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PMA25 - Lake Irvine Feasibility Report

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Prepared For:
North Central Minnesota Joint Powers Board
Beltrami Soil and Water Conservation District

Contents

Executive Summary

The North Central Minnesota Joint Powers Board (NCMJPB) commissioned an analysis within the City of Bemidji, MN, investigating the potential for water quality modifications to a ditch draining to Lake Irvine. Lake Irvine is impaired for nutrients and is hydrologically connected to Lake Bemidji, putting it at risk of future impairment. Though much work has been identified to alleviate nutrient loading to, and within, Lake Irvine throughout its watershed, the ditch conveys high loads of nutrients from the City. Some of this loading is captured within two detention basins located within the drainage area of the ditch and the ditch itself is likely providing sediment and nutrient removal functions in its current condition. However, modeling of modifications of the ditch suggests that significant load reductions can be achieved.

The NCMJPB partnered with the Beltrami Soil and Water Conservation District (SCWD) and the City of Bemidji (City) for this analysis. This analysis builds on an initial phase of similar work performed in 2014 (*Bemidji Stormwater Water Quality Best Management Practice Retrofit Analysis*, Mississippi Headwaters Board) that focused on treatment opportunities in select subwatersheds within the municipal boundary. That study highlighted Priority Management Area 25 (PMA25;), suggesting high potential to treat urban runoff from the east side of Lake Irvine conveyed by the ditch paralleling the Paul Bunyan Trail system. In addition, Enbridge Inc. approached the Mississippi Headwaters Board as a partner to seek out opportunities to partner on projects that treat not only stormwater but could also be designed to potentially capture and contain spills from oil pipelines. PMA 25's ditch is the focus of this current assessment.

This report presents the results of a feasibility assessment to modify the Ditch to treat stormwater runoff before it enters Lake Irvine. Part One of this document presents the results of the study. Part Two describes the methods used to perform the complete assessment. Part Three provides supporting figures.

RECOMMENDATION

Many potential strategies were considered to treat stormwater runoff within, and immediately outside of, the Lake Irvine Ditch. Strategies were refined in terms of site suitability, potential impacts to wetlands, ease of construction and maintenance, installation and maintenance costs and several other criteria. Four alternatives were then selected for in-depth analysis to estimate annual phosphorus and sediment removal, estimated costs of installation, and estimated costs of 50 years of operation and maintenance. These were combined to generate an annual cost per pound of treated phosphorus in order to make a recommendation. There may be additional value beyond this evaluation metric that would persuade stakeholders to select a final alternative (i.e., meandering of the ditch to develop a naturalized creek section may be attractive to the City of Bemidji in lieu of future development goals).

The results of this analysis suggest that Alternative 2 (the creation of an iron-enhanced sand filter (IESF) at the last culvert of the ditch, dredging of legacy sediments to create storage, establishment of dense, native wetland vegetation in the last ditch segment and creation of a sediment capture forebay at the ditch's headwaters) yields the greatest return on investment. Dredging the accumulated sediment in the channel opens up more storage capacity for new sediments carrying phosphorus to be trapped.

Vegetation serves to also strip water of its sediment load, and assimilate phosphorus as it grows. The IESF filters dissolved phosphorus from the remaining water. Collectively, these processes likely remove 157 more pounds of phosphorus per year than the current system. The estimated installation cost of $160,000 plus 50 years of maintenance yields a 50-year present day value of $203,400, resulting in an average annual value of $25/LB-phosphorus as compared to $49 and $64 per pound for alternatives 3 and 4, respectively.

PART ONE. PERFORMANCE AND COST EVALUATION

Project Goals and Analysis Set Up

In order to select alternatives to consider for feasibility assessment, several considerations were made starting with a stakeholder meeting to discuss partner goals (*see* Issues and Goals Identification, in Part Two). Following this meeting, the City provided spatial and surveyed invert stormwater infrastructure data. The PMA 25 ditch was then surveyed by Beltrami SWCD with survey points tied to LiDAR data to create a complete topography data set within its valley (see, Attachment). City Land Use data, soils data, and a digital elevation model from the State of Minnesota were paired with storm sewer data to complete a GIS database for the project. These data enabled the use of GIS to delineate three subwatersheds draining to the ditch as well as define their composition (land use, soils, topography and existing ponds;). The NCMJPB and Beltrami SCWD provided ditch flow and water quality data to later be used for model calibration purposes (see Ditch Flow and Water Quality monitoring, in part Two).

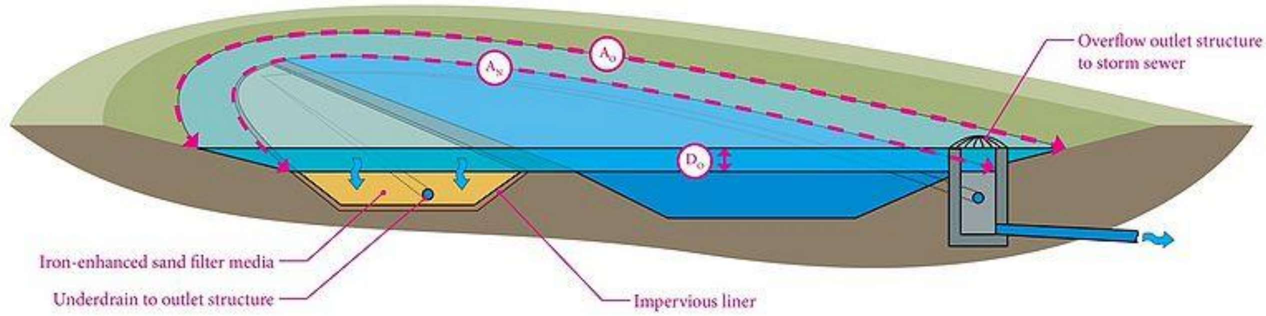
Several potential strategies were considered for promotion to feasibility assessment (see Alternatives Screening, in Part Two). Strategies considered include both in-channel options, outside of, and immediately adjacent to the channel, or combinations of the two. Screening criteria were developed to screen options until three alternatives were selected for feasibility assessment. After a second stakeholder meeting, a fourth alternative was added at the City's request.

Alternative 1 – Forebay at Stormwater Outfall into Pool 1, Dredge Pools 1 through 4 (Figure 8)

This alternative constructs a maintenance forebay at the head of the ditch and dredges pools 1 through 4 to remove legacy sediments (four pools are defined by three culverts over the length of the ditch, with pool 1 being at the headwaters and pool 4 the last segment before the ditch discharges to Lake Irvine). This option also recommends the replacement of each of the three culverts as at least one was reported as collapsed by the SWCD. All culverts were partially buried by sediment during the ditch survey. For the sake of this assessment, dredging was limited to an elevation roughly equivalent to replaced culverts inverts with culverts being leveled. Depth of dredging was limited beyond this point given the narrow nature of the ditch floor. Further dredging would likely necessitate the need to grade the ditch valley's bluff leading to increased costs for limited phosphorus treatment gains. There is also limited capacity to raise culverts to induce additional ponding given the limited hydraulic gradient between the inlet to the ditch and its outlet. Care was taken to not induce tail water conditions to the watershed's storm sewer network, though a fine tuning of culvert invert placement may be possible and best determined by a design phase hydraulic analysis.

Alternative 2 – Forebay at Stormwater Outfall into Pool 1, Dredge Pools 1 and 4, IESF in Pool 4, Wetland Vegetation in Pool 4 (Figure 9)

This alternative similarly includes creation of a maintenance forebay but limits dredging to Pools 1 and 4. It also includes the construction of an Iron-enhanced Sand Filter (IESF) and wetland vegetation within Pool 4. Wetland vegetation increases channel roughness, retarding stormwater flows through it. This induces additional sediment settling in the water column. Additionally, sediment particles bond to vegetation further abstracting sediment and its bound phosphorus. This alternative adopts the same culvert replacement strategy as Alternative 1.



Iron Enhanced Sand Filter Bench in Wet Pond

Alternative 3 - Forebay at Stormwater Outfall into Pool 1, Dredge Pools 1 through 4, IESF in Pool 4, Wetland Vegetation in Pools 2, 3 and 4 (Figure 10)

This alternative builds on Alternative 3 by complete dredging over its entire length. In this alternative, wetland plantings are recommended in 3 of the 4 pools to increase roughness over a substantially longer flow path. This alternative adopts the same culvert replacement strategy as Alternative 1.

Alternative 4 – Meander Stream Segments and Include IESF At Outlet Cell (Figure 11)

Alternative 4 adopts all components of Alternative 3, though dredging is achieved through the creation of a small cross-sectional area channel through all pools. In addition, pools 2 and 3 are meandered to create a minor creek aesthetic for future residential development by the City. This meandering was a request of the City to enhance the property. Meandering entails regrading of the ditch/creek valley planform and thus incurs additional costs. To minimize these costs, only pools 2 and 3 alignment were adjusted with an attempt to balance cut-fill, though some fill is expected to be exported from the channel valley. This alternative allows for a vegetated floodplain to take on bankfull-exceeding flows and collect sediment. Culverts are also replaced, as in the previous alternatives, which allow for passage of bankfull-exceeding events to the next pool, though it will be required to downsize culverts between pool 2 and 3 to facilitate transfer of water from the channel to the floodplain. A hydraulic model during design phase will be required to size these to also ensure tailwater conditions do not impeded drainage of the watershed's storm sewer.

Modeled water quality treatment by alternative

P8 Urban Catchment Model software (Walker; http://www.wwwalker.net/p8/) was used to model average annual sediment and phosphorus export to the PMA 25 ditch and each alternative's treatment capacity. As outlined above, each alternative was modeled as a swale with varying roughness induced by vegetation (or lack thereof) on flows. The IESF was modeled with smaller storm flows routed through the filter material and a portion of larger flows not treated by the IESF being routed to the outlet. Results are presented in Table 1, below.

TABLE 1. ALTERNATIVE SCENARIOS AVERAGE ANNUAL WATER QUALITY MODEL RESULTS.

		Alternative Treatment		Net Annual Removal from Previous Alternative		Net Annual Removal from Existing Conditions	
	Description	TP Removed (LB)	TSS Removed (LB)	Delta TP Removed (LB)	Delta TSS Removed (LB)	Delta TP Removed (LB)	Delta TSS Removed (LB)
Existing	Open ditch	60	52,254	-	-	-	-
Alternative 1	Forebay*	60	52,254	0	0	0	0
Alternative 2	Forebay*, IESF (Pool 4), and Pool 4 Wetland Veg	221	73,974	161	21,720	161	21,720
Alternative 3	Forebay*, IESF (Pool 4), and Pool 2, 3, and 4 Wetland Veg	230	74,676	9	702	170	22,422
Alternative 4**	Forebay*, IESF (Pool 4), meandering Pools 2, 3, and 4, and Pool 2, 3, and 4 Wetland Veg	233	75,283	3	607	173	23,029

*Forebay was assumed to not significantly remove annual loading, though it is expected that a fraction of watershed loads will be captured.
**Results will vary as affected by designed channel sinuosity: higher sinuosity will result in lesser channel gradient, slower velocities, and higher sediment settling.

Present day value estimation

Present Day Values were estimated for a 50-year period considering installation costs, annual maintenance and intermittent maintenance for each of the four alternatives (*see* Appendix: Present Day Value). The following provides a description of the installation and maintenance costs associated with each alternative. Details for encumbered annual and intermittent maintenance costs are provided in the Present Day Value section of Part 2.

Alternative 1

Installation

Estimates for soil excavation, regrading, and disposal were calculated to assess the Alternative's capital cost. Cost estimates include general grading and restoration required following heavy equipment's disturbances. Estimates also include the cost to replace any road or trail surfaces that will be disturbed during the removal and replacement of culverts. Mobilization, traffic control, engineering fees, and a 30% contingency were all included in the final cost.

Annual Maintenance

Alternative 1 includes yearly maintenance to account for inspections and minor vegetation management and trash removal. Yearly maintenance costs are expected to be near $350 (*see*, Part Two: Methods - Present Day Value).

Intermittent Maintenance

Alternative 1 includes intermittent maintenance to manage the streams' banks. Every 2 years, it is assumed that the culvert aprons will need to be unclogged and any mulch will need to be replaced.

Every 4 years, soil will need to be tilled. Every 5 years, the new forebay will require dredging. Every 30 years, the entire channel will require dredging. The cost of each of these intermittent maintenance practices varies (*see*, Part Two: Methods - Present Day Value)..

Alternative 2

Installation

Estimates for soil excavation, regrading, and disposal were calculated to assess the Alternative's capital cost. Cost estimates include general grading and restoration required following heavy equipment's disturbances. Estimates also include the cost to replace any road or trail surfaces that will be disturbed during the removal and replacement of culverts. Mobilization, traffic control, engineering fees, and a 30% contingency were all included in the final cost .

Annual Maintenance

Alternative 2 includes yearly maintenance to account for inspections and minor vegetation management and trash removal. Yearly maintenance costs are expected to be near $350 (*see*, Part Two: Methods - Present Day Value).

Intermittent Maintenance

Alternative 2 includes intermittent maintenance to manage the streams' banks. Every 2 years, it is assumed that the culvert aprons will need to be unclogged and any mulch will need to be replaced. Every 4 years, soil will need to be tilled. Every 5 years, the new forebay will require dredging. Every 10 years, the IESF will require a replacement of the iron-sand media (96 yd^3). Every 30 years, the entire channel will require dredging. Each year for the first 5 years following installation, extra maintenance will be required on the wetland vegetation planted in Pool 4. The cost of each of these intermittent maintenance practices varies (*see*, Part Two: Methods - Present Day Value).

Alternative 3

Installation

Estimates for soil excavation, regrading, and disposal were calculated to assess the Alternative's capital cost. Cost estimates include general grading and restoration required following heavy equipment's disturbances. Estimates also include the cost to replace any road or trail surfaces that will be disturbed during the removal and replacement of culverts. Mobilization, traffic control, engineering fees, and a 30% contingency were all included in the final cost.

Annual Maintenance

Alternative 3 includes yearly maintenance to account for inspections and minor vegetation management and trash removal. Yearly maintenance costs are expected to be near $350 (*see*, Part Two: Methods - Present Day Value).

Intermittent Maintenance

Alternative 3 includes intermittent maintenance to manage the streams' banks. Every 2 years, it is assumed that the culvert aprons will need to be unclogged and any mulch will need to be replaced. Every 4 years, soil will need to be tilled. Every 5 years, the new forebay will require dredging. Every 10 years, the IESF will require a replacement of the iron-sand media (96 yd^3). Every 30 years, the entire channel will require dredging. Each year for the first 5 years following installation, extra maintenance will be required on the wetland vegetation planted in Pools 2, 3, and 4. The cost of each of these intermittent maintenance practices varies (*see*, Part Two: Methods - Present Day Value).

Alternative 4

Installation

Estimates for soil excavation, regrading, and disposal were calculated to assess the Alternative's capital cost. Cost estimates include general grading and restoration required following heavy equipment's disturbances. Estimates also include the cost to replace any road or trail surfaces that will be disturbed during the removal and replacement of culverts. Mobilization, traffic control, engineering fees, and a 30% contingency were all included in the final cost.

Annual Maintenance

Alternative 4 includes yearly maintenance to account for inspections and minor vegetation management and trash removal. Yearly maintenance costs are expected to be near $350 (*see*, Part Two: Methods - Present Day Value).

Intermittent Maintenance

Alternative 3 includes intermittent maintenance to manage the streams' banks. Every 2 years, it is assumed that the culvert aprons will need to be unclogged and any mulch will need to be replaced. Every 4 years, soil will need to be tilled. Every 5 years, the new forebay will require dredging. Every 10 years, the IESF will require a replacement of the iron-sand media (96 yd^3). Every 30 years, the entire channel will require dredging. Each year for the first 5 years following installation, extra maintenance will be required on the wetland vegetation planted in Pools 2, 3, and 4. The cost of each of these intermittent maintenance practices varies (*see*, Part Two: Methods - Present Day Value).

Cost-benefit results by alternative

To relatively compare the value of each alternative relative to each other, each alternative's 50-year present day value was divided by 50-years of average sediment and phosphorus removal (Table 2). The resulting comparative metric partially informs the decision to implement a strategy for the PMA 25 ditch. Additional values related to habitat improvement, aesthetic appeal and level of maintenance may also inform the decision. However, these additional values should be weighed by the affected stakeholders. Given the results of the costs versus treatment capacity of each alternative alone, Alternative 2 yields the best incremental value per dollar spent and is thus recommended for consideration by the stakeholders.

TABLE 2. COST BENEFIT RESULTS

	Installation Cost	Annual Maintenance Cost	Intermittent Maintenance Cost	50-yr Present Day Value	Annual $/LB TSS	Annual $/LB TP
Alternative 1	$114,100	$320	VARIES[1]	$145,992	$0	$0
Alternative 2	$159,850	$320	VARIES[1]	$203,400	$0.19	$25
Alternative 3	$359,680	$320	VARIES[1]	$418,550	$0.37	$49
Alternative 4	$490,000	$320	VARIES[1]	$550,337	$0.48	$64

[1]See Part Two: Methods - Present Day Value

PART TWO. METHODS

Part two adds additional detail to each step of the feasibility study.

Issues and Goals Identification

To assist in driving the analysis of PMA 25 ditch modification for stakeholders two meetings were held to ascertain known watershed, ditch and Lake issues, concerns and goals. An initial meeting was held the stakeholders to gather information on issues, identify relevant existing data as well as gaps and to plot the course of the assessment. Follow up conversations with the City, the SWCD, the Mississippi Headwaters Board and the NCMJPB to add to issues discussions as well as to request data. A second meeting was held to present progress of the assessment and to request stakeholder feedback on the selection of the three alternatives. At this time, the City requested the fourth alternative (meandering of the ditch) that was later included in modeling and cost estimation.

Pipeshed Delineation

The City's stormwater database (GIS) was used along with a digital elevation model in GIS to delineate a refined watershed for PMA 25. This process included a digital terrain analysis that allowed for cutting in of culverts and confirmation of surface pit settings within the water quality model. The PMA 25 watershed was further divided into three subwatersheds to accommodate drainage areas services by two detention ponds. City and SWCD staff provided additional stormsewer survey data (invert elevations of manholes and catch basins) to help validate or correct drainage assumptions before watershed delineation was performed in GIS. Draft subwatershed delineations were validated with the City engineer before proceeding to alternatives screening and modeling.

Alternatives Screening

Potential PMA 25 ditch modification strategies were screened based on several metrics to facilitate selection of alternatives to take to full feasibility assessment (Table 3). Strategies were considered both within the ditch as well as above the ditch, outside of the ditch's valley. Screening suggested that several options were infeasible mainly given some combination of overall costs and difficulty to install or maintain, though several additional metrics led to strategy elimination. Three alternatives were initially identified in the screening process to move to feasibility assessment.

TABLE 3. POTENTIAL ALTERNATIVES SCREENING METRIC RESULTS

Alternative	Site Suitability (Y/N)	Special Permit (Y/N)	Wetland Mitigation (None, M, H)	Impact on Developable Land (L, M, H)	Treatment Capacity (L, M, H)		Conducive to Spill Management (Y/N)	Cost (L, M, H)				Construction Ease (L, M, H)	O&M Ease (L, M, H)
					TSS	TP		Design	Permit	Build	O&M		
Within Ditch													
Dry Pond	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wet Pond	Y	N	M	M	M	L	T	M	M	M/H	M	H	M/H
Single wetland	Y	N	M	M	M	M	Y	M	M	M/H	M	M	M/H
Wetland Cells at culvert(s)	Y	N	H	L	M	M	Y	M	H	M	M	L	M/H
Surface sand/soil/enhanced filters	Y	N	M	L	M	H	N	M	M	L/M	H	M	H
Infiltration basin	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Infiltration trench (BENCH)	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bioretention (BENCH)	Y	N	L	L	M	M	N	L	L	L/M	M	M	M
Bioinfiltration (BENCH)	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biofiltration (BENCH)	Y	N	L	L	M	M	N	L	L	L/M	M	M	M
In-stream-injection system	Y	Y	None	L	L	H	N	H	L	M/H	H	M	H
Pond + dosing system	Y	Y	M	M	M	H	Y	H	M	H	H	H	H
Above Ditch													
Dry Pond	Y	N	N	M	H	H	N	M	N/A	M	M	M	M
Wet Pond	Y	N	N	M	M	L	N	M	N/A	M	M	M	M
Single wetland	Y	N	N	M	M	M	N	M	N/A	M	M	M	M
Surface sand/soil/enhanced filters	Y	N	N	M	M	H	N	M	N/A	L	M	M	M
Infiltration basin	Y	N	N	M	H	H	N	M	N/A	L	M	M	M
Infiltration trench	Y	N	N	M	H	H	N	M	N/A	L	M	M	M
Bioretention	Y	N	N	M	H	H	N	L	N/A	L	M	M	M
Bioinfiltration	Y	N	N	M	H	H	N	L	N/A	L	M	M	M
Biofiltration	Y	N	N	M	H	H	N	L	N/A	L	M	M	M
Pond dosing system	Y	Y	N	M	M	H	N	H	M	H	H	H	H

Regulatory Setting

A review of jurisdictional ownership and permitting needs was performed to lay the foundations for later design. PMA 25 is not currently managed by a drainage authority or the City and there remains some ambiguity to the regulatory implications of implementing any of the alternatives considered in this assessment, though substantial clarity has been gained in the process. It is important to note the costs associated with wetland impacts remains to be determined at the design phase of project development, though it is likely that these costs will not affect the recommendations presented in this report.

The following is a log of discussions with the various regulatory authorities that potentially need to be coordinated with for any of the alternatives presented herein.

- Federal
    - The US Army Corps of Engineers, St. Paul District Bemidji Office (218-444-6381) is the regulatory authority for Section 404, Wetlands/ Waters of the United States that are likely present in South.
        - Offsite wetland delineation required onsite possibly required to identify aquatic resources and quantify impacts if filling or dredging within South Ditch
        - Dredging sidecasting must occur outside of wetland
        - NWI shows approximately 1.25 acres in ditch between Mn 197/Washington Ave and Lakeview Drive
        - Dredging and inundation will possibly be allowable without a permit depending on the project setting
    - US Fish & Wildlife Service IPAQ review shows potential northern long-eared bat habitat in tree areas. Coordination possible
- State
    - Brent Mason, DNR area hydrologist was contacted. The ditch is not considered a public water and therefore no Public Waters permitting would be required for the project.
    - Additionally, the ordinary high water level (OWH) for Lake Irving has not been determined. However, Lake Irving is considered by DNR to be equalized with Lake Bemidji and the OHW for Lake Bemidji is 1,340.0.
- County
    - County ditch JD 33 is in the vicinity of South Ditch. Bruce Hasbargen, Beltrami County Engineer, confirmed South Ditch is not part of JD 33.
    - Additionally, the County Board is not the drainage authority for South Ditch.
- Wetland Conservation Act
    - William Best, Beltrami County (218-333-4171) is LGU Contact for purposes of WCA. He was familiar with the ditch, and agreed that work in the ditch would be approved under WCA. It is possible that exemptions or no-loss findings could occur depending on the nature of work in the ditch.
    - Several area wetlands were discussed including one north of Arrow Printing along HWY 197. Any exemptions or no-loss findings would need to ensure no impacts to adjacent wetlands from lateral effects.

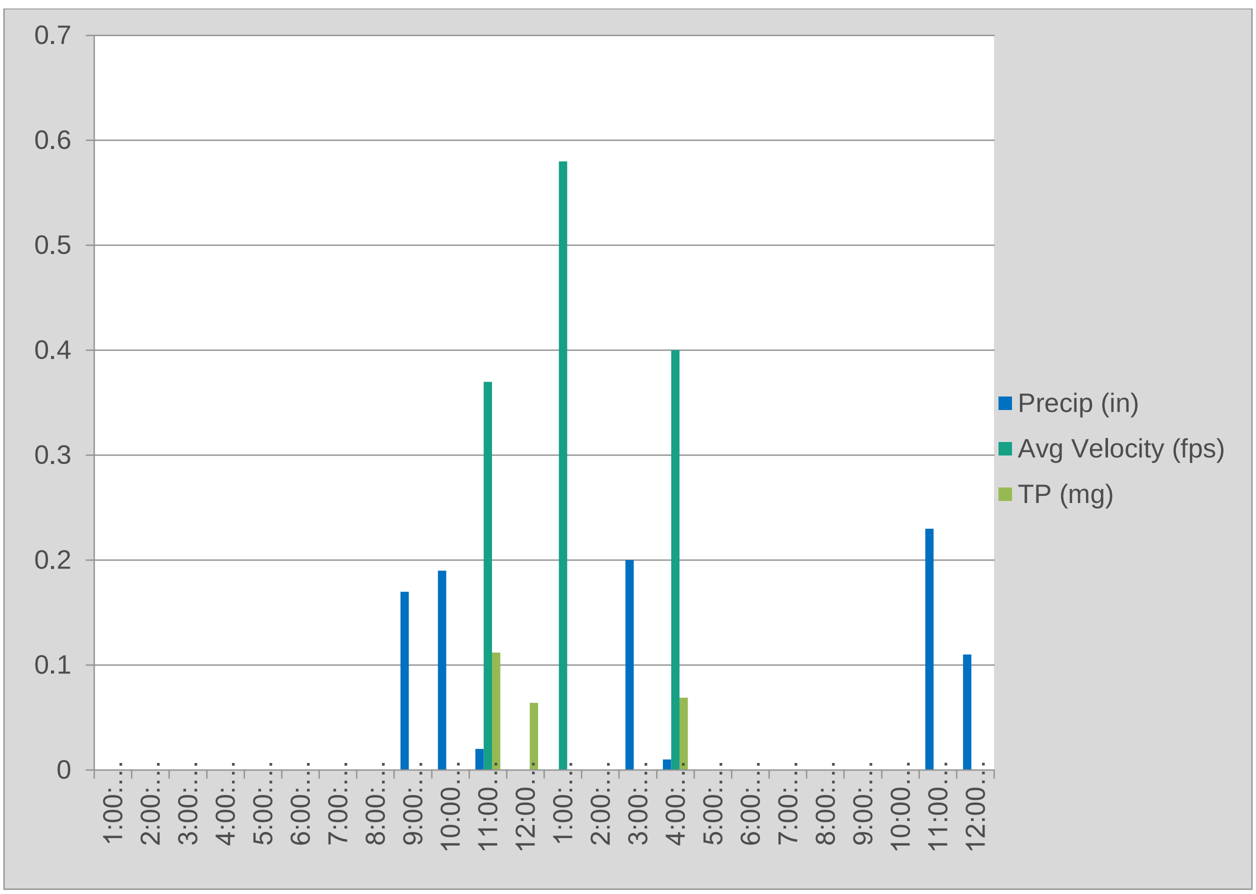
- Submittal of a joint application for the WCA approval could occur when preliminary plans are available.
- City
  - Application for Tree Removal

Ditch Flow and Water Quality monitoring

The Beltrami SWCD set up the monitoring stations and collected data used for assisting model calibration in this assessment. 2017 was a substantially dry year for precipitation and that in combination with precipitation timing led to a small data set to work with. As a result, there was not enough data available to validate the model against several rainfall events.

Of the flow data that was collected, one event was adequate for model calibration of flow and water quality (Figure 1).

FIGURE 1. MONITORING RESULTS FOR PMA 25 DITCH (X-AXIS REPRESENTS HOURLY INCREMENTS OF THE STORM FLOW AND Y-AXIS REPRESNTS RESPONSE).



Ditch flow monitoring and water surface elevation (WSE) data was provided to the MPCA to generate a regression rating curve. The regression curve also assisted in calibrating the model. The MPCA believed the WSE data were adequate but there were a low number of paired flow measurements and discharge readings to correlate with the WSE data. However, with the limited data available, MPCA did propose two rating curves based on an abrupt change in WSE in late June. Figure 2, below indicates WSE over the monitoring period. The data suggests two ratings need to be made for the summer period based on this WSE change (Figure 3, Figure 4 and Figure 5). Note, Lake Irving WSE did not change as abruptly during the same period, and in fact remained relatively the same, suggesting a blockage in the ditch/culverts downstream of the flow monitoring point. The MPCA rating curve for June appeared to have a strong correlation and was used for the selected rainfall event's ditch flow used for calibration, in the P8 model.

FIGURE 2. WATER SURFACE ELEVATION MONITORING RESULTS.

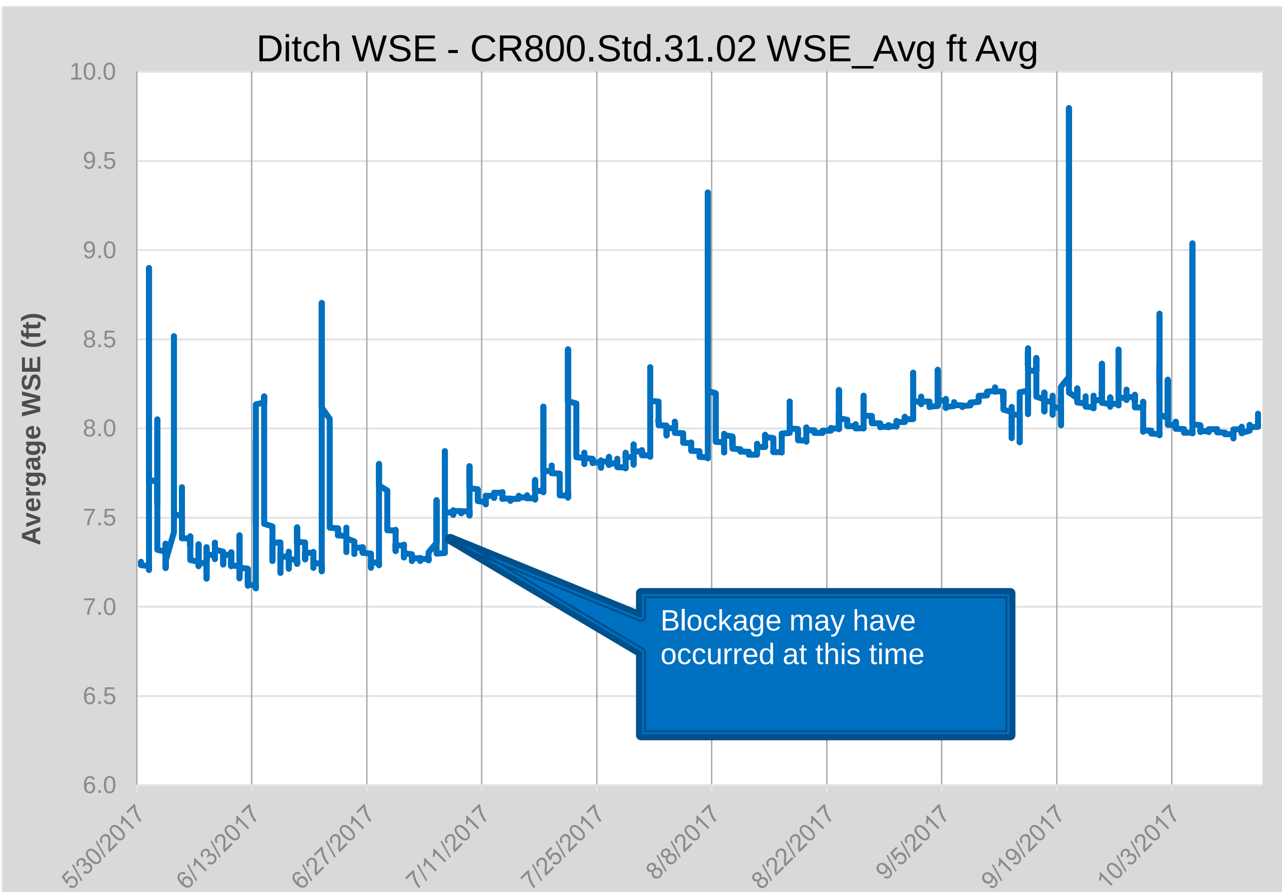


FIGURE 3. RATING CURVE USED IN MODEL CALIBRATION.

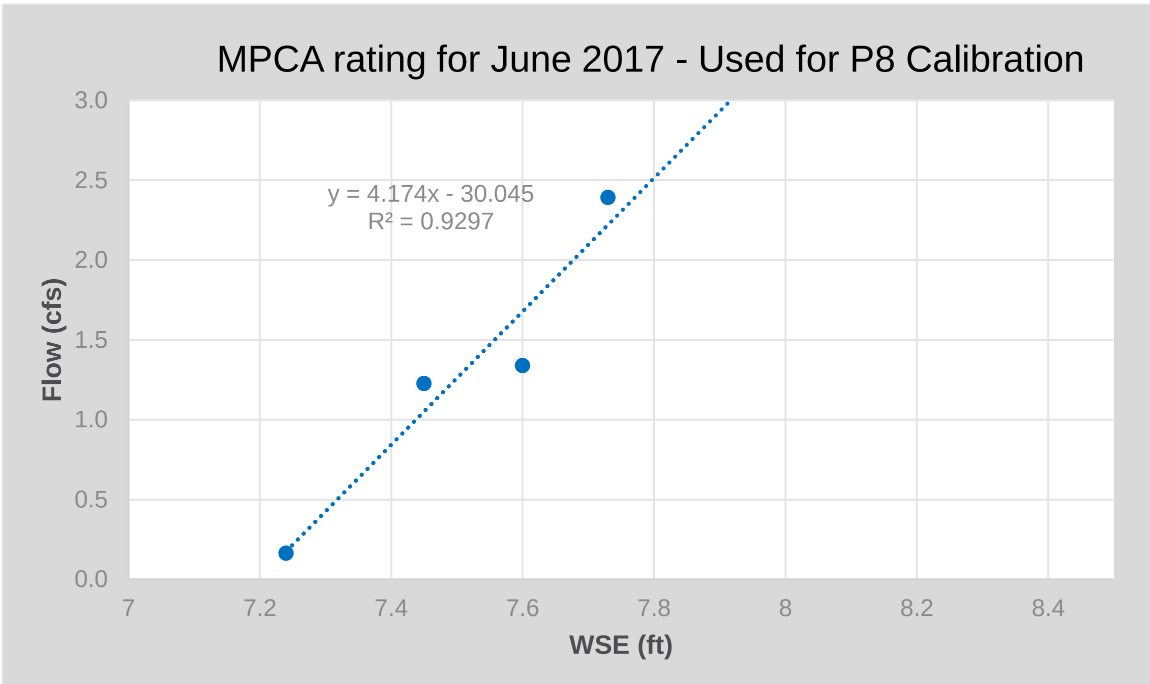


FIGURE 4. MID-TO-LATE SUMMER RATING CURVE NOT USED FOR CALIBRATION.

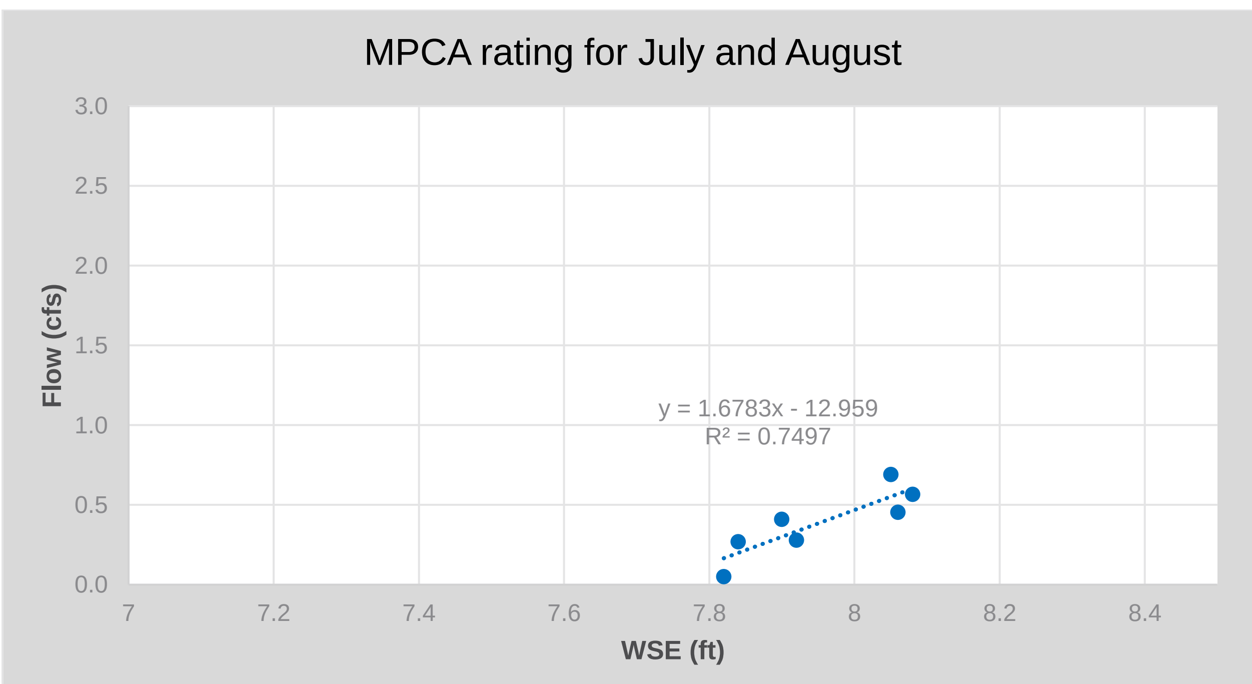
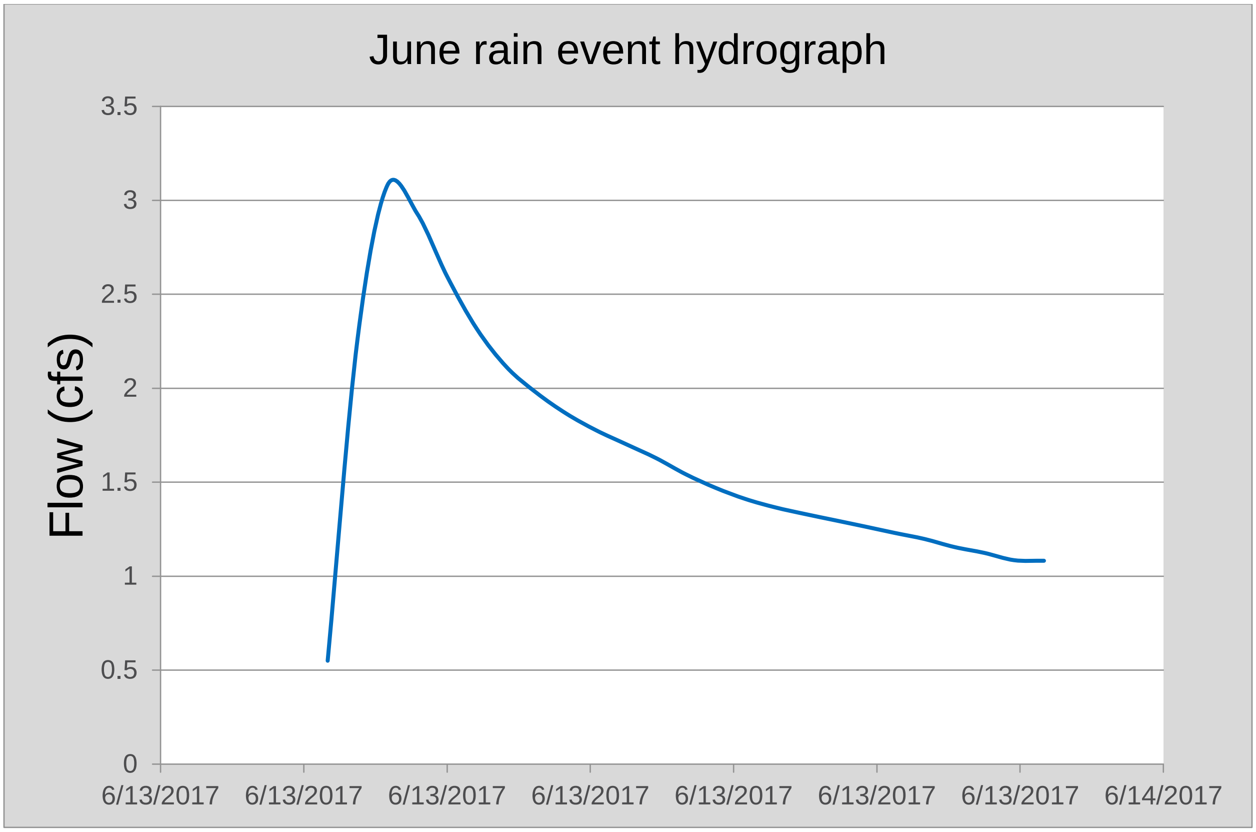


FIGURE 5. CALIBRATION EVENT HYDROGRAPH.



Modeling

Each Pipeshed's stormwater effluent water quality was modeled within P8 Urban Catchment Model (version 3.5; Walker, 2015). Land use classifications from the 2014 analysis were retained for this effort. NRCS soils obtained from the NRCS Web Soil Survey were used for classification of hydrologic soil groups. As-built surveys, where available, were obtained from the City and referenced for development of existing ponding and effect on water quality.

The existing conditions model was used to assess the performance of various BMP alternatives in relation to the average removal of pollutants over the entire time series. P8 uses settling time and filtration efficiencies to estimate load reductions of BMPs. In all cases, default settings for sediment-pollutant associations, particle settling times and particle filtration efficiencies were retained.

Present Day Value

The Water Environment Research Federation's *BMP and LID Whole Life Costs Model Version 2.0* was used to determine the present day value of select alternatives. Engineers estimated costs for designing and building were entered into this model as implementation costs. Routine, corrective and infrequent maintenance costs were also entered at various points within a 50 year timeframe. The combination of implementation costs, maintenance costs and adjustments to inflation generated a final present day value for each selected alternative.

Alternative 1

YEAR	ANNUAL	INTERMITTENT	YEAR	ANNUAL	INTERMITTENT
1	$ 313	$ -	26	$ 313	$ 2,159
2	$ 313	$ 2,159	27	$ 313	$ -
3	$ 313	$ -	28	$ 313	$ 2,607
4	$ 313	$ 2,607	29	$ 313	$ -
5	$ 313	$ 1,448	30	$ 313	$ 16,959
6	$ 313	$ 2,159	31	$ 313	$ -
7	$ 313	$ -	32	$ 313	$ 2,607
8	$ 313	$ 2,607	33	$ 313	$ -
9	$ 313	$ -	34	$ 313	$ 2,159
10	$ 313	$ 3,607	35	$ 313	$ 1,448
11	$ 313	$ -	36	$ 313	$ 2,607
12	$ 313	$ 2,607	37	$ 313	$ -
13	$ 313	$ -	38	$ 313	$ 2,159
14	$ 313	$ 2,159	39	$ 313	$ -
15	$ 313	$ 1,448	40	$ 313	$ 4,055
16	$ 313	$ 2,607	41	$ 313	$ -
17	$ 313	$ -	42	$ 313	$ 2,159
18	$ 313	$ 2,159	43	$ 313	$ -
19	$ 313	$ -	44	$ 313	$ 2,607
20	$ 313	$ 4,055	45	$ 313	$ 1,448
21	$ 313	$ -	46	$ 313	$ 2,159
22	$ 313	$ 2,159	47	$ 313	$ -
23	$ 313	$ -	48	$ 313	$ 2,607
24	$ 313	$ 2,607	49	$ 313	$ -
25	$ 313	$ 1,448	50	$ 313	$ 3,607

Alternative 2

YEAR	ANNUAL	INTERMITTENT	YEAR	ANNUAL	INTERMITTENT
1	$ 313	$ 662	26	$ 313	$ 2,159
2	$ 313	$ 2,821	27	$ 313	$ -
3	$ 313	$ 662	28	$ 313	$ 2,159
4	$ 313	$ 2,821	29	$ 313	$ -
5	$ 313	$ 2,110	30	$ 313	$ 21,443
6	$ 313	$ 2,159	31	$ 313	$ -
7	$ 313	$ -	32	$ 313	$ 2,159
8	$ 313	$ 2,159	33	$ 313	$ -
9	$ 313	$ -	34	$ 313	$ 2,159
10	$ 313	$ 12,267	35	$ 313	$ 1,448
11	$ 313	$ -	36	$ 313	$ 2,159
12	$ 313	$ 2,159	37	$ 313	$ -
13	$ 313	$ -	38	$ 313	$ 2,159
14	$ 313	$ 2,159	39	$ 313	$ -
15	$ 313	$ 1,448	40	$ 313	$ 12,267
16	$ 313	$ 2,159	41	$ 313	$ -
17	$ 313	$ -	42	$ 313	$ 2,159
18	$ 313	$ 2,159	43	$ 313	$ -
19	$ 313	$ -	44	$ 313	$ 2,159
20	$ 313	$ 12,267	45	$ 313	$ 1,448
21	$ 313	$ -	46	$ 313	$ 2,159
22	$ 313	$ 2,159	47	$ 313	$ -
23	$ 313	$ -	48	$ 313	$ 2,159
24	$ 313	$ 2,159	49	$ 313	$ -
25	$ 313	$ 1,448	50	$ 313	$ 12,267

Alternative 3

Year	Annual	Intermittent	Year	Annual	Intermittent
1	$ 313	$ 4,053	26	$ 313	$ 2,159
2	$ 313	$ 6,212	27	$ 313	$ -
3	$ 313	$ 4,053	28	$ 313	$ 2,159
4	$ 313	$ 6,212	29	$ 313	$ -
5	$ 313	$ 5,501	30	$ 313	$ 25,619
6	$ 313	$ 2,159	31	$ 313	$ -
7	$ 313	$ -	32	$ 313	$ 2,159
8	$ 313	$ 2,159	33	$ 313	$ -
9	$ 313	$ -	34	$ 313	$ 2,159
10	$ 313	$ 12,267	35	$ 313	$ 1,448
11	$ 313	$ -	36	$ 313	$ 2,159
12	$ 313	$ 2,159	37	$ 313	$ -
13	$ 313	$ -	38	$ 313	$ 2,159
14	$ 313	$ 2,159	39	$ 313	$ -
15	$ 313	$ 1,448	40	$ 313	$ 12,267
16	$ 313	$ 2,159	41	$ 313	$ -
17	$ 313	$ -	42	$ 313	$ 2,159
18	$ 313	$ 2,159	43	$ 313	$ -
19	$ 313	$ -	44	$ 313	$ 2,159
20	$ 313	$ 12,267	45	$ 313	$ 1,448
21	$ 313	$ -	46	$ 313	$ 2,159
22	$ 313	$ 2,159	47	$ 313	$ -
23	$ 313	$ -	48	$ 313	$ 2,159
24	$ 313	$ 2,159	49	$ 313	$ -
25	$ 313	$ 1,448	50	$ 313	$ 12,267

Alternative 4

YEAR	ANNUAL	INTERMITTENT	YEAR	ANNUAL	INTERMITTENT
1	$ 313	$ 4,400	26	$ 313	$ 2,159
2	$ 313	$ 6,559	27	$ 313	$ -
3	$ 313	$ 4,400	28	$ 313	$ 2,159
4	$ 313	$ 6,559	29	$ 313	$ -
5	$ 313	$ 5,848	30	$ 313	$ 25,619
6	$ 313	$ 2,159	31	$ 313	$ -
7	$ 313	$ -	32	$ 313	$ 2,159
8	$ 313	$ 2,159	33	$ 313	$ -
9	$ 313	$ -	34	$ 313	$ 2,159
10	$ 313	$ 12,267	35	$ 313	$ 1,448
11	$ 313	$ -	36	$ 313	$ 2,159
12	$ 313	$ 2,159	37	$ 313	$ -
13	$ 313	$ -	38	$ 313	$ 2,159
14	$ 313	$ 2,159	39	$ 313	$ -
15	$ 313	$ 1,448	40	$ 313	$ 12,267
16	$ 313	$ 2,159	41	$ 313	$ -
17	$ 313	$ -	42	$ 313	$ 2,159
18	$ 313	$ 2,159	43	$ 313	$ -
19	$ 313	$ -	44	$ 313	$ 2,159
20	$ 313	$ 12,267	45	$ 313	$ 1,448
21	$ 313	$ -	46	$ 313	$ 2,159
22	$ 313	$ 2,159	47	$ 313	$ -
23	$ 313	$ -	48	$ 313	$ 2,159
24	$ 313	$ 2,159	49	$ 313	$ -
25	$ 313	$ 1,448	50	$ 313	$ 12,267

PART 3. FIGURES

FIGURE 6. PROJECT LOCATION.

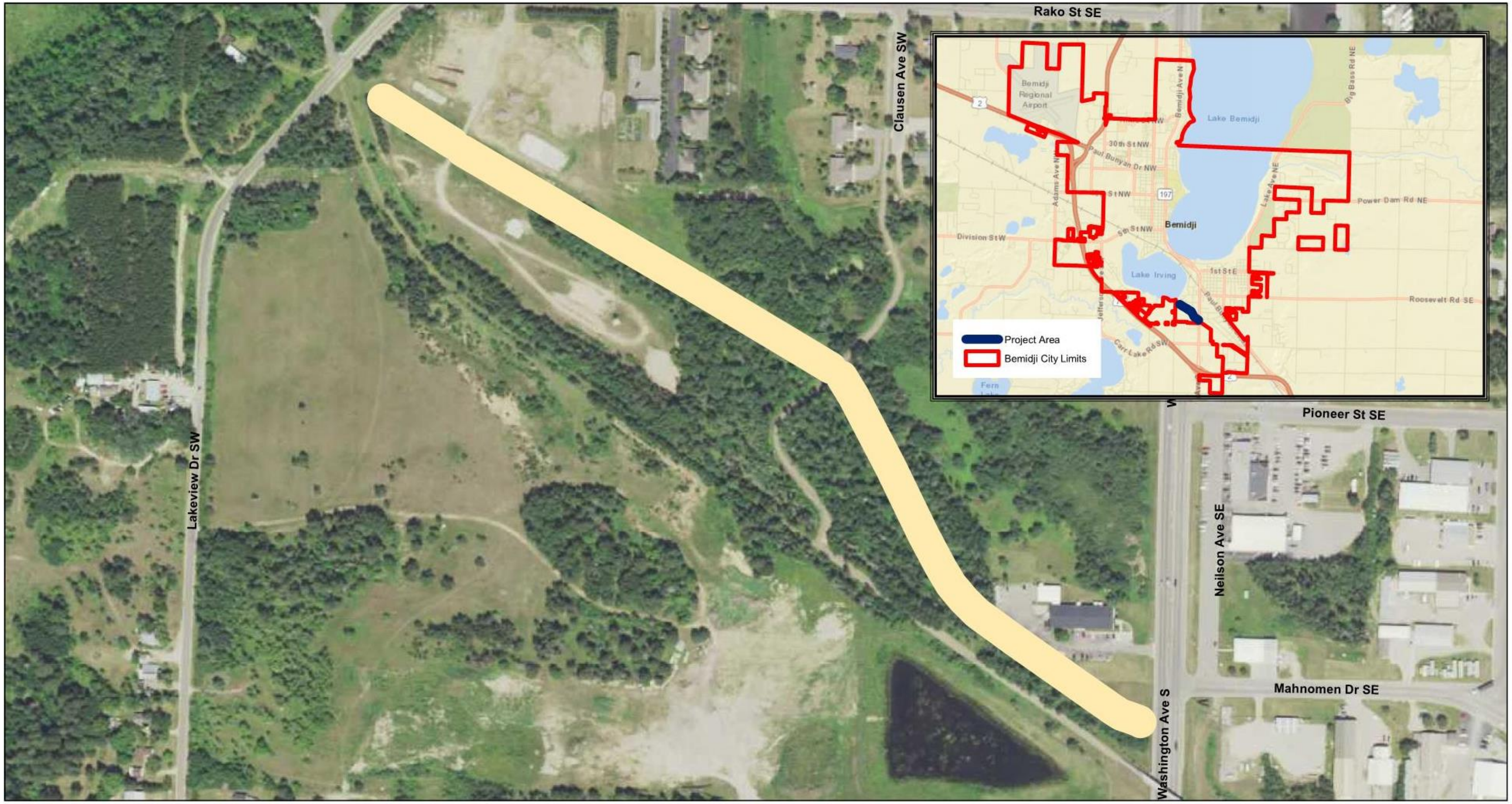


FIGURE 6
Project Location

Legend

Existing Stream Centerline

Data Source:
Coordinate System: NAD 1983 UTM Zone 15N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

0 0.05 0.1
Miles

1 inch = 250 feet

N

HRGreen

HRG PLOT: 11:25:26 AM 8/16/2018 BY: cduntem FILE: J:\2017\170503\Design\Deliverables\Lake Irvine\AerialProjectLocation.mxd

FIGURE 7. CONTRIBUTING WATERSHED, TOPOGRAPHY AND STORM SEWER.

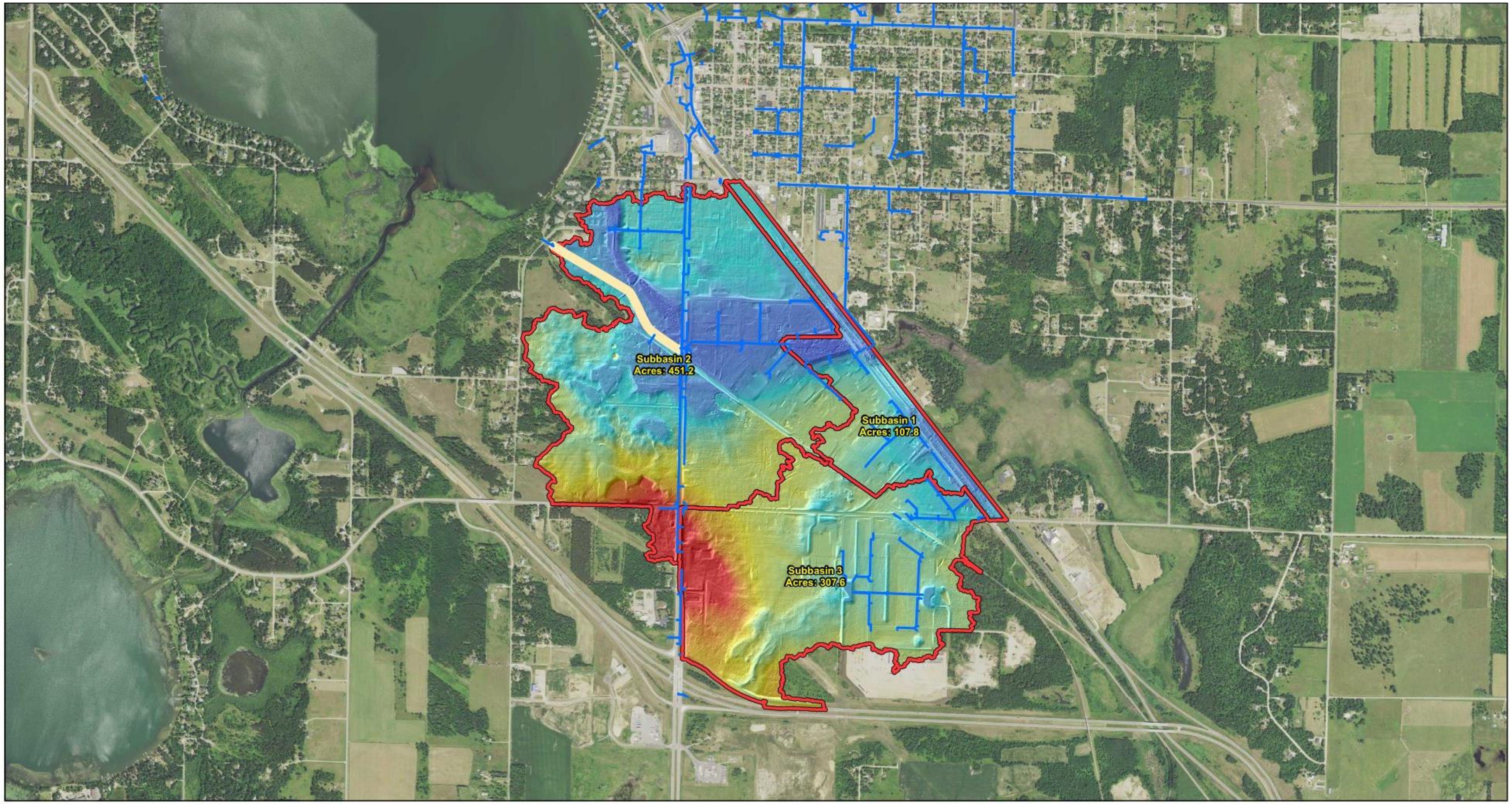


FIGURE 7
Contributing Watershed, Topography and Storm Sewer

Legend

- Stormwater Pipes
- Existing Stream Centerline
- Irvine Subwatersheds

Elevation
High : 433
Low : 408

Data Source:
Coordinate System: NAD 1983 UTM Zone 15N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

HRGreen

0 0.25 0.5
Miles
1 inch = 1,500 feet

N

HRG PLOT: 12:00:08 PM 8/16/2018 BY: cduntem FILE: J:\2017\170503\GIS\Bemidji\Watershed.mxd

FIGURE 8. ALTERNATIVE 1.

FIGURE 8 - ALTERNATIVE 1
Forebay at Stormwater Outfall into Pool 1, Dredge Pools 1 through 4

Legend

- Replaced Culvert
- Forebay Rip Rap
- Forebay
- Dredged Channel
- Existing Stream Centerline

Data Source:
Coordinate System: NAD 1983 UTM Zone 15N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

HRGreen

0 0.05 0.1
Miles

1 inch = 250 feet

N

HRG PLOT: 11:16:17 AM 8/16/2018 BY: cduntem FILE: J:\2017\170503\GIS\Bemidji\Bemidji_Alts.mxd

FIGURE 9. ALTERNATIVE 2.

FIGURE 9 - ALTERNATIVE 2
Forebay at Stormwater Outfall into Pool 1, Dredge Pools 1 and 4, IESF in Pool 4, Wetland Vegetation in Pool 4

Legend

- Replaced Culvert
- IESF Extent
- Forebay Rip Rap
- Forebay
- Dredged Channel
- Wetland Vegetation
- Existing Stream Centerline

Data Source:
Coordinate System: NAD 1983 UTM Zone 15N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

HRGreen

0 0.05 0.1
Miles

1 inch = 250 feet

N

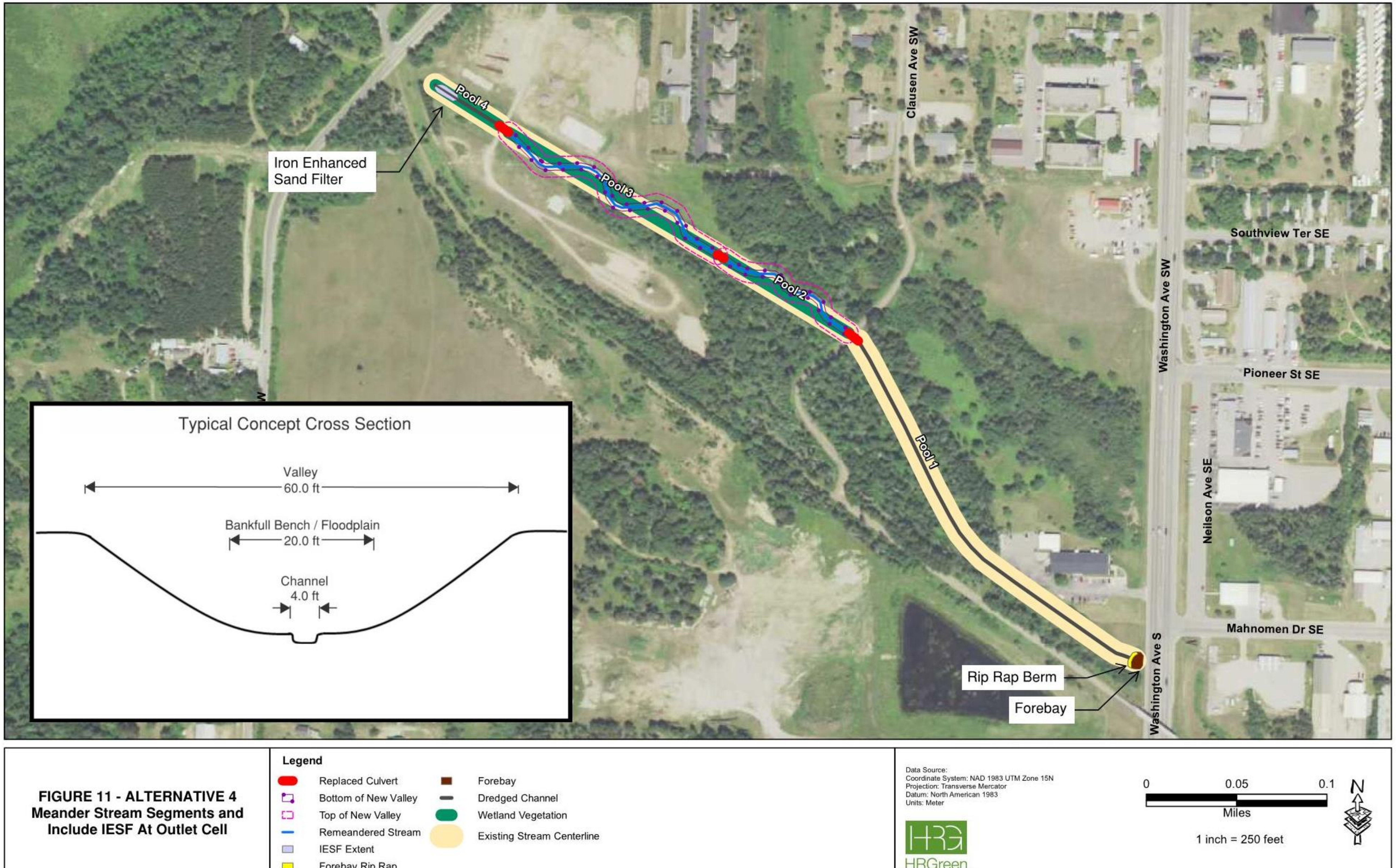
HRG PLOT: 11:10:43 AM 8/16/2018 BY: cduntem FILE: J:\2017\170503\GIS\Bemidji\Bemidji_Alts.mxd

FIGURE 10. ALTERNATIVE 3.

FIGURE 10 - ALTERNATIVE 3
Forebay at Stormwater Outfall into Pool 1, Dredge Pools 1 through 4, IESF in Pool 4, Wetland Vegetation in Pools 2, 3 and 4

HRG PLOT: 11:15:05 AM 8/16/2018 BY: cduntem FILE: J:\2017\170503\GIS\Bemidji\Bemidji_Alts.mxd

FIGURE 11. ALTERNATIVE 4.



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