WHISKEY CREEK SUBWATERSHED WATER QUALITY RETROFIT ANALYSIS

Engaging conservationists, city staff, the and the community for a targeted stormwater implementation plan, city ordinances, redevelopment and future development of the Hwy 371 corridor

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Crow Wing Soil and Water Conservation District

Central Regional Sustainable Development Partnership

University of Minnesota
Driven to Discover℠

HDR

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1 INTRODUCTION

The Crow Wing Soil and Water Conservation District (SWCD) was granted a University of Minnesota Central Region Partnership (CRSDP) Grant to conduct an analysis (Analysis) of the Whiskey Creek (Creek) watershed for potential locations for effective stormwater water quality best management practices to address nutrient and sediment discharges to the Creek. In light of the CRSDP grant requirements and the overarching conservation goals of the SWCD, the expressed overarching goal of the study was summarized as follows:

> "Engage local officials, city staff, and the community on a stormwater implementation plan, city ordinances, redevelopment and future development of the Hwy 371 corridor"

Additional goals for the analysis (as expressed by the SWCD and the CRDSP) include:

- Explicitly identify the best urban locations of specific stormwater water quality best management practices (BMPs) as determined by their annual cost per pound (LB) of treatment over a 30-year period
- Begin to address the expressed needs of local community groups, agencies and the Landscape Arboretum in relation to proactive management of Whiskey Creek
- Engage students form the Central Lakes College (CLC) in the analysis
- Enhance relationships between local citizens and the University of Minnesota
- Support environmental, social and economic sustainability

The analysis was comprised of an initial project scoping meeting with all partners, a collection and assessment of existing data and needs, a field reconnaissance of the subwatershed, water quality and flow sampling within the Creek, a desktop screening for additional opportunities and to define the area of interest (AOI), an existing conditions model of the AOI, a treatment-scaled model of proposed retrofit strategies and a cost-benefit analysis. Results of the scoping meeting, existing data review and desktop screening reduced the Creek's subwatershed to a smaller subwatershed defined as the AOI. The existing conditions model was constructed by assigning land use categories with related estimates of directly-connected impervious, indirectly-connected impervious and pervious land cover as well as depression storage.

2 WHISKEY CREEK SUBWATERSHED

2.1 Watershed Characteristics

The Whiskey Creek Subwatershed is primarily located within the northern portion of Baxter's urban district with a small area of Brainerd Study Area included along the west bank of the Mississippi River (Figure 1). The subwatershed is comprised primarily of commercial land uses with a significant portion of natural, open space and freeway infrastructure. Sands with occasional areas of shallow groundwater dominate the soils in this subwatershed (Independent Testing Technologies, 1999, 2001a, 2001b, 2004). Runoff from the watershed discharges to Whiskey Creek in the vicinity of Fleet Farm and an abandoned golf course property at the intersection of Golf Course Drive N and Excelsior Rd N. The creek makes it way through the Northland Arboretum and a major wetland before emptying into the Mississippi River.

The subwatershed contains areas that seldom contribute flows to Whiskey Creek (personal communication with Trevor Walter, City of Baxter). For the purposes of this study, an Area of Interest (Figure 2) was defined that eliminated those portions of the subwatershed considered non-contributing for all storm events lesser than a 100-yr frequency.

2.2 Stormwater Infrastructure

Both Baxter and Brainerd provided Geographic Information Systems (GIS) databases of public stormwater infrastructure containing inlets, pipes, outlets, swales and ponds(Figure 3, Figure 4). This information was reviewed for flow routing and subsequent pipeshed delineation. The residential portion of the subwatershed west of HWY 371 and the Landscape Arboretum's grounds were excluded from further analysis given the expected low frequency and magnitude of stormwater contribution to Whiskey Creek relative to the remaining AOI.

3 METHODS

3.1 Land Use Characterization

Contiguous land use groupings were delineated in GIS from aerial photography then characterized into WinSLAMM Standard Land Use codes (Appendix 1). Pipeshed boundaries were then used to clip and summarize land uses (Table 1). Walker (2007) provides guidance on adjusting parameter settings for each land use to "calibrate" the P8 model to produce expected WinSLAMM results (Table 2, Appendix 2). This step was deemed valuable given WinSLAMM's robust empirical land use specific data set related to runoff and pollutant build up and wash off in Midwestern states. Soils for the AOI were considered hydrologic soil group A with all pipeshed drainage areas having a Curve Number (CN) of 69.

3.2 EXISTING STORMWATER TREATMENT PRACTICES

Existing pond storage was estimated assuming a 2:1 slope and a live dead storage depth of 3-ft. Live storage was estimated as 3-ft as well. All ponds and drainage areas were constructed within HydroCAD with orifice outlets of diameters relative to City stormsewer data. No infiltration was allowed for the ponds. A 10-yr, type-2 storm event was used to model stage-dependent outflow (cubic feet per second discharge, cfs). P8 Urban Catchment Model (Walker, 1997) was then used to re-create stage-dependent storage and outflow (cfs) using this information.

3.3 SCOPING, DESKTOP REVIEW AND FIELD RECONNAISSANCE

An initial stakeholder scoping meeting was followed by a desktop review of the subwatershed and a field reconnaissance. The scoping meeting defined the goals of each stakeholder as well as brought each participant to a unified understanding of existing conditions within the subwatershed, including the locations and extent of areas of interest and existing stormwater infrastructure (both conveyance and treatment systems). A field visit to key locations identified in the desktop review of the subwatershed allowed all stakeholders and HDR staff to identify both potential BMP retrofit opportunities as well as non-contributing and site-limiting sites not conducive to retrofitting at this stage.

3.4 EXISTING CONDITIONS AND TREATMENT MODEL RUNS

The AOI initial conditions mode setup was performed in two ways. The first incorporated the entire AOI into one system allowing for summed load estimates to the Mississippi River. The second divided the system into four smaller Groups based on their related outflow point (common receiving water body) for efficiency of iterative treatment strategy modeling runs (Figure 4). Iterative treatment scaling model runs for various BMP solutions were then investigated for each existing conditions model network.

New water quality ponds, pond modifications, permeable asphalt and bioretention systems were considered within the AOI. A new pond at the abandoned golf course was modeled using information from an existing proposal (Wildseth, Smith and Nolting, 2013). Existing pond modifications were in the form of addition of an iron-enhanced sand filter (IESF) as the primary outlet. Treatment analysis of the IESF considered facilities in 500 ft^2 increments with two feet of live storage and an infiltration rate of 6 inches per hour for the media. Dissolved phosphorous removal was set o 90% efficiency for all water passing through the IESF. Bioretention cells were similarly assessed by modeling one cell of incremental size at the outfall of the drainage area representing the sum of individual bioretention storage. One foot of ponding was modeled with no under-drain and 1.2 inches per hour infiltration capacity.

3.5 VALUE ANALYSIS SETUP

To measure each potential BMP against each other in terms of cost and performance, a value-based assessment was performed. First, each iterative treatment scenario for each BMP was run to estimate the annual treatment of Total Phosphorus (TP) and Total Suspended Solids (TSS). The total cost of the BMP design and installation costs as well as annual maintenance costs were then estimated. An operational period of 30-years was selected to accommodate the effects of maintenance costs and life cycle for all BMPs. "Value" was then defined as an annually low $/LB-TP of treatment as follows:

$$\text{VALUE (Annual \$/LB-TP)} = \frac{[(\text{design and installation costs})+(30 \text{ years X annual TP removed})]}{(30 \text{ years X annual maintenance cost})}$$

4 RESULTS

4.1 Existing Conditions Model Results

Estimates of TSS and TP loads were made in P8 software (Table 3,Table 4. Existing Conditions Catchment Loading and Treatment of TP). Estimates were produced for each individual BMP as well as for assemblages of catchments at their combined outfall. In the latter case, estimates were made for various assemblages starting from the Whiskey Creek-Mississippi confluence then upstream. The entire AOI is estimated to produce 335,097 lbs-TSS and 823.5 lbs-TP annually. Of these generated loads, existing BMP treatment is expected to remove 52% of the TSS and 22% of the TP, annually. Existing individual pond treatment appears to range from 29-81% for TSS and 5-51% for TP within the AOI.

Not all catchments within the AOI produced or treated TSS and TP equally. Catchment 12's southeastern quadrant (Catchment E12s in results tables), produced the highest loading and has no significant treatment at its immediate outfall to Whiskey Creek (73,259 lbs-TSS and 229.5 lbs-TP, annual loading). Other catchments with no proximal, significant treatment (3, 5, 6, and 10) range in loading from 831-20,598 lbs-TSS and 2.6-64.6 lbs-TP, annually.

4.2 Potential Best Management Practices Model Results

Consideration of availability and efficiency of existing BMPs along with site "buildability" drove the selection process of where to investigate strategies for a first-tier retrofit plan. Locations for recommended retrofit BLP locations exist within catchments 2, 3, 7 and at the beginning of the daylit portion of Whiskey Creek along Excelsior Rd N (\Figure 5). Although there are many other potential retrofit opportunities throughout the AOI, these locations are likely to produce the highest return on investment over a 30-year period for various reasons.

Catchment's 2 and 3 were identified as a high value locations for potential application of either permeable asphalt parking stalls or bioretention islands (Table 5, Table 6,Table 7). Both are part of the same parcel but are within different municipalities, draining to separate outfalls. Site 3 is nearly 100% impervious parking lot with opportunities to retrofit strips of permeable parking to break up the lot into smaller drainage areas. Alternatively, there is ample room for parking stall striping adjustment and drive lane modification to accommodate bioretention cells. These BMPs would treat runoff only from the parcel they reside in and would require modifications to the extent of sand and salt use applied during winter, improved lot sweeping/vacuuming, and, in the case of bioretention cells, a sediment forebay. For both catchments, porous asphalt appears to be more valuable than bioretention cells in terms of water quality performance, but if the added benefits of improved aesthetics, shade and traffic calming/pedestrian safety are considered, bioretention may prove more valuable if designed with these values in mind.

Catchment 7 was also identified as a location for a valuable retrofit (Table 8). An existing pond treating this catchment can be modified to include an IESF bench to capture dissolved phosphorus from its outflows at high efficiency. The decision in regards to how extensive the IESF is built will depend mostly on overall AOI-wide pollutant removal goals for the Mississippi River and existing budget as the value estimates are flat-lined for each successive treatment level (i.e., they are the same). Installation and maintenance costs for this option are low and there is ample room and access for the IESF as well, making this an attractive strategy.

The proposed Whiskey Creek Pond is another highly attractive opportunity as it treats the majority of the commercial area contributing to the Creek as well as the largest, highest contributing load catchment in the AOI (E12s). In addition, that same catchment has little, far less valuable, opportunities for on-site treatment. The proposed design provided to HDR by the City of Baxter is estimated to receive over 151,000 lbs of TSS and 560 lbs of TP annually. The proposed design would treat TSS at 56% and TP at 26% while the addition of increased area for an IESF would slightly improve those results (Table 9). The modeling results for the IESF are somewhat attenuated given the magnitude of TP load coming to the site and would expect to improve if pond design was increased to above 50% TP removal. At that point, the suspended sediments would sufficiently be removed with the remaining TP load being dominated by dissolved phosphorus (P). The incremental improvement on TP removal at that point would therefore become much greater given that IESF's target dissolved-P and do so for a small cost.

When considering the options described herein, the most valuable strategy identified to address water quality concerns for Whiskey Creek would be to develop a retrofit plan starting with Catchment 7's 60%-TP removal option followed by the Whiskey Creek Pond with a 1000 ft^2 IESF primary outlet (Table 10).

5 REFERENCES

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6 TABLES

Table 1. Land Use (in acres) for Whiskey Creek Catchments

	Catchment														
Land Use[1]	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*Total*
DUP											5.4	0.9			6.3
FREE	7.1	2.5	0.5		0.2	0.0	0.0	0.4	15.7	3.3	10.9	61.2	7.0	11.5	120.3
HDRNA	5.0					2.8	1.5								9.4
INST													1.0		1.0
LDR												0.5	21.0		21.5
LI	6.3														6.3
MDRNA												0.4	1.0		1.4
MFRNA	5.0														5.0
OFPK	0.4								5.8	7.4	4.9	41.9	10.5	5.5	76.4
OSUD	29.4				14.7	2.5	0.0	27.0	9.5	19.4	37.1	0.9	1.8	1.9	144.2
PARK	128.8	0.4	4.5		0.7								0.8		135.2
SCH			1.6	3.2	2.0										6.7
SCOM												0.4			0.4
SHOP	12.5	19.8	18.8	19.8			36.9		21.3	23.2	1.5	133.9	7.4	16.6	311.8
SUB				0.1			14.8							0.7	15.5
Total	194.6	22.7	25.3	23.0	17.5	5.3	53.3	27.4	52.4	53.3	59.8	240.0	50.5	36.2	861.2

[1]Land use codes are described in Appendix 1

Table 2. P8 calibration to WinSLAMM Land Use Definitions

Land Use	Depression Storage (in)	Pervious Fraction	Indirectly-Connected Fraction	Directly Connected Fraction
DUP	0.02	0.609	0.121	0.271
FREE	0.022	0	0	1
HDRNA	0.017	0.469	0.131	0.399
INST	0.017	0.364	0.036	0.6
LDR	0.026	0.796	0.079	0.126
LI	0.029	0.205	0.088	0.707
MDRNA	0.029	0.622	0.135	0.242
MFRNA	0.025	0.462	0.063	0.474
OFPK	0.019	0.263	0.006	0.731
OSUD	0.027	0.951	0	0.049
PARK	0.01	0.856	0.041	0.103
SCH	0.026	0.421	0.014	0.565
SCOM	0.025	0.079	0.014	0.907
SHOP	0.023	0.083	0	0.917
SUB	0.04	0.904	0.04	0.056

[1]Land use codes are described in Appendix 1

Table 3. Existing Conditions Catchment Loading and Treatment of TSS

Contributing Catchment	Total TSS-Load (lbs/yr)	Sample Point/BMP	1st Receiving Water Body	Treatment of Upstream Load*	
				Total TSS-Trapped (lbs/yr)	Load Reduction (%)
Entire AOI	335,097	Lower Whiskey Creek	Mississippi River	173,990	52
1, 2, 3, 4, 5, 9n, 9s, 10, 11 E12n, E12s, W12n, W12s, 13, 14	154,264	Wetland	Lower Whiskey Creek	0	0
1, 2, 9n, 9s, 10, 11 E12n, E12s, W12n, W12s, 13, 14	212,615	Arboretum Ponds	Wetland	76,525	36
E12n, E12s, W12n, W12s, 13, 14	151,435	Upper Whiskey Creek	Arboretum Ponds	0	0
1	28,431	Arboretum Ponds	Wetland	0	0
2	13,793	Arboretum Ponds	Wetland	0	0
3	12,689	No BMP	Wetland	0	0
4	13,303	Pond-4	Wetland	9,186	69
5	1,368	No BMP	Wetland	0	0
6	831	No BMP	Lower Whiskey Creek	0	0
7	23,534	Pond-7	Lower Whiskey Creek	17,523	75
10	20,598	No BMP	Upper Whiskey Creek	76,525	36
11	12,806	Swale-11	Arboretum Ponds	8,922	70
9n	10,179	Arboretum Ponds	Wetland	0	0
9s	16,532	Pond-9s	Arboretum Ponds	11,637	70
E12n	21,553	Swale-E12n	Upper Whiskey Creek	13,395	62
E12s	73,259	No BMP	Upper Whiskey Creek	0	0
W12n	17,241	Swale-W12s	Upper Whiskey Creek		
W12s	31,602	Swale-W12s	Upper Whiskey Creek	20,058	29
13	16,752	Swale-W12s	Upper Whiskey Creek		
14	20,628	Pond-14	Upper Whiskey Creek	16,744	81

Table 4. Existing Conditions Catchment Loading and Treatment of TP

Contributing Catchment	Total TP-Load (lbs/yr)	Sample Point/BMP	1st Receiving Water Body	Treatment of Upstream Load*	
				Total TP-Trapped (lbs/yr)	Load Reduction (%)
Entire AOI	823.5	Lower Whiskey Creek	Mississippi River	207.1	22
1, 2, 3, 4, 5, 9n, 9s, 10, 11 E12n, E12s, W12n, W12s, 13, 14	778.6	Wetland	Lower Whiskey Creek	0.0	0
1, 2, 9n, 9s, 10, 11 E12n, E12s, W12n, W12s, 13, 14	787.4	Arboretum Ponds	Wetland	79.3	10
E12n, E12s, W12n, W12s, 13, 14	565.8	Upper Whiskey Creek	Arboretum Ponds	0.0	0
1	89.9	Arboretum Ponds	Wetland	0.0	0
2	43.2	Arboretum Ponds	Wetland	0.0	0
3	39.8	No BMP	Wetland	0.0	0
4	41.7	Pond-4	Wetland	15.2	37
5	4.3	No BMP	Wetland	0.0	0
6	2.6	No BMP	Lower Whiskey Creek	0.0	0
7	73.8	Pond-7	Lower Whiskey Creek	31.5	43
10	64.6	No BMP	Upper Whiskey Creek	0.0	0
11	40.3	Swale-11	Arboretum Ponds	15.7	39
9n	31.9	Arboretum Ponds	Wetland	0.0	0
9s	51.8	Pond-9s	Arboretum Ponds	19.7	38
E12n	67.5	Swale-E12n	Upper Whiskey Creek	20.3	30
E12s	229.5	No BMP	Upper Whiskey Creek	0.0	0
W12n	54.0	Swale-W12s	Upper Whiskey Creek	12.9	5
W12s	99.0	Swale-W12s	Upper Whiskey Creek		
13	52.6	Swale-W12s	Upper Whiskey Creek		
14	64.6	Pond-14	Upper Whiskey Creek	32.8	51

Table 5. Catchment 3 Permeable Asphalt Stalls Modeled Treatment Results

		Base Loading	Exist. Treat.	Net treat. %	Existing Load	NEW TREATMENT OPT-A New treat.	OPT-A Net %	OPT-B New treat.	OPT-B Net %	OPT-C New treat.	OPT-C Net %
TREATMENT	TP (lb/yr)	39.8	0	0%	39.8	11.9	30%	15.9	40%	19.9	50%
	TSS (lb/yr)	12,689	0	0%	12,689	6,767	53%	7,887	62%	8,889	70%
	Number of Stalls					38		54		76	
	Total BMP Area					5100	sqft	7,514	sqft	10,316	sqft
	BMP Type					Permeable Asphalt		Permeable Asphalt		Permeable Asphalt	
COST	Materials/Labor/Design					$51,000		$75,140		$103,160	
	Promotion & Admin Costs					$0		$0		$0	
	Probable Project Cost					$51,000		$75,140		$103,160	
	Annual O&M					$765		$1,127		$1,547	
	30-yr Cost/lb-TP					$207		$228		$251	
	30-yr Cost/1,000lb-TSS					$364		$460		$561	

Table 6. Catchment 3 Bioretention Island Modeled treatment Results

		Base Loading	Exist. Treat.	Net treat. %	Existing Load	NEW TREATMENT OPT-A New treat.	OPT-A Net %	OPT-B New treat.	OPT-B Net %	OPT-C New treat.	OPT-C Net %
TREATMENT	TP (lb/yr)	39.8	0	0%	39.8	11.9	30%	15.9	40%	19.9	50%
	TSS (lb/yr)	12,689	0	0%	12,689	6,743	53%	7,872	62%	8,883	70%
	Number of Islands					10		14		20	
	BMP Size (each)					500	sqft	500	sqft	500	sqft
	BMP Type					Bioretention		Bioretention		Bioretention	
COST	Materials/Labor/Design					$80,000		$112,000		$160,000	
	Promotion & Admin Costs					$200		$200		$200	
	Probable Project Cost					$84,200		$112,200		$160,200	
	Annual O&M (each cell)					$250		$250		$250	
	30-yr Cost/lb-TP					$435		$455		$520	
	30-yr Cost/1,000lb-TSS					$434		$507		$629	

Table 7. Catchment 2 Permeable Asphalt Stalls Modeled Treatment

		Base Loading	Exist. Treat.	Net treat. %	Existing Load	NEW TREATMENT					
						OPT-A		OPT-B		OPT-C	
						New treat.	Net %	New treat.	Net %	New treat.	Net %
TREATMENT	TP (lb/yr)	43.2	0	0	43.2	13	30%	17.3	40%	21.6	50%
	TSS (lb/yr)	13,793	0	0	13,793	7,360	53%	8,574	62%	9,663	70%
	Number of BMP's					1		1		1	
	BMP Size					5563	sq ft	8165	sq ft	9663	sq ft
	BMP Type					Permeable Asphalt		Permeable Asphalt		Permeable Asphalt	
COST		Materials/Labor/Design				$55,630		$81,650		$96,630	
		Promotion & Admin Costs				$200		$200		$200	
		Probable Project Cost				$55,830		$81,850		$96,830	
		Annual O&M				$834		$1,125		$1,449	
		30-yr Cost/lb-TP				$207		$229		$217	
		30-yr Cost/1,000lb-TSS				$366		$461		$484	

Table 8. Catchment 7 Iron Enhanced Sand Filter Modeled treatment

		Base Loading	Exist. Treat.	Net treat. %	Existing Load	NEW TREATMENT					
						OPT-A		OPT-B		OPT-C	
						New treat.	Net %	New treat.	Net %	New treat.	Net %
TREATMENT	TP (lb/yr)	73.8	31.5	43%	42.3	6.5	51%	12.9	60%	20.6	71%
	TSS (lb/yr)	23,534	17,523.00	74%	6,011	971	79%	1,952	83%	3,175	88%
	Number of BMP's					1		1		1	
	BMP Size					500	sqft	1,150	sqft	2,180	sqft
	BMP Type					Iron-enhanced Sand Filter		Iron-enhanced Sand Filter		Iron-enhanced Sand Filter	
COST		Materials/Labor/Design				$6,000		$13,800		$26,160	
		Promotion & Admin Costs				$0		$0		$0	
		Probable Project Cost				$6,000		$13,800		$26,160	
		Annual O&M				$100		$100		$100	
		30-yr Cost/lb-TP				$46		$43		$47	
		30-yr Cost/1,000lb-TSS				$309		$287		$306	

TABLE 9. WHISKEY CREEK POND MODELED TREATMENT

		Base Loading	Exist. Treat.	Net treat. %	Existing Load	NEW TREATMENT					
						OPT-A		OPT-B		OPT-C	
						New treat.	Net %	New treat.	Net %	New treat.	Net %
TREATMENT	TP (lb/yr)	565.8	0	0	565,8	146.9	26%	160	28%	167.1	30%
	TSS (lb/yr)	151,435	0	0	151,435	84,206	56%	86,329	57%	87,454	58%
	Number of BMP's					1		1		1	
	BMP Size					670,000	Cu ft	670,000	Cu ft	670,00 0	Cu ft
	BMP Type					Stormwater Wetland		Stormwater Wetland w/ IESF (1000 ft^2)		Stormwater Wetland w/ IESF (2000 ft^2)	
COST		Materials/Labor/Design				$250,000		$265,000		$280,000	
		Promotion & Admin Costs				0		0		0	
		Probable Project Cost				$250,000		$265,000		$280,000	
		Annual O&M				$250		$350		$450	
		30-yr Cost/lb-TP				$58		$57		$58	
		30-yr Cost/1,000lb-TSS				$102		$106		$112	

TABLE 10. RANKED SUMMARY OF TREATMENT VALUES

CATCHMENT # and TREATMENT LEVEL	Annual Value ($/LB-TP)	Annual TP Captured (LBs)	Annual TSS Captured (LBs)	Estimated Installation Cost
7-IESF, 60%	$43	12.9	1,952	$13,800
7-IESF, 50%	$46	6.5	971	$6,000
7-IESF, 70%	$47	20.6	3,175	$26,160
WC Pond, 28%	$57	160.0	86,329	$265,000
WC Pond, 26%	$58	146.9	84,206	$250,000
WC Pond, 30%	$58	167.1	87,454	$280,000
3-Porous Asphalt, 30%	$207	11.9	6,767	$51,000
2-Porous Asphalt, 30%	$207	13	7,360	$55,830
2-Porous Asphalt, 50%	$217	21.6	9,663	$96,830
3-Porous Asphalt, 40%	$228	15.9	7,887	$75,140
2-Porous Asphalt, 40%	$229	17.3	8,574	$81,850
3-Porous Asphalt, 50%	$251	19.9	8,889	$103,160
3-Bioretention, 30%	$435	11.9	6,743	$84,200
3-Bioretention, 40%	$455	15.9	7,872	$112,200
3-Bioretention, 50%	$520	19.9	8,883	$160,000

7 FIGURES

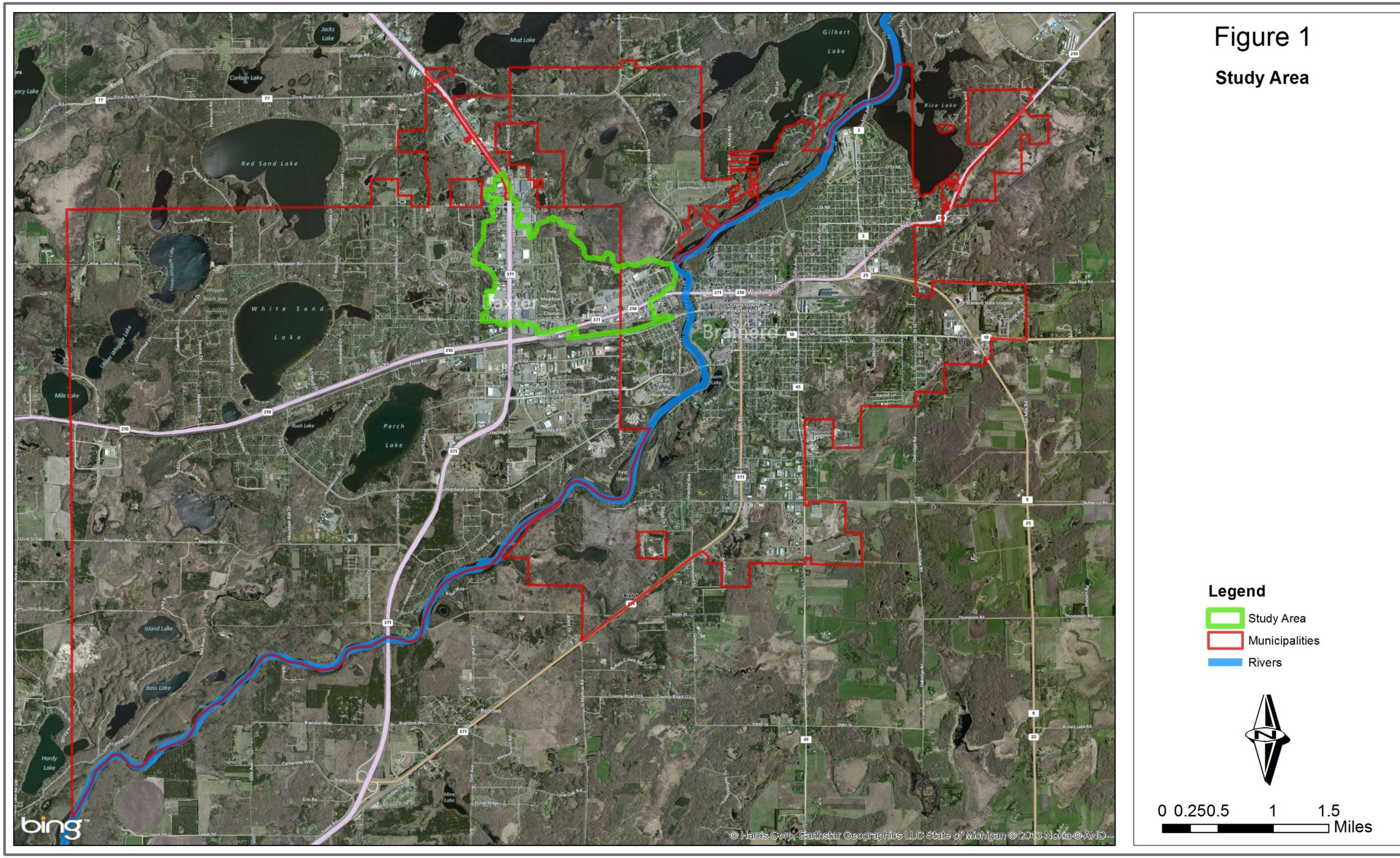

Figure 1. Project Location

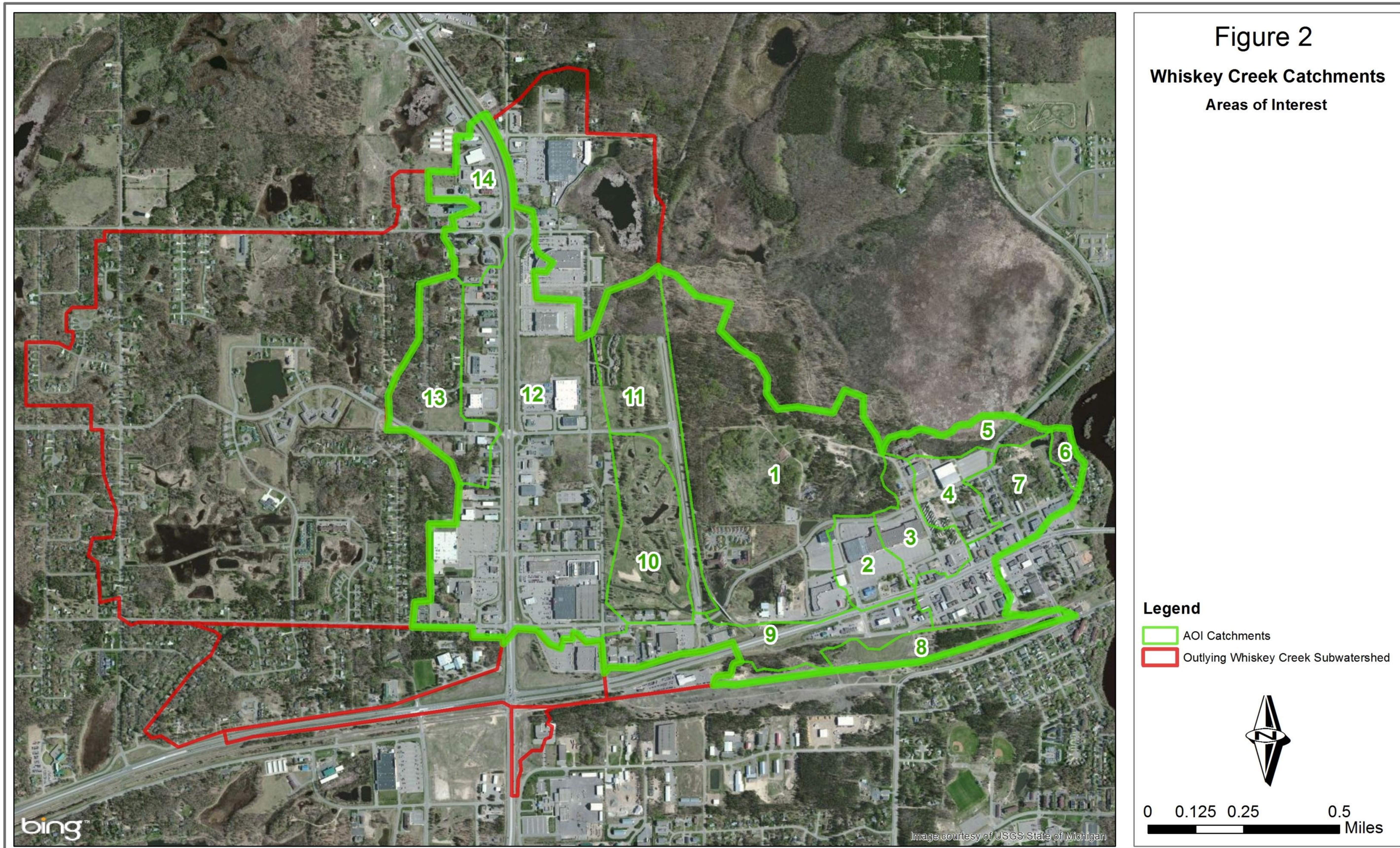

FIGURE 2. WHISKEY CREEK AREA OF INTEREST CATCHMENTS

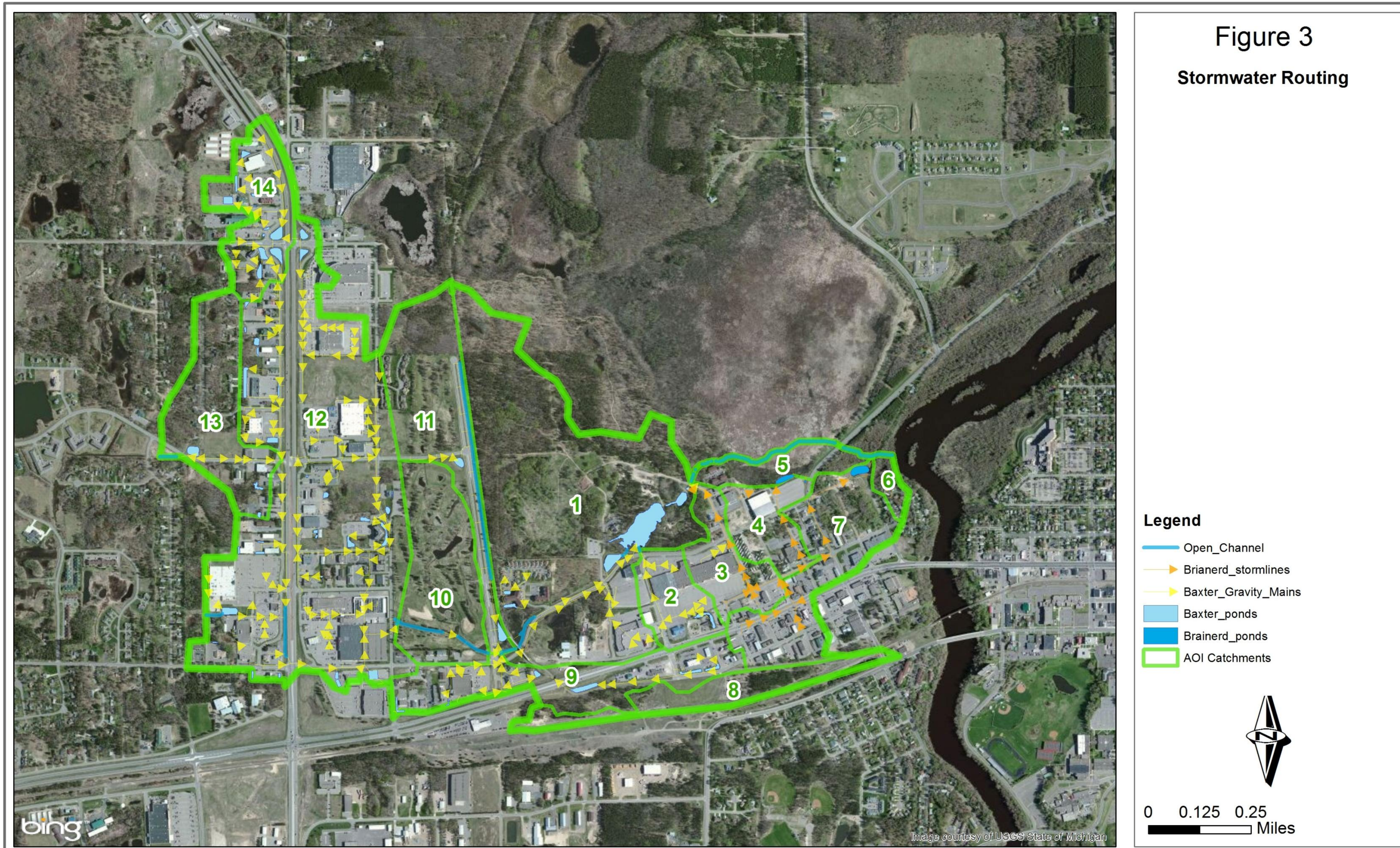

FIGURE 3. STORMWATER PIPE FLOW DIRECTION AND POND LOCATIONS

BMP	City ID	BMP	City ID
Pond 4	Brainerd:	Pond Ar	Baxter: sw-131, 180, 178
Pond 7	Brainerd:	Swale E12n[1]	N/A
Pond 9s	Baxter: sw-118, 158	Swale E12s[1]	N/A
Pond 14	Baxter: sw-21, 22, 23, 38, 41, 42, 43, 44, 45, 46, 47, 48	Swale W12n[1]	N/A
		Swale W12s	Brainerd: N/A

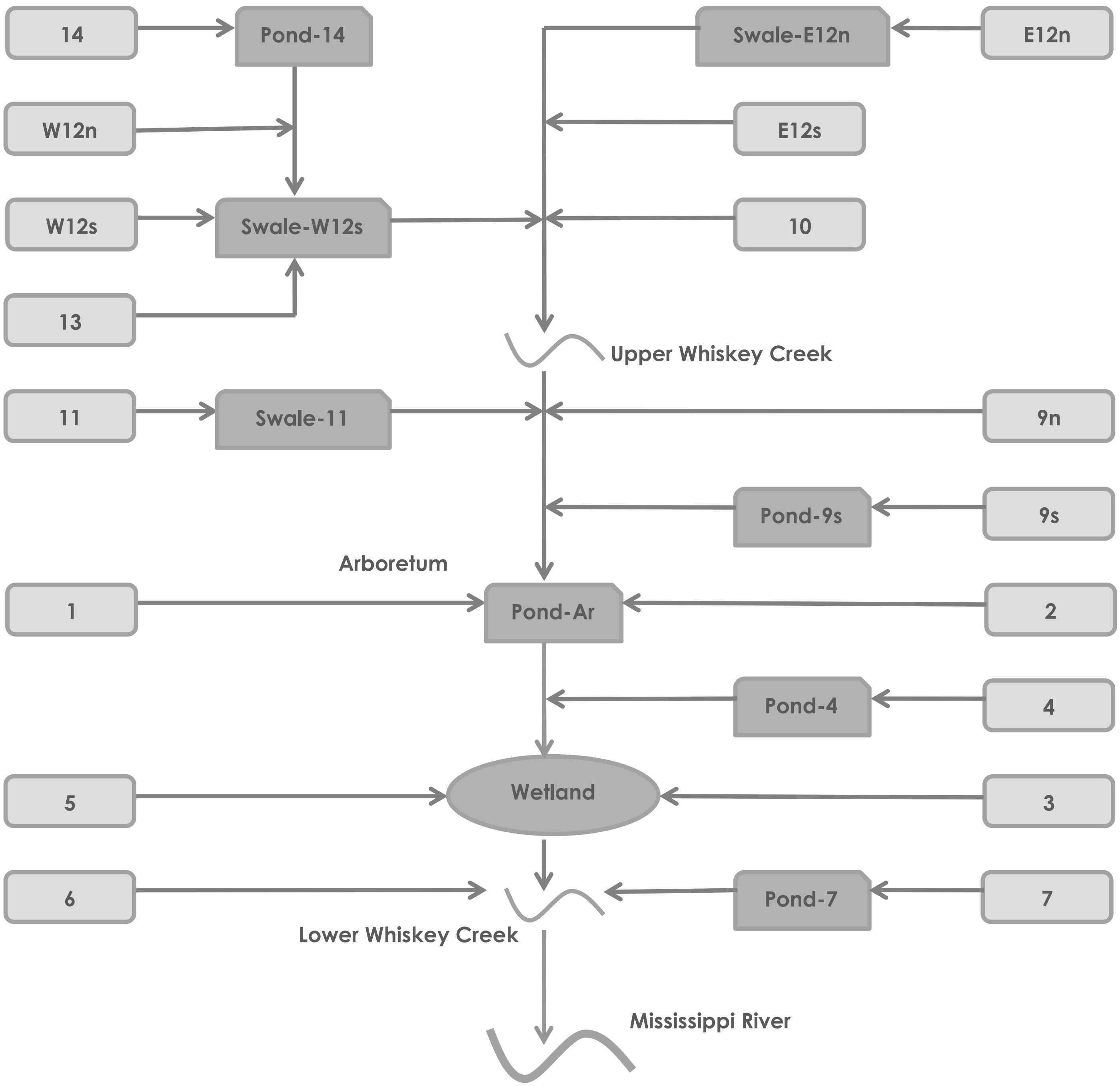

FIGURE 4. STORMWATER ROUTING SCHEMATIC FOR MODELING

\Figure 5. Locations of the Highest Value BMP Retrofit Opportunities in the AOI

8 APPENDICES

Appendix 1 – WinSLAMM Land Use Descriptions

RESIDENTIAL LAND USES

HDRNA - High Density Residential without Alleys: Urban single family housing at a density of greater than 6 units/acre. Includes house, driveway, yards, sidewalks, and streets.

HDRWA - High Density Residential with Alleys: Same as HDRNA, except alleys exist behind the houses.

MDRNA - Medium Density Residential without Alleys: Same as HDRNA except the density is between 2 - 6 units/acre.

MDRWA - Medium Density Residential with Alleys: Same as HDRWA, except alleys exists behind the houses.

LDR - Low Density Residential: Same as HDRNA except the density is 0.7 to 2 units/acre.

DUP - Duplexes: Housing having two separate units in a single building.

MFRNA - Multiple Family Residential: Housing for three or more families, from 1 - 3 stories in height. Units may be adjoined up-and-down, side-by-side; or front-and-rear. Includes building, yard, parking lot, and driveways. Does not include alleys.

HRR - High Rise Residential: Same MFRNA except buildings are High Rise Apartments; multiple family units 4 or more stories in height.

MOBH - Mobile Home Park: A mobile home or trailer park, includes all vehicle homes, the yard, driveway, and office area.

SUB - Suburban: Same as HDRNA except the density is between 0.2 and 0.6 units/acre.

COMMERCIAL LAND USES

SCOM - Strip Commercial: Those buildings for which the primary function involves the sale of goods or services. This category includes some institutional lands found in commercial strips, such as post offices, courthouses, and fire and police stations. This category does not include buildings used for the manufacture of goods or warehouses. This land use includes the buildings, parking lots, and streets. This land use does not include nursery, tree farms, vehicle service areas, or lumber yards.

SHOP - Shopping Centers: Commercial areas where the related parking lot is at least 2.5 times the area of the building roof area. Parking areas usually surrounds the buildings in this land use. This land use includes the buildings, parking lot, and streets.

OFPK - Office Parks: Land use where non-retail business takes place. The buildings are usually multi storied buildings surrounded by larger areas of lawn and other landscaping. This land use includes the buildings, lawn, and road areas. Types of establishments that may be in this category includes: insurance offices, government buildings, and company headquarters.

CDT - Commercial Downtown: Multi-story high-density area with minimal pervious area, and with retail, residential and office uses.

INDUSTRIAL LAND USES

MI - Medium Industrial: This category includes businesses such as lumber yards, auto salvage yards, junk yards, grain elevators, agricultural coops, oil tank farms, coal and salt storage areas, slaughter houses, and areas for bulk storage of fertilizers.

LI - Non-Manufacturing: Those buildings that are used for the storage and/or distribution of goods waiting further processing or sale to retailers. This category mostly includes warehouses, and wholesalers where all operations are conducted indoors, but with truck loading and transfer operations conducted outside.

INSTITUTIONAL LAND USES

SCH - Education: Includes any public or private primary, secondary, or college educational institutional grounds. Includes buildings, playgrounds, athletic fields, roads, parking lots, and lawn areas.

INST - Miscellaneous Institutional: Churches and large areas of institutional property not part of CST and CDT.

HOSP - Hospital: Multi-story building surrounded by parking lots and some vegetated areas.

OTHER URBAN LAND USES

PARK - Parks: Outdoor recreational areas including municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas.

OSUD - Undeveloped: Lands that are private or publicly owned with no structures and have a complete vegetative cover. This includes vacant lots, urban fringe areas slated for development, greenways, and forest areas.

CEM - Cemetery: This land use file covers cemeteries, and includes road frontage along the cemetery, and paved areas and buildings within the cemetery.

FREEWAY LAND USES

FREE - Freeways: Limited access highways and the interchange areas, including any vegetated rights-of-ways.

APPENDIX 2 – P8 PARAMETERIZATION FOR WINSLAMM CODES

Catchment	Acres	Land Use	Depression Storage (in)	Pervious Fraction	Indirectly Connected Fraction	Directly Connected Fraction
1	7.08	FREE	0.022	0.000	0.000	1.000
1	5.04	HDRNA	0.017	0.469	0.131	0.399
1	6.33	LI	0.029	0.205	0.088	0.707
1	5.00	MFRNA	0.025	0.462	0.063	0.474
1	0.43	OFPK	0.019	0.263	0.006	0.731
1	29.36	OSUD	0.027	0.951	0.000	0.049
1	128.79	PARK	0.010	0.856	0.041	0.103
1	12.54	SHOP	0.023	0.083	0.000	0.917
2	2.54	FREE	0.022	0.000	0.000	1.000
2	0.43	PARK	0.010	0.856	0.041	0.103
2	19.75	SHOP	0.023	0.083	0.000	0.917
3	0.48	FREE	0.022	0.000	0.000	1.000
3	4.45	PARK	0.010	0.856	0.041	0.103
3	1.55	SCH	0.026	0.421	0.014	0.565
3	18.78	SHOP	0.023	0.083	0.000	0.917
4	3.15	SCH	0.026	0.421	0.014	0.565
4	19.83	SHOP	0.023	0.083	0.000	0.917
4	0.06	SUB	0.040	0.904	0.040	0.056
5	0.16	FREE	0.022	0.000	0.000	1.000
5	14.65	OSUD	0.027	0.951	0.000	0.049
5	0.72	PARK	0.010	0.856	0.041	0.103
5	1.95	SCH	0.026	0.421	0.014	0.565
6	0.00	FREE	0.022	0.000	0.000	1.000
6	2.79	HDRNA	0.017	0.469	0.131	0.399
6	2.52	OSUD	0.027	0.951	0.000	0.049
7	0.02	FREE	0.022	0.000	0.000	1.000
7	1.54	HDRNA	0.017	0.469	0.131	0.399
7	0.01	OSUD	0.027	0.951	0.000	0.049
7	36.92	SHOP	0.023	0.083	0.000	0.917
7	14.77	SUB	0.040	0.904	0.040	0.056
8	0.35	FREE	0.022	0.000	0.000	1.000
8	27.02	OSUD	0.027	0.951	0.000	0.049
9	15.74	FREE	0.022	0.000	0.000	1.000
9	5.84	OFPK	0.019	0.263	0.006	0.731
9	9.51	OSUD	0.027	0.951	0.000	0.049
9	21.34	SHOP	0.023	0.083	0.000	0.917
10	3.27	FREE	0.022	0.000	0.000	1.000
10	7.36	OFPK	0.019	0.263	0.006	0.731
10	19.44	OSUD	0.027	0.951	0.000	0.049
10	23.21	SHOP	0.023	0.083	0.000	0.917
11	5.42	DUP	0.020	0.609	0.121	0.271
11	10.94	FREE	0.022	0.000	0.000	1.000
11	4.90	OFPK	0.019	0.263	0.006	0.731
11	37.08	OSUD	0.027	0.951	0.000	0.049
11	1.50	SHOP	0.023	0.083	0.000	0.917
12	0.90	DUP	0.020	0.609	0.121	0.271
12	61.19	FREE	0.022	0.000	0.000	1.000
12	0.47	LDR	0.026	0.796	0.079	0.126

12	0.37	MDRNA	0.029	0.622	0.135	0.242
12	41.89	OFPK	0.019	0.263	0.006	0.731
12	0.92	OSUD	0.027	0.951	0.000	0.049
12	0.38	SCOM	0.025	0.079	0.014	0.907
12	133.90	SHOP	0.023	0.083	0.000	0.917
13	6.97	FREE	0.022	0.000	0.000	1.000
13	1.03	INST	0.017	0.364	0.036	0.600
13	21.00	LDR	0.026	0.796	0.079	0.126
13	0.98	MDRNA	0.029	0.622	0.135	0.242
13	10.45	OFPK	0.019	0.263	0.006	0.731
13	1.79	OSUD	0.027	0.951	0.000	0.049
13	0.81	PARK	0.010	0.856	0.041	0.103
13	7.43	SHOP	0.023	0.083	0.000	0.917
14	11.53	FREE	0.022	0.000	0.000	1.000
14	5.50	OFPK	0.019	0.263	0.006	0.731
14	1.87	OSUD	0.027	0.951	0.000	0.049
14	16.63	SHOP	0.023	0.083	0.000	0.917
14	0.65	SUB	0.040	0.904	0.040	0.056