Enhanced Street Sweeping Analysis

Martin and Linwood Lakes: Direct Drainage Subwatersheds

Report Prepared for Linwood Township by

ANOKA CONSERVATION DISTRICT

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Background

Street sweeping is a cost-effective way to reduce nutrient and sediment loads entering lakes, streams and wetlands from storm sewers. Sweeping is typically completed in the spring to remove accumulated sediment from winter road treatment, and again in the fall to reduce leaf litter. However, trees adjacent to roadways can be a significant contributor of nutrient loading throughout the year as they drop seeds, pollen, leaves, and other organic debris. Similarly, large gaps in traditional fall and spring sweeping schedules give these materials time to re-accumulate and flush into storm drains before they can be removed.

Figure 1. Leaves, seeds, and other tree debris accumulating in road gutters will eventually wash into storm drains and downstream waterbodies unless they are removed.

Enhanced street sweeping is the incorporation of additional sweeping protocols, the timing and location of which are targeted to maximize water quality protection. One way to prioritize locations for enhanced sweeping is to quantify tree canopy cover overhanging and immediately adjacent to roadways; this is because tree canopy cover is highly correlated with the amount of recoverable organic materials on roadways (Kalinosky, 2015) and average total phosphorus concentrations in stormwater runoff (Janke et al. 2017). Tree canopy data can then be combined with stormwater infrastructure information to identify roadways likely contributing most to nutrient inputs derived from fallen tree materials.

An enhanced street sweeping analysis was completed for residential areas draining directly to Martin and Linwood lakes; these lakes are on the State impaired waters list and are priorities for improvement in local water plans. The majority of paved streets in these drainage areas are currently swept once per year in the late spring/ early summer. However, these well-established neighborhoods contain high quantities of mature trees and some stormwater infrastructure, resulting in several roadways that are excellent candidates for enhanced street sweeping protocols. This report describes enhanced street sweeping scenarios that would maximize the cost efficiency of pollutant removal from these roadways.

Methods

Study Areas

All residential areas within or immediately adjacent to the direct drainage subwatershed for Martin Lake and the direct drainage subwatershed for the southern shore of Linwood Lake (see *Appendix A* for maps) were included in enhanced street sweeping considerations. Streets elsewhere throughout Linwood Lake's direct drainage subwatershed were not considered because they are unpaved and/or lack stormwater infrastructure, and thus are not suitable or recommended for enhanced street sweeping. Subwatershed boundaries for both lakes were delineated using ArcGIS software with high resolution LiDAR and storm sewer datasets.

Tree Canopy Assessment

Tree canopy cover within the study areas was analyzed following methodology in the *Tree Canopy Assessment Protocol for Enhanced Street Sweeping Prioritization*, produced by Emmons and Oliver Resources Inc. (EOR) for the Lower St. Croix Watershed Partnership (LSCWP).

Figure 2. Roadway buffers, derived from MNDOT right-of-way widths, within which tree canopy coverage was calculated.

First, centerline data was compiled for all paved roadways within or immediately adjacent to the targeted subwatershed boundaries. Longer roads, such as East Martin Lake Dr., were split into smaller sections to increase the resolution of canopy cover estimates along them. Next, each roadway was assigned a right-of-way width corresponding with its MNDOT functional classification (*Appendix B*). Right-of-way values were then referenced to generate a buffer around each roadway, and deciduous tree canopy abundance within these buffers (total % coverage) was quantified by intersecting them with the *Twin Cities Metro Area (TCMA) Urban Tree Canopy Classification* dataset (*Figure 2*). Altogether, these processes allowed for canopy cover comparisons within the study areas (see *Appendix C* for maps), and correspondingly the prioritization of roadways most likely to contribute nutrient-rich stormwater derived from tree materials.

Stormwater Infrastructure Considerations

Both subwatersheds selected for enhanced sweeping considerations contain stormwater infrastructure such as catch basins, subsurface storm sewers, stormwater ponds, and biofiltration/ bioinfiltration areas (see *Appendix D* for stormwater infrastructure maps). These features were mapped and considered alongside tree canopy information to further gauge stormwater connectivity to Martin and Linwood lakes.

Street Sweeping Priority Ratings

Once subwatersheds were delineated and stormwater infrastructure was assessed, all candidate roadways were classified into one of three categories based on connectivity to priority lakes:

- **High Priority:** Paved roadways/ segments of roadways located within priority subwatershed boundaries and draining directly to a BMP and/or stormwater outfall at the lake's edge.
- **Lower Priority:** Paved roadways/ segments of roadways lying within priority subwatershed boundaries, but not directly connected to a stormwater BMP and/or storm sewer outfall; often, these streets drain to and through upland or wetland areas adjacent to the lake.

- **Not Recommended:** Paved roadways/ segments of roadways confirmed to fall outside of the subwatershed boundaries with no connection to priority lakes through storm sewer networks. These were not included in load recovery and cost estimates.

Because tree canopy cover is high across all candidate roadways, it was not used to assign these priority rankings. However, canopy coverage is higher on average for high priority roads compared to lower priority roads. Canopy cover can be used to further prioritize streets as needed (higher cover = higher priority) if there are limitations to the number of miles that can be swept.

Sweeping Schedules, Routes, and Scenarios

Three street sweeping schedules were developed: one which reflects current practices (one sweeping annually, completed in late spring), another which adjusts the timing of spring sweeping and adds an additional sweeping in the fall (totaling two sweepings annually), and a third which includes two sweepings per spring and fall (totaling four sweepings annually). The two enhanced sweeping schedules were developed using research findings, recommendations, and a planning calculator tool described in the street sweeping guidance manual (Kalinosky et al., 2014).

Two sweeping routes were developed: one that includes all paved streets in the Martin and Linwood Lake subwatersheds (those ranked as high *and* low priority), and another that includes *only* high priority streets in the Marin and Linwood Lake subwatersheds.

Given the street sweeping schedules and routes described above, a total of five sweeping scenarios were generated and compared: one for existing sweeping practices, and four for enhanced street sweeping options (*Table 1*).

Table 1: Street sweeping scenarios compared for roads in the direct drainage subwatersheds for Martin and Linwood lakes.

Sweeping Scenario	Sweeping Route, Frequency &Timing
Existing (Current) Sweeping	Most paved roads; 1X Annually in May
Enhanced Sweeping: Option 1	All paved roads; 2X Annually (1X in March and October)
Enhanced Sweeping: Option 2	All paved roads; 4X Annually (1X in March, May, October, November)
Enhanced Sweeping: Option 3	Only high priority roads; 2X Annually (1X in March and October)
Enhanced Sweeping: Option 4	Only high priority roads; 4X Annually (1X in March, May, October, November)

Cost and Pollutant Recovery Estimates

Pollutant load recovery, cost, and cost effectiveness estimates for the aforementioned sweeping scenarios, routes, and schedules were compared using the planning calculator tool produced by Kalinosky and others (2014). This calculator uses statistical models informed by tree canopy cover and MN-based street sweeping studies to predict the amount of solids and nutrients that can be recovered through street sweeping. A cost of $500 per mile ($250 per curb mile, based on current rates experienced by Linwood Township to contract street sweeping services) was applied to each candidate sweeping plan to compare costs and cost effectiveness.

NOTE: Pollutant load reductions achieved through street sweeping are dependent on several factors, such as when and how often streets are swept and the type of machinery that is used. For example, sweeping immediately prior to a major storm event and using a regenerative-air sweeper rather than a mechanical sweeper are both actions that will yield higher nutrient recovery rates. All load recovery, *cost, and cost effectiveness values described herein are only estimates used for relative comparisons between candidate sweeping scenarios. The load recovery planning calculator was not calibrated with data from water quality sampling or laboratory analyses of recovered street materials from the study areas.*

Findings and Recommendations

Streets Assessed and Classified

In total, 6.25 miles of candidate streets were evaluated. Of this, 2.65 miles (5.3 curb miles) are identified as high priority options for enhanced street sweeping, 2.5 miles (5 curb miles) are identified as lower priority options for enhanced sweeping, and 1.1 miles were determined to lie outside of the subwatershed boundaries and are therefore not recommended for enhanced sweeping. See *Appendix G* for a breakdown of curb miles within each subwatershed.

Canopy Cover

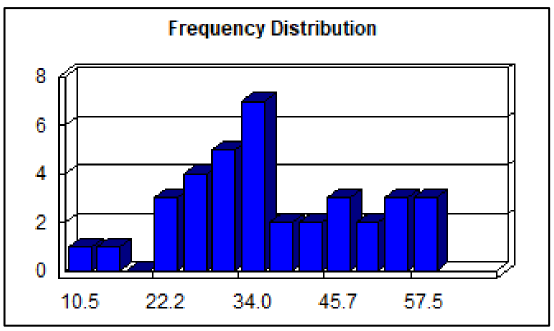


Figure 3. Frequency distribution of roadway canopy cover (% cover within roadway buffer)

Average tree canopy cover for candidate streets/ street segments ranged from 10% - 61%; however, the vast majority of streets contained very high canopy cover, with most exceeding 25% (*Figure 3*). Streets identified as high priority for enhanced sweeping averaged 43% canopy cover in the Martin Lake subwatershed and 54% canopy cover in the Linwood Lake subwatershed. While streets classified as lower priority contained lower canopy coverage on average, most still exceeded 25%. See *Appendix G* for more details on canopy coverage.

Load Recovery and Cost Estimates

March and October are the most cost-effective times to complete street sweeping, followed by other months in the spring and fall (*Appendix F*). Current street sweeping practices (occurring in May on most paved roads in the priority watersheds) yield an estimated phosphorus (P) recovery rate of 6.9 lbs/year at an average cost of $331/ lb P recovered. In comparison, all four enhanced street sweeping scenarios explored in this analysis yielded higher phosphorus recovery rates and improved the cost effectiveness of phosphorus removal. Targeting only high priority streets further improved load recovery and cost effectiveness. See *Table 2* for a summary of candidate street sweeping scenarios, and *Appendix G* for all planning calculator outputs.

Table 2. Load recovery and cost estimates for existing and candidate sweeping practices in the priority watersheds [1,2,3]

Load Recovery and Cost Estimates for Street Sweeping Scenarios					
	Existing (Current)	**Option 1***	**Option 2**	**Option 3**	**Option 4***
Month Swept	**Frequency**	**Frequency**	**Frequency**	**Frequency**	**Frequency**
March		1	1	1	1
May	1		1		1
October		1	1	1	1
November			1		1
Streets Swept	Most High and Lower Priority	All High *and* Lower Priortiy	All High *and* Lower Priority	All High Priority	All High Priority
Total Curb Miles Swept/ Year	9.1	20.6	41.2	10.6	21.2
Est. Sweeping Cost/ Year	$2,200	$5,192	$10,384	$2,772	$5,344
Est. Phosphorus Recovery (total lbs/year)	6.9	31.2	46.8	20.2	29.9
Average Cost Effectiveness ($/ lb Phosphorus Recovered)	$331.00	$166.00	$222.00	$137.00	$178.00

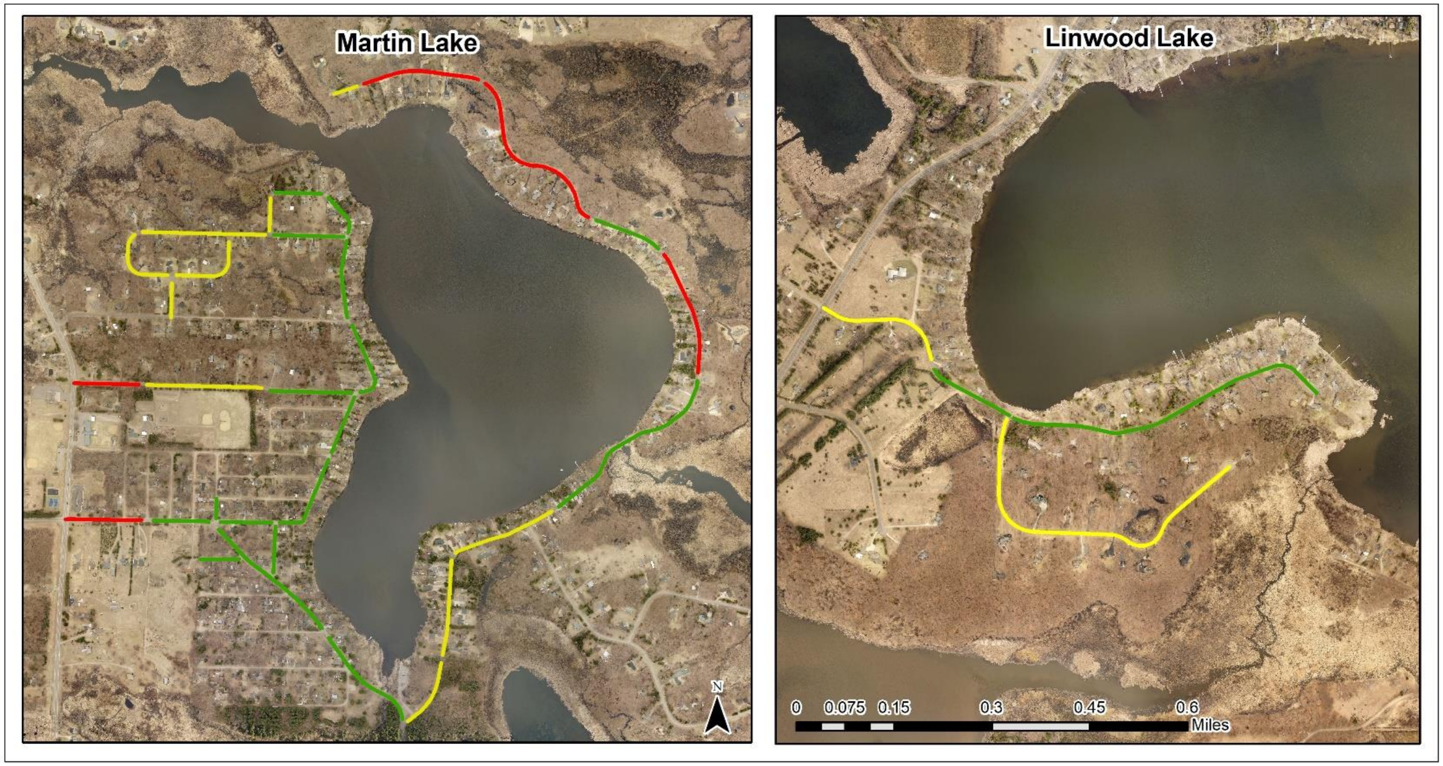
[1]Pollutant recovery values are derived from the street sweeping planning calculator and represent the total load that is predicted to be removed from the streets annually. Values do not represent load reductions to priority lakes.
[2]Calculations for areas exceeding 30% canopy cover are extrapolated by the planning calculator.
*[3]Estimates for existing practices only represent streets or sections of streets that are currently swept **and** located within the target subwatershed boundaries. It does not account for other streets that are currently swept outside of these boundaries.*

Recommendations

To maximize cost effectiveness for phosphorus removal and water quality benefits to Martin and Linwood Lakes, Option 4 is recommended. At a total cost of approximately $5,344/year, the schedule and routes under this approach would greatly increase phosphorus recovery by prioritizing high-canopy cover streets connected to priority lakes through stormwater infrastructure. However, because street sweeping services are currently contracted by Linwood Township, high mobilization expenses (if applicable) from multiple sweepings may impact the cost effectiveness of Option 4. If this is the case, Option 1 is recommended. This option is similar in total cost, cost effectiveness, and pollutant recovery rates, but sweeping is spread across both high and lower priority roads.

In summary, the recommended street sweeping schedule(s) would benefit water quality in Martin and Linwood lakes by reducing pollutant loads in the stormwater that enters them. Sweeping immediately following snowmelt removes accumulated winter pollutants before they can be flushed into sewers by heavy spring rains. Sweeping in the fall removes leaf litter and other organic debris identified as major contributors to nutrient loads in stormwater. An additional sweeping on priority roads during these seasons will further reduce accumulated pollutants in street gutters, such as pollen and seeds in the late spring and leaves that continue blowing/ falling onto roads following the initial autumnal leaf-drop and sweeping.

Enhanced Street Sweeping Route and Schedule Options



Load Recovery and Cost Estimates for Street Sweeping Scenarios	Existing (Current)	Option 1*	Option 2	Option 3	Option 4*
Month Swept	**Frequency**	**Frequency**	**Frequency**	**Frequency**	**Frequency**
March		1	1	1	1
May	1		1		1
October		1	1	1	1
November			1		1
Streets Swept	Most High and Lower Priority	All High *and* Lower Priortiy	All High *and* Lower Priority	All High Priority	All High Priority
Total Curb Miles Swept/ Year	9.1	20.6	41.2	10.6	21.2
Est. Sweeping Cost/ Year	$2,200	$5,192	$10,384	$2,772	$5,344
Est. Phosphorus Recovery (total lbs/year)	6.9	31.2	46.8	20.2	29.9
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MAP LEGEND

Sweeping Priority Ranking

- High Priority
- Lower Priority
- Not Recommended

***Option 4 is recommended for enhanced sweeping. However, if mobilization costs for contracted sweeping services are high and worsen the cost effectiveness of Option 4, Option 1 is recommended.**

Figure 4. Street sweeping route and schedule options for the direct drainage subwatersheds of Martin and Linwood Lakes. Cost and phosphorus recovery estimates for each sweeping option are provided in the table. Option 4 is the top recommendation, followed by Option 1.

References

Lower St. Croix Watershed Partnership (LSCWP) and Emmons and Oliver Resources Inc. (EOR). Tree Canopy Assessment Protocol for Enhanced Street Sweeping Prioritization. 2022.

Janke, Benjamin D., Jacques C. Finlay, and Sarah E. Hobbie. 2017. Trees and Streets as Drivers of Urban Stormwater Nutrient Pollution. Sci. Technol. DOI: 10.1021/acs.est.7b02225 Environ.

Kalinosky, P., L.A. Baker, S.E. Hobbie, R. Binter, and C. Buyarski. 2014. User Support Manual: Estimating Nutrient Removal by Enhanced Street Sweeping. Minneapolis, MN.

Kalinosky, P.M. 2015. Quantifying Solids and Nutrient Recovered Through Street Sweeping in a Suburban Watershed. A Thesis Submitted to the Faculty of University of Minnesota. Minneapolis, MN.

Appendices

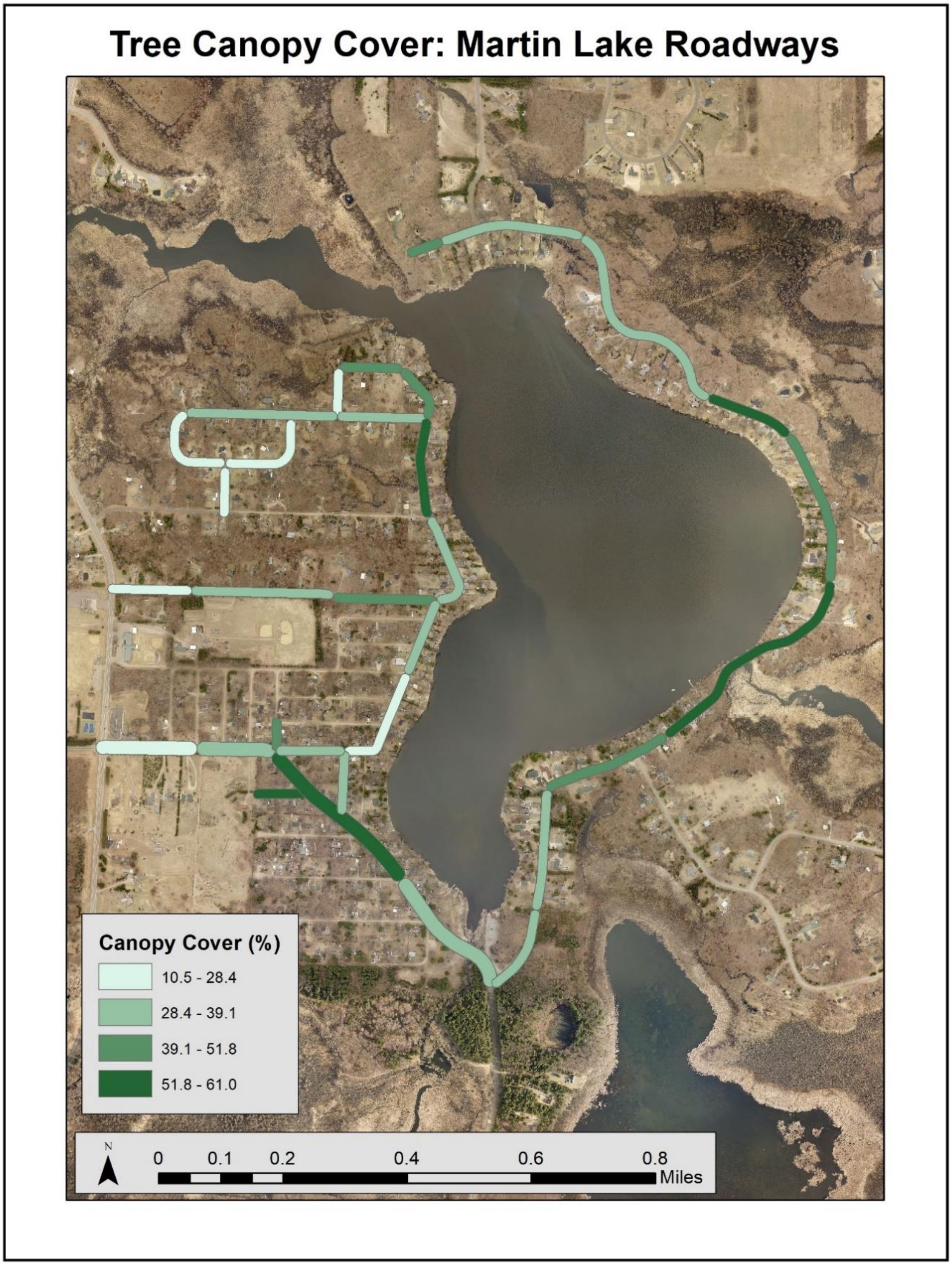
Appendix A: Targeted Lake Subwatersheds

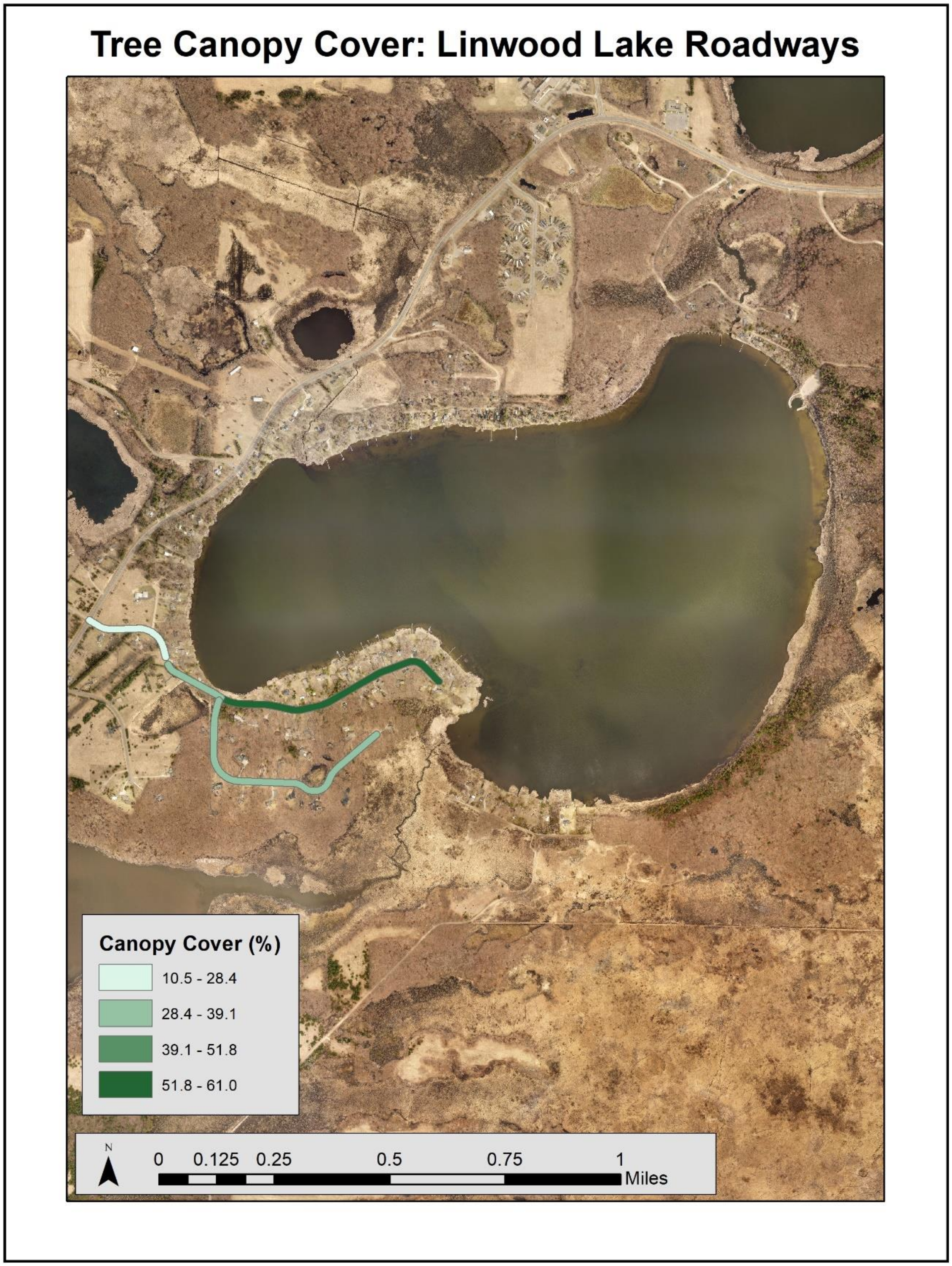
South Linwood Lake Subwatershed

Appendix B: MN Department of Transportation Roadway Classifications

MNDOT Roadway Classifications: Linwood Lake

Appendix C: Roadway Tree Canopy Cover

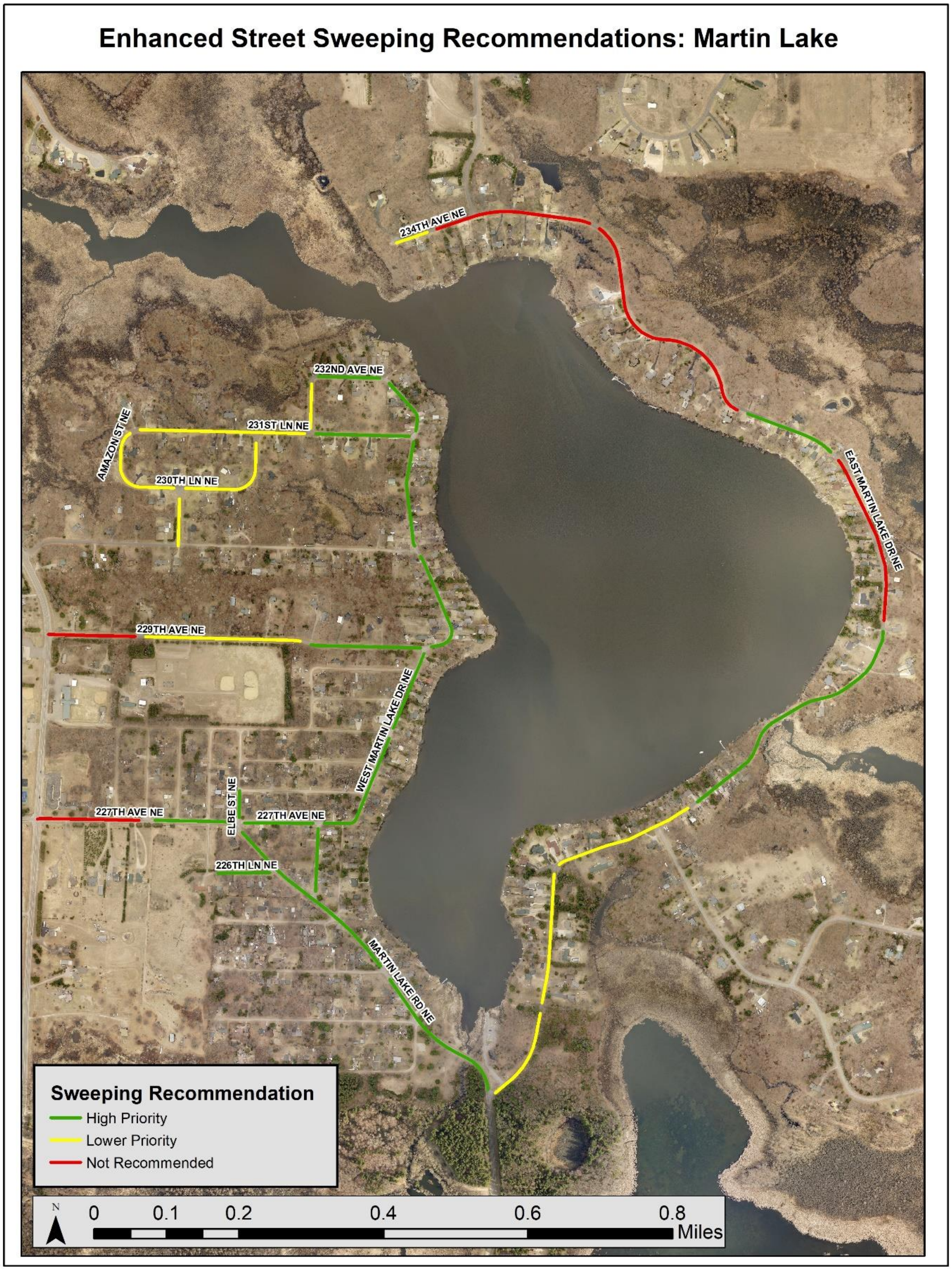



Tree Canopy Cover: Linwood Lake Roadways
Canopy Cover (%)
10.5 - 28.4
28.4 - 39.1
39.1 - 51.8
51.8 - 61.0
N
0
0.125
0.25
0.5
0.75
1
Miles

Appendix D: Stormwater Infrastructure


Linwood Lake Stormwater Infrastructure
Catch Basin
Stormwater Pond
Storm Sewer
Discharge Point
N
0
0.075
0.15
0.3
0.45
0.6
Miles

Appendix E: Enhanced Street Sweeping Recommendations



Enhanced Street Sweeping Recommendations: Linwood Lake

Appendix F: Planning Calculator Monthly Estimates – Example

Monthly Phosphorus Recovery and Cost Estimates for Martin Lake				
Month	Sweeping Events	Phosphorus, lb	Cost, $	$ Cost, lb/P
January	0	0	$ -	$ -
February	0	0	$ -	$ -
March	1	6	$1,011.00	$163.18
April	1	4	$1,011.00	$239.72
May	1	3	$1,011.00	$298.26
June	1	3	$1,011.00	$349.66
July	1	2	$1,011.00	$517.95
August	1	2	$1,011.00	$421.71
September	1	2	$1,011.00	$410.46
October	1	6	$1,011.00	$158.31
November	1	4	$1,011.00	$273.93
December	0	0	$ -	$ -

Appendix G: Planning Calculator Outputs for all Street Sweeping Scenarios

Existing Street Sweeping: Current (1X Annually in May)							
Route	Average % Canopy Cover	Total Curb Miles Swept Annually	Dry solids, lb	Nitrogen, lb	Phosphorus, lb	Cost, $	Average $ Cost/ lb P
Sub-Totals	**41**	**9.10**	**7317**	**122.8**	**6.9**	**$ 2,275.00**	**$ 331.77**
Martin: Existing Practice	41	6.30	5123	87.0	4.8	$ 1,575.00	$ 328.13
Linwood: Existing Practice	40	2.80	2194	35.8	2.1	$ 700.00	$ 340.26

Enhanced Street Sweeping: Option 1 (All Streets 2X Annually; 1X in March, 1X in October)							
Route	Average % Canopy Cover	Total Curb Miles Swept Annually	Dry solids, lb	Nitrogen, lb	Phosphorus, lb	Cost, $	Average $ Cost/ lb P
Sub-Totals	**41**	**20.60**	**32377**	**467.8**	**31.2**	**$ 5,192.00**	**$ 166.30**
Martin: High Priority Streets	43	8.00	13069	180.6	12.6	$ 2,022.00	$ 160.71
Martin: Lower Priority Streets	39	7.00	9868	116.0	9.2	$ 1,770.00	$ 191.57
Martin: All Streets	41	15.00	22938	297	21.8	$ 3,792.00	*$ 173.78*
Linwood: High Priority Streets	54	2.60	7280	156.8	7.6	$ 750.00	$ 99.13
Linwood: Lower Priority Streets	25	3.00	2160	14.4	1.8	$ 650.00	$ 354.31
Linwood: All Streets	40	5.60	9440	171	9.4	$ 1,400.00	*$ 148.93*

Enhanced Street Sweeping: Option 2 (All Streets 4X Annually; 1X in Each: March, May, October, & November)							
Route	Average % Canopy Cover	Total Curb Miles Swept Annually	Dry solids, lb	Nitrogen, lb	Phosphorus, lb	Cost, $	Average $ Cost/ lb P
Sub-Totals	**41**	**41.20**	**47111**	**774.1**	**46.8**	**$ 10,384.00**	**$ 222.10**
Martin: High Priority Streets	43	16.00	19591	312.8	19.7	$ 4,044.00	$ 205.67
Martin: Lower Priority Streets	39	14.00	14328	197.0	13.5	$ 3,540.00	$ 261.50
Martin: All Streets	41	30.00	33918	510	33.2	$ 7,584.00	*$ 228.44*
Linwood: High Priority Streets	54	5.20	9457	235.4	10.2	$ 1,300.00	$ 126.87
Linwood: Lower Priority Streets	25	6.00	3736	28.8	3.3	$ 1,500.00	$ 453.44
Linwood: All Streets	40	11.20	13193	264	13.6	$ 2,800.00	*$ 206.57*

Enhanced Street Sweeping: Option 3 (High Priority Streets ONLY, 2X Annually; 1X in March, 1X in October)							
Route	Average % Canopy Cover	Total Curb Miles Swept Annually	Dry solids, lb	Nitrogen, lb	Phosphorus, lb	Cost, $	Average $ Cost/ lb P
Sub-Totals	**41**	**10.60**	**20349**	**337**	**20.2**	**$ 2,772.00**	**$ 137.23**
Martin: High Priority	43	8.00	13069	180.6	12.6	$ 2,022.00	$ 160.48
Linwood: High Priority	54	2.60	7280	156.8	7.6	$ 750.00	$ 98.68

Enhanced Street Sweeping: Option 4 (High Priority Streets ONLY, 4X Annually; 1X in Each: March, May, October, & November)							
Route	Average % Canopy Cover	Total Curb Miles Swept Annually	Dry solids, lb	Nitrogen, lb	Phosphorus, lb	Cost, $	Average $ Cost/ lb P
Sub-Totals	**41**	**21.20**	**29048**	**548.2**	**29.9**	**$ 5,344.00**	**$ 178.73**
Martin: High Priority	43	16.00	19591	312.8	19.7	$ 4,044.00	$ 205.67
Linwood: High Priority	54	5.20	9457	235.4	10.2	$ 1,300.00	$ 126.87