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Pike Lake Subwatershed Assessment

Prepared for:

Shingle Creek WMC
City of Plymouth

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List of Acronyms

BMP	Best Management Practice
CN	Curve Number
GIS	Geographic Information System
LiDAR	Light Detection and Ranging
MIDS	Minimal Impact Design Standards
MPCA	Minnesota Pollution Control Agency
NRCS	National Resource Conservation Service
NURP	Nationwide Urban Runoff Program
P8	Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds
SCS	Soil Conservation Service
SWCD	Soil and Water Conservation District
TP	Total Phosphorus
TSS	Total Suspended Solids

1.0 Summary

The Shingle Creek Watershed Management Commission (SCWMC) Third Generation Watershed Management Plan Implementation Plan calls for systematically completing subwatershed assessments in high-priority areas to reduce pollutant loads and runoff volumes throughout the watershed.

The Plymouth portion of the Pike Lake watershed is a moderately impervious area that developed under varying levels of stormwater controls and discharges to the impaired Pike Lake. The purpose of this study is to help the City of Plymouth reduce pollutant loads and runoff volumes discharging to Pike Lake through implementation of stormwater of Best Management Practices (BMPs).

A watershed model (P8) was developed to determine existing TP loading from the City of Plymouth portion of the Pike Lake watershed. P8 model output was used to identify several potential locations for stormwater BMPs throughout the study area. Each BMP was then evaluated to determine appropriate size along with estimated cost and phosphorus load reductions. Thus, this report provides the City a BMP cost benefit analysis which will help prioritize future stormwater BMP implementation. This study identified 20 potential BMP options throughout the project study area. If all of the proposed BMPs were implemented, TP loading to Pike Lake would be reduced by approximately 49 pounds per year.

Section 3.0 of this report presents results of the modeling analysis, Section 4.0 provides general descriptions of the types BMPs proposed in this report, and Section 5.0 presents the list of proposed BMPs and cost-benefit analysis.

2.0 Background

2.1 PURPOSE

The purpose of this study is to provide the City of Plymouth with a variety of stormwater BMP options to help reduce phosphorus loads to Pike Lake. Approximately 1,071 acres drain to Pike Lake, 33% of which are located within the City of Plymouth. Pike Lake is currently classified as 'Impaired' for excess nutrients by the Minnesota Pollution Control Agency (MPCA). A Total Maximum Daily Load (TMDL) Study for Pike Lake was completed in 2010, concluding that nutrient loads (TP) from the watershed need to be reduced by approximately 37%, or approximately 165 pounds per year to help the lake meet state water quality standards.

The City of Plymouth portion of the Pike Lake watershed contains a mix of land uses with a moderate impervious area that developed under varying levels of stormwater management and BMPs. This report focuses on areas with minimal and/or undersized stormwater treatment and identifies opportunities for implementing BMPs to reduce phosphorus loads. Section 4 of this report provides general descriptions of several types of stormwater BMPs, and Section 5 provides specific BMP options throughout the study area. The BMPs identified in this report could be implemented immediately or over time if/when funding becomes available or future capital improvement/redevelopment projects are incorporated throughout the study area.

2.2 STUDY AREA

The area identified for potential improvement is shown in Figure 2-1. This area covers approximately 354 acres of land within the City of Plymouth and is generally bounded by Quinwood Lane to the west, Bass Lake Road to the south, Nathan Lane to the east, and Pike Creek (Plymouth-Maple Grove border) to the north. The study area only includes the City of Plymouth portion of the Pike Lake watershed that drains directly to Pike Lake and to Pike Creek which discharges to Pike Lake on the southwest corner of the lake. The study area does not include the Maple Grove portion of the Pike Lake watershed (approximately 650 acres), and therefore this report does not include potential in-channel practices within Pike Creek and the Pike Creek corridor. These practices will be evaluated as part of the Commission's 5-year TMDL Review for Pike Lake which is currently underway and will be completed in 2018.

Approximately 49% of the study area already incorporates some form of stormwater management. There are 32 constructed stormwater ponds (See Appendix B) and smaller basins that capture and store runoff from the City prior to discharging to Pike Creek or directly to Pike Lake. The smaller basins were likely small wetlands and low-lying areas that have been incorporated into the City drainage/storm sewer network.

Figure 2-1. Pike Lake Subwatershed Assessment Study Area.

2.3 LAND USE

Land use within the study area is a mix of single and multifamily developed, golf course, park land, industrial and other land uses based on the 2010 Met Council Land Use Layer (Table 2-1).

Table 2-1. Land use within the study area.

Land Use	Study Area	
	Acres	*Percent*
Single Family	119	*34%*
Golf Course	71	*20%*
Park, Recreational, or Preserve	70	*20%*
Industrial and Utility	37	*10%*
Open Water/Wetland	23	*6%*
Multifamily	20	*6%*
Undeveloped	10	*3%*
Retail and Other Commercial	4	1%
Total	354	100%

2.4 SOIL TYPE

The hydrologic soil group classifications based on Natural Resources Conservation Service (NRCS) Web Soil Survey data for the study area is predominantly groups A and B/D (Table 2-2 and Figure B-2 in Appendix B). Type A soils are very conducive to infiltration, while type B/D soils are conducive to infiltration if proper drainage is provided.

Table 2-2. Hydrologic soil groups within the Study Area

Hydrologic Soil Type	Study Area	
	Acres	*Percent*
A	203	*57%*
A/D	--	--
B	9	*3%*
B/D	77	*22%*
C	26	*7%*
C/D	14	*4%*
D	25	*7%*
Total	354	100%

3.0 Modeling

3.1 P8 MODELING METHODOLOGY

Wenck evaluated stormwater runoff volume and water quality in the study area by reviewing existing conditions using Geographic Information Systems (GIS) and data provided by City. Wenck modeled the existing area hydrology and water quality using the computer program P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds). P8 is a computer model originally developed for the United States Environmental Protection Agency (USEPA) for simulating the generation and transport of stormwater runoff pollutants in watersheds. P8 is a useful diagnostic tool for evaluating and designing watershed improvements and BMPs. The model requires user input on watershed characteristics, basin attributes, local precipitation and temperature, and other parameters relating to water quality and basin removal performances. Due to annual variability in historical precipitation records and subsequent model results, the P8 model was executed for a 10-year precipitation record to obtain average loading estimates that were used in the analysis.

The watershed characteristics used for the P8 model includes the NRCS hydrologic soil group, land use classification, and the impervious fraction of the land in the watershed. The land use classification was obtained from the 2010 Met Council land use layer as described in Section 2.3 and soil data was obtained from the NRCS Web Soil Survey as described in Section 2.4. The hydrologic soil group characterizes infiltration capacity of the soils and runoff characteristics. ArcView GIS software was used extensively in assessing watershed characteristics.

In P8, pervious and impervious areas are modeled separately. Runoff volumes from pervious areas are computed using the SCS Curve Number (CN) method. Runoff from impervious areas begins once the cumulative storm rainfall volume exceeds the specified depression storage, with the runoff rate equal to the rainfall intensity.

Because P8 calculates runoff separately from pervious and impervious areas, it was necessary to determine the impervious fraction of each watershed. For the P8 model, the impervious areas were assumed to be all directly connected. An impervious area is considered directly connected if runoff flows directly from it into the conveyance system via continuous paved areas. The directly-connected impervious fraction was calculated for each watershed based on the land use(s), with each land use having an assumed impervious percent. The assumed percent impervious associated with each land use is listed in Appendix A.

Within each watershed a pervious CN was calculated based on the soil type and land use. The pervious CN was area weighted in each subwatershed using the values described in Appendix A.

The P8 model requires an hourly precipitation record (rain and snowfall) and daily temperature record. Precipitation and temperature data were obtained from the New Hope Weather Station.

The treatment devices utilized in P8 provide collection, storage, and/or treatment of watershed discharges. A variety of treatment devices can be modeled in P8, including detention basins (wet or dry), infiltration basins, swales, buffers, aquifers, and pipes.

Detention basin (stormwater ponds) volume information was obtained from City as-built plans (when available) with data gaps filled in using Light Detection and Ranging (LiDAR) data. For vegetated wetland areas that do not have as-built information, it was assumed that the permanent pool depth was 1 foot. For open water wetland areas, it was assumed that the permanent pool depth was 2 feet.

Basin outlet information was obtained from as-built plans (when available). If as-built plans were not available, the outlet was assumed to be the hydraulic equivalent of a 12-inch diameter culvert. LiDAR and aerial photography were used to approximate overland outlets where identified and as-built information was not available.

The NURP50 sediment particle distribution and concentration file was selected for the P8 models. The component concentrations in the NURP50 file represent the 50th percentile (median) values compiled in the Environmental Protection Agency's (EPA's) Nationwide Urban Runoff Program (NURP).

At this time, no water quality data has been collected in this portion of the Pike Lake watershed. Thus, the P8 model used in this assessment was not calibrated, adjusted, or validated to any observed data. It should be noted that the Shingle Creek WMC will be monitoring flow and water quality in Pike Creek in 2017, however these data were not available at the time this report was completed.

3.2 EXISTING CONDITIONS P8 MODEL

Wenck created an existing conditions P8 model for the entire study area to mimic the watershed as it is today by routing runoff through the city storm sewer system, stormwater ponds, and surface channels/streams. The study area was broken into 41 individual subwatersheds as shown in Figure B-1 and Appendix B.

Under existing conditions, the entire study area generates approximately 91 pounds of TP annually. It is important to point out that these estimates include the expected removals due to the 18 existing stormwater BMPs throughout the study area. The existing conditions P8 model estimates that these BMPs currently remove approximately 64 pounds annually. Figure B-1 in Appendix B shows the locations of the existing stormwater practices throughout the study area. Figures B-4 and B-5 in Appendix B give breakdowns of existing TP loads by subwatershed. It is clear from these figures that the subwatersheds with the highest annual pollutant loads tend to be those that do not have existing BMPs in place and/or are highly impervious.

4.0 BMP Options

The purpose of this study is to identify a variety of BMP options to reduce stormwater pollutant loads within the study area. This section provides general descriptions of a few BMPs that were proposed within the study area to reduce phosphorus and sediment loads and runoff volumes. Specific locations for these BMPs will be discussed in Section 5.

4.1 INFILTRATION BASINS

Infiltration basins combine surface storage, infiltration, biological treatment, plant uptake, and evapotranspiration into a single BMP. Stormwater is collected into the treatment area which consists of a grass buffer strip, sand bed, ponding area, organic or mulch layer, planting soil, and plants. The infiltration system incorporates the more natural means of managing stormwater than any other treatment type.

Infiltration basin along a parking lot in St. Paul, MN.

The adjacent photo shows an infiltration basin along the perimeter of a parking lot in downtown St. Paul. Note the ribbon curb that defines the edge of the pavement but also allows runoff to flow over the curb, through the vegetated buffer and into the bioretention basin.

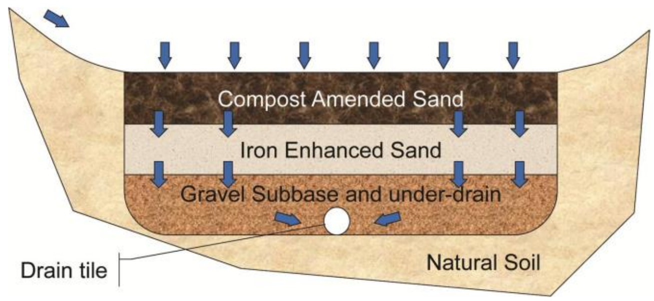
Opportunities to include infiltration systems in the landscape include landscaping islands, cul-de-sacs, parking lot margins, commercial setbacks, open space, rooftop drainage and streetscapes (i.e., between the curb and sidewalk). Infiltration basins are extremely versatile because of their ability to be incorporated into landscaped areas. Maintenance activities typically include sediment removal and maintenance of the vegetation. Invasive species need to be managed, dead vegetation must be removed, and dead plants must be replaced.

4.2 IRON-ENHANCED SAND FILTERS

Iron-enhanced sand filters (IESF) are filtration BMPs that incorporate filtration media mixed with iron. The iron removes several dissolved constituents, including phosphate, from stormwater. Iron-enhanced sand filters could potentially include a wide range of filtration BMPs with the addition of iron; however, iron is not appropriate for all filtration practices due to the potential for iron loss or plugging in low oxygen or persistently inundated filtration practices.

Iron-enhanced sand filters may be applied in the same manner as other filtration practices and are more suited to urban land use with high imperviousness and moderate solids loads. Because the primary treatment mechanisms are filtration and chemical binding and not volume reduction, vegetating the filter is not needed and may impair the filter function.

Iron-enhanced sand filters require underdrains that serve to convey filtered and treated stormwater and to aerate the filter bed between storms. The exit drain from the iron-enhanced sand filter should be exposed to the atmosphere and above downstream high water levels in order to keep the filter bed aerated. Iron-enhanced sand filters may be used in a treatment sequence, as a stand-alone BMP, or as a retrofit. If an iron-enhanced sand filter basin is used as a stand-alone BMP, an overflow diversion is recommended to control the volume of water, or more specifically, the inundation period in the BMP. As with all filters, it is important to have inflow be relatively free of solids or to have a pre-treatment practice in sequence.



Maintenance of the iron-enhanced sand filters consists of removing accumulated sediment and debris, pulling out all vegetation throughout the growing season, and tilling the soil to prevent clumping and preferential flow paths.

4.3 STREET SWEEPING

Street sweeping can be a cost effective tool for nutrient reduction, especially for directly connected impervious areas near streams or lakes. Sediment and nutrient removal by street sweeping is influenced by the amount of canopy cover, sweeping frequency, and month of sweeping. Typically, nutrient loads recovered by street sweepers are higher in routes with higher canopy cover, and in the fall and spring. Spring (March and April) is the best time for cleaning up solids, including road salt, sand, and fines left behind from soil and debris entrained in snow after the snow melts. Fall sweeping, after fall leaf drop, is also a very important time for nutrient recovery.

5.0 Proposed BMPs

5.1 OVERVIEW OF PROPOSED BMPS

Wenck used the existing conditions P8 model described in Section 3.2 to identify high potential loading subwatersheds throughout the study area that may be good candidates for stormwater BMP practices. It is clear from the existing conditions model (see Figure B-1 in Appendix B) that the subwatersheds with the highest annual pollutant loads tend to be those with large amounts of impervious area and those that have undersized or no stormwater BMPs in place. Thus, BMP siting mainly focused in these subwatersheds and several project opportunities were identified to reduce TP loads to Pike Lake.

5.2 BMP SIZING, DESIGN, AND POLLUTANT REDUCTION CONSIDERATIONS

Wenck used methodology and research presented in MPCA's Minnesota Stormwater Manual (link) to evaluate sizing, design, and pollutant reductions for the BMPs sited in this study. In general, the infiltration practices sited in this report were sized to retain and infiltrate 1.1 inches of runoff (consistent with MPCA's Minimal Impact Design Standards) and to meet a drawdown time of 48 hours or less. In some cases, footprint size and/or soil limitations would not allow for treatment of 1.1 inches of runoff and therefore the BMPs were adjusted accordingly. Similar to infiltration practices, the filtration practices were sized to treat the 1.1 inch runoff event, where possible, and meet a drawdown time of 48 hours or less.

TP reductions for all infiltration and filtration practices were calculated based on each BMP's estimated water quality treatment volume and the recommended pollutant removal efficiency for each general BMP type presented in the Minnesota Stormwater Manual. Street sweeping in the directly connected impervious areas of the study area was evaluated using the University of Minnesota's Planning Calculator for Estimating Nutrient Removal through Street Sweeping. This calculator is designed to provide a rough estimate of the solids and nutrients (phosphorus and nitrogen) loads that can be recovered through street sweeping based on the timing and frequency of sweeping operations and an estimate of the percent tree canopy cover over the streets to be swept. The calculator was calibrated to conditions in Prior Lake, MN and is recommended for use in the greater Twin Cities metropolitan Region or geographic areas with comparable climate and vegetation.

5.3 PLANNING LEVEL COST ESTIMATES

Planning level cost estimates were developed and a cost benefit analysis was performed to aid in prioritization of proposed BMPs. The cost estimates are based on past experience with BMP retrofit projects and regional treatment projects. The cost estimates include:

- Construction costs for the proposed BMP, such as: mobilization, site preparation, outlet modification, minor storm sewer or structural work, and erosion control
- Level 2 sediment disposal costs (if any) according to the MPCA guidance
- Engineering costs (typically 10% of BMP cost)
- 30% contingency cost
- Annual maintenance estimate (included in the 30-year cost)
- Larger maintenance project estimate every 10 years (included in the 30-year cost)

These costs do not include wetland mitigation, major structural work, and/or land/easement acquisition. All costs were rounded to reflect planning level estimates. Therefore, it is recommended that a more detailed feasibility assessment and cost estimate be prepared for specific projects the City wishes to pursue.

5.4 LIMITIATIONS AND ASSUMPTIONS

Due to limited information, potential BMP locations presented in this section require further investigation before they can be implemented. Topography, soil types, utilities, and future land use are needed to proceed with final design. All of the proposed projects have potential design challenges and cost considerations should be fully investigated prior to consideration. During final design and monitoring, a proposed project may not meet estimated pollutant removal effectiveness and/or the cost estimates presented in this report due to design challenges that may be identified during the design process. BMP performance can also vary from year to year based on climatic conditions and other environmental factors. In addition, ongoing and consistent maintenance activities are required to maintain performance. This includes sediment removal, vegetation maintenance, filter maintenance and monitoring.

5.5 PROPOSED BMP REDUCTIONS AND COST BENEFIT ANALYSIS

As discussed in Section 3.2, the current condition P8 model for the study area estimates average loading of approximately 91 pounds of TP annually. The distributions of loads were used to identify potential BMP opportunities to reduce pollutant loading throughout the study area.

Twenty potential BMPs were sited throughout the study area (See Figures B-6 and B-7 in Appendix B). In siting and developing the list of proposed BMPs, Wenck focused primarily on public owned property such as easements, parks, and City/County/State right of way as they are usually easier to implement, maintain, and manage over the life of the practice. If all the proposed BMPs were implemented, Pike lake would see reduced TP loads of approximately 49 pounds (54%) per year. In addition, the proposed BMPs would infiltrate approximately 12 acre-feet of runoff per year. As discussed in Section 2.1, the TMDL phosphorus reduction target is 37%, or approximately 165 pounds per year from both Plymouth and Maple Grove. Table 5-1 is a summary of the estimated TSS and TP reductions, construction cost estimates, 30-year life cycle costs, and cost benefit analysis for the proposed BMPs. Below is a general description of each proposed BMP.

Iron-enhanced Sand Filter Benches (Subwatersheds 9, 37, 2, 11, 10)

The P8 model indicates that the BMP practices (ponds) in subwatersheds 2, 9, 10, 11, and 37 have large drainage areas and the water leaving these ponds is high in phosphorus (see Figures B-4 and B-5 in Appendix B). The model also suggests that ponds 9, 10, and 11 are overloaded and undersized and therefore do not effectively treat the sediment and phosphorus loads delivered to these systems. Excavation of these ponds to increase treatment capacity was considered, however this was not a feasible option due to limited space, high potential costs, and minimal load reduction benefits (<1.0 lbs/yr TP reduction).

It was determined that a better retrofit option for these ponds would be to install IESF benches. The proposed IESF benches would be sized to treat the 1.1 inch storm event and the footprint of the filters would work within the space limitations of each site. These IESF benches would be capable of removing a significant amount of TP (3.8-10.5 lbs/yr) and are relatively cost-effective options (Table 5-1).

Enhanced Street Sweeping (Subwatersheds 9, 11-18)

Street sweeping in subwatersheds 9, and 11-18 was evaluated using the University of Minnesota Street Sweeping Calculator. These subwatersheds were targeted for enhanced street sweeping since they drain directly to Pike Creek or Pike Lake with no stormwater treatment. Currently, the City conducts sweeping in these areas three times per year:

- First sweeping completed by April 30th
- Second sweeping conducted between June 1st and June 8th
- Third sweeping conducted between August 16th and August 31st

Based on this schedule, it is estimated that approximately 4.9 pounds per year of TP is currently removed in subwatersheds 9, and 11-18 by street sweeping. Increasing sweeping frequency to six times per year in these subwatersheds would remove approximately two times more phosphorus (11.7 lbs/yr) than the current schedule. The street sweeping calculator suggests that conducting sweeping events in March, October and November, in addition to the current April, June, and August schedule would result in the highest TP removal. Table 5-1 summarizes the estimated costs and phosphorus removal benefits of the added street sweeping. The City's estimated cost of $56.50 per curb mile was used to estimate the sweeping costs presented in Table 5-2. These results indicate that enhanced street sweeping is more cost effective than the neighborhood raingardens proposed for these subwatersheds (see discussion below). However, depending on how many raingardens are constructed, the raingardens offer slightly higher annual TP load reductions and also provide volume reduction benefits.

Neighborhood Raingardens (Subwatersheds 11, 12, 13, 15, 16, 19)

Fourteen infiltration basins/raingardens were sited throughout subwatersheds 11-13, 15, 16, and 19 (see Figure B-6 in Appendix B). Most of these practices are located in the neighborhood north of Bass Lake Road, however three infiltration basins were also sited within the Bass Lake Road center median. The neighborhood raingardens would be installed above selected storm sewer catchments and include curb-cuts to capture and treat as much water as possible prior to discharging to the main City storm sewer. The Bass Lake Road basins would treat stormwater runoff from the road as well as the small drainage area south of Bass Lake Road.

The infiltration basins/raingardens were sized to treat the 1.1 inch rain event where possible, however, due to private property and space limitations near the catchments, some of the gardens would not be able to treat the 1.1 inch event. If all of the raingardens were constructed, they would potentially infiltrate 12 acre-feet of runoff per year and remove approximately 11 pounds of TP (Table 5-1). Some of the raingardens rank significantly higher than others in terms of cost per pound of TP removed.

Golf Course Monitoring/Assessment (Subwatersheds 26-30)

A significant portion of the study area (approximately 36%) is located in the Eagle Lake Youth Golf Center, a Three Rivers Park District-owned golf course. Golf courses, particularly public-owned golf courses, offer good potential for retrofit stormwater BMP opportunities due to space and ownership. The Eagle Lake Youth Golf Center has very little impervious area and there are no contributing areas upstream of the center. The only impervious development is a clubhouse and parking lot located on the southeast corner of the property (subwatershed 27). Runoff from the clubhouse and parking lot are treated by a series of ponds in subwatersheds 27, 28, and 29 prior to discharging to Pike Lake. Thus, stormwater retrofit potential within the golf course is currently limited. However, the City and/or Park District could evaluate potential TP loading from the golf course by collecting a handful of flow and TP measurements from the pond located in subwatershed 29. Lidar contours indicate that this pond drains a significant portion of the golf course, including outflow from ponds 26, 27, 28 and 30, and any outflow from this pond flows directly to Pike Lake.

Table 5-1. Proposed BMP pollutant load reductions and cost analysis for the City of Plymouth portion of the Pike Lake watershed.

BMP ID	Priority	BMP Type	Volume Reduction [acre-ft/yr]	TP Reduction [lbs/yr]	Construction Cost	Life Cycle Cost [30 yrs]	Life Cycle Cost per pound of TP Removed
Subs: 9,11-18	1	Street Sweeping	NA	6.8	$763/yr	$22,890	$112
9	2	IESF Bench	NA	10.5	$148,000	$203,000	$645
37	3	IESF Bench	NA	8.7	$181,000	$249,000	$960
2	4	IESF Bench	NA	4.9	$127,000	$175,000	$1,200
11	6	IESF Bench	NA	3.5	$119,000	$163,000	$1,570
10	7	IESF Bench	NA	3.8	$131,000	$180,000	$1,575
Raingarden Total	5	Raingardens	12.1	11.1	$180,000	$441,000	$1,320
TOTAL				49.3	**$886,000**	**$1,433,890**	
12b	5 (1)	Neighborhood Raingarden Detail	1.0	1.9	$10,000	$10,000	$435
13c	5 (2)		2.9	2.4	$20,000	$20,000	$670
16a	5 (3)		3.0	2.4	$20,000	$20,000	$670
12c	5 (4)		0.3	0.6	$10,000	$10,000	$1,350
12d	5 (5)		0.3	0.5	$10,000	$10,000	$1,490
12a	5 (6)		0.3	0.5	$10,000	$10,000	$1,625
15b	5 (7)		0.5	0.4	$10,000	$10,000	$1,830
13b	5 (8)		0.8	0.6	$15,000	$15,000	$1,900

BMP ID	Priority	BMP Type	Volume Reduction [acre-ft/yr]	TP Reduction [lbs/yr]	Construction Cost	Life Cycle Cost [30 yrs]	Life Cycle Cost per pound of TP Removed
15a	5 (9)		0.5	0.4	$10,000	$10,000	$1,990
11a	5 (10)		0.5	0.2	$10,000	$10,000	$3,360
19a	5 (11)		0.7	0.3	$15,000	$15,000	$3,545
11b	5 (12)		0.7	0.3	$15,000	$15,000	$3,720
19b	5 (13)		0.4	0.2	$15,000	$15,000	$5,870
13a	5 (14)		0.1	0.1	$10,000	$10,000	$8,725

6.0 Conclusions and Recommendations

The current condition P8 model for the study area estimates average loading of approximately 91 pounds of TP annually. If all the proposed BMPs presented in Section 5 were implemented, the study area would see reduced TP loads of approximately 49 pounds per year (54% reduction). The Pike Lake TMDL study, which was completed in 2010, established a phosphorus watershed load reduction goal of 37%, or approximately 165 pounds per year for the entire Pike Lake watershed. Thus, the BMPs proposed in this report would go a long way in helping achieve the TMDL goals for Pike Lake, as well as improving overall water quality in downstream waterbodies throughout the Shingle Creek watershed.

It is recommended that the City focus initial efforts on implementing the proposed BMPs they feel are most "shovel-ready" given estimated project cost and site conditions/feasibility. This assessment identified a few larger BMPs, such as the iron-enhanced sand filters, that remove a significant amount of TP and rank high in terms of cost-benefit, but have high capital/construction costs. It is recommended that the City investigate these BMPs further by performing a more detailed feasibility analysis for each BMP option. This may include monitoring to determine in-pond phosphorus concentrations to determine if these ponds are exporting high levels of particulate and dissolved phosphorus.

7.0 References

Minnesota Pollution Control Agency. 2010. Cedar Island, Pike, and Eagle Lakes Nutrient TMDL. https://www.pca.state.mn.us/sites/default/files/wq-iw8-22e.pdf

Minnesota Pollution Control Agency. 2014. Managing Dredge Materials In the State of Minnesota.

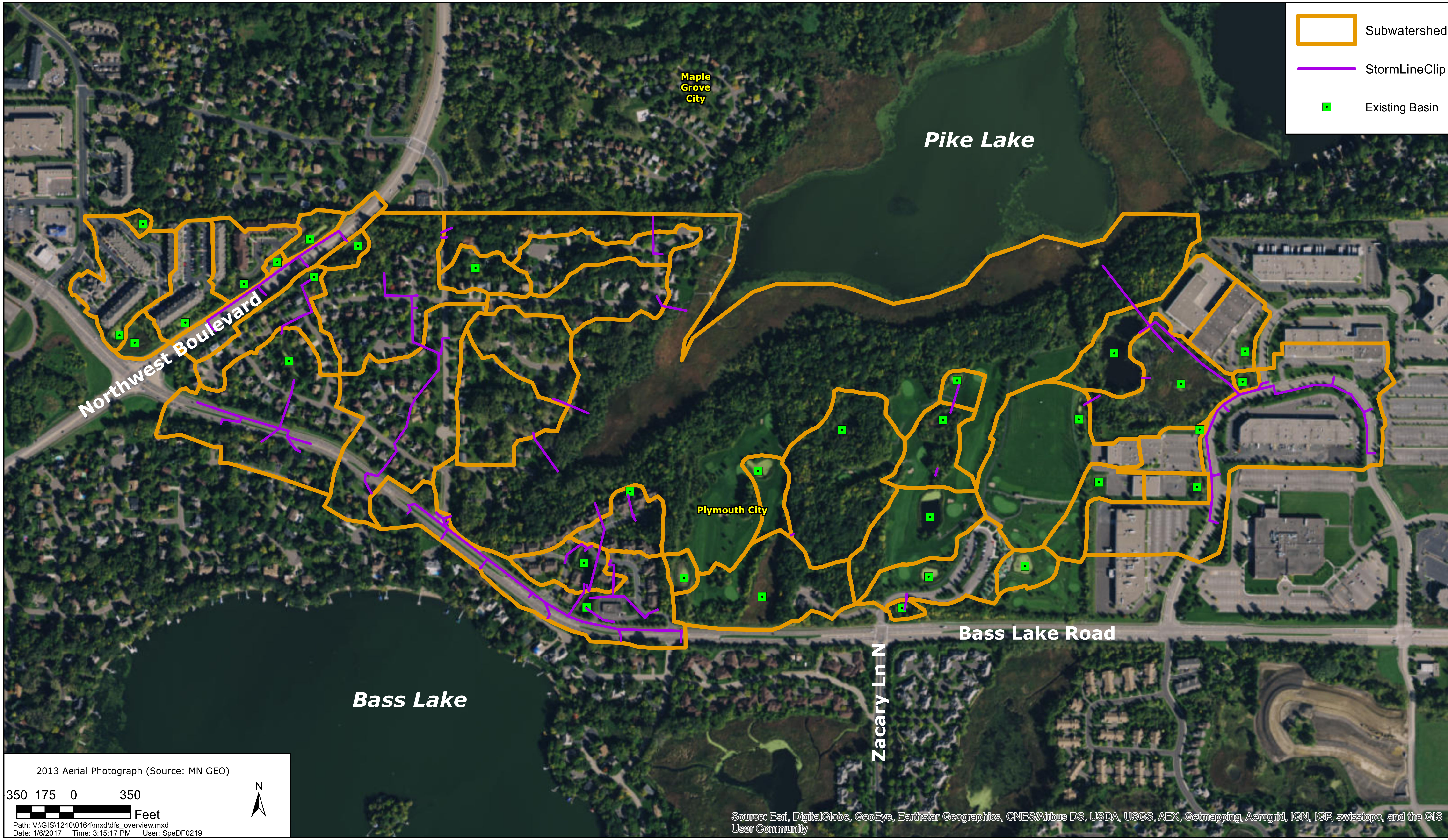
Minnesota Pollution Control Agency. 2015. Managing Stormwater Sediment Best Management Practice Guidance.

Appendix A:
Watershed Model Supporting Materials

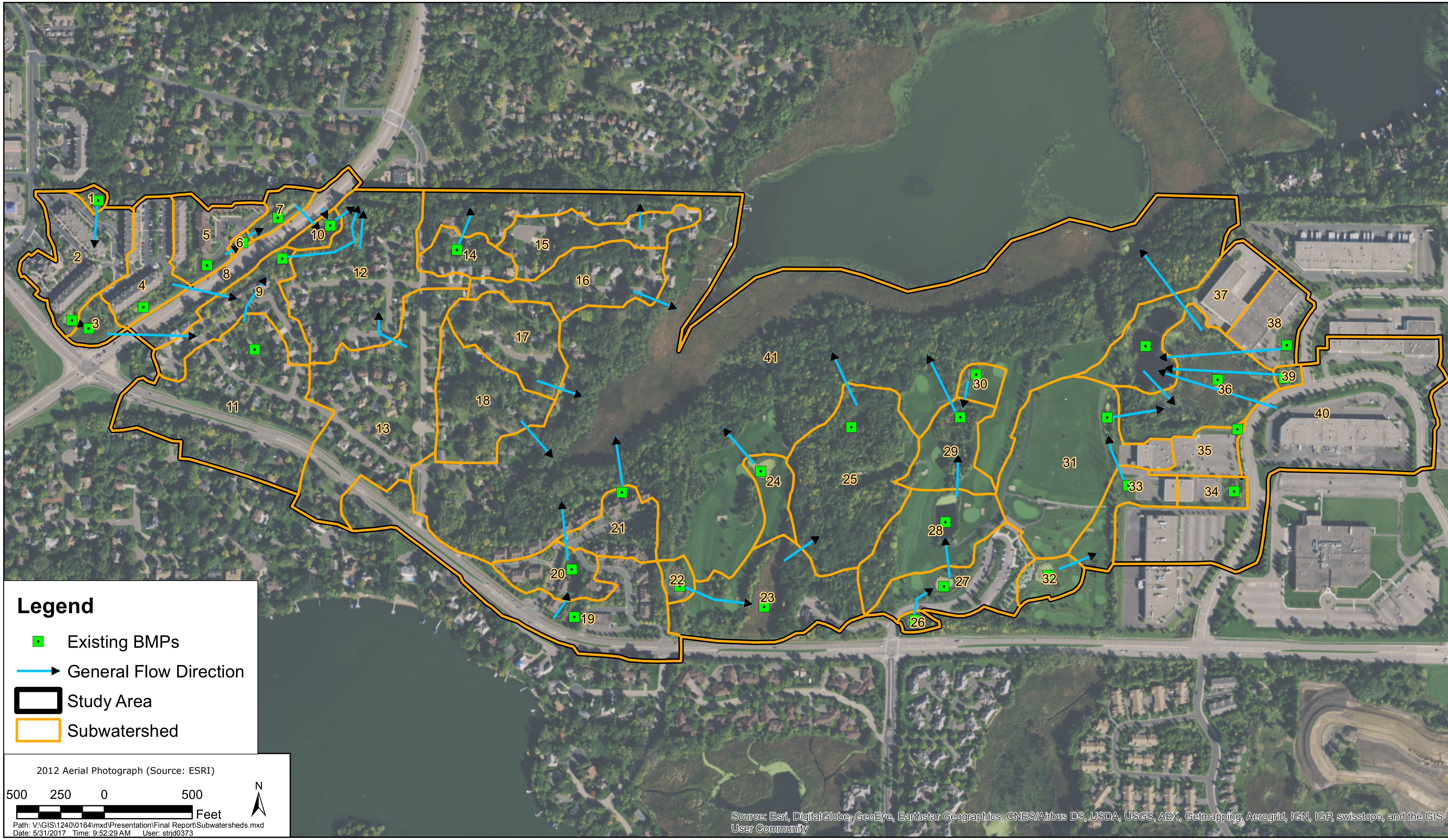
Table A-1: Estimated impervious percent and pervious curve numbers for each land use type used in the P8 model.

Land Use	Impervious Fraction (%)	Pervious Curve Number				
		A	B	B/D	C	C/D
Agricultural	5	49	69	76.5	79	81.5
Farmstead	10	49	69	76.5	79	81.5
Industrial and Utility	50	68	79	84.0	86	87.5
Institutional	32	39	61	70.5	74	77.0
Major Highway	50	49	69	76.5	79	81.5
Mixed Use Residential	60	39	61	70.5	74	77.0
Multifamily	60	39	61	70.5	74	77.0
Open Water	0	85	85	85.0	85	85.0
Park, Recreational, or Preserve	10	39	61	70.5	74	77
Retail and Other Commercial	67	49	69	76.5	79	81.5
Single Family Attached	30	39	61	70.5	74	77
Single Family Detached	20	39	61	70.5	74	77
Undeveloped	5	39	61	70.5	74	77

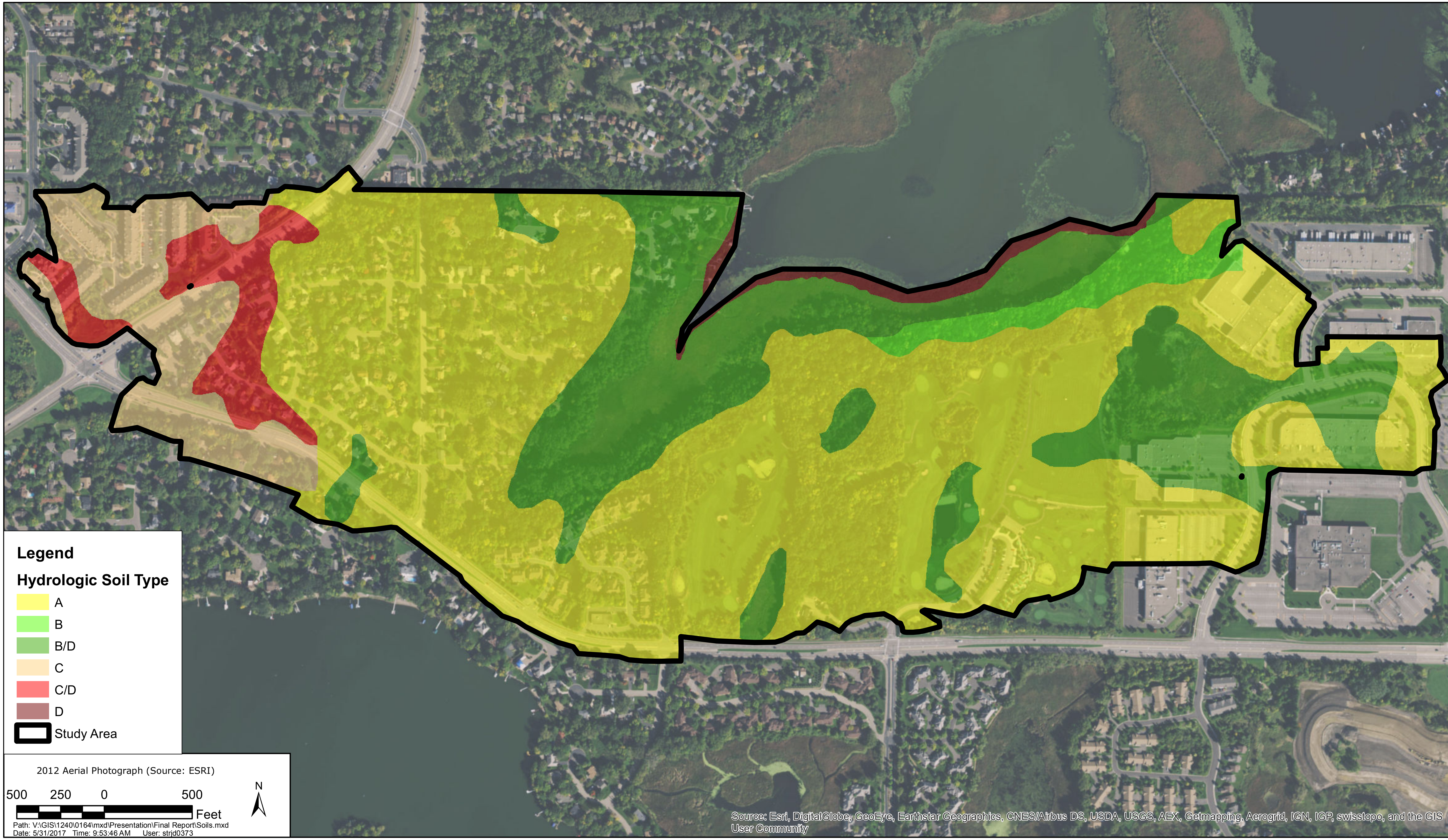
Appendix B:
Proposed BMP Supporting Figures



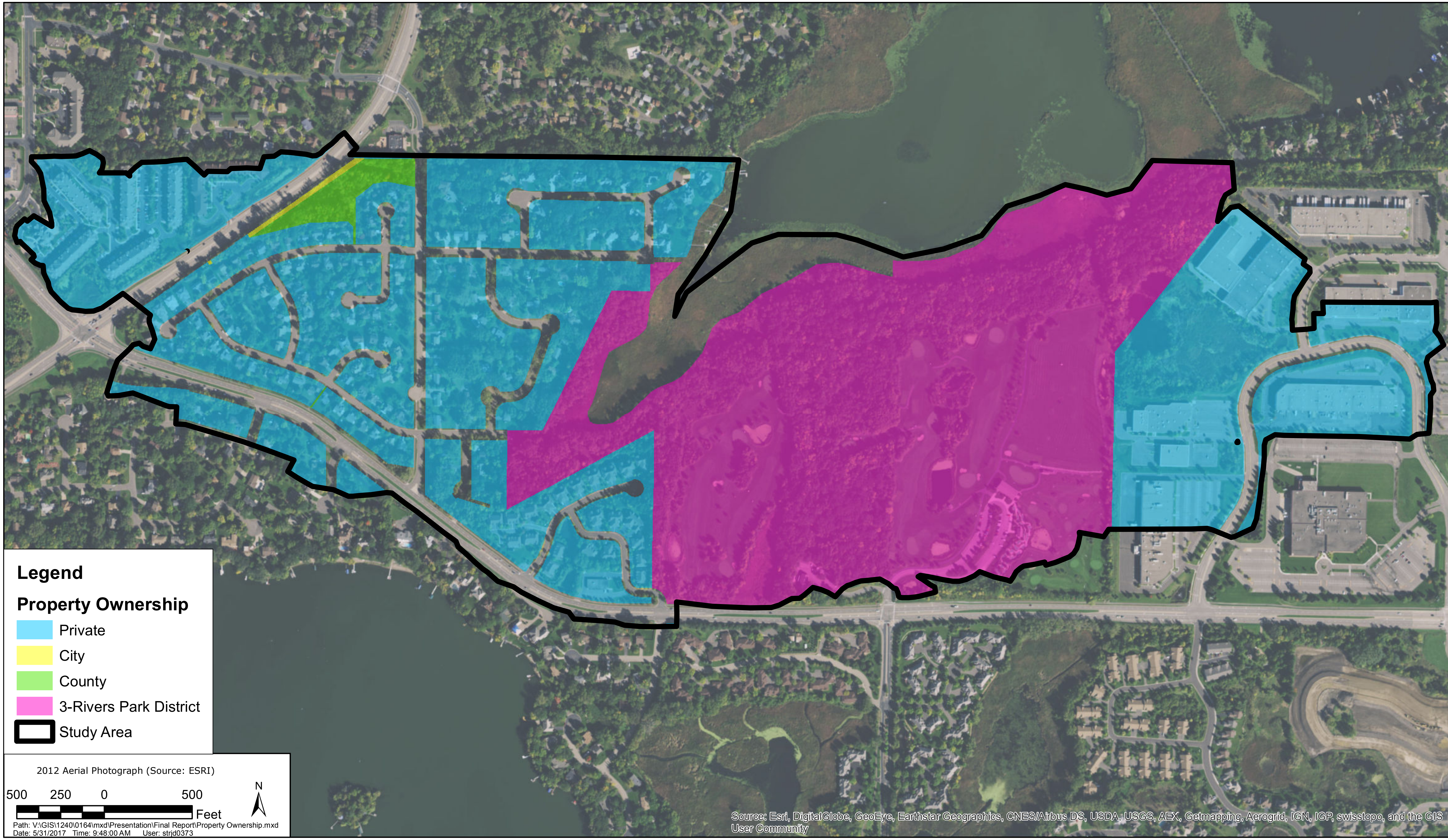
SHINGLE CREEK WMC - PIKE LAKE SUBWATERSHED ASSESSMENT	WENCK ASSOCIATES Responsive partner. Exceptional outcomes.	DEC 2016
Study Area		Figure 1



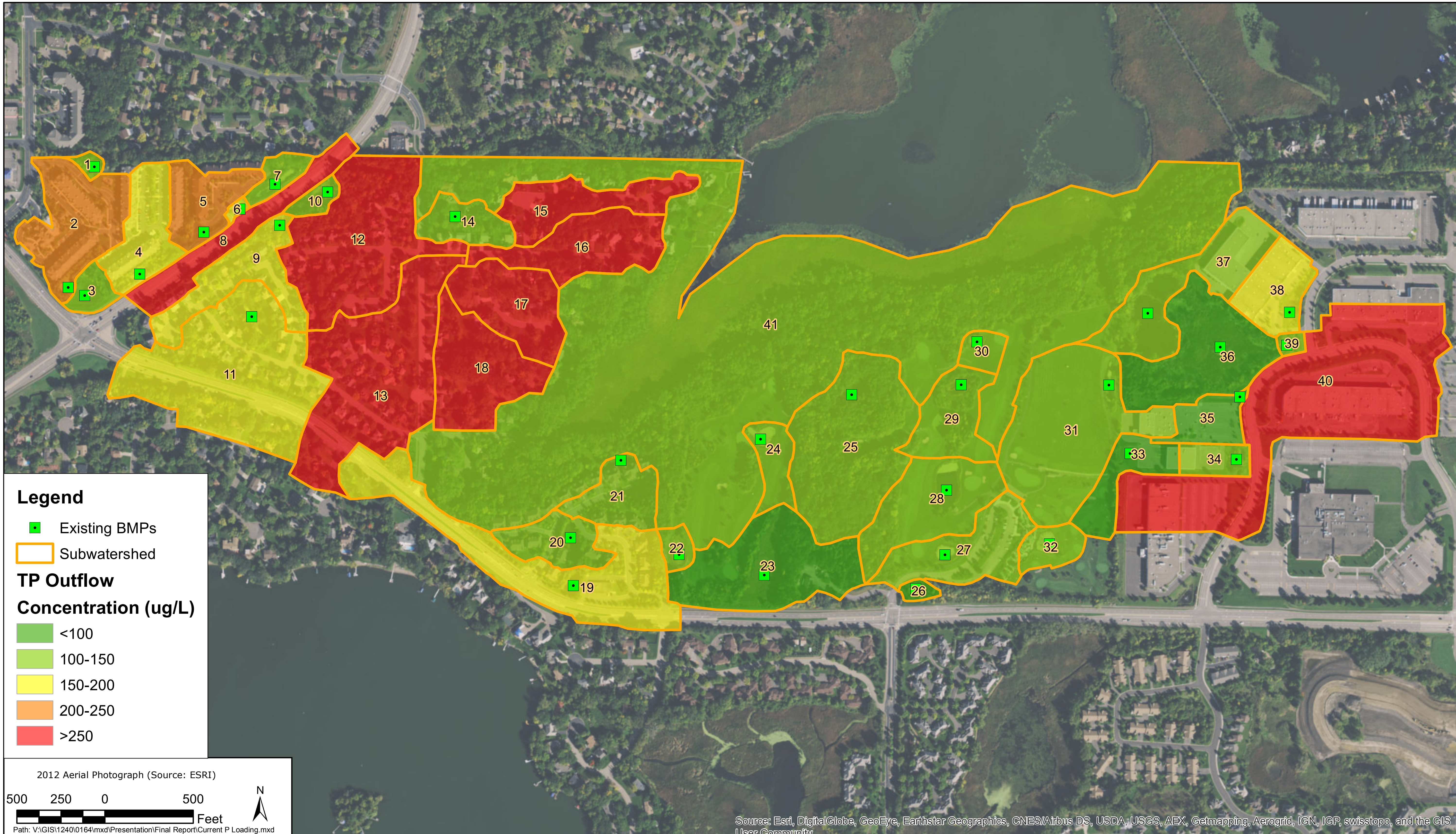
PIKE LAKE SUBWATERSHED ASSESSMENT	WENCK ASSOCIATES Responsive partner. Exceptional outcomes.	JUNE 2017
Subwatersheds and Existing BMPs		B-1



PIKE LAKE SUBWATERSHED ASSESSMENT	WENCK ASSOCIATES Responsive partner. Exceptional outcomes.	JUNE 2017
Soil Type		B-2



PIKE LAKE SUBWATERSHED ASSESSMENT	WENCK ASSOCIATES	JUNE 2017
Property Ownership	Responsive partner. Exceptional outcomes.	B-3



PIKE LAKE SUBWATERSHED ASSESSMENT

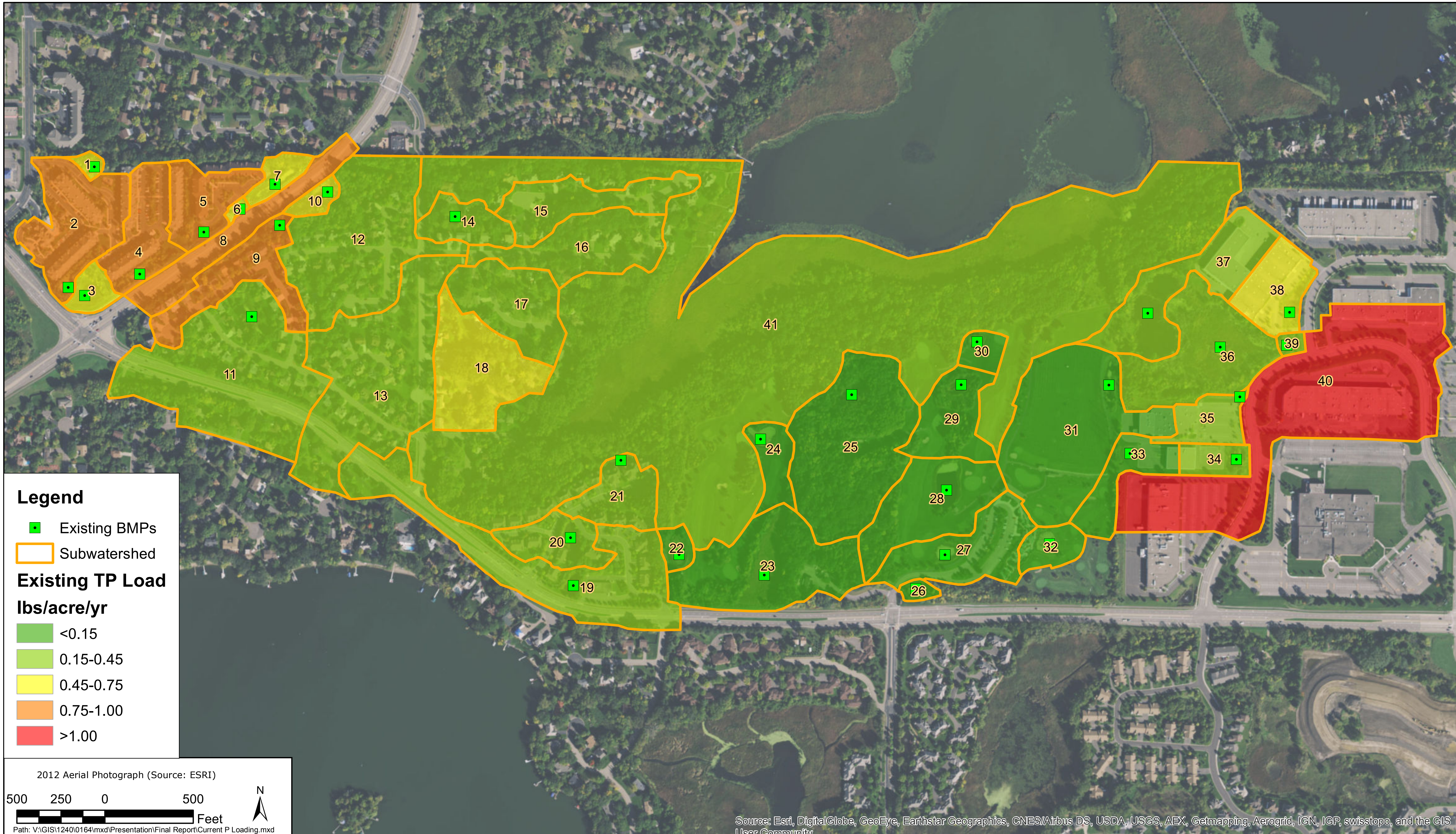
Existing TP Outflow Concentration

WENCK ASSOCIATES

Responsive partner. Exceptional outcomes.

JUNE 2017

B-4



PIKE LAKE SUBWATERSHED ASSESSMENT

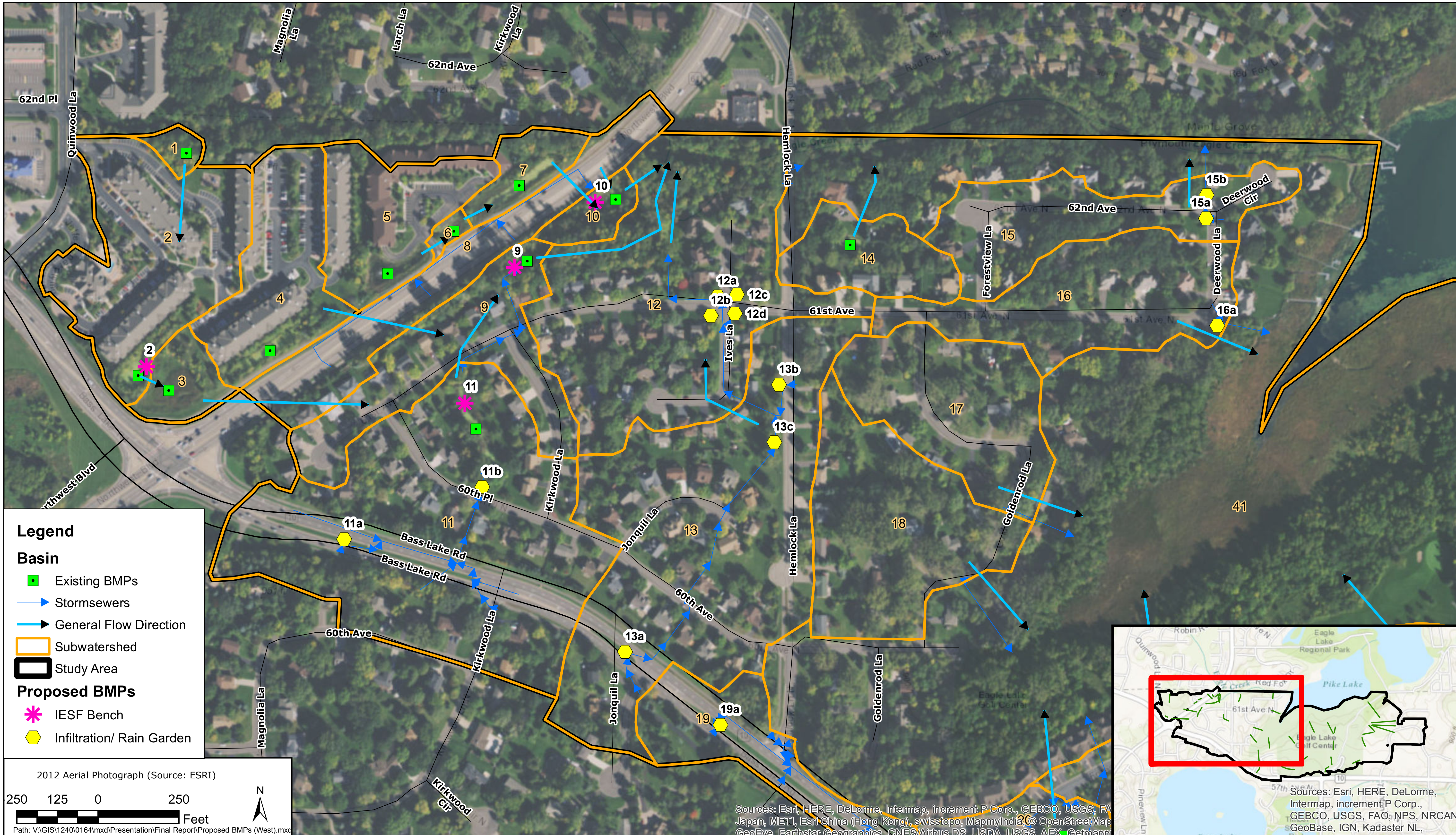
Existing TP Load by Subwatershed

WENCK ASSOCIATES

Responsive partner. Exceptional outcomes.

JUNE 2017

B-5



PIKE LAKE SUBWATERSHED ASSESSMENT

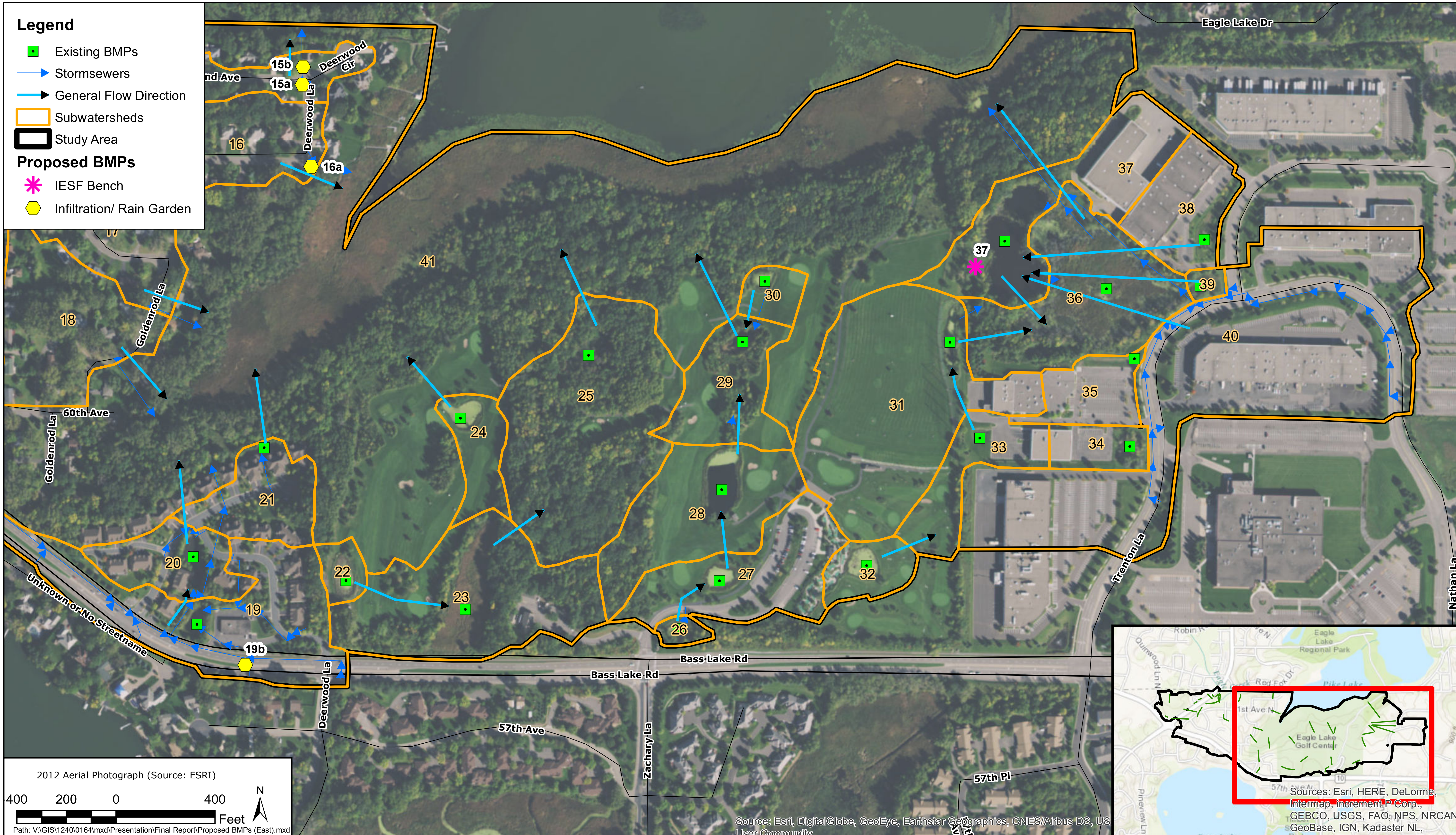
Proposed BMPs (West)

WENCK ASSOCIATES

Responsive partner. Exceptional outcomes.

JUNE 2017

B-6



PIKE LAKE SUBWATERSHED ASSESSMENT

Proposed BMPs (East)

WENCK ASSOCIATES

Responsive partner. Exceptional outcomes.

JUNE 2017

B-7