

Management Option Simulation Model

User Manual

By

Collaborative for Sediment Source Reduction

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User Manual

This user manual instructs on the use and interpretation of the management option simulation model (MOSM) to evaluate watershed management scenarios. The model includes a *quick start guide* (see **Readme** tab of MOSM) that provides basic instructions on specifying management scenarios, executing simulations, and reading the model outputs. This user manual provides additional descriptions of the computational modules and more in-depth guidance on specifying user inputs: specification of management options' costs and effectiveness, selection criteria, and management design dimensions. This manual also instructs on saving management scenarios and archiving control input/output tables.

Table of Contents

1. Overview	3
2. User inputs.....	6
2.1. Control Inputs	7
3. Executing the model	10
3.1. Resetting the control input table.....	10
4. Interpreting the MOSM outputs	10
4.1. Reference scenarios and chart.....	10
4.2. Saving management scenarios	11
4.3. Model outputs.....	12
4.4. Saving the entire MOSM control inputs and outputs	14
Appendix A: I/O Detail input.....	15
Appendix B: MOSM's computational modules and spatial scales	20
Appendix C: Input databases	21

1. Overview

Management Option Simulation Model (MOSM) is designed to evaluate the effectiveness of different suites of management options in reducing sediment in the Le Sueur (MOSM-LSRB) and the Greater Blue Earth (MOSM-GBERB) (Figures 1 and 2). Management option allocation can be specified within different geomorphic zones of individual watersheds and the model runs to estimate the cost and effectiveness at reducing fine sediment loading. This section contains a broad description of the model's structure and provides a general instruction on running the model. More details of management settings and allocation criteria can be found in Appendix A.

MOSM consists of three computational modules: (1) Management Option (MO) allocation, (2) water routing, and (3) sediment loading (Figure 3). See Appendix B for brief descriptions of the computational modules, and refer to the *MOSM Computational Module Handbook* for full descriptions of these modules. A list of management options and their descriptions can be found in Table 1. Appendix C describes MOSM's input database, including MO database, water yield data, and sediment delivery data, used by the model's computational modules. MOSM operates in *Microsoft Excel* with the computational modules written in *Visual Basics Application*. The interface of the model consists of multiple spreadsheet tabs as described in Table 2.

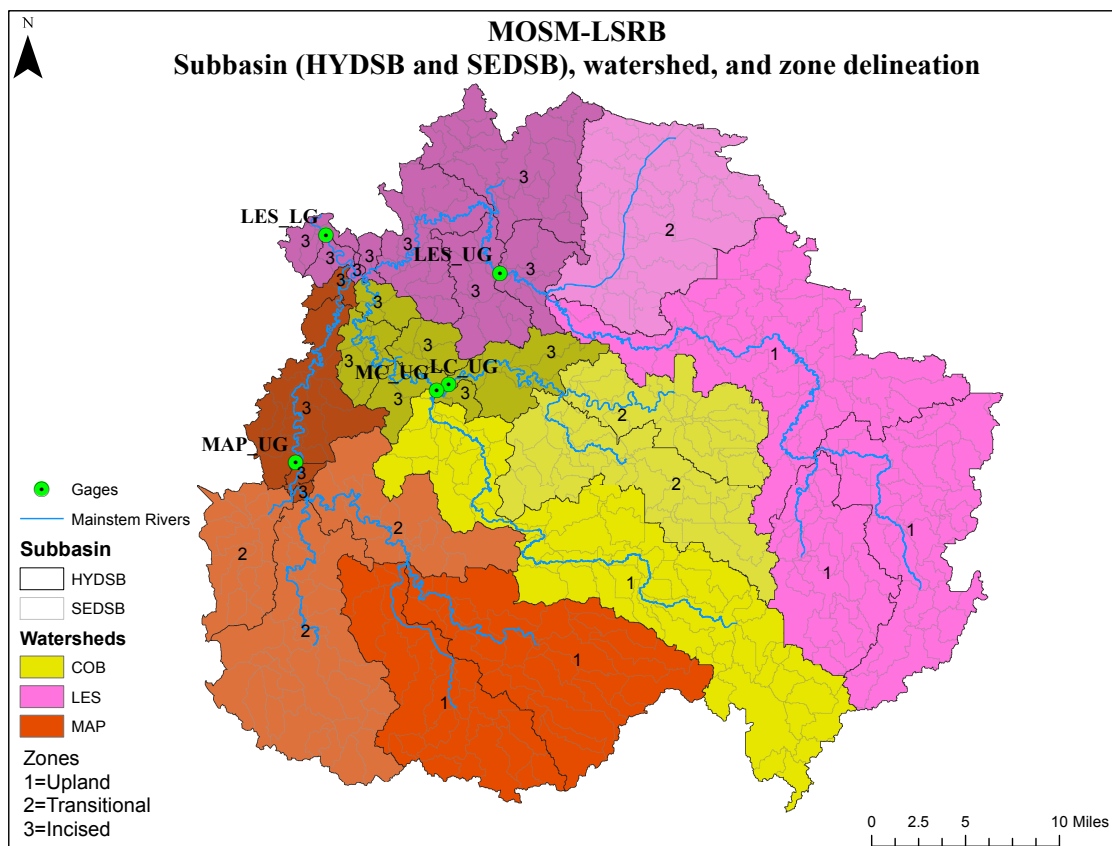


Figure 1: The Le Sueur River Basin (LSRB) consists of three subwatersheds (Le Sueur, Cobb, and Maple), in which three geomorphic zones (1=upland, 2=transitional, and 3=incised) are defined. MOSM-LSRB simulates sediment loading at five gage locations, three above the knick points (Maple near Sterling Center (MAP_UG), Little Cobb (LC_UG), and Le Sueur at St. Clair (LES_UG)) and one below the incised zone (Le Sueur below the confluence with the Maple and Cobb Rivers (LES_LG)). Main Cobb at the confluence with Little Cobb (MC_UG) is a virtual gage where its sediment loading is interpolated using the Maple and Little Cobb data.

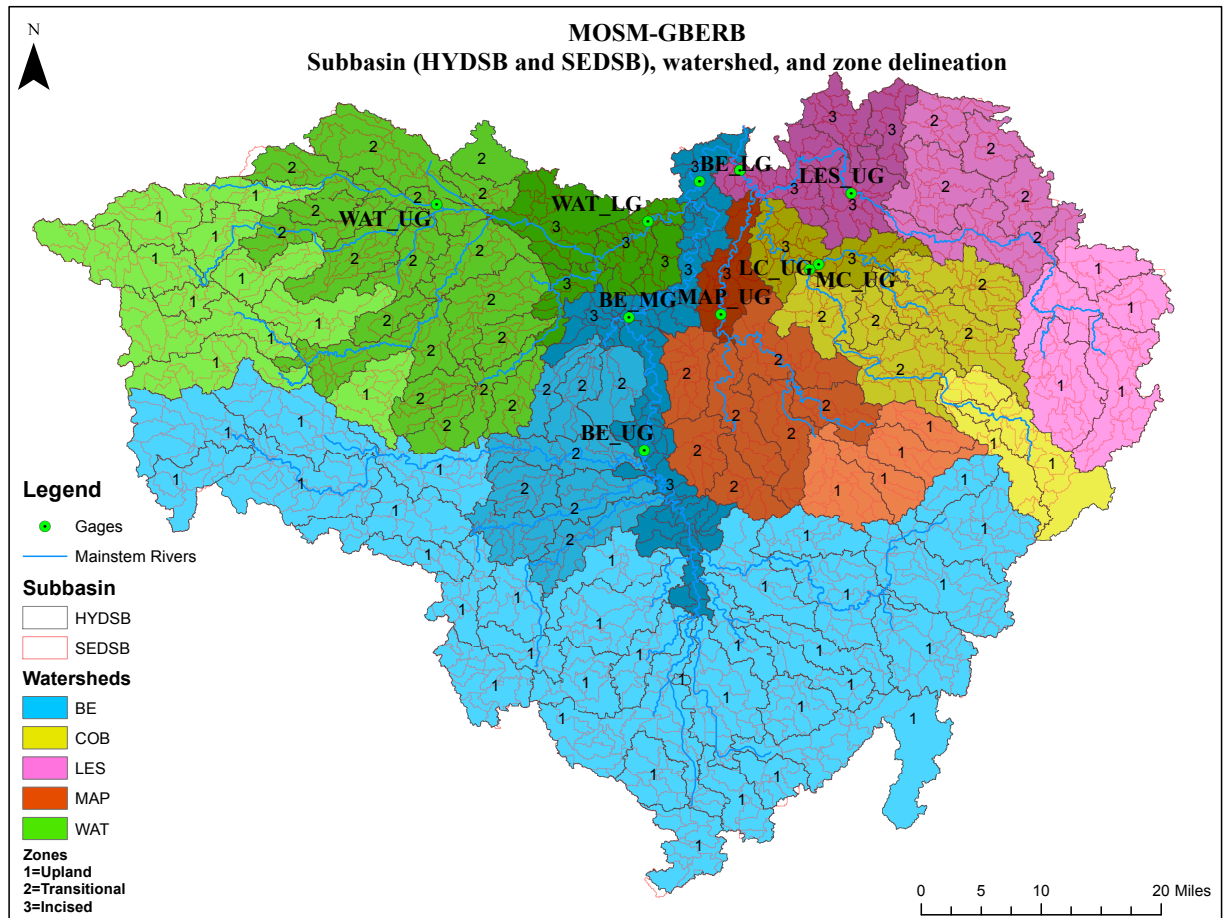


Figure 2: The Greater Blue Earth River Basin consists of five subwatersheds (Le Sueur, Cobb, Maple, Blue Earth, and Watonwan), in which three geomorphic zones (1=upland, 2=transitional, and 3=incised) are defined. MOSM-GBERB simulates sediment loading at eight gage locations, five above the knick points (Watonwan near La Salle (WAT_UG), Blue Earth near Winnebago and Elm Creek (BE_UG), Maple near Sterling Center (MAP_UG), Little Cobb (LC_UG), and Le Sueur at St. Clair (LES_UG)) and three below the incised zone (Watonwan near Garden city (WAT_LG); Blue Earth near Rapidan below the confluence with the Watonwan River (BE_LG); and Le Sueur below the confluence with the Maple and Cobb Rivers (LES_LG)). Virtual gages include the Main Cobb at the confluence with Little Cobb where its sediment loading is interpolated using the Maple and Little Cobb data (MC_UG), and Winnebago to Knick point along the Blue Earth River, for which its sediment loading is extracted from the Integrated Sediment Budget (BE_MG).

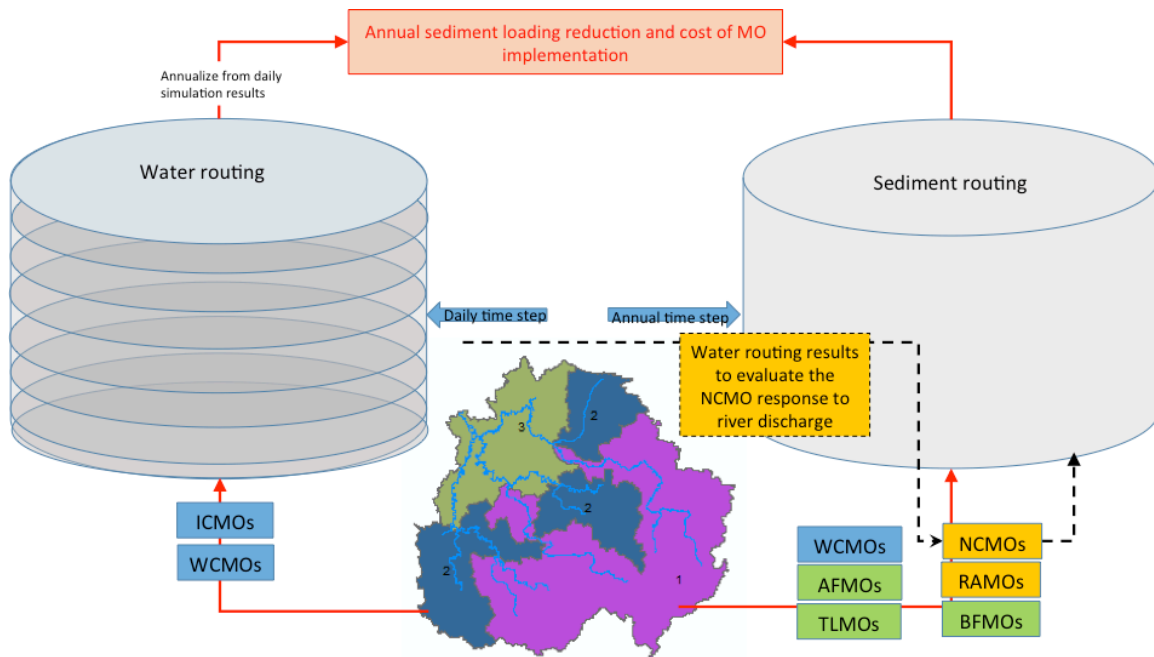


Figure 3: The overall MOSM structure consists of management option allocation, and water and sediment routing modules to simulate the annual sediment loading at the mouth of watershed

Table 1: Each management option type addresses a particular sediment source (field, ravines, or bluffs), and can include multiple specific management practices

MO Types	Description	Location of implementation	Example management practices
Tillage MO (TLMO)	Crop production and tillage management	Field	Conservation tillage, reduced tillage, conventional tillage
Agricultural Field MO (AFMO)	Field erosion management	Field	Grassed water ways
Water Conservation MO (WCMO)	Field water storage to attenuate peak river discharge	Field	Water Retention ponds, wetland restoration
In-channel Water Conservation MO (ICMO)	In-channel water storage to attenuate peak river discharge	Channel	Temporary water storage in channel
Buffer MO (BFMO)	Vegetation planting near channel	Field near channel	Buffer strips
Ravine MO (RAMO)	Ravine tip stabilization to reduce branch growth	Ravines	Ravine tip stabilization
Near Channel MO (NCMO)	Bluff erosion management	Bluffs	Bluff stabilization, toe protection

Table 2: Description of MOSM interface

Contents of MOSM tabs	
Readme:	Provides basic instructions on running the model
MO cost example:	Lists example management options for each MO type with cost and maintenance details
CONTROL:	Management Option input scenarios are entered in this tab. Summary model outputs can be found in this tab (see Section 2.1).
I/O Detail:	Detail input and output information, total MO extent, and the number of sites across the watershed can be found in this tab. The user can specify site selection criteria as well as MO design elements here (see Section 2.2).
Reference Scenario Chart:	Simulated sediment loading reductions and costs of reference and user scenarios are plotted (see Section 4.1).
Reference Scenarios:	The reference scenarios, which are plotted in the Reference Scenario Chart, can be found in this tab (see Section 4.2).
Your Scenarios:	User scenarios are archived in this tab whenever Save your scenarios button is pressed on the CONTROL tab after running the model (see Section 4.2).
Output detail:	Simulated sediment loading is displayed against observed values from five gage locations (see Section 4.3).

General instructions on running the model

Model operation and output recording are accomplished in the MOSM tabs (Table 2). Following is a general instruction on running a deterministic management scenario simulation:

- 1) Go to **CONTROL** tab.
- 2) Specify MO scenarios by entering various extents of managements (Table 1) in different zones of the watershed (Figures 1 and 2)
- 3) Press **RUN MOSM**; when the model completes the simulation, it will alert the user.
- 4) Examine the model outputs on the **Reference Scenario Chart** and **Output Detail** tabs.
- 5) If necessary, save scenario outputs by pressing **Save your scenarios** on **CONTROL** tab.
- 6) If necessary, save the entire scenario input for future reference by pressing **Export all INPUT & OUTPUT**. This will create a new workbook.

Section 2 outlines user inputs to specify MO allocation. Section 3 instructs on how to simulate management scenarios. Section 4 guides in interpretation of the model outputs.

2. User inputs

The model consists of multiple spreadsheet tabs (Table 2). User-inputs are entered in green tabs and model outputs are displayed in yellow tabs. As a rule of thumb, green cells take user inputs and yellow cells display the model outputs.

2.1. Control Inputs

Management option scenario inputs

In the **CONTROL** tab, various management scenarios, consisting of various extents and different combinations of management options (MOs) can be evaluated. Figure 4a shows a part of the control table where the model user can input various extents of MOs in three zones of the watersheds (Figures 1 and 2). The control table also includes descriptions of each MO as cell comments (see the red tabs in Figure 4).

For TLMO, all cropland, determined from landuse/landcover maps, is eligible for implementation, and the inputs are entered as percentage of corn-soybean rotation with conventional tillage practices (T1), continuous corn with conventional tillage practices (T2), and corn-soybean rotation with winter rye cover crop (T3). The USDA National Agricultural Statistics Service (NASS)'s cropland data layer (CDL) from 2006 to 2010 (the model's reference years) indicates that about 80% of the Greater Blue Earth River Basin's cropland consists of corn to soybean rotation, and 20% consists of continuous corn production¹. This is the default setting of TLMO. The sum of the percentage must equal to 100%. For example, the model user can choose to decrease T1 allocation from 80% to 50% of all cropland; while, keeping T2 allocation at 20% and increasing T3 allocation from 0% to 30% (i.e., $50\%+20\%+30\%=100\%$). In this case, the sediment loading would decrease since this scenario will reduce soil erosion rates with an increase in the proportion of cropland in cover crop implementation. If better knowledge about the reference period crop production and tillage practices is available, the default setting of TLMO may be changed for any of the zones of the watersheds (see Appendix A).

For all other management options, input extents are entered in spatial units (e.g., acres or feet length), and the maximum extent of all available sites is listed in the **management option extent input table** (Figure 4a). For example in the MOSM-LSRB, there are 4,676 acres of potential Water Conservation Management Option (WCMO) sites to choose from in the transitional zone (Zone 2 in Figure 1) of the Le Sueur watershed². The maximum management site extents are intended to guide the users in determining appropriate extents of MOs in each zone of the subwatershed based on topographic, landuse/landcover, and soil characteristics of the watershed (see Appendix A of the *MOSM Computational Module Handbook* for further information).

Management option cost calculation

After entering the MO extents for allocation, the model user may enter specific values in the **management cost/effectiveness input table** (Figure 4b). As Table 1 illustrates, each MO type can include multiple specific management practices, and the costs and effectiveness would vary with specific management practices. For example, a complete stabilization of bluffs may reduce soil erosion rate by almost 100%, while bioengineering practices (installation of wooden revetment or root wads) may not achieve 100% soil erosion reduction but it will have other ecological benefits not quantified in MOSM. Further examples of

¹ United States Department of Agriculture, 2009. CropScape - NASS CDL Program [WWW Document]. URL <https://nassgeodata.gmu.edu/CropScape/> (last accessed 7.3.17).

² The extents of available sites for MOSM-LSRB and MOSM-GBERB differ due to different zone delineation, guided by SWAT's subbasin delineation for water yield data.

specific management practices, cost, and the source information can be found under **MO cost example** tab. We determined the default MO efficiency inputs from a range of values found in the literature, mainly from *The Agricultural BMP Handbook for Minnesota*³, and from expert interviews. MOSM's **CONTROL** tab includes descriptions of different types of cost and effectiveness of each MO as cell comments (see the red tabs in Figure 4b).

MOSM calculates the annualized cost (C_{ann}) for each MO, which is defined as the uniform end-of-year payment over the lifetime of a MO. These expenditures include installation (P_{inst}) and maintenance (P_{mntn}) costs over the lifetime (n) of the MO, as well as opportunity costs (foregone net revenues from crops if productivity is lowered or land is taken out of production, as measured by the land value (P_{land})) with interest rate (i):

$$C_{ann} = \left[\left(\frac{P_{inst} + P_{land}}{1 + i} \right) \left(\frac{(1 + i)^n \cdot i}{(1 + i)^n - 1} \right) + P_{mntn} \right] * A \quad [1]$$

Where A is the extent of allocated MO. MOs on agricultural fields (AFMO and WCMO (agricultural land cost), and BFMO (marginal land cost) are assumed to take land out of agricultural production when implemented; thus, the land acquisition cost (P_{land}) is included in the annualized cost calculation. The default cost of agricultural and marginal land is assumed to be \$8,297/acre in 2016 based on the farmland values determined from crop productivity index (CPI) rating and web soil survey data in the Blue Earth County⁴. For example, if WCMO costs \$1,500 to install and \$250 maintain per acre, the model adds the value of land acquisition at \$8,297/acre in the cost calculation and spread out the cost over the life time of the management with a specified interest rate (default set at 5%). The interest rate, cost of management installation and maintenance, and land value can be changed on **CONTROL** tab to accommodate different financial situations and specific management options under each type.

Stochastic simulation

On the **CONTROL** tab, users can specify the model stochasticity input. The model is capable of running up to 1,000 Monte Carlo (MC) simulations where 1,000 plausible sediment delivery ratios on field (SDR_f) and in stream (SDR_s) are used to simulate sediment loading. If the value of 1 is entered, the model runs deterministically using the best-calibrated parameters to calculate SDR_f and SDR_s (see *MOSM Computational Module Handbook*). With the stochastic setting, MOSM evaluates the implications of a wide ranging sediment delivery and loading estimates on sediment management decision, highlighting that a same investment can result in low or high sediment reduction simulations, depending on the management types, locations, and extents.

³ Miller, T. & Peterson, J. Ag BMP Handbook for Minnesota. (2012). Available at: <http://www.mda.state.mn.us/protecting/cleanwaterfund/research/agbmphandbook.aspx>.

⁴ Blue Earth County, MN Farmland Prices and Values | AcreValue [WWW Document], 2016. URL <https://www.acrevalue.com/map/MN/Blue-Earth/> (accessed 8.29.16).

River	LeSueur			Cobb			Maple			Extent	Extent
Zone	Upland	Trans	Incised	Upland	Trans	Incised	Upland	Trans	Incised	inputed	selected
Cover and Tillage Management Option (TLMO) ALLOCATION											
Extent of all farm land (ac)	131,976	37,736	50,961	76,825	58,506	28,588	84,280	81,556	19,711	570,138	acre
Corn-Soy Rotation with conventional tillage (%)	80	80	80	80	80	80	80	80	80	456,110	-
Continuous Corn with conventional tillage (%)	20	20	20	20	20	20	20	20	20	114,028	-
Corn-Soy Rotation with Winter Rye Cover Crop (%)	-	-	-	-	-	-	-	-	-	-	-
Agricultural Field Management Option (AFMO) ALLOCATION											
Extent of all MOs (ft)	489,638	153,344	163,291	259,759	192,325	94,596	254,013	230,363	44,849	1,882,178	AFMO*W [ac]
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-
Buffer Strip Management Option (BFMO) ALLOCATION											
Extent of all MOs (ft)	1,070,389	332,417	600,050	615,745	475,117	379,555	647,512	647,400	175,287	4,943,473	BFMO*W [ac]
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-
Water Conservation Management Option (WCMO) ALLOCATION											
Extent of all MOs (ac)	15,424	4,676	6,637	7,791	5,142	3,324	7,871	8,158	1,553	60,577	WCMO [ac]
Input extent (ac)	-	-	-	-	-	-	-	-	-	-	-
In-Channel Management Option (ICMO) ALLOCATION											
Extent of all MOs (ft)	358,396	196,427	154,818	146,696	135,845	34,959	293,607	181,222	3,064	1,505,034	ICMO [ft]
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-
Ravine Management Option (RAMO) ALLOCATION											
number of ravine tips	-	-	275	-	-	132	-	14	196	617	RAMO [tips]
Input number of tips	-	-	-	-	-	-	-	-	-	-	-
Near-Channel Source Management Option (NCMO) ALLOCATION											
Extent of all MOs (ft)	69,774	3,061	60,676	8,222	4,091	44,997	3,520	11,175	46,831	252,346	NCMO [ft]
Input extent (ft)	-	-	-	-	-	-	-	-	-	-	-

Figure 4a: Management option extent input table of MOSM CONTROL tab (MOSM-LSRB is used as an example for its brevity)

MO efficiency	Installation	Ann. Maintenance	Life Span	Total
%	Cost	Cost	(yr)	Cost (\$/yr)
Tillage Management (TLMO) EFFECTIVENESS & COST				
	Install. (\$/ac)	Mntnc [\$/(ac*yr)]	(yr)	Total (\$/yr)
	39	90	1	0
	41	86	1	0
	60	110	1	0
Agricultural Field Management (AFMO) EFFECTIVENESS & COST				
Sed. Delivery	Install. (\$/ac)	Mntnc [\$/(ac*yr)]	Life Span	Cost (\$/yr)
75 %	3,200	64	10	0
Buffer Strip Management (BFMO) EFFECTIVENESS & COST				
Sed. Delivery	Install. (\$/ac)	Mntnc [\$/(ac*yr)]	Life Span	Cost (\$/yr)
65 %	1,000	45	10	0
Water Conservation Management (WCMO) COST				
Sed. Delivery	Install. (\$/ac)	Mntnc [\$/(ac*yr)]	Life Span	Cost (\$/yr)
90 %	1,500	250	25	0
In-Channel Management (ICMO) COST				
	Install. (\$/ft)	Mntnc [\$/(ft*yr)]	Life Span	Total (\$/yr)
	250	1.4	10	0
Ravine Management (RAMO) EFFECTIVENESS & COST				
Sed. Erosion	Install. (\$/TIP)	Mntnc [\$/(tip*yr)]	Life Span	Total (\$/yr)
25 %	6,000	35	10	0
Near-Channel Source Management (NCMO) EFFECTIVENESS & COST				
Sed. Erosion	Install. (\$/ft)	Mntnc [\$/(ft*yr)]	Life Span	Total (\$/yr)
75 %	400	0.7	5	0

Figure 4b: Management option cost/effectiveness input table of MOSM CONTROL tab

If you want to control more of the management design inputs and allocation criteria, refer to Appendix A.

3. Executing the model

To execute the model after specifying the model inputs, user will press **RUN MOSM** button on the **CONTROL** tab. When the model completes the simulation, the model will alert the user and display the simulation outputs.

Press this button to clear pervious inputs ---> **Reset input table**

Press this button to clear pervious inputs and implement X% BFMO ---> **Reset with buffers**

Buffers (X%)= -

MC runs: 1

RUN MOSM

User input only in Green Cells

Figure 5: MOSM simulation is executed by pressing the **RUN MOSM** button on the **CONTROL** tab

3.1. Resetting the control input table

User input scenarios in the control input table may be cleared by pressing the **Reset input table** button on the **CONTROL** tab. Cover and tillage management option will be set to default values, and the input table for all other management options will be set to zero. The **Reset with buffers** button clears all other MOs but sets BFMO at X% (see Figure 5: “Buffers (X%)”). X is set as 30% by default, assuming that existing buffers during the model’s calibration period covers 70% of streams and ditches⁵.

4. Interpreting the MOSM outputs

After running the simulation of the user specified management scenario, the model automatically plots its cost and sediment reduction against a number of reference scenarios (Section 4.1). Management scenarios as well as the complete inputs and outputs may be saved for reference (Sections 4.2 and 4.4). The summary simulation output of the user specified scenario can be found under the **CONTROL** tab, and the corresponding detailed outputs can be found in the **Output Detail** tab (Section 4.3).

4.1. Reference scenarios and chart

After the user runs a management scenario simulation, the model plots the scenario’s annual cost and reduction in sediment loading at the mouth of the basin outlet against a number of reference scenarios (individual MOs implemented at 2%, 5%, 10%, 50%, and 100% of total available extents) (Figure 6).

⁵ We did not know the extent of existing buffers in the study site at the time of the model development; thus, we set BFMO candidate sites with all mapped stream and ditches (see Appendix A of the *MOSM Computational Module Handbook*) so we can enter appropriate simulation extent as more information become available.

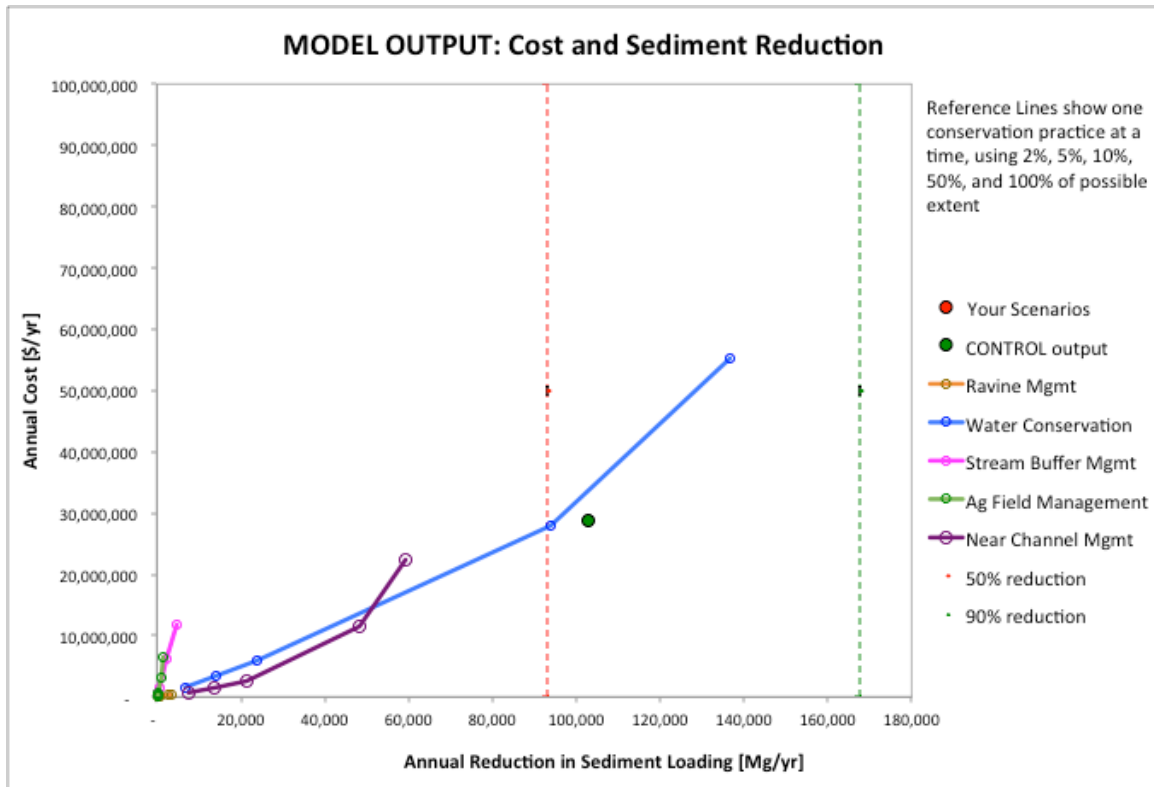


Figure 6: Reference scenario chart shows a number of reference scenarios (individual MO implemented at various extents) and management scenario CONTROL output (green circle). Red dotted line and green dotted line shows sediment reduction goals set at 50% and 90% reductions, respectively.

The chart in Figure 6 also shows the sediment reduction recommendations: South Metro Mississippi River upstream of Lake Pepin requires at least a 50% reduction in sediment load⁶; and the total maximum daily load (TMDL) for the Minnesota River and Le Sueur River recommends sediment reduction of 90% or greater to meet the water quality standards⁷. The “CONTROL output” (green circle) indicates the outputs of the most recent scenario run with MO allocation specified in the **CONTROL** tab. “Your Scenario” (red circle) indicates the management scenario archived by the user (Section 4.2).

4.2. Saving management scenarios

Under the **CONTROL** tab, **Save your scenarios** button allows the user to archive and name their scenarios (Figure 7). Management scenario outputs, up to 20 scenarios, can be saved to compare against reference and other user-specified scenarios (e.g., “my scenario 1” and “my scenario 2” in Figure 8). Saved scenarios, including sediment loading reduction, cost of MO implementation, and summary extents of MOs can be found in **Your Scenarios** tab.

⁶ Minnesota Pollution Control Agency. South Metro Mississippi — Turbidity: TMDL Project. *Minnesota Pollution Control Agency* (2010). Available at: <https://www.pca.state.mn.us/water/tmdl/south-metro-mississippi---turbidity-tmdl-project>.

⁷ Minnesota State University, Mankato Water Resources Center. *Turbidity Total Maximum Daily Load study - Greater Blue Earth River Basin*. (2012).

Microsoft Excel

You can save up to 20 scenarios. Enter the i^th number of scenario you are saving now. e.g.) 1, 2,..., or 20

Microsoft Excel

Enter the name of the scenario you would like to record. e.g. T1AFz310% for T1 tillage plus AFMO at 10% of sites in zone 3

Figure 7: When the **Save your scenarios** button is activated, the user is prompted to enter the sequence and name of the current scenario. The model saves the scenario and plots it in the reference scenario chart (red circles in Figure 9).

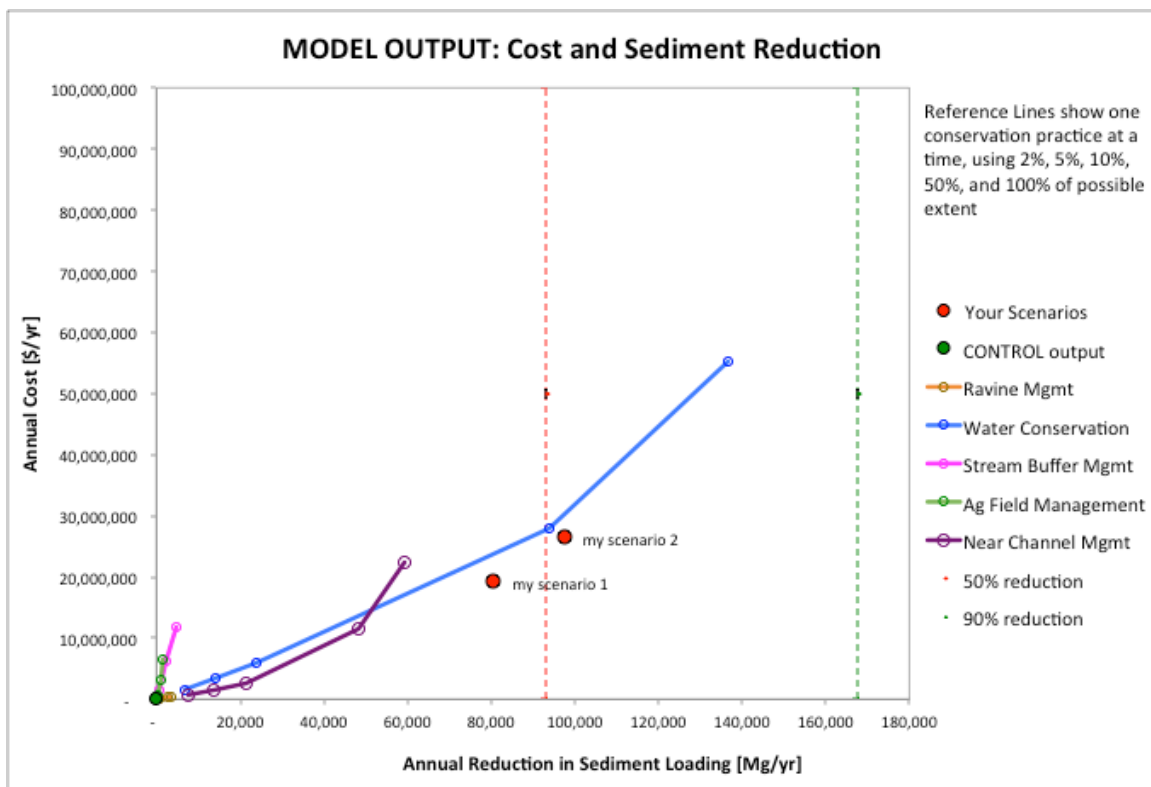


Figure 8: Reference scenario chart showing the saved scenarios (“my scenario 1” and “my scenarios 2” shown in red circles)

4.3. Model outputs

On the **CONTROL** tab, the **Simulation Output Summary** Table displays the annual sediment loading and reduction achieved by input management scenario, compared to the reference condition in 2006-2010. The **Cost Summary** Table displays the upfront land acquisition cost, annual costs of installation and maintenance of management options over the lifetime, total annual cost, and the unit cost of removing a metric ton of sediment (Figure 9). MO cost breakdown chart shows the relative yearly expenses of implementing different management options in the scenario.

The annual cost of management options excludes the cost of the reference period crop production and tillage practices (see Section 2.1). For example, implementation of 80% corn-soybean rotation and 20% continuous corn across the Le Sueur River Basin costs \$73,352,790/year given the default TLMO implementation and maintenance costs, including cost of seeding, tillage, fertilizers, and pesticides (see **default cost of operation** table in Figure 9). This reference period cost is subtracted from the cost of any additional management options, including different TLMO, AFMO, BFMO, WCMO, ICMO, RAMO, and BFMO implementation specified by the user as described in Section 2.1 (see **cost summary** table in Figure 9).

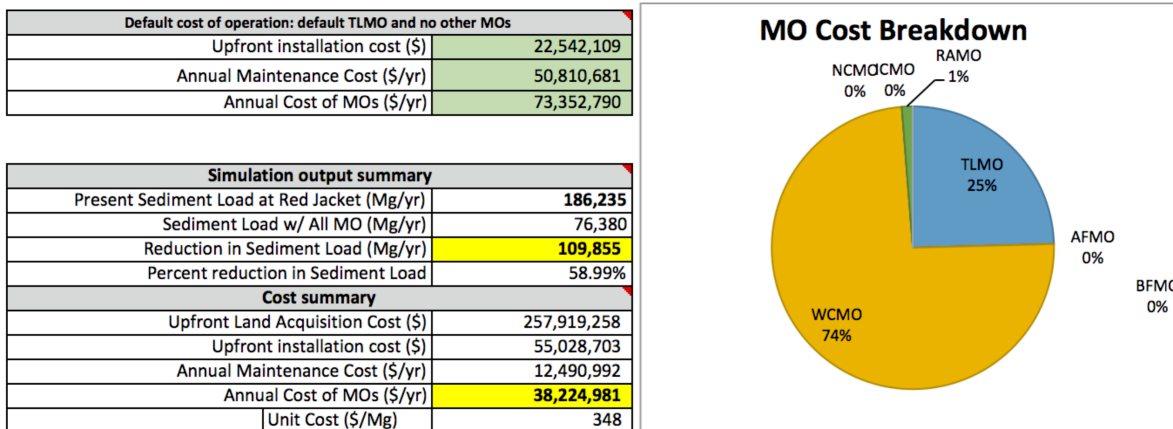


Figure 9: Summary simulation outputs and MO cost breakdown chart (from MOSM-LSRB)

MOSM-LSRB simulates sediment loading at the gages located along the Maple, Cobb, and Le Sueur Rivers (Figure 1). MOSM-GBERB simulates sediment loading at the gages located along the Watonwan, Blue Earth, Maple, Cobb, and Le Sueur Rivers (Figure 2). In the **Output Detail** tab, the model user can view the reference condition sediment loading at the gage locations and compare with the simulated loadings (Figure 11). When the model is run using the stochastic setting (see Section 2.1), the outputs include average, standard deviation, minimum, maximum, 10th percentile, and 90th percentile values of the output population. At the top of the **I/O Detail** tab, the user may specify the percentile values of the stochastic outputs. For more user input details in the **I/O Detail** tab, see Appendix A.

Percentile output=	10 %
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Statistical summary of 1000 MC simulation outputs

Annual Sediment loading outputs without MOs							
Sediment Loading [Mg/yr]	Observed (2006-2010)	Average simulated	Standard Deviation	Min	Max	10th percentile	90th percentile
Upper Maple at Sterling Center, CR18	10,085	10,773	6,478	3,772	92,709	6,028	17,136
Main Cobb at confluence with Little Cobb	5,155	6,084	2,654	1,898	25,880	3,512	9,422
Little Cobb outlet nr Beauford	4,771	4,843	2,349	1,575	28,240	2,815	7,499
Upper Le Sueur at St. Clair gage	28,769	29,754	16,619	8,341	204,974	15,840	48,185
Le Sueur outlet nr Rapidan, MN66	186,553	190,972	37,078	133,269	574,727	158,182	232,573
Above Winnebago and Elm Creek	94,434	92,386	86,385	41,007	402,148	61,202	133,192
Upper Watonwan	37,400	37,371	32,629	20,991	172,634	27,967	49,107
Winnebago to Knick	140,236	150,323	121,769	83,788	566,719	110,968	201,313
Kinck to BE @ Rapidan	250,548	260,412	78,750	159,397	921,240	202,935	332,815
SUM of BE and LES	437,101	451,384					
Annual Sediment loading with MOs							
Sediment Loading [Mg/yr]	short name	Average simulated	Standard Deviation	Min	Max	10th percentile	90th percentile
Upper Maple at Sterling Center, CR18	U Maple	10,627	6,387	3,737	91,539	5,955	16,894
Main Cobb at confluence with Little Cobb	U Cobb	6,010	2,627	1,879	25,650	3,467	9,312
Little Cobb outlet nr Beauford	L Cobb	4,668	2,175	1,568	26,329	2,773	7,117
Upper Le Sueur at St. Clair gage	U Le Sueur	29,539	16,525	8,276	203,903	15,715	47,855
Le Sueur outlet nr Rapidan, MN66	Outlet	190,205	36,647	133,022	569,437	157,765	231,318
Above Winnebago	AW	91,621	85,694	40,927	397,310	60,884	131,825
Upper Watonwan	UW	37,326	32,747	20,991	169,054	27,963	49,019
Winnebago to Knick	WK	149,570	121,223	83,732	560,233	110,704	199,886
Kinck to Outlet	KO	260,071	78,925	159,386	912,439	202,869	332,095
SUM of BE and LES		450,277					
	Average reduction in loading=	1,108					
	% reduction in loading=	0.25%					

Figure 10: MOSM outputs under Output Detail tab show observed sediment loading from the reference period, 2006-2010, and simulated sediment loading at five gage locations shown in Figure 11. When the model is run using the stochastic setting (see Section 2.1), output statistics of all Monte Carlo outputs (average simulation output, standard deviation, minimum and maximum outputs, and percentile statistic) are included.

4.4. Saving the entire MOSM control inputs and outputs

The entire MOSM control input table (Figure 4) and summary output table (Figure 10) can be archived as a separate spreadsheet by pressing **Export all INPUT & OUTPUT** button. The user will be prompted to enter the name of the new workbook, upon which the model creates a new workbook containing all information in the **CONTROL** tab. This tool is useful when the user wishes to save the detailed MO scenario inputs and outputs for a future reference.

Appendix A: I/O Detail input

The “I/O Detail” tab allows user to enter more detailed model specifications including MO selection and allocation criteria, and MO design specifications (design depth, width, etc.).

TLMO

Default TLMO implementation conditions can be changed by specifying the proportions of T1, T2, and T3 allocations across different zones and watersheds in **TLMO reference condition table (a)** (Figure 12) (the user may have to scroll to the right on the **I/O Detail** tab to access this table). The default TLMO allocation is 80% corn-soybean rotation and 20% continuous corn with conventional tillage across all farmland. These values of allocation can be changed if better information about farmland allocation is available for any zones of the subwatersheds.

Erosion factors of T1, T2, and T3 may be changed in **TLMO reference condition table (b)**. The default values are determined from the C factor of the USLE guideline and the literature on different crop production practices⁸. This value determines the erodibility (alpha values in Table (c)) of different crop-tillage options.

Alpha values, 1, 2, and 3 in **TLMO reference condition table (c)** indicate the calculated soil erosion coefficients, based on the reference period tillage practice allocation and soil erosion factors associated with these practices. See the *MOSM Computational Module Handbook* for detailed description of how the effects of TLMO on soil erosion are quantified.

After adjusting the default TLMO setting, the user must reset the model by pressing **Reset Default-TLMO setting**. This activates the modules to reset the input table and default cost of operation on **CONTROL** tab.

⁸ Miller, G.A., Amemiya, M., Jolly, R.W., Melvin, S.W., Nowak, P.J., 1982. Soil Erosion and the Iowa Soil 2000 Program (No. 11462), Staff General Research Papers Archive. Iowa State University, Department of Economics.

Gabriels, D., Ghekiere, G., Schiettecatte, W., Rottiers, I., 2003. Assessment of USLE cover-management C-factors for 40 crop rotation systems on arable farms in the Kemmelbeek watershed, Belgium. *Soil and Tillage Research* 74, 47–53. doi:10.1016/S0167-1987(03)00092-8

TLMO reference condition (2006-2010) set up for soil loss calculation									
(a) Percent area allocation of crop-tillage practice for the reference period									
River	LeSueur			Cobb			Maple		
Zone	Upland	Trans	Incised	Upland	Trans	Incised	Upland	Trans	Incised
Reference Period Tillage Management Option (TLMO) Allocation									
Extent of all farm land (ac)	132,311	37,856	51,096	77,037	58,601	28,643	84,943	81,737	19,785
Corn-Soy Rotation (%)	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
Continuous Corn (%)	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Corn-Soy Rotation with Winter Rye cover crop (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reset Default-TLMO setting	Note: This sets the baseline tillage practice status at the study site where the baseline soil loss rates corresponding to these three types of TLMO is calculated. Consequently, the changes in the proportions of tillage practice will result in different soil erosion in respect to the baseline tillage option input here.								
(b) Soil erosion factors of the crop-tillage options									
Crop-tillage options	Soil erosion factor (C-factor of the USLE)								
Corn-Soy rotation with conventional till	1.31	"Soil Erosion and the Iowa Soil 2000 Program" by Miller (1988)							
Continuous corn with conventional till	1	"Soil Erosion and the Iowa Soil 2000 Program" by Miller (1988)							
Corn-Soy rotation with Winter Rye cover crop	0.35	"Assessment of USLE cover-management C-factors for 40 crop rotation systems on arable farms in the Kemmelbeek"							
(c) Soil loss factor for the sediment loading module calculated based on the reference period allocation and soil erosion factor									
River	LeSueur			Cobb			Maple		
Zone	Upland	Trans	Incised	Upland	Trans	Incised	Upland	Trans	Incised
alpha1	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050	1.050
alpha2	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
alpha3	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280

Figure 11: TLMO reference condition tables (a) percent TLMO allocation; (b) soil erosion factors; and (c) soil erosion coefficient calculation

AFMO

Detailed AFMO inputs include:

- Site selection criteria: the model user may specify their preference on which individual management sites should be selected first based on site-specific conditions. Site selection choices are:
 - A*: Select sites with largest upstream drainage area first
 - B: Select larger sites located on hydric soil first
 - C: Select sites that are closest to stream network first
 *denotes the model's default input.
- Design width: the model user may specify the design width of AFMO. For example, grassed waterways have typical design width of 100 ft (the default value in the model).
- X: This input parameter specifies the degree at which the drainage areas of the AFMO and WCMO overlap when they are both allocated. This option allows evaluation of effects of proximity of AFMO and WCMO on sediment reduction.
 - e.g.) X=0 indicates no overlap between AFMO and WCMO drainage areas (AFMO and WCMO are located far from one another within any given subbasins)
 - X=0.5 indicates 50% overlap of smaller of drainage area of either AFMO or WCMO into the larger one (AFMO and WCMO are close enough that parts of their drainage areas overlap)
 - X=1 indicates complete overlap where the smaller of drainage area of either AFMO or WCMO will be subsumed by the larger one (AFMO and WCMO are closely located such that they have common drainage area)

BFMO

Detailed BFMO inputs include:

- a) Allocation selection criteria: the user may specify preference of MO selection from MO database. Site selection choices are:
 - A: Select sites with largest upstream drainage area first
 - B*: Select sites furthest upstream first (i.e., Zone 1)
 - C: Select sequentially: sites on streams, canal ditches, connectors, and then sites on artificial paths
- b) Buffer widths: BFMO's design widths for the natural and artificial streams can be specified. The default inputs of 50 feet and 16.5 feet along natural and artificial streams reflect the Department of Natural Resources (DNR) guideline.

WCMO

Detailed WCMO inputs include:

- a) Allocation selection criteria: the user may specify preference of MO selection from MO database. Site selection choices are:
 - A: Select sites with lower crop productivity index (CPI) value and higher natural depth first
 - B*: Select sites with higher natural depth, located on hydric soils first
 - C: Select sites closer to the existing wetlands and Conservation Reserve Program sites first
- b) Drainage factor: determines the WCMO drainage area based on WCMO surface area. The default value of 8.9 indicates that the WCMO drains the area 8.9 times its surface area (see *MOSM Computational Module Handbook*)⁹.
- c) Design depth: a user may specify the design depth of the WCMOs. This input will influence the storage capacity of the allocated WCMOs and consequent attenuation of the peak flow and sediment loading from near-channel sources affected by peak flow. Usually, this factor should influence the cost of management installation. See the management cost table in **MO Cost Example** tab, and Section 2.1 on entering different management costs.
- d) Alpha: indicates the proportion of WCMO surface area where the stored water would flow out. For example, alpha=0.5 indicates that water would flow out through the half of the circumference of WCMO (WCMO is modeled as a cylindrical storage with surface area determined from the topographic map of the watershed).

ICMO

Detail ICMO inputs include:

- a) Allocation selection criteria: a user may specify preference of MO selection from MO database. Site selection choices are:
 - A: Select sites on longest ditches first
 - B*: Select sites closest to subbasin outlets
 - C: Select sites in furthest from the incised zone (i.e., Zone 1)

⁹ The Default value of 8.9 comes from an extensive flow accumulation value analysis in <Mitchell, N., 2015. Achieving peak flow and sediment loading reduction through increased water storage in the Le Sueur Watershed, Minnesota: a modeling approach (Master of Science Thesis). University of Minnesota, Duluth>.

- b) Drainage factor: determines the ICMO drainage area based on ICMO surface area. For instance, input value of “2” will indicate that ICMO drains twice its surface area.
- c) ICMO geometry: a user may specify the design depth, weir width (WW), notch width (NW), and notch height (NH)¹⁰ (Figure 13).

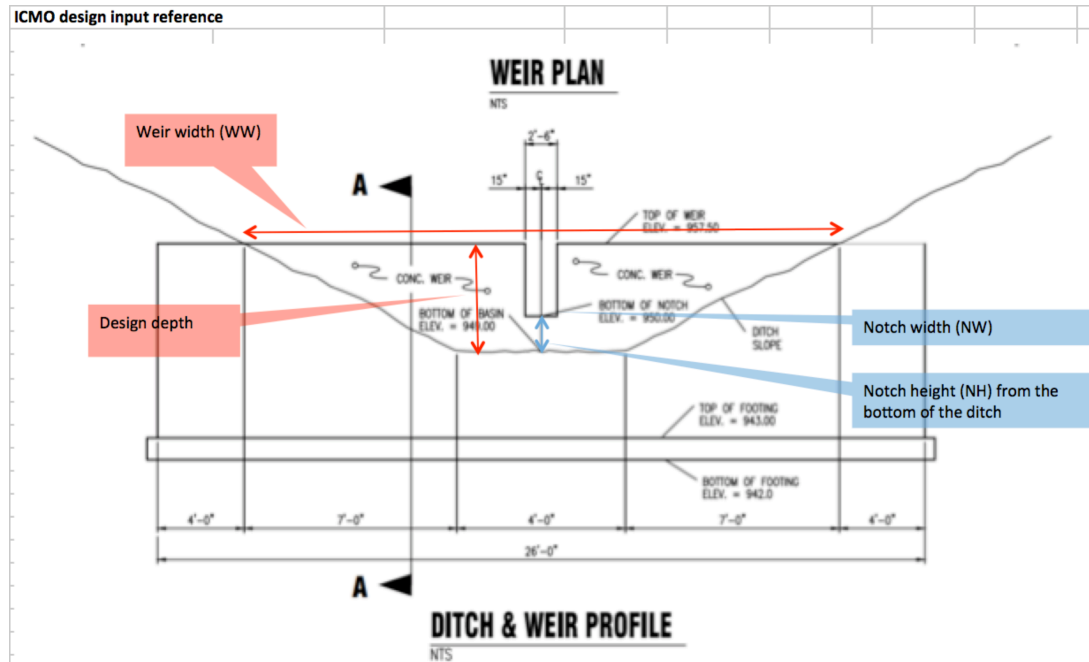


Figure 12: ICMO weir plan with design inputs in MOSM

RAMO

Detail RAMO inputs include:

- a) Allocation selection criteria: a user may specify preference of MO selection from MO database. Site selection choices are:
 - A*: Select sites on ravines with largest sediment loading rate per branch
 - B: Select sites by the ravine's evolution states (0-3)
 - 0: ravine empties into channel
 - 1: ravine ends on a terrace/abandoned channel without prominent fan
 - 2: ravine has an alluvial fan
 - 3: ravine is captured by lower ravine on terrace or abandoned channel, which connects to main channel
- b) Fraction of sediment source in ravine, F_r : indicates the fraction of sediment addressed by RAMO. Typically, 20% of sediment outputs from ravines are sourced from upstream of ravines. Thus, the default value of $F_r = 80\%$ ensures that the model addresses only the sediment sourced from within ravines.

¹⁰ The default design inputs are modeled after the proposed County Ditch 34 in Blue Earth County, Minnesota (I&S Group; Project No. 11-13808)
https://blueearth.drainagedb.net/portal/LoadPortalAttachment.php?idPath=documentsdrainage/cd34/cd34_20150305_095632-CD34_RPT_E_F_02052015.pdf

NCMO

Detail NCMO inputs include:

- a) Allocation selection criteria: a user may specify preference of MO selection from MO database. Site selection choices are:
 - A: Select sites on the tallest bluffs with largest open surface area first
 - B*: Select sites on the bluffs with largest sediment load first

Appendix B: MOSM's computational modules and spatial scales

MOSM operates in Microsoft Excel with subroutines written in the Visual Basics for Applications (VBA). Refer to the *Computational Module Handbook* for detailed descriptions of each computational module.

There are three main computational modules in MOSM:

- (1) *The MO allocation algorithm* assigns management options (MOs) based on various attributes of candidate MOs and areal extents of available sites in the watershed. All available sites have been mapped, and the user is able to input the extent of each MO to implement per subbasin across the watershed.
- (2) *The water routing algorithm* simulates water storage with WCMO and ICMO and consequent reduction in peak river discharge in the incised zone. The model routing algorithm is linked to the near-channel sediment supply (NCSS) model, which establishes the relationship between peak river discharge and sediment loading from near-channel sources in the incised zone, to predict sediment-loading reduction from water storage.
- (3) *The sediment routing algorithm* calculates the reduction in sediment loading from implementing TLMO, AFMO, WCMO, BFMO, RAMO, and NCMO. In addition, sediment-loading reduction from near-channel sources from simulated water storage in subroutine (2) is incorporated in the overall sediment loading reduction calculation.

There are three spatial scales corresponding to the subroutines (Figures 1 and 2):

- (1) **Zone:** Each subwatershed associated with the main rivers (e.g., Maple, Cobb, Le Sueur, Blue Earth, and Watonwan) has three zones based on topographic characteristics (Figures 1 and 2 show the zone delineations): upland, transitional, and incised zones. The upland zone is characterized by flat topography unaffected by the base level drop to the Minnesota River Valley, while the incised zone is characterized by deeply incised river corridors near the mouth of each river. The transitional zone is located between the upland and incised zones. The model allocates MOs based on the extent specified by the user within each zone.
- (2) **HYDSB:** The model routes the water from each of the hydrologic subbasin (HYDSB) downstream at a daily time scale. There are 30 HYDSBs in the Le Sueur River Basin (LSRB) and 111 HYDSBs across the Greater Blue Earth River Basin (GBERB).
- (3) **SEDSB:** The model calculates watershed sediment loading from each of the sediment subbasins (SEDSB). Sediment sources are field, ravines, streambanks, and bluffs. There are 529 SEDSB in the LSRB and 1622 in the GBERB.

Appendix C: Input databases

There are three input databases corresponding to the subroutines (Figure 13).

- (1) *MO database* consists of candidate MO sites identified through various spatial analysis using topographic, land cover, and soil maps. Table 3 summarizes the MO extents and main spatial data sources used to identify the candidate sites. These databases can be found in MOSM under the grey tabs: **TLMO**, **AFMO**, **WCMO**, **ICMO**, **RAMO**, and **NCMO** (these tabs may be shown by right clicking the tabs and selecting “unhide”).
- (2) *Water yield data* from a calibrated SWAT model is used to determine the water yield to streams from each HYDSB. This database can be found in MOSM in the blue tab: **SWAT_WY** (this tab may be shown by right clicking the tabs and selecting “unhide”).
- (3) *SEDSB SDRf, SDRs, and NCS loading* are outputs of the Topofilter model. Topofilter simulates the sediment delivery ratio on field (SDR_f) and in stream (SDR_s) based on the watershed topography and soil loss from field and near channel sources (NCS), and evaluates the consequent sediment loading (product of soil loss and sediment delivery ratio) against observed sediment loading at the gages (Figure 11). NCS loading include ravines, streambanks, and bluffs, and is evaluated from the integrated sediment budget. The database on SDR and NCS loading can be found under orange tabs: **SDR** and **Reachdata** (these tabs may be shown by right clicking the tabs and selecting “unhide”).

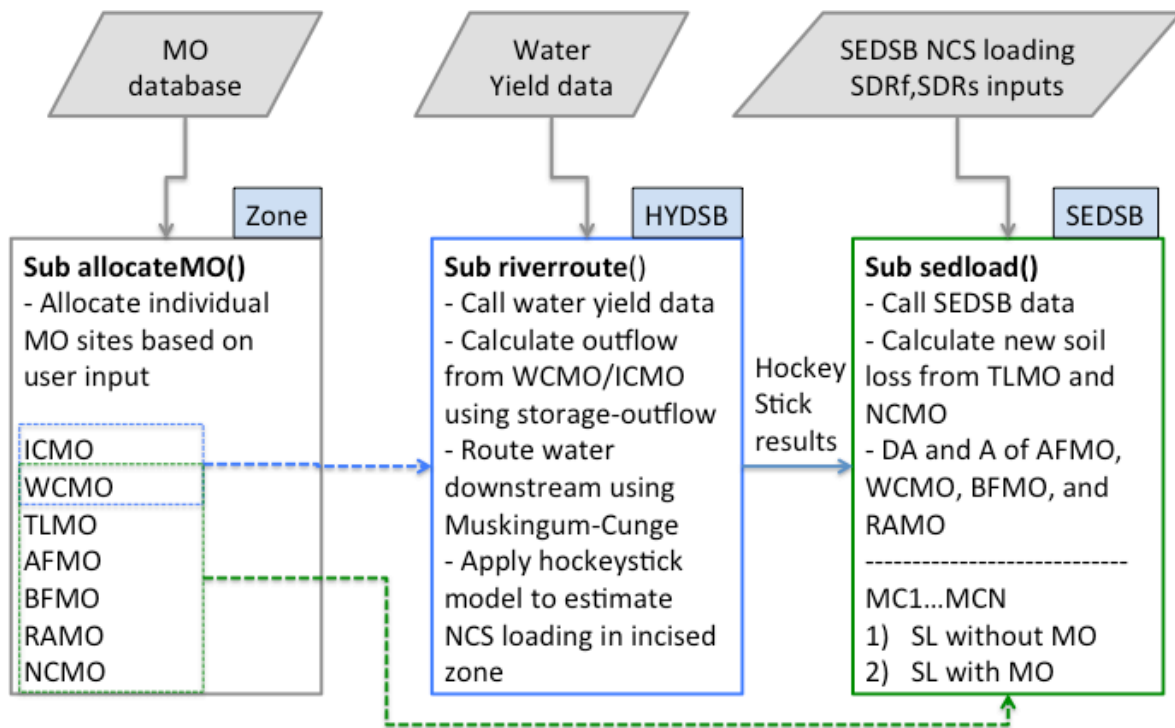


Figure 13: MOSM subroutines and input data

Table 3: MO extent summary and sources for the Greater Blue Earth River Basin

MO	Number of sites	Extents	Units	Main spatial data source
TLMO	N/A	1,840,605	Acre	National Land Cover Data 2011
AFMO	5,777	994	Mile	30 m Digital Elevation Model
BFMO	1,732	2,950	Mile	National Hydrography Dataset
WCMO	24,129	173,073	Acre	30 m Digital Elevation Model
ICMO	1,457	697	Mile	Water Resources Center's ditch map
RAMO	307	1,421	Acre	Ravine shape file from sediment budget
NCMO	3,449	142	Mile	Bluff shape file from sediment budget