Nutrient Tracking Tool (NTT)

Technical Report

Version 23-10

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Abbreviations

APEX	Agricultural Policy Environment eXtender
AOI	Areas of Interest
AU	Animal Unit
C	USLE Crop Management Channel Factor
CP	Conservation Practices
CT	Conservation Tillage
CBS	Contour Buffer Strip
DEM	Digital Elevation Map
EPIC	Environmental Policy Integrated Climate
ET	Evapotranspiration
FCO	Field Controlled Ponds
FFPQ	Fraction of Buffer/ floodplain flow; Partitions flow through filter strips
FOTG	Field Office Technical Guide
FS	Filter Strip/Grass Buffer
FDSF	Furrow Diking Safety Factor
GW	Grassed Waterways
GRZ	Grazing
LL	Land Leveling
M3	Mehlich-3
MM	Modified Morgan
MWF	Monthly Weather Files
N	Nitrate/Nitrogen
NASS	National Agriculture Statistics Service
NCRS	Natural Resource Conservation Service
NLEAP	Nitrate Leaching and Economic Analysis Package

NSTP	Non-Structural Practices
NTT	Nutrient Tracking Tool
NTT-RE	Nutrient Tracking Tool – Research and Education
P	Phosphorus
PARM	Parameter
PND	Pond
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PEC	Erosion Control Practice Factor
RFB	Riparian Forest Buffer
SOM	Soil Organic Matter
SL	Soil Surface Slope
SLP	Average Field Slope
STP	Soil Test Phosphorus
SBS	Streambank Stabilization
SF	Stream Fencing (Livestock Access Control)
STPs	Structural Practices
SURGGO	Soil Survey Geographic Database
TS	Terrace Systems
TIAERMT	Texas Institute for Applied Environmental Research Modeling Team
DRT	Tile Drainage
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USGS	United States Geological Service
NED	National Elevation Dataset
WQT	Water Quality Trading

Introduction

This report documents the development and evaluation of the Nutrient Tracking Tool (NTT), a web-based tool used to evaluate nutrient and sediment losses from crop and pasture land. NTT was developed to evaluate conservation practices for US farms using the Agricultural Policy Environment eXtender Model (APEX) (Williams et al., 2000). NTT uses field-specific topography, soil, weather, and agronomic management data sources. The tool was designed such that comparisons of multiple conservation management alternatives can be for a single field or farm order to identify how changes in management or implementation of conservation practices will affect water quality and yield. NTT has applications in farm planning, producer outreach, Total Maximum Daily Loads (TMDLs), market-based programs such as water quality trading, as well as education and research. Finally, NTT can also serve as an easy-to-use interface for the APEX model.

Currently, there are two versions of NTT available:

- The NTT version which includes the essential NTT functions required for use for general public.
- The Research and Education (NTT-RE) version which will be used by researchers and educational institutes for teaching and training purposes. NTT-RE includes additional functions allowing the user to view and edit soil layers, view crop water and nutrient stresses, and modify the APEX parameters for calibration and validation purposes. Both versions of NTT use identical versions of the APEX model, parameter files, and simulation methods.

This report is structured as follows:

- Section one provides a general description of NTT and its development process. The datasets that have been compiled for use in NTT and for populating the APEX model will also be described in this section.

- Section two addresses the methodology for simulating structural and nonstructural conservation practices within NTT.

The NTT Users manuals available on the NTT and NTT-RE websites provide additional information, features and functionality that are not discussed in this report.

1. NTT Development

1.1 Overview of NTT

The Nutrient Tracking Tool (NTT) is an internet application that allows individuals interested in assessing non-point source runoff from farms evaluate different

scenarios for nutrient and sediment reduction. Farmers, government officials, researchers and other users can determine the impacts of various conservation practices and other scenarios on nutrient and sediment losses from individual fields. In addition, impacts on crop yields and other indicators of relevance are provided to the user.

1.1.1 Historical Background

USDA-NRCS developed the Nitrogen Trading Tool as a farmer-friendly web-based application that can be used to calculate nitrogen load reductions for use in a WQT program. The Nitrogen Trading Tool is focused on nitrogen because its estimations are based on the Nitrate Leaching and Economic Analysis Package (NLEAP; Shafer et al., 1991). While very useful, its exclusive focus on nitrogen limited the applicability of the Nitrogen Trading Tool and to evaluation of very few N-related management scenarios. In fact, in many agricultural watersheds, particularly those with significant livestock numbers, phosphorus is the nutrient of primary concern. Phosphorus losses from agricultural fields have been linked to eutrophication of downstream waters in many areas in North American and Europe (Rekolainen and Sharpley, 1997).

To address the limitations of the Nitrogen Trading Tool, USDA-NRCS commissioned Texas Institute for Applied Environmental Research Modeling Team (TIAERMT) at Tarleton State University to develop the Nutrient Tracking Tool (NTT) for Water Quality Trading (WQT). While the Nutrient Tracking Tool does not calculate WQT nutrient credits directly, the load reductions provided by the tool can be used along with WQT program trade ratios to calculate nutrient and sediment credits (Saleh et al., 2011). The current version of NTT also can be used for other water quality/quantity and air quality programs.

NTT was developed using the Agricultural Policy Environmental eXtender (APEX; Williams et al., 2000). APEX, is a computer simulation model that has significant reputation for estimating the impacts of field-scale practices on a wide array of environmental indicators including air and water-borne pollutants. Inclusion of APEX also allows users to evaluate other farm level conservation practices such as filter strips, terraces, buffer strips, etc., that could not be evaluated using the Nitrogen Trading Tool. As a result of this effort, users also have access to various other relevant indicators (e.g., water quantity, sediment losses and crop yield changes) to help them make informed decisions about conservation practice implementation.

1.2 Key Features of NTT

The NTT program consists of following three main components:

- Web interface, which is visible to the user;
- Computer simulation programs, which run in the background in response to user requests; and
- Supporting databases, subsets of which can be viewed and customized by the user, based on the selections they make via the NTT web interface.

1.2.1 Web Interface

NTT is a web-based program. Users can access the tool by using their internet browser to go to the main NTT home page: (http://ntt.tiaer.tarleton.edu; for general users and (http://ntt-re.tiaer.tarleton.edu; full version for research and educational purposes). The current versions have all required data to be simulated for lands within the mainland US and Puerto Rico territory. (Note: NTT has been tested for a number of sites within the US and we continue to do ongoing testing as new research data for new sites becomes available. Please see section 2 for more details.) Users can select the state and county relevant for their applications and then proceed to define scenarios and run NTT to obtain estimates of nutrient and sediment losses as well as other indicators for each scenario they define.

NTT is a user-friendly program where virtually all the data required to simulate a scenario are available on the NTT server. NTT provides regional default management scenarios that can be used as is or be modified by the user. In addition, users can evaluate structural and non-structural conservation practices that are typical for their area. Site-specific information used in the simulation (i.e., soils, weather and slope) are determined based on the user-defined area of interest (AOI) or field in a GOOGLE based mapping system (Figure 1).
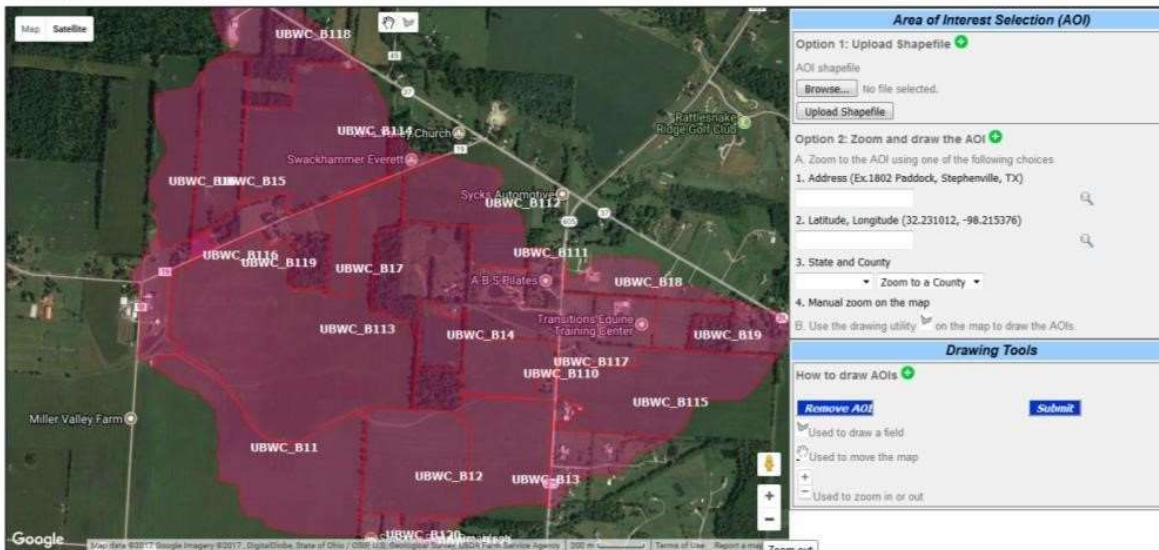
Figure 1.   NTT GOOGLE-based mapping system

All other data required for the area of interest can be selected by users from dropdown list boxes in the NTT user interface. If users desire to estimate nutrient and sediment losses for management practices that are not available in the NTT default choices, they can select other options to either modify existing management practices (operations) or create new ones.

A farm or small watershed can be subdivided as much as necessary to ensure that each subarea is relatively homogeneous in terms of soil, land use, management, etc. NTT also has a field routing feature that allows the user to evaluate the interactions

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between subareas involving surface runoff, return flow, sediment deposition, nutrient transport, and groundwater flow.

1.2.2 NTT's **Computer Simulation Programs**

APEX (version 0806) is the core simulation model in NTT. APEX was selected for the NTT application because of its prediction capability regarding N and P losses, crop yields, and sediment losses during evaluations of numerous management alternatives, such as installing filter strips. APEX also has other capabilities than can be useful in future potential augmentations of the tool, such as simulation of pesticide losses and carbon cycles.

APEX is a modified version of the Environmental Policy Integrated climate model (EPIC) (Williams, 1990), a field-level model that was developed in the early 1980s to assess the effects of management strategies on water quality. APEX extends the functionality of EPIC by allowing the simultaneous simulation of multiple contiguous subareas (fields) for a wide range of soil, landscape, climate, crop rotation, and management practice combinations. It is designed for the whole farm or small watershed analyses, and can be used for applications, such as filter strip impacts on nutrient losses from manure application fields, that require the configuration of at least two subareas. Alternatively, it can be run for single fields in the same manner that is allowed in models such as EPIC. The ability to simulate liquid applications from animal waste storage ponds or lagoons is a key component in APEX. Other components include weather, hydrology, soil temperature, erosion-sedimentation, nutrient cycling, tillage, dairy management practices, crop management and growth, pesticide and nutrient movement, and costs and returns of various management practices.

Recently, the carbon fate and transport functions of the CENTURY model (Parton, 1996) were incorporated into APEX (version 0604 and higher), which allows APEX to simulate carbon dynamics in the soil-plant system. APEX also has groundwater and reservoir components. A field or small watershed can be subdivided as much as necessary to ensure that each subarea is relatively homogeneous in terms of soil, land use, management, et. The routing mechanisms in APEX provide for evaluation of interactions between subareas involving surface runoff, return flow, tile flow, sediment deposition, irrigation, nutrient transport, and groundwater flow.

1.2.3 Supporting Databases

All the datasets required for running NTT are housed on the NTT server for ready user access. However, users may enter management information that is different from the pre-defined set available on the NTT program for their county of interest and can also save their information for future use. The following are the NTT databases that are available on the NTT server for states and counties in the U.S.

Weather data: Precipitation, minimum and maximum temperature, from 1987-2021 at 4-KM^2 resolution are obtained from the USDA Parameter-elevation Regressions on Independent Slopes Model (PRISM) database. The weather data are updated yearly to access the latest information.

The monthly Weather files (MWF) are required by APEX "weather gen" routine to generate all the missing weather data (e.g., solar radiation) for ET calculation. Therefore, NTT program generates the MWF at 4-km^2 grid resolution using the PRISM data for any part of US mainland. This makes the calculation of ET more precise in APEX.

The weather data in NTT is automatically generated for the area of interest based on its vicinity to specific weather station(s).

Soil Data: Soil data, including soil texture, calcium carbonate, PH, bulk density, and organic carbon, are obtained from the USDA-NRCS soil survey (SURGGO) databases. Currently NTT hosts a copy of USDA-SURGGO at its site which is accessed by a GOOGLE-based mapping system. The soil database in NTT is also updated annually. Also, the soil routine in NTT will modify and replace the missing data from soil survey as follows:

a. Soil layers where sand, silt, and clay are not present are not selected
b. Soil layers with depth=0 are not selected
c. Soil layers where depth<=5 mm and silt and sand = 0 and organic matter > 25 and bulk density < 0.8 are not selected
d. Only soils with area type "Non-MLRA Soil Survey Areas" are selected
e. Soil layers with Organic Carbon Concentration less than 0.0 is set to 0.0
f. Soils with Albedo <= 0 use default 0.37
g. Soil layers PH is validated to be between 3.5 and 9
h. Soil layers Organic Carbon Concentration is validated to be at least 0.0
i. Soil layers Bulk density is validated to be between 1.1 and 1.79
j. Default for soil P is 3.0
k. If sand, silt and bulk density are missing the values are estimated from Saxton et al., (1986) method as shown on Table 1. However, the user has the opportunity modify these values in NTT-RE version.
l. If soil depth is duplicated twice only one of the layers is added
m. If first layer depth is >10 mm a new first layer is added with depth = 10 mm
n. Apply Saxton (1986) equations to calculate bulk density, field capacity, wilting point, hydraulic conductivity.

Table 1.   Soil texture properties estimated from Saxton et al., (1986) method

Texture	Sand	Silt	Clay	BD
sandy clay loam	53.2	20.6	26.2	1.49
silty clay loam	8.9	58.9	32.2	1.2
loamy sand	80.2	14.6	5.2	1.44
sandy loam	63.4	26.3	10.3	1.46
sandy clay	52	6	42	1.49

silt loam	15	67	18	1.31
clay loam	29.1	39.3	31.6	1.33
silty clay	7.7	45.8	46.5	1.21
sand	84.6	11.1	4.3	1.45
loam	41.2	40.2	18.6	1.4
silt	4.9	85	10.1	1.42
clay	12.7	32.7	54.6	1.24

NTT requests the user to input the soil test phosphorus (STP), if available. NTT will convert STP values obtained from various methods to Mehlich-3 (M3) before these are inputted in soil data database (The STP-depth is set at 0-6 inch depth by default). The user STP input in NTT is converted to Mehlich-3 equivalent using the following equations:

1. Modified Morgan (MM) method (Winchell et al., 2011)

   $M3 = 6.718 \times MM - 11.83 \times PH - 32.757 \times MM/AL + 90.73$

2. Fe_strip method (Peter et al., 2007)

   $M3 = 0.10 + 1.61 \times Fe\text{-strip } P$

3. Olsen_P method (Peter et al., 2007)

   $M3 = 14.8 + 1.54 \times Olsen\ P$

4. Modified (Bray -1) method (Peter et al., 2007)

   $M3 = 10.8 + 0.99 \times (Bray\text{-}1)\ P$

Finally, the soil routine in NTT computes the soil surface slope (SL) using the 30-m DEM resolution for each soil type for simulated area. The slope is calculated by averaging the slope for cells in each polygon and averaging the result for each soil type.

1	2	3	4	5	6	7	8	9	10
11 A	12	13	14	15	B 16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51 C	52	53	54	55	D 56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110

Soil Type 1
Soil Type 2
Soil Type 3
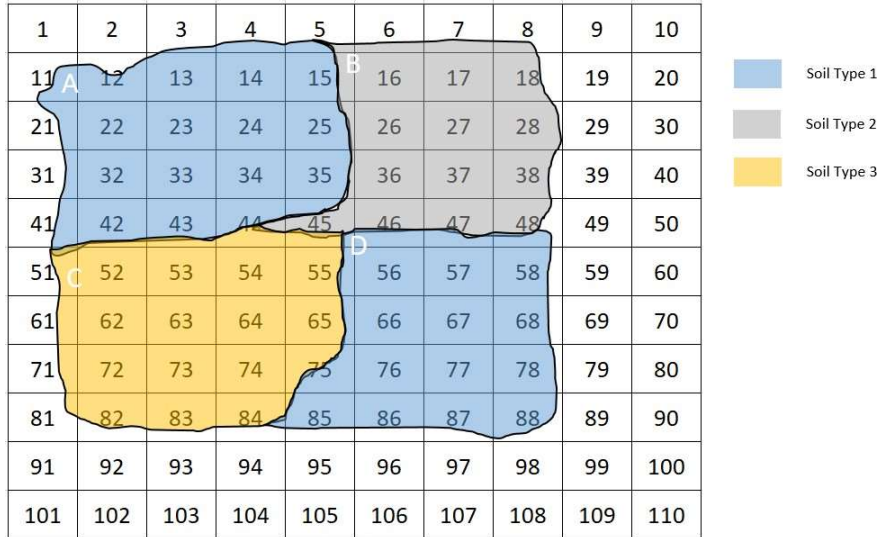
For example, slope for soil type 1 in above field is calculated from:

$$\frac{S_{12}+S_{13}+S_{14}+S_{15}+S_{22}+S_{23}+S_{24}+S_{25}+S_{32}+S_{33}+S_{34}+S_{35}+S_{42}+S_{43}+S_{44}}{S_A}$$

$$15$$

Slope for polygon D:

$$\frac{S_{56}+S_{57}+S_{58}+S_{66}+S_{67}+S_{68}+S_{75}+S_{76}+S_{77}+S_{78}+S_{85}+S_{86}+S_{87}+S_{88}}{S_D}$$

$$14$$

And since the soil A and D are the same type, then:

$$S_{\text{Soil }1}=\frac{S_A*A_A+S_D*A_D}{A_A+A_D}$$

Where $S=\dfrac{heigh_t}{length}$ and S_{12} is calculated slope of cell no. 12, and S_A is calculated slope of soil polygon A, and $S_{\text{Soil }1}$ is slope of subarea with soil type 1. A similar process is followed for up to three soil types for each selected field.

This dataset was extracted from the USGS National Elevation Dataset (NED) 1/3 arc second data. A slope grid was calculated from the elevation grid for use in the NTT program.

Management Schedule Data: The default major local cropping rotations and conservation practices management systems at the state-level are available for all parts

of the US mainland. However, users can insert their own and/or modify any default management system based on their own management practices. For the instructions please refer to NTT user's manual.

The tillage operations, fertilizer application rates and timing, and conservation practices (CPs) have also been customized at the state-level. The tillage information was obtained from local producers, local agencies and published documentation. Fertilizer applications were modified based on the local historical yields published by The National Agriculture Statistics Service, USDA (NASS 2017). Lists of CPs were obtained from USDA-NRCS Field Office technical Guide (FOTG) (www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=NRCSDEV11_001020)

1.2.4 Scope, Capabilities, and Limitations of NTT Applications

The capabilities and scope of NTT applications are based primarily on the range of applications afforded by APEX, its core simulation model. Currently, NTT can simulate most crop operations – any crop operations that can be simulated in APEX. NTT can also simulate several structural conservation practices. Table 2 summarizes the most common CPs simulated by NTT. The applications that are yet to be tested or incorporated in the NTT interface are marked with an asterisk.

Table 2.   Range Structural practices (conservation practices) available in NTT

Category	Application
Field operations	Tillage
	Nutrient applications (source, rate, timing, placement, fertilizer)
	Irrigation and fertigation
	Liming
	Grazing (continuous &rotational)
	Planting and harvest
	Burning
	Pesticide applications*
Structural practices	Grass Buffer
	Buffer zone and grass waterways
	Terraces
	Forest buffer
	Wetlands
	Streambank Stabilization (Restoration)
	Stream Fencing
	Pond/Water & Sediment Control Basin
	Land leveling

	Contour Buffer
	Tile drains
	Reservoir
	Drainage Water Management
	Bioreactors
	Saturated Buffers

Since APEX is a field-scale model, the results obtained from NTT are edge-of-field estimates impacted by the given scenarios.

2. Testing and Evaluating the APEX Model

Testing and evaluating the APEX model within NTT consists of sensitivity analysis and verification processes. The sensitivity analysis process is an important step to evaluate the reliability and robustness of a model, while, the verification process assists us in examining the accuracy of model output by comparison with independent experimental data.

The following procedures are preferably performed in an NTT verification process:

Calibration: this includes parameterization of the model (according to the range of parameters determined during the sensitivity analysis) using any existing independent experimental data. This step is usually limited to the period of available measured data, usually much less than the 35-year period of a typical NTT model simulation. In the calibration process, model input parameters are adjusted for the area of interest so that simulation results closely match results from measure data. There are four major stages followed to validate for region of concern (e.g., State level).

Stage 1: To obtain a general parameterization for each state/region, a series of NTT runs simulating common crop rotations, soils, and weather patterns for the region is done and the results are compared with expected crop yield and nutrient and sediment loss values obtained from the USDA National Agriculture Statistics Service (NASS 2017) and any local data.

Stage 2: During this stage, the field-scale measured data from various sources (e.g., local measured studies and collaborators) are used to finalize the regional APEX parameters. For states/regions where no field-scale measured data are available this step is skipped. However, parameters will be re-tested and updated once these data are available.

Stage 3: The final parameters obtained from stages 1 and 2 will be used to repeat the process described in stage 1. However, the various conservation practices, common to

the local region, are also simulated and evaluated with the information obtained from local resources (e.g., USDA-NRCS) for all soils and weather conditions during this stage.

Stage 4: The results obtained from stage 3 are presented to local stakeholders (e.g., local producers, agencies, and research centers) and collaborators.

2.1 Sensitivity Analysis Procedure for APEX

The model sensitivity procedure is performed to determine the most important parameters to consider in the verification process. Sensitivity analysis also helps ensure that the most appropriate range of parameters is used for various management and structural practice conditions.

Sensitivity analysis was performed for APEX within NTT by adjusting each input variable in a predetermined fashion. After each input adjustment NTT's calculation tool was run to produce the output corresponding to that input adjustment. The output data were then stored in a database file for subsequent processing. In this section of the report the procedures and results of sensitivity tests that were performed on APEX program within NTT is outlined.

The following specific adjustments were made in each input variable prior to running NTT's calculation tool.

1. Fertilizer application rate and precipitation: Fertilizer application rates and precipitation values were adjusted upwards by 50% and downward by 50%. These adjustments were made by simply multiplying the original input value by 1.5 (for the 50% upward adjustment) and by 0.5 (for the 50% downward adjustment).

2. Minimum and maximum temperature: Minimum and maximum temperature records were also adjusted upwards by 50% and downward by 50%. However, because temperature values can be negative, the adjustments were performed differently. To adjust a temperature value upwards by 50%, it was multiplied by 1.5 if its original value was positive and by 0.5 if its original value was negative. Conversely, to adjust the temperature value downwards by 50%, it was multiplied by 0.5 if its original value was positive and by 1.5 if its original value was negative.

3. Date variables: Dates for field operations were adjusted differently. For the NTT sensitivity analyses, operation dates were adjusted upwards and downwards by the following specific number of days in an iterative fashion (Table 3).

Table 3.   Date Adjustments Used in NTT Sensitivity Analyses

Iteration	Date adjustments (days)
1	0

2	-1
3	1
4	-3
5	3
6	-7
7	7
8	-30
9	30

4. Other parameters: Other NTT input and model parameters were adjusted by selecting two separate values within the range of acceptable values of each parameter. The NTT simulations were then repeated for each parameter adjustment using those two values in turn in two separate simulations. The following table (Table 4) shows the parameters adjusted, the acceptable range of values, and the values used for the sensitivity simulations.

Table 4.   Input (A) and Model (B) Parameter Values Used in Sensitivity Analyses Simulations

Parameter	Description	Range		Values used
		Lower	Upper	II
A: Input Parameters				
	Slope (m/m)	0	0.1	0.1
	Slope length (m)	0	100	80
	Erosion control practice factor	0	1	0.9
	Soil pH	3	9	9
	Soil Organic carbon concentration (%)	0.1	10	5
	Initial soluble P concentration (Mg/kg)	0	500	500
	Bulk density (Mg/m³)	0.5	2	1.8
	Fraction of organic C in passive pool	0.3	0.7	0.7
	Saturated hydraulic conductivity (mm/hr.)	0.00001	100	40
	Runoff curve number	30	90	85

	Fertilizer application depth (mm)	0	500	200
	Plant population (#/ha)	0	500	500
	RFPO	0	1	0.9
B: Model Parameters				
Parm 7	N Fixation	0	1	1
Parm 8	Soluble P runoff Coefficient	10	20	20
Parm 14	Nitrate leaching ratio	0.1	1	1
Parm 46	RUSLE C-factor coefficient	0.5	1.5	1.5
Parm 47	RUSLE C-factor coefficient	0.5	1.5	1.5
Parm 49	Maximum rainfall interception by plant canopy	2	15	15
Parm 52	Tillage effect on residue decay rate coefficient	5	15	15

For each sensitivity analysis iteration, all other variables were held fixed at their preadjustment levels while the values of the variable being investigated were adjusted using the procedure described above. Here in, as example each sensitivity analysis iteration was performed for all the soils in Delaware County, Ohio, to avoid biases that might be introduced by different soil types. Delaware County, Ohio was chosen. The results presented in the following section are averages across all soil types in Delaware County, Ohio. Results for specific soil types and for specific crop rotations would show much greater output variable sensitivity than the averages reported here portray.

The sensitivity of an output variable to a change in an input parameter is generally defined as:

$$s = \frac{\Delta y / y}{\Delta x / x} = \frac{(y_1 - y_0)/ y_0}{(x_1 - x_0)/ x_0}$$

where s is the sensitivity of the output variable y to a change in the input parameter x, x_0 is the initial parameter value with corresponding model output y_0 for the output variable of interest, and x_1 is the second value of the parameter, corresponding to a

model estimate of y_1 for the output variable of interest. Thus, ^{s} represents the

percentage change in the output variable for a one percent increase in the input parameter.

Except for operation dates, output variable sensitivities were computed for each output variable and for each input parameter. The results presented here for operation dates are simply the percentage changes in the output variables for each of the predefined changes in operation dates. In general, a safe rule of thumb is that if the percentage change in the output variable is greater than the percentage change in the input parameter (the sensitivity has an absolute value greater than 1), then the output variable is very sensitive to changes in that input parameter. In many practical applications output variables with much smaller sensitivity values are still regarded as very sensitive. The value beyond which a variable is regarded as sensitive depends largely on the specific application.

2.2 Results of NTT Sensitivity Analyses for Upper Big Walnut Creek, Ohio

Results are presented in this section for sensitivity testing that was performed using the following variables. Minimum and maximum temperature values were adjusted and simulated jointly. Dry and moist bulk density parameters were also adjusted jointly.

All other variables were adjusted separately. Results are first presented in tabular format for user and weather parameters that were adjusted 50% up and 50% down. Then the results for model parameters are presented in charts.

2.2.1 NTT Sensitivity Analyses Results for User and Weather Parameters

A.   Fertilizer application rate sensitivity:

Application rates for all fertilizer nutrients (nitrogen and phosphorus) were adjusted upward and downward by 50% for all operations. The results presented in Table 4 are averages across all soil types and all crop rotations. The summary results Table 4 suggest that soluble nutrient indicators are particularly sensitive to inorganic fertilizer application rates.

Table 4. Sensitivity of Output Variables to Fertilizer Application Rates: Average Across All Soil Types and Crop Rotations

	Percentage change in output indicator from a	
Output variable	50% increase in fertilizer rate	50% decrease in fertilizer rate
Organic N	2.1	4.8

Organic P	13.5	-9.7
Nitrate	57.7	-42.0
Soluble P	30.0	-31.1
Leached N	2.2	-9.8
Volatilized N	5.4	-5.7
Flow	-1.4	4.3
Sediment	-5.4	14.1
Total N	38.0	-25.5
Total P	17.9	-15.3

B.   Operation date sensitivity:

Field operation dates were adjusted from the original crop management information in order to determine how sensitive output indicators are to changes when field operations are performed. For this sensitivity test, all field operation dates were adjusted by a specific number of days (-1, 1, -3, 3, -7, 7, -30, and 30 days) depending on the specific iteration reached. Since field operation dates are never the same from one farm to another or across years, this input parameter is one that will certainly vary markedly within a watershed.

The results of the sensitivity analyses simulations are presented in Table 5. As expected larger changes in operation dates have much greater impacts – though not necessarily larger sensitivity ratios – than smaller changes in operation dates.

Table 5.   Sensitivity of Output Variables to Field Operation Dates: Average Across All Soil Types and Crop Rotations

Output variable	Percentage change in output variable when operation date is changed							
	-1 day	+1 day	-3 days	+3 days	-7 days	+7 days	-30 days	+30 days
Organic N	-1.3	-3.4	1.9	-3.0	2.6	0.3	4.0	-1.1
Organic P	-2.0	-3.7	1.6	-2.7	2.8	0.1	6.8	-2.1
Nitrate	-1.3	-1.9	-1.3	-0.6	2.9	-0.7	7.9	7.6
Soluble P	-1.2	-1.0	0.3	-1.4	0.9	-0.5	4.0	-0.7

Leached N	0.2	3.3	-7.0	3.8	-12.5	2.0	-27.2	10.1
Volatilized N	-1.0	-0.7	-0.3	-1.1	-0.5	1.2	-1.9	11.6
Flow	-0.6	-0.6	0.1	-0.6	0.1	0.1	-1.4	-2.0
Sediment	-1.7	-3.8	1.2	-0.3	1.7	2.1	4.2	4.5
Total N	-1.3	-2.4	-0.2	-1.5	2.8	-0.3	6.5	4.5
Total P	-1.8	-3.0	1.2	-2.4	2.3	-0.1	6.0	-1.8

C. Temperature sensitivity:

To evaluate temperature sensitivity, daily maximum and minimum temperatures were adjusted upward or downward by the same percentage in each simulation. For the temperature sensitivity runs, all the daily maximum and minimum temperature records were adjusted upward or downward (depending on the iteration) for all the years of simulation prior to the NTT simulation. The average results shown here (Table 6) indicate that all output variables are very sensitive to temperature changes. Furthermore, the results indicate that, for the UBWC, output variables are more sensitive to a 50% reduction in maximum and minimum temperatures than a 50% increase in the same.

Table 6.   Sensitivity of Output Variables to Temperature Variations: Averages Across All Soil Types and Crop Rotations

	Percentage change in output indicator from a	
Output variable	**50% increase in temperature**	**50% decrease in temperature**
Organic N	18.1	110.3
Organic P	23.3	145.4
Nitrate	258.1	310.8
Soluble P	41.2	63.4
Leached N	-63.7	3057.6
Volatilized N	-11.9	-38.0
Flow	35.0	83.9
Sediment	21.6	161.1
Total N	93.8	173.5

Total P	24.8	138.7

D.   Precipitation sensitivity:

Precipitation sensitivity was performed by adjusting the precipitation data in all daily weather records for all years of simulation prior to each NTT simulation. The 50% upward and downward adjustments in precipitation data essentially represent very wet and extremely dry weather conditions in the UBWC watershed, while maintaining the frequency of historic precipitation events. Summary output from NTT simulations suggests that all output variables are very sensitive to precipitation amounts (Table 7). Once again, the results have been somewhat modulated by averaging across all soil types and all crop rotations. The sensitivity for specific soil types or crop rotations would be higher than the results reported here would indicate.

Table 7.   Sensitivity of Output Variables to Precipitation: Average Across All Soil Types and Crop Rotations

Output variable	Percentage change in output indicator from affected by change in precipitation	
	50% increase in precipitation	50% decrease in precipitation
Organic N	100.0	-70.9
Organic P	107.9	-74.1
Nitrate	11.5	272.8
Soluble P	70.2	-46.3
Leached N	5283.4	-100.0
Volatilized N	-5.6	-33.4
Flow	98.9	-47.9
Sediment	160.2	-77.6
Total N	72.1	37.5
Total P	104.8	-71.8

2.2.2 NTT Sensitivity Analyses Results for Input and Model Parameters

The following charts display the results of NTT sensitivity simulations based on adjustments in model parameters. Each pair of plots represents output variable sensitivity charts in response to changes in various parameters. The first chart for each output variable shows sensitivities to soil and other parameters. The second chart shows sensitivity to APEX PARM file parameters.

A: Input parameters
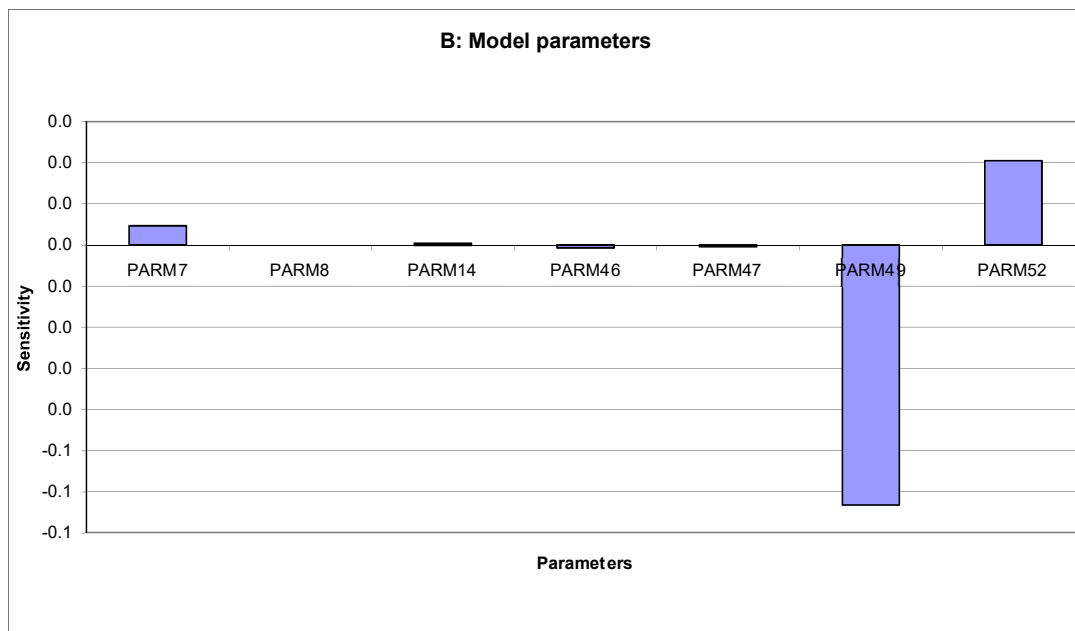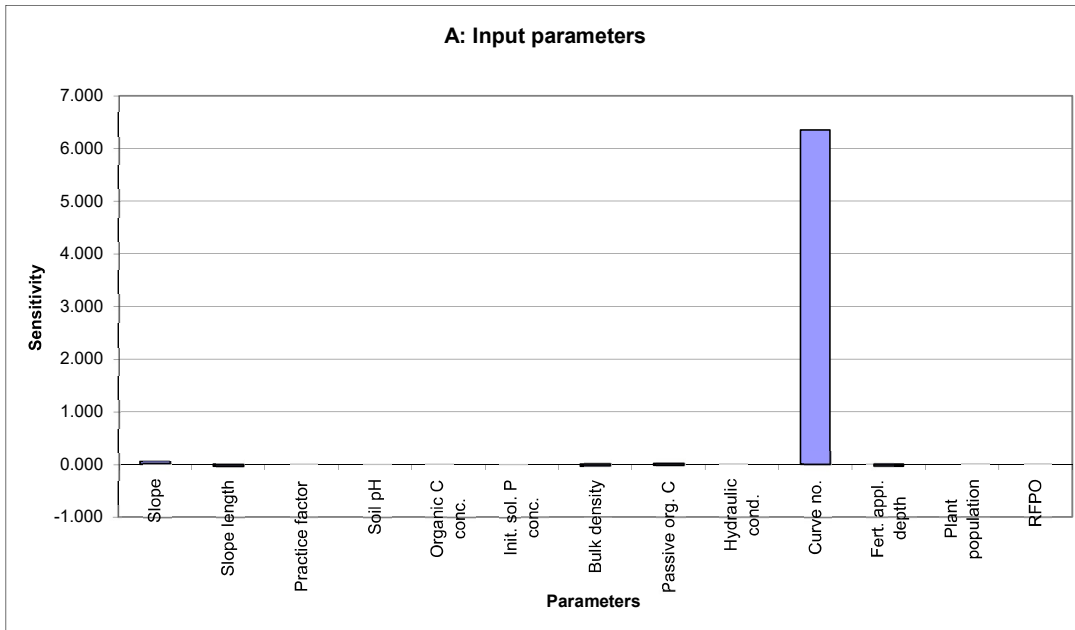
B: Model parameters

Figure 2.   Sensitivity of Edge-of-Field Runoff to NTT Input and Model Parameters

A: Input parameters

Sensitivity values for parameters: Slope ≈ 1.55, Slope length ≈ 0.22, Practice factor ≈ 1.04, Soil pH ≈ 0, Organic C conc. ≈ 0.04, Init. sol. P conc. ≈ 0, Bulk density ≈ -0.23, Passive org. C ≈ 0, Hydraulic cond. ≈ 0, Curve no. ≈ 2.04, Fert. appl. depth ≈ 0, Plant population ≈ 0, RFPO ≈ 0.

X-axis: Parameters
Y-axis: Sensitivity (range -0.500 to 2.500)

B: Model parameters

Sensitivity values: PARM7 ≈ 0.01, PARM8 ≈ 0, PARM14 ≈ 0, PARM46 ≈ -0.33, PARM47 ≈ 0.18, PARM49 ≈ -0.12, PARM52 ≈ 0.47.

X-axis: Parameters
Y-axis: Sensitivity (range -0.4 to 0.6)

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Figure 3.   Sensitivity of Edge-of-Field Sediment Losses to NTT Input and Model Parameters
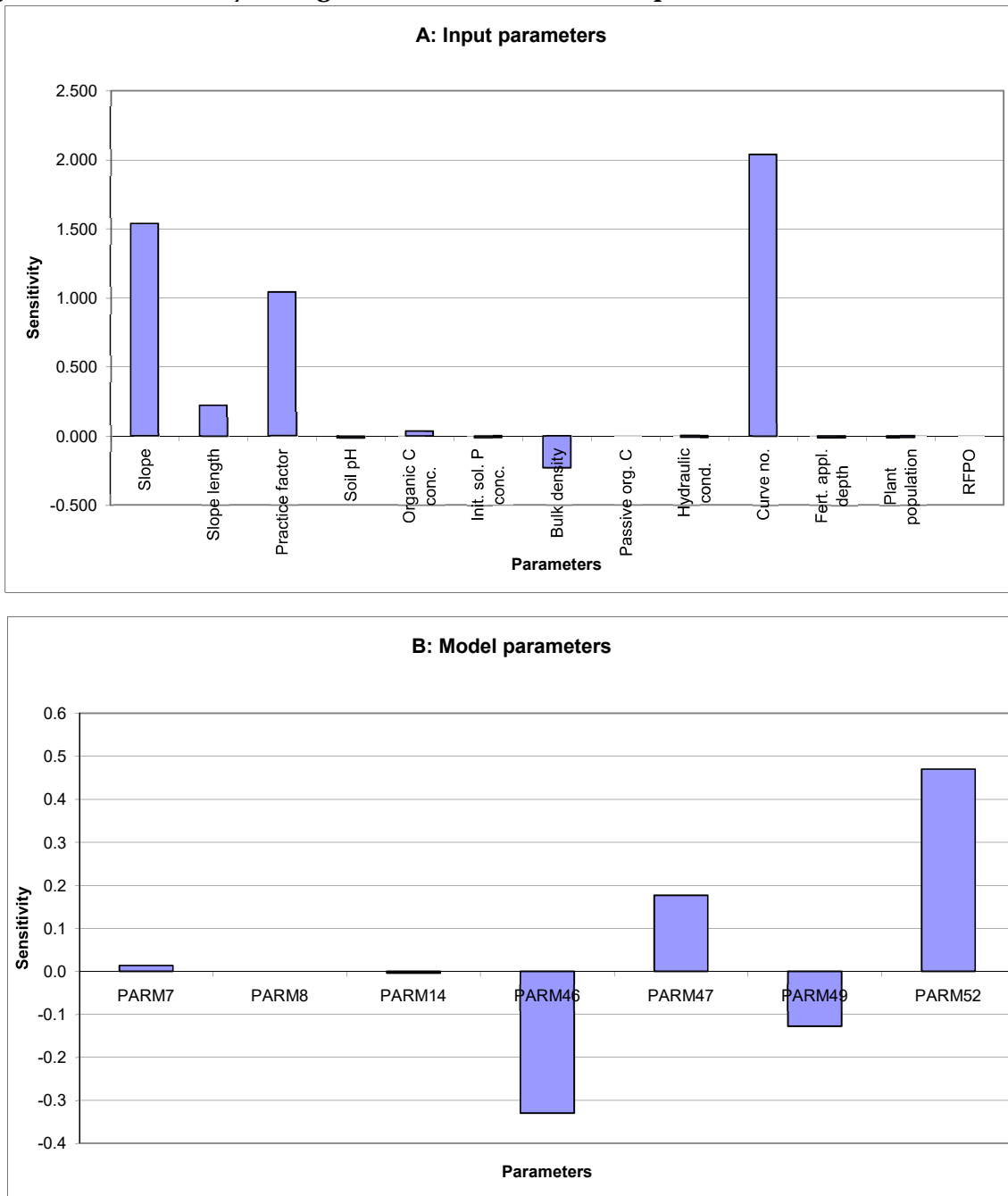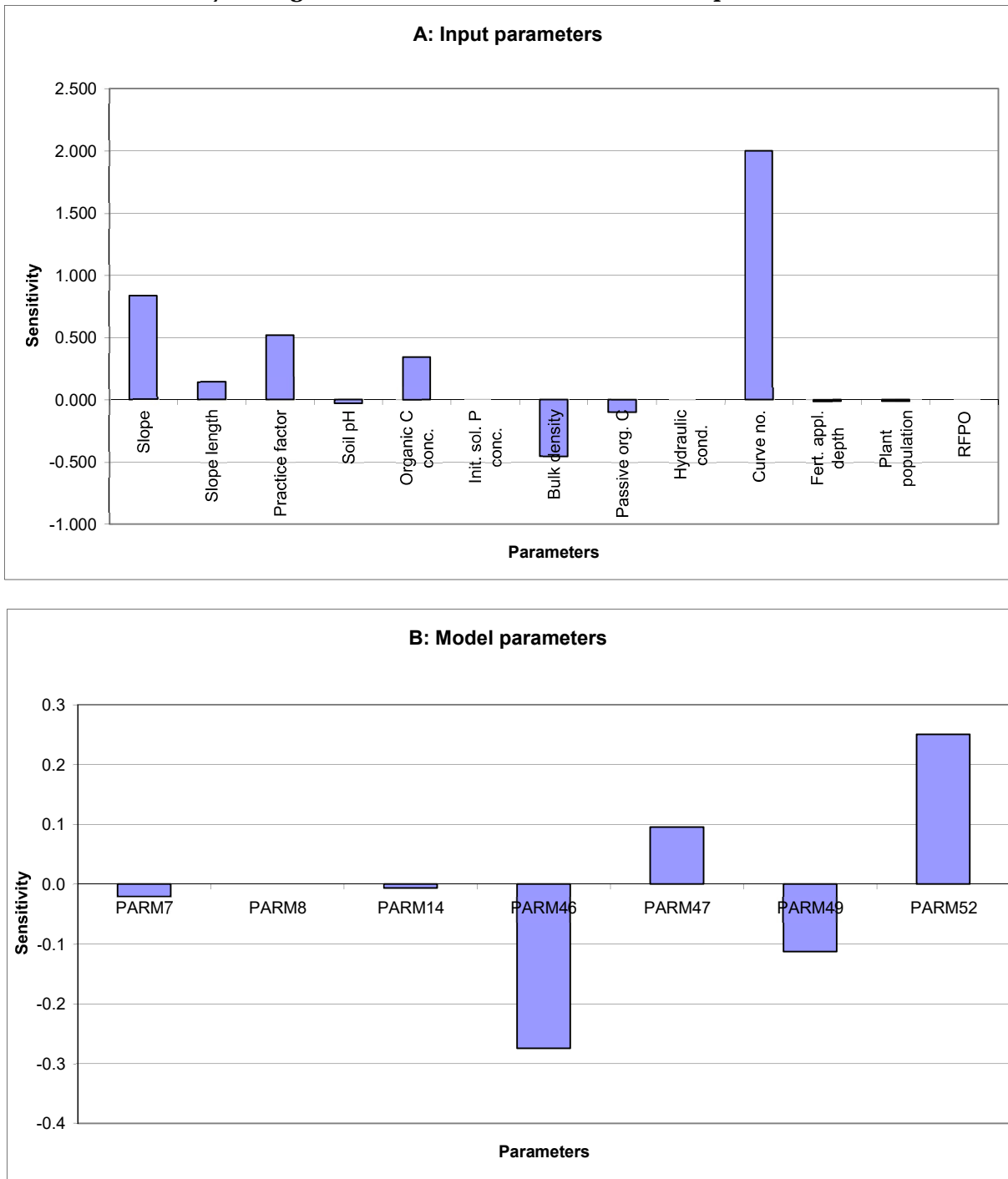
**Figure 4.   Sensitivity of Edge-of-Field Organic N Losses to NTT Input and Model
Parameters**

Figure 5.   Sensitivity of Edge-of-Field Nitrate Losses to NTT Input and Model Parameters

Figure 6.   **Sensitivity of Edge-of-Field Total N Losses to NTT Input and Model Parameters**

Figure 7. **Sensitivity of Edge-of-Field Organic P Losses to NTT Input and Model Parameters**

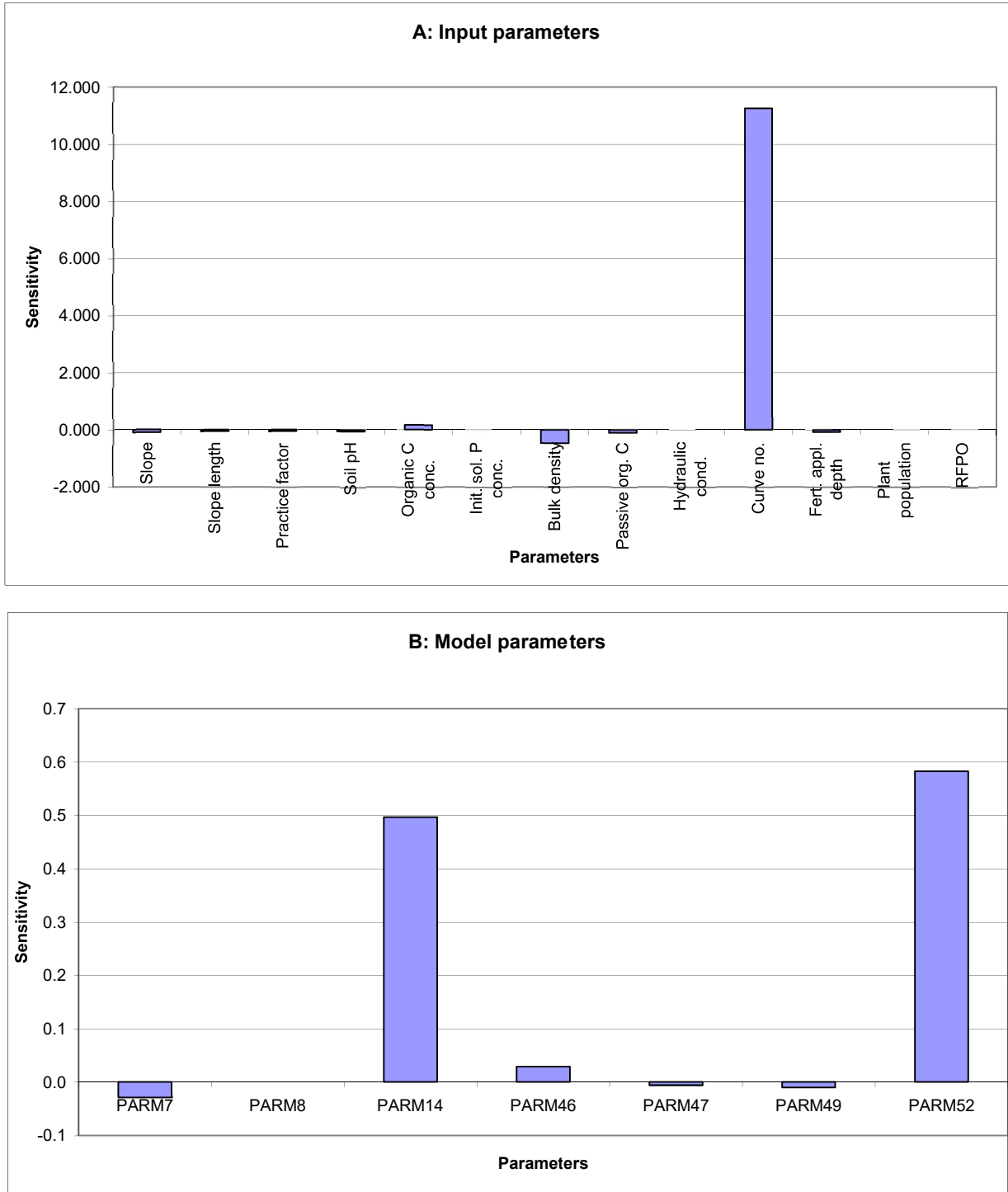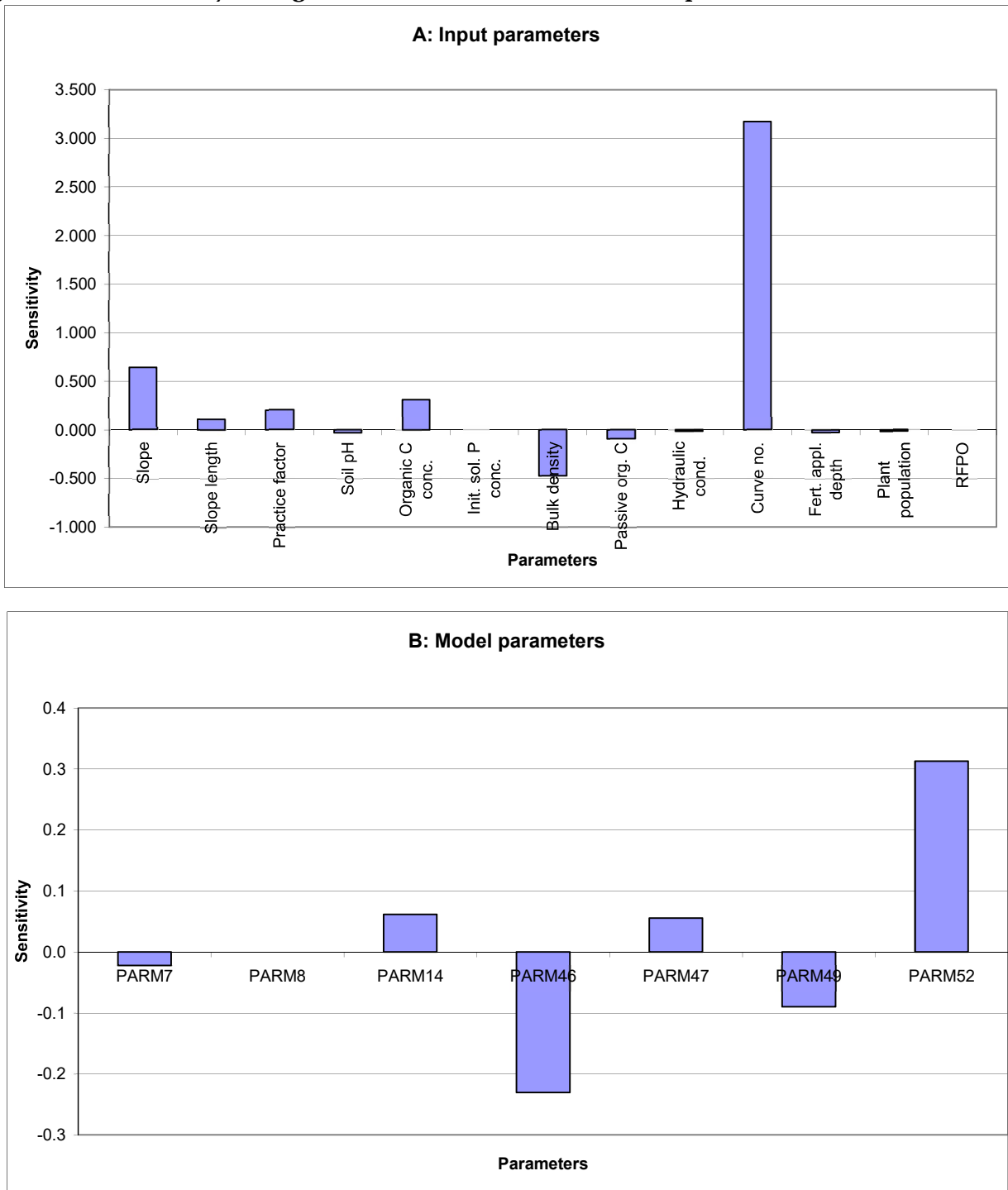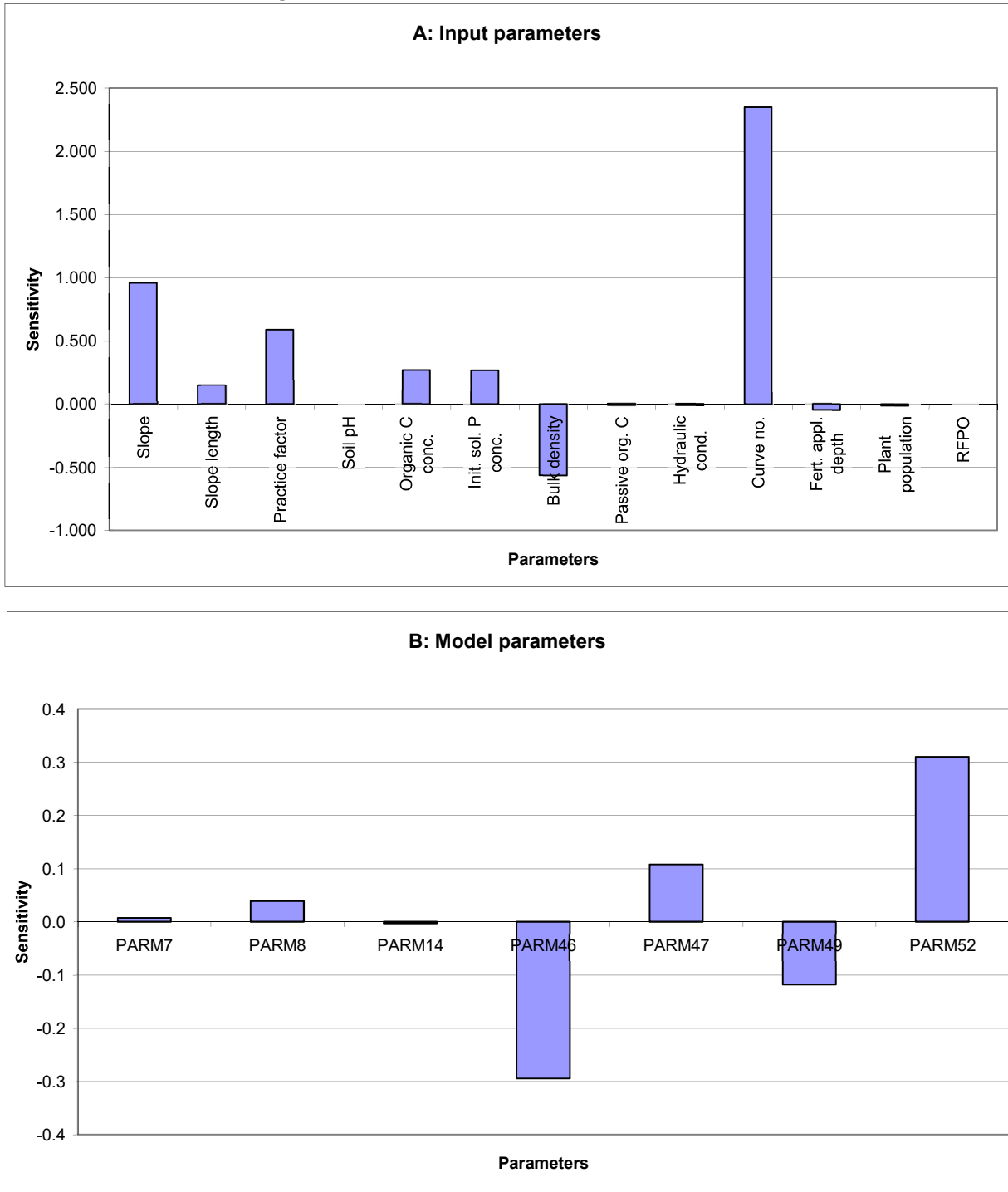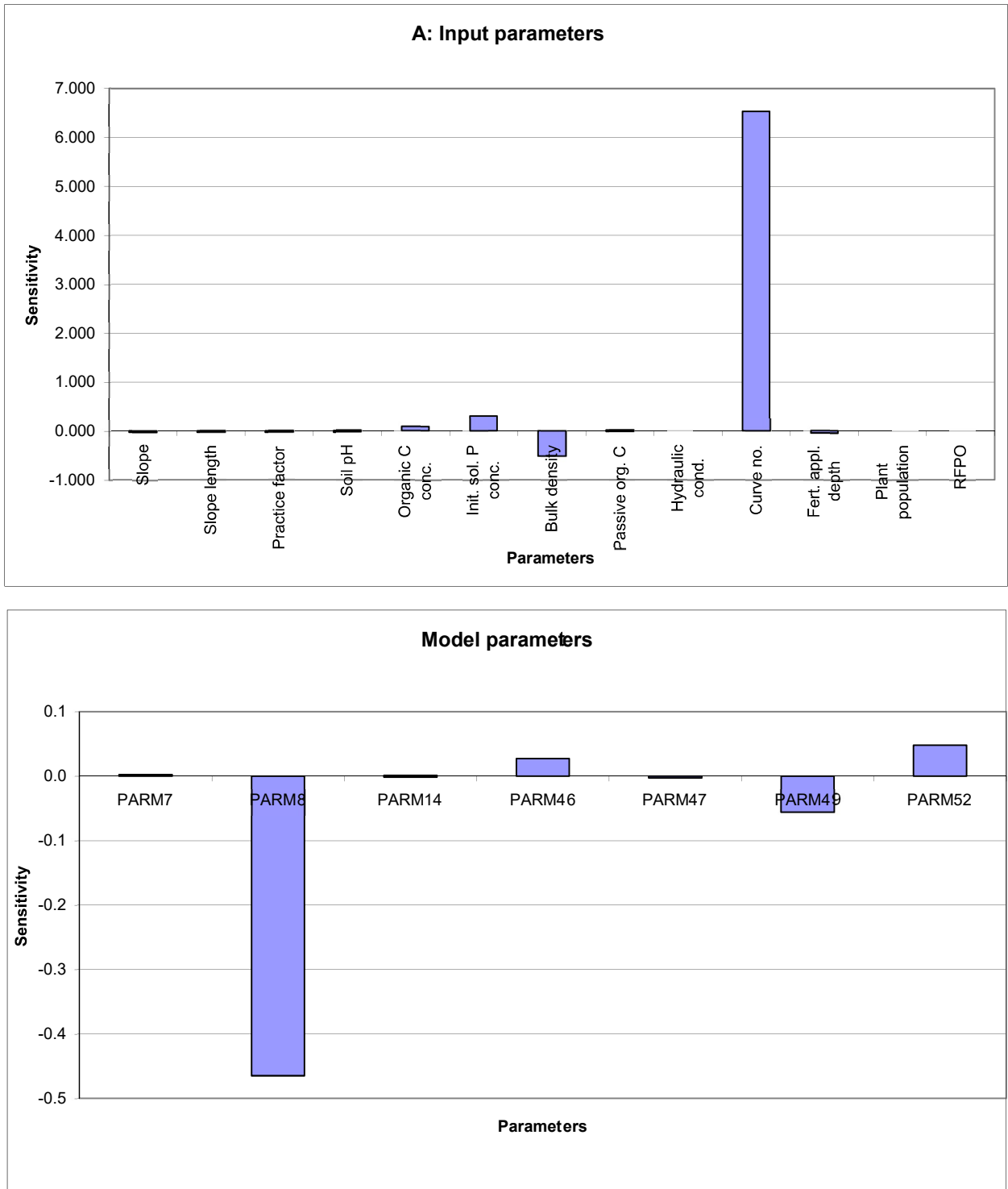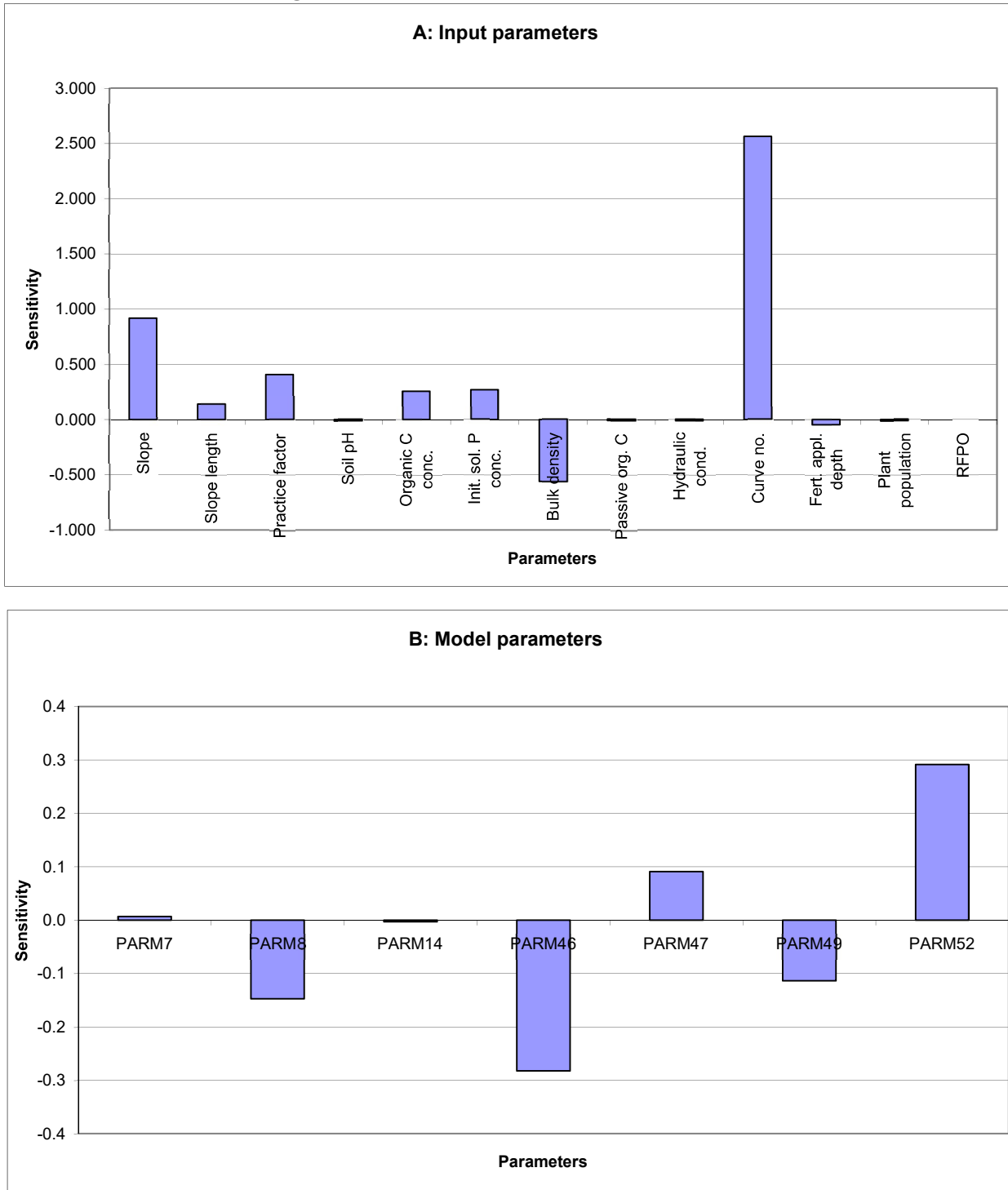**Figure 8.   Sensitivity of Edge-of-Field Soluble P Losses to NTT Input and Model Parameters**

Figure 9.   Sensivity of Edge-of-Field Total P Losses to NTT Input and Model Parameters

3. Evaluation of Conservation Practices

The NTT interface has been developed to allow users to select specific practices to be simulated on each field in a conservation plan. This listing of conservation practices available in NTT was provided in previous in Table 2. The user interface and backend database were developed to provide users the feedback on how each practice will be implemented by NTT to parameterize APEX. As much as possible, the interface and database were designed to make the necessary parameter adjustments to APEX automatically, with limited additional user interaction. For some types of practices, the user must provide additional information (such as the specific location of a grassed waterway) in order for APEX to be accurately parameterized. For these types of practices, NTT provides additional user feedback as guidance for properly setting the additional inputs.

In the NTT program, conservation practices are categorized into the structural practices (STPs) and non-structural practices (NSTPs). In general, NSTPs include practices such as tillage, nutrient management, cropping system changes, and other cropland activities based on knowledge and experience of farmers. In other words, NSTPs are management practices that a farmer or land manager implements and are usually based on annual decisions, which involve changing the way cropland is managed to achieve production or conservation goals. In contrast, STPs are considered as more permanent practices and require more than annual management decisions and usually require engineering designs, surveying, and other technical work.

A wide variety of conservation practices have been proposed for reducing sediment and nutrient losses in runoff from agricultural lands. In many instances, field experiments suggest much higher levels of effectiveness than what is realized in practice, particularly at the watershed outlet. To enhance appreciation of the variability of these practices, the following sections provide a brief outline of the most prevalent conservation practices and the ranges of effectiveness associate with them.

3.1 Simulation of Non-Structural Practices (NSTPs)

NTT provides flexible options for simulating alternative tillage practices as well as nutrient applications on crop and/or pasture lands at the "Management Scenarios" page.

The underlying APEX model within NTT simulates each individual field operation separately. Nutrient applications are specified by date of application, frequency within a year, rate, form (i.e., dry or liquid commercial fertilizer and/or solid or liquid manure application), and mode (i.e., surface or injected) of application. A fertilizer data file that is modified by the NTT program allows users to specify any combination of nitrogen and phosphorus in each nutrient application. Any number of nutrient applications can be made on each day of the simulation period. Thus, the tool provides great flexibility for evaluating a wide range of nutrient management practices including split nitrogen applications, reduced nutrient rates, and other changes in timing, frequency, as well as method and depth of nutrient application.

The APEX model within NTT simulates the fate and transport of nutrients and the resulting impacts on crop yields, sediment losses, and associated nutrient losses from the field.

NTT also provides flexibility in simulating tillage operations by selecting the tillage operation from the list of "tillage operation" list. The impacts of tillage operations on soil conditions are controlled by various APEX parameters as well as a tillage data file that contains corresponding parameters for each tillage operation. The tillage parameters can be modified, and these parameters control tillage depth, harvesting efficiency, field efficiency of tillage operations, and many other factors that indicate how each tillage pass is performed on the field.

Tillage practices as well as nutrient applications are part of the major NSTPs on cropland or pasture. Tillage operations are done mainly as part of the preparation of land for planting, weed control, and/or harvesting operations. These operations also impact the amount, mode, and form of nutrient (fertilizer and/or manure) and herbicides applied. Tillage operations including the depth, timing, frequency, and type also affect water quality and quantity and crop production. Conservation tillage (CT) practices can reduce soil erosion from wind and water. CT can also positively impact water quality by reducing nutrient losses (both soluble and insoluble).

Planting systems, such as no-till, that leave the soil surface undisturbed until the time of planting consistently leave the highest levels of crop residue and involve planting or drilling seed into a narrow seedbed prepared by coulters (no-till), ridge-scrapers (ridgetill), disk openers and other attachments. These systems result in lower loss of sediment and sediment-bound nutrients, higher water uptake by the plant, and higher soil organic matter due to residues remaining on the soil surface. CT systems change the soil's physical properties, such as an increased infiltration rate caused by the development of macropores in the soil created by earthworm activity, soil cracking and root growth. Similar to nitrogen and phosphorus, most herbicides attach to soil particles or dissolve in surface runoff. Thus, CT also effectively reduces herbicide runoff. Most studies show that no-till systems usually reduce herbicide runoff by up to 70 percent compared to conventional systems.

Other farm management practices such as cover crops, contour buffer strips, various crop rotations, change of land use. Prescribed grazing, and many combinations of NSTPs and STPs could be simulated (evaluated) in NTT. In the following sections some of these practices will be discussed.

3.2 Simulation of Structural Practices (STPs)

A number of the farm structural practices described in the USDA-NRCS "National Conservation Practice Standards (www.nrcs.usda.gov/wps/portal/nrcs/detail/nationa/technical/?cid=NRCSDEV11_001020) can be evaluated by NTT. These structural practices address soil management through stabilization and control of water and soil on and off agricultural fields. The following practices are among the most common management of STPs that can be simulated in NTT:
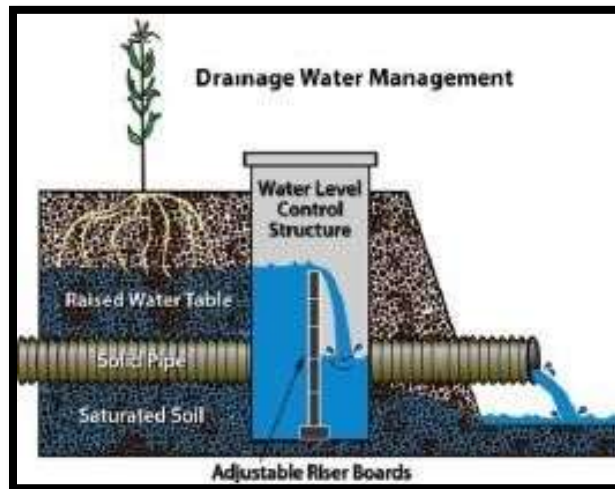
3.2.1 Tile Drainage (DRT)

Figure 10. A typical agricultural tile drainage system (http://www.ny.nrcs.usda.gov)

Tile drainage is a practice for removing excess water from the subsurface of soil intended for agriculture. Drainage brings excessive soil moisture levels down for optimal crop growth. Tile drainage is often the best recourse for reducing high subsurface water levels to improve crop yields. Too much subsurface water can be counterproductive to agriculture by preventing root development, and thereby inhibiting the growth of crops. Excessive water also can limit access to the land, particularly by farm machinery.

Tile drainage simulation in NTT increases subsurface flow, which may provide an avenue for increased nutrient losses, particularly nitrate-nitrogen (NO3-N) and soluble P, in subsurface flow. Drainage via underground drainage systems is treated as a modification of the natural lateral subsurface flow of the area. Drainage is simulated by the user indicating the depth of the drainage system (TD) and the time required for the drainage system to reduce plant stress (DFT). The value of DRT is set at two-day as a default in NTT for simulating tile drainage. Saleh (2021) recently modified the current APEX tile drain routine to correctly simulate the drainage water in soil profiles. **Tile Drainage Management options:**

There are three management options available in NTT to manage drainage water (Saleh, 2021):

1. **Tile Bioreactors:** The primary purpose of a bioreactor is to remove nitrates from subsurface tile drainage water at the edge of a field prior to the water entering a ditch or a stream. Bioreactors do not interrupt any practices occurring in the field, nor do they change the effectiveness of tile drainage systems. A bioreactor is considered an edge-of-field practice.

   According to Iowa Department of Natural Resource Guidelines

(https://www.iowadm=nr.gov/Portals/idnr/uploads/water/wse/isu_reducingnutrientloss.pdf) the default nitrate reduction value for this practice is set at 43%.

2. **Drainage Water Management**: The process of managing the drainage volume and water table elevation by regulating the flow from a surface or subsurface agricultural drainage system. This practice is applicable to agricultural lands with surface or subsurface agricultural drainage systems to allow management of drainage volume and water table by changing the elevation of water level at the outlets. This practice is used to accomplish one or more of the following purposes:

   • Reduce soluble N and P loadings from drainage systems into downstream receiving waters.
   • Improve productivity, health, and vigor of plants.
   • Reduce oxidation of organic matter in soils.

Drainage water management in NTT simulation is as follows:

A. Tile drainage depth (IDR) adjustment during the cropping season.

B. Tile Drain Open Period: The period of time in a year when the tile drain is open. Otherwise it is open all year.

C. Adjustments made in NTT for parameter 83 include conversions of depth in feet entered by the user to meters and a parameter value assignment based on the converted value. The following table shows the adjustments:

Depth (Meters)	Parameter Value
Depth ≤ 0.1	0.0
Depth ≤ 0.2	0.2
Depth ≤ 0.3	0.4
Depth ≤ 0.4	0.6
Depth ≤ 0.5	0.8
Depth ≤ 0.6	1.0
Depth ≤ 0.7	1.2
Depth ≤ 0.8	1.4
Depth ≤ 0.9	1.8

Depth ≤ 1.0	2.0
Depth ≤ 1.2	2.1
Depth ≤ 1.4	2.2
Depth ≥ 1.6	2.4

D. Adjustment of Parameter 83 in the following equation that estimates drainage system lateral hydraulic conductivity and is calculated in APEX (Williams et al., 1985) as:

HCL = (Parameter 83 * SATC, (PO – S15) / 24 * DRT

Where:

HCL – lateral hydraulic conductivity

SATC – saturated conductivity

PO – porosity

S15 – wilting point

DRT – time for drainage to reduce plant stress

3. **Saturated Buffer:** Subsurface tile drainage systems are a transformative landscape feature to improve agricultural productivity in the US Midwest, but this infrastructure has been linked to chronic nitrate-nitrogen (N) pollution.

A. saturated buffer is relatively new edge-of-field conservation practice to reduce nitrate loads from tile-drained areas, where, rather than drainage water flowing directly to the stream or ditch through the outlet pipe, the drainage water is diverted to flow as shallow groundwater through a vegetated buffer's soil. A water level control structure and perforated diversion pipe are used to reroute the drainage water into the buffer subsurface, essentially reconnecting the stream buffer's hydrology (Jaynes and Isenhart, 2014). Nitrate removal in a saturated buffer occurs through plant uptake, microbial immobilization, and denitrification (Jaynes and Isenhart, 2014, 2018; Davis et al., 218). During large drainage events, a portion of the drainage water will overtop the control structure's stop logs and flow directly to the stream, thus limiting drainage backup in the field (Jaynes and Isenhart, 2014).

Potential saturated buffers (i) are located in tile-drained areas; (ii) do not need to be existing vegetated buffers, although well-established perennial vegetation

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aids in nitrate removal (Jaynes and Isenhart, 2018); (iii) have soils containing at least 1.2% soil organic matter (SOM) in the top 76 cm so the soil is carbon sufficient to fuel denitrification; and (iv) do not have high conductivity subsoil layers (e.g., no sand lenses or gravel layers) so the buffer can remain saturated to promote anoxic conditions required for denitrification (USDA—NRCS, 2016).

NTT calculates this practice using the following steps:

a. NTT routes the drainage water and nitrate through a filter strip. Therefore, it is required that user establish a Grass Buffer/Forest Buffer for the project scenario (Please refer to Section 3.2.2 and 3.2.3).
b. NTT delivers a portion of the field drainage water directly to the stream and the remaining as shallow subsurface water into the Grass Buffer/Forest Buffer area.
c. The routed water to the Grass Buffer/Forest Buffer area is treated by soil OC before being returned to the stream by the tile drainage system.

3.2.2 Grass Buffer

Figure 11. An agricultural field with a Grass Filter Strip at the edge of the field (http://www.oh.nrcs.usda.gov)

A Grass Buffer is an area of vegetation, generally narrow in width and long across the downslope edge of a field, that slows the rate of runoff, allowing sediments, organic matter, and other pollutants that are being conveyed by the water to be removed by settling out. They are generally in locations when runoff water leaves a field with the intention that sediment, organic material, nutrients, and chemicals can be filtered from the runoff water. Grass Buffers are also known as vegetative filter or buffer strips. Strips slow runoff water leaving a field so that larger particles, including soil and organic material can settle out. Due to entrapment of sediment and the establishment of vegetation, nutrients can be absorbed into the sediment that is deposited and remain on the field landscape, enabling plant uptake.

A Filter Strip/Grass Buffer is specified in NTT by indicating its width and the type of crop planted. The width of filter strip is used to calculate its area. The entered FS area along with its width by user will identify the FS shape. If the user indicates that the FS is included in the AOI, then the area of filter strip is subtracted from the main farmland and is simulated as a separate field (i.e., subarea) and is considered a routing reach. If the FS is not included in the AOI, then the FS is simulated as a separate field and the area of the main farmland is kept as is. Flow, sediment, and nutrients are routed from the farmland (i.e., upland field) to the filter strip before leaving the edge of the farmland.

In NTT, filter strips function by providing for better infiltration of soluble nutrients, trapping of sediment, and increasing uptake of water and nutrients by the filter strip vegetation. One side-effect of filter strip (when FS is included in the user's AOI) is the reduction of crop yield because of removal of land for the filter strip. Another side effect is the high concentration of sediment in the filter strips area under excessive upland soil erosion when the proper land management is not practiced in the farmland. Management for the FS includes planting of a proper FS crop that can be selected from a dropdown list by the user. Also, the fraction of upland flow that goes through the FS need to be entered by the user. Finally, the FS field's Manning's n, channel C (USLE Crop Management Channel Factor, RCHC) and Channel Manning's n are all adjusted according to the recommended values obtained from APEX to reduce channel erosion in the vegetation strips under this scenario. The modified upland field area is used to adjust the final field crop yield.

3.2.3 Forest Buffer (FB)

Figure 12.   An image of FB (http://www.oh.nrcs.usda.gov)

FB is a grassed and forested (predominantly trees and shrubs) zone of land adjacent to a body of water such as a river, stream, pond, lake, or marshland. The FB includes a grass filter strip or grass buffer, and an area of forest buffer that includes planted pine as well as a perennial grass. The routed water, sediment, and nutrients from the upland first passes through grass filter strip and the forested area trap sediment and increases infiltration, thereby reducing sediment and nutrient losses. Plant uptake of nutrients by vegetations (trees and grass) in the FB also reduces nutrient losses. FB is

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simulated in a manner like the filter strip practice with the additional assumption that there are trees and shrubs along the length of the FB zone in addition to the grasses that are growing in the simulated area.

Similar to FS, field (FB) Manning's n, channel c (RCHC) and Channel Manning's n are all adjusted to reduce channel erosion under this scenario.

Flow from cropland is routed across the grass strip and then routed through the forest buffers. Both grass and forest zones are simulated as floodplains. In the FB the fraction of surface runoff, simulated as overland flow (FFPQ; 0-1/0) is defined by the user. The remaining surface flow is assumed to pass through small channels, which are parameterized in APEX as a single reach channel. Slope length for the FS and FB are computed based on the upland field slope. Similar to FS, area of upland field is adjusted by subtracting the area of the FB if the user indicates that the FB is included in their AOI. The modified upland field area is used to adjust the final crop yield.

3.2.4 Grassed Waterways (GW)

Figure 13.   An example of agricultural land with GW system (http://www.wi.nrcs.usda.gov)

Grassed waterways (GW) are natural or constructed vegetated channels that conduct and dispose of overland flow from upstream areas. The vegetative cover slows the water flow, minimizing channel surface erosion. The GW can reduce sedimentation of nearby water bodies and pollutants in runoff. The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and sorption by the soil. Entrapment of sediment and the establishment of vegetation allow nutrients to be absorbed into trapped sediments to remain in the agricultural field rather than being deposited into waterways.

GWs typically work by increasing surface roughness which reduces the velocity of flow. GW is simulated as a separate subarea in NTT. Therefore, a separate management file with a new selected crop by users is generated for this subarea. The input width of the waterway by user is used to calculate its area. The area of upland field is adjusted by subtracting the area of the GW. Therefore, similar to FS, this results in reduction of total field crop production. The modified upland field area is used to adjust the final

crop yield. Also, field (grassed waterway) Manning's n, channel c (RCHC) and Channel Manning's N are all adjusted to reduce channel erosion in the vegetation strips under this scenario.

3.2.5 Contour Buffer Strip (CBS):

Figure 14. **An image of CBS farming system (http://www.wi.nrcs.usda.gov)**

Contour buffer strip (CBS) is an area of land maintained in permanent vegetation (such as perennial grass) that helps to protect soil and water quality on agricultural lands. Buffer strips trap sediment and enhance filtration of nutrients and pesticides by slowing down runoff that could enter the surface waters.

The CBS practice is usually costly due to the land area taken out of production and is adopted only for the situations when soil loss and nutrient losses are jeopardizing the land health and sustainable crop production. The area of upland field is reduced in the contour buffer strip area which ultimately results in lower crop production. However, this practice could provide benefits in terms of the significant reduction in nutrient and sediment losses leaving the farmland area.

The contour buffer strip is simulated based on the width of the buffer and main field crop and management practices, and the type of the crop planted and management on the buffer strips. The number of strips and area are calculated according to the total field area and the widths of buffer and main field, which are inputs to the model. The surface and subsurface flow are routed from one strip to another until it reaches the edge of the field. Also, the grassed-buffer strip Manning's n, channel c (RCHC) and Channel Manning's n are all adjusted to reduce channel erosion in the vegetation strips under this practice. Note: for each subarea found in NTT each contour buffer strip will adjust Manning's n, channel c (RCHC) and Channel Manning's n, to the same values as the previous subarea. The area of upland field is adjusted by subtracting the total area of the CBS (permanently vegetated) portion of the field. The modified upland field area is used to adjust the final crop yield.

3.2.6 Stream Fencing (Livestock Access Control) (SF)

Figure 15.   A stream in a pasture land, protected from animal access by a SF (http://www.pa.nrcs.usda.gov)

Stream fencing (SF) is used to keep the animals out of streams in order to improve the water quality and reduce streambank erosion. Fencing will prevent animal defecation in streams, which constitutes a direct contribution of manure, manure nutrients, and pathogens to the surface water resource. In addition, stream fencing prevents bank erosion and protects the aquatic habitat. The presence of stream fencing also creates a vegetated area between the fence and the stream that serves as a filter strip. This will help to improve the water quality as secondary CP.

In NTT, SF is only available as a STP if the user includes grazing operations in the scenario and animals have access to the stream. NTT uses user inputs on type of animals, number of AUs, days grazed and hours per day in the stream as inputs for simulating SF. From these inputs NTT calculates the daily amounts of manure produced by the selected animal (including horses, dairy cows, swine, cattle, sheep, and goats), that is deposited into the stream. In NTT, stream fencing eliminates or reduces direct nutrient deposition in streams by animals as point source and stops the destabilization of stream banks that is often caused by livestock traffic. This done by simulating the area between the fence and edge of stream as SF. The user has the choice to describe the area, efficiency, and the type of grass growing for the new SF. It is important to know that NTT would not allow the selection of another SF for the same stream channel from the "Management Scenarios" page.

The defecated manure from animals in the stream is considered as a point source of nutrients in the water. The amounts of nutrients (N and P) in solid and liquid forms are calculated based on the type of manure produced from the specific animal (provided by the user or default values) and the period of the year they spend a portion of their time in the stream.

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3.2.7 Terrace System (TS)

Figure 16. **A steep landscape with TS to prevent or minimize soil erosion (http://www.ga.nrcs.usda.gov)**

A terrace system (TS) is a leveled section of a hill sited cultivated area, designed as a method of soil conservation to slow or prevent the rapid surface runoff of water. This practice is applied as part of a resource management system designed to reduce erosion by reducing slope length and retaining runoff for moisture conservation. This practice applies where soil erosion caused by water and excessive slope length is a problem, excess runoff is a problem, and there is a need to conserve water.

Terraces decrease hill slope-length, reduce formation of gullies, and intercept and conduct runoff to a safe outlet thereby reducing sediment content in runoff water. Often, in application the landscape is formed into multiple terraces, given a stepped appearance.

Terracing in NTT is simulated by reducing the "erosion control practice factor" (PEC) and CN2 by 10%. The PEC factor reduction is based on field slope. Table 8 provides the PEC factor reduction as related to field slope.

Table 8. **Upland field slope and PEC factor**

Upland Field Slope % (SLP)	PEC Factor (0-1)
0 to 2	0.60
2.1 to 8	0.50
8.1 to 12	0.60
12.1 to 16	0.70
16.1 to 20	0.80

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20.1 to 25	0.90
>25	1

3.2.8 Pond (PND)

Figure 17.   An example of pond (http://www.il.nrcs.usda.gov)

A pond (PND) is a water impoundment made by constructing and embankment or by excavating a pit or dugout. Ponds are usually constructed to provide water for livestock, fish and wildlife, recreation, fire control, development of renewable energy systems and other related uses, and to maintain or improve water quality.

In NTT a pond is simulated as an in-field practice. The fraction of the field controlled by ponds (FCO) is the only input data required for simulating ponds. The water, sediment, and nutrient storage and release area calculated in NTT daily.

3.2.9 Streambank Stabilization (Restoration) (SBS)

Figure 18.   A type of SBS practice with rock protection (http://www.nrcs.usda.gov)

Erosive stream banks are re-shaped and seeded, and sometimes protected with rock rip-rap or seeded with bio-engineering materials under this management practice.

Stabilizing the streambanks protects water quality, improves fish habitat, and the vegetation provides habitat for birds and small animals.

Upon the selection of this management practice by the user, the channel USLE C and K along with Channel Manning N factors are adjusted in NTT to reflect the effect of this management practice on water quality in the stream channels.

3.2.10 Land Leveling (LL)

Figure 19.   Land leveling as part CP to reduce sediment and nutrient losses (http://www.la.nrcs.usda.gov)

LL will facilitate the efficient use of water on irrigated land and is accomplished by reshaping the surface of land to be irrigated, to planned lines and grades. To simulate this management practice in NTT, users need to provide the percent reduction of the average field slope (SLP) after the land treatment. NTT will use the new average field slope for simulating the leveled field.

3.2.11 Grazing (GRZ)

Figure 20.   An example of a dairy cow grazing operation (http://www.nrcs.usda.gov)
Grazing operations also have significant effects on nutrient and sediment losses. Appropriate grazing management will serve to reduce denuded areas, and minimize soil loss, and enhance pasture establishment.

Grazing operations in NTT can be simulated for different types of animals (including beef cattle, dairy cows, horses, goats and sheep). Each simulated farm is represented as an owner (or even multiple owners) in NTT each owner may have up to ten herds or groups of animals. Each herd is characterized by forage intake rate in kg/head/day, grazing efficiency (accounts for waste by trampling, etc.), manure production rate from defecation in kg/head/day, urine production in liters/head/day, and carbon and soluble and organic N and P fractions in the manures.

Grazing may occur throughout the year or may be allowed only at certain times. There are two types of grazing managements available in NTT:

1. **Continuous Grazing:** Under this system, grazing may be started and stopped for any fields by using a start and stop grazing command in the management file. Grazing corn stubble after harvest is a good example of initiating and stopping grazing. In addition, grazing stops automatically when a user adjustable "grazing limit" for each herd is reached. The "grazing limit" is the minimum vegetation biomass cover. However, this limit might be adjusted for different management practices. In NTT user provides the following information:

    a. Start and end dates of grazing on the field. For example, January 1 to December 30 of the selected year.
    b. Type of animals being grazed on the field.
    c. Total animal units (AUs) being grazed on the field (scenario AOI). AUs definitions are based on the concept that a 1000-pound (454 kg) cow is one animal unit.
    d.   Hours grazed/in field per day.

    e.   Animals have access to a stream.
        1)   Hours per day in stream.

2. **Rotational Grazing:** The rotational grazing operation, unlike continuous grazing, assumes that the pasture is divided into paddocks and that livestock are moved through the paddocks as needed. Thus, each paddock is given a recovery period between grazing events, improving vegetative cover. The rotation grazing is an automated process in NTT and requires the following user's input.

    a.   Total hours per day that animals are grazed in the field.
    b.   Start and end dates of grazing on the field.
    c.   Type of animals being grazed on the field.
    d.   Total animal units (AUs) being grazed on the field (scenario AOI).
    e.   Total hours per day that animals are grazed in the field (see continuous grazing for examples).
    f.   Number of days livestock will spend in each paddock before being rotated to a new paddock.
    g.   Number of days that the pasture is rested between rotational grazing cycles.

    h.   Animals have access to a stream.
        1)   Hours per day in stream.

3.2.12 Irrigation and Fertigation

Figure 21.   A center pivot (sprinkler) irrigation, an example of one of the different types of irrigation simulated in NTT (http://www.al.nrcs.usda.gov)

Irrigation plays an important role in crop production and in protecting delicate crops (e.g., vineyards) from freezing events during winter. Irrigation can cause runoff and consequently loss of nutrient and sediment from the field.

NTT simulates four types of irrigation (sprinkler, drip, furrow/flood, and furrow diking) by following two methods:

1. **AUTOMATIC**: If automatic irrigation is used, the amount applied per application is equal to the maximum single application amount and frequency set by the user for each farm. Under auto-irrigation option, the irrigation is applied when the irrigation trigger (frequency and plant water stress level) is reached. Frequency is the days when user is irrigating and water stress is simply the percentage of plant-water stress (0-100%) set by the user. For instance, the user might wish to make irrigation available to the plant at 0.0 percent stress level (IEF = 0), however, might not be able to irrigate every 14 days. The irrigation characteristics in NTT set by user governs the auto-irrigation process in NTT.
2. **MANUAL**: If manual irrigation is used, irrigation is applied according to the amounts and dates specified by the user in the Operations page.

Runoff based on irrigation efficiency (EFI) is removed through runoff prior to infiltration into the soil. EFI default values are: furrow = 65%, sprinkler/center pivot = 70%, drip = 85%, and furrow diking = 90%. If the amount of irrigation is greater than the amount of water needed to bring the soil to field capacity, the model will run off the remaining water based on irrigation efficiency. For instance, for furrow irrigation at 55% efficiency 55% of applied water will infiltrate into the soil and remaining 45% will be lost as surface runoff., fill the profile to field capacity and the remaining water will be percolated through the soil. Soluble nutrients are leached through the soil or removed with runoff.

Fertigation by NTT is like general irrigation; however, user can apply N by entering the annual applied N rate (lbs./ac) with irrigation water. NTT also can provide the auto N application in fertigation process. In this case you should set the N concentration at 0.0.

Furrow dikes are a type of surface (furrow) irrigation system. Furrow dikes are a small earthen dam formed periodically between the ridges of a ridge-furrow tillage system or, alternatively, small basins created in the loosened soil behind a ripper shank or chisel. The furrow diking practice is known by many names, including tied ridges, furrow damming, basin tillage, basin listing, and micro basin tillage. The dikes or basins store potential runoff on the soil surface, allowing the water to infiltrate thus, decreasing storm or irrigation runoff and increasing storage and plant available water in the soil. The required input data for furrow diking are similar to those of auto irrigation and are easily entered in the NTT management screen. The "Furrow diking safety factor" (FDSF) is entered by NTT by default to zero for APEX. FDSF is the fraction of furrow dike volume available for water storage. FDSF controls the volume of water than can be stored in the dike before water tops over the dike. This variable is used to account for uncertainty in the volume of the furrow dike.

3.2.13 Reservoir (RV)

Figure 22.   A sample of reservoir as conservation practice (USD-NRCS)

Reservoirs are constructed on the farmland by producers to treat wastewater and contaminated runoff from agricultural processing, livestock, and aquaculture facilities. A well-constructed reservoir could improve the quality of storm water runoff or other contaminated water by withholding runoff water. The reservoir is simulated at the outlet of a farm. The following information is needed by the user to simulate reservoirs in NTT program.

Table 9.   The parameters required input by user to simulate reservoir

Parameter	Definition
RSEE	Elevation at emergency spillway (ft)
RSAE	Total reservoir surface area at emergency spillway elevation (RSEE) (Ac)
RSVE	Runoff volume from reservoir catchment area at emergency spillway elevation (inches)
RSEP	Elevation at principal spillway (ft)
RSAP	Total reservoir surface area at principal spillway elevation (RSEP) (ac)
RSVP	Volume at principal spillway elevation in (in)
RSV	Initial reservoir volumes in (in)
RSRR	Average principal spillway release rate in days. Days to draw down from the emergency spillway to the principle spillway volume
RSYS	Initial sediment concentration in reservoirs in (ppm)
RSYN	Normal sediment concentration in reservoirs (ppm)
RSHC	Hydraulic conductivity of reservoir bottoms (mm/h)
RSDP	Time required in days for the sediment in the reservoir to return to the normal concentrations following a runoff event
RSBD	Bulk density of sediment in reservoir (t/m3)

3.2.14 Wetland

Figure 23. **A type of wetland, simulated in NTT as shallow reservoir with growing vegetation (http://www.chisagoswcd.org)**

Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support under normal circumstances a prevalence of vegetation typically adapted for life in saturated soil conditions. Nutrient and sediment retention in wetlands systems occurs via sorption, precipitation, and incorporation. Wetlands include swamps, marshes, bogs and similar areas. In addition, wetlands can be constructed on the farmland by producers to treat wastewater and contaminated runoff from agricultural processing, livestock, and aquaculture facilities. A well-constructed wetland could improve the quality of storm water runoff or other contaminated water by withholding runoff water. The wetland parameters are similar to those of reservoirs (please refer to 3.2.12). The wetland area is simulated as a shallow reservoir (one foot deep) at the outlet of the simulated farm with growing wetland vegetation.

Table 10. **The default parameters set in NTT to simulate a shallow-depth wetland**

Parameter	Value
RSEE	0.31
RSAE	User input
RSVE	50
RSEP	0.30
RSAP	User Input * 0.9
RSVP	25.0
RSV	20.0
RSRR	20.0
RSYS	300.0
RSYN	300.0
RSHC	0.001

RSDP	360
RSBD	0.80

The surface area of wetland (ASAE) must be inputted by the user.

Simulated wetlands trap sediment, reduce runoff, increase infiltration and increase uptake of water and nutrients by the vegetation in the area covered by the wetland. In the future version of NTT, the users will be able to modify/input the wetland physical properties. Similarly, users would be able to simulate reservoir as well.

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