Agricultural Watershed Restoration Project
Logan Creek Watershed

Final Report
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Prepared for
Whitewater Watershed Joint Powers Board

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Executive Summary

The Whitewater Watershed Joint Powers Board (WJPB) was selected by the Board of Water and Soil Resources (BWSR) as a recipient of an Agricultural Watershed Restoration (AWR) Grant for the Logan Creek watershed. The goal for AWR projects is to demonstrate long-term restoration of surface water quantity and quality through the restoration of natural hydrologic function to agricultural working lands. AWR projects are intended to develop a framework for defining and implementing feasible and practical practices for restoring water quantity and quality.

Logan Creek is a tributary to North Branch Whitewater River, and is located in northeastern Olmsted County in south-eastern Minnesota. The Minnesota Pollution Control Agency (MPCA) has listed Logan Creek as impaired for aquatic recreation due to fecal coliform bacteria and for aquatic life due to turbidity. The Logan Creek watershed is about 10,814 acres and contains 6.8 miles of perennial flow and 33.1 miles of intermittent flow streams. Logan Creek has a steep stream gradient (28 feet/mile) and the watershed consists of well-drained soils with karst (spring and sinkhole) features.

Logan Creek is a flashy stream system with high turbidity corresponding with high flow rates and stream degradation. A significant number of conservation practices have already been implemented in the watershed, but the water quality modeling indicates that further improvements can be derived from **both** improved hydrology and streambank stabilization. The MPCA estimates that an overall turbidity reduction of 55% would be required to meet the 25 NTU standard.

For this project, the Soil and Water Assessment Tool (SWAT) model was used to evaluate the long-term efficacy of best management practices (BMPs) intended to minimize flow volume from the landscape, slow the overland flow rate and function in a karst environment. The calibrated SWAT model was used to evaluate changes to watershed land cover or crop rotations, crop management, distributed detention, and implementation of streambank stabilization with rotational grazing/exclusion of animals. The average annual flow volumes and sediment loads for each implementation modeling scenario were summarized and compared to the 55 percent sediment load reduction goal for meeting the turbidity standard.

Table EX-1 provides a summary of the estimated costs and benefits associated with implementation of each of the load reduction scenarios that were modeled. The results show Scenarios #5 and #6 are the only combinations of implementation practices that would meet or nearly meet the load reduction goal of 55 percent. However, both BMP scenarios also include the highest landowner practice costs and forgone income. As a result, unless a market can be established for switchgrass that is better than hay or is more comparable to corn and soybeans, the combination of BMPs in Scenario #7 likely represents the most feasible and cost-effective approach for improving water quality in the watershed under the current economic conditions.

Table EX-1 Summary of estimated costs and benefits for management scenarios.

BMP Scenario #	BMP Scenario Description	Sediment Reduction Percentage	Present Value Cost ($)		Cost-Benefit ($/MT/yr)		
			Public	Landowner	Public	Landowner	Total
1	Stream stabilization	20%	$823,000	$320,000	$3,254	$1,267	$4,521
2	Distributed detention	8%	$223,000	$134,000	$2,131	$1,281	$3,412
3	Conservation tillage	9%	$156,000	$997,000	$1,380	$8,824	$10,204
4	Perennial biofuel crop replacing all corn/soybeans	23%	$188,000	$3,319,000	$640	$11,269	$11,909
5	Perennial biofuel crop replacing all corn/soybeans w/ stream stabilization	60%	$1,012,000	$3,639,000	$1,320	$4,749	$6,069
6	Perennial biofuel crop, corn-alfalfa-CT rotation w/ stream stabilization	52%	$1,032,000	$3,423,000	$1,537	$5,100	$6,637
7	¼ perennial biofuel crop; ½ corn-alfalfa rotation and ¼ small grains with CT; stream stabilization	42%	$1,087,000	$3,211,000	$2,021	$5,969	$7,990

It is recommended that the WJPB and project partners conduct field-scale and stream corridor assessments to further prioritize implementation of the proposed practices. It is also recommended that the project partners continue watershed monitoring and updating the available data for BMP implementation.

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1.0 Project Background

The Whitewater Watershed Joint Powers Board (WJPB) was selected by the Board of Water and Soil Resources (BWSR) as a recipient of an Agricultural Watershed Restoration (AWR) Grant for the Logan Creek watershed. The goal for AWR projects is to demonstrate long-term restoration of surface water quantity and quality, on a subwatershed scale, through the restoration of natural hydrologic function to agricultural working lands. AWR projects are intended to develop a framework, or blueprint, for defining and implementing feasible and practical practices for restoring water quantity and quality within impaired agricultural watersheds in Minnesota.

Logan Creek is a tributary to North Branch Whitewater River, and is located in northeastern Olmsted County in south-eastern Minnesota (Figure 1-1). The Minnesota Pollution Control Agency (MPCA) has listed Logan Creek as impaired for aquatic recreation due to fecal coliform bacteria and for aquatic life due to turbidity. The Logan Creek watershed is about 10,814 acres and contains 6.8 miles of perennial flow and 33.1 miles of intermittent flow streams. Logan Creek has a steep stream gradient (28 feet/mile) and the watershed consists of well-drained soils with karst (spring and sinkhole) features.

The Whitewater River and Logan Creek subwatershed have been studied in the past. Watershed assessment and modeling (AgNPS version 3.65) of the Logan Creek subwatershed was completed by the NRCS (1997), including the development of a sediment budget. The Logan Creek Subwatershed Project, Measuring Implementation Effectiveness in the Whitewater River Watershed, Southeastern Minnesota, 1999-2004 was recently completed by MPCA (2005). This project involved the preliminary development of a Soil and Water Assessment Tool (SWAT) model for the Logan Creek subwatershed.

For this project, the SWAT model was used to evaluate the long-term efficacy of best management practices (BMPs) intended to minimize flow volume from the landscape, slow the overland flow rate and function in a karst environment. This report discusses the development of the SWAT model for the watershed, and an assessment of management scenarios and costs for improving the hydrology and water quality of Logan Creek. The report is organized as follows: Section 2 describes the watershed characteristics and stream water quality relative to the State turbidity standard; Section 3 presents the model development, and the results of the model calibration and validation; Section 4 summarizes the results of the simulated watershed management practices to reduce the sediment load at the watershed outlet; and Section 5 provides the conclusions and recommendations.

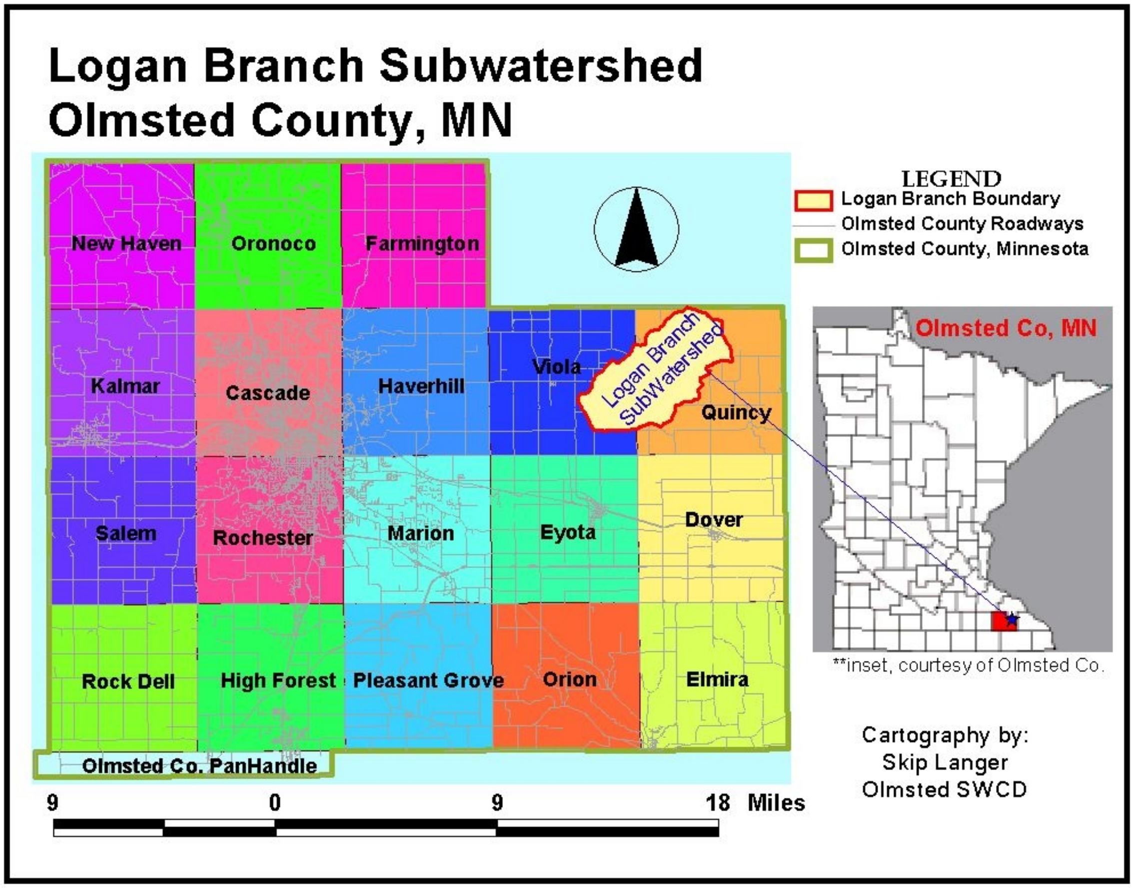


Figure 1-1. Logan Creek watershed location map.

2.0 Watershed Characteristics

2.1 Land Use/Land Cover

The Logan Creek Watershed contains 65 farms with 49% of the land cover in row cropland, 28% is pastureland, and 23% is forested or brushland. Modeled land cover characteristics were determined from a USDA generalized landcover/landuse data base for 2006 (see Figure 2-1). As shown in Figure 2-1, most of the watershed is agricultural cropland with various row crop and alfalfa rotations. There are a number of small ponds spread throughout the watershed, but there are little or no natural wetland areas. Since runoff from impervious and road surfaces drain across pervious areas before reaching surface waters, these areas were represented in the watershed modeling based on the adjacent land use/land cover. There are no urban areas, and no point sources in the Logan Creek subwatershed.

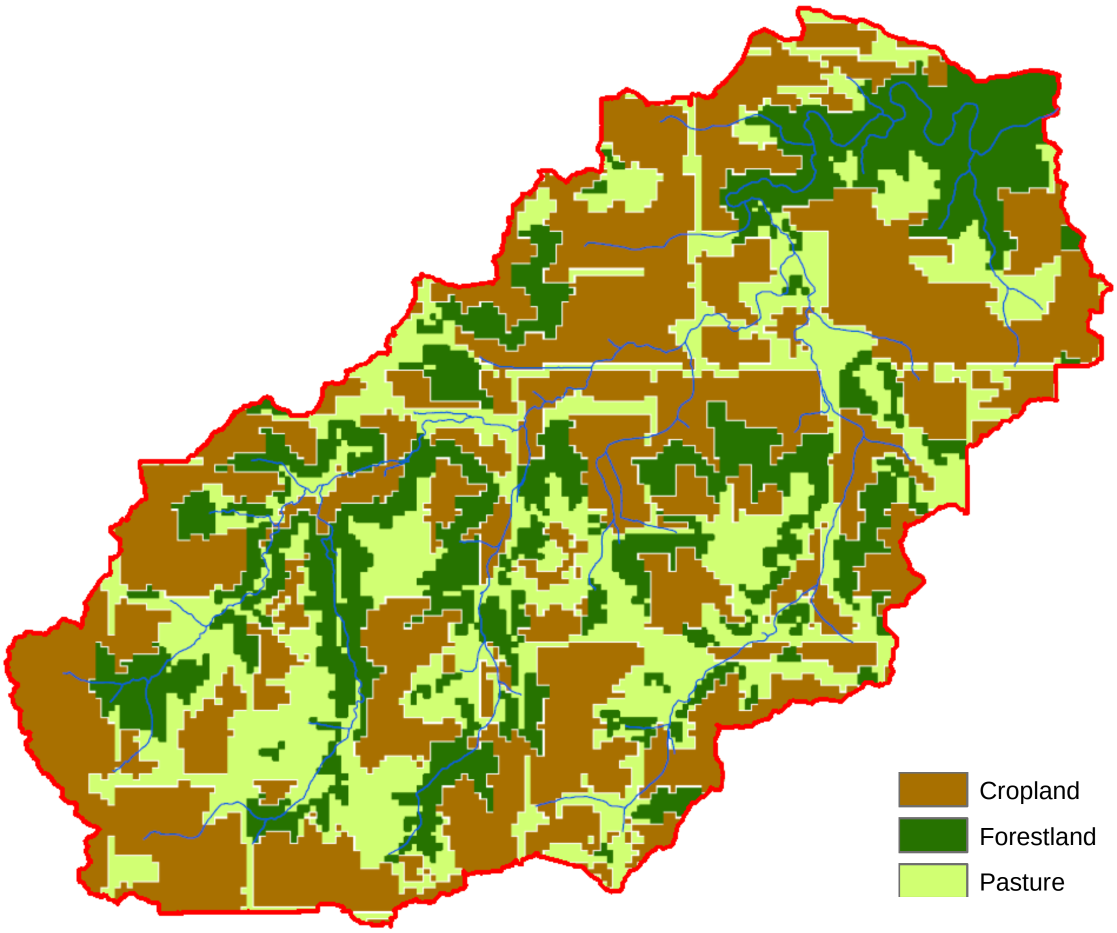


Figure 2-1. Logan Creek watershed generalized land cover.

2.2 Topography

The watershed was delineated using the available 3-meter digital eleveation model (DEM) LiDAR data, which were the southeast Minnesota "flood" LiDAR data (MDNR, 2008) cropped to the boundaries of the Logan Creek watershed. Watershed slopes were calculated using the LiDAR data. The topographic data shows that approximately 12% of watershed has slopes exceeding 6 percent. Earlier work in support of the Logan Creek Subwatershed

Project (MPCA, 2005) indicated that 34% of the cultivated land fell into this critical slope category. The same analysis with the LiDAR data indicated that less than 1% of the agricultural land had slopes exceeding 6 percent following overlays with the land use data described in Section 2.1. Figure 2-2 depicts the shaded relief or hillslopes in the aerial photo of the watershed. It is evident that agricultural cropland has flatter slopes while in the wooded areas the slopes increase very sharply, along with slopes of more than 20% in some of the headwater riparian areas.

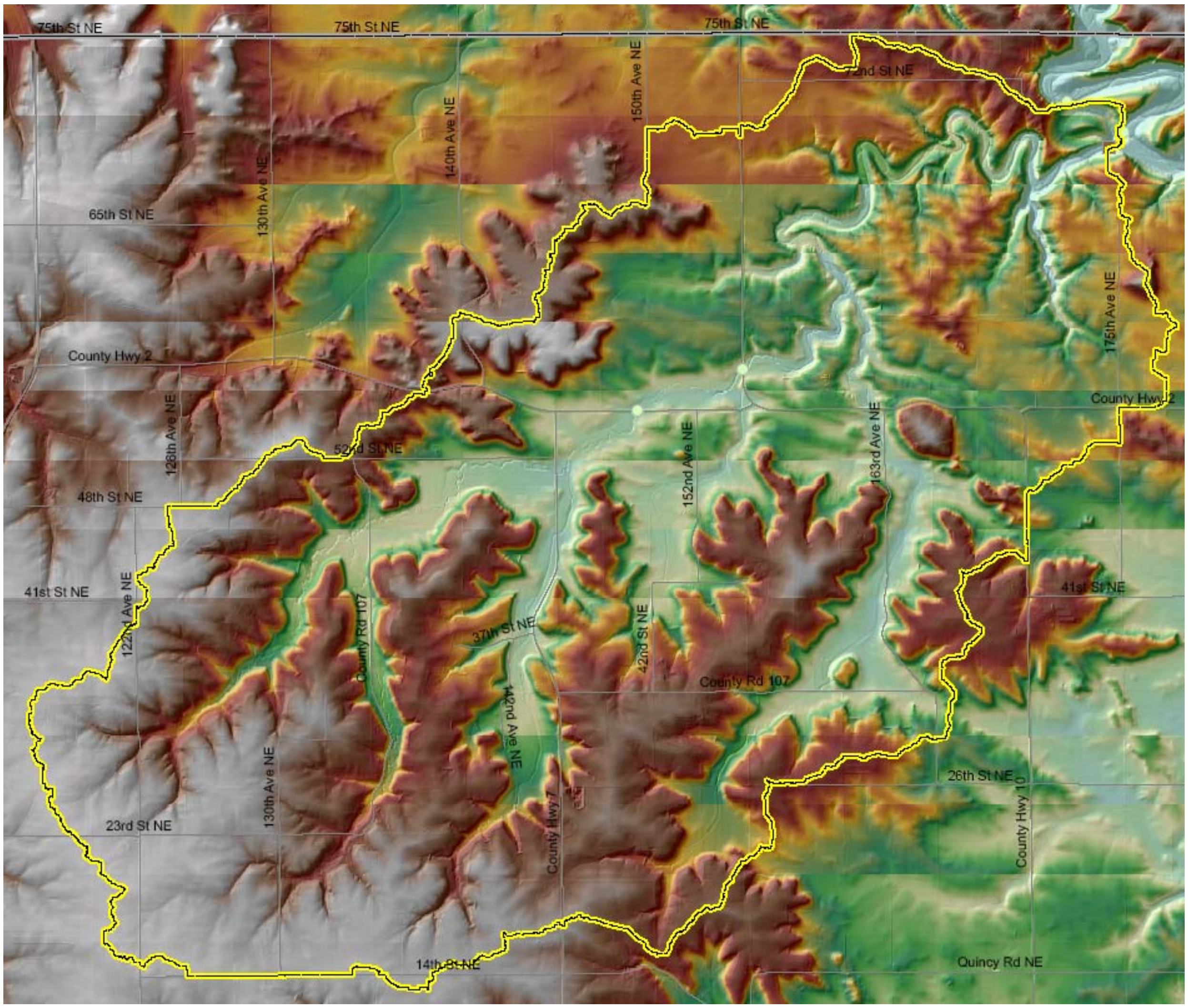


Figure 2-2. Logan Creek watershed topography.

2.3 Soils

The general soil type in the Logan Creek subwatershed and vicinity is the Mt. Carroll-Otter-Joy Association. This association is described as "nearly level to moderately steep, well drained, very poorly drained, and somewhat poorly drained silty soils on uplands and in upland drainage ways" (USDA, 1980). The Mt. Carroll soils are on the summits and side slopes, and are well drained. They are soils formed in deep loess with slopes ranging from 2-25%. The Otter soils consist of deep, very poorly drained soils in upland drainageways. Slopes range from 0-2%. The Joy series consist of deep, somewhat poorly drained soils that are moderately permeable, on slopes ranging from 1-4%.

A soil map was derived from STATSGO, a 1:250,000 scale NRCS soil database (Figure 2-3). Soil characteristics associated with STATSGO soil map units such as depth of each horizon, particle size distribution, organic matter content, and vertical hydraulic conductivity were provided by a SWAT model database. The SSURGO soil database, consistent with the Olmsted County soil survey, was considered for use in the SWAT modeling in place of the STATSGO soils database. It was determined that most (95-99%) of the watershed consisted of hydrologic soil group "B" soils (USDA, 1980), and that the use of SSURGO data would add approximately five to ten times more model complexity without significantly changing the soil characteristics.

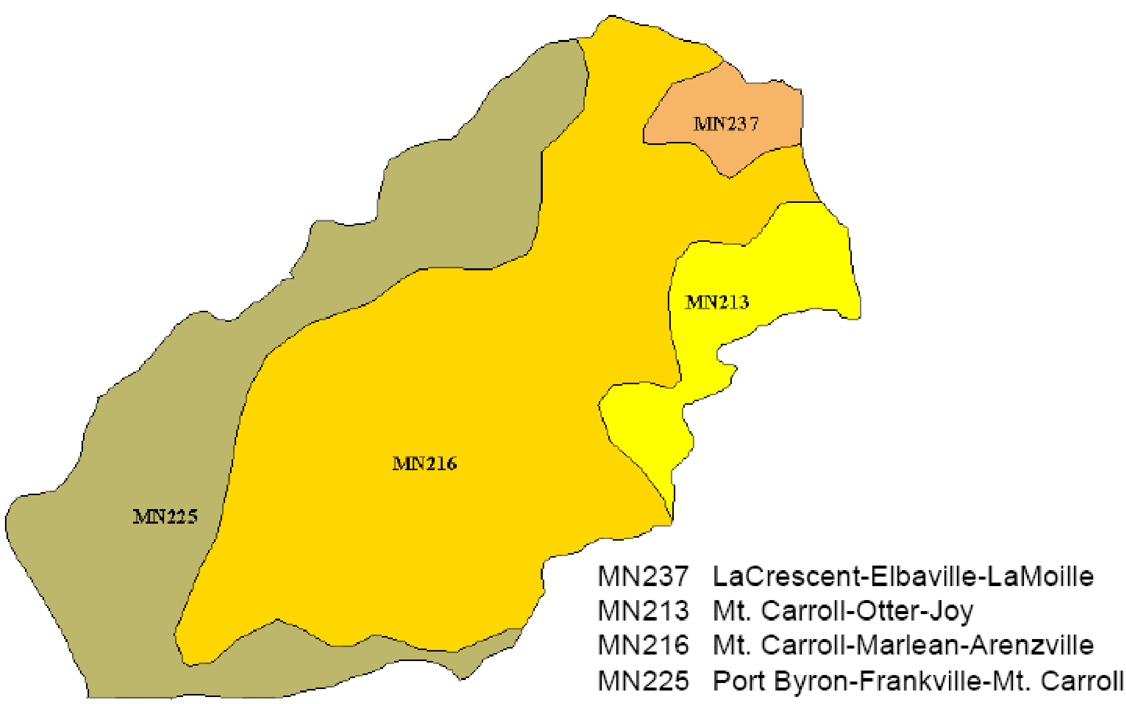


Figure 2-3. Logan Creek watershed STATSGO soils map.

2.4 Hydrology and Current Water Quality

Since April 2000, the watershed has been monitored for flow and sediment-related parameters by the MPCA. Between mid-summer 2001 and early November 2004, MPCA staff operated continuous monitoring equipment at the upper watershed monitoring station in the middle of the watershed (shown in Figure 2-4). The continuous monitoring parameters included stage, turbidity, pH, dissolved oxygen, and conductivity. Flow measurements were made to develop a relationship between stage and flow. From March through November of 2004, MPCA conducted grab sampling, and analysis for sediment-related constituents, at the upper watershed continuous site as well as at the lower monitoring station at the mouth of Logan Creek. At the upper watershed site, WSU also collected and had the grab samples analyzed for sediment-related constituents in 2000, 2001 and 2002. A station report from the MDNR/MPCA (2004) cooperative stream gaging program is available for the upper Logan Creek site (station ID 40037001).

The MPCA is currently listing streams as impaired for turbidity when 10 percent or more the measurements exceed the 25 NTU turbidity standard. Using the continuous turbidity and flow monitoring data from the Logan Creek site collected between 2001 and 2004, MPCA (2004) determined that the 90th percentile turbidity value was 56 NTUs, which suggests that an overall turbidity reduction of 55% would be required to meet the 25 NTU standard. This reduction percentage was used as the goal for this project to set the sediment load target for each of the management scenarios discussed in Section 4.

2.5 Farming Systems and Practices

Three crop rotations were applied to the cropland area determined from the USDA (2006) landcover database and modeled such that the following certified crop acreage percentages for 2004 would be grown for all of the simulated years, after combining the corn-grain and sweet corn into one corn crop and allowing the combination of the remaining miscellaneous crops (11.9% of the total cropland area) to be lumped into the three main crops for the purposes of defining the hydrologic response units in the watershed:

- Corn 52%
- Soybeans 34%
- Alfalfa 14%

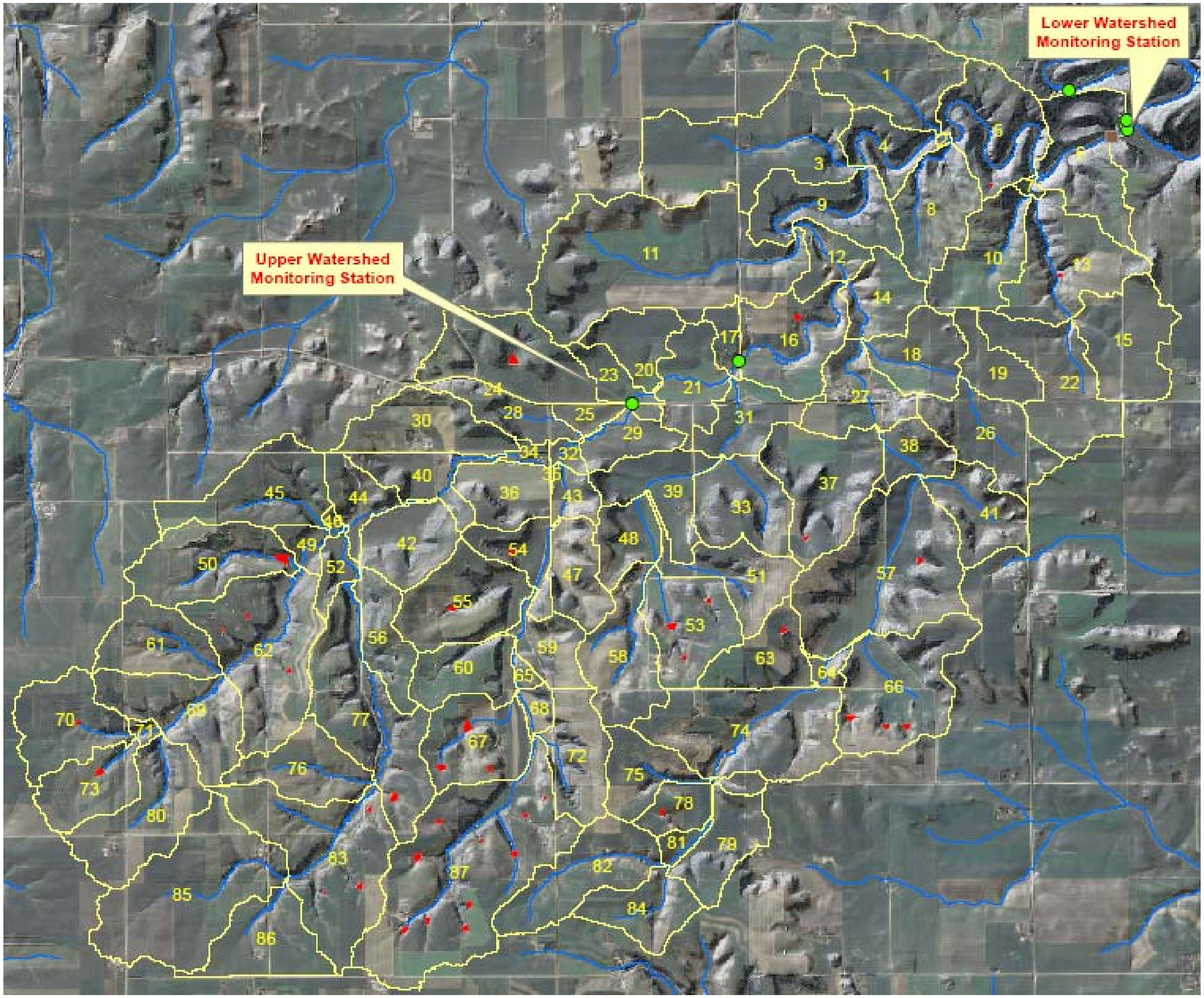


Figure 2-4. Logan Creek watershed monitoring stations (shown in green) and existing detention basins (in red).

The following crop rotations used in the model to ensure that the aforementioned crop acreage percentages, and the appropriate level of conservation tillage, would occur throughout the watershed area over the 10-year simulation period:

- C-SB and SB-C 34% each
- C-C-C-A-A-A and A-A-A- C-C-C 14% each
- Continuous corn 4%

The 2007 Minnesota Tillage Transect Survey data available for the Logan Creek watershed represented approximately 43 percent of the cropland and indicated that conservation tillage (mulch, ridge, no-till) has been practiced for approximately half of the corn and soybean acreage, based on the individual fields contained in the 2002 Olmsted crop coverage. Aerial photography (FSA, 2008) was used to identify existing ponds and terraces/strip cropping. Pond surface areas (see Figure 2-4) and the fraction of the subbasin draining to the pond were determined in GIS for each of the respective subbasins delineated in SWAT. Approximately ten percent of the watershed area receives treatment from the existing ponds. An average permanent pool water depth of 18 inches was assumed for each pond. The SWAT model slope-length factor was reduced by 50 percent for all of the cropped areas in the subbasins with existing terraces.

Information on planting, tillage and harvesting dates for 2002 were collected for Logan Creek watershed through a comprehensive farmers' survey (as discussed in MPCA, 2005). Also, data were collected on timing, method of application, and type of fertilizer or manure through a landowners-operators survey within the watershed.

As a result of modeling load reduction alternatives, a cover crop was modeled in place of an earlier model run involving conservation tillage, but did not result in a relative improvement in the sediment loadings for the watershed. As a result, BMP scenario #7 (see Section 4.5.3) relied only on conservation tillage, and did not include a cover crop in the simulated BMP combination. In practice, it is expected that the use of a cover crop could take the place of conservation tillage and result in similar sediment loading reductions.

3.0 Model Selection, Development and Performance

SWAT (Soil and Water Assessment Tool; Arnold et al., 1993) is a basin-scale continuous distributed water quality simulation model capable of predicting long-term effects of alternative land management practices. Major components of the model include hydrology, erosion, nutrients, pesticides, crop growth, and agricultural management. Hydrologic processes include surface runoff, tile drainage, snow-melt runoff, infiltration, lateral flow and plant uptake. The SWAT model classifies precipitation as snow when the average air temperature is less than the snowfall temperature and melts it when the maximum temperature exceeds the snowmelt temperature. Melted snow is treated as rainfall for estimating surface runoff and percolation. Daily average soil temperature is simulated at the soil surface and the center of each soil layer. Soil temperature at the surface is calculated as a function of maximum and minimum air temperature, snow cover, plant cover and residue cover for the day being simulated and the preceding four days. The temperature of the soil layers are calculated as a function of soil surface temperature, mean air temperature and the depth of the soil at which variations in the climatic conditions will not affect the soil temperature. The weather input for SWAT consists of daily values of daily precipitation, and maximum/minimum air temperature. The model has the option of generating the air temperature data if they are not available. Solar radiation, wind speed and relative humidity are also generated by the model. The model allows for consideration of reservoirs and ponds/wetlands, as well as inputs from point sources.

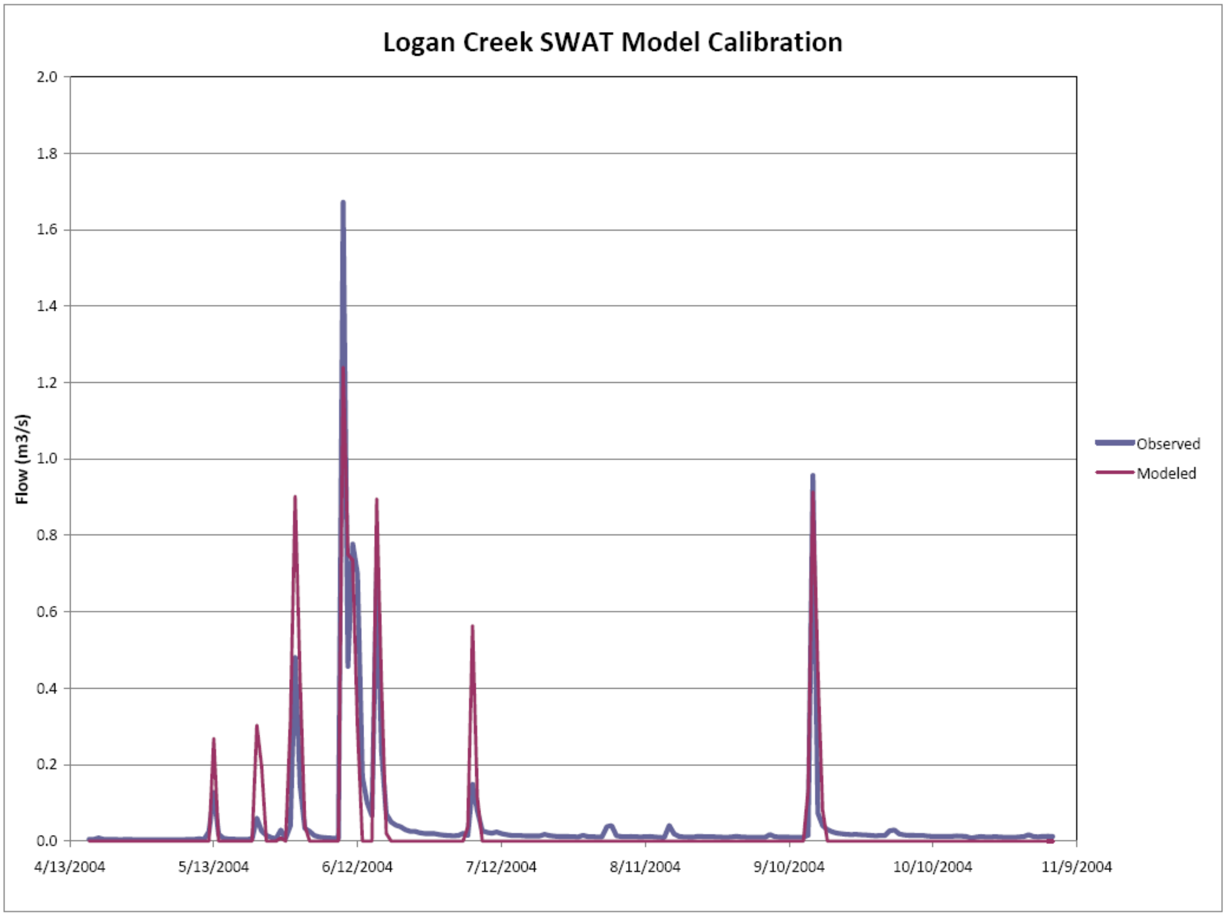
Input for the SWAT model was derived at two different scales: the subwatershed and the hydrologic response unit (HRU). HRUs are developed by overlaying soil type, slope and land cover. It is noted that HRUs in the current version (2.5) of SWAT are not defined by a flow direction and the spatial location within each subbasin does not influence sediment loading to the stream. In addition to the crop rotations described in Section 2.5, SWAT was also used to model the pasture and woodland land cover HRUs in each subwatershed. A total of 700 HRUs were set up in the SWAT model for the 87 subbasins covering the Logan Creek watershed (shown in Figure 2-4). SWAT varies the runoff curve numbers seasonally during the simulations, but the baseline (full canopy) runoff curve numbers used for forest, pasture, row crops, alfalfa, oats, conservation tillage, and biofuel crops were 60, 73, 83, 63, 73, 70 and 59, respectively.

Climatic data such as daily values of precipitation (for missing values at the monitoring station) and mean temperature required for simulation were derived from a nearby weather station (Elgin, NWS#212486). Other climatic data such as average relative humidity and wind speed was generated as part of the model simulation.

The available data on implementation of existing BMPs for the rural landscapes were compiled (as described in Section 2.5), along with the stream physical data collected via stream valley cross sections completed (most recently) by the Minnesota Department of Natural Resources (DNR), and by the USDA in 1964 and 1993. The SWAT model simulates the total sediment load, i.e. the amount of sand, clay and silt particles detached, eroded and transported to the outlet of the watershed. Since the continuous turbidity data (described in Section 2.4) is going to be a measure of suspended sediment (both organic and inorganic) under most flow conditions, it would not include the bedload transported in the bottom of the stream channel. As a result, the stream cross-section, slope and channel material data collected by the DNR near the upper watershed monitoring station was used, along with the flow duration data from the continuous monitoring, in the surface-based bedload equation of Wilcock and Crowe (2003) to estimate the bedload during the monitored time periods. The estimated bedload and suspended sediment loads were combined for the calibration and validation time periods to enable comparisons with the SWAT modeling results. The SWAT model was calibrated using measured water quantity and quality data from most of 2004 (50.79 inches precipitation between 2/27/04 and 11/04/04) and validated with the available monitoring data from 2003 (17.43 inches precipitation between 3/27/03 and 7/21/03), which represented all of the remaining continuous turbidity data consistent with the calibration dataset. The calibration time period from 2004 was selected for model calibration because it was a wetter year and there was more water quality monitoring data during that year. Estimated bedload represented approximately 57 percent of the estimated total sediment load during the model calibration time period.

The estimated bedload contribution is considerably higher than the Whitewater sediment budget report from NRCS (1997), which had a bedload percentage estimate in the range of 5-15%. The USACE (2003) made estimates of bedload in the Upper Mississippi River and major tributaries. While they noted that while a common technique is to use the 5-15% (of total sediment load) estimate, several Wisconsin Rivers (the Chippewa, Black and Wisconsin Rivers) have bedloads at 40-50% of the total load. The Zumbro River at Kellogg is estimated at 36%, and the Root River @ Houston at 15%. These bedload estimates pertain to larger river systems that are not expected to possess the smaller substrate grain sizes and high bed slopes present in the monitored reach of Logan Creek. It was expected that the higher bedload percentage estimate for the Logan Creek calibration could be partially attributed to the fact that several higher flow events occurred during 2004. A review of the literature was conducted to determine how the predicted maximum bedload transport rates compared to other studies and whether the 57% bedload estimate was reasonable for the monitored reach of Logan Creek during the calibration period. The predicted maximum unit-width bedload transport rate for Logan Creek is approximately the same as the maximum measured bedload transport rates published by Emmett (1980) and Lisle (1986) for streams with similar channel gradients. Semmelmann et al. (1988) reported several cases where the relative bedload importance was more than 50% of total suspended sediment, including one case where bedload exceeded the total suspended sediment load. They reported that a considerable degree of relative bedload importance was associated with conditions where bed sediment is predominant in the suspended load size distributions and the relative importance of size fractions which are contained in bed material and in suspended load is similar. Pitlick et al. (2009) also indicated that similarity in bedload and substrate grain size distributions suggests a clear link between the load and the source with the bedload and substrate grain sizes exchanging with each other almost on a one-for-one basis. Since the pebble counts for the upper Logan Creek cross-sections indicated that the bed material is almost entirely silt and fine sand, comparable to what is washing off from the watershed, it is realistic to conclude that this portion of the creek would experience a high amount of relative bedload importance.

Although the water quality data were available from 2000-2004, the simulations were made over 10 years to reduce the errors associated with initial conditions. Model calibration was done by comparing predicted daily flows against measured data. After flows were calibrated, sediment loads were calibrated by adjusting parameters that control stream bank erosion and sediment deposition in streams and ditches. The model accuracy was expressed in terms of the Nash-Sutcliffe efficiency (NSE) between measured and predicted values and a graphical comparison of the flow hydrographs at the upper watershed monitoring location. The NSE results are shown in Table 3-1 and Figure 3-1 shows the graphical comparison between the observed and SWAT model predicted flows. NSE values above 0.75 are considered very good and a value of 0.49 would be considered satisfactory for a monthly time step (Moriasi et al., 2007), but since the values shown in Table 3-1 are for a daily time step, any NSE values



above 0.3 are considered to meet the target threshold for flow. Figure 3-1 shows that under low flows, when more stream flow is derived from ground water, the SWAT model diverges from the measured stream flows due to the karst features within the upper watershed.

Table 3-1 Nash-Sutcliffe efficiencies for SWAT Model calibration/validation.

Time Periods	Daily Flow (cubic meters per second)	Daily Total Sediment Load (metric tonnes)
Calibration—2004	0.75	0.82
Validation—2003	0.73	0.49

Figure 3-1. Logan Creek SWAT model flow calibration results.

Figure 3-2 shows the simulated sediment yield from watershed runoff in each subbasin during 2004. The results show that, prior to delivery to the stream channel, the sediment loadings are somewhat lower in the subbasins that have existing detention ponds, possess smaller slope-lengths or consist mostly of forested land use. The subbasins with the highest sediment yields have steeper land with higher proportions of cropland. In general, subbasin sediment yield is fairly uniform throughout the watershed with most of the loading rates in the range of 0.5 to 2.5 MT/hectare.

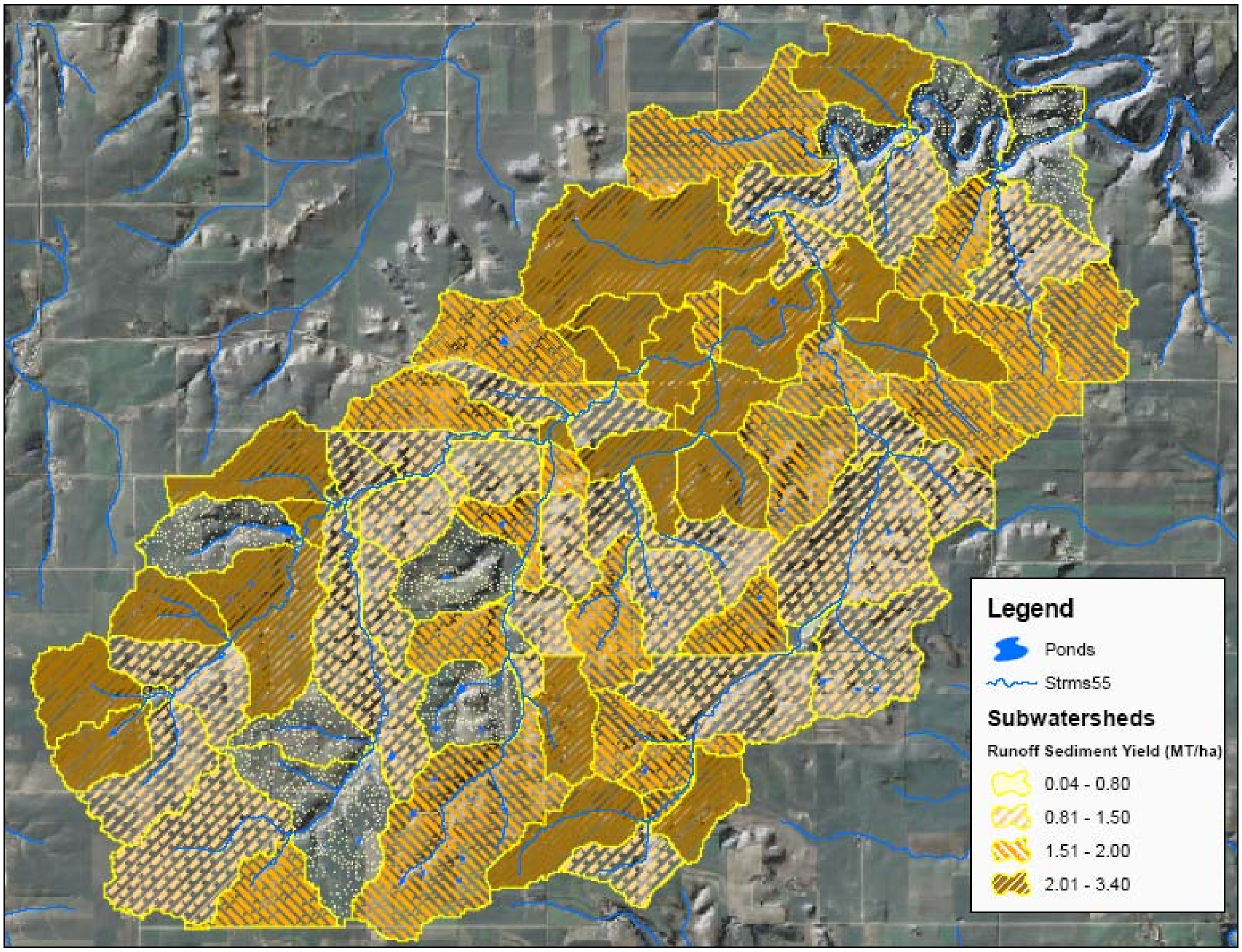


Figure 3-2. Logan Creek SWAT model subbasin runoff sediment yield—2004 simulation.

4.0 Evaluation of Load Reduction Scenarios

The calibrated SWAT model was used to evaluate changes to watershed land cover or crop rotations, crop management, distributed detention, and implementation of streambank stabilization with rotational grazing/exclusion of animals. The peak flow and average annual volumes and sediment loads for each implementation modeling scenario were summarized and compared to the 55 percent sediment load reduction goal for meeting the water quality standard for turbidity, based on the modeling results from 2001-2004.

The modeling results and analysis in this section includes a critical evaluation of the load reduction scenarios, including effects on hydrology, pollutant reduction effectiveness of practices, economic effectiveness and anticipated landowner acceptance of the various practices and other implementation challenges. All of the public (EQIP program payments) and landowner costs were estimated for each practice in each load reduction scenario using the 2009 Minnesota EQIP Conservation Practice Payment Schedule (NRCS, 2009). Since the individual practices prescribed for each load reduction scenario have varying lifetimes, payment limits, restrictions and operation and maintenance requirements, both the public and landowner costs were estimated using a present value analysis (in 2009 dollars). Landowner costs include forgone income (where applicable) and all of the cost estimates are based on a 20 year term with a 5% interest rate. For this analysis, landowner costs did not include the acquisition of technical knowledge category, as itemized in EQIP.

4.1 Stream Stabilization

A watershed tour and examination of the stream reaches indicated several riparian sites, primarily within pastureland, where poor vegetation growth exacerbated by livestock and shading was contributing to streambank erosion. This load reduction scenario involves the implementation of practices intended to control access to, and stabilize, streambanks in pastured portions of the perennial stream reaches and control access to the remaining pastured streambanks in the watershed. These assumptions translate to 5.1 miles of stream reaches that need access control and stabilization and another 11.7 miles that would just need access control. The costs for this scenario were estimated based on the EQIP rates and estimated quantities for the following practices:

- Access control (NRCS Standard #472)—154 acres
- Stream crossing (NRCS Standard #578)—1,500 linear feet
- Streambank and shoreline protection (NRCS Standard #580)—533,000 square feet
- Fence (NRCS Standard #382)—124,000 feet
- Watering facility (NRCS Standard #614)—15 sites

The SWAT model predicts an average annual sediment load reduction of 253 metric tons, or 20%, which is more than a third of the 705 metric ton (55%) goal for the watershed. Based on all of the modeling results, it is expected that the load reduction goal cannot be met without stabilizing most of the streambanks in this watershed, especially along the perennial stream reaches.

The total capital cost for the public and landowners is $823,000 and $574,000, respectively. More than two thirds of the respective public and landowner costs are associated with the estimated capital costs for bioengineering along the stream reaches requiring streambank protection. Approximately one third of the cost to the landowners is associated with operation and maintenance. The assumptions for this scenario are conservative and it is possible that a detailed assessment of the stream reaches in the watershed would indicate that access control or removal of shade, alone, would enable streambanks to re-establish the vegetation that would be necessary for proper stabilization in several locations.

4.2 Distributed Detention

The second scenario involves the implementation of distributed detention with infiltration of cropland runoff in a portion of each one of the 87 subbasins in the watershed. It was assumed that one cropland HRU in each subbasin would undergo treatment as a pothole device for the purposes of determining the water quality benefits. The SWAT model predicts an average annual sediment load reduction of 105 metric tons, or 8%, which is considerably lower than the 705 metric ton (55%) goal for the watershed. The estimated runoff volume reduction for the watershed was 7 percent for this scenario. The watershed area receiving treatment in this scenario represented 12 percent of the overall watershed area or 24 percent of the total cropped areas.

As discussed in Section 2.5 and shown in Figure 2-4, nine of the subbasins already had varying levels of water quality treatment occurring under existing/calibrated conditions. The current functioning of the existing ponds was assumed to be at optimum levels, but could not be verified for this study. Greater implementation of distributed detention than what was modeled for this scenario may be feasible and practical, but it is recommended that the functioning of the existing detention practices and outlet protection be evaluated along with stream stabilization to prioritize those portions of the watershed that would benefit from additional detention.

The costs for this scenario were estimated based on the EQIP rates for water and sediment control basin (NRCS Standard #638) and broad base terrace (NRCS Standard #600). The total capital cost for the public and landowners is $223,000 and $304,000, respectively. Approximately 75 percent of the cost for the landowners with this scenario is in the form of operation and maintenance. The practice lifetimes for the basin and terrace are 15 and 10 years, respectively. It should be noted that the SWAT model results are predicated on the BMPs consistently infiltrating runoff and functioning as they would at the beginning of their respective design lives, year-over-year. Also, the costs do not include any cost for lost production, nor is it expected that these BMPs can feasibly be implemented in a way that captures enough cropland runoff from most of the watershed, which is what would likely be required to meet the load reduction goal.

4.3 Conservation Tillage

The third scenario involves the implementation of conservation tillage for the existing corn and soybeans in the watershed that are not currently grown with adequate residue. It was assumed that all corn and soybean crop lands in the modeled subbasins would be have conservation tillage for the purposes of determining the water quality benefits. The SWAT model predicts an average annual sediment load reduction of 113 metric tons, or 9%, which is considerably lower than the 705 metric ton (55%) goal for the watershed. The estimated runoff volume reduction for the watershed was 10 percent for this scenario.

The costs for this scenario were estimated based on the EQIP rates for conservation tillage (NRCS Standard #329) with three annual payments. The total capital cost for the public and landowners is $156,000 and $997,000, respectively. Most of the cost for the landowners ($945,000) with this scenario is in the form of forgone income, which would apply between the third and twentieth years for determining the present value costs. Forgone income for this scenario is based on a 5% reduction in yield (as cited in NRCS, 2009). It should be noted that the forgone income of $945,000 applies to 2,384 acres over 20 years, which equates to a present value of $19.82 per acre per year. This cost may represent an approximate amount that would be needed as an incentive to overcome the perception of lost yield.

4.4 Perennial Biofuel Crop Replacing Corn and Soybeans

The fourth scenario involves replacement of the existing corn and soybeans grown in the watershed with the planting of a biofuel crop in these cropland areas. It was assumed that the corn/soybean crop lands in the modeled subbasins would be replaced by switchgrass for the purposes of determining the water quality benefits. The SWAT model predicts an average annual sediment load reduction of 295 metric tons, or 23%, which is slightly less than half of the 705 metric ton (55%) goal for the watershed. The estimated runoff volume reduction for the watershed was 17 percent for this scenario.

The costs for this scenario were estimated based on the EQIP rates for conservation crop rotation (NRCS Standard #328). The total capital cost for the public and landowners is $188,000 and $3,319,000, respectively. Most of the cost for the landowners ($3,130,000) with this scenario is in the form of forgone income. Forgone income for this scenario may be more than what is shown here (and cited in NRCS, 2009), unless a market can be established for switchgrass that is comparable to hay. A biomass facility in relatively close proximity to the watershed may improve the market for switchgrass relative to hay, but it may not overcome the market price differences with corn and soybeans without some added incentive. It should be noted that the forgone income of $3,130,000 applies to 4,768 acres over 20 years, which equates to a present value of $32.83 per acre per year.

4.5 Combination of Options

Several BMP combinations were evaluated to determine the most feasible and cost-effective scenario to reduce the sediment load at the outlet of the watershed. After reviewing the above scenarios, three of the most effective BMP combination scenarios were further evaluated and discussed below.

4.5.1 Perennial Biofuel Crop Replacing All Row Crops and Stream Stabilization

This load reduction scenario (Scenario #5) represents implementation of a combination of the BMPs in Scenarios #1 and #4. The SWAT model predicts an average annual sediment load reduction of 766 metric tons, or 60%, which exceeds the 705 metric ton (55%) goal for the watershed. The total capital cost for the public and landowners is $1,012,000 and $3,892,000, respectively. As with Scenario #4, most of the cost for the landowners ($3,130,000) with this scenario is in the form of forgone income.

4.5.2 Biofuel Crop, Corn (Cons.Tillage)-Alfalfa Rotation with Stabilization

This load reduction scenario (Scenario #6) represents implementation of a combination of the BMPs that is the same as Scenarios #5, but with 776 acres of the existing cropland in a corn (with conservation tillage) and alfalfa rotation. The SWAT model predicts an average annual sediment load reduction of 671 metric tons, or 52%, which is just shy of the 705 metric ton (55%) goal for the watershed. The total capital cost for the public and landowners is $1,032,000 and $3,677,000, respectively. As with Scenarios #4 and #5, most of the cost for the landowners ($2,945,000) with this scenario is in the form of forgone income. Comparing this scenario to Scenario #5 indicates that conservation tillage is not providing water quality benefits that are comparable to what can occur with more of the perennial biofuel crop planted.

4.5.3 Biofuel Crop, Corn-Oats(Cons.Tillage)-Alfalfa Rotation with Stabilization

This load reduction scenario (Scenario #7) represents implementation of a combination of the BMPs that are similar to Scenario #6, but with a quarter of all existing cropland in corn, a quarter of all existing cropland in oats (both corn and oats with conservation tillage), a quarter in switchgrass and the remainder in alfalfa during any one growing season. The SWAT model predicts an average annual sediment load reduction of 538 metric tons, or 42%, which is slightly lower than the 705 metric ton (55%) goal for the watershed. The total capital cost for the public and landowners is $1,087,000 and $3,465,000, respectively. As with Scenarios #4 through #6, most of the cost for the landowners ($2,731,000) with this scenario is in the form of forgone income. Comparing this scenario to Scenarios #5 and #6 indicates that conservation tillage is not providing water quality benefits that are comparable to what can occur with more of the perennial biofuel crop planted.

5.0 Conclusions

Logan Creek is a flashy stream system with high turbidity corresponding with high flow rates and stream degradation. A significant number of conservation practices have already been implemented in the watershed, but the water quality modeling indicates that further improvements can be derived from **both** improved hydrology and streambank stabilization.

Table 5-1 provides a summary of the estimated costs and benefits associated with implementation of each of the load reduction scenarios discussed in Section 4. The results show Scenarios #5 and #6 are the only combinations of implementation practices that would meet or nearly meet the load reduction goal of 55 percent. However, both BMP scenarios also include the highest landowner practice costs and forgone income. As a result, unless a market can be established for switchgrass that is better than hay or is more comparable to corn and soybeans, the combination of BMPs in Scenario #7 likely represents the most feasible and cost-effective approach for improving water quality in the watershed under the current economic conditions.

Table 5-1 Summary of estimated costs and benefits for management scenarios.

BMP Scenario #	BMP Scenario Description	Sediment Reduction Percentage	Present Value Cost ($)		Cost-Benefit ($/MT/yr)		
			Public	Landowner	Public	Landowner	Total
1	Stream stabilization	20%	$823,000	$574,000	$3,254	$2,270	$5,524
2	Distributed detention	8%	$223,000	$304,000	$2,131	$2,903	$5,033
3	Conservation tillage	9%	$156,000	$997,000	$1,380	$8,824	$10,204
4	Perennial biofuel crop replacing all corn/soybeans	23%	$188,000	$3,319,000	$640	$11,269	$11,909
5	Perennial biofuel crop replacing all corn/soybeans w/ stream stabilization	60%	$1,012,000	$3,893,000	$1,320	$5,081	$6,401
6	Perennial biofuel crop, corn-alfalfa-CT rotation w/ stream stabilization	52%	$1,032,000	$3,677,000	$1,537	$5,478	$7,016
7	¼ perennial biofuel crop; ½ corn-alfalfa rotation and ¼ small grains with CT; stream stabilization	42%	$1,087,000	$3,465,000	$2,021	$6,441	$8,462

It is recommended that the WJPB and project partners conduct field-scale and stream corridor assessments to further prioritize implementation of the proposed practices. It is also recommended that the project partners continue watershed monitoring and updating the available data, including:

- Water quality/quantity, precipitation and stream corridor assessments, etc.
- Document characteristics of BMPs and other improvements

- Document BMP maintenance and costs
- Update modeling (in the future) as practices are implemented and more data becomes available

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