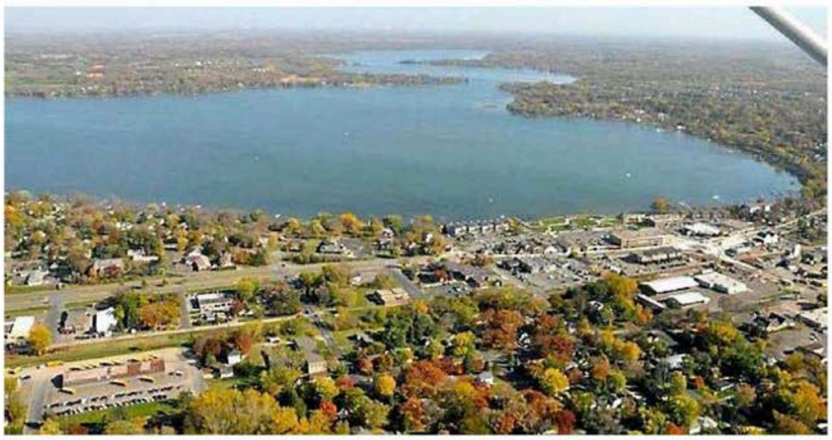
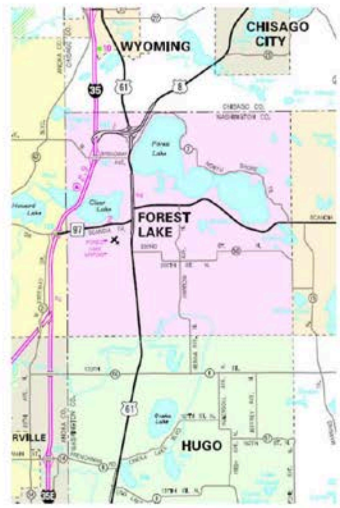
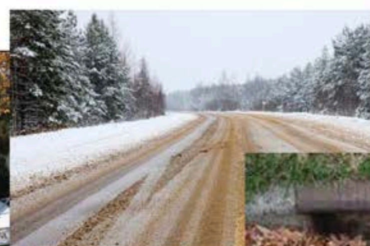
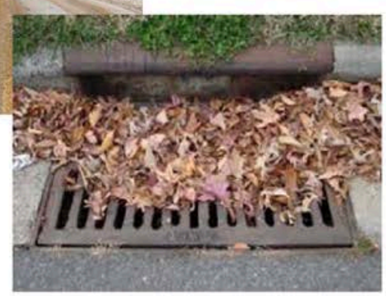
City of Forest Lake
Street Sweeping Management Plan
2018









Forest Lake
AS GOOD AS IT SOUNDS

COMFORT LAKE
- WATERSHED DISTRICT -
FOREST LAKE
Protecting Your Water Resources

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) 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 street with high efficiency sweepers (vacuum type or similar) sweeping streets 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, quantified expected phosphorus load reductions, itemized costs of enhanced street sweeping (including purchase and subcontract options), and recommended funding options for an enhanced street sweeping program in the City of Forest Lake, MN.

The City currently sweeps approximately 240 curb miles twice annually (according to the City's 2016 sweeping contract). Current sweeping practices improve road safety and appearance, recovers approximately 127 lb of phosphorus (TP) and 148,188 lb of solids (TS) from road surfaces each year, and removes approximately 51 lb of TP and 61,402 lb of TS loads each year to Clear, Comfort, Shields, Keewahtin (formerly Sylvan/Halfbreed), and Forest Lakes. Key findings from this Street Sweeping Management Plan indicate that twice monthly sweeping in the City of Forest Lake with regenerative air (or similar) technology has the potential to reduce loading to Clear, Comfort, Shields, Keewahtin, and Forest Lakes by an additional 137 lb of TP and 169,793 lb of TS compared to the reductions achieved through current contract sweeping practices.

For the purpose of this study, streets were aggregated into sweeping zones (Figure 4-6) based on connectivity to downstream water resources, storm water management type, and tree canopy cover characteristics (Table 4-2). In zones where streets drain directly to a downstream resource, the primary benefit of street sweeping is pollutant reduction to downstream resources and improved water quality. In zones where street runoff is intercepted by structural best management practices (BMPs), the primary benefit of street sweeping is increased longevity of BMP treatment efficiency.

Guidelines for sweeping based on the sweeping priorities for each zone are outlined in Section 7 of this report. It is recommended that streets located within zones identified as high priority for water quality be swept monthly to bi-weekly throughout the sweeping season. Enhanced sweeping at a frequency of 4-7 times per season is recommended for streets located in areas designated as high priority for BMP longevity. It is also recommended that the City maintain an observation log during sweeping operations and adjust sweeping frequency as needed to address conditions that may arise due to construction activity, storms, traffic patterns, or other unique considerations.

Based on the findings from the Plan, the City of Forest Lake is pursuing purchase of a regenerative air street sweeper so that an Enhanced Street Sweeping program can be adopted as part of the City's regular street maintenance program. Using an in-house sweeping program, sweeping zones that are a high priority for water quality could be swept up to 12 times per year and sweeping zones that are a high priority for BMP longevity could be swept up to 7 times per year, for about the same cost as spring and fall only sweeping contract services.

1. INTRODUCTION

Street sweeping is the practice of removing particulates (salt, sand, and soil) and organic matter (leaves, seeds, flowers) 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 vacuum sweeping streets at higher frequency, based on the variable generation of particulates and organic matter to streets.

Enhanced street sweeping has been identified as the most cost-effective best management practice (BMP) for treating stormwater runoff from the direct drainage area of several large recreational lakes in the City of Forest Lake: Forest Lake in the Comfort Lake-Forest Lake Watershed District (CLFLWD) and Clear Lake in the Rice Creek Watershed District (RCWD). The CLFLWD and the City have discussed the benefits of modifying their existing street sweeping program from one spring regenerative air and one fall mechanical sweep to more than two sweeps per year with a regenerative air vacuum sweeper. But implementation of an enhanced street sweeping program has been hindered by the lack of a prescriptive plan for the optimal timing and frequency of additional sweeps or the amount of additional staff needed by the City.

The objectives of this plan are to identify road-specific street sweeping timing and frequency, quantify expected phosphorus load reductions to area lakes, and itemize costs of enhanced street sweeping (including purchase and subcontract options) to support the adoption of an enhanced street sweeping program by the City of Forest Lake as part of their regular street maintenance program. The ultimate goal of this project is develop a formal agreement between the RCWD, the CLFLWD, and the City of Forest Lake to implement enhanced street sweeping for at least 10 years.

2. BENEFITS

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, such as street sweeping, are the primary tool available to protect downstream water quality. Stormwater systems in newer neighborhoods tend to include structural BMPs such as detention ponds and infiltration basins. While these BMPs provide water quality treatment for stormwater runoff from streets, accumulated sediments must be removed periodically to maintain BMP pollutant removal efficiency. Street sweeping is a good housekeeping measure that can extend the maintenance life cycle of stormwater BMPs in these areas by reducing pollutant loads.

Most cities do some amount of street sweeping each year to improve road safety and appearance, but street sweeping also offers a cost-effective and efficient means to reduce pollutant loads to storm sewer infrastructure and to downstream water resources (Beretta et. al (2011), SPU (2009), Kalinosky et. al (2013), others). 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.

2.1. Compliance with Non-degradation Policies

The City of Forest Lake lies within the jurisdiction of two watershed districts: the Comfort Lake Forest Lake Watershed District (CLFLWD) and the Rice Creek Watershed District (RCWD). Stormwater management rules for both of these watersheds include non-degradation policies that apply to both water quality and volume control. Enhanced street sweeping may provide assurance for non-degradation of water quality by reducing pollutant loads, and may address non-degradation of stormwater volume by reducing loss of storage volume through decreased sediment loading to stormwater ponds.

2.2. Protection of Water Resources

Shields Lake, Forest Lake, Comfort Lake, Keewahtin Lake, Sunrise River in the CLFLWD, and Clear Lake in the RCWD, all receive surface water from City of Forest Lake streets. Some streets discharge their untreated runoff directly into receiving waters, while others enter the City's stormwater management systems prior to discharge. All the lakes except Keewahtin Lake have comprehensive diagnostics studies that identify total phosphorus (TP) and total solids (TS) as pollutants of concerns and define reductions needed to ensure that beneficial uses are maintained.

The 2010 Comfort Lake-Forest Lake Watershed District Six Lakes Total Maximum Daily Load (TMDL) Study identified a TP reduction goal of 952 lb/yr, or 83%, to Shields Lake and a TP reduction goal of 123 lb/yr, or 5%, to Comfort Lake. The Clear Lake Diagnostic Study identified a TP reduction goal of 140 lb/yr, or 13%, to Clear Lake. The DRAFT Forest Lake Diagnostic Study identified a TP reduction goal of 96 lb/yr, or 26%, in the direct drainage area to Forest Lake. Street sweeping was identified as a cost-effective BMP in all of these lake studies.

2.3. Good Housekeeping and Maintenance

Street sweeping is a good housekeeping practice that can extend the maintenance life cycle of structural BMPs and road surfaces and consequently reduce the cost of maintenance over time. 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 pollutant removal capacity. By reducing pollutant loading to structural BMPs, street sweeping can preserve the sediment storage capacity and pollutant removal efficiency of structural BMPs.

Sweeping can also be part of 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 can also become areas where vegetation establishes, making pavement more susceptible to cracking and freeze/thaw damage.

2.4. Safety and Aesthetics

Historically, safety and aesthetics are the primary reasons that municipalities sweep streets. Accumulated sand and trash detract from curb appeal, may contribute to clogging and flooding at storm inlets, and may pose a safety risks to bicycles and pedestrians.

3. CURRENT PRACTICES AND POLICIES

The City of Forest Lake currently sweeps all paved roads twice per year: once in the spring using a mechanical broom sweeper and again in the fall using a vacuum sweeper. Sweeping is done using a contract sweeping service. The City also owns an older (>10 years) mechanical broom sweeper. This sweeper is used as needed in conjunction with City maintenance and construction work.

The City of Forest Lake 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. In the City's current SWPPP (August 1, 2013), street sweeping is included as a BMP that will be used to address approved TMDL studies with approved Waste Load Allocations (WLA); and as a pollution prevention/good housekeeping BMP. The SWPPP states that the City will modify and implement a Street Sweeping Plan (Part II.D.6.f); will measure/track the total length of street swept both per sweep and annually; and will implement revised programs when necessary (Part II.D.5).

4. SWEEPING ZONES

Street surfaces are connected to surface waters via storm water 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 over-street tree canopy.

4.1. 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 over-street canopy than newer neighborhoods or those with typical suburban street layout patterns. Areas with denser tree canopy can act as pollutant 'hot spots' due to the large amount of accumulation of organic litter on street surfaces.

Over street tree canopy cover was quantified for all paved roads included in the 2016 contract for sweeping services using high-resolution land cover data (1-meter) developed by the University of Minnesota. Average over-street tree canopy covers for each sweeping zone were estimated by intersecting deciduous canopy cover data with road surface polygons created from curb line data (Figure 4-1 and Table 4-1). Over street tree canopy cover tends to be less dense in commercial/industrial and recently developed areas (e.g. SR/C3 in Table 4-1 and Figure 4-3); and densest in older residential neighborhoods (e.g. FL1 in Table 4-1 and Figure 4-5). Examples of average tree canopy cover are shown in Figure 4-3 through Figure 4-5.

4.2. Curb-Miles

The length of street to be swept within each sweeping zone was estimated from road centerline data (Figure 4-2 and Table 4-1). The total 'curb-miles' to be swept in each zone is equal to the total length of paved road (centerline) in the zone multiplied by two (representing the curb on both sides of the street). Curb-miles include rural cross section roads but not gravel roads. Additional road lanes that might be swept were not included in load recovery estimates, but should be swept as possible along with curb/outer lanes.

4.3. 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 4-2) and zones are illustrated in Figure 4-6 and Figure 4-7. Maps of individual sweeping zones are included in Appendix A.

Table 4-1. Summary of curb-mile and tree canopy characteristics by defined sweeping zone

Subwatershed	Zone ID	Curb-miles			Average Over-street Canopy Cover
		Curb & Gutter	Rural Paved	Zone Total	
Clear Lake	CL1	1.4	12.1	13.5	8%
	CL2	9.1	0.1	9.2	6%
	CL3	45.1	2.3	47.4	1%
Forest Lake	FL1	13.0	4.3	17.3	17%
	FL2	9.5	3.5	12.9	6%
	FL3	8.0	10.7	18.7	8%
	FL4	4.5	22.7	27.2	11%
	FL5	0.0	11.0	11.0	7%
	FL6	2.0	26.8	28.8	6%
Keewahtin Lake	Keewahtin	0.0	5.4	5.4	7%
Shields Lake	Shields	0.2	5.3	5.4	7%
Sunrise/ Comfort	SR/C1	19.2	1.1	20.3	7%
	SR/C2	7.5	1.1	8.6	2%
	SR/C3	9.5	3.4	12.9	1%
	TOTAL	**128.9**	**109.9**	**238.8**	**7%**

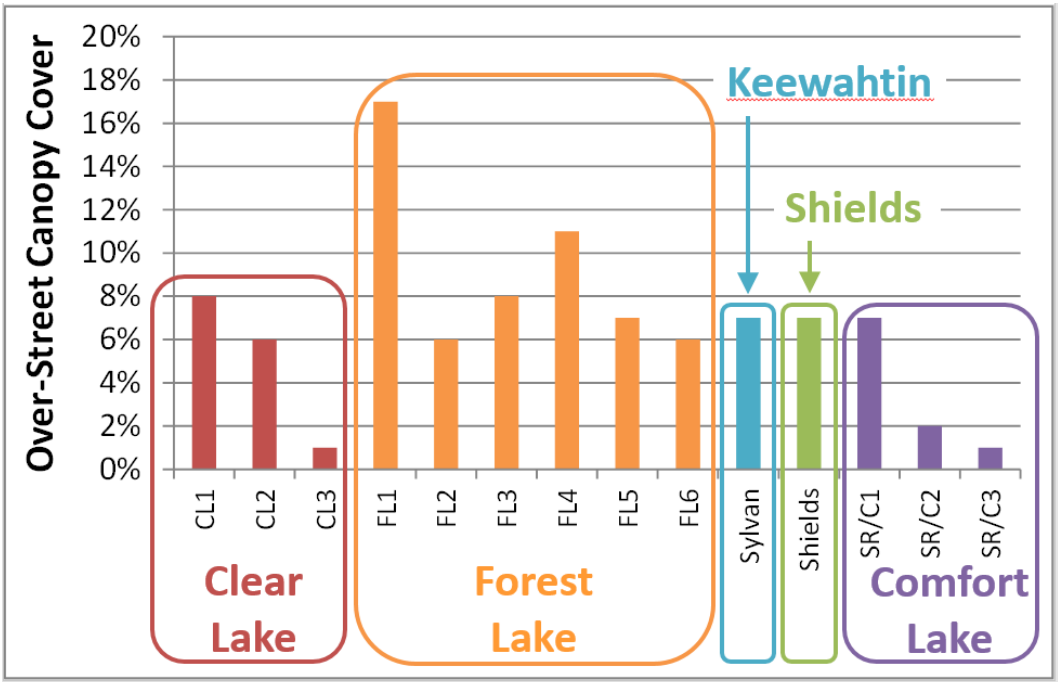

Figure 4-1. Over-street tree canopy cover by sweeping zone

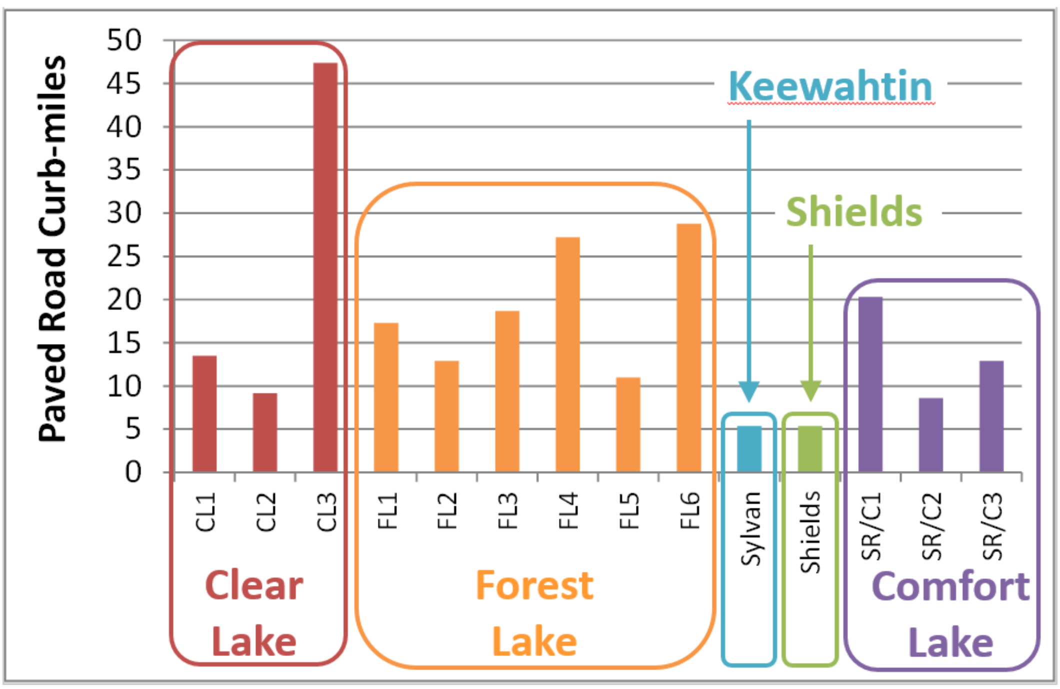

Figure 4-2. Paved road curb-miles by sweeping zone

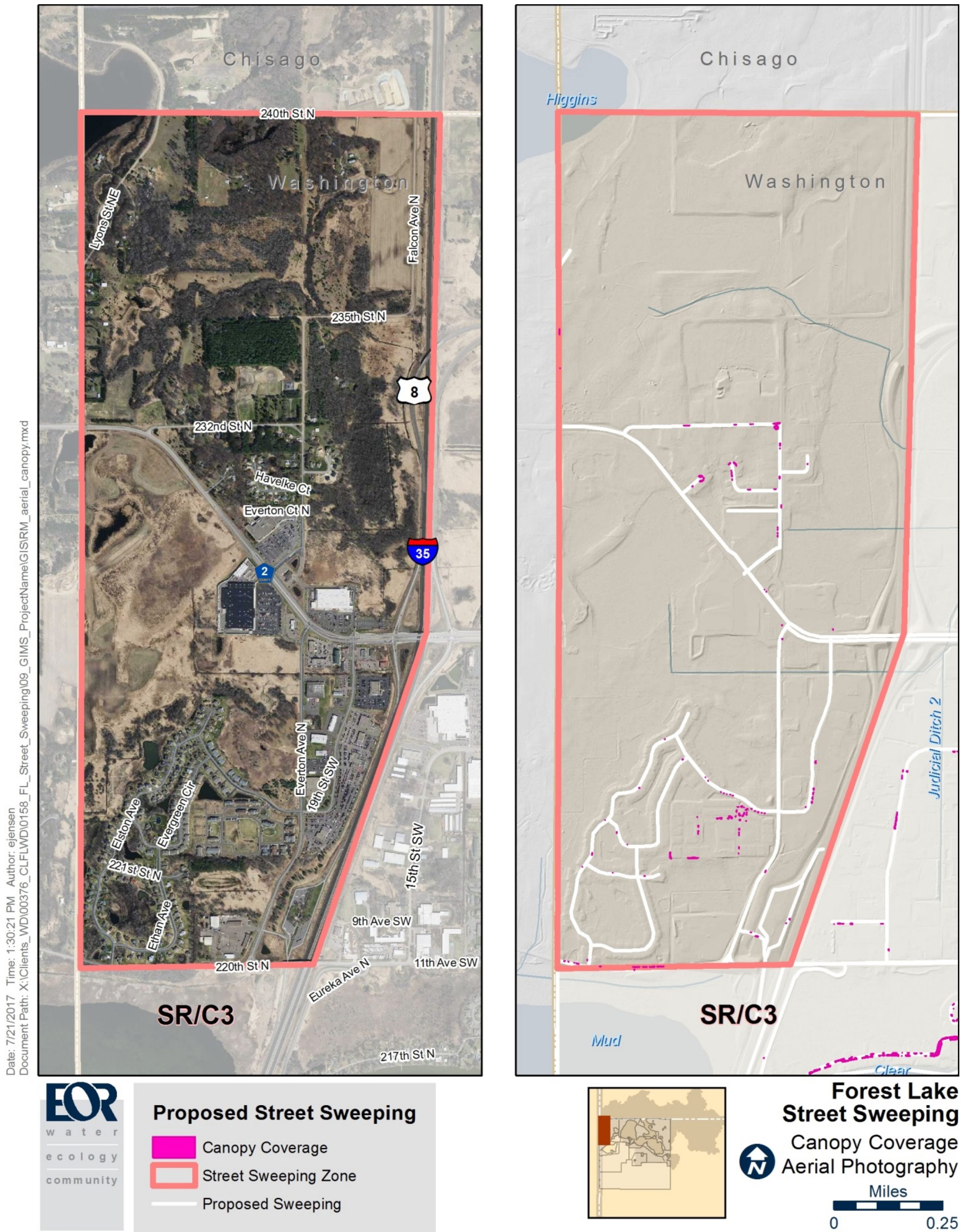

Figure 4-3. Arial photograph and tree canopy cover map for Sunrise River/Comfort Lake-3 (SR/C3), a low canopy sweeping zone with approximately 1% average over-street tree canopy cover.

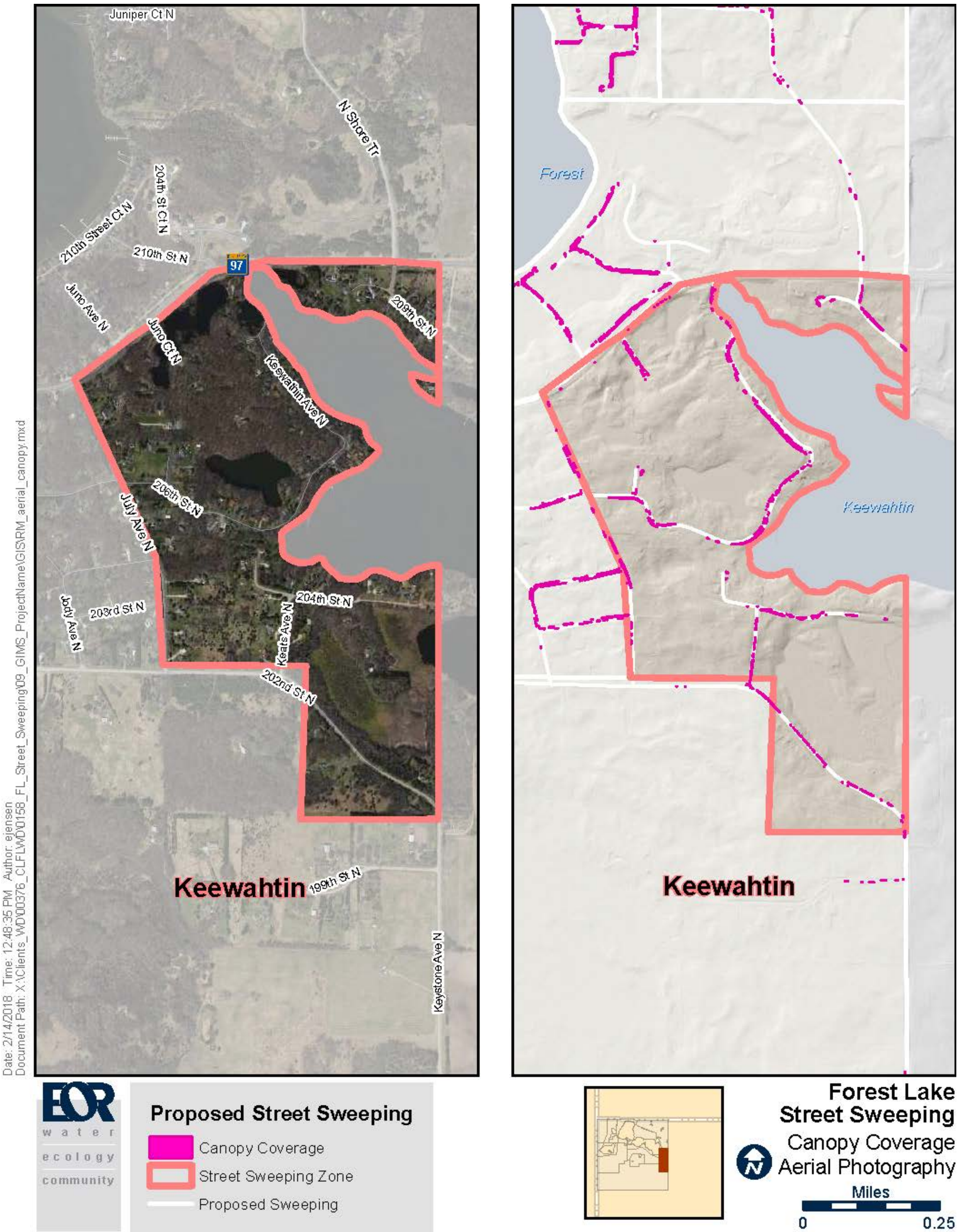

Figure 4-4. Arial photograph and tree canopy cover map for Keewahtin Lake, a moderate canopy sweeping zone with approximately 7% average over-street tree canopy cover.

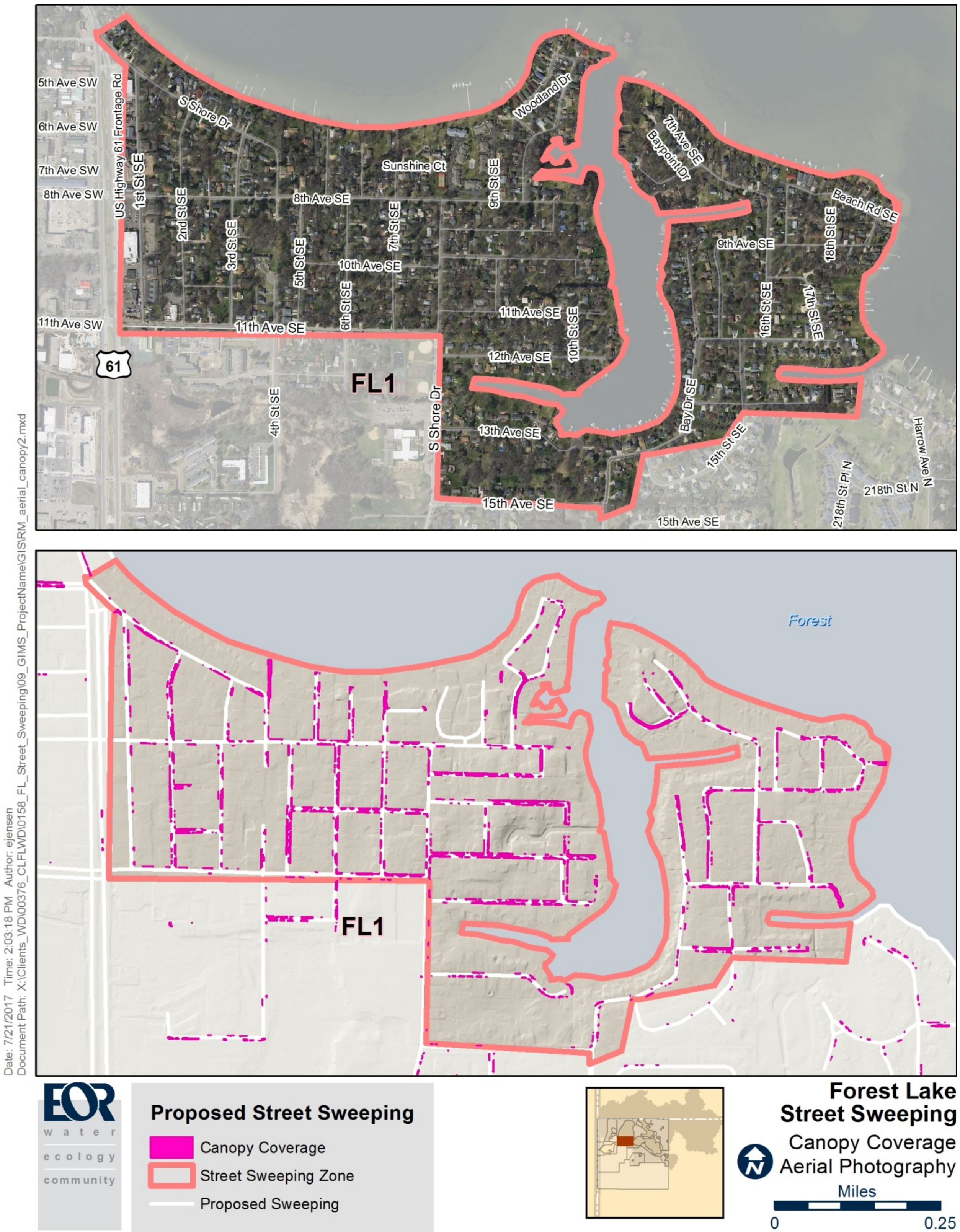

Figure 4-5. Arial photograph and tree canopy cover map for Forest Lake-1, a high canopy sweeping zone with approximately 17% average over-street tree canopy cover.

Table 4-2. Summary of defining characteristics for street sweeping zones in the City of Forest Lake.

Downstream Resource	Zone ID	Description				
		Connectivity[1]	Stormwater Managment[2]	Primary Street Type	Over-street Tree Canopy[3]	Primary Land Use[4]
Clear Lake	CL1	Direct Drainage Area	Rural, Rate & Volume BMPs	Rural	Mature, moderate	Residential
	CL2	Upstream Drainage Area	Pipes, Rate & Volume BMPs	Curb & gutter	Mature, little - moderate	Mixed, Residential
	CL3		Rate & Volume BMPs		Immature, minimal-moderate	Mixed, Residential, Industrial
Forest Lake	FL1	Direct Drainage Area	Pipes		Mature, dense	Residential
	FL2				Mature, little-dense	Commercial and Residential
	FL3		Rural, Rate & Volume BMPs	Rural, Curb & gutter	Mixed, moderate	Residential
	FL4			Rural	Mature, dense	
	FL5	Upstream Drainage Area			Mature, moderate	
	FL6					
Keewahtin Lake	Keewahtin	Direct Drainage Area				
Shields Lake	Shields					
Sunrise River/ Comfort Lake	SR/C1	Upstream Drainage Area	Pipes	Curb & gutter		
	SR/C2		Rate & Volume BMPs		Immature, no-little	Business, Industrial
	SR/C3					Business, Residential

[1]Zones designated as 'Direct' drainage areas are located within the direct drainage area of the receiving water body based on surface drainage characteristics. 'Upstream' drainage areas generally drain to surface waterbodies/conveyances located upstream of the designated receiving water. [2] Rural = conveyance via overland flow and ditch systems, 'Rate & Volume BMPs' = includes structural BMPs identified through City of Forest Lake Water Resources Inventory Map. [3]Tree canopy cover over and within 2 feet of the curb or shoulder line. [4] City of Forest Lake Zoning Maps

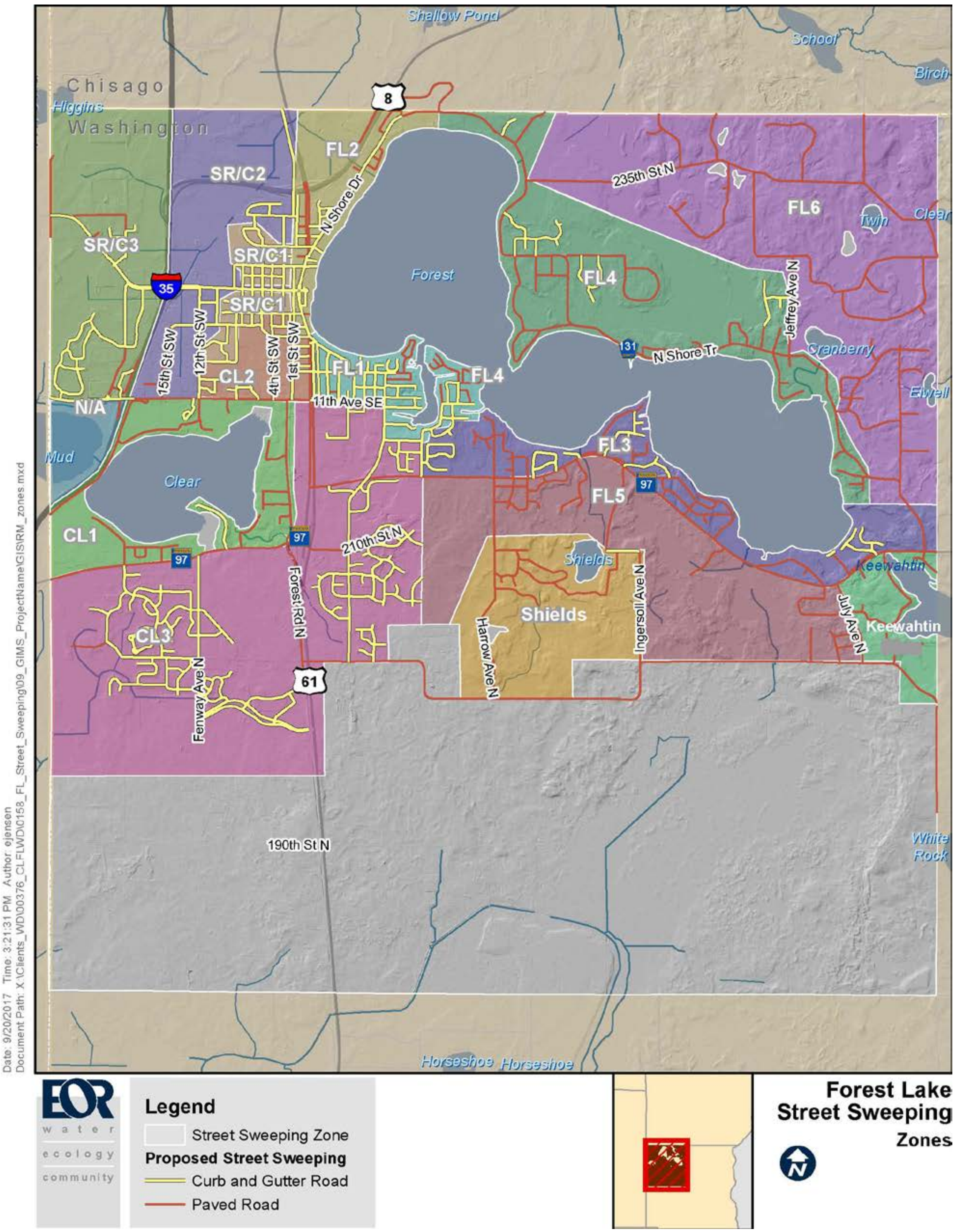

Figure 4-6. City of Forest Lake sweeping zones. Maps of individual zones are included in Appendix A.

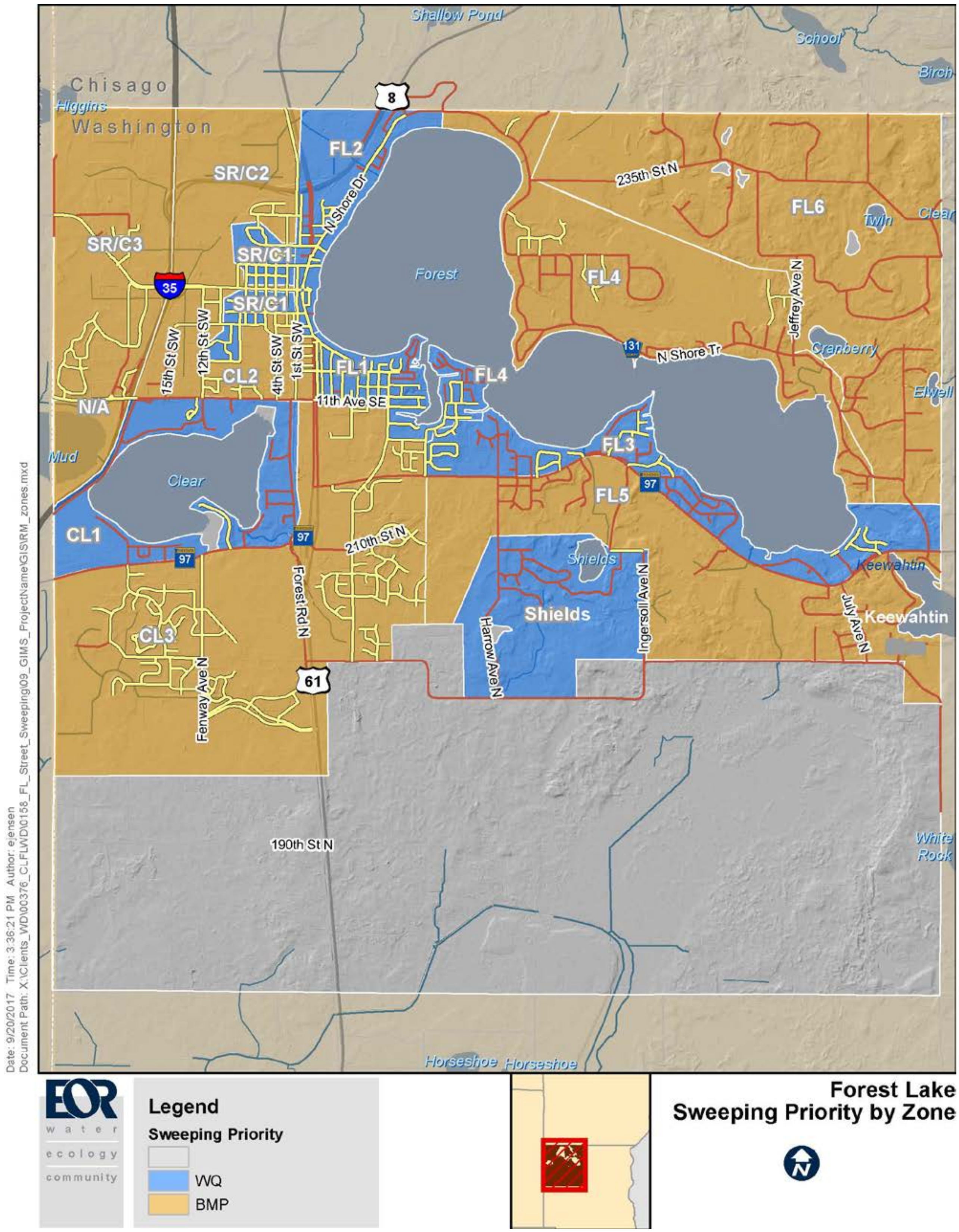

Figure 4-7. City of Forest Lake sweeping priorities by sweeping zone.

5. LOAD RECOVERY AND LOAD REDUCTION ESTIMATES

The amount of pollutant reduction 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 effects from downstream BMPs that also reduce pollutant loads. For the purposes of this plan, load recovery and load reduction estimates were calculated for solids and phosphorus, the pollutants of concern for street maintenance and lake water quality, respectively.

5.1. Load Recovery

Average pollutant recovery was estimated 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 amount 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, which may affect solids loading to streets, typically vary somewhat from year to year.

Pollutant load recovery was estimated for two sweeping technologies: mechanical broom, and regenerative air sweepers. The calculator tool used to estimate pollutant load recovery was developed using load recovery observations for regenerative air sweeping technology. To estimate load recovery for sweeping with a mechanical broom sweeper, load recovery estimates from the street sweeping calculator were reduced by 20% for baseline sweepings (first spring and fall sweepings), and by 30% for subsequent sweepings to reflect the lower pick–up efficiency of mechanical broom sweepers compared to regenerative air and vacuum type sweepers. The rationale for this discount is described in Appendix B.

Load recovery estimates are based on street sweeping during the snow-free season (assumed to be April 1 – October 31). Recovery of solids and nutrients was estimated for five sweeping scenarios (Table 5-1). Estimated solids and phosphorus recovery for each sweeping scenario are summarized for receiving waterbodies in Table 5-2 and for individual sweeping zones in Table 11-1 through Table 11-5. For the purpose of summarizing potential load recovery, sweeping scenarios are simplistic, with all streets being swept at the same frequency. Zone-specific sweeping frequency recommendations are included in Section 7.

Current sweeping practices are expected to remove approximately 26 to 32 lb-TP/yr in the Clear Lake sweeping zone, 56 to 70 lb-TP/yr in the Forest Lake sweeping zone, 2 to 3 lb-TP/yr each in the Shields Lake and Keewahtin Lake sweeping zones, and 16 to 20 lb-TP/yr in the Sunrise River/Comfort Lake sweeping zones (Table 5-2). In general, although the amount of material recovered *per sweep* is expected to decrease as sweeping frequency increases, the increase in the total amount of material recovered through additional sweepings may be significant (Figure 5-1). Compared to baseline, recovery of phosphorus could be increased by approximately 62% if an additional sweeping is added in the spring and fall, 125% if street are swept monthly, 250% if street are swept twice per month, and 350% if streets are swept weekly (Figure 5-2).

Table 5-1. Street sweeping scenarios used in load recovery and load reduction estimates.

Sweeping Scenario[1]	Number of Sweeps per Year	Description
Baseline	2	Once 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

[1]All scenarios are based on sweeping during the snow free season – assumed to be April 1 –October 31

Table 5-2. Summary of estimated annual total solids and phosphorus recovery for the street sweeping scenarios described in Table 5-1 by receiving waterbody.

	Clear Lake		Forest Lake		Shields Lake		Keewahtin Lake		Sunrise River/ Comfort Lake	
Sweeping Scenario	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**
Baseline[1]	34,300	29	71,685	63	3,045	3	3,045	3	21,300	18
Enhanced Baseline	61,600	50	129,230	109	5,570	5	5,570	5	38,250	31
Monthly	95,460	72	199,500	157	8,470	7	8,470	7	59,280	45
Bi-weekly	151,960	113	312,400	240	13,500	10	13,500	10	94,360	71
Weekly	192,530	141	402,350	309	17,090	13	17,090	13	119,550	89

[1]Based on 2016 contract service practices (mechanical broom sweeper used for spring sweeping, regenerative air sweeper used for in the fall sweeping). Estimates for all other scenarios are based on sweeping with a vacuum type sweeper.

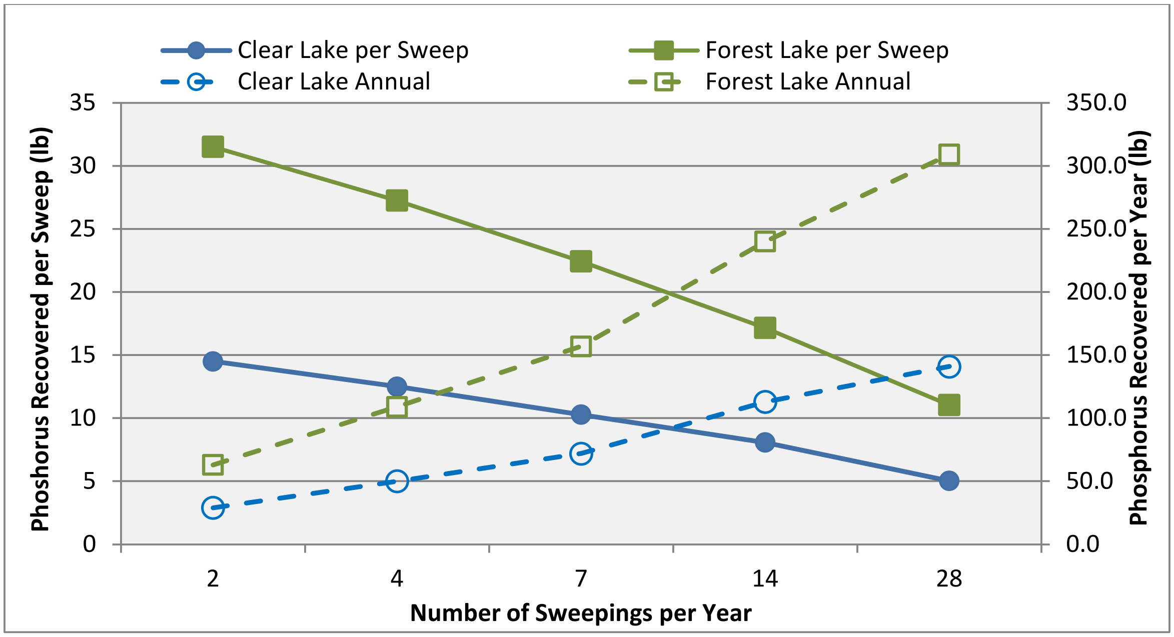

Figure 5-1. Predicted phosphorus recovery per sweep and per year vs. number of sweepings for Clear Lake and Forest Lake Sweeping zones.

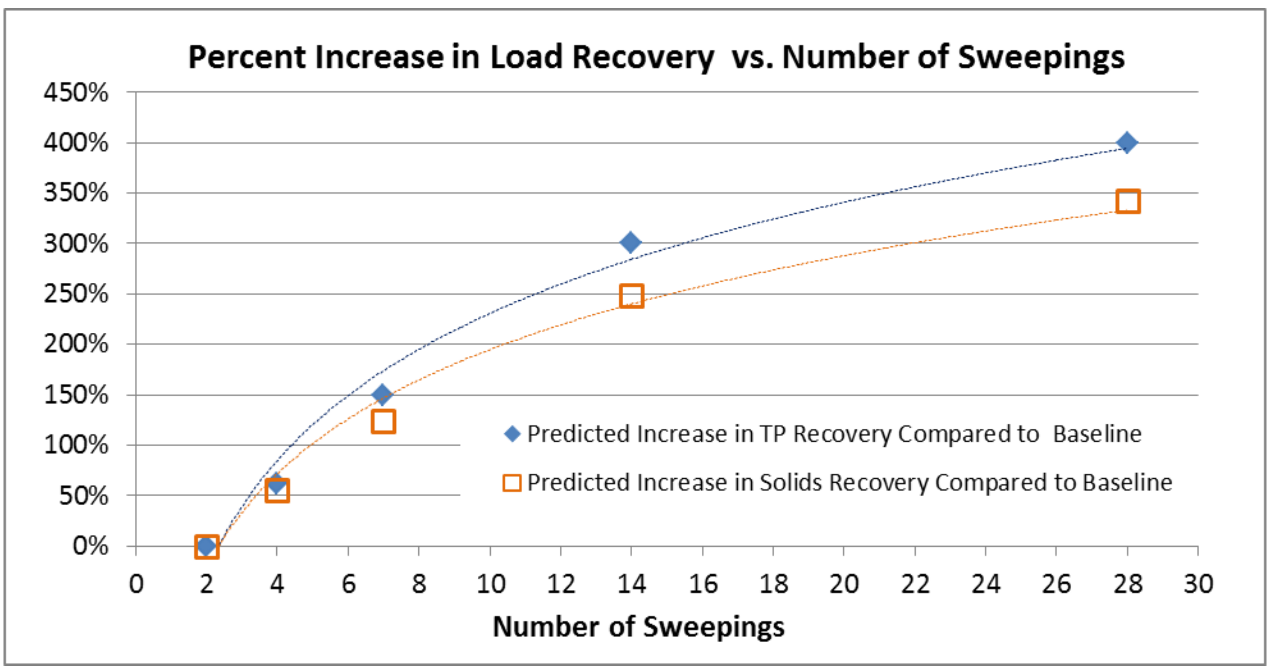

Figure 5-2. Predicted percent increase in load recovery of phosphorus and solids vs. number of sweepings.

5.2. Load Reductions

Load reductions to downstream water resources are not equal to recovered loads because downstream structural BMPs can also remove pollutants before street runoff discharges to surface waters. To estimate pollutant reductions to downstream water resources, it was necessary to take into account the pollutant removal of BMPs located along the flow path between streets and downstream receiving waterbodies.

For the purpose of this study, detailed water quality modeling at the city scale was not practical. A simple spreadsheet model was developed to estimate the overall pollutant removal capacity of existing BMPs based on the number and type of existing BMPs within each sweeping zone. Water quality BMP types identified within street sweeping zones and their typical pollutant removal efficiencies are listed in Table 5-3. The overall removal efficiency of BMPs within each zone was computed as a weighted average based on the approximate curb-miles of street intercepted by each BMP. The length of curb-miles intercepted, and the number and location of BMPs, were estimated from the City of Forest Lake surface drainage and storm sewer data (GIS) and Water Resource Inventory Map (May 2015).

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

- Over time, all solids on the street surface will be transferred 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.

Estimated total solids and total phosphorus reductions to downstream waterbodies are summarized in Table 5-2 and by individual sweeping zone in Table 11-1 through Table 11-5.

Current sweeping practices are expected to reduce total phosphorus loading by approximately 6 to 7 lb/yr to Clear Lake, 33 to 41 lb/yr to Forest Lake, 1 lb/yr to Shields Lake and Keewahtin Lake, and 6 to 7 lb/yr to the Sunrise River/Comfort Lake (Table 5-5). Compared to baseline, phosphorus reductions could be increased by approximately 62% if an additional sweep is added in the spring and fall, 125% if streets are swept monthly, 250% if streets are swept twice per month, and 350% if streets are swept weekly (Table 5-2).

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 ≈ 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 5-3. Typical BMP removal efficiencies (Minnesota Stormwater Manual) used to estimate the collective pollutant removal efficiency of BMPs within each sweeping zone.

	No BMPs	Detention Pond	Multiple Ponds	Dry Swale	Wetlands	Infiltration Practices (volume infiltrated)
TP	0%	50%	75%	50%	40%	100%
TSS	0%	85%	95%	85%	73%	100%

TP = total phosphorus; TSS = total suspended solids

Table 5-4. Estimated collective pollutant removal by existing stormwater BMPs within each sweeping zone based on the number and type of BMPs and estimated length of street treated by BMPs.

Receiving Waterbody	Sweeping Zone	Estimated Pollutant Removal Efficiency	
		TS	TP
Clear Lake	CL1	86%	54%
	CL2	93%	75%
	CL3	98%	88%
Forest Lake	FL1	0%	0%
	FL2	27%	18%
	FL3	22%	18%
	FL4	89%	64%
	FL5	95%	72%
	FL6	96%	71%
Shields Lake	Shields	93%	75%
Keewahtin Lake	Keewahtin	93%	64%
Sunrise River/ Comfort Lake	SR/C1	85%	50%
	SR/C2	92%	75%
	SR/C3	98%	88%

Table 5-5. Estimated annual total solids and phosphorus reductions to downstream waterbodies for street sweeping scenarios described in Table 5-1.

	Clear Lake		Forest Lake		Shields Lake		Keewahtin Lake		Sunrise River/ Comfort Lake	
Sweeping Scenario	TS	TP	TS	TP	TS	TP	TS	TP	TS	TP
Baseline[1]	1,989	6.4	53,830	37.0	465	0.7	601	0.9	4,517	6.4
Enhanced Baseline	3,570	11	74,804	64	1,370	1.1	1,943	1.6	13,390	11
Monthly	5,540	16	115,290	91	2,120	1.6	3,010	2.3	20,760	16
Bi-weekly	8,810	25	178,350	137	3,370	3.0	4,790	4.0	33,040	25
Weekly	11,160	31	232,520	180	4,270	3.0	6,070	5.0	41,860	31

[1]Low end based on sweeping with mechanical broom, high end based on sweeping with vacuum type sweeper. Estimates for all other scenarios are based on sweeping with a vacuum type sweeper.

6. COST-BENEFIT ANALYSIS

Total annual program costs and cost-benefit ($/lb-P removed) were estimated for baseline, enhanced baseline, monthly, and bi-weekly sweeping scenarios. For contract sweeping, the cost-basis ($/curb-mile) is assumed to be constant for all sweeping scenarios. The cost per curb-mile was calculated using the total cost of spring sweeping services divided by the total curb-miles swept. The total cost of sweeping services was taken from the City of Forest Lake 2016 street sweeping service contract. For a City-owned vehicle, the cost-basis ($/curb-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 2017 component costs and assumptions listed in Table 6-1.

Table 6-1. 2017 street sweeping annual cost assumptions for the City of Forest Lake

Category	Annual Cost Assumption
Vehicle Depreciation [1]	$27,032/yr
Vehicle refurbishment	$5,000 every 3 years
Vehicle Maintenance	$2,000-$3,000/yr
Labor (wages + benefits)	$45/hr
Diesel Fuel	$3/gal
Disposal Cost	$1/yd^3 of material

[1] Based on data collected from City of Edina Public Works Department for purchase of a 2014 Elgin Crosswind regenerative air sweeper. An annual inflation rate of 2% was assumed in estimating the sweeper purchase price. Assumes a vehicle purchase price of $250,000, and an anticipated salvage value = $35,000.

Additional cost assumptions used in the City owned-vehicle cost-benefit calculations include:

- Sweepers are owned by the City of Forest Lake
- Typical sweeper operational speed = 4.5 mph
- An additional 1 hour of labor is required for every 2 hours of sweeping time
- Total transit miles (brush off) are about 3 times the total swept miles
- On average, sweeper fuel consumption is 5 mpg
  = [(brush off time, empty) + (brush on time) + (brush off time, full capacity)]/ [distance traveled]]
- The average dry bulk density of sweeper waste is approximately 2,025 lb/yd^3 and has a moisture content of approximately 25% when collected (Kalinosky et al., 2014)
- The City has sufficient staffing to operate the sweepers as needed
- One city-wide sweep includes approximately 239 curb-miles of sweeping (approximately twice the length of the roadway).
- Approximately 10 work days are needed to complete a single city-wide sweep (includes both sweeper operation time and required additional labor)
- For city-wide weekly sweeping, a second sweeper is needed to complete all sweeping in the scenario. The costs for this scenario are based on the purchase, maintenance, and operation

of two street sweepers. Although a second sweeper was included in this hypothetical scenario, zone-specific sweeping recommendation for sweeping (Section 7) were developed based on the purchase and operation of only one sweeper.

Based on these assumptions, the cost-benefit for baseline sweeping is $139 per curb-mile for a contract sweeper, and $78 per curb-mile for a City-owned sweeper (Table 6-2). For baseline sweeping (spring/fall only) with a City-owned sweeper, the total cost of sweeping is driven by capital outlay for the vehicle (vehicle depreciation). Because this component of the cost is essentially flat, the cost-benefit ($/curb-mile) of in-house sweeping decreases (improves) as the vehicle is utilized for additional sweepings (Figure 6-1). In contrast, the cost-benefit of contract sweeping is constant ($139/curb-mile), making additional sweepings no more cost effective than baseline sweeping.

Sweeping is most cost-effective when solids loading to streets is greatest. Since solids loading varies over the course of the year, adding sweepings at certain times of the year (summer) is less cost-effective than adding sweepings at peak loading times (spring and fall). Although sweeping operations can be further optimized to take advantage of these differences, the cost estimates presented in Section 5 are based on regular sweeping at the frequency specified for each scenario.

Reducing pollutant discharge to the City's stormwater management infrastructure will also extend the treatment capacity of those BMPs, and reduce maintenance costs. While difficult to quantify, these additional pollutant reductions and decreased costs add to the cost-effectiveness of street sweeping as a water quality BMP. Items not included in the cost calculation, but which may add cost for the City to implement an enhanced street sweeping program, include:

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

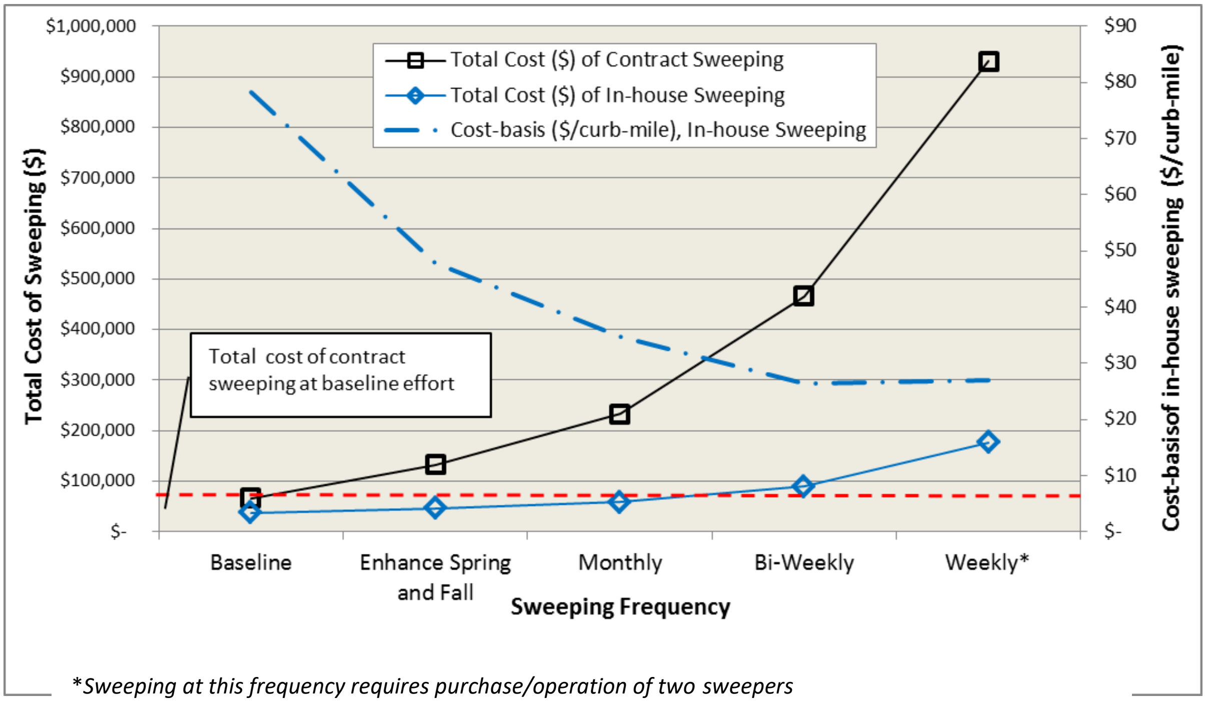

Figure 6-1. Total cost of sweeping and cost-benefit of sweeping (in-house sweeping only) vs. sweeping frequency for contract service and in-house street sweeping.

Table 6-2. Baseline scenario (spring/fall only sweeping) total annual cost ($) and annual cost-benefit ($/lb-P reduced) of street sweeping by sweeping zone.

Sweeper Type	HUC 12 Watershed	Total Annual Average Cost ($)	10-year Cost-Benefit	
			Phosphorus Recovery from Streets ($/lb-P)	Phosphorus Reduction to Receiving Waterbody ($/lb-P)
Contract Sweeper	Clear Lake	$19,544	$613	$2,758
	Forest Lake	$32,293	$461	$791
	Shields Lake	$1,504	$518	$2,074
	Keewahtin Lake	$1,512	$522	$1,467
	Sunrise River/Comfort Lake	$11,648	$582	$1,643
	TOTAL	**$66,500**	**$521**	**$1,172**
City-Owned Sweeper	Clear Lake	$11,049	$346	$1,559
	Forest Lake	$18,290	$261	$448
	Shields Lake	$851	$293	$1,174
	Keewahtin Lake	$856	$295	$830
	Sunrise River/Comfort Lake	$6,587	$329	$929
	TOTAL	**$37,633**	**$295**	**$663**

7. RECOMMENDATIONS

The City of Forest Lake can reduce the cost of, and increase the pollutant recovery achieved during spring and fall, street sweeping through purchase of a high efficiency street sweeper. Based on an amortization period of 10-years (vehicle purchase), the cost of spring and fall sweeping can be reduced by approximately 45% using an in-house program compared to a contract sweeping service (Section 6). Use of a high efficiency sweeper is also expected to increase pollutant recovery by approximately 20% for fall sweeping compared to contract service sweeping which uses a mechanical broom sweeper for fall sweepings (2016 contract service).

Guidelines for sweeping by zone are shown in Table 7-1 for three levels of effort:

1) Base Priority number of sweepings based on the sweeping priorities for each zone
    a. Water quality benefit zones: 7 times per year
    b. Maintenance benefit zones: 4 times per year
2) Recommended number of sweepings based on the sweeping priorities for each zone
    a. Water quality benefit zones: 12 times per year
    b. Maintenance benefit zones: 7 times per year
3) Maximum number of sweepings based on sweeping full time (including expected maintenance activities) using one sweeper every 4 of 5 week days during the sweeping season.

Each sweeping zone was assigned a street sweeping priority based on the zone characteristics (Table 4-2 and Figure 4-7). Zones comprised primarily of streets that drain directly to a downstream resource, the primary benefit of street sweeping is improving lake water quality. In areas where street runoff is intercepted by structural BMPs, the primary benefit of street sweeping is preservation of BMP efficiency.

Total costs for each of the scenarios are outlined in Table 7-1. Detailed load recovery, load reduction, and cost estimates are summarized by sweeping zone in Table 11-6 through Table 11-8 (see Appendix C). Using an in-house sweeping program without grant funding for purchase of a regenerative air sweeper: sweeping zones swept primarily for water quality benefit could be swept up to 12 times per year and sweeping zones swept primarily for maintenance benefit could be swept up to 7 times per year, for about the same total annual cost as the City's existing spring/fall only contract sweeping total annual cost (Recommended number of sweepings scenario in Table 7-1 and Table 11-1).

In August of 2017, the City of Forest Lake submitted a BWSR FY18 Clean Water Fund Projects & Practices grant application to purchase a regenerative air sweeper. In December 2017, the full proposal amount was approved, contributing $220,000 in grant funding towards the purchase of a regenerative air sweeper. With this grant funding and using an in-house sweeping program: the Maximum Number of Sweepings scenario in Table 7-1 can be achieved for a total annual cost similar to the City's existing spring/fall only contract sweeping total annual cost.

<u>Specific recommendations for an enhanced street sweeping program in the City of Forest Lake</u>:

1. Purchase a regenerative air, or similar high efficiency sweeper, and develop an in-house sweeping program for regular street sweeping.
    - To maximize the water quality and maintenance reduction benefits, use a high efficiency sweeper for all regular sweepings.
    - Consider using the mechanical broom style sweeper owned by the City for targeted, tandem sweeping in areas susceptible to sediment and debris, or during times of high sediment and debris loading. Tandem sweeping consists of sweeping first with a mechanical broom sweeper followed shortly thereafter by a high efficiency sweeper to maximize the pick-up of both large and small debris and sediment.
    - Consider grant or cost-sharing opportunities (Watershed Districts or other partners) to assist with the purchase of a new street sweeper or sweeping program.
2. Increase sweeping frequency in sweeping zones that are high priority for water quality (CL1, FL1, FL2, FL3, Shields, and SR/C1) to 12 times per snow-free season.
    - Sweeping zones that are high priority for water quality are comprised mainly of streets that drain directly to a downstream resource. In these areas, street sweeping is one of the few BMPs that can be readily implemented.
    - For waterbodies with approved TMDLs (Shields Lake, Comfort Lake), total phosphorus reduction achieved through street sweeping can estimated and tracked by interpolation using the load reduction estimates outline Table 5-5 - Table 11-5.
3. Increase sweeping frequency in sweeping zones that are high priority for BMP preservation and maintenance reduction (CL2, CL3, FL4, FL5, FL6, Keewahtin, SR/C2, and SR/C3) to 7 times per snow-free season
    - Regional street sweeping studies indicate that sediment loading on street surfaces remains relatively intense throughout the spring season (Kalinosky, 2015). Additional sweepings in the spring may help to maximize recovery winter residuals and sediment deposited during spring runoff events.
    - Additional sweepings in late spring and in the fall may also help to maximize recovery of organic litter/nutrients in areas with mature canopy cover (Kalinosky, 2015).
4. Considering using an observation log to track areas of high loading. Modify street sweeping frequency to address observations.
5. Sweep as needed to address other concerns such as:
    - Keeping storm inlets free of debris
    - Sweeping regularly in areas of active construction
    - Sweeping regularly for debris removal/aesthetics in high profile areas of the City

Table 7-1. Cost-benefit of recommended street sweeping scenarios based on sweeping zone characteristics

Waterbody	Sweeping Zone	Sweeping Priority[1]	Curb-miles	Number of Sweepings		
				Base Priority	Enhanced (Recommended)	Maximum
Clear Lake	CL1	WQ	13.5	7	**12**	28
	CL2	P/M	9.2	4	**7**	7
	CL3	P/M	47.4	4	**7**	7
Forest Lake	FL1	WQ	17.3	7	**12**	28
	FL2	WQ	12.9	7	**12**	28
	FL3	WQ	18.7	7	**12**	14
	FL4	P/M	27.2	4	**7**	7
	FL5	P/M	11.0	4	**7**	7
	FL6	P/M	28.8	4	**7**	7
Shields Lake	Shields	WQ[2]	5.4	7	**12**	14
Keewahtin Lake	Keewahtin	P/M	5.4	4	**7**	7
Sunrise River/Comfort Lake	SR/C1	WQ[2]	20.3	7	**12**	14
	SR/C2	P/M	8.6	4	**7**	7
	SR/C3	P/M	12.9	4	**7**	7
Total Curb-miles				1,220	**2,085**	2,900
Solids Reduction Compared to Baseline (20 tons/yr)				+26	**+48**	+66
Phosphorus Reduction Compared to Baseline (57 lb/yr)				+54	**+110**	+140
Estimated Annual Cost				$53,810	**$68,301**	$82,296
Estimated Annual Cost – Reduced Sweeper Purchase Price[3]				$32,232	**$46,294**	$60,394

[1] WQ = Water quality benefit (direct drainage areas of lakes), P/M = BMP preservation and maintenance benefit (indirect water quality benefit to lakes)

[2] TMDL watershed

[3] With grant funding of $220,000 towards the cost of a regenerative air sweeper

Table 7-2. Total sediment reductions to receiving waterbody by sweeping scenario

Waterbody	Total Sediment Reduction (ton/yr)							
	Existing Baseline (2 times per year)	Enhanced Baseline (4 times per year)	Monthly (7 times per year)	Twice Monthly (14 times per year)	Weekly (28 times per year)	Base Priority (4-7 times per year)	Enhanced/ Recommended (7-12 times per year)	Maximum (7-28 times per year)
Clear Lake	2,210	3,572	5,536	8,812	11,164	4,637	6,909	8,589
Forest Lake	34,015	55,341	85,201	130,449	232,517	82,395	120,554	153,658
Shields Lake	254	410	635	1,012	4,272	635	635	1,012
Keewahtin Lake	240	387	600	955	6,073	387	600	600
Comfort Lake	2,405	3,887	6,024	9,589	41,858	3,887	8,209	8,851
ALL	**39,123**	**63,597**	**97,996**	**150,816**	**295,882**	**91,942**	**136,908**	**172,710**

Table 7-3. Total phosphorus reductions to receiving waterbody by sweeping scenario

Waterbody	Total Phosphorus Reduction (lb/yr)							
	Existing Baseline (2 times per year)	Enhanced Baseline (4 times per year)	Monthly (7 times per year)	Twice Monthly (14 times per year)	Weekly (28 times per year)	Base Priority (4-7 times per year)	Enhanced/ Recommended (7-12 times per year)	Maximum (7-28 times per year)
Clear Lake	7	11	16	25	31	13	20	23
Forest Lake	41	64	91	137	180	83	122	146
Shields Lake	0.7	1.1	1.6	2.6	3.2	1.6	1.6	2.6
Keewahtin Lake	1.0	1.6	2.3	3.7	4.6	1.6	2.3	2.3
Comfort Lake	7	11	16	25	31	11	22	23
ALL	**57**	**89**	**127**	**194**	**251**	**111**	**167**	**197**

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Berretta C., S. Raje, and J.J. Sansalone. Quantifying Nutrient Loads Associated with Urban Particulate Matter (PM), and Biogenic/Litter Recovery Through Current MS4 Source Control and Maintenance Practices. University of Florida, College of Engineering, Gainsville, Florida: Florida Stormwater Association Education Foundation (FSAEF); 2011 Final Report: 31 May 2011.

Kalinosky, P., 2015. Quantifying Solids and Nutrient Recovered Through Street Sweeping in a Suburban Watershed. Master's Thesis, University of Minnesota

Kalinosky, P., Baker, L., Hobbie, S., Bintner, R., Buyarski, C. 2013. User Support Manual: Estimating Nutrient Removal by Enhanced Street Sweeping, University of Minnesota for Minnesota Pollution Control Agency (MPCA).

Minnesota Department of Transportations (MNDOT). 2008. Resource for Implementing a Street Sweeping Best Practice, MN/RC – 2008RIC06.

Seattle Public Utilities (SPU). 2009. Seattle Street Sweeping Pilot Study, Monitoring Report. Seattle, WA: Seattle Public Utilities in association with Herrera Environmental Consultants.

Sutherland R. C. 2008. Real World Street Cleaner Pickup Performance Testing. World Sweeper.com, Street and Municipal Sweeping: Studies.

Sutherland R. C., S. L. Jelen. 1997. Chapter 9 - Contrary to Conventional Wisdom, Street Sweeping can be an Effective BMP. Pages 1-14. In W. James, editor. Advances in Modeling the Management of Stormwater Impacts, Vol 5, CHI, Guelph, Canada.

9. APPENDIX A: STREET SWEEPING ZONE MAPS

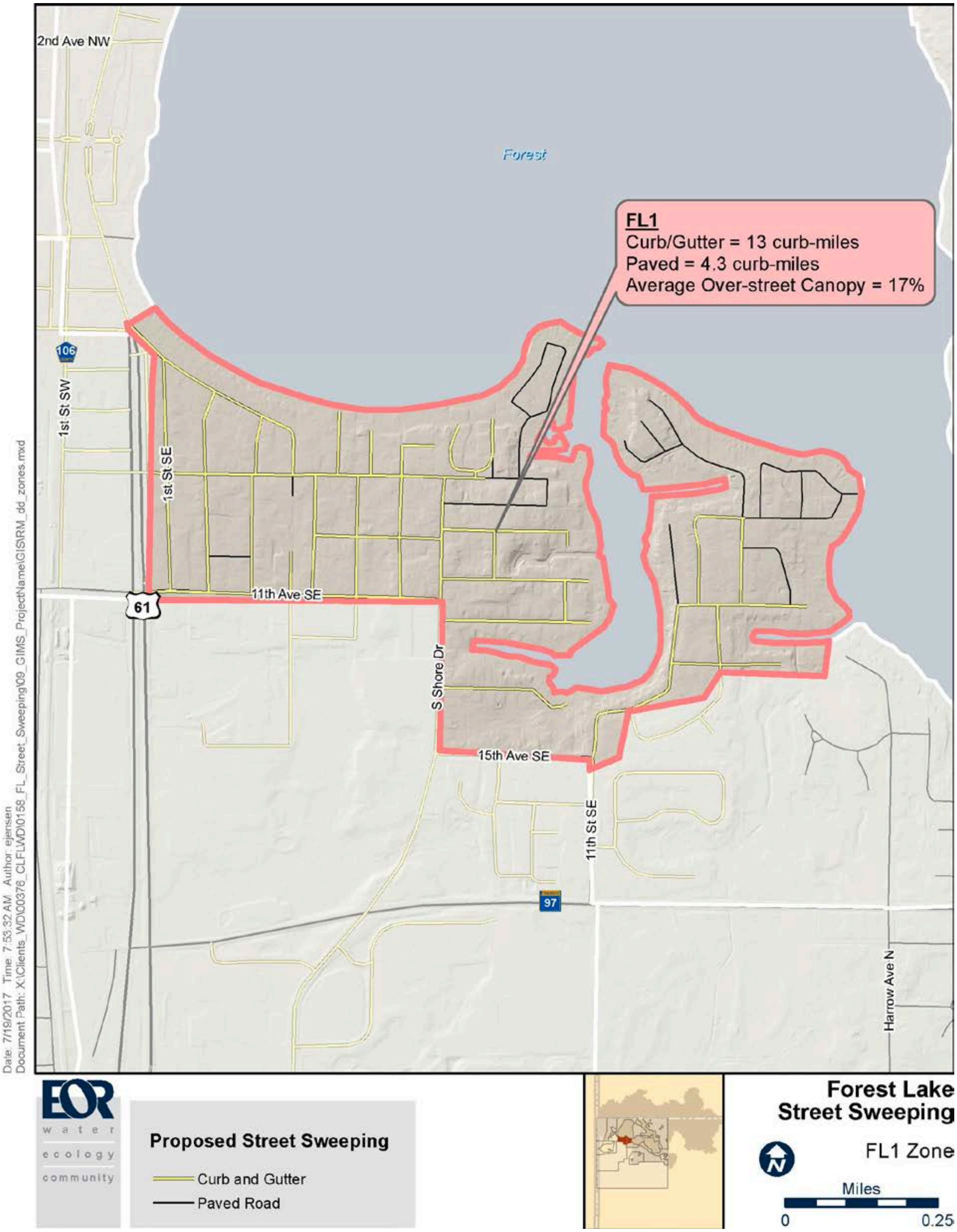

Figure 9-1. Sweeping Zone Forest Lake 1 (FL1).

Figure 9-2. Sweeping Zone Forest Lake 2 (FL2).

Figure 9-3. Sweeping Zone Forest Lake 3 (FL3).

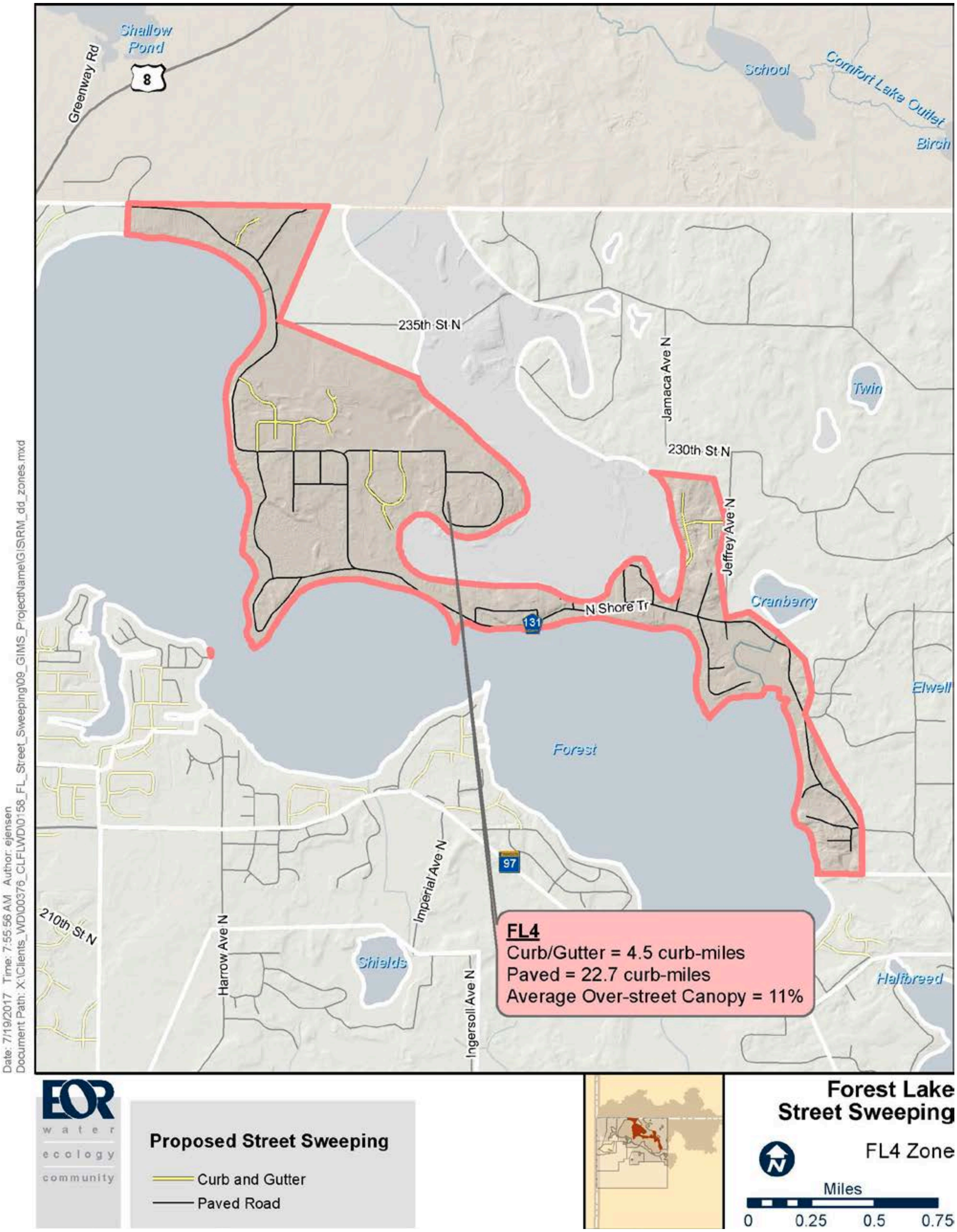

Figure 9-4. Sweeping Zone Forest Lake 4 (FL4).

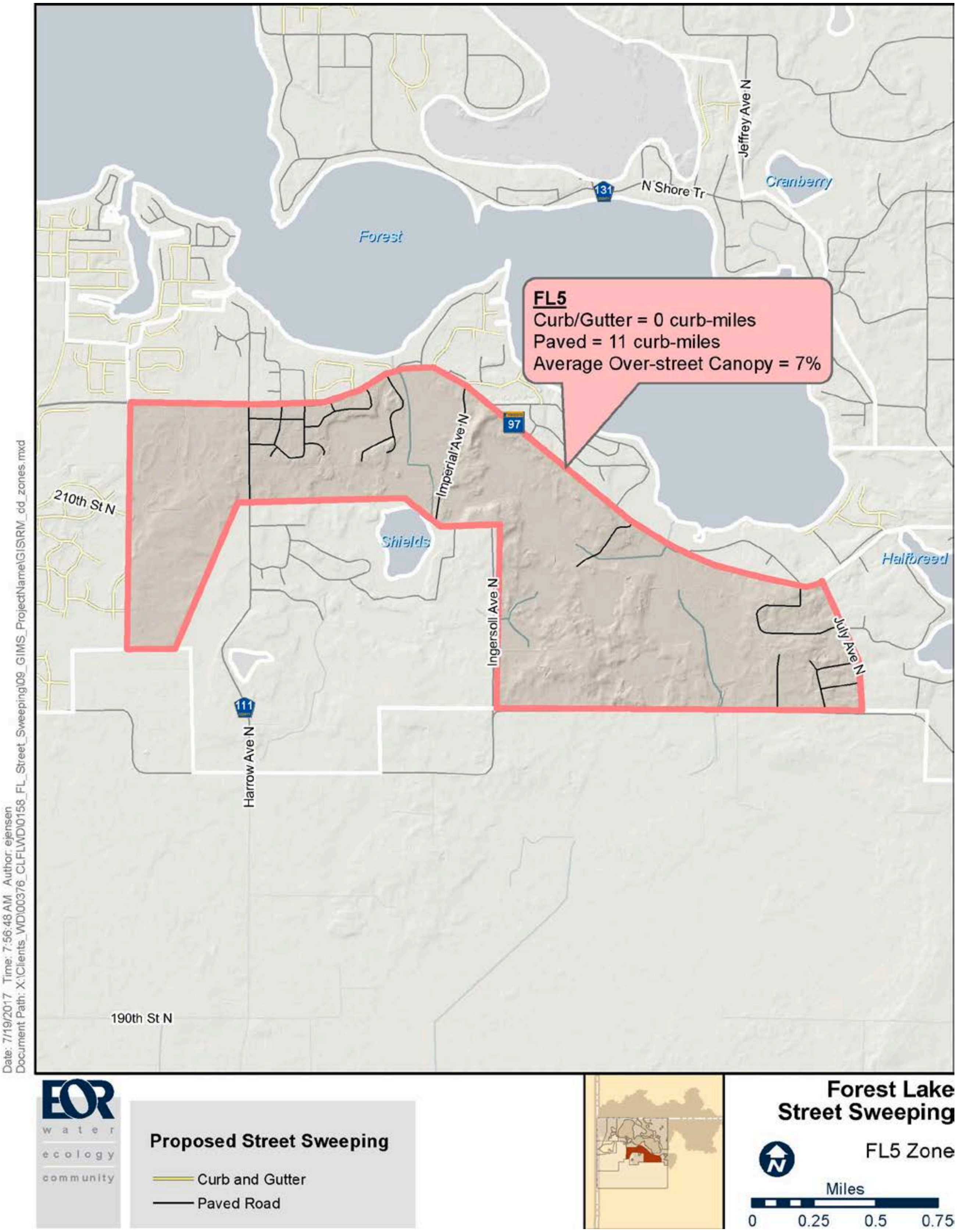

Figure 9-5. Sweeping Zone Forest Lake 5 (FL5).

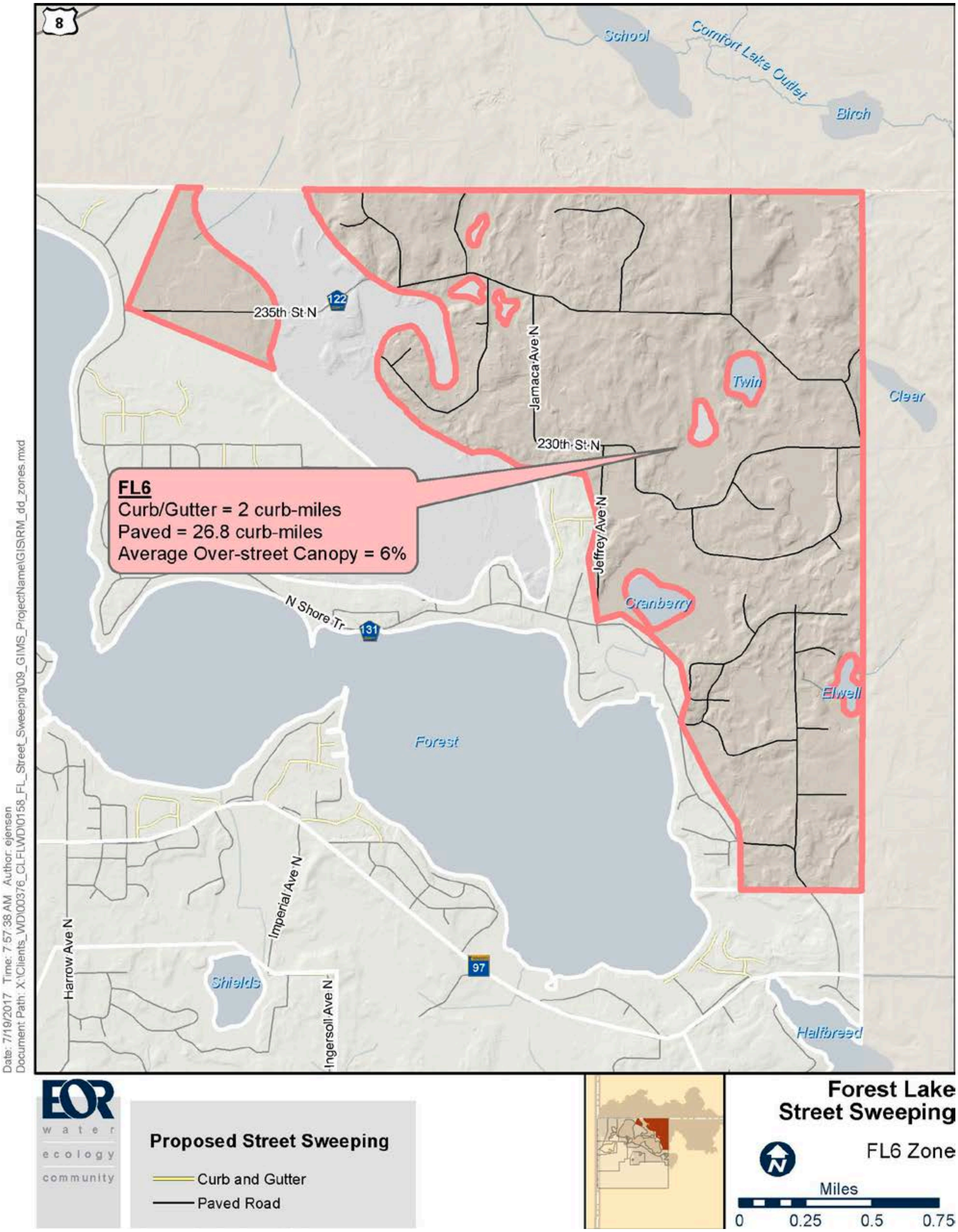

Figure 9-6. Sweeping Zone Forest Lake 6 (FL6).

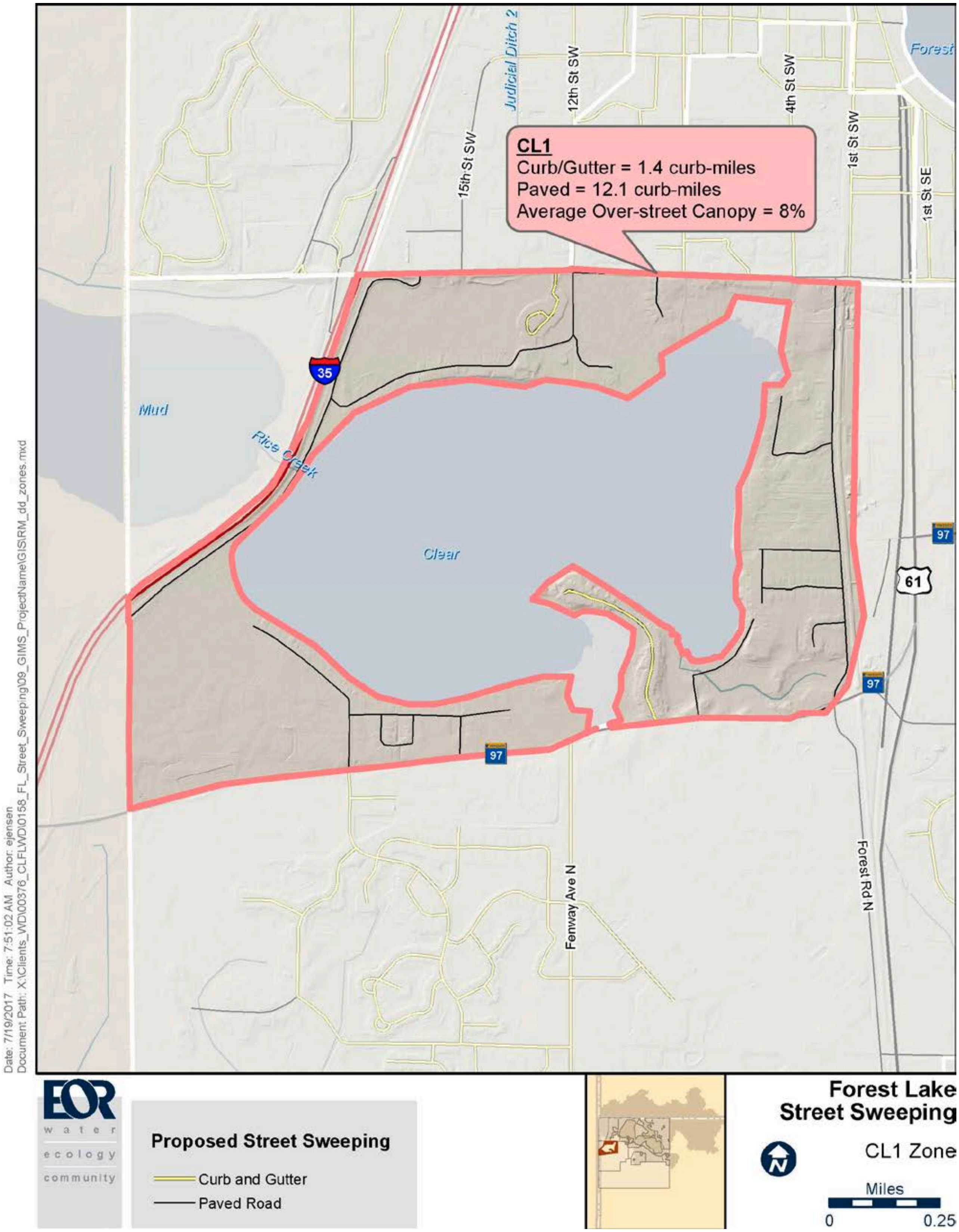

Figure 9-7. Sweeping Zone Clear Lake 1 (CL1).

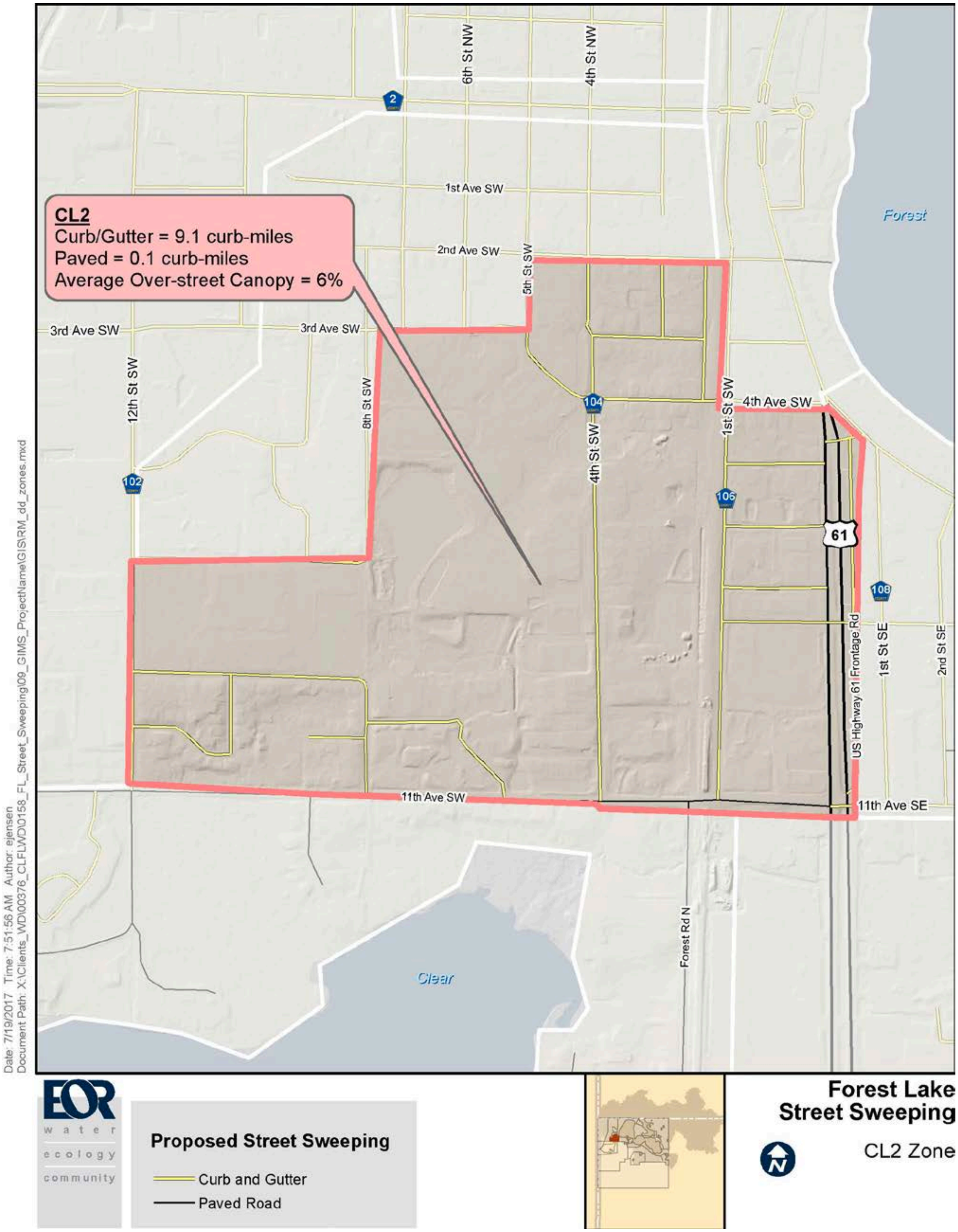

Figure 9-8. Sweeping Zone Clear Lake 2 (CL2).

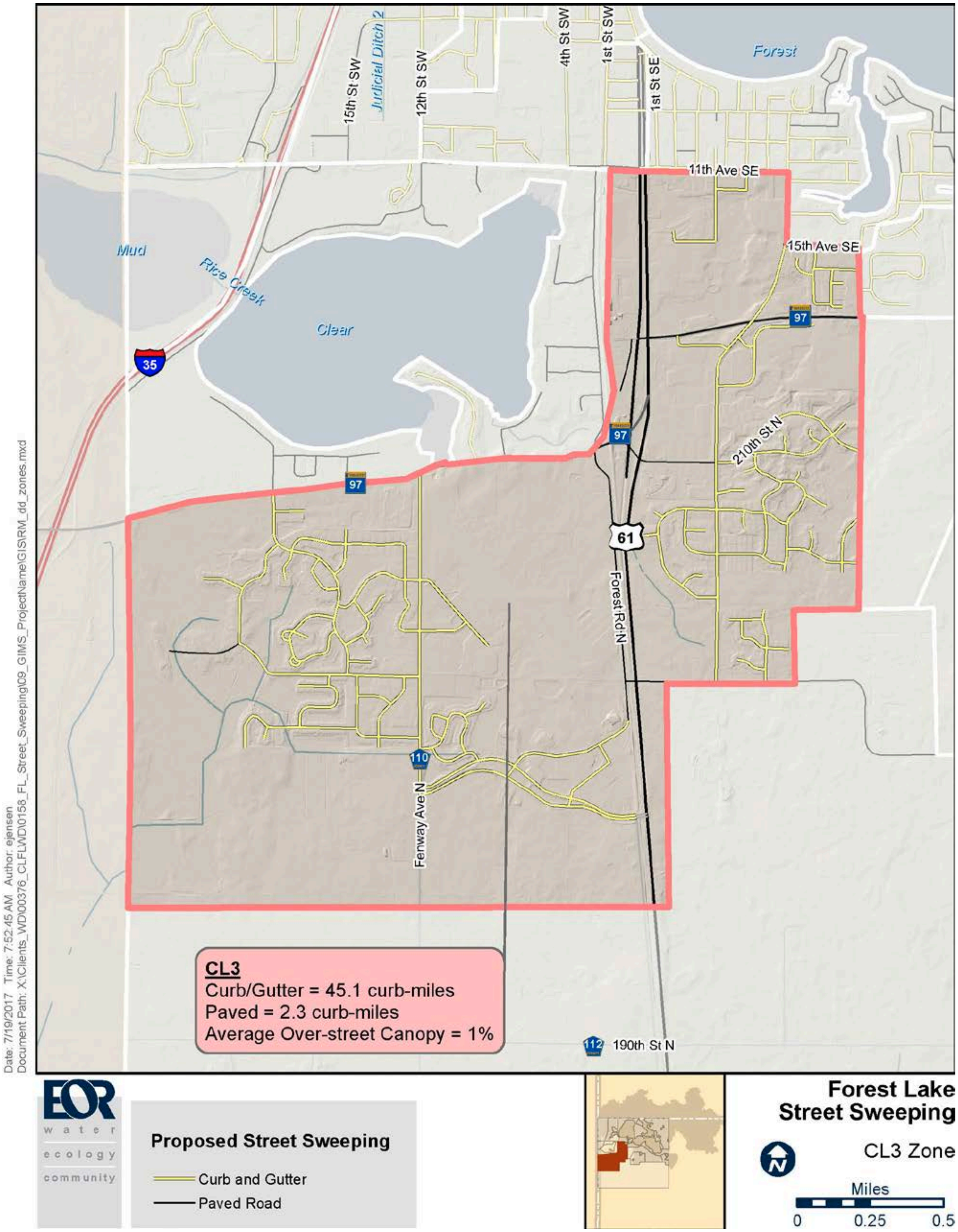

Figure 9-9. Sweeping Zone Clear Lake 3 (CL3).

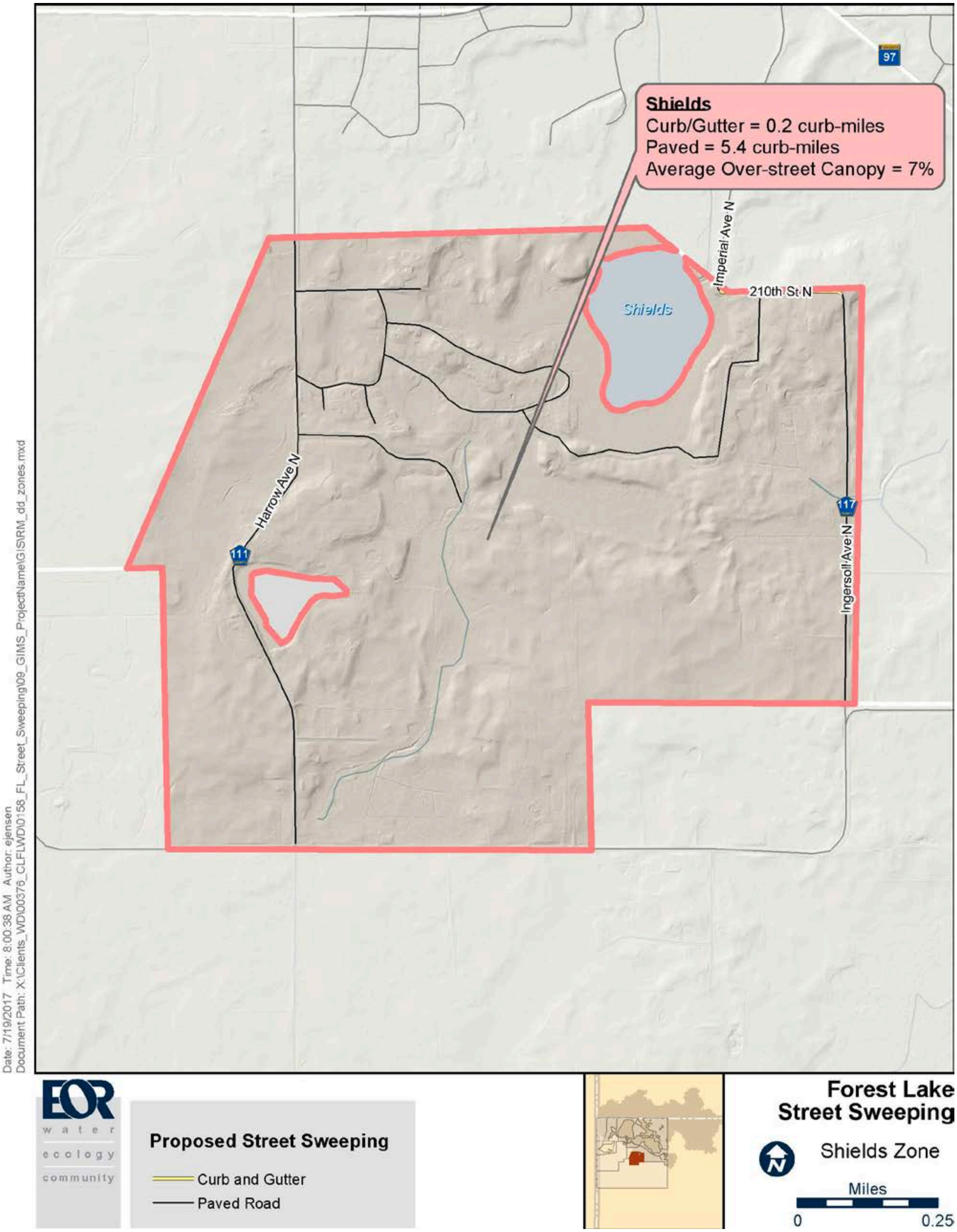

Figure 9-10. Sweeping Zone Shields Lake (Shields).

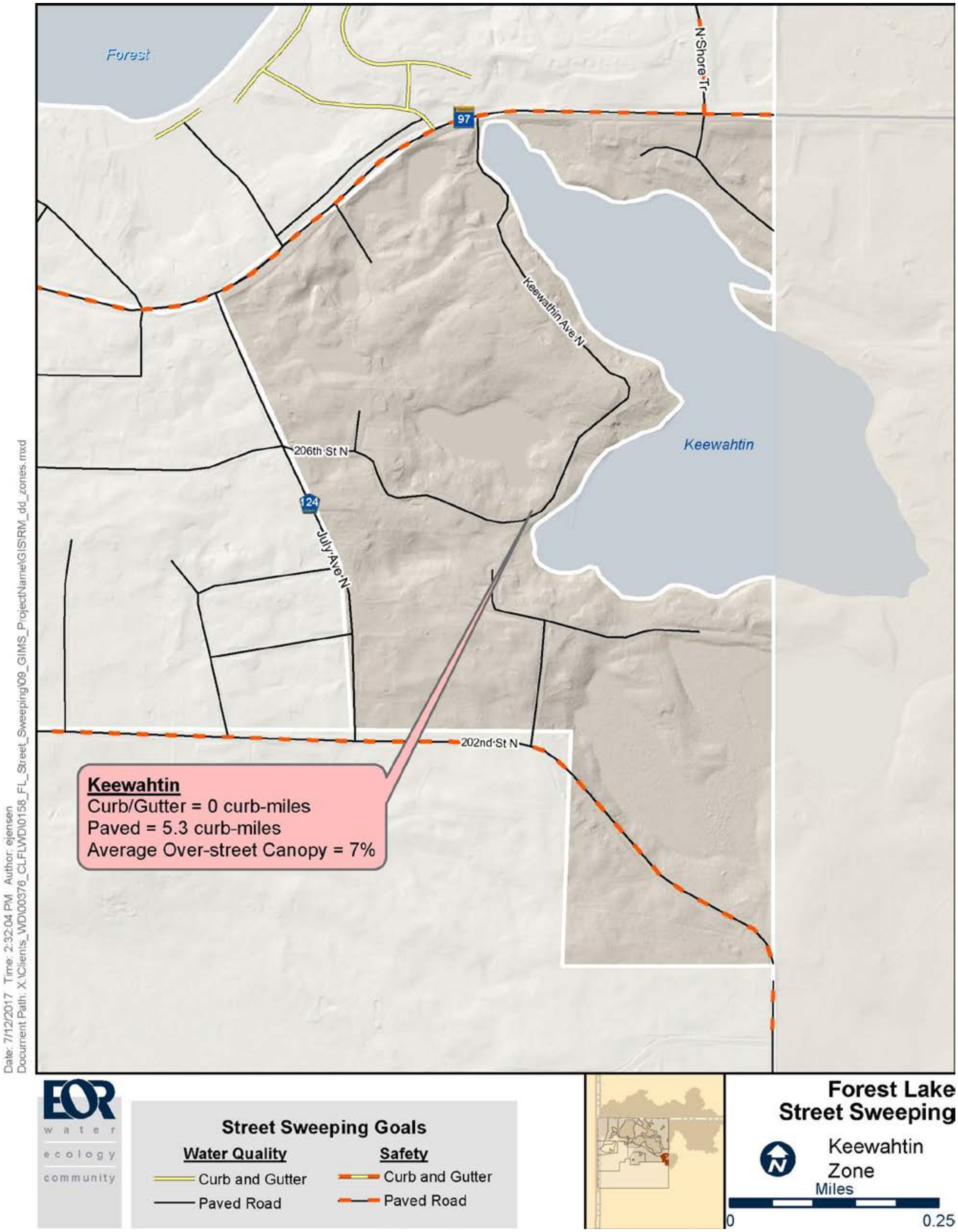

Figure 9-11. Sweeping Zone Keewahtin Lake (Keewahtin).

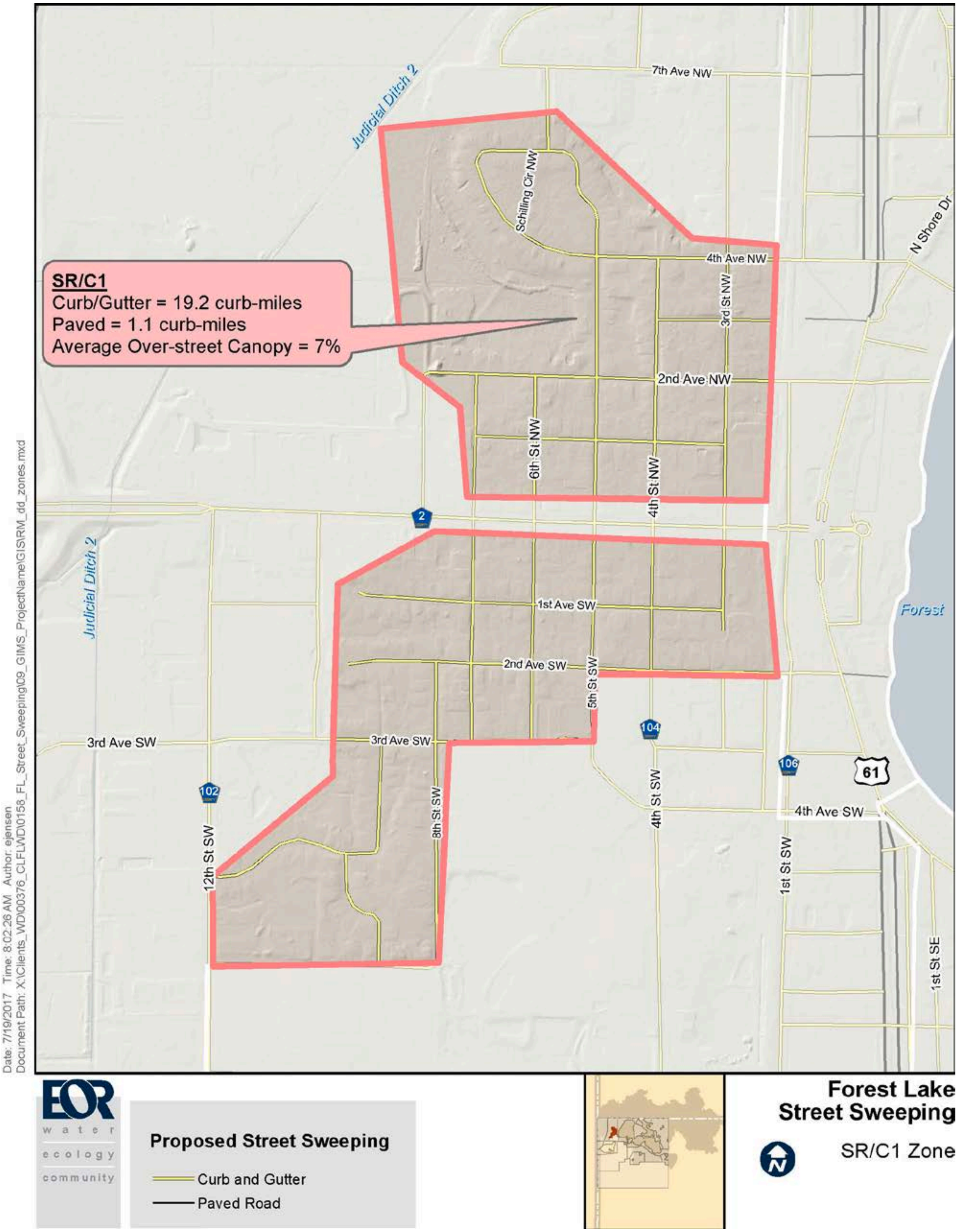

Figure 9-12. Sweeping Zone Sunrise River/Comfort Lake 1 (SRC1).

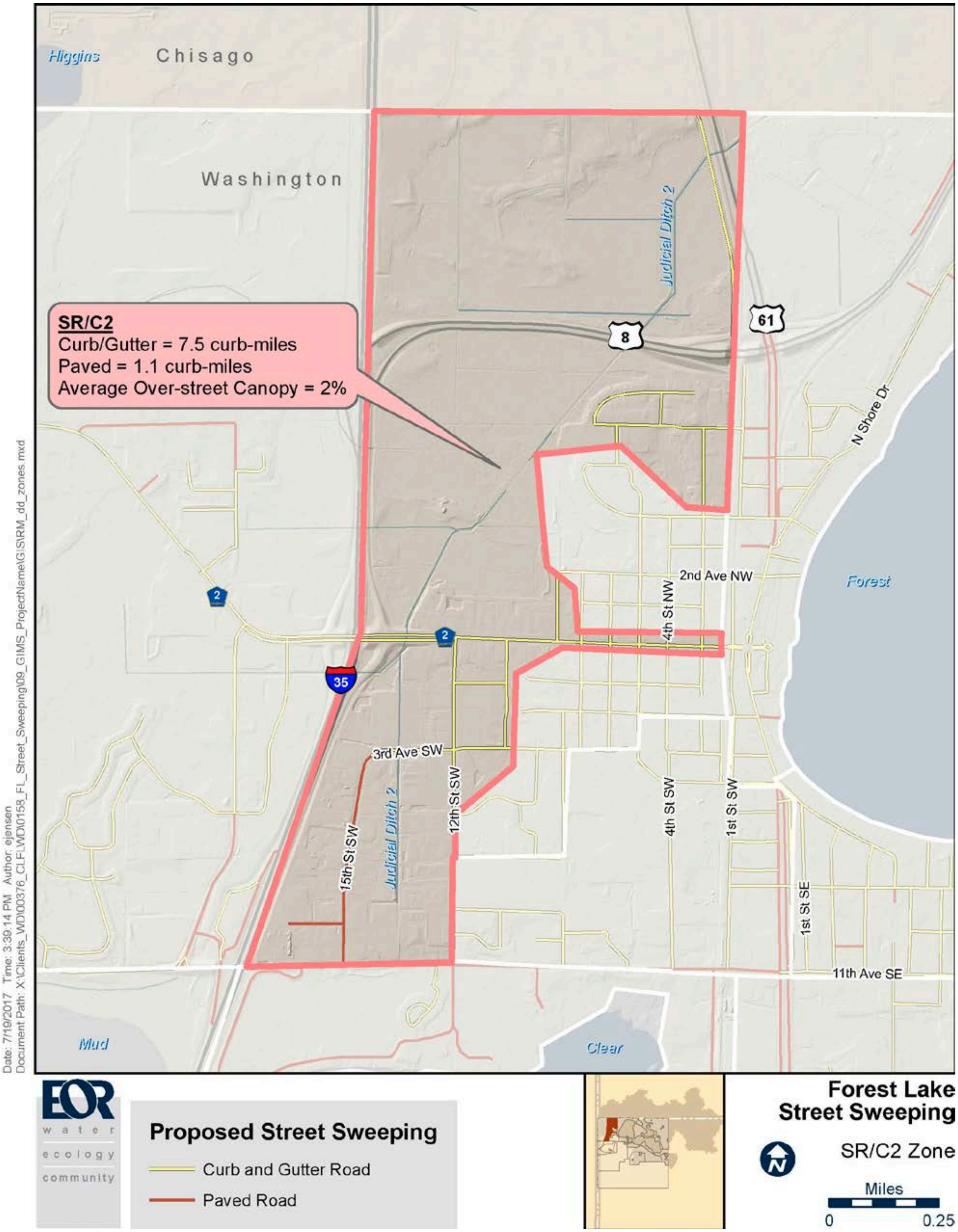

Figure 9-13. Sweeping Zone Sunrise River/Comfort Lake 2 (SRC2).

Figure 9-14. Sweeping Zone Sunrise River/Comfort Lake 3 (SRC3).

10. APPENDIX B: MECHANICAL BROOM LOAD RECOVERY ASSUMPTIONS

Based on a review of street sweeper performance testing literature, mechanical broom type sweepers are estimated to have overall pick-up efficiency that is 20% to 40% less than that of higher efficiency sweepers, on average. The range of reported street sweeper pick-up efficiencies is fairly broad, but some trends are consistent across different sources. The pick-up performance of most street sweepers decreases with particle size, but higher efficiency sweepers (regenerative air or vacuum) generally outperform mechanical sweepers across all particle size classes (Table 10-1). For the largest material (rocks, trash), differences in pick-up efficiency may be minimal. For recovery of smaller particles and adhered pollutants, it may be beneficial to use a higher efficiency sweeper.

In addition to variation with particle size, the overall pick-up efficiency of sweepers tends to increase with loading intensity (Figure 10-1). When streets are relatively clean (lower intensity street dirt loading), pick-up efficiency may be reduced. The trend is most noticeable for mechanical broom type sweepers. The difference in overall pick-up efficiency for mechanical broom type sweepers compared to higher efficiency sweepers ranges from about 40% less at lower intensity loading rates to about 20% less at higher intensity loading rates. Street loading tends to be most intense in early spring, when roads (winter residuals) and during peak fall leave drop (Kalinosky et. al, 2013). During these limited time periods, the pick-up efficiency of mechanical broom sweepers may be within 0% to 25% of the total pick-up efficiency for higher efficiency sweepers. At other times of the year, solids loading on street surfaces tends to be less intense and may include more fine material such as pollen and silt (Kalinosky, 2015). During these times, the pick-up efficiency of mechanical broom sweepers is expected to be somewhat lower (25% to 40% less) than higher efficiency sweepers.

Table 10-1. Comparison of removal efficiencies, mechanical broom and vacuum sweeper technologies, fine and coarse particle size ranges as reported in MNDOT, 2008.

Class Name	Material Particle Size (mm)	Removal Efficiency (%) [mechanical broom sweeper]		Removal Efficiency (%) [vacuum sweeper]	
Gravel	2.0	Range 60 - 79%[1] 9 - 40%[2]	Average 69%[1] 21%[2]	Range n/a[1] 31 – 94%[2]	Average n/a[1] 71%[2]
Medium to very coarse sand	0.25 – 2.0				
Very fine to fine sand	0.050 – 0.250				
Silt	0.002 – 0.050 [3]	Range 16 – 48 %[1] 13 – 13 %[2]	Average 21%[1] 13%[2]	Range n/a[1] 39 – 81 %[2]	Average n/a[1] 60%[2]
Clay	< 0.002				

[1] Pitt, Robert, Bannerman, R. and Sutherland, R. 2004. The Role of Street Cleaning in Stormwater Management. Paper presented at Water World and Environmental Resources Conference 2004, Environmental and Water Resources Institute of the American Society of Civil Engineers, Salt Lake City, Utah. May 27 – June 1, 2004, Table 1.

[2] Breault, R.F., Smith, K.P., and Sorenson, J.R., 2005. Residential street-dirt accumulation rates and chemical composition, and removal efficiencies by mechanical- and vacuum-type sweepers, New Bedford, Massachusetts, 2003–04: U.S. Geological Survey Scientific Investigations Report 2005-5184, 27 p., Table 6.

[3] Particle size is representative of PM10

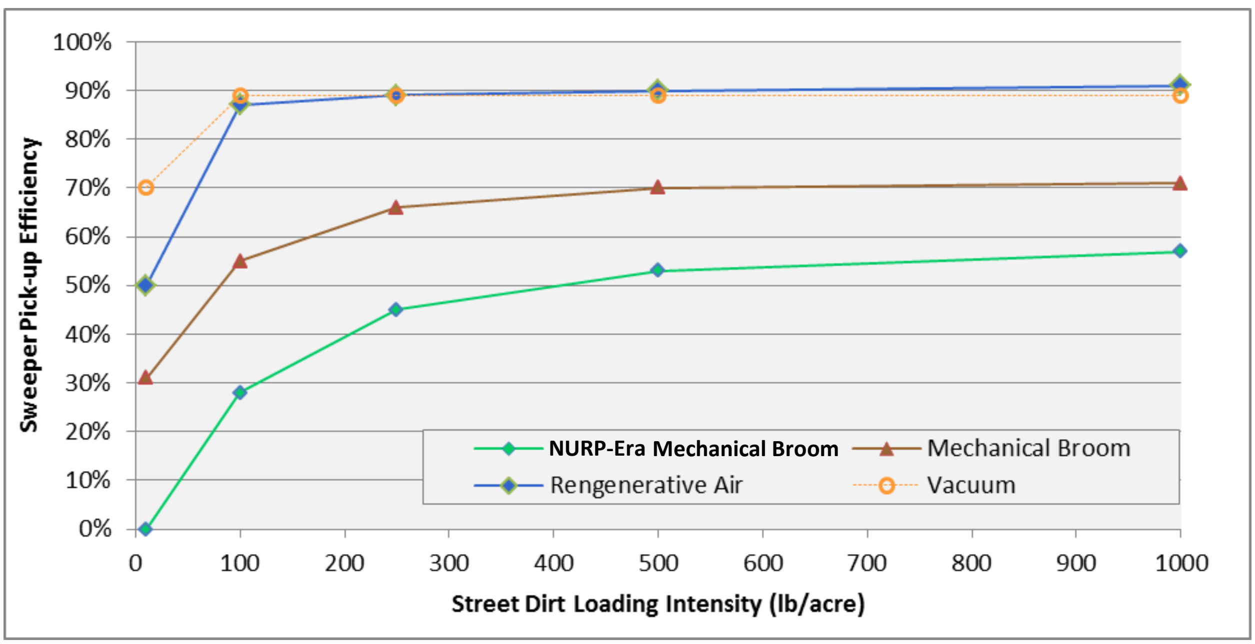

Figure 10-1. Pick-up efficiencies vs. loading intensity for different sweeper types (Sutherland and Jelen, 1997). Efficiencies are based on pick up of street dirt simulant, NURP particle size distribution 13% fine (d < 63 µm), 40% medium (250 µm ≤ d ≤ 2000 µm), and 47% coarse (d ≥ 2000 µm).

11. APPENDIX C: ESTIMATED SOLIDS AND PHOSPHORUS RECOVERY, REDUCTION, AND COSTS BY SWEEPING SCENARIO

11.1. Baseline Scenario (2 times per year)

Table 11-1. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for BASELINE sweeping (once each spring and fall) using mechanical broom and regenerative air technologies. Costs for a City-owned sweeper are based on regenerative air or comparable high-efficiency technology.

Total number of Sweepings = 2			LOAD RECOVERY				LOAD REDUCTION				COSTS					
			Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
			Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	**Sweeping Zo**	**Curb-miles**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**
Clear Lake	CL1	13.5	7019	6.1	8774	7.6	959	2.8	1199	3.5	$ 3,763	$ 495	$ 1,087	$ 2,131	$ 280	$ 616
	CL2	9.2	4442	3.8	5553	4.7	333	0.9	416	1.2	$ 2,565	$ 546	$ 2,183	$ 1,451	$ 309	$ 1,235
	CL3	47.4	19027	15.7	23784	19.6	476	2.0	595	2.5	$ 13,215	$ 674	$ 5,394	$ 7,467	$ 381	$ 3,048
		Subtotal	**30,489**	**25.5**	**38,111**	**31.9**	**1,768**	**5.7**	**2,210**	**7.1**	**$ 19,544**	**$ 613**	**$ 2,758**	**$ 11,049**	**$ 346**	**$ 1,559**
Forest Lake	FL1	17.3	12,545	11.6	15,681	14.5	12545	11.6	15681.0	14.5	$ 4,823	$ 333	$ 333	$ 2,739	$ 189	$ 189
	FL2	12.9	6,230	5.4	7,787	6.7	5108	4.4	5659.5	5.5	$ 3,606	$ 538	$ 656	$ 2,040	$ 304	$ 371
	FL3	18.7	9,723	8.4	12,154	10.5	8012	6.9	9516.4	8.7	$ 5,213	$ 496	$ 603	$ 2,951	$ 281	$ 341
	FL4	27.2	15,801	14.0	19,751	17.5	5621	5.0	2108.0	6.2	$ 7,563	$ 432	$ 1,215	$ 4,286	$ 245	$ 688
	FL5	11.0	5,512	4.7	6,890	5.9	1552	1.3	366.6	1.7	$ 3,062	$ 519	$ 1,843	$ 1,733	$ 294	$ 1,043
	FL6	28.8	13,907	11.9	17,384	14.9	3984	3.4	683.2	4.3	$ 8,026	$ 539	$ 1,881	$ 4,541	$ 305	$ 1,064
		Subtotal	**63,718**	**56.0**	**79,647**	**70.0**	**36,822**	**32.6**	**34,015**	**40.8**	**$ 32,293**	**$ 461**	**$ 791**	**$ 18,290**	**$ 261**	**$ 448**
Shields Lake	Shields	5.4	**2,706**	**2**	**3,382**	**2.9**	**676.4**	**0.6**	**253.7**	**0.7**	**$ 1,504**	**$ 518**	**$ 2,074**	**$ 851**	**$ 293**	**$ 1,174**
Keewahtin Lake	Keewahtin	5.4	**2,706**	**2**	**3,382**	**2.9**	**961.6**	**0.8**	**239.6**	**1.0**	**$ 1,512**	**$ 522**	**$ 1,467**	**$ 856**	**$ 295**	**$ 830**
Sunrise River/Comfort Lake	SR/C1	20.3	10,172	8.8	12,715	11.0	5086.0	4.4	1907.3	5.5	$ 5,664	$ 515	$ 1,030	$ 3,206	$ 291	$ 583
	SR/C2	8.6	3,582	3.0	4,478	3.7	895.6	0.7	335.9	0.9	$ 2,392	$ 647	$ 2,586	$ 1,352	$ 365	$ 1,462
	SR/C3	12.9	5,178	4.2	6,473	5.3	647.3	0.5	161.8	0.7	$ 3,592	$ 678	$ 5,421	$ 2,029	$ 383	$ 3,063
		Subtotal	**18,933**	**16.0**	**23,666**	**20.0**	**6,629**	**5.7**	**2,405**	**7.1**	**$ 11,648**	**$ 582**	**$ 1,643**	**$ 6,587**	**$ 329**	**$ 929**
		TOTAL	**118,550**	**102.2**	**148,188**	**127.7**	**46,857**	**45.4**	**39,123**	**56.7**	**$ 66,500**	**$ 521**	**$ 1,172**	**$ 37,633**	**$ 295**	**$ 663**

11.2. Enhanced Baseline Scenario (4 times per year)

Table 11-2. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for enhance spring and fall sweeping (2-spring, and 2-fall sweepings) using mechanical broom and regenerative air technologies. Costs for a City-owned sweeper are based on regenerative air or comparable high-efficiency technology.

Total number of Sweepings = 4

			LOAD RECOVERY				LOAD REDUCTION				COST					
			Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
			Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	Sweeping Zor	Curb-miles	TS	TP	TS	TP	TS	TP	TS	TP	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)
Clear Lake	CL1	13.5	10805	9.0	14,182	11.8	1476	4.1	1938	5.4	$ 7,527	$ 638	$ 1,401	$ 2,611	$ 221	$ 486
	CL2	9.2	6839	5.7	8,976	7.4	513	1.4	673	1.9	$ 5,130	$ 693	$ 2,773	$ 1,779	$ 240	$ 961
	CL3	47.4	29288	23.3	38,442	30.5	732	2.9	961	3.8	$ 26,430	$ 867	$ 6,932	$ 9,147	$ 300	$ 2,399
		Subtotal	**46,931**	**38.0**	**61,600**	**49.7**	**2,721**	**8.4**	**3,572**	**11.0**	**$ 39,087**	**$ 786**	**$ 3,542**	**$ 13,537**	**$ 272**	**$ 1,227**
Forest Lake	FL1	17.3	19,310	17.2	25,345	22.5	19310	17.2	25345	22.5	$ 9,646	$ 429	$ 429	$ 3,361	$ 149	$ 149
	FL2	12.9	9,939	8.4	13,086	11.1	8150	6.9	9511	9.1	$ 7,211	$ 650	$ 792	$ 2,501	$ 225	$ 275
	FL3	18.7	14,966	12.5	19,644	16.4	12333	10.3	15381	13.5	$ 10,426	$ 636	$ 772	$ 3,617	$ 221	$ 268
	FL4	27.2	24,322	20.7	31,924	27.1	8653	7.4	3407	9.6	$ 15,125	$ 558	$ 1,569	$ 5,254	$ 194	$ 545
	FL5	11.0	8,484	7.0	11,136	9.2	2389	2.0	593	2.6	$ 6,124	$ 666	$ 2,364	$ 2,124	$ 231	$ 820
	FL6	28.8	21,407	17.7	28,098	23.1	6132	5.1	1104	6.6	$ 16,053	$ 695	$ 2,426	$ 5,565	$ 241	$ 841
		Subtotal	**98,428**	**83.6**	**129,233**	**109.4**	**56,966**	**48.9**	**55,341**	**64.0**	**$ 64,585**	**$ 590**	**$ 1,010**	**$ 22,422**	**$ 205**	**$ 351**
Shields Lake	Shields	5.4	**4,165**	**3.4**	**5,467**	**4.5**	**1041**	**0.9**	**410**	**1.1**	**$ 3,007**	**$ 668**	**$ 2,673**	**$ 1,043**	**$ 232**	**$ 927**
Keewahtin Lake	Keewahtin	5.4	**4,165**	**3.4**	**5,467**	**4.5**	**1480**	**1.2**	**387**	**1.6**	**$ 3,025**	**$ 672**	**$ 1,891**	**$ 1,049**	**$ 233**	**$ 656**
Sunrise River/Comfort Lake	SR/C1	20.3	15,657	13.0	20,551	17.0	7828.6	6.5	3083	8.5	$ 11,328	$ 666	$ 1,333	$ 3,929	$ 231	$ 462
	SR/C2	8.6	5,514	4.4	7,237	5.8	1378.4	1.1	542.8	1.5	$ 4,784	$ 825	$ 3,300	$ 1,656	$ 286	$ 1,142
	SR/C3	12.9	7,971	6.3	10,462	8.3	996.3	0.8	261.6	1.0	$ 7,183	$ 865	$ 6,923	$ 2,486	$ 300	$ 2,396
		Subtotal	**29,142**	**23.8**	**38,250**	**31.1**	**10,203**	**8.4**	**3,887**	**11.0**	**$ 23,295**	**$ 749**	**$ 2,120**	**$ 8,071**	**$ 260**	**$ 735**
		TOTAL	**182,831**	**152.2**	**240,017**	**199.2**	**72,412**	**67.8**	**63,597**	**88.7**	**$ 133,000**	**$ 668**	**$ 1,499**	**$ 46,122**	**$ 232**	**$ 520**

11.3. Monthly Scenario (7 times per year)

Table 11-3. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for monthly sweeping using mechanical broom and regenerative air technologies. Costs for a City-owned sweeper are based on regenerative air or comparable high-efficiency technology.

Total number of Sweepings = 7

			LOAD RECOVERY				LOAD REDUCTION				COSTS					
			Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
			Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	**Sweeping Zor**	**Curb-miles**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**
Clear Lake	CL1	13.5	16262	12.7	21,978	17.0	2222	5.8	3003	7.7	$ 13,172	$ 775	$ 1,701	$ 3,332	$ 196	$ 430
	CL2	9.2	10292	7.9	13,910	10.6	772	2.0	1043	2.7	$ 8,978	$ 847	$ 3,388	$ 2,269	$ 214	$ 856
	CL3	47.4	44082	32.7	59,576	43.9	1102	4.1	1489	5.5	$ 46,252	$ 1,054	$ 8,429	$ 11,666	$ 266	$ 2,126
		Subtotal	**70,636**	**53.2**	**95,464**	**71.5**	**4,096**	**11.8**	**5,536**	**15.9**	**$ 68,403**	**$ 957**	**$ 4,307**	**$ 17,267**	**$ 241**	**$ 1,087**
Forest Lake	FL1	17.3	29,063	24.1	39,279	32.4	29063	24.1	39279	32.4	$ 16,880	$ 521	$ 521	$ 4,292	$ 132	$ 132
	FL2	12.9	14,432	11.1	19,505	14.9	11834	9.1	14176	12.2	$ 12,620	$ 847	$ 1,033	$ 3,189	$ 214	$ 261
	FL3	18.7	22,526	17.6	30,443	23.6	18562	14.5	23836	19.4	$ 18,246	$ 773	$ 938	$ 4,616	$ 196	$ 237
	FL4	27.2	36,607	29.1	49,474	39.1	13023	10.4	5280	13.9	$ 26,470	$ 677	$ 1,903	$ 6,706	$ 172	$ 482
	FL5	11.0	12,770	9.9	17,258	13.3	3596	2.8	918	3.7	$ 10,716	$ 806	$ 2,862	$ 2,710	$ 204	$ 724
	FL6	28.8	32,220	24.7	43,545	33.2	9230	7.1	1711	9.5	$ 28,092	$ 846	$ 2,954	$ 7,100	$ 214	$ 747
		Subtotal	**147,618**	**116.6**	**199,504**	**156.5**	**85,308**	**67.9**	**85,201**	**91.2**	**$ 113,024**	**$ 722**	**$ 1,239**	**$ 28,613**	**$ 183**	**$ 314**
Shields Lake	Shields	5.4	**6,269**	**4.8**	**8,472**	**6.5**	**1567.2**	**1.2**	**635.4**	**1.6**	**$ 5,262**	**$ 810**	**$ 3,238**	**$ 1,331**	**$ 205**	**$ 819**
Keewahtin Lake	Keewahtin	5.4	**6,269**	**4.8**	**8,472**	**6.5**	**2228.0**	**1.7**	**600.2**	**2.3**	**$ 5,294**	**$ 814**	**$ 2,291**	**$ 1,338**	**$ 206**	**$ 579**
Sunrise River/Comfort Lake	SR/C1	20.3	23,566	18.3	31,849	24.5	11782.9	9.1	4777.4	12.3	$ 19,824	$ 809	$ 1,618	$ 5,012	$ 205	$ 409
	SR/C2	8.6	8,299	6.2	11,216	8.3	2074.8	1.5	841.2	2.1	$ 8,372	$ 1,009	$ 4,035	$ 2,113	$ 255	$ 1,018
	SR/C3	12.9	11,997	8.9	16,214	11.9	1499.6	1.1	405.4	1.5	$ 12,570	$ 1,056	$ 8,451	$ 3,170	$ 266	$ 2,131
		Subtotal	**43,862**	**33.3**	**59,279**	**44.7**	**15,357**	**11.8**	**6,024**	**15.8**	**$ 40,767**	**$ 912**	**$ 2,578**	**$ 10,295**	**$ 230**	**$ 651**
		TOTAL	**274,653**	**212.8**	**371,191**	**285.7**	**108,556**	**94.5**	**97,996**	**126.9**	**$ 232,750**	**$ 815**	**$ 1,835**	**$ 58,844**	**$ 206**	**$ 464**

11.4. Twice Monthly Scenario (14 times per year)

Table 11-4. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for twice monthly sweeping using mechanical broom and regenerative air technologies. Costs for a City-owned sweeper are based on regenerative air or comparable high-efficiency technology.

Total number of Sweepings = 14

			LOAD RECOVERY				LOAD REDUCTION				COSTS					
			Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
			Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	**Sweeping Zor**	**Curb-miles**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**
Clear Lake	CL1	13.5	16055	12.2	34,985	26.9	3466	8.9	4780	12.3	$ 26,344	$ 979	$ 2,150	$ 5,034	$ 187	$ 411
	CL2	9.2	68762	50.5	22,143	16.8	1204	3.1	1661	4.2	$ 17,956	$ 1,069	$ 4,275	$ 3,429	$ 204	$ 816
	CL3	47.4	110185	82.4	94,834	69.4	1719	6.3	2371	8.7	$ 92,505	$ 1,333	$ 10,663	$ 17,643	$ 254	$ 2,034
		Subtotal	**195,002**	**145.1**	**151,962**	**113.1**	**6,389**	**18.3**	**8,812**	**25.1**	**$ 136,805**	**$ 1,210**	**$ 5,445**	**$ 26,107**	**$ 231**	**$ 1,039**
Forest Lake	FL1	17.3	22,512	17.1	57,349	44.3	41712	32.5	57349.0	44.3	$ 33,760	$ 762	$ 762	$ 6,474	$ 146	$ 146
	FL2	12.9	35,137	27.1	31,048	23.5	18460	14.0	22565.5	19.3	$ 25,239	$ 1,074	$ 1,310	$ 4,820	$ 205	$ 250
	FL3	18.7	57,102	45.0	48,460	37.2	28955	22.3	37943.4	30.7	$ 36,492	$ 981	$ 1,190	$ 6,974	$ 187	$ 227
	FL4	27.2	19,919	15.3	78,753	61.8	20314	16.0	8405.0	22.0	$ 52,939	$ 857	$ 2,408	$ 10,127	$ 164	$ 461
	FL5	11.0	50,260	38.2	27,472	21.0	5609	4.3	1461.8	5.9	$ 21,433	$ 1,021	$ 3,625	$ 4,095	$ 195	$ 692
	FL6	28.8	226,643	175.2	69,316	52.5	14397	11.0	2724.1	15.0	$ 56,185	$ 1,070	$ 3,736	$ 10,730	$ 204	$ 714
		Subtotal	**411,574**	**318.0**	**312,398**	**240.3**	**129,447**	**100.1**	**130,449**	**137.2**	**$ 226,048**	**$ 941**	**$ 1,648**	**$ 43,219**	**$ 180**	**$ 315**
Shields Lake	Shields	5.4	**9,778**	**7.5**	**13,486**	**10.3**	**2444.6**	**1.9**	**1011.5**	**2.6**	**$ 10,525**	**$ 1,022**	**$ 4,087**	**$ 2,011**	**$ 195**	**$ 781**
Keewahtin Lake	Keewahtin	5.4	**36,760**	**28.2**	**13,486**	**10.3**	**3475.4**	**2.7**	**955.3**	**3.7**	**$ 10,587**	**$ 1,028**	**$ 2,892**	**$ 2,023**	**$ 196**	**$ 552**
Sunrise River/Comfort Lake	SR/C1	20.3	12,946	9.6	50,698	38.7	18380.1	14.1	7604.7	19.4	$ 39,649	$ 1,025	$ 2,049	$ 7,574	$ 196	$ 391
	SR/C2	8.6	18,714	13.8	17,854	13.2	3236.4	2.4	1339.1	3.3	$ 16,745	$ 1,269	$ 5,074	$ 3,195	$ 242	$ 968
	SR/C3	12.9	68,419	51.6	25,809	18.9	2339.2	1.7	645.2	2.4	$ 25,141	$ 1,330	$ 10,642	$ 4,795	$ 254	$ 2,030
		Subtotal	**100,079**	**74.9**	**94,361**	**70.8**	**23,956**	**18.2**	**9,589**	**25.0**	**$ 81,534**	**$ 1,152**	**$ 3,260**	**$ 15,564**	**$ 220**	**$ 622**
		TOTAL	**753,193**	**573.7**	**585,693**	**444.8**	**165,712**	**141.1**	**150,816**	**193.5**	**$ 465,500**	**$ 1,047**	**$ 2,405**	**$ 88,923**	**$ 200**	**$ 459**

11.5. Weekly Scenario (28 times per year)

Table 11-5. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for weekly sweeping using mechanical broom and regenerative air technologies.

Total number of Sweepings = 28			LOAD RECOVERY				LOAD REDUCTION				COSTS					
			Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
			Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	**Sweeping Zor**	**Curb-miles**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**TS**	**TP**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**	**$**	**$/lb-P (RECOVERY)**	**$/lb-P (REDUCTION)**
Clear Lake	CL1	13.5	31904	24.3	44,324	33.6	4359	11.1	6056	15.3	$ 52,689	$ 1,568	$ 3,443	$ 10,025	$ 298	$ 655
	CL2	9.2	20192	15.2	28,053	21.0	1514	3.8	2104	5.3	$ 35,912	$ 1,710	$ 6,840	$ 6,831	$ 325	$ 1,301
	CL3	47.4	86483	62.7	120,149	86.8	2162	7.8	3004	10.9	$ 185,010	$ 2,131	$ 17,052	$ 35,168	$ 405	$ 3,241
		Subtotal	**138,579**	**102.2**	**192,526**	**141.4**	**8,036**	**22.7**	**11,164**	**31.4**	**$ 273,610**	**$ 1,935**	**$ 8,713**	**$ 52,024**	**$ 368**	**$ 1,657**
Forest Lake	FL1	17.3	57,019	46.3	79,216	64.0	57019	46.3	79216.0	64.0	$ 67,521	$ 1,055	$ 1,055	$ 12,870	$ 201	$ 201
	FL2	12.9	28,314	21.3	39,336	29.4	23217	17.4	32255.1	24.1	$ 50,478	$ 1,717	$ 2,094	$ 9,602	$ 327	$ 398
	FL3	18.7	44,193	33.7	61,396	46.6	36417	27.7	50592.9	38.4	$ 72,985	$ 1,566	$ 1,901	$ 13,887	$ 298	$ 362
	FL4	27.2	71,818	55.9	99,776	77.3	25550	19.9	35495.8	27.5	$ 105,878	$ 1,370	$ 3,850	$ 20,157	$ 261	$ 733
	FL5	11.0	25,053	18.9	34,805	26.2	7054	5.3	9800.3	7.4	$ 42,865	$ 1,636	$ 5,810	$ 8,155	$ 311	$ 1,105
	FL6	28.8	63,212	47.5	87,820	65.7	18107	13.6	25156.4	18.8	$ 112,370	$ 1,710	$ 5,971	$ 21,375	$ 325	$ 1,136
		Subtotal	**289,609**	**223.4**	**402,349**	**309.2**	**167,364**	**130.2**	**232,517**	**180.2**	**$ 452,097**	**$ 1,462**	**$ 2,509**	**$ 86,045**	**$ 278**	**$ 477**
Shields Lake	Shields	5.4	**12,298**	**9.3**	**17,086**	**12.9**	**3074.6**	**2.3**	**4271.5**	**3.2**	**$ 21,050**	**$ 1,632**	**$ 6,527**	**$ 4,005**	**$ 310**	**$ 1,242**
Keewahtin Lake	Keewahtin	5.4	**12,298**	**9.3**	**17,086**	**12.9**	**4371.0**	**3.3**	**6072.6**	**4.6**	**$ 21,175**	**$ 1,641**	**$ 4,618**	**$ 4,028**	**$ 312**	**$ 879**
Sunrise River/Comfort Lake	SR/C1	20.3	46,233	35.0	64,231	48.4	23116.6	17.5	32115.5	24.2	$ 79,297	$ 1,638	$ 3,277	$ 15,086	$ 312	$ 623
	SR/C2	8.6	16,282	11.9	22,620	16.5	4070.5	3.0	5655.0	4.1	$ 33,490	$ 2,030	$ 8,119	$ 6,367	$ 386	$ 1,543
	SR/C3	12.9	23,537	17.1	32,699	23.6	2942.1	2.1	4087.4	3.0	$ 50,281	$ 2,131	$ 17,045	$ 9,558	$ 405	$ 3,240
		Subtotal	**86,052**	**64.0**	**119,550**	**88.5**	**30,129**	**22.6**	**41,858**	**31.3**	**$ 163,068**	**$ 1,843**	**$ 5,214**	**$ 31,011**	**$ 350**	**$ 992**
		TOTAL	**538,837**	**408.2**	**748,597**	**564.9**	**212,975**	**181.2**	**295,882**	**250.7**	**$ 931,000**	**$ 1,648**	**$ 3,714**	**$ 177,113**	**$ 314**	**$ 706**

NOTE: A second sweeper is needed to complete city-wide weekly sweeping. Although the cost calculations for this scenario include the purchase, operation, and maintenance of a second sweeper (Section 6), recommendations for sweeping are based on use of a single sweeper (Section 7).

11.6. Base Priority Scenario

Table 11-6. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for Base Priority enhanced sweeping scenario using mechanical broom and regenerative air technologies (Table 7-1).

Sweeping Scenario:
1. Zones designated as 'WQ' swept monthly during the sweeping season.
2. Zone designated as 'P/M' swept twice each in the spring and fall

					LOAD RECOVERY				LOAD REDUCTION				COSTS					
					Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)									
					Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Contract Sweeping			City-Owned Sweeper		
Waterbody	Sweeping Zone	Sweeping Priority[1]	Curb-miles	# Sweepings	TS	TP	TS	TP	TS	TP	TS	TP	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)
Clear Lake	CL1	WQ	13.5	7	16262	12.7	21,978	17.0	2222	5.8	3003	7.7	$ 52,700	$ 1,568	$ 3,444		$ 298	$ 655
	CL2	P/M	9.2	4	6839	5.7	8,976	7.4	513	1.4	673	1.9	$ 8,980	$ 847	$ 3,389	$ 6,831	$ 325	$ 1,301
	CL3	P/M	47.4	4	29288	23.3	38,442	30.5	732	2.9	961	3.8	$ 46,262	$ 1,054	$ 8,430	$ 35,168	$ 405	$ 3,241
				Subtotal	**52,388**	**41.6**	**69,396**	**54.9**	**3,467**	**10.1**	**4,637**	**13.4**	**$ 107,942**	**$ 1,225**	**$ 4,605**	**$ 52,024**	**$ 368**	**$ 1,657**
Forest Lake	FL1	WQ	17.3	7	29,063	24.1	39,279	32.4	29063	24.1	39279.0	32.4	$ 67,535	$ 1,055	$ 1,055	$ 12,870	$ 201	$ 201
	FL2	WQ	12.9	7	14,432	11.1	19,505	14.9	11834	9.1	14176.1	12.2	$ 50,489	$ 1,717	$ 2,094	$ 9,602	$ 327	$ 398
	FL3	WQ	18.7	7	22,526	17.6	30,443	23.6	18562	14.5	23836.4	19.4	$ 36,500	$ 981	$ 1,191	$ 13,887	$ 298	$ 362
	FL4	P/M	27.2	4	24,322	20.7	31,924	27.1	8653	7.4	3407.1	9.6	$ 26,475	$ 677	$ 1,903	$ 20,157	$ 261	$ 733
	FL5	P/M	11.0	4	8,484	7.0	11,136	9.2	2389	2.0	592.6	2.6	$ 10,719	$ 806	$ 2,862	$ 8,155	$ 311	$ 1,105
	FL6	P/M	28.8	4	21,407	17.7	28,098	23.1	6132	5.1	1104.3	6.6	$ 28,098	$ 846	$ 2,955	$ 21,375	$ 325	$ 1,136
				Subtotal	**120,234**	**98.2**	**160,385**	**130.3**	**76,633**	**62.1**	**82,395**	**82.9**	**$ 219,817**	**$ 1,017**	**$ 1,506**	**$ 86,045**	**$ 278**	**$ 477**
Shields Lake[2]	Shields	WQ	5.4	7	**6,269**	**4.8**	**8,472**	**6.5**	**1567.2**	**1.2**	**635.4**	**1.6**	**$ 10,527**	**$ 1,022**	**$ 4,088**	**$ 4,005**	**$ 310**	**$ 1,242**
Keewahtin Lake	Keewahtin	P/M	5.4	4	**4,165**	**3.4**	**5,467**	**4.5**	**1480.3**	**1.2**	**387.3**	**1.6**	**$ 5,295**	**$ 815**	**$ 2,292**	**$ 4,028**	**$ 312**	**$ 879**
Sunrise River/Comfort Lake[2]	SR/C1	WQ	20.3	7	15,657	13.0	20,551	17.0	7828.6	6.5	3082.7	8.5	$ 39,657	$ 1,025	$ 2,049	$ 15,086	$ 312	$ 623
	SR/C2	P/M	8.6	4	5,514	4.4	7,237	5.8	1378.4	1.1	542.8	1.5	$ 8,374	$ 1,009	$ 4,036	$ 6,367	$ 386	$ 1,543
	SR/C3	P/M	12.9	4	7,971	6.3	10,462	8.3	996.3	0.8	261.6	1.0	$ 12,573	$ 1,057	$ 8,452	$ 9,558	$ 405	$ 3,240
				Subtotal	**29,142**	**23.8**	**38,250**	**31.1**	**10,203**	**8.4**	**3,887**	**11.0**	**$ 60,604**	**$ 1,029**	**$ 2,645**	**$ 31,011**	**$ 350**	**$ 992**
				TOTAL	**212,198**	**171.9**	**281,970**	**227.3**	**93,351**	**83.0**	**91,942**	**110.5**	**$ 404,185**	**$ 1,064**	**$ 2,050**	**$ 177,113**	**$ 314**	**$ 706**

[1] WQ = direct water quality benefit (direct drainage areas), P/M = BMP preservation and maintenance reduction (indirect water quality benefit).

[2] TMDL watershed.

11.7. Recommended Scenario

Table 11-7. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for Recommended enhanced sweeping scenario using mechanical broom and regenerative air technologies (Table 7-1).

Sweeping Scenario:
1. Zones designated as 'WQ' swept twice monthly during the sweeping season. Sweeping can be reduced to once monthly during July and August.
2. Zone designated as 'P/M' swept monthly.

					LOAD RECOVERY				LOAD REDUCTION				COSTS					
					Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
					Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	Sweeping Zone	Sweeping Priority[1]	Curb-miles	# Sweepings	TS	TP	TS	TP	TS	TP	TS	TP	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)
Clear Lake	CL1	WQ	13.5	12	23299	18.4	32,031	25.2	3183	8.4	4376	11.5	$ 22,586	$ 896	$ 1,968	$ 5,297	$ 210	$ 462
	CL2	P/M	9.2	7	10292	7.9	13,910	10.6	772	2.0	1043	2.7	$ 8,980	$ 847	$ 3,389	$ 2,108	$ 199	$ 796
	CL3	P/M	47.4	7	44082	32.7	59,576	43.9	1102	4.1	1489	5.5	$ 46,262	$ 1,054	$ 8,430	$ 10,838	$ 247	$ 1,975
				Subtotal	**77,673**	**59.0**	**105,517**	**79.7**	**5,057**	**14.4**	**6,909**	**19.6**	**$ 77,828**	**$ 977**	**$ 3,968**	**$ 18,244**	**$ 229**	**$ 930**
Forest Lake	FL1	WQ	17.3	12	41,640	35.0	57,245	47.9	41640	35.0	57245.0	47.9	$ 28,944	$ 604	$ 604	$ 6,916	$ 144	$ 144
	FL2	WQ	12.9	12	20,677	16.1	28,426	22.0	16955	13.2	20659.8	18.0	$ 21,638	$ 984	$ 1,199	$ 5,127	$ 233	$ 284
	FL3	WQ	18.7	12	32,273	25.4	44,368	34.8	26594	20.9	34739.5	28.7	$ 31,286	$ 899	$ 1,091	$ 7,306	$ 210	$ 255
	FL4	P/M	27.2	7	36,607	29.1	49,474	39.1	13023	10.4	5280.2	13.9	$ 26,475	$ 677	$ 1,903	$ 6,223	$ 159	$ 447
	FL5	P/M	11.0	7	12,770	9.9	17,258	13.3	3596	2.8	918.3	3.7	$ 10,719	$ 806	$ 2,862	$ 2,582	$ 194	$ 689
	FL6	P/M	28.8	7	32,220	24.7	43,545	33.2	9230	7.1	1711.3	9.5	$ 28,098	$ 846	$ 2,955	$ 6,546	$ 197	$ 688
				Subtotal	**176,186**	**140.2**	**240,316**	**190.3**	**111,037**	**89.3**	**120,554**	**121.8**	**$ 147,160**	**$ 773**	**$ 1,208**	**$ 34,700**	**$ 182**	**$ 285**
Shields Lake[2]	Shields	WQ	5.4	12	**6,269**	**4.8**	**8,472**	**6.5**	**1567.2**	**1.2**	**635.4**	**1.6**	**$ 5,264**	**$ 810**	**$ 3,239**	**$ 1,237**	**$ 190**	**$ 761**
Keewahtin Lake	Keewahtin	P/M	5.4	7	**6,269**	**4.8**	**8,472**	**6.5**	**2228.0**	**1.7**	**600.2**	**2.3**	**$ 5,295**	**$ 815**	**$ 2,292**	**$ 1,244**	**$ 191**	**$ 538**
Sunrise River/Comfort Lake[2]	SR/C1	WQ	20.3	12	33,763	26.4	46,417	36.2	16881.7	13.2	6962.6	18.1	$ 33,992	$ 939	$ 1,878	$ 7,969	$ 220	$ 440
	SR/C2	P/M	8.6	7	8,299	6.2	11,216	8.3	2074.8	1.5	841.2	2.1	$ 8,374	$ 1,009	$ 4,036	$ 1,963	$ 236	$ 946
	SR/C3	P/M	12.9	7	11,997	8.9	16,214	11.9	1499.6	1.1	405.4	1.5	$ 12,573	$ 1,057	$ 8,452	$ 2,946	$ 248	$ 1,980
				Subtotal	**54,060**	**41.5**	**73,847**	**56.4**	**20,456**	**15.9**	**8,209**	**21.7**	**$ 54,939**	**$ 974**	**$ 2,536**	**$ 12,877**	**$ 228**	**$ 594**
				TOTAL	**320,456**	**250.4**	**436,624**	**339.4**	**140,346**	**122.6**	**136,908**	**167.0**	**$ 290,485**	**$ 856**	**$ 1,739**	**$ 68,301**	**$ 201**	**$ 409**

[1] WQ = direct water quality benefit (direct drainage areas), P/M = BMP preservation and maintenance reduction (indirect water quality benefit).

[2] TMDL watershed.

11.8. Maximum Scenario

Table 11-8. Estimated total solids and phosphorus recovery, load reduction, and sweeping cost estimates for Maximum enhanced sweeping scenario using mechanical broom and regenerative air technologies (Table 7-1).

Sweeping Scenario:
1. Zones designated as 'WQ' swept either weekly or twice monthly during the sweeping season.
2. Zone designated as 'P/M' swept monthly.

					LOAD RECOVERY				LOAD REDUCTION				COSTS					
					Estimated Watershed Load Recovery (lb/yr)				Reduction to Waterbody through Sweeping (lb/yr)				Contract Sweeping			City-Owned Sweeper		
					Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper		Mechanical Broom Sweeper		Vacuum/Regen Air Sweeper							
Waterbody	Sweeping Zone	Sweeping Priority[1]	Curb-miles	# Sweepings	TS	TP	TS	TP	TS	TP	TS	TP	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)	$	$/lb-P (RECOVERY)	$/lb-P (REDUCTION)
Clear Lake	CL1	WQ	13.5	28	31904	24.3	44,324	33.6	4359	11.1	6056	15.3	$ 52,700	$ 1,568	$ 3,444	$ 10,671	$ 318	$ 697
	CL2	P/M	9.2	7	10292	7.9	13,910	10.6	772	2.0	1043	2.7	$ 8,980	$ 847	$ 3,389	$ 1,831	$ 173	$ 691
	CL3	P/M	47.4	7	44082	32.7	59,576	43.9	1102	4.1	1489	5.5	$ 46,262	$ 1,054	$ 8,430	$ 9,408	$ 214	$ 1,714
				Subtotal	**86,278**	**64.9**	**117,810**	**88.1**	**6,233**	**17.1**	**8,589**	**23.4**	**$ 107,942**	**$ 1,225**	**$ 4,605**	**$ 21,909**	**$ 249**	**$ 935**
Forest Lake	FL1	WQ	17.3	28	57,019	46.3	79,216	64.0	57019	46.3	79216.0	64.0	$ 67,535	$ 1,055	$ 1,055	$ 13,650	$ 213	$ 213
	FL2	WQ	12.9	28	28,314	21.3	39,336	29.4	23217	17.4	28589.2	24.1	$ 50,489	$ 1,717	$ 2,094	$ 10,166	$ 346	$ 422
	FL3	WQ	18.7	14	35,137	27.1	48,460	37.2	28955	22.3	37943.4	30.7	$ 36,500	$ 981	$ 1,191	$ 7,447	$ 200	$ 243
	FL4	P/M	27.2	7	36,607	29.1	49,474	39.1	13023	10.4	5280.2	13.9	$ 26,475	$ 677	$ 1,903	$ 5,549	$ 142	$ 399
	FL5	P/M	11.0	7	12,770	9.9	17,258	13.3	3596	2.8	918.3	3.7	$ 10,719	$ 806	$ 2,862	$ 2,309	$ 174	$ 617
	FL6	P/M	28.8	7	32,220	24.7	43,545	33.2	9230	7.1	1711.3	9.5	$ 28,098	$ 846	$ 2,955	$ 5,720	$ 172	$ 601
				Subtotal	**202,067**	**158.3**	**277,289**	**216.2**	**135,039**	**106.2**	**153,658**	**145.9**	**$ 219,817**	**$ 1,017**	**$ 1,506**	**$ 44,842**	**$ 207**	**$ 307**
Shields Lake[2]	Shields	WQ	5.4	14	**9,778**	**7.5**	**13,486**	**10.3**	**2444.6**	**1.9**	**1011.5**	**2.6**	**$ 10,527**	**$ 1,022**	**$ 4,088**	**$ 2,141**	**$ 208**	**$ 831**
Keewahtin Lake	Keewahtin	P/M	5.4	7	**6,269**	**4.8**	**8,472**	**6.5**	**2228.0**	**1.7**	**600.2**	**2.3**	**$ 5,295**	**$ 815**	**$ 2,292**	**$ 1,080**	**$ 166**	**$ 468**
Sunrise River/Comfort Lake[2]	SR/C1	WQ	20.3	14	36,760	28.2	50,698	38.7	18380.1	14.1	7604.7	19.4	$ 39,657	$ 1,025	$ 2,049	$ 8,064	$ 208	$ 417
	SR/C2	P/M	8.6	7	8,299	6.2	11,216	8.3	2074.8	1.5	841.2	2.1	$ 8,374	$ 1,009	$ 4,036	$ 1,704	$ 205	$ 821
	SR/C3	P/M	12.9	7	11,997	8.9	16,214	11.9	1499.6	1.1	405.4	1.5	$ 12,573	$ 1,057	$ 8,452	$ 2,557	$ 215	$ 1,719
				Subtotal	**57,056**	**43.2**	**78,128**	**58.9**	**21,954**	**16.7**	**8,851**	**22.9**	**$ 60,604**	**$ 1,029**	**$ 2,645**	**$ 12,325**	**$ 209**	**$ 538**
				TOTAL	**361,448**	**278.8**	**495,185**	**380.0**	**167,899**	**143.7**	**172,710**	**197.2**	**$ 404,185**	**$ 1,064**	**$ 2,050**	**$ 82,296**	**$ 217**	**$ 417**

[1] WQ = direct water quality benefit (direct drainage areas), P/M = BMP preservation and maintenance reduction (indirect water quality benefit).

[2] TMDL watershed.