP was to identify activities used to verify that the data and information compiled for reference or use in this project were complete, accurate, and of the type, quantity, and quality required.

The appropriateness of the data and their intended use were assessed with respect to the data source, the data collection timeframe, and the scale of the geographic area that the data represent. Preference was given to data that have undergone peer or public review (e.g., those published in government reports) over data sources that typically do not receive a review (e.g., conference proceedings, trade journal articles, personal estimates). However, where peer-reviewed data did not exist, parameters and assumptions were developed from the next highest quality available sources. Preference was given to more recent data over older data. In this report, the sources of all data and any identified assumptions and limitations are presented.

Climate impacts as presented in Chapter 2 of this report focus on large-scale events such as widespread flooding. These impacts are used in Chapter 3 to identify potential vulnerable waste and supporting urban infrastructure. While flooding is a common outcome of climate events in the Davenport region, the occurrence and intensity of flooding is not simply be due to such events. Other factors can impact flooding such as a substantial increase in impervious area in the watershed due to urbanization, implementation of flood prevention measures (e.g., levees, draining canals, etc.). In addition, localized flooding in Davenport is linked to at rainfall and snowfall / snowmelt amounts in upstream Mississippi watershed locations.

Addition climate impacts could also disrupt waste collection and management operations. For example, extreme precipitation events can lead to flooding landfill gas wells resulting in the wells being disconnected from the landfill gas header pipe and areas within the site without gas collection and control. Extreme precipitation events also lead to side slope erosion causing landfill cover integrity issues. This provides landfill gas a path of least resistance to escape the gas collection and control system and contribute to fugitive loss of methane and co-pollutants where this occurs. Power outages can also cause disruptions in the processing of waste at transfer stations, recycling and composting facilities and prevent pollution control systems (e.g., leachate pumps). Forecasting the occurrence and severity of such impacts to infrastructure is beyond the scope of this report.

The assessment of sustainability in Chapter 4 uses a scenario modeling approach comparing current conditions to hypothetical future scenarios (e.g., increasing recycling and composting, switching to electric waste collection vehicles, etc.) As such, there is significant uncertainty implicit in the results and results should be interpreted as relative rather than absolute.

Chapter 2:
Historical Weather Events

Over the last eighty years, precipitation in Iowa has increased in frequency and intensity. This change has impacted hydrologic flows and an increase in riverine and stream flows by 20-50% has been observed (US EPA, 2011). In this chapter, historical weather events and trends characterized to provide context for assessing the vulnerability of waste and urban infrastructure to climate impacts.

2.1 Characterization of Historic Weather Events

Natural disasters and weather extremes that affect the Davenport region are mainly associated with Mississippi River flood events, hail, and thunderstorms. **Table 1** lists historical events (from 1950 to 2010) (USA.com, 2021). It is unknown if the number of "Flood" events refers to river or flash flooding or both. In addition to those extreme events, the Bi-State Regional Commission (2020) pointed to road impacts from freeze-thaw cycles, road and river navigation impacts from fog, and impairment of visibility from fires.

Table 1. Extreme Weather Events from 1950 to 2010 Recorded in the Davenport Region

Event Type	Count
Avalanche	0
Blizzard	54
Cold	118
Dense Fog	89
Drought	52
Dust Storm	0
Flood	**1,369**
Hail	**3,825**
Heat	82
Heavy Snow	155
High Surf	0
Hurricane	0
Ice Storm	108
Landslide	1
Strong Wind	168
Thunderstorm Winds	**6,529**
Tropical Storm	0
Wildfire	5
Winter Storm	303
Winter Weather	349
Other	888

Source: USA.com, 2021

NOAA's Storm Events Database (NOAA, 2021) lists flash flood, hail, thunderstorm, and winter storm events from 1950 through 2021. The database documents the occurrence of storms and other significant weather phenomena which have "sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce." (NOAA, 2021), and as such is not a complete listing of all storm events that have occurred in an area. For example, a hail event in the spring of 2020 caused roof damage in 30,000 homes (Morris, 2021). **Table 2** summarizes the recorded storm events retrieved for Davenport from 2015 through 2021. Only those events are listed for which the database provided a Davenport location (e.g., Davenport city name and/or street name). In addition, an August 2020 straight-line derecho produced 80 mph maximum windspeeds and downed power lines and trees (Dunn, 2021 and Bi-State Regional Commission, 2020).

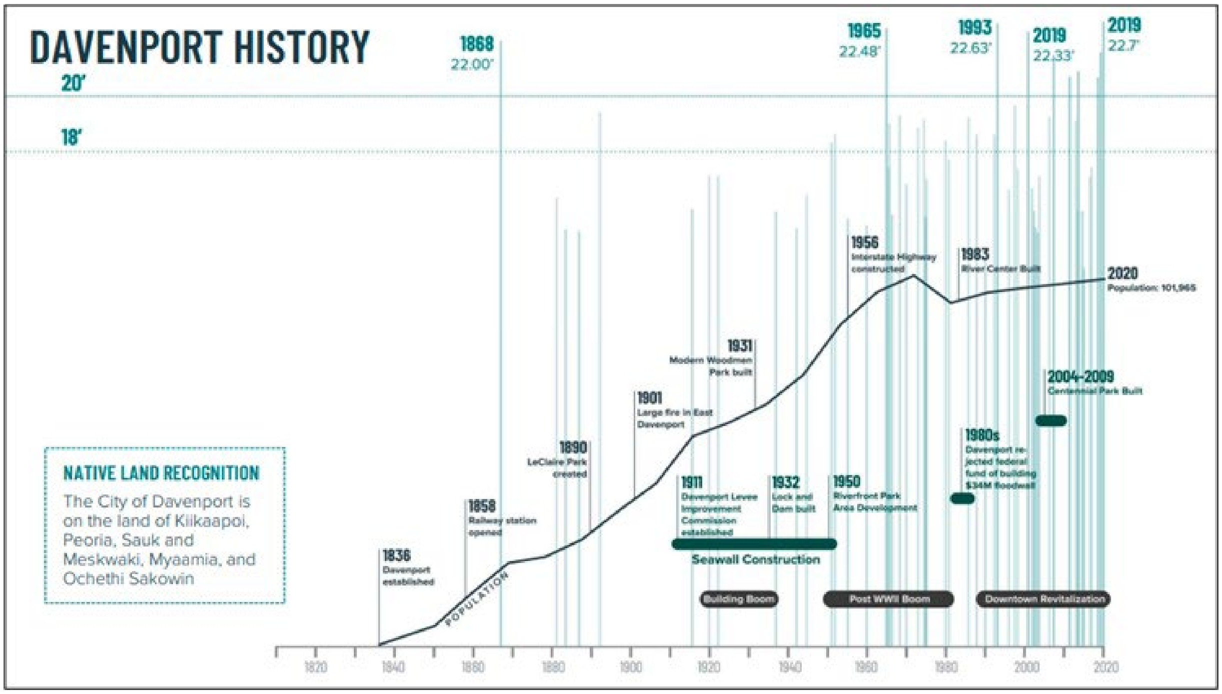
Table 2. NOAA Storm Events in Davenport between 2015 and 2021

Year, Month	Event Location
Flash Floods	
2020, March	Thunderstorms producing torrential rainfall directly impacted the Quad Cities Metropolitan area late in the evening March 27th. Streets were flooded 1 to 3 feet deep in downtown areas of Davenport and Bettendorf, resulting in stalled cars.
2019, April	A temporary flood barrier failed, immediately inundating a portion of downtown Davenport. The Mississippi River flood water rushed into a portion of the downtown business district, flooding parked cars in streets and parking lots, and inundating the ground floor and basements of businesses in the immediate area.
2019, May	Many reports of main streets in Davenport under 1 to 2 ½ feet of water due to torrential rainfall.
2018, June	Widespread significant flash flooding. Numerous major and neighborhood streets 2 to 4 feet under water.
2017, September	Water up to the doors at the intersections of Fairmount and Locust Streets, and Clark and Denison Streets.
2015, July	A large amount of water crossed 29th Street near Duck Creek Park to the depth of 12 inches. Deep water also crossed Locust Street between Eastern Avenue and Bridge Street. Also, water was over the road at 49th Street west of Division from Robins Creek.
Hailstorms	
2018, June	Dime to nickel size hail at Interstate 80-mile marker 292. Lightning also struck a power pole which caught on fire.
2016, May	Dime sized hail in Davenport.
2015, June	Quarter size hail was reported at 4th and Warren in Davenport.
Thunderstorms	
2020, July	A tree was blown down at the corner of 35th street and Marquette.
	A 6-inch diameter limb down at Brady Street and 29th Street.
2020, June	Large tree blown down at Arlington Ave and East 15th Street in Davenport.
	Davenport, Iowa Airport ASOS reported a 61 mph gust. Winds were sustained at 45 mph for over 10 minutes.
2019, June	Large tree branch blown down at 1624 West Columbia Ave.
2018, July	A measured maximum wind gust of 75 mph was recorded on the NWS Quad Cities RSOIS system.
	The Davenport Airport ASOS weather station recorded a maximum wind gust of 59 mph.
2017, September	Large tree down on Kirkwood Blvd.
2017, March	Wind measurement was from the Davenport Airport (DVN) ASOS site.
	Several trees were down in the Ridgeview area.
2017, June	Winds were measured by the Davenport Airport, KDVN ASOS, with a peak wind of 62 mph, and maximum sustained wind of 48 mph for a 5-minute period ending at 10:02 PM.

Year, Month	Event Location
2017, July	This wind gust of 61 mph was measured by the Davenport Airport ASOS site.
2017, June	Winds were measured by Iowa DOT RWIS at I-80 and I-280 interchange.
2016, July	4-to-6-inch diameter branches were broken off and blown 100 to 200 yards. The tree was along U.S. 61 north of Le Claire Road east of Eldridge.
2016, August	Davenport Public Works reported trees down on Locust and Grant Streets in the city.
	The public reported several trees down in Davenport.
2016, July	A large, old tree fell onto three vehicles near Davenport Avenue and Kirkwood Boulevard during the early morning. A few utility lines were also knocked down by the tree.
	Tree branches were down along the 2200 block of North Washington Street in Davenport.
	A few 4-to-6-inch diameter tree branches were down near Royal Oaks Drive and Marquette Street.
	Many tree limbs over 3 inches in diameter were blown down near 42nd and Division Street. An 8-inch diameter tree was also snapped off near its base.
2015, August	Estimated wind gust to be 60 mph and blew down a 3-to-4-inch diameter tree branch.
Winterstorms	
2021, January	The official NWS observation at the Davenport Municipal Airport was 4.1 inches of snow/sleet.
	The official NWS observation at Davenport Municipal Airport was 7.0 inches of snow/sleet.
	Official NWS observations at the Davenport Municipal Airport were 0.7 of snow and sleet. A public report of 2.5 inches of snow and sleet 2 miles west southwest of Davenport. One mile west of Bettendorf estimated a quarter of an inch of freezing rain. A quarter of an inch of ice 2 miles east northeast of Davenport.
2021, February	Rain and wintry mix started during the day, leading to snow (heavy at times), where between 2 and 5 inches of snow fell throughout Scott County. Strong winds with a peak gust at 51 mph reported at the Davenport Airport ASOS.
2021, March	The official NWS observation at the Davenport Municipal Airport reported 2.6 inches of snow and sleet. 8 tenths of which fell as sleet.

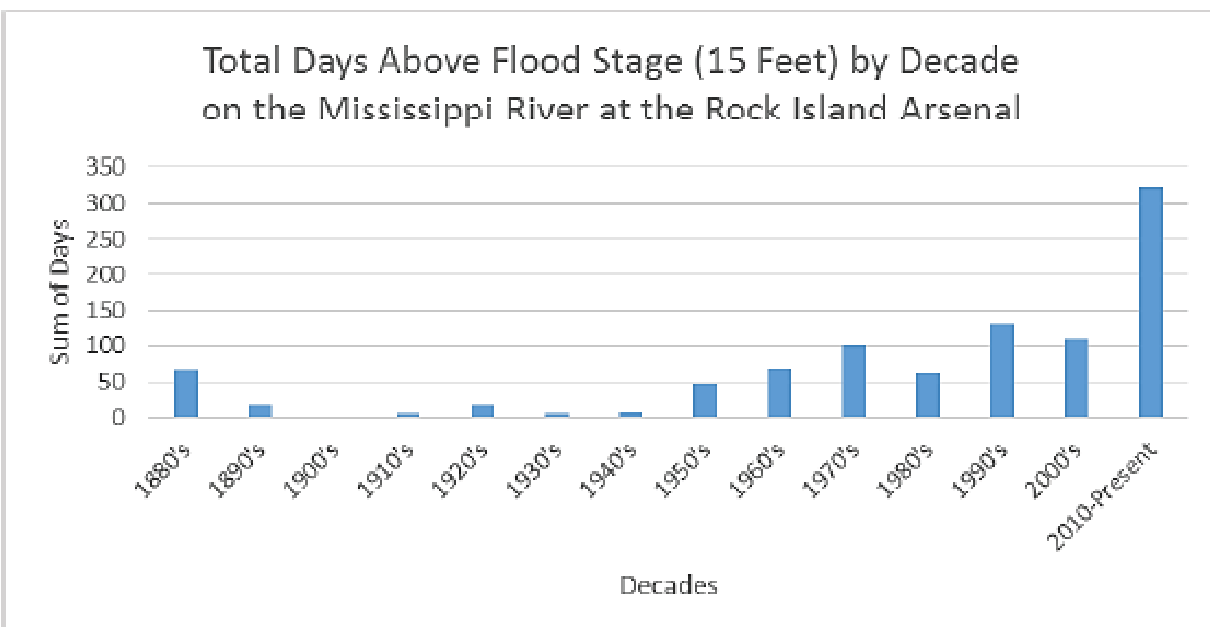
Source: NOAA, 2021

The City of Davenport shares 9 miles of direct Mississippi riverfront. Figure 2 provides a historical summary of flood events since 1878 as recorded by a river level gauge (near the present Lock and Dam 15) and appears to indicate an increase in recorded flood events (City of Davenport, 2021). **Figure 3** demonstrates the increasing number of days where the Mississippi River was about flood stage (15 ft) (Bi-State Regional Commission, 2020).



Source: City of Davenport, 2021

Figure 2. History of Flooding Events in the City of Davenport



Source: Bi-State Regional Commission

Figure 3. Mississippi Flood Stages 1880's-Present

2.2 Impact Boundaries and Potentially Affected Solid Waste Management Facilities

Data and information to delineate historical flood impact boundaries for the City of Davenport were available from the Iowa Flood Information System (IFIS, 2021) and used in combination with locations of existing solid waste management infrastructure to create a map of impact boundaries and potentially affected solid waste management facilities as shown in **Figure 4**.

With respect to solid waste infrastructure in the Davenport region, Waste Commission of Scott County operates four solid waste management facilities (Waste Commission, 2021). These facilities include:

- Scott Area Landfill
- Scott Area Recycling Center
- Household Hazardous Material Facility
- Electronics Recovery Center

As shown on **Figure 4**, none of the Scott County facilities appear to be located immediately within impact boundaries, however severe creek flooding such as Duck Creek have occurred. Per the Scott County Waste Commission, Duck Creek flooding in 1990 had a significant impact on the landfill (Morris, 2021). The 1990 Duck Creek flood has also been reported to have impacted more than 8,000 homes and resulted in excess of $25 million in damages (Academic, 2021).

The City of Davenport operates the Davenport Compost Facility which is located adjacent to the Mississippi River between I-280 and US 61. This facility is situated in the Mississippi flood hazard zone and was closed or could not be accessed during April, May, and June 2019 flood events (City of Davenport, 2019). The facility has been inaccessible in the last 25 years due to flooding for approximately 75 days. The facility closes when the river stage is greater than 19 feet. Most floods to-date in Davenport have been 18 feet or less (Dunn, 2021). During closure, service was successfully maintained by relocating drop-off to the landfill (Morris, 2021).

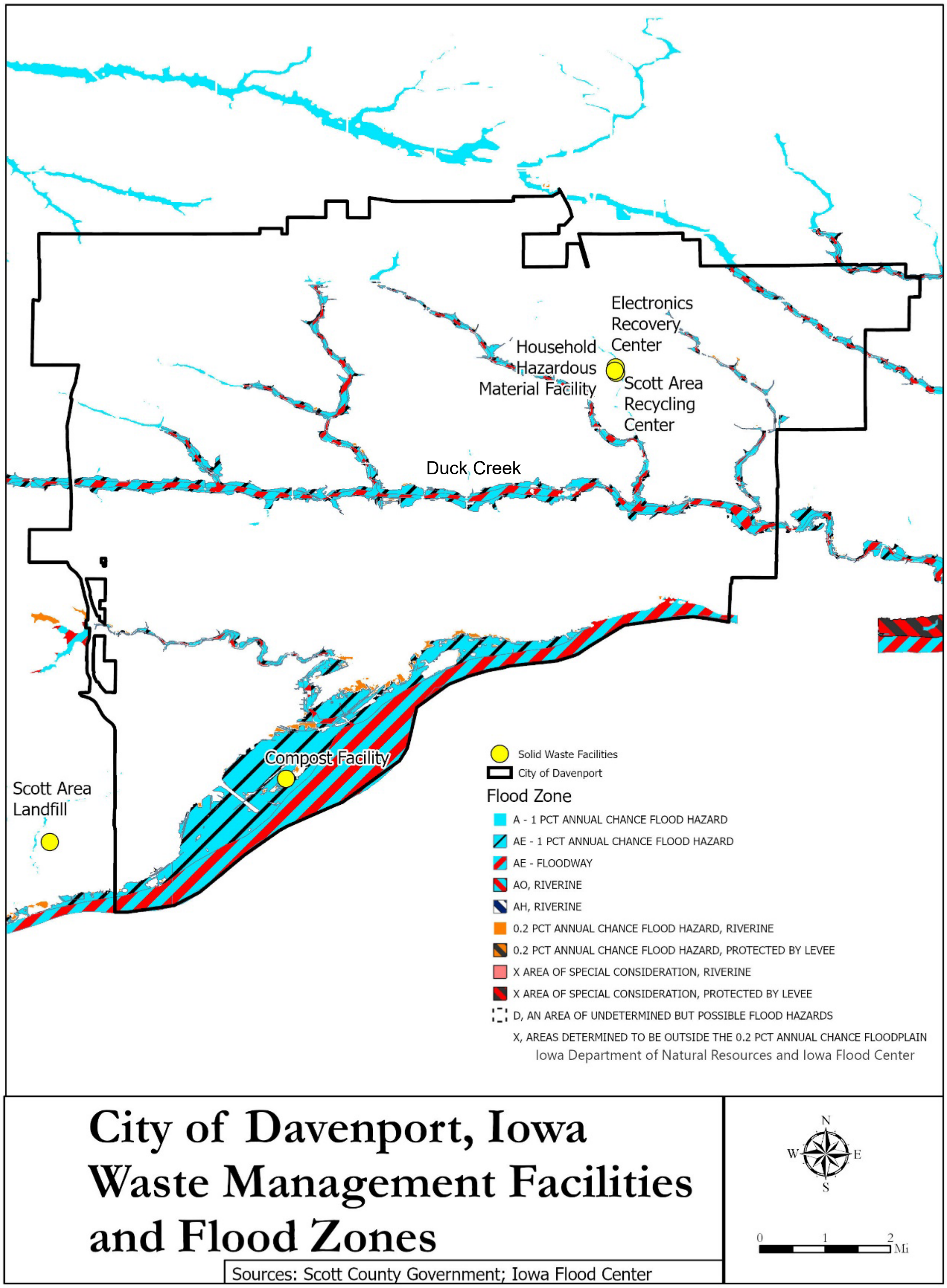


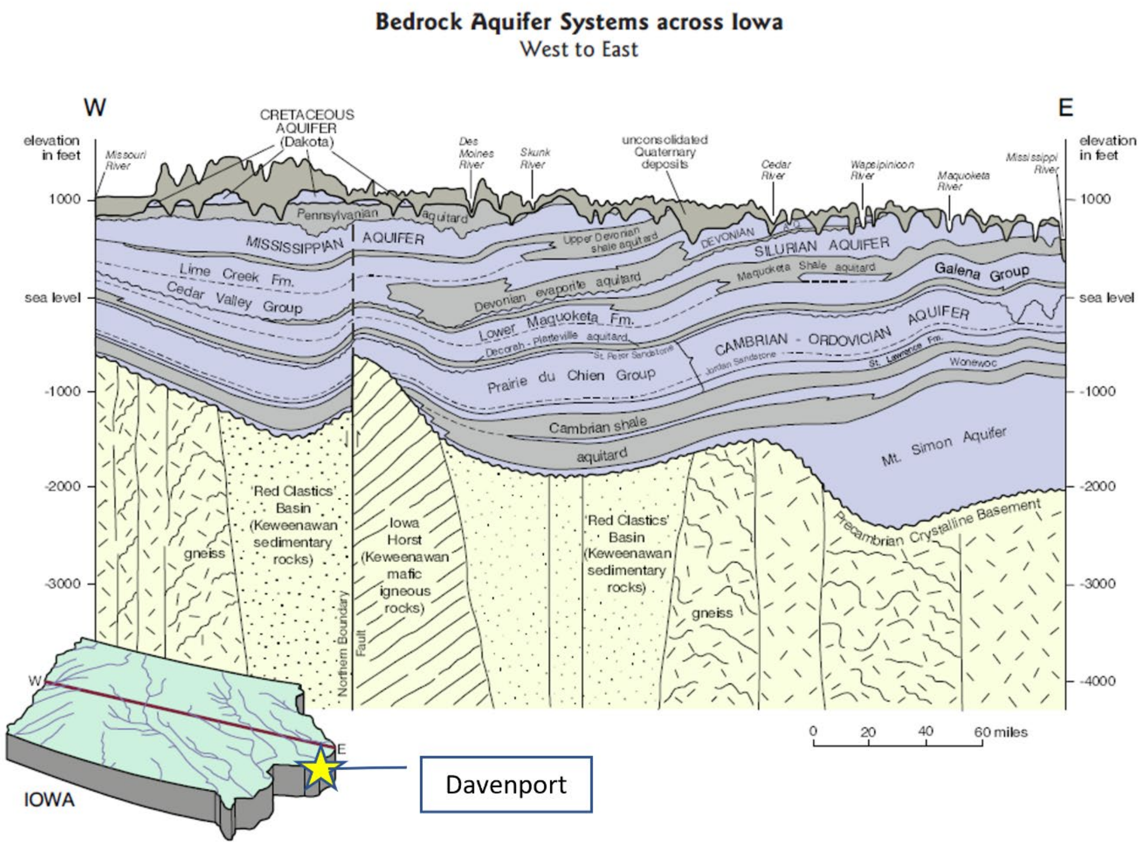
Figure 4. Map of Flood Boundaries and Davenport Region Solid Waste Management Infrastructure

2.3 Potential Groundwater Impacts From Storm and Flooding Events

This section summarizes groundwater resources in Iowa and more specifically Scott County and Davenport, IA and examines tools to analyze impacts from storm and flooding events on groundwater and waste management facilities.

Groundwater resources in the Davenport region

In Iowa, approximately 80 percent of the population relies on groundwater as the major drinking water source (Prior, 2003). Groundwater resources in Iowa can be categorized into surficial (unconsolidated Quaternary deposits) aquifers and bedrock aquifer systems. The hydrogeologic cross-section (**Figure 5)** shows the aquifer systems across Iowa.

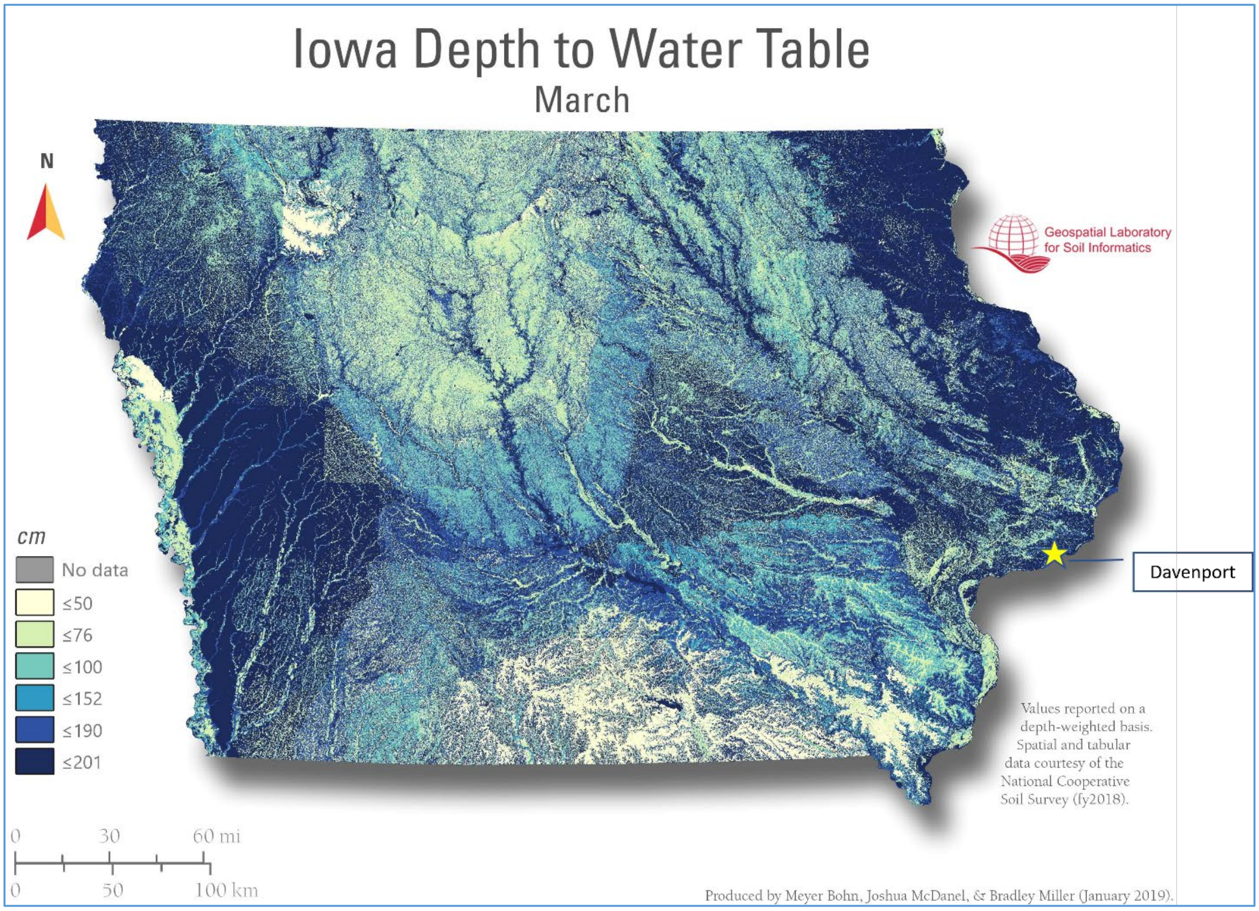


Source: based on Prior et al, 2003

Figure 5. Iowa Aquifer System

In the Davenport area, unconfined surficial alluvial sand and gravel aquifers are present and are hydraulically connected to the Mississippi River, which causes fluctuations in the water table levels depending on river stages. The water table in the surficial aquifer system across Iowa can be found between 3 and 30 feet below ground surface (Prior, 2003). **Figure 6** shows March 2018 depths to groundwater for Scott County and Davenport (Bohn, 2019). The water table is shallow at less than 200 centimeters or less than 6.6 feet. Due to their shallow unconfined nature, the surficial aquifer is especially vulnerable to contaminant infiltration during flooding and surface disturbances. As reported in 2012

(Quad-City Times, 2012), a construction diversion tunnel project in Davenport encountered shallow groundwater and had to pump and remove approx. 4.5 million gallons.

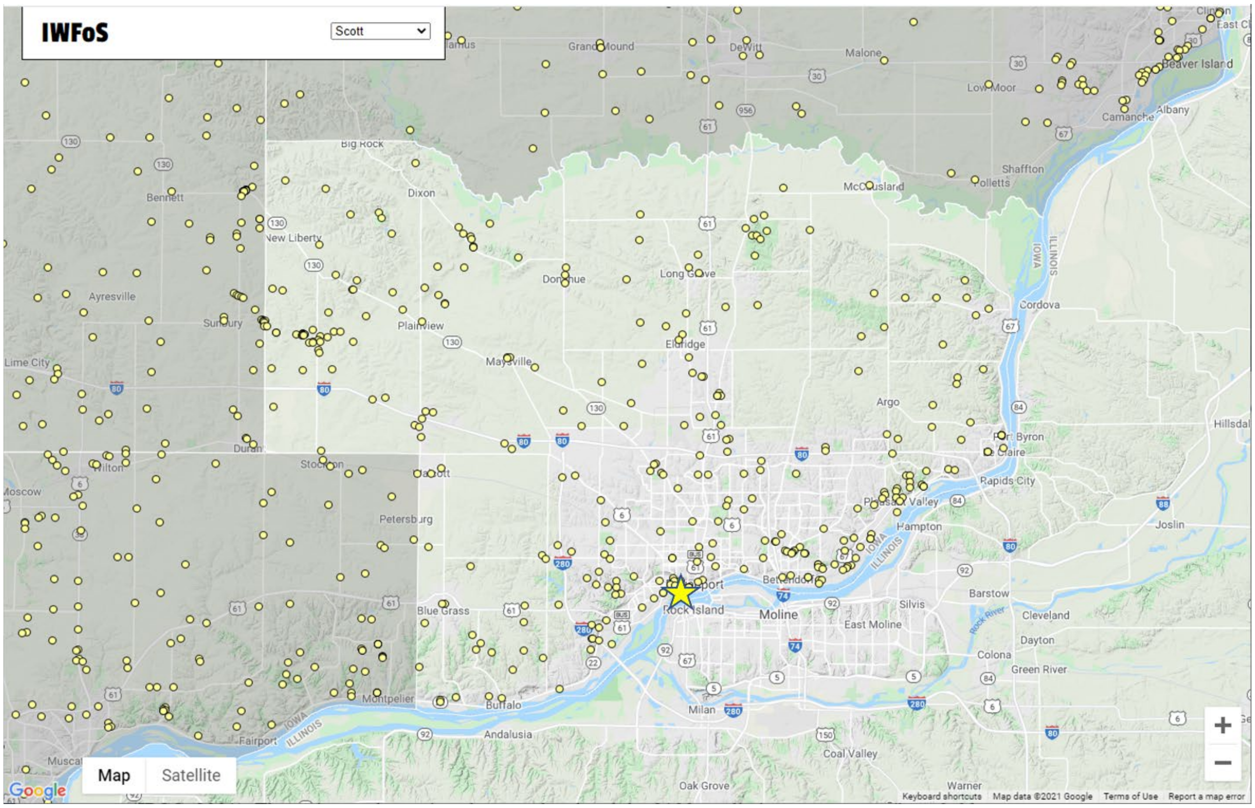


Source: based on Bohn, 2019

Figure 6. March 2018 Depths to Groundwater for Scott County and Davenport

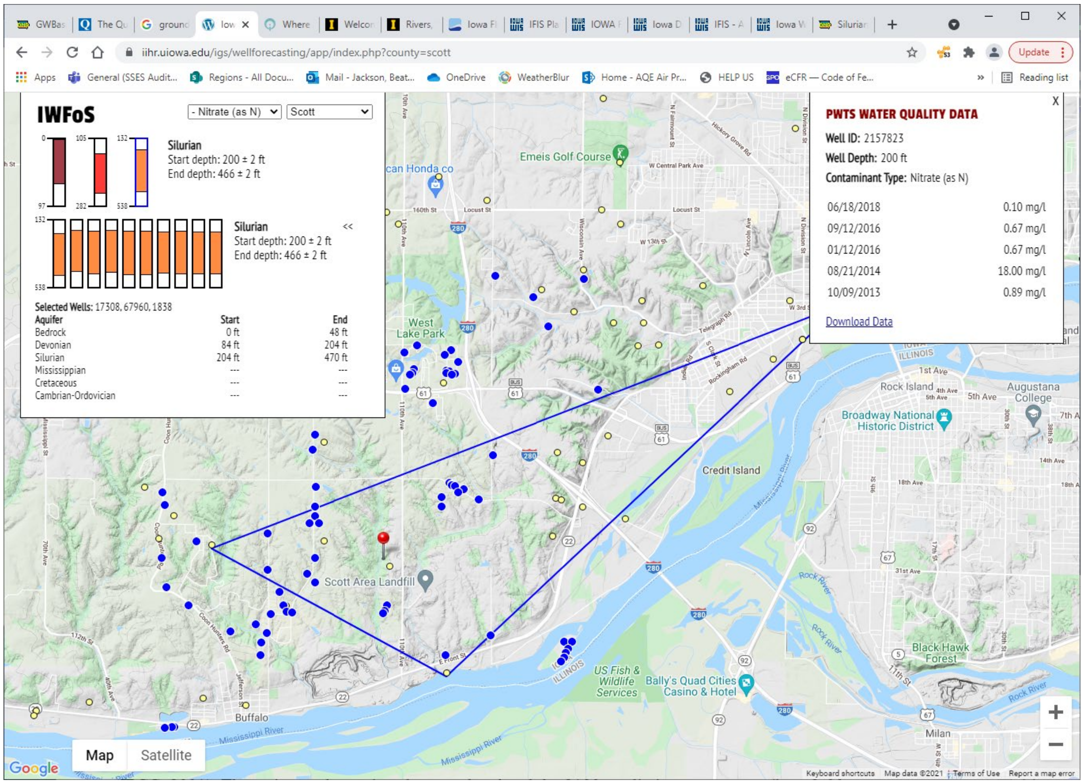
As the cross-section in Figure 4 shows, Iowa is underlain by several bedrock aquifers separated by less permeable confining units such as shale (Prior, 2003). Among the bedrock aquifers, the confined Silurian-Devonian aquifer is present in all of Scott County and provides a significant, good water quality resource (<500 mg/L total dissolved solids). The underlying confined Jordan Aquifer of the Cambrian-Ordovician Aquifer system also provides significant amounts of groundwater. The Jordan Aquifer is used extensively, but due to its poor water quality (>1,000 mg/L total dissolved solids) mainly withdrawn for municipal and industrial uses (Prior, 2003 and USGS, 1984). Because these bedrock aquifers are confined, infiltration of contaminants during flooding or surface disturbance is generally not expected, however contaminated water can flood and compromise deep aquifer wells.

While water for Davenport and neighboring Bettendorf is provided by the Mississippi River through the Iowa American Water Company (City of Davenport, 2019), some citizens in the Davenport and surrounding areas rely on private wells (**Figure 7**). Per the Iowa Well Forecasting System (IWFoS, 2021), private wells appear to be drawing water from these deeper bedrock aquifers (**Figure 8)**. The red pin depicts the selected well location for which the system then generates an area (shown as a triangle anchored by 3 wells) with respective aquifer information.



Source: IWFoS, 2021. Note: yellow star represents Davenport

Figure 7. Private Wells in Scott County

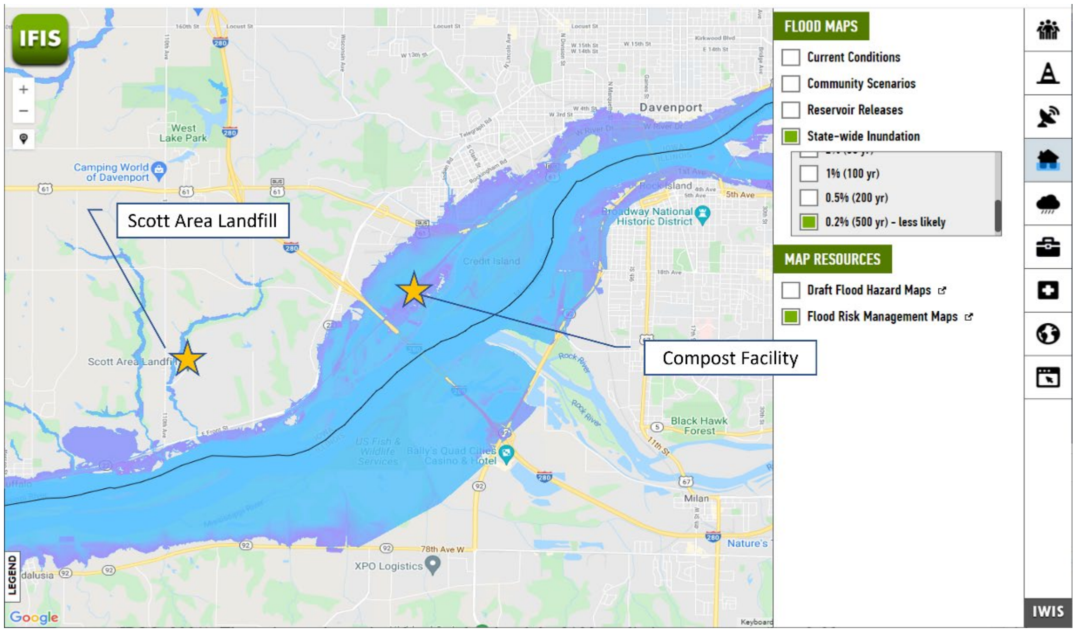


Source: IWFoS, 2021

Figure 8. IWFoS Aquifer and Water Quality Data

IWFoS is a web-based platform that provides well geology and water quality information. As can be seen on Figure 8**,** this interface lets the user select a county, a well (red pin) and an aquifer system (top three bars). For each of the aquifer systems, depths to this aquifer in the selected and paired wells are shown. The user can also select a water quality parameter (Nitrate (as N), Coliform, Fecal Coliform or Arsenic) to be displayed (blue dots). Clicking on the blue dots reveal the Well ID, well depth, and contaminant concentrations and associated dates. While the water quality data do not appear to be updated frequently the user can determine if a well may be susceptible to contaminant infiltration which may increase during flooding.

In addition, well locations can be compared against flood maps to assess the potential for a well being exposed to flood waters. **Figure 9** shows the extent of a 500-yr flood as shown on an Iowa Flood Information System (IFIS) map (IFIS, 2021). IFIS is a web-based platform that offers flood related information such as real-time flood conditions, alerts as well as flood maps. When projecting the extent of a 500-year flood, it appears that the Scott Area Landfill is not located in a flood zone, however the City's compost facility is.



Source: IFIS, 2021

Figure 9. IFIS 500-year Flood Map

Analysis of effects on groundwater levels and resulting impacts on landfills

This section summarizes approaches and tools that can be used to analyze the effects of flooding on groundwater levels and resulting potential impacts to waste management facilities. Groundwater elevation increases may impact landfills, especially if liners are compromised or missing.

There are currently nine operating permitted waste disposal facilities in Scott County, of which several are in or near Davenport (marked with an asterisk in **Table 3**) (IADNR, 2021). The Scott Area Landfill has a synthetic liner and leachate collection and recirculation systems. The recycling, hazardous materials and electronics recovery sites are co-located (Waste Commission, 2021). As Figure 9 shows, the Scott County Landfill is not located in the flood zone, however the City of Davenport Compost Facility would be impacted by severe flood scenarios such as 50-year through 500-year floods (the various flood maps are available on the Iowa Flood Information System (IFIS) website. The Compost Facility is served by permanent berms that defend major flood stages up to 24 feet. A new berm system will be constructed in 2022/2023 as part of a berm system going in to protect the neighboring Wastewater Treatment Plant (Dunn, 2021)

Table 3. Permitted Solid Waste Facilities in Scott County

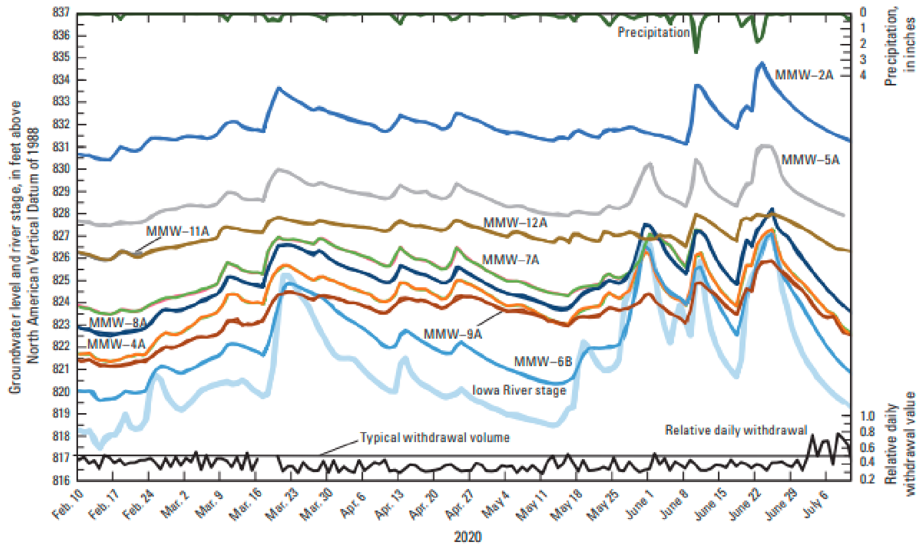
Permit #	Type
*27-RCC-1996: Waste Commission of Scott County	Household Hazardous Materials
*82-ADP-01-03: Scott County Sanitary Landfill	Appliance De-manufacturing Permit
*82-CRT-01-04: Electronics Recovery Center	CRT Recycling Permit
*82-SDP-09-92: Scott Area Sanitary Landfill	Municipal Landfill
*82-SDP-12-93: City of Davenport Sludge Composting Facility	Composting Facility
82-SDP-16-97: Continental Cement Co CKD Landfill	Industrial Landfill
RC-4397: Eastern Iowa Recyclers, Inc.	Redemption Center Registration
RC-4551: Can City - Eldridge	Redemption Center Registration
RC-4879: Pilot Travel Center (#43)	Redemption Center Registration

Source: IADNR, 2021

Our research did not reveal any information about flood induced groundwater level changes in the immediate Davenport area. However, a United States Geological Survey report (USGS, 2021) was found that examined the effect of groundwater withdrawals, river stage, and precipitation on water-table elevations in the Iowa River alluvial aquifer near Tama, approximately 108 miles northwest of Davenport. Data for a 5-month period (February through July 2020) were analyzed to determine how Iowa River stages, groundwater withdrawals, and precipitation impact groundwater elevations (**Figure 10**). The graph clearly shows that the water table rises in groundwater wells (MMW-*) during elevated Iowa River stages. Especially in June, increased precipitation causes high river stages and water tables. During July, when precipitation was minimal or absent and groundwater withdrawals were high, both the river stage and the water table dropped significantly. While not in the Davenport area, another older 1980 groundwater study (Palmquist et al, 1980), compared surficial aquifer groundwater levels and Skunk River and Ballard Creek stage levels between February and April 1980. **Figure 11** demonstrates that groundwater elevations in wells (OW-*) rise with elevated river stages.

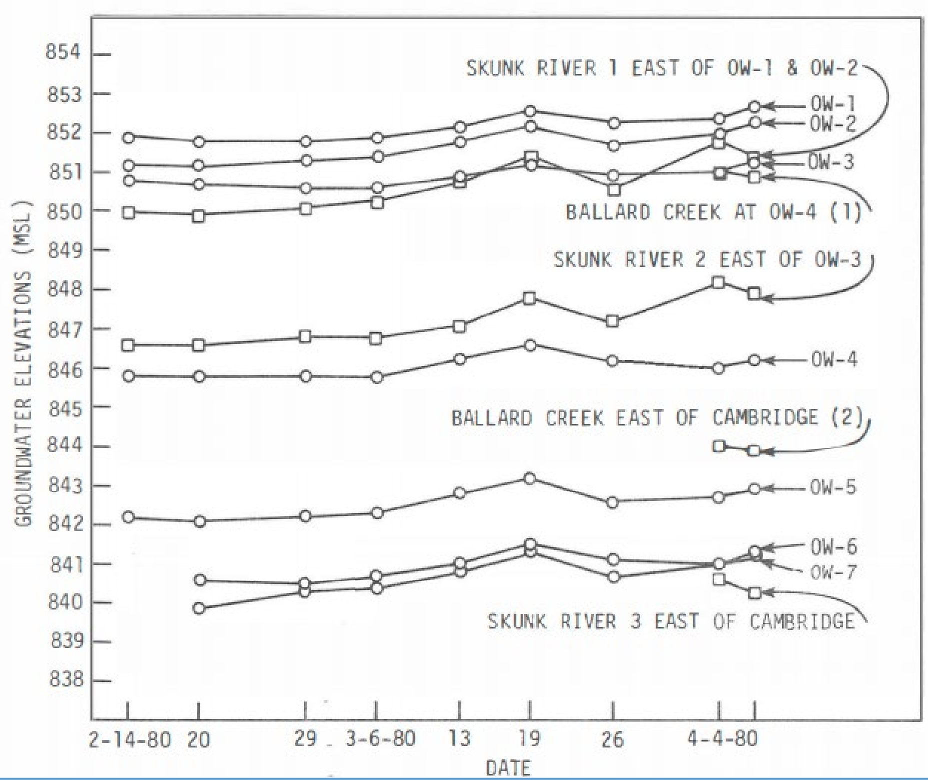
Furthermore, a 2014 Water Summary Update (IADNR, 2014) reported on shallow groundwater and flood interaction in northwest Iowa. The summary states that

> *"With a major flood event like northwest Iowa is currently experiencing, groundwater levels (recharge) normally lag behind the surface water levels, especially if the wells are located a distance from the river. With significant flood water covering the river valleys, the question is when groundwater recharge will occur, not if it will occur"*



Source: USGS, 2021

Figure 10. Relationship between Groundwater Elevations and Iowa River Stages



Source: Palmquist et al, 1980

Figure 11. Relationship between Groundwater Elevations and Skunk River and Ballard Creek Stages

Our research also did not identify any specific tools designed to evaluate the impact of groundwater levels on Scott County or Davenport waste facilities and potential resulting contaminant releases. However, under the previous work on the Effect of Sea-Level Rise Induced Changes to Groundwater and Impacts to Landfills for Norfolk, VA (RTI, 2016), several methods were identified that could evaluate the impact of rising groundwater elevations on landfills and estimate resulting potential releases and transport of contaminants.

A tiered approach has been adopted or used by numerous state and federal agencies to evaluate risks associated with exposures to pollutants in the environment in a conservative manner. To be successful, tiered approaches need to have clearly defined and measurable endpoints between tiers. In general, a tiered approach begins with a Tier 1 screening level assessment which includes a simplified conceptual model of the environmental setting and pollutant release mechanism(s) combined with conservative exposure assumptions for humans and habitats. If unacceptable risks are identified (predicted exposure > threshold screening value), then a Tier 2 assessment is implemented by refining the release-exposure scenario to include more realism to reflect key sensitive scenario and site-specific conditions. If unacceptable risks persist, then a detailed site-specific conceptual model is developed and evaluated under a Tier 3 analysis. Iowa's Department of Natural Resources Groundwater Status Report (IADNR, n.d.) has implemented such a tiered approach for its Landfill Program.

If climate impacts result in a more permanent rise in the groundwater table elevation. a possible Tier 1 scenario for landfills would be to assume direct contact of the liner system with the water table resulting in groundwater exposures equal to measurements or estimates of landfill leachate concentrations which are then compared to screen levels corresponding to specific receptors and exposure pathways. Alternatively, if water table elevations are not expected to rise to that extent, national ground water dilution-attenuation factors (DAFs) available in EPA tools (e.g., U.S EPA Region 5 Delisting Risk Assessment Software [DRAS][4]) can be applied to expected leachate concentrations for screening comparisons. Tier 2 analyses consisting of deterministic or probabilistic fate and transport simulations can be conducted using existing EPA tools (e.g., Industrial Waste Management Evaluation Model [IWEM][5]) that require a minimum of key site- or location-specific data to predict potential landfill releases subject to changes in water table elevations.

Established open-source ground water flow and transport software (e.g., USGS MODFLOW[6]) for detailed Tier 3 site-specific investigations are available. Existing EPA, Office of Land and Emergency Management (OLEM) and ORD models specific to sources (land disposal units) and fate and transport pathways (ground water, air, surface water) with supporting data can be combined and customized to address conditions specific to climate-impacted landfills (i.e., no unsaturated zone). For example, existing EPA, OLEM and ORD solid/hazardous waste models and data—including the Scientific Advisory Board (SAB) reviewed Multimedia, Multi-pathway, Multi-receptor Exposure and Risk Assessment technology (3MRA, U.S. EPA, 2003) modules (**Figure 12**) and next generation of these models currently being developed within the HE^{2}RMES (Human and Ecological Exposure & Risk in Multimedia Systems) domain within EPA's FRAMES v 2 (Framework for Risk Analysis in Multimedia Environmental Systems, version 2) — can be adopted or adapted to investigate exposures to populations and ecosystems

[4] Available (accessed July 29, 2016) at https://www.epa.gov/hw/hazardous-waste-delisting-risk-assessment-software-dras
[5] Available (accessed July 29, 2016) at https://www.epa.gov/smm/industrial-waste-management-evaluation-model-version-31
[6] Available (accessed July 29, 2016) at http://water.usgs.gov/ogw/modflow/MODFLOW.html

from climate-impacted landfill (and other land disposal units). To support such modeling efforts, comprehensive physical and chemical properties, human and ecological benchmarks, and the EPA exposure factors are necessary for modeling waterborne (and airborne) contaminant exposures. These modeling systems could also be modified and leveraged to estimate potential impacts from climate–related power loss.

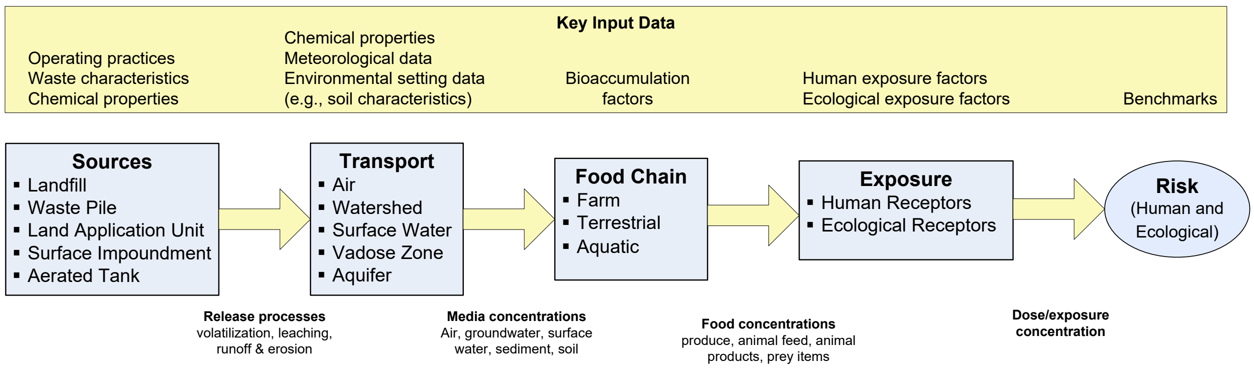


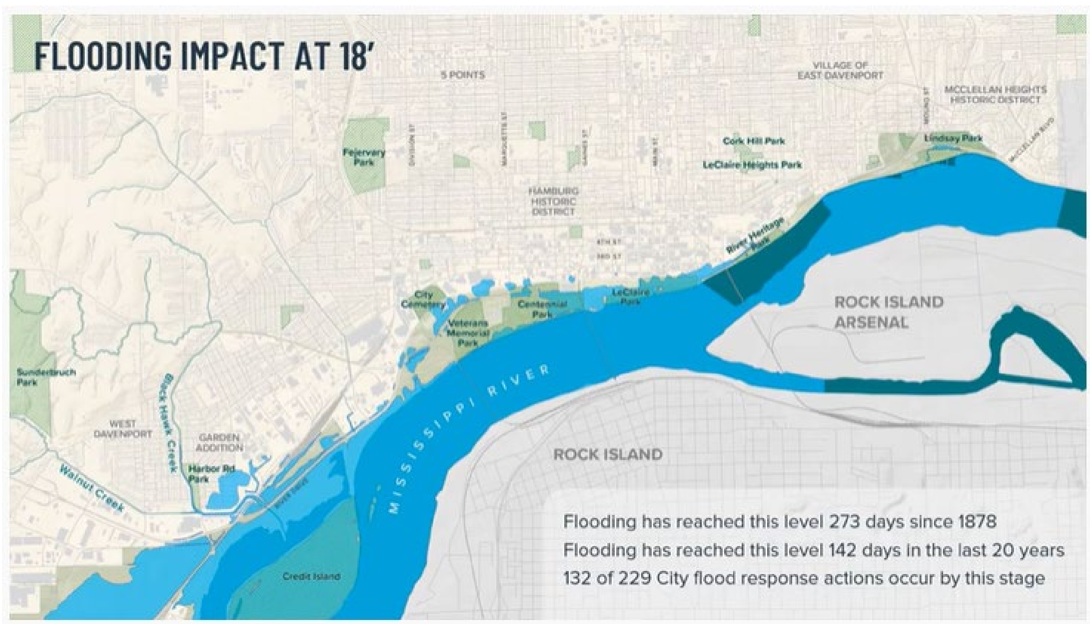
Figure 12. Overview of OLEM 3MRA Modules to Model Releases, Fate and Transport, Exposures, and Risks from Waste Management Units

Chapter 3:
Vulnerability of Solid Waste and Urban Infrastructure to Climate Impacts

The primary climate impact facing Davenport is seasonal flooding of the Mississippi River as well as increasing intensity, duration, and frequency of precipitation events that can also lead to flooding. In this chapter, historical and projected future trends in precipitation and flooding are characterized and the vulnerability of waste and urban infrastructure assessed.

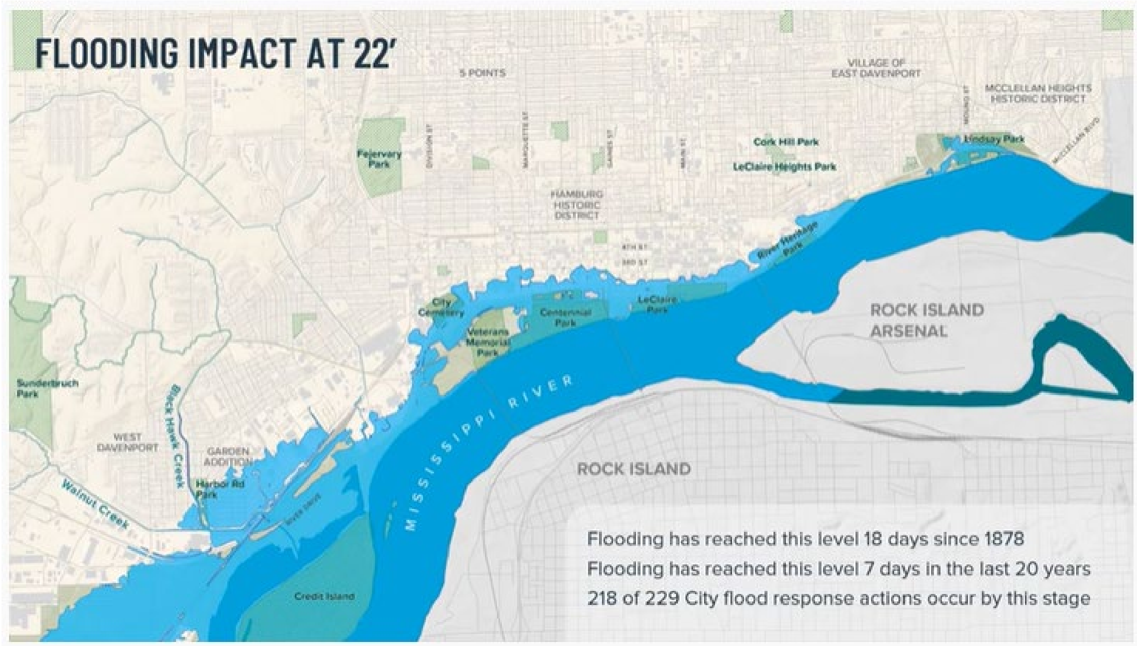
3.1 Characterization of Rainfall and Flooding

The City of Davenport shares nine miles of direct riverfront. A 2021 Davenport Flood Study (2021) provides maps of impacted areas and historical data for 18 ft and 22 ft flood stages (see **Figures 13 and 14**). A summary of flood events is shown on Figure 2 and appears to indicate an increase in recorded flood events **(**City of Davenport, 2021).



Source: City of Davenport, 2021

Figure 13. Flooding Impacts at 18 ft Flood Stage



Source: City of Davenport, 2021

Figure 14. Flooding Impacts at 22 ft Flood Stage

3.1.1 Rainfall Intensity, Depth, and Frequency

Flood events are characterized by rainfall frequency and intensity. The amount of rainfall is quantified by intensity, duration, and depth (Iowa SUDAS, 2015). Intensity is measured as depth divided by duration. To evaluate changes in rainfall intensity, depth, and frequency (IDF), a comparison of data from a 1955 IDF curve for Davenport developed by the US Department of Commerce is made with data from a 2015 Iowa Statewide Urban Design and Specifications manual. **Figure 15** shows that a 5-minute event with a 4.2 inches/hour intensity has the probability of occurring every two years, whereas a more severe 5-minute event with a nine inches/hour intensity would likely only occur every 100 years.

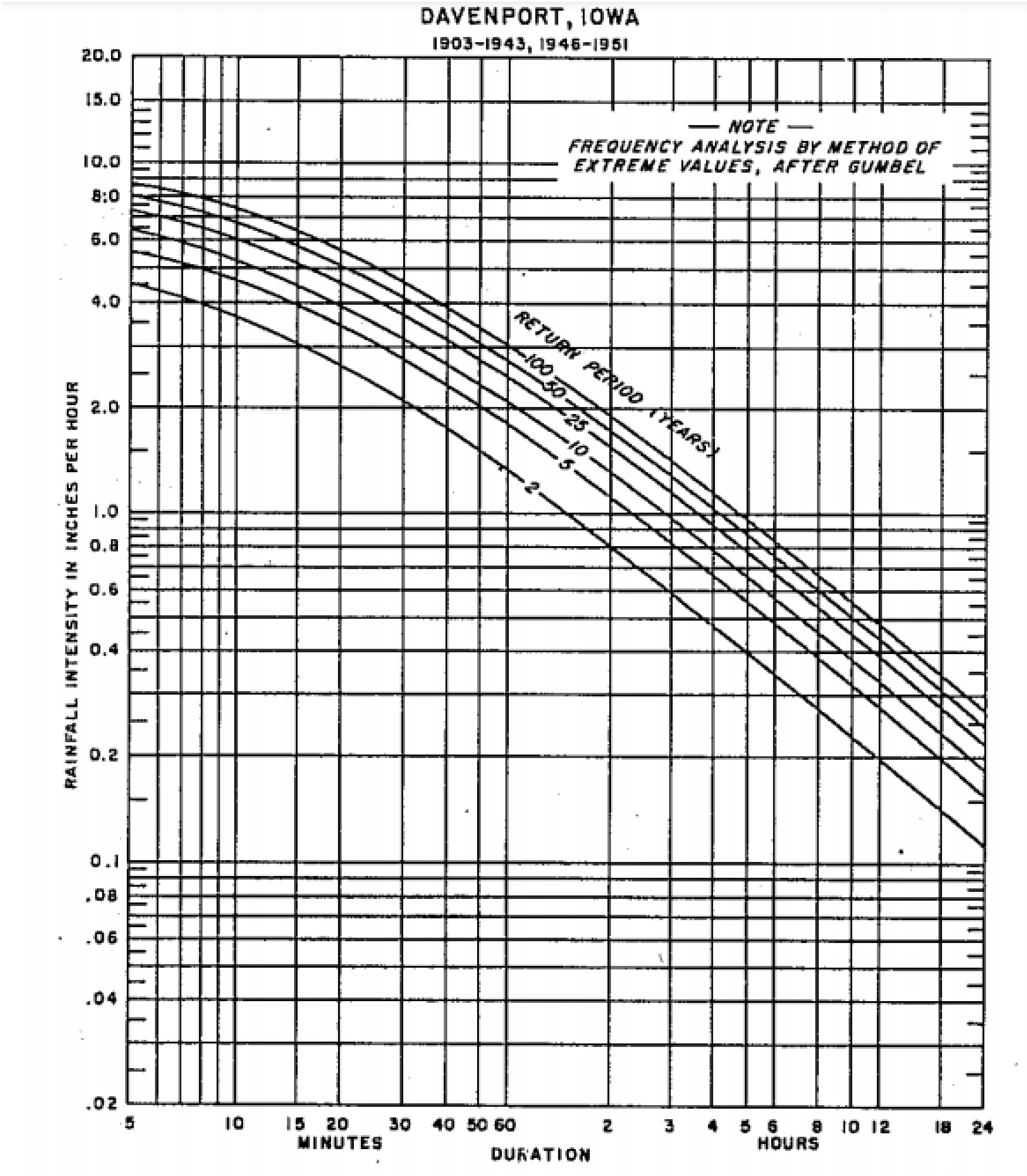


Figure 15. IDF Curve for Davenport with Rainfall Data from 1903-1943 and 1946-1951.

A manual from Iowa State University includes IDF curves for each region within the state that can be used as a guide for rainfall depth and intensity for various return periods, which is the average length of time between events that have the same duration and rainfall volume. **Figure 16** shows rainfall depth and intensity for East Central Iowa at return periods between one year and 500 years. "D" is the total depth of rainfall for a given storm duration in inches and "I" is the rainfall intensity for given storm duration in inches/hour. The chart shows that a 5-minute event with an intensity of 5.3 inches/hour intensity has the probability of occurring every two years, whereas a more severe 5-minute event with a 11.6 inches/hour intensity probably only occurs every 100 years.

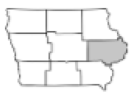
	Return Period															
	1 year		*2 year*		*5 year*		*10 year*		*25 year*		*50 year*		*100 year*		*500 year*	
Duration	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***	***D***	***I***
5 min	0.38	4.56	0.44	5.30	0.54	6.56	0.63	7.65	0.76	9.18	0.86	10.3	0.97	11.6	1.23	14.8
10 min	0.55	3.33	0.64	3.87	0.8	4.8	0.93	5.58	1.11	6.70	1.26	7.60	1.42	8.54	1.80	10.8
15 min	0.67	2.70	0.78	3.14	0.97	3.88	1.13	4.53	1.36	5.45	1.54	6.18	1.73	6.94	2.20	8.81
30 min	0.95	1.90	1.11	2.22	1.38	2.76	1.61	3.22	1.94	3.88	2.20	4.40	2.47	4.95	3.14	6.29
1 hr	1.23	1.23	1.44	1.44	1.80	1.80	2.11	2.11	2.58	2.58	2.96	2.96	3.36	3.36	4.37	4.37
2 hr	1.51	0.75	1.77	0.88	2.22	1.11	2.62	1.31	3.22	1.61	3.71	1.85	4.24	2.12	5.60	2.80
3 hr	1.68	0.56	1.96	0.65	2.47	0.82	2.93	0.97	3.63	1.21	4.22	1.40	4.85	1.61	6.50	2.16
6 hr	1.97	0.32	2.30	0.38	2.89	0.48	3.45	0.57	4.3	0.71	5.02	0.83	5.8	0.96	7.87	1.31
12 hr	2.28	0.19	2.65	0.22	3.31	0.27	3.93	0.32	4.88	0.40	5.68	0.47	6.56	0.54	8.87	0.73
24 hr	2.60	0.10	3.01	0.12	3.75	0.15	4.42	0.18	5.44	0.22	6.29	0.26	7.22	0.30	9.64	0.40
48 hr	2.98	0.06	3.43	0.07	4.22	0.08	4.93	0.10	6.01	0.12	6.90	0.14	7.86	0.16	10.3	0.21
3 day	3.28	0.04	3.72	0.05	4.51	0.06	5.24	0.07	6.32	0.08	7.22	0.10	8.19	0.11	10.7	0.14
4 day	3.53	0.03	3.98	0.04	4.78	0.04	5.50	0.05	6.58	0.06	7.49	0.07	8.46	0.08	10.9	0.11
7 day	4.17	0.02	4.67	0.02	5.53	0.03	6.29	0.03	7.39	0.04	8.30	0.04	9.25	0.05	11.6	0.06
10 day	4.75	0.01	5.30	0.02	6.24	0.02	7.04	0.02	8.20	0.03	9.12	0.03	10.0	0.04	12.4	0.05

Figure 16. Rainfall Depth and Intensity for East Central Iowa for Return Periods 1 - 500 years.

The IDF curves use historic rainfall data and appear to indicate that since the publication from 1955, the intensity has increased by 1.1 inches/hour for a 5-minute event with a probability of occurring every two years, while the intensity has increased by 2.6 inches/hour for a 5-minute event with a probability of occurring every 100 years.

Data from IDF curves indicate that there has been an increase in inches/hour for events that have a probability of occurring as often as every two years, as well as those events that have a likelihood of occurring every 100 years. Heavier downpours are expected to continue to occur, especially during spring and summer precipitation events, and the resulting changes in stream flow will increase the risk of riverine and flash flooding in and around Davenport.

3.1.2 Flooding Risk

A direct relationship between rainfall measurements and flood incidence is not well-established (U.S. EPA, 2011). This is because flooding is dependent on the travel time of riverine waterbodies within the hydrologic network. Flooding is a function of both time and space and therefore, rainfall experienced days before it reaches a community may play a major role in the flooding that occurs at a location hundreds of miles away (U.S. EPA, 2011). According to the U.S. EPA's "Iowa Climate Change and Resilience Report" (2011), there are three challenges associated with projecting future hazards resulting from climate change:

1. "Changes in rainfall do not directly correspond to changes in flooding. Traditional measures of rainfall extremes relate to only about half of future flood events. This means that it is difficult to determine future flood risks on the basis of projected increases in heavy rainfall."
2. "Rainfall projections vary greatly. In many cases, small changes in weather patterns could significantly alter the intensity and location of rainfall."

3. “Methods for mapping future riverine flooding are not well established, making it difficult to estimate property damage and other economic losses.”

3.2 Characterization of Infrastructure Vulnerability

Flooding risks were evaluated for five waste management facilities in Davenport, Iowa. Potential future impacts of climate change at each location were evaluated using the First Street Foundation Flood Model (FSF-FM, First Street Foundation, 2020). The model estimates flooding at the individual property level and uses “flood frequency analysis of river gauge records to characterize extreme river flows”. These five facilities are shown in **Figure 17** and include:

- Scott Area Landfill
- Davenport Compost Facility
- Scott Area Recycling Center*
- Electronics Recovery Center*
- Household Hazardous Material Facility*

(*Note that these facilities are co-located.)

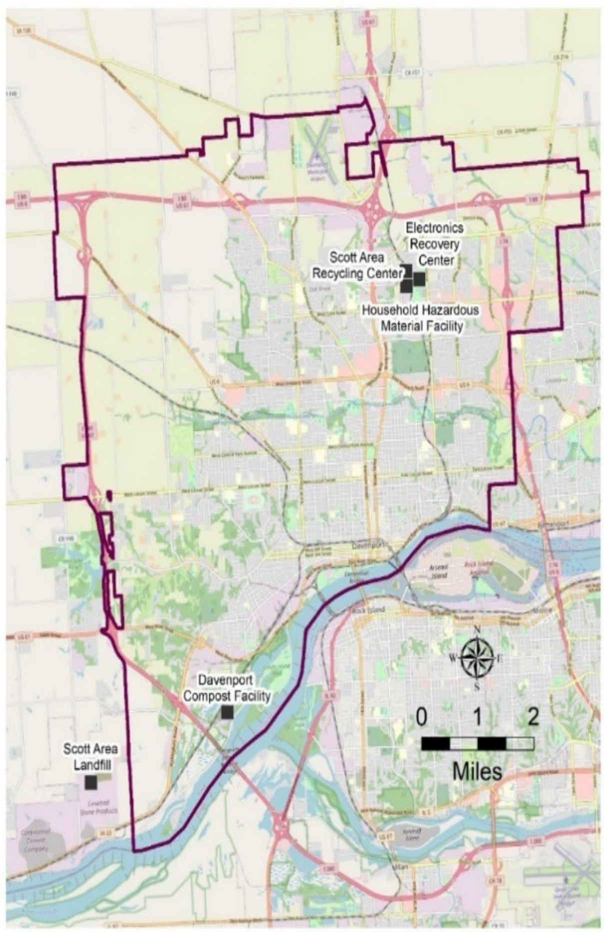


Figure 17. Waste Management Infrastructure in Davenport, Iowa

The First Street Foundation Flood Model (FSF-FM) model indicates that the locations of Davenport's waste facilities are moderately at risk for flooding over the next 30 years. The risk of flooding at four out of the five facilities is negligible, but the flooding risk for the Compost facility is substantial. Within the next 15 and 30 years, the model shows that the Compost facility can be inundated with between 2.8 and 9.1 feet of water. The impacts of flooding on these five waste facilities and Davenport urban infrastructure elements are described in further detail below.

3.2.1 Scott County Landfill

The Scott County Landfill, shown in **Figure 18**, is not located in a flood zone and the FSF-FM indicates that the property is likely not at risk for flooding. The model predicts that there is no likelihood of a flood event at 15- and 30-year time points into the future.

Figure 18. Scott County Landfill

3.2.2 City of Davenport Compost Facility

The City of Davenport Compost Facility is located in a 100-year floodplain and is less than two-tenths of a mile away from the Mississippi River (**Figure 19)**. The FSF-FM indicates that the property is at severe risk of flooding and that risk is increasing as weather patterns change.

Figure 19. Davenport Compost Facility and Proximity to the Mississippi River

Figure 20 illustrates the likelihood of at least one occurrence of flooding at this facility over the next 15 years. There is an 85% chance that there will be a 1-inch inundation event, an 81% chance of an event that will cause inches of flooding, and a 76% chance that there will be an event involving 12-inches of water.

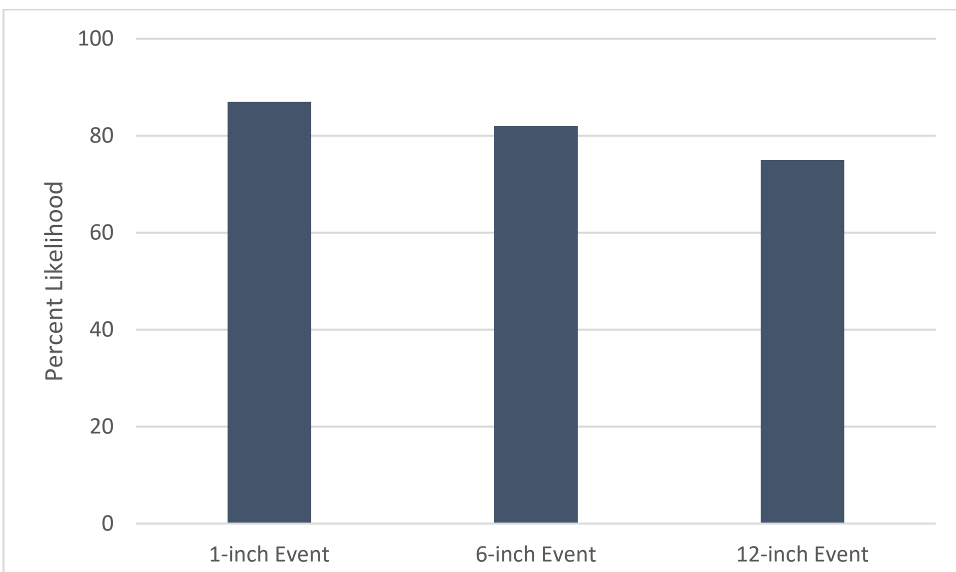


Figure 20. Likelihood of Flooding within the Next 15 Years at the Davenport Compost Facility

Flood Factor provides 15 and 30-year projections of flooding at the Davenport Compost facility and they are shown in **Figure 21**. The model shows that there is a 20% chance that no water will flood the building within the next 15 and 30 years. However, in 2036, it is 1% likely that 6.5 feet of water will inundate the building and 5% likely that 2.8 feet of water will reach the building. In the worst-case scenario, the model predicts that it is 0.2% likely that 9 feet of water will reach the largest building on the property. The 30-year projection is nearly identical to the 15-year projection for the Compost facility. The only difference is that the flooding depth with a 0.2 percent event increases to 9.1 feet.

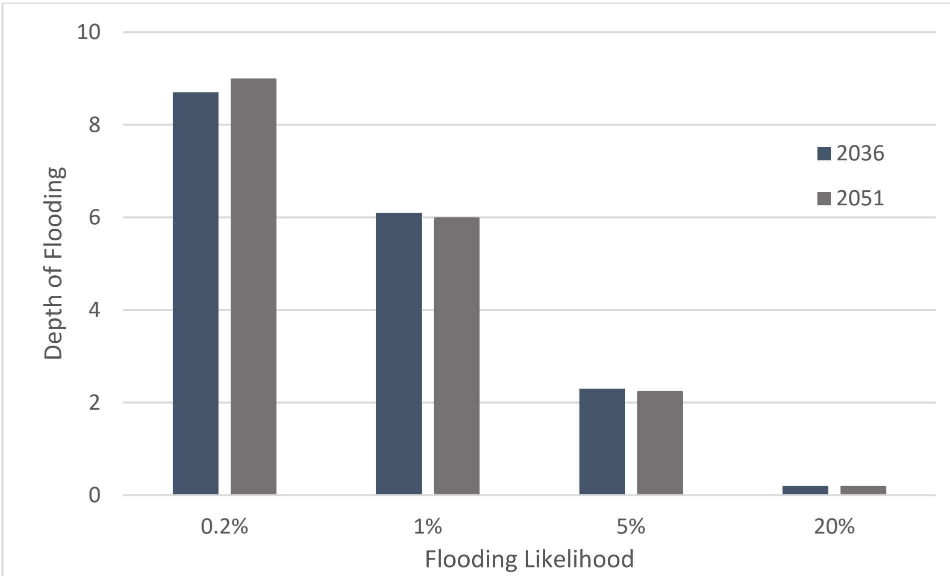


Figure 21. Fifteen and Thirty-Year Projected Flood Risk for Davenport Compost Facility

3.2.3 Scott Area Recycling Center, Electronics Recovery Center, Household Hazardous Material Facility

The Scott County Recycling Center, Electronics Recovery Center, and Households Hazardous Material Facility, shown in **Figure 22**, are located on the same parcel. Although the property is not located in a floodplain, Deere Creek it is approximately 300 feet from the site.

The online interface for the FSF-FM model does not provide data for all commercial properties and this site is one of those properties. To assess future flood potential, we use a residential property located 0.1 mile to the east as a proximity. This property has a minimal risk of flooding and at both 15 and 30 years into the future, the 0.2%, 1%, 5%, and 20% risks of flooding is negligible.

Figure 22. Scott County Recycling Center, Electronics Recovery Center, and the Household Hazardous Material Facility

3.2.4 Supporting Urban Infrastructure

Urban infrastructure systems are made up of interconnected networks that transport goods and services and provide the foundation for a myriad of functions that occur within a populated area. When natural weather disasters occur, there could be widespread damage to transportation infrastructure (and utilities) that support waste management. Waste collection from residences and businesses can be delayed or suspended. Flooding and debris on the roads causing narrowing or complete impassability for collection vehicles as well as deterioration or damage to roads and bridges could severely impact waste collection.

Transporting waste to management facilities could also be temporarily halted or transportation routes may have to be altered as roads and streets are flooded or narrowed and supporting transportation infrastructure (bridges and tunnels) damaged or unsafe for passage. Low-lying waste facilities could be cut off from normal routes or damaged from flooding, necessitating planning for alternative routing and possibly alternative facilities. In this section, vulnerabilities are summarized for different elements of Davenport's urban infrastructure that support waste management.

Mississippi River Transportation

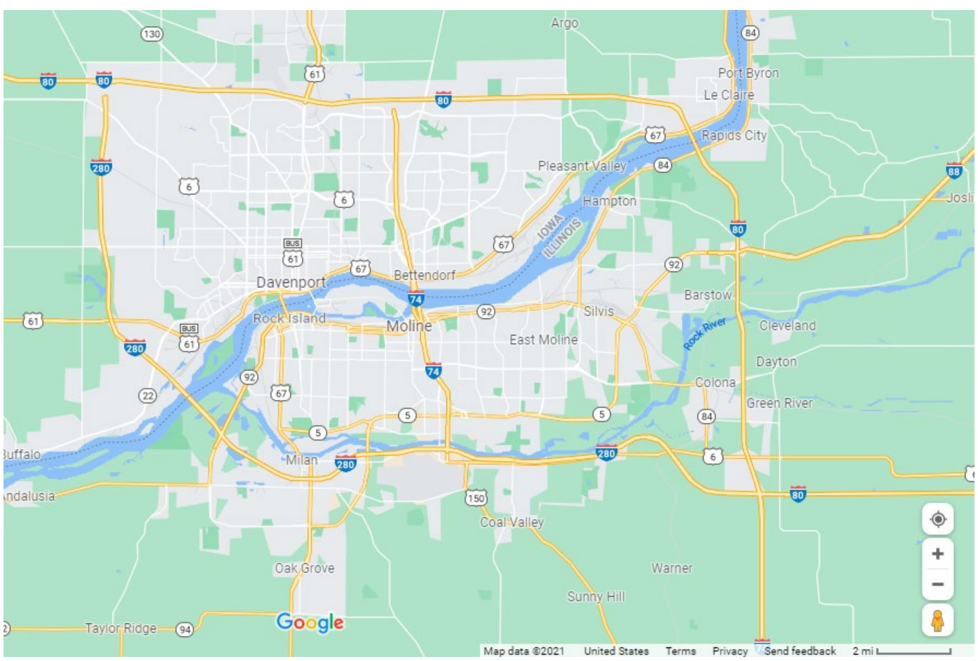
Mississippi River barge transportation capacity is influenced by river flooding events and weather conditions. Approximately 25 – 30 million tons have passed through the Quad Cities locks (annual average over five years) (City of Davenport, 2005).

Five bridges connect the Iowa and Illinois Quad Cities (**Figure 23**):

- Interstate I-74 east of Davenport
- Interstate I-280 southwest of Davenport
- Interstate I-80 far east of Davenport
- Local Government Bridge (aka Arsenal Bridge) connecting Davenport and Rock Island
- Local Centennial Bridge connecting Davenport and Rock Island

Several 2019 flood events (March-June 2019 and September-October 2019) triggered by snowmelt and heavy rain events, impacted access to the Government/Arsenal and Centennial bridges. Access to the Government Bridge was temporarily closed from April 29, 2019 through May 8, 2019 due to the failure of a flood barrier on April 29th. At the height of the 2019 flood, a lane had to be closed which reduced access to the Centennial Bridge. Also, construction of a new I-74 bridge added to traffic congestion on the Centennial Bridge and Government Bridge during this time. The loss of access to the Government Bridge resulted in travel issues and delays on the Centennial Bridge. New systems are in place to prevent this access issue in the future (Dunn, 2021).

Disrupted access to Interstate bridges was not reported (City of Davenport, 2019). In 2008, Cedar River flooding caused a four-day closure of I-80 across the eastern half of Iowa, which caused 120-mile detour between Davenport and Des Moines (ISU, 2018).



Source: Google Maps

Figure 23. Quad Cities Roadways and Bridges

Per a 2020 resilience report for the Quad Cities (Bi-State Regional Commission, 2020), two aging Mississippi River lock and dams (Lock and Dam 14 and 15) are maintained by the US Army Corps of Engineers on a "fix-as-fails" basis. However, in addition to flood stages from storm events, 1988, 2005, and 2012 drought conditions resulted in limited barge traffic on the Mississippi River due to low water levels (Bi-State Regional Commission, 2020).

Road Infrastructure

The following interstates, highways, trails, and scenic byways are located in Davenport, pass through Davenport, or pass through the greater Quad Cities area (**Table 4**) (City of Davenport, 2005 and 2019; IOWADOT, 2011; ISU, 2018; Dunn, 2021). Reported flooding impacts to these roadways provide insight to common infrastructure that can be affected by climate impacts and cause disruption to MSW management services.

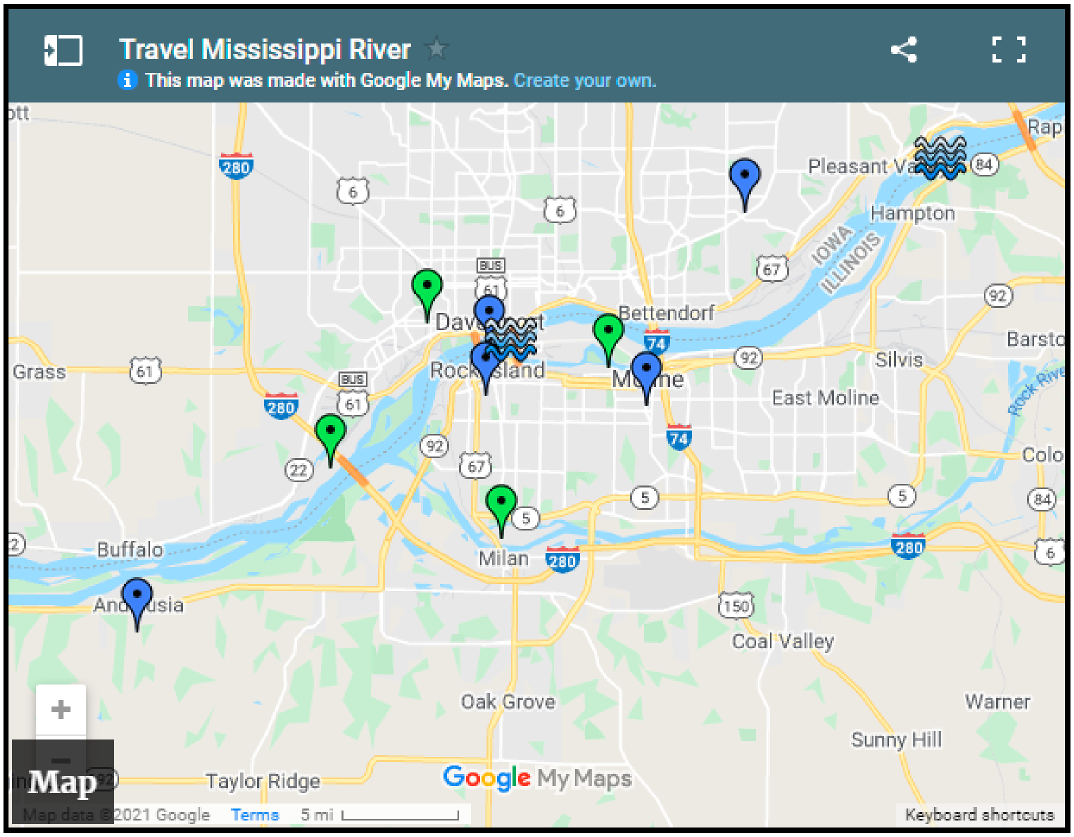
Table 4. Impacts of Flooding on Interstates, Highways, Trails, and Scenic Byways

Name	Description	Flood Impacts
I-74	Primary north-south interstate; runs through Davenport (**Figure 23**)	No flooding or disruption of access was reported for the 2019 flood events In 2008, flooding caused a four-day closure of I-80 causing a 120-mile detour between Davenport and Des Moines (outside of the City of Davenport boundaries)
I-280	Beltway, west-southwest of Davenport (**Figure 23**)	
I-80	North and east of Davenport (**Figure 23**)	
I-88	Connects Quad Cities with Chicago; runs east of the Quad Cities (**Figure 23**)	
US 67	Runs parallel to the Mississippi River in the eastern Davenport area (**Figure 23**)	Closed between US 61 and I-74 near Davenport during the April 2011 flood event
US 61	Runs parallel to the Mississippi River in the central Davenport area (**Figure 23**)	Repeated and prolonged closures during 2019 flood events. US 61 is closed anytime river levels exceed 18 ft. Some spotty access remains for through-traffic to stage 21 ft and no access at 22 ft.
US 6	Runs east-west through Davenport (**Figure 23**)	No flooding or disruption of access was reported for the 2019 flood events
Great River Road	Part of a 3,000-mile network along the Mississippi River running from Canada to the Gulf of Mexico (**Figure 24**). Includes the Nahant Marsh.	Repeated and prolonged closure in Davenport where the River Road and US 61 intersect
American Discovery Trail (ADT)	Proposed 6,356-mile coast-to-coast multi-use recreational trail. Runs through downtown Davenport as the Riverfront Trail (**Figure 25**) and is co-located with the Mississippi River Trail	Various trails were closed during the 2019 flood events. All riverfront trails are impacted beginning with spotty flooding at 14 ft and generally fully flooded by 16.5 ft.
Mississippi River Trail (MRT)	For 11 miles, runs through Davenport downtown along the Mississippi riverfront (**Figure 26**). Part of 2,000 miles between Mississippi River headwaters and Gulf of Mexico under development.	
Hiawatha Pioneer Trail	Trail was abandoned in 2008 and is no longer supported by the IA Department of Transportation	

In addition, the 2025 Comprehensive Plan refers to a total of 43 roadway bridges that are maintained by the City. Temporary loss of access to the Government/Arsenal Bridge did occur in 2019 due to a flood barrier breech. However, all other bridges across Davenport or to the river remained open with the exception of the rail/bridge located on River Dr just east of S Concord. **Table 5** summarizes secondary/tertiary roadways and bridges that were impacted by the flooding events. In addition to floods, an extreme heat event in 2017 was reported to have caused the 56-hundred block of Valley Dr. in neighboring Bettendorf to buckle (Lense, 2017).

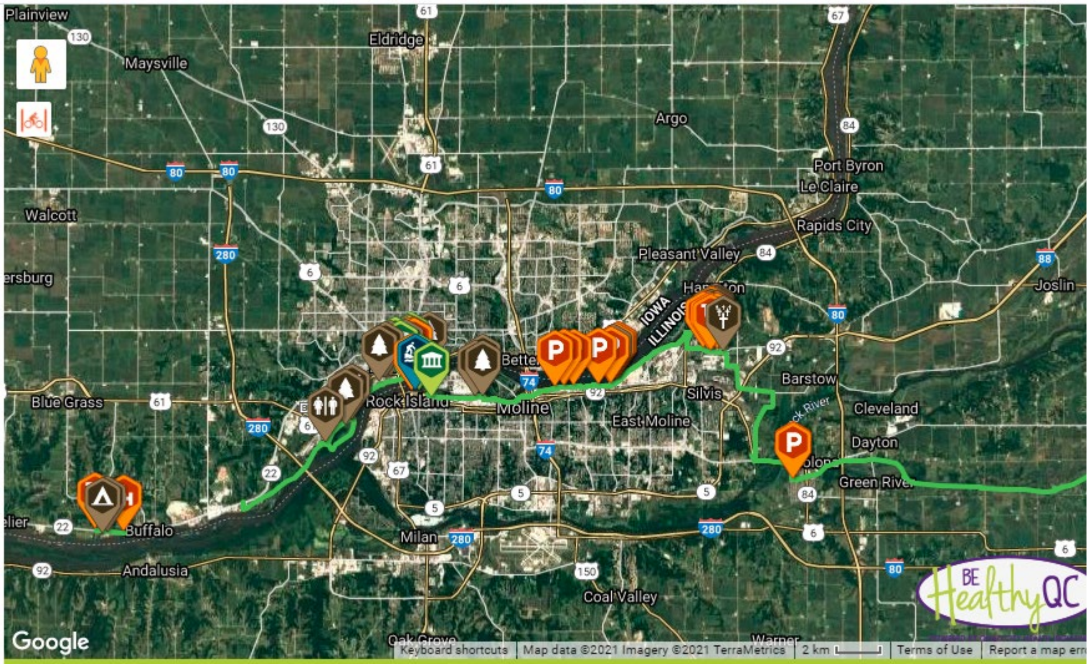
Table 5. Roadway Closures during the 2019 Flood (City of Davenport, 2019)

Date	Repeated or Prolonged Closure/Access Details
November 2019	S Concord closed between River Dr and Utah until river levels fall below 14 ft.
October 2019	– S Concord between River Dr and Utah. – Gaines St S of River Dr and portions of River Drive. River Dr is impassable between Gaines and Myrtle and between Pershing and Perry. – Credit Island. – Recreational trail between Marquette and Credit Island until river levels fall below 14.5 ft. – Riverfront walk between LeClaire Park and Marquette.
September 2019	– S Concord between River Dr and Wapello and between River Dr and Utah. – Gaines St S of River Dr. – Credit Island and the recreational trail between Marquette and Credit Island. – Riverfront walk between LeClaire Park and Marquette.
July 2019	S Concord between River Dr and Miller Ave and between River Dr and Wapello.
June 2019	– W 2nd St between Division and Brown Streets. – Access the Centennial Bridge from 3rd, 4th and Gaines Streets. – Wapello between River Dr and S Concord. – River Dr/Hwy 61 between Rockingham Rd/Hwy 22 and 8th St in Bettendorf. – S Concord between Utah and River Dr. – Miller Ave between S Concord and Railroad Ave. – Beiderbecke is closed. – Credit Island, Centennial and LeClaire Parks, and the Riverfront Recreational Trail between Credit Island and Davenport City Limits/Bettendorf.
May 2019	– W 2nd St closed to through traffic between Division and Brown Streets. – River Dr between Rockingham Rd/Hwy 22 and Bettendorf. – Bettendorf closure of River Dr at 6th, 8th and Forest. – River's Edge Sport Facility.
April 2019	– All streets between Main and Iowa Streets south of 2nd St. – 2nd St closed to through traffic between Division and Iowa Streets. – W 2nd St closed to through traffic between Division and Brown Streets. – Wapello between River Dr and S Concord is closed. – S Concord between Utah and River Dr. – Miller Ave between S Concord and Railroad Ave. – Beiderbecke, River's Edge Sport Facility, Historic Union Station. – Credit Island, Centennial and LeClaire Parks, and the Riverfront Recreational Trail. between Credit Island and Davenport City Limits/Bettendorf. – River Dr/Hwy 61 between Rockingham Rd/Hwy 22 and River St.
March 2019	– River Dr between Division St and Bridge Ave. – S Concord between Utah and River Dr. – Periodic lane reductions and closures on River Dr. – Wapello and Miller between Railroad Ave and S Concord. – Miller Ave between S Concord and Railroad Ave. – Beiderbecke, Credit Island, Historic Union Station. – The Riverfront Recreational Trail between Credit Island and LeClaire Park.



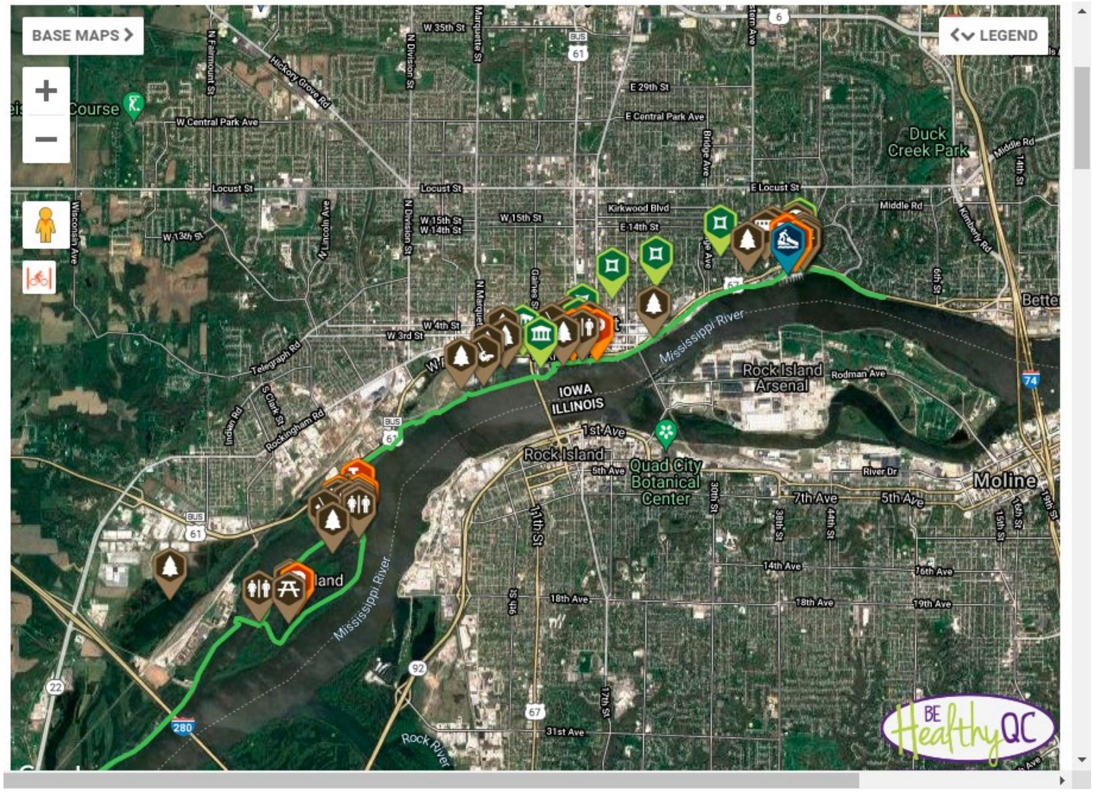
Source: IDED, 2021

Figure 23. Great River Road Attractions in and near Davenport



Source: QCTrails, 2021

Figure 24. American Discovery Trail in and near Davenport



Source: QCTrails, 2021

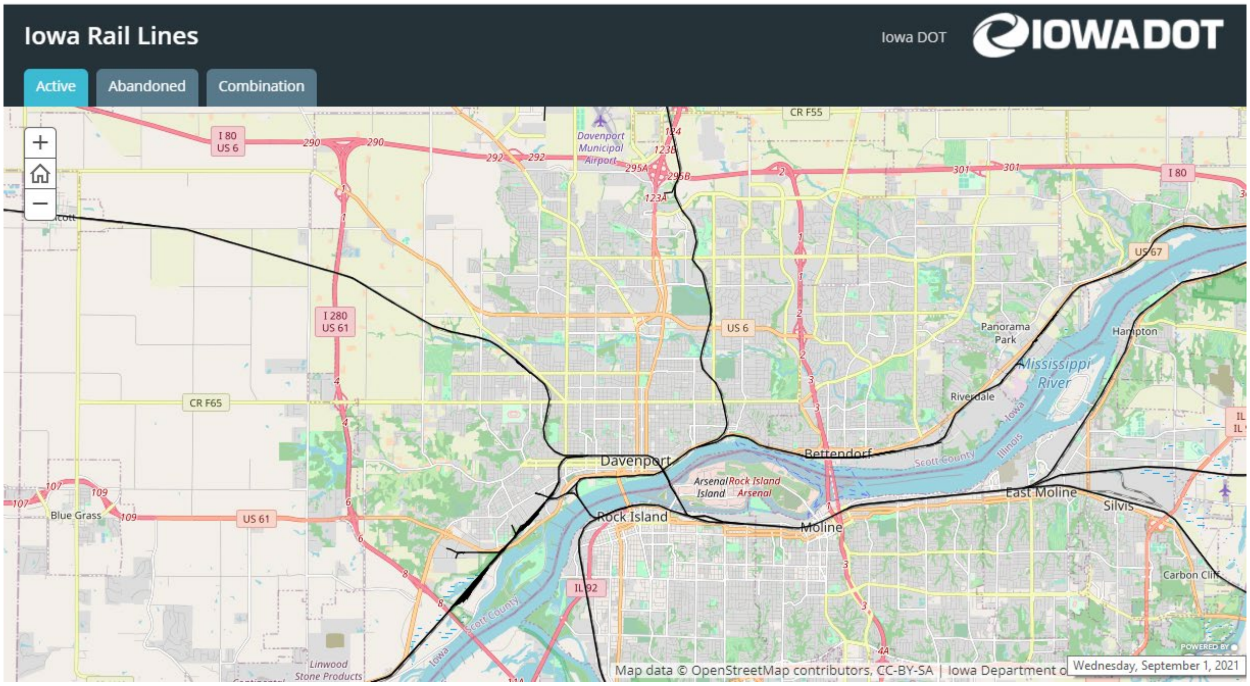
Figure 25. Mississippi River Trail (MRT)

Rail Infrastructure

Figure 26 shows the active rail lines that run through Davenport (IOWADOT, 2021):

- Iowa Interstate RR Ltd., runs east-west
- Canadian Pacific; Dakota, Minnesota and Eastern, runs north-south
- Canadian Pacific; Dakota, Minnesota and Eastern; BNSF, runs east-west along the Mississippi River

The Iowa DOT reported that during 2010 flood events Dakota, Minnesota and Eastern Railroad was going to be shut down in Davenport when Mississippi River levels reached 17.3 ft and rail traffic was going to be rerouted (Iowa DOT, 2010). In 2019, Canadian Pacific Railroad (CP Rail) began to raise train tracks by 20 inches in three downtown locations (Perry, Main and Brady Streets) (Hansen, 2019). Also, CP Rail plans to continue rail traffic through approximate river stage 21 ft when Iowa American Water Company has to close their flood control gates and access to the tracks is lost at that location (Dunn, 2021).



Source: IOWADOT, 2021

Figure 26. Active Rail Lines in and near Davenport

Air Infrastructure

Air traffic is supported by Quad City International Airport in the nearby Moline, Illinois and the Davenport Municipal Airport, located in northern Davenport, near I-80 and US 61. Interruption of air traffic was not reported during the 2019 flood events (City of Davenport, 2019).

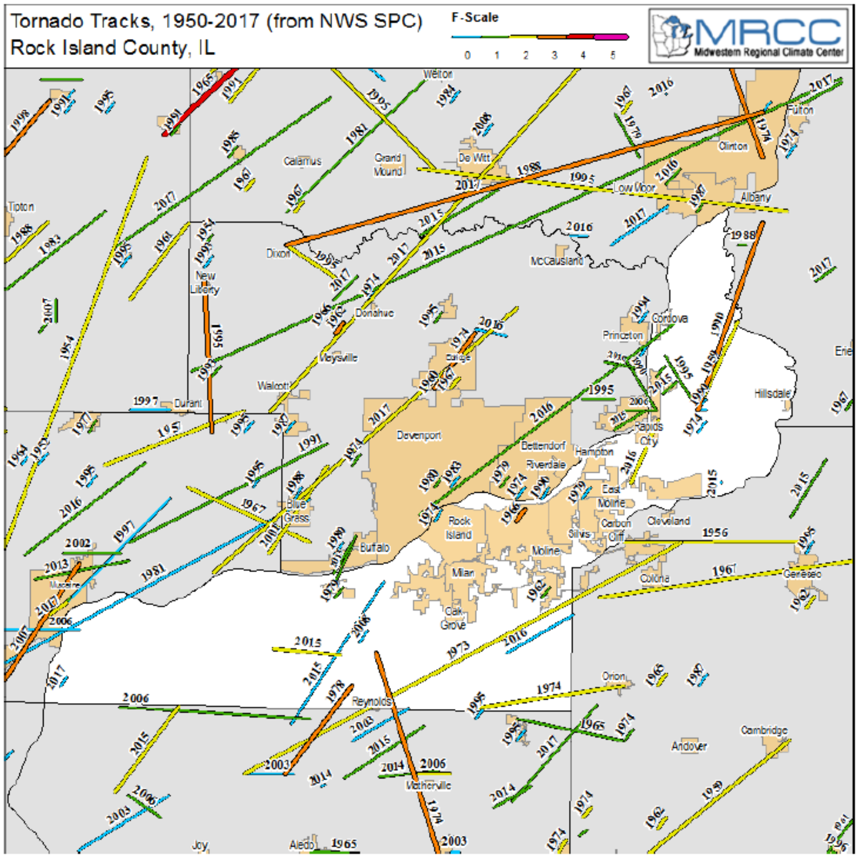
Transit Infrastructure

The City of Davenport maintains a public transportation service, CitiBus, which is supported, together with the long-distance bus systems Trailways and Greyhound, by a Ground Transportation Center (City of Davenport, 2005). Furthermore, paratransit exists through River Bend Transit (RBT), as well as vanpool services and a seasonal water taxi service through MetroLINK. The Ground Transportation Center remained operational during the 2019 flood events (City of Davenport, 2019). Minor detours to CitiBus and Transit routes are necessary during River Drive closures (Dunn, 2021). The Rock Island MetroLINK transit station is protected by a levee on the Island’s northern border (Bi-State Regional Commission, 2020).

Gas and Electric Utilities

Power in Scott County is supplied by three major entities (Alliant Energy, Illinois Power Company, MidAmerican Energy Company) and municipality owned utilities. Four pipelines supply natural gas (A.N.R. Pipeline, Natural Gas Pipeline of America, Northern Border Pipeline Northern Natural Gas Pipeline) (Scott County, 2021). Some downed power lines were reported during the 2019 flood events (City of Davenport, 2019).

The National Weather Service reported nine tornados in 2015 in the Quad Cities area, some resulting in downed power lines (National Weather Service, 2021). **Figure 27** shows tornado tracks and associated strength for the Davenport area since from 1950 to 2017.



Source: Bi-State Regional Commission, 2020

Figure 27. Tornado Tracks 1950-2017

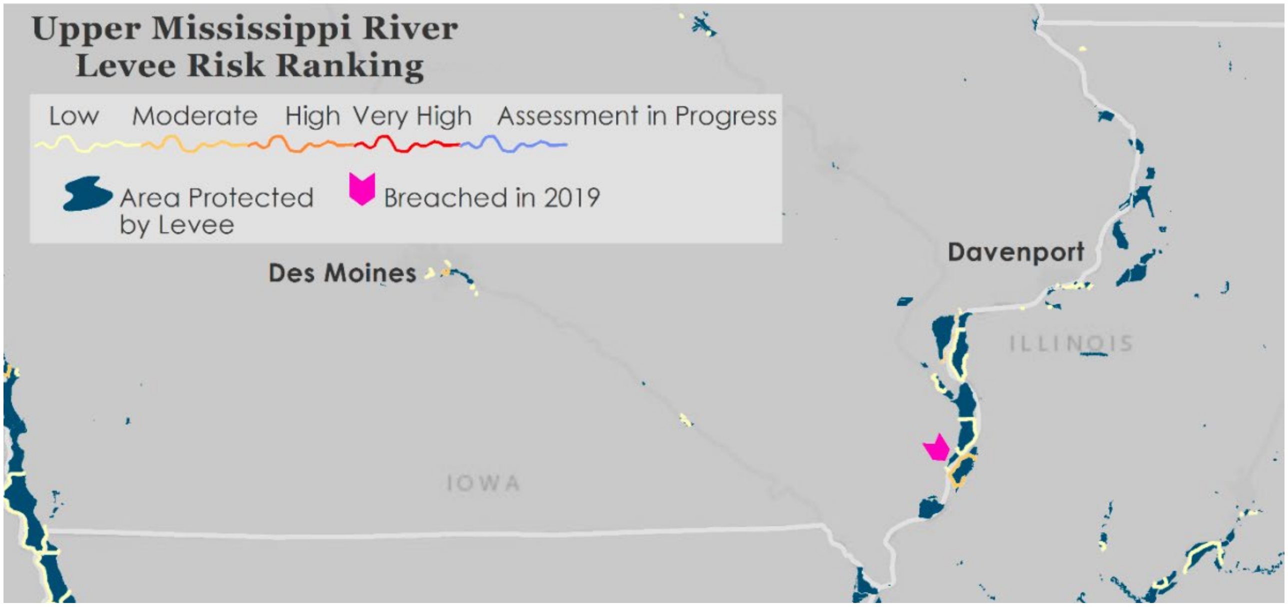
Water Supply

Water for Davenport and neighboring Bettendorf is provided through the Iowa American Water Company. Sanitary sewer service is provided by municipally owned systems (Scott County, 2021). Sanitary sewer overflows conditions were reported during the 2019 flood events (City of Davenport, 2019).

Levee Infrastructure

Figure 28 shows areas protected by levees, levee risk ranking and levee breaches in the Davenport area. Davenport has a low to moderate risk ranking. No levee breaches were reported during the April 2019 flood event.

During the event, failure of temporary flood barriers caused widespread downtown flooding (ELPC, n.d.). Currently, Davenport is without a permanent flood barrier, however, Davenport uses a variety of structural and non-structural strategies including both retreating from the river and letting it flow in some areas and preventing encroachment of municipal infrastructure and transportation routes (Dunn, 2021).



Source: ELPC, n.d.

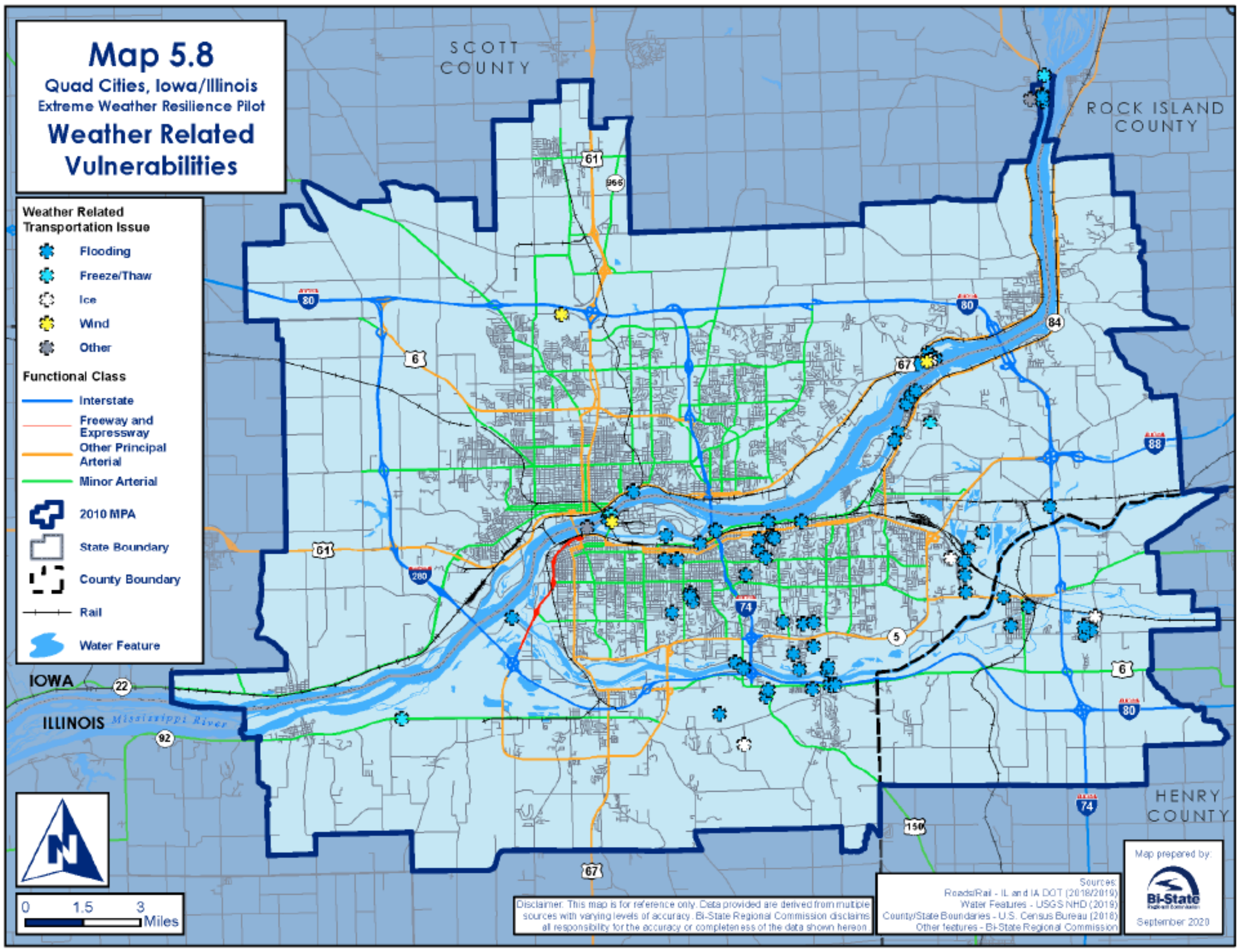
Figure 28. Levee Risk Ranking

Quad Cities Vulnerability Assessment

The Bi-State Regional Commission (2020) conducted a vulnerability assessment and identified the following vulnerable infrastructure (listed here for Davenport only) (also see **Figure 29**):

- Transportation network areas and road segments and corridors vulnerable to flooding:
  - North Fairmount Street
  - Hickory Grove Road
  - North Division Street
  - North Harrison Street
  - North Brady Street
  - Eastern Avenue
  - Kimberly Road
  - Northern access to Centennial Bridge
  - Interstate 74 Bridge
  - Arsenal Bridge
- High traffic corridors vulnerable to extreme temperature and freeze/thaw cycles causing pavement buckling, fracturing joint heaving, and potholes:
  - Hickory Grove Road
  - West 53rd Street and North Division Street
  - 53rd Street corridor
  - Northwest Boulevard near Northpark Mall
  - Welcome Way/North Harrison Street near Duck Creek
  - Locus Street/Middle road Corridor
  - Interstate 74 Bridge
  - Centennial Bridge
  - Interstate 280 Bridge
- Corridors susceptible to ice and snow:

- Interstates 80, 280, 74, and 88
- U.S. 61, 6, and 67
- Highway 22
- West Kimberly Road/Hickory Grove Road
- 53rd Street
- East Kimberly Road
- River Drive
- Utica Ridge Road
- Middle Road
- Northwest Blvd



Source: Bi-State regional Commission, 2020.

Figure 29. Weather Related Vulnerabilities in the Quad Cities Region

Chapter 4:
Sustainability Assessment of Current MSW Management and Potential Future Measures

Chapter 2 provided a summary of historic weather events and trends in the Davenport region. Chapter 3 included assessment of the vulnerability of waste infrastructure to likely climate events that impact the region. In Chapter 4, a sustainability assessment is presented characterizing the cost, environmental life-cycle impacts and environmental justice aspects of MSW management. Analyses of the current MSW systems and targeted measures that can be implemented by the City of Davenport to improve sustainability and resilience were conducted using EPA's MSW DST and EJ Screen. Presented in this chapter are background on Davenport's MSW management system, measures that were analyzed, key assumptions employed in modeling, and summary of results and findings.

4.1 Davenport's MSW Management System

The City collects and manages 80,000 metric tons per year from 40,400 households as well as commercial and institutional generators. The City also operates drop-off sites for organics and recyclables. The fraction of different materials in the waste stream is important to understanding the potential for recycling, composting and other potential waste management alternatives. The composition of MSW generated by Davenport in shown in **Figure 30**. Approximately 45% of the materials are recoverable recyclables and 20% are compostable materials. At present, a total of approximately 21% of the materials generated are recovered for recycling or composted.

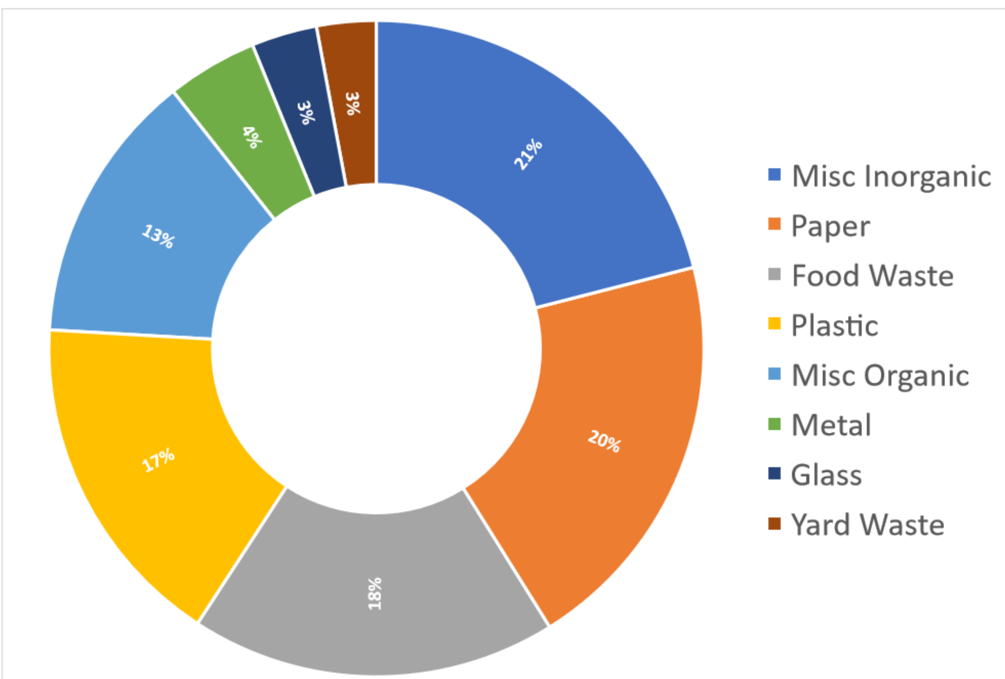


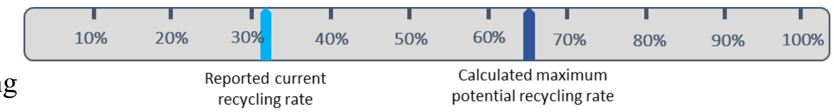
Figure 30. Davenport MSW Percent Composition (as generated)

Davenport region waste management facilities are mapped in **Figure 31**. The current solid waste management system includes recycling, organics composting, and landfill disposal facilities. The Waste Commission of Scott County operates the following regional solid waste management facilities:

- Scott Area Regional Landfill
- Scott Area Recycling Center (i.e., materials recovery facility [MRF])
- Electronics Recovery and Household Hazardous Material Center

The City of Davenport operates one solid waste management facility:

- Davenport Compost Facility



At present, a total of 21% of the materials and organics generated are currently recovered for recycling or composting. Based on the composition of materials in the MSW stream, it was estimated that 45% of the materials in the MSW stream are potentially recoverable recyclables and 20% are potentially compostable organics (yard and food waste), equaling a total maximum potential recycling rate of 65%. **Figure 32** illustrates the flow of the 80,000 metric tons of MSW generated per year from the point to collection to ultimate disposition.

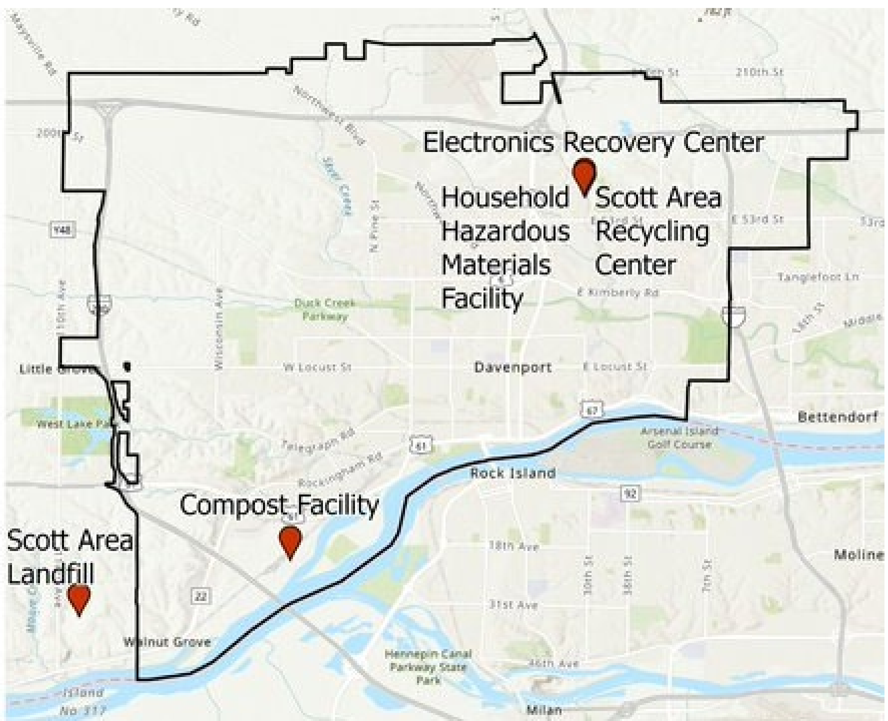


Figure 31. Davenport Area Waste Management Facilities

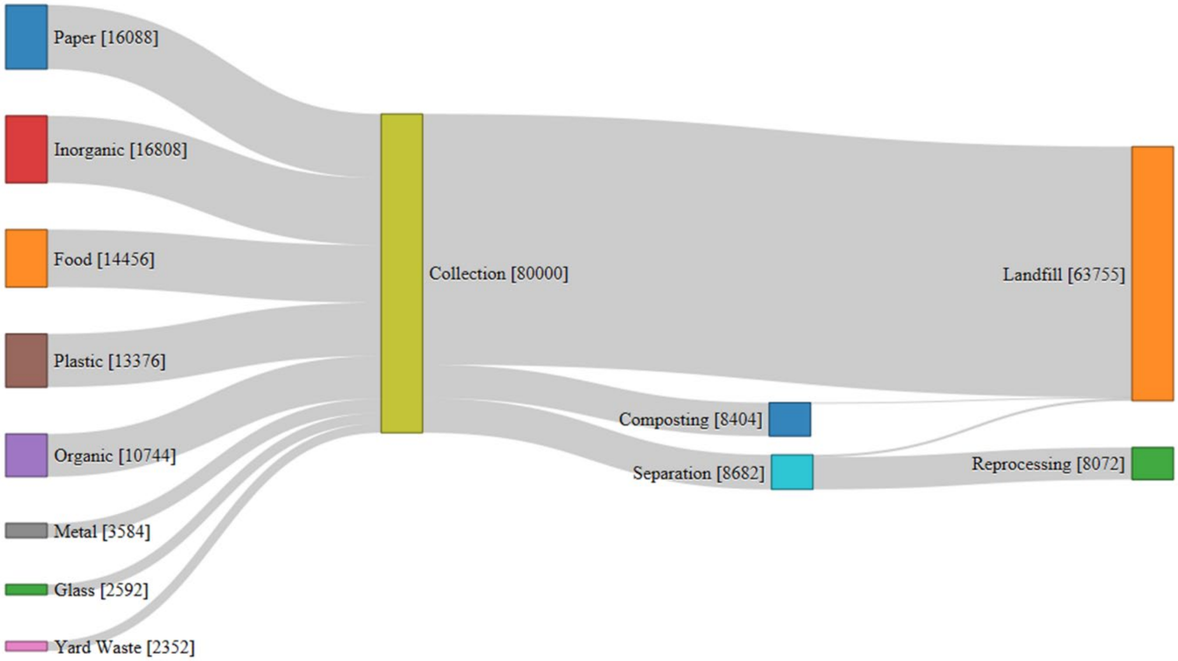


Figure 32. Davenport Flow of MSW Materials Through End-of-Life Pathways
(valuesV represent metric tons as generated, collected, and sent to management endpoints). Not corrected for significant figures.

4.2 Climate Events and Waste Infrastructure Vulnerability

Climate events that affect the Davenport area primarily include Mississippi River and secondary river and stream flood events. As shown in **Figure 33**, none of the Waste Commission of Scott County facilities are located immediately within flood impact boundaries. However, the City of Davenport Compost Facility is vulnerable due to its location adjacent to the Mississippi River and situated within the Mississippi flood hazard zone. The facility has closed or could not be accessed during April, May, and June 2019 flood events (City of Davenport, 2019). The facility has been inaccessible for 75 days during the past 25 years due to flooding. During closure, yard waste drop-off service is relocated to the landfill until it can be transport to the compost facility. The City received a grant in 2019 from the Department of Commerce's Economic Development Administration to improve flood protection measures at the compost facility. Specific measures being implemented include construction of an earthen berm system to the height of three feet over a 500-year flood event (river stage 28.5) and installation of interior pumping systems that ensure the plant continues to operate efficiently and effectively during high water events from the Mississippi River.

In addition to flooding of the Mississippi River, severe creek flooding of other rivers and streams such as Duck Creek have occurred repeatedly. Per the Scott County Waste Commission, Duck Creek flooding in

1990 had a significant impact on the landfill due to the significant amount of debris generation that required disposal. Also prevalent in Davenport are hail and thunderstorms, road deterioration from freeze-thaw cycles and road and river transportation impacts due to impairment of visibility from fog and fires.

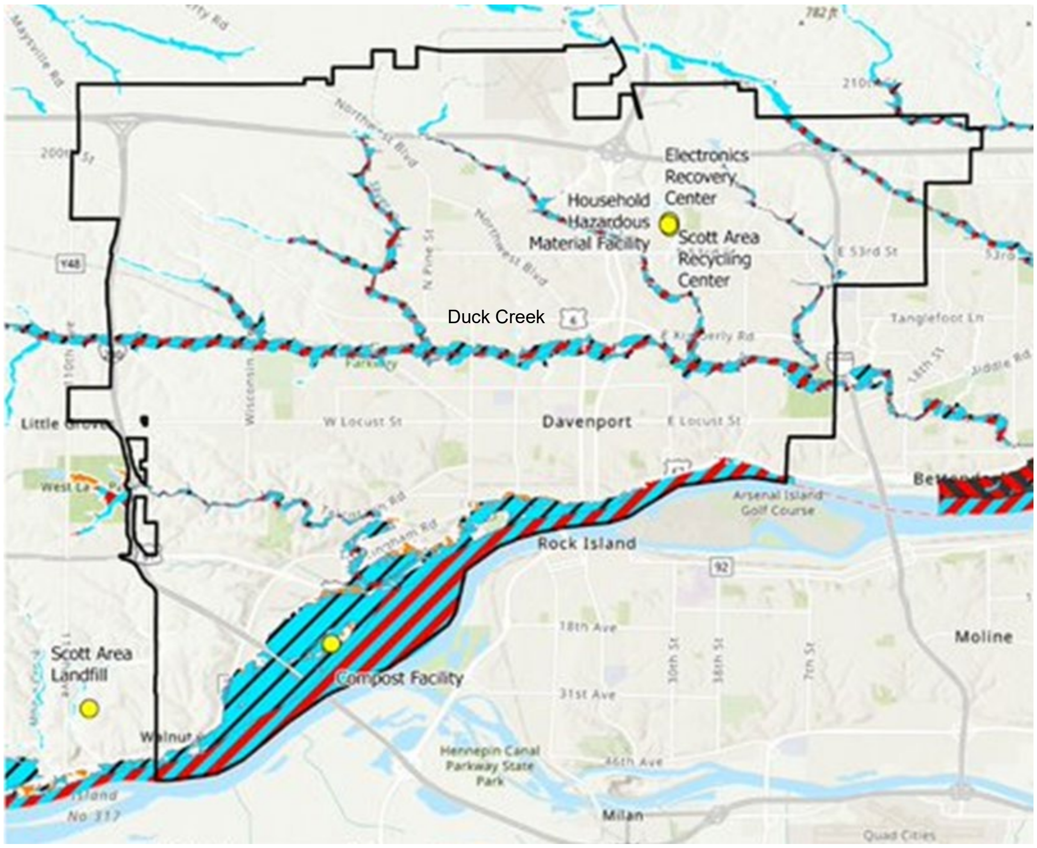


Figure 33. Davenport Region Flood Risk and Waste Infrastructure Locations

4.3 Waste Management Scenario Analyses

The US EPA's MSW DST was used to conduct targeted analyses of topics. The MSW DST includes national average default data and assumptions for waste collection and management operations. The tool was tailored to reflect City of Davenport conditions using available data and information about local waste generation and composition, waste collection and hauling, existing management infrastructure, and regional energy and market factors. Cost and life cycle environmental aspects were calculated using the MSW DST to assess the benefits of:

- current and maximum potential recycling and composting rates,
- switching from diesel powered to electric waste collection vehicles,
- adding a new compost facility to enhance organics management capacity.

The methods used in the MSW DST to calculate cost are consistent with "full cost accounting" principles and includes capital, operating and maintenance, and labor costs for waste collection and transportation, recycling, treatment, and disposal activities. Revenue from the sale of recyclables, compost product, and energy products are also captured and netted out of cost. The calculated cost is not representative of a tipping or gate fee charged by any facility.

Energy and environmental impact methods are based on life cycle assessment (LCA). LCA is a type of systems analysis that accounts for the complete set of upstream and downstream (cradle-to-grave) energy and environmental aspects associated with systems. In the context of waste management systems, an LCA tracks the energy and environmental aspects associated with all stages of waste management from waste collection, transfer, materials recovery, treatment, and final disposal. For each waste management operation, energy and material inputs and emissions and energy and/or material outputs are calculated. In addition, the life cycle energy and emissions associated with fuels, electrical energy, and material inputs are captured. Likewise, the potential benefits associated with energy and/or materials recovery displacing energy and/or materials production from virgin resources are captured. Taking a life-cycle perspective encourages waste planners to consider the environmental aspects of the entire system including activities that occur outside of the traditional framework of activities from the point of waste collection to final disposal.

Cost and life cycle carbon footprint and life cycle impact from the scenario analyses performed for Davenport are shown in the sections below.

Current and Maximum Recycling and Composting

To assess the benefits of Davenport's current and maximum potential materials recycling and organics composting rates, the following scenarios were modeled using the MSW DST:

- no recycling (landfill only),
- current recycling and composting rates (21%), and
- maximum potential recycling and composting rates (65%).

The analysis assumes that existing recycling and composting facilities have the capacity to meet maximum recycling and composting rates, or new facilities will be built to meet the capacity needs. The current and estimated maximum potential amounts of material recycled and composted are shown in **Table 6**. In **Table 7**, key assumptions used in the MSW DST to conduct the scenario analysis are listed.

Table 6. Assumed Quantities (Metric Tons) of MSW Sent to Management Facilities by Scenario

Scenario	Collection	MRF	Compost	Landfill
No Recycling	79,970	0	0	79,970
Current Recycling	79,970	8,682	8,404	35,123
Maximum Recycling	79,970	31,537	48,444	6,765

Table 7. Key Assumptions Used in the Scenario Analysis

Parameter	Assumption / Setting
General	
Waste Generation	79,970 metric tons
Waste Composition	Davenport average (*see Figure 30*)
Waste Collection Frequency	1 time per week
Transportation Distances*	
Collection to MRF	6 miles one way

Collection to Compost	6 miles one way
Collection to Landfill	15 miles one way
Recycling (MRF)	
Basic Design	Single-stream; semi-automated
Composting	
Basic Design	Windrow
Accepted Material	Yard waste and food waste
Landfill	
Basic Design	Conventional, Subtitle D Type
Landfill Gas Collection Efficiency	75%
Landfill Gas Management	Energy recovery
Assumed Electricity Offset	Regional average

Summary level MSW DST outputs for each of the recycling scenarios is provided in **Table 8**. Detailed results for each scenario are included in Attachment A. Presentation and discussion of select results are provided in the sections that follow.

Table 8. Net Total MSW DST Results* by Recycling Scenario

Impacts	No Recycling (0%)	Current Recycling (21%)	Maximum Recycling (65%)
C Emissions (kg CO2-eq) IPCC AR5 20-year	77,898,989	45,421,219	2,733,379
C Emissions (kg CO2-eq) IPCC AR5 100-year	29,731,311	13,365,547	-15,768,403
Cumulative fossil energy resources (MJ-Eq)	171,172,414	49,830,555	-292,408,912
TRACI acidification (moles of H+-Eq)	1,390,290	-2,328,573	-9,151,080
TRACI eutrophication (kg N-Eq.)	4,630	10,312	14,804
TRACI photochemical oxidation (kg NOx-Eq)	38,215	-569	-71,749
USEtox ecotoxicity total (CTUe)	10,607,759	-120,061,799	-333,825,510
USEtox human toxicity total (CTUh)	1	-4	-14
CO2-Fossil (kg)	3,427,223	-7,787,642	-33,235,852
CO2-Biogenic (kg)	15,378,156	16,455,163	18,060,053
CO2-Stored (kg)	-23,365,484	-19,095,997	-10,498,635
CH4-Fossil (kg)	29,607	1,475	-53,187
CH4-Biogenic (kg)	913,910	665,105	362,418
N2O (kg)	-84	1,496	2,814
CO (kg)	35,460	-45,714	-178,766
NOx (kg)	34,020	-2,605	-70,216
SOx (kg)	2,179	-72,250	-191,517
PM>10 (kg)	-2,339	-120,798	-300,621
PM10 (kg)	2,485	3,087	848
PM2.5 (kg)	2,677	1,251	-2,540
NMVOC (kg)	27,787	25,485	10,958
Lead (kg)	9	3	-9
Cost ($)	5,522,022	13,742,475	12,147,837

*Raw results, uncorrected for significant figures.

Net Annual Cost

Cost results for Davenport show that landfill disposal of all waste would be the least cost option. By maximizing its recycling and composting rate, Davenport could reduce its overall net total cost by virtue of increasing revenues from the sale of recovered materials and compost product. Recycling and composting could be increased through implementation of measures such as education and outreach to waste generators, expanding recycling and organics collection, adding recycling and composting capacity, and/or enhancing end markets for recyclable material and compost product. Additional analyses would be needed to determine options that would benefit the City. in costs for increasing recycled materials. The exact amount of revenue that can be achieved is highly dependent on material markets where prices by material can fluctuate significantly over time. For this analysis, recovery rates for all recyclable (glass, paper, plastic, metals) and compostable (yard and food waste) materials were increased to their maximum level.

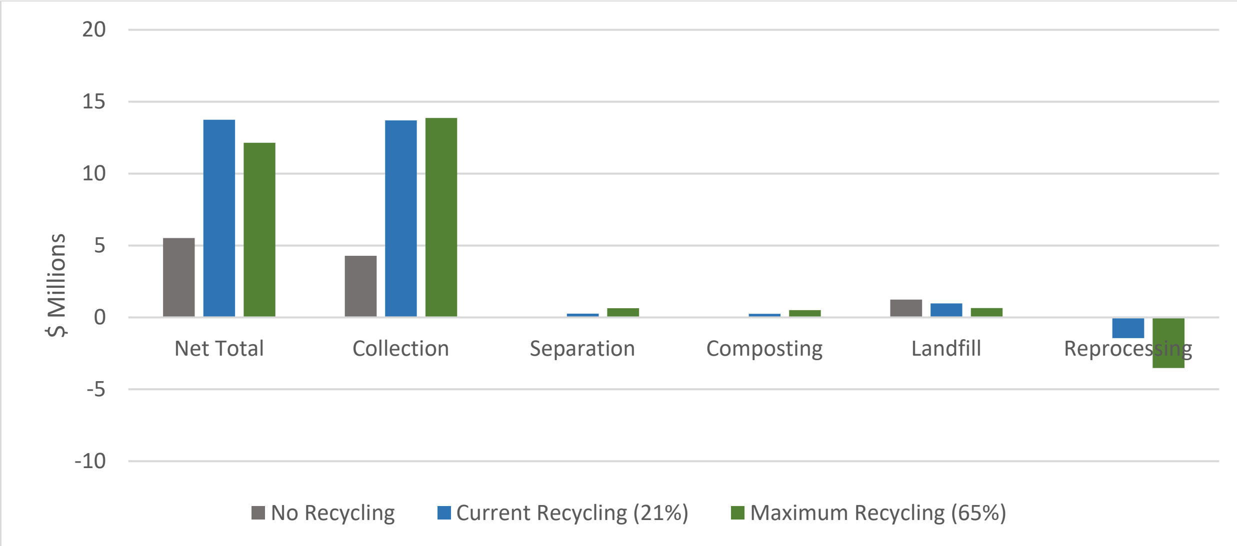


Figure 34. Net Total Annual Cost for Recycling Scenarios Analyzed

Net GHG Emissions

Greenhouse gas (GHG) emissions contribute to the greenhouse effect and can lead to climate change and its associated impacts. From the waste sector, GHG emissions result from the combustion of fossil fuels in the collection and transportation of waste from curbside processing at recycling, composting, and disposal facilities. GHG emission reductions or offsets can result from the displacement of fossil fuels electricity generation, materials recycling, and diversion of organic wastes from landfills where they would product methane (CH_4) emissions. Net annual GHG emissions estimated by the MSW DST includes emissions from collection and transportation, recycling, treatment and disposal processes less GHG emission reductions or savings from recycling and/or energy recovery. GHG emissions are reported by the MSW DST in units of metric tons of CO_2 equivalent emissions ($MTCO_2$-eq), and derived as follows:

$$(\textit{metric tons } CO_2 * 1) + (\textit{metric tons } CH_4 * CH_4 \textit{ GWP})$$

The 100-year CH_4 GWP of 28 and the 20-year CH_4 GWP of 84 are based on IPCC's Sixth Assessment Report (2021) and used to show the impact that different GWP time scales have on landfill carbon emissions. In general, GHG emission reductions from materials management activities can be the result of:

- Avoiding methane emissions from biodegradation of organic wastes in landfills.
- Materials recovery and recycling offsets GHG emissions by avoiding the consumption of energy that otherwise would be used in materials production processes.
- Energy recovery (e.g., via landfill gas to energy) offsets GHG emissions by displacing electricity that otherwise would be produced by the regional electric utility grid mix of fuel sources.

As shown in **Figure 35**, Davenport is currently saving approximately 18,000 (using 100-year CH_4 GWP) to 36,000 (using 20-year CH_4 GWP) $MTCO_2$-eq per year through its recycling and composting programs. If the City were to maximize its recycling and composting rates, approximately 47,000 (100-year CH_4 GWP) to 82,000 (20-year CH_4 GWP) $MTCO_2$-eq in savings could be realized. As noted in the cost analysis, this may also be a more cost-effective scenario.

For this analysis, recovery rates for all recyclable (glass, paper, plastic, metals) and compostable (yard and food waste) materials were increased to their maximum level to yield decreased carbon emissions associated with landfill disposal and increased carbon savings from material recycling.

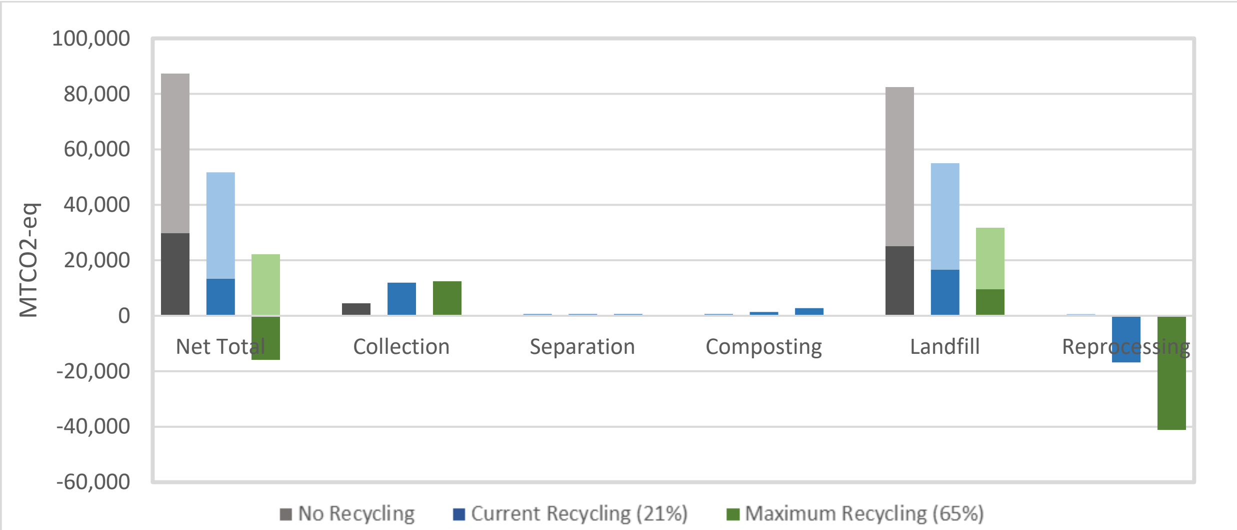


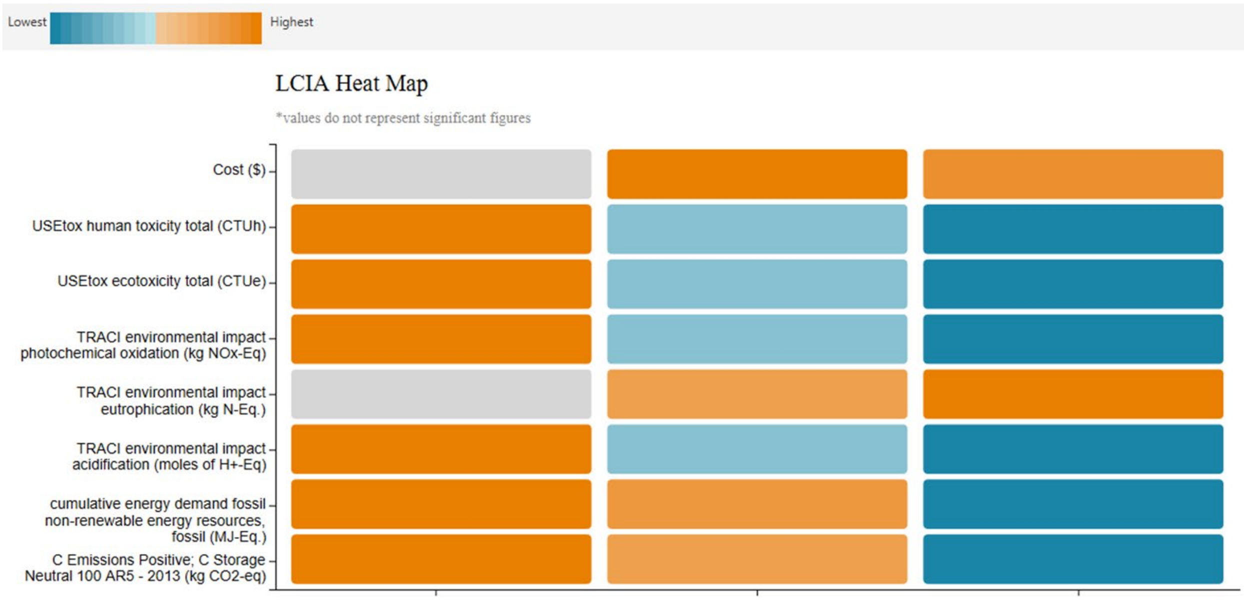
Figure 35. Net Total Annual GHG Emissions for Recycling Scenarios Analyzed
(note: darker areas represent results using 100-year methane GWP; lighter area are results if the 20-year methane GWP is used)

LCA Impacts

Life cycle impact assessment (LCIA) results comparing each Davenport scenario can help city and waste infrastructure and program decision makers better understand and balance environmental, economic, and social factors. The LCIA results generated by the MSW DST use EPA's Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)[7]. TRACI relies on characterization factors quantify the potential impacts that inputs and releases (i.e., emissions) have on specific impact categories in common equivalence units. For example, a commonly known equivalency unit for various GHG pollutants is CO_2-equivalent emissions.

As shown in the LCIA heat map (**Figure 36)**, Davenport's current recycling (including composting) rate provides lower levels of impact than if all waste were landfilled. The City can implement measures to maximize recycling and further reduce waste management related impacts.

[7] Available at: Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI) | US EPA



No Recycling **Current Recycling** **Maximum Recycling**

Figure 36. LCIA Results for Recycling Scenarios Analyzed

Switching to Electric Waste Collection Vehicles

The City of Davenport, Scott County, and private haulers use diesel collection vehicles. Based on MSW DST output, an equivalent of 68 collection vehicles and almost 4 million gallons of diesel fuel are needed per year to collect and haul the city's waste. An analysis was done to estimate the potential cost and environmental benefits of switching to electric collection vehicles. Based on the annual tonnage of MSW collected and hauling distances to local management facilities, along with average diesel and electric vehicle prices and current regional diesel and electricity prices, the cost and environmental differential of switching to electric vehicles was calculated. As shown in **Figure 37**, and over the lifetime of a vehicle, the capital cost for electric collection vehicles is higher than diesel vehicles. However, the operational cost, driven by the price of diesel fuel ($3/gallon) versus electricity (11.2 cents/kilowatt hour), is significantly lower for electric vehicles.

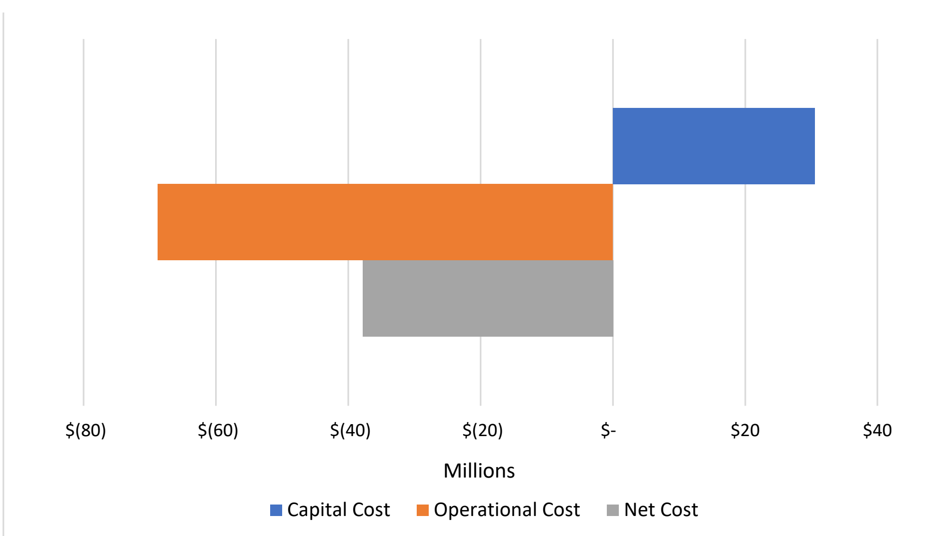


Figure 37. Total Cost (savings) for Switching to Electric Collection Vehicles

Thus, the overall net cost favors electric collection vehicles. The capital cost for electric collection vehicles and current and future forecasted prices for diesel and electricity are important assumptions that should be reviewed carefully.

The emissions differential between electric and diesel collection vehicles is driven by carbon emissions with electric vehicles providing an estimated 255,000 $MTCO_2$ of carbon emissions savings per year. Davenport and the State of Iowa have a significant portion of wind power on their electricity grid and thus a relatively low carbon emission factor per kilowatt hour (kwh) of electricity produced as compared to other states that rely more heavily on fossil fuels. As shown in **Figure 38**, electric vehicles can also reduce emissions of local criteria air pollutants. This reduction will need to be viewed in context of potential increases emission in pollutants from regional electric utilities. As shown in Figure 38, switching to electric collection vehicles results in savings of particulate matter (PM) and sulfur dioxide (SO_2) emissions. Note that PM10 represents inhalable particles with diameters that are generally 10 micrometers and smaller; PM2.5 includes fine inhalable particles with diameters that are generally 2.5 micrometers and smaller.

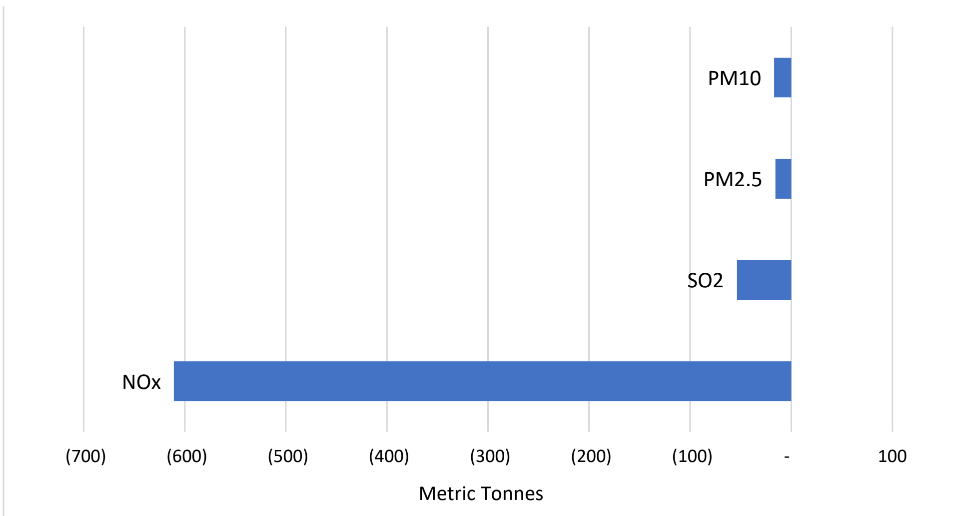


Figure 38. Annual Criteria Pollutant Emissions Reduction of Switching to Electric Vehicles

Expansion of Compost Capacity

Due to the current location of the Davenport Compost Facility in the Mississippi River floodplain and hazard plain and vulnerability to frequent river flood events, expansion of compost capacity via a new facility was analyzed. A likely new location for the compost facility would be at the Scott Regional Landfill which would be approximately ten miles further from the current facility location and result in:

- an annual increase of $142,000 in transportation cost.
- an annual increase of 1,110 $MTCO_2$-eq emissions.

Since the primary difference associated with a new additional facility is assumed to only include the transportation distance from the collection route(s) to the compost facility, potential increases in local emissions of criteria air pollutants, as shown in **Figure 39**, associated with this increased transportation distance should also be considered. One option to reduce the increase in emissions due to a new facility location could be to employ electric collection vehicles for organics.

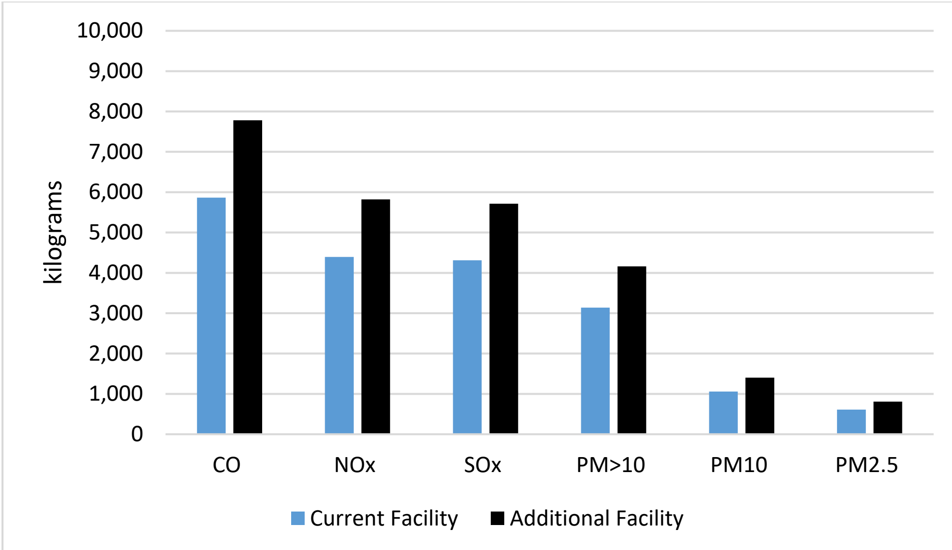


Figure 39. Annual Transportation Emissions to Current and New Additional Compost Facility

4.4 Environmental Justice

Environmental justice is another element of sustainability and critical to EPA's mission to protect human health and the environment. The evaluate potential environmental justice concerns, EPA's EJScreen[8] was used to map select environmental and demographic socioeconomic indices in relation to Davenport region waste facility locations. Sharing EJ data and information can enhance the sustainability of waste infrastructure by helping communities like Davenport to identify and address potential environmental justice concerns.

Air pollution affects human health in communities across the country. In **Figure 40**, EJScreen Air Toxics Respiratory Hazard Index was layered with Davenport area waste management infrastructure to provide a map of potential local air respiratory hazard in relation to waste management facilities. Respiratory pollutants and related impacts are a common health concern associated with waste management activities and facilities. The Air Toxics Respiratory Hazard Index indicates the ratio of exposure concentration to health-based reference concentration. Darker areas on the map are those with lower air respiratory hazard; lighter areas are those with higher hazard rating.

Figures 41 and 42 provide demographic socioeconomic indicators including low-income and people of color indices. These indices were also layered with Davenport area waste management infrastructure to provide a map of potential environmental justice concerns in relation to waste management facilities.

[8]Available at: EJScreen: Environmental Justice Screening and Mapping Tool | US EPA:

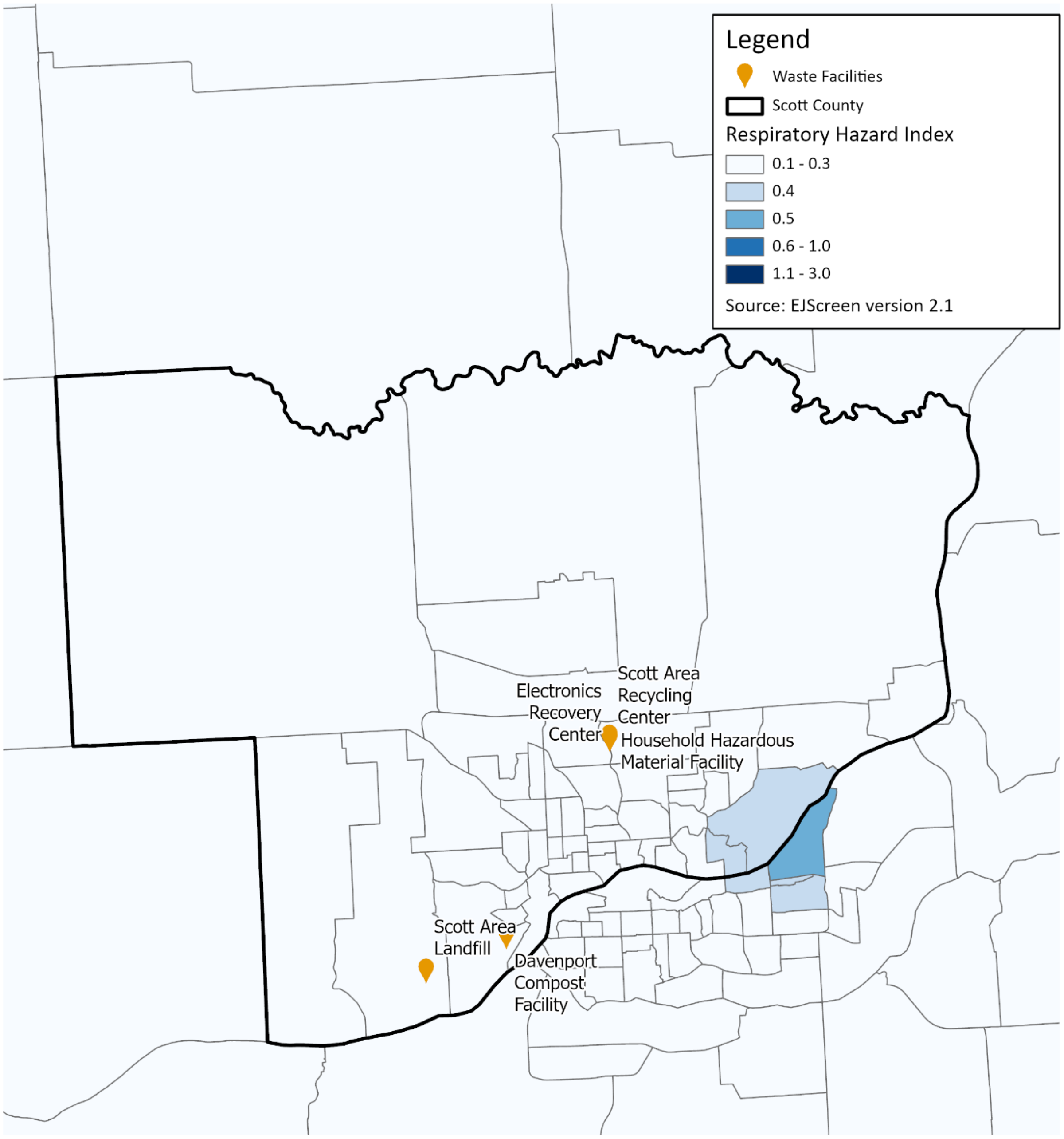


Figure 40. EJ Screen Air Toxics Respiratory Hazard Indicator and Waste Management Facilities in the Davenport Region

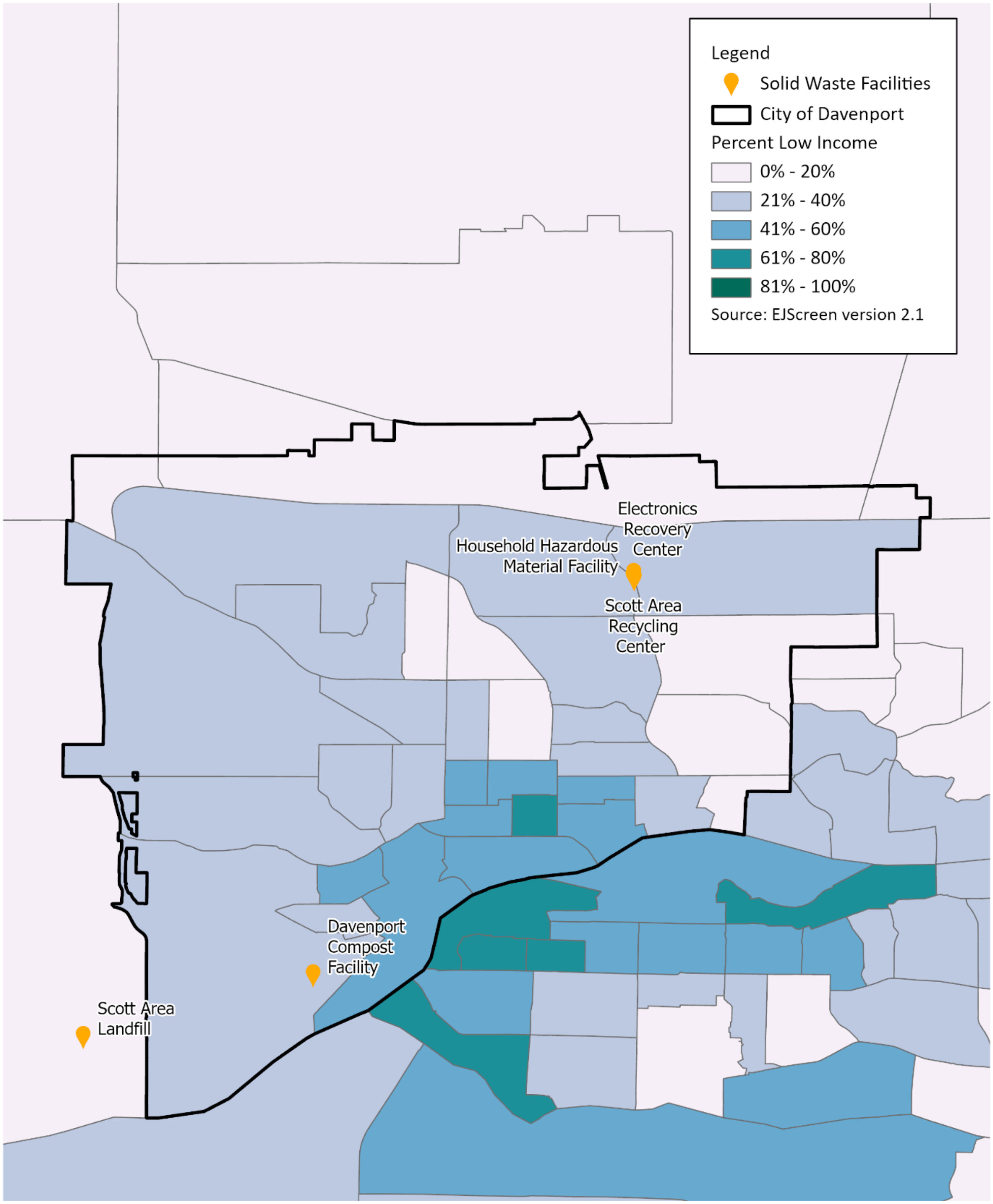


Figure 41. EJ Screen Low Income Indicator and Waste Management Facilities in the Davenport Region

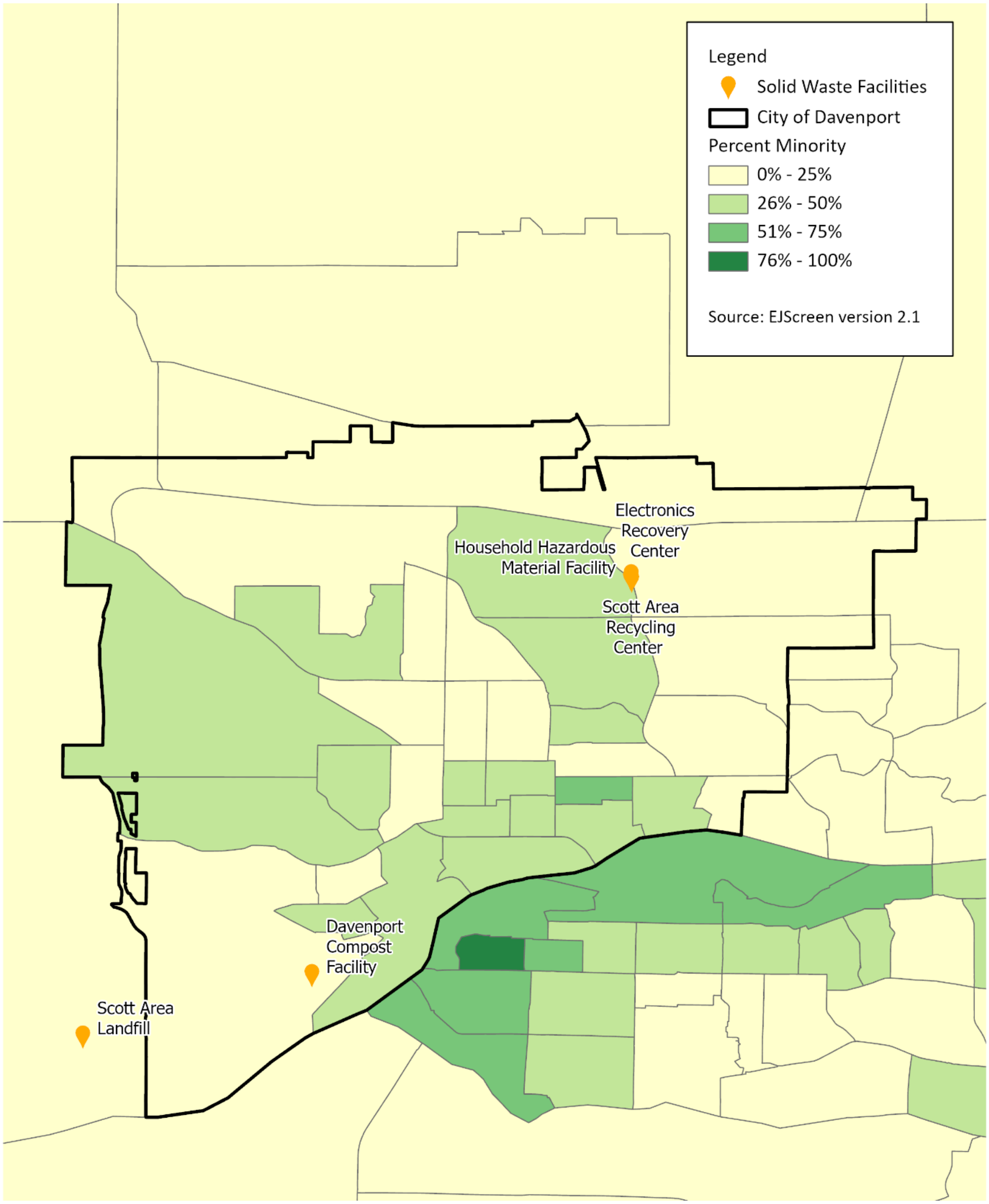


Figure 42. EJ Screen People of Color Indicator and Waste Management Facilities in the Davenport Region

Chapter 5:
Concluding Remarks

This report examines the resilience of waste collection and management infrastructure to climate impacts (e.g., flooding) and sustainability—including cost, environmental impacts and environmental justice aspects of facility siting. The data sources, methods, and tools presented can be applied to river and flood-prone communities to evaluate their vulnerabilities. This project intended to provide a guideline for better understanding of risks posed by changing climate (e.g., flooding) and possible impacts on waste management infrastructure and its operation. Existing tools and data resources created by the State of Iowa (e.g., Iowa Flood Information System) were used to characterize potential climate events and associated impacts. Tools from the U.S. Environmental Protection Agency (EPA) including the Disaster Debris Recovery Tool (DDRT) was used to identify regional waste management infrastructure and the Municipal Solid Waste Decision Support Tool (MSW DST) was used to characterize the cost and life-cycle environmental impacts of MSW management and infrastructure options. EPA's Environmental Justice tool, EJScreen, was also used to evaluate social aspects of waste facility locations

Climate-related impacts can generally be categorized into three components: temperature, precipitation, and flooding (via storms, sea level rise, hurricane storm surge). Literature has been focused on precipitation and flooding impacts rather than temperature related impacts. Therefore, the study focused on precipitation and flooding impacts.

The City of Davenport, Iowa was selected as a case study site based on its location on the Mississippi River, availability of data, and proximity to a varied set of waste facilities. Over the last 80 years, precipitation in Iowa has increased in frequency and intensity. This change has impacted hydrologic flows and led to an increase in riverine and stream flows by 20-50% has been observed (US EPA, 2011). Natural disasters and weather extremes that affect the Davenport region are mainly associated with Mississippi River flood events, hail, wind, and thunderstorms. In addition to those extreme events, the Bi-State Regional Commission (2020) pointed to road impacts from freeze-thaw cycles, road and river navigation impacts from fog, and impairment of visibility from fires. Historic precipitation and flooding data were collected and overlaid with the waste management infrastructure (specifically keeping in mind location, access, and engineering design). Potentially vulnerable infrastructure was identified and mapped.

A scenario-based approach was taken to evaluate current benefits of Davenport's MSW management system and potential future interventions to address climate vulnerability and sustainability. Specifically, the cost and environmental aspects associated with potential future new compost facility to expand organics management capacity. Since the Davenport Compost Facility location in the Mississippi floodplain the location for a new facility was assumed to be at the Scott County landfill. The City pursued and received a grant in 2019 from the Department of Commerce's Economic Development Administration to improve flood protection at the Davenport Compost Facility. The grant is being used to construct an earthen berm system to the height of three feet over a 500-year flood event (river stage 28.5). In addition, the project will install interior pumping systems that ensure the plant continues to operate efficiently and effectively during high water events from the Mississippi River. Regional geology and groundwater resources are characterized in Section 2.3 and potential vulnerability of those resources to flooding events. Analysis of specific impacts to groundwater resources was not performed and beyond the scope of this report.

In addition, the cost and environmental aspects of switching to electric waste collection vehicles were analyzed using the MSW DST results for annual collection vehicle miles traveled and fuel consumption and comparing to cost and emissions if an equivalent number of electric collection vehicles. EJ aspects of current facilities were also evaluated using data and information about local hazardous air pollution, low-income, and people of color from EPA's EJScreen.

The results from this project are two-fold: 1) to better understand the nature of climate impacts on communities and how those impacts can affect waste management infrastructure, and 2) to assess the sustainability aspects of MSW management. There are some caveats to this analysis. For example, the analysis looked at individual facility flooding; however, other factors might influence the availability of the waste management facility such as inundation of access roads, or worker availability in the event of a storm. These aspects of waste management could be covered under emergency management planning processes. The study is not intended for emergency management or analysis of options during an event.

The insights gathered from scenario analysis revealed that there can be opportunities to be leveraged if intensity and frequency of precipitation events continue to increase for the region. Planners could utilize these opportunities to better design the system to be more resilient and responsive at cheaper costs, and in some cases resulting in better environmental outcomes (e.g., reduced air emissions). These opportunities include:

- enhancing facility flood resiliency (or relocating vulnerable facilities) such as the current efforts by Davenport to construct berms and install pumping systems at their compost facility;
- expanding recycling and composting through measures such as education and outreach to waste generators, expansion of recycling and organics collection, recycling and composting capacity, and/or enhancing end markets for recyclable material and compost product; and
- switching the waste collection vehicle fleet (or part of the fleet) to electric vehicles.

Additional analyses would be needed to determine which options would be a best-fit and benefit the City most.

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Attachment A
Detailed Scenario Modeling MSW DST Results

Table A-1. MSW DST Results for the No Recycling (Landfill Only) Scenario

Impacts	Total	Collection	Transportation	Separation	Composting	Landfill	Reprocessing
C Emissions (kg CO2-eq)	77,898,989	4,848,141	0	0	0	73,050,847	0
Cumulative fossil energy resources (MJ-Eq)	171,172,414	76,990,490	0	0	0	94,181,923	0
TRACI acidification (moles of H+-Eq)	1,390,290	530,518	0	0	0	859,772	0
TRACI eutrophication (kg N-Eq.)	4,630	526	0	0	0	4,105	0
TRACI photochemical oxidation (kg NOx-Eq)	38,215	6,087	0	0	0	32,128	0
USEtox ecotoxicity total (CTUe)	10,607,759	11,747,876	0	0	0	-1,140,117	0
USEtox human toxicity total (CTUh)	1	1	0	0	0	0	0
CO2-Fossil (kg)	3,427,223	4,192,735	0	0	0	-765,512	0
CO2-Biogenic (kg)	15,378,156	27,402	0	0	0	15,350,754	0
CO2-Stored (kg)	-23,365,484	1,293	0	0	0	-23,366,777	0
CH4-Fossil (kg)	29,607	6,857	0	0	0	22,750	0
CH4-Biogenic (kg)	913,910	37	0	0	0	913,873	0
N2O (kg)	-84	42	0	0	0	-126	0
CO (kg)	35,460	7,733	0	0	0	27,727	0
NOx (kg)	34,020	5,778	0	0	0	28,242	0
SOx (kg)	2,179	5,667	0	0	0	-3,488	0
PM>10 (kg)	-2,339	4,130	0	0	0	-6,470	0
PM10 (kg)	2,485	1,395	0	0	0	1,090	0
PM2.5 (kg)	2,677	803	0	0	0	1,874	0
NMVOC (kg)	27,787	5,520	0	0	0	22,267	0
Lead (kg)	9	2	0	0	0	6	0
Cost ($)	5,522,022	4,282,280	0	0	0	1,239,742	0

Table A-2. MSW DST Results for the Current Recycling Scenario

Impacts	Total	Collection	Transportation	Separation	Composting	Landfill	Reprocessing
C Emissions (kg CO2-eq)	13,365,547	11,931,343	675	167,614	1,384,198	16,695,663	-16,813,945
Cumulative fossil energy resources (MJ-Eq)	49,830,555	204,283,307	10,074	2,077,219	-138,462	79,414,128	-235,815,712
TRACI acidification (moles of H+-Eq)	-2,328,573	1,408,453	240	49,124	769,125	730,629	-5,286,145
TRACI eutrophication (kg N-Eq.)	10,312	1,395	0	31	6,125	3,044	-283
TRACI photochemical oxidation (kg NOx-Eq)	-569	16,158	5	617	6,524	25,076	-48,949
USEtox ecotoxicity total (CTUe)	-120,061,799	31,175,403	1,661	427,630	-671,632	41,123	-151,035,983
USEtox human toxicity total (CTUh)	-4	2	0	0	0	0	-7
CO2-Fossil (kg)	-7,787,642	11,126,005	626	154,782	-16,389	-292,919	-18,759,747
CO2-Biogenic (kg)	16,455,163	72,752	4	2,097	860,329	11,273,424	4,246,557
CO2-Stored (kg)	-19,095,997	3,430	0	106	-584,161	-18,512,997	-2,375
CH4-Fossil (kg)	1,475	18,195	1	247	-93	18,694	-35,570
CH4-Biogenic (kg)	665,105	99	0	2	16,875	648,324	-195
N2O (kg)	1,496	111	0	5	1,964	-90	-495
CO (kg)	-45,714	20,514	1	157	-59	22,275	-88,602
NOx (kg)	-2,605	15,338	5	613	6,478	22,260	-47,299
SOx (kg)	-72,250	15,045	1	436	-318	-1,801	-85,613
PM>10 (kg)	-120,798	10,961	1	161	-37	-4,794	-127,089
PM10 (kg)	3,087	3,701	0	8	-19	873	-1,475
PM2.5 (kg)	1,251	2,131	0	37	25	1,513	-2,456
NMVOC (kg)	25,485	14,644	1	70	84	16,852	-6,166
Lead (kg)	3	6	0	0	0	5	-8
Cost ($)	13,742,475	13,700,209	3,311	260,670	250,902	971,170	-1,443,787

Table A-3. MSW DST Results for the Maximum Recycling Scenario

Impacts	Total	Collection	Transportation	Separation	Composting	Landfill	Reprocessing
C Emissions (kg CO2-eq)	-15,768,403	12,426,018	1,646	408,815	2,768,396	9,636,345	-41,009,622
Cumulative fossil energy resources (MJ-Eq)	-292,408,912	212,755,280	24,567	5,066,388	-276,923	65,182,048	-575,160,272
TRACI acidification (moles of H+-Eq)	-9,151,080	1,466,781	585	119,816	1,538,250	616,524	-12,893,036
TRACI eutrophication (kg N-Eq.)	14,804	1,452	1	76	12,251	1,715	-690
TRACI photochemical oxidation (kg NOx-Eq)	-71,749	16,828	11	1,505	13,048	16,246	-119,388
USEtox ecotoxicity total (CTUe)	-333,825,510	32,467,875	4,050	1,042,999	-1,343,265	2,383,277	-368,380,445
USEtox human toxicity total (CTUh)	-14	2	0	0	0	0	-16
CO2-Fossil (kg)	-33,235,852	11,587,297	1,527	377,516	-32,777	586,066	-45,755,481
CO2-Biogenic (kg)	18,060,053	75,765	10	5,114	1,720,659	5,901,050	10,357,456
CO2-Stored (kg)	-10,498,635	3,572	1	258	-1,168,322	-9,328,352	-5,792
CH4-Fossil (kg)	-53,187	18,950	2	603	-185	14,199	-86,756
CH4-Biogenic (kg)	362,418	103	0	4	33,750	329,036	-475
N2O (kg)	2,814	116	0	12	3,928	-36	-1,207
CO (kg)	-178,766	21,365	3	384	-119	15,704	-216,103
NOx (kg)	-70,216	15,973	11	1,494	12,956	14,713	-115,364
SOx (kg)	-191,517	15,668	3	1,064	-635	1,198	-208,813
PM>10 (kg)	-300,621	11,416	1	392	-75	-2,382	-309,973
PM10 (kg)	848	3,854	1	21	-38	609	-3,599
PM2.5 (kg)	-2,540	2,219	0	91	51	1,088	-5,990
NMVOC (kg)	10,958	15,252	2	170	168	10,405	-15,039
Lead (kg)	-9	6	0	0	0	4	-18
Cost ($)	12,147,837	13,872,401	7,842	635,781	501,803	651,442	-3,521,432