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For Hennepin County

Lake Rebecca Feasibility Assessment

Cover Image

First Snow at Ditched Wetland by Derek Lash

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1. INTRODUCTION

Hennepin County, Three River's Park District (TRPD) and the Pioneer-Sarah Creek Watershed Management Commission identified the Lake Rebecca subwatershed as a priority for protection and restoration through conservation efforts and best management practices. The targeted area for this work will be the privately owned portion of the subwatershed outside of the Three River's Park District land. The project involves multiple phases of work with several objectives including:

1. Estimate surface flow volume and timing to all major inlets to Lake Rebecca,
2. Estimate the existing pollutant loading to Lake Rebecca,
3. Identify and prioritize feasible BMPs based on cost and expected pollutant removal and,
4. Design selected BMPs and drainage solutions.

This report describes the process, results, and recommended strategies for runoff treatment to Lake Rebecca.

1.1. Background

The Lake Rebecca subwatershed is located within the South Fork Crow River watershed and in the northwest corner of Hennepin County. The subwatershed has an area of approximately 1,540 acres. The terrain of the subwatershed contains gently rolling hills with small depressional wetlands dispersed throughout. The land use varies from natural wetlands and forest surrounding the lake which is owned by the Three River's Park District, to mostly agricultural land use in the headwaters. Within the agricultural areas there are two horse boarding facilities that have feedlots and pasture within their property. The soils in the Lake Rebecca subwatershed are poorly drained with hydrologic soil classifications of mostly C and C/D and therefore most of the agricultural areas in the watershed are expected to be drain tiled. Improvements to the drainage system in the subwatershed has been identified as one of the priorities of this project with improvements to the stream within the Three Rivers Park District occurring in parallel to this study.

2. POLLUTANT LOAD ANALYSIS

Multiple approaches were used to approximate the pollutant loading to Lake Rebecca and to identify hotspots within the watershed. The first approach involves a review of the flow and water quality data collected in the watershed. This data is used to identify if there is a water quality concern in the watershed and as verification in modeling the watershed. The other two approaches involve using models to approximate pollutant loading within the watershed. The GIS analysis approach uses the existing South Fork Crow River HSPF model to map out the predicted pollutant loading rates by land use and soil type. The second approach uses the Stormwater Management Model (SWMM) to approximate pollutant loading and finer scale runoff conditions in the watershed allowing for individual BMP scenario running. The SWMM model can be used in future phases of the project to estimate pollutant load reductions as BMP designs are refined. The methods and results of these approaches are described in the section below.

2.1. Watershed Delineation

Tributary watersheds were delineated for all major inlets to Lake Rebecca using a hydro-enforced LiDAR derived digital elevation model (DEM) The DEM was hydro-enforced using a user defined layer to burn through artificial dams such as roads in the watershed. The user defined layer identified locations where there is likely a culvert based on review of aerial imagery and the DEM. Subcatchments within the major tributary watersheds were delineated to accurately model the contributing area to culvert locations; to large storage features; and to separate, as much as possible, distinct land cover types i.e. natural from agricultural lands. In the end, 49 subcatchments were delineated within the Lake Rebecca drainage area ranging from 1.1 to 418.9 acres with an average area of 32.2 acres.

2.2. Monitoring Review

Monitoring the flow and water quality conditions in a watershed is a vital part of watershed management. Flow and water quality conditions are monitored at several locations within the Lake Rebecca watershed by TRPD. For this study the flow and water quality data were used to calculate the pollutant loading to Lake Rebecca and as verification of model accuracy. The monitoring data collected at monitoring station RN, located at the outlet of the main tributary to Lake Rebecca, was used in this study because that site had the longest data record and was the outlet of the area of interest for this project where projects are likely to be built. According to the Minnesota Pollution Control Agency (MPCA) Environmental Data Access (EDA) surface water website, water quality data was collected at site RN for ten years (2009-2018). The last three of which (2016-2018), were paired with flow monitoring and thus used to derive loads in this analysis.

Table 1 shows the estimated flow weighted mean concentration (FWMC) for total suspended solids (TSS) Nitrogen as N (TN), Orthophosphate (OP), and Total Phosphorus (TP). Compared to reference TP concentrations for the Southern River Nutrient region of Minnesota in Minnesota Rules 7050.0222, the TP concentrations in the main tributary are likely elevated and contributing to the increasing TP concentrations in Lake Rebecca. In addition, the majority of TP is OP. OP is more likely to contribute to algae growth than other forms of TP and is more difficult to remove than particulate phosphorus. The TSS concentrations at the site are below reference concentrations for the Southern River Nutrient region. The pollutant concentrations were related with flow using a Log-Log regression analysis. The low coefficient of determination (R^2) and regression slopes close to zero, shows that a mixture of constant sources contribute to the pollutant loads in the main tributary. Examples of these in the watershed are feedlots, septic systems, drain tile flow, wetland release, as well as some driven by rainfall runoff.

Table 1 Observed Flow Weighted Mean Concentration and Log-Log Regression Analysis Results for the Main Tributary to Lake Rebecca (TRPD Monitoring Station RN; MPCA Station ID S005-815)

Year	Total Suspended Solids (mg/L)	Nitrogen as N (mg/L)	Orthophosphate (µg/L)	Total Phosphorus (µg/L)	Orthophosphate/Total Phosphorus (%)
Reference	65	-	-	150	-
2016	42.1	2.37	279	448	62%
2017	32.4	2.12	242	494	49%
2018	32.8	-	275	541	51%
Mean	35.8	2.23	263	491	54%
Log Flow~Log Pollutant Regression Analysis					
R^2	0.032	0.021	0.013	0.015	NA
Slope	0.25	-0.06	0.06	0.08	NA

Because of the limited correlation between pollutant concentrations and flow, the pollutant loads at the outlet of the main tributary were calculated by multiplying the FWMC by the measured volume. The estimated flow volume and pollutant loads are shown in Table 2. Estimated pollutant loads have inherent uncertainty because of the inability to collect continuous water quality conditions in the stream and instead the reliance on grab samples throughout the year. Therefore, the predicted uncertainties in the load estimates are shown in parathesis in Table 2 as the coefficient of variation (CV). The CV is the standard error divided by the mean of the load estimate. Calculated loads with CV less than 0.3 are considered reasonable estimates according to Met Council standard operating procedures. The calculated TSS load in 2016 is the only load with greater uncertainty than this standard. On average the estimated loads represent approximately 52 percent of the year from mid-April to mid-November.

Table 2 Observed Load to Lake Rebecca from the Main Tributary.

Year	Number of Days	Volume (ac-ft)	Total Suspended Solids (tons)	Nitrogen as N (lbs)	Orthophosphate (lbs)	Total Phosphorus (lbs)
2016	172	231	13.3 (0.73)	1,490 (0.27)	176 (0.09)	281 (0.10)
2017	207	222	9.8 (0.24)	1,280 (0.06)	146 (0.10)	298 (0.11)
2018	195	280	12.5 (0.29)	-	210 (0.11)	413 (0.14)
Mean	191.3	244	11.8 (0.29)	1,380 (0.12)	177 (0.05)	321 (0.07)

2.3. HSPF Analysis

To predict pollutant loads throughout the year and throughout a watershed, often a water quality model is needed. The Lake Rebecca watershed is included in the existing HSPF model for the South Fork Crow River (Reisinger and Love, 2012). The South Fork Crow River HSPF model provides high level predicted pollutant loads at the outlet of Lake Rebecca and pollutant loading rates based on soils and land cover within the watershed. The HSPF model was calibrated to the outlet of the South Fork Crow River at Delano, Bridge Ave. The calibrated predicted runoff volumes were shown to be within 3% of the observed runoff volume and the water quality parameters TSS, TP, and TN were shown to be well calibrated. Using the HSPF model, the predicted pollutant loading rates by land cover and soil data for 2009-2015 were mapped to the Lake Rebecca watershed using the mapping scheme shown in Table 3. The total volume and pollutant loads were compared to the observed pollutant loads at monitoring site RN (Table 4). Use of the HSPF loading rates, overestimated the volume of runoff, the TSS load, the TN load while under-estimating the TP load. The likely reason for these differences include:

- Different time periods between monitoring period (2016-2018) and modeling period (2009-2015).
- While this subwatershed was included in the HSPF model calibration, it was not calibrated to observed data in this subwatershed.
- The predicted pollutant loading rates do not include landscape storage and removal processes that would remove pollutants prior to reaching monitoring site RN such as the caved in outlet on the wetland along the northern edge of the ZHS Ranch.
- The predicted pollutant loading rates do not include legacy loading to wetlands that may be released and result in the greater observed TP loads.
- Some uncertainty in monitoring data is expected based on the monitoring plan and the method of collecting samples via grab samples. The associated uncertainty in the observed loads is estimated as the CV in Table 2.

Table 3. HSPF Predicted Loading Rates in Lake Rebecca by Land Cover and Hydrologic Soil Group (2009-2015)

2019 National Land Cover Dataset	HSPF Land Cover Category	NRCS Hydrologic Soil Group Layer	HSPF Soil Category	Predicted Volume (ac-ft/ac/yr)	Predicted Sediment (tons/ac/yr)	Predicted TN (lbs/ac/yr)	Predicted TP (lbs/ac/yr)
Open Water	Wetland	NA	NA	0.422	0.003	1.278	0.051
Developed, Open Space	Developed			0.751	0.068	4.547	0.210
Developed, Low Intensity	Developed			0.751	0.068	4.547	0.210
Developed, Medium Intensity	Developed			0.751	0.068	4.547	0.210
Developed, High Intensity	Developed EIA			2.148	0.123	10.962	0.376
Barren Land	Rangeland	A, B	AB	0.466	0.0189	1.843	0.075
		C, D, A/D, B/D, C/D	CD	0.440	0.022	1.823	0.074
Deciduous Forest	Forest	A, B	AB	0.221	0.003	0.753	0.030
		C, D, A/D, B/D, C/D	CD	0.221	0.003	0.761	0.031
Evergreen Forest	Forest	A, B	AB	0.221	0.003	0.753	0.030
		C, D, A/D, B/D, C/D	CD	0.221	0.003	0.761	0.031
Mixed Forest	Forest	A, B	AB	0.221	0.003	0.753	0.030
		C, D, A/D, B/D, C/D	CD	0.221	0.003	0.761	0.031
Shrub/Scrub	Rangeland	A, B	AB	0.466	0.0189	1.843	0.075
		C, D, A/D, B/D, C/D	CD	0.440	0.022	1.823	0.074
Grassland	Rangeland	A, B	AB	0.466	0.0189	1.843	0.075
		C, D, A/D, B/D, C/D	CD	0.440	0.022	1.823	0.074
Pasture/Hay	Pasture	A, B	AB	0.517	0.033	2.913	0.126
		C, D, A/D, B/D, C/D	CD	0.494	0.043	2.970	0.131
Cultivated Crops	Cropland High Till	NA	NA	0.711	0.076	17.378	0.828
Woody Wetlands	Wetland			0.422	0.003	1.278	0.051
Emergent Herbaceous Wetlands	Wetland			0.422	0.003	1.278	0.051

Table 4. Predicted and Observed Pollutant Loads at Monitoring Site RN

Loading Estimate	Volume (ac-ft/yr)	Total Suspended Solids (tons/yr)	Nitrogen as N (lbs/yr)	Total Phosphorus (lbs/yr)
Observed Apr-Nov Load (2016-2018)	244	11.8	1,380	321
Predicted Apr-Nov Load (2009-2015)	396	35.9	5530	263

Figure 1 shows the flow paths and predicted runoff annual runoff volume from each tributary to Lake Rebecca. The tributaries are labeled with the predicted runoff volume to Lake Rebecca. The drainage area surrounding Lake Rebecca excludes the lake surface area to prevent double counting of runoff during the development of any future lake response model. The flow through the Lake Rebecca watershed is shown with flow paths and flow arrows denoting the direction of flow. Wetlands are included using the National Wetland Inventory (NWI) layer and are coded to show the dominant flow condition in each wetland according to the hydrogeomorphic wetland classification system. Waterbodies included as part of the National Hydrologic Dataset (NHD) are shown with purple hash markings. The largest source of runoff volume to Lake Rebecca is the tributary draining the area surrounding Dogwood St. which is also the most agriculturally developed subwatershed. This tributary will be the focus of the BMP siting analysis.

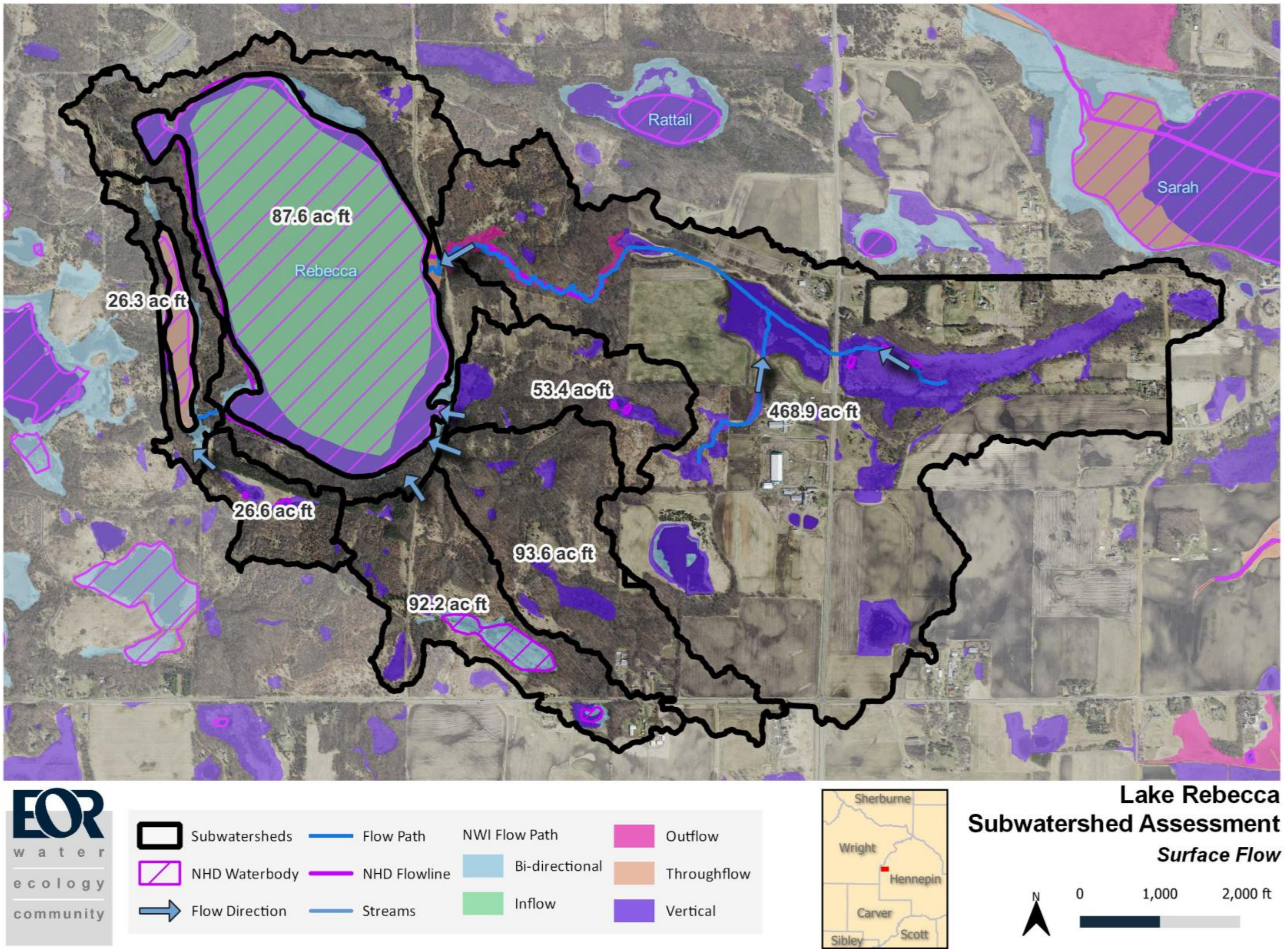


Figure 1. HSPF runoff yield predicted average annual flow volume (2009-2015) to Lake Rebecca and surface flow paths.

2.4. PCSWMM Modeling

Using the subcatchments described in Section 2.1, a WMM model version 5.1.013 was constructed for the Lake Rebecca watershed to assist in the design and effectiveness estimation of potential BMPs. Computational Hydraulics International's PCSWMM software platform was chosen for construction of the model. PCSWMM is an enhanced visual dashboard that integrates a GIS platform to run EPA SWMM models. Therefore, the model files and results are interchangeable for use with other GIS platforms and the EPA SWMM software.

Hydrologic parameters in the model were derived from the 2019 National Landcover Dataset (NLCD). Infiltration in the model was estimated using Green and Ampt infiltration parameters calculated from the NRCS gSSURGO database. Hydraulic information in the model came from a TRPD culvert inventory, survey conducted by Stantec for an ongoing project in the watershed, and a survey of pipes conducted by Hennepin County as part of this project. Missing hydraulic information and natural channel elevations were estimated using the LiDAR derived DEM. To predict the water quality benefit along with flows, pollutant export coefficients were added into the PCSWMM model. The export coefficients were derived from the loading rates predicted in the PCSWMM model for the different land uses that are defined in the model. An additional land use category was added to represent the wetlands with soils that are likely saturated with TP directly downstream of the horse boarding facilities as they have been receiving manure laden runoff for many years. The export coefficient for these wetlands was set to 500 µg/L based on the estimated flow weighted mean concentration for the tributary of 489 µg/L.

The model's accuracy was checked by comparing the predicted results to observed data measured in 2016 and 2017. To improve the results several changes were made to the model including:

- Adding a constant baseflow of 0.4 to 0.525 cfs to the model to represent potential groundwater inputs in the watershed;
- Increasing the land use export coefficients to match more closely the predicted loads with observed loads;
- Adding a sediment settling equation to model the likely sedimentation that occurs in the two wetlands; and
- Increasing the forest land use TSS export coefficient by an additional five times as a surrogate to stream erosion occurring in ditch from the agricultural fields to the lake.

The sedimentation equation added to the model is shown in Equation 1 where C is effluent concentration, TSS is the influent concentration, DEPTH is the depth of the pool and DT is the model time step.

Equation 1

$$C = TSS * e^{-\frac{0.0593}{3600} * DEPTH * DT}$$

The export coefficients used in the final model are shown in Table 5 along with typical ranges cited in the Minnesota Stormwater manual. The export coefficients used in the model are generally within typical ranges except for the high estimated TSS concentrations from cropland, developed areas, and the low estimated TP concentrations from pasture. The increases in export coefficients between those used in

HSPF and PCSWMM is most likely due to the difference in scale the models are representing. The HSPF model is modeling the watershed at a much larger scale where one element in the model represents the entire Lake Rebecca watershed while the PCSWMM model includes resolution down to the individual field scale.

Table 5 Modeled Land Use Export Coefficients.

Land use	TSS (mg/L)		TP (µg/L)	
	Modeled	MN Stormwater Manual Typical Range	Modeled	MN Stormwater Manual Typical Range
Cropland High Till	236	50-160	1,287	126-1,348
Developed	199	42-101	309	180-400
Developed EIA	126	42-101	192	180-400
Forest AB	167	26-140	153	30-450
Forest CD	158	26-140	156	30-450
Pasture AB	142	75-150	270	350-450
Pasture CD	191	75-150	291	350-450
Rangeland AB	89	75-150	177	30-450
Rangeland CD	112	75-150	186	30-450
Wetland	15.3	NA	132	NA
Wetland Nutrient Imbalanced	15.3	NA	1,500	NA
Feedlots	295	NA	2,541	NA
Lake	0	NA	0	NA

The performance of the PCSWMM model is fair for not being calibrated extensively (Table 6). Predicted volumes and loads are generally within 20% of the observed except for TSS in 2016. However, the observed TSS load has a high error as well. Possible improvements to the model include calibrating the flows to 2016 and 2017 observed data, potentially adding a groundwater component to the model to improve the accuracy of flow through the large wetland complex and drain tile in the cropland. The water quality model performance could be improved by calibrating to the observed concentrations in 2016 and 2017 and using a more sophisticated model within PCSWMM. For the purposes of this study relative results are sufficient to compare and prioritize BMPs in a pre-to-post comparison.

Table 6 PCSWMM Model Performance compared to Observed data in 2016 and 2017

	2016		2017	
	Observed	Predicted	Observed	Predicted
Volume (ac-ft)	231	182	222	213
TP Load (lbs)	281	225	298	244
TSS Load (tons)	13	6	10	8
NSE	0.03		-0.94	
Volume Error (%)	-21%		-4%	
TP Error (%)	-20%		-18%	
TSS Error (%)	-54%		-14%	

3. BMP FEASIBILITY ANALYSIS

Prioritizing BMPs involves brainstorming potential BMPs based on available data about the watershed such as topography, soils, land use, and land ownership, predicting the potential water quality benefit of each BMP based on a combination of modeled loading, literature value removal efficiencies, and estimating the probable cost using engineering judgement from sources indicated in Subsection 3.3 BMP Cost Estimation. The below section describes the process used to identify and prioritize BMPs in the Lake Rebecca watershed.

3.1. BMP Identification

BMPs were identified in the watershed using GIS analysis, field review, and engineering judgment. The GIS analysis included using the Agricultural Conservation Planning Framework (ACPF) The ACPF tool identifies potential locations for BMPs from high resolution DEM and land cover data. The initial set of BMPs were then reviewed and refined using engineering judgment. Further refinement of the BMPs occurred after field review by EOR in 12/08/2021 and by the County in May 2022 and July 2022. Shown in Figure 2 are four areas where field review found that improvements could be made. The final locations of potential BMPs reviewed as part of this project are shown in Appendix A. Construction Drawings. The potential BMPs include grassed waterways, water and sediment control basins (WASCOBs), impoundment BMPs (control structures and created wetlands), inlet buffers, and field buffers.

Figure 2. Potential projects identified during field review. The upper left image is a slightly incising channel outlet from a wetland (Control Structure 10). The upper right image is an incised channel in Waterway 12 from tile blow out. The lower left image is an approximately 250 ft gully in Waterway 4. The lower right image is a seasonally wet Wetland 11 established following tile blowout.

3.2. BMP Load Reduction

TSS and TP load reductions for each BMP were predicted by using the PCSWMM model. Each BMP was modeled individually with load reductions reported at the inlet to Lake Rebecca by comparing the predicted load with the BMP to the base model without BMPs. The literature values used to predict the load reductions are shown in Table 7.

Table 7 Agricultural Best Management Practices Predicted Pollutant Load Reductions (%)

Best Management Practice	Total Suspended Solids		Total Phosphorus	
	Modeled (%)	Source	Modeled (%)	Source
Nutrient Management Plans	0%	HSPF SAM	17%	HSPF SAM
Cover Crops[1]	(100-74%)*(Crop EMC-Rangeland EMC)+Rangeland EMC	HSPF SAM	(100%-29%)*(Crop EMC-Rangeland EMC)+Rangeland EMC	HSPF SAM
No Till[1]	(100%-80%)*(Crop EMC-Rangeland EMC)+Rangeland EMC	HSPF SAM	(100%-68%)*(Crop EMC-Rangeland EMC)+Rangeland EMC	HSPF SAM
Prescribed Grazing	40%	Sovell et al. 2000	Sediment bound P assumption[2]	
Prairie Restoration	Used Rangeland Export Coefficients		Used Rangeland Export Coefficients	
Feedlot/Manure[3] Management	80%	Agricultural BMP Handbook for Minnesota	80%	Agricultural BMP Handbook for Minnesota
Grassed Waterways	Length Dependent	Agricultural BMP Handbook for Minnesota	Sediment bound P assumption[2]	
Tile Intake/Tile Buffer	53%	Agricultural BMP Handbook for Minnesota	Sediment bound P assumption[2]	
WASCOB	64%	Agricultural BMP Handbook for Minnesota	Sediment bound P assumption[2]	
Field Buffer Strip	86%	Agricultural BMP Handbook for Minnesota	Sediment bound P Assumption[2]	
Wetland Restoration	Equation 1	Development of a Rural Stormwater Management Model	20% + Removal of estimated legacy TP[4]	Agricultural BMP Handbook for Minnesota

		to Mange Water Quality in the Lake Huron Watersheds		
Two-Stage Ditch	15%	Ohio State University	Sediment bound P Assumption[2]	
Covered Storage	Developed Export Coefficients		Used Developed Export Coefficients	
Draintile Outlet Control Structure	0%		50% Cropland Export Coefficient	Agricultural BMP Handbook for Minnesota

[1]Literature pollutant load reductions made cover crops and no-till more effective than prairie restoration which is not possible.

[2]The majority of BMPs are designed to remove particulates. For TP removal it was assumed that 60% of the phosphorus was sediment bound.

[3]For feedlot and manure management a specific design was not evaluated. Instead, it was assumed a range of BMPs would be implemented with the goal of removing at least 80% of the contaminated runoff.

[4]A wide range of TP removal from wetlands range from 0% to 50% but because of the potential for legacy TP removal an optimistic TP removal of 20% was used.

3.3. BMP Cost Estimation

To secure public grant funding for the BMPs, a schematic-concept level of completion engineering and construction estimates have been calculated. This estimate level includes a 25% Construction Contingency, which is based on a 'Schematic Design' definition of 'Percentage of Engineering Completed'. To calculate approximate professional fees, FEMA's Public Assistance Cost Estimating Tool for Engineering and Design Services was utilized. Depending when funding is applied for, the costs may need to be adjusted utilizing an estimated accuracy range of -15.0% to +25.0% for a Class 4 Estimate Class (1% to 15% Schematic Design) based on ASTM E2516-11. Costs developed for maintenance are based on Operations and Maintenance Considerations specified in The Agricultural BMP Handbook for Minnesota. Each of the BMPs include annual inspection, as well as periodic vegetation management, erosion repairs, and operation procedures.

To prepare accurate engineering, construction, and maintenance cost estimates, bid tabulations of similar publicly bid projects were reviewed, as well as MnDOT Average Bid Prices and RS Means Site Work & Landscape Cost for similar work items (including operation & maintenance). In addition, for BMPs that no costs were available the unit costs were derived from literature values in the Agricultural BMP Handbook for Minnesota. Lastly, for the more complicated BMPs a range of unit costs were used to better reflect the scale of the BMP. The unit costs used in this study are shown in Table 8 and overall costs for each BMP are shown in Appendix B. Agricultural BMP Prioritization.

Table 8 Best Management Practice Unit Costs

Best Management Practice	Unit of Measure	Unit Cost ($/unit)
Nutrient Management Plans	Area (ac)	$4.08/ac[1]
Cover Crops	Area (ac)	$213.24/ac[1]
No Till	Area (ac)	$23.84/ac[1]
Prescribed Grazing	Area (ac)	$36.91/ac[1]

Prairie Restoration	Area (ac)	$3,750/ac
Feedlot/Manure Management	NA	NA
Grassed Waterways	Length (ft)	$78/ft
Tile Intake/Tile Buffer	Area (ac)	$3,750/ac
WASCOB	Berm Length (ft)	$738/ft
Culvert Buffer	Area (ac)	$3,750/ac
Field Buffer Strip	Area (ac)	$3,750/ac
Wetland Restoration	Area (ac)	$15,728 - $92,557/ac
Outlet Control Structure	Structure	$31,000/structure
Constructed Wetland	Area (ac)	$338,000
Soil Scrapes	Area (ac)	$106,000

[1] Unit Cost derived from the Agricultural BMP Handbook for Minnesota

3.4. Additional Prioritization Considerations

3.4.1. Permit Requirements

Depending on the source of funding, permit requirements may vary. There are some funding sources that will allow for an ag exemption and limit the requirements. However, typically land altering activities such as grading and demolition with heavy equipment will require a permit for earthmoving activities and erosion & sediment control. In addition, any work within a wetland, water of the state, or floodplain may require permitting.

Permits from the City of Independence (Independence), City of Greenfield (Greenfield) Pioneer-Sarah Creek Watershed Management Commission (PSCWMC), Hennepin County (County), Minnesota Pollution Control Agency (PCA), and the Wetland Conservation Act (WCA) may be applicable.

For this project, it is anticipated at a minimum a consultation with the Local Government Unit (LGU) will be necessary to determine the potential for wetland impacts. For WCA, Independence and Greenfield are the LGU and should be consulted early on in the process to determine what permit requirements may fall within their jurisdiction. As discussed above, impacts may be deemed ag-exempt but that will only be determined through the WCA permitting process and a Technical Evaluation Panel (TEP) pre-Joint Permit Application (JPA) meeting.

It should also be expected the contractor will need to contract Gopher State One Call to verify utilities around the construction areas prior to the start of construction, as well as prepare construction staging and safety plans, and alert the landowners of pending work.

In summary, a pre-project meeting with the LGU and funding sources will be necessary before any work starting.

3.4.2. Wildlife Habitat Considerations

Best Management Practice	Habitat Benefit
Nutrient Management Plans	
Cover Crops	✓

No Till	
Prescribed Grazing	✓
Prairie Restoration	✓
Feedlot/Manure Management	
Grassed Waterways	✓
Tile Intake/Tile Buffer	✓
WASCOB	
Culvert Buffer	✓
Field Buffer Strip	✓
Wetland Restoration	✓
Outlet Control Structure	

3.4.3. Climate Change Considerations

Over the next century climate change is expected to continue to alter the hydrologic conditions in the Midwest and because of the connection between the hydrologic cycle and the nutrient cycles, nutrient transport within the Lake Rebecca watershed will be altered as well. Some of the expected climate change trends that will contribute to altered nutrient transport within the watershed include:

- Increase in precipitation with more heavy rain events,
- Increase in daily minimum temperatures due to increased humidity and,
- Increase in daily maximum temperature (Angel et al. 2018).

The increase in heavy rain events and humidity will likely increase the runoff and nutrient transport potential especially during the spring resulting in likely more frequent BMP maintenance requirements and potentially less treatment as more storms surpass the BMP design storm. However, the increasing daily maximum temperature will lessen the potential nutrient transport especially in the summer as the soil dries quicker from increased evapotranspiration. Furthermore, the changes in temperature will alter the magnitude of biological processes that remove nutrients for instance Lake Rebecca may experience more frequent and larger algae blooms because of warmer water temperatures or wetlands maybe able to remove more nitrates as biological activity increases with warmer temperature. All these aspects and relationships with temperature and the hydrologic cycle make predicting the change in BMP performance difficult to predict.

3.5. BMP Prioritization

BMPs in the Lake Rebecca watershed were prioritized using the cost effectiveness with respect to TP removal. TP removal was considered the primary pollutant of concern because TP concentrations at Lake Rebecca exceeded state standard concentrations, but TSS concentrations have not. The cost effectiveness was calculated by annualizing the estimated engineering, construction, and maintenance cost of each BMP assuming a 25-year lifespan and a 3% interest rate. The pollutant load reductions, predicted cost, and cost effectiveness for each BMP are listed by TP cost effectiveness in Appendix B. Agricultural BMP Prioritization. To aid in quickly determining the prioritization based solely on the cost effectiveness with respect to TP removal, that parameter column in Appendix B has been colored coded (dark green: highest priority; red: lowest priority).

4. CONCLUSIONS AND RECOMMENDATIONS

Planning level costs and all predicted pollutant load reductions at any stage of a project are inherently uncertain. Therefore, BMP implementation should focus on known issues identified in the field, projects that will reduce the input of pollutants in the watershed, and value willing landowners. Projects that were identified in the field are shown in Figure 2. These areas correspond to Control Structure 10, Waterway 12, Waterway 4, and Wetland Restoration 11 as shown on Plan Sheet 06 of 12 in Appendix A. The physical evidence of erosion supersedes the cost-effectiveness analysis performed for this project. The next set of projects that should be focused on as part of this project are the practices that limit the amount of phosphorus and nitrogen in the watershed. This involves nutrient management plans for all the properties that grow crops and improved manure management and pasture management within the horse boarding facilities. Manure management within the horse boarding facilities should focus on preventing runoff from contacting horse manure and limit the area of open feed lots within the facilities where horses have access to the same lot for most of the year. The County has indicated they have been in communication with the operator of the Horsemen property to discuss potential improvements to address manure management. Once the known issues have been fixed and source reduction strategies have been exhausted to the extent practical based on cost and land-owner willingness, then the remaining practices identified in this project should be considered based on the cost-benefit analysis shown in Appendix B. Agricultural BMP Prioritization. Practices that were shown to be more beneficial in terms of phosphorus removal were generally field buffers and modifications to wetlands. For practices involving wetlands more thought should go into the next phase of the project as permitting, flooding concerns, and water quality benefit uncertainty are higher for these projects. Work in wetlands will require consultation with the LGU for WCA impacts. Furthermore, for this initial project a simplified outlet structure was used for all wetland features and flooding impacts from the project were not considered. Lastly, recent research (Brunet et al. 2021; Taguchi et 2020; Minnesota Stormwater Manual) has added a lot more uncertainty surrounding the phosphorus benefit of wetland type BMPs. Finally for practices identified with lower cost-effectiveness, more thought should go into if they provide benefit in other ways besides TP. For instance, grassed waterways and WASCOBs are more focused on preventing soil erosion and TSS and may have high-cost benefits when evaluated for TSS instead of TP

4.1. Next Steps

Once BMPs are selected, additional tasks are necessary to advance the project from a schematic-concept level of design to implementation. Supplementary topographic survey and field investigation (visual inspection and soils investigation) will be necessary to gain a full understanding of existing conditions at each BMP site. Additionally, any sites in or near wetlands will need to be reviewed for WCA and Corps potential impacts. As the design advances, public utility clearance through a design locate ticket will need to be submitted to Gopher State One Call to ensure no public utilities exist. Private utilities will need to be located by landowners.

APPENDIX A. CONSTRUCTION DRAWINGS

ALL ELEVATIONS ARE
IN NAVD 88 - DATUM

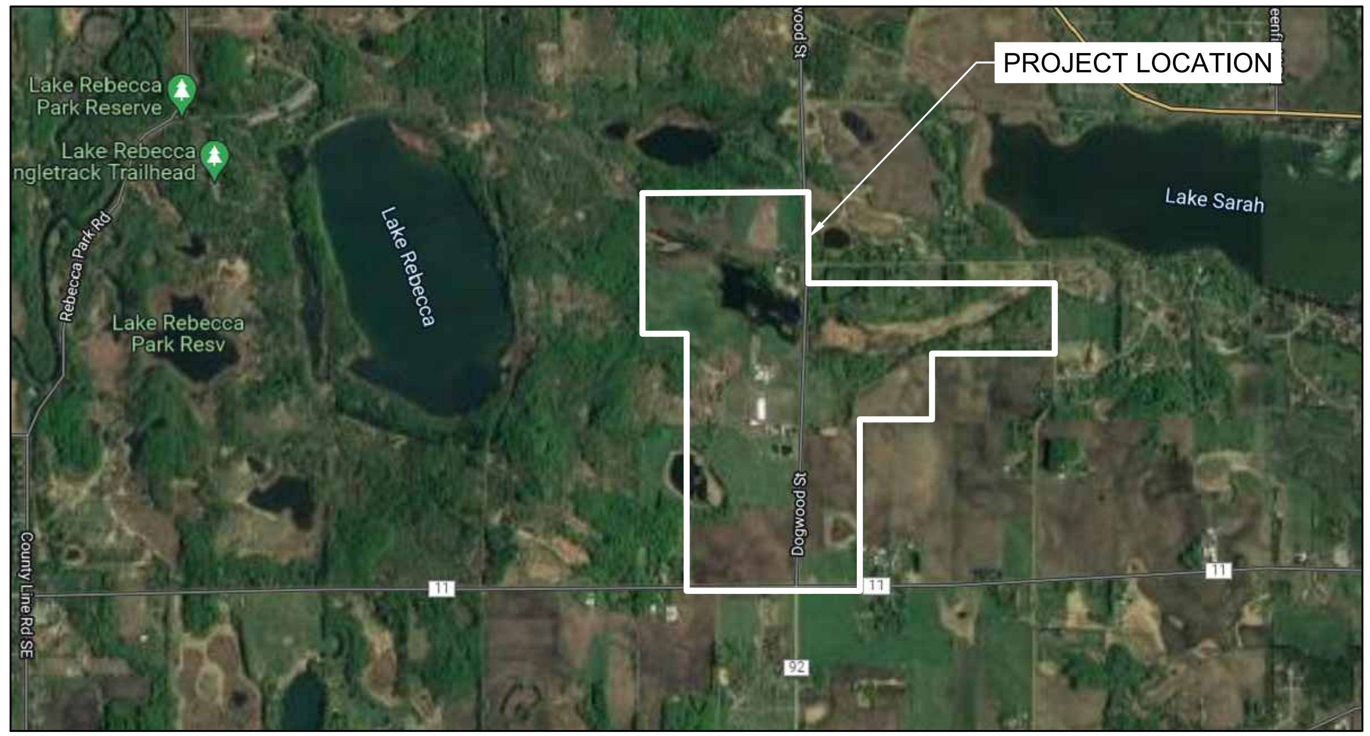
ENVIRONMENT AND ENERGY, LAND & WATER UNIT, HENNEPIN COUNTY

LAKE REBECCA SUBWATERSHED STUDY

INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA

LEGEND

FEATURE	EXISTING	PROPOSED
SILT FENCE		
DELINEATED WETLAND	WET	
OVERHEAD ELECTRIC LINES	OHW	
BURIED ELECTRIC LINES	E-U	
FIBER OPTIC LINES	FO	
BURIED TELEPHONE	T-U	
CHAIN LINK FENCE	X X X X	
FEMA FLOOD PLAIN		
CONTOUR		
WETLANDS	WET	
SEDIMENT LOGS		



Sheet List Table	
Sheet Number	Sheet Title
01	TITLE SHEET
02	PROJECT OVERVIEW
03	AREA - 1
04	AREA - 2
05	AREA - 3
06	AREA - 4
07	DETAIL SHEET 1
08	DETAIL SHEET 2
09	DETAIL SHEET 3
10	DETAIL SHEET 4
11	DETAIL SHEET 5
12	DETAIL SHEET 6

* THIS PLAN SET CONTAINS 12 PLAN SHEETS

EXISTING UTILITIES

THE LOCATION OF UNDERGROUND FACILITIES AND/OR STRUCTURES AS SHOWN ON THE PLANS ARE BASED ON AVAILABLE RECORD AT THE TIME THE PLANS WERE PREPARED AND ARE NOT GUARANTEED TO BE COMPLETE OR CORRECT. THE SUBSURFACE UTILITY INFORMATION SHOWN IS UTILITY QUALITY LEVEL D, AS DETERMINED USING THE GUIDELINES OF "CI/ASCE 38-02 STANDARD GUIDELINES FOR THE COLLECTION AND DEPICTION OF EXISTING SUBSURFACE UTILITY DATA." THE CONTRACTOR IS RESPONSIBLE FOR CONTACTING ALL UTILITIES 72 HOURS PRIOR TO CONSTRUCTION TO DETERMINE THE EXACT LOCATION OF ALL FACILITIES AND TO PROVIDE ADEQUATE PROTECTION OF SAID UTILITIES DURING THE COURSE OF WORK.

CONSTRUCTION NOTE

CONTRACTOR SHALL TAKE ALL NECESSARY MEASURES TO MAINTAIN OPERATION OF EXISTING UTILITIES THROUGHOUT THE DURATION OF THE PROJECT. IN THE EVENT THAT AN INTERRUPTION OF SERVICE IS UNAVOIDABLE IN ORDER TO COMPLETE THE WORK, CONTRACTOR SHALL PROVIDE ADEQUATE NOTIFICATION TO ALL AFFECTED BUSINESSES A MINIMUM OF 3 WORKING DAYS IN ADVANCE OF ANY INTERRUPTION.

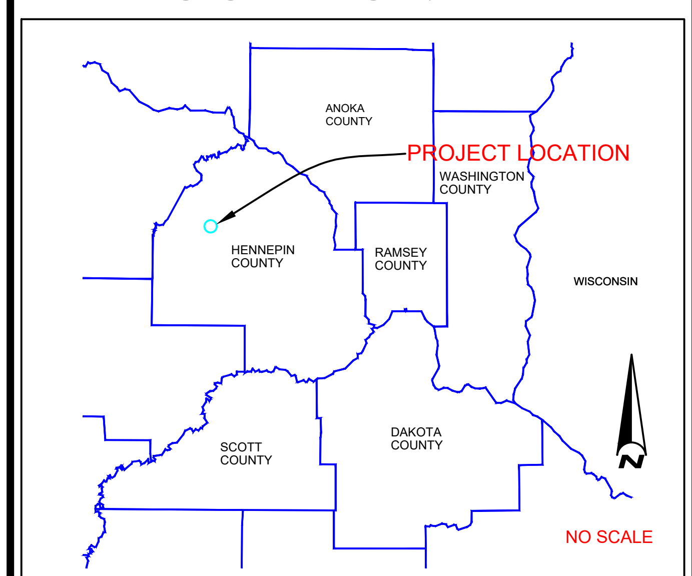
GOPHER STATE ONE-CALL

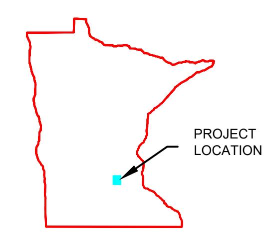
IT IS THE LAW THAT ANYONE EXCAVATING AT ANY SITE MUST NOTIFY GOPHER STATE ONE CALL (GSOC) SO THAT UNDERGROUND ELECTRIC, NATURAL GAS, TELEPHONE OR OTHER UTILITY LINES CAN BE MARKED ON OR NEAR YOUR PROPERTY BEFORE ANY DIGGING BEGINS. A 48-HOUR NOTICE, NOT INCLUDING WEEKENDS, IS REQUIRED. CALLS CAN BE MADE TO GSOC AT 1-800-252-1166 OR (651)454-0002, MONDAY THROUGH FRIDAY (EXCEPT HOLIDAYS) FROM 7 A.M. TO 5 P.M.

GSOC GOPHER STATE ONE CALL

811

LOCATION MAP





GOVERNING SPECIFICATIONS

THE 2020 EDITION OF THE MOST CURRENT MINNESOTA NRCS CONSTRUCTION SPECIFICATIONS SHALL GOVERN, EXCEPT WHERE NOTED OTHERWISE. OTHERWISE THE MINNESOTA DEPARTMENT OF TRANSPORTATION "STANDARD SPECIFICATIONS FOR CONSTRUCTION" SHALL GOVERN

ALL TRAFFIC CONTROL DEVICES AND SIGNING SHALL CONFORM TO MINNESOTA MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES, INCLUDING FIELD MANUAL FOR TEMPORARY CONTROL ZONE LAYOUTS.

CLIENT
ENVIRONMENT AND ENERGY, LAND & WATER UNIT, HENNEPIN COUNTY
THE 701 BUILDING, 701 4TH AVE. S.,
MINNEAPOLIS, MN 55415
COUNTY GRANT MANAGER:
KRISTOPHER GUENTZEL

ENGINEER
EMMONS & OLIVIER RESOURCES, INC.
1919 UNIVERSITY AVE W. SUITE 300
ST PAUL, MN 55104
TELEPHONE: (651) 770-8448
FAX: (651) 770-2552
eorinc.com

Plot Date: 01/10/2023
Drawing name: X:\clients_county\00210_hennepin\0012_lk_rebecca_feas\09_GIMS\dwg\CD-Drawing_210-0012.dwg
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NOT FOR CONSTRUCTION

SUBMISSION DATE: 08-01-2022
DESIGN BY DRL
DRAWN BY BR
EOR PROJECT NO. 00210-0012

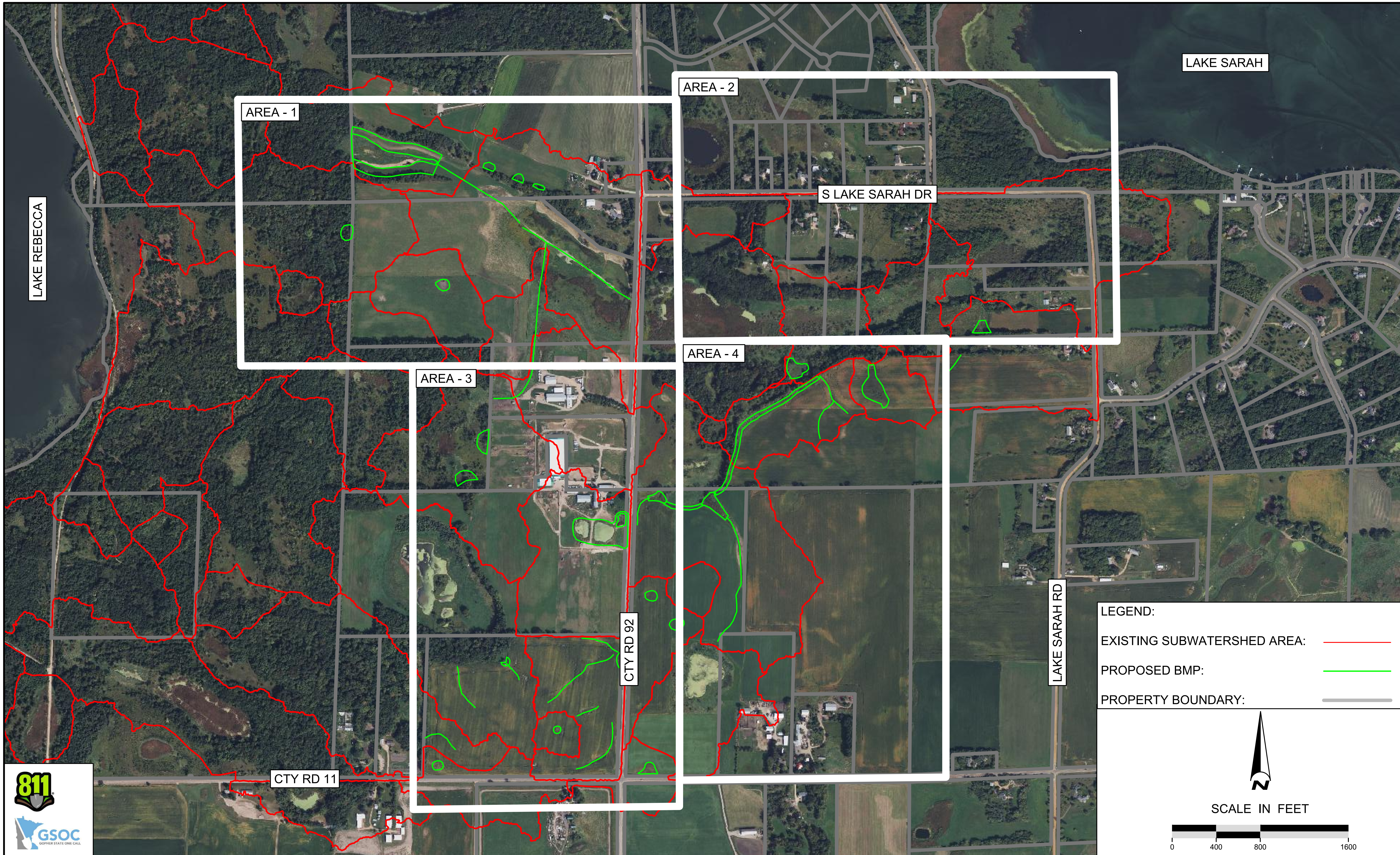
EOR water ecology community
Emmons & Olivier Resources, Inc.
1919 Univ. W #300
St Paul, MN 55104
Tele: 651.770.8448
www.eorinc.com

HENNEPIN COUNTY MINNESOTA

LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. ----
CITY PROJECT NO. ---

TITLE SHEET



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LAKE REBECCA SUBWATERSHED STUDY
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STATE PROJECT NO. ----
CITY PROJECT NO. ---

PROJECT OVERVIEW

SHEET 02 OF 12 SHEETS

Plot Date: 01/10/2023
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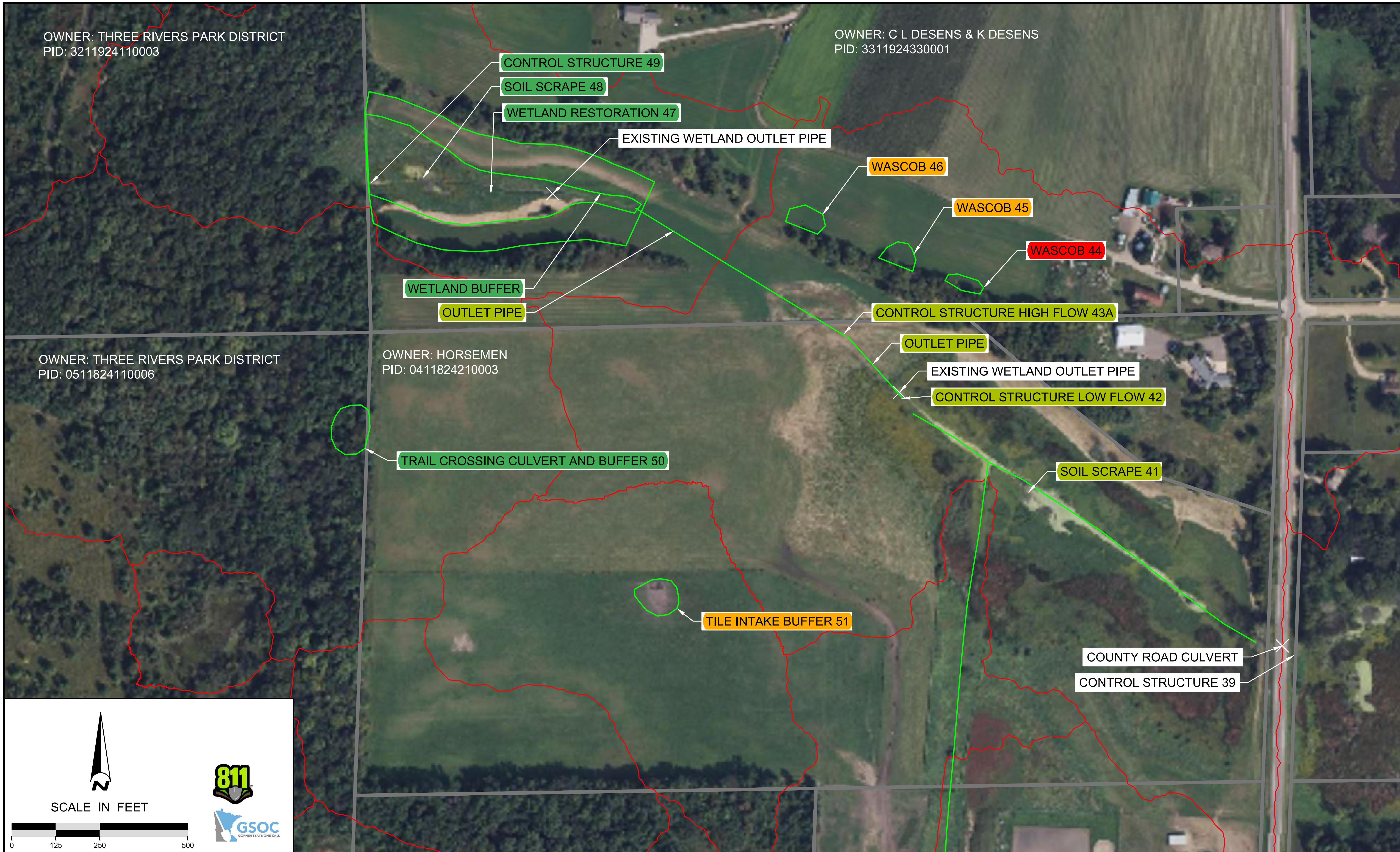

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LAKE REBECCA SUBWATERSHED STUDY
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STATE PROJECT NO. ---- | CITY PROJECT NO. ---

AREA - 1

SHEET 03 OF 12 SHEETS

Plot Date: 01/10/2023
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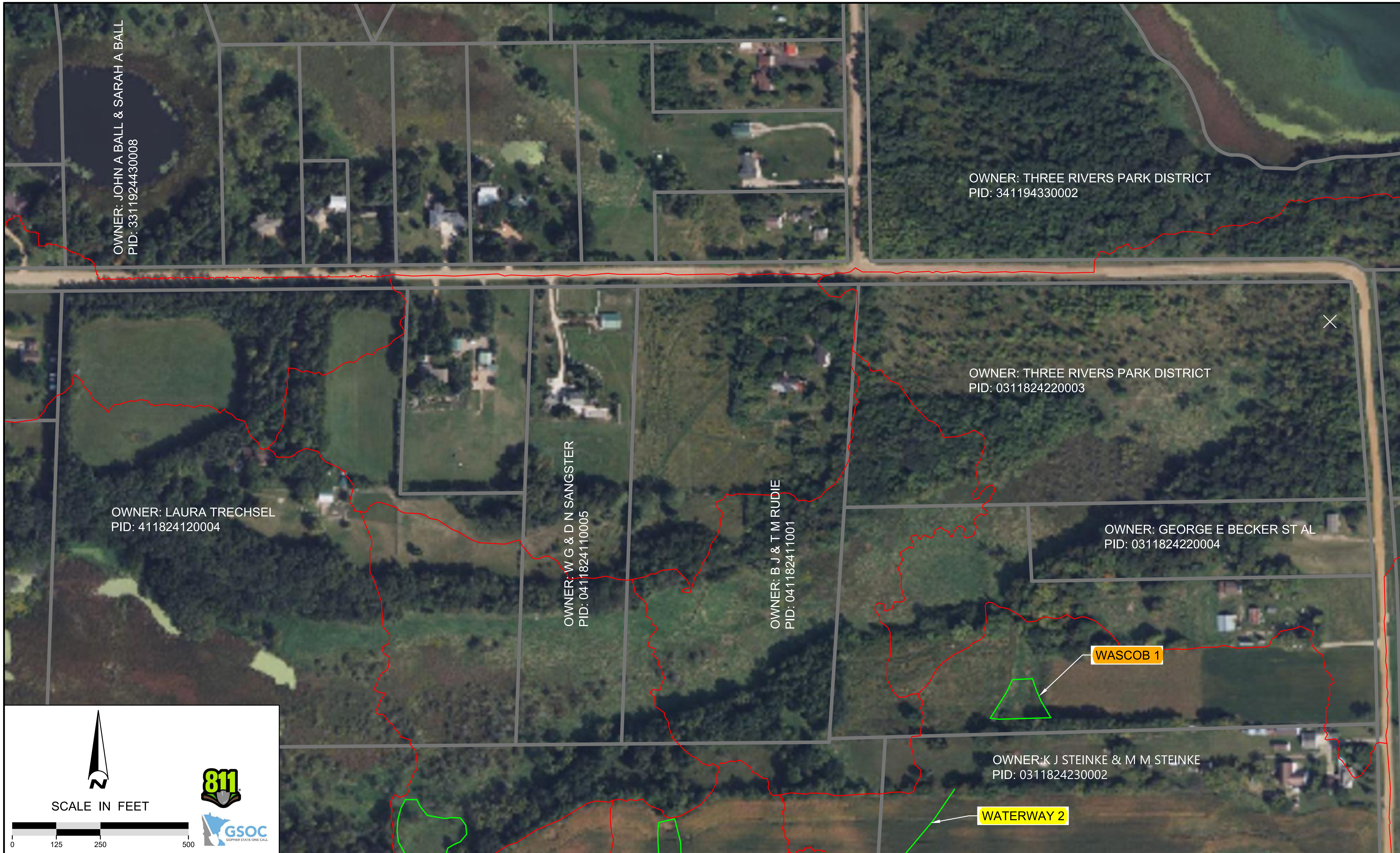

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AREA - 2

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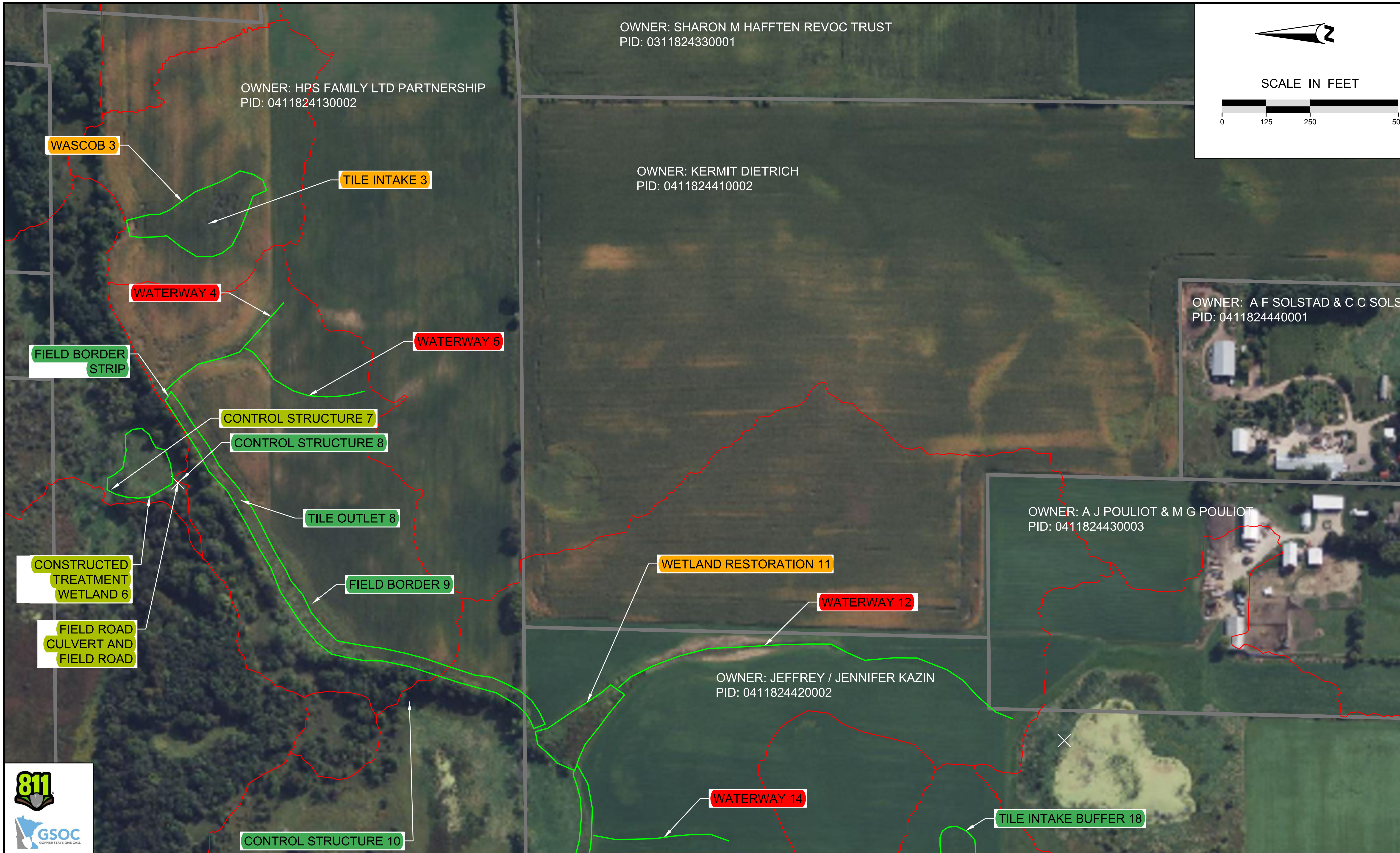
AREA - 3

SHEET 05 OF 12 SHEETS



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LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. ---- | CITY PROJECT NO. ---

AREA - 4

SHEET 06 OF 12 SHEETS

Plot Date: 01/10/2023
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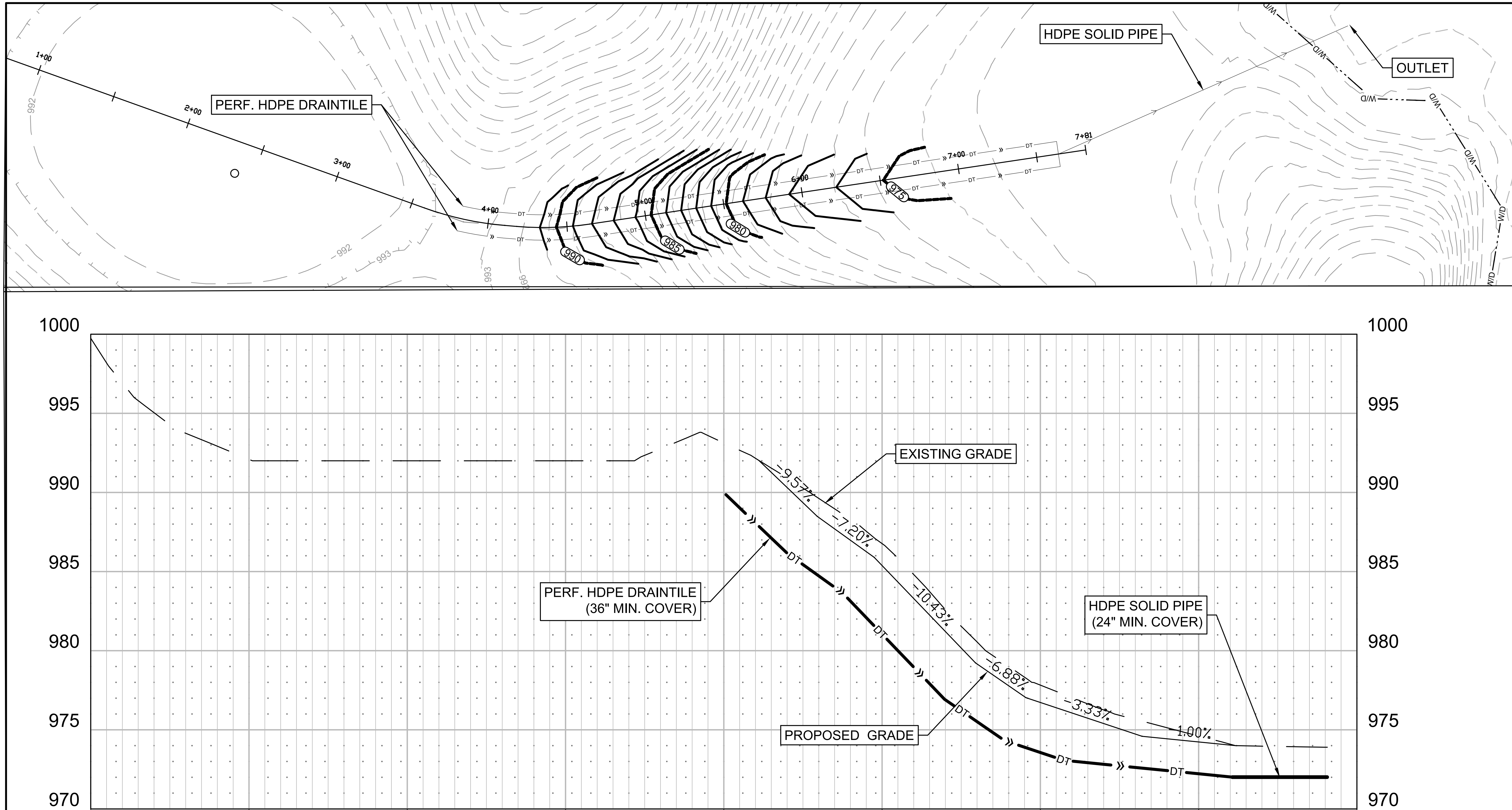

01
07

WATERWAY PLAN AND PROFILE (TYP.)

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LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. ----
CITY PROJECT NO. ---

DETAIL SHEET 1

SHEET 07 OF 12 SHEETS

Plot Date: 01/10/2023
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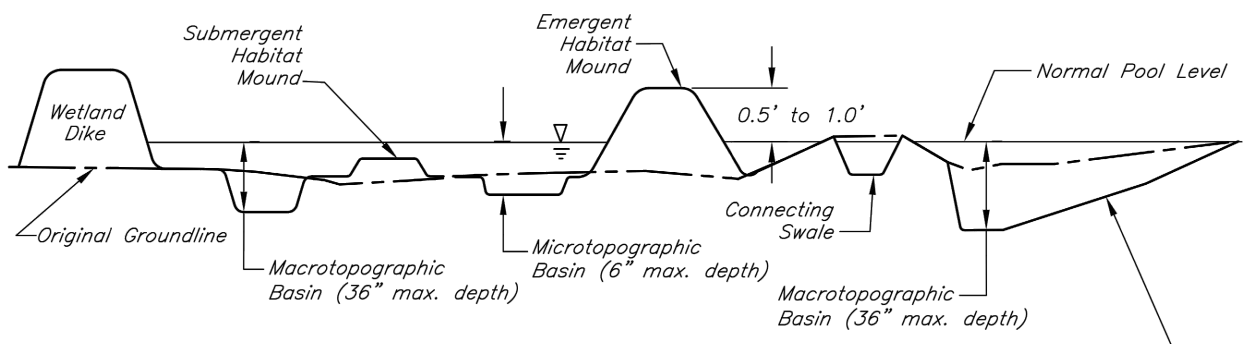
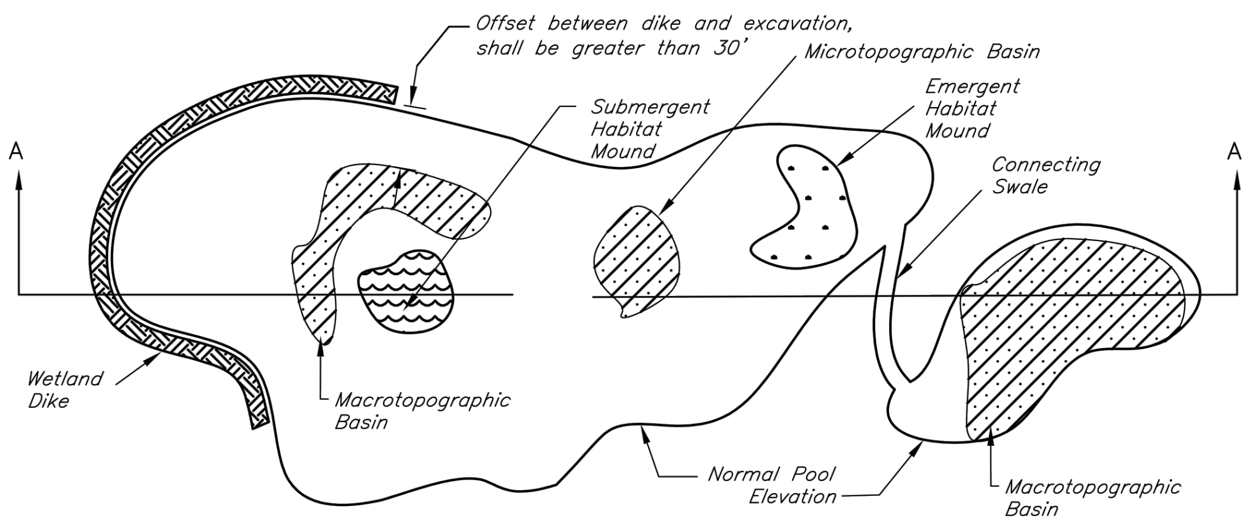


TYPICAL SECTION A–A
(NOT TO SCALE)



TYPICAL WETLAND FEATURES
(NOT TO SCALE)

NOTE:
This drawing represents the conceptual layout of a wetland complex showing the various features that may be used in a wetland restoration or enhancement. Refer to the site plan, sheet ___ of ___, for the layout of features specific to this project, and to the related detail drawings.

Overall Water Depth Guidelines for Site	
Depth	Areal Coverage
0"–18"	>67%
0"–12"	>50%
12"–24"	20–30%
>36"	<5%

STANDARD DWG. IA–1301

DATE Dec. 2008 | PAGE 1 OF 1

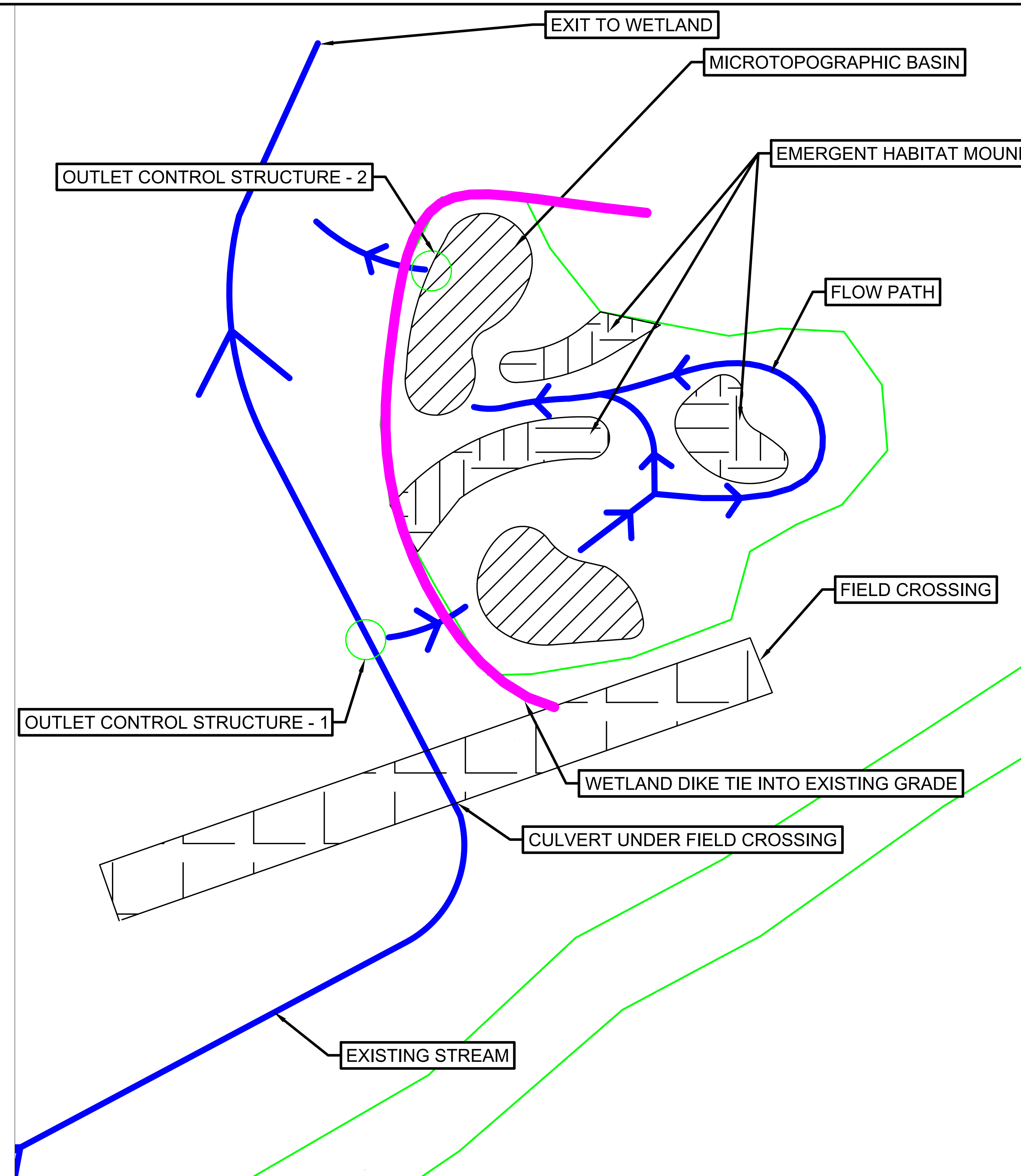
USDA United States Department of Agriculture
Natural Resources Conservation Service

SHALLOW WATER EXCAVATION

Designed ____ Date
Drawn ____
Checked ____
Approved ____

File Name
Drawing Name
Sheet of

01 / 08 CONSTRUCTED WETLAND - DETAIL 1 (TYP.)



02 / 08 CONSTRUCTED WETLAND - DETAIL 2 (TYP.)

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NOT FOR CONSTRUCTION

SUBMISSION DATE: 08-01-2022
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EOR PROJECT NO. 00210-0012

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HENNEPIN COUNTY MINNESOTA

LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA

STATE PROJECT NO. ---- | CITY PROJECT NO. ---

DETAIL SHEET 2

SHEET 08 OF 12 SHEETS

Plot Date: 01/10/2023
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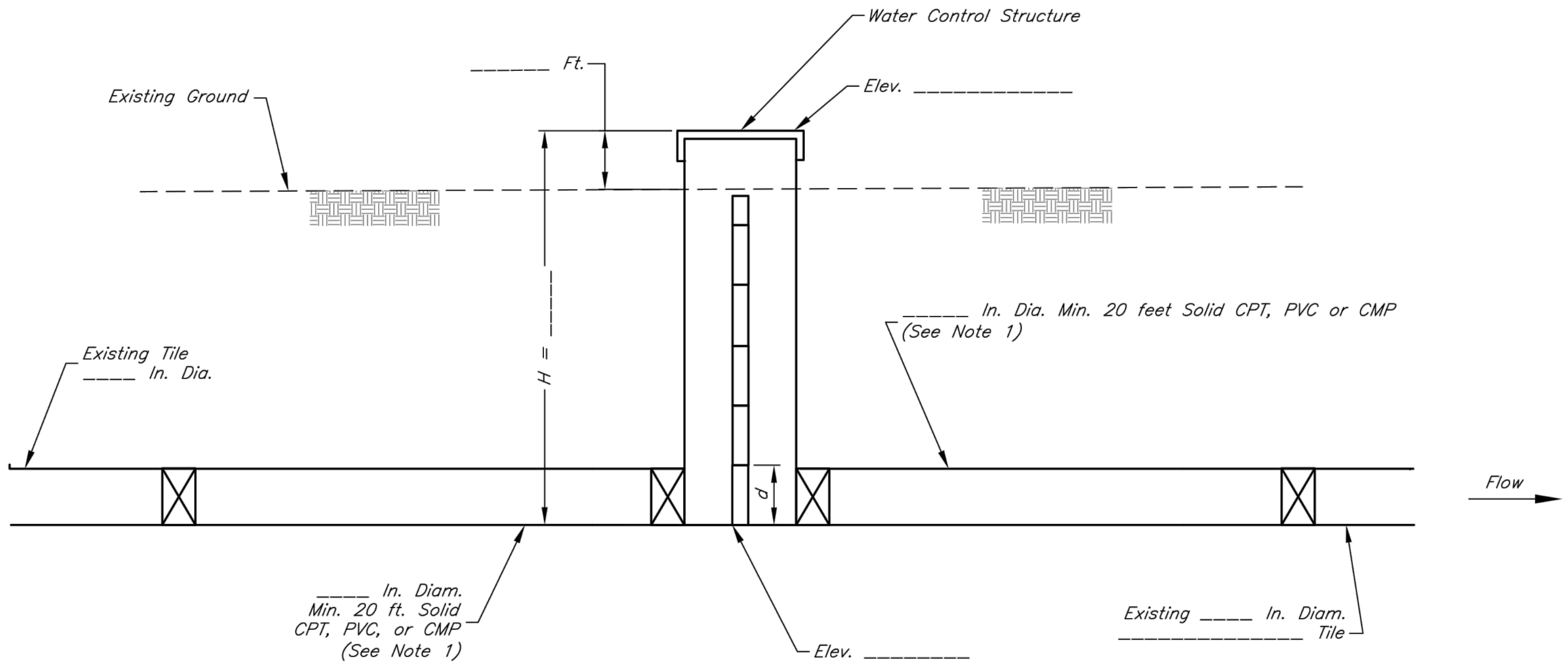
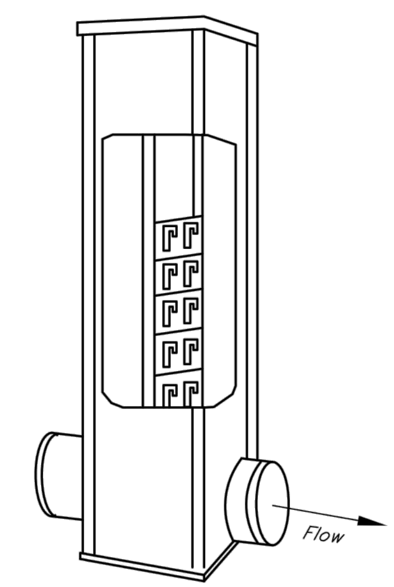


CROSS SECTION

NOTES:

1. A minimum of 20 feet of solid tile or pipe shall be installed adjacent to the water control structure on both the upstream and downstream sides of the structure.
2. Couplings between the water control section and the solid tile shall be water tight.



IN-LINE CONTROL STRUCTURE

Materials Schedule Water Control Structure			
No.	Width/Diameter(Inches)	H (Inches)	d (Inches)

Non Perforated___CPT Or___PVC Or___CMP	
Length (Feet)	Diameter (Inches)

Couplers	
No.	Diameter (Inches)

Minnesota Standard Drawing
Revised 8/31/11 – JAH

Designed .
Drawn .
Checked .
Approved .
Date

IN-LINE WATER CONTROL STRUCTURE
. County, Minnesota

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

Drawing Name
MN-ENG-213
Eng. Job Class
.
Sheet . of .

01
09
OUTLET CONTROL STRUCTURE - DETAIL 1 (TYP.)

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NOT FOR CONSTRUCTION

SUBMISSION DATE: 08-01-2022
DESIGN BY DRL
DRAWN BY BR
EOR PROJECT NO. 00210-0012

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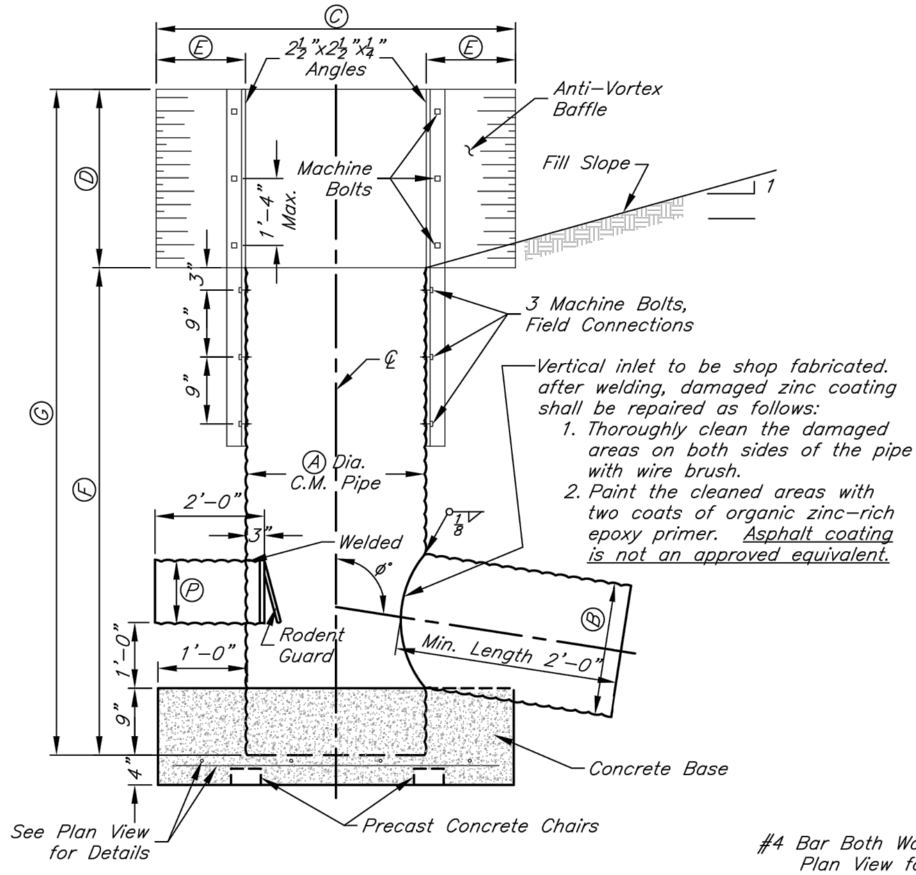
MINNESOTA

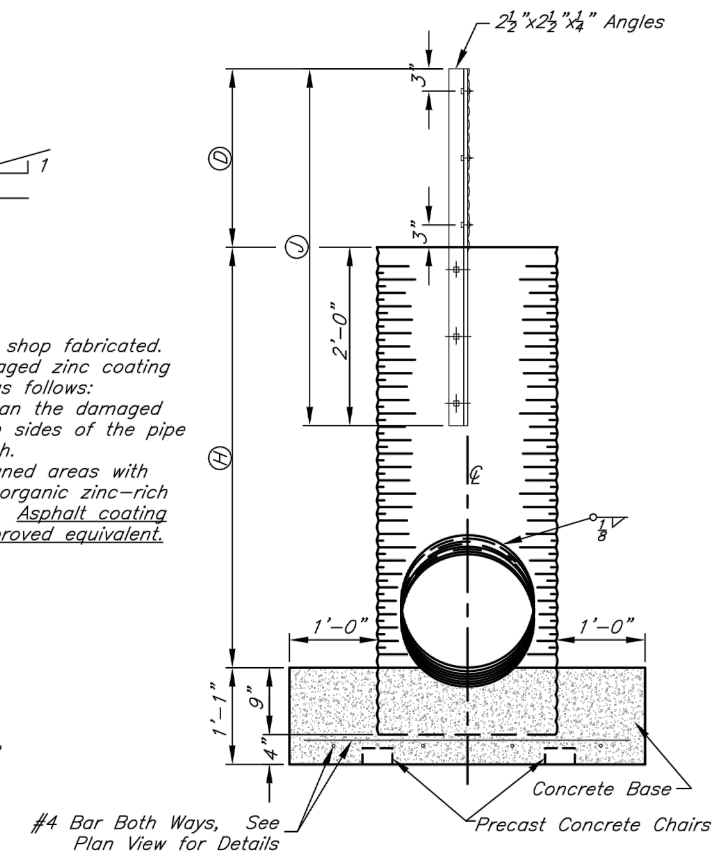
LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA
STATE PROJECT NO. ----
CITY PROJECT NO. ---

DETAIL SHEET 3
SHEET 09 OF 12 SHEETS

Plot Date: 01/10/2023
Drawing name: X:\clients_county\00210_hennepin\0012_lk_rebecca_feas\09_GIMS\dwg\CD-Drawing_210-0012.dwg
Xrefs: P-Base2, X-Base

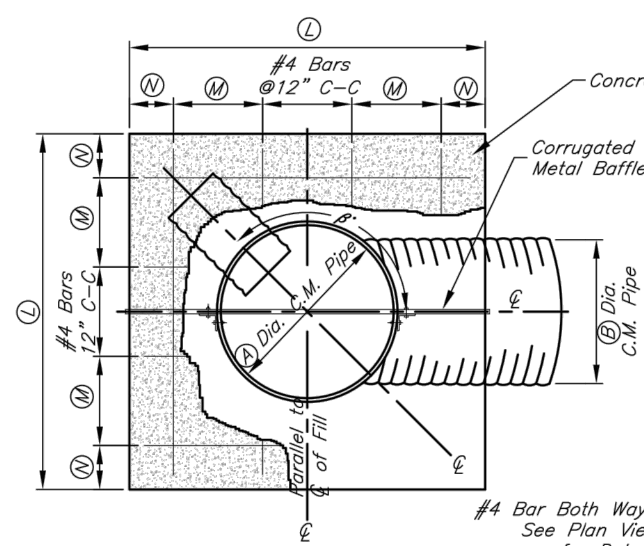


SECTION ELEVATION ON CENTERLINE

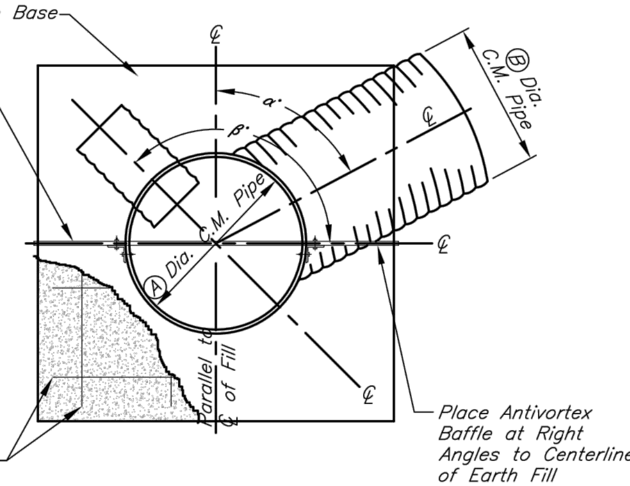


DOWNSTREAM ELEVATION

TABLE SHOWING DIMENSIONS AND MATERIAL			
Structure Number			
Gully or Lateral			
Station			
DIMENSIONS			
A			
B			
C			
D			
E			
F			
G			
H			
J			
L (Equals A Plus 2 ft.)			
M			
N			
P			
C.M. Pipe Thickness for A Dia.			
C.M. Pipe Thickness for B Dia.			
C.M. Sheet Thickness for Baffle			
MATERIAL ITEMS — QUANTITY REQUIRED			
2 1/2" X 2 1/2" X 1/4" Angles x J, Galv.			
D x C Corrugated Metal Sheets, Galv.			
1/2" x 1 1/4" Steel Cadmium Plated Machine Bolts			
1/2" Steel Split Lock Washers			
1/2" Steel Cadmium Plated Nuts			
#4 Reinforcing Steel Bars, Lin. Ft.			
#4 Reinforcing Steel Bars, Lb.			
Volume of Concrete, Cu. Yd.			
ø° Degrees–Angle			
α° Degrees–Angle			
β° Degrees–Angle			
Slope of B Dia. Pipe in ft./ft.			



PLAN VIEW



ALTERNATE PLAN VIEW
(Use When Pipe is Skewed)

REQUIREMENT TABLE x in Box Indicates Detail Needed	
Antivortex Baffle Shown is Required	☐
Antivortex Baffle Shown is not Required	☐
Trash Rack With Baffle is Required See Sheet ______ for Details	☐
Safety Guard is Required See Sheet ______ for Details	☐

Corrugated metal pipe shall be either helical corrugations with lock seam construction or annular corrugations with close riveted, caulked seam construction.

NOTES
1. All holes for bolts shall be 9/16" dia.
2. Precast concrete chairs shall be used to support the reinforcing steel bars. Precast concrete chairs shall be manufactured of 3000 psi concrete and shall have tie wires securely anchored in the chair or a V–shaped groove at least 3/4 inch in depth molded into the upper surface to receive the steel bar at the point of support. Precast concrete chairs shall be moist at the time concrete is placed.
3. When L is full foot:
   M = 12", N = 6"
   When L is full foot plus 6 inches
   M = 11", N = 6"
4. Length of reinforcing steel bars is L minus 6 inches

Date	
Designed MAK	6/96
Drawn GRH	4/04
Revised	
Approved	

CORRUGATED METAL PIPE VERTICAL INLET GRADE STABILIZATION STRUCTURE
______ County, Minnesota

NRCS Natural Resources Conservation Service United States Department of Agriculture

Drawing Name MN–ENG–305
Eng. Job Class
Sheet . of .

01 / 10 OUTLET CONTROL STRUCTURE - DETAIL 2 (TYP.)

NO	DATE	BY	REVISION
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NOT FOR CONSTRUCTION

SUBMISSION DATE: 08-01-2022
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EOR PROJECT NO. 00210-0012

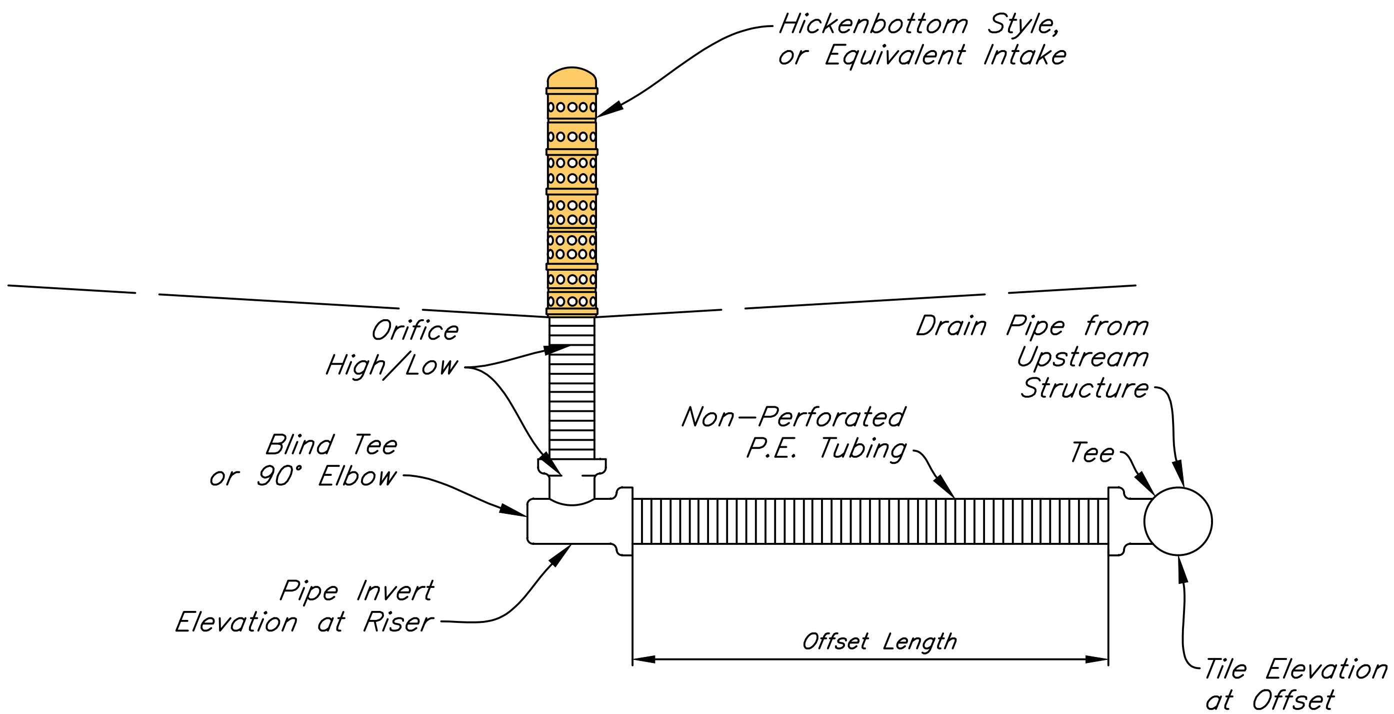
EOR water ecology community
Emmons & Olivier Resources, Inc.
1919 Univ. W #300
St Paul, MN 55104
Tele: 651.770.8448
www.eorinc.com

HENNEPIN COUNTY MINNESOTA

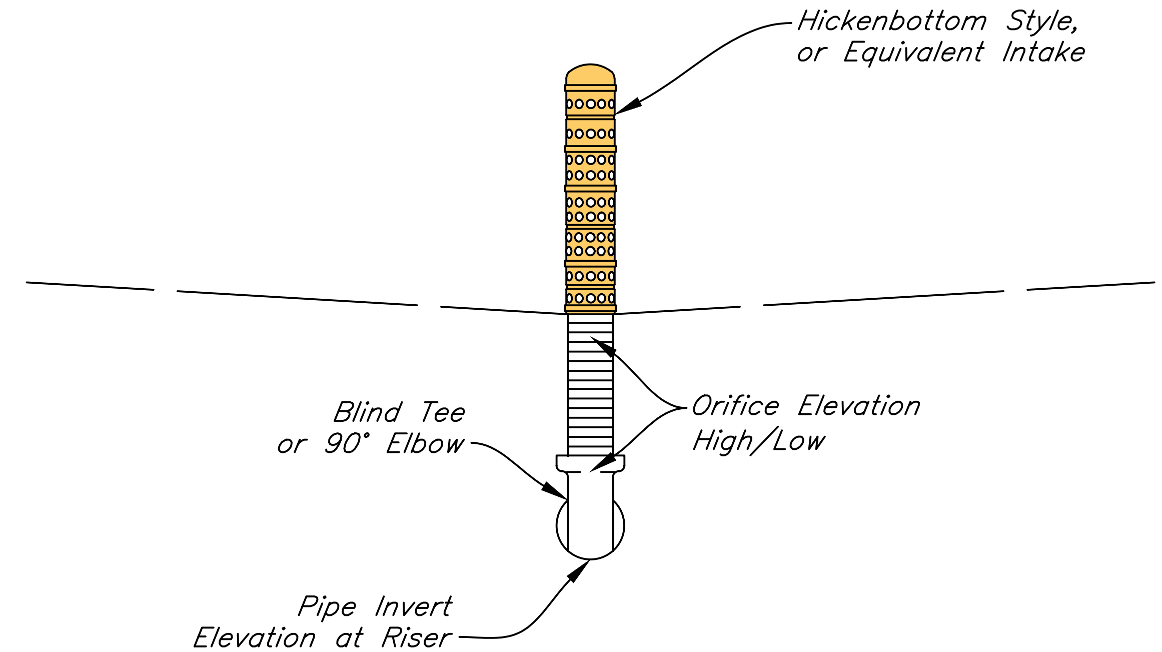
LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA
STATE PROJECT NO. ---- CITY PROJECT NO. ---

DETAIL SHEET 4
SHEET 10 OF 12 SHEETS

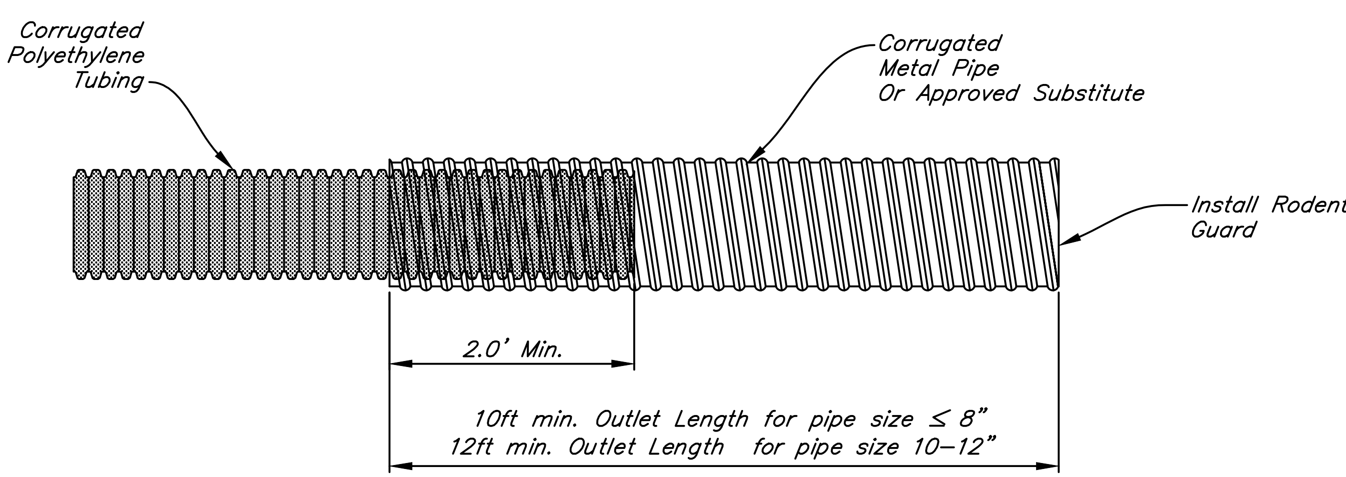
Plot Date: 01/10/2023
Drawing name: X:\clients_county\00210_hennepin\0012_lk_rebecca_feas\09_GIMS\dwg\CD-Drawing_210-0012.dwg
Xrefs: P-Base2; X-Base



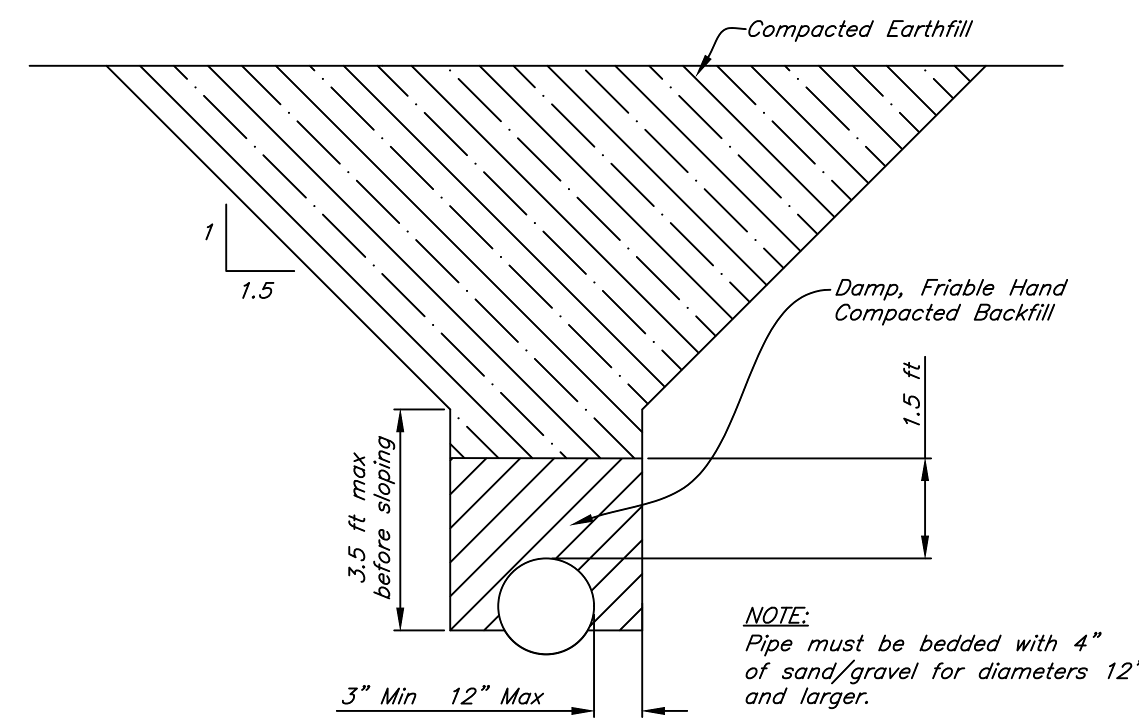
01 / 11 OFFSET INTAKE DETAIL (TYP.)



02 / 11 DIRECT INTAKE DETAIL (TYP.)



03 / 11 TILE OUTLET DETAIL (TYP.)



04 / 11 TRENCH UNDER EMBANKMENT (TYP.)

NO	DATE	BY	REVISION
6			
5			
4			
3			
2			
1			

NOT FOR CONSTRUCTION

SUBMISSION DATE: 08-01-2022
DESIGN BY DRL
DRAWN BY BR
EOR PROJECT NO. 00210-0012

EOR Emmons & Olivier Resources, Inc.
water ecology community
1919 Univ. W #300
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HENNEPIN COUNTY MINNESOTA

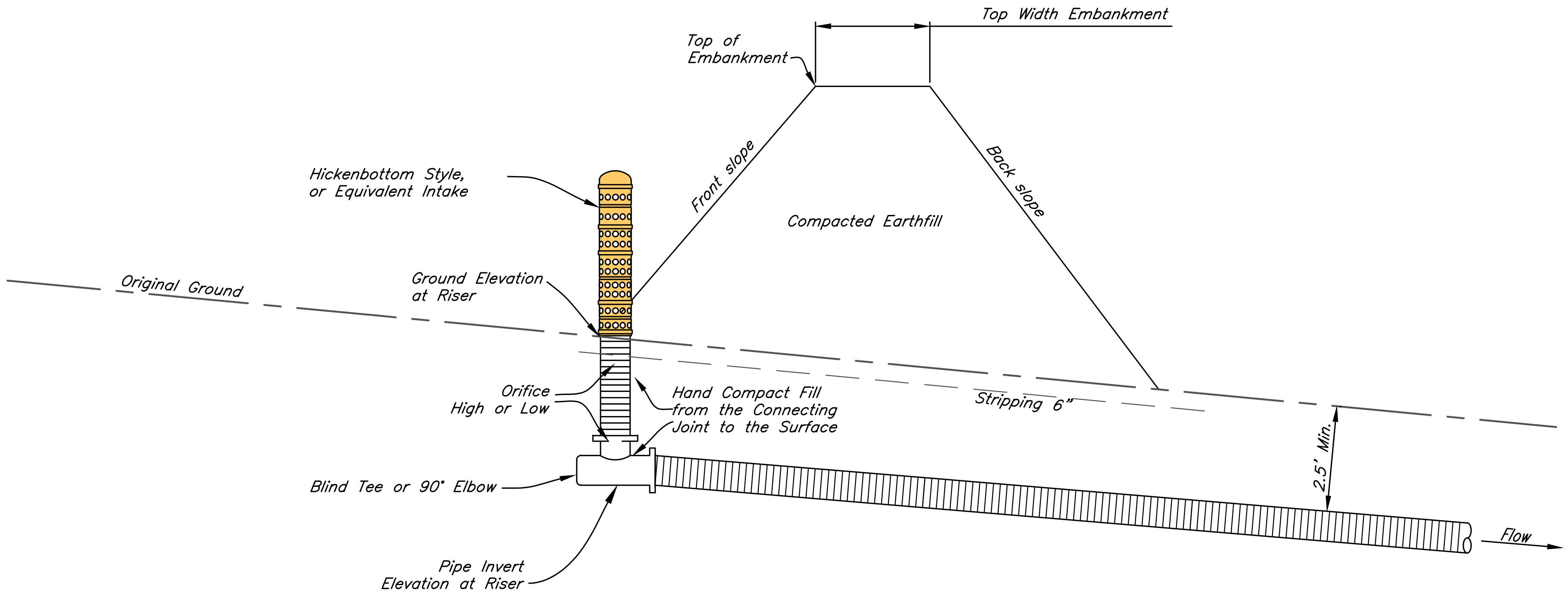
LAKE REBECCA SUBWATERSHED STUDY
INDEPENDENCE, HENNEPIN COUNTY, MINNESOTA

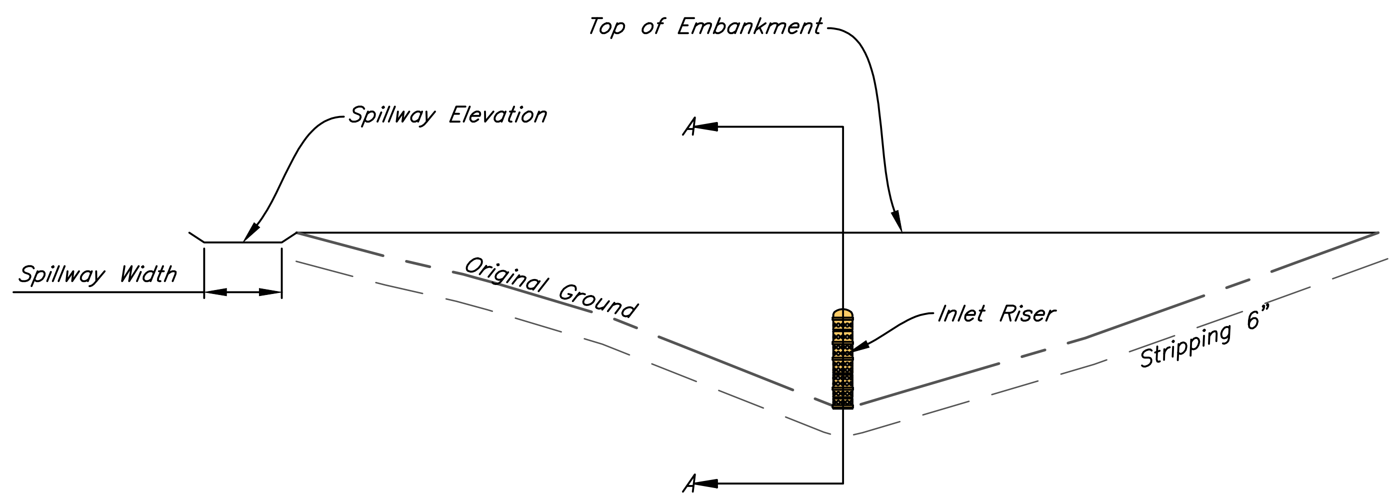
STATE PROJECT NO. ----
CITY PROJECT NO. ---

DETAIL SHEET 5

SHEET 11 OF 12 SHEETS

Plot Date: 01/10/2023
Drawing name: X:\clients_county\00210_hennepin\0012_lk_rebecca_feas\09_GIMS\dwg\CD-Drawing_210-0012.dwg
Xrefs:, P-Base2, X-Base





01
12

WASCOB DETAIL (TYP.)

NO	DATE	BY	REVISION
6			
5			
4			
3			
2			
1			

NOT FOR CONSTRUCTION

SUBMISSION DATE: 08-01-2022

DESIGN BY DRL | DRAWN BY BR

EOR PROJECT NO. 00210-0012

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DETAIL SHEET 6

SHEET 12 OF 12 SHEETS

Plot Date: 01/10/2023
Drawing name: X:\clients_county\00210_hennepin\0012_lk_rebecca_feas\09_GIMS\dwg\CD-Drawing_210-0012.dwg
Xrefs:, P-Base2, X-Base

APPENDIX B. AGRICULTURAL BMP PRIORITIZATION TABLE

Appendix B. Agricultural BMP Prioritization Table

POTENTIAL IMPROVEMENTS				ECOLOGY BENEFITS		PREDICTED LOAD REDUCTION AT LAKE REBECCA		ENGINEERING AND CONSTRUCTION COST	MAINTENANCE COST	25- YEAR LIFE CYCLE COST BENEFIT		COMMENT
BMP ID		Description	Parcel	Wildlife Habitat Improvement	Native Vegetation	TP (lb/yr)	Sediment (lb/yr)			TP ($/lb)	TSS ($/lb)	
Landowner Category #1	37	Covered Storage	Horsemen			N/A	N/A	N/A	N/A	N/A	N/A	
	39	Outlet Control Structure	Hennepin County			N/A	N/A	$31,000	$1,593	N/A	N/A	This structure will need to be reviewed as part of the design for BMP #6.
	41	Soil Scrape *(wetland restoration)*	Horsemen	✓	✓	79.66	---	$1,694,156	$4,830	$1,221.37	---	The TP value is based on the removal of legacy TP through soil excavation. Wetland Sediment Samples will need to be collected and analyzed to determine the TP concentration.
	42	Outlet Control Structure *(low flow)*	Horsemen			---	---	*(Incl. w/#41)*	*(Incl. w/#41)*	*(Incl. w/#41)*	*(Incl. w/#41)*	Included with BMP #41. This structure will need to be reviewed as part of the design for BMP #6.
	43 A	Outlet Control Structure *(high flow)*	Horsemen			---	---	*(Incl. w/#41)*	*(Incl. w/#41)*	*(Incl. w/#41)*	*(Incl. w/#41)*	Included with BMP #41. This structure will need to be reviewed as part of the design for BMP #6.
	51	Tile Intake Buffer	Horsemen	✓		0.34	90	$866	$1,096	$3,350.14	$12.73	
Landowner Category #2	1	WASCOB	Slavec			2.40	230	$140,220	$1,752	$4,085.22	$42.63	
	2	Waterway	Steinke	✓		0.45	23	$17,734	$2,112	$6,929.22	$136.54	
	3	WASCOB *(tile intake buffer)*	HPS Family			2.50	150	$100,118	$2,848	$3,439.01	$57.32	
	4	Waterway	HPS Family	✓		0.71	36	$53,075	$2,112	$10,173.68	$200.48	
	5	Waterway	HPS Family	✓		----	---	*(Incl. w/#4)*	*(Incl. w/#4)*	*(Incl. w/#4)*	*(Incl. w/#4)*	Included with BMP #4.
	6	Constructed Treatment Wetland	HPS Family	✓	✓	6.40	1230	$185,000	$2,782	$2,343.62	$12.19	Downstream structures (BMPs #39, 42, and 43A) may need to be rebuilt to ensure this wetland does not flood from the wetland to the north.
	7	Outlet Control Structure	HPS Family			---	---	*(Incl. w/#6)*	(Incl. w/#6)	*(Incl. w/#6)*	*(Incl. w/#6)*	Included with BMP #6.
	8	Outlet Control Structure	HPS Family			34.50	2480	$31,000	$1,593	$97.77	$1.36	
	9	Field Buffer	HPS Family	✓	✓	24.11	1223	$22,130	$1,564	$117.59	$2.32	
	10	Outlet Control Structure	HPS Family			17.90	410	$31,000	$1,593	$188.45	$8.23	Evidence of high flows incising banks in the vicinity of the existing wetland. Outlet Control Structure should include restoration of banks.
	11	Wetland Restoration	Kazin	✓	✓	1.00	22.95	$47,957	$1,644	$4,389.08	$191.62	May require additional investigation of tile observed in the field.

	12	Waterway	Kazin	✓		0.46	23	$94,378	$2,112	$16,448.04	$324.12	Severe incised channel was observed in the field. May require additional tile investigation. With easement approval could pair Waterway implementation with repair to wetland outlet at the south end of this Waterway location.
	13	Field Buffer	Kazin	✓	✓	---	---	*(Incl. w/#9)*	*(Incl. w/#9)*	*(Incl. w/#9)*	*(Incl. w/#9)*	Included with BMP #9.
	14	Waterway	Kazin	✓		0.24	12	$30,248	$2,112	$15,898.14	$313.28	
	15	WASCOB	Kazin			5.96	300	$103,320	$1,752	$1,288.64	$25.62	
	16	Waterway	Kazin	✓		1.56	80	$22,929	$2,112	$2,197.93	$42.86	
	17	Tile Buffer	Kazin	✓		3.20	130	$1,748	$1,096	$716.36	$17.63	
	18	Tile Buffer	Kazin	✓		---	---	*(Incl. w/#17)*	*(Incl. w/#17)*	*(Incl. w/#17)*	*(Incl. w/#17)*	Included with BMP #17.
	19	Wetland Restoration	Kazin	✓	✓	6.50	200	$48,129	$1,644	$678.15	$22.04	
	20	WASCOB	Klinkner			1.90	80	$107,010	$1,752	$4,156.50	$98.72	
	21	Waterway	Klinkner			0.43	22	$28,124	$2,112	$8,720.27	$171.84	
	22	Waterway	Klinkner			0.55	28	$59,191	$2,112	$10,067.32	$198.38	
	23	Waterway	Klinkner			0.25	13	$16,659	$2,112	$12,166.52	$239.75	
	24	Waterway	Klinkner			0.69	35	$47,010	$2,112	$6,946.90	$136.89	
	25	Tile Buffer	Klinkner	✓		0.20	10	$304	$1,096	$5,567.43	$111.35	
	26	Tile Buffer	Klinkner	✓		4.50	1615	$588	$1,096	$251.07	$0.70	
	27	Waterway	Klinkner	✓		0.58	29	$26,844	$2,112	$6,334.19	$124.82	
	28	Waterway	Klinkner	✓		0.94	48	$33,063	$2,112	$4,247.52	$83.70	
	29	Waterway	Klinkner	✓		0.65	33	$15,713	$2,112	$4,669.48	$92.01	
	30	WASCOB	Klinkner			2.75	140	$61,992	$1,752	$1,930.95	$38.05	
	44	WASCOB	Desens			0.49	25	$81,918	$1,752	$13,090.82	$257.96	
	45	WASCOB	Desens			1.42	72	$76,752	$1,752	$4,326.65	$85.26	
	46	WASCOB	Desens			1.17	59	$81,180	$1,752	$5,484.67	$108.08	

	47	Wetland Restoration	Desens	✓	✓	83.88	3970	$262,693	$4,881	$238.05	$5.03	This Wetland Restoration is recommended based on field observations of the wetland's condition.
	48	Soil Scrape *(wetland restoration)*	Desens	✓	✓	---	---	*(Incl. w/#47)*	*(Incl. w/#47)*	*(Incl. w/#47)*	*(Incl. w/#47)*	Included with BMP #47. The Soil Scrape is recommended based on field observations of wetland condition.
	49	Outlet Control Structure	Desens			---	---	*(Incl. w/#47)*	*(Incl. w/#47)*	*(Incl. w/#47)*	*(Incl. w/#47)*	Included with BMP #47. This Outlet Control Structure is recommended based on field observations of existing tile.
Landowner Category #3	33	WASCOB	Three Rivers Park District			2.40	122	$118,080	$1,752	$3,555.08	$70.05	
	34	WASCOB	Three Rivers Park District			2.71	137	$163,098	$1,752	$4,107.77	$80.95	
	35	Soil Scrape *(wetland restoration)*	Three Rivers Park District	✓	✓	5.79	60	$127,566	$3,237	$1,824.01	$176.05	
	36	Outlet Control Structure	Three Rivers Park District			---	---	*(Incl. w/#35)*	*(Incl. w/#35)*	*(Incl. w/#35)*	*(Incl. w/#35)*	Included with BMP #35.
	50	Culvert Buffer	Three Rivers Park District	✓		1.72	87	$1,189	$1,564	$948.84	$18.70	
Landowner Category #4	31	Field Buffer	Kuka	✓	✓	1.64	70	$9,525	$1,564	$1,287.20	$30.16	
	32	WASCOB	Kuka			5.96	300	$76,752	$1,752	$1,032.81	$20.53	

Key: Cost Range of TP ($/lb)

Cost Range of TP($/lb)		Color Key
Low	High	
$0.00	$1,000	
$1,000	$3,000	
$3,000	$7,000	
$7,000	$10,000	
$10,000	$16,000	