Pacific Northwest
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PNNL-34603

Organic Waste Resource Assessment for the Detroit Region

August 2023

Timothy Seiple

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99354

Executive Summary

This study summarizes major sources of organic waste in the Detroit region to (1) characterize target feedstock quantity and distribution for techno-economic analysis (TEA), and (2) guide the design of blended feedstock conversion experiments using hydrothermal liquefaction (HTL).

Feedstocks considered in this review include (1) municipal wastewater sludge solids (untreated) and scum; (2) bulk municipal solid waste (MSW); (3) the organic fraction of municipal solid waste (OFMSW); (4) non-recycled paper; (5) non-residential food waste including institutional, industrial, and commercial (IIC) sources; (6) confined animal manures (i.e., dairy, feedlot beef, and market swine); (7) waste fats, oils and greases (FOG); (8) agricultural residues. The scope of the investigation was limited to previously modeled or publicly available reporting data. Bulk MSW data were only collected for context and to prepare estimates of OFMSW by waste type and are not included in estimates of total HTL feedstock.

Because the TEA analysis boundary was not defined prior to conducting the resource assessment, the data are summarized within six potentially relevant spatial contexts (boundaries), including (1) City of Detroit (census); (2) Great Lakes Water Authority (GLWA) service area; “Tri-county” urban area (census); “Metro” Detroit-Warren-Dearborn Metropolitan Statistical Area (MSA) (census); Detroit-Warren-Ann Arbor Combined Statistical Area (CSA) (census); and the Michigan Councils of Government (COG) Region-1. All the spatial contexts are entirely within the State of Michigan, and some overlap one another. A broader context could be developed to include data from surrounding states or Canada.

Excluding bulk MSW, approximately 11,000 dry metric tons per day (t/d) of organic feedstocks have been inventoried at the facility level within the Detroit CSA. Comprehensive data for wastewater scum, residential food waste, and forest residue are not readily available, but could be modeled. Agricultural residues and composted OFMSW are highly seasonal, whereas other feedstocks occur steadily throughout the year but may vary hourly to weekly.

Based on the results of the resource assessment, we recommend HTL experiments and resource recovery focus on

1. Untreated wastewater sludge solids and scum
2. OFMSW (i.e., food waste, yard waste, wood)
3. Non-recycled paper
4. Source separated non-residential food waste
5. Certain plastics

Implementing HTL at the Detroit WRRF is a great opportunity to help divert and reuse several nuisance waste components (i.e., plastic, paper, food waste) that often occur together (e.g., fast food debris) and currently pose local and national waste management and recycling challenges.

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1.0 Introduction

The City of Detroit is in the southeastern part of the state of Michigan in Wayne County. Table 1 and Figures 1–2 summarize relevant spatial contexts that could serve as analysis boundaries for our study. Census designated boundaries include place, urban area, core based statistical area (CSBA) metropolitan, and combined statistical area (CSA). Other potential analysis boundaries include the Great Lakes Water Authority (GLWA) service area and the Michigan Councils of Government (COG) Region-1 boundary. It is also useful to recognize that the City of Detroit is at the center of the broader Great Lakes megalopolis. The spatial contexts used in this study do not always coincide with jurisdictional reporting boundaries (e.g., Urban Areas), nor do all jurisdictions monitor all waste streams.

Table 1. Summary of potential analysis contexts for Detroit

Census Designation (informal name)	Census GEOID	Area (mi^2)	2020 Pop. (million)	Poverty (%)	Diameter (miles)
Place (“City”)	2622000	140	0.6	30.2	15
Great Lakes Water Authority Service Area	n/a	1013	–	–	35
Urban Area (“Tri-County”)	23824	1300	3.8	14.2	40
Detroit-Warren-Dearborn MSA (“Metro”)	19820	3900	4.4	13.4	65
Michigan Councils of Government Region-1	n/a	4502	4.8	13.3	65-110
Detroit-Warren-Ann Arbor CSA	220	6500	5.4	13.5	65–140
Great Lakes Megalopolis (“Region”)	n/a	–	>60.0	–	~550

Census Place

Detroit “City” proper is the largest census designated place in Michigan and the 27th largest US city by population.

Urban Area

The urbanized area of Detroit includes the Detroit city core and the surrounding Macomb, Oakland, and Wayne counties, also referred to as the Tri-County area.

Metropolitan Statistical Areas (MSA)

The general concept of a core based statistical area is that of a core urban area together with adjacent communities having a high degree of economic, and social integration. They are defined by the United States Office of Management and Budget (OMB, 2020) for federal planning. CBSAs can be classified based on population and commuting activity into Metropolitan Statistical Areas (MSA) (≥ 50 000 ppl.) and Micropolitan Areas (10–50 000 ppl.). Boundaries change and are not guaranteed to be statistically comparable over time. The boundaries used in this study are represented by the 2020 U.S. Census Bureau 1:500,000 cartographic files (U.S. Census, 2020). The Detroit–Warren–Dearborn MSA, also known as “Metro” Detroit, is comprised of six counties including Lapeer, Livingston, Macomb, Oakland, St. Clair, and Wayne.

Combined Statistical Area (CSA)

Adjacent MSAs may be merged into larger Combined Statistical Areas (CSAs). The Detroit-Warren-Ann Arbor CSA is comprised of ten counties including the same six counties in the MSA, plus Genesee, Lenawee, Monroe, and Washtenaw.

Great Lakes Water Authority (GLWA) Service Area

The Great Lakes Water Authority (GLWA) service area overlaps most of the census Urban Area boundary and does not coincide cleanly with jurisdictional boundaries. The GLWA collection system is comprised of 19 sewer districts, which are generally hydraulically and operationally

independent during dry weather conditions. The sewer service districts are fully described in the GLWA 2020 Master Plan (GMP) (GLWA, 2020).

Michigan Councils of Government (COG) Regions

Michigan Councils of Government (COG) organizes Michigan into 14 regions that group counties together based on economic, political, and geographic similarities. COG Region-1 contains the City of Detroit and includes Livingston, Macomb, Monroe, Oakland, Saint Claire, Washtenaw, and Wayne counties. In terms of size, it is in between the MSA and CSA. The Region-1 boundary overlaps portions of the census MSA and CSA boundaries.

Great Lakes Megalopolis

Detroit is located at the center of an economically connected group of metropolitan areas around the Great Lakes region that spans parts of the US and Canada and includes Chicago, Detroit, Cleveland, Buffalo, Rochester, Toronto, Pittsburg, Columbus, Cincinnati, Louisville, Indianapolis, St. Louis, and Milwaukee. This region has more than 60 million inhabitants and is the most populated and largest megalopolis in North America.

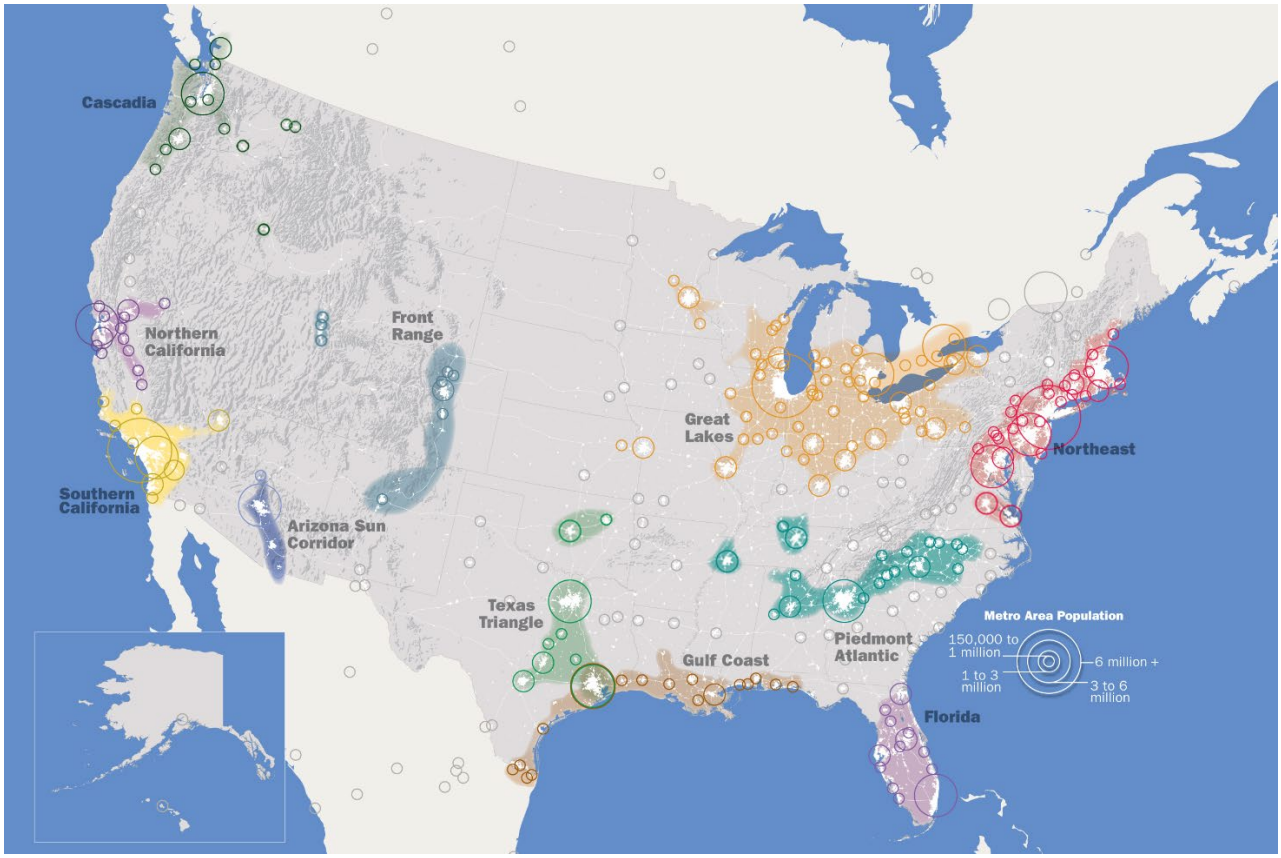

Figure 1. Megalopolis regions in the U.S. (RPA, 2008)

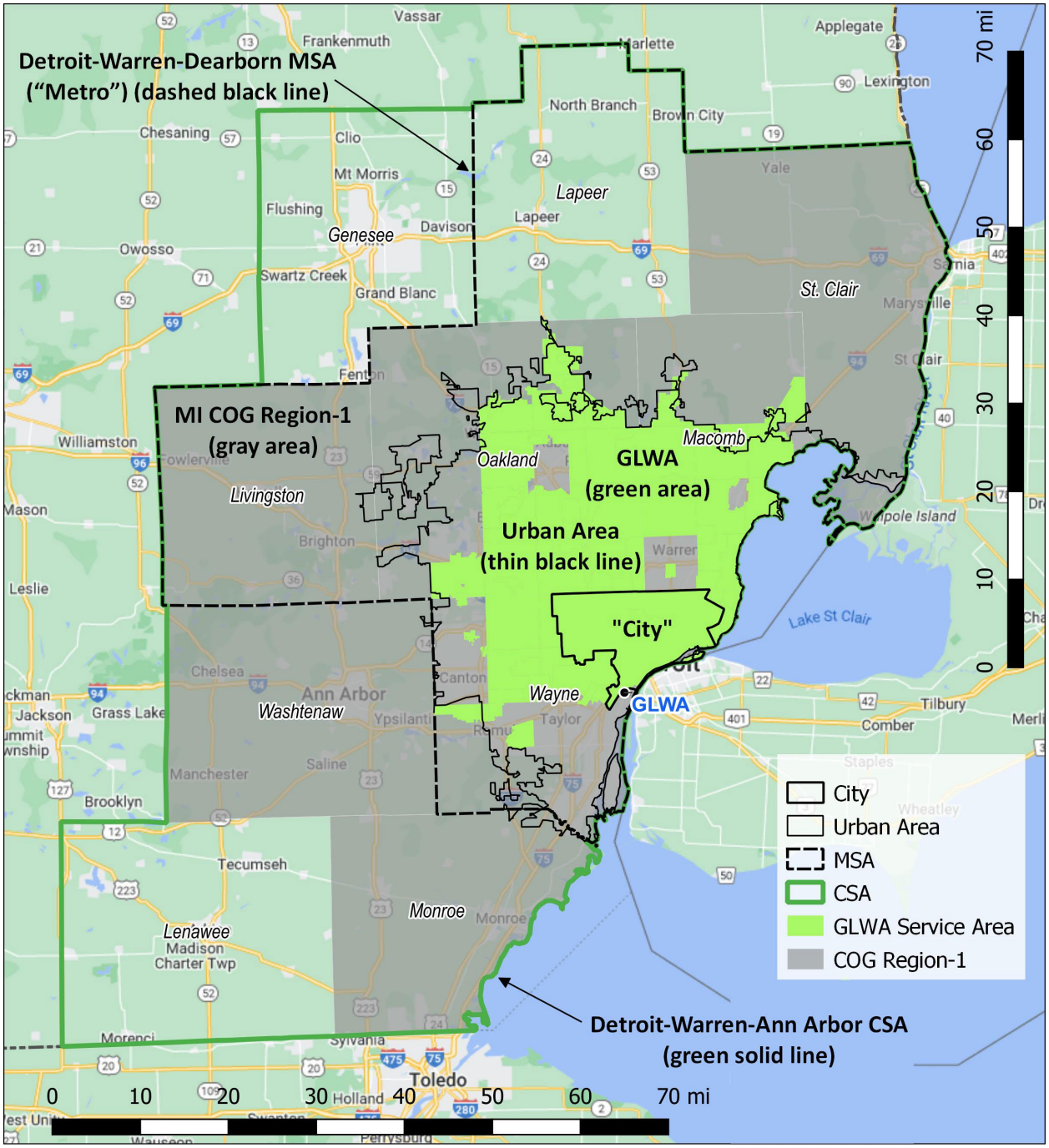

Figure 2. Hierarchy of spatial contexts for the Detroit region

2.0 Feedstocks

This study considers all organic waste bioresources disposed in the Detroit region (with imports when data are available), including for municipal sludges, manures, waste fats, oils, and grease (FOG), food waste, organic fractions of municipal solid waste (OFMSW), non-recycled paper, and agricultural residues. Table 2 summarizes total available feedstock (dry metric tons per year) within each spatial context defined in Table 1, except the Great Lakes Megalopolis.

Table 2. Total available organic feedstocks in Detroit area by scale

Scale	WRRF Solids[1]	Bulk MSW[2]	OF-MSW[3]	Disposed Paper[4]	Food[5]	Manure[6]	FOG	Ag. Residue
	(Dry metric tons per day)							
City	569	-	-	-	*12-82*	-	-	-
GLWA	569[7]	9,422	2,129	2,263	*58-354*	-	128	5
Urban Area	701	5,360	849	857	*76-448*	-	128	1
MSA	724	15,297	3,301	3,430	84-507	32	135	439
COG Region-1	788	18,521	4,003	4,157	*94-560*	32	145	649
CSA	843	19,455	4,224	4,371	103–618	207	156	1,025

[1] Based on PNNL modeled estimates of untreated sludge solids, excluding wastewater scum
[2] Represents reported disposed municipal solid waste (MSW), including imports but excluding waste exported for disposal outside of Michigan or wastes removed from the waste stream prior to disposal (i.e., incineration, AD, waste reduction, or recycling)
[3] Represents reported recycled (composted) and disposed organic fraction (OF) of MSW; excludes organic industrial waste (IW), and waste that is exported for disposal, incinerated, or anaerobically digested
[4] Represents non-recycled paper that is disposed with MSW; excludes incinerated waste
[5] Based on EPA modeled estimates of total available industrial, institutional, and commercial (IIC) food waste excess
[6] Based on PNNL modeled estimates of total recoverable confined manure for beef, dairy and market swine
[7] GLWA reporting data indicate an average of 85 tons per month (1020 t/y) of scum (FOG) are available for conversion

Excluding bulk MSW (included only for reference), approximately 11,000 dry metric tons per day (t/d) of organic feedstocks have been inventoried at the facility level within the Detroit CSA. Comprehensive data for wastewater scum, residential food waste, and forest residue are not readily available, but could be modeled or elicited. Agricultural residues and composted OFMSW are highly seasonal, whereas other feedstocks occur steadily throughout the year but may vary hourly to weekly.

2.1 Municipal Wastewater Sludge Solids

Total recoverable (“untreated”) and disposed (“treated”) municipal wastewater solids were characterized by Seiple et al., 2020a and Seiple et al., 2020b for >15000 publicly owned wastewater facilities throughout the United States. Table 3 and Figures 3–4 summarize water resource recovery facilities (WRRF) and sludge feedstock inventoried in the Detroit region. Recoverable solids represent the total solids removed from primary and secondary treatment, prior to any stabilization or treatment and without sidestream losses. Disposed solids are the modeled equivalent to biosolids, which are typically landfilled, surface applied, incinerated, dried, or composted. The differences between recoverable and disposed solids estimates are due to applied solids treatment processes, such as anaerobic digestion and stabilization, which can increase or decrease solids mass.

Table 3. WRRF count, flow, recoverable solids, and disposed solids by scale

Scale	Count	Avg. Daily Flow (MM gal/d)	GLWA Flow (% of Total)	Recoverable Solids (dry metric t/d)	Disposed Solids (dry metric t/d)
City	1	660	100	569	276
GLWA	1	660	100	569	276
Urban Area	15	813	81	701	378
MSA	44	840	79	724	398
COG Region-1	55	901	73	788	448
CSA	81	973	68	843	479

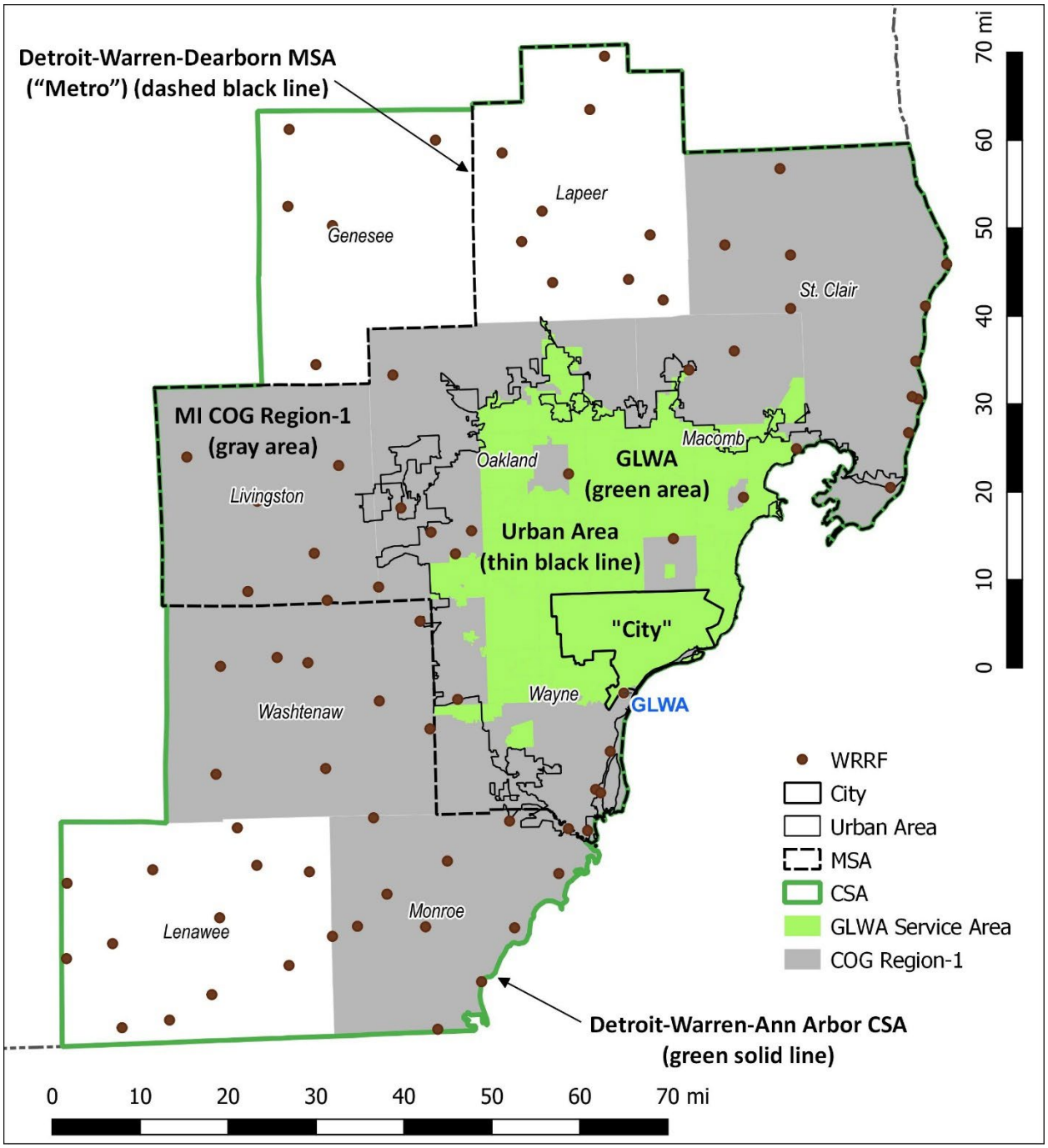

Figure 3. WRRF locations in the Detroit region

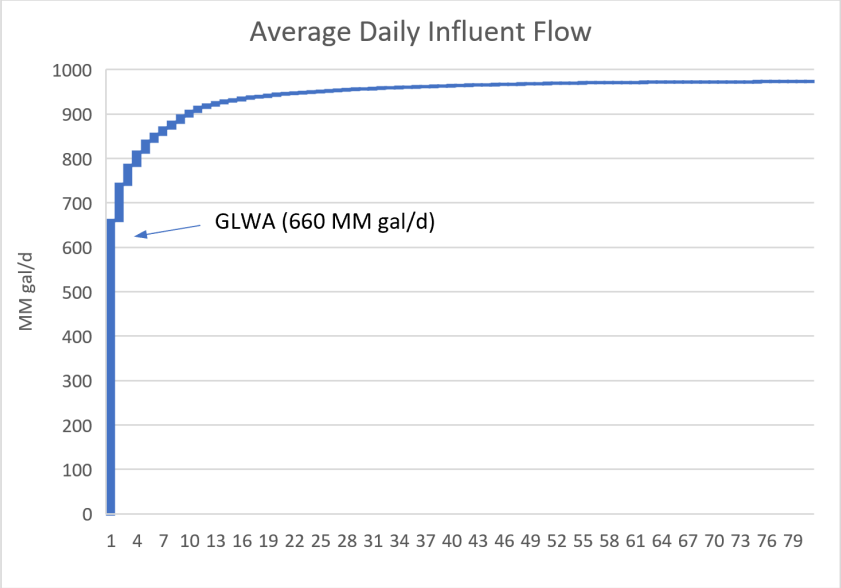

Figure 4. Waterfall diagram of influent flow for 81 WRRFs in Detroit CSA

As illustrated by Figure 4, the GLWA WRRF is by far the largest wastewater treatment facility in the region. It serves 2.7 million people and accounts for 68% of total influent flow in the Detroit CSA. Modeled estimates for the largest facilities can be quickly improved by calibrating them with available facility reporting data.

For GLWA, we can reference data in the GLWA 2020 Master Plan (GMP). According to Table 4, GLWA typically generates 394 dry metric tons per day (434 dry short t/d) of disposable biosolids, based on an 11-year average (2008-2018). The data in Table 4 also reflect GLWA's recent transition from incineration and landfilling to solids drying. In 2018, a total of 69% of solids were dried, 28% were incinerated, and 4% were landfilled.

Table 4. Historic biosolids production for GLWA (adapted from GMP Table 7-13)

Year	Landfilled	Land Applied	Burned	Dried	Total	Total	Total
	dry US t/y					dry US t/d	dry metric t/d
2008	55,863	-	102,276	-	158,139	433	393
2009	41,761	-	111,394	-	153,155	420	381
2010	51,833	-	109,662	-	161,494	442	401
2011	62,220	4,937	105,209	-	172,365	472	428
2012	53,367	13,241	111,094	-	177,702	487	442
2013	59,826	18,963	102,448	-	181,237	497	451
2014	71,376	11,072	104,727	-	187,175	513	465
2015	45,610	4,542	90,605	6,958	147,715	405	367
2016	40,538	1,326	21,089	67,022	129,975	356	323
2017	25,073	-	25,845	90,361	141,280	387	351
2018	4,774	-	36,610	91,183	132,567	363	329
MIN	4,774	-	21,089	-	129,975	356	323
MAX	71,376	18,963	111,394	91,183	187,175	513	465
AVG	46,567	4,916	83,724	23,229	158,437	434	**394**

Reported daily average biosolids production is approximately half-way between the modeled recoverable and disposed solids estimates. There are several reasons why this may occur.

- Modeled estimates of total suspended solids (TSS) are based on literature factors which do not account for the continuous variability of flow and solids content in actual wastewater. For example, the average daily flow value used in the model (660.5 MM gal/d) is 5% higher than the average daily flow reported by GLWA (630 MM gal/d) but does not account for above average or peak flows (GLWA's permit allows for 1,700 MM gal/d peak primary and 930 MM gal/d peak secondary flow).
- When partitioning influent solids by waste phase, the model represented a single disposal pathway for GLWA (AD and dewatering), which does not account for increases in mass due to the addition of chemicals or lime or decreases in mass due to better performance for incineration or drying.
- Modeled estimates do not reflect continuous process improvement incentivized by cost savings to reduce biosolids mass, such as better grit removal.

Figure 5 summarizes the short-term variability of total thickened solids production at GWLA and illustrates the difficulty in estimating sludge production due to variability in sample frequency (e.g., daily, weekly, monthly), location of sampling (thickened sludge, dewatered sludge, ash), and sampling technique (grab sample, pump curves, truck scale), especially when multiple sludge treatment pathways occur at the same site.

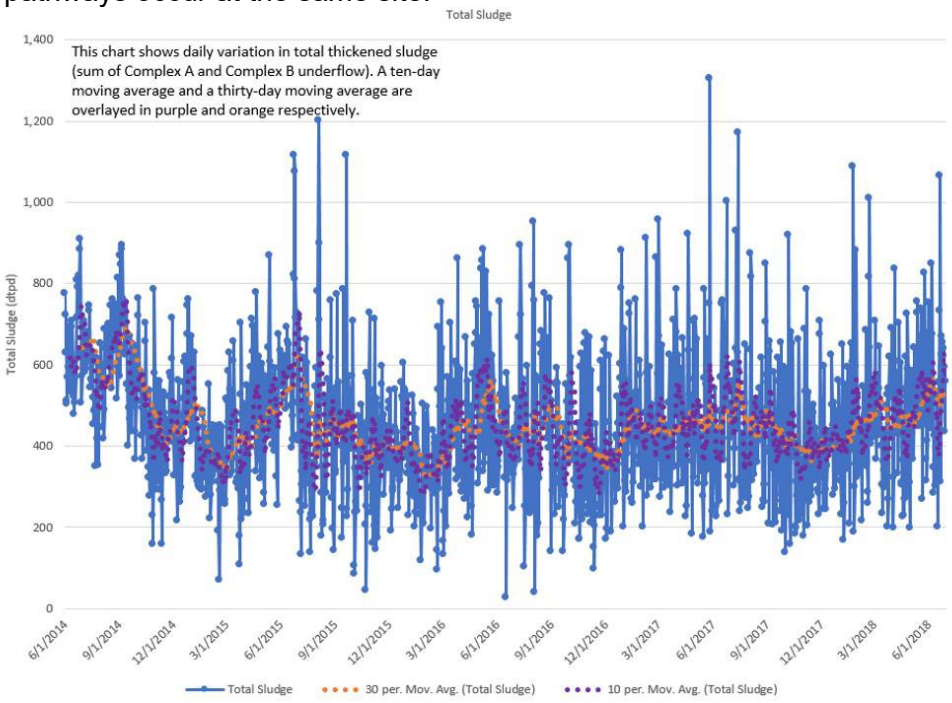

Figure 5. Daily, 10-day and 30-day moving average of total thickened sludge (GMP Table 7-13)

Tables 5–7 project the long-term variability of wastewater flow, wastewater composition, and sludge production as a function of changes in population, climate, unit processes, and operations management. Projections indicate sludge production is expected to increase by less than 10% by 2060.

Table 5. Existing and projected influent flows (GMP Table 7-2)

Parameter	Existing	2045	2060
	(MM gal/d)		
Average Daily Flow	630	651 – 662	668 – 679
Maximum Daily Flow	1257[1]	1299 – 1321	1333 – 1355
Peak Hourly Flow	1902[2]	1700	1700
Minimum Daily Flow	389	376 – 400	380 – 404

1– Existing maximum daily flow represents the 98th percentile of flow from an historical 3-year period
2– The historical (3-year) peak hourly flow exceeded the primary treatment capacity of 1,700 mgd

Table 6. Existing and projected influent loadings (adapted from GMP Table 7-3)

Constituent	Existing		2045		2060	
	(lb./d)	(mg/L)	(lb./d)	(mg/L)	(lb./d)	(mg/L)
BOD	581,000	111	616,000	112	641,000	113
TSS	744,000	142	788,000	143	820,000	145
VSS	554,000	105	586,000	106	610,000	108
Ammonium-N	63,100	12	*	*	*	*
TP	13,300	2.5	14,500	2.6	15,300	2.7

1– Does not include plant recycles
2– Concentrations based on higher flow projection
*– No ammonium permit limit is expected

Table 7. Existing and projected sludge production (adapted from GMP Table 7-14)

Parameter	Existing (FY15-FY17)	Existing Max Month	2060	2060 Max Month
		dry metric t/d		
TPS TSS	308	459	318	463
TWAS TSS	107	121	132	168
Total TSS	415	580	451	630

The GLWA Master Plan also reports some useful cost data. Average unit cost data for each solid's disposal pathway are presented in GMP Table 7-12, with a detailed cost breakdown by disposal pathway presented in Technical Memorandum 5B. Cost estimates for alternative future solids processing workflows are described in GMP Table 7-17 and a process diagram is presented in Figure 3-10.

Table 8 Solids Disposal Unit Cost Summary (GMP Table 7-12)

Parameter	C-II Incineration (8 multi-hearth)	Landfill/Land Apply (COF)	Biosolids Drying Facility (BDF)
Total Cost	$8,465,192	$2,361,055	$16,630,738
Sludge (dry t/y)	39,939	10,659	69,160
Sludge (%)	33	9	58
Unit Cost ($/dry t)	212	222	240

Table 9. WWRF sites within the Detroit CSA with modeled recoverable and disposed solids

FACILITY	CITY	Influent Flow (MM Gal/d)	Cum. Flow (%)	Recoverable (Dry metric t/d)	Disposed (Dry metric t/d)
TOTAL	***N = 81***	***973.1***		***843***	***479***
DETROIT STP	DETROIT	660.5	68	569	276
WYANDOTTE WWTP	WYANDOTTE	81.0	76	74	64
FLINT WPCF	FLINT	43.3	81	31	11
YCUA WWTP	YPSILANTI	24.2	83	29	26
WARREN WWTP	WARREN	30.0	86	21	7
MONROE METRO WWTP	MONROE	13.4	88	15	8
HURON VALLEY-SOUTH	ROCKWOOD	14.0	89	13	12
ANN ARBOR WWTP	ANN ARBOR	15.1	91	13	11
RAGNONE (DIST.#2) WWTP	MONTROSE	14.0	92	12	10
PORT HURON WWTP	PORT HURON	11.0	93	9	8
PONTIAC STP	PONTIAC	8.0	94	7	6
TRENTON WWTP	TRENTON	6.2	95	5	5
ADRIAN WWTP	ADRIAN	4.9	95	4	2
MT CLEMENS WWTP	MOUNT CLEMENS	3.8	96	3	2
BEDFORD TOWNSHIP STP	ERIE	3.0	96	3	1
COMMERCE TWP WWTP	COMMERCE	3.0	96	3	2
MARYSVILLE STP	MARYSVILLE	2.4	96	2	2
FLUSHING WWTF	FLUSHING	2.2	97	2	2
GROSSE ISLE TOWNSHIP	GROSSE ILE	2.2	97	2	2
WALLED LAKE WWTP	NOVI	2.2	97	2	2
GENESEE COUNTY DIST. 3	LINDEN	2.1	97	2	2
BERLIN TWP STP	NEWPORT	1.5	97	1	1
ALGONAC STP	ALGONAC	1.4	98	1	1
SALINE STP	SALINE	1.4	98	1	1
WIXOM STP	WIXOM	1.1	98	1	1
SOUTH LYON WWTP	SOUTH LYON	1.1	98	1	1
ST CLAIR STP	ST CLAIR	1.1	98	1	1
HOWELL STP	HOWELL	1.1	98	1	1
LAPEER STP	LAPEER	1.0	98	1	1
CHELSEA STP	CHELSEA	0.9	98	1	1
TECUMSEH STP	TECUMSEH	0.8	98	1	1
MARINE CITY STP	MARINE CITY	0.8	99	1	1
MILAN WWTP	MILAN	0.8	99	1	1
ROMEO VILLAGE STP	ROMEO	0.8	99	1	1

HOLLY STP	HOLLY	0.7	99	1	0.5
BRIGHTON STP	BRIGHTON	0.7	99	1	0.5
ROLLIN-WOODSTOCK STP	ADDISON	0.6	99	0.5	0.4
MANCHESTER STP	MANCHESTER	0.6	99	0.5	0.4
NEW BALTIMORE	NEW BALTIMORE	0.6	99	0.5	0.4
EAST CHINA REG CS	EAST CHINA	0.6	99	0.5	0.4
HARTLAND TWP. CS	HARTLAND	0.6	99	0.5	0.4
BLISSFIELD STP	BLISSFIELD	0.6	99	0.5	0.4
MILFORD WWTP	MILFORD	0.6	99	0.4	0.4
HUDSON STP	HUDSON	0.5	99	0.4	0.4
DUNDEE STP	DUNDEE	0.5	99	0.4	0.3
NORTHFIELD STP	WHITMORE LAKE	0.5	99	0.4	0.3
FOWLERVILLE WWSL	FOWLERVILLE	0.4	99	0.3	0.3
CARLETON LAGOON	CARLETON	0.4	99	0.3	0.3
ST. CLAIR RIVER SA WWTP	EAST CHINA	0.4	100	0.3	0.3
DEXTER STP	DEXTER	0.4	100	0.3	0.3
IMLAY CITY STP	IMLAY CITY	0.4	100	0.3	0.3
ARMADA WWTP	ARMADA	0.3	100	0.3	0.2
ALMONT WWTP	ALMONT	0.3	100	0.3	0.2
CLINTON STP	CLINTON	0.3	100	0.2	0.2
MORENCI SEWAGE SYSTEM	MORENCI	0.3	100	0.2	0.2
Hamburg Twp WWTP	WHITMORE LAKE	0.2	100	0.2	0.2
LUNA PIER STP-CS	LUNA PIER	0.2	100	0.2	0.2
YALE STP	YALE	0.2	100	0.1	0.1
PETERSBURG WWTP	PETERSBURG	0.2	100	0.1	0.1
BRITTON-RIDGEWAY SEWERAGE	BRITTON	0.2	100	0.1	0.1
PINCKNEY STP	Pinckney	0.2	100	0.1	0.1
ROCKWOOD WWTP-CS	ROCKWOOD	0.2	100	0.1	0.1
MEMPHIS STP	MEMPHIS	0.2	100	0.1	0.1
IDA-RAISINVILLE WWSL	IDA TWP	0.1	100	0.1	0.1
CAPAC STP	CAPAC	0.1	100	0.1	0.1
NORTH BRANCH WWTP	NORTH BRANCH	0.1	100	0.1	0.1
COLUMBIAVILLE WWTF	COLUMBIAVILLE	0.1	100	0.1	0.1
DRYDEN WWTF	DRYDEN	0.1	100	0.1	0.1
DEERFIELD (ARGENTINE)	DEERFIELD	0.1	100	0.1	0.1
CLIFFORD STP	CLIFFORD	0.1	100	0.1	0.1
MAYBEE LAGOON	MAYBEE	0.1	100	0.1	0.1
ONSTED STP	ONSTED	0.1	100	0.1	0.05

OTISVILLE LAGOON CS	OTISVILLE	0.1	100	0.1	0.05
SALEM TOWNSHIP STP	SALEM	0.1	100	0.1	0.05
METAMORA WWTF	METAMORA	0.1	100	0.1	0.05
LOCH ALPINE STP	ANN ARBOR	0.1	100	0.05	0.04
Elba Twp WWTP Lagoon	LAPEER	0.1	100	0.04	0.04
FAIRFIELD TWP (JASPER)	JASPER	0.1	100	0.04	0.04
CLAYTON LAGOON	CLAYTON	0.04	100	0.03	0.03
FAIRFIELD TWP (WESTON)	FAIRFIELD TWP	0.04	100	0.03	0.03
EMMETT LAGOON	St. Clair	0.03	100	0.02	0.02

2.1.1 Wastewater Scum

Wastewater "scum" is typically skimmed from influent flow and from primary and secondary clarifiers. Primary scum typically consists of fats, oils, grease (FOG), and floating contaminants such as debris, plastic, and rubber products. Secondary scum is comprised mostly of floating activated sludge or biofilm, depending on treatment process. Scum quantity and moisture content are not typically measured (The Wastewater Blog, 2020).

The FOG component of wastewater scum is a low-cost waste that can serve as a high value feedstock for biofuels production via HTL. Untreated domestic wastewater contains 50 to 100 mg of oil and grease per liter of influent flow (Metcalf & Eddy 5th Ed.). Only a small portion of the FOG within wastewater is captured by grease traps and skimming. Most of the FOG passes through the system and is managed by secondary treatment. Therefore, scum removal rates are much lower than total loading. In the future, WRRFs could respond to the high value of FOG for fuel by implementing techniques to maximize FOG collection.

For example, The GLWA WRRF treats an average of 630 million US gallons per day of wastewater, which contains an estimated 120 metric tons per day of FOG (45,000 t/y), assuming an average concentration of 50 mg/L for low strength wastewater. However, GLWA reporting data indicate a monthly average removal rate of 85 tons per month (1,031 t/y in 2022). Given the disparity between loading and observed removal rates, we do not attempt to estimate wastewater scum for other WRRFs. Reporting data on removal rates should be collected from major WRRFs in the Detroit region.

2.2 Bulk Solid Municipal Waste

Michigan state solid municipal waste (MSW) quantity and composition is reported annually by the Michigan Department of Environment, Great Lakes, and Energy (EGLE). The latest data are presented in the *Report on Solid Waste Landfilled in Michigan for Fiscal Year 2022* (EGLEa, 2023). Figure 6 presents Michigan state-wide solid waste disposal totals and rates from 2013-2022. In 2022, a total of 17.3 MM wet short t/y of waste were disposed at captive and non-captive landfills, an increase of 2.1% from 2021. The average rate of change from 2013 to 2022 is +1.8%. The ratio of in-state to imported waste was steady for the past decade with in-state waste comprising 76% of total waste and the balance coming from Canada (19%) and other states (5%), primarily Ohio, Massachusetts, Indiana, and Wisconsin. More detailed compositional breakdowns are available in the EGLE annual report. Michigan's total non-captive landfill capacity is estimated to be 220 million wet short tons (660 million cubic yards), which is equivalent to approximately 28 years, assuming constant future generation, imports, diversion, and disposal rates.

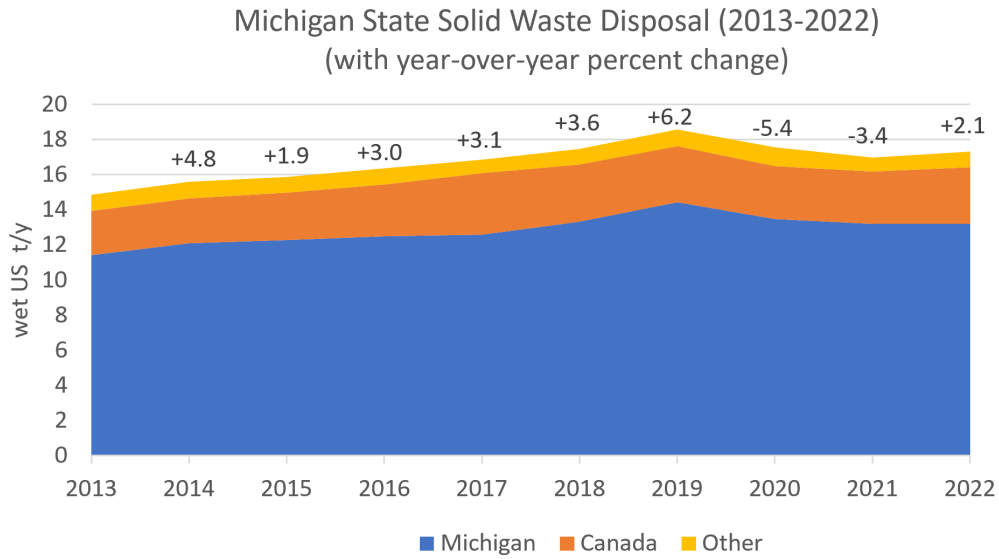

Figure 6. Historic solid waste production for the state of Michigan

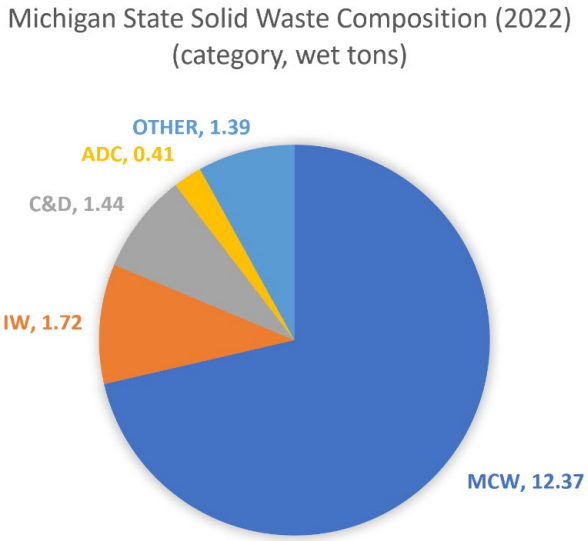

Figure 7. Percent solid waste by category for Michigan in 2022

Table 9 summarizes the types of waste in each waste disposal category according to the Michigan EGLE. Organics occur in multiple categories, are mixed with other materials. The EGLE reporting data do not account for waste exported for disposal outside of Michigan, incinerated waste, or waste removed from the waste stream prior to disposal (waste reduction or recycling). For example, the Kent County Waste to Energy Facility in Grand Rapids and the Detroit Renewable Power facility in Detroit incinerated 500 wet tons per day and 3,300 wet tons per day, respectively in 2014. Therefore, disposal data are not necessarily indicative of total waste generation or total recoverable waste. Note also that food processing residuals and food processing waste are classified as Industrial Waste and are therefore not included in the MCW-organics reporting data.

Table 10. Approved waste types by EGLE solid waste category

Municipal & Commercial Waste (MCW)
Commercial Waste; Garbage; Household Waste; Medical Waste (Regulated); Municipal Solid Waste Incinerator Ash
Industrial Waste (IW)

Ashes; Auto Shredder Residue*; Cement Kiln Dust (CKD); Coal Ash; Coal Bottom Ash; Flue Gas Desulfurization Material; ***Food Processing Residuals***; ***Food Processing Waste***; Foundry Sand; Industrial Waste; Lime Kiln Dust; Low-Hazard Industrial Waste; Pulp and Paper Mill Ash; Pulp and Paper Mill Material; Sludge; Segregated Wastes (Coal Ash; Wood Ash; CKD; Wastewater Sludge; Wood Sediment; Paper Sediment; Foundry Sand); Wood Ash
Construction and Demolition (C&D)
Construction and Demolition Waste; Scrap Wood; Treated Wood; Wood
Alternate Daily Cover (ADC)
Class B: Chipped Tires; Coal or Wood Ash; Foundry Sand; Sludge Class C: Contaminated Soils; Auto Shredder Residue
OTHER
Asbestos; Contaminated Soils (not used as ADC); and technologically enhanced naturally occurring radioactive material (TENORM).

* Auto Shredder Residue: non-metallic (fluff) waste material from shredded vehicles and household and commercial appliances

Facility level annual solid waste volumes are reported by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) Report on Solid Waste Landfilled in Michigan for fiscal year 2022 (EGLEa, 2023), however the report tables do not provide a unique identifier or location coordinates. Therefore, a landfill dataset was reconstructed using authoritative data sources available online.

Landfill locations were obtained from the Part 115 Landfills database (EGLEb, 2023) as of June 22, 2023. For the same set of landfills, the three most complete recent years (2020–2022) of reporting data for annually disposed waste volumes by waste category were obtained manually from annual landfill reports available online through the Waste Data System (WDS) portal. Of the 79 “Active – Accepting” facilities location records, there were 67 distinct WDSIDs with data in WDS, of which 63 had a total waste volume greater than zero. A total of 46 records with data were for MSW landfills (Type II MSW Landfill).

As-reported annual waste volumes (cubic yards per year) were converted to mass (wet short tons per year) assuming one short ton of waste is equivalent to 3.0 cubic yards of compacted MSW, which is consistent with the approach used in the Report on Solid Waste Landfilled in Michigan. Note, the Michigan NextCycle Gap Analysis 2021 Update (MI, 2021) uses a conversion factor of 3.3 yd^3/t. Wet mass estimates were converted to a dry weight basis using average moisture factors presented below. Applying the moisture factors to 2022 waste reporting data, the weighted average moisture content of all disposed compacted waste is approximately 32%.

Table 11. Average moisture content of disposed waste by EGLE category

Type	Avg. % Moisture
MCW (MSW)	40
IW	20
C&D	10
ADC	5
OTHER	10

Table 12. Reported volume (wet yd^3/y) of disposed solid waste by scale and category in 2022

Scale	Count	MCW[1]	IW	C&D	ADC	OTHER	TOTAL
City	0	-	-	-	-	-	-
GLWA	5	12,679,590	907,587	244,636	157,159	2,966,564	16,955,537
Urban Area	5	4,803,455	1,186,731	514,776	46,334	2,368,143	8,919,439
MSA	11	19,224,746	2,010,128	2,131,885	601,565	3,145,648	27,113,973
COG Region-1	17	23,297,617	2,490,219	2,546,049	782,234	3,721,826	32,837,944
CSA	19	24,494,830	2,617,591	2,809,538	842,209	3,737,133	34,501,300
Michigan	63	37,114,120	5,152,873	4,307,136	1,239,188	4,176,721	51,990,037

1– Includes 40,697 cubic yards per year of MSW incinerator ash

Table 13. Total mass (dry metric t/d) of disposed MSW by scale and type in 2022

Scale	Count	MCW	IW	C&D	ADC	OTHER	TOTAL
City	0	-	-	-	-	-	-
GLWA	5	6,303	602	182	124	2,212	9,422
Urban Area	5	2,388	787	384	36	1,766	5,360
MSA	11	9,556	1,332	1,590	473	2,345	15,297
COG Region-1	17	11,581	1,650	1,898	616	2,775	18,521
CSA	19	12,176	1,735	2,095	663	2,787	19,455
Michigan	63	18,449	3,415	3,212	975	3,114	29,165

We can also model MSW and OFMSW at solid waste transfer station locations (MI, 2023). Data are also available to illustrate MSW inflows and outflows by landfill.

2.3 Organic Fraction of Municipal Solid Waste (OFMSW)

The organic fraction of municipal solid waste (OFMSW) generally includes food waste, yard waste, wood, and other compostable paper and packaging. In the absence of comprehensive estimates of total generated organic waste streams, we reconstruct total available OFMSW by combining data on recycled and disposed organics.

Michigan's reporting data on OFMSW only consider Municipal & Commercial Waste (MCW) organics material disposed in-state and excludes recoverable organics in other waste categories such as industrial wastes (e.g., food processing residuals and waste; pulp and paper mill material; sludges; wood sediment; paper sediment), construction and demolition wastes (e.g., scrap wood), as well as exported, incinerated, anaerobically digested, or otherwise diverted wastes.

Disposed OFMSW

Michigan solid waste disposal reporting data do not differentiate organics from total disposed waste. Therefore, we apply previously published factors to estimate total disposed OFMSW by material type. The *Economic impact potential and characterization of municipal solid waste in Michigan* (WMSBF, 2016) reported organics represent an average of 35.2% of total disposed MSW by weight, with mass fractions of total MSW by organic waste type given as 13.6, 9.0, 5.2, 5.0, and 2.4 percent of total MCW for food waste, other organics, wood, yard waste, and soil respectively. These factors are applied to facility level reporting data for 2022 total annual MCW (MSW) mass (wet US tons per year), as prepared in Section 2.2. Wet mass estimates are converted to a dry weight basis assuming average moisture factors for compacted OFMSW by waste type. Based on these factors, the weighted average moisture content of disposed OFMSW in 2022 is 44%.

Table 14. Moisture factors for compacted OFMSW by waste type

Type	Avg. % Moisture
Food	70
Wood	35
Yard	60
Other	10
Soil	10

For comparison, the Michigan NextCycle Gap Analysis 2021 Update (MI, 2021), reported an average of 38.5% of Michigan's total disposed MCW mass (3.08 wet short t/y) is comprised of organics (based on a volume-to-mass conversion factor of 3.3 cubic yards per wet ton MSW applied to 2019 in-state, non-ash MCW volumes as reported in the *Report on Solid Waste Landfilled in Michigan for Fiscal Year 2019*). The report did not provide mass fractions by organic waste type. NextCycle estimated 3.08 million wet short tons per year of total disposed organics, but this estimate only included waste disposed in-state, whereas we apply the mass fractions to total waste disposed in-state, which includes waste imports.

Table 15. Volume (wet yd^3/y) of disposed compacted OFMSW by scale and category (2022)

Scale	Count MCW >0	Food	Wood	Yard	Other	Soil	TOTAL
City	0	-	-	-	-	-	-
GLWA	4	1,724,424	659,339	633,980	1,141,163	304,310	4,463,216
Urban Area	3	653,270	249,780	240,173	432,311	115,283	1,690,816
MSA	8	2,614,566	999,687	961,237	1,730,227	461,394	6,767,111
COG Region-1	10	3,168,476	1,211,476	1,164,881	2,096,786	559,143	8,200,761
CSA	12	3,331,297	1,273,731	1,224,741	2,204,535	587,876	8,622,180
Michigan	46	5,047,520	1,929,934	1,855,706	3,340,271	890,739	13,064,170

Table 16. Mass (dry metric t/d) of disposed compacted OFMSW by scale and category (2022)

Scale	Count MCW >0	Food	Wood	Yard	Other	Soil	TOTAL
City	0	-	-	-	-	-	-
GLWA	4	429	355	210	851	227	2,072
Urban Area	3	162	135	80	322	86	785
MSA	8	650	538	319	1,290	344	3,141
COG Region-1	10	788	652	386	1,563	417	3,806
CSA	12	828	686	406	1,644	438	4,002
Michigan	46	1,255	1,039	615	2,491	664	6,064

Recycled OFMSW

In this study, the recycled portion of OFMSW is represented by composted organics. The Michigan EGLE publishes the location of all active registered compost sites (EGLE, 2023c). Facility level annually composted waste volumes (cubic yards per year) are reported by site (total) and material type (yard, food, wood, other) in the Michigan Waste Data System (WDS). Composted organics data do not account for material treated with anaerobic digestion (AD), which is not reported to EGLE. Data were extracted for 2019 as a representative data year because it has a more complete reporting record compared to 2020-2022. Volume estimates were converted to a mass basis (wet short tons) assuming 450 lb. per cubic yard. Wet mass estimates were converted to a dry weight

basis using average moisture factors for yard waste (60%), wood (35%), food (70%), and other compostables (10%).

According to EGLE composting reporting data for 2019, a total of 1,670,803 cubic yards (375,931 wet short tons) of organic material, representing 22% of total recycled MSW, were brought to 94 different composting sites. Based on as-reported annual volumes, composted organics are composed of 92.5% yard waste, 4.3% wood, 1.3% food waste, 1.9% other organics, such as compostable material, manures, drywall, paunch, carcasses, etc. In 2019, the weighted average moisture content of total as-delivered compostable material is approximately 58%. Only 10 out of 116 active reporting composting facilities in the state reported accepted food waste.

Table 17. Total annual volume (cubic yards) of recycled OFMSW by scale and category in 2022

Scale	Count OFMCW >0	Yard	Wood	Food	Other	TOTAL
City	0	-	-	-	-	-
GLWA	4	254,451	-	-	390	254,841
Urban Area	5	283,376	1,566	-	390	285,332
MSA	12	703,023	3,566	1,295	1,680	709,564
COG Region-1	18	847,270	17,524	3,303	1,450	869,547
CSA	24	955,295	19,256	3,303	2,032	979,886
Michigan	94	1,545,796	72,041	21,130	31,836	1,670,803

Table 18. Total dry mass (dry metric t/d) of recycled OFMSW by scale and category in 2022

Scale	Count OFMCW >0	Yard	Wood	Food	Other	TOTAL
City	0	-	-	-	-	-
GLWA	4	57	-	-	0.2	57
Urban Area	5	63	0.6	-	0.2	64
MSA	12	157	1.3	0.2	0.8	160
COG Region-1	18	190	6	0.6	0.7	197
CSA	24	214	7	0.6	1.0	222
Michigan	94	346	26	4	16	392

Total Dry OFMSW

Statewide, 6,456 dry metric t/d (4.73 million wet short t/y) of total organics are available for waste-to-energy, including 6,064 dry metric t/d (4.35 million wet short t/y) of compacted disposed organics and 392 dry metric t/d (0.38 million wet short t/y) of compacted recycled (composted) organic material.

Table 19. Total dry mass (metric t/d) of OFMSW by scale and type in 2022

Scale	Count	Yard	Wood	Food	Other	Soil	TOTAL	TOTAL Exc. Soil
City	2	-	-	-	-	-	-	-
GLWA	11	267	355	429	851	227	2,129	1,902
Urban Area	13	143	136	162	322	86	849	763
MSA	30	476	539	650	1,291	344	3,301	2,956
COG Region-1	39	576	658	789	1,564	417	4,003	3,586
CSA	47	620	693	829	1,645	438	4,224	3,787
Michigan	140	961	1,065	1,259	2,507	664	6,456	5,792

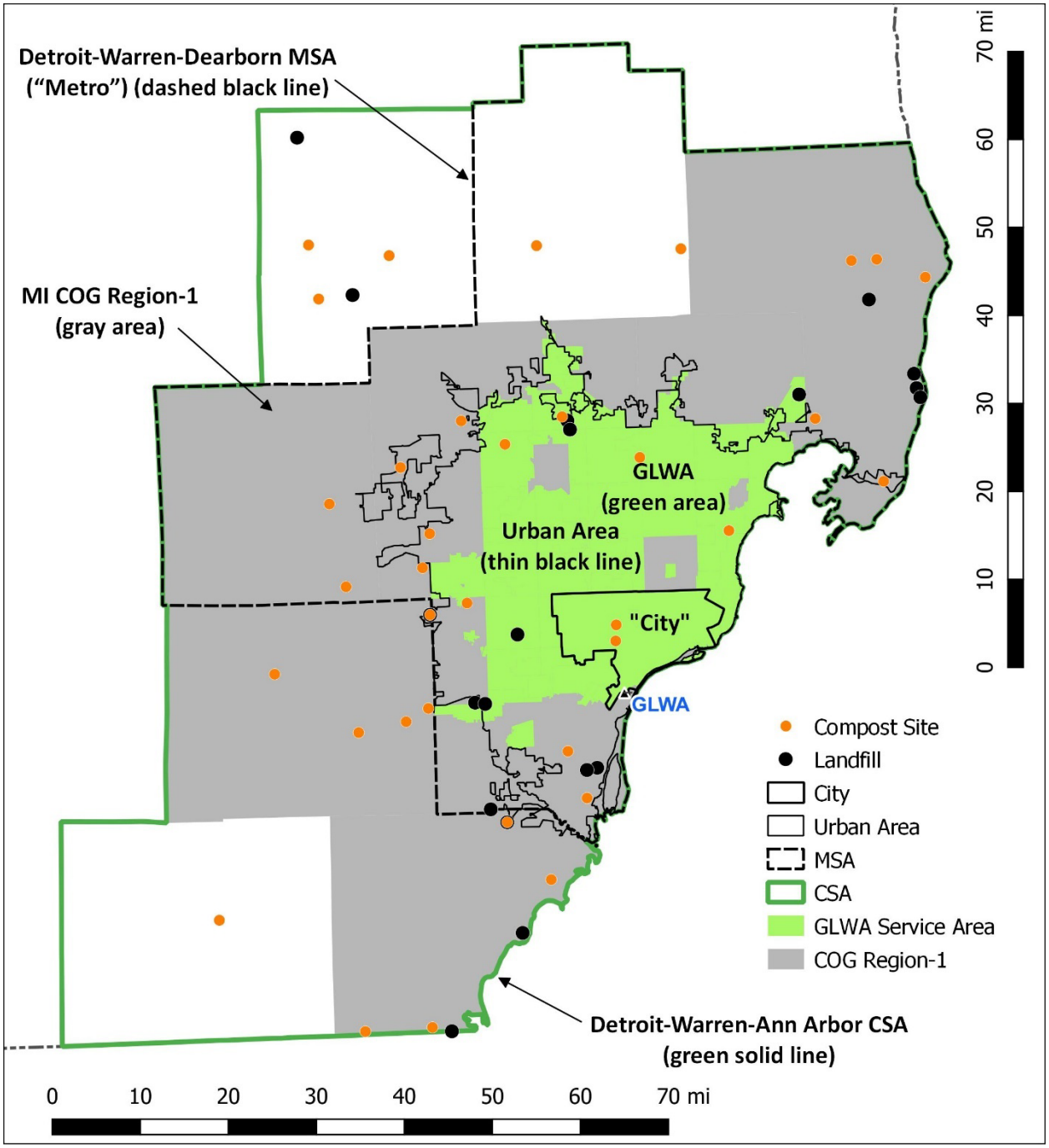

Figure 8. Active MSW Landfill and Compost facilities within the Detroit CSA

Table 20. Landfills in Detroit CSA with 2022 total bulk MSW volume and mass by category

WDSID	TYPE	MCW	IW	C&D	ADC	OTHER	TOTAL	MCW	IW	C&D	ADC	OTHER	TOTAL
		Volume (compacted cubic yards per year)						Mass (compacted dry metric tons per day)					
398972	Type II MSW Landfill	7,610,791	138,771	82,130	120,966	392,617	8,345,275	3,783	92	61	95	293	4,324
412717	Type II MSW Landfill	3,155,441	681,341	44,663	0	2,344,752	6,226,197	1,569	452	33	0	1,748	3,802
390701	Type II MSW Landfill	3,893,591	310,203	1,183,759	324,790	156,210	5,868,553	1,935	206	883	256	116	3,396
475946	Type II MSW Landfill	3,319,386	26,920	364,868	122,543	538,158	4,371,876	1,650	18	272	96	401	2,438
412314	Type II MSW Landfill	1,301,549	76,629	14,742	36,193	205,804	1,634,918	647	51	11	28	153	891
399054	Type II MSW Landfill	1,036,205	25,775	367,012	46,334	0	1,475,326	515	17	274	36	0	842
410118	Type II MSW Landfill	817,966	128,040	269,320	70,629	0	1,285,955	407	85	201	56	0	748
470393	Type II MSW Landfill	753,485	92,350	43,001	58,125	38,019	984,980	375	61	32	46	28	542
452546	Type II MSW Landfill	797,395	15,305	67,158	2,653	22,874	905,385	396	10	50	2	17	476
470517	Type II MSW Landfill	473,366	114,030	238,348	38,759	13,538	878,041	235	76	178	31	10	529
406671	Type II MSW Landfill	723,846	13,343	25,141	21,216	1,769	785,315	360	9	19	17	1	405
470494	Type II MSW Landfill	611,809	8,987	103,101	0	23,391	747,288	304	6	77	0	17	404
392616	Type III Existing Industrial Landfill	0	468,770	0	0	0	468,770	0	311	0	0	0	311
397800	Type III-Coal Ash Surface Imp.	0	337,670	0	0	0	337,670	0	224	0	0	0	224
392562	Type III Existing Industrial Landfill	0	154,448	0	0	0	154,448	0	102	0	0	0	102
498055	Type III-Coal Ash Surface Imp.	0	11,576	0	0	0	11,576	0	8	0	0	0	8
498056	Type III-Coal Ash Surface Imp.	0	11,576	0	0	0	11,576	0	8	0	0	0	8
444069	Type III C&D Waste Landfill	0	0	6,294	0	0	6,294	0	0	5	0	0	5
470471	Type III C&D Waste Landfill	0	1,858	0	0	0	1,858	0	1	0	0	0	1

Table 21. Landfills in Detroit CSA with 2022 disposed OFMSW volume and mass by waste type

WDS ID	WDS TYPE	FOOD	WOOD	YARD	OTHER	SOIL	TOTAL	FOOD	WOOD	YARD	OTHER	SOIL	TOTAL
		Volume (compacted cubic yards per year)						Mass (compacted dry metric tons per day)					
398972	Type II MSW Landfill	1,035,068	395,761	380,540	684,971	182,659	2,678,998	257	213	126	511	136	1243
390701	Type II MSW Landfill	529,528	202,467	194,680	350,423	93,446	1,370,544	132	109	65	261	70	636
475946	Type II MSW Landfill	451,436	172,608	165,969	298,745	79,665	1,168,424	112	93	55	223	59	542
412717	Type II MSW Landfill	429,140	164,083	157,772	283,990	75,731	1,110,715	107	88	52	212	56	516
412314	Type II MSW Landfill	177,011	67,681	65,077	117,139	31,237	458,145	44	36	22	87	23	213
399054	Type II MSW Landfill	140,924	53,883	51,810	93,258	24,869	364,744	35	29	17	70	19	169
410118	Type II MSW Landfill	111,243	42,534	40,898	73,617	19,631	287,924	28	23	14	55	15	134
452546	Type II MSW Landfill	108,446	41,465	39,870	71,766	19,137	280,683	27	22	13	54	14	130
470393	Type II MSW Landfill	102,474	39,181	37,674	67,814	18,084	265,227	25	21	12	51	13	123
406671	Type II MSW Landfill	98,443	37,640	36,192	65,146	17,372	254,794	24	20	12	49	13	118
470494	Type II MSW Landfill	83,206	31,814	30,590	55,063	14,683	215,357	21	17	10	41	11	100
470517	Type II MSW Landfill	64,378	24,615	23,668	42,603	11,361	166,625	16	13	8	32	8	77

Table 22. Compost sites in Detroit CSA with 2019 recycled OFMSW volume and mass by waste type

		YARD	WOOD	FOOD	OTHER	TOTAL	YARD	WOOD	FOOD	OTHER	TOTAL
WDS ID	TYPE	Volume (compacted cubic yards per year)					Mass (compacted dry metric tons per day)				
464248	compost facility	196,900	0	0	0	196,900	44	0	0	0	44
453392	compost facility	118,864	0	0	0	118,864	27	0	0	0	27
483982	compost facility	115,948	0	0	0	115,948	26	0	0	0	26
475946	compost facility	92,451	0	0	0	92,451	21	0	0	0	21
484448	compost facility	64,577	8,892	2,008	100	75,577	14	3	0	0	18
484744	compost facility	74,276	193	0	0	74,469	17	0	0	0	17
465694	compost facility	70,597	1,373	0	0	71,970	16	0	0	0	16
489462	compost facility	46,069	0	0	0	46,069	10	0	0	0	10
411914	compost facility	24,508	4,626	0	0	29,134	5	2	0	0	7
492216	compost facility	19,500	1,200	0	0	20,700	4	0	0	0	5
484412	compost facility	15,627	2,000	1,295	960	19,882	3	1	0	0	5
492325	compost facility	18,000	0	0	250	18,250	4	0	0	0	4
484930	compost facility	17,245	0	0	390	17,635	4	0	0	0	4
484079	compost facility	17,010	0	0	330	17,340	4	0	0	0	4
486650	compost facility	15,556	0	0	0	15,556	3	0	0	0	3
440170	compost facility	12,537	0	0	0	12,537	3	0	0	0	3
486584	compost facility	9,370	440	0	0	9,810	2	0	0	0	2
497417	compost facility	8,935	0	0	0	8,935	2	0	0	0	2
484692	compost facility	5,720	0	0	0	5,720	1	0	0	0	1
444069	compost facility	5,520	0	0	0	5,520	1	0	0	0	1
400889	compost facility	2,394	0	0	0	2,394	1	0	0	0	1
484418	compost facility	1,726	532	0	2	2,260	0	0	0	0	1
484978	compost facility	1,125	0	0	0	1,125	0	0	0	0	0
489465	compost facility	840	0	0	0	840	0	0	0	0	0

2.4 Non-recycled paper

The same methodology used to estimate OFMSW may be applied to assess the amount of non-recycled paper that is disposed. The *Economic impact potential and characterization of municipal solid waste in Michigan* (WMSBF, 2016) indicates non-recycled (disposed) paper represents an average of 22% of total disposed MSW by weight. Mass factors for mixed paper, corrugated paper, and newsprint (12%, 8%, 2%) can be applied to facility level reporting data for total disposed MSW in 2022 as prepared in Section 2.2 (e.g., 12,371,373 wet US tons of MSW per year or 37,114,120 compacted wet yd^3/y). Wet mass values are converted to a dry weight basis assuming an average moisture factor of 10%. A minor amount of additional non-recycled paper is composted and incinerated each year. Recycled material prices are very dynamic. Current market prices should be reviewed before estimating material value.

Table 23. Total disposed paper in Michigan in 2022

	Mixed Paper	Corrugated	Newsprint	TOTAL
Mass fraction (% MSW)	12.07	8.42	1.22	21.71
Disposed (wet US t/y)	1,493,225	1,041,670	150,931	2,685,825
Disposed (dry metric t/d)	3,682	2,569	372	6,623

Table 24. Total dry mass of disposed paper by scale and type in 2022

Scale	Count	Mixed	Corrugated	Newsprint	TOTAL
		dry metric tons per day			
City	0	-	-	-	-
GLWA	4	1,258	877	127	2,263
Urban Area	3	477	332	48	857
MSA	8	1,907	1,330	193	3,430
COG Region-1	10	2,311	1,612	234	4,157
CSA	12	2,430	1,695	246	4,371

Table 25. Active landfills in Detroit CSA with 2022 disposed paper volume and mass

	Mixed	Corrugated	Newsprint	TOTAL	Mixed	Corrugated	Newsprint	TOTAL
WDS ID	Volume (compacted cubic yards per year)				Mass (compacted dry metric tons per day)			
398972	306,207	213,610	30,951	550,768	755	527	76	1,358
390701	156,652	109,280	15,834	281,766	386	269	39	695
475946	133,550	93,164	13,499	240,213	329	230	33	592
412717	126,954	88,563	12,832	228,349	313	218	32	563
412314	52,366	36,530	5,293	94,189	129	90	13	232
399054	41,690	29,083	4,214	74,987	103	72	10	185
410118	32,909	22,958	3,326	59,193	81	57	8	146
452546	32,082	22,380	3,243	57,705	79	55	8	142
470393	30,315	21,148	3,064	54,527	75	52	8	134
406671	29,123	20,316	2,944	52,382	72	50	7	129
470494	24,615	17,171	2,488	44,275	61	42	6	109
470517	19,045	13,286	1,925	34,256	47	33	5	84

2.5 Non-Residential Food Waste

The US EPA estimates that 15% (41 MM wet short t/y) of total national MSW is comprised of food waste, and that 94% of this waste was landfilled and the remaining 6% is composted (EPA, 2020a). Food waste stock flows may vary spatially and by demographic and season (Armington et al., 2020).

For waste-to-energy modeling, food waste may be represented as a component of solid waste (OFMSW) and diverted from the point-of-disposal (see previous section), or it can be modeled at the point-of-generation as source-separated organics (SSO), or some intermediate diversion point in between based on aggregated point source data (i.e., collection route exit points). Food waste is typically classified as residential and non-residential. Residential food waste represents the largest portion of food waste and is typically modeled based on census data and literature factors for single versus multi-family residents. Non-residential food waste includes industrial, institutional, and commercial (IIC) wastes, and is generally a cleaner waste stream that is easier to access.

The EPA Excess Food Opportunities Map (version 2.1) (EPA, 2020a; EPA, 2020b) provides modeled establishment-level estimates (low and high) of total annual generated non-residential post-harvest food waste for 1.2 million establishments in 76 different North American Industry Classification System (NAICS) categories, which are grouped into seven food waste sectors

- Correctional facilities
- Educational institutions
- Food manufacturers and processors
- Food wholesale and retail
- Healthcare facilities
- Hospitality industry
- Restaurants and food services

The EPA estimates account for total available post-harvest (processed, semi-processed, or raw) food intended for human consumption without discounting for recoverability to reflect already diverted food waste. Unharvested crops or on-farm processing excess food, or excess food or other organic material disposed of by the residential sector are not included. The dataset was prepared by applying sector-specific literature factors for waste generation (e.g., by pounds per revenue per year or similar using number of students, beds, inmates, etc.) and composition (lipid, protein, simple or complex carbs, mixed, glycerin) to appropriate facility level attributes (revenue, employees, number of beds, number of students, etc.).

According to EPA, most US non-residential food waste establishments and associated food waste are within the restaurant and food service or food wholesale and retail sectors, with important inputs also coming from food manufacturing and processing. Estimates of annual food waste tonnages vary widely between the “Low” and “High” scenarios, especially for food wholesale and retail. The technical methodology nor the meta indicate whether estimates are on a dry or wet weight basis. We assume estimates are reported in wet short tons per year and adjust to metric dry weight basis assuming 70% moisture content.

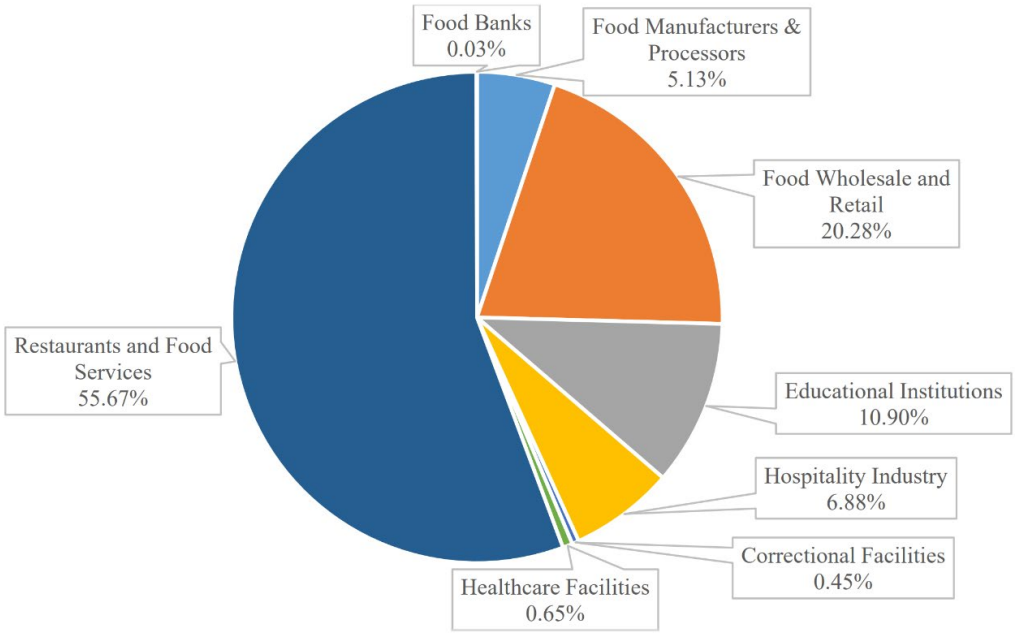

Figure 9. Percent food waste generating establishments by sector (US EPA, 2020)

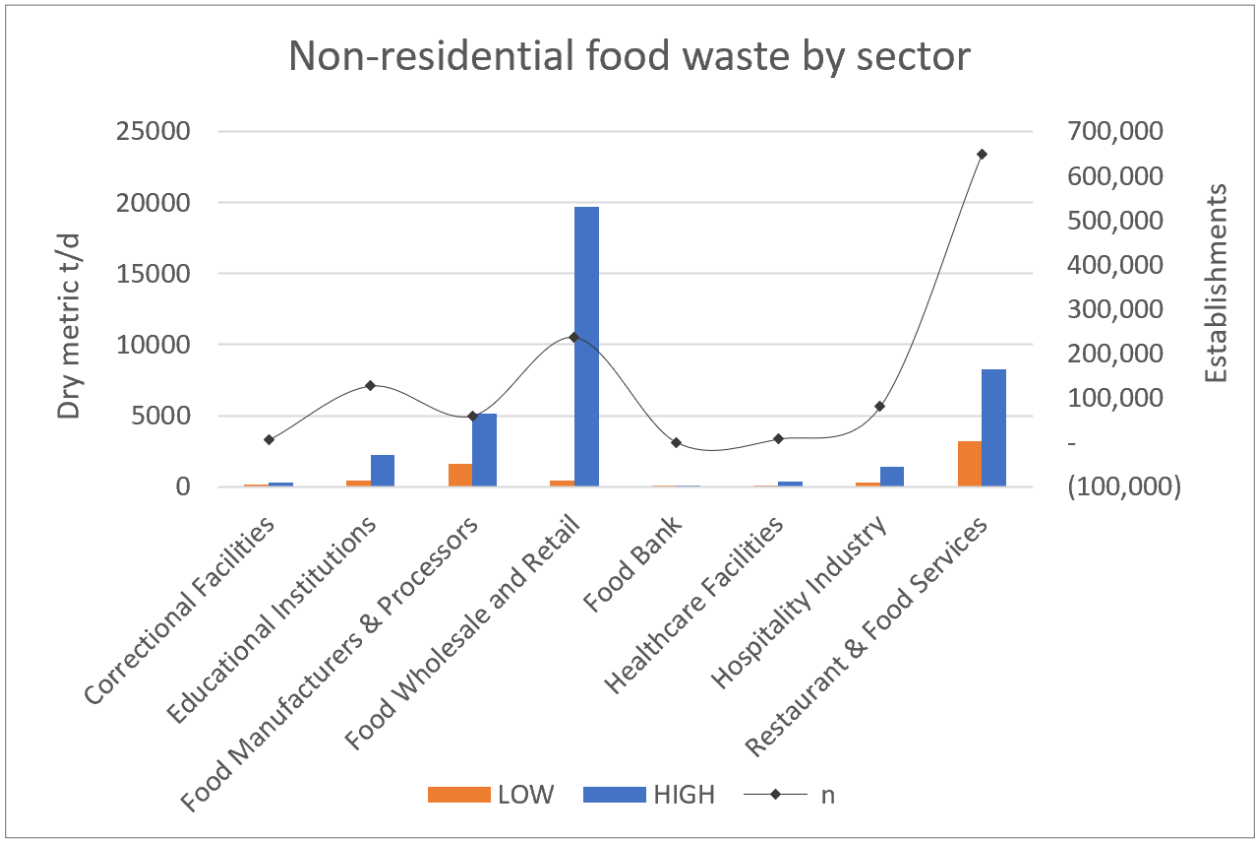

Figure 10. US non-residential food excess ("Low" and "High") by sector

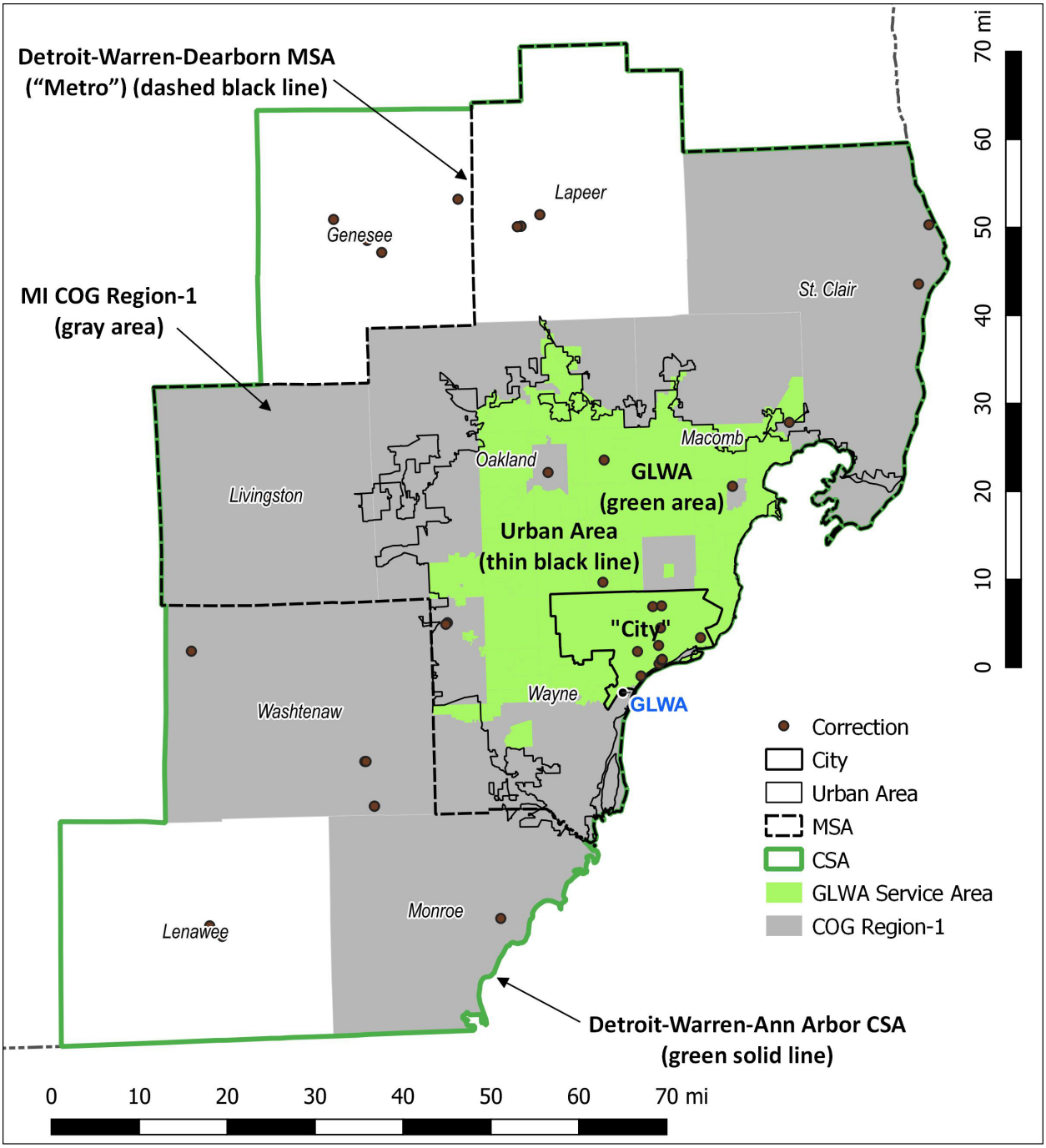

Figure 11. Correctional facilities in proximity to Detroit

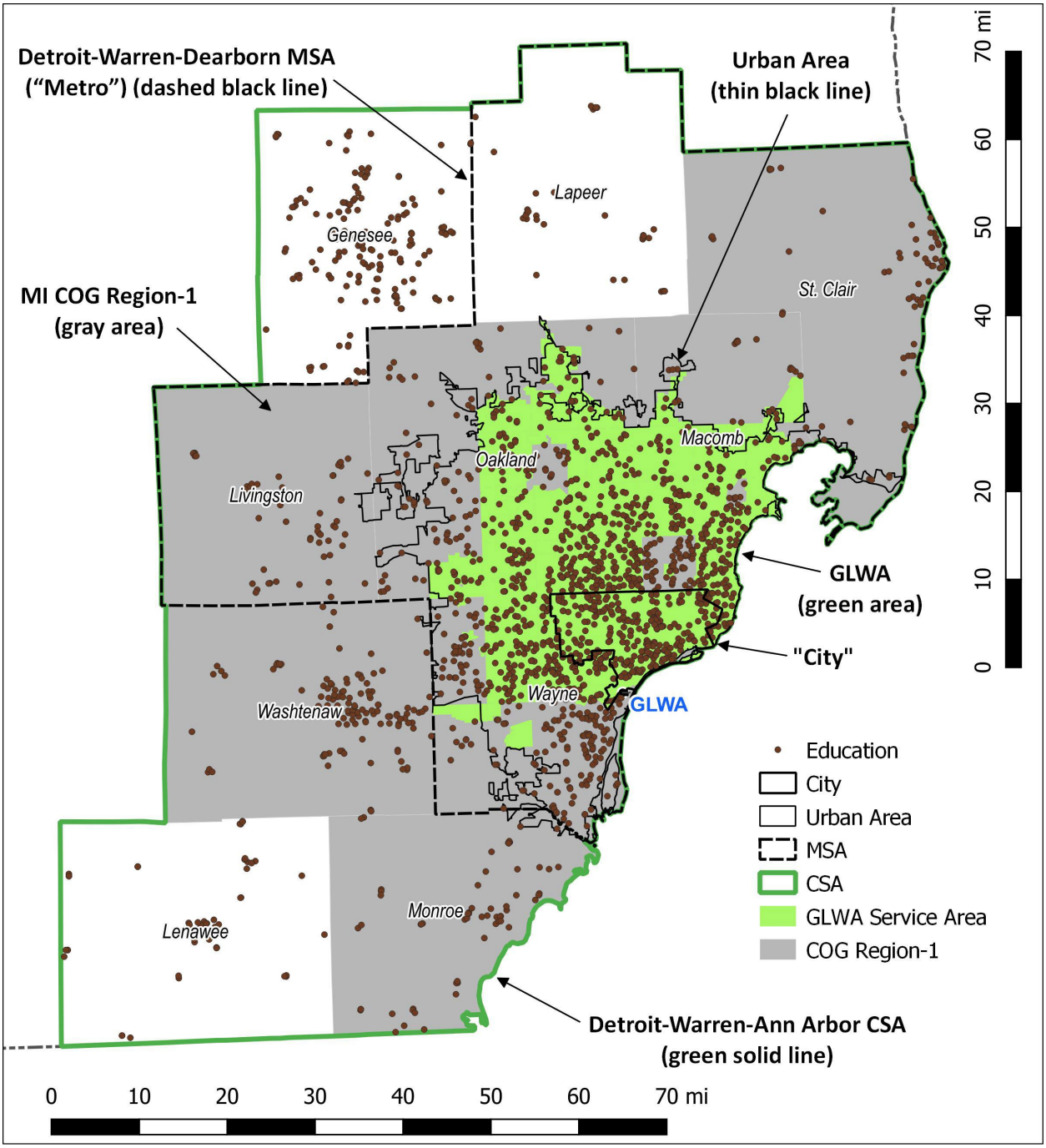

Figure 12. Educational facilities in proximity to Detroit

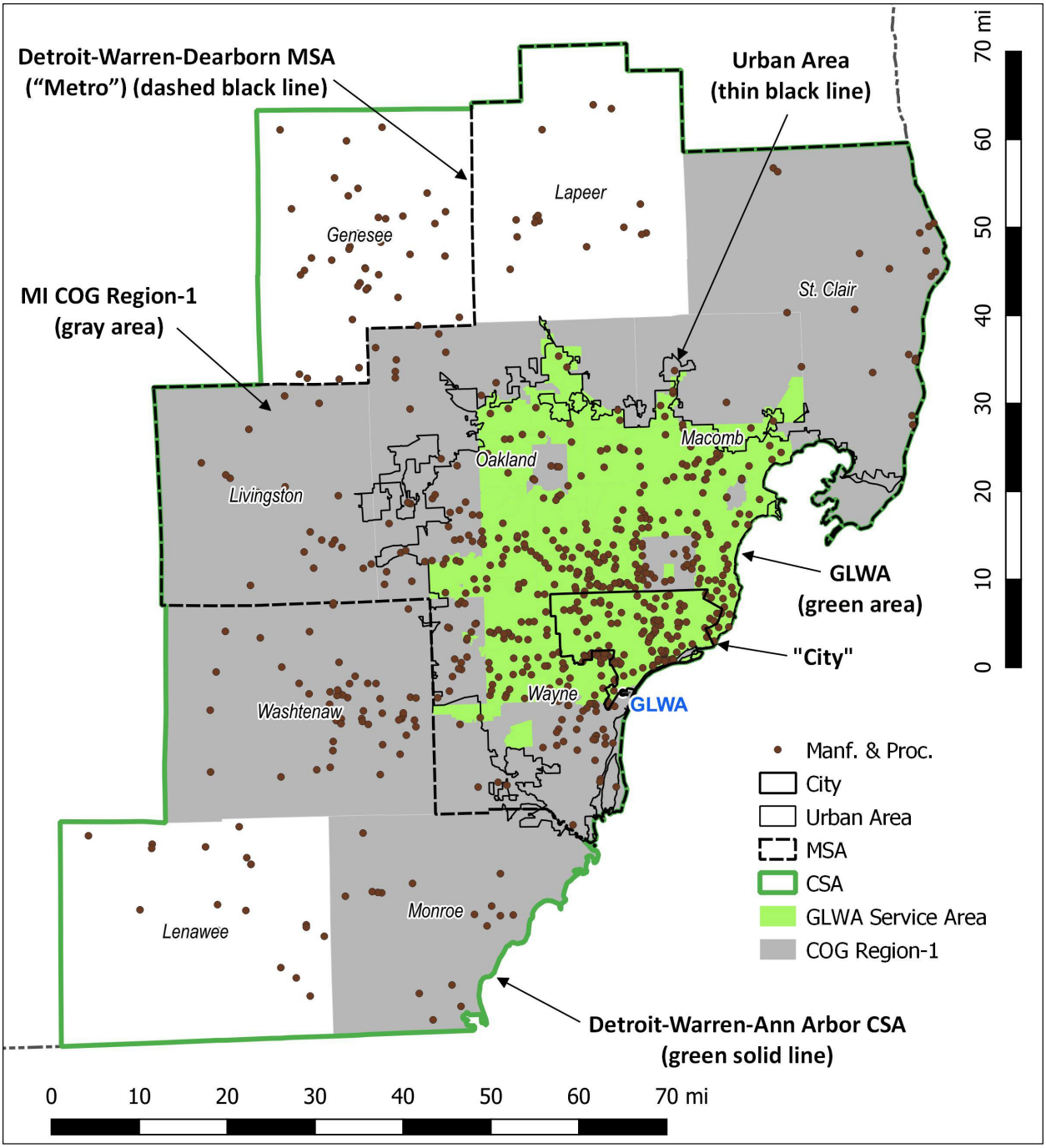

Figure 13. Food manufacturers and processors in proximity to Detroit

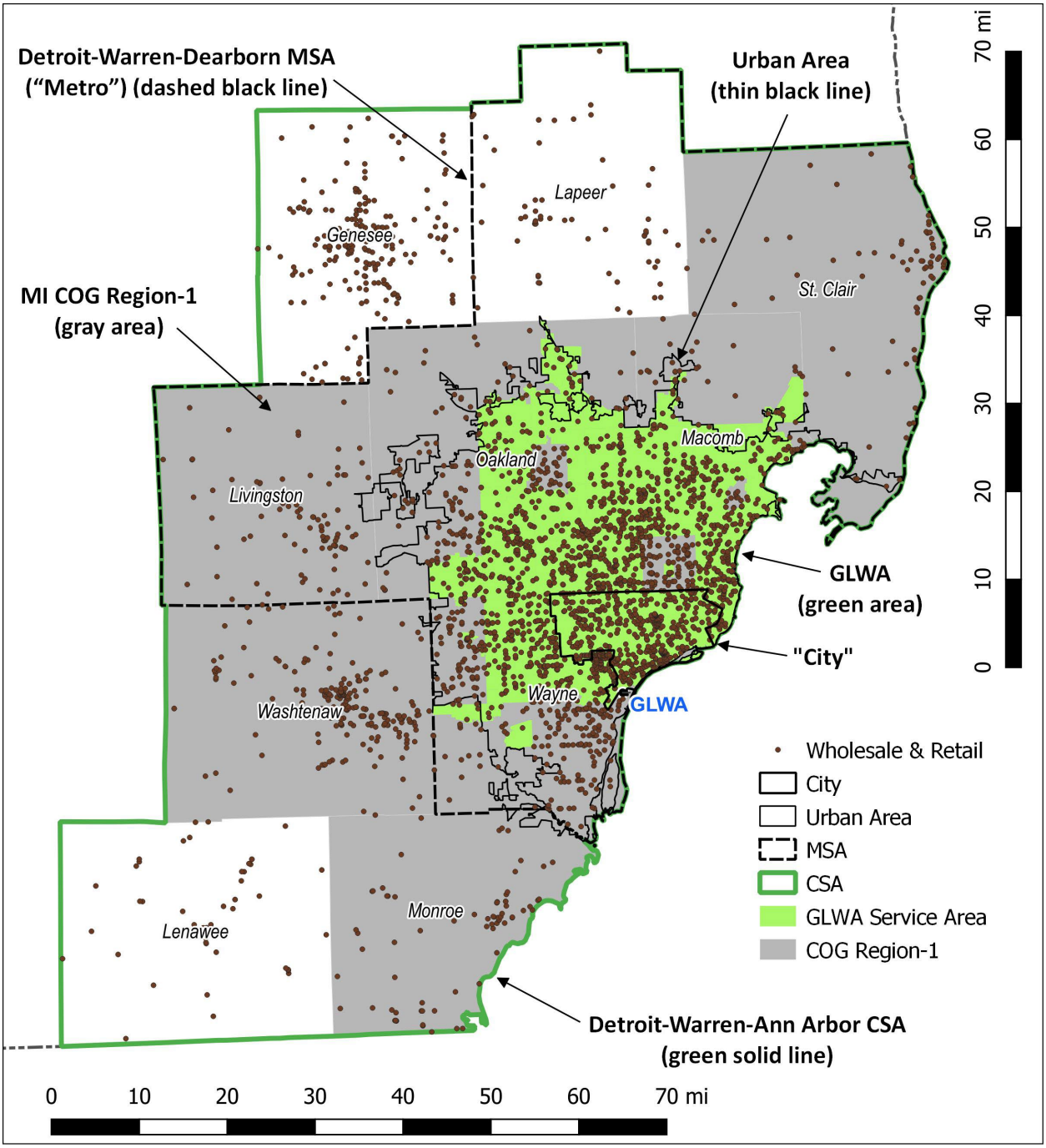

Figure 14. Food wholesale and retail

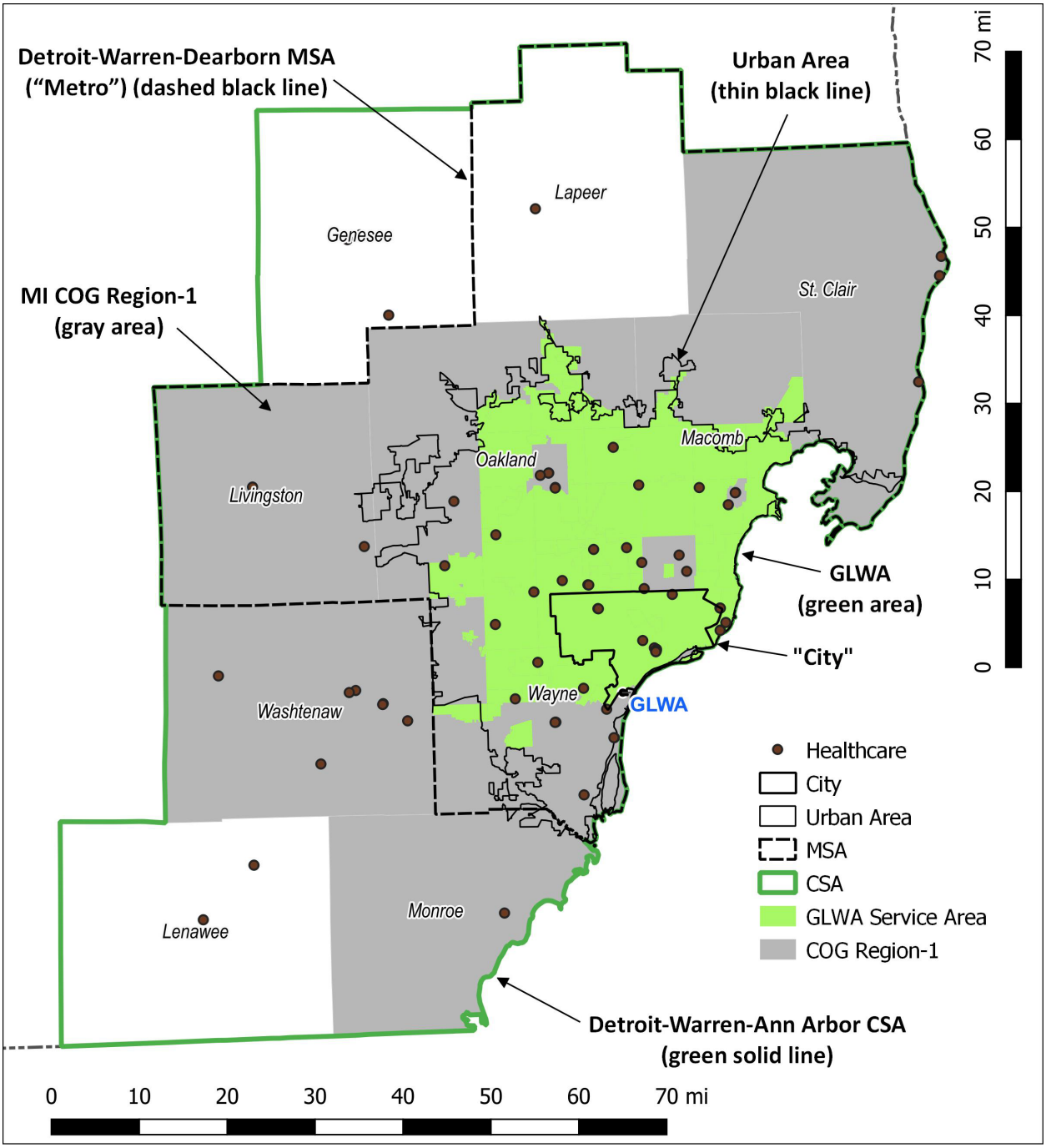

Figure 15. Healthcare facilities in proximity to Detroit

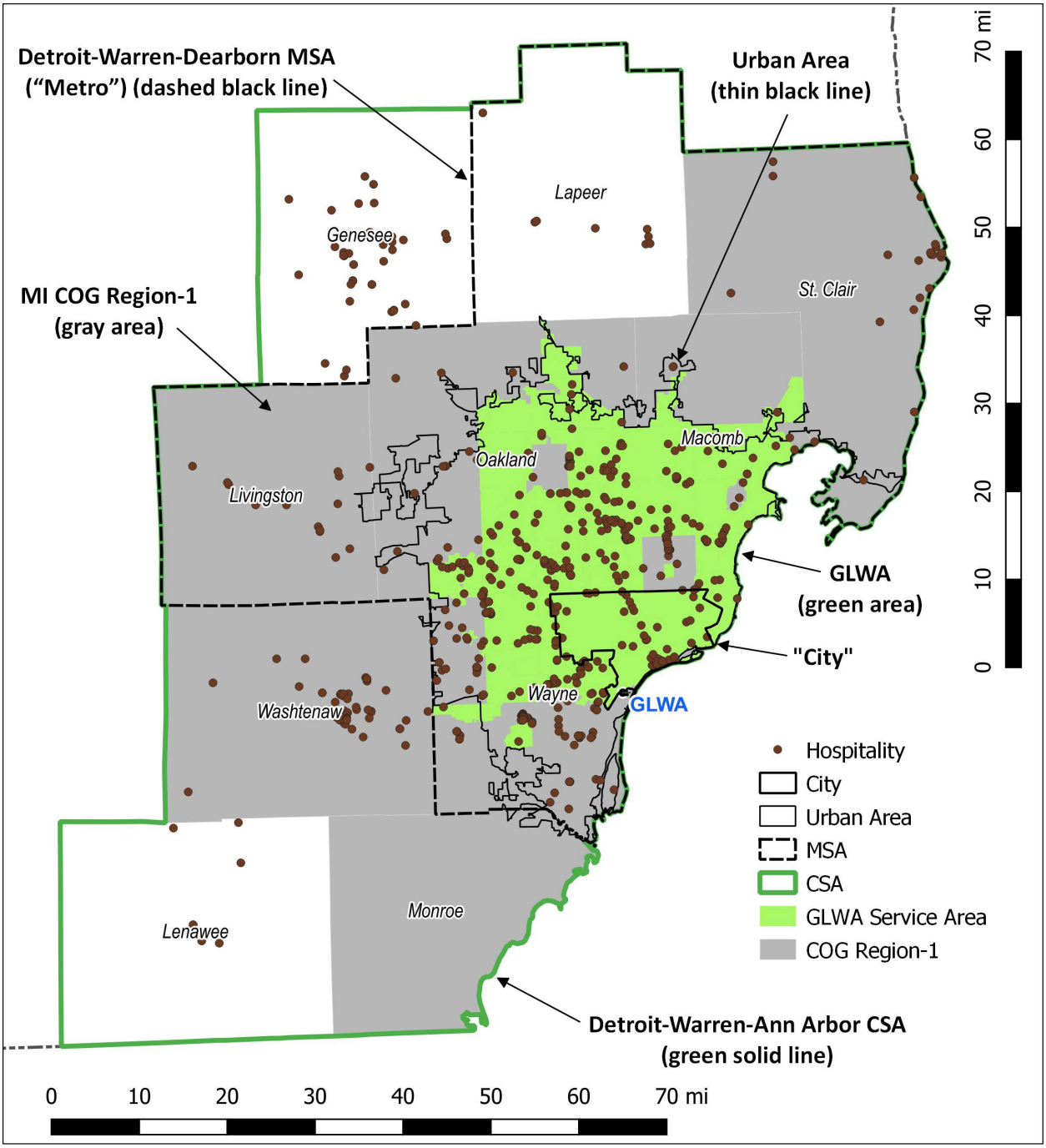

Figure 16. Hospitality facilities in proximity to Detroit

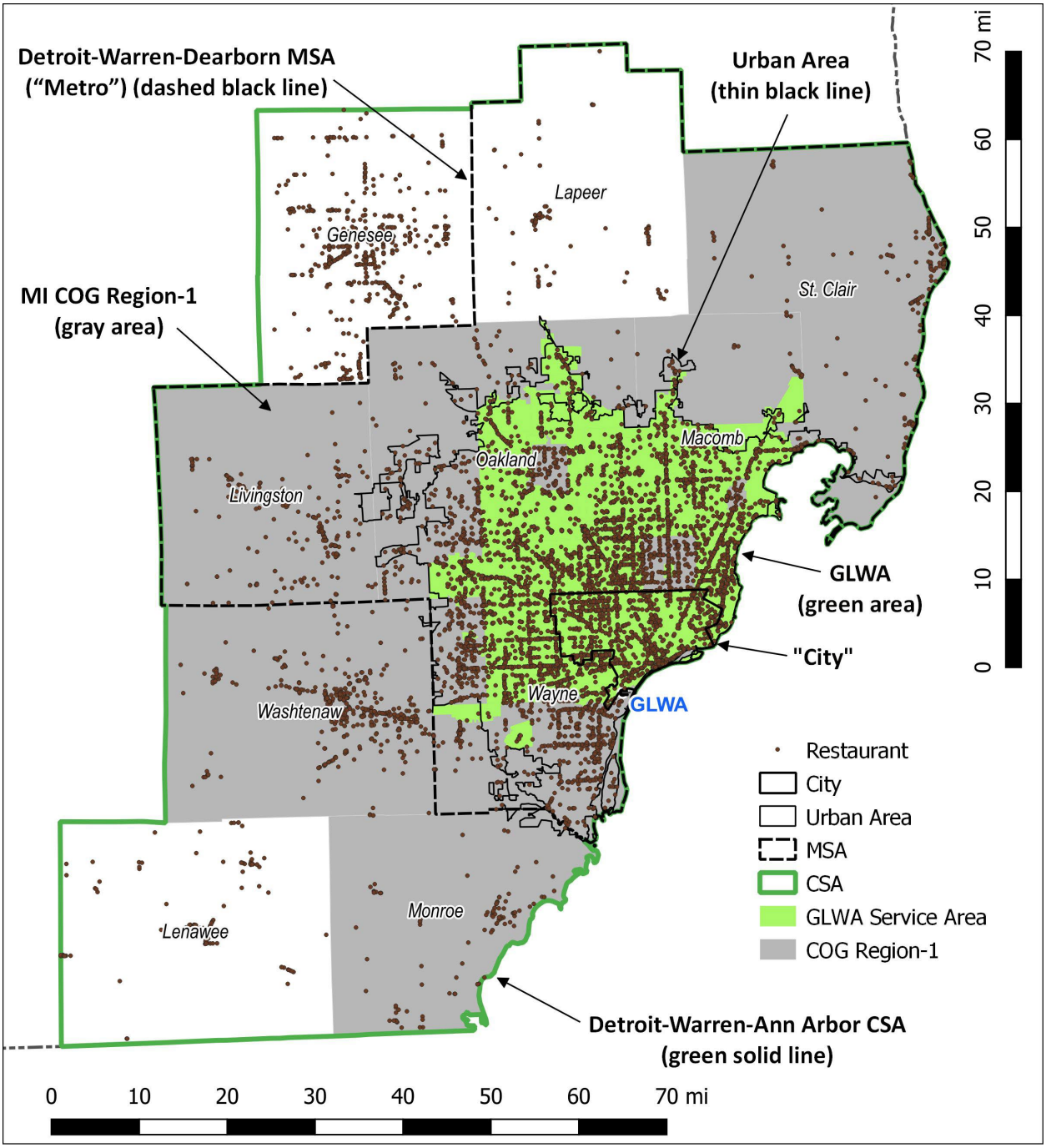

Figure 17. Restaurants and food services in proximity to Detroit

Table 26. US non-residential food excess ("Low" and "High") by sector

Sector	Count				Low			High		
	Geo	n	%	Null	Wet US t/y	Dry metric t/d	% Mass	Wet US t/y	Dry metric t/d	% Mass
Correctional Facilities	Address	5,269	0.5	-	273,161	204	2.7	493,452	368	0.8
Educational Institutions	{x,y}	127,203	10.9	2,839	709,981	529	7.1	3,650,262	2722	6.0
Food Manuf. & Processors	Address	59,914	5.1	6,649	2,568,745	1915	25.5	8,238,871	6143	13.6
Food Wholesale & Retail	Address	236,666	20.3	67	719,774	537	7.2	31,695,473	23633	52.5
Food Bank	{x,y}	316	0.03	154	50,313	38	0.5	50,313	38	0.1
Healthcare Facilities	{x,y}	7,569	0.6	650	117,995	88	1.2	633,248	472	1.0
Hospitality Industry	{x,y}	80,312	6.9	80	430,275	321	4.3	2,275,293	1697	3.8
Restaurant & Food Services	Address	649,541	55.7	15,692	5,186,196	3867	51.6	13,321,752	9933	22.1
TOTAL		*1,166,790*	*100.0*	*26,131*	10,056,440	*7498*	*100.0*	60,358,664	*45005*	*100*

Table 27. Detroit CSA non-residential food excess ("Low" and "High") by sector

Sector	Occurrences			Low			High		
	n	%	Null	Wet US t/y	Dry metric t/d	% Mass	Wet US t/y	Dry metric t/d	% Mass
Correctional Facilities	42	0.2	0	2,168	2	2	3,917	3	0
Educational Institutions	1980	12	27	10,962	8	8	56,047	42	7
Food Manuf. & Processors	718	4	39	19,877	15	14	63,747	48	8
Food Wholesale and Retail	3426	20	1	12,843	10	9	450,699	336	54
Healthcare Facilities	72	0.4	4	1,839	1	1	9,869	7	1
Hospitality Industry	720	4	1	4,120	3	3	21,785	16	3
Restaurant & Food Services	9897	59	239	85,963	64	62	222,786	166	27
TOTAL	16855	100	311	137,772	103	100	828,850	618	100

The average of the low and high non-residential food waste is 360 dry metric t/d, which is generally consistent with the 439 dry metric t/d of non-residential food waste disposed as part of Michigan's 828 dry metric t/d OFMSW (PNNL, 2023), assuming 53% of total disposed OFMSW is from commercial sources (NextCycle, 2021).

Table 28. Detroit CSA non-residential food waste by NAISC code

NAICS Code	NAICS Code Description	Low	High	Low	High
		wet US t/y		dry metric t/d	
Food Manufacturers and Processors		**19877**	**63747**	**14.8**	**47.5**
112930	Fur-Bearing Animal and Rabbit Production	2	6	0.0	0.0
311211	Flour Milling	0	0	0.0	0.0
311212	Rice Milling	0	0	0.0	0.0
311213	Malt Manufacturing	11	36	0.0	0.0
311221	Wet Corn Milling	180	578	0.1	0.4
311224	Soybean and Other Oilseed Processing	539	1729	0.4	1.3
311225	Fats and Oils Refining and Blending	5	14	0.0	0.0
311230	Breakfast Cereal Manufacturing	12	37	0.0	0.0
311313	Beet Sugar Manufacturing	0	0	0.0	0.0
311314	Cane Sugar Manufacturing	0	0	0.0	0.0
311340	Nonchocolate Confectionery Manufacturing	1299	4167	1.0	3.1
311351	Chocolate and Confectionery Manufacturing	0	0	0.0	0.0
311352	Confectionery Manufacturing from Purchased Chocolate	14	44	0.0	0.0
311411	Frozen Fruit, Juice, and Vegetable Manufacturing	34	109	0.0	0.1
311412	Frozen Specialty Food Manufacturing	354	1135	0.3	0.8
311421	Fruit and Vegetable Canning	605	1939	0.5	1.4
311422	Specialty Canning	187	601	0.1	0.4
311423	Dried and Dehydrated Food Manufacturing	9	27	0.0	0.0
311511	Fluid Milk Manufacturing	64	205	0.0	0.2
311512	Creamery Butter Manufacturing	10	33	0.0	0.0
311513	Cheese Manufacturing	308	989	0.2	0.7
311514	Dry, Condensed, and Evaporated Dairy Product Manufacturing	490	1572	0.4	1.2
311520	Ice Cream and Frozen Dessert Manufacturing	520	1666	0.4	1.2
311611	Animal (except Poultry) Slaughtering	79	252	0.1	0.2
311612	Meat Processed from Carcasses	2074	6651	1.5	5.0
311613	Rendering and Meat Byproduct Processing	9	29	0.0	0.0
311615	Poultry Processing	205	658	0.2	0.5
311710	Seafood Product Preparation and Packaging	74	238	0.1	0.2
311811	Retail Bakeries	961	3079	0.7	2.3
311812	Commercial Bakeries	2023	6489	1.5	4.8
311813	Frozen Cakes, Pies, and Other Pastries Manufacturing	1340	4300	1.0	3.2
311821	Cookie and Cracker Manufacturing	163	522	0.1	0.4
311824	Dry Pasta, Dough, and Flour Mixes	223	715	0.2	0.5
311830	Tortilla Manufacturing	100	320	0.1	0.2
311911	Roasted Nuts and Peanut Butter Manufacturing	0	0	0.0	0.0
311919	Other Snack Food Manufacturing	578	1853	0.4	1.4

311920	Coffee and Tea Manufacturing	112	358	0.1	0.3
311930	Flavoring Syrup and Concentrate Manufacturing	41	130	0.0	0.1
311941	Mayonnaise, Dressing, and Other Prepared Sauce Manf.	389	1247	0.3	0.9
311942	Spice and Extract Manufacturing	514	1648	0.4	1.2
311991	Perishable Prepared Food Manufacturing	864	2773	0.6	2.1
311999	All Other Miscellaneous Food Manufacturing	2196	7043	1.6	5.3
312111	Soft Drink Manufacturing	711	2282	0.5	1.7
312120	Breweries	1376	4412	1.0	3.3
312130	Wineries	156	501	0.1	0.4
312140	Distilleries	1048	3362	0.8	2.5
Food Wholesale and Retail		**12843**	**450699**	**9.6**	**336.1**
424410	General Line Grocery Merchant Wholesalers	1009	22197	0.8	16.6
424420	Packaged Frozen Food Merchant Wholesalers	163	1617	0.1	1.2
424430	Dairy Product (except Dried or Canned) Wholesalers	299	5292	0.2	3.9
424440	Poultry and Poultry Product Merchant Wholesalers	39	2940	0.0	2.2
424450	Confectionery Merchant Wholesalers	270	6027	0.2	4.5
424460	Fish and Seafood Merchant Wholesalers	304	6468	0.2	4.8
424470	Meat and Meat Product Merchant Wholesalers	706	7497	0.5	5.6
424480	Fresh Fruit and Vegetable Merchant Wholesalers	883	9261	0.7	6.9
424490	Other Grocery and Related Products Wholesalers	1513	56451	1.1	42.1
445110	Supermarkets and Other Grocery (except Convenience)	4781	180975	3.6	134.9
445210	Meat Markets	260	16081	0.2	12.0
445220	Fish and Seafood Markets	47	5053	0.0	3.8
445230	Fruit and Vegetable Markets	581	15515	0.4	11.6
445291	Baked Goods Stores	540	65630	0.4	48.9
445292	Confectionery and Nut Stores	92	16497	0.1	12.3
445299	All Other Specialty Food Stores	221	31097	0.2	23.2
452311	Warehouse Clubs and Supercenters	1135	2101	0.8	1.6
Educational Institutions		**10962**	**56047**	**8.2**	**41.8**
n/a	Public Elementary & Secondary	7240	34090	5.4	25.4
n/a	Private Elementary & Secondary	466	2194	0.3	1.6
n/a	Postsecondary	3257	19763	2.4	14.7
Hospitality Industry		**4120**	**21785**	**3.1**	**16.2**
713210	Casinos (except Casino Hotels)	516	2727	0.4	2.0
721110	Hotels and Motels	3037	16057	2.3	12.0
721120	Casino Hotels	568	3001	0.4	2.2
Correctional Facilities		**2168**	**3917**	**1.6**	**2.9**
922140	Correctional Institutions	2168	3917	1.6	2.9
Healthcare Facilities		**1839**	**9869**	**1.4**	**7.4**
622110	General Medical and Surgical Hospitals	1746	9373	1.3	7.0

622210	Psychiatric and Substance Abuse Hospitals	0	0	0.0	0.0
622310	Specialty Hospitals	92	496	0.1	0.4
Restaurants and Food Services		**85963**	**222786**	**64.1**	**166.1**
722320	Caterers	2328	7830	1.7	5.8
722330	Mobile Food Services	222	444	0.2	0.3
722511	Full-Service Restaurants	42750	111446	31.9	83.1
722513	Limited-Service Restaurants	40172	102018	30.0	76.1
722514	Cafeterias, Grill Buffets, and Buffets	451	909	0.3	0.7
722515	Snack and Nonalcoholic Beverage Bars	39	140	0.0	0.1

Table 29. Detroit CSA NAICS codes ranked by “Low” food waste potential

NAICS Code	NAICS Code Description	Low	High
722511	Full-Service Restaurants	31.9	83.1
722513	Limited-Service Restaurants	30.0	76.1
n/a	Public Elementary & Secondary	5.4	25.4
445110	Supermarkets and Other Grocery (except Convenience) Stores	3.6	134.9
n/a	Postsecondary	2.4	14.7
721110	Hotels and Motels	2.3	12.0
722320	Caterers	1.7	5.8
311999	All Other Miscellaneous Food Manufacturing	1.6	5.3
922140	Correctional Institutions	1.6	2.9
311612	Meat Processed from Carcasses	1.5	5.0
311812	Commercial Bakeries	1.5	4.8
622110	General Medical and Surgical Hospitals	1.3	7.0
424490	Other Grocery and Related Products Merchant Wholesalers	1.1	42.1
312120	Breweries	1.0	3.3
311813	Frozen Cakes, Pies, and Other Pastries Manufacturing	1.0	3.2
311340	Nonchocolate Confectionery Manufacturing	1.0	3.1
452311	Warehouse Clubs and Supercenters	0.8	1.6
312140	Distilleries	0.8	2.5
424410	General Line Grocery Merchant Wholesalers	0.8	16.6
311811	Retail Bakeries	0.7	2.3
424480	Fresh Fruit and Vegetable Merchant Wholesalers	0.7	6.9
311991	Perishable Prepared Food Manufacturing	0.6	2.1
312111	Soft Drink Manufacturing	0.5	1.7
424470	Meat and Meat Product Merchant Wholesalers	0.5	5.6
311421	Fruit and Vegetable Canning	0.5	1.4
445230	Fruit and Vegetable Markets	0.4	11.6
311919	Other Snack Food Manufacturing	0.4	1.4
721120	Casino Hotels	0.4	2.2

445291	Baked Goods Stores	0.4	48.9
311224	Soybean and Other Oilseed Processing	0.4	1.3
311520	Ice Cream and Frozen Dessert Manufacturing	0.4	1.2
713210	Casinos (except Casino Hotels)	0.4	2.0
311942	Spice and Extract Manufacturing	0.4	1.2
311514	Dry, Condensed, and Evaporated Dairy Product Manufacturing	0.4	1.2
n/a	Private Elementary & Secondary	0.3	1.6
722514	Cafeterias, Grill Buffets, and Buffets	0.3	0.7
311941	Mayonnaise, Dressing, and Other Prepared Sauce Manufacturing	0.3	0.9
311412	Frozen Specialty Food Manufacturing	0.3	0.8
311513	Cheese Manufacturing	0.2	0.7
424460	Fish and Seafood Merchant Wholesalers	0.2	4.8
424430	Dairy Product (except Dried or Canned) Merchant Wholesalers	0.2	3.9
424450	Confectionery Merchant Wholesalers	0.2	4.5
445210	Meat Markets	0.2	12.0
311824	Dry Pasta, Dough, and Flour Mixes	0.2	0.5
722330	Mobile Food Services	0.2	0.3
445299	All Other Specialty Food Stores	0.2	23.2
311615	Poultry Processing	0.2	0.5
311422	Specialty Canning	0.1	0.4
311221	Wet Corn Milling	0.1	0.4
311821	Cookie and Cracker Manufacturing	0.1	0.4
424420	Packaged Frozen Food Merchant Wholesalers	0.1	1.2
312130	Wineries	0.1	0.4
311920	Coffee and Tea Manufacturing	0.1	0.3
311830	Tortilla Manufacturing	0.1	0.2
622310	Specialty (except Psychiatric and Substance Abuse) Hospitals	0.1	0.4
445292	Confectionery and Nut Stores	0.1	12.3
311611	Animal (except Poultry) Slaughtering	0.1	0.2
311710	Seafood Product Preparation and Packaging	0.1	0.2
311511	Fluid Milk Manufacturing	<0.1	0.2
445220	Fish and Seafood Markets	<0.1	3.8
311930	Flavoring Syrup and Concentrate Manufacturing	<0.1	0.1
722515	Snack and Nonalcoholic Beverage Bars	<0.1	0.1
424440	Poultry and Poultry Product Merchant Wholesalers	<0.1	2.2
311411	Frozen Fruit, Juice, and Vegetable Manufacturing	<0.1	0.1
311352	Confectionery Manufacturing from Purchased Chocolate	<0.1	<0.1
311230	Breakfast Cereal Manufacturing	<0.1	<0.1
311213	Malt Manufacturing	<0.1	<0.1
311512	Creamery Butter Manufacturing	<0.1	<0.1

311613	Rendering and Meat Byproduct Processing	<0.1	<0.1
311423	Dried and Dehydrated Food Manufacturing	<0.1	<0.1
311225	Fats and Oils Refining and Blending	<0.1	<0.1
112930	Fur-Bearing Animal and Rabbit Production	<0.1	<0.1
311211	Flour Milling	<0.1	<0.1
311212	Rice Milling	<0.1	<0.1
311313	Beet Sugar Manufacturing	<0.1	<0.1
311314	Cane Sugar Manufacturing	<0.1	<0.1
311351	Chocolate and Confectionery Manufacturing from Cacao Beans	<0.1	<0.1
311911	Roasted Nuts and Peanut Butter Manufacturing	<0.1	<0.1
622210	Psychiatric and Substance Abuse Hospitals	<0.1	<0.1

2.6 Confined Animal Manures

Total recoverable manure solids from confined animal operations were characterized previously as part of the National Wet Waste Inventory (NWWI) (Seiple et al., 2020c).In total, the NWWI documents eleven confined manure operations producing approximately 75,604 dry metric tons per year (207 dry t/d) of confined manure solids occur within the Detroit CSA. Approximately 90% of recoverable manure solids are from dairy operations occurring in Lenawee County, with the balance coming from beef (7%) and swine (3%) operations.

Table 30. NWWI confined manure sources count and recoverable solids by scale

Scale	Count	Recoverable Solids (dry metric t/d)
City	0	0.0
GLWA	0	0.0
Urban Area	0	0.0
MSA	2	31.8
COG Region-1	2	31.8
CSA	12	207.1

Table 31. NWWI inventoried manure sources in Detroit CSA

UID	Type	Dry metric t/d
15826	dairy	41.7
15924	dairy	31.9
16033	dairy	24.3
16066	dairy	23.4
16251	dairy	18.3
16356	dairy	16.3
7894	beef	15.5
16437	dairy	15.4
17271	dairy	8.5
17790	dairy	6.1
21349	swine	5.8

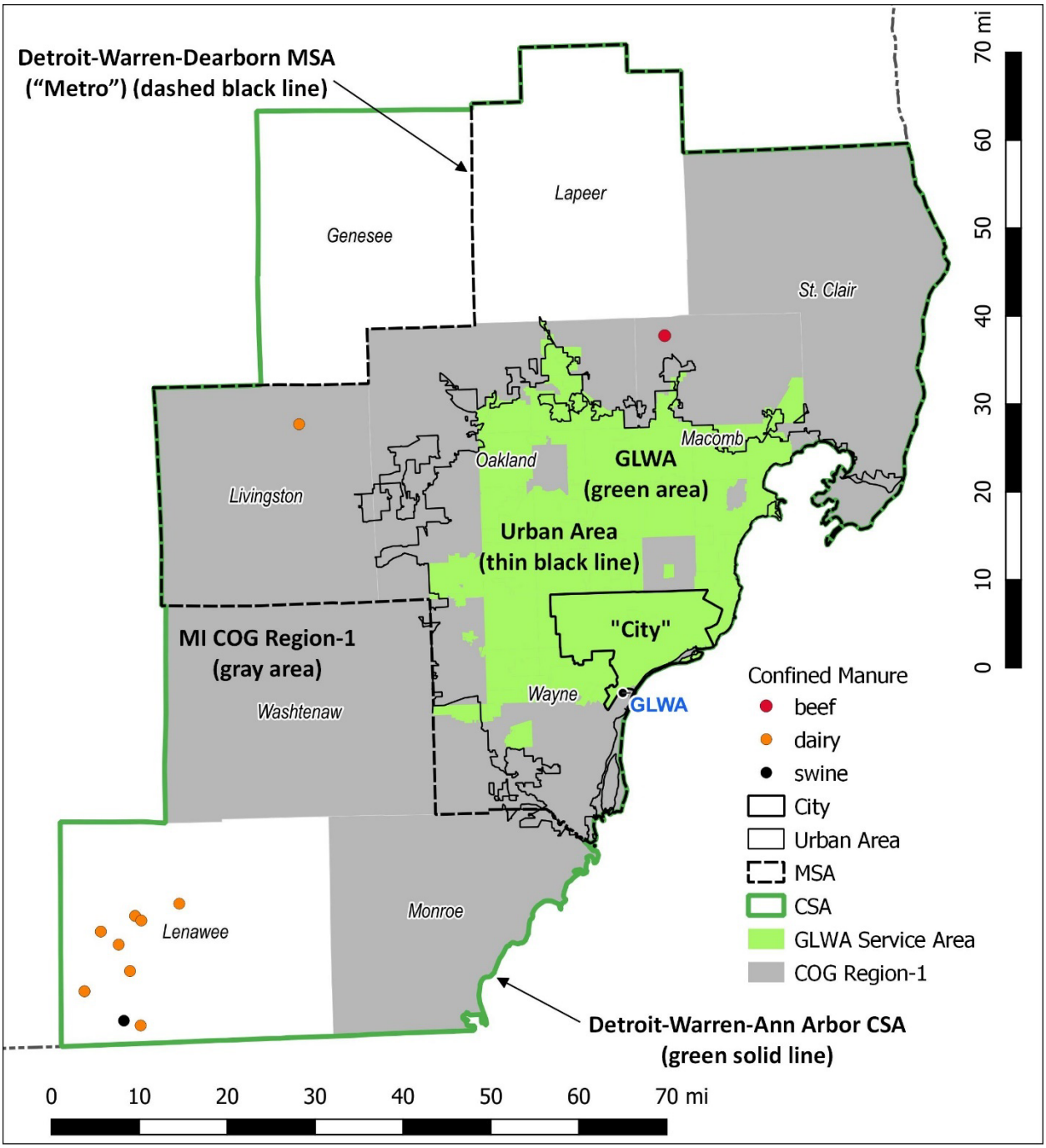

Figure 18. NWWI inventoried manure sources in Detroit CSA

2.7 Fats, Oils and Greases

Total waste fats, oils, and greases (FOG) were characterized previously by Milbrandt et al., 2018, which were also included in the National Wet Waste Inventory (NWWI) (Seiple et al., 2020c). FOG estimates include yellow grease, brown grease, and animal fats including inedible beef tallow, inedible pork fat (choice white grease), and inedible poultry fat. Edible fats and lard were excluded but other higher uses were not accounted for. Yellow and brown grease based on per capita factors, 4 and 6 kg/person/year respectively, and 2010 census population data for approximately 3,500 urban areas. Waste animal fats were estimated based on 2012 USDA state level animal slaughter data and edible and inedible fat factors per live weight from the literature and were then downscaled to known rendering plant locations. For purposes of waste-to-energy modeling, we combine yellow and brown greases and all animal fats and assume all waste FOG contains zero moisture.

Table 32. Summary of US waste FOG resources

Type of Waste FOG	Data Scale	Year	n	MM metric dry t/y
yellow and brown grease	Urban centroids	2010	3,573	2.51
livestock fat (beef and pork)	State downscaled to rendering plant	2012	232	2.13
poultry fat	State downscaled to rendering plant	2012	74	0.75
TOTAL			3,879	5.39

Approximately 57,041 dry metric tons per year (156 dry metric t/d) of waste FOGs are generated in the Detroit area, with 84% (131.6 dry metric t/d) comprised of combined yellow and brown grease, primarily from Detroit, and 16% (24.7 dry metric t/d) of animal fat at one rendering plant in Wayne County.

Table 33. NWWI waste FOG sources count and available solids by scale

Scale	Count	Solids (dry metric t/d)
City	0	0.0
GLWA Service Area	2	127.8
Urban Area	2	127.8
MSA	11	134.8
COG Region-1	13	144.5
CSA	19	156.3

Table 34. NWWI inventoried FOG sources in Detroit CSA

UID	Type	Dry metric t/d
11	grease	103.2
3621	livestock fat	24.7
105	grease	9.8
123	grease	8.5
258	grease	3.3

329	grease	2.4
479	grease	1.4
510	grease	1.2
1124	grease	0.4
1613	grease	0.2
1708	grease	0.2
1977	grease	0.2
2048	grease	0.2
2193	grease	0.1
2731	grease	0.1
2735	grease	0.1
2736	grease	0.1
3007	grease	0.1
3388	grease	0.1

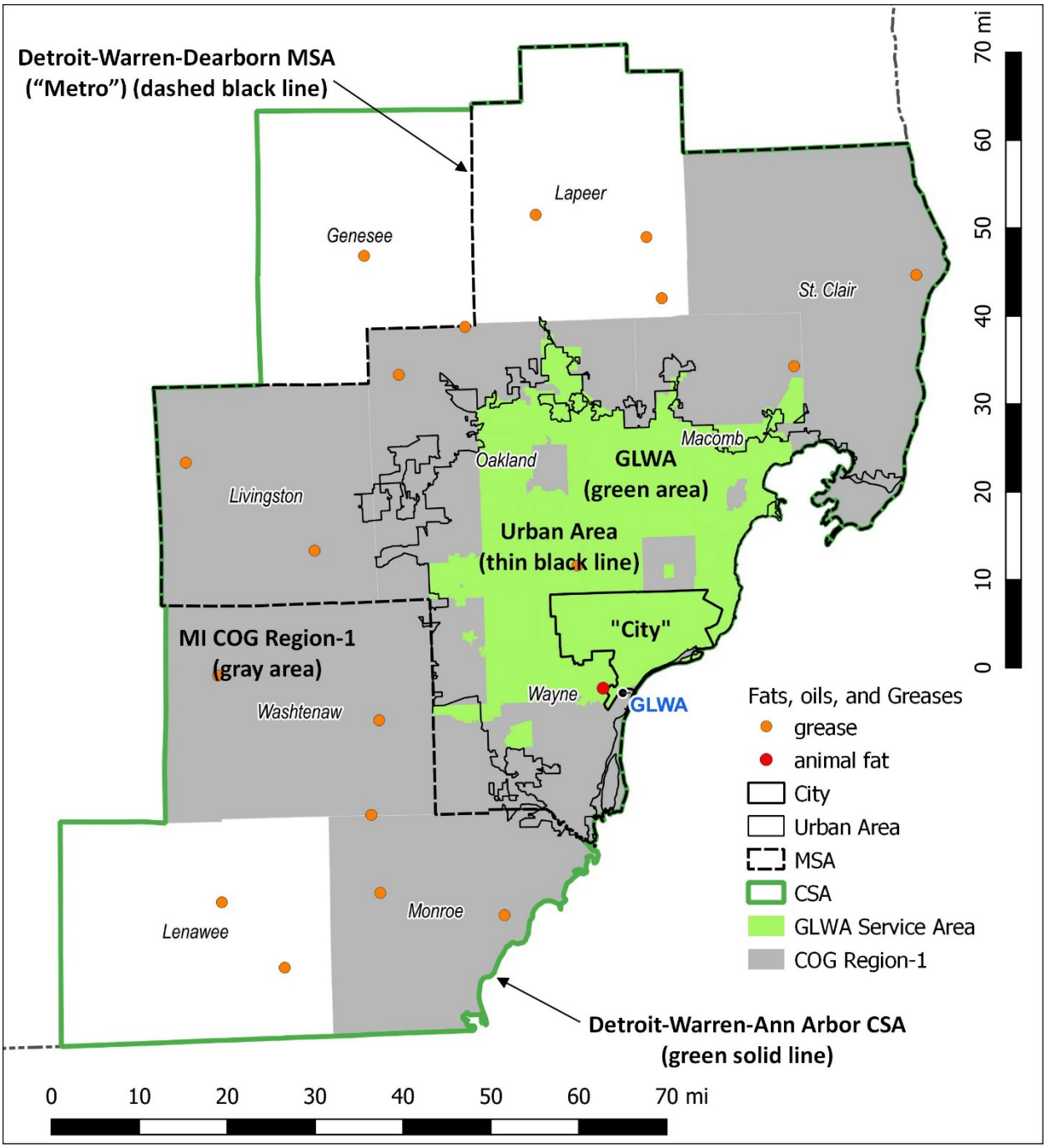

Figure 19. NWWI inventoried FOG sources in Detroit CSA

2.8 Agricultural Residues

A total of 150-207 million metric dry tons per year of recoverable agricultural residue: corn stover (75%), wheat straw (20%), and other grain straws (barley, oat, sorghum) were previously estimated by Muth et al., 2013; Biddy et al., 2017; USDA, 2015; USDOE 2016.

Barley straw, oat straw, and sorghum stubble do not occur in the Detroit area. Approximately 1,025 metric dry t/d of agricultural residue are available in the Detroit CSA, including 918 dry t/d of corn stover and 107 dry t/d of wheat straw. No agricultural residues occur within the city.

Table 35. Agricultural residues in the Detroit area

Scale	TOTAL	Barley Straw	Corn Stover	Oat Straw	Sorghum Stubble	Wheat Straw
	Residue (dry metric t/d)					
City	-	-	-	-	-	-
GLWA Service Area	4.7	-	4.6	-	-	0.1
Urban Area	1.3	-	0.9	-	-	0.4
MSA	439	-	430	-	-	9
COG Region-1	649	-	594	-	-	54
CSA	1,025	-	918	-	-	107

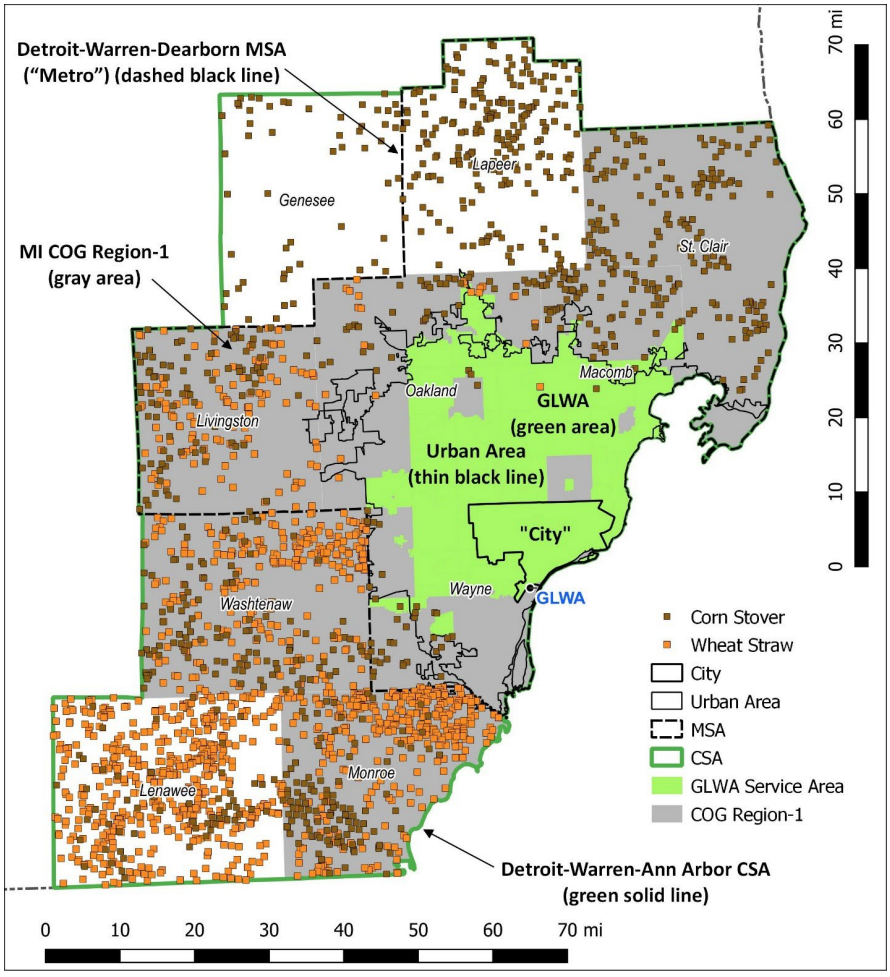

Figure 20. Agricultural residues in the Detroit CSA

2.9 Forest Residues

Forest residues are not currently part of existing organic waste inventories. We are in the process of modeling total recoverable forest residues and will add them to the inventory when completed.

2.10 Residential Food Waste

Spatially explicit residential food waste estimates are not available below the county level. These data could be modeled using census data for single and multi-family homes. Other organizations are reportedly in the process of doing so. If the data are not provided by the end of fiscal 2023, we can model the data in FY2024.

Residential food waste data could be used to support a sensitivity case that assumes a future source separated organics (SSO), or similar organics ban is implemented in Detroit, making residential food waste more readily available.

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