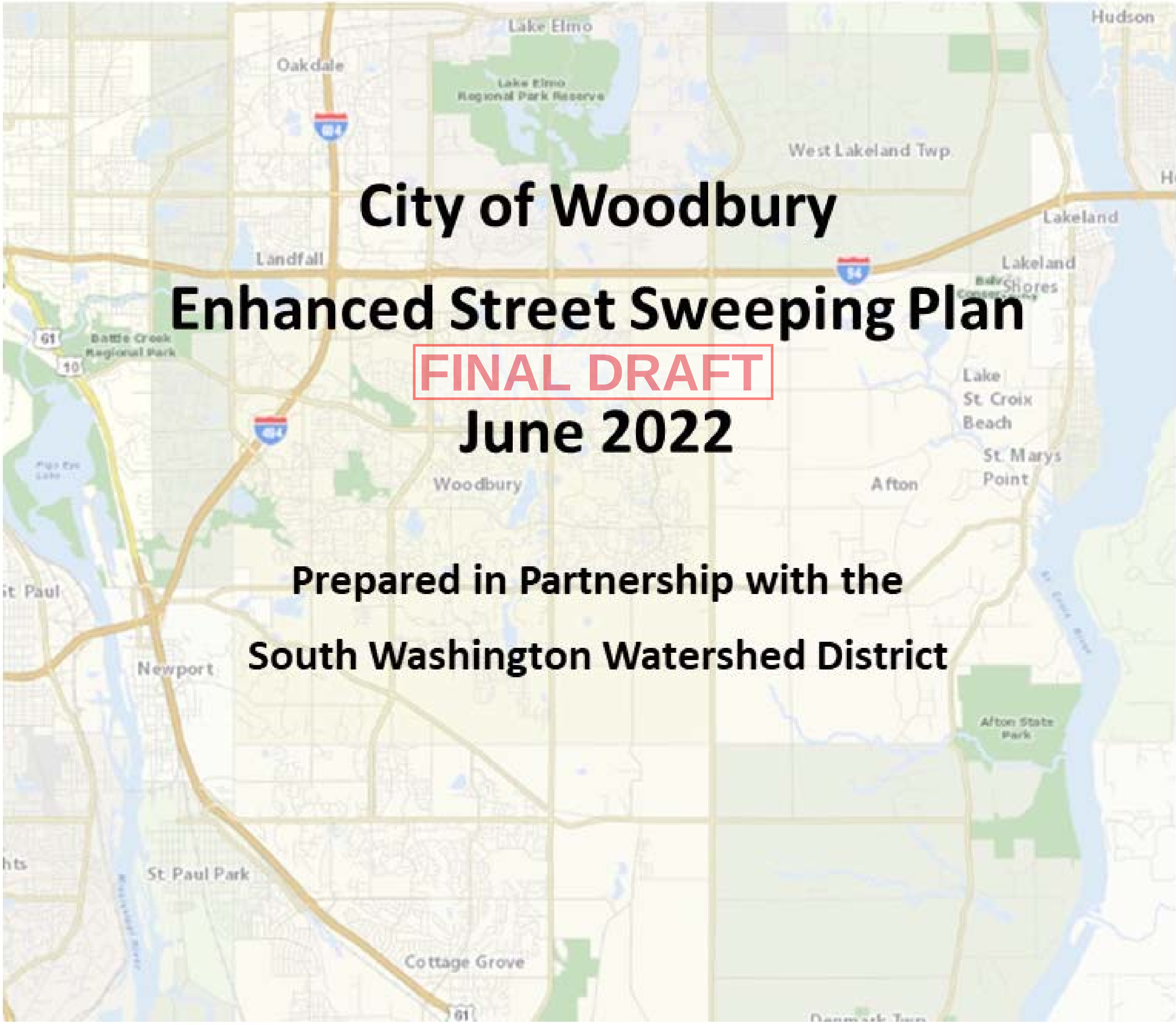

City of Woodbury

Enhanced Street Sweeping Plan

FINAL DRAFT

June 2022

Prepared in Partnership with the

South Washington Watershed District

SOUTH WASHINGTON WATERSHED DISTRICT

CITY OF Woodbury

EOR water ecology community

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EXECUTIVE SUMMARY

Street sweeping is the practice of removing particulates (salt, sand, and soil) and organic matter (leaves, seeds, flowers, etc.) from streets using mechanical broom or vacuum street sweeping vehicles to reduce the amount of pollutants and sediment discharged to stormwater conveyance systems. Traditional municipal street sweeping programs typically involve mechanically sweeping all City streets once in the spring and once in the fall. Enhanced municipal street sweeping programs typically involve sweeping streets with high efficiency sweepers (vacuum type or similar) at higher frequency based on the variable generation of particulates and organic matter to streets.

This Plan identifies road-specific street sweeping timing and frequency, quantifies expected phosphorus load reductions, itemizes costs of enhanced street sweeping (including purchase and subcontract options), and recommends funding options for an enhanced street sweeping program in the City of Woodbury, MN.

The City currently sweeps approximately 606 lane-miles of city-owned roads twice annually, 458 of which lie within South Washington Watershed District. Current sweeping practices improve road safety and appearance and recover (load taken out of the streets) approximately 296 lb of phosphorus (TP) and 277 tons of solids (TS) from City's roads surfaces each year. Key findings from this Street Sweeping Management Plan indicate enhancing the current baseline sweeping practices could increase pollutant recovery by 188 lb of TP and 270 tons of TS for one additional sweeping each in the spring and fall (4 sweeping per year total), and by 660 lb of TP and 776 tons of TS for twice monthly sweepings.

Pollutant recovery through street sweeping also results in a reduction (load prevented from discharging in a downstream waterbody) in TS and TP pollutant loading to stormwater practices and downstream waterbodies. Due to the complex nature of phosphorus transport and transformation, it is difficult to directly correlate recovery to specific load reductions for downstream waterbodies. However, the estimates provided in this report can provide a relative comparison for the sweeping scenarios evaluated. The analysis indicated that compared to estimated load reductions for the baseline effort, the enhanced sweeping scenario (4 sweepings per year) can further reduce TP loading to downstream waterbodies by 92 lb for the baseline effort and by 324 lb for the twice monthly scenario.

For this study, streets were aggregated into sweeping zones at a neighborhood scale considering water resource drainage boundaries, land use type, and tree canopy cover characteristics. Zones are shown in shown in Figure 5 and key characteristics for each sweeping zone are summarized in Table 1. Because much of the City's growth has occurred in recent decades, stormwater infrastructure includes stormwater BMPs that provide some level of protection for downstream resources. For these reasons, sweeping zones were prioritized based on water quality management goals for the downstream resource, (City of Woodbury, 2040 Surface Water Management Plan, SWWD 2018 Lake Management Plan), rather than a lack of existing infrastructure.

Recommendations for sweeping frequency by zone are outlined in Section 8 of this report. The analysis identified four priority zones which would benefit from increasing frequency of sweeping to twice monthly: SW-3, SW-4, SW-5, and SW-7. Sweeping in these zones will primarily benefit Wilmes Lake North, Wilmes Lake

South, Powers Lake, and Colby Lake. All other sweeping zones in the City of Woodbury Surface Water Management Plan, would benefit from monthly sweeping (7 sweepings per season) for protection of downstream water quality and BMP longevity. Recommendations are presented in a 2-tiered format to provide options for gradual implementation of an in-house Enhanced Street Sweeping Program for the City of Woodbury.

1. INTRODUCTION

This study was commissioned by the South Washington Watershed District (SWWD) to support the adoption of an enhanced street sweeping program by the City of Woodbury as part of their surface water management plan and regular Best Management Practice (BMP) maintenance program. The objectives of this study are to identify road-specific recommendations for the timing and frequency of street sweeping, quantify the resulting phosphorus and sediment load reductions to area lakes, itemize the costs of implementing an enhanced street sweeping program, and provide a cost-benefit analysis for recommendations with respect to water quality goals and current maintenance practices.

Enhanced street sweeping has been identified as a potential BMP for treating stormwater runoff to several large recreational lakes in the City of Woodbury: Colby, La, Markgrafs, Wilmes, and Powers Lakes in the SWWD and Battle Creek and Carver Lakes in the Ramsey-Washington Metro Watershed District (RWMWD). The SWWD and the City have discussed the benefits of modifying their existing street sweeping program from one spring and one fall sweep to more than two sweeps per year.

2. BENEFITS

Most cities do some amount of street sweeping each year to improve road safety and appearance, but recent research into the potential water quality benefits of street sweeping has shown that street sweeping is a cost-effective and efficient means to reduce pollutant loads to storm sewer infrastructure and downstream water resources (Selbig, 2016; Kalinosky et. al 2013, others). In response to this growing body of evidence, many cities across the country have implemented robust sweeping programs as an integral part of storm and surface water management (MN Stormwater Manual, Buranen, 2018):

- The City of Forest Lake, MN sweeps 120 miles of streets monthly at a minimum and twice monthly in sensitive areas.
- The City of Blaine, MN owns 4 street sweepers that are used to sweep 240 miles of street twice each spring and fall for a total of 4 times per year and weekly in downtown and lake water quality areas.
- The City of St. Cloud, MN operates 3 mechanical broom and 2 regenerative air sweepers during the snow-free season and, in addition to spring and fall cleanings, sweeps streets 1-4 times in the summer depending on stormwater management priority.

- The City of Englewood, CO's street sweeping program includes 121 miles of street that are swept curb-to-curb (parking ban) in the spring and fall with monthly 'routine' sweeping (no parking ban) during the summer.
- The City of Odessa, TX sweeps 490 miles using five sweepers, with streets swept twice per month and downtown areas swept minimally three times per month.

Stormwater management in older neighborhoods tends to be comprised mainly of catch basin and pipe networks that convey stormwater runoff directly from streets to surface waters with little or no structural BMPs in place to intercept and treat stormwater. Therefore, source control measures like street sweeping are the primary tools available to protect downstream water quality.

In newer neighborhoods, stormwater management systems tend to include structural BMPs such as detention ponds and infiltration basins which performance is highly sensitive to solids accumulation. While these BMPs provide water quality treatment for stormwater runoff from streets, they accumulate sediment which must be removed periodically to maintain BMP pollutant removal efficiency.

Additional benefits of street sweeping include reduced clogging and flooding of storm drains, reduced maintenance to downstream stormwater infrastructure, improved safety for pedestrians, and reduced presence of pests. Finally, street sweeping presents the advantages of ease of adaptation and preventative management, as opposed to reactive measures. Scheduling, frequency, and routes are easily altered and implemented to meet current needs and budget and experimented with to increasing efficiency.

2.1. Protection of Water Resources

Numerous waterbodies within the City of Woodbury receive runoff from Woodbury streets. These include eight DNR Public Waters that are identified as key water resources in the City's 2040 Local Surface Water Management Plan (WSB, 2019): Bailey Lake, Colby Lake, La Lake, Markgrafs Lake, Powers Lake, and Wilmes Lake, located within the SWWD; and Battle Creek Lake and Carver Lake, located within in the RWMWD. Some streets discharge their untreated runoff directly into receiving waters, while others enter the City's stormwater management systems prior to discharge.

All of Woodbury's lakes located within the SWWD have comprehensive diagnostics studies that identify total phosphorus (TP) and total solids (TS) as pollutants of concern and define reductions needed to ensure that beneficial uses are maintained. The 2018 South Washington Watershed District Six Lake Management Plan Study identified TP reduction goals of 1,303 lb/yr, or 63% of the total load, to Colby Lake, 17 lb/yr, or 28%, to La Lake, 209 lb/yr, or 63%, to Markgrafs Lake, 265 lb/yr, or 26%, to North Wilmes, and 108 lb/yr, or 14%, to South Wilmes Lake, respectively. Street sweeping was identified as a cost-effective BMP in all these lake studies. These same lakes are included on Minnesota's 2020 Impaired Waters List and are slated to undergo the TMDL process by 2024.

2.2. Compliance with Permits & Policies

2.2.1. MS4 Permit Requirements

The City of Woodbury is a Municipal Separate Storm Sewer System (MS4) community subject to stormwater regulation under the Clean Water Act and Minnesota Rule 7090. As such, the City is required to develop a Storm Water Pollution Prevention Plan (SWPPP) to reduce the discharge of pollutants from their storm sewer. Street sweeping can be used to fulfill some of the MS4 permit requirements. The City submitted a revised SWPPP to the state in April 2021 following issuance of a new MS4 General Permit (MNR040000) by the Minnesota Pollution Control Agency in November 2020.

Good Housekeeping and Maintenance

Under the terms of Permit MNR040000, MS4s are required to implement an Operations and Maintenance Program to prevent or reduce discharge of pollutant from any MS4-owned facilities. Source control measures like street sweeping are encouraged as part of this good housekeeping practice. Although not specifically identified as a housekeeping practice by the City in the current SWPPP, the sweeping that is completed each year does reduce the discharge of pollutants from City's streets and parking areas in compliance with the terms of the permit.

Impaired Waters and Approved TMDLs

Under item 22.1 of the General Permit – Discharges to Impaired Waters with a USEPA-Approved TMDL, MS4s must document progress towards Wasteload Allocations (WLAs) where the MS4 discharges to an impaired water with a USEPA-approved TMDL. There is one waterbody within the City's jurisdictional boundary with an active USEPA-approved TMDL: Fish Creek is impaired for aquatic recreation and an E.coli TMDL was approved in 2017. There are no applicable WLAs for this TMDL, but the City has identified removal of organic matter via street sweeping as an action that will be taken to reduce the amount of bacteria entering the creek. The City may have WLAs for other TMDLs in the near future. Several lakes within the City boundary are impaired for aquatic recreation due to excess nutrient with TMDL studies expected by 2025.

Education and Outreach

Street sweeping programs can provide opportunities for public engagement and education. The City of Forest Lake, MN added a colorful wrap with pollutant removal statistics and water quality themes to their street sweeper and implemented a 'spot the sweeper' program to garner public interest and support. Many cities, including Woodbury, use social media like Facebook, NextDoor, Twitter, or YouTube, to post educational segments on City's maintenance practices. Educational notices and articles are also commonly shared through municipal newsletters.

2.2.2. Non-degradation Policies

The City of Woodbury lies within the jurisdiction of three watershed districts: the South Washington Watershed District (SWWD), Ramsey-Washington Metro Watershed District (RWMWD), and Valley Branch Watershed District (VBWD). Stormwater management rules for these watersheds include non-degradation policies that apply to both water quality and volume control. Enhanced street sweeping provides additional assurance for non-degradation of water quality by reducing pollutant loads and contributes to non-degradation of stormwater volume by reducing loss of storage volume through decreased sediment loading to stormwater ponds and other BMPs. RWMWD policies include requirements that cities within watershed jurisdiction provide descriptions of municipal maintenance practices and call out street sweeping as an example. Similarly, SWWD requires programs for BMP maintenance. A complete list of water resources related agreements and permits can be found in the Section 5 of the City's [2040 Local Surface Water Management Plan].

2.3. Safety, Aesthetics, and Public Relations

Historically, safety and aesthetics have been the primary reasons for municipal street sweeping. Accumulated sand and trash detract from curb appeal, may contribute to storm sewer clogging (and subsequent flooding), and may pose a safety risk to bicycles and pedestrians.

Several articles have detailed the popularity of street sweepers with City staff and residents, both as a public education opportunity for water resource protection and as a cleanliness and aesthetic public benefit (e.g., Buranen, 2017, 2018). In Milwaukee, for example, residents even called for increased sweeping, leading the City's Public Works Department to experiment with double sweeping to twice per month in test sites around the University (Stormwater Magazine, 2014).

2.4. Maintenance Benefits

2.4.1. Local Flood Protection

Regular sweeping can reduce clogging and flooding at storm drain inlets. In 2011-2012, the City of Prior Lake, MN participated in a 2-year study of intensive, targeted street sweeping. City staff reported that storm drain clogging was a non-issue in street sweeping zones, resulting in far fewer maintenance calls from residents (Bintner, 2012). Echoing this observation, Plaquemine, LA City staff recommended street sweeping as the "best tool" for preventing issues with flooding and in drainage systems that typically plague small Bayou towns (Buranen, 2015).

2.4.2. Roadway Maintenance Life

Sweeping can also play a part in a preventative maintenance plan to extend the life of pavement surfaces. Sweeping removes sand and fines which wear down pavement when vehicles pass over paved surfaces. Fine particles that collect in cracks provide a substrate for vegetation to colonize cracks, making pavement more susceptible to freeze/thaw damage and further cracking.

2.4.3. BMP Maintenance Life Cycles

The pollutant removal efficiency of structural BMPs that are designed to remove sediment such as settling ponds, filter strips, and catch basin sumps, decreases as sediment storage capacity is depleted. Eventually, sediment must be removed from the practice to restore removal capacity. By reducing sediment loading to structural BMPs, street sweeping can extend sediment storage capacity and improve pollutant removal efficiency.

3. CURRENT PRACTICES

3.1. Street Sweeping

The City of Woodbury currently sweeps its 606 curb miles of paved roads twice per year: once in the spring to clear salt and tracked sand from roads; and once in the fall to reduce leaf litter on streets. 458 of these lane miles lie within SWWD and the rest divided between RWMWD and VBWD. In addition, the City contains 81.6 miles of roads operated and maintained by the County which were not included in this analysis. The City owns two street sweepers: an Elgin Crosswind regenerative air sweeper and an Elgin Pelican mechanical boom sweeper with water spray for dust control. Both sweepers are used along with a fleet of contracted street sweepers during the spring and fall to complete city-wide street cleaning.

3.2. Other Maintenance Practices

3.2.1. Roadway Maintenance and Rehabilitation

The City's Public Works Department oversees pavement repair (e.g., filling potholes), preservation (e.g., seal-coating, rejuvenation), and rehabilitation (e.g., mill-and -overlay) projects. These road maintenance and rehabilitation practices contribute to the reduction of solids recovered from the City's streets surfaces. The City could benefit from street maintenance schedule coordination with street sweeping.

3.2.2. Storm Sewers and Catch Basins

Public Works staff inspect and clean city-owned catch basins on a regular basis. Sump catch basins and manholes are common practice in places (typically the fully developed areas in the City) where other BMPs are not available. The time and cost associated to cleaning catch basins and manholes would be significantly reduced by enhanced street sweeping.

3.2.3. Stormwater BMP Maintenance

Woodbury's Public Works staff inspects all stormwater ponds and outfalls once every four years and in response to resident concerns.

4. SWEEPING ZONES

Street surfaces are connected to surface waters via stormwater conveyance systems and can be a significant source of pollution to downstream water resources. Key factors that influence pollutant accumulation on streets include pavement type and condition, traffic volume, maintenance practices, adjacent land use, and right-of-way tree canopy.

Streets were aggregated into sweeping zones based on connectivity to downstream water resources, existing stormwater management practices, and right-of-way tree canopy cover characteristics. These considerations are discussed in Sections 4.1 through 4.3, and proposed sweeping zones are summarized in Section 4.4. While not designed as driving routes, zones are composed of contiguous street segments to the degree possible for route management.

4.1. Primary Water Resources

Estimated pollutant reduction benefits are quantified for the eight (8) lakes identified as key water resources in the City's 2040 SWMP: Bailey, Colby, La, Markgrafs, Powers, Wilmes, Battle Creek and Carver; four (4) large wetlands located upstream of a key resource: Tamarack east and west, Evergreen Park, and Marsh Creek Pond; and for watershed areas that discharge stormwater to resources outside the City's boundary.

Table 1. Summary of defining characteristics for street sweeping zones in the City of Woodbury.

Major Watershed		Primary Water Resources	Watershed Characteristics			Lane Miles[4]	
			Stormwater BMPs[1]	Primary Land Use[2]	Right-of-way Tree Canopy[3]	City	County[5]
SWWD	Central Draw	North Wilmes Lake	39	R-4, GW, B-1,2,3	5%	31.0	*2.0*
SWWD	Central Draw	South Wilmes Lake	25	R-4, GW, B-1,2,4	2%	40.6	*8.7*
SWWD	Central Draw	*Evergreen Wetland*[6]	19	R-4, B-2,3	6%	21.0	*1.3*
SWWD	Central Draw	Markgrafs Lake	20	B-1, 2, 3, MX, R-2	2%	14.3	*4.5*
SWWD	Central Draw	Powers Lake	37	R-2,4	4%	32.2	*0.0*
SWWD	Central Draw	*Fish Lake*[6]	16	R-2,4	5%	22.2	--
SWWD	Central Draw	Colby Lake	101	R-1,2,4	6%	129.0	*11.1*
SWWD	Central Draw	Bailey Lake	96	R-2,4, B-3, MX	4%	99.9	*22.7*
SWWD	Central Draw	*Marsh Creek Pond*[6]	35	R-4	9%	33.2	*3.9*
SWWD	Central Draw	Central Draw[7]	5	R-4; R-1	2%	11.6	*1.7*
SWWD	East Mississippi	La Lake	*n/a*	R-2	2%	0.9	*0.2*
SWWD	East Mississippi	Ria Lake	3	R-2	<1%	n/a	*0.6*
SWWD	East Mississippi	East Mississippi[7]	15	R-2	19%	8.3	*1.7*
SWWD	**West Draw**		27	R-2,4	6%	14.1	*7.3*
RWMWD	Battle Creek	Battle Creek Lake	32	R-2,4, GW, BCD, MX, B-1,2,3,4	11%	14.6	--
RWMWD	Battle Creek	*Tamarack Wetland East*	38	R-4, B-1	7%	23.9	*9.4*
RWMWD	Battle Creek	*Tamarack Wetland West*	9	R-4, MCD	<1%	6.6	*2.6*
RWMWD	Battle Creek	Battle Creek[7]	1	R-2,4, B-2	16%	14.9	--
RWMWD	**Carver Lake**		83	R-2, R-4, BCD, B-1,2,3, MCD, GW, I-1	10%	74.7	*3.9*
VBWD	**Valley Branch Creek**		30	R-4, BCD, MX, GW, B-2,3	<1%	13.0	*2.7*

[1] Number of BMPs located within the resource drainage area based on City of Woodbury BMP digital inventory, does not include wetlands or DNR public waters.
[2] City of Woodbury Zoning Map, January 2022.
[3] Tree canopy cover over and within 20 feet of the curb or shoulder line.
[4] Turn lanes and merge lanes are not included.
[5] Century Avenue and Manning Avenue were not included in the study.
[6] This waterbody is a wetland located upstream of the primary water resource.
[7] Portion located within the Woodbury municipal boundary and downstream of primary water resources (Bailey Lake, Ria Lake, Battle Creek Lake).

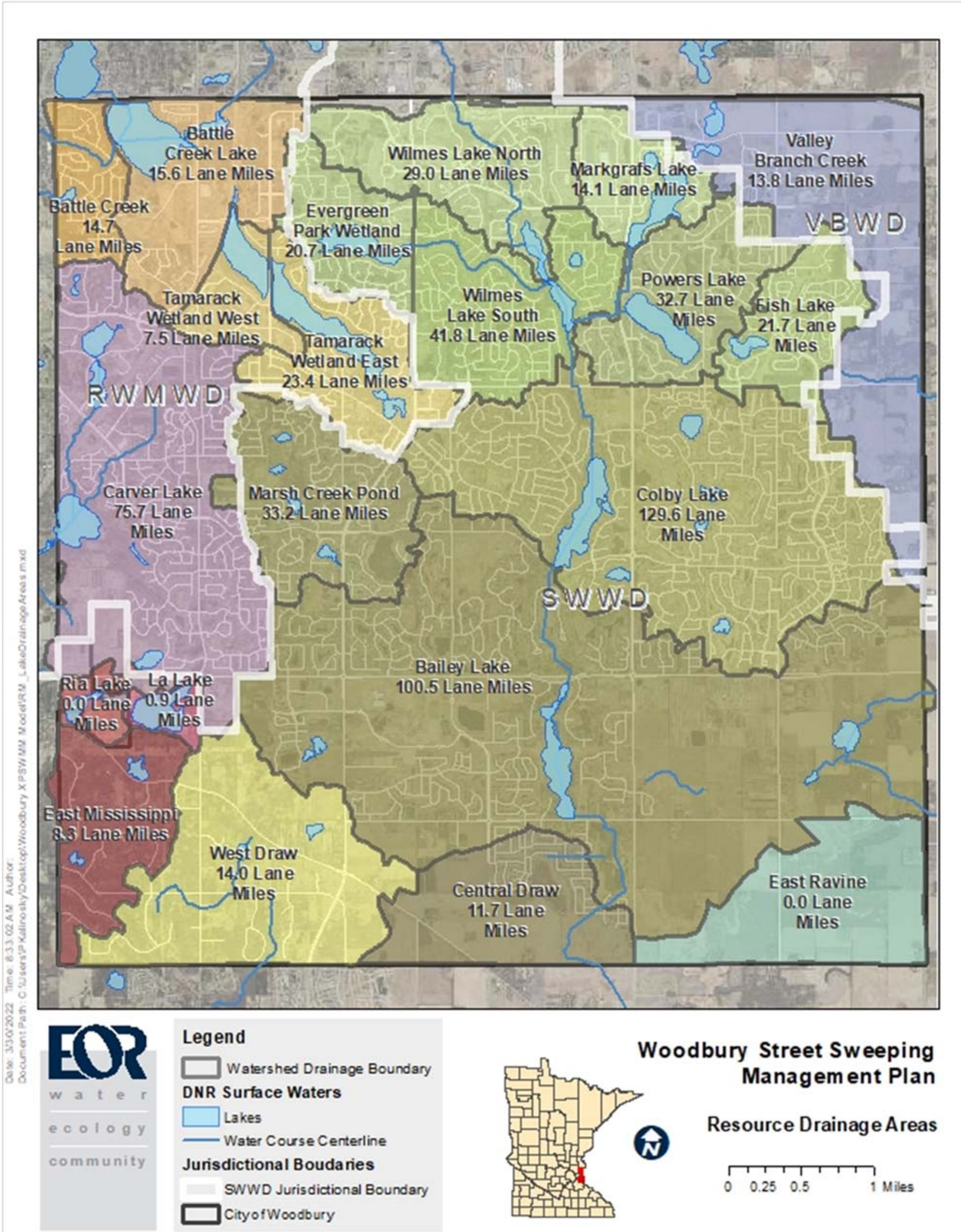

Figure 1. Drainage areas and total lane miles for Woodbury lakes and wetlands included in the study.

4.2. Tree Canopy

Tree canopy is particularly important when considering nutrient pollution. Organic litter from trees can be the primary source of total solids and nutrient loading on street surfaces during certain times of the year in areas of modest to dense tree canopy cover (Kalinosky, 2015). Older neighborhoods laid out in grid fashion tend to have more mature trees in front yard areas and denser right-of-way (ROW) canopy than newer neighborhoods or those with typical suburban street layout patterns. Trees located within front yard setback areas are more likely to contribute leaf litter and duff to road surfaces. Areas with denser tree canopy can act as pollutant 'hot spots' due to the large amount of accumulated organic litter on street surfaces.

Tree canopy cover was quantified over and within a 20-foot buffer of roadway curb lines for all paved public roads within developed portions of the City of Woodbury. The City of Woodbury maintains a geospatial dataset of their boulevard tree inventory. The tree inventory data were overlaid and merged with areas of deciduous tree canopy as identified in the TCMA 1- Meter Land Cover Classification dataset. The TCMA 1- is a high-resolution land cover dataset for the metropolitan area developed by the University of Minnesota in 2015.

Average tree canopy cover for individual street segments were estimated by intersecting deciduous canopy cover data with buffered road surface polygons created from roadway centerline data. Road segment canopy cover data were then aggregated using spatial weighting to calculate the average ROW tree canopy cover within the drainage area of primary water resources (Figure 2) and each proposed sweeping zone (Table 2).

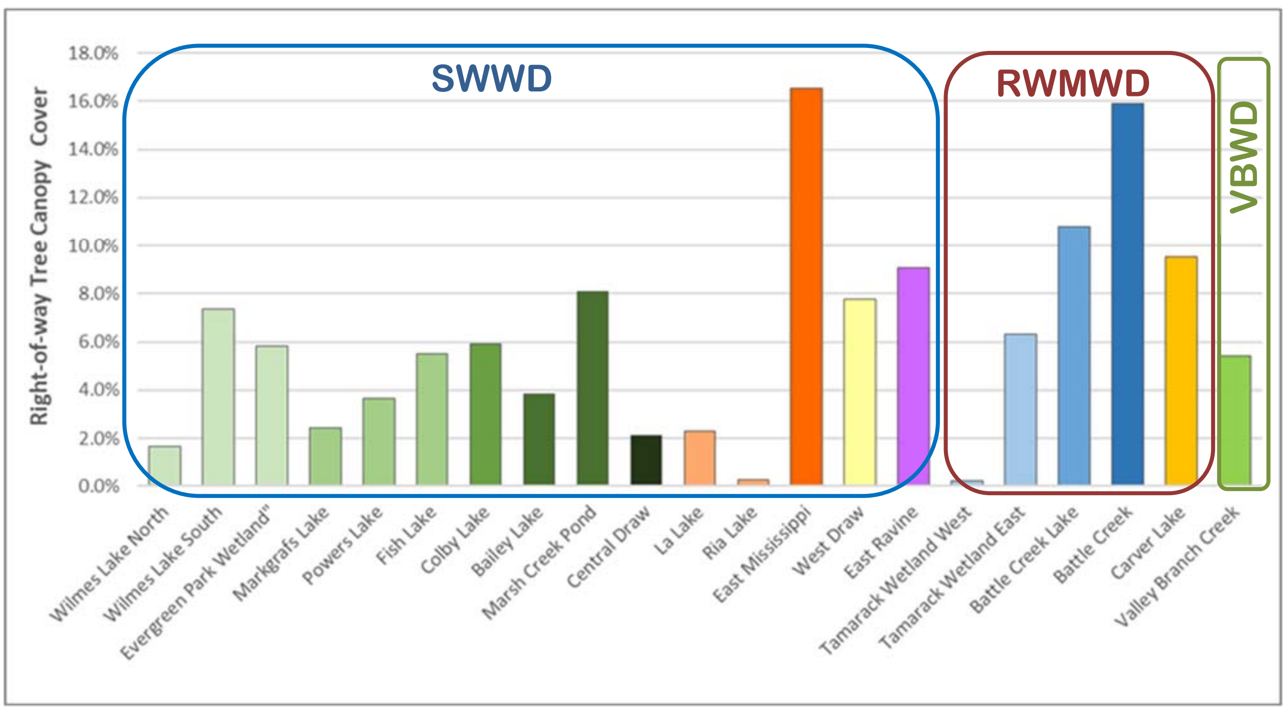

Figure 2. Average right-of-way tree canopy cover for City of Woodbury water resources by watershed district

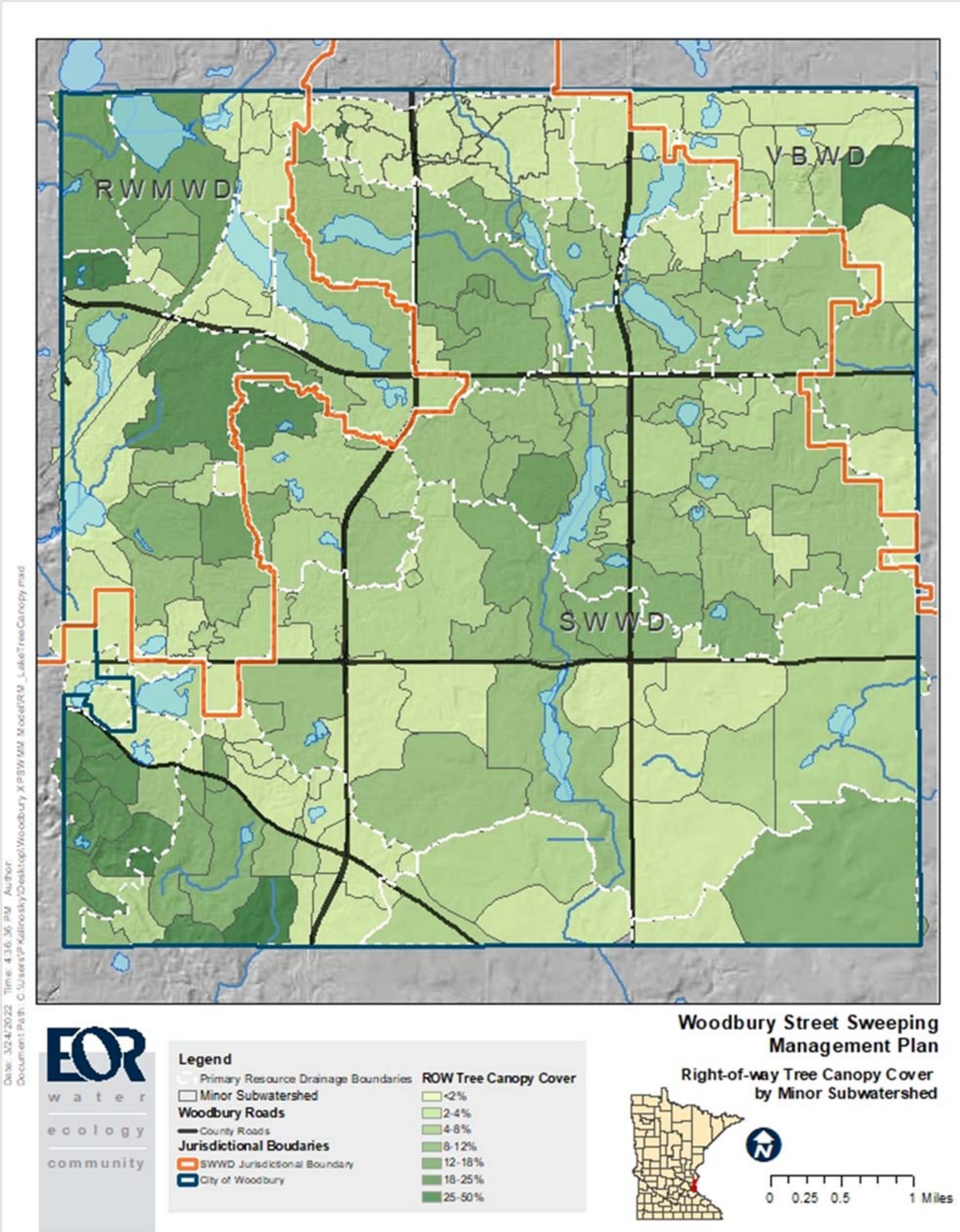

Figure 3. Average ROW tree canopy cover aggregated by minor subwatershed.

4.3. Lane-Miles

The length of street to be swept within each sweeping zone was estimated from road centerline data (Figure 4). The total 'lane-miles' to be swept in each zone is equal to the total length of paved City roadway (centerline) multiplied by the number of driving lanes. Length of turn lanes and merge lanes is a negligible percentage of the total length and difficult to accurately quantify. For these reasons, turn lanes and merge lanes are not included in lane-mile totals. Additionally, most turn and merge lanes are associated with county roads which are shown in grey in Figure 4. County roads were included in the study, but pollutant recovery was estimated separately due to differences in ownership and maintenance responsibility.

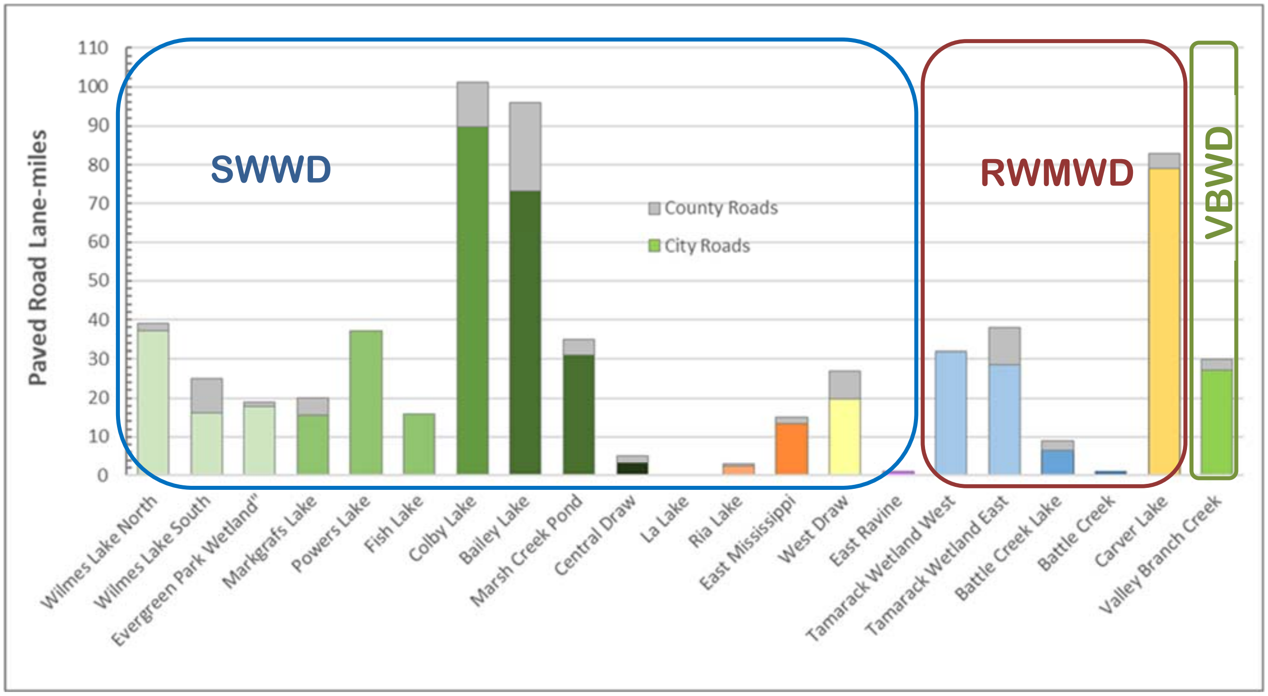

Figure 4. Paved road lane-miles within the City of Woodbury water resource drainage areas by watershed district.

4.4. Proposed Sweeping Zones

Streets were aggregated into sweeping zones based on connectivity to downstream water resources, storm water management type, and tree canopy cover characteristics. Sweeping zone characteristics are summarized in (Table 2) and sweeping zones are mapped in Figure 5. Maps of individual sweeping zones are included in Appendix A.

Table 2. Summary of Proposed Sweeping Zones

Zone ID	Downstream Resource	Lane Miles		Average ROW Tree Canopy (%)	Workdays Needed, Single Sweeper[1]
		Zone Total	% by Waterbody Drainage Area		
SW-1	Battle Creek Lake	0.6	3.8%	2.0	**0.9**
	Evergreen Wetland	9.2	55.0%		
	Wilmes Lake North	6.9	41.2%		
	SW-1 Total Lane Miles	**16.7**	*100%*		
SW-2	Markgraf's Lake	5.9	25.0%	4.0	**1.2**
	Wilmes Lake North	17.3	73.2%		
	Wilmes Lake South	0.4	1.8%		
	SW-2 Total Lane Miles	**23.6**	*100%*		
SW-3	Colby Lake	1.1	3.8%	5.0	**1.5**
	Markgraf's Lake	2.1	7.3%		
	Powers Lake	3.7	13.0%		
	Wilmes Lake North	6.8	23.9%		
	Wilmes Lake South	14.7	52.0%		
	SW-3 Total Lane Miles	**28.4**	*100%*		
SW-4	Colby Lake	0.3	0.6%	4.0	**2.2**
	Fish Lake	18.7	43.7%		
	Powers Lake	23.5	54.6%		
	Valley Branch Creek	0.5	1.1%		
	SW-4 Total Lane Miles	**43.0**	*100%*		
SW-5	Colby Lake	0.4	1.8%	9.0	**1.2**
	Wilmes Lake South	23.0	98.2%		
	SW-5 Total Lane Miles	**23.4**	*100%*		
SW-6	Bailey Lake	17.2	49.2%	4.0	**1.8**
	Colby Lake	6.2	17.4%		
	Marsh Creek Pond	7.8	22.3%		
	Tamarack Wetland East	2.2	6.2%		
	Wilmes Lake South	1.6	4.7%		
	SW-6 Total Lane Miles	**35.0**	*100%*		
SW-7	Bailey Lake	17.6	33.0%	8.0	**2.8**
	Colby Lake	35.1	65.5%		
	Wilmes Lake South	0.8	1.5%		
	SW-7 Total Lane Miles	**53.5**	*100%*		
SW-8	Colby Lake	53.1	97.2%	5.0	**2.8**
	Fish Lake	1.3	2.3%		
	Valley Branch Creek	0.3	0.5%		
	SW-8 Total Lane Miles	**54.7**	*100%*		
SW-9	Bailey Lake	11.6	26.0%	4.0	**2.3**
	Colby Lake	32.7	73.3%		
	Valley Branch Creek	0.3	0.73%		
	SW-9 Total Lane Miles	**44.6**	*100%*		
SW-10	East Mississippi	8.3	35.9%	14.0	**1.2**
	La Lake	0.9	4.1%		
	West Draw	13.9	60.1%		
	SW-10 Total Lane Miles	**23.1**	*100%*		
SW-11	Bailey Lake	47.4	80.1%	4.0	**3.0**
	Central Draw	11.6	19.6%		

Zone ID	Downstream Resource	Lane Miles		Average ROW Tree Canopy (%)	Workdays Needed, Single Sweeper[1]
		Zone Total	% by Waterbody Drainage Area		
	West Draw	0.2	0.3%		
	SW-11 Total Lane Miles	**58.2**	*100%*		
M-1	Battle Creek Lake	0.1	0.5%	4.0	**1.1**
	Evergreen Wetland	11.6	52.8%		
	Tamarack Wetland East	10.2	46.4%		
	Wilmes Lake South	0.1	0.3%		
	M-1 Total Lane Miles	**22.0**	*100%*		
M-2	Carver Lake	1.20	5.8%	14.0	**1.1**
	Marsh Creek Pond	9.09	44.2%		
	Tamarack Wetland East	10.29	50.0%		
	M-2 Total Lane Miles	**20.6**	*100%*		
M-3	Bailey Lake	7.10	19.6%	6.0	**1.9**
	Carver Lake	16.95	46.7%		
	Marsh Creek Pond	12.22	33.7%		
	M-3 Total Lane Miles	**36.3**	*100%*		
RMW-1	Battle Creek	14.89	66.8%	7.0	**1.2**
	Battle Creek Lake	2.37	10.6%		
	Carver Lake	5.02	22.5%		
	RMW-1 Total Lane Miles	**22.3**	*100%*		
RMW-2	Battle Creek Lake	11.53	35.7%	7.0	**1.8**
	Carver Lake	12.82	39.6%		
	Evergreen Wetland	0.23	0.71%		
	Tamarack Wetland East	1.18	3.7%		
	Tamarack Wetland West	6.58	20.4%		
	RMW-2 Total Lane Miles	**32.3**	*100%*		
RMW-3	Carver Lake	38.70	90.4%	6.0	**2.2**
	Marsh Creek Pond	4.10	9.6%		
	RMW-3 Total Lane Miles	**42.8**	*100%*		
VB-1	Fish Lake	2.20	8.6%	5.0	**0.9**
	Markgraf's Lake	6.32	24.8%		
	Powers Lake	5.08	19.9%		
	Valley Branch Creek	11.88	46.6%		
	VB-1 Total Lane Miles	**25.5**	*100%*		
	TOTAL	**606**			**31.6**

[1] Based on a single lane pass. Used to determine the number of sweepers needed to complete the sweeping scenario within the specified timeframe. For example, a single sweeper would not fulfill the sweeper demand for monthly city-wide street sweeping since 31.6 days. Two sweeper working full time could compete a single lane pass in 31.6 divided by 2, or about 16 workdays. Additional details provided in Appendix C.1.

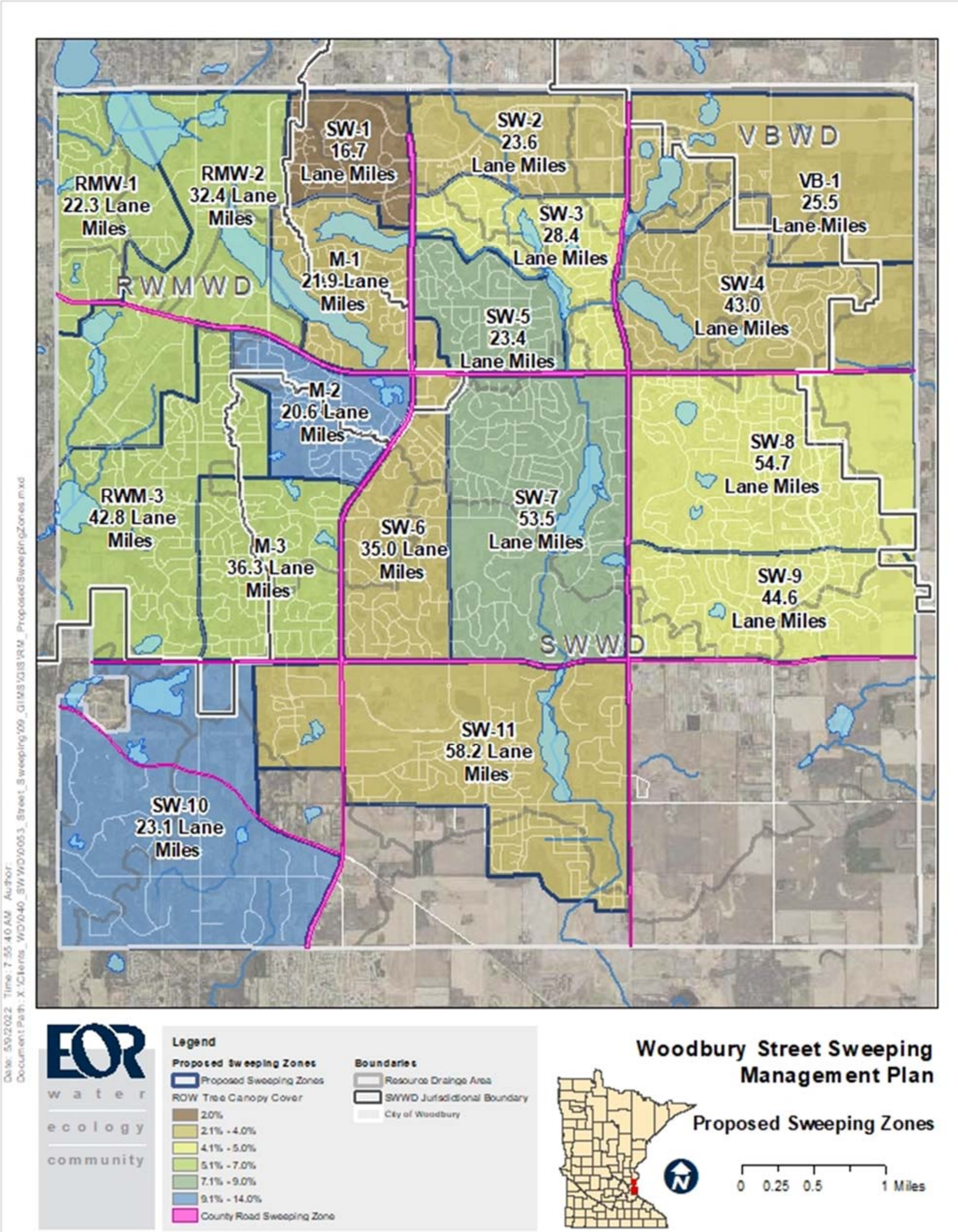

Figure 5. City of Woodbury sweeping zones. Maps of individual zones are included in Appendix A.

5. LOAD RECOVERY AND LOAD REDUCTION ESTIMATES

Pollutant reductions can be characterized in two ways for street sweeping: the total amount of pollutant collected from the street surface (load recovery); and the total reduction in load to a downstream surface water (load reduction). Load recovery is greater than load reduction due to treatment provided by BMPs that reduce pollutant loads along the flow network from street surface to water resources. For the purposes of this plan, load recovery and load reduction estimates were calculated for Total Solids (TS) and Total Phosphorus (TP), the pollutants of concern for BMP maintenance and lake water quality.

5.1. Load Recovery

To facilitate comparisons, potential pollutant recovery was estimated for the simplistic sweeping scenarios listed in Table 3 with all streets being swept during the snow-free season (April 1 – October 31). Average pollutant recovery was estimated for the sweeping scenarios using a street sweeping planning calculator tool developed by the University of Minnesota, 'Estimating Nutrient and Solids Load Recovery through Street Sweeping' (Kalinosky, et. al, 2014). The tool predicts the average annual mass of solids and nutrients that can be recovered from streets based on the length of street to be swept, the timing (month) and frequency of sweeping, and density of tree canopy cover over the street. The tool was calibrated using street sweeping data collected over a 2-year period in Prior Lake, MN and is intended for use in comparable settings (climate and geography). Actual pollutant recovery is expected to vary somewhat compared to estimates. Factors such as precipitation, climate, and land disturbing activities may affect solids loading to streets and typically vary somewhat from year to year.

Table 3. Street sweeping scenarios used in load recovery and load reduction estimates.

Sweeping Scenario	Number of Sweeps per Year	Description
Baseline	2	One sweeping each in the spring and fall
Enhanced Baseline	4	Two sweepings each in the spring and fall
Monthly	7	Once per month sweeping during the snow-free season
Bi-weekly	14	Twice per month sweeping during the snow free season
Weekly	28	Four sweepings per month during the snow free season

Pollutant recovery estimates (TS, TP) for each scenario are summarized by downstream resources in Table 4. The 'Baseline' scenario represents the City's current sweeping practice. Current practice is estimated to remove about 277 tons of gross solids containing 296 pounds of phosphorus each year.

Table 4. Summary of estimated annual total solids and phosphorus recovery by receiving waterbody for the street sweeping scenarios described in Table 3.

Watershed District | Major Watershed		Primary Water Resources	Sweeping Scenario | Predicted Pollutant Recovery from City Street Surfaces									
			Baseline		Enhanced Baseline		Monthly		2 X Per Month		Weekly	
			TS (tons)	TP (lb)	TS (tons)	TP (lb)	TS (tons)	TP (lb)	TS (tons)	TP (lb)	TS (tons)	TP (lb)
SWWD	**Central Draw**	Wilmes Lake North	13.0	13.8	25.6	22.5	44.5	33.0	49.4	44.5	76.8	79.8
		Wilmes Lake South	19.5	20.9	38.4	34.1	66.8	50.0	74.0	67.4	115.1	120.8
		Evergreen Park Wetland	8.6	9.1	17.0	14.9	29.6	21.9	32.8	29.6	51.0	53.0
		Markgrafs Lake	6.1	6.5	12.0	10.5	20.8	15.5	23.1	20.8	35.9	37.4
		Powers Lake	13.7	14.6	27.0	23.8	47.0	34.9	52.1	47.0	81.0	84.3
		Fish Lake	9.4	10.0	18.6	16.3	32.3	24.0	35.8	32.3	55.7	57.9
		Colby Lake	58.2	62.2	115.1	101.7	200.0	149.1	221.6	201.0	344.7	360.2
		Bailey Lake	43.8	46.7	86.6	76.3	150.5	112.0	166.8	150.9	259.4	270.5
		Marsh Creek Pond	16.3	17.5	32.2	28.6	55.9	41.9	61.9	56.5	96.3	101.3
		Central Draw	4.9	5.2	9.7	8.5	16.8	12.5	18.7	16.8	29.0	30.2
	East Mississippi	La Lake	0.6	0.6	1.1	1.0	2.0	1.5	2.2	2.0	3.4	3.6
		East Mississippi	5.1	5.5	10.0	9.0	17.4	13.2	19.3	17.9	30.0	32.0
	West Draw		8.6	9.3	16.9	15.3	29.4	22.4	32.6	30.2	50.7	54.1
		SWWD TOTAL	**207.6**	**221.9**	**410.4**	**362.7**	**712.9**	**531.9**	**790.2**	**717.1**	**1228.9**	**1285.1**
RWMWD	**Battle Creek**	Battle Creek Lake	6.8	7.3	13.5	11.9	23.4	17.5	26.0	23.6	40.4	42.3
		Tamarack Wetland West	3.1	3.3	6.1	5.4	10.7	8.0	11.8	10.8	18.4	19.3
		Tamarack Wetland East	12.1	13.0	23.8	21.3	41.4	31.2	45.9	42.0	71.4	75.4
		Battle Creek	7.0	7.5	13.9	12.3	24.1	18.1	26.8	24.3	41.6	43.6
	Carver Lake		34.5	36.9	68.1	60.3	118.4	88.4	131.2	119.2	204.0	213.5
		RWMWD TOTAL	**63.5**	**68.1**	**125.5**	**111.2**	**218.0**	**163.1**	**241.7**	**219.9**	**375.8**	**394.1**
VBWD		Valley Branch Creek **/TOTAL**	5.5	5.8	10.8	9.5	18.8	14.0	20.9	18.8	32.4	33.7
		ALL	**276.6**	**295.8**	**546.7**	**483.4**	**949.8**	**709.0**	**1052.8**	**955.9**	**1637.2**	**1713.0**

Pollutant load recovery trends for the estimates in Table 4 are shown graphically in Figure 6 and Figure 7. The graphics show how the efficiency of TS and TP load recovery (lb per lane-mile) decreases as the number of sweepings per year is increased while total recovery (lb/yr) increases. As it pertains to water quality benefits, these trends should be interpreted as - 'even a few additional sweeping can increase recovery significantly' and 'sweeping frequency is directly correlated with annual pollutant recovery.'

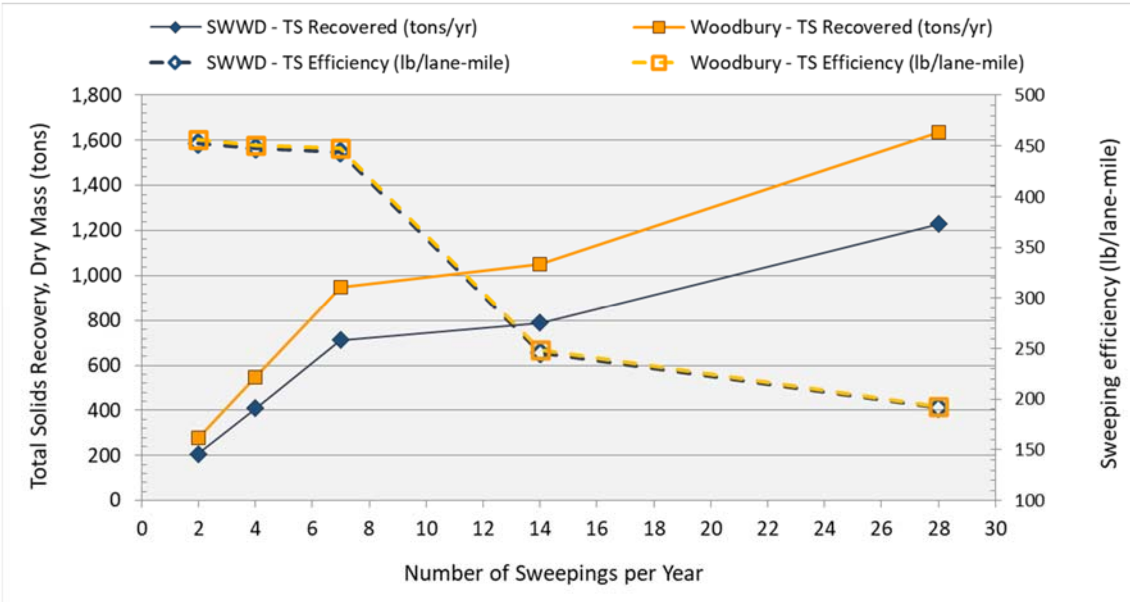

Figure 6. Cumulative total solids and average total solids recovery vs. number of sweepings per year for waterbodies in the SWWD and the City of Woodbury.

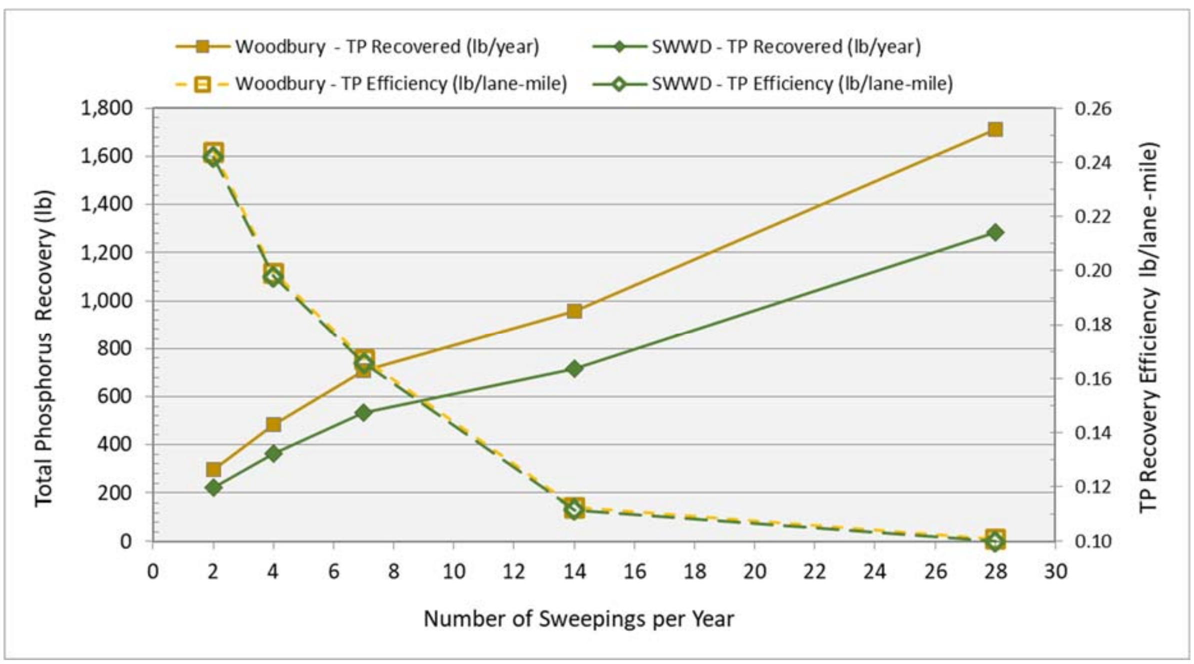

Figure 7. Cumulative total phosphorus and average total phosphorus recovery vs. number of sweepings per year for waterbodies in the SWWD and the City of Woodbury.

5.2. Load Reduction Potential

The potential load reductions reported in this study are equal to the estimated mass of pollutants recovered through street sweeping minus the estimated mass of pollutants retained in upstream BMPs based on modeled removal pollutant removal efficiencies. Uncertainties in this method stem include uncertain in recovery estimates (Section 5.1), uncertainty in BMP treatment efficiency estimates (Table 6), but also uncertainty in pollutant transport, especially phosphorus. A significant portion of the TP present in organic matter (e.g., leaves, grass clips) will not be released into the downstream water resource through decomposition or other mechanisms and will not be biologically available to impact the water resource. The effects of these complex interactions on load reduction estimates are beyond the scope of this study. Therefore, due to the limitation of the method used, the load reductions shown in this report should be used for relative comparisons of potential water quality benefits for different street sweeping scenarios; and should not be directly equated to the TP load reduction targets stablished in Lake Diagnostic studies, TMDLs, and other reports.

Estimated pollutant load reductions to downstream waterbodies are based on the following assumptions:

- Over time, all solids on the street surface will be transported to the storm sewer system and ultimately to downstream waterbodies.
- The design efficiency of modeled BMPs can be applied to solids which typically collect on street surfaces (including organic material).
- The design efficiency of modeled BMPs is preserved through regular maintenance.

The SWWD maintains water quality models (P8) of the district's primary water resources (Houston Engineering, 2010-2017) including Wilmes- (north and south segments), Markgrafs-, Powers-, and Fish Lake. For these resources, pollutant load reductions to downstream resources were estimated by applying the modeled removal efficiency of BMPs located upstream of the water resource of interest to load recovery estimates.

For water bodies outside the SWWD and those not represented in water quality models, estimates for the collective pollutant removal capacity of upstream BMPs were derived by applying median BMP removal efficiencies (MN Stormwater Manual, Table 5) to the City of Woodbury's BMP inventory. BMP removal efficiencies were assigned to the minor subwatershed containing each BMP. A weighted-average, based on the length of roadway contained within the minor subwatershed, was then used to aggregate minor subwatersheds and estimate collective removal efficiencies for BMPs within each water resource drainage area.

Estimated collective pollutant removal efficiencies for BMPs upstream of individual water resources are summarized in Table 6 and pollutant load reductions (total solids and total phosphorus) for each sweeping scenario are summarized in Table 7. Since the number and kind of structural BMPs vary among sweeping zones, sweeping appears to be more effective as a water quality BMP in areas with few structural BMPs (load reduction $\approx$ load recovery). However, sweeping in zones with many structural BMPs is still important to help preserve the removal efficiency of those BMPs and consequently protect downstream water quality.

Table 5. Median BMP removal efficiencies (Minnesota Stormwater Manual) used to estimate the collective pollutant removal efficiency of BMPs located upstream of resources for which water quality modeling data were not available.

Pollutant	No BMPs	Stormwater Wetland	Wet Pond*	Pervious Pavement	Dry Pond[1]	Infiltration Practices	
						Volume Infiltrated[2]	Overflow Volume[2]
TP	0%	40%	50%	45%	20%	100%	*n/a*
TSS	0%	55%	84%	72%	35%	100%	*n/a*

TP = total phosphorus; TSS = total suspended solids

[1]Value for wet swale

[2]Applied to RG BMP, 100% applied to 5 acres, overflow to remainder, underground 10 acres, permeable pavement – SA of pavement, 5-acres for dry swale : https://stormwater.pca.state.mn.us/index.php?title=Stormwater_infiltration_BMPs_-_contributing_drainage_area

*Medium Removal efficiency:
https://stormwater.pca.state.mn.us/index.php?title=Pollutant_removal_percentages_for_stormwater_pond_BMPs

Table 6. Estimated collective pollutant removal efficiency for existing stormwater BMPs within each resource drainage area.

Watershed District	Receiving Waterbody	Estimated Pollutant Removal Efficiency	
		TS	TP
SWWD	Wilmes Lake North	69%	52%
	Wilmes Lake South	83%	61%
	Evergreen Park Wetland	72%	45%
	Markgrafs Lake	88%	71%
	Powers Lake	96%	65%
	Fish Lake	93%	61%
	Colby Lake	94%	68%
	Bailey Lake	63%	38%
	Marsh Creek Pond	80%	47%
	Central Draw	53%	33%
	La Lake	55%	40%
	Ria Lake	100%	100%
	East Mississippi	59%	35%
	West Draw	71%	44%
RWMWD	Tamarack Wetland East	64%	42%
	Tamarack Wetland West*	62%	37%
	Battle Creek Lake	63%	41%
	Battle Creek	74%	40%
	Carver Lake	67%	41%
VBWD	Valley Branch Creek	69%	38%

Table 7. Theoretical annual pollutant load reductions (total solids and phosphorus) to waterbodies for street sweeping scenarios described in Table 3.

Watershed District | Major Watershed		Primary Water Resources	Sweeping Scenario | Predicted Pollutant Reduction to Downstream Waterbody									
			Baseline		Enhanced Baseline		Monthly		2 X Per Month		Weekly	
			TS (tons)	TP (lb)	TS (tons)	TP (lb)	TS (tons)	TP (lb)	TS (tons)	TP (lb)	TS (tons)	TP (lb)
SWWD	Central Draw	Wilmes Lake North	4.0	6.6	7.9	10.8	13.8	15.9	15.3	21.4	23.8	38.3
		Wilmes Lake South	3.3	8.1	6.5	13.3	11.4	19.5	12.6	26.3	19.6	47.1
		Evergreen Park Wetland	2.4	5.0	4.8	8.2	8.3	12.1	9.2	16.3	14.3	29.1
		Markgrafs Lake	0.7	1.9	1.4	3.1	2.5	4.5	2.8	6.0	4.3	10.8
		Powers Lake	0.5	5.1	1.1	8.3	1.9	12.2	2.1	16.5	3.2	29.5
		Fish Lake	0.7	3.9	1.3	6.4	2.3	9.3	2.5	12.6	3.9	22.6
		Colby Lake	3.5	19.9	6.9	32.5	12.0	47.7	13.3	64.3	20.7	115.3
		Bailey Lake	16.2	29.0	32.0	47.3	55.7	69.4	61.7	93.6	96.0	167.7
		Marsh Creek Pond	3.3	9.3	6.4	15.2	11.2	22.2	12.4	30.0	19.3	53.7
		Central Draw	2.3	3.5	4.6	5.7	7.9	8.4	8.8	11.3	13.6	20.2
	East Mississippi	La Lake	0.3	0.4	0.5	0.6	0.9	0.9	1.0	1.2	1.5	2.2
		East Mississippi	2.1	3.6	4.1	5.9	7.1	8.6	7.9	11.6	12.3	20.8
	West Draw		2.5	5.2	4.9	8.6	8.5	12.5	9.5	16.9	14.7	30.3
		SWWD TOTAL	**41.8**	**101.5**	**82.5**	**165.9**	**143.4**	**243.2**	**158.9**	**327.9**	**247.2**	**587.7**
RWMWD	Battle Creek	Tamarack Wetland East	2.5	4.2	4.9	6.9	8.4	10.2	9.3	13.7	14.5	24.5
		Tamarack Wetland West	1.2	2.1	2.3	3.4	4.1	5.0	4.5	6.8	7.0	12.2
		Battle Creek Lake	4.5	7.7	8.8	12.5	15.3	18.4	17.0	24.8	26.4	44.5
		Battle Creek	1.8	4.5	3.6	7.4	6.3	10.8	7.0	14.6	10.8	26.2
	Carver Lake		11.4	21.8	22.5	35.6	39.1	52.1	43.3	70.3	67.3	126.0
		RWMWD TOTAL	**21.3**	**40.3**	**42.1**	**65.8**	**73.2**	**96.6**	**81.1**	**130.2**	**126.1**	**233.3**
VBWD		Valley Branch Creek **/TOTAL**	1.7	3.6	3.4	5.9	5.8	8.7	6.5	11.7	10.1	20.9
		ALL	**64.8**	**145.4**	**128.0**	**237.6**	**222.4**	**348.5**	**246.5**	**469.8**	**383.3**	**841.9**

6. MATERIAL MANAGEMENT

Once collected, swept material must be disposed of properly, a process which may incur additional costs to the City. These costs include the dump trucks and associated costs used to transport sweeper waste from sweeper operations to the landfill, the costs charged by the landfill for disposal, and any additional disposal costs required to compost organic material, including sorting, or separating the material into different waste streams. The City may wish to consider two disposal scenarios:

1. Dispose of all collected sweepings as solid waste without screening
2. Screen and separate sweepings by trash and debris, recycling, and composting and dispose of each category separately

Currently, the City owns three dump trucks which transport sweeper waste approximately 10-15 miles away from sweeper operations. According to City meeting minutes on November 17, 2021, the landfill charges $4 per cubic yard for leaves and $8 per cubic yard for dirt. The City does not maintain a municipal compost site so local options for composting leaf litter and other organic sweeping material will be explored in this section.

6.1. Non-Compostable

Non-compostable street sweepings include all material that do not qualify as compostable or recyclable. This typically includes particulate matter, trash and debris, metals, bits of road, and other various materials, all of which will likely reach its end point in the landfill. The City may wish to consider reuse opportunities for swept material: the MPCA lists a few common uses such as mixing with salt or sand for winter ice application, fill for engineered purposes on commercial industrial developments, and daily cover material for a permitted solid waste landfill able to accept alternate daily cover.

The first disposal scenario includes the disposal costs of solid waste to the landfill, measured by cubic yard. Additionally, the waste must be stored in accordance with solid waste storage standards which may contribute to additional costs if the City does not operate sufficient facilities with enough capacity for an increased amount of sweeping waste. These standards include providing a liner, run-on control systems to collect water, and inspections, as well as requiring that the storage site be located outside of floodplains, shorelands, wild or scenic river districts, wetlands, and areas where emissions from stored material would violate air quality standards.

However, screened sweeper waste does not require storage under solid waste storage standards; rather it only needs to meet MPCA industrial stormwater permit requirements. If the storage facility qualifies for a “no exposure” certification, costs can be further reduced. As such, the second scenario will cost the City hourly for the labor of screening and separating the sweepings; this scenario will also impose the costs charged per cubic yard by disposal facilities for accepting the various waste streams. These streams will likely include solid waste, recycling, and composting.

6.2. Compostable Material

A handful of studies in the Twin Cites metro area have quantified the coarse organic content of street sweepings over the snow-free season. On an annual basis, coarse organics make up about 25% of total the total mass of sweeping collected. Coarse organic inputs will vary spatially and temporally depending on ROW tree canopy and local vegetation. During the fall leaf-drop season, coarse organic material generally comprised a majority of the solids collected from street surfaces, but summer sweeping can contain large amount of grass clipping, flower, pollen, or duff. As such, a local or on-site composting facility for coarse organic material would provide significant labor and disposal cost savings.

The cost of sweeper waste disposal operations is estimated in Appendix C.3. A detailed comparison of costs for material management alternatives was beyond the scope of this study; however, the following key findings may be useful in for planning material management in the future as the cost of individual components changes.

- The cost total associated with disposal of sweeping (Appendix C.3) make up about **1% of the total cost of sweeping** for all scenarios.
    - Fuel is the largest component of disposal costs (75%)
- Roughly 25% of the material collected from street is organic and could be composted if screened from sweepings. Hauling this material to a local facility would save money on fuel and disposal costs.
- Several municipalities in the TCMA reuse the non-compostable component of sweeping for fill. If the City finds that they have a shortage of fill material for City project, this object should be further investigated.

7. COST-BENEFIT ANALYSIS

Total annual program costs and cost-benefit ($/lb-P removed) were estimated for the sweeping scenarios summarized in Section 5. For a city-owned and operated sweeping program, the cost-basis ($/lane-mile) is not constant but rather depends on the sweeper type and financing and the cost of vehicle maintenance, labor, and fuel. Total costs for each sweeping scenario were calculated using the component costs and assumptions listed in Table 8 and the following assumptions:

- Sweepers are owned by the City of Woodbury
- Typical sweeper operational speed = 3 – 5 mph
- An additional 1 hour of labor is required for every 4 hours of sweeping time
- Total transit miles (brush off) are about 16 miles on average for travel to/from the sweeping route.
- On average, sweeper fuel consumption is 5 mpg
- The average bulk density of the material collected from streets is 80 lb/cf including water content
- The City has sufficient staffing to operate the sweepers as needed
- One city-wide sweep includes approximately 655 lane-miles of sweeping.
- The sweeper can be operational approximately 140 workdays between April 1st and October 31st each year (30 weeks total). This calculation accounts for federal holidays and 7 additional workday of non-operation due to maintenance, inclement weather, or staffing shortages.
- At high sweeping frequencies (greater than once per month), city-wide sweeping would require purchase of an additional sweeper(s).

Items not included in the cost calculation, but which may add cost to an enhanced street sweeping program, include:

- Administrative staff time
- Public outreach and notification
- Signage and installation

Table 8. Cost basis assumptions, in-house street sweeping program.

Category	Cost	Data Source(s)
Vehicle Depreciation		
Elgin Crosswind	$20,400	Dealer quote for similar sweeper ($269,000, Crosswind), ($209,000, Pelican); 10-year life span, 4% Interest, resale value after 10-year 25% to 30% of purchase price
Elgin Pelican	$15,100	
Vehicle Refurbishment & Maintenance		
Elgin Crosswind	$9,190	Maintenance and refurbishment schedule for Tymco regenerative air sweeper for 1, 000 – 2,000 hours of use per year.
Elgin Pelican	$6,892	
Labor (wages + benefits)	$75 per hour	
Fuel	$4.25 per gallon	Max daily average cost of diesel fuel across MN, February, 2022
Disposal Fees		
Non-compostable material	$8/CY	City of Woodbury Public Works
Compostable material	$4/CY	

Sections 7.1 and 7.2 show costs for in-house sweeping compared to costs for the same level of service using a contract sweeping service. For contract sweeping, the cost-basis ($/lane-mile) is assumed to be constant for all sweeping scenarios. The cost per lane-mile was calculated using the total cost of spring sweeping services divided by the total lane-miles swept.

Additional details for both in-house and contract sweeping cost estimates are provided in Cost Benefits – Detailed Calculations

7.1. Cost Efficiency Comparisons

The cost-efficiency estimates summarized in this section are focused mainly on in-house sweeping program options that include the purchase of 1 or 2 new street sweepers. Based on the number of municipal lane-miles to be swept (Table 2), it would take a single sweeper about 31.6 workdays to complete a single lane pass of all municipal roads. With two sweepers a single lane pass can be completed in about 16 workdays. Because spring and fall sweepings often require more than one lane pass to effectively reduce solids accumulation, and these cleanings are more time-sensitive than sweepings that occur between spring and fall, it is not feasible that even baseline sweeping could be completed using the sweepers currently owned by the City of Woodbury without putting a strain on the City's resources. If sweepers are needed for construction or road maintenance projects, there will likely be a shortage of vehicles at certain times of the year.

Based on the assumptions outlined in Table 8 and Appendix C, the cost-basis for baseline sweeping is $102 per lane-mile for a contract sweeper, and roughly $93 per lane-mile for a city-owned sweepers (Figure 8, Table 10). For baseline sweeping (spring/fall only) with city-owned sweepers, the total cost of sweeping is driven by capital outlay for sweepers (60% in Figure 9). Because capital outlay cost is essentially flat, the cost-efficiency ($/lane-mile) of in-house sweeping improves (lower cost basis, $/land-mile) as each vehicle is utilized for additional sweepings (24% for the 14 sweepings per year in Figure 9). Total labor costs follow the inverse pattern as more labor per sweeper is needed.

If additional sweepers are needed to complete the specified number of sweepings, the total cost increases by an increment equal to the vehicle depreciation and maintenance cost in Table 8; causing an initial decrease in cost-efficiency (higher $/lane-mile). These dynamics are shown in Table 10. For each of the vehicle purchase options listed under the 'Cost-basis of Sweeping,' the cost-efficiency improves as sweeping frequency is increased. For each of the sweeping scenarios, adding additional vehicles decreases the cost-efficiency, however, it should be noted then number of vehicles needed is dependent on the desired sweeping frequency.

In contrast, the cost-efficiency of contract sweeping is constant ($102/lane-mile), making additional sweepings no more cost effective than baseline sweeping.

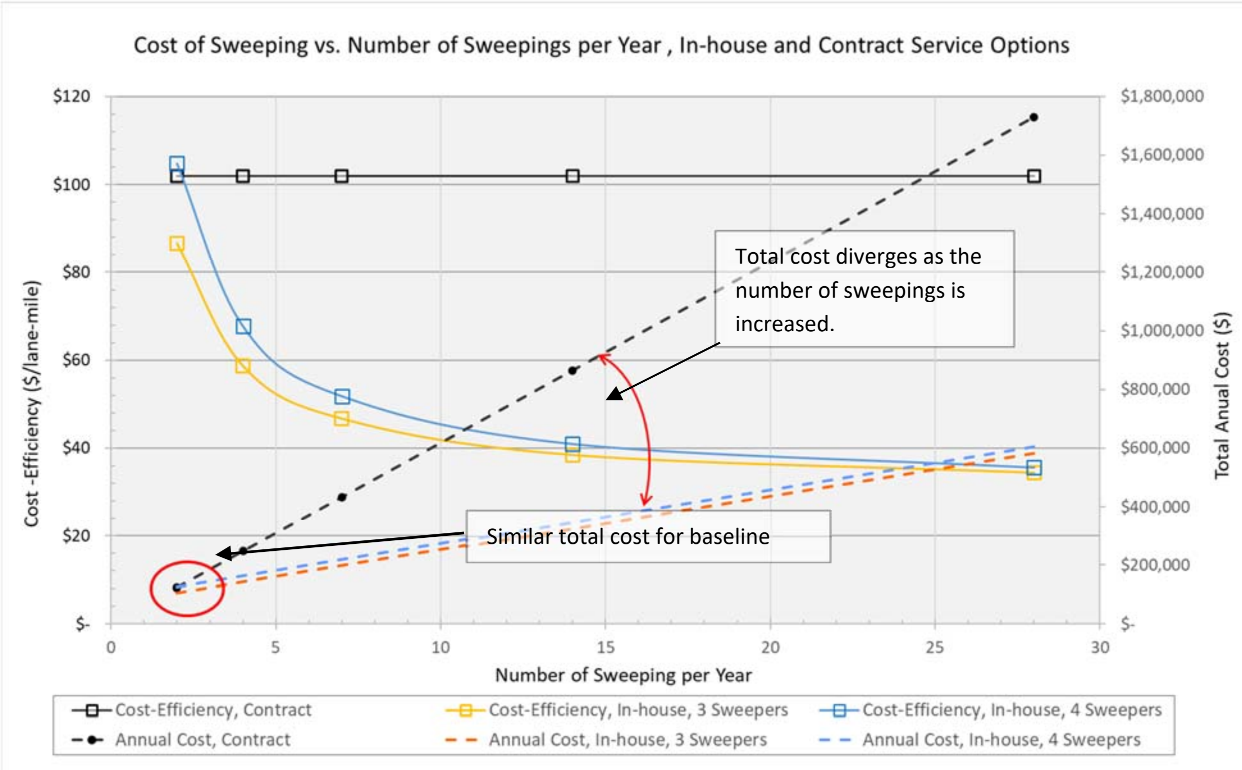

Figure 8. Cost of inhouse and contract sweeping for sweeping scenarios using 3 (1 new) and 4 (2 new) sweepers.

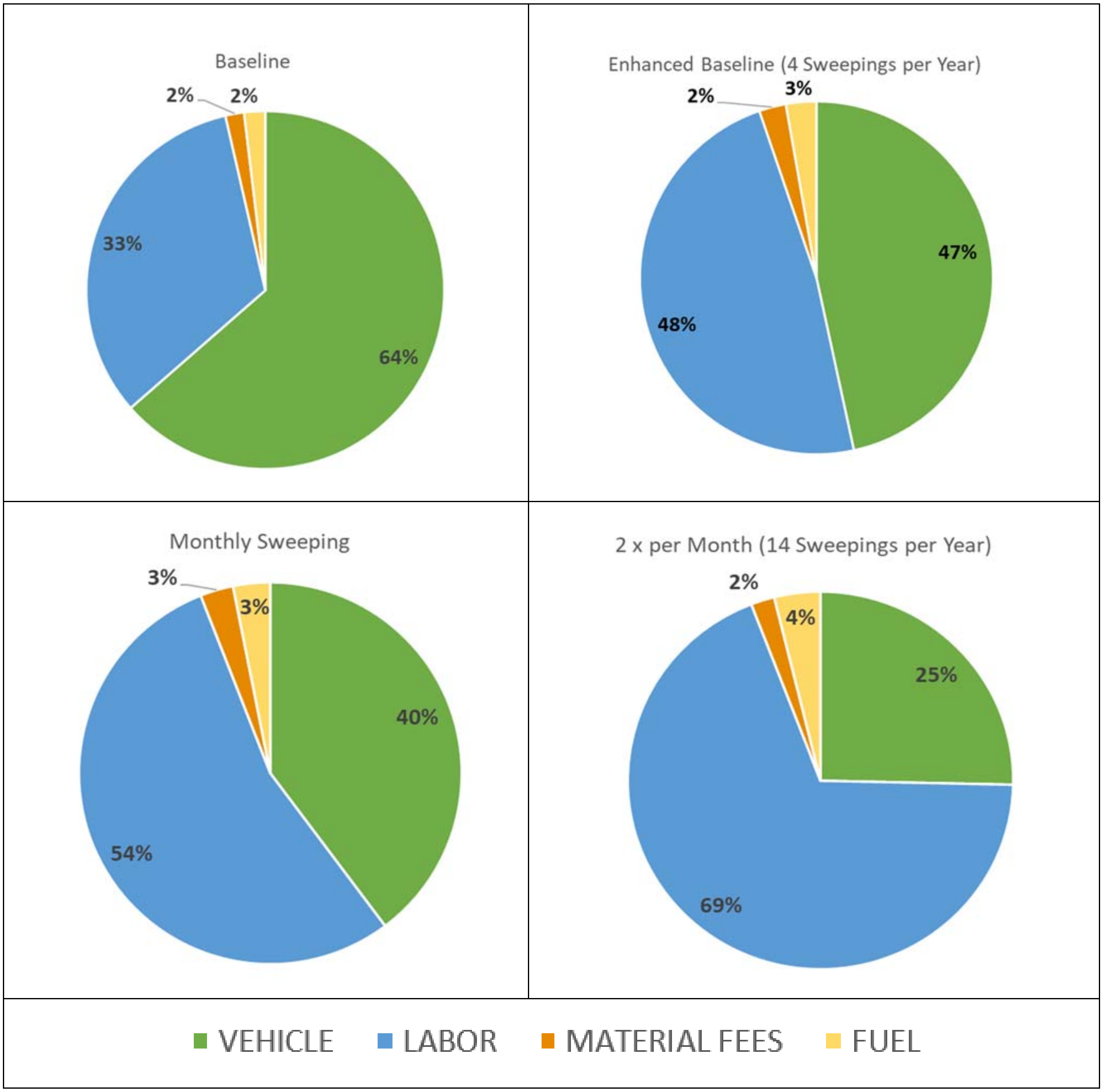

Figure 9. Vehicle (depreciation and maintenance), labor (sweeping and hauling operations), material disposal fees, and fuel costs as percent of the total cost of sweeping program options summarized in Table 10.

Table 9. Estimated total annual costs and cost-efficiencies for in-house street sweeping for the scenarios presented in Section 5 and different vehicle purchase options.

Sweeping Scenario	Total Lane-Miles Swept	ANNUAL COST for Different Sweeper Purchasing Options			Cost of basis of Sweeping ($/mi)		
		Option 1 (no purchase)	Option 2 (purchase 1)	Option 3 (purchase 2)	Option 1 (no purchase)	Option 2 (purchase 1)	Option 3 (purchase 2)
Baseline	1,212	$75,477	$105,067	$127,059	$62	$87	$105
Enhanced Baseline	2,424	$112,656	$142,246	$164,238	$46	$59	$68
Monthly	4,241	$168,423	$198,013	$220,005	$40	$47	$52
2X per Month	8,483	$296,411	$326,001	$347,993	$35	$38	$41
Weekly	16,965	$553,368	$582,958	$604,950	$33	$34	$36

1. Use sweepers currently owned by City of Woodbury - (1) Elgin Crosswind and (1) Elgin Pelican

2. Purchase one (1) additional high-efficiency sweeper

3. Purchase two (2) additional high-efficiency sweepers OR (1) additional high-efficiency sweeper and (1) broom sweeper

CELL SHADING KEY

White	*Numbers of sweepers is not a constrain in the scenario*
Light tan	*Number of sweepers could be a constraint if multiple lane passes are needed, or sweepers are in demand for other purposes like construction cleanup.*
Dark olive	*Scenario Requires additional sweepers*

Table 10. Comparison of estimated annual costs for in-house and contract service street sweeping for the street sweeping scenarios presented in Section 5.

Sweeping Scenario	Total Lane-Miles Swept	City of Woodbury Street Sweeping Program		Estimated Annual Cost for Contract Service Cost[2]
		Recommended Vehicle Purchase[1]	Estimated Annual Cost	
Baseline	1,212	Option 2: Purchase (1) additional sweeper	$105,067	$123,624
Enhanced Baseline	2,424		$142,246	$247,248
Monthly	4,241	Option 3: Purchase two (2) additional sweepers	$220,005	$432,582
2X per Month	8,483		$347,993	$865,266
Weekly	16,965		$604,950	$1,730,430

[1] Number of sweepers is not a constraint based on recommended purchase (see Table 9).

[2] Cost basis = $102 per lane-mile based on review of municipal bid awards. See Appendix C for cost-basis estimate details.

7.2. Pollutant Removal Cost Benefit

The primary objective of this study is to provide street sweeping recommendations to the City of Woodbury for the purpose of protecting water resources within the City's jurisdiction. To that end, we evaluated the cost benefit of each street sweeping scenarios with respect to total phosphorus management. Cost-effectiveness, measured as $ per pound of phosphorus recovered, tends to improve with cost-efficiency, but also depends on the timing of sweeping. Sweeping is most cost-effective in the spring and fall with total solids loading on street surfaces is greatest. Additional sweeping, during the late spring and summer months, does increase pollutant recovery on an annual basis; however, these sweepings are less productive (lower lb/lane-mile) when compared to spring and fall sweepings. Therefore, the cost-effectiveness for monthly sweeping is somewhat decreased when compared to the 'Enhanced Baseline' scenario in Table 11. Entries that are outlined in red correspond to scenarios that were used to develop sweeping recommendations (Section 8). For these scenarios, the cost-effectiveness of phosphorus recovery is roughly $300 - 350 per pound.

When quantified with respect to the estimated TP reductions to downstream water resources, the cost-effectiveness of sweeping is somewhat decreased (higher cost per pound). For the highlighted scenarios, the cost-effectiveness for pollutant reduction is about $650 per pound of TP. As discussed in Section 5.2, the TP load reductions presented in this report should be used for comparison of sweeping scenarios and not directly translated to reduction target quantified through other methods. Similarly, the cost-effectiveness estimates quantified for this study, do not capture the full scope of material benefits that sweeping can provide. Street sweeping reduces the mass of sediment as associated pollutants discharged to the City's stormwater infrastructure and, in doing so, can help preserve the treatment capacity or extend the maintenance life cycle of downstream BMPs. Due to the scarcity of research on this topic, a detailed cost-estimate of these benefits was beyond the scope of this study, nonetheless, co-benefits like this, if quantified would improve the cost-effectiveness of sweeping compared to the estimated provided here.

Table 11. Total costs and cost-efficiency with respect to phosphorus management for potential in-house sweeping scenarios.

Sweeping Scenario	Total Costs		Average Cost-Efficiency ($/lb-TP)	
	Annual Cost	$/lane-mile	Pollutant Recovery	Pollutant Reduction
	Vehicle Purchase Option 2: (1) Additional High-Efficiency Sweeper			
Baseline	$105,067	$87	$355	$723
Enhanced Baseline	$142,246	$59	$295	$599
Monthly	$198,013	$47	$279	$568
2X per Month	$326,001	$38	$337	$694
Weekly	$582,958	$34	$340	$692
	Vehicle Purchase Option 3: (2) Additional Sweepers (1 or both high-efficiency)			
Baseline	$127,059	$105	$429	$874
Enhanced Baseline	$164,238	$68	$340	$691
Monthly	$220,005	$52	$310	$631
2X per Month	$347,993	$41	$360	$741
Weekly	$604,950	$36	$353	$719

(Grey shading:) Number of sweeping vehicles could be a constrain depending on the need for more than one lane pass during period of heavy solids loading (spring, fall) and/or the demand for sweepers for construction projects.

8. RECOMMENDATIONS

Recommendations for sweeping by sweeping zone are listed in Table 12. In addition to prioritization of key water resources, the sweeping recommendations provided in this section were developed using the following guiding questions:

1) The City currently uses a contract service to complete spring and fall street cleanings.
    - What level of service can be provided for comparable cost if an in-house sweeping program is developed?
2) The City has expressed an interest in developing an enhanced street sweeping program for protection of Woodbury's key water resources.
    - Enhanced sweeping city-wide, would include 4 sweeping year minimally up to weekly sweeping. What level of service can be provided for comparable cost if an in-house sweeping program is developed when compared to contract sweeping?

The analyses completed for this study showed that for baseline sweeping, the cost of an in-house program is somewhat less than, but comparable to, using a contract service. However, as the frequency of sweeping is increased from 4 times per year, in-house sweeping is an increasingly more cost-effective option.

The recommended sweeping scenario is a hybrid of the scenarios outlined in red under the Vehicle Purchase Option 2 (purchase 2 additional sweepers) in Table 11. It prioritizes sweeping in zones SW-2, -3, -4, -5, and -7 with a frequency of twice monthly (12-14 sweepings per year). Sweeping in these zones will most benefit the following key water resources: Wilmes North and South -Lakes, Markgrafs Lake, Powers Lake, and Colby Lake. All other sweeping zones in the City would benefit from monthly sweeping (7 sweepings per season) for water quality and BMP longevity.

Estimated pollutant recovery and pollutant load reductions for downstream water resources for the recommended scenario are summarized in Table 13. For the fully implemented recommendations, the estimated pollutant recovery is 979 tons of total solids and 779 pounds of total phosphorus. Compared to baseline pollutant load reductions, sweeping at recommended frequency is estimated to reduce TP loads to key resources by the following amounts:

Key Water Resource	Pollutant Reduction Compared to Baseline Sweeping (lb-TP/yr)
Wilmes Lake (North and South)	13.6
Markgraf's Lake	3.5
Power's Lake	10.7
Colby Lake	33.0
Bailey Lake	45.3
Battle Creek Lake	5.9
Carver Lake	30.4
Valley Branch Creek	5.2

Recommendations for Program Implementation

It may be easiest to implement recommendation over a period of 2 to 3 years to adapt staffing and equipment schedules.

Year 1:

- Buy 1 high-efficiency sweeper and implement monthly sweeping in all zones
- If staffing limitations or sweeper demand for other needs (construction, road maintenance) limits the availability of sweeper for enhanced sweeping practices, prioritize sweeping zones that target key water resources.

The estimated annual cost for implementation of at this level of effort is **$198,013**. This cost is comparable to the cost of contract sweeping for the Enhanced baseline scenario (4X per year) in all zones ($247,248).

Year 2 or 3:

- Purchase an additional sweeper. Choose high-efficiency or mechanical sweeper depending on cross-over demand with other sweeping needs (construction, road maintenance projects).
- Add sweepings up to twice monthly in zones that target priority water resources.

The estimated annual cost for implementation at this level of effort is **$351,766** or about $65 per lane-mile swept. This cost is less than the cost of contract sweeping for monthly sweeping in all zones ($432,582).

Year 4 and beyond:

- Adapt sweeping practices to target key water resources as impacted by new development, BMP performance; changes in tree canopy or infrastructure, or other factors that influence watershed pollutant loads.

Table 12. Recommended Sweeping Scenario

Sweeping Zone	Primary Resource Targeted	Workdays Needed, Single Sweeper[1]	Total Lane-Miles	Proposed Sweeping Schedule	Estimated Annual Cost[2]
SW-1	Wilmes Lake North	0.9	16.7	Monthly	$7,552
SW-2	Wilmes Lake North	1.2	23.6	Twice Monthly	$21,344
SW-3	Wilmes Lake North	1.5	28.4	Twice Monthly	$25,685
SW-4	Powers Lake Markgraf's Lake	2.2	43	Twice Monthly	$38,889
SW-5	Wilmes Lake South	1.2	23.4	Twice Monthly	$21,163
SW-6	Bailey Lake	1.8	35	Monthly	$15,827
SW-7	Colby Lake	2.8	53.5	Twice Monthly	$48,385
SW-8	Colby Lake	2.8	54.7	Monthly	$24,735
SW-9	Colby Lake	2.3	44.6	Monthly	$20,168
SW-10	East Mississippi West Draw	1.2	23.1	Monthly	$10,446
SW-11	Bailey Lake	3.0	58.2	Monthly	$26,318
M-1	Tamarack Wetland Evergreen Wetland	1.1	22	Monthly	$9,948
M-2	Tamarack Wetland	1.1	20.6	Monthly	$9,315
M-3	Carver Lake Marsh Creek Pond	1.9	36.3	Monthly	$16,415
RMW-1	Battle Creek	1.2	22.3	Monthly	$10,084
RMW-2	Battle Creek Lake	1.8	32.3	Monthly	$14,606
RWM-3	Carver Lake	2.2	42.8	Monthly	$19,354
VB-1	Valley Branch Creek Markgrafs Lake	0.9	25.5	Monthly	$11,531
	TOTAL	**31.6**	**606**		$351,766

[1] Based on a single lane pass. Used to determine the number of sweepers needed to complete the sweeping scenario within the specified timeframe. For example, a single sweeper would not fulfill the sweeper demand for monthly city-wide street sweeping since 31.6 days. Two sweeper working full time could compete a single lane pass in 31.6 divided by 2, or about 16 workdays.
In house street sweeping program, all sweepers city-owned and operated.

Table 13. Estimated pollutant load recovery and load reduction to downstream water resources for the sweeping recommendations summarized in Table 13.

Watershed District | Major Watershed		Primary Water Resources	Total Lane Miles		Sweeping Scenario | Recommended Sweeping Frequency					
					Estimated Pollutant Recovery			Estimated Pollutant Reduction		
			Zone	Scenario	TS (tons/yr)	TP (lb/yr)	$/lb-TP	TS (tons/yr)	TP (lb/yr)	$/LB-TP
SWWD	Central Draw	Wilmes Lake North	30.9	264	48.4	42.1	$405	15.0	20.2	$843
		Wilmes Lake South	40.7	555	73.8	66.8	$537	12.5	26.1	$1,376
		Evergreen Park Wetland	21	*147*	29.6	21.9	$433	8.3	12.1	$788
		Markgrafs Lake	14.3	114	22.1	18.5	$399	2.7	5.4	$1,374
		Powers Lake	32.3	416	51.3	45.1	$596	2.1	15.8	$1,702
		Fish Lake	22.2	287	35.3	31.0	$598	2.5	12.1	$1,533
		Colby Lake	128.9	1160	206.6	165.2	$454	12.4	52.9	$1,417
		Bailey Lake	100	823	153.7	119.7	$444	56.9	74.2	$716
		Marsh Creek Pond	33.2	232	55.9	41.9	$357	11.2	22.2	$674
		Central Draw	11.6	81.3	16.8	12.5	$420	7.9	8.4	$627
	East Mississippi	La Lake	0.9	6.6	2.0	1.5	$284	0.9	0.9	$474
		East Mississippi	8.3	57.9	17.4	13.2	$282	7.1	8.6	$434
	West Draw		14.1	98.4	29.4	22.4	$298	$284	12.5	$533
		SWWD TOTAL	**458.4**	**4242**	**742.1**	**602.0**	**$479**	$455	**271.3**	**$1,062**
RWMWD	Battle Creek	Battle Creek Lake	14.6	102	23.4	17.5	$376	17.2	10.8	$610
		Tamarack Wetland West	6.6	46.1	10.7	8.0	$373	4.1	2.6	$1,145
		Tamarack Wetland East	23.8	166.7	41.4	31.2	$345	16.1	10.1	$1,066
		Battle Creek	14.9	104.3	24.1	18.1	$373	3.6	3.3	$2,042
	Carver Lake		74.7	522.9	118.4	88.4	$402	$382	29.9	$1,187
		RWMWD TOTAL	**134.6**	**942**	**218.0**	**163.1**	$392	$373	**56.7**	**$1,128**
VBWD		Valley Branch Creek **/TOTAL**	13	94	18.9	14.2	$450	$429	7.2	$886
		ALL	**606**	**5278**	**979.1**	**779.3**	**$460**	**240.1**	**$429**	**$1,069**

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APPENDIX A. STREET SWEEPING ZONE MAPS

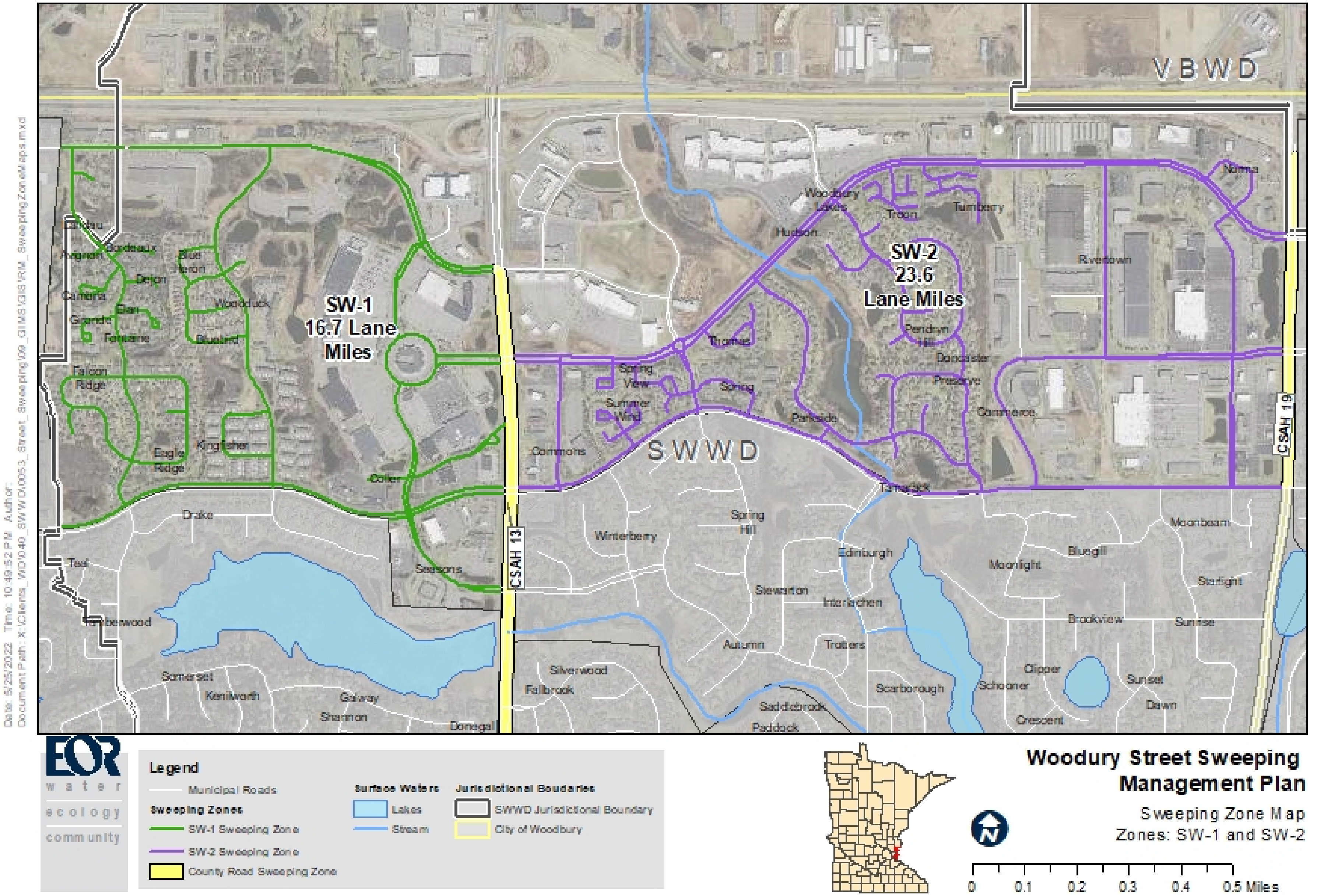

Figure 10. Sweeping Zones SW-1 and SW-2

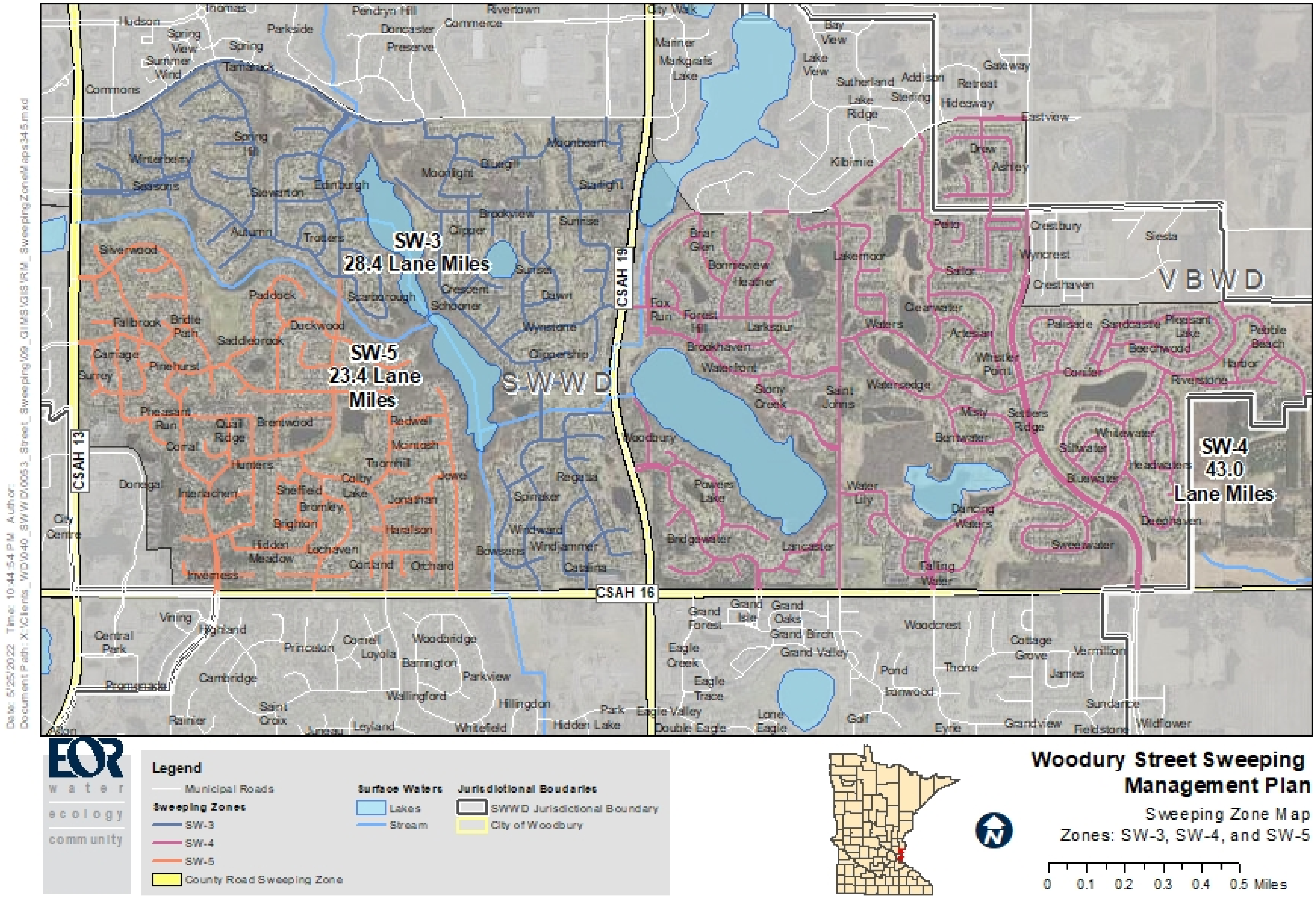

Figure 11. Sweeping Zones SW-3, SW-4, and SW-5.

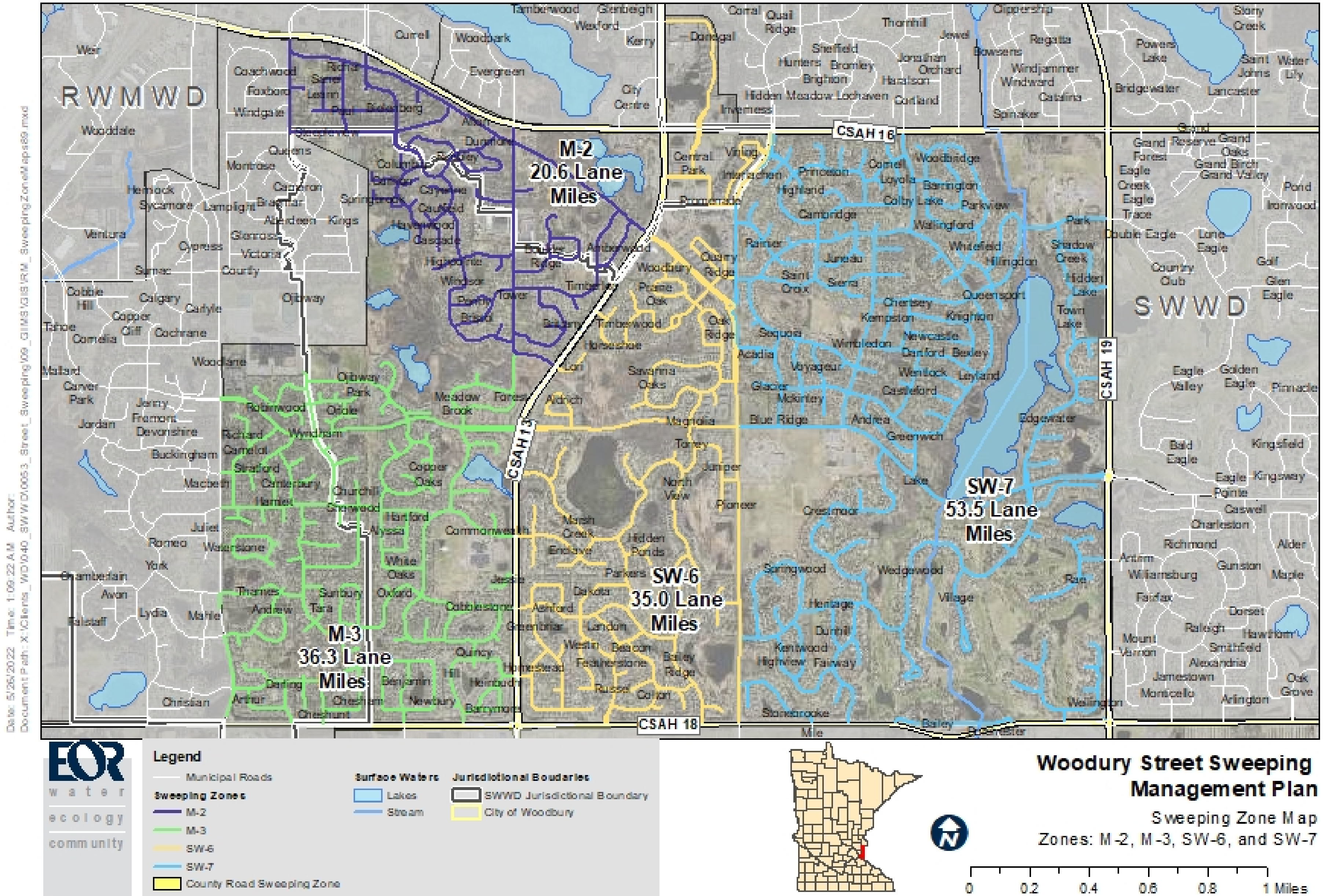

Figure 12. Sweeping Zones M-2, M-3, SW-6, SW-7.

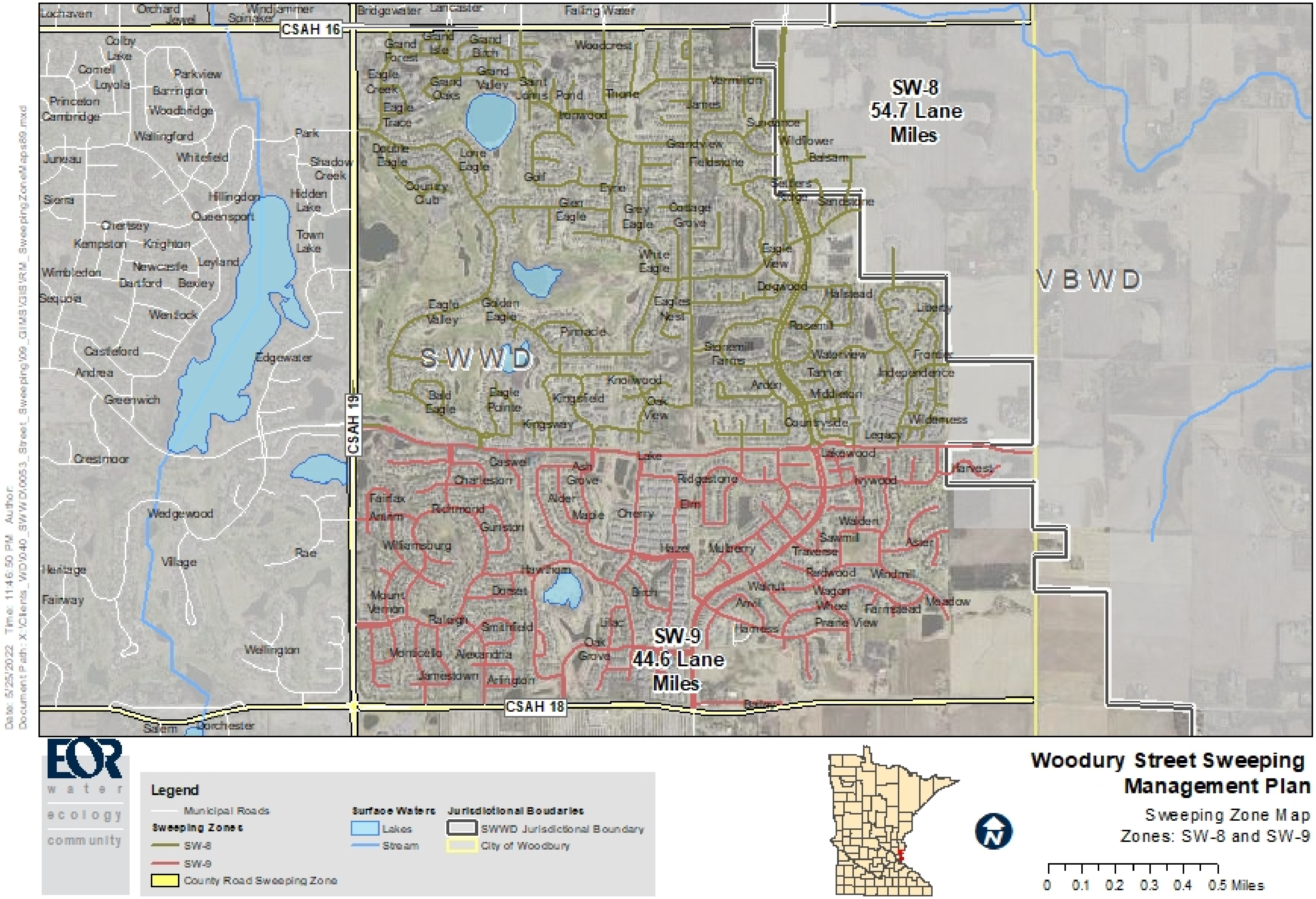

Figure 13. Sweeping Zones SW-8 and SW-9.

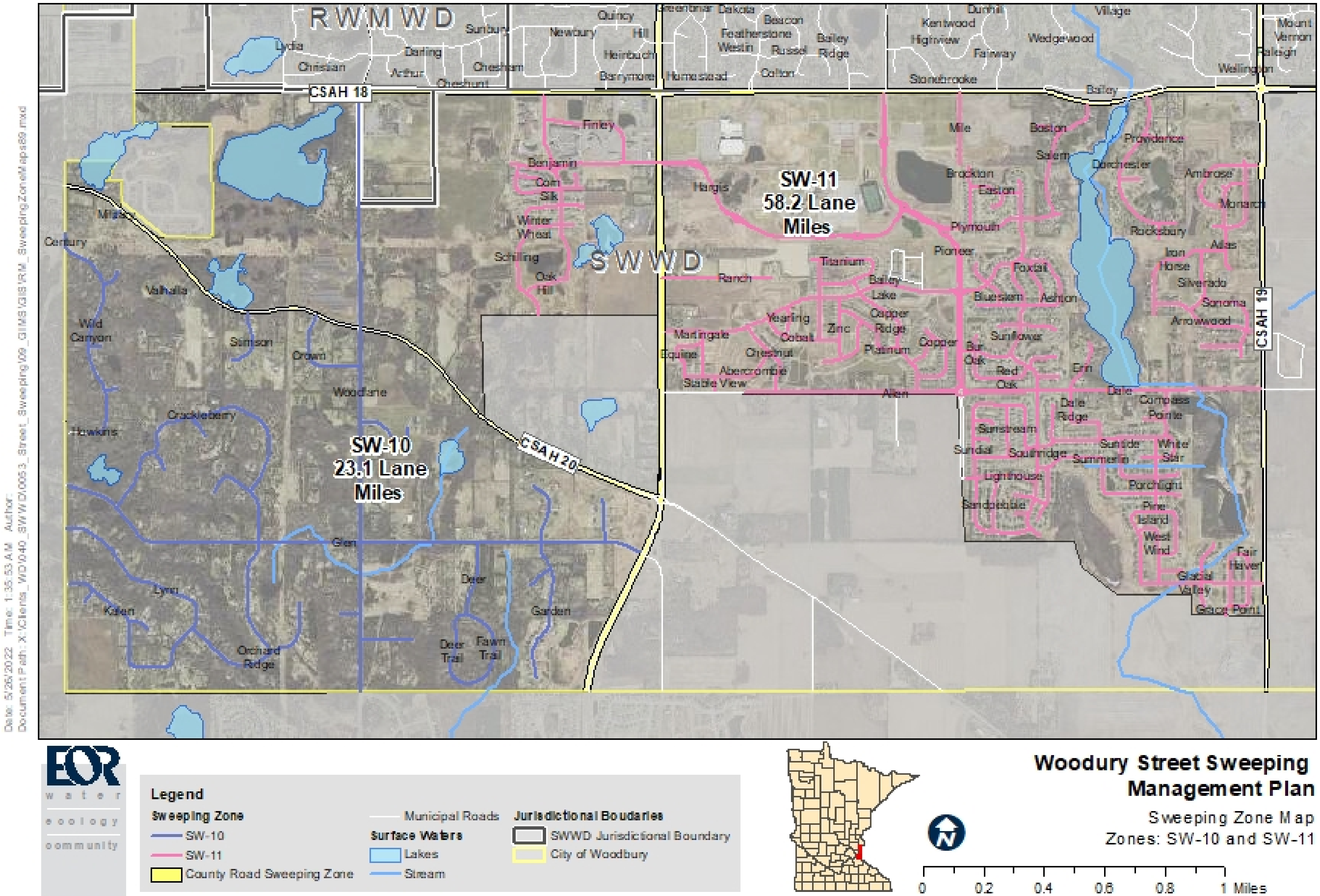

Figure 14. Sweeping Zones SW-10 and SW-11.

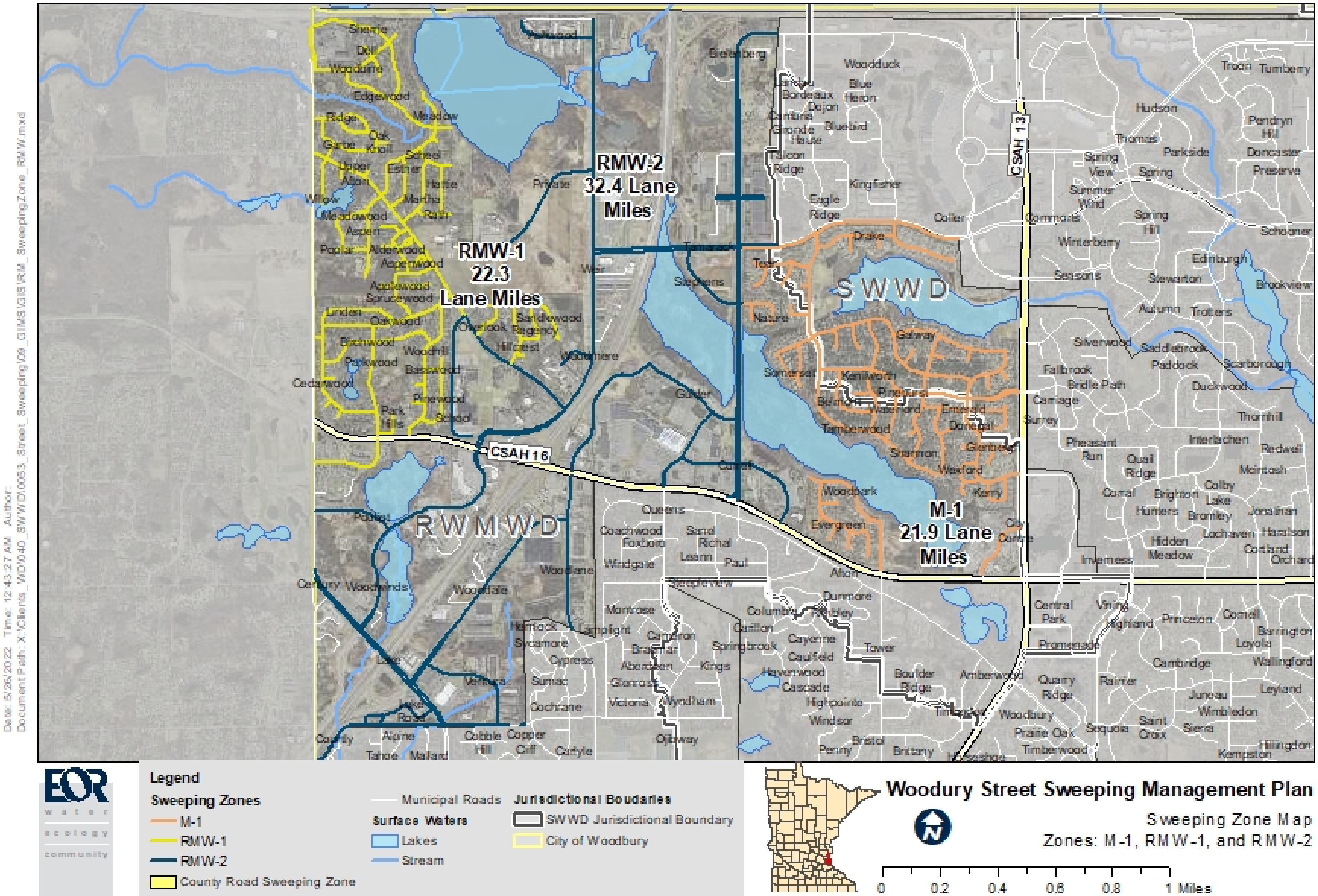

Figure 15. Sweeping Zones M-1, RMW-1, and RMW-2

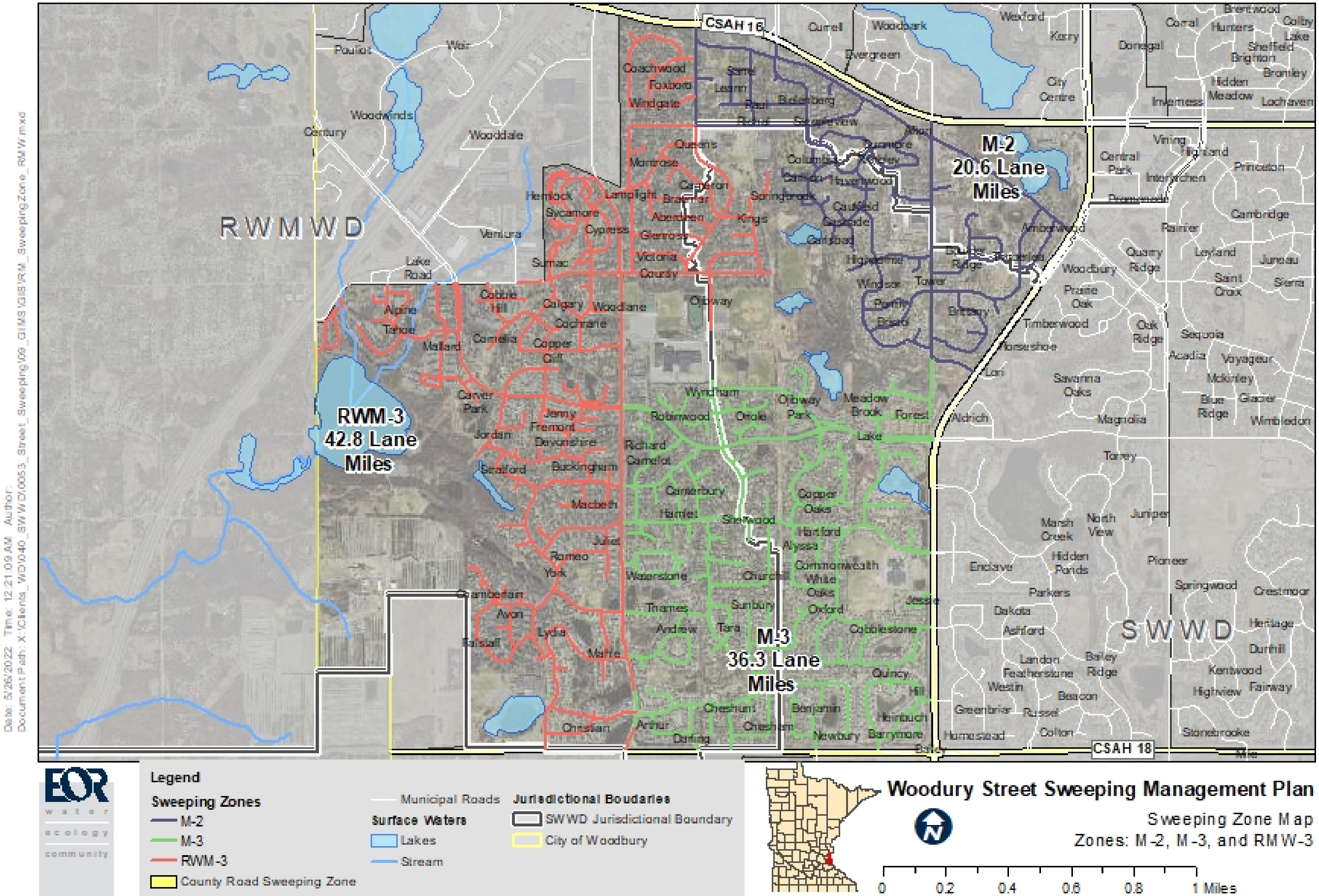

Figure 16. Sweeping Zones M-2, M-3, and RMW-3.

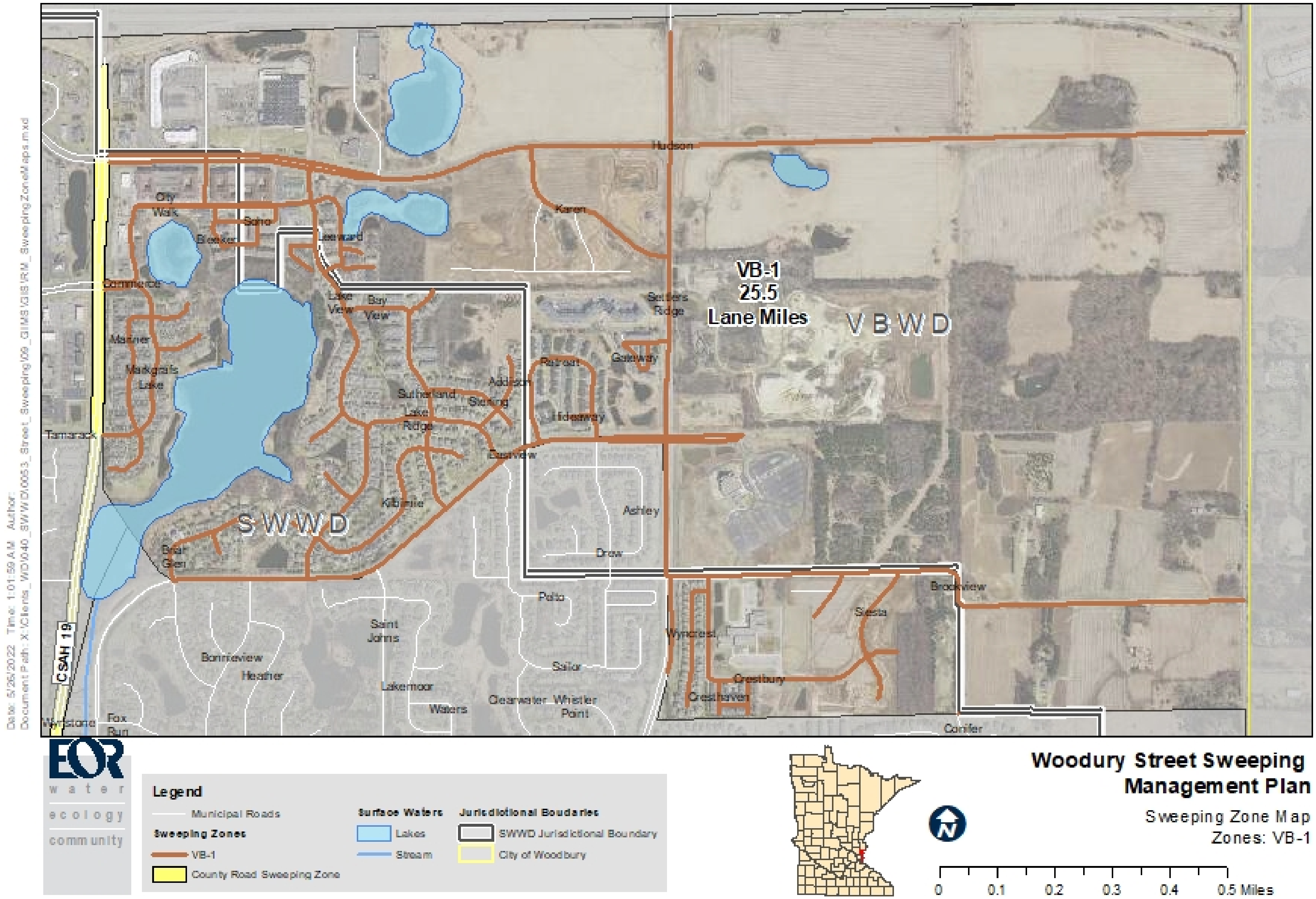

Figure 17. Sweeping Zones VB-1.

APPENDIX B. COLLECTIVE BMP REMOVAL EFFICIENCIES FOR LOAD REDUCTION CALCUATIONS

Modeled Resources

The SWWD provide water quality models (P8) for several lakes in the SWWD. Since street sweeping zones boundaries do not correspond to modeled subwatershed boundaries, a collective BMP removal efficiency was calculated at the watershed-scale applied and applied to pollutant recovery from street re-aggregated by water resource drainage area (as shown in Table 4 and Table 6).

The collective removal efficiency of BMPs was calculated as follows:

The total pollutant **load retained by BMPs** in the watershed = **Watershed Load** – **Lake Inflow Load**

The **collective removal efficiencies of BMPs** = (**Watershed Load** – **Load Retained by BMPs**) / **Watershed Load**

Table 14. Summary of TSS load estimates from SWWD P8 lake models used to calculate the collective TSS removal efficiency of modeled BMPs in the water resource drainage area.

	TSS Load (lb/yr)				
Waterbody	Watershed Load	Direct Drainage	Total Inflow	Retained by Upstream BMPs	**Collective BMP Removal Efficiency**
Wilmes North	247307	5184	82062	76878	69%
Wilmes South	268463	21156	65822	44666	83%
Markgrafs	160482	62617	81421	18804	88%
Powers Lake	981769	159777	203726	43949	96%
Fish Lake	392417	14522	42195	27673	93%
Colby Lake	544221	86410	121141	34731	94%

Table 15. Summary of TP load estimates from SWWD P8 lake models used to calculate the collective TP removal efficiency of modeled BMPs in the water resource drainage area.

	TP Load (lb/yr)				
Waterbody	Watershed Load	Direct Drainage	Total Inflow	Retained by Upstream BMPs	**Collective BMP Removal Efficiency**
Wilmes North	599	12.1	296.9	285	52%
Wilmes South	648	48.52	302.4	254	61%
Markgrafs	383	150.9	261.9	111	71%
Powers Lake	1146	183.3	583.3	400	65%
Fish Lake	460	17.7	196.6	179	61%
Colby Lake	2312	366.4	1104.1	738	68%

All Other Resources

Where modeled efficiencies were not available the median removal efficiencies reported in Table 5 were applied to the City's BMP inventory and area-weighted based on the district drainage area. A sample of the BMP inventory with median BMP removal efficiencies is shown in Table 16.

Table 16. Summary of BMPs by drainage district and downstream water resource for Tamarack East and Tamarack West wetland.

District	Downstream Waterbody	BMP Type	Count	District Area (ac)	Estimated Impervious (ac)	% Impervious Treated	SWS TSS Removal	SWS TP Removal
BC-18	Tamarack East	WET POND	1	183.2	64.1	100%	84%	50%
BC-18	Tamarack East	WETLAND	1	183.2	64.1	100%	55%	40%
BC-18.0.1	Tamarack East	DRY POND	2	135.2	47.3	21%	7%	4%
BC-18.1	Tamarack East	WET POND	1	17.3	6.1	100%	84%	50%
BC-18.10	Tamarack East	WET POND	1	10.2	3.6	100%	84%	50%
BC-18.11	Tamarack East	WET POND	1	9.8	3.4	100%	84%	50%
BC-18.12	Tamarack East	WET POND	1	3.8	1.3	100%	84%	50%
BC-18.3a	Tamarack East	WET POND	1	2.2	0.8	100%	84%	50%
BC-18.3b	Tamarack East	WET POND	1	3.8	1.3	100%	84%	50%
BC-18.3c	Tamarack East	WET POND	1	1.4	0.5	100%	84%	50%
BC-18.3d	Tamarack East	WET POND	1	1.8	0.6	100%	84%	50%
BC-18.3e	Tamarack East	WET POND	1	2.6	0.9	100%	84%	50%
BC-18.3f	Tamarack East	WET POND	1	5.9	2.1	100%	84%	50%
BC-18.3g	Tamarack East	WET POND	3	40.3	14.1	100%	84%	50%
BC-18.4	Tamarack East	WET POND	1	17.3	6.1	100%	84%	50%
BC-18.5	Tamarack East	WET POND	1	29.3	10.2	100%	84%	50%
BC-18.6	Tamarack East	WET POND	1	25.0	8.7	100%	84%	50%
BC-18.7	Tamarack East	WET POND	1	39.2	13.7	100%	84%	50%
BC-18.8	Tamarack East	WET POND	1	34.8	12.2	100%	84%	50%
BC-18.9	Tamarack East	WET POND	1	12.8	4.5	100%	84%	50%
BC-17	Tamarack West	RAIN GARDEN	5	52.7	18.4	100%	100%	100%
BC-17	Tamarack West	WET POND	1	52.7	18.4	100%	84%	50%
BC-17	Tamarack West	WETLAND	1	52.7	18.4	100%	55%	40%
BC-17.0.1	Tamarack West	DRY POND	5	104.9	36.7	68%	24%	14%
BC-17.0.1	Tamarack West	WET POND	1	104.9	36.7	100%	84%	50%
BC-17.1	Tamarack West	WET POND	1	5.6	2.0	100%	84%	50%
BC-17.2	Tamarack West	WET POND	1	31.4	11.0	100%	84%	50%
BC-17.3	Tamarack West	WET POND	2	23.2	8.1	100%	84%	50%
BC-17.4	Tamarack West	WET POND	1	15.7	5.5	100%	84%	50%

APPENDIX C. COST BENEFITS – DETAILED CALCULATIONS

For this study, cost estimates for street sweeping included the following three categories.

Total Cost = {Labor Cost} + {Equipment Cost} + {Material Management Cost}

Appendix C.1. Labor Cost

The following assumptions were used to calculate labor costs as part of the sweeping scenario cost estimates. All quantities are based on information collected from the City of Woodbury and/or City engineers from other Twin Cities municipalities for similar sweeping analyses.

Table 17. Summary of sweeping labor cost calculation assumptions.

Item	Rate
Labor Rate	
Average Labor Rate (wages + benefits)	**$75.00/hr**
Labor Time	
Sweeper Operation Time	
Average brush-on operational speed	3.5 mph
Average brush-off operational speed	35 mph
Non-driving time related to sweeping (maintenance, fueling, dumping, other)	1 hour for every 4 hours of driving
Hours available per 1.0 FTE	
Cost-basis, 1.0 FTE Baseline	8.0 hr/day (40 hr/wk.)[1]
Snow-free season weekdays	153 days (30.6 weeks)
Holidays and PTO	10 days (2 weeks)
Work-basis, hours available per day	7.5 hr/day (37.5 hr/week)[1]

[1]The time needed to sweep proposed zones was calculated using the average hours available per day (7.5 hr) and the associated cost for that work was calculated by applying the labor rate to an 8-hour day.

Table 18. Estimated annual cost of labor for street sweeping by sweeping scenario.

Scenario	Brush-on Time (hr/yr)	Brush-off Time (hr/yr)	Non- driving Time (hr/yr)	Labor Cost ($/yr)
Baseline (Spring/Fall 1 X each)	346	29	87	**$34,617**
Enhanced Baseline (Spring/Fall 2 X each)	692	58	173	**$69,234**
Monthly all Routes	1212	101	303	**$121,160**
2X Monthly all Routes	2424	201	606	**$242,321**
Weekly all Routes	4847	403	1212	**$484,641**

Appendix C.2. Equipment Cost

Table 19. Breakdown of vehicle purchase and maintenance cost, annualized.

Item	Elgin Crosswind[1] (or similar)		Elgin Pelican[2] (or similar)	
	Owned[3]	New	Owned[3]	New
Capital Outlay				
Purchase Price New	*($269,000)*	$279,000	*($201,000)*	$209,000
Applicable Grant Contribution (SWWD)	*$115,000*	---	---	---
Outlay = (Purchase Price New – Grant Contribution)	$154,000	$279/000	$201,000	$209,000
Annual Capital Depreciation				
Useful Lifespan of Vehicle	10 years			
Anticipated Resale Value	$75.000		$58,000	
Depreciation = (Outlay – Resale)/Lifespan	$15,296	$32,318	$14,300	$15,100
Yearly Maintenance, Refurbishment, and Fuel				
Dealer Estimate - based on 4-year maintenance cycle for standard high usage and wear items[4]	$9,190		$6,892	
Air filter and lubricants per 1000 hours of use[5]	~1,800[4]			
Average vehicle mileage[5, 6]	6.25 mph			
Cost of diesel fuel[5,7]	$5.50 per gallon			
Annualized Maintenance Cost	$9,190		$6,892	
Annualized Sweeper Cost				
= Depreciation + Annual Maintenance	**$24,486**	**$41,508**	**$21,192**	**$21,992**

[1]Regenerative Air or similar high efficiency sweeper

[2] Mechanical broom sweepers with dust spray

[3]Currently owner by the City – (1) Elgin Crosswind and (1) Elgin Pelican Sweeper

[4]See product information sheet from Tymco, Appendix C.5.

[5]The cost of fuel, filters, and lubricant is accounted for in the total cost of sweeping based on estimated hours or miles of use for each sweeping scenario.

[6]Prior Lake, MN sweeping study.

[7]Average cost of diesel in Minnesota for the period May 15th – Jun 15th, 2022, AAA.

Table 20. Summary of total vehicle-related costs for sweeping scenarios based on minimum number of sweepers needed to complete sweeping within the allotted timeframe.

Scenario	Sweeper Assumption	Annualized Vehicle Cost				
		# Sweepers	Total Operation Miles	Fuel & Other Consumables	Depreciation & Maintenance	TOTAL
Baseline (Spring/Fall 1 X each)	City -owned Crosswind City -owned- Pelican (1) New Elgin Crosswind (or similar)	3	1,212	$1,878	$67,872	$69,750
Enhanced Baseline (Spring/Fall 2 X each)		3	2,424	$3,755		$71,627
Monthly all Routes	City -owned Crosswind City -owned- Pelican (1) New Elgin Crosswind (or similar) (1) New Elgin Pelican (or similar)	4	4,241	$6,572	$89,872	$96,444
2X Monthly all Routes		4	8,483	$13,143		$103,015
Weekly all Routes	City -owned Crosswind City -owned- Pelican (3) New Elgin Crosswind (or similar) (1) New Elgin Pelican (or similar)	6	16,965	$26,287	$133,872	$160,159

Appendix C.3. Materials Management Cost

The following assumptions were used to calculate the disposal costs of sweeper waste.

Table 21. Summary of sweeper waste management assumptions.

Item	Rate
Vehicle Assumptions – Dump Truck (hauling)	
Maximum hauling capacity[1]	8 CY / 16 ton hoist capacity
Average vehicle fuel efficiency[2]	6.5 mpg
Cost of diesel fuel[3]	$4.25 per gallon
Sweeper Waste	
Average bulk density (lb/ft) – Inorganic[4]	88 lb/cf
Average bulk density (lb/ft) - Coarse Organic[5]	15 lb/cf
Average annual composition by solids type[6]	75% inorganic/25% organic
Sweeper hopper capacity[7]	8 CY (Elgin Crosswind)/3.5 CY (Elgin Pelican)
Sweeper Waste Management Labor Costs	
Labor Time = transit time + related non-driving time	
Distance to disposal site[8]	36 miles
Average transit speed	45 mph
Non-drive time required per haul	0.5 hour
Labor Rate	
(Same as sweeping operations, see Appendix C.1).	
Disposal Fees	
Non-compostable (inorganic) material[8]	$8 /CY
Compostable (organic) material[8]	$4 /CY
Mass-weighted disposal fee (75% inorganic/25% organic)	$7 /CY

[1] Typical value for truck with box length 10 – 12 feet, Monroe Municipal Equipment, All Season Bodies - Monroe Municipal Truck Equipment (monroetruck.com).

[2] Trux, Inc, *How to Effectively Reduce Fuel Consumption*.

[3] Average cost of diesel in Minnesota for the period Feb 15th – March 15th, AAA.

[4] Bulk density of silty sand, MN Stormwater Manual

[5] Bulk density of yard waste, average for leaves (Minnesota, 342 lb/CY) and uncompacted yard waste (250 lb/CY), and compacted yard waste (640 lb/CY), USEPA Volume-to-Weight Conversion Factors, April 2016.

[6] Sweeper waste composition, Prior Lake Street Sweeping Study (Kalinosky, et al, 2013).

[7] Vehicle specifications, vendor website.

[8] Project communications, City of Woodbury Public Works staff.

Table 22. Estimated annual cost of disposal-related costs for street sweeping scenarios.

Scenario	Total Material Volume (CY/yr)	Disposal Fees	Fuel ($/yr)	Labor ($/yr)	Disposal Cost ($/yr)
Baseline (Spring/Fall 1 X each)	12	$151	$1,927	$466	$2,544
Enhanced Baseline (Spring/Fall 2 X each)	24	$299	$3,508	$920	$4,727
Monthly all Routes	41	$519	$6,218	$1,597	$8,334
2X Monthly all Routes	45	$574	$6,893	$1,765	$9,232
Weekly all Routes	70	$894	$10,863	$2,752	$14,509

Appendix C.4. Contract Sweeping Cost Estimate

The cost of sweeping using a contract service was estimated using public bid tabulations for municipal street sweeping services and data collected by EOR for previous street sweeping studies (Table 23). Only quotes for annual or city-wide street cleaning were included in comparisons. The cost-basis for other sweeping services – e.g., construction site maintenance and parking lot sweeping – was not reviewed since this cost-basis tends to be hourly rather than by distance swept and lighter-duty sweepers are often used. Quoted rates for street sweeping services varied significantly among the bids reviewed, from a low rate of approximately $28.33 per lane-mile to a high of $147.84. Variation in bids is due in part to local economic factors. Other less transparent factors include:

- Number, type, and condition of sweepers – sweepers come in different sizes, and some are more effective than others when targeting grit vs. leaves. vs. trash, etc.
- Operational speed and number of sweeper passes per lane – assumptions regarding the number of lane passes requested/needed to clean streets may vary among service providers.
- Distance to municipality – mobilization costs were not quantified explicitly in any of the bid tabulations that were reviewed but may be accounted for in unit pricing.
- Disposal-related costs –It is not clear how sweeper waste management responsibilities may factor into pricing for other bids. Only the Oak Park Heights quote (2014) included an explicit item for disposal.
- Reimbursable expenses – It was not clear in the bid tabulations whether expenses were included or if some quotes included reimbursement for fuel costs.

Based on the surveyed rate, a value of $102 per lane-mile was used to estimate the cost of contract services. This value represents the median cost of all entries in Table 23.

Table 23. Summary of municipal street sweeping bids reviewed for contract sweeping service cost estimates.

#	City	Year	Proposed Lane Miles	Quote	Cost per lane mile
1	Cottage Grove, MN	2020	(City -wide)	$85.00/hr	~$28.33[1]
2	Forest Lake, MN	2017	239 x 2	$66,500	$139
3	Oak Park Heights, MN	2014	Spring/Fall Sweeping	$115/hr + $1.20/CY disposal fee	$32.85[1] + disposal fees ($44.95 adjust for 4% annual inflation)
4	Downer's Grove, IL (Greater Chicago)	2022	224 x 12 sweepings	$143,673.60 spring	$53.45 Spring
5			240 x 3 sweepings	$73,526.40 fall	$102.12 fall
6	St. Charles, IL (4 bids)	2021	276 x 8 sweepings	$211,372 average	$95.73
7				$82,481 low	$35.36
8				$280,120 high	$127.32
9	Westerville, OH	2020	Annual street sweeping	$0.028/curb-foot	$147.84
10	Fairfield, OH	2018-20	City streets 1x, 2x, or 4x per month	$0.01339/curb-foot	$70.70
11	Laude, MO	2022	21 centerline miles x 12	$70,560	$280/centerline mile *$70 - $140/ lane-mile*
12	Victoria, TX (3 bids)	2020	648 highway, 375 arterial, 740 local, 400 extra lane pass for heavy debris	$251,784.30 (low bid)	$116.41

[1]Based on a single lane pass at an average operational speed of 3.0 mph

Appendix C.5. Detailed Costs - Vehicle Maintenance

Sample Manufacturer's Data Sheet, Tymco Model 600

TYMCO

REGENERATIVE AIR SWEEPERS

TYMCO MODEL 600
PROJECTED PARTS USAGE/STOCKING REQUIREMENTS
BASED ON 1000-1200 HOURS USE PER YEAR

Prices based on TYMCO 2021 published price list

Section	PART NO	DESCRIPTION	UNIT LIST PRICE	QUANTITY 1ST YR.	2ND YR.	3RD YR.	4TH YR.	4 YR TOTALS
1	11221	Power Band, Blower - Std	$523.00				1	$523.00
	11108	Tapor Lock Bushing	$66.00			1	1	$132.00
	5010937	Seal, Blower Housing	$17.00		1	1	1	$51.00
	502556	Water Pump, Electric ('95 & Later)	$278.00		1	1	1	$834.00
	20809	Tip, Water Spray	$16.00			5		$80.00
	10837	Strainer, Spray Nozzle	$11.00			5		$55.00
	5010839	Pickup Head Spring (Light Duty)	$28.00				2	$56.00
	5010840	Pickup Head Spring (Heavy Duty)	$30.00				2	$60.00
	12910	Gutter Broom Lock Valve Assy	$153.00			1	1	$306.00
	500360	Seal, Hopper Transition	$56.00		1	1	1	$168.00
	500902	Seal, Dump Door	$334.00				1	$334.00
	500362	Seal, Inspection Door	$43.00			1	1	$86.00
	5013731	Seal Kit, Torque Motor	$139.00			1	1	$278.00
	5012771	Seal Kit, G.B. & PUH Cylinder	$84.00			1	1	$168.00
	5014244	Seal Kit, Dump Cylinder	$166.00				1	$166.00
	505172	Cartridge Valve	$257.00			1		$257.00
	504622	Valve Assembly, Hydraulic	$420.00				1	$420.00
	5010960	Spring, Gutter Broom	$31.00			1	1	$62.00
	503014	Check Valve	$121.00			1	1	$242.00
	504459	Vickers Coil - 12 V DC w/Deut.	$147.00		1	1	1	$441.00
		YEARLY COST PROJECTION TOTALS		$0.00	$498.00	$1,527.00	$2,694.00	**$4,719.00**
2	501513	Blower Wheel (Coated)	$3,928.00			1		$3,928.00
	KT1102	Liner Kit, Blower Housing	$1,550.00		1	1	1	$4,650.00
	501020	Curtain Set, Pickup Head	$400.00	2	2	2	2	$3,200.00
	500392	Wire Segments, Vertical Digger	$300.00	10	10	10	10	$12,000.00
	5010785	Liner, Separator	$2,228.00				1	$2,228.00
	5011671	Hose, Pressure (Heavy Duty)	$624.00				1	$624.00
	5011671	Hose, Suction (Heavy Duty)	$624.00			1		$624.00
	502116	Transition, Urethane - w/Seal	$695.00		1		1	$1,390.00
	5010265	Skid Guard - Left Hand	$52.00		1		1	$104.00
	5010266	Skid Guard - Right Hand	$52.00		1		1	$104.00
	502569	2" Wide Duo Skid® Plate Assembly	$793.00		2		2	$3,172.00
		YEARLY COST PROJECTION TOTALS		$3,800.00	$7,735.00	$9,902.00	$10,587.00	**$32,024.00**

SECTION 1 = STANDARD HIGH USAGE PARTS SECTION 2 = WEAR ITEMS

*******Verify parts prices with TYMCO Parts Department before quoting.*******

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*****COSTS FOR THE FOLLOWING LISTED ITEMS MUST ALSO BE TAKEN INTO CONSIDERATION*****

3

1. FILTERS

Auxiliary Engine	Truck (per manufacturer's suggestion)	Sweeper Hydraulic System
Oil Filter (every 100 hrs) **Air Filter** (per restriction indicator) **Fuel Filter** (as required)	**Oil Filter** **Air Filter** **Fuel Filter** **Transmission Filter**	(per restriction indicator)

2. LUBRICANTS

Sweeper	Truck (Interval twice factory recommendation)
1. Auxiliary Engine Oil **2. Hydraulic Oil** (Approximate 25 Gallons Capacity) After first 2000 hrs & every 2000 hrs thereafter **3. Grease** **4. Coolants**	**1. Grease** **2. Engine Oil** (every 100 hrs) **3. Differential Oil** **4. Transmission** **5. Coolants**

4

LABOR	**OVERHEAD**
DEPRECIATION	**MISCELLANEOUS REPAIRS**
FUEL	(Flats, Light Bulbs, etc.)

SECTION 3 = MISCELLANEOUS MAINTENANCE SECTION 4 = VARIABLE EXPENSES

NOTE: All Sweeper replacement parts are based on TYMCO list prices.

The above is a projected parts usage list for a TYMCO Model 600 covering four years under normal use. This document is intended to provide a general projection for planning purposes based on our own experience and feedback from the field over the years, but should not be interpreted as being totally accurate. The format is separated into four sections showing, first, the standard parts that are considered to possibly fail over the periods shown. Secondly, the parts that we consider to be wear items on which monies should be routinely budgeted. The third section is a statement concerning miscellaneous expenditures related to maintenance and upkeep of the sweeper. Dollar amounts shown in this section are based on current prices in our locale and will, no doubt, vary in different parts of the country. A Model 600 mounted on a FC Freightliner Cargo truck with a 5.9 Liter engine was used to collect this data. The fourth section contains variables such as local labor rates, overhead costs, etc. and it is mentioned only as a reminder of factors to be considered and no attempt has been made to establish a dollar figure on it.

In working up a cost proposal on a TYMCO Model 600, it must be taken into account that the first 1000 hours or one year, whichever comes first, is covered under warranty and non-wear parts failures are provided at no charge FOB Waco, Texas.

Proper care and operation of the machine play a large role in such projections as does the environment in which it is used. Negligent operation, cleaning and shoddy maintenance practices have the potential of increasing cost 25% or more over a year's period. In addition, the unnecessary use of the pickup head broom will further add cost. The figures in this document reflect the acerave use of the broom at approximately 20%.

The environmental aspect that comes into play primarily concerns the type of material and surface that the sweeper encounters. Constant exposure to sand, chip seal, rotomill and stripe grindings tend to accelerate wear and, of course, increase cost.

Another major consideration is the number of hours the sweeper is used in a year's time. This projection is based on 1000-1200 hours of operation per year, and cost can be expected to increase proportionally with the increased usage beyond that figure.