EXTERNAL MEMORANDUM

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Date: July 30, 2021

Subject: Water Quality Trading (Appendix for Legislative-Citizen Commission on Minnesota Resources [LCCMR] Report)

Water quality trading (WQT) can provide a cost-effective stormwater National Pollutant Discharge Elimination System (NPDES) permit compliance option when working in an appropriate watershed. In this memorandum, total phosphorus (TP) unit cost comparisons for stormwater NPDES permit entities that implement urban best management practices (BMPs) in previously developed neighborhoods are compared with the unit costs for purchased credits generated by three different BMPs implemented in nonpermitted, nonpoint-source (NPS) areas.

Equation 1 shows the equation used to get urban BMP unit costs. The total cost in the equation is the annualized capital cost (implementation costs for the BMP) [Hakanson Anderson and Hennepin County Department of Environment and Energy, 2016; Barr Engineering Company, 2013] plus the annualized operation and maintenance (O&M) costs. The TP reduced (pounds per year [lb/yr]) is the BMP modeled treatment efficiency-based TP reductions per year.

$$U = \frac{T}{TP_{red}} \qquad (1)$$

where:

U = urban BMP unit costs

T = total cost

TP_{red} = TP reduced (lb/yr).

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Similarly, Equation 2 shows the equation used to get the total Credit Offset Unit Costs. The total cost in Equation 2 is the capital cost (75 percent of the cost of BMP implementation) plus the annual O&M costs (estimated). The adjusted TP reduced (lb/yr) is the modeled annual TP (lb/yr) reduced by the WQT trade ratio. The trade ratio multiplies the buyer's discharged TP demand for offsets by factors to address uncertainties introduced, equivalencies between discharge pollutant forms, site attenuation loss differences reducing TP delivered to Fountain Lake, and a retirement policy factor. The trade ratio is used to provide assurance that the offset is equal to or greater than the amount of TP discharged by the buyer. The total annualized costs in Equation 2 were derived by applying the Office of Management and Budget [1992].

$$C = \frac{T}{AP_{\text{red}}} \tag{2}$$

where:

C = credit offset unit costs

T = total capital cost

AP_{red} = adjusted TP reduced (lb/yr) with water quality trading trade ratio.

The detailed methods and results for determining the annualized unit costs for credits are provided in the sections at the end of this memorandum for WQT TP reduction BMP projects for bank stabilization, cropland rye cover crop, and a Water and Sediment Control Basin (WASCOB). Table 1 provides a summary of the credit unit costs for all three BMPs. The urban annualized unit costs gathered from the Hakanson Anderson and Hennepin County Department of Environment and Energy [2016] and Barr Engineering Company [2013] are provided in Tables 2 and 3. These citations provided urban BMP unit costs for rain gardens, stormwater ponds, streambank and shoreland stabilizations, and a gully stabilization.

Table 1. Three Nonpoint-Source Best Management Practice Credit Unit Costs

BMP Type	TP Reduction at Site (lb TP/yr)	Credits Generated per Year[(a)]	2019 Annualized Credit Unit Cost ($/lb TP)	Buyer Credit Cost[(b)]; Offsetting One Pound of TP Discharge ($/lb TP)
Rye Cover Crop (1 Acre)	0.50	0.37	554.75	1,165
WASCOB	697	330	27	58
Bank Stabilization	57	40	249	523

(a) Credits Generated per Year = Site TP Reduction × Subwatershed Location Factor of 0.677 for the rye cover crop and WASCOB BMPs and a 1.0 Location Factor for the bank stabilization project, which is located on the shore of Fountain Lake. The Location Factor addresses the phosphorus sequestered by river and tributary channel attenuation between the BMP site's subwatershed and Fountain Lake. The attenuation rate was modeled by the HSPF that is being used for the pending Fountain Lake Nutrient Total Maximum Daily Load (TMDL).

(b) Buyer Credit Cost = Annual Credit Unit Cost × a 2.1 to 1.0 trade ratio. The trade ratio is applied as a multiplier to the Buyer's required offset demand, whereas for every 1 pound TP discharged, 2.1 TP credits must be purchased. The trade ratio is applied to addresses introduced uncertainty in pollutant loads, pollutant equivalency (addressing differences in TP impacts that result from the Buyer and Seller discharging different TP ratios of soluble and particulate phosphorus), and a credit retirement factor providing additional benefit for the water resource.

Table 2. Urban Annualized Costs for Ardmore Area Subwatershed in Hakanson Anderson and Hennepin County Department of Environment and Energy [2016]

Project Type (20- to 50-yr Life)	Drainage Area (acres)	P Reduction (lb/yr)	2016 Unit Cost ($/lb TP/yr)	2020 Unit Cost ($/lb TP/yr)
Rain Gardens (2)	3.3 2.0	1.1 0.6	1,533 973	1,686 1,070
Stream Stabilization	N/A	0.2	3,330	3,630
Gully Stabilization	N/A	3.4	277	305
Shoreland Restoration	N/A	2.0	550	605
Pond Excavation	2.9	1.8	1,414	1,555
Pond Excavation	4.1	1.8	882	970
Pond Excavation	8.0	1.1	1,562	1,718
Pond Excavation	2.7	1.2	1,315	1,446
Pond Excavation	1.6	1.0	1,458	1,604

Table 3. Urban Annualized Costs for Fountain Lake From Barr Engineering [2013]

Project Type (20-yr Life)	TP Reduction (lb/yr)	Minimum 2013 Unit Cost ($/lb TP/yr)	Minimum 2020 Unit Cost ($/lb TP/yr)	Maximum 2013 Unit Cost ($/lb TP/yr)	Maximum 2020 Unit Cost ($/lb TP/yr)
Rain Gardens (3)	1.0–14.0	1,657 649 1,667	1,972 772 1,996	1,675 930 1,667	1,993 1,107 1,996
Water Quality Treatment Pond	7–11	1,435	1,708	4,521	5,378
Water Quality Treatment Pond	7–11	1,371	1,631	4,309	5,128
Water Quality Treatment Pond	2–3	7,091	8,438	21,229	25,263
Water Quality Treatment Pond	5–8	1,591	1,893	5,109	6,080
Water Quality Treatment Pond	12–17	1,344	1,599	3,800	4,522
Water Quality Treatment Pond	17–26	1,707	2,031	5,231	6,225
Water Quality Treatment Pond	45–68	1,055	1,255	3,197	3,804
Water Quality Treatment Pond	24–36	1,230	1,464	3,705	4,409
Water Quality Treatment Pond	6–10	1,508	1,795	5,034	5,983

Table 4 presents the final stormwater unit cost comparison. The unit cost comparison is for a 1 pound of TP unit cost comparison between a retrofit installed urban BMP in a high-density neighborhood and a purchased amount of credits to offset 1 pound of discharge. The credit unit cost reflects TP reductions made from three different BMPs and their associated watershed locations, plus a trade ratio multiplier to address an equal or greater reduction in TP. The unit costs for urban practices are averaged values based on the combined list of practice costs provided by the Hakanson Anderson [2016] and Barr [2013] citations.

Table 4. One Pound of Total Phosphorus Unit Cost Comparison Between a Retrofit Installed Urban Best Management Practice in a High-Density Neighborhood and a Purchased Amount of Credits to Offset 1 Pound of Discharge

Urban BMP TP Unit Costs			Equivalent Credit Offset Unit Costs	
Consulting Firm	Project Type	Average Unit Price ($/lb TP)	Water Quality Trading Credit Project Type Plus Administrative, Operation, and Maintenance	Water Quality Trading Buyer's Offset Cost ($/lb TP)
Hakanson Anderson	Rain Gardens	1,378	Cover Crops (@ 75% of Capitalization Cost; Practice is Replaced Each Year)	1,164
	Stream Stabilization	3,630		
	Gully Stabilization	305	WASCOB (@ 75% Capital Cost Plus O&M and Replacement Costs)	58
	Shoreline Stabilization	605		
	Pond Excavation	1,459	Bank Stabilization (100% of Capitalization Costs)	523
Barr	Rain Gardens	1,580		
	Water Quality Treatment Ponds	1,672 (With the Two Highest Cost Sites Removed)		

Credit offset unit costs are typically a cost-effective alternative to stormwater urban BMP implementation; however, as shown by the urban gully stabilization project unit cost estimate and the urban shoreline stabilization project, there can be exceptions to this statement. As such, WQT is not meant to be applied as the only means of compliance; instead, WQT is meant to be integrated into an implementation plan that considers and prioritizes projects based on the unit cost of the urban BMP and the available credit offset project costs. For all other practices, the WASCOB and bank stabilization offset unit costs were at least an order of magnitude less expensive.

TOTAL PHOSPHORUS CREDIT UNIT COST OF WATER AND SEDIMENT CONTROL BASIN

INTRODUCTION AND SUMMARY OF FINDINGS

This memorandum presents the methods and results for determining the annualized cost estimates for WQT buyers to purchase credits generated by installing a WASCOB using the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Practice Standard 638. A WASCOB (Figure 1) is an earth embankment or a combination ridge and channel that is constructed across the slope of a minor drainageway to trap sediment and slowly release water to a stable outlet. The WASCOB field implementation payment schedule is a $37,100.00 up-front payment plus an assumed design and construction oversight cost of $6,500.00 and an annual WQT administrator fee capped at $250.00 (2019 dollars). The WASCOB credit unit price estimate range is from $16.50 to $18.50 per credit.

Table 5 provides a summary of the analysis findings for two subwatersheds with different location factors. Once the edge-of-field TP reduction is known, the credits produced are entered into an equivalent annual cost (EAC) calculation based on the implementation payment made by the WQT program buyer. The competing public funding programs are the USDA Environmental Quality Incentives Program (EQIP) and Minnesota State Cost-Share conservation programs that offer producers up to 75 percent of the cost to implement WASCOB practices. Table 6 presents the results of the EAC for each of the two subwatershed location options.

Figure 1. A Water and Sediment Control Basin (Photograph Credit: Swift Soil and Water Conservation District).

Table 5. Water and Sediment Control Basin Minnesota Board of Water and Soil Resources Edge-of-Field Total Phosphorus Reductions for Two HSPF Location Factors Generating Credits

Baseline Condition	Baseline TP Loading (lb/acre)	With WASCOB Added	Edge-of-Field TP Reduction (lb/acre)	Shell Rock River HSPF Subwatershed Number and Location Factor (%)	Additional Bioavailability Factor for Subsoils (%)	Credits per Site per Year
Reduced Tillage	697	0	697	HSPF A19 67.7	70	330
Reduced Tillage	697	0	697	HSPF A101 74.3	70	363

lb/acre = pounds per acre.

The WASCOB credit's EAC unit cost is considerably lower than cover-crop EACs, although the implementation cost is sizeable. The correction of channelized flow erosion sites has the cost-effective advantage of reducing large TP loads. In addition, the NRCS practice life is 10 years if maintained properly, which allows for a one-time capital cost investment to supply credits for 10 years.

Table 6. Equivalent Annual Costs for Water and Sediment Control Basin Generated Credits With Capitalization Payments of $37,100.00 Per Acre (75 Percent of the Full Cost) Plus a Design and Construction Oversight Fee of $6,500.00 and an Annual Water Quality Trading Administrative Fee of $250.00

Baseline Condition	Credits per Acre of Cover Crop by HSPF Subwatershed	Equivalent Annual Cost/ Credit @ 50% of True Cost + $6,500 Design Charge and $250.00 Administrative Transaction Fee ($)	Buyer Cost per 1 lb of TP Discharged Using a 2.1 to 1.0 Trade Ratio ($)
Reduced Tillage	HSPF A19 330	18.19	38.20
Reduced Tillage	HSPF A101 363	16.54	34.73

METHODS

TOTAL PHOSPHORUS REDUCTION ELIGIBILITY POLICIES

The quantification method followed the pilot program policies and protocols for site evaluations of credit generation. The following WQT policies were applied:

- Unit of trade (credit) equals 1 pound of TP reduction adjusted by a site location factor and the buyer's demand reflects a 2.1 to 1.0 trade ratio for credits to offset 1 pound of discharged TP.
- Use of approved quantification methods
  - Minnesota Board of Water and Soil Resources (BWSR) Pollution Reduction Estimator
  - HSPF modeling to determine the watershed location factor.
- Established baselines
  - Current conditions reflect field operations that have existed for the previous 3 years
  - State-required Minnesota Buffer Law implementation may or may not apply to a given site
  - Channelized flow will pass through buffers without being treated
  - Zero additional reductions are applied to the baseline for the Minnesota Buffer Law.

TOTAL PHOSPHORUS REDUCTION CREDIT GENERATION PROTOCOLS

The protocols were fulfilled by locations assumed to be in HSPF Subwatersheds A19 and A101:

- Field Physical Characteristics: The example contributing area to the three WASCOB structures is 15 acres in size.
- Tile Drainage: The NRCS Hydrologic Soil Group rankings are B/D (if drained, moderate infiltration; if not drained, low infiltration); however, because of the sizeable slope (an approximate average of 9 percent), subsurface tiling is assumed to be unnecessary on the hill.
- Nutrient Management: The Minnesota BWSR Pollution Reduction Estimator spreadsheet (https://bwsr.state.mn.us/water-quality-tools-and-models) assumes a default average TP soil concentration of 1 pound per ton of silt soil and 1.15 pounds per ton of clay soil.
- Baselines: Baseline scenarios were created for reduced tillage with or without buffers. Channelized flow and associated pollutants are not treated by buffers. The channelized flow of this magnitude is assumed to cut a flow path through the buffer vegetation.

EQUIVALENT ANNUALIZED COST FOR A 10-YEAR COVER-CROP CREDIT GENERATION CONTRACT

The annualized total unit cost is calculated using the *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* [Office of Management and Budget, 1992]. The annualized total unit cost analysis inputs are as follows:

- Capitalization cost of $37,100.00
- Inflation rate of 2.5 percent
- Nominal discount rate of 7.0 percent
- WQT credit project life of 10 years
- NRCS practice life of 10 years
- One-time service fee for the broker design and construction oversight of $6,500.00
- Annual transaction cost of 10 percent of capital cost capped at $250.00 per year
- O&M costs provided by producer.

The payment examples selected were based on cost data provided by a Soil and Water Conservation District (SWCD) conservation technician who removed all of the producer information and submitted only the cost data and Minnesota BWSR Pollution Reduction Estimator results. Buyers are assumed to purchase credits generated by installing three WASCOB structures using the NRCS Practice Standard 638. The WASCOB 2016 cost of $33,700.00 was converted to 2019 dollars using the Engineering News Record price index for September 2019 cost ratios. The 2019 implementation cost is $37,100.00. In addition, service fees were added for a one-time $6,500 broker design and construction oversight charge and a 10 percent per year WQT administrator fee, which was capped at $250.00 per year in 2019 dollars. The administrator fee increases over time to compensate for inflation.

The competing public funding programs are the USDA EQIP and Minnesota State Cost-Share conservation programs that, in combination, offered the producer 75 percent of the cost to implement a WASCOB practice.

OTHER CONSIDERATIONS

Not all WASCOB practices will generate this level of annual credits at this cost. The data provided for this WASCOB credit generation site example are for a site that produced a large annual erosion rate. Numerous gullies form over 2 to 5 years. When the gully formation experiences a longer time period, the amount of credits generated by the site are the direct volume method divided by the number of years; therefore, a 2-year gully formation time would half the number of credits generated. The EAC estimates would likewise increase inversely. Only receiving half of the credits would double the project's credit unit cost.

TOTAL PHOSPHORUS CREDIT UNIT COST OF FOUNTAIN LAKE BANK STABILIZATION

INTRODUCTION AND SUMMARY OF FINDINGS

This memorandum presents the methods and results for determining the annualized cost estimates for WQT buyers to purchase credits generated by installing a Fountain Lake bank stabilization project designed by a registered Professional Engineer. The bank stabilization project has an estimated capital cost of $137,000.00. The unit cost of bank stabilization-derived credits is $249.00 with a buyer offset of $523.00. The high cost per credit is most likely caused by the list of conservative assumptions used in calculating the site credits. The calculation process used bank dimensions and lateral recession rates (LRRs) that were conservatively estimated, as explained in the Methods section. Using the actual bank dimensions would reduce the conservative nature of the inputs.

Table 7 provides a summary of the analysis findings for the baseline settings in the Fountain Lake Subwatershed. The bank stabilization project is assumed to fully remove bank slumping and return the site's erosion to the normal, minimal addition of phosphorus to the lake. The Minnesota Buffer Law does not apply to this site or other nonagricultural (non-ag) field sites. Once the bank stabilization TP reduction is known, the credits per project are entered into an EAC calculation based on the implementation payment made by the WQT program buyer. The EAC analysis adds a $250.00 (2019 dollars) WQT administrative fee and an O&M fee based on 2 percent of the capital cost applied over the 20-year project life. The annual costs are adjusted for inflation by the EAC analysis, which results in a total cost summed across the 20-year project life of $6,796.00 for administrative fees and $71,742.00 for O&M. Table 8 summarizes the EAC results for these assumptions. If City managers view this project as a park project (a service for their citizens), the O&M cost may not need to be factored into the credit cost. The bank stabilization project EAC results without O&M are provided in Table 9.

Table 7. Pioneer Park Bank Stabilization Project Credit Determination Using the Minnesota Board of Water and Soil Resources Pollution Reduction Estimator Results, Location Factor, and Additional Required Equivalence Factor for Bank Erosion Projects

Baseline Condition	Baseline TP Loading (lb)	After Bank Stabilization	TP Reduction (lb)	Lake Subwatershed Location Factor	Bank Soils Additional Equivalence Factor	Bank Stabilization Project (credits/yr)
Eroding Bank	57	0	57	1.00	0.70	40

lb = pounds
credits/yr = credits per year.

Table 8. Equivalent Annual Costs for Bank Stabilization Generated Credits With a Total Practice Cost of $137,000.00 Plus a $250.00 Annual Administration Fee and 2 Percent Operation and Maintenance Fee Cost Across 20 Years

Baseline Condition	Credits/ Year	Equivalent Annual Cost/Credit $137,000 Capitalization 2% O&M $5,000 Administration Transaction Fee ($)	Buyer Cost/1 lb TP Discharged Using a 2.1 to 1.0 Trade Ratio ($)
Bank Erosion	40	248.99	522.87

Table 9. Equivalent Annual Costs for Bank Stabilization Generated Credits With a Capitalization Cost of $137,000.00 Plus a $250.00 Annual Administration Fee Across 20 Years

Baseline Condition	Credits/ Year	Equivalent Annual Cost/Credit $137,000 Capitalization and $5,000 Administration Transaction Fee ($)	Buyer Cost/1 lb TP Discharged Using a 2.1 to 1.0 Trade Ratio ($)
Bank Erosion	40	180.49	379.02

METHODS

TOTAL PHOSPHORUS REDUCTION ELIGIBILITY POLICIES

The quantification method followed the pilot program's policies and protocols for site evaluations of credit generation. The following WQT policies were applied:

- Unit of trade (credit) equals 1 pound of TP reduction adjusted by a site location factor and the buyer's demand reflects a 2.1 to 1.0 trade ratio for credits to offset 1 pound of discharged TP.
- Use of approved quantification methods
  - Minnesota BWSR Pollution Reduction Estimator
  - HSPF modeling to determine the watershed location factor.
- Established baselines
  - Current conditions reflect bank slumping across the previous 24 years.

TOTAL PHOSPHORUS BANK STABILIZATION REDUCTION CREDIT GENERATION PROTOCOLS

The quantification method followed the bank erosion evaluation guidance as provided in *Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual* [Michigan Department of Environmental Quality, 1999] (Training Manual). The Training Manual is acknowledged by the U.S. Environmental Protection Agency (EPA) as the basis for the algorithms in the Region 5 model for nonurban BMPs and remains available for guidance on the EPA *Polluted Runoff: Nonpoint Source (NPS) Pollution* website (https://www.epa.gov/nps/region-5-model-estimating-pollutant-load-reductions). The Training Manual provides a supporting narrative for the equation calculation provided in the Minnesota BWSR Pollution Reduction Estimator "Stream & Ditch" spreadsheet tab of the Excel workbook (https://bwsr.state.mn.us/water-quality-tools-and-models). The "Stream & Ditch" spreadsheet was designed with channel erosion in mind; however, the lake-bank erosion from wave and ice action provides a sufficiently similar erosive energy that deposits sediments and nutrients into the lake. Using the Training Manual process, the direct volume method was applied using the Channel Erosion Equation (CEE) to calculate the annual average sediment reduction using the direct volume method:

$$\text{CEE} = \text{Length (ft)} \times \text{Height (ft)} \times \text{LRR (ft/yr)} \times \text{Soil Weight (ton/ft}^3\text{)} \tag{3}$$

The following quote from the Training Manual discussion on bank erosion provided valuable insights:

> *This calculation contrasts the original bank slope with the existing repose. The rate at which bank deterioration has taken place is an important variable to determine. The Lateral Recession Rate (LRR) is the thickness of soil eroded from a bank surface (perpendicular to the face) in an average year. Recession rates are measured in feet per year. However, channel bank may not erode for a period of years when no major runoff events occur. When a major storm does occur, the bank may be cut back tens of feet for a short distance. It is necessary to assign recession rates to banks with such a process in mind. If ten feet of bank has been eroded, the ten feet must be adjusted to an average annual lateral recession rate rather than a recession rate for one storm.*
>
> *Selecting the lateral recession rate is the most critical step in estimating channel erosion using the direct volume method. A historical perspective is required in many instances. Old photographs, old survey records, and any information that tells you what a bank looked like at known times in the past are very useful. In most instances, such information is lacking and field observations and judgment are needed to estimate recession rates.*
>
> *Exposed bridge piers, suspended outfalls or culverts, suspended fence lines, and exposed tree roots are all good indicators of lateral recession rate. Discoloration of bridge piers may show the original channel bottom elevation. Given the date of bridge installation, a recession rate can be*

calculated for that reach of stream. Culverts are generally installed flush with a bank surface. The amount of culvert exposed and age of the culvert will allow you to calculate a lateral recession rate.

Exposed tree roots are probably the most common field evidence of later recession. Consult references to familiarize yourself with tree height and appearance as related to tree age. Roots will not grow towards a well-drained, exposed, eroding channel bank. The amount of root exposed should be increased by at least a factor of 2X to account for soil that was in the bank and that the root was growing in. By multiplying the length of root exposed by at least two and dividing by the age of the tree, an estimated lateral recession rate can be obtained.

As can be seen in the discussion above, there are few instances where you will be able to measure lateral recession rates in the field. Experience and professional judgment are generally required to estimate recession rates for channel erosion. Because of this the following information has been compiled for your use which relates recession rates.

INPUT DATA FOR THE CHANNEL EROSION EQUATION

The direct volume method's equation was determined as follows:

- **Length of Bank**: 685 feet (ft), as provided on the WSB Engineering preliminary plan view presented in Figure 2.
- **Height of Bank**: A 10-ft average height.

The bank-height estimate was determined using data supplied in the WSB Engineering site plan view shown in Figure 2. The plan view provides the topography survey results gathered on December 11, 2017. The noted data provided in Figure 2 indicate that the normal water level during the survey was close to the Minnesota Department of Natural Resources (MN DNR) ordinary high-water level of 1,215.10 ft (elevation). Table 10 presents a summary of topographic survey points made on the lake bank's slope. The top-of-bank evaluation is not provided at each profile location as recorded by this site plan; therefore, professional judgment was used to select a conservative average bank height of 10 ft. The data needed to improve this estimate may be available in the WSB topographic survey records.

LATERAL RECESSION RATE

A conservative LRR of 0.2 feet per year (ft/yr) was selected.

As explained in the Training Manual narrative, "…there are few instances where you will be able to measure LRRs in the field. Experience and professional judgment are generally required to estimate recession rates for channel erosion." Therefore, to estimate the Pioneer Park bank stabilization project's LRR, a weight-of-evidence approach was developed.

The Training Manual Figure 1 (presented as Table 11) was used to select the appropriate LRR (ft/yr) by completing the following steps:

1. A long-term aerial image process was developed based on Google Earth recorded photographs and the site's length-measurement tool. Two historical aerial photographs captured the Pioneer Park imagery during spring periods without tree canopy in March 2015 (Figures 3 and 4) and April 1991 (Figure 5). These two photographs provided a 24-year record of bank position.
2. By using the Google Earth measurement icon on the 2015 image, a 137.58-ft line was plotted on the map. The line extends from the southwest corner of the city park building to the water

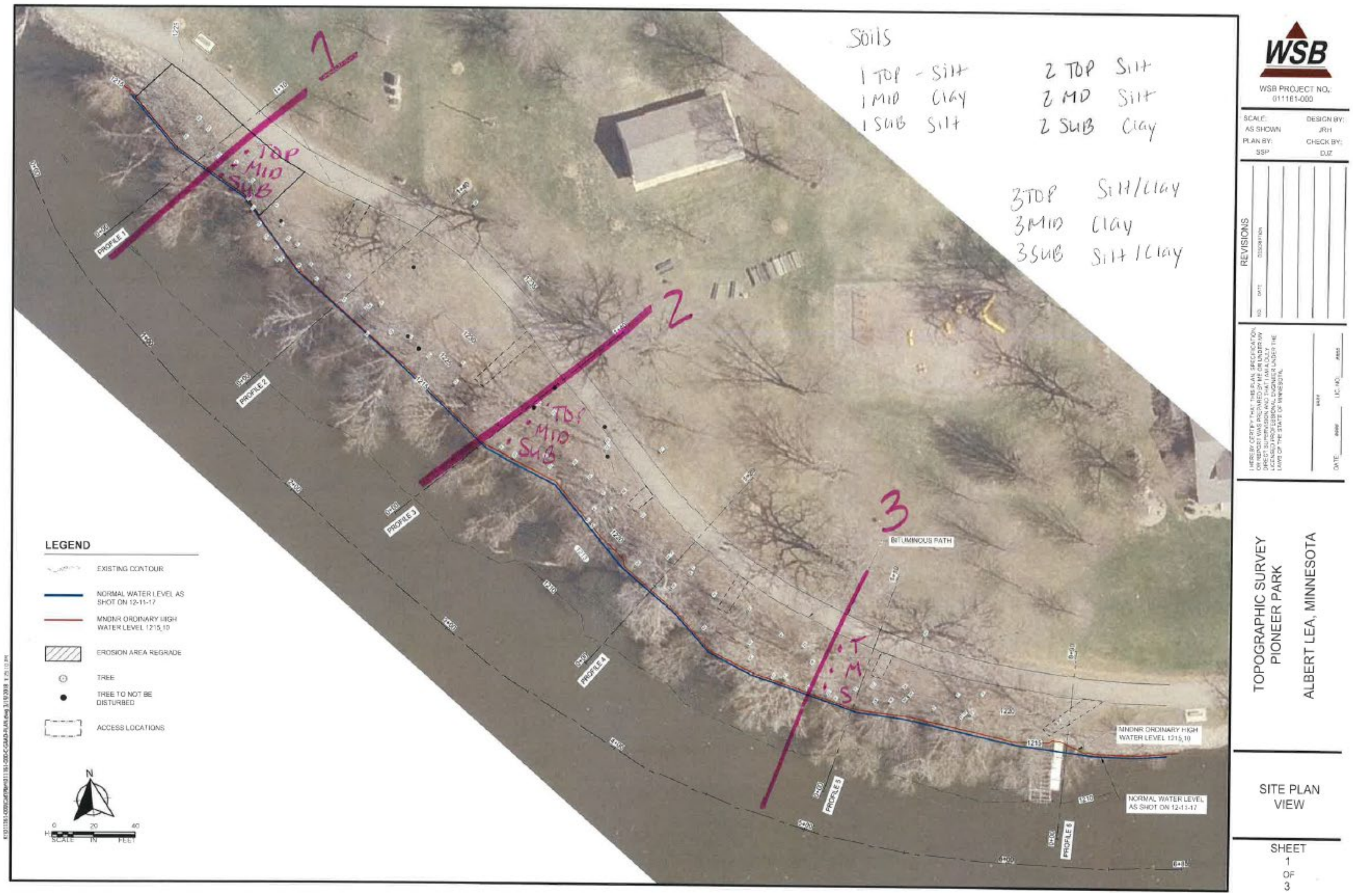

Figure 2. WSB Engineering Site Plan View of the Pioneer Park Bank Stabilization Project.

edge. Unique features were identified that would allow a second line to be drawn on the same trajectory. The line passes through two unique tree branch features; the first is a tree with a branch that runs parallel with the line for a short period before bending up, and the second is a branch intersection with the tree trunk.

3. Using the two unique tree features, a measurement line was created from the bituminous path to the water edge that lies on the same trajectory. This second line was created to benefit future water-edge location determination using a smaller scale.
4. Switching to the April 1991 aerial image (Figure 5), keeping the Google Earth measurement in place allowed a new bank position point (pt) to be selected. A pin was set and named at the location of the line intersection with the 1991 water edge (Figure 6).
5. Using the time slider icon to return to the 2015 aerial image was completed while keeping the existing measurement line. This provided an aerial image with better clarity and set the LRR equation erosion period to be 24 years. On the 2015 image, a second Google Earth measurement line from the pin named “1991 edge of water pt” to the 2015 water edge was created. The Google Earth ground-length measurement is 6.14 ft.
6. The 6.14 ft result was divided by 24 years to determine the preliminary LRR result of 0.26 ft/yr.
7. The Moderate Category LRR of 0.2 ft/yr (conservative) in Table 11 was selected.

Table 10. Topographic Survey of Bank-Slope Evaluations and Bank-Height Estimates

<table>
<tr><th>Transect Profile</th><th>MN DNR Ordinary High-Water Level (ft)</th><th>Elevation of Bituminous Path (ft)</th><th>Elevations: Bank Topographic Survey Point and Approximate Vertical Location on Bank (ft)</th><th>Recorded Topographic Height (ft)</th></tr>
<tr><td>#1</td><td rowspan="6">1,215.10</td><td>1,225</td><td>1,225</td><td>10</td></tr>
<tr><td>#2</td><td>—</td><td rowspan="2">1,235
(Top End of Bank)</td><td>~20</td></tr>
<tr><td>#3</td><td>1,235</td><td>~20</td></tr>
<tr><td>#4</td><td>—</td><td>1,220
(Low End of Bank)</td><td>~10</td></tr>
<tr><td>#5</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>#6</td><td>Exceeds 1,220</td><td>1,220
(Mid-Bank)</td><td>~10</td></tr>
<tr><td colspan="4">Conservative Average</td><td>10</td></tr>
</table>

THE DIRECT VOLUME METHOD EQUATION RESULTS

The results of the direct volume method equation (CEE = length × height × LRR) was 1,370 cubic ft of soil per year. This estimate was based on the conservative LRR assumption in Step 7 of 0.2 ft/yr instead of 0.26 ft/yr in Step 6, reducing the LRR estimate by 411 cubic ft per year—a 30 percent implicit safety factor.

DETERMINING DRY WEIGHT AND SOIL PHOSPHORUS CONTENT

SELECTING THE BANK-SOIL TYPE (I.E., SAND, SILT, CLAY, PEAT)

The bank-soil type selection was made based on field observations recorded by Shell Rock River Watershed District (SRRWD) staff and is noted on the WSB Engineering site plan view in Figure 2. All three soil-sampling cross sections recorded that two-thirds of the bank were predominantly silt and one-third was clay. The Minnesota BWSR Pollution Reduction Estimator model only allows one soil type to be entered. Therefore, the model input for the direct volume method result of 1,370 cubic ft was divided into two volume ratios matching the recorded observations: 914 cubic ft of silt and 456 cubic ft of clay.

Table 11. Michigan Department of Environmental Quality Training Manual Reference on Lateral Recession Rates of Stream/Ditch Banks as Estimated by Field Observations [Michigan Department of Environmental Quality, 1999]

Lateral Recession Rate (ft/yr)	Category	Description
0.01–0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06–0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang.
0.3–0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence comers missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Figure 3. March 2015 Pioneer Park Bank Stabilization Project Fixed-Point Measurement Between Park Building and Water Edge Using Google Earth. Lateral recession rate Steps 1 and 2.

MINNESOTA BOARD OF WATER AND SOIL RESOURCES POLLUTANT REDUCTION ESTIMATOR RESULTS

Collected soil phosphorus samples are 8 percent less on average than default soil concentrations assigned to soil types used in the Minnesota BWSR Pollution Reduction Estimator quantification method. One soil test is an exception where a sampled value is 59 percent more than the default values used in the quantification method. The low soil concentrations combined with low soil carbon concentrations are a strong indicator of the need for the additional equivalence factor required for conservation practices that correct subsoil erosion-related phosphorus loading. The following results are based on conservative assumptions for bank height and LRR:

- Silt soil fraction TP loading: 39 lb per year
- Clay soil fraction TP loading: 18 lb per year
- **Total TP loading:** 57 lb per year.

Figure 4. March 2015 Pioneer Park Bank Stabilization Project Fixed-Point Measurement Between Bituminous Path and Water Edge Using Google Earth. Lateral recession rate Step 3.

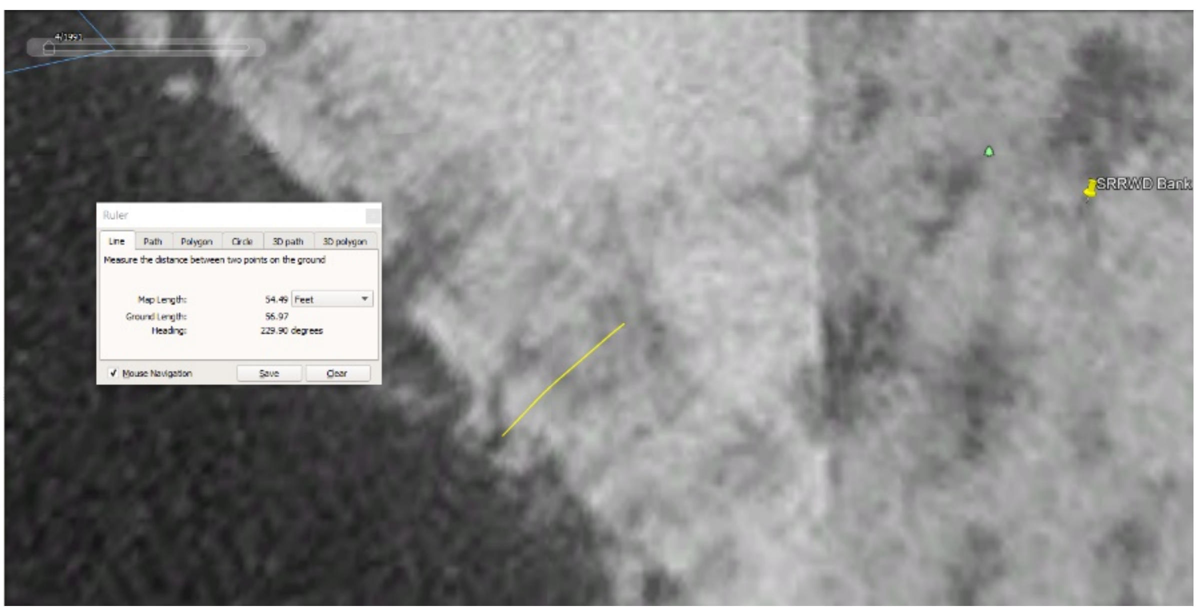

Figure 5. Switching to April 1991 Aerial Image in Google Earth. Lateral recession rate Step 4.

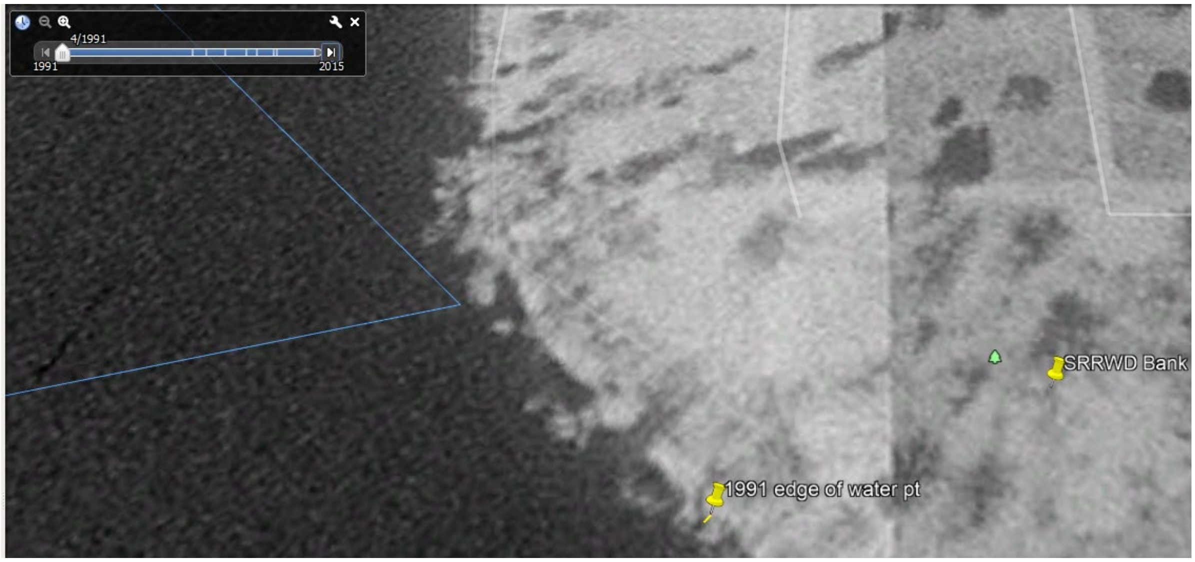

Figure 6. Set 1991 Edge of Water Point and Switch Back to 2015 Image. Lateral recession rate Step 4. This image captured that the “1991 edge of water pt” pin was set appropriately, although this screen capture occurred after lateral recession rate Step 5 had taken place.

LOCATION FACTOR

The lake bank is located on Fountain Lake; therefore, the location factor is 1.00.

BANK ADDITIONAL EQUIVALENCE FACTOR

This additional equivalence factor addresses the low subsoil TP concentrations and considers the related low levels of soil carbon present in subsoils. The additional equivalence factor reduces the site credit total by 30 percent.

EQUIVALENT ANNUALIZED COST FOR A 10-YEAR COVER-CROP CREDIT GENERATION CONTRACT

The annualized total unit cost is calculated using numbers from Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses [Office of Management and Budget, 2019]. The annualized total unit cost analysis inputs are:

- Inflation rate of 2.5 percent
- Nominal discount rate of 3.0 percent
- WQT credit project life of 20 years
- Bank stabilization practice life of 20 years
- Project capitalization cost of $137,000.00
- Annual O&M cost of 2 percent, responsibility of the city, which generates $71,750.00 across the project life
- 20-year WQT administrator transaction cost capped at $250.00 per year and equaling a 20-year cost of $6,796.00.

Because city managers could view this project as a park service for their citizens, the O&M cost of the bank stabilization project could be a part of the park department budget. Therefore, the EAC calculation can be calculated without an O&M cost factored into the EAC-derived credit price.

TOTAL PHOSPHORUS CREDIT UNIT COST OF COVER CROPS SUBJECT

INTRODUCTION AND SUMMARY OF FINDINGS

This Section presents the methods and results for determining the annualized cost estimates for WQT buyers to purchase credits generated by installing a rye cover crop using the NRCS Practice Standard 340. The cover crop 2019 field implementation cost is $68.00 per acre. The unit cost of a cover-crop-derived credit ranges from $180.00 to $400.00 with buyer offsets ranging from $380.00 to $870.00 per pound of TP discharged. The cost per credit is high because the practice must be fully replaced every year and the reduction of TP pounds per acre is at or less than 1 pound per acre (Table 12).

Table 12. Nutrient Tracking Tool Edge-of-Field Total Phosphorus Reductions for Different Baseline Scenarios Combined With HSPF Location Factors for Sites to Determine Cover-Crop Generated Credits

Baseline Condition	Baseline TP Loading (lb/acre)	With Rye Cover Crop Added	Edge-of-Field TP Reduction (lb/acre)	Location Factor		Credits Generated Per Acre
Intensive Tillage	1.8	1.1	0.7	HSPF Subwatershed A19	0.677	0.47
Intensive Tillage With Buffer Law	1.4	0.9	0.5			0.33
Reduced Tillage	1.2	0.7	0.5			0.33
Reduced Tillage With Buffer Law	1.0	0.6	0.4			0.27
Intensive Tillage	1.8	1.1	0.7	HSPF Subwatershed A101	0.743	0.52
Intensive Tillage With Buffer Law	1.4	0.9	0.5			0.37
Reduced Tillage	1.2	0.7	0.5			0.37
Reduced Tillage With Buffer Law	1.0	0.6	0.4			0.29

The number of credits generated per acre was determined for four baseline conditions in two subwatersheds with different location factors. Once the credit per acre was known, the EAC was calculated using the costs for two public funding programs: the USDA NRCS EQIP and Minnesota Agricultural Water Quality Certification Program (MAWQCP). The pilot WQT project will likely compete with these programs to attract farmers that are interested in installing cover crops. The MAWQCP offers producers a grant of 75 percent of the cost to implement cover crops ($51.00 per acre of the $68.00 implementation cost). This grant program has a cap of $5,000.00 per year, per producer. The EQIP program offers producers 50 percent of the cost to implement cover crops or $34.00 per acre. The combined total of all USDA Farm Bill payments is capped at $450,000.00 per year, per farm. Tables 13 and 14 present the results of the EAC for each of the two public program payment levels.

An advantage of the WQT framework that is evident in Tables 12 through 14 is that program administrators and buyers can target cost-effective sites (e.g., those sites not subject to the Minnesota Buffer Law) and favorable subwatershed location factors. The reduction in cost-effectiveness is illustrated by comparing the HSPF Subwatershed A19 EACs and the slight increase in credit amount impact on the associated EACs in the HSPF Subwatershed A101. Other ways to target improved edge-of-field TP reductions and lower EACs would be to select other appropriate fields with steeper slopes and/or higher soil TP concentrations.

Table 13. Equivalent Annual Costs for Cover-Crop Generated Credits With Payments of $51.00 per Acre (75 Percent of the Full Cost as per the Minnesota Agricultural Water Quality Certification Program Guidelines)

Baseline Condition	Credits per Acre of Cover Crop by HSPF Subwatershed		Equivalent Annual Cost per Credit @ 75% of True Cost + 10% Transaction Fee ($)	Buyer Cost per 1 lb TP With a 2.1 to 1.0 Trade Ratio ($)
Intensive Tillage	A19	0.47	202.15	424.51
Intensive Tillage With Buffer Law		0.33	287.90	604.60
Reduced Tillage		0.33	287.90	604.60
Reduced Tillage With Buffer Law		0.23	413.08	867.47
Intensive Tillage	A101	0.52	182.71	383.69
Intensive Tillage With Buffer Law		0.37	256.78	539.24
Reduced Tillage		0.37	256.78	539.24
Reduced Tillage With Buffer Law		0.29	327.62	687.99

Table 14. Equivalent Annual Costs for Cover Crop Generated Credits With Payments of $34.00 per Acre (50 Percent of the True Full Cost As per Environmental Quality Incentives Program Guidelines)

Baseline Condition	Credits per Acre of Cover Crop by HSPF Subwatershed		Equivalent Annual Cost per Credit @ 50% of True Cost + 10% Transaction Fee ($)	Buyer Cost per 1 lb TP With a 2.1 to 1.0 Trade Ratio ($)
Intensive Tillage	A19	0.47	105.20	220.92
Intensive Tillage With Buffer Law		0.33	149.83	314.64
Reduced Tillage		0.33	149.83	314.64
Reduced Tillage With Buffer Law		0.23	214.97	451.45
Intensive Tillage	A101	0.52	95.08	199.68
Intensive Tillage With Buffer Law		0.37	133.63	280.63
Reduced Tillage		0.37	133.63	280.63
Reduced Tillage With Buffer Law		0.29	170.50	358.04

METHODS

TOTAL PHOSPHORUS REDUCTION ELIGIBILITY POLICIES

The quantification method followed the pilot program's policies and protocols for site evaluations of credit generation. The following WQT policies were applied:

- Unit of trade (credit) equals 1 pound of TP reduction adjusted by a site location factor and the buyer's demand reflects a 2.1 to 1.0 trade ratio for credits to offset 1 pound of discharged TP.

- Use of approved quantification methods
  - USDA Nutrient Tracking Tool (NTT) for edge-of-field reduction estimates
  - HSPF modeling to determine the watershed location factor.
- Established baselines
  - Current conditions reflect field operations that have existed for the previous 3 years
  - State-required Minnesota Buffer Law implementation.

TOTAL PHOSPHORUS REDUCTION CREDIT GENERATION PROTOCOLS

The protocols were illustrated by creating an area of interest in the USDA NTT on a randomly selected field west of the city of Albert Lea and south of Interstate 90. The NTT calculations from this field were used in four different phosphorus-reduction scenarios in two different HSPF subwatersheds. In this way, an illustration of impacts from different settings was created for baselines (Minnesota Buffer Law and site tillage history) and HSPF Location Factors. The small example field selected was 7.97 acres in size. The soils' unit names are as follows:

- Webster clay loam, 1.8 percent slope, 3.86 acres
- Glencoe clay loam, 0.9 percent slope, 2.06 acres
- Clarion loam, 4.9 percent slope, 2.06 acres
- Field average slope = 2.5 percent.

TILE DRAINAGE

The NRCS Hydrologic Soil Group rankings are C/D (low-infiltration rates, 74 percent of the field) and B (moderate infiltration rates, 26 percent of the field). The assumed standard tile density is 4-ft depths.

NUTRIENT MANAGEMENT

Using the Olen soil phosphorus test type at 19 parts per million (ppm) (very high), annual corn application rates would be 60 lb/acre and soybean application rates would be 40 lb/acre. Note that while the soil test is considered to be very high according to the University of Minnesota Extension fertilizer guidelines [Kaiser et al., 2011], and while the phosphorus application rate is also high, a sufficient number of producers are assumed to apply this nutrient management approach as part of their own method to assure their yield goals will be met. The nitrogen application rates entered are 180 lb/acre corn for a 184 bushel per acre (bu/acre) yield.

BASELINES

Baseline scenarios were created for intensive tillage, intensive tillage with buffer, reduced tillage, and reduced tillage with buffer. Table 12 provides a summary of eligible field phosphorus reductions as output by the NTT model with a location factor discount for the two modeled subwatersheds (i.e., HSPF Subwatershed A19/Location Factor 0.667 and HSPF Subwatershed A101/Location Factor 0.743).

EQUIVALENT ANNUALIZED COST FOR A 10-YEAR COVER-CROP CREDIT GENERATION CONTRACT

The annualized total unit cost is calculated using the Office of Management and Budget [2019]. The annualized total unit cost analysis inputs are as follows:

- Inflation rate of 2.5 percent
- Nominal discount rate of 3.0 percent
- One-time project life service fee for the broker to provide a seeding establishment plan of $65.00

- WQT credit project life of 10 years
- Cover-crop NRCS practice life of 1 year requiring nine practice replacements
- Annual transaction cost of 10 percent of capital cost, or $6.80/acre/year, capped at $250.00 per project.

As identified above, the WQT program administrator collects an administrative fee of 10 percent to facilitate third-party verification, documentation, monitoring, and reporting activities on behalf of the buyer.

SOUTHERN MINNESOTA BEET SUGAR COOPERATIVE PAID CREDIT PRICES BELOW EQUIVALENT ANNUAL COST FINDINGS

Cover crops are the predominant credit generating practice used in the Southern Minnesota Beet Sugar Cooperative (SMBSC) WQT NPDES permit. The SMBSC permit has recorded hundreds of acres of spring cover-crop purchases per year. This practice is valuable for sugar beets that are just emerging because sugar beet sprouts are vulnerable to wind damage. Producers are incentivized to implement this practice rather than potentially having to replant or lose acres of crop. Another incentive for accepting a low-credit payment is that these sugar beet growers are shareholders in the SMBSC. The growers realize that for their crop to remain profitable, the SMBSC facility overhead must remain cost-effective. This example demonstrates that credit buyers may negotiate lower-than-cost credit prices in situations where the producer obtains other benefits.

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