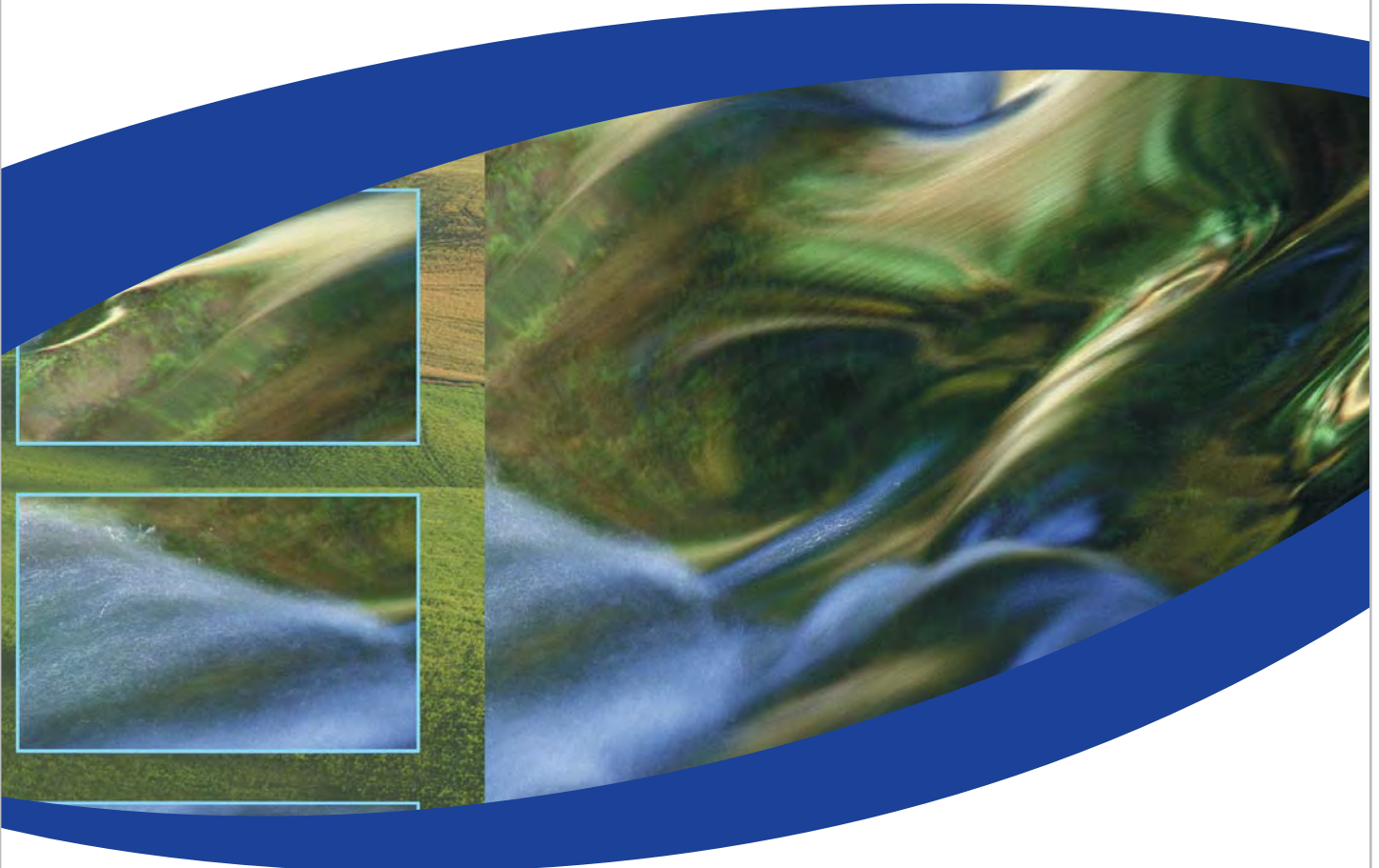


# Use of Models to Reduce Uncertainty and Improve Ecological Effectiveness of Water Quality Trading Programs

Evaluation of the Nutrient Trading Tool and the Watershed Analysis Risk Management Framework





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Watershed Analysis Risk Management Framework*

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## Abstract

Through a United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Conservation Innovation Grant, collaborators working on the development of the interstate Ohio River Basin Water Quality Trading Program ([www.epri.com/ohiorivertrading](http://www.epri.com/ohiorivertrading)) have conducted a robust analysis to evaluate possible approaches for using water quality models for crediting nutrient load reductions from agricultural best management practices (BMPs). A credit estimation method that ensures reliable and repeatable results is a critical element in a successful water quality trading (WQT) program and something that is not always scientifically informed. This effort considers one approach for creating a scientifically informed approach that uses a combination of field-scale and watershed-scale models for crediting agricultural conservation practices. The Nutrient Trading Tool (NTT) and the Watershed Analysis Risk Management Framework (WARMF) were selected to evaluate the non-point source load reductions at the field scale and watershed scale, respectively.

The project assessed both NTT (field-scale) and WARMF (watershed-scale) models to determine the strengths and weaknesses for use in WQT. NTT was also tested by a select group of Ohio agricultural Technical Service Providers, Certified Crop Advisors, and Soil and Water Conservation Districts for applicability, user-friendliness, information content, and reliability. The project has identified that both NTT and WARMF have demonstrable uses for supporting essential elements of credit calculations and policy development in WQT programs. Recognition of benefits and limitations with these tools will be critical for realizing their full potential in a WQT context. Efforts must be made to gather sufficient data and literature support for model calibration and validation. While WARMF has been tested and applied in many locations across the United States, NTT has yet to receive a similar level of scrutiny and application. Vetting by local experts and knowledgeable program participants of both the data and assumptions used by modelers is highly recommended, especially for NTT which relies on field-specific information. In addition, recommended NTT model improvements will enhance the accuracy and performance of the tool, the results of which will increase trust and use by program participants. WQT programs can adjust for introduced errors and uncertainties by using a combination of eligibility conditions and an explicit trade ratio. These decisions can be informed by sensitivity analysis of the calibrated models, incorporation of model “goodness of fit” results, and best professional judgment. Output of these tools can be combined to provide an appropriate level of user-friendliness and pragmatic use of best available science for crediting, policy decisions, and program administration.

The project also considered characteristics of a future on-line trading registry.

**Keywords**

Agriculture, Best Management Practices, Modeling, WARMF, Water Quality Trading, Nutrient Trading Tool



## Executive Summary

A United States Department of Agriculture (USDA) Conservation Innovation Grant has funded this robust analysis that evaluates approaches to use existing field-scale and watershed-scale models for crediting agricultural conservation practices that result in nutrient load reductions. This report identifies the strengths, weaknesses, and needs for these tools to be effectively utilized in water quality trading (WQT) applications. In particular, this project focused on evaluating tools as part of a large-scale effort to develop and implement interstate WQT in the Ohio River Basin (ORB). This effort is being led by Electric Power Research Institute (EPRI) with funding and support from the U.S. Environmental Protection Agency (USEPA), USDA, EPRI, Ohio River Valley Water Sanitation Commission (ORSANCO), American Farmland Trust, University of California–Santa Barbara, Hunton & Williams, Duke Energy, Hoosier Energy, Tennessee Valley Authority, American Electric Power, Miami Conservancy District in Ohio, Kieser& Associates, and the Ohio Farm Bureau Federation.

WQT programs are being evaluated and developed in numerous watersheds across the nation. The independent development of so many WQT programs, particularly those focusing on agricultural (non-point source) credit supply, has resulted in the use of a variety of nutrient reduction calculation methodologies. The USDA Natural Resources Conservation Service (NRCS), USEPA, state agencies, and various private and public organizations are interested in identifying tools that can reliably estimate the water quality credits associated with agricultural conservation practices. The best available science, easy-to-use tools, and prudent assumptions to estimate credits will form a solid foundation for a WQT program and build trust among stakeholders.

Reliable credit estimation methods are a critical element in any WQT program because both credit buyers and credit sellers rely upon these techniques and tools to meet regulatory requirements and contractual obligations. While most WQT programs aim to develop rigorous credit estimation methods, ease of use by those in agriculture or other credit-generating sectors must also be considered. To address the balance between accuracy and ease of use, the Nutrient Trading Tool (NTT) was designed and developed by the USDA-NRCS, the USDA Agricultural Research Service (ARS), and Texas Institute for Applied Environment Research (TIAER)<sup>1</sup>. NTT has a relatively easy-to-use interface that calculates edge-of-field sediment and nutrient load reductions through a combination of field-specific information and environmental assumptions.

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<sup>1</sup> See: <http://ntt.tarleton.edu/nttwebhelp/nttwebhelp.htm#Introduction/AboutNTT.htm> for a description of the tool by developers at TIAER.

However, it is not yet clear that the tool can be rigorously and accurately applied in on-the-ground trading programs.

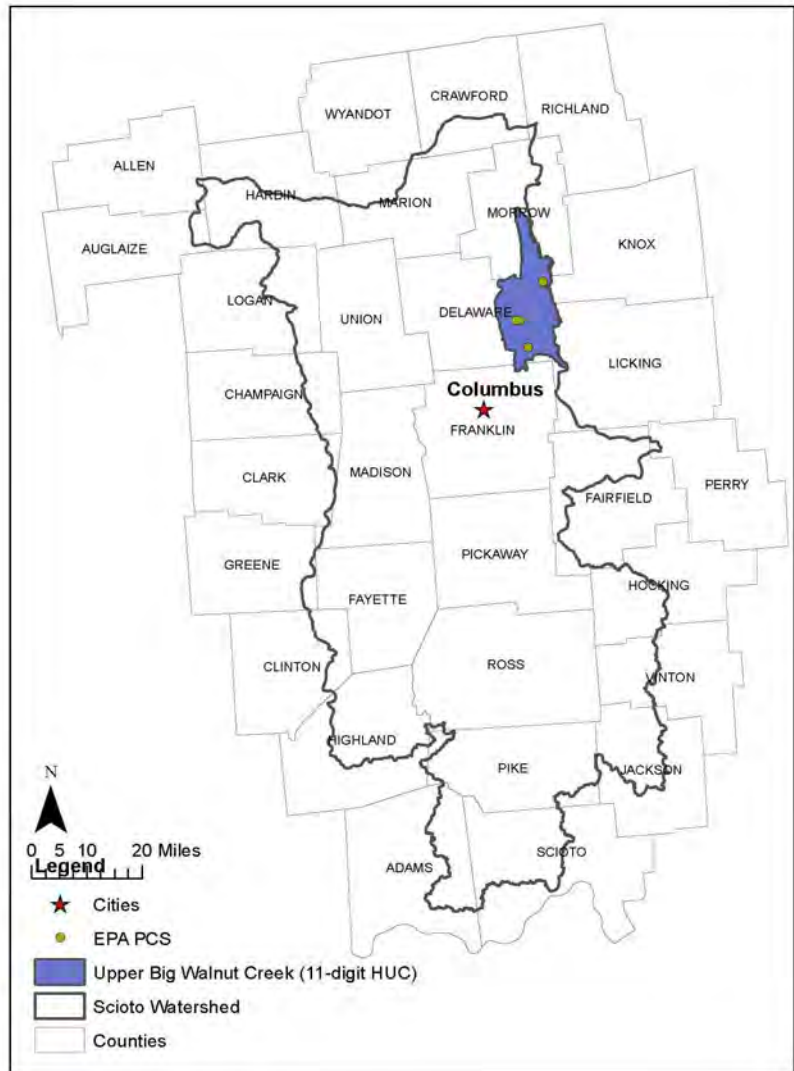
The integrity of WQT programs for meeting environmental compliance goals fundamentally rests upon the reliable prediction of environmental benefits associated with credit exchanges. Edge-of-field calculation tools that estimate nutrient load reductions at the farm scale lack the function to estimate benefits at a downstream point where credits are purchased and applied toward permit compliance. Even with robust credit estimation approaches, there is an inherent uncertainty associated with predicting the nutrient load reductions in complex ecological systems. To help reduce this uncertainty, the project team evaluated the Watershed Analysis Risk Management Framework (WARMF)<sup>2</sup> model to estimate downstream benefits from conservation practices on upstream farms.

The desired outcome from pairing NTT and WARMF was to identify a scientifically based approach for creating crediting equations and appropriate trade ratios. The EPA's Water Quality Trading Toolkit for Permit Writers recommends a credit estimation technique based upon an equation that discounts the pollutant reduction at the edge-of-field location by a defined trade ratio (EPA, 2007). A trade ratio is typically made up of several discounting factors, including an equivalency factor, location factor, and uncertainty factor. For this evaluation, NTT was used to estimate edge-of-field nutrient reductions from agricultural best management practices (BMPs). Outputs of NTT were fed into WARMF, which could then be used to develop watershed-specific trade ratios based on watershed-specific attenuation of nutrients between buyers and sellers.

The Upper Big Walnut Creek (UBWC) watershed was selected as the case study watershed to run both models. The UBWC is an 11-digit hydrologic unit code (HUC) watershed (05060001-130) in central Ohio that comprises 190 square miles or 121,600 acres (493 km<sup>2</sup> or 49,300 hectares). It is part of the Scioto River watershed within the Ohio River Basin, with the greatest portion of the UBWC watershed falling within Delaware County in Ohio (see Figure ES-1). The UBWC watershed was selected primarily because previous work there suggested that data sets were available that could be used to calibrate and validate both models. Although substantially less data was available than originally anticipated, the team was still able to complete model calibrations. However, site-specific model validation could not be completed.

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<sup>2</sup> See: <http://www.epa.gov/athens/wwqtsc/html/warmf.html>



*Figure ES-1  
Location of the Upper Big Walnut Creek Within Scioto Watershed in  
Central Ohio*

### **NTT Findings**

In general, the project findings indicate that the 2010 version of NTT reviewed here has the potential to strongly advance the crediting methodologies for edge-of-field load reductions. NTT provides methods that are repeatable and use the best available science in a format that agricultural professionals understand and find relatively easy to use. Table ES-1 summarizes salient findings on the suitability of using NTT for credit estimation in a WQT program as well as modifications needed to better accommodate trading applications.

*Table ES-1  
Strengths and Weaknesses of NTT as a WQT Credit Estimation Tool*

Strengths	Weaknesses
NTT provides standardized, automated data entry allowing users to produce repeatable results.	Various corrections are needed regarding unit labels and consistent use of significant digits.
Nutrient and sediment loading reductions as well as crop yield results are provided, allowing producers to better assess whole farm impacts and consider opportunity costs.	Supporting information is needed in the form of guidance documentation and bibliographies of non-point source loading data for calibration (all of which should be vetted by local professionals).
Professional service providers find this to be an easy-to-use tool.	The user interface needs to be adapted to better facilitate baseline calculations for agricultural credit generation.
Loading estimates are provided with a higher accuracy based on the mechanistic modeling framework (when properly calibrated).	Specific BMP load reduction calculations must be applied correctly, particularly with sheet and rill erosion applications versus gully erosion calculations.
Estimates for additional nutrient forms (dissolved and particulate) are provided as model outputs.	User manuals are needed for NTT operation and crediting that would include: <ul style="list-style-type: none"> <li>• Guidance assessing the contributing area</li> <li>• Data-gathering techniques for model inputs of field data</li> </ul>
Additional loading pathways (shallow groundwater) are considered in the model.	Upgraded reporting functions are needed for presenting loading results on a monthly and/or seasonal basis in addition to the current results reported as annual loads.
The tool provides management and tracking capabilities for producers in addition to information for WQT.	Surface water loading estimates should not be combined with deep aquifer contributions, as in the version reviewed in this study.
A robust list of best management practice (BMP) selections is available.	Needed improvements for crediting BMPs include: <ul style="list-style-type: none"> <li>• Incorporating a method for stream bank/bluff stabilization reductions</li> <li>• Allowing user input of site-specific soil phosphorus test results</li> <li>• A method for calculating loads when drainage management practices are being employed in the field</li> <li>• Allowing users to vary depths of wetland and associated treatment efficiencies</li> <li>• Allowing users to override the Web Soil Survey default slope values when site-specific data are available</li> </ul>
The model has the ability to expand the list of BMPs for credit calculations.	
Methods to estimate load reductions from multiple practices in one field (as treatment trains) are used in the model.	
	The apparent lack of version control on the model creates concern regarding the ability to compare model runs and track model updates.

Details of some of the key beneficial attributes of NTT presented in Table ES-1 include the following:

- ***Load reductions from multiple pathways***

The NTT model contributes robust credit results that include more forms and pathways of loading than other field estimation tools used for calculating non-point source load reductions. NTT calculates sediment attached and surface runoff pathways, but adds dissolved forms of nutrients and shallow-aquifer lateral flow paths as well. Loading of dissolved forms of nutrients often remains uncouned in common empirical calculations. Although not traditionally associated with WQT programs, NTT's estimation of deep-aquifer load reductions could be used in source water protection programs utilizing WQT.

- ***Robust list of BMPs***

NTT has the capability to calculate nutrient and sediment load reductions for many common BMPs. This makes it a potentially beneficial tool for a new WQT program because NTT provides a robust list of BMPs that would be eligible to generate credits. Additionally, other BMPs can be added because model development produces either: 1) specific protocols used during field assessments to define selection methods for the model inputs or 2) model algorithms that are adjusted to allow the necessary inputs and data processing techniques.

- ***Multiple BMP management***

NTT has the capability to provide load reduction estimates on fields where multiple BMPs have been implemented. This allows for long-term tracking of producer activities. This becomes a valuable model attribute as baseline conditions may require the use of multiple BMPs or as site management goals require the use of several BMPs in concert. A system with this capability will be able to better manage changes in baseline and other WQT program policies than common empirical calculation tools.

While NTT appears to be a reliable and accurate load reduction tool when calibrated to local or regional data (particularly in comparison to empirical calculations), this project identified several ways in which NTT might be improved to better fit the needs of a WQT program framework. Additional details for such improvements, which are summarized in Table ES-1, include the following:

- ***Allowing for additional site-specific inputs***

Allowing a user to enter information specific to a particular data field in NTT could improve the accuracy of load reductions. With input from technical service providers, the project team identified the following inputs that might improve accuracy:

- Specific field slopes that would override the value determined by the Web Soil Survey (WSS) component
  - Soil phosphorus concentrations from soil tests on specific fields
- ***Applying correct physical assumptions***

Specific BMP load reduction calculations must be applied correctly and calibrated to specific agricultural settings. For example, the load reduction attributed to grass waterways for gully corrections underestimates results. The model bases estimates upon factors determined by the sheet and rill prediction equations within the Revised Universal Soil Loss Equation (RUSLE) or Modified Universal Soil Loss Equation (MUSLE). These both predict sheet and rill erosion based on sheet flow regimes, whereas gully erosion occurs from channelized runoff. Differences in reduction calculations can have a significant impact in WQT, where pollutant reductions from one site will be used to offset loading from another.
- ***Refining load reduction estimates***

The NTT calibration and output results were questioned by technical service providers. This emphasizes the need to vet the output results for all parameters with local experts in both agronomy and non-point source runoff estimation. Technical service providers felt that once this was done, they could use this tool in many services they currently provide, in addition to WQT.
- ***Adding to the Web Soil Survey component***

There were several recommendations on ways to improve how the WSS tool is used to delineate a field:

  - Allow for the direct upload of shape files to increase the accuracy of field delineation.
  - For fields that fall within two counties, the field should be able to be evaluated in a single run, instead of requiring two separate runs.
  - Add topography contours and tile drainage systems to better determine the contributing area of a particular field.
- ***Estimating load reductions for shorter periods***

The model currently outputs results in annual loads. WQT programs are required to be contemporaneous with National Pollution Discharge Elimination System (NPDES) permit reporting and monitoring periods, which can be monthly, seasonal, or annual rolling averages. If outputs could be estimated on a shorter timeframe, NTT would be useful for more WQT applications.
- ***Accounting for WQT baselines***

NTT allows the user to define specific field management practices, but requires another scenario to be run in order to discount the load

reduction resulting from BMPs that are required by a program to meet a baseline prior to credit generation. In some programs, a percentage reduction must be applied to the edge-of-field reduction as a baseline. Options to incorporate baseline considerations will provide clarity for farmers to distinguish edge-of-field load reductions from credit generation potential for an applicable baseline. The benefits for farmer participation in WQT may change dramatically between these two calculations.

- ***Adjusting for parcels not adjacent to a stream***

Currently, NTT provides load reduction estimates for fields that are not adjacent to a stream network. The accuracy of these estimates is compromised by not accounting for attenuation within neighboring fields and shallow-groundwater transport when the field management measures of the parcels between the field of interest and the stream are not taken into account. As NTT is set up in the 2010 version, only parcels adjacent to a stream can be accurately credited.

- ***Model version control***

The project team could not verify that the versions of NTT were being tracked or recorded. For example, when edits were made to the model, it was simply reloaded to the web without notifying users or noting that the model version had changed. It was possible to get different model results using the same input data, depending on when the model was run. The absence of diligence around version control presented difficulties in the short time of our assessment and will undermine the credit calculation methodology, scientific robustness, and user trust in a functioning program. The lack of version control will seriously limit NTT's use in a scientifically robust WQT program.

- ***Enhancing model outputs***

The project team identified additional outputs that NTT could add to benefit the credit estimation process:

- The standard deviation for the 12-year period of watershed conditions that NTT uses for a long-term estimate of pollutant loading reductions
- Load reduction calculations for drainage management BMPs by incorporating drainage tile densities or inventories of surface tile intakes

As part of this project, a one-day NTT workshop was held on August 26, 2010, at the Ohio Farm Bureau in Columbus, Ohio. The workshop solicited feedback from agricultural technical service providers and producers to evaluate the user-friendliness of NTT. Input from this workshop and from a follow-up online survey provided useful feedback about the model. None of the features of NTT were rated as "very poor/not user-friendly." The soil survey map via the online Web Soil Survey (WSS) and the soil input features were rated as "excellent/very user-friendly," whereas other model features were rated as "neutral to good."

Overall, NTT is a useful tool that can be applied for estimating load reductions as part of WQT in the Ohio River Basin and elsewhere. Most critical to its use will be calibration, verification, and vetting. Vetting will be required by state agencies to ensure that staff believe in the results. Technical service providers and producers will also want to be sure that the tool is applicable at the local scale, particularly in describing crop yields under new BMPs. Where BMPs are being implemented but not yet included in NTT, other calculation tools will be needed. Many of the issues and recommended additions identified here should be addressed as the tool is continually updated and improved. Inappropriate computational approaches or insufficient calculation capabilities should be priorities to correct, as well as reporting features that are necessary to compare temporal loads with buyer needs. Depending on when such model updates are implemented, it is likely that a large-scale trading program as envisioned for the ORB will initially need to rely upon a mix of calculation tools that are accepted by the stakeholders, not just NTT.

When using NTT as a crediting tool in a WQT program, it is also necessary to recognize its limitations at the watershed scale. NTT edge-of-field load reduction calculations will not be equivalent to downstream credits used by distant buyers because NTT is not capable of estimating attenuation factors in the watershed. For this reason, a watershed model is necessary. As such, the WARMF model was also examined in this study using the same UBWC case study to determine watershed scale impacts of agricultural BMPs.

## **WARMF Findings**

WARMF was originally developed by EPRI and has been implemented in over 30 watersheds throughout the United States and abroad, and is available for download directly from the EPA. The model is used for decision-support in watershed management and for regulatory activities, specifically in the development of total maximum daily loads (TMDLs). The engineering module of WARMF contains a dynamic watershed simulation tool that calculates daily surface runoff, groundwater flow, non-point source loads, hydrology, and water quality of river segments and stratified reservoirs. In the model, a watershed is divided into a network of land catchments, river segments, and reservoir layers. Land catchments are further divided into land surface and soil layers. These watershed compartments are seamlessly connected for hydrologic and water quality simulations. The land surface is characterized by its land uses and cover, which may include rain and snow that is deposited on the land catchments. The model performs daily simulations of snow and soil hydrology to calculate surface runoff and groundwater accretion to river segments. The water is then routed from one river segment to the next downstream river segment until it reaches the terminus of the watershed. The associated point and non-point loads are also routed through the system. Heat budget and mass balance calculations are performed to calculate the temperature and concentrations of various water quality constituents in each soil layer, river segment, and lake layer.



WARMF can model common agricultural BMPs of interest at the watershed scale while reporting in-stream water quality responses. At the watershed scale, changes to a land management practice can be assigned over a large land area with the resulting change in watershed nutrient loading divided across the area simulated. The result is a yield-determined average in lbs/acre or kg/ha . The results from WARMF were in a similar range as the NTT predictions for tributary catchments. However, issues at this scale, such as attenuation of pollutant loads, the combined effects of integrating many sources, and watershed model averaging techniques, can work together to mask the change in land management applications. Therefore, model results from projections based on different scales such as those of NTT (edge-of-field) and WARMF (watershed catchment) cannot be directly compared. Accordingly, the appropriate selection of location, equivalency, and uncertainty factors should be used to address these differences within a WQT program.

Table ES-2 summarizes some of the most salient points from this study about the suitability of WARMF in the context of WQT.

Table ES- 2  
 WARMF Model Strengths and Weaknesses Related to Water Quality Trading.

Strengths	Weaknesses
The model provides watershed loading and concentration estimates of key parameters (including flow, sediment, nitrogen, and phosphorus) at both the subwatershed and watershed scale.	Model set up, calibration, and validation processes require a qualified modeler.
<p>Watershed modeling provides necessary information to inform decisions/policies at a watershed scale including:</p> <ul style="list-style-type: none"> <li>• Setting appropriate stakeholder expectations (regarding water quality responses to varying levels of practice adoption)</li> <li>• Assist in identification of "local hot spots"</li> <li>• Setting appropriate transaction boundaries for buyers and sellers based on water quality outcomes of trades</li> <li>• Assessing trading program effectiveness</li> <li>• Targeting BMPs that provide higher benefits implemented at scale</li> <li>• Assessing WQT policy elements and related impacts on water quality</li> </ul>	<p>Water quality, meteorological data, and pollutant source inventories can be limiting factors in the simulation accuracy of the model when data sets are weak for:</p> <ul style="list-style-type: none"> <li>• Water quality monitoring</li> <li>• Wastewater effluent sampling for nutrients</li> <li>• Local meteorological data</li> <li>• Non-point source runoff data</li> </ul>
Methods to assess channel attenuation processes for nutrients are available in WARMF, thus providing location factors to assess in-stream attenuation of edge-of-field loads.	<p>Limiting non-point source data inventories that diminish model accuracy include:</p> <ul style="list-style-type: none"> <li>• Non-compliant septic systems</li> <li>• Crop management and BMPs</li> <li>• Urban storm water</li> <li>• Livestock management</li> </ul>
Once a watershed has been modeled, only periodic modeling updates are required.	<p>Watershed modeling must apply averaging at scale to overcome:</p> <ul style="list-style-type: none"> <li>• Data limitations</li> <li>• Complications of processing a large number of model iterations</li> </ul>
<p>Assessment results are valid for several years:</p> <ul style="list-style-type: none"> <li>• Creating predictability and market stability</li> <li>• Allowing location factors to be generated as look-up tables</li> <li>• Avoiding the need for field representatives to run WARMF</li> </ul>	<p>Relevant WARMF modeling simplifications include:</p> <ul style="list-style-type: none"> <li>• Farm nutrient applications are equally distributed across a month and a subwatershed.</li> <li>• Average concentrations for wastewater discharges though daily discharges can vary substantially.</li> <li>• Soils use area-weighted averages from the Soil Survey Geographic (SSURGO_ database.</li> <li>• River processes are based on mixed tank reactor assumptions, producing one predicted water quality concentration of a potentially long reach of the a river or tributary catchment.</li> </ul> <p>Averaging suggests an approach to average in-stream predictions from WARMF outputs in one-month time steps (or longer, depending on data gaps), despite the model's capability to report in daily time steps</p>

Specific details for these attributes include the following.

- ***Supporting policy decisions***

WARMF can support initial WQT program discussions and the development of program policies on the issue of “local hot spots.” For example, if monitoring assessments validate high concentrations predicted by the model, then the WQT program can be adjusted so that the use of WQT credits does not contribute to the violation of water quality standards.

- ***Selecting location factors***

WARMF can provide information on attenuation at a subwatershed and watershed level that will facilitate the appropriate selection of location factors for a credit equation that would account for location differences between buyers and sellers.

- ***Evaluating program effectiveness***

WARMF can provide a clearer watershed understanding that could increase levels of BMP adoption, assist in monitoring plan development, help define policies that provide incentives for desired behaviors, and discourage unwanted behaviors.

- ***Determining eligible trading boundaries***

WARMF model outputs can assist WQT and watershed managers when determining allowable transaction areas (trading zones) or the appropriate spatial extent for WQT. Setting boundaries based on the attenuation of pollutant loading and identification of significantly limiting physical features (such as reservoirs) can be assessed by using a calibrated watershed model such as WARMF. In addition, using WARMF when developing a WQT framework for low flow or seasonal periods can better inform WQT managers of the potential conditions that limit the appropriate use of WQT programs.

Considerations necessary for WARMF model use in WQT include the following, as summarized in Table ES-2.

- ***Periodic model updates***

For long-term WQT program considerations, it will be important to periodically update the model as watershed-specific monitoring data over a substantial period become available or when land use changes are significant. For updating the model, a qualified modeler would be needed. A WQT program may benefit by developing a bibliography of studies or separate protocols to guide the modeler through decision making when selecting input coefficients and different sources of input data. This guidance can also be based on the sensitivity analysis of critical parameters.

- *Appropriate time steps*

This report found that the daily time steps in WARMF for model results should be averaged across a month at a minimum, depending on the goodness of fit for watershed model calibration. This is typically due to the limitations of available data, which include pollutant source data, local meteorological information and/or averaging assumptions used to overcome issues of stochastic variability, and limited inventories of multiple sources (for example, fertilizer and manure application timing for multiple fields within a subwatershed). Averaging results over a period such as a month or longer is a way to address these data source limitations. Monthly or longer time steps are more consistent with discharge compliance requirements for phosphorus and nitrogen loading.

Overall, findings from this project indicate that WARMF is well suited as a watershed model to inform WQT program needs at scale. However, a lack of robust water quality monitoring over long periods limits opportunities to validate WARMF model calibrations. In all cases, model sensitivity analyses and characterization of uncertainty as preliminarily examined in this study can be overcome by the use of discounting factors in the trading ratio of a crediting equation.

### **NTT and WARMF Model Linkages**

Though output from NTT and WARMF both serve to provide critical information necessary to calculate loading reductions and their equivalency at scale, actual linkage of these models is not recommended from this study. This is due in part to the differences in scale between the two models. Figure ES-2 shows the capabilities of each model to simulate loads or water quality at different levels of stream order (a surrogate for watershed scale). Each model should be used to supply a component of the crediting equation in a way that adequately links the two scales effectively. Table ES-3 summarizes the credit equation and indicates which components of the formula the model results can assist in providing.

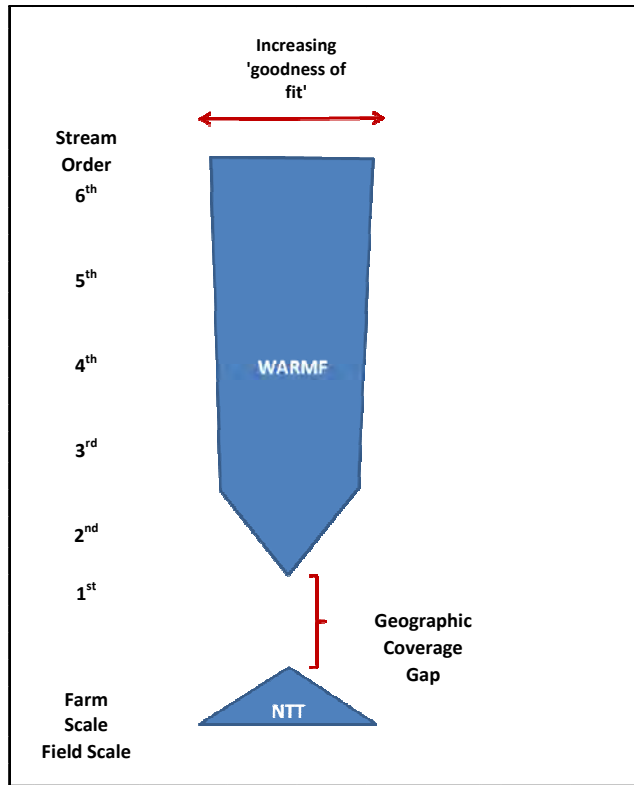


Figure ES-2  
 Generalized Schematic Comparing NTT and WARMF Model Capabilities to Simulate Loads and Water Quality, Respectively, at Varying Watershed Scales

Table ES-3  
 WQT Credit Equation Inputs from WARMF and NTT Models

Credit Equation Component Contribution	WARMF Model Output	NTT Model Output	Outside Information Needed
Load Reduction Estimate		X	
<b>Trade Ratio Factors</b>			
Location Factor	X		
Equivalence Factor	X	X	X
Uncertainty Factor	X	X	X
Policy Factor(s)	X (Provides development information)	X (Provides development information)	X

It is important to note that NTT provides only the load reduction component of the credit equation, and it must be linked to other factors, as listed below, to estimate the appropriate credit equivalent for a downstream buyer:

- ***Location Factor***

A ratio can be applied that will account for the attenuation of nutrients that naturally occur in the watershed between the point of reduction (the seller) and the point of crediting (the buyer).

- ***Equivalence Factor***

A ratio can be applied to address differences between the characteristics of the discharges associated with a specific buyer and seller. These differences typically focus on discharged nutrient bioavailability.

- ***Uncertainty Factor***

An uncertainty factor can be applied based on unavoidable errors associated with cumulative estimation processes. The factor takes into account the conservative assumptions implicit in the process as well as compounding and canceling variability in final values.

- ***Policy Factors***

A series of WQT program framework decisions may be adopted or necessary to take into account program prerequisites for eligibility and baseline requirements to achieve desired program outcomes. Policies may advance achieving environmental goals by discounting the credit value to accomplish net benefits for the water resource, rewarding practitioners installing prioritized BMPs, creating benefits for early credit buyers, or other methods to incorporate ancillary benefits.

During WQT program development, watershed managers can address each of these issues by completing different evaluations specific to each topic and producing applicable protocols. These may be derived from models (as denoted in Table ES-3) or from existing literature.

## **Full-Scale Program Tracking**

Finally, this report discusses other components that are necessary to track and verify reductions from agricultural BMPs in a full-scale trading program. This tracking could come in the form of an on-line registry and potentially be coupled with credit estimation tools and necessary trading protocols derived from NTT, WARMF, and/or other appropriate resources. Numerous decisions regarding program development will be necessary, including:

- Selecting preferences regarding the range of simple to complex tools for a registry
- Determining whether an automated or web-based registry is needed or appropriate

- Deciding on the level of personal information of buyers and sellers necessary for trades
- Selecting tools necessary for tracking spatial information about credit generating practices that will provide assurances that credits from sites are not sold more than once
- Determining policy requirements regarding the level at which credit transactions are publicly available for review to add transparency and trust to the program, and deciding whether this includes cost details

## Summary

In summary, the project has identified that the edge-of-field non-point source nutrient loading model, NTT, and the watershed model, WARMF, have capabilities for supporting essential elements of credit calculations and policy development for WQT. Recognition of benefits and limitations with these tools will be critical for realizing their full potential as discussed in this report. Efforts must be made to gather sufficient data and literature support for local/regional model calibration (and validation where possible). Vetting by local experts and knowledgeable program participants of the data and assumptions used by modelers is highly recommended for both models. In addition, recommended NTT model improvements will enhance the accuracy and performance of the tool, the results of which will increase trust and use by program participants. Notable calculation issues for select BMPs should be a priority for USDA-NRCS updates on NTT. For BMPs not covered by NTT, other calculation tools will be needed until NTT is updated. With appropriate calibration, WARMF appears ready to apply to a WQT context without additional updates.

The output of both modeling tools can be combined to provide an appropriate level of user-friendliness and pragmatic use of best available science for crediting, policy decisions, and WQT program administrative needs. WQT programs can adjust for introduced errors and uncertainties in the credit calculation process by using a combination of eligibility conditions and an explicit trade ratio. These decisions can be informed by sensitivity analysis of the calibrated models, incorporation of model “goodness of fit” results, and best professional judgment. Given the results of this analysis, the project collaborators of the Ohio River Basin Water Quality Trading Project are continuing to calibrate WARMF in other areas of the basin and intend to apply it as the watershed scale model. NTT has potential to be applied as the edge-of-field load reduction estimator when modeling results can be reasonably verified, priority model weaknesses are addressed, and local stakeholders support its application.





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# Section 1: Introduction

This report is the compilation of efforts for the U.S. Department of Agriculture, National Resources Conservation Service (USDA-NRCS) under a 2009 Conservation Innovation Grant (CIG). It is the first step in what will likely be several to test, integrate, and utilize consistent tools for calculating and tracking credits generated by agriculture for water quality trading (WQT) in the Ohio River Basin (ORB) (see Figure 1-1). The large-scale effort to develop and implement a WQT program for nutrients in the ORB is being led by Electric Power Research Institute (EPRI) with funding from the Environmental Protection Agency (EPA), USDA, the Electric Power Research Institute (EPRI), and project collaborators. These collaborators include the Ohio River Valley Water Sanitation Commission (ORSANCO), American Farmland Trust, University of California–Santa Barbara, Hunton & Williams, Duke Energy, Hoosier Energy, Tennessee Valley Authority, American Electric Power, Miami Conservancy District, Kieser & Associates, and the Ohio Farm Bureau Federation. The eight-state congressionally delegated compact, ORSANCO, is facilitating multi-state participation.

Trading is most often used as a cost-effective compliance alternative by regulated dischargers of treated wastewater that are facing high costs for new treatment technologies. Technology upgrades are often necessary to meet increasingly stringent pollution reduction requirements for these wastewater discharges to surface waters. Because of cost differentials between technology and agricultural conservation practices, the past decade has seen growing interest in WQT involving agriculture. Credit trading can provide additional income for farmers, improve operational efficiencies and production, reduce environmental impacts to water and air, and improve the overall perception of agriculture among the general public.

This CIG-funded effort provides a robust analysis that evaluates a field-scale and watershed-scale model for crediting agricultural conservation practices that result in non-point source loading reductions. This report identifies the strengths, weaknesses, and needs for these tools to be effectively utilized in trading applications. It also discusses the benefits and challenges of combining field-scale and watershed-scale models in developing a crediting framework for interstate buyers and sellers in the ORB.

WQT programs are being evaluated and independently developed in numerous watersheds across the nation.<sup>3</sup> For those focusing on agricultural credit supply, a variety of nutrient reduction calculation methodologies and tools for non-point sources (often specific to a local program or a state) have been employed. This use of different tools can result in program inconsistencies and inefficiencies when expanded across watershed and political boundaries. The USDA-NRCS, EPA, state agencies, and various private and public organizations are striving to identify common sets of tools that can reliably estimate water quality credits associated with implementation of agricultural conservation practices. This will help to provide efficient and consistent support for agricultural and point source trading partners in these programs and lead to credit market stability.

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<sup>3</sup> See, for example: [http://www.envtn.org/State\\_Programs\\_Rules.html](http://www.envtn.org/State_Programs_Rules.html)

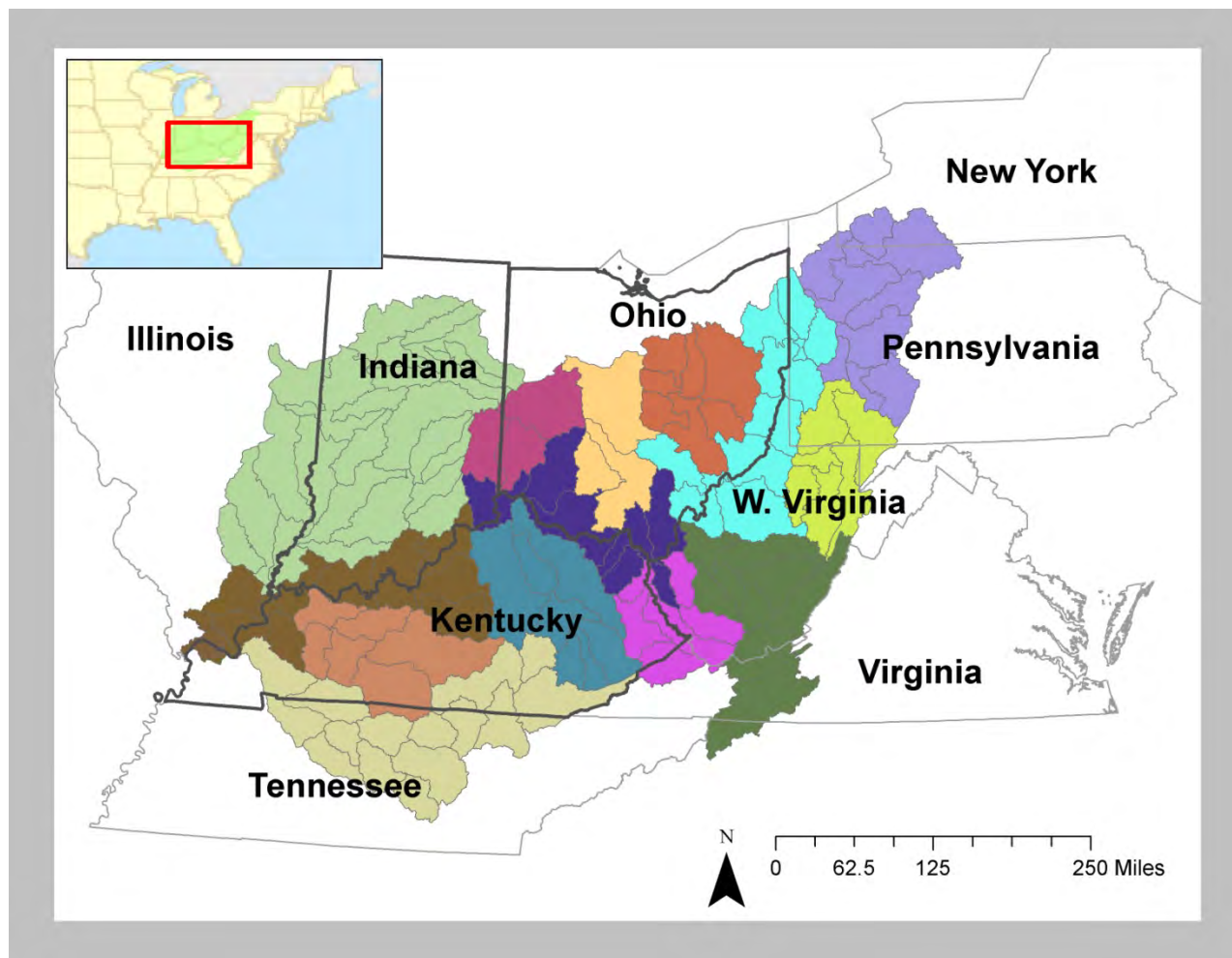


Figure 1-1  
The Ohio River Basin With Subwatersheds Colored

The integrity of WQT programs to meet environmental compliance goals fundamentally rests upon the reliable prediction of environmental outcomes associated with credit exchanges. Inadequate or inaccurate credit estimation methods lead to ever increasing doubt and uncertainty regarding the environmental effectiveness of a WQT program. This, in turn, can lead to overly protective credit discounting factors and/or trading ratios that may sacrifice trading cost-effectiveness. Even with robust credit estimation approaches or models, there is still an inherent uncertainty associated with predicting the environmental outcomes of complex ecological systems. However, sophisticated calculation approaches can be subject to uncertainty if the number of model inputs required far exceeds those that can actually be measured or estimated in the agricultural setting. Sophistication can also limit the number of

program implementers capable of utilizing such tools, thereby excluding broader agricultural participation and increasing transaction costs. These considerations provide a backdrop for the challenge to identify a balance between usability, accuracy, and complexity in crediting tools.

The USDA is attempting to address this balance with the development of the Nutrient Trading Tool<sup>4</sup> (NTT) to provide a standardized method for calculating edge-

<sup>4</sup> See: [http://www.wsi.nrcs.usda.gov/products/w2q/mkt\\_based/docs/nitrogen\\_credit\\_trading.pdf](http://www.wsi.nrcs.usda.gov/products/w2q/mkt_based/docs/nitrogen_credit_trading.pdf) or <http://ntt.tarleton.edu/nttwebars/%28S%28xwjc31ackzy5xg45dmcfgd55%29%29/Default.aspx>

of-field reductions for sediment and nutrient loading reductions associated with agricultural practices. A prototype NTT already capable of estimating reductions for numerous best management practices (BMPs) is examined here. Having one broadly accepted field-scale tool capable of estimating nutrient load reductions from BMPs across the nation (using local and/or regionally specific data) could greatly reduce program costs and increase buyer acceptability of credits.

Coupling site-specific calculation tools such as NTT with watershed and/or water quality models can help determine watershed attributes necessary to define trading conditions and opportunities at scale. In this report, NTT is paired with the Watershed Analysis Risk Management Framework (WARMF).<sup>5</sup> While NTT calculates only edge-of-field delivery, this project evaluates how associated agricultural BMP load reduction estimates can be adjusted by WARMF to calculate nutrient and sediment credits appropriate for trading with buyers located elsewhere in the basin or watershed.

The value of expanding and integrating NTT with watershed assessment tools, such as WARMF, into WQT programs is immense. By developing one set of calculation tools, program participants can have confidence in the crediting methodology and the resulting in-stream benefits. A singular credit calculation framework can also be coupled with credit tracking tools and an on-line registry that provide the opportunity for one credit exchange/trading platform.

This report explores the use of these tools by testing NTT within the Upper Big Walnut Creek (UBWC) in central Ohio (a tributary to the Scioto River northeast of Columbus) and assessing its ability to scale up for use throughout the ORB. This was accomplished by testing several BMP applications in NTT using detailed local data, holding a peer review of the model by agricultural technical service providers, and conducting sensitivity analyses to better understand the capabilities of the model for phosphorus and nitrogen load reductions. Options for coupling economic modules for conservation practices in NTT were preliminarily identified as well.

Results of these efforts are presented in the following chapters:

2. Credit Estimation Methodology
3. Addressing WQT Issues with Models
4. Evaluating NTT and WARMF for WQT Crediting
5. A Credit Calculation Interface to Combine Model Results
6. Credit Registry Interface
7. Conclusions
8. References

Appendices provide additional details on:

- A NTT Field Scale Model
- B Workshop Proceedings with agricultural consultants and technical service providers
- C NTT Online Survey Results
- D Ohio Department of Natural Resources Evaluation of NTT
- E WARMF Watershed Scale Model
- F Economic Evaluation of Conservation Practices
- G NTT User's Guide

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<sup>5</sup> <http://www.epa.gov/athens/wwqtsc/html/warmf.html>





## Section 2: Credit Estimation Methodology

Adopting a credit estimation method that will ensure reliable and repeatable results is one of the keys to developing a successful WQT program. This chapter explores the key elements that should be considered when developing and adopting a credit estimation methodology, including pollutant parameter selection and credit definitions, crediting equations, trading ratios, and various other trading program considerations. It provides the backdrop for the assessment of more detailed applications using NTT and WARMF for the ORB.

### Pollutant Parameter Selection and Credit Definition

The suitability of a particular pollutant in any trading program must be evaluated on a watershed basis. The most common conventional pollutants used in water quality trading programs in the United States are nitrogen, phosphorus, and sediment. The EPA's *Water Quality Trading Toolkit for Permit Writers* (EPA, 2009; referred to hereafter as "the toolkit") supports trading of these conventional pollutants. The ORB application focuses specifically on nitrogen and phosphorus.

Regardless of the pollutant parameter selected for trading, each pollutant must be expressed as a consistent unit of trade. The EPA toolkit defines a credit as the amount of pollutant, expressed in mass that is reduced over a specific time period, in excess of the required reduction for a particular source (EPA, 2009). Similarly, the Ohio Trading Rules define a credit in terms of "quantity" of pollutant reduced in excess of water quality baseline requirements that occurs within a specific time period (Ohio Environmental Protection Agency [OEPA], 2007). In the Great Miami River watershed in Ohio, credits are traded as pounds of nitrogen and phosphorus reduced per year (Miami Conservancy District, 2005).

### WQT Credit Equation

Accuracy and repeatability of the crediting methodology and the resulting outputs are fundamental tenets of a WQT program. Crediting equations typically consider the calculation of reduced pollutant loading from BMP

implementation at the edge-of-field location as well as the loading impacts on the targeted water bodies. These non-point source credit estimation calculations vary widely among the many independently developed WQT programs. The credit equation formula and the magnitude of discount factors applied will depend on the physical, biological, and political characteristics of the watershed, as well as the types of non-point source reduction approaches and pollutants being targeted to generate credits. The toolkit recommends a credit estimation technique based upon the following equation, which focuses on nutrient loading reductions:

$$\text{Credit} = \text{Mass of pollutant reduced at edge-of-field (lbs/acre/yr TP or TN)} * \text{Trade Ratio}$$

The trade ratio depicted here can represent several considerations that may include some or all of the following factors:

- **Equivalency factor:** Nutrient trading equivalence factors are typically expressed as a percent to account for aquatic bioavailability of each source's discharged nutrient loading. For example, wastewater treatment plant (WWTP) discharges often have a higher fraction of dissolved phosphorus than agricultural runoff from a field where much of the phosphorus may be in particulate form attached to eroded soils.
- **Location factor:** Sediment/nutrient redeposition and stream channel attenuation create opportunities for one discharger's nutrient loading to have a different impact on a distant water resource than that of an equivalent load from another source discharging at a different site in the watershed. A location factor can be assigned to credits based on available watershed monitoring or modeling information. A discount for overland delivery to the edge-of-field location may also be needed, depending on whether the non-point source loading calculation includes this consideration. (The NTT model includes this overland delivery, so an additional discounting factor is not necessary with the use of this tool.)
- **Uncertainty factor:** Uncertainty within credit estimation methods can be attributed to input parameter variability, over-simplification,

assumptions made in the absence of data, variations in laboratory analyses or sampling methods, and/or stochastic variability in the environment affecting averaged non-point source loading assumptions. An uncertainty factor can serve as a safety factor that ensures that one nutrient credit generated (for example, 1 pound TP/growing season) in a trade will actually be greater than or equal to a credit from the buyer's discharge.

- **Policy factor:** These can include numerous possible policy factors, such as incentives for early participation, preferred BMPs as determined by the watershed community, and credit retirement for a net benefit to the water resource.

In some WQT applications, information to define these factors is lacking, or the factors do not apply to the water resource application. In these instances, simple default trading ratios might be used to advance trading opportunities, or policy decisions might be made whereby credits can be generated only upstream of a buyer. These two approaches are used, for example, in the Great Miami River trading program (MCD, 2005), where sufficient monitoring and modeling data were not available nor was an actual regulatory requirement yet in place. Trading ratios there are used as incentives for early reductions by WWTPs in advance of anticipated regulatory needs. The upstream-credit-only condition dampens concerns for pollution hot spots that are typically associated with location factors. Regardless of the potential differences between clearly defined trading ratio factors or default trading ratios, adaptive management is considered critical to the Great Miami trading program (MCD, 2005).

Where trade ratio discounting factors are used to determine the pollutant credits from a particular non-point source BMP, they may be applied to the estimated load reduction with the calculation of generated credits, or they may be applied to the demand side to adjust the number of credits required for a trade. These discounting factors can be selected by project managers or policy makers using scientific, model-based, local/regional, or geopolitical data for a particular watershed.

Policy factors can be selected to advance watershed management goals beyond the science used in credit estimation for an equal offset. Policy factors are incentives or discounts applied to credits based on the program's desired outcomes. For instance, a policy

factor can be used to ensure that an additional net benefit for the water resource occurs with each water quality credit trade. Other policy factors can be used to give preference for credit generation in a particular location or within a specified land use. The incentivized (that is, lower) trade ratios adopted in the Great Miami trading program represent another form of policy factor to encourage loading reductions before nutrient standards were in place that would drive the regulatory need for WWTP credit acquisition (MCD, 2005).

When considering all the potential trade ratio factors described above, the final credit calculation equations can have many forms. Below is one such form where these factors are applied in two parts. The first equation calculates the field credits generated, adjusting these to be equivalent to the WWTP discharge with equivalency and location factors. The second equation addresses factors for uncertainty and policy that increase the number of credits that must be purchased for a given discharger purchasing credits (EPA toolkit, 2003):

$$\text{Credits}_{\text{generated}} = \text{Mass of Pollutant}_{\text{reduced in the field}}^* [\text{Equivalency Factor}^* \text{Location Factor}]$$

$$\text{Credits}_{\text{bought}} = \text{Mass of Pollutant}_{\text{needed for offsets}}^* [\text{Uncertainty Factor} + \text{Net Benefit Factor}]$$

These equations may be considered as just one illustration of how trade ratio discounting factors may be applied in trading programs relying upon non-point source credits. Fundamentally, how a crediting platform for WQT can readily address potentially applicable factors will influence the viability and utility of such a program to cost-effectively meet compliance goals with agricultural credits.

## WQT Program Stipulations

General stipulations can be built into a WQT program to promote flexibility while still avoiding undesirable environmental outcomes with pollutant trading. These stipulations can help avoid local pollutant "hot spots," ensure the use of best available science, and encourage transparency and repeatability. Examples from the Ohio Water Quality Trading Rules (Ohio Environmental Protection Agency, 2007) on trading stipulations are discussed here in the context of related considerations for ORB WQT program stakeholders.

## **Policy Restrictions**

Many WQT programs have policy restrictions on how credits can be generated or used. For example, some farming communities may want to ensure that WQT does not result in intentional idling of farmland in order to generate pollution reduction. In order to address this potential issue, a WQT program could include a specific restriction on generating credits from conversion or idling of productive farmland. Restrictions on the use of federal or state cost-share funding and grants have also been incorporated into many WQT programs. This restriction ensures that reductions from WQT are above and beyond the reductions already funded in the watershed (that is, it stops credit generators from “double-dipping” or taking not only money from cost-share programs but also WQT credits for a single BMP).

Pennsylvania has included a protective policy measure in their WQT policies for farmland protection. The Department of Environmental Protection drafted a policy restriction on generating nutrient or sediment credits from idling productive farmland.<sup>6</sup> In this way, landowners who simply stop farming a portion of their land are not eligible to generate credits from that tract. This restriction illustrates how WQT policies and rules can be used to protect the values and priorities of stakeholders and the public that might be of concern when developing WQT programs.

The Ohio WQT Rules (Ohio Environmental Protection Agency, 2007) define how trading cannot cause a violation of water quality standards or cause adverse local impacts (hot spots). Some trading programs, including the Ohio WQT Rules, stipulate that a credit buyer must, therefore, purchase credits from an upstream source. In this way, upstream reaches benefit from the pollutant reduction, and local resource impacts or hot spots can be avoided below the discharge point of the buyer. The Ohio WQT Rules stipulate that the OEPA Director may also incorporate other special conditions into a National Pollution Discharge Elimination System (NPDES) permit, such as setting a cap on how much of the effluent limit can be offset with WQT credits.

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<sup>6</sup> See: <http://www.dep.state.pa.us/river/Nutrient%20trading.htm>

WQT policies and rules can also include restrictions on what funds may be used to generate credits. For example, the Ohio WQT Rules (Ohio Environmental Protection Agency, 2007) stipulate that federal funds cannot be used to generate credits, but the percentage of local contributions used to fund the BMP can be used to generate credits. In this way, the rule encourages WQT that produces additional reductions in a watershed, beyond what existing federal cost-share programs already accomplish without WQT.

## **Transparency and Repeatability**

Some of the major concerns of stakeholders when developing a WQT program are building transparency into the process and assurance that credit calculations are repeatable. Both transparency and repeatability provide stakeholders with a greater level of comfort that credits are real and surplus and will deliver expected water quality benefits. WQT programs can set requirements to help build transparency and repeatability into trading. Transparency is most often achieved through public registries of credits. In addition to posting for public viewing all of the credits that are generated and exchanged, programs can require that specific information be collected and kept on file by a trusted agency or state regulator.

In Ohio Trading Rule 3745-5-04(K), a qualified soil and water conservation professional, for example, is required to complete a number of steps in the trading process to ensure consistent crediting from pollutant reductions and determine accurate baselines for non-point sources. Rule 3745-5-08(B) requires that credits be calculated using the load reduction spreadsheet created by the Ohio Department of Natural Resources (Ohio Environmental Protection Agency, 2007). This spreadsheet ensures consistent, repeatable, and reliable crediting of pollutant reductions. If the BMP of choice is not included in the required load reduction spreadsheet, the rules stipulate that the reduction must be calculated using generally acceptable engineering methods deemed approvable by the director (Ohio Environmental Protection Agency, 2007).

Tools such as the load reduction spreadsheet help to ensure that the best available science is being used to calculate load reductions and credits. As scientific understanding improves over time and methodology and as crediting equations change, estimation tools such as spreadsheets can be updated. The same principle applies to online credit calculators. Online crediting

tools, such as the spreadsheet tool, provide certainty that the process is repeatable to qualified practitioners. In addition, online tools provide easy access for all users and can provide assistance materials or formats that can help users accurately complete the calculator using the correct information (which is discussed further in the following sections).

### **Verification Requirements**

A common stipulation of WQT programs is verifying that a BMP is properly installed and maintained to ensure pollutant reductions continue for the duration of the credit commitment. As part of a verification plan, a third-party entity typically is used to perform a site visit to confirm that a BMP has been installed correctly and is initially functioning. Following the first visit, an annual site inspection is generally required for structural practices where credits are generated and sold over a longer time period (generally, over the life of the practice for agricultural BMPs as defined by NRCS). Under general requirements of the Ohio WQT Rules (Ohio Environmental Protection Agency, 2007), a qualified soil and water conservation professional must conduct field inspections to verify the proper installation of a BMP and ensure proper functioning over time (or document BMP failures). In addition, conservation professionals are charged with conducting water quality monitoring at the program level in order to evaluate BMP effectiveness and inform methods for quantifying pollutant reductions and crediting.

### **Credit Estimation Methods Within the Trading Area**

Existing WQT programs in and around the ORB use a variety of credit calculation methods. These methods are typically adapted from best known science used and accepted by the agricultural sector (for example, USDA-

NRCS methods) or regulatory agencies (EPA or state-approved pollutant reductions methods). Many states have elected to use the Chesapeake Bay model outputs to develop and apply discount factors and baselines and use acceptable, science-based methods for calculating the edge-of-field reductions from non-point source BMPs. Table 2-1 provides details on the pollutant reduction calculations used by a number of WQT programs in the ORB or within states that have a portion of their footprint in the ORB. Note that some of the programs listed in Table 2-1 have trading programs that apply only to the Chesapeake Bay portions of their states.

During the development of most WQT programs, administrators typically review and select an “approved” nutrient reduction methodology for credit generation, although many state WQT rules, policies, and guidance allow credit generators to present alternative calculation methods for approval. In Ohio, individual WQT programs must specify what methodology they will use for calculating nutrient reductions in their WQT plan. In Pennsylvania, calculations in the nitrogen and phosphorus reduction spreadsheets are provided for guidance, but each credit generator must present a full credit proposal for state review, at which time the state and select experts evaluate whether the crediting method selected is appropriate and sufficient.

Typically, providing credit generators with pre-approved crediting methodology encourages more participation in the WQT program. When a WQT program uses standard agricultural reduction calculations or a standardized reduction calculator, potential credit generators have more access to and a better understanding of the trading process.

Table 2-1

Nutrient Reduction Estimation Methods Used by WQT Programs in and Around States Within the Ohio River Basin for Non-Point Sources

Program	Reduction Estimation Methods	Credit Calculator
<b>Maryland Nutrient Trading Program</b> [1] Chesapeake Bay Watershed, MD	Proprietary calculator utilizing Chesapeake Bay model outputs	Yes
<b>Miami Conservancy District</b> [2] Great Miami River Watershed, OH	Ohio Department of Natural Resources Load Reduction Spreadsheet EPA Region 5 Model RUSLE Pollutants Controlled Calculations/ Documentation for Section 319 Watersheds Training Manual	No
<b>New York City Watershed Phosphorus Offset Pilot Program</b> [3] Catskill, Delaware, and Croton systems, NY	Select models such as: Simple Method Urban Catchment Model Stormwater Management Model (NRC, 2000)	No
<b>State of Ohio Water Quality Trading Rules</b> [4] Statewide	Ohio DNR Load Reduction Spreadsheet Generally acceptable engineering methods (approved by Director) Other methods approved by Director	Yes (Spreadsheet)
<b>Pennsylvania Nutrient and Sediment Trading Program</b> [5] Susquehanna and Potomac River Watersheds, PA	Proprietary calculator utilizing Chesapeake Bay model outputs	Yes (NutrientNet and spreadsheet)
<b>Sugar Creek Trading Program</b> [6] Sugar Creek Watershed, OH	Ohio DNR Load Reduction Spreadsheet	No
<b>Virginia Trading Program</b> [7] Shenandoah-Potomac River, Eastern Shore, Rappahannock River, York River, and James River Watersheds, VA	Standard agricultural reduction calculations with BMP efficiencies from Chesapeake Bay model (v. 4.3)	Yes (Worksheet)
<b>West Virginia Trading Program</b> [8] Potomac River Watershed, WV	Department-accepted agricultural calculations (Similar to Pennsylvania) Proprietary calculator utilizing Chesapeake Bay model outputs	Yes (NutrientNet)

[1] <http://www.mda.state.md.us/nutrad/ntwhatis.php#Non-pointSource>

[2] <http://www.ohiodnr.com/soilandwater/programs/agpollutionabate/default/tabid/8856/Default.aspx>

[3] <http://www.dep.state.fl.us/water/watersheds/docs/ptpac/DartmouthCompTradingSurvey.pdf>

[4] [http://www.epa.ohio.gov/dsw/rules/3745\\_5.aspx](http://www.epa.ohio.gov/dsw/rules/3745_5.aspx)

[5] <http://www.dep.state.pa.us/river/Nutrient%20trading.htm#Calculation>

[6] <http://www.epa.state.oh.us/LinkClick.aspx?fileticket=i0dV2%2FdIa6s=&tabid=3518>

[7] [http://www.deq.virginia.gov/export/sites/default/vpdes/pdf/VANPSTradingManual\\_2-5-08.pdf](http://www.deq.virginia.gov/export/sites/default/vpdes/pdf/VANPSTradingManual_2-5-08.pdf)

[8] <http://www.wri.nrcce.wvu.edu/programs/pwqb/>

## WQT Trading Tools

Providing a credit calculator with built-in trade discounts or ratios increases the accuracy of credit calculations, which can translate into less administrative or oversight burden, more accurate credit pricing, more assurance to credit buyers, and greater overall reliability and transparency in the WQT program. Pennsylvania, for example, has developed a sophisticated Microsoft Excel spreadsheet calculator that incorporates several trade discounts or ratios using outputs from the Chesapeake Bay model. The spreadsheet calculator is also relatively easy to use, but requires more detailed information about the BMP site, such as soil type, past nutrient management practices, and existing BMPs. A recent trend in WQT programs is the development and use of integrated, online trading platforms such as NutrientNet.<sup>7</sup> NutrientNet provides trading participants with several tools to assist them in calculating reductions and credits, registering credits with the appropriate authority, finding trading partners, and executing credit trades. It is an example that illustrates how a trading platform can be constructed for creating consistent, reliable, and cost-effective entry and participation into a WQT program.

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<sup>7</sup> See: <http://www.nutrientnet.org/>

# Section 3: Addressing WQT Issues with Models

Watershed-scale and edge-of-field non-point source estimation models can be used to calculate nutrient load reductions and predict watershed responses to provide WQT managers with repeatable estimation techniques. The accuracy of model outputs can be improved with input from local experts familiar with specific watershed conditions and agricultural practices. The use of models also provides transparency in WQT programs by giving stakeholders and concerned citizens the opportunity to test the veracity of crediting methods.

This chapter provides a description of model applications in the context of WQT crediting equations. It includes:

- A discussion on the limitations of models scale and resolution
- How models can provide the best available science for defining trade ratio factors
- Evaluating trading program benefits with monitoring and modeling

## Model Scale and Resolution

Linking field-scale and watershed-scale modeling results to predict water quality pollutant load reductions and credit values at differing locations in a watershed is useful. But WQT managers first need to acknowledge and address the complexities of working within two different scales using different assessment tools. Changing the assessment scale (that is, differences introduced by estimation tools for a given field versus those at a watershed scale) can provide different pollutant yields using the same units expressed, for example, as pounds per acre. These varying model results can stem from differing attenuation factors used for overland delivery compared to in-stream attenuation. Differences in results can also reflect introduced uncertainty into load reduction estimation approaches. For example, detailed site-specific field information can be used in assessing BMP reductions in field-scale models. For watershed models, such detailed farm applications and other site-specific physical conditions must be averaged over a much larger area because of the limitations of a watershed model that has

to assess potentially hundreds of farm fields at a finite resolution. Subsequent chapters in this report will illustrate how WQT program managers can acknowledge these differences and work within each model's limitation to define appropriate crediting strategies.

## Equivalence, Location, and Uncertainty Considerations

Outputs from watershed-scale and field-scale models have to be combined with and adjusted by additional information to address the need for WQT credit estimation. With refined resolution for edge-of-field reductions, producers and others recognize that the field-scale model is important for assigning equitable credit values that honor the differences between agricultural fields. This finite resolution brings a sense of fair play to the credit estimation itself and the WQT market in general, compared to methods that use averaged information. To become tradeable credits, these field-scale reduction results may need to be adjusted by location, equivalence and uncertainty factors, policy issues like baselines, eligible trading boundaries, net benefit factors, and socio-political directives set forth by the trading program (as discussed in Chapter 2).

A watershed model can provide location factors if water quality can be simulated across the basin. The watershed model can also inform program decisions necessary to address U.S.EPA WQT policy regarding water quality standards that states, "Establishing defined trading areas that coincide with a watershed or TMDL boundary results in trades that affect the same water body or stream segment and helps ensure that water quality standards are maintained or achieved throughout the trading area and contiguous waters."<sup>8</sup> Further, watershed modeling can also address the

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<sup>8</sup> U.S. Environmental Protection Agency (2003). Water Quality Trading Policy. Office of Water. January 13, 2003. Available on-line at: <http://www.epa.gov/owow/watershed/trading/tradingpolicy.html>.

portion of the EPA policy referring to management of “local hot spots” by identifying potential locations within the watershed where a trade might create a new or exacerbated impairment. This, in turn, can lead to resources being allocated to monitor and assess the water body in question and results being used to set appropriate trading areas, leading to adaptive management adjustments in the WQT framework and crediting tools.

Both watershed- and field-scale models can likely address delivery, and both can be evaluated for their ranges of introduced uncertainty using analysis techniques to determine the uncertainty in the calculated credits. Remaining factors for load adjustment include equivalence factors and selected policy factors, which need to be determined using outside resources specific to the source and/or programmatic decisions.

### **Program Verification at Scale**

Where trades are limited in number, WQT programs typically have a small impact on source reductions compared to other non-trading-related implementation programs. Regardless of this disparity in the scale of

implementation, trading programs are often required to verify improvements associated with each trade. This is challenging because routine monitoring and analysis—even absent trading—cannot adequately discern pollutant loading reductions efforts, new loads from unmonitored growth, or weather variability. Thus, monitoring to track smaller trading applications is even more challenging. Watershed modeling combined with targeted monitoring offers the potential to better inform WQT program assessments by forecasting projected reductions associated with WQT activities.

This chapter has discussed the value of utilizing standardized models and what roles these can play in improving WQT programs. Benefits can be realized in precision, accuracy, and transparency of credit calculations, as well as in informing WQT program development and adjustment periods. These are important programmatic upgrades for supporting the science and ecological basis for trading at scale. Whereas other programs may simply use trading ratios in the absence of watershed modeling or empirical calculations for edge-of-field loading calculations, the analysis here of mechanistic field- and watershed-scale models is a critical step in program advancement.



# Section 4: Evaluating NTT and WARMF for WQT Crediting

This chapter evaluates NTT as a field-scale model and WARMF as a watershed-scale model using a specific application in the Upper Big Walnut Creek (UBWC), a sub-basin to the Scioto River watershed in central Ohio. Strengths and weaknesses for the accurate crediting of agricultural BMPs were considered for each model. This evaluation included model calibration, sensitivity analysis, various BMP model runs, and feedback from potential users. Detailed assessments of each model as originally written by project collaborators are appended (Appendix A: NTT; Appendix B: WARMF). While many studies have previously considered WARMF accuracy, to our knowledge, this is the most detailed assessment that has been conducted for NTT.

## Study Area

The Upper Big Walnut Creek watershed was selected as the sample watershed to run both models. The UBWC is an 11-digit hydrologic unit code (HUC) watershed (05060001-130) in central Ohio that comprises 190 square miles or 121,600 acres (493 km<sup>2</sup> or 49,300 hectares). It is part of the Scioto River watershed within the Ohio River Basin. It contains land area in portions of Delaware County, Morrow County, Licking County, Knox County, and Franklin County (see Figure 4-1), with the greatest portion of the UBWC falling within Delaware County (66%). The USDA-NRCS has an agricultural research station located in the watershed, and the basin has been designated as a Conservation Effects Assessment Project (CEAP) area.

The watershed is predominantly rural and drains into Hoover reservoir, which is northeast of Columbus, Ohio, and serves as a drinking water source for the city. Overall, predominant land uses are cropland, pastureland, and a growing proportion of urban land uses. The UBWC contains approximately 45,100 acres (183 km<sup>2</sup>) of cropland, which constitute approximately 37% of the land cover of the watershed. Corn, soybeans, and wheat are the main crops grown in the watershed. The four major soil associations in the UBWC are Bennington-Pewamo-Cardington, Centerberg-Bennington, Cardington-Alexandra, and Amanda-Centerburg.

The UBWC watershed was selected primarily because of the previous CEAP work in the UBWC watershed where data sets have been established that provided useful information for the calibration of both models.

## Nutrient Trading Tool Evaluation

The Nutrient Trading Tool (NTT) is an Internet application that allows individuals interested in assessing non-point source runoff from farms to 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.

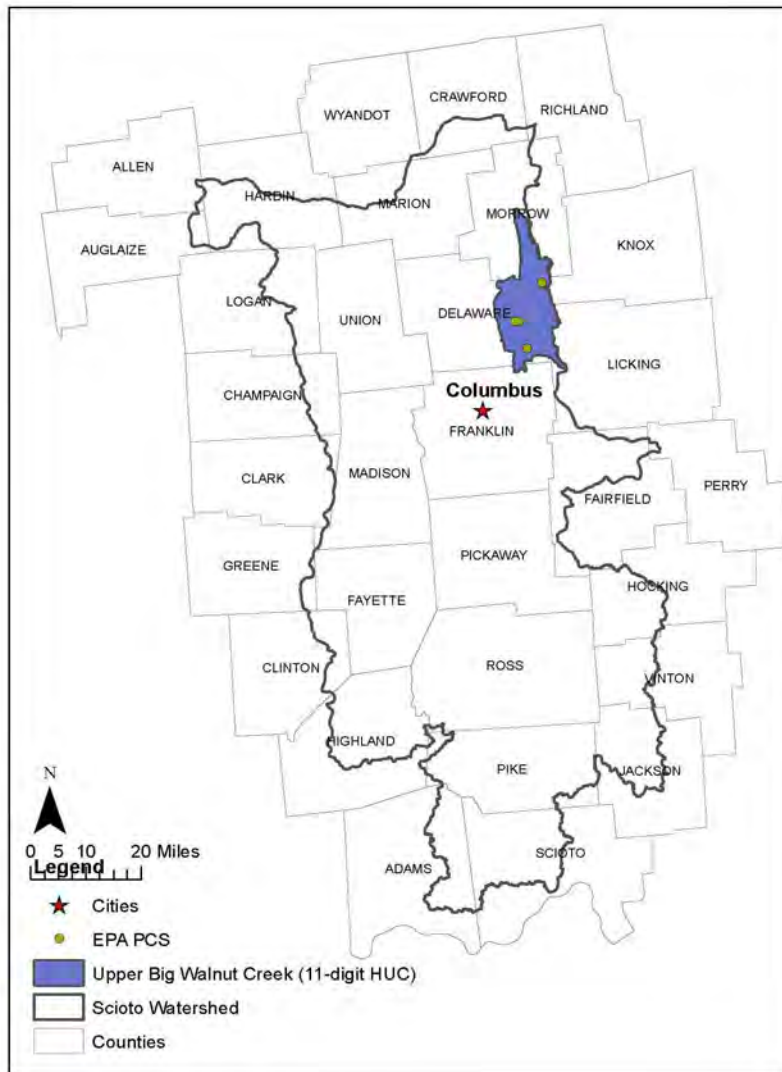


Figure 4-1  
Location of the Upper Big Walnut Creek Within Scioto Watershed in Central Ohio

### NTT Background

USDA-NRCS originally developed the Nitrogen Trading Tool as a user-friendly, web-based application that can calculate nitrogen load reductions from an individual farm. The Nitrogen Trading Tool focused on this nutrient because its estimation routines are based on the Nitrate Leaching and Economic Analysis Package, or NLEAP (Shaffer, et al., 1991). While very useful, its exclusive focus on nitrogen limited the applicability of the tool. In fact, in many agricultural watersheds, particularly those with significant livestock numbers, phosphorus is the nutrient of primary concern.

In an effort to address the limitations of the Nitrogen Trading Tool, USDA-NRCS developed the Nutrient Trading Tool (NTT) in collaboration with the Texas Institute for Applied Environmental Research (TIAER). The strengths, scope, and capabilities of the expanded NTT are based on its core simulation model, the Agricultural Policy Environmental eXtender, or APEX (Williams, et al., 2000). NTT was developed with APEX in place of NLEAP within the same user-friendly, web-based interface of the Nitrogen Trading Tool. APEX is a computer simulation model that has a successful record of estimating the impacts of field-scale practices on a wide array of environmental indicators, including air- and water-borne pollutants. The inclusion of APEX also allows users to evaluate other farm-level conservation practices, such as filter strips,

terraces, and buffer strips that could not be evaluated using the Nitrogen Trading Tool. As a result, users also have access to various other relevant indicators (for example, water quantity, sediment losses, and crop yield changes) to help them make informed decisions about conservation practice implementation.

Since NTT is a relatively user-friendly program, virtually all the data required for a number of states and counties are already available on the NTT server. NTT provides pre-loaded management alternatives for users who are interested in evaluating typical BMPs for their fields. Site-specific information is already accessible to the model, so the user provides the size of the field or land area they wish to evaluate by selecting the area of interest on the USDA’s Web Soil Survey (WSS) website. All other data required for these areas can be selected by users from drop-down list boxes on the NTT web pages. If users desire to estimate nutrient and sediment losses for BMPs that are not available in the NTT pre-loaded alternatives, the user can select options to either modify existing BMPs (operations) or create new ones. The NTT program consists of three main components:

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

*Table 4-1  
Range of NTT Best Management Practice Applications*

<b>Category</b>	<b>Application</b>
Field operations	Tillage
	Nutrient applications
	Irrigation
Structural practices	Filter strip
	Buffer zone
	Terraces
	Riparian forest buffer
	Wetlands
	Contour farming
	Tile drainage

All the data sets required for running NTT in selected states and counties are housed on the NTT server for ready user access. The following are the NTT databases that are available on the NTT server for selected states and counties that are also being developed for the remaining counties in the United States:

- Weather (precipitation, minimum temperature, maximum temperature)
- Soils
- Crop parameters
- Tillage parameters
- Properties of major fertilizer and manure products
- Typical management practices for each major crop in selected crop management zones

Currently, NTT can simulate any crop operations that can be simulated in APEX. NTT can also simulate a number of structural conservation practices. However, due to its core intent of being user-friendly, the conservation practices that are presently available in NTT are a subset of what can be simulated in APEX—essentially only the practices for which a user-friendly interface has been developed for the APEX model. Table 4-1 summarizes the range of BMPs that can be simulated with NTT.

## Model Calibration

While it was anticipated that substantial data would be available in UBWC due to the existing CEAP effort, water quality monitoring data in the UBWC watershed suitable for NTT calibration were limited. Flow, sediment, and nutrient data collected at four stream sites in the watershed were used for calibration of NTT. It is important to note that since NTT is a field-scale tool, field-scale data are more applicable. However, the project team was able to perform some calibration using the stream site data that was made available by King (2010). (Specific details of these UBWC NTT applications as originally authored by TIAER can be found in Appendix A of this report.)

For calibration purposes, the monthly stream loadings were converted to annual loads. Then the annual stream loadings were converted to annual per unit loads in order to compare them to NTT loads. The annual per unit area loads for the four stream sites are presented in Table 4-2 (see also Appendix A). Since NTT output is at the field scale, multiple NTT runs for the predominant crop rotations in the watershed were compared to the subwatershed loads from King (2010) (Table 4-2 and Appendix A). The NTT output was considered reasonable if the average loads estimated by the tool were in line with the subwatershed load from the four sites on a per unit area basis. However, the comparisons would not be exact since some urban and other non-agricultural land uses are also reflected in the measured data.

Table 4-2  
UBWC Data from King (2010) (See Appendix A for Additional Details.)

Indicator/Year	Unit	Site A	Site B	Site C	Site D	Average
<b>2005</b>						
Precipitation	Inches	32.70	37.61	38.12	38.12	36.64
Flow	Inches	19.79	18.18	22.91	24.13	21.25
Total N	lb/acre	46.69	21.88	12.81	17.13	24.63
Total P	lb/acre	1.08	0.70	0.37	0.50	0.66
<b>2006</b>						
Precipitation	Inches	35.74	34.57	43.56	44.54	39.60
Flow	Inches	21.77	13.18	17.92	24.00	19.22
Total N	lb/acre	48.46	18.50	16.02	24.32	26.82
Total P	lb/acre	1.67	0.61	0.46	0.98	0.93
<b>Average</b>						
Precipitation	Inches	34.22	36.09	40.84	41.33	38.12
Flow	Inches	20.78	15.68	20.41	24.07	20.24
Total N	lb/acre	47.57	20.19	14.42	20.72	25.73
Total P	lb/acre	1.38	0.66	0.42	0.74	0.80

During NTT calibration, several input parameters were adjusted to more closely mimic observed yields and water monitoring data. Most of the crop parameter data remained unchanged after the calibrations were completed. The only substantial changes that had to be

made were in the crop management information. Specifically, in the case of winter wheat, the “kill” operation that determines where the crop ceases growth was adjusted to ensure that wheat growth was terminated at the appropriate time, right before planting of the next crop. Also, the APEX harvest operations

used for different crops were adjusted to ensure that the correct biomass and grain harvests were being simulated by the model.

### **BMP Model Analysis**

Six conservation practices were considered for the NTT application in the UBWC based on conversations with experts in the watershed area (King, 2010). Of the six practices, five were simulated with NTT. The sixth practice, bank stabilization, was not included in the NTT application for this project due to limitations within the tool to adequately capture the typical design of bank stabilization structures. The five practices simulated in NTT include the following:

- **Water table management (control drainage):** Water table management encompasses a number of conservation practices. For this study, tile drainage was simulated using NTT.
- **Nutrient management:** Nutrient management comprises a host of practices that entail improved use of crop nutrients on the farm. These include manure nutrient crediting, judicious use of manure and inorganic fertilizer sources, incorporation of manure and fertilizer nutrients, legume nutrient crediting, timing of nutrient applications, plant tissue tests prior to nutrient applications, soil nutrient tests prior to nutrient applications, split nutrient applications, and variable rate technologies, among others.
- **No-till:** No-till production was simulated for each cropping system and compared against the conventional tillage reference scenario for the same crops.
- **Cover crop:** Cover crops were evaluated by comparing a scenario including cover crops after conventional tillage to the conventional tillage reference scenario without cover crops.
- **Hayfield establishment:** Hayfield establishment was evaluated by replacing the current cropping system with a permanent alfalfa crop. For simplicity and because no alfalfa management information was available that included an annual crop, the hayfield establishment scenario evaluated in the present study consisted of a permanent alfalfa crop with a one-time establishment period for the 24-year simulation.

### **Sensitivity Analysis**

Sensitivity analyses are used to evaluate how specific changes in model input parameters affect the output of a model; in other words, how output variables respond to changes in input parameters. The NTT output presented to users is based on very complex mathematical processes. Sensitivity analyses allow modelers to determine how output variables are sensitive to changes in input parameters. This section of the report outlines the results of sensitivity tests that were performed on NTT using data pertaining to the UBWC watershed. In most cases, data for Delaware County, Ohio, used as county-level data were most applicable. Delaware County, Ohio, covers a greater portion of the UBWC watershed than any other county.

To assist the model setup and calibration process, a sensitivity analysis was performed on NTT. The sensitivity analysis can systematically determine how much uncertainty is introduced when individual input coefficients contain errors or are based on default values/assumptions. A sensitivity analysis was performed for NTT by adjusting each input variable in a pre-determined fashion. After each input adjustment, NTT was run to produce the output corresponding to that particular input adjustment. The output data were then stored in a database file for subsequent processing.

A sensitivity analysis benefits program managers in two ways. First, it identifies introduced uncertainty by comparing the range of output change against the desired resolution of the model. If the model is within a tolerable range, the setup and calibration decisions can be simplified. For instance, if the use of regional average or default data is adequate, the modeler can focus on improvements to calibration in other areas. The second benefit arises when the comparison indicates that an input parameter significantly affects modeling results. If the change in output is significant across the expected range of values for an input parameter, then collection of relevant site-specific data may be warranted. Input parameter sensitivity combined with BMP implementation costs (or difficulty in collecting local data) can be an indicator of when field measurement protocols are needed to collect critical field information. Examples of cost-effective data collection efforts might be soil phosphorus test results, a field's actual yield history in bushels per acre (kg per hectare), or whether alternative data from another source are necessary for model setup. These steps also have the potential to help assess the model's cumulative uncertainty by

understanding where and why the model is sensitive to various parameters. This information can be used to ensure that overlapping uncertainties are not compounded by imprudent use of discount factors.

For the NTT sensitivity analysis, the following specific adjustments were made in each input variable to examine model output responses:

- **Fertilizer application rate and precipitation:** Fertilizer application rates and precipitation values were adjusted upward by 50% and downward by 50%.
- **Minimum and maximum temperature:** Minimum and maximum temperature records were also adjusted upward by 50% and downward by 50%.
- **Date variables:** Dates for field operations were adjusted differently. For the NTT sensitivity analyses, operation dates were adjusted upward and downward by a select number of days in an iterative fashion (0, -1, 1, -3, 3, -7, 7, -30, and 30 days).
- **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 (see Table A-4 in Appendix A).

Full results from the sensitivity analysis are included in Appendix A. A summary of the main findings from these results is included here:

- **Fertilizer application rate:** The summary results suggest that soluble nutrient indicators are particularly sensitive to inorganic fertilizer application rates (see Table A-5 in Appendix A).
- **Operation date:** As expected, larger changes in operation dates have much greater impacts—though not necessarily larger sensitivity ratios—than smaller changes in operation dates.
- **Temperature:** Results indicate that all output variables are very sensitive to temperature changes. Furthermore, the results indicate that output variables are more sensitive to a 50% reduction in maximum and minimum temperatures than to a 50% increase in the same.
- **Precipitation:** Outputs from simulations suggest that all output variables are very sensitive to precipitation amounts. It is important to remember

that these 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 in Appendix A would indicate.

The parameters highlighted here are equally split between the data collected by a field representative and the data gathered by the modeler in charge of calibration. Fertilizer application rates and implement operation dates would be important field assessment protocol elements to identify and guide the producer's field representative in data collection. Likewise, temperature and precipitation inputs are important, and program managers should make every effort to periodically update data sources and scrutinize meteorological data sets within the area of interest.

## NTT Workshop

On August 26, 2010, the project team facilitated an NTT workshop with NRCS and key Ohio agricultural Technical Service Providers (TSPs), Certified Crop Advisors (CCAs), and Soil and Water Conservation District (SWCD) staff at the Farm Bureau Federation offices in Columbus, Ohio. Eighteen agricultural professionals serving in these professional roles attended the NTT workshop. Of these, fifteen were familiar with market-based approaches to conservation, and three were already familiar with NTT and had tested it prior to the workshop using a short guide provided to them. One of the workshop participants had experience with the Great Miami Conservancy District-based trading tools, but no one claimed experience with any other trading tools. (See Appendix C for Workshop Proceedings and full results of the on-line participant feedback survey.)

The following key topics were identified as significant characteristics of a WQT program credit estimation model:

- Accuracy
- Must-have features
  - Ability to input soil test results
  - Ability to add data on tile drainage features in summary form when predicting loading in fields with subsurface tiling
  - Ability to add site-specific data on crop yields
  - Ability to add livestock operation BMPs

- Ease of use
- List of desired BMPs

These items are discussed in detail below.

### **NTT Accuracy**

TSPs asked a number of sophisticated questions about the modeling underlying NTT, which were directed toward understanding its accuracy and reliability. They asked about how NTT determines yield goals, about underlying weather data, and about how NTT models water flow over filter strips (sheet flow versus channelized flow). The TSPs also asked about the relationship and possible redundancy between NTT and some of the other tools that are coming on-line (For example, software is now available to help TSPs with nutrient management planning and comprehensive nutrient management planning).

In comparing conventional tillage to a no-till scenario, some TSPs felt that the yield estimates as a whole were too low. The current use of genetically engineered crop varieties (genetically modified organisms or GMOs ) has been advancing the bushel per acre yield increases in the range of 3 bushels per acre (approximately 195 kg/ha) per year. The current estimates in the NTT examples were considered to be significantly low—as much as 30 bushels per acre (1950 kg/ha) too low in some settings. The model estimate should be adjusted to maintain credibility with producers and the agricultural professionals assisting them. However, everyone seemed comfortable with presenting the data in terms of bushels per acre (kilograms per hectare).

Many stated that their library of tools does not estimate non-point source runoff; therefore, they had no history or basis to make comparisons of nutrient and sediment loading against NTT.

### **Must-Have Features for NTT**

The following features are those that have been identified in this analysis and by TSPs as being important functions of NTT:

- **Ability to input results of soil tests**

Most, if not all, of the TSPs rely on soil tests they perform in their clients' fields to determine the amount of residual phosphorus available for plant growth. Many are finding enough residual

phosphorus and are advising their clients not to add any more phosphorus to the soil. The increase of available soil phosphorus associated with continuous additions of phosphorus fertilizer results, in the long term, in excessive phosphorus levels. Without being able to enter these results, they worried that NTT may predict a yield loss even though there is enough residual phosphorus in the soil to support plant growth. This, in turn, might lead producers to apply more phosphorus . Given the problems caused by surplus phosphorus in the system, NTT could create real problems if it erroneously predicts yield losses. The TSPs felt strongly that they need to be able to enter the results of their soil tests into NTT.

- **Ability to add data on crop yields**

The TSPs also felt strongly that they should be able to input their own data on clients' crop yields. They felt that the NTT-generated yield predictions—at least in some cases—were “not even close.” They are seeing much greater yields related to newer varieties, hybrids, and better genetics. They pointed out that plant growth (in turn linked to crop yields) may influence nitrogen and phosphorus uptake by the plants and how much nitrogen and phosphorus are ultimately lost from the farm field.

- **Ability to add data on drainage tiles**

The use of agricultural drainage tiles is common and can influence wind erosion; crop yields; and phosphorus, potassium, and nitrogen losses. Sometimes tiling can help plants remove more nitrogen and phosphorus , and other times it can increase nutrient losses. The TSPs felt that NTT has to handle more than just “tile” or “no tile.” They suggested using the percentage of field tilled, maybe the percent of efficiency, perhaps being able to input the density of tiles, or maybe adding a coefficient for systematic tiles and lateral tiles. Information about how much water flow goes through tile lines and the ability to enter the number of surface tile intakes was also considered useful, but participants recognized that this would call for very technical input.

- **Ability to model livestock management options**

The TSPs would like to model livestock as well as cropping systems. For example, crops grown for silage could be evaluated for adoption as cover

crops. They commented that while manure application is heavily regulated along the East Coast, producers in the Midwest are likely to leave manure in the fields following grazing.

### **Improving Ease of Use**

Overall, participants felt that many of the questions raised could be answered by providing model information in a guidebook and perhaps in a Frequently Asked Questions and Answers section online. Some TSPs felt that the ability to draw shape files and “clip out” soils data worked well, although they were concerned about the need for accurate juxtaposition of parcel data. They also appreciated having a drop-down menu. Others felt that it was more important to be able to input site-specific soils information from their clients’ operations. One participant remarked that he would not use NTT if he had to individually create/draw out each shape file; he said it would make much more sense to be able to input his own shape files. It would take too much time to re-create shape files for a large number of parcels. Another TSP suggested that since the Revised Universal Soil Loss Equation (RUSLE) is already in the model, they would like to be able to transfer data they have previously entered into RUSLE.

### **Additional BMPs for NTT**

The TSPs felt the management option of using automatic global positioning systems (GPS) for fertilizer application (which prevents the operator from overlapping applications) along with variable rate fertilizer application linked to specific areas in the field was important to include in NTT. They also supported a wetlands option, but pointed out that wetland simulations need to be vetted by local experts since there are several different equations used across the United States that take into account factors such as area and retention time.

### **Using NTT to Calculate Water Quality Trading Credits**

Taking into account differences in flow regimes within streams will be particularly important to determine whether non-point source load reductions are occurring during the same time span as point source loadings. A participant from an urbanized area pointed out that there are many waterways with elevated levels of phosphorus in the spring from non-point sources and elevated levels of phosphorus in August from point

sources. Another TSP recommended adding a digital elevation model (DEM) to NTT to help estimate runoff and discharge rates.

### **Potential Benefits of NTT**

The TSPs thought that they might be able to use NTT to do cost-benefit analyses. They felt that NTT will make it easier to quantify environmental benefits for their clients and that it is a step up from what they have now. NTT ties in nitrogen and phosphorus losses with conservation systems that RUSLE cannot do. Hopefully, NTT will allow them to zero in on the dissolved phosphorus component that is becoming increasingly important and show their clients how much leakage of phosphorus is occurring and how much reduction in phosphorus they can achieve.

### **Other Comments**

The 18 agricultural professionals expressed consensus agreement that farmers will probably want as much freedom as possible to manage their specific farm operation styles within the NTT program. They also felt that it would be difficult for farmers to question percentage reductions in nutrient runoff since they do not normally deal with that kind of information. Many of their clients are not computer-savvy, and others do not have the time or interest to collect and analyze field data and use it to make complex decisions. One participant pointed out that another reason to use TSPs as the NTT operator is that the WQT credit buyers would probably want a highly qualified person at the TSP level to oversee the credit process because real money is exchanged and real liability is attached to those credits.

Regarding whether or not the use of NTT was intuitive, the participants agreed that it was easier to use than RUSLE2. However, they commented that NTT was not necessarily intuitive and that they definitely needed guidance on how to load the soils data, but that the rest was “okay.” This could be tracked over time with a series of follow-up questions to determine if ease of use is truly a limiting factor or if the newness of the event triggered anxieties that will disappear with more exposure to the model.



## Supplemental Information on NTT

### Information on the Use of Crediting Tools from ORB Producers

In 2009 and 2010 American Farmland Trust (AFT) hosted three listening sessions with producers in the ORB partly funded by an EPA Targeted Water Grant to EPRI. One of the questions asked of producers was what kind of crediting tool or tools would make their participation in a WQT market more likely. Respondents strongly support the development of a web-based crediting tool. Participating producers have offered the following feedback to AFT regarding such tools:

- Web-based tools are a good idea, particularly for young farmers. NTT can help producers download soils, crops, and farming practices and determine the number of credits generated based on their farm and how they manage it. However, farmers would need to have access to rural broadband to make rapid download possible.
- Any crediting tool should also provide information about yield impacts from installing conservation practices that can generate credits. The producers in the listening sessions so far have informed us that reducing the cost per acre for producers is one interest, but most farmers want to produce more. If practices reduce yield, then the perception may be that this is the same as a reduced profit. In some situations, yield becomes a more important factor than net costs, especially if landowner/landlord compensation is based upon yield.
- Although credits in the Great Miami River WQT program are determined by running RUSLE for each farm field, RUSLE is a cumbersome model for a credit equation. An average credit number per practice would be better. However, using an average may not be sufficiently robust. NTT provides a standard equation and easier delivery path and can be used by each farmer to calculate credits from implementing practices on their fields.
- If a WQT program wants to encourage the use of a web-based tool, it could offer greater incentives to those who do their work online and register online (for example, a Turbo-Tax approach). Producers might be able to use SWCDs or the library if they lack a computer, although most farmers would need to do that kind of work at night.

## Results of NTT Feedback Survey

### NTT Online Survey Results

Ten of the 18 participants (55%) attending the NTT workshop on August 26, 2010, also filled out the online survey. A detailed summary of the questions and responses is provided in Appendix C. In general, the responses were very positive.

When asked who the likely users of NTT would be, only 10% thought that NTT would be used by farmers. The more likely users were TSPs (90%), NRCS staff (80%) and CCAs (70%). Some also felt that researchers (30%) and SWCD staff (20%) would also find NTT useful. All respondents felt that quantifying sediment and nutrient loading for producers was necessary and all indicated that they would participate in a WQT market by providing evaluation services for their clients. In addition, a significant percentage of respondents saw NTT as valuable for assisting land management and farm planning processes. The NTT-derived factors deemed most useful when facilitating farm planning and operation discussions included nitrogen (100%), phosphorus (100%), crop yields (80%), and sediment (70%), with no other factors identified.

Based on the scenarios that the respondents ran by themselves, 80% stated that the nutrient and sediment reduction estimates and/or yield estimates were within an expected range. Twenty percent of the respondents were surprised by the estimate, with one stating that the yields were too low and another wanting more verification than just a few scenarios. One respondent really had no idea as to what to expect, so the values generated did not have any meaning for this individual.

The respondents identified the most useful features of NTT as the quantification of non-point source edge-of-field pollutant loading (90%) and the option to define and check the baseline scenarios for being eligible for trading (60%).

When asked whether they found it easy to run NTT, 70% said no. The fields or windows causing concerns (and the specific improvements requested to make it easier to use) are captured below. Quoted comments included:

- “Need to be able to enter the area for the waterways alternative. The current tool seems to assume an area equal to 5% of the watershed.” (It is assumed that this was meant to be 5% of the field.)

- “The interface I felt was a bit cumbersome, especially if I needed to go back to a previous page and make changes.”
- “Capturing WSS and changing specific practices.”
- “I think the current format is good. However, I don’t think this is easy. I think a few of the pull downs could be more state or region specific.”
- “The interface was not exactly easy to figure out at first glance. The ability to modify all of the different options should be prioritized and not hidden away. This tool will be used for very specific situations; therefore, it should be as painless as possible to customize the description. No two farms are the same anywhere in the world.”
- “Maps load very slowly. Outlining AOI takes too long for each field. We need to be able to import shape files for field boundaries.”

Only 20% of the respondents were aware of similar non-point source runoff estimation tools (that is, the EPA Region 5 spreadsheet model), but they felt that the other models were not as useful and that NTT was

an advancement. Based on the short training in the NTT workshop, 60% of the respondents said they would now be comfortable using NTT, and 40% said they would need additional practice (or self-training), mainly to run through more customized management options or to fully understand the program before taking it to clients.

Finally, the respondents were asked to rate the user-friendliness of NTT features. These are captured in Figure 4-2. None of the features were rated as very poor (not user-friendly at all), and only the soil survey map and soil inputs rated at least one excellent. They rated the user-friendliness of NTT overall as good (60%) or neutral (40%). Half were neutral about the user manual, while 30% rated it as good and 20% rated it as poor. The soil survey map received the highest user-friendly ratings, with 90% of respondents rating it as good and 10% rating it as excellent. However, response to the soil inputs was highly variable with ratings of 50% neutral, 30% good, 10% excellent, and 10% poor. The management selection inputs were rated as good (40%), neutral (30%), and poor (30%). Reporting was rated as good (60%) and neutral (40%).

	Very poor/Not user friendly at all	Poor	Neutral	Good	Excellent/Very user friendly	Response Count
Users Manual	0.0% (0)	20.0% (2)	50.0% (5)	30.0% (3)	0.0% (0)	10
Soil Survey Map	0.0% (0)	0.0% (0)	0.0% (0)	90.0% (9)	10.0% (1)	10
Soil Inputs	0.0% (0)	10.0% (1)	50.0% (5)	30.0% (3)	10.0% (1)	10
Management Selection Inputs	0.0% (0)	30.0% (3)	30.0% (3)	40.0% (4)	0.0% (0)	10
Reporting	0.0% (0)	0.0% (0)	30.0% (3)	70.0% (7)	0.0% (0)	10
Overall User friendliness	0.0% (0)	0.0% (0)	40.0% (4)	60.0% (6)	0.0% (0)	10
					<i>answered question</i>	10
					<i>skipped question</i>	0

Figure 4-2  
Survey Response Results Regarding NTT User-Friendliness

## Ohio Department of Natural Resources Evaluation of NTT

In a letter to Dusty Hall of the Miami Conservancy District in Ohio, Rob Hamilton of the Ohio Department of Natural Resources (ODNR) provided initial comments and reactions regarding NTT as part of contractual agreements under the EPA Targeted Watershed Grant #WS-00E74201-0 to the District. This EPA project specifically examined the use of NTT in the Great Miami River trading program compared to the program's current use of the EPA Region V spreadsheet model for calculating agricultural non-point source credits. Mr. Hamilton attended the NTT Workshop at the Ohio Farm Bureau Federation Office on August 26, 2010, under this CIG project. In general, Mr. Hamilton reported that the initial impression and reaction of local SWCD staff to NTT was positive. The complete letter, included as part of a final report to the EPA by the Miami Conservancy District, can be viewed in Appendix D (used with permission).<sup>9</sup>

Comments from ODNR were used by this project to consider conclusions and recommendations about NTT.

### NTT Model Strengths For WQT Credit Estimation

NTT's standardized calculators and automated data entry in a uniform (and controlled) framework by field representatives provide more repeatable results between technicians when compared to other credit estimation methods. Other WQT credit estimators can provide substantial variability in model outputs because of introduced variability by use of professional judgment in field estimations for sheet erosion. A recently completed EPA Targeted Watershed Grant in Michigan (Kieser & Associates, LLC and Gun Lake Tribe, 2010) illustrated how various field technicians and other professionals could arrive at wildly varying credit amounts using USDA's RUSLE2 equations coupled with the relatively simple, empirically driven trading platform, NutrientNet. The comparatively finite ability for selection of credit equation inputs or interpretations in

NTT provide a distinct advantage for obtaining repeatable results for the same field with the same BMP applications from potential NTT users.

Unlike other loading calculators, NTT provides useful yield information that technical professionals and agricultural producers can use in their cost of implementation evaluations and planning. In addition, NTT outputs have the potential to provide carbon and pesticide quantifications (although these estimation components were not evaluated in the scope of this project).

The agricultural professionals at the NTT workshop provided important feedback. The TSPs' comfort with NTT regarding the agronomic capabilities and non-point source implications is evident. While many would like an easier tool, the majority of respondents were comfortable with the operation and understanding required to select model input parameters. The NTT model application appears to have struck a balance between using an estimation method based on best available science and setting pragmatic input requirements and expectations for the intended users.

The NTT model also provides robust credit results that include more forms and pathways of loading than other field estimation tools commonly used in non-point source load reduction estimation. For example, the Region V model equations (also known as STEP-L) have been used in the Ohio Great Miami WQT program as well as for the foundation of other equations in the Minnesota trading permits and Michigan demonstration of the NutrientNet web-based program. However, associated credits for phosphorus and nitrogen reductions in these equations consider sediment-attached nutrients only. Such nutrient loading must be connected through surface runoff pathways. NTT calculates sediment attached and surface runoff pathways, but adds dissolved forms of nutrients and shallow aquifer lateral flow paths as well. In addition, the deep-aquifer estimated loading reduction can be used in drinking source water protection programs targeted by public wellhead protection efforts.

NTT calibration and output results questioned by TSPs at the workshop underline the need to vet the output results for all parameters by local experts in both agronomy and non-point source runoff estimation. Once this is done, the trained TSPs felt that they could use this tool in many services they currently provide to producers, not just WQT.

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<sup>9</sup> Information was provided by Dusty Hall with the requested citation of: Quarterly Report #5, Targeted Watersheds Grant #WS-00E74201-0, Great Miami River Watershed Water Quality Credit Trading Program Implementation Project; Recipient: The Miami Conservancy District, 38 E. Monument Avenue, Dayton, Ohio 45402

NTT provides the capability to perform nutrient and sediment load reduction estimation results for many common BMPs. This allows for a rather robust list of starting BMPs for new WQT programs to begin transactions. Other BMPs can be added into the program's daily operations as program/model development produces either: 1) specific protocol(s) used during field assessments to define selection methods for the model inputs or 2) adjustments of the model algorithms themselves to allow the necessary inputs and processing techniques.

NTT also provides the capability to provide mechanistically modeled loading estimates on fields where multiple BMPs have been implemented. Additive effects of BMPs on loading cannot be similarly modeled by other empirical credit calculators. This not only provides more realistic assessment of environmental benefits from multiple conservation practices, but also allows for sequential and long-term tracking of reductions. Such ability is valuable as operational selections may need to use multiple BMPs to achieve the desired load reduction goals. A system with this capability will also adapt better to WQT program changes in trading baselines and policies.

### **NTT Limitations for WQT**

Edge-of-field non-point source models require site-specific data to produce reliable and accurate results. To successfully calibrate field models, regional agricultural production techniques and soils research, as well as water quality monitoring results for surface and groundwater releases, are essential data requirements for the many different practices being assessed. Specifically, the NTT evaluation has identified a few additional model features that could improve WQT applications. The following is a list of these features where an improvement or restriction in use is needed:

1. **Bibliography of non-point source water quality data:** Many watersheds or regions in the United States have limited non-point source runoff data to provide or facilitate field-scale model calibration. A bibliography of peer-reviewed research papers, monitoring data, and cooperating experts could better facilitate the professional validation needed to corroborate the calibration efforts where NTT is being used in local or regional applications.
2. **Local validation:** A team of local professionals is needed to vet model results within the local area and to fully understand the introduced uncertainty by using NTT. This team can also potentially serve the purpose of guiding methods that reduce this uncertainty and associated credit discounting. Increased understanding regarding an uncertainty factor may result in an increased portion of the load reduction being allocated as salable credits.
3. **Guidance on existing model estimation methods:** Professional validation teams can guide existing model estimation methods for BMP treatment efficiency. Across the nation, multiple WQT programs have the opportunity for using NTT (currently in use by WQT programs in Maryland and the Willamette River Basin in Oregon, being considered in the Ohio River Basin WQT project and the Great Miami River Basin). Each distinct region may use different BMP specifications for buffers, stream bank stabilization, wetland installations, livestock operations, etc., and, potentially, different credit calculation approaches. The national application of NTT might, therefore, require the availability of different load reduction estimation methods.
4. **Verify parameters selected for models:** The preliminary sensitivity analysis of the NTT model indicates that several model parameters and site input data can significantly change the estimated nutrient loading values. A WQT project can evaluate the potential sources of information necessary to guide selection of the parameter values. In addition, the quality or rigor behind the regional information source(s) themselves could be evaluated to understand the expected range of variability. Sensitivity analysis data presented in Appendix A outlines NTT modeler input parameters that are the most sensitive regarding estimation of varying forms of nutrients, as well as user inputs of field data.
5. **Adjustments in parcel crediting:** NTT operation requires an understanding of the land management practices on the contributing area to provide an edge-of-field load reduction, but does not address potential overland attenuation. Therefore, parcels credited should be adjacent to the stream network. In settings where the field is not adjacent to the stream network, questions arise regarding the land use practices and groundwater pathways for the land between the field and the receiving stream. Hence, the current setup of NTT cannot address the attenuation questions on the adjacent land associated with redeposition, attenuation, and re-

entrainment in surface runoff between the modeled field and the water body.

A number of features in the current version of NTT will present certain challenges in WQT applications. Updated or new/desired features may address some of these. Such considerations are outlined here.

1. NTT does not currently have the capability to provide estimates of nutrient load reduction from stream bank or stream bluff stabilization. Other WQT programs provide nutrient load reduction estimates for these sources. These calculations are most often based on site-specific measurements and simple volume voided calculation methods that are fundamentally different from the upland erosion-based estimates produced by the APEX field model platform used in NTT. Other stream bank and bluff equations consider site-specific physical conditions such as soil type, nutrient content, length of eroding bank, bank height, and lateral recession rate over time to predict the mass of nutrient discharged to the stream (Michigan Department of Environmental Quality, 1999). Application of this latter method has the additional benefit of being able to address erosion problems caused by livestock access, human activities, and/or groundwater seepage, which create energy sources and physical changes to soil structure not currently accounted for by NTT. Examples using this alternative measurement approach for calculating credits are found in the Minnesota Pollution Control Agency NPDES Permit MN0031917 (Minnesota Pollution Control Agency, 2007) regarding the Rahr Malting National Pollution Discharge Elimination System (NPDES) trading permit<sup>10</sup>. NTT can be modified in the future to provide a suitable site-specific method of nutrient load reductions from correction of bank and bluff stabilization.
2. The NTT version originally examined in this project did not have provisions for inputting site-specific soil phosphorus test data. Historic phosphorus applications can raise soil phosphorus content well above what cropping uptake can remove, even across a decade or two. The NTT method currently calculates phosphorus content in the soil based on current management operations. As a consequence, the phosphorus content can be underestimated using default values assigned by the model. As the model also estimates crop yields, decisions on BMP implementation need to be accurately depicted for planning and crediting purposes. Fang (2002) found that soil testing performed in studies in southern Minnesota resulted in phosphorus content that varied across a range of 351–1,110 ppm TP (500 ppm equals approximately 1 pound of phosphorus per ton of soil, which is commonly found in that region). Given the variability of soil phosphorus content, NTT would better serve agriculture with the ability to add site-specific soil phosphorus data.
3. Tile drainage assessment features provided by NTT should be enhanced to provide an opportunity for the operator to select the tile density and whether intakes are present at the site. Subsurface tiling within the Midwest can consist of a single tile (with or without surface tile intakes) connecting isolated wet spots or wetlands, pattern tiling (a herringbone pattern of connected tile), or a combination of the two. Each of these system designs results in a different drainage coefficient. The typical drainage coefficient for patterned tiling in Minnesota ranges between 1/4 to 1/2-acre inches of drainage per day. The drainage contractor selects the density and type of system to install according to the soils, slopes, and area precipitation. Other variables in the design are pipe diameter, depth, and spacing. As indicated by these potential differences from site to site, the volume drained by different tiling configurations affects pollutant loading. The reduction estimate using control drainage alternatives can be equally as variable. Most TSPs do not have drainage contractor experience and are unfamiliar with drainage coefficients. To facilitate NTT crediting of these systems, a simplified surrogate input would be needed.
4. Another NTT option suggested by users is the ability to vary the depth of a wetland BMP and adjust the ratio of contributing area. This changes the residence time of the wetland. Denitrification is a bacterial process in anaerobic wetlands, and if the wetland does not have anaerobic conditions or is allowed to flush too rapidly, insufficient conditions exist to denitrify.
5. NTT could benefit from allowing practitioners to enter a field slope to override the WSS determined default value. However, guidance regarding how to

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<sup>10</sup> See: [http://www.epa.gov/npdes/pubs/wq\\_casestudy\\_factsht5.pdf](http://www.epa.gov/npdes/pubs/wq_casestudy_factsht5.pdf)

appropriately estimate such slopes and restrictions regarding the limits of allowed adjustments should also be provided.

6. NTT output tables contain small errors regarding unit labels and provide excess decimal places beyond what would be considered as the appropriate significant digits.
7. NTT currently assesses load reduction by comparing a “before” and “after” estimated BMP implementation result. Users can enter current day management practices and the alternative management practices they desire to evaluate. However, the selection of baseline requirements in a WQT program may confound the process by adding additional steps to estimate credits. In certain cases, WQT programs require an intermediate load reduction to be implemented as a baseline loading requirement before achieving a level of nutrient or sediment reduction that could be creditable. These intermediate steps to calculate baseline could be addressed by the WQT program in various manners. One approach could be to establish checklists in NTT of necessary management practices that must be in place prior to trading. Another option is to set required percent load reductions (for example, reflecting a baseline requirement associated with total maximum daily loads (TMDLs) before additional reductions are considered eligible for credit generation. NTT can likely manage all necessary baseline calculation steps by providing instructions in the field operation protocols and/or including possible default selections in the WQT crediting tool platform (for example, NTT providing an input request for a WQT program baseline percent reduction).
8. The credit summary output of NTT includes nutrient losses from surface runoff and from shallow-aquifer and deep-aquifer pathways. All of these pathways can be considered a nutrient release into the environment; however, not all are delivered to the water resource being protected by WQT. Deep-aquifer loading is rarely appropriate for WQT crediting, given the time scales between resultant receiving stream impacts from the short-term load using delayed reductions associated with longer-term groundwater delivery. Stream and lake loadings are typically comprised of shallow-aquifer groundwater and surface runoff loading components. The deep-aquifer quantification should not be removed from the NTT output

because these loading reduction estimates are valuable for discussions surrounding drinking source water protection in a wellhead supply area. However, their inclusion in the calculation of surface water credits is not appropriate.

9. NTT currently outputs results in terms of annual loads. Some WQT program applications require that reductions associated with credits be contemporaneous with the NPDES permit reporting and monitoring period requirements. Typical permits have monthly, seasonal, or annual rolling averages. Therefore, NTT could be more utilitarian if it provided average outputs in monthly and annual results.
10. NTT has the potential to credit drainage management BMPs. Currently, NTT does not require information regarding the tile density and spacing, inventories of surface tile intakes, and the contributing areas. Therefore, variability in the quantity of water and concentrations of pollutants in drainage water are not appropriately estimated.

### **Supporting Protocols or Tools Needed For NTT**

WQT credits are calculated based on runoff or flow paths associated with the contributing area passing through or under a BMP. In the Web Soil Survey (WSS), this is determined by the use of the Area of Interest (AOI) drawing tool that allows the practitioner to select the specific boundaries of a farm field. Certain BMPs (for example, nutrient management, high residue tillage practices, and cover crops) are applied to the entire field. The practitioner then selects the entire row cropped area as the AOI. Other BMPs (for example, buffers and filter strips) treat only the portion of a field that passes through the practice. In both cases, a protocol is needed to guide practitioners with proper methods to apply to the NTT setup when using the WSS site. This will help to minimize introduced errors. For example, using the largest magnification possible to select the AOI reduces the contributing area delineation errors associated with incorrectly selecting the field border.

Topographic maps (United States Geological Survey [USGS] Quad maps that provide 10-foot contours or Light Detection and Ranging [LiDAR] maps that provide 2-foot contours) are beneficial for selecting surface flow paths. A discussion held in the TSP workshop indicated that some TSPs would prefer to

load their Geographic Information System mapping information for the field rather than use the WSS site. This concept should be explored further. However, difficulties might arise around gathering the appropriate soil characteristics, formatting, and delineation of the contributing area when it is smaller than the field borders.

Crediting of animal livestock operational changes field by field can easily lead to false reductions if the operation simply transfers the intensity of grazing or manure management to another field without actually managing all fields. The proper crediting process requires an assessment of the whole herd's impact regarding all fields receiving manure or being grazed, including fertilizer application rates and off-site sales of manure. Therefore, crediting changes with livestock manure operation in NTT requires development of a protocol that appropriately evaluates the entire livestock operation.

## **WARMF Model Evaluation**

As a part of this CIG project, information developed at the farm level using NTT was extended to a larger watershed scale analysis of the Upper Big Walnut Creek (UBWC) using the Watershed Analysis Risk Management Framework model (WARMF). WARMF is one of the models being used to inform the Ohio River Basin WQT program.<sup>11</sup> WARMF can potentially be used to determine the benefits of different trades, provide insights with regard to areas that are not meeting water quality objectives that may not be detected by a monitoring program, conditions that can bring those areas into compliance with the objectives, and the potential benefits of implementing particular BMPs at a larger basin scale. In this project, it was used to preliminarily examine its capabilities for informing decisions on trading program development—particularly when coupled with NTT. WARMF model background, calibration to UBWC monitoring data, comparisons to NTT, and future applications for trading are summarized here. Details of the UBWC WARMF application as originally authored by the University of California–Santa Barbara project team members can be found in Appendix E of this report.

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<sup>11</sup> See: [http://my.epri.com/portal/server.pt?open=512&objID=423&&PageID=235468&mode=2&in\\_hi\\_userid=230564&cached=true](http://my.epri.com/portal/server.pt?open=512&objID=423&&PageID=235468&mode=2&in_hi_userid=230564&cached=true)

## **Background**

WARMF is a state-of-the-art, dynamic model that links catchments, river segments, and other water bodies to form a seamless watershed model computing hydrology (water flows) and water quality based on physical, chemical, and biological processes. WARMF was developed by Systech Engineering for EPRI (EPRI, 2001) as a decision-support system for water quality applications. It is now in the public domain<sup>12</sup> and is being used for broader water quality applications by the EPA and other users.

Site-specific adaptation of the WARMF model version 6.2 to the UBWC watershed required input data, parameter estimation and calibration, and analysis in order to estimate hydrologic and water quality conditions throughout the basin. The WARMF model was employed to establish a basis of spatially explicit surface water quality conditions in the UBWC watershed in order to assess the quantity and timing of point source and non-point source loads in a pilot trading area. In addition to simulating flow, the water quality constituents simulated in detail were nutrients (phosphorus and nitrogen components). While other water quality parameters can also be simulated, they were not been calibrated in the UBWC application due to insufficient water quality data.

## **WARMF Calibration and Model Runs**

Calibration of water quality or watershed models to available data is a necessary step to ensure that mathematical calculations are reasonably simulating observed results. Subsequent to calibration is model validation, which uses assigned model coefficients from the calibration run to verify that these original assumptions are realistic when compared to a separate data set. Demonstrated capabilities to reasonably simulate independent data sets lend credibility to more accurate model forecasting of water quality outcomes from future BMP applications. For the UBWC modeling application in this project, funding was limited to WARMF model calibration. This was considered sufficient to preliminarily examine opportunities and needs for linking watershed and field-scale models in a potential trading platform.

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<sup>12</sup> See: <http://www.epa.gov/athens/wwqts/html/warmf.html>

Several of the data sets used to set up the UBWC WARMF model application were prepared and preprocessed using BASINS 4.0, a non-proprietary framework available through the EPA.<sup>13</sup> BASINS 4.0 includes a web data extractor for downloading data from several national data sets, including data from the EPA, USGS, USDA, and other agencies. The basic GIS databases needed for the BASINS/WARMF framework are the digital elevation model (DEM) data, hydrography, land use, soil, weather station locations, and associated observed data (see Table 4-3).

The delineation tool in BASINS 4.0<sup>14</sup> was used to determine the catchments that make up the UBWC watershed for modeling within WARMF. The Watershed Delineation module of BASINS relies on the National Elevation Dataset (NED) for topography and the hydrologic extent (watershed boundary) of the UBWC study area. Within the WARMF Engineering module, each of the 97 river networks contains a distinct river segment and is further divided into land surface and soil layers. These compartments are seamlessly connected for hydrologic and water quality simulations. The soils are characterized by area, thickness, depth, and soil types. The land surface is characterized by its land uses and cover, which may include forested areas, agriculture lands, or urbanized cities. The Soil Survey Geographic database (SSURGO) is used to characterize the soils. It is the most detailed level of electronically available soil mapping data done by the Natural Resources Conservation Service (NRCS). Finally, the USDA's Cropland Data Layer (CDL) was incorporated into the model. This is a crop-specific land cover data layer with a resolution of 56 meters. The CDL is produced using satellite imagery from the Indian Remote Sensing RESOURCESAT-1 (IRS-P6) Advanced Wide Field Sensor (AWiFS) collected during the 2009 growing season.

Four major point sources were considered in the UBWC based on Ohio EPA NPDES records. The data file for each point source was generated based on these records. Discharge information, including flow and effluent concentrations for ammonium, nitrate, and phosphate, were available for all NPDES-permitted

point sources. Some characteristics of these sources are presented in Table E-5 in Appendix E. Nutrient loading from septic systems in the UBWC was characterized using data provided by the 1990 U.S. Census (the most recent census with septic system data).

To simulate the processes related to hydrology and nutrient fate and transport, more than 100 parameters are needed for each single catchment and reach combination. The estimation and calibration of parameters are performed in a stepwise process using data inputs mentioned here. First, the hydrologic response is calibrated using the observed hydrology. Then the water chemistry is calibrated, simultaneously adjusting parameter values for phosphorus and nitrogen compounds. The Hydrologic Autocalibration tool in WARMF was used to simulate the surface water runoff, groundwater flow, and the transport of surface water to the stream network. Observed stream flow records were available from the USGS and the USDA/CEAP study for 6 of the 97 catchments within the UBWC watershed delineation. Results from simulations for the catchments are included in Appendix E.

Calibration of water quality for the nutrients (nitrogen and phosphorus) relied on the data from the USDA CEAP study for four small catchments located in various reaches in the UBWC. There are three major classes of parameters that can be adjusted to better represent water quality, namely, the initial concentrations (in the soils, river water column, and sediments); the adsorption coefficients for the soils and sediments; and the reaction rates in soils, water column, and sediments.

The results of the calibration are presented in Figures E-12 through E-15 and Table E-10 in Appendix E. The temporal patterns indicate that there are some differences in temporal correspondence between the observed peaks and valleys of the flow and concentration profiles. While the overall temporal pattern of flow is reasonably well represented for streams like Sugar Creek and Long Run, there was a peak flow event in July 2005 for Rattlesnake Creek and Duncan Run (both toward the southern part of UBWC) that was not predicted by the model. The parameters adjusted for calibration do not influence the timing of the observed highs and lows, which are controlled by hydrologic events such as snow melt, strong storms, and low flows.

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<sup>13</sup> See: <http://water.epa.gov/scitech/datait/models/basins/index.cfm>

<sup>14</sup> See: <http://www.epa.gov/waterscience/BASINS/>



Table 4-3  
Data Sets Used in the WARMF Setup

File Name	Description	Source
National Elevation Dataset (NED)	Topography	USGS
SSURGO	Soils data	NRCS
2001 National Land Cover Dataset 2008 Ohio Cropland Data Layer	Land use	USDA, National Agricultural Statistics Service
Meteorology	Precipitation and other weather parameters	NOAA (NCDC)
Air quality	Atmospheric deposition	USEPA (NADP & CASTNET)
Gage stations	Observed hydrology	USGS
Water quality stations	Observed water quality	USEPA, USDA
Point source data	Flow and discharges	Ohio EPA
Non-point source data	Land management practices	USDA
Census	Urban areas, households	U.S. Census Bureau

WARMF model calibration for the UBWC in this preliminary application had a Nash Sutcliffe Efficiency (NSE) coefficient of 0.42 for a 10-year comparison. Model calibrations with NSEs less than 0.5 should preclude model use for any monthly and annual contemporaneous comparisons without using a high uncertainty factor. A more robust data set and vetting with local experts knowledgeable of the watershed setting can often help improve model calibration to enhance its utility for examining contemporaneous comparisons.

Once the hydrologic and water quality calibrations were completed for the four UBWC catchments, parameter values were applied to the rest of the watershed. The model was then run to evaluate the response for various catchments within the watershed. As expected, flow increases progressively going from the headwaters, down the main stem, and to the outlet of the UBWC watershed. Since the Hoover Reservoir was not explicitly modeled in this application, the flows below

catchment 60 (see Figure E-16 in Appendix E) in the main stem are for illustration purposes only and do not necessarily reflect the movement of water within the reservoir. The flow in the tributaries (which is a function of their size) thus ranged from 1–225 acre-ft/day. Some tributaries were large enough to have continuous flow throughout the year, while others were intermittent, with no flow conditions in parts of the year.

Figure 4-3 presents the mean TN and TP concentrations in various catchments of the UBWC according to WARMF modeling efforts. This figure is illustrative of how this model can inform a trading program in defining potential trading areas and hot spots by forecasting those reaches that are expected to have low, medium, and high concentrations. As with flow, the simulated concentrations in the reservoir in the lower portion of UBWC are only illustrative and may not reflect the actual concentration levels in the reservoir.

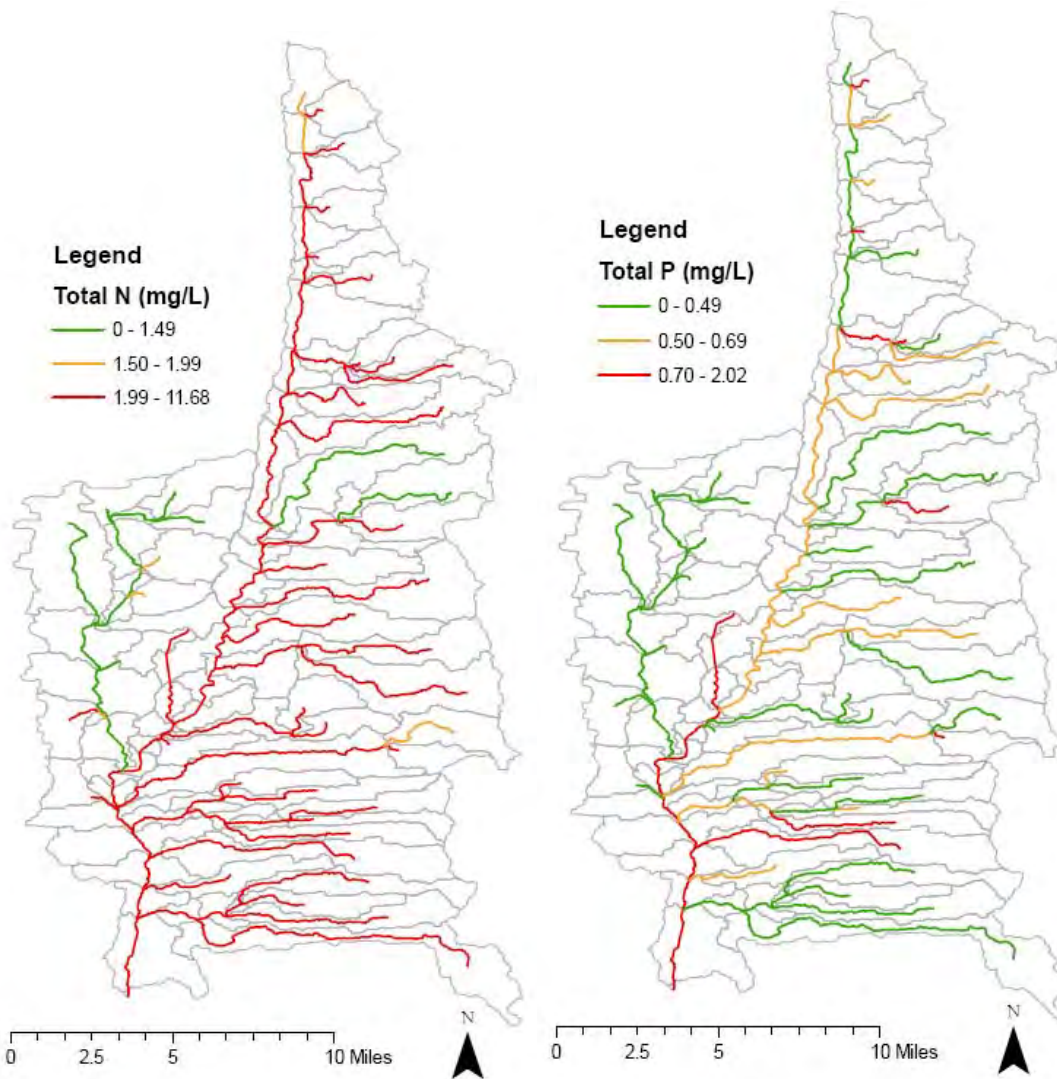


Figure 4-3  
 Mean Nutrient Concentrations in the UBWC, as Predicted by WARMF

Table 4-4 shows the modeled predicted mean nutrient concentrations in different sections of the UBWC. Modeled results suggest that nutrient concentrations were lower in the tributaries than in the main stem, and generally lower for the western tributaries compared to the eastern (potentially reflecting the differences in stream flow and fertilizer application for the different

regions). This particular application illustrates how a watershed model can show regional differences even within smaller basins such as the UBWC to potentially inform trading programs on such issues as defining location and policy factors.

Table 4-4

WARMF Estimated Mean Nutrient Concentrations in Eastern, Western, and Main Stem UBWC (as mg/l)

UBWC Reaches	Estimated Mean Concentrations ± 1 Standard Deviation			
	NH4	NO3	TN	TP
Eastern Tributaries	0.14 +/-0.05	1.64 +/- 0.63	2.81 +/- 0.97	0.45 +/- 0.29
Western Tributaries	0.12 +/- 0.03	0.76 +/- 0.28	1.23 +/- 0.40	0.14 +/- 0.08
Main Stem UBWC	0.07 +/- 0.02	2.20 +/- 0.70	3.62 +/- 0.81	0.62 +/- 0.12

**Modeled BMPs**

Following calibration efforts of WARMF using available UBWC monitoring data, the model was used to examine results from simulations of similar BMPs assessed by NTT. Recognizing the differences in modeled geographic scale, the intent of this exercise was to generally compare loading reduction estimates for similar BMPs between these models. The following BMPs were modeled at the catchment scale using the WARMF model:

- Nutrient management
- No till
- Cover crops
- Row cropping conversion to alfalfa
- Conversion to corn/soybean/winter wheat rotation
- Tile drainage

WARMF input parameter values were adjusted to mimic expected mechanistic changes in agricultural practices associated with various BMPs based on best professional judgment of the modelers (see Appendix E for details). The UCSB modeling team generally concluded that predicted BMP reductions from both models were generally comparable, despite the mechanistic differences and assumptions established within NTT and those applied in WARMF to simulate similar BMPs. Since each catchment in the WARMF model has its own mix of crops and soils that are averaged over a much larger area that NTT calculates for individual fields, the results cannot be compared directly between the two models, but can be used to determine whether the simulated reductions are reasonable.

WARMF BMP load reduction results for select BMPs that were most comparable to NTT simulated BMPs are shown in Table 4-5 for the UBWC.

Table 4-5

Average TN and TP Reductions Simulated by WARMF for Different Crops and Soils in UBWC (refer to Appendix E for simulation details and assumptions)

BMP	TN reduction	TP reduction
No till	19%	42%
Cover crop	30%	41%
Alfalfa	95%	92%
Tile drainage	22%	2%

This use of the model illustrates how a watershed simulation can inform a trading program by forecasting which BMPs may have greater water quality crediting

potential at scale in a basin than others. Such results can be balanced with local initiatives and farmer interests to inform credit supply decisions. A summary of preliminary WARMF simulation results here illustrates

the type of watershed information that can be used for such purposes:

- **Nutrient management:** For nutrient management as a BMP application, the WARMF model was used to explore a 25% decrease or increase in fertilizer application from the recommended values across catchments. Results indicate that nutrient management within the watershed has a much greater impact on the concentrations at the outlet than in the upper reaches of the UBWC.
- **No-till:** No-till was modeled in WARMF by reducing the soil erosion parameters (that is, the Rainfall Detachment and the Flow Detachment Factors) that are specific to each land use for corn, soybean, and winter wheat uses, as well as the combinations of these land uses. Such changes suggested notable decreases in sediment export and, thus, a decrease in the associated TP export. In these simulations, no-till appears to be more effective in reducing TP export than TN export.
- **Cover crops:** Cover crops were modeled assuming that the soils normally left uncovered after harvesting corn or soybean were covered in the winter by reducing the Rainfall Detachment and Flow Detachment Factors. Such an approach in WARMF suggests that cover crops can effectively reduce TP and TN loads in the tributary streams and, to a lesser extent, in the main stem.
- **Conversion to alfalfa:** The conversion of current crops to alfalfa was modeled in WARMF simply by considering the same input values for all crops as for alfalfa (that is, no nitrogen application). Although there is less productivity, the crop grows for a longer period of the year with the soil covered by a crop throughout the fall and winter. The results suggest that the conversion of a cropland to alfalfa can result in the greatest reduction in TN and TP. Although such a large-scale conversion of production is not practical or foreseeable, model results can suggest the level of conversion needed with this type of a BMP in relation to potential credit demand.
- **Tile drainage:** Tile drainage was artificially simulated in WARMF by considering removal of shallow groundwater (using a pumping function in the model) and discharging it into a drainage channel that connects directly to the stream segment in that catchment (a diversion into the stream). Results illustrated how flow volume is

reduced under this type of BMP in the tributary streams, with some decrease in TP and TN.

### **WARMF Sensitivity Analysis**

A sensitivity analysis was performed for the WARMF model parameters that directly or indirectly influence hydrologic and nutrient processes using the UBWC applications. This provided information on which parameters have the greatest influence on determining the model output (flow and concentrations in the tributaries and main stem of UBWC). Such information can, in turn, be used by WQT program developers and managers to assign discounting factors in crediting equations to account for uncertainty associated with system attributes that are not well understood or monitored.

Since the model sensitivity analysis is rather time-intensive, one of the calibrated catchments, Sugar Creek, was used as the basis for the evaluation. The sensitivity analysis examined individual model parameters one at a time. Each parameter was varied by +50% and -50% of its calibrated value, or  $\pm 50\%$  of the range of literature values commonly assigned for the parameter. The simulation output for flow, ammonium, nitrate, total nitrogen, and total phosphorus was then compared to the original output for the calibrated Sugar Creek simulation.

The results of this sensitivity analysis for Sugar Creek flows to variations in catchment and watershed-wide parameters are presented in Table E-14 in Appendix E. The conclusions of the sensitivity analysis include the following:

- **Precipitation:** The model is most sensitive to precipitation weighting, which is a parameter that assigns a weight to the precipitation from the meteorological station to increase or decrease the amount of water received. This parameter plays a major role in the total amount of water that flows through the catchment and into the creek. Such sensitivity illustrates potential limitations to modeling when localized precipitation data are not available and have to be drawn from distant sources.
- **Magnitude and skew of the evaporation coefficients:** These are negatively correlated, meaning that an increase in evaporation will result in less flow, as expected.

- **Soil layer thickness:** The thickness of the soil layers is very important, and is negatively correlated since an increase in soil thickness of a layer results in more water stored in groundwater, reducing flow in the creek.
- **Saturated moisture and horizontal hydraulic conductivity:** An increase in saturated moisture (capacity) results in more water storage in groundwater, leading to reduced flows. An increase in horizontal hydraulic conductivity results in more flow out of the soil layer into the creek, so it is positively correlated.

Other parameters do not play a significant role in predicting flow in this catchment. Similar behavior would likely be expected for other catchments.

The results of the sensitivity of the four water quality parameters (ammonium, nitrate, total nitrogen, and total phosphorus) for Sugar Creek are presented in Attachment C of Appendix E. Of paramount importance are five parameters that are related to hydrology, namely precipitation, evaporation coefficients (magnitude and skewness), soil layer thickness, soil saturated moisture, and the soil hydraulic conductivity. These model parameters have a significant effect on almost all of the concentrations of nutrients, with total nitrogen and nitrate exhibiting the higher sensitivity.

Other soil parameters that influence total nitrogen and nitrate concentrations in the river are soil erosivity, ammonium and nitrate adsorption coefficient, soil cation exchange capacity, and the initial concentration of nitrate in the soil. Land use (crop) specific factors that influence total nitrogen and nitrate concentrations in the river are the flow detachment factor, cropping factor, long-term growth factor, leaf growth factor, crop productivity, annual nutrient uptake distribution, and plant composition. This illustrates the challenge for watershed models to simulate outcomes at smaller scales where variability from one field to the next can be substantial, thus requiring larger land areas to be modeled to accommodate averaging of these conditions. Watershed model calibration inherently requires this averaging because water quality data collected in-stream realistically reflect the collective (averaged) impacts of upstream contributions. Such contributions are rarely monitored at the field-scale, which points to the value of NTT for WQT crediting.

### **WARMF Model Strengths For WQT Credit Estimation Methods**

The WARMF model is capable of processing critical parameters often found in WQT transactions including flow, sediment, nitrogen, and phosphorus. In addition, the model can process other water quality parameters (for example, dissolved oxygen) that were not calibrated or evaluated as part of this study. The use of a watershed model in the WQT program framework directly ties into the credit estimation process by providing attenuation results to develop the trade ratio location factors. In a parallel vein, the model is a simplification of the real world and, as such, introduces uncertainty that must be assessed and accounted for with conservative assumptions and explicit uncertainty factors applied within the trade ratio. Modeling information must also be reliable and transparent within the stated limitations as demonstrated by statistically based goodness-of-fit testing results. With these considerations, use of the WARMF model can benefit WQT programs by enhancing the WQT manager's watershed understanding during program development, operation, and adaptive management phases.

The model setup, calibration, and validation processes for WARMF are complex and should be performed by a qualified modeler. As such, the application of WARMF to obtain location and attenuation factors would best be performed by the modeler. Location factors can be developed by the modeler by entering a significant/artificial change in loading into one subwatershed and examining the effect on downstream loadings. When repeated for each subwatershed, the introduced differences between what was loaded upstream and what was delivered downstream can provide attenuation information for the applicable period analyzed. Combining the results of each subwatershed's model run into a lookup table provides a way for the WARMF model results to be communicated to field personnel and program managers. In this manner, neither the field representative nor manager needs to be proficient with WARMF. This method also avoids requiring a direct computational coupling of the watershed model and field scale model.

Other model attributes that support trading are largely predicated on the basis of having a reasonably calibrated model that uses sufficient water quality monitoring data and current land use inventories. These attributes include the following:

- WARMF model attributes can support the WQT program during discussions and development of program policies surrounding identification of “local hot spot” issues. This can come from modeling scenarios before trades and can be confirmed with additional monitoring if it is a concern.
- Modeling will assist with program effectiveness evaluations. An improved watershed understanding will increase levels of adoption, assist in monitoring plan development, help define policies that provide incentives for desired behaviors, and discourage unwanted behaviors.
- WARMF modeling can forecast average BMP load reductions (pounds/acre) at scale by simulating a significant level of adoption in a given watershed and dividing the load reduction by the unit area under the new management practice. This type of forecasting will assist discussions regarding targeting of BMPs based on cost-effectiveness and potential reductions that might be achieved with broader adoption. (These estimates will not compare directly with NTT field results due to averaging assumptions as previously discussed and due to the WARMF watershed assessment applying to all fields, those in close proximity to streams and those more distant.)
- WARMF model updates are required only periodically. Updates can be performed when a significant period of record with updated water quality data is available or if land use and/or climatic data changes are significant. Maintaining consistent location factors for substantial periods also helps stabilize the trading market as investors have reasonable assurances for longer-term transactions. WARMF outputs assist WQT and watershed managers when determining allowable transaction boundaries and other restrictions/policies that must take into consideration attenuation factors and hot spots.

### **WARMF Model Limitations**

Averaging of select watershed conditions across scale and for select model inputs raises the need to understand what is being averaged, how this will affect the output of WARMF, and how this output can be used. Relevant considerations include:

- Nutrient applications by individual farmers are assumed to be equally distributed across a given month. This assumption works well at larger scales

where a larger number of farmers are involved, but may skew the daily results when applied to a smaller watershed that experiences application timings that vary substantially from the average.

- Average concentrations used for WWTP discharges in the model may actually represent concentrations that vary substantially from day to day or month to month. For example, some WWTPs sample their effluent only once per week, once per month, or sometimes not at all (for a particular nutrient). Thus, variability in point source model input must be acknowledged as an average of stochastic and/or uncertain conditions.
- Local meteorological data may be limited across broad geographic areas (or of insufficient detail to be directly input into the model). Manipulation of meteorological data for a watershed model can require extrapolation of a weather station’s data across a catchment. This introduces differences in timing, intensity, and amount of precipitation that actually occurs in any given reach in a watershed. This can create challenging, if not irreconcilable, differences in a model’s flow predictions compared to flow gauging station data.
- Soils results from the SSURGO database are averaged using area weighting and applied to the entire catchment.
- Most challenging is that, at the catchment level, the in-stream chemical loading from WARMF assumes a completely mixed tank reactor by segment. This means that there is no longitudinal estimation of source loadings and response concentrations within the smallest subwatershed delineations. Therefore, predicted in-stream concentrations are presented as an average for an entire stream segment, and loads represent an average of the contributing drainage to that segment.

The UBWC applications suggest that the model capably manages these challenges with sufficient data for model inputs and coefficients or within the bounds of explicit uncertainty associated with data gaps. Some of the model input and land use considerations that will require more robust information to improve WARMF model calibration include:

- Inventories of non-compliant septic system and septage nutrient concentrations are needed.

- Urban storm water runoff estimates require assessments/assumptions regarding the runoff volumes and nutrient and sediment concentrations.
- Nutrient data for WWTP discharges can be sporadic or largely unavailable.
- Inventories of livestock populations and nutrient content of manure are limited (for feedlots and grazed pasture model input needs).
- Row cropping descriptions including nutrient application rates, operational methods, and crop growth factors are difficult to collect, even by local professionals, and vary from year to year.

These data gaps and farm management assumptions affect the temporal resolution of the model. This, in turn, affects the reliability of the model output. Even though WARMF uses a daily time step, a minimum time step that should be considered sufficient for trading purposes, even in a well-modeled watershed, might, therefore, be on the order of a month. This will also depend on how the model is being used to inform the crediting process. Seasonal or annual time steps for

using model results to set trading program policy may be more appropriate in watersheds where model setup and calibration are constrained by limited data. Where models have not yet been applied in a basin, assumptions used in other similarly modeled watersheds might be used with additional consideration for credit uncertainty discounting.

Three overarching considerations for using WARMF in trading program development and implementation will expand opportunities for more robust applications of this model:

- Use in watersheds and/or regions with robust, long-term water quality monitoring and non-point source loading data to allow for rigorous model setup, calibration, and validation of the watershed model
- Availability of experienced modelers to support program development and evaluations
- Peer review of local or regional modeling applications by local experts to ensure that model assumptions appropriately depict land management conditions and available data





# Section 5: A Credit Calculation Interface to Combine Model Results

This chapter discusses potential methods to create an interface that combines the field-scale NTT and watershed-scale WARMF model outputs along with other necessary supporting data to estimate a trading credit. In addition, this chapter introduces a process to evaluate various interface options for developing a robust trading platform.

## Combining Model Results in a Credit Calculation Interface

A commonly voiced concern by WQT participants is that edge-of-field calculation methods must recognize the unique characteristics of each field and each farming operation. NTT offers a pragmatic, mechanistic loading tool that can accommodate a producer's site-specific setting and operations in these regards. WARMF can provide information for trading programs at a larger geographic scale to ensure ecological protection. Together, output from these two models can be combined with other supporting factors to create an ecologically sound crediting estimation process that provides a level of equity between farm sites, while helping to characterize potential water quality outcomes.

Both models process very similar data to arrive at their results. After being calibrated and validated for an area, the models can provide repeatable and reliable chemical loading and water resource evaluations. The NTT model predicts a field's losses of nutrients, sediments, and other constituents or possibly a farm operation's overall loading (when multiple fields are assessed). This represents a fraction of the catchment where WARMF begins its estimation process, leaving a disconnect in scale between the two models. Figure 5-1 graphically

depicts the geographic scales, performance, and gaps in the ability of these models to reliably simulate loading outcomes that can be translated to trading credits. This gap can be overcome when creating the WQT program framework if it is understood and acknowledged in crediting schemes.

Because of the differences in the mechanistic assumptions used in the models that create these disparities in scale, it would appear that directly integrating one model into the other would pose substantial challenges. Instead, using each model to supply components of the crediting equation introduced in Chapter 2 provides a simple and reasonable alternative to effectively bridge this gap.

Table 5-1 summarizes the credit equation elements and indicates which components the field-scale and watershed-scale models can address. The table also identifies information gaps where supplemental information (extraneous to the models) is needed.

Additional information needs noted in Table 5-1 can be addressed by using the scientific literature. Factors derived in this manner need to be assigned as metrics that are consistent with the math-based crediting equation (for example, dimensionless multipliers or fractions). For instance, the equivalence factor can be defined by first performing a literature review for the watershed or basin. If local information is not available, then other information sources should be considered for the source types associated with potential buyers and sellers. A ratio of the credit generator's bioavailability divided by the credit buyer's bioavailability can be developed as an equivalence factor for each combination of trading partners.

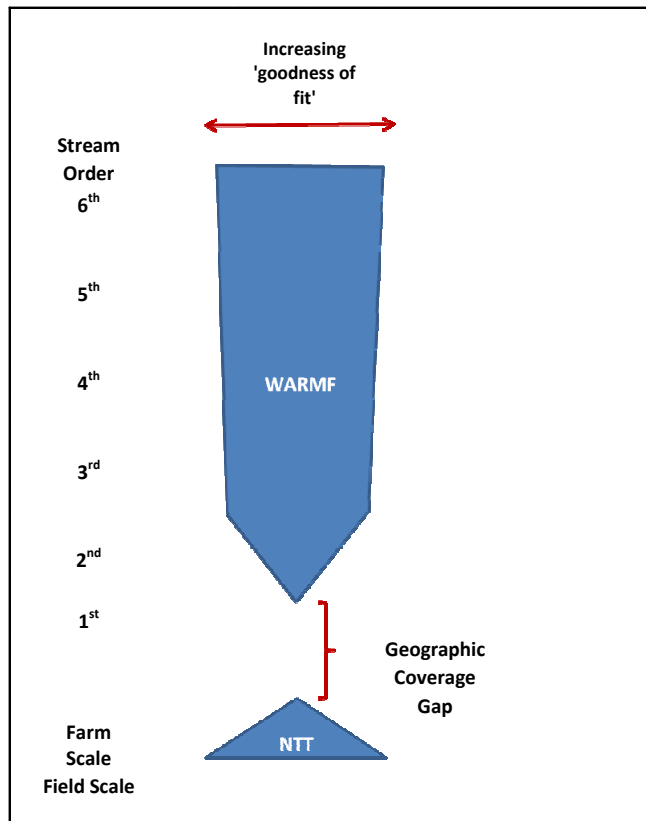


Figure 5-1  
 Generalized Schematic Comparing NTT and WARMF Model Capabilities to Accurately Simulate Loads or Water Quality (Respectively) at Varying Watershed Scales<sup>15</sup>

Table 5-1  
 WQT Credit Equation Inputs Provided by Models and Additional Information Needs

Credit Equation Component	WARMF Model Output	NTT Model Output	Additional Information Needed
BMP Load Reduction Estimate		X	
<b>Trade Ratio Factors:</b>			
Location Factor	X		
Equivalence Factor	X	X	X
Uncertainty Factor	X	X	X
Policy Factor(s)	X	X	X

<sup>15</sup> In most cases, the farm scale and field scale will be smaller than the 1st stream order or catchment. "Goodness-of-fit" refers to statistical methods that describe how well a model is able to simulate actual data. With increasing stream order (that is, larger watersheds), WARMF predictive capabilities will improve. The opposite condition will apply to NTT.

Development of the uncertainty factor can be facilitated by performing an uncertainty analysis on output from the two models. For example, Monte Carlo or “jackknife” statistical analyses will provide a standard deviation and mean value considering an expected value (see Appendix E for more detail). The expected values can then be adjusted by a statistically based variable such as the coefficient of variation (standard deviation divided by the mean) to account for the range of expected variability for each of the models (Kieser, 2009). A Monte Carlo assessment can also be run on the crediting equation using expected ranges of each discounting factor to determine the coefficient of variation for the entire crediting equation (Kieser, 2009).

Finally, for each source category involved in the WQT program, watershed policy factors may be wanted that dictate eligibility or net benefit factors. These factors do not have any added uncertainty as they tend to be driven by stakeholder wishes. As such, they can be inserted into the crediting process either by assigning a trade ratio discount factor or instituting a prerequisite before being able to generate or purchase a credit.

To illustrate how the crediting equation fits into the process from initially engaging producer participation through making credits available, Figure 5-2 diagrammatically shows how the flow of this information is packaged to deliver a credit. Steps will include:

1. Gather personal information from the participating farmer using standardized forms or computerized templates, apply relevant baseline conditions, and ensure eligibility based on location with trading boundaries and trading policy requirements. (This is often completed by producer representatives such as Soil and Water Conservation District staff.)
2. Compute edge-of-field reductions using NTT and field-specific information.

3. Apply location factors, where appropriate, from look-up tables related to the buyer and seller sites (look-up tables derived from a watershed model such as WARMF).
4. Apply equivalency factors from look-up tables and other uncertainty and policy factors to the reduction calculation, as appropriate for credit determination.
5. Track the credit information system in an accounting system that records relevant personal and site information that will facilitate third-party verification of site activities and provide for public agency management.
6. Provide relevant credit information in a registry that is accessible to buyers and the public (additional information on credit registries is provided in Chapter 6).

Farmer participation (directly or through technical service providers) can be facilitated with any of the following:

- A WQT Program Handbook including instructions, forms, and templates.
- A calculator such as a spreadsheet that allows for automated conversions of NTT edge-of-field reductions into credits using any applicable trading ratio factors and baselines for the farmer’s BMP installation. This simple credit calculator interface (which should be similar to the NTT interface) would have locked functions with specific instructions on use to minimize introduction of errors through using incorrect mathematical calculations, entering wrong values, or applying the wrong formulas.
- A WQT program interface that links the calculator to a registry using consistent forms and protocols to help ensure efficient and repeatable credit registration.

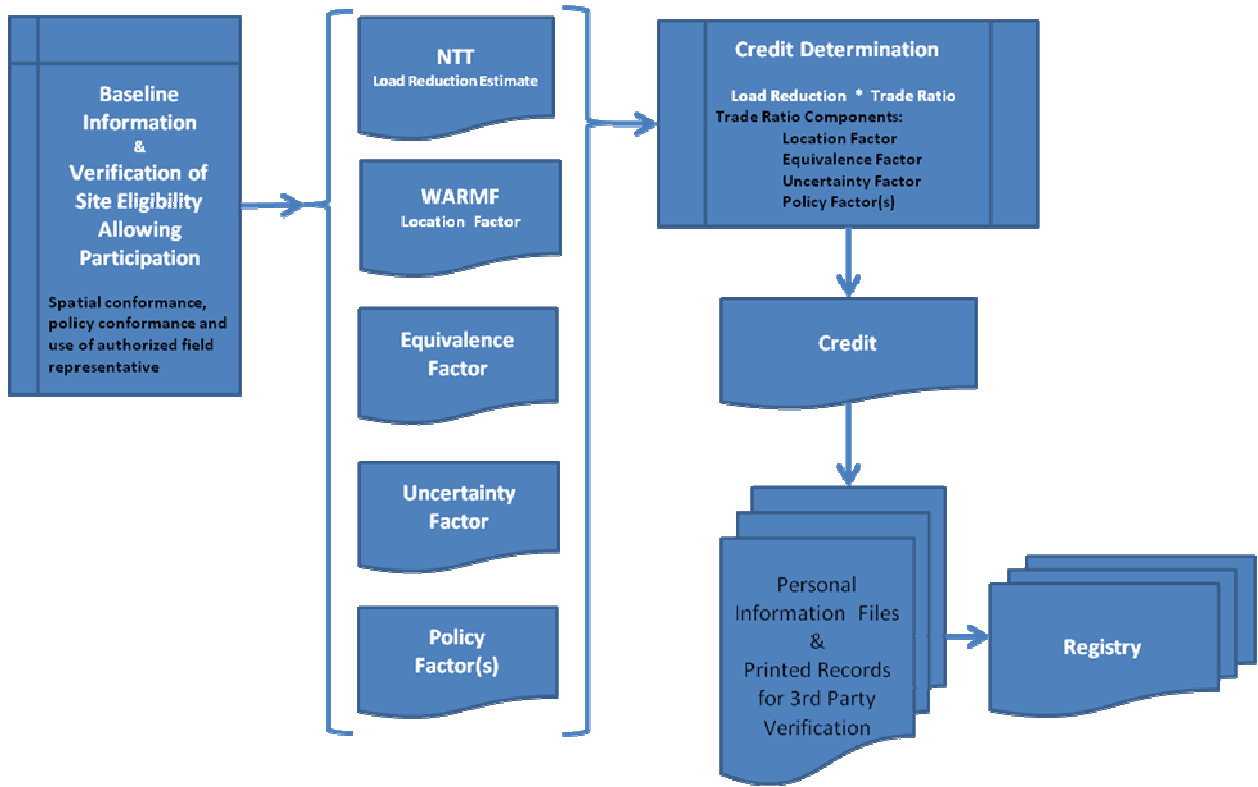


Figure 5-2  
Crediting Methodology Flow Diagram for Integrating Calculation Components

## Section 6: Credit Registry Interface

One of the keys to developing a successful WQT program is having a publicly available system to record all of the pertinent information and data for each trade executed. This system should function as a registry that links personal information with BMP information to accurately track the details of each credit transaction. Because registries can provide transparency for a WQT program, it is important to consider how often and how easily the public can access such information. Answers to these preliminary questions about public access will help guide administrators in designing or selecting the most appropriate registry format.

This chapter will discuss the considerations that a WQT program will make in order to select and develop the most suitable trading registry. Information on WQT program components described in the previous chapters will be discussed as related to the development of a single, integrated trading platform that can also serve as a registry for the WQT program.

### Data Collection

Currently, the USDA-NRCS does not track and provide personal information (PI) from individual farm tracts or BMP sites to the public. This information is generally kept confidential in order to protect farmers and increase participation in Farm Bill conservation programs. Getting farmers to provide PI to a program that does not promise confidentiality can be challenging. A transparent WQT program will require credit buyers and sellers to provide PI. The WQT program will typically validate and track this information for each practice used to generate credits and each site where credits are applied to a buyer's permit.

As part of the process of developing a WQT program framework, program developers will need to determine which protocol for collecting PI is most suitable for their setting. Because of the broad scale of the ORB, an online system where credit generators log in and enter PI and BMP information into a defined template or form may be most desirable. An online system can provide easy distribution of PI collection forms and rapid collection of information. Developers will need to

determine how many farmers have access to and are comfortable with submitting PI through an online system versus downloading forms and submitting the information via email or mail.

Another protocol that will need to be examined is how to verify credits as related to BMP implementation and maintenance. In Michigan, the state does not verify the credit or BMP directly. Michigan's Water Quality Trading Rules<sup>16</sup> are designed in such a way that the buyer takes on all liability of credit failure, so verification of a BMP would most likely be part of a separate contract between buyer and seller. The state simply confirms that all of the required PI and BMP information is complete when the credit generator submits their credits to the state's registry. Once the regulatory agency deems the information to be complete, the credits would be posted to the registry with the most important information available online and the rest available by request. As an alternative, some WQT programs have a Soil and Water Conservation District or state environmental agency visit the BMP site to verify the practice before the credit can be validated. In Pennsylvania, the Department of Environmental Protection requires the credit generator to provide an acceptable verification plan. Credits are registered once the plan is fully executed.

In addition to PI, the WQT program may want to collect and track credit price. This information may or may not become available to the public, depending on the program and its market structure. To obtain this information, program developers will need to develop a protocol similar to PI collection where credit buyers must submit information about the credit transaction price to the WQT program administrator. Online forms are used by many WQT programs so that data can be easily transferred to an online registry. In certain programs, for example, the Great Miami River trading program, pricing is not available to the public because this program operates a reverse auction to solicit

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<sup>16</sup> See:

[http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin\\_Num=32303001&Dpt=EQ&RngHigh](http://www.state.mi.us/orr/emi/admincode.asp?AdminCode=Single&Admin_Num=32303001&Dpt=EQ&RngHigh)

agriculturally generated credits. Thus, disclosure of privately submitted bids applying for trading funds is not necessarily advantageous to this program's objective to obtain least-cost credits. Although trading credit costs may or may not be disclosed, economic information is important to farmers when they are considering program participation as credit sellers. Current assessment tools cannot factor in personal reasons in setting costs, but evolving tools can inform the discussion. (Such an economic evaluation of conservation practices is included in Appendix F as a supplemental analysis to NTT.)

A readily accessible credit registry can help assure the public (and potential credit buyers) that the credits being traded are real. Program developers may require that some spatial identification of a BMP site be available to provide assurance that the credits for the site are being sold only once per BMP. A mapping tool similar to the WSS used for NTT could be used to track BMP implementation locations.

WQT program developers may also decide whether the registry will collect and track information related to the contractual agreement between credit buyer and seller, if this type of contract exists. In programs where a clearinghouse or similar framework is used, there may not be a separate contract between buyer and seller. Such information may not always be posted on a particular registry, but it could be kept on file and made available to the public if necessary. This information potentially adds another level of assurance to the public that credit exchanges are backed by legally binding agreements. These private contracts also generally outline buyer and seller roles and responsibilities.

## Existing WQT Program Tools

When it comes to collecting data from sellers, many WQT programs have selected online platforms. Several of the online registries have incorporated BMP calculators or crediting tools to create a single, integrated system. These systems provide users with a one-stop-shopping experience where they can reliably and consistently calculate WQT credits, register credits with the WQT program administrator, and connect with buyers and sellers to identify trading partners. These online platforms generally provide public access to data related to validated credits and credit transactions. Such tools may also publically list credit prices, which can assist buyers and sellers in price discovery and provide more direct access to a credit market.

A summary of different types of WQT tools being employed in U.S. trading programs is provided in Table 6-1. The table supplies information on the different trading components that each tool offers, including whether the tool provides an avenue for public access. Few online tools provide all of these functions in one easy-to-use system. Larger WQT platforms such as NutrientNet provide many different components in one online system, but this all-in-one tool requires adaption and setup for each specific setting, which can add substantial costs to develop and maintain (Kieser& Associates, LLC and Gun Lake Tribe, 2010). For most of these trading platforms, supplemental training and guidance materials are necessary to ensure proper use of the tools. All of the costs and benefits for these various platforms should be considered by WQT program developers in order to select the most suitable system for their particular applications.

Table 6-1  
Platforms Developed for Water Quality Trading Programs

Tool	Reduction Calculator	Credit Calculator	Credit Registry	Marketplace	Public Access
<b>USDA Nutrient Trading Tool*</b> [1] - Load reduction tool that calculates change in nutrient, sediment, and crop yield for different management practices.	X				X
<b>NutrientNet – PA</b> [2] - On-line credit estimation tool and marketplace for the Chesapeake Bay Basin in PA.	X	X		X	X

Table 6-1 (continued)  
 Platforms Developed for Water Quality Trading Programs

Tool	Reduction Calculator	Credit Calculator	Credit Registry	Marketplace	Public Access
<b>PA Department of Environmental Protection Spreadsheet Calculator**</b> [3] - Tool available for download in MS Excel format to estimate load reduction and credit yield from select BMPs.	X	X			X
<b>NutrientNet – MI</b> [4] - On-line credit estimation tool, marketplace, and registry developed for the Kalamazoo River TMDL in MI.	X	X	X	X	X
<b>OH DNR Spreadsheet Calculator</b> [5] - Tool available for download in MS Excel format to estimate load reductions from limited number of BMPs.	X				X
<b>Bay Bank Registry***</b> [6] - The Bay Bank selected Markit Environmental Registry to provide an ecosystem credit and conservation program registry for the Chesapeake Bay region (currently under development).			X	X	X
<b>NutrientNet/NTT- MD</b> [7] - On-line credit calculator under development, coupling both models/platforms, marketplace, and registry features developed for nutrient trading in MD (public access currently unavailable, but anticipated when the system is live).	X	X	X	X	X
<b>Trading Protocols – Willamette Partnership</b> - Web site with access to trading protocols, including four different credit calculators, verification protocol, and Markit Environmental Registry.	X	X	X	X	X

[1] <http://ntt.tarleton.edu/nttwebars/>

[2] <http://pa.nutrientnet.org/>

[3] <http://www.dep.state.pa.us/river/Nutrient%20Trading.htm>

[4] <http://kalamazoo.nutrientnet.org/>

[5] <http://www.ohiodnr.com/soilandwater/programs/agpollutionabate/default/tabid/8856/Default.aspx>

[6] [http://www.thebaybank.org/tools/bay\\_bank\\_registry](http://www.thebaybank.org/tools/bay_bank_registry)

[7] <http://md-stage.nutrientnet.org>

\* NTT currently requires calibration at the county level, but USDA has plans to develop a version that can be used nationwide using average agricultural default values.

\*\* The PA DEP maintains a separate, public credit registry on the same nutrient trading web site where the spreadsheet can be downloaded. The program also has a version of the online trading tool NutrientNet that includes tools to calculate reductions and credits and a marketplace.

\*\*\* The Bay Bank is also working with The Other Firm to develop a full online trading platform that will calculate environmental credits for different practices.

In summary, the decision to develop a registry should include the following considerations:

- The attributes of calculation, verification, and tracking tools to meet buyer, seller, and regulatory needs
- Costs for an automated or web-based registry compared to the volume of expected trades
- The level of personal information required of the farmer
- Appropriate data gathering practices (web interface, hard copy forms) and data management approaches that are easy to use, affordable, and that provide the appropriate level or rigor for the scale of the project
- Methods to confirm that available credits have been verified
- Tracking and sharing of contract information for the transactions
- Tracking of credit costs for program planning, marketplace information, and/or public transparency



## Section 7: Conclusions

This project is the first rigorous effort to evaluate NTT and WARMF model applications within a WQT program framework. It has identified the potential of these tools for improving the accuracy, transparency, and repeatability of water quality credit calculations. Few water quality trading programs have linked field-scale and watershed model applications for improved crediting, or rigorously tested model uncertainty specifically for trading ratio considerations. The examinations in this study suggest that NTT is a robust edge-of-field tool capable of mechanistic model predictions of a variety of agricultural BMPs for WQT. WARMF is also a suitable model for deriving factors to credit these BMP reductions at a watershed scale.

Improvements in model applications, features, and uses for the crediting process have been noted. Fundamentally, these relate to the need for adequate data sets, a peer-review process, sufficient supporting protocols, and user training. Given that all models are imitations of real world systems, it must be recognized that they are never perfect in predicting natural systems. Thus, the project team has identified adjustments and supporting steps that will improve the accuracy of the credit estimation process, given the models capabilities and limitations.

The NTT modeling platform is packaged such that agricultural professionals can run the previously calibrated APEX model by simply entering familiar input parameters for each farm field application. NTT model results provide estimates of edge-of-field loading for sediments, nutrients, and volume of surface runoff, as well as bushel per acre yields for existing and new management practices. The differences in loading between existing and new practices are directly portrayed as the load reduction. The majority of the professionals testing the operation of the model in this project commented that NTT could benefit their clients substantially. The NTT platform adequately balances the level of complexity of the model by utilizing a software interface that is functional with an appropriate level of required technical details.

Overall, the NTT model appears to be a robust tool that can be adequately operated by agricultural field

professionals across large-scale applications including those for trading. There are, however, important issues identified in this study that need to be addressed in terms of computational approaches for select BMPs, model upgrades, and application considerations in order for trading participants to have confidence and trust in model outputs. For any application of NTT, peer review of the model calibration and of related assumptions must be central.

The WARMF model is a much more sophisticated tool regarding use, data requirements, and best professional judgment in its operation. Peer review of specific model applications is also deemed important to ensure that assumptions for model inputs and coefficients are consistent with the local setting and that local data are appropriate for model setup, calibration, and validation. The WARMF model structure has been peer reviewed following EPA guidelines and has been in use throughout the United States since 2003. However, WARMF should be used only by experienced watershed modelers. WARMF's use in crediting tool applications does not, however, require its continuous or repeated use. This tool can provide a variety of important watershed factors that can be applied in a crediting equation, rather than running the model for every trade. For example, a calibrated and validated WARMF model can provide necessary trading ratio factors related to the location of buyers and sellers, uncertainty in environmental and predictive outcomes, and it can inform policy factors that might establish trading area boundaries.

For crediting purposes, data from the WARMF model can be generated either by running the tool behind the scenes or by simply tabularizing data and providing lookup menus for relevant trade ratio factors. The latter approach will be much more cost-effective because it will not require constant services of a professional modeler. Tabularized lookup data will allow field professionals to more readily use a crediting equation that converts NTT edge-of-field reductions to a delivered credit. Data from a lookup menu could also be linked to spatial information in a credit calculator interface to automatically select appropriate trade ratio factors or other applicable considerations such as

agricultural baselines. This structure reduces the level of complexity needed when operating the credit estimation process. Recognizing that the location factor requires only periodic updates also simplifies the crediting approach.

Other uses of WARMF include assisting in the development of policies and framework decisions such as prioritizing BMP options, targeting or prioritizing key geographical areas, evaluating program effectiveness, and determining potential hot spots. Periodic model updates will assist with WQT program adaptive management when new monitoring data become available, policies change, or other factors necessitate recalibration of the model. Such model updates should be limited to longer timeframes in order to potentially avoid frequent changes in trading program rules and credit equation calculations.

This study has revealed that the NTT and WARMF models do not have to be computationally linked to provide a useful credit estimation platform. The credit equation is not complete without field reduction loading estimates, location factors, equivalency factors (for example, bioavailability ratios between sources), and an uncertainty factor, most of which can be provided by NTT and/or WARMF. Assuming appropriate application of the models, the uncertainty factor can be derived for the introduced errors associated with all components of the credit equation described in Chapter 2. Uncertainty is introduced in NTT through assumptions used in defining field boundaries and select model inputs. In WARMF, uncertainty will be introduced from the assignment of location factors derived from model runs, which are directly affected by calibration data limitations of the basin being modeled. From test applications of WARMF for the Upper Big Walnut Creek application in this study, it was shown that uncertainty can be characterized by sensitivity and uncertainty analyses performed on model inputs and outputs, by the range of trade ratio factors in the crediting equation, and by peer review of the model outputs. These are important issues to recognize and define since variability and uncertainty introduced through the crediting process can yield self-cancelling or compounding discount factors. Trading ratios must account for these issues in the context of environmental and economic outcomes, particularly when considering interstate trades at a broad geographic scale.

## **Limitations of NTT**

Evaluation of the NTT model by project team members and agricultural professionals raised questions regarding bushel per acre yields, phosphorus reduction projections, BMP treatment efficiencies, tile drainage projections, and WSS data capture. Some agricultural professionals reviewing NTT considered predicted yields to be low based on their client's use of genetically modified crops (GMOs). They commented that GMOs have been raising the yield about 10 bushels per acre every three years. Similar concern was raised with the inability for professionals to load the phosphorus concentration results from soil tests. Treatment efficiencies for certain BMPs were questioned, or current NTT capabilities were not sufficient (for example, wetlands, gully erosion, stream bank restorations). Tile drainage assessment features provided by NTT were insufficient to provide an opportunity for the operator to select the tile density and did not account for intakes that are present at the site. The TSPs and Ohio DNR also expressed concerns with the WSS tool and how it delineated the area of interest. The site selection tool provides a line that was considered to be too coarse and/or was considered to be less accurate than some of the TSPs' GIS-based field maps. If the GIS-based soil maps could be used instead, the accuracy would be improved.

Challenges associated with these WQT trading applications can be addressed with modifications to the tool and/or by engaging local peer review. The current version of NTT examined in this application did not have the accompanying documentation or version control, although a users' manual was developed by this project for the 2010 version of NTT applied here (Appendix G).

## **Limitations of WARMF**

WARMF modeling efforts demonstrated the potential uses of WARMF to assist WQT program development and implementation. The model input demands are relatively high and may not be met when entering into watersheds without adequate water quality monitoring data. In addition, the model's use of averaging techniques (common to all watershed models) creates some limitations for finite assessment of individual or a small number of trades. For example, WARMF averages fertilizer applications and point-source effluent loading across a month. Stochastic variability in both rainfall timing and amount, as well as limitations in

available daily and/or site-specific data, limits the accuracy of any watershed model to depict daily water quality conditions. The WARMF model also assumes a completely stirred tank reactor in the catchment reach. This assumes that new sources are added at a uniform concentration across the entire catchment's reach. The loading from an upstream catchment is passed downstream into the next catchment where attenuation functions are applied; however, new sources entering a catchment for the first time do not experience attenuation within the first catchment they enter. This assumption limits the assessment results to the scale determined by catchment size. Thus, WARMF is able to report only incremental increases and attenuation dynamics of nutrients periodically as determined by the catchment end points.

These model techniques and assumptions are common to most watershed models and necessary due to the limitations of modeling at a finer field scale and the voluminous information required to do so with any reliability. These model assumptions require that an appropriate output time step (not daily) be applied such as monthly or greater for deriving WQT trade ratio factors. In watersheds with very limited data, a goodness-of-fit statistical test should be used to guide WQT program managers on how to identify an appropriate time step that is consistent with the desired application of model output (monthly, seasonal, or annual).

The calibration of the model in the Upper Big Walnut Creek test case was limited by the available observed data, which were gathered over two years at an extremely small scale of 400 ha (988 acres) and in just four catchments of the larger UBWC watershed. The calibration was further complicated by the lack of meteorological station data within the UBWC. Thus, precipitation information did not reflect the actual rainfall conditions in the 400 ha catchments. After limited calibration of the model was completed using data from the four research catchments, assigned coefficients were used to model the larger UBWC basin. The added uncertainty introduced in these modeling applications to define trade ratio factors is simply unavoidable. This does not necessarily diminish the use of WARMF in trading applications. It simply emphasizes the need to account for this uncertainty in the crediting process.

## **Program Needs for Supporting Materials**

Many of the credit equation components presented in Chapter 2 can be derived from NTT and WARMF. Supplemental peer-reviewed resources and/or local and regional data will be necessary to address the remaining components. These may be needed to appropriately assess equivalency and uncertainty factors.

Methods to produce equivalency factors already exist in literature. The WQT project definition of bioavailability may be sufficiently provided in NTT predictions of various nutrient fractions; therefore, only the point-source effluent bioavailability component would need to be calculated. Uncertainty can be addressed by performing a model sensitivity analysis as illustrated in this study.

This evaluation gives WQT program developers and managers several options to investigate and address the uncertainty regarding the model input coefficients. Options include conducting inexpensive monitoring that can reduce the variability (for example, soil testing), increasing the uncertainty factor, or selecting different program credit estimation frameworks that would be appropriate in various settings/applications. Additional statistical analyses can be applied to model outputs or to the crediting equation itself to further address uncertainty. The cumulative effect of all parameter variability will include instances where such variability cancels or compounds uncertainty, which warrants examination.

Policy factors may be applied to crediting equations to incentivize targeted BMPs and/or geographic areas as well as to provide longer-term benefits for the early buyer participants. These factors typically do not introduce uncertainty. The WARMF and NTT models can be combined with other data evaluations such as an economic analysis or incorporated with targeted water quality priorities. These types of outside supporting evaluations provide assurances that the WQT program fits within the watershed planning efforts and advances the water quality improvement goals.

To increase precision in field-scale assessments for NTT input data, field data collection protocols and guidance manuals will result in more repeatable credit valuation between field representatives. These protocols and guidance tools also reduce the variability of the values used as inputs. Examples of areas where these

materials can improve program results based on this study include:

- Delineating BMP contributing areas or parceling the field into homogeneous areas
- Determining when to collect additional nutrient soil test samples
- Tracking whole herd manure land applications to assure program managers that the problem is not being transferred to an adjacent field or subwatershed

## **Suggestions**

The following suggestions are offered regarding the use and improvements of the two models for crediting applications in a WQT program.

### **Use of NTT**

NTT appears suitable for WQT crediting applications, although several considerations must be made before relying solely upon this tool for edge-of-field calculations:

- National WQT programs would strongly benefit from continued USDA-NRCS support of NTT. Updates of the model code, changes in data sources and required data proofing, and web support are all vital components that require significant resources that may best be managed at a national level and with rigorous oversight.
- NTT implementation for a WQT program should be vetted by a panel of local experts to confirm the estimates of yield and edge-of-field sediment, nutrient, and runoff reductions.
- NTT should allow operators to adjust the NTT soil phosphorus content based on soil test results.
- The load reduction results summary page should be adjusted to include the summation of surface runoff, shallow-aquifer, and deep-aquifer loading estimates to reflect only the surface non-point source loading and shallow-aquifer loading and runoff recharge to a stream. (The deep aquifer should not be a portion of the WQT credit. However, deep-aquifer losses are important to different water protection programs such as wellhead protection for public water supplies.)
- Formal documentation of NTT to support local peer review by experts is needed, including version

control. This would facilitate a more accurate calculation of load reductions.

- Although using the NRCS WSS tool provides more robust information than previous crediting tools have offered, certain problems can be introduced by this process:
  - Errors in site delineation occur by using the wrong scale of magnification or inaccuracy due to the coarser lines in the WSS tool.
  - A single field with a footprint in two counties (for example, crossing a county line) must be parceled out by county to successfully capture soil survey results.
  - The WSS tool does not show topographic contours or tile drainage systems that are necessary for determination of the contributing area.
- Local programs are encouraged to develop appropriate protocols for the field representatives to assist with gathering the site assessment and modeling inputs.
- WQT program managers need to evaluate the nutrient bioavailability differences between sources within their watershed to develop equivalency factors.
- WQT program managers are encouraged to run sensitivity and uncertainty analysis procedures to determine appropriate uncertainty factors.
- NTT applications should be limited to fields that are adjacent to the stream network to avoid complications with redeposition, lack of adjacent field management practice information, or groundwater attenuation factors not being accounted for in calculations.
- Currently, the model produces an expected annual average value based on 12 different years. The weather inputs across these 12 years change the daily values according to physical factors such as temperature, precipitation amount, and intensity. An output regarding standard deviation would increase the understanding of the credit value and year-to-year variability. Additionally, WQT programs can use this type of information when making decisions about the appropriateness of trading under different flow regimes.
- NTT should allow for the option of a shorter time period for modeling results since EPA guidance

requires WQT to be contemporaneous. Currently, the model results are reported as an annual average, which does not provide contemporaneous reporting results for NPDES permits with effluent limits, which can be based on shorter average time periods.

- As one professional agriculture reviewer commented: “Shoot the slow moving rabbits first!” NTT is a useful tool and can be applied for many applications immediately, including WQT in the ORB after accounting for the limitations and approaches recommended here. Many of the identified complex issues can be addressed over time, though computational issues or errors need to be corrected.

### **Use of WARMF**

WARMF is a suitable watershed model for informing WQT program design and implementation recognizing the following considerations:

- When setting up the WARMF model, the smallest subwatershed should be used that the data will allow. As such, a watershed model integrates multiple sources and, therefore, can best forecast average BMP load reductions (kg/ha or pounds/acre) only by applying a significant level of adoption in a given watershed and dividing the cumulative load reduction by the area land under the new BMP.
- Frequent WARMF model updates for a watershed or basin in which trading is occurring are not necessary. These could be done every five to ten years, as new monitoring data become available, and following substantial periods of land use change or large-scale BMP implementations that are sufficiently documented.
- WARMF can be used to establish trading boundaries based on the attenuation of pollutant loading and identification of significantly limiting physical features (such as reservoirs).
- WARMF model operation is best conducted by a qualified modeler for initial program development and periodic modeling updates.
- The limited availability of water quality and discharge data can be an issue for WARMF model simulations. Where data is inadequate, or where model “goodness of fit” results are weak, uncertainty factors can be used to address location or other crediting equation factors. These are less than

optimal, however, because they tend to diminish credit value.

- WARMF modeling time steps are daily, but model results should be averaged across a minimum of one month. The averaging techniques employed by the model code, the stochastic nature of nutrient monitoring from streams, sporadic WWTP discharge data, and other sources can all contribute to increased variability of model output. Averaging outputs over a longer period is reasonable, considering this issue as well as discharger compliance for nutrients that are typically monthly or greater averages.
- A sensitivity and uncertainty analysis should be conducted of WARMF watershed simulations used for trading program development. This evaluation should focus on providing effective methods to reduce variability in model results, addressing uncertainty in crediting methods, and developing appropriate WQT monitoring plans.

### **Linking Tools for Credit Estimation**

The direct computational linkage of NTT and WARMF does not appear to be necessary to support crediting procedures in a WQT program. Rather, a simpler interface to address varying policy issues, baselines, and other local/state requirements will be more efficient and will provide a less cumbersome approach when compared to the complex architecture of linked models. Considerations for this recommendation are as follows.

- NTT and WARMF output can be used to develop look-up tables for trade ratio factors to calculate a reliable WQT credit. Currently, it is envisioned that the recommended credit interface would combine a field professional’s results from running NTT with individual coefficients representing:
  - Spatially determined location factors based on WARMF or other watershed attenuation assessments
  - Equivalence factors based on the ratio of bioavailability of nutrients between buyers and sellers (which can be based on literature citations, actual testing, and/or model outputs)
  - Uncertainty factors based on the range of variability for each of the credit equation components

- As part of the public transparency necessary in WQT programs, a bibliography of national and regional non-point source loading studies germane to the crediting tool applications would assist the program's peer-review process. Where watersheds and/or regions have limited water quality data and non-point source inventories, these bibliographies should help foster trading in the absence of such details.
- WQT programs may benefit from applying economic analysis techniques to educate participants and evaluate/forecast pricing potential. While economic assessments cannot factor in personal reasons to set costs for trading program participation, evolving tools may inform the discussion. Such an economic evaluation of conservation practices is included in Appendix F as a supplemental analysis to NTT.

### **Registry**

For a large-scale trading program as envisioned for the Ohio River Basin, tracking of trades through a credit registry may be necessary. Such a tracking program can be integrated into a crediting platform of NTT and a credit calculation interface. Regardless of form or function, the registry will likely need to evaluate and develop the following:

- A protocol for collecting personal information and BMP information from credit generators
- A protocol for verifying that credit generating practices are in place.
- A protocol for gathering information on credit transactions (for example, sale of credits to WWTPs and application for NPDES permits)
- Tracking and display capabilities for all of the pertinent information related to the generation and sale of credits

In summary, the project has identified that the edge-of-field non-point source nutrient loading model, NTT, and the watershed model, WARMF, have demonstrable uses, abilities, and capabilities for supporting essential elements of credit calculations and policy development for an ORB WQT framework. Recognition of benefits and limitations with these tools will be critical for realizing their full potential as discussed in this report. Efforts must be made to gather sufficient data and literature support for local/regional model calibration (and validation where possible). Vetting by local experts and knowledgeable program participants of the data and assumptions used by modelers is highly recommended for both models. In addition, recommended NTT model improvements will enhance the accuracy and performance of the tool, the results of which will increase trust and use by program participants. Notable calculation issues for select BMPs should be a priority for USDA-NRCS updates.

WQT programs can adjust for introduced errors and uncertainties by using appropriate trade ratios. These decisions can be informed by sensitivity analysis of the calibrated models, incorporation of model "goodness of fit" results, and best professional judgment. Where gaps occur in model coverage and/or model output between the field level and watershed scale, additional watershed data, other tools, and best professional judgment for applying uncertainty factors can be used.

For crediting BMPs not covered by NTT, other calculation tools will be needed until NTT is updated. Output of both modeling tools (and supplemental information where necessary) can be combined to provide an appropriate level of user-friendliness and pragmatic use of best available science for crediting. The use of one set of models for a multi-state WQT program, though a challenge for broad adoption, ensures that a pound of nutrient reduction in one state will equal a pound of nutrient offset in another.

## Section 8: References

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# Appendix A: NTT Field Scale Model

This Appendix was prepared in its entirety by Tarleton University, under contract with EPRI.

## Overview of NTT

The Nutrient Trading 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. NRCS commissioned the development of NTT for Water Quality Trading (WQT), and while it 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.

## 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; Shaffer et al., 1991). While very useful, its exclusive focus on nitrogen limited the applicability of the Nitrogen Trading Tool. 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 America and Europe (Sharpley and Rekolainen, 1997).

In an effort to address the limitations of the Nitrogen Trading Tool, USDA-NRCS developed NTT in collaboration with TIAER. The strengths, scope and capabilities of NTT are based on its core simulation model, the Agricultural Policy Environmental eXtender (APEX; Williams et al., 2000).

NTT was developed by using APEX in place of NLEAP within the same farmer-friendly and web-based interface. 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.

## Key Features of NTT

NTT is a web-based program. Users can access the beta version of the program by using their internet browser to go to the main NTT home page: <http://ntt.tarleton.edu/nttwebars/>. The current version has been tested for a number of sites within the US and additional testing is being performed in various states. 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 relatively a user-friendly program. Virtually all the data required for a number of states and counties are already available on the NTT server. NTT provides canned management alternatives to users that are interested in evaluating practices that are typical for their area. The specific information is already preloaded and the user provides the size of the field or land area they wish to evaluate by selecting the area of interest on the WSS site. All other data required for these areas can be selected by users from drop-down list boxes on the NTT web pages. If users desire to estimate nutrient and sediment losses for management practices that are not available in the NTT canned alternatives, the user can select options to either modify existing management practices (operations) or create new ones.

The NTT program consists of three main components:

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

### ***NTT's Computer Simulation Programs***

APEX is the core simulation model in NTT. APEX was selected for this trading tool 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 that can be useful in future potential augmentations of the tool, such as simulation of pesticide losses and carbon cycles.

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, etc. The routing mechanisms provide for evaluation of interactions between subareas involving surface runoff, return flow, sediment deposition, nutrient transport, and groundwater flow.

### ***Supporting Databases***

All the datasets required for running NTT in selected states and counties where NTT has been tested 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 selected states and counties and are being developed for the remaining counties in the U.S.

- Weather (precipitation, minimum temperature, maximum temperature)

- Soils
- Crop parameters
- Tillage parameters
- Properties of major fertilizer and manure products
- Typical management practices for each major crop in selected crop management zones

### **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 virtually all crop operations – any crop operations that can be simulated in APEX. NTT can also simulate a number of structural conservation practices. However, due to its core intent of being user friendly the conservation practices that are presently available in NTT are a subset of what can be simulated in APEX – essentially only the practices for which a user-friendly interface has been developed in NTT to the APEX model. The following table summarizes the range of NTT applications. The applications that are yet to be tested or incorporated in the NTT interface are marked with an asterisk.

Since APEX is a field-scale model, the results obtained from the NTT applications are edge-of-field estimates of the impacts of the scenarios estimated. The NTT outputs in themselves are not nutrient credits. They are simply nutrient load (edge-of-field nutrient loss) reductions that must be multiplied by various WQT program factors in order to arrive at the credit value for the conservation practice to be implemented on that field of interest. As APEX, as used here was not designed as a watershed simulator, other tools or methods must be used to generate those adjustments.

Table A-1  
Range of NTT Applications

Category	Application
Field operations	Tillage
	Nutrient applications
	Irrigation
	Pesticide applications*
	Other chemical applications
Structural practices	Filter strip
	Buffer zone
	Terraces
	Riparian forest buffer
	Wetlands
	Contour farming
	Tile drainage

**Application of NTT to UBWC**

The upper Big Walnut Creek (UBWC) watershed was selected for the NTT application in this CIG project primarily because previous work in the UBWC watershed had established some data sets that could be used for validation of NTT as well as for WARMF calibration efforts. In particular, current farm cultural practices and water monitoring data had been collected in the watershed, which are two critical data for the NTT and WARMF simulations.

**Site Description**

The UBWC (Figure A-1) is an 11-digit Hydrologic Unit Code (HUC) watershed (05060001-130) located in central Ohio. The watershed is predominantly rural and drains into Hoover reservoir, which is to the

northeast of the City of Columbus, Ohio, and serves as a drinking water source for the city. The watershed covers portions of Delaware (66%), Morrow (21%), Licking (9%), Knox (3%), and Franklin (1%) counties in central Ohio. The UBWC drains an area of about 190 square miles with an average annual precipitation of 40 inches.

The predominant land uses are cropland, pastureland, and a growing proportion of urban land uses. Corn, soybeans, and wheat are the main crops grown in the watershed. The four major soil associations in the UBWC are Bennington-Pewamo-Cardington, Centerberg-Bennington, Cardington-Alexandra, and Amanda-Centerburg.

**Data Requirements and Sources**

Table A-2  
Data Used for NTT with Sources

<b>Data</b>	<b>Requirement</b>	<b>Source</b>
General location data		
	Weather	NTT Database
	Precipitation	NTT Database
	Daily	NTT Database
	Monthly	NTT Database
	Annual	NTT Database
	Temperature	NTT Database
	Daily	NTT Database
	Monthly	NTT Database
	Annual	NTT Database
	Soil data	USDA-NRCS Soil Data
	Texture	USDA-NRCS Soil Data
	Slope	USDA-NRCS Soil Data
	Slope length	USDA-NRCS Soil Data
	Infiltration rate	USDA-NRCS Soil Data
	Initial Soil P	NA
	Organic matter	USDA-NRCS Soil Data
	Bulk density	USDA-NRCS Soil Data
	Land use distribution	Brandt (2010), NRI Data
	Cropland	Brandt (2010), NRI Data
	Pasture	Brandt (2010), NRI Data
	Forestry	Brandt (2010), NRI Data
	Urban	Brandt (2010), NRI Data
	Water	Brandt (2010), NRI Data
Farm management practices		RUSLE2, Brandt (2010)
	Crop rotation history	Brandt (2010), NRI Data
	Farm cultural practices	RUSLE2, Brandt (2010)
	Crop operations	RUSLE2, Brandt (2010)
	Dates	RUSLE2, Brandt (2010)
	Frequency	RUSLE2, Brandt (2010)
	Equipment	RUSLE2, Brandt (2010)
	Irrigation	NA
	Chemicals, seeds	RUSLE2, Brandt (2010)
	Other supplies	RUSLE2, Brandt (2010)
	Crop yields	USDA NASS Data

Table A-2 (continued)  
 Data Used for NTT with Sources

<b>Data</b>	<b>Requirement</b>	<b>Source</b>
Conservation practices		King (2010), Brandt (2010)
	History of conservation practices	King (2010); Brandt (2010)
Water monitoring and other calibration data		King (2010)
	Flow	King (2010)
	Nutrients	King (2010)
	Nitrogen	King (2010)
	Runoff –N (NO3)	King (2010)
	Sediment-bound N	King (2010)
	NH3-N	NA
	N2O-N	NA
	leached-N (NO3)	NA
	tile drain-N (NO3)	NA
	Phosphorus	King (2010)
	Runoff –P (PO4)	King (2010)
	Sediment	King (2010)
	Leached	NA
	Tile drain	NA

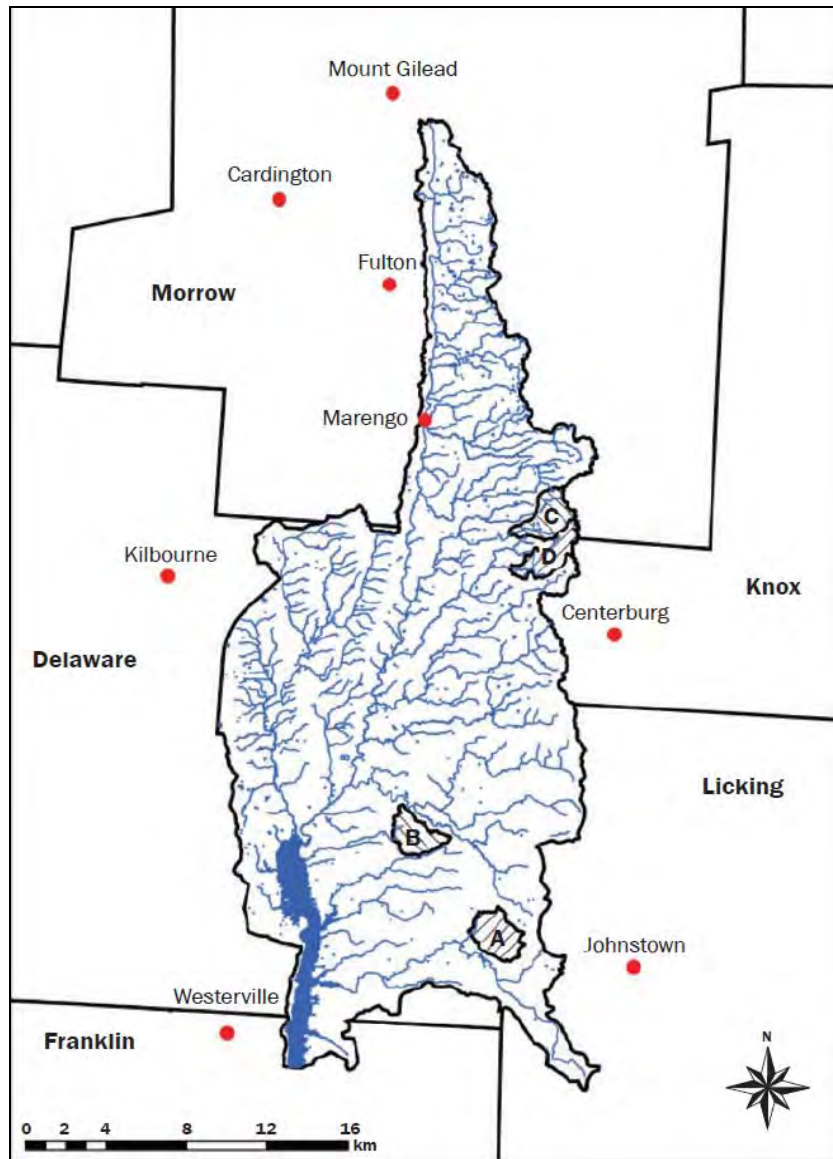


Figure A-1  
Upper Big Walnut Creek Watershed in Central Ohio

### Conservation Practices Considered

Six conservation practices were considered for the NTT application in the UBWC based on conversations with experts in the watershed area (King, 2010). Of the six practices, five were simulated with NTT. The sixth practice, bank stabilization, was not included in the NTT application for this project due to current limitations within the tool to adequately capture the typical design of bank stabilization structures. The five practices simulated in NTT are discussed below.

### Water Table Management (Control Drainage)

Water table management encompasses a number of conservation practices. For this study, tile drainage was simulated using NTT. The NTT web interface currently includes tile drainage as the only water table management practice that can readily be evaluated by users. Tile drainage was evaluated by assuming a “baseline” that did not include tile drainage. Then a tile drainage scenario was simulated in NTT and compared against the “baseline” no-tile lines scenario. In the tile drainage scenario, it was assumed that tile lines would

be placed 4 feet into the ground. NTT provides no other options for specifying tile drainage, such as lateral spacing.

## Nutrient Management

Nutrient management encompasses a host of practices that entail improved use of crop nutrients on the farm. These include manure nutrient crediting, judicious use of manure and inorganic fertilizer sources, incorporation of manure and fertilizer nutrients, legume nutrient crediting, timing of nutrient applications, plant tissue tests prior to nutrient applications, soil nutrient tests prior to nutrient applications, split nutrient applications, and variable rate technologies, among others. In the present NTT application, the nutrient management scenario was defined based on the data available on current farm practices.

Conversations with experts in the central Ohio area (Brandt, 2010) indicated that most farmers apply commercial fertilizer at rates that are about or somewhat lower than recommended crop nutrient requirements. In particular, about 50% of farmers in the watershed apply nutrients within 10 lb/acre of the recommended rates, about 20 to 30% apply nutrients over 15 to 20 lb/acre/year above recommended rates, and the remainder apply nutrients below recommended rates. These figures indicate that crop farmers in the watershed are better users of crop nutrients than is generally perceived of the agricultural community in the U.S. in general. Consequently, two alternative scenarios were evaluated to determine the effects of nutrient management regimes.

- A. 25% more nutrient applications than current levels
- B. 25% less nutrient applications than current levels

Each alternative regime was applied to the hypothetical field simulated in NTT and for each of the soil types used in the simulations. The results reported here are simple averages of the individual results by soil type.

## No-Till

Information on current farm practices indicate that no-till is actually quite common in the UBWC (Brandt, 2010). Many soybean farmers practice no-till. On the other hand, no-till corn production is common only on

the steeper slopes. In the flat areas, most farmers grow corn with conventional tillage practices. In general, the most common practice for corn-soybeans is no-till soybeans following conventional tillage corn.

To evaluate no-till practices for each cropping system, a conventional tillage scenario was simulated for that cropping system and used as a reference point for comparison even though it was not necessarily the prevailing practice. No-till production for that cropping system was simulated and compared against the conventional tillage reference scenario. Detailed information on the alternative tillage practices were obtained initially from the USDA-NRCS RUSLE2 database and then refined through communications with experts in the central Ohio area (Brandt, 2010).

## Cover Crop

While field trials are being conducted in central Ohio regarding the use of cover crops as a conservation practice, its use in practice in the UBWC is yet very limited (Brandt, 2010). For the present study, cover crops were evaluated by comparing a scenario including cover crop after conventional tillage to the conventional tillage reference scenario without cover crops. Data available in the RUSLE2 database on field operations suggested the following cover crop scenarios involving rye and clover:

- Corn-soybeans-rye
- Corn-soybeans-winter wheat-clover

In the present effort sweet clover was assumed to be the specific variety of clover for purposes of the NTT simulations. The RUSLE2 operation dates were slightly modified to match the specific crop operations that had been established for the regular cropping system. The above cover crop scenarios were extended to the other cropping systems as follows:

- Corn-rye
- Soybeans-rye
- Soybeans-winter wheat-rye

In each case, addition of the cover crop entailed a planting operation in the fall after harvest of the regular crop. The cover crop was terminated by a regular tillage operation in the spring. The specific dates differed based on the cropping system that was being augmented with the cover crop.

## Hayfield Establishment

Hayfield establishment was evaluated by replacing the current cropping system with a permanent alfalfa crop. While in many regions of the U.S. alfalfa is normally replaced by an annual crop after several years of growth and then reestablished, information for the crop management zone that covers central Ohio indicated that some alfalfa stands may last up to six or more years. For simplicity and because no alfalfa management information was available that included an annual crop, the hayfield establishment scenario evaluated in the present study consisted of a permanent alfalfa crop with a one-time establishment period for the 24-year simulation.

### **NTT Verification Using the Available Measured Data**

The only data available for NTT calibration for conditions in the UBWC watershed were water monitoring (flow, sediment and nutrient) data collected at four stream sites in the watershed. Since NTT is a

field-scale tool, field-scale data are more applicable. However, the research team was able to perform limited calibration using the stream site data that was made available by King (2010).

For NTT calibration purposes, the monthly stream loadings were converted to annual loads. Then the annual stream loadings were converted to annual per unit area loads in order to compare them with NTT. The annual per unit area loads for the four stream sites are presented in Table A 3. Data have been converted from metric units. Since NTT output is at the field scale multiple NTT runs for the predominant crop rotations in the watershed were compared to the subwatershed loads from King (2010) (Table A 3). The NTT output was considered reasonable if the average loads estimated by the tool were in line with the subwatershed load from the four sites on a per unit area basis. However, the comparisons would not be exact since some urban and other nonagricultural land uses are also reflected in the measured data shown in Table A 3.

*Table A-3  
Measured Data from King (2010)*

<b>Indicator</b>	<b>Unit</b>	<b>Site A</b>	<b>Site B</b>	<b>Site C</b>	<b>Site D</b>	<b>Average</b>
<b>2005</b>						
Precipitation	Inches	32.70	37.61	38.12	38.12	36.64
Flow	Inches	19.79	18.18	22.91	24.13	21.25
Total N	lb/acre	46.69	21.88	12.81	17.13	24.63
Total P	lb/acre	1.08	0.70	0.37	0.50	0.66
<b>2006</b>						
Precipitation	Inches	35.74	34.57	43.56	44.54	39.60
Flow	Inches	21.77	13.18	17.92	24.00	19.22
Total N	lb/acre	48.46	18.50	16.02	24.32	26.82
Total P	lb/acre	1.67	0.61	0.46	0.98	0.93
<b>Average</b>						
Precipitation	Inches	34.22	36.09	40.84	41.33	38.12
Flow	Inches	20.78	15.68	20.41	24.07	20.24
Total N	lb/acre	47.57	20.19	14.42	20.72	25.73
Total P	lb/acre	1.38	0.66	0.42	0.74	0.80



During NTT calibration several input parameters were adjusted to mimic more closely observed yields and water monitoring data. Most of the crop parameter data remained unchanged after the calibrations were completed. The only significant changes that had to be made were in the crop management information. Specifically, in the case of winter wheat, the “kill” operation that determines when the crop ceases growth was adjusted to ensure that wheat growth was terminated at the right time, right before planting of the

next crop. Also, the APEX harvest operations used for different crops were adjusted to ensure that the correct biomass and grain harvests were being simulated by the model. Output from the calibrated NTT program for various environmental indicators and yields are reported in tables A4 and A5. While total N predictions are in line with the measured data from the four sites, total P loads from the NTT tool are much higher and flow is much lower than the values reported in the measured data.

*Table A-4  
NTT Environmental Output for Conventional Tillage Practices - Used as Baseline*

<b>CONVENTIONAL</b>	<b>Total N</b>	<b>Total P</b>	<b>Flow</b>	<b>Sediment</b>
Corn	23.4	2.7	7.7	6.5
Soy	9.7	1.5	8.4	2.9
Corn-soy	16.2	2.2	8.1	4.7
Corn-soy-wheat	22.7	2.7	6.8	6.0
Soy-wheat	17.6	1.9	6.4	3.8

*Table A-5  
NTT Crop Yield Output*

<b>Crop</b>	<b>Yield</b>	<b>Units</b>
Corn	140.6	bu/acre
Soybeans	48.6	bu/acre
Winter wheat	21.0	bu/acre
Alfalfa	4.9	tons/acre

Because the only data available were stream site data for two years, it was not possible to use traditional goodness of fit tests such as the Nash-Sutcliffe E value or the R<sup>2</sup> value. However, a comparison of the reported measured data and the NTT output indicate a reasonable performance of the model under the UBWC watershed conditions.

### **Sensitivity Analyses**

Sensitivity analysis is the evaluation of how specific changes in input parameters affect the output of a system; in other words, how output variables respond to specific changes in input parameters. While NTT is relatively user friendly, the NTT output presented to users is based on very complex mathematical processes. Sensitivity analyses permits us to determine how various output variables are sensitive to changes in input parameters. This section of the report outlines the

results of sensitivity tests that were performed on NTT using data pertaining to the UBWC watershed. In most cases, data for Delaware County, Ohio were used as county level data were most applicable and Delaware County, Ohio covers a greater portion of the UBWC watershed than any other county.

**Uses of Sensitivity Analysis:**

Sensitivity analysis has a variety of uses. The following are among the most relevant uses of sensitivity testing for NTT users.

1. Determines which are the relevant variables to include in an uncertainty analysis procedure
2. Informs users regarding the input variables that are most crucial to ascertain in order to obtain reliable results from NTT
3. Provides an indication of which input factors or management parameters can be relied upon to help achieve desired changes in output variables.

**Variables for NTT Sensitivity Analysis**

NTT output is impacted by scores of input variables. For the present application, the variables of most relevance in agricultural emissions credit generation were the focus of attention. These variables included model parameters as well as user input data. The list of variables included in the simulations is described in a later section.

**Sensitivity Analysis Procedure for NTT**

Sensitivity analysis was performed for 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. The following specific adjustments were made in each input variable prior to running NTT’s calculation tool.

**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).

**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.

**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 A-6  
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

**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 A-7) shows the parameters adjusted, the acceptable range of values, and the values used for the sensitivity simulations.

For each sensitivity analysis iteration, all other variables were held fixed at their pre-adjustment levels while the

values of the variable being investigated were adjusted using the procedure described above. Each sensitivity analysis iteration was performed for all the soils in Delaware County, Ohio, in order to avoid biases that might be introduced by different soil types. Delaware County, Ohio was chosen because it covers a greater portion of the UBWC watershed than any other county. 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.

Table A-7  
Input (A) and Model (B) Parameter Values Used in Sensitivity Analyses Simulations

Code	Description	Range		Values used	
		Lower	Upper	I	II
<u>A: Input Parameters</u>					
	Slope	0	0.1	0.05	0.1
	Slope length	0	100	20	80
	Erosion control practice factor	0	1	0.1	0.9
	Soil pH	3	9	5	9
	Soil Organic carbon concentration	0.1	10	0.5	5
	Initial soluble P concentration	0	500	50	500
	Bulk density	0.5	2	1.1	1.8
	Fraction of organic C in passive pool	0.3	0.7	0.35	0.7
	Saturated hydraulic conductivity	0.00001	100	2	40
	Runoff curve number	30	90	65	85
	Fertilizer application depth	0	500	20	200
	Plant population	0	500	5	500
	RFPO	0	1	0.1	0.9
<u>B: Model Parameters</u>					
Parm 7	N Fixation	0	1	0.1	1
Parm 8	Soluble P runoff Coefficient	10	20	10	20
Parm 14	Nitrate leaching ratio	0.1	1	0.1	1
Parm 46	RUSLE C-factor coefficient	0.5	1.5	0.5	1.5
Parm 47	RUSLE C-factor coefficient	0.5	1.5	0.1	1.5
Parm 49	Maximum rainfall interception by plant canopy	2	15	2.5	15
Parm 52	Tillage effect on residue decay rate coefficient	5	15	5	15

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.

With the exception of 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.

*Table A-8  
Sensitivity of Output Variables to Fertilizer Application Rates: Average Across All Soil Types and Crop Rotations*

Output variable	Percentage change in output indicator from a	
	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

## Results of NTT Sensitivity Analyses

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.

### NTT Sensitivity Analyses Results for User and Weather Parameters

1. Fertilizer application rates
2. Operation dates
3. Minimum and maximum temperature
4. Precipitation

#### 1. 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 here (Table A 8) are averages across all soil types and all crop rotations. The summary results (Table A 8) suggest that soluble nutrient indicators are particularly sensitive to inorganic fertilizer application rates.

## 2. 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 in 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 A 9. As expected larger changes in operation dates have much greater impacts – though not necessarily larger sensitivity ratios – than smaller changes in operation dates.

Table A-9

*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

## 3. 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 A 10) 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 A-10

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

Output variable	Percentage change in output indicator from a	
	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

4. *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 A 11). 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 A-11

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

Output variable	Percentage change in output indicator from a	
	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

## 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.

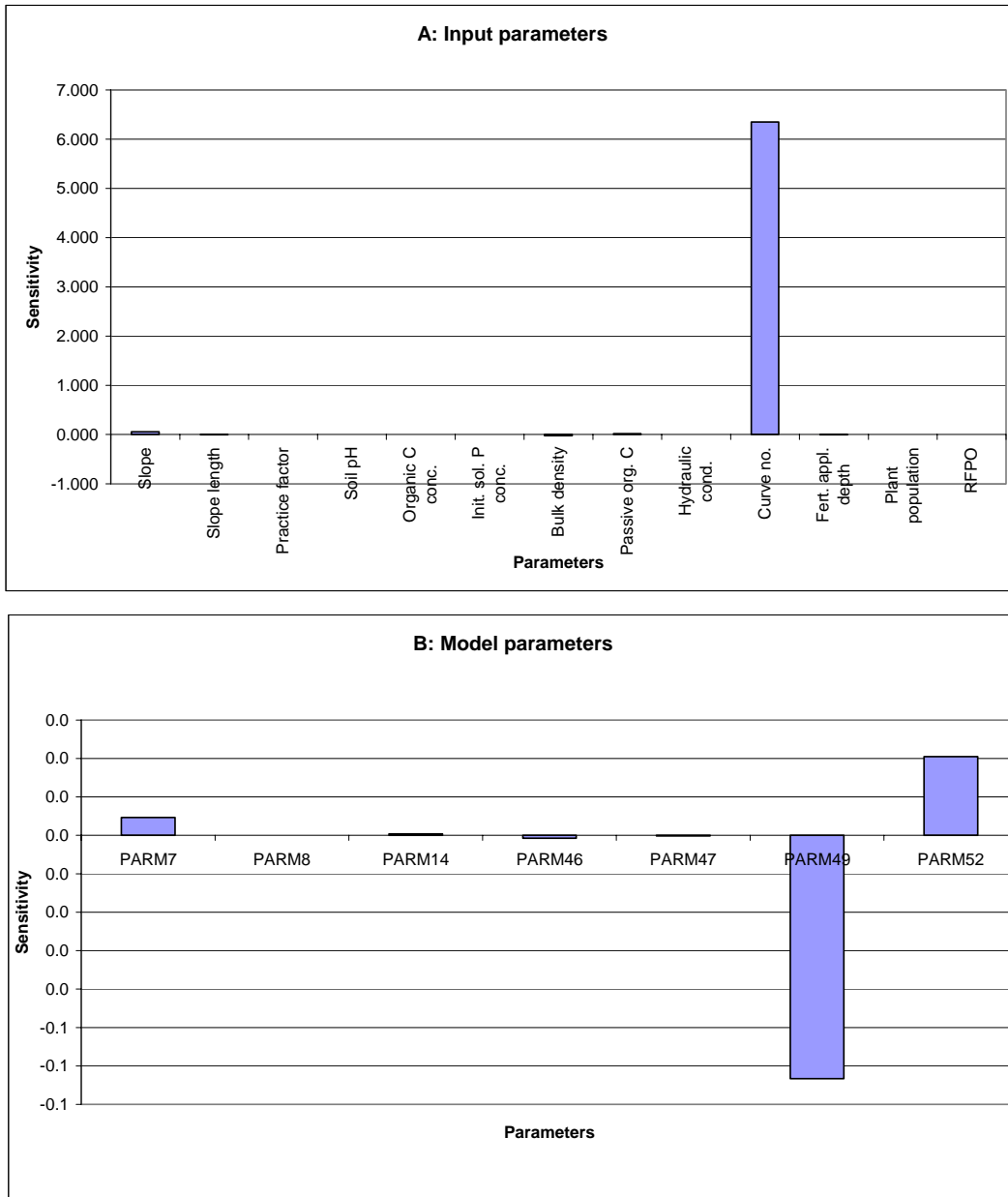


Figure A-2  
Sensitivity of Edge-of-Field Runoff to NTT Input and Model Parameters

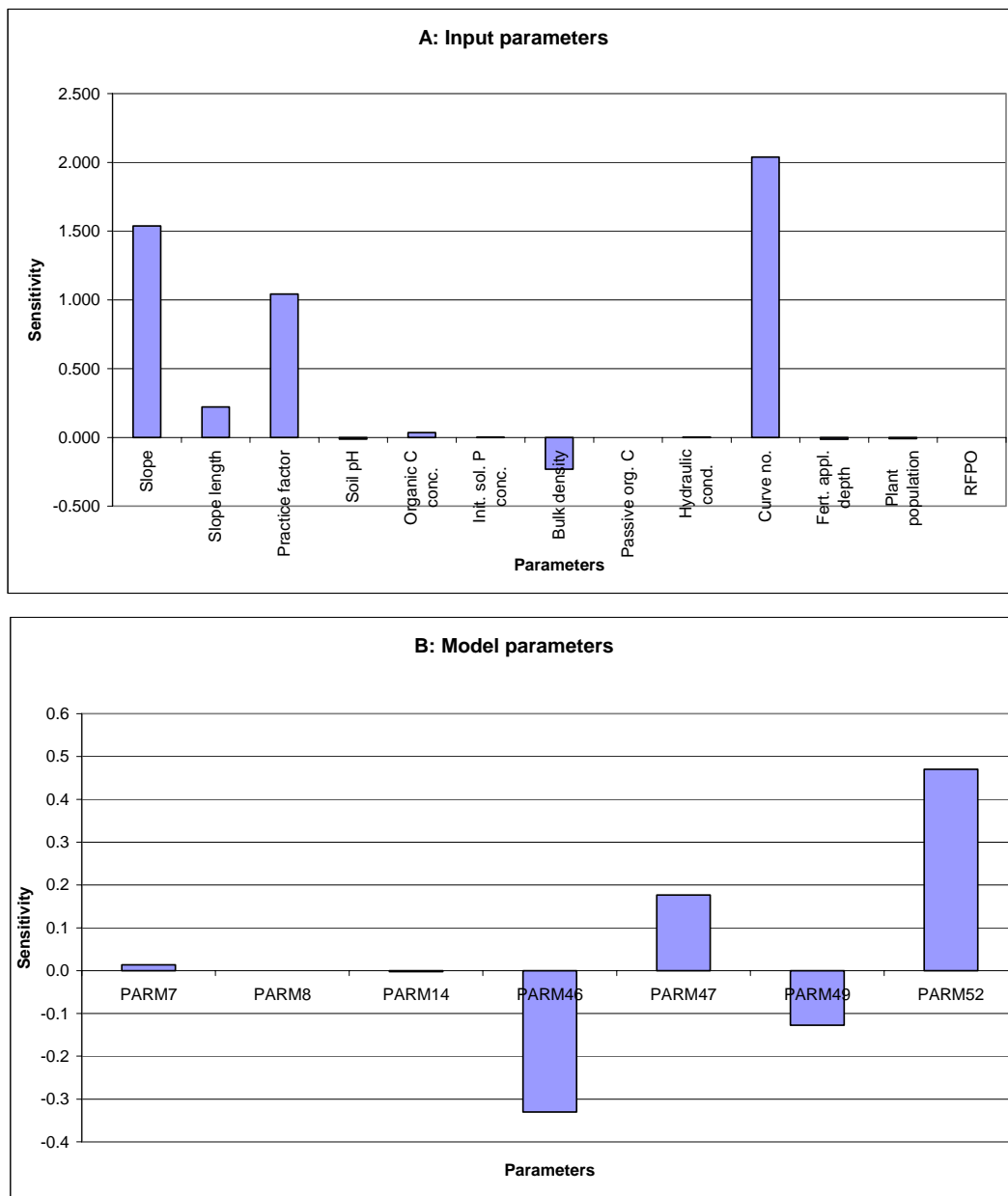


Figure A-3  
Sensitivity of Edge-of-Field Sediment Losses to NTT Input and Model Parameters



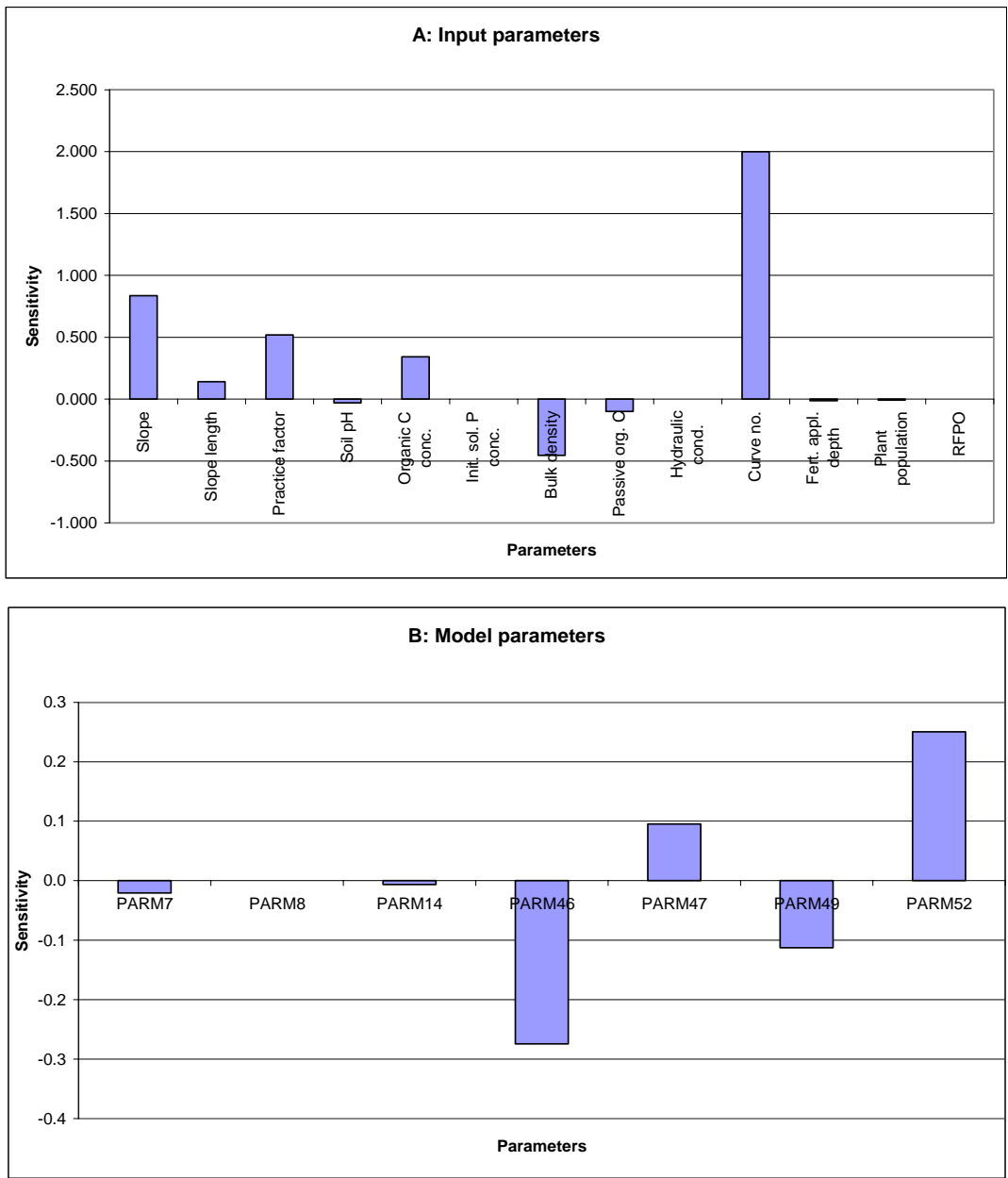


Figure A-4  
Sensitivity of Edge-of-Field Organic N Losses to NTT Input and Model Parameters

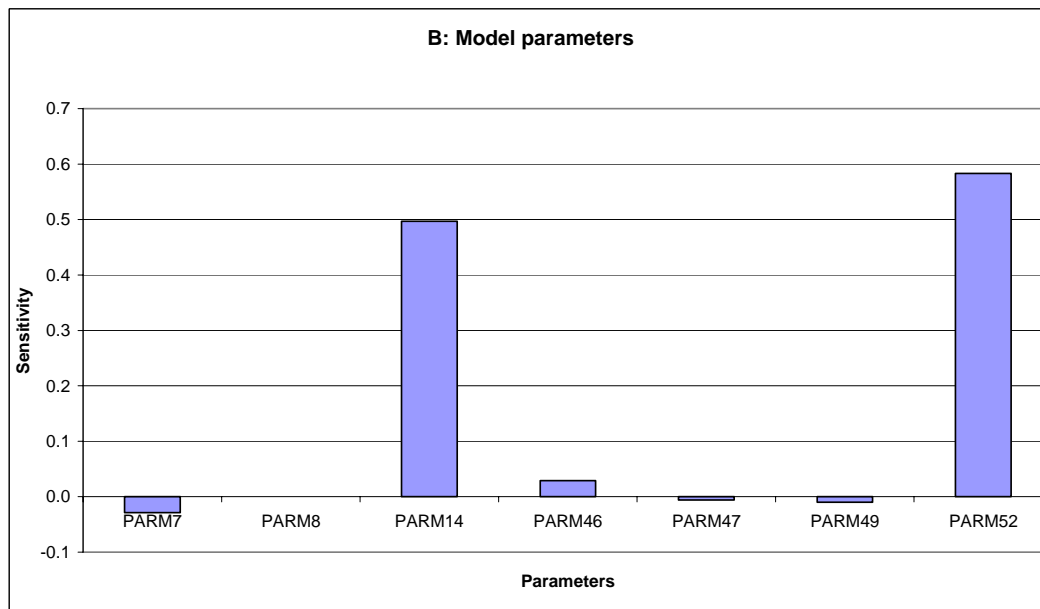
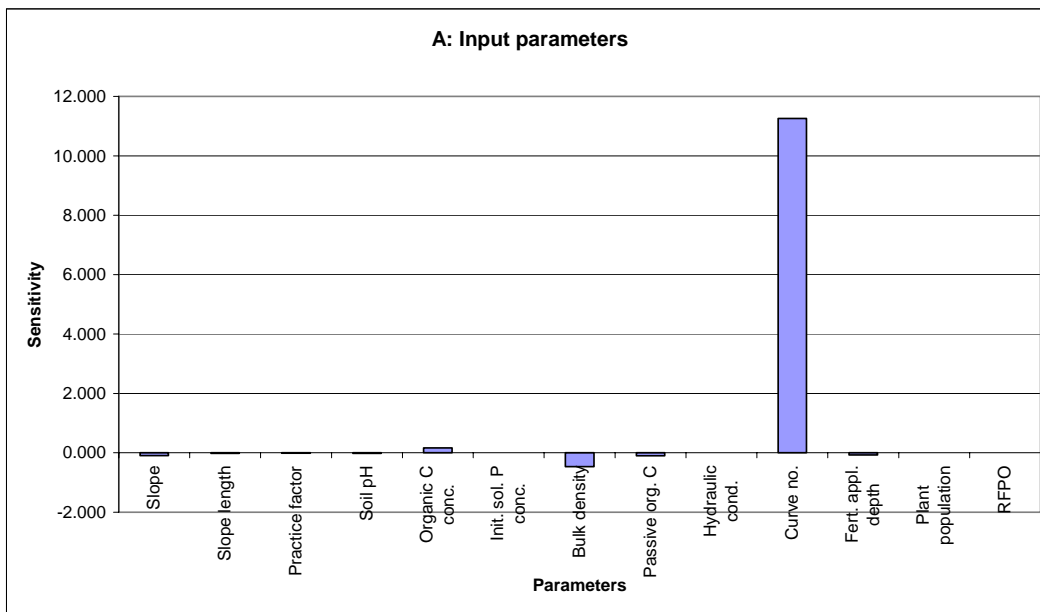


Figure A-5  
Sensitivity of Edge-of-Field Nitrate Losses to NTT Input and Model Parameters

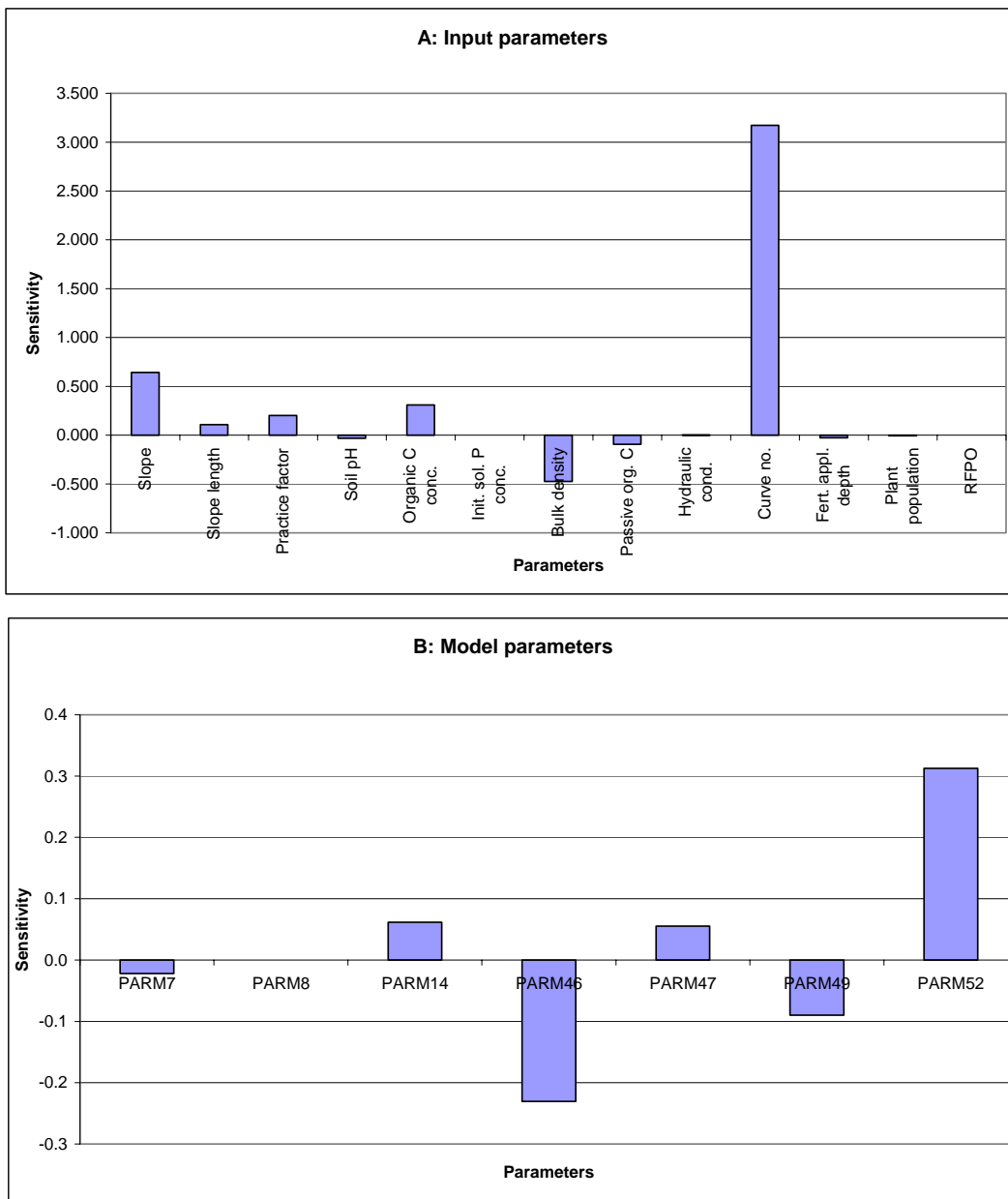


Figure A-6  
Sensitivity of Edge-of-Field Total N Losses to NTT Input and Model Parameters

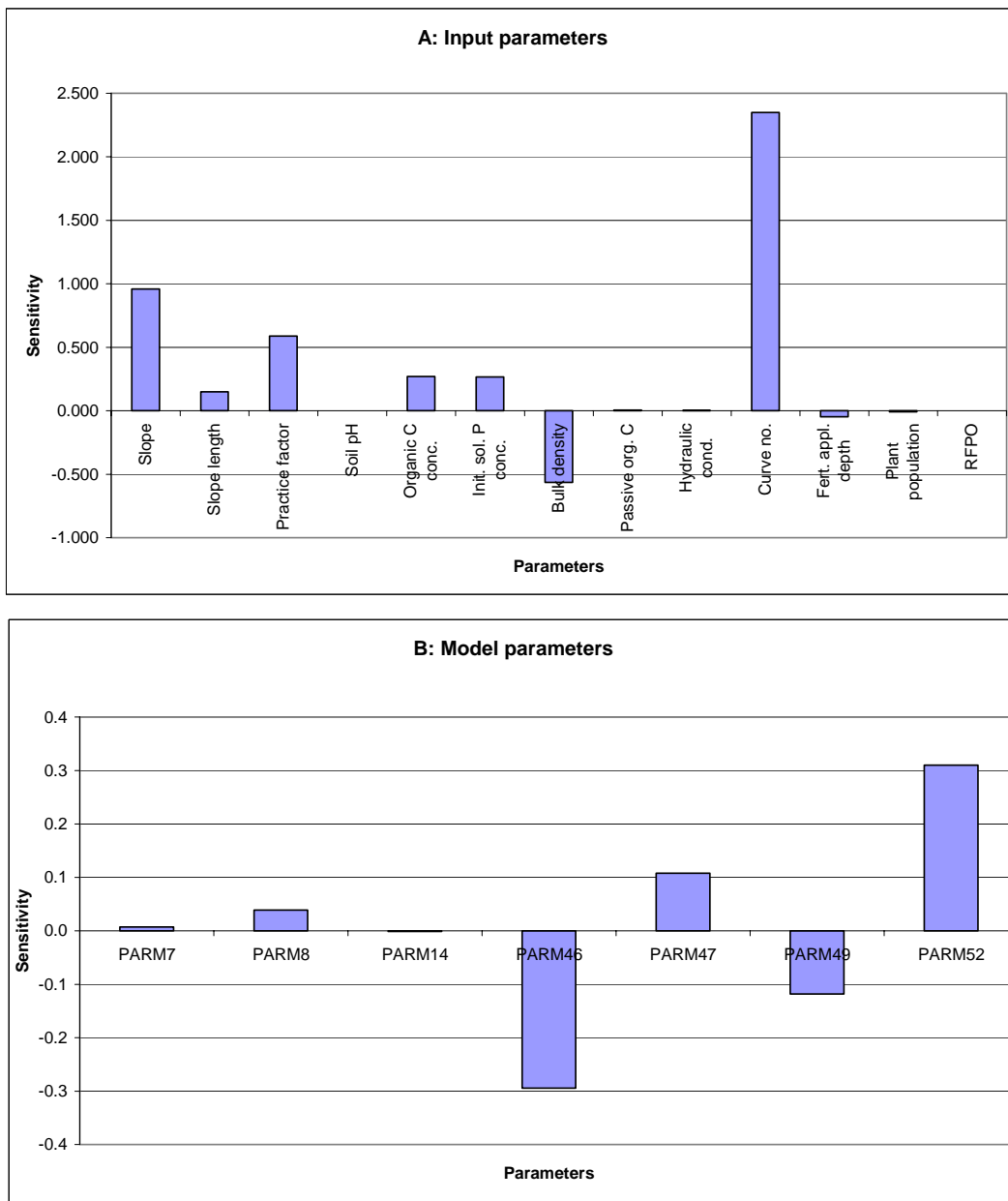


Figure A-7  
Sensitivity of Edge-of-Field Organic P Losses to NTT Input and Model Parameters

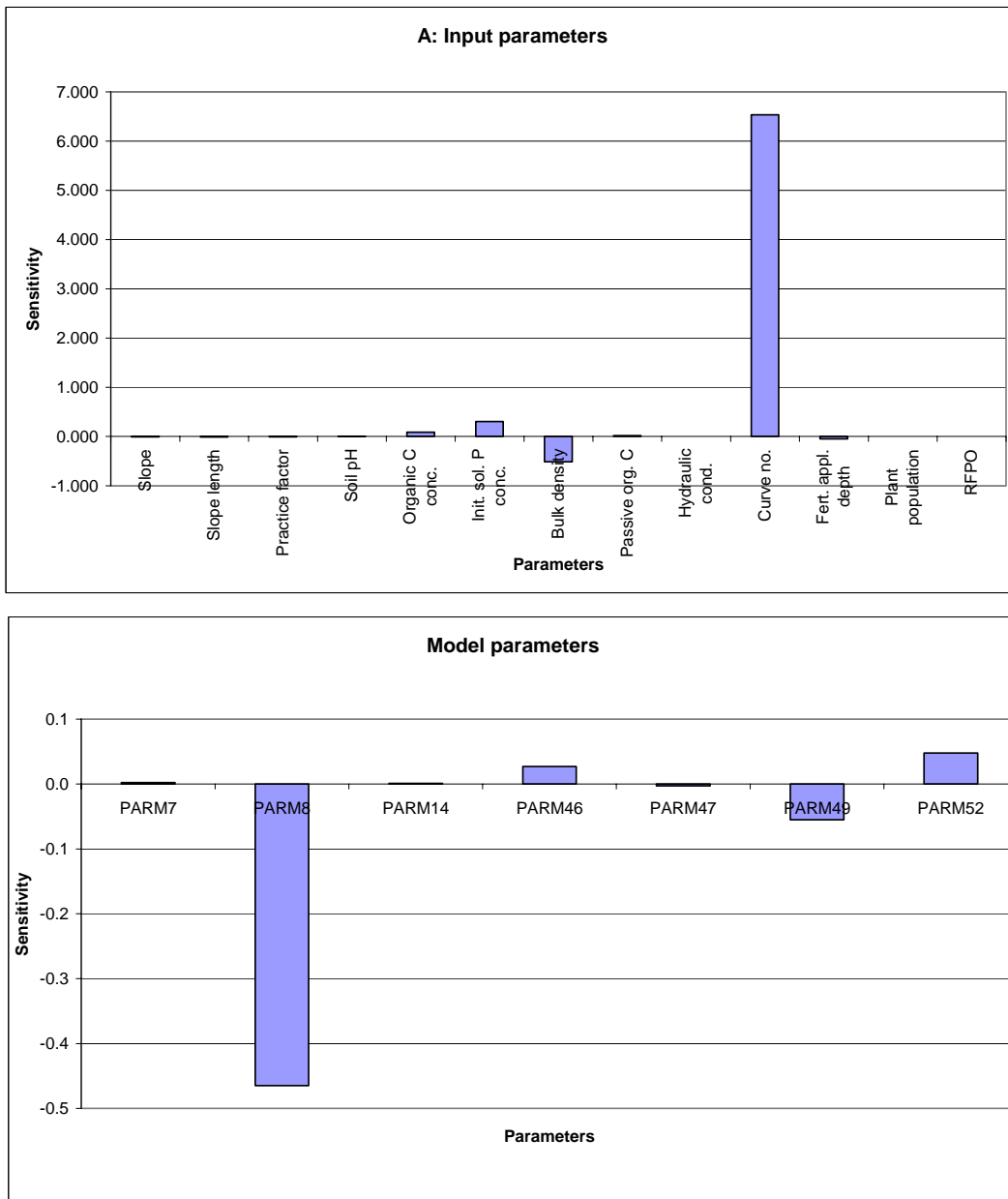


Figure A-8  
Sensitivity of Edge-of-Field Soluble P Losses to NTT Input and Model Parameters

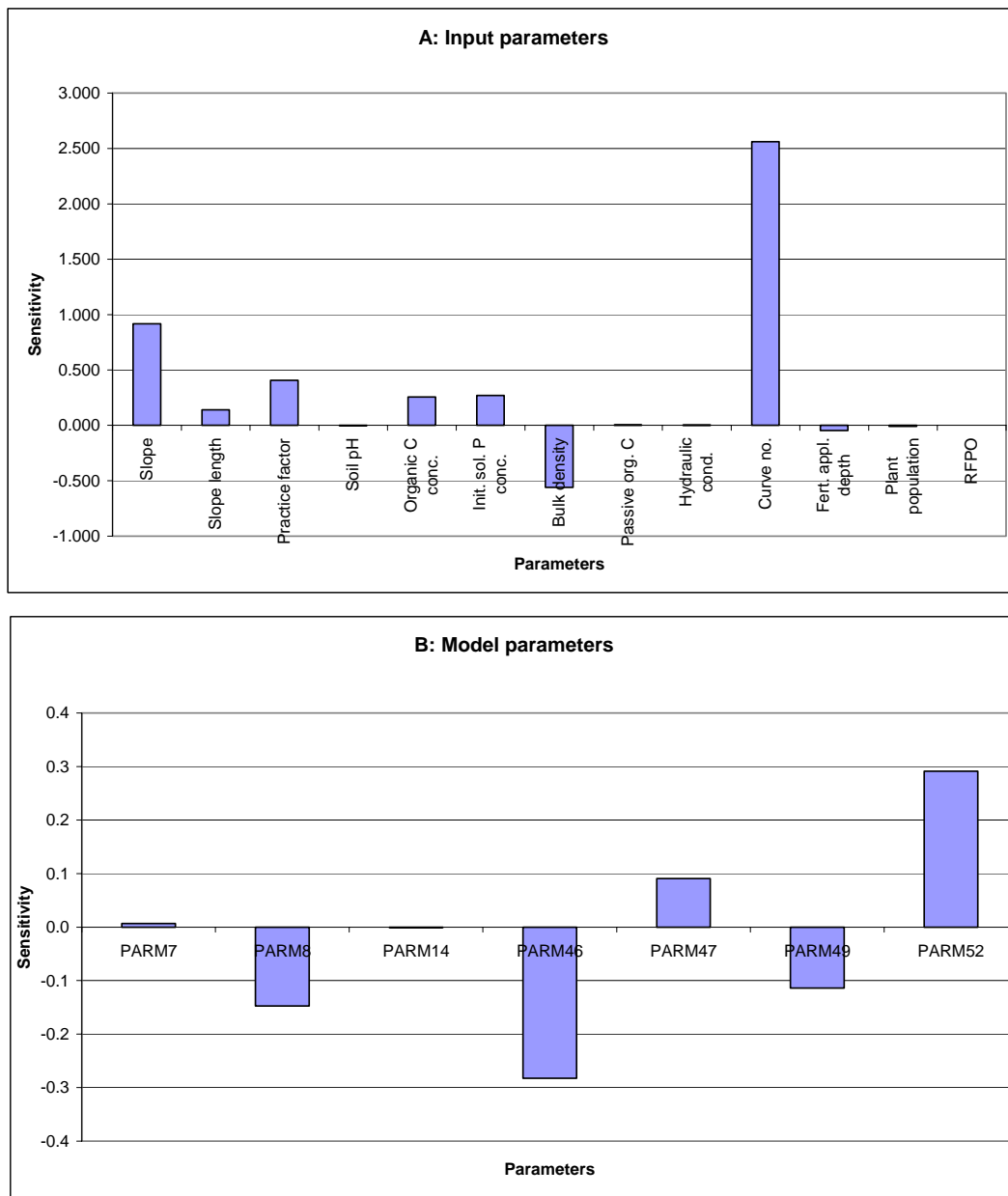


Figure A-9  
Sensitivity of Edge-of-Field Total P Losses to NTT Input and Model Parameters

## **Protocol for NTT Use in the UBWC**

### ***Protocol for NTT use***

NTT has been designed to be very user friendly. However, users need to keep in mind a number of factors that will affect the reliability of NTT results and the efficiency of its overall use. The following sections provide an overview of various considerations that impact the efficacy of the tool for water quality trading.

#### **NTT use in the UBWC**

In the current project, NTT was specifically tested using conditions applicable to the upper Big Walnut Creek (UBWC) watershed. Consequently, the tool will perform very well when used in this watershed without any significant calibration effort. Furthermore, the management data used for the UBWC application is largely similar to management practices used in other watersheds in central Ohio. Thus, the calibrated NTT tool should perform appreciably well in watersheds that are in the same general area as the UBWC.

NTT applications in the UBWC have been further facilitated by the production of a user guide that contains illustrative examples and steps featuring conditions in Delaware County, Ohio – the county that covers the greatest portion of the UBWC watershed. A user guide (Appendix G) was distributed to local technical service providers in an NTT workshop on conducted in August 2010. The majority of the attendees of the workshop found the user guide to be very helpful.

#### **NTT preparation for State of Ohio**

As part of the current project, a significant effort was made to ready NTT for use in any watershed in Ohio. This effort primarily included database development as well as some limited calibration to account for conditions in other Ohio watersheds.

### ***Database development for State of Ohio***

While weather data are readily available in NTT format for most counties in the U.S., soil data are not readily available in the NTT interface for many states. NTT uses the SSURGO (Soil Survey Geographic) database. SSURGO refers to digital soils data produced and distributed by the Natural Resources Conservation

Service (NRCS) - National Cartography and Geospatial Center (NCGC).

The Soil Data Mart web page (<http://soildatamart.nrcs.usda.gov>) provides a mechanism to access the SSURGO official data (spatial and tabular). It does not physically store the pre-packaged datasets, but instead generates them in real-time in an access database format as requests are made by a customer. The Soil Data Mart only provides access to the current version of data for a soil survey area. However, it is also possible to download a larger amount of soils (county, state, or the whole country) data covering more than one soil survey area using the Soil Data Access web page (<http://sdmdataaccess.nrcs.usda.gov>), which accesses the same SSURGO database. This web page allows users to enter a customized query in a SQL statement in which it is possible to include different soil survey areas and request different kind of information. The information requested is then packed in a text file and submitted to an e-mail address.

For NTT database development the SSURGO soil data was downloaded through the Soil Data Access site by state. In an effort to expedite NTT applications to other watersheds in Ohio the soils data for all counties in Ohio were downloaded using the Soil Data Mart. After the soil information had been downloaded a program was ran to update the NTT database for Ohio using the downloaded text file containing all of the soils information.

#### **Transferability to other Ohio watersheds/applications**

Use of NTT in other Ohio watersheds has been partly facilitated by the work performed in the UBWC watershed and development of the soils database for the entire state. Due to the similarities of management practices across the state it is expected that NTT will perform fairly well in Ohio without significant calibration efforts. Some limited calibration will be expected due to climate and topography differences. However, the diversity of management practices (i.e., tillage alternatives, nutrient management options, etc.) has already been captured during NTT testing for the UBWC. The key task that remains for effective use of NTT in other Ohio watersheds is that of verifying the input databases, particularly the management information for the specific watersheds or areas of

interest. Additional considerations in any NTT applications are given in the next section.

### **Protocol for successful NTT applications**

The accuracy of NTT estimates of nutrient and sediment losses associated with conservation practices depends on the input data. If the input data are grossly inaccurate the output will also be wrong, regardless of how well the tool has been calibrated and is suited to the area of interest. The following steps need to be taken to ensure successful use of NTT in a specific application.

#### Input data verification

Significant testing of NTT has revealed the input parameters that each of the output variables are most sensitive to and these results from sensitivity analysis simulations are reported in a previous section in this report. The results of sensitivity analyses indicate that output variables are particularly sensitive to the values of certain input parameters, including the following.

- Operation dates (especially when off by 30 days or more)
- Temperature
- Precipitation
- Runoff curve number

A complete list of input parameters that lead to significant output responses can be inferred from the sensitivity analysis section presented above. On the other hand, significant changes in the certain input parameters (e.g., soil pH) in the NTT sensitivity simulations did not result in any appreciable changes in the output variables of interest.

The sensitivity analyses results imply that users need to pay particular attention to the input parameters that invoke significant output response. While all input parameters are important for the proper use of NTT, those that are associated with large changes in output variables need to be given particular attention. For instance, when users are off by a few days when specifying the date of a field operation, the impacts on output variables is rather small. However, if they are off by about a month, significant changes in the values of output variables may result. Thus when estimating the impacts of conservation practices on nutrient and sediment losses, users should ensure that operation

dates are no more than a week or so off the actual times when those would occur.

If it proves impracticable to accurately ascertain the values of certain input parameters, it is recommended that a range be established within which the input parameter value is believed to lie with a reasonable degree of confidence. Multiple NTT simulations can then be performed with at least two or more values within that range to determine the most likely range of the effects of the conservation practice on output variables. If the output variables are very sensitive to the established range of the input variable, it may be necessary to halt further NTT simulations until the value of that input parameter has been established beyond reasonable doubt.

#### NTT testing

Prior to using NTT for conservation practice evaluations, it is recommended that the tool be tested for sample fields where data are available and that are similar to the field to be evaluated. Depending on the availability of data, NTT can be tested by comparing crop yields from a few selected fields that are similar to the area of interest but have some notable difference. For instance, if soil type information is available, as well as slope, weather and crop management information, and associated crop yield data, NTT simulations can be run for these fields. Crop yield estimations from NTT can be compared to the historical data to determine whether the tool is performing adequately under those conditions.

In addition to crop yield data, NTT can also be tested to determine how well it predicts values of the following key output variables using conditions pertaining to selected fields.

- Total edge-of-field nitrogen losses
- Total edge-of-field phosphorus losses
- Total edge-of-field sediment losses

NTT results should be tested using conditions pertaining to two or more fields for which data on edge-of-field nutrient and sediment losses are available. If the output from the tool provides a reasonable estimation of the comparative differences between nutrient and sediment losses of the selected fields, then it would likely provide reasonable estimates for conservation practice evaluations on the field of interest.



## Field selection

As thoroughly explained in the NTT user guide (Appendix G), the first step in using NTT to evaluate a conservation practice is to select the field or area of interest for which the practice would apply. Careful selection of the area of interest would have an important bearing on the reliability of the NTT results. Pertinent characteristics of fields such as slope, slope length, soil type, and even weather, all impact the effectiveness of a conservation practice. It is recommended that the area of interest be defined to closely mimic the conditions of the field before and after implementation of the conservation practice.

## Interpretation of NTT output

Output from NTT simulations are reported as annual averages over the last 12 years of a 24-year simulation period. Thus it is incorrect to represent NTT output as the results for any given year. When using NTT results in a credit calculation framework it must always be recognized that the NTT output represent an average over varying weather patterns from year to year. Currently NTT does not provide a statistical summary that captures the range of variability in the values of output variables over the last 12 years of simulation.

## Results and Discussion: Summary of Findings

Upon completion of model set up, NTT was used to simulate the five conservation practices listed above. In this process, the simulations were repeated for all the soil types in the soils database file for Delaware County, Ohio, over 60 soils in all. The resulting NTT outputs, averaged across all soil types, were compared to the respective baseline values. Percentage changes from corresponding baseline values are reported in Table A-12. As mentioned above, the nutrient management simulation reported here does not constitute a real conservation practice per se, but was simulated to highlight the implications of nutrient management options that entail somewhat higher or lower fertilizer application rates (Table A 12).

The results of the NTT simulations suggest significant performance of most of the conservation practices with regards to total N, total P and sediment loss reduction. In particular, no-till, cover cropping, and alfalfa planting in place of conventionally tilled row crop farming are projected to reduce nutrient and sediment losses. Also, as expected, a lower fertilizer application rate would reduce nutrient losses and a higher fertilizer rate would increase nutrient losses relative to current levels. The tile drain system usually results in higher levels of nutrients in the subsurface flow for most soils. This is mainly due to interception of infiltrated water and soluble nutrient (e.g., nitrate) in lower soil profiles by tile system.

Table A-12

Summary NTT Output for Alternative Scenarios: Percentage Changes from Baseline

	Organic N	Nitrate	Leached N	Tile Drain N	Volatilized N	Nitrous Oxide	Organic P	Soluble P	Leached P	Tile Drain P	Flow	Sediment
<b>NO-TILL</b>												
Corn	-68.8	-5.1	50.0	–	-18.4	-2.2	-61.9	-8.7	97.6	–	-34.7	-68.9
Soy	-50.2	-38.7	138.7	–	-3.4	-8.8	-56.8	16.2	244.1	–	-32.9	-72.6
Corn-soy	-67.9	-12.4	90.3	–	-15.6	-8.0	-70.0	-4.7	164.7	–	-35.6	-77.7
Corn-soy-wheat	-29.8	-29.1	21.6	–	-7.7	-11.3	-28.7	-7.8	45.3	–	-30.8	-36.6
Soy-wheat	-31.4	-35.7	18.9	–	-4.4	0.1	-31.7	1.0	40.7	–	-34.2	-48.9
<b>COVER CROP</b>												
Corn	-30.3	0.7	-33.5	–	24.5	-16.9	-30.0	-0.8	-16.5	–	-3.7	-37.4
Soy	-36.5	-19.0	-18.9	–	16.7	-26.9	-41.1	-6.0	-8.8	–	-4.1	-45.7
Corn-soy	-28.7	-7.7	-15.2	–	10.5	-12.3	-29.6	-3.1	-8.5	–	-1.6	-33.7
Corn-soy-wheat	-60.3	-20.6	-24.3	–	33.0	-14.5	-60.1	12.7	-21.4	–	3.4	-70.2
Soy-wheat	-79.6	-11.2	-3.7	–	53.7	-16.5	-86.7	6.5	33.6	–	-11.4	-93.4
<b>ALFALFA</b>												
Corn	-95.5	-83.4	-22.4	–	104.7	-85.4	-98.3	-57.5	-20.3	–	-48.9	-99.3
Soy	-89.7	-38.1	80.6	–	193.9	-21.7	-96.8	-50.1	89.3	–	-52.9	-98.4
Corn-soy	-93.6	-76.1	14.8	–	142.5	-74.3	-97.9	-55.8	7.6	–	-51.1	-99.0
Corn-soy-wheat	-94.8	-68.8	-50.8	–	137.2	-70.6	-98.3	-51.4	-63.7	–	-41.9	-99.2
Soy-wheat	-91.2	-12.4	-57.2	–	147.4	-43.7	-97.4	-45.6	-70.9	–	-38.4	-98.7
<b>TILE DRAINAGE (just one soil type - CaC2, Cardington silt loam, 6 to 12 percent slopes, eroded)</b>												
Corn	-0.7	-7.4	-100.0	–	1.1	1.0	0.0	-1.9	–	–	-1.6	-1.7
Soy	0.0	0.0	–	–	0.0	0.0	0.0	0.0	–	–	-0.2	-0.1
Corn-soy	-0.5	-1.8	–	–	1.5	0.7	-2.4	-2.1	–	–	-1.3	-1.2
Corn-soy-wheat	0.0	6.1	-100.0	–	0.0	1.6	0.0	-1.3	-100.0	–	-0.2	-0.4
Soy-wheat	1.0	5.0	-100.0	–	1.5	-1.1	0.0	0.0	-100.0	–	-0.2	0.2

### Role of NTT in Water Quality Trading Infrastructure

As explained previously, NTT does not calculate credits directly. The load reductions provided by NTT are the end result of the tool. These load reductions can then be used to calculate credits. In the present study, the input parameters used to simulate each conservation practice were also used to simulate the same practices in WARMF. The WARMF model plays a key role in estimating some of the location and other adjustment

factors that need to be applied to the NTT output in a WQT program in order to arrive at the credit estimates. Thus, no physical linkage between NTT and WARMF was necessary in this application. However, the output produced from the two models is consistent since a similar set of input parameters were used to simulate all the conservation practices. More detailed explanation of the credit calculation process is given in another section of this report.

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## Attachment A: Crop Management Information used in Simulations

### Conventional Tillage

Table A-13

Field operations for conventional tillage systems in the UBWC watershed

				<b>CONVENTIONAL TILLAGE SYSTEMS</b>		
						Fertilizer rate
Corn	Corn	5	1	1	Disk, tandem secondary op.	
	Corn	5	4	1	Cultivator, field 6-12 in sweeps	
	Corn	5	3	1	Elemental N	150
	Corn	5	3	1	Elemental P	60
	Corn	5	5	1	planter, double disk opnr	
	Corn	10	20	1	Harvest, killing crop 50pct standing stubble	
	Corn	10	21	1	Kill crop*	
	Corn	11	1	1	Chisel, st. pt.	
Soybeans	Soybeans	5	5	1	disk, tandem light finishing	
	Soybeans	5	8	1	Elemental N	15
	Soybeans	5	8	1	Elemental P	40
	Soybeans	5	9	1	Cultivator, field 6-12 in sweeps	
	Soybeans	5	10	1	Drill or airseeder, double disk	
	Soybeans	10	5	1	Harvest, killing crop 20pct standing stubble	
	Soybeans	10	6	1	Kill crop*	
	Soybeans	10	22	1	Chisel, st. pt.	
Corn-soybeans	Corn	5	1	1	Disk, tandem light finishing	
	Corn	5	3	1	Elemental N	150
	Corn	5	3	1	Elemental P	60
	Corn	5	4	1	Cultivator, field 6-12 in sweeps	
	Corn	5	5	1	planter, double disk opnr	
	Corn	10	20	1	Harvest, killing crop 50pct standing stubble	
	Corn	10	21	1	Kill crop*	
	Corn	11	1	1	Chisel, st. pt.	
	Soybeans	5	1	2	Disk, tandem light finishing	
	Soybeans	5	8	2	Elemental N	15
	Soybeans	5	8	2	Elemental P	40
	Soybeans	5	10	2	Cultivator, field 6-12 in sweeps	
	Soybeans	5	10	2	Drill or airseeder, double disk	
	Soybeans	10	5	2	Harvest, killing crop 50pct standing stubble	
	Soybeans	10	6	2	Kill crop*	
	Soybeans	10	22	2	Chisel, st. pt.	

Table A-13 (continued)

Field operations for conventional tillage systems in the UBWC watershed

**CONVENTIONAL TILLAGE SYSTEMS**

Corn-soybeans-winter wheat

Corn	5	1	1	Disk, tandem secondary op.	
Corn	5	3	1	Elemental N	150
Corn	5	3	1	Elemental P	60
Corn	5	4	1	Cultivator, field 6-12 in sweeps	
Corn	5	5	1	planter, double disk opnr	
Corn	10	20	1	Harvest, killing crop 50pct standing stubble	
Corn	10	21	1	Kill crop*	
Soybeans	11	1	1	Chisel, st. pt.	
Soybeans	5	5	2	disk, tandem light finishing	
Soybeans	5	8	2	Elemental N	15
Soybeans	5	8	2	Elemental P	40
Soybeans	5	9	2	Cultivator, field 6-12 in sweeps	
Soybeans	5	10	2	planter, double disk opnr	
Soybeans	10	5	2	Harvest, killing crop 20pct standing stubble	
Soybeans	10	6	2	Kill crop*	
Winter wheat	10	12	2	disk, tandem light finishing	
Winter wheat	10	13	2	Elemental N	25
Winter wheat	10	13	2	Elemental P	50
Winter wheat	10	13	2	Cultivator, field 6-12 in sweeps	
Winter wheat	10	15	2	Drill or airseeder, double disk	
Winter wheat	4	25	3	Elemental N	60
Winter wheat	7	1	3	Harvest, killing crop 50pct standing stubble	
Winter wheat	7	2	3	Kill crop*	
Corn	9	15	3	Chisel, st. pt.	

Soybeans-winter wheat

Soybeans	5	5	1	disk, tandem light finishing	
Soybeans	5	8	1	Elemental N	15
Soybeans	5	8	1	Elemental P	40
Soybeans	5	9	1	Cultivator, field 6-12 in sweeps	
Soybeans	5	10	1	planter, double disk opnr	
Soybeans	10	5	1	Harvest, killing crop 20pct standing stubble	
Soybeans	10	6	1	Kill crop*	
Winter wheat	10	12	1	disk, tandem light finishing	
Winter wheat	10	13	1	Elemental N	25
Winter wheat	10	13	1	Elemental P	50
Winter wheat	10	13	1	Cultivator, field 6-12 in sweeps	
Winter wheat	10	15	1	Drill or airseeder, double disk	
Winter wheat	4	25	2	Elemental N	60
Winter wheat	7	1	2	Harvest, killing crop 50pct standing stubble	
Winter wheat	7	2	2	Kill crop*	
Soybeans	9	15	2	Chisel, st. pt.	

\*Model command that stops all future growth of this specific crop unless planted again.

## No-Till

Table A-14

Field operations for conventional tillage systems in the UBWC watershed

<b>NO-TILL SYSTEMS</b>					Fertilizer rate
corn	5	3	1	Nitrogen fertilizer application	150
corn	5	3	1	Phosphorus fertilizer application	60
corn	5	5	1	planter, double disk opnr	
corn	10	20	1	Harvest, killing crop 50pct standing stubble	
corn	10	21	1	Kill crop*	
Soybeans					
soybeans	5	8	1	Nitrogen fertilizer application	15
soybeans	5	8	1	Phosphorus fertilizer application	40
soybeans	5	10	1	Drill or airseeder, double disk	
soybeans	10	5	1	Harvest, killing crop 20pct standing stubble	
soybeans	10	6	1	Kill crop*	
Corn-soybeans					
corn	5	3	1	Nitrogen fertilizer application	150
corn	5	3	1	Phosphorus fertilizer application	60
corn	5	5	1	planter, double disk opnr	
corn	10	20	1	Harvest, killing crop 50pct standing stubble	
corn	10	21	1	Kill crop*	
soybeans	5	8	2	Nitrogen fertilizer application	15
soybeans	5	8	2	Phosphorus fertilizer application	40
soybeans	5	10	2	Drill or airseeder, double disk	
soybeans	10	5	2	Harvest, killing crop 50pct standing stubble	
soybeans	10	6	2	Kill crop*	
Corn-soybeans-winter wheat					
corn	5	3	1	Nitrogen fertilizer application	150
corn	5	3	1	Phosphorus fertilizer application	60
corn	5	5	1	planter, double disk opnr	
corn	10	20	1	Harvest, killing crop 50pct standing stubble	
corn	10	21	1	Kill crop*	
soybeans	5	8	2	Nitrogen fertilizer application	15
soybeans	5	8	2	Phosphorus fertilizer application	40
soybeans	5	10	2	Drill or airseeder, double disk	
soybeans	10	5	2	Harvest, killing crop 20pct standing stubble	
soybeans	10	6	2	Kill crop*	
winter wheat	10	13	2	Nitrogen fertilizer application	25
winter wheat	10	13	2	Phosphorus fertilizer application	50
winter wheat	10	15	2	Drill or airseeder, double disk	
winter wheat	4	25	3	Nitrogen fertilizer application	60
winter wheat	7	1	3	Harvest, killing crop 50pct standing stubble	
winter wheat	7	2	3	Kill crop*	

Table A-14 (continued)

Field operations for conventional tillage systems in the UBWC watershed

**NO-TILL SYSTEMS**

Soybeans-winter wheat					
soybeans	5	8	1	Nitrogen fertilizer application	15
soybeans	5	8	1	Phosphorus fertilizer application	40
soybeans	5	10	1	Drill or airseeder, double disk	
soybeans	10	5	1	Harvest, killing crop 20pct standing stubble	
soybeans	10	6	1	Kill crop*	
winter wheat	10	13	1	Nitrogen fertilizer application	25
winter wheat	10	13	1	Phosphorus fertilizer application	50
winter wheat	10	15	1	Drill or airseeder, double disk	
winter wheat	4	25	2	Nitrogen fertilizer application	60
winter wheat	7	1	2	Harvest, killing crop 50pct standing stubble	
winter wheat	7	2	2	Kill crop*	

\*Model command that stops all future growth of this specific crop unless planted again.

**Cover Crop**

Table A-15

Field operations for cropping systems that include cover crops in the UBWC

**COVER CROP SYSTEMS**

Corn					Fertilizer rate
Rye	4	20	1	Kill cover crop*	
Corn	5	1	1	Disk, tandem secondary op.	
Corn	5	4	1	Cultivator, field 6-12 in sweeps	
Corn	5	3	1	Elemental N	150
Corn	5	3	1	Elemental P	60
Corn	5	5	1	planter, double disk opnr	
Corn	10	20	1	Harvest, killing crop 50pct standing stubble	
Corn	10	21	1	Kill crop*	
Corn	11	1	1	Chisel, st. pt.	
Rye	11	2	1	Plant cover crop	
Soybeans					
Rye	4	20	1	Kill cover crop*	
Soybeans	5	5	1	disk, tandem light finishing	
Soybeans	5	8	1	Elemental N	15
Soybeans	5	8	1	Elemental P	40
Soybeans	5	9	1	Cultivator, field 6-12 in sweeps	
Soybeans	5	10	1	Drill or airseeder, double disk	
Soybeans	10	5	1	Harvest, killing crop 20pct standing stubble	
Soybeans	10	6	1	Kill crop*	
Soybeans	10	22	1	Chisel, st. pt.	
Rye	10	25	1	Plant cover crop	

Table A-15 (continued)

Field operations for cropping systems that include cover crops in the UBWC

**COVER CROP SYSTEMS**

Corn-soybeans

Rye	4	20	1	Kill cover crop*	
Corn	5	1	1	Disk, tandem light finishing	
Corn	5	3	1	Elemental N	150
Corn	5	3	1	Elemental P	60
Corn	5	4	1	Cultivator, field 6-12 in sweeps	
Corn	5	5	1	planter, double disk opnr	
Corn	10	20	1	Harvest, killing crop 50pct standing stubble	
Corn	10	21	1	Kill crop*	
Corn	11	1	1	Chisel, st. pt.	
Soybeans	5	1	2	Disk, tandem light finishing	
Soybeans	5	8	2	Elemental N	15
Soybeans	5	8	2	Elemental P	40
Soybeans	5	10	2	Cultivator, field 6-12 in sweeps	
Soybeans	5	10	2	Drill or airseeder, double disk	
Soybeans	10	5	2	Harvest, killing crop 50pct standing stubble	
Soybeans	10	6	2	Kill crop*	
Soybeans	10	22	2	Chisel, st. pt.	
Rye	10	25	1	Plant cover crop	

Corn-soybeans-winter wheat

Sweet clover	4	20	1	Kill cover crop*	
Corn	5	1	1	Disk, tandem secondary op.	
Corn	5	3	1	Elemental N	150
Corn	5	3	1	Elemental P	60
Corn	5	4	1	Cultivator, field 6-12 in sweeps	
Corn	5	5	1	planter, double disk opnr	
Corn	10	20	1	Harvest, killing crop 50pct standing stubble	
Corn	10	21	1	Kill crop*	
Soybeans	11	1	1	Chisel, st. pt.	
Soybeans	5	5	2	disk, tandem light finishing	
Soybeans	5	8	2	Elemental N	15
Soybeans	5	8	2	Elemental P	40
Soybeans	5	9	2	Cultivator, field 6-12 in sweeps	
Soybeans	5	10	2	planter, double disk opnr	
Soybeans	10	5	2	Harvest, killing crop 20pct standing stubble	
Soybeans	10	6	2	Kill crop*	
Winter wheat	10	12	2	disk, tandem light finishing	
Winter wheat	10	13	2	Elemental N	25
Winter wheat	10	13	2	Elemental P	50
Winter wheat	10	13	2	Cultivator, field 6-12 in sweeps	
Winter wheat	10	15	2	Drill or airseeder, double disk	
Winter wheat	4	25	3	Elemental N	60
Winter wheat	7	1	3	Harvest, killing crop 50pct standing stubble	
Winter wheat	7	2	3	Kill crop*	
Corn	9	15	3	Chisel, st. pt.	
Sweet clover	10	1	3	Plant cover crop	



Table A-15 (continued)

Field operations for cropping systems that include cover crops in the UBWC

**COVER CROP SYSTEMS**

Soybeans-winter wheat					
Sweet clover	4	20	1	Kill cover crop*	
Soybeans	5	5	1	disk, tandem light finishing	
Soybeans	5	8	1	Elemental N	15
Soybeans	5	8	1	Elemental P	40
Soybeans	5	9	1	Cultivator, field 6-12 in sweeps	
Soybeans	5	10	1	planter, double disk opnr	
Soybeans	10	5	1	Harvest, killing crop 20pct standing stubble	
Soybeans	10	6	1	Kill crop*	
Winter wheat	10	12	1	disk, tandem light finishing	
Winter wheat	10	13	1	Elemental N	25
Winter wheat	10	13	1	Elemental P	50
Winter wheat	10	13	1	Cultivator, field 6-12 in sweeps	
Winter wheat	10	15	1	Drill or airseeder, double disk	
Winter wheat	4	25	2	Elemental N	60
Winter wheat	7	1	2	Harvest, killing crop 50pct standing stubble	
Winter wheat	7	2	2	Kill crop*	
Soybeans	9	15	2	Chisel, st. pt.	
Sweet clover	10	1	2	Plant cover crop	

\*Model command that stops all future growth of this specific crop unless planted again.

**Hayfield Establishment**

Table A-16

Field operations for alfalfa cropping system in UBWC

					Fertilizer rate
Alfalfa	8	15	1	Drill or airseeder, double disk	
Alfalfa	6	1	2	Harvest, hay, legume	
Alfalfa	6	5	2	Elemental P	15
Alfalfa	7	15	2	Harvest, hay, legume	
Alfalfa	7	19	2	Elemental P	15
Alfalfa	9	1	2	Harvest, hay, legume	
Alfalfa	9	5	2	Elemental P	15
Alfalfa	6	1	3	Harvest, hay, legume	
Alfalfa	6	5	3	Elemental P	15
Alfalfa	7	15	3	Harvest, hay, legume	
Alfalfa	7	19	3	Elemental P	15
Alfalfa	9	1	3	Harvest, hay, legume	
Alfalfa	9	5	3	Elemental P	15

## Attachment B: Soil Types used in Simulations

Table A-17

Soil types included in simulations

#	MapUnit	MapSymbol	Group	Component
1	172035	AmD2	C	Amanda
2	172036	AmE	C	Amanda
3	172037	AmF	C	Amanda
4	172038	BeA	C/D	Bennington
5	172039	BeB	C/D	Bennington
6	172045	CeC2	C	Centerburg
7	172046	CnA	C/D	Condit
8	172048	GaC2	B	Gallman
9	172049	GbA	B	Gallman
10	172050	GbB	B	Gallman
11	172051	GcB	B	Gallman
12	172052	GwB	D	Glynwood
13	172054	GzC3	D	Glynwood
14	172055	HeF	C	Heverlo
15	172056	HyA	C/D	Hyatts
16	172057	HyB	C/D	Hyatts
17	172058	JmA	B/D	Jimtown
18	172059	LbF	D	Brecksville
19	172059	LbF	D	Latham
20	172060	LeE	A	Leoni
21	172061	LoA	C	Lobdell
22	172062	LsA	B/D	Sloan
23	172062	LsA	C	Lobdell
24	172063	LvB	C	Loudonville
25	172064	LyD2	C	Lybrand
26	172065	LyE2	C	Lybrand
27	172066	LzD3	C	Lybrand
28	172067	MaB	B	Martinsville
29	172068	MbB	B	Martinsville
30	172069	McD2	B	Mentor
31	172070	MfA	B/D	Millgrove
32	172071	MgA	B/D	Millgrove
33	172072	MhA	B/D	Millgrove
34	172073	MoB	C	Milton
35	172074	MoC2	C	Milton
36	172075	MpD2	C	Lybrand
37	172075	MpD2	C	Milton
38	172076	PaA	B	Pacer
39	172077	PwA	C/D	Pewamo
40	172080	RdC2	D	Rarden
41	172081	RdF2	D	Rarden
42	172082	RoA	B	Rossburg

# Appendix B: NTT Workshop Proceedings

**Proceedings from:  
The Nutrient Trading Tool Testing Session with  
Ohio Technical Service Providers and Certified  
Crop Advisors**

Held at:  
Ohio Farm Bureau Federation, Columbus, Ohio  
August 26, 2010

On August 26, 2010, the project team participated in an NRCS-led testing session within the key Ohio agricultural Technical Service Providers (TSPs), Certified Crop Advisors (CCAs) and Soil and Water Conservation District (SWCD) staff at the Farm Bureau offices in Columbus, Ohio. Eighteen agricultural professionals serving in these professional roles attended the NTT training session. Of these, 15 were familiar with market-based approaches to conservation and three were already familiar with NTT and had tested it prior to the workshop using the short guide provided prior to the workshop. One of the participants had experience with the Great Miami Conservancy District based trading tools but no one expressed experience with any other trading tools.

Mark Kieser, Kieser& Associates, LLC (K&A) provided a quick overview of the Ohio River Basin Water Quality Trading Market project and Harbans Lal, USDA NRCS, provided an overview of market-based conservation and the role that NRCS is playing in supporting the development of these markets. The ensuing questions indicated that the participants had a strong interest in the emerging markets in the ORB:

**Q:** Can producers sell credits from practices that have been installed with federal cost-share dollars? We can see situations where it may be more advantageous for farmers to refuse federal cost-share dollars for a conservation practices in order to be able to sell resulting credits into a WQT market.

**Discussion:** Even though USDA- NRCS policy indicates that the landowner retains ownership of credits created as a result of cost-share programs, it is less clear and consistent across states and/or watersheds how those credits will be valued, or the degree to which

a landowner will receive full value of those credits. The underlying requirement of a practice generating an environmental ‘advancement,’ value added or additional value often becomes the issue. This remains open for debate and discussion and underscores the value and necessity for early involvement of all stakeholders in establishing trading rules and guidelines.

**Q:** Can the TSPs play a role as middlemen?

**Discussion:** TSPs could act as aggregators, identifying opportunities for trading credits, collecting them, verifying them, bundling them and selling them or as brokers, collecting fees based upon credit transactions. The TSPs are in a unique position to fill both of these roles since they are already working with farmers and are on the front lines, helping farmers identify likely credits. However, farmers may see this as a conflict of interest for the TSP to perform these dual roles. Although certified crop advisors are serving as aggregators in Pennsylvania, most programs seem to be using third party middlemen like clearing houses, brokers or SWCDs.

**Q:** One TSP in the Lake Erie watershed asked about whether his clients might have an opportunity to sell credits since they are outside of the ORB watershed. In this case, Ohio has state WQT rules and local WQT programs are starting to emerge, including one that may serve parts of the Lake Erie watershed.

## **NTT Discussion**

**Questions:** *(Note: these questions may indicate a need to provide additional information to NTT users if not already available in guidebook or on line):*

**Q:** Where do the yield goals come from? [Answer given: The APEX model generates yield impacts based on what you indicate you are doing in the field.]

**Q:** This model is based on estimates but, as a consultant, I am focusing on a very small area, relying on my own soil tests and yield data and working from reality. I don’t see how this tool can improve on that. If the numbers are not close to what we’re actually seeing

in the field and we don't have confidence in the numbers, then a producer will not participate. I need to have to have sufficient confidence in the model to the degree that it mirrors actual client production and nutrient input information.

Q: Are the percent reduction numbers that NTT provides edge-of-field estimates or are they estimates measured from the actual body of water? [Answer given: they are edge-of-field estimates].

Q: Does NTT assume sheet flow over filter strips or can it handle concentrated or channelized flows? [Answer given: NTT does have a function that can be changed and the modelers recognize that filter strips will experience different flow rates].

Q: Since the Revised Universal Soil Loss Equation (RUSLE) is already in the model, can we transfer the data we have already entered into RUSLE? [Answer given: Yes but you will not be able to use the yield data].

Q: How many weather stations provide information to NTT? [Answer given: NTT now incorporates weather information from one weather station per county].

Q: Do you have the ability to model livestock as well as cropping systems? If not, you should (example: crops grown for silage versus cover crops versus silage cover crops with manure/ residue, etc.). Also, livestock operations are more concentrated now and that needs to be taken into account. In general, manure application is more heavily regulated on the east coast so we see collected manure in the East versus uncollected manure left in the fields by livestock in Ohio.

As the suggestions became more complex and technical, one participant remarked "we need to shoot the slow running rabbits first!"

Q: What are our tillage choices? [Answer given: the model accommodates all types of tillage choices using drop down menus.]

Q: Although we're talking about edge-of-field nutrient reductions, we absolutely have to take drainage tiles into consideration. [Answer given: Quite right – tiles are "beachfront property" (i.e. they can deliver nutrients almost directly into the body of water with minimal processing)].

Q: Soil tests may be adequate for P and if we enter our results, it may take P out of the equation but would the model then predict a yield loss even though there is enough residual P in the soil to support plant growth? [Answer given: We don't know. We haven't factored this in yet. It should]. The participant went on to emphasize that NTT would create real problems if it predicts yield losses when we're trying so hard to get clients not to apply P because they have surplus P in their soils.

Q: Can we input the density of tiles? You would want to make this as simple as possible, perhaps adding a coefficient for systematic tiles and lateral tiles. Maybe we could use the percentage of field tiled or the percent of efficiency? Tile concentration has a major impact on water quality – the model has to handle more than just "tile" or "no tile." And tiles can go either way – sometimes they can help raise crop yields and plants remove more N and P and other times they can increase nutrient run-off.

Q: Some of the participants had just attended a Ohio State University nutrient management plan development workshop that provided a comprehensive overview of NMP/CNMP development using the suite of free software tools that have been developed to help streamline the NMP/CNMP writing process (e.g. the University of Missouri "Clipper" website; MapWindow GIS with MMP Tools; Manure Management Planner (MMP) and RUSLE2)(more information available from the MMP website: <http://www.agry.purdue.edu/mmp>). They noted the similarity between NTT and the Missouri Clipper program and whether the programs were sharing information. [Answer given: The researchers working on the NMP/CNMP development are also part of the USDA NRCS water quality/quantity team that is working on NTT and they are trying to bring the tools together. They are aware that too much redundancy could generate confusion.]

Q: Doesn't the model need to strive towards certainty and precision, especially if we are going to be selling credits as a commodity? [Answer given: EPA assesses uncertainty and incorporates it into the trading ratio].

## Suggestions on Desired Features

Ability to input independent data: What if we have clients with ten years of documented yield data that indicate yields above those generated by NTT? Can we use that more accurate data? [Answer given: If you have a real scenario, you should be able to use it but the model can't do that right now. It may be able to give you standard deviations. In the future, NTT may be able to project optimal yields].

Further discussions indicated that the participants felt the NTT-generated yields – at least in some cases – were “not even close.” The participants are seeing much greater yields related to newer varieties, hybrids and better genetics. They emphasized the need to be able to input real world numbers. They estimated that corn yields have increased by 3 bushels/acre every year over the last 50 years. One participant with actual documented yields felt it would be useful to be able to overlay his data on the soils maps. Another participant pointed out that actual yields may not be necessary since the focus is on relative yields (e.g. differences between yields with conventional tillage and conservation tillage). Others felt that plant growth (in turn linked to crop yields) may influence nitrogen and phosphorus uptake by the plants and how much N and P is ultimately lost from the farm field.

Participants also emphasized the need for NTT to take into account how much P and N are already in the system and how nutrients are being applied (e.g. broadcast, split application, etc). NTT does offer the option of entering customized management schemes and the option of entering the results of independent soil tests may be added to NTT at a later date.

Other data to consider adding to NTT: NTT offers information about attached P, ortho P, and where P ends up (plants, leached, nitrous oxide, sediment, tile system, etc.). NTT may add the ability to incorporate soil test results at a later date.

- Some participants felt that soil tests should be required. The soils they deal with are already very high in P and this existing P should be taken into account so surplus P is not erroneously applied.
- Information about how much water flow goes through tile lines and the ability to enter the number of surface tile intakes was considered useful

but participants recognized that this would call for very technical input.

### **Other BMPs to add to NTT:**

- Automatic SWAT control for fertilizer application (prevents operator from overlapping applications)
- Drainage water table management (weirs) [NTT does not have access to a water table model at this time].
- Wetlands [NTT can simulate wetlands]. It was pointed out that wetland simulations need to be vetted by local experts since there are 10 different equations in use across the U.S. that take into account area, retention time, etc.
- Information about what is going on in the stream (from a participant who works in an urbanized area). There are a lot of waterways with elevated levels of P in the spring from non-point sources and elevated levels of P in August from point sources. With WQT trading, differences in flow regimes will be important. We will need to have load reductions during the right time spans. [The model can project a monthly output from the farm field. WQT programs may need to have reductions with a six-month time span for smaller watersheds, perhaps an annual time span for a much larger watershed like the Mississippi River].
- Digital Elevation Models: Can we introduce a DEM behind the scenes? This may help us estimate flow and discharge rates. Other models seem to be going in that direction. [Answer given: The complexity of the program may introduce additional errors because the user doesn't have enough information and it may be hard to change all of the parameters in the correct order. We must balance accuracy with practicality. Also, we have a limited number of people who can implement this program and oversee it and we want to keep it simple enough to use.]

## Comments on Test Scenarios

Cover crops: WQT markets will need documented best management practices (BMPs) that can generate credits to start with so we asked the participants which cover crops they are using. They said they are still experimenting with different cover crops and are trying to get the management practices right. As a result, in the test scenario, rye was chosen as the cover crop and the result was a 55 percent reduction in nutrient runoff.

Credit calculation: Once the results were projected, participants asked how the results could be used to calculate credits. This led to an explanation of program-related trading ratios that take into account the location of the farm operation, distance from body of water and discount factors for the type of P (if it differs from the form of P being discharged by the point source). The Pennsylvania trading program provides examples of trading ratios with two discount steps incorporated into the ultimate credit value. Another tool, possibly linked to NTT, would automatically apply this information to the NTT results and tally up the number of credits generated.

Soils data: Some felt the ability to draw shape files and “clip out” for soils data worked just fine although they were concerned about the need for accurate juxtaposition of parcel data. They also appreciated having a drop-down menu. Others felt it was more important to be able to input site-specific soils information from their clients’ operations. One participant remarked that he would not use NTT if he had to individually create/draw out each shape file and he said it would make much more sense to be able to input his own shape files. It takes too much time to create shape files for a large number of parcels.

Yield data: In comparing conventional tillage to a no-till scenario, the yield drops seem too high. Something in the model may need adjusting. However, everyone seemed comfortable with presenting the data in terms of bushels/acre.

## Who Would Use NTT?

The TSPs agreed that farmers would probably want as much freedom as possible to operate within the NTT program. They also felt it would be difficult for farmers to question percentage reductions in nutrient runoff since they do not normally deal with that kind of information. Many of their clients are not computer-savvy and others do not have the time nor the interest in collecting and crunching field data and making complex decisions. One participant pointed out that the WQT credit buyers would probably want someone at a TSP level who was highly qualified to help determine those credits since real money is exchanged and real liability is attached to those credits.

On whether or not the use of NTT was intuitive, the participants agreed it was easier to use than RUSLE2 – that it was not necessarily intuitive and they definitely needed guidance on how to load the soils data but that the rest was “okay.” [NTT intends to simplify the process with soils and perhaps offer some canned management scenarios but users will still be able to put in custom management. Ultimately, soils and weather will be loaded automatically].

Potential benefits of NTT:

- We may be able to use this tool to do cost-benefit analyses.
- This will make it easier to quantify environmental benefits for our clients.
- This is a step up from what we have now. It ties in N and P losses with conservation systems – RUSLE2 can’t do that!
- This may allow us to zero in on the dissolved P component that is becoming increasingly important. It may help us show how much leakage of P is occurring and how much reduction in P we can achieve.

## Supplemental Information

### **Information on the Use of Crediting Tools from ORB Producers**

American Farmland Trust has hosted three listening sessions with producers so far in the Ohio River Basin. One of the questions we ask producers is what kind of crediting tool or tools would make their participation in a water quality trading market more likely. They strongly support the development of a web-based crediting tool. They have offered the following caveats:

- Web-based tools are a good idea, particularly for young farmers (e.g. Iowa State calculator for ACRE). The NutrientTrading Tool can help producers download soils, crops and farming practices and determine the number of credits generated based on their farm and how they manage it. However, you need to make sure that farmers have access to rural broadband to make rapid download possible.
- Any crediting tool should also provide information about yield impacts from installing conservation practices that can generate credits. The producers in the listening sessions so far have informed us that reducing cost per acre for producers is one interest,

but most farmers want to PRODUCE more. If practices reduce yield, then the perception may be that this is the same as a reduced profit. In some situations, yield becomes a bigger factor than net, especially if landowner/landlord compensation is based upon yield.

- Although credits in the Miami Conservancy WQT program are determined by running the Revised Universal Soil Loss Equation (RUSLE) for each farm field, RUSLE is a cumbersome model for a credit equation. An average credit number per practice would be better. However, using an average may not be robust enough. USDA NRCS's nutrient trading tool (NTT) provides a standard equation and easier delivery path and can be used by each farmer to calculate credits obtainable from implementing practices on his or her fields.
- If a WQT program wants to encourage the use of a web-based tool, it could offer greater incentives to those who do their work online and register online (e.g. Turbo-Tax). Producers might be able to use SWCDs or the library if they lack a computer although most farmers need to do that kind of work at night.





# Appendix C: NTT Online Survey Results

Ten of the 18 participants (55 percent) attending the NTT training/feedback session on August 26, 2010 completed an on-line survey. The following tables

provide the eleven questions and a summary of the agricultural professional's responses:

Table C-1

Who are the likely users of NTT; please consider the data input requirements when answering this question (check all that apply):


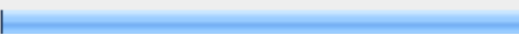
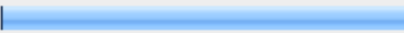

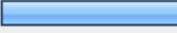
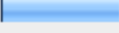
	Response Percent	Response Count
Farmers 	10.0%	1
Technical Service Providers 	90.0%	9
Crop Advisors 	70.0%	7
NRCS Staff 	80.0%	8
Researchers 	30.0%	3
Other (please specify) 	20.0%	2
<i>answered question</i>		10
<i>skipped question</i>		0

Table C-2

Based on the current services that you provide, are there situations that quantifying sediment and nutrient loading for producers is necessary?

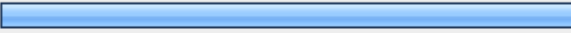
	Response Percent	Response Count
Yes 	100.0%	10
No	0.0%	0
<i>answered question</i>		10
<i>skipped question</i>		0

Table C-3

In the future (assuming a strong water quality trading market exists) would you participate in a trading market by providing evaluation services for your clients?

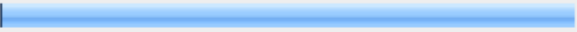
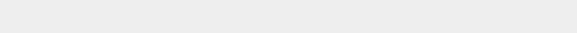
	Response Percent	Response Count
Yes 	100.0%	10
No 	0.0%	0
<b>answered question</b>		<b>10</b>
<b>skipped question</b>		<b>0</b>

Table C-4

In what context would you use a validated version of NTT (check all that apply):


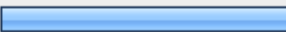
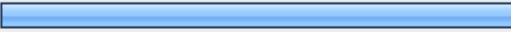
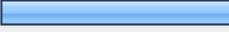

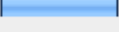
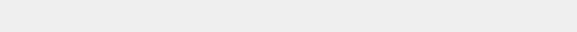

	Response Percent	Response Count
Water Quality Trading 	100.0%	10
Land management options 	50.0%	5
Conservation practice evaluation 	90.0%	9
Farm planning 	40.0%	4
Field-scale research 	10.0%	1
TMDL 	20.0%	2
Would not use 	0.0%	0
Other (please specify) 	10.0%	1
<b>answered question</b>		<b>10</b>
<b>skipped question</b>		<b>0</b>

Table C-5

Which NTT derived factors would be used when facilitating farm planning and operation discussions? (check all that apply)

	Response Percent	Response Count
Nitrogen	100.0%	10
Phosphorous	100.0%	10
Sediment	70.0%	7
Crop yields	80.0%	8
Other (please specify)	0.0%	0
<b>answered question</b>		<b>10</b>
<b>skipped question</b>		<b>0</b>

Table C-6

Based on the scenarios you have run, were the nutrient and sediment reduction estimates and/or yield estimates within an expected range?

	Response Percent	Response Count
Yes	80.0%	8
No	20.0%	2
If no, please explain.		3
<b>answered question</b>		<b>10</b>
<b>skipped question</b>		<b>0</b>

Table C-7

Which features of the NTT did you find useful? (check all that apply)

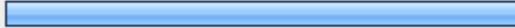
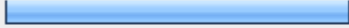


	Response Percent	Response Count
Quantification of nonpoint source edge of field pollutant loading 	90.0%	9
Option to define and check the baseline scenarios for being eligible for trading 	60.0%	6
Bushel per acre estimates 	10.0%	1
No features were useful	0.0%	0
Other (please specify) 	10.0%	1
<i>answered question</i>		<b>10</b>
<i>skipped question</i>		<b>0</b>

Table C-8

Considering the current NTT computer interface, do you find running NTT easy?

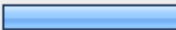
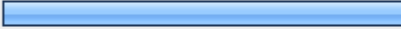
	Response Percent	Response Count
Yes 	30.0%	3
No 	70.0%	7
If no, please describe the windows or fields causing the concern and the specific improvements requested to make it easier to use (i.e., capturing the WSS soil data and saving it...)		6
<i>answered question</i>		<b>10</b>
<i>skipped question</i>		<b>0</b>

Table C-9

Are you aware of similar non-point source runoff estimation tools?



	Response Percent	Response Count
Yes 	20.0%	2
No 	80.0%	8
If yes, what are they and how do they compare to NTT with respect to usefulness?		2
<i>answered question</i>		10
<i>skipped question</i>		0

Table C-10

Based on the training you received in Columbus, would you feel comfortable using the tool now?

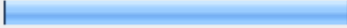

	Response Percent	Response Count
Yes 	60.0%	6
No 	40.0%	4
If no, how many additional hours of training would you need?		5
<i>answered question</i>		10
<i>skipped question</i>		0

Table C-11

Please rate the following features with respect to user friendliness:

	Very poor/Not user friendly at all	Poor	Neutral	Good	Excellent/Very user friendly	Response Count
Users Manual	0.0% (0)	20.0% (2)	50.0% (5)	30.0% (3)	0.0% (0)	10
Soil Survey Map	0.0% (0)	0.0% (0)	0.0% (0)	90.0% (9)	10.0% (1)	10
Soil Inputs	0.0% (0)	10.0% (1)	50.0% (5)	30.0% (3)	10.0% (1)	10
Management Selection Inputs	0.0% (0)	30.0% (3)	30.0% (3)	40.0% (4)	0.0% (0)	10
Reporting	0.0% (0)	0.0% (0)	30.0% (3)	70.0% (7)	0.0% (0)	10
Overall User friendliness	0.0% (0)	0.0% (0)	40.0% (4)	60.0% (6)	0.0% (0)	10
<i>answered question</i>						10
<i>skipped question</i>						0

### Key Points and Comments

Ten responses is a high turnout rate for the number of professionals requested to take the survey but does not represent the agricultural professionals in the nation. The survey (manual and training session) would need to be replicated several more times over to achieve statistically significant finding. In spite of this, the survey does provide the project team with a strong perspective on NTT’s attributes and user friendliness.

All respondents felt that quantifying sediment and nutrient loading for producers was necessary and all indicated that they would participate in a water quality trading market by providing evaluation services for their clients. In addition use of NTT was seen as valuable in assisting for land management and farm planning processes to a significant percentage of respondents.

The NTT-derived factors deemed most useful when facilitating farm planning and operation discussions included nitrogen (100 percent), phosphorus (100 percent), crop yields (80 percent) and sediment (70 percent) with no other factors identified.

When asked whether they found it easy to run NTT, 70 percent said no. The fields or windows causing

concerns (and the specific improvements requested to make it easier to use) were:

- Need to be able to enter the area for the waterway alternative. The current tool seems to assume an area equal to 5% of the watershed.
- The interface I felt was a bit cumbersome, especially if I needed to go back to a previous page and make changes.
- Capturing WSS and changing specific practices
- I think the current format is good. However, I don’t think this is easy. I think a few of the pull downs could be more state or region specific.
- The interface was not exactly easy to figure out at first glance. The ability to modify all of the different options should be prioritized and not hidden away. This tool will be used for very specific situations, therefore it should be as painless as possible to customize the description. No two farms are the same anywhere in the world.
- Maps load very slowly. Outlining AOI takes too long for each field. We need to be able to import shape files for field boundaries.

Only 20 percent of the respondents were aware of similar non-point source runoff estimation tools (the EPA Region 5 model) but both felt it was not as useful and that NTT was a step up from this model.

### ***Summary and Findings of Survey***

In all, none of the features were rated as very poor/not user friendly at all, while only the soil survey map (WSS) and soil inputs (NTT) received the excellent ratings. The majority of the responses indicate the pollutant parameter edge-of-field load and bushel per acre estimates are valuable for their farm related activities with or without WQT. The majority also responded that the calibration was within an expected value range. However, when questions focused on the operation of the model the majority of the responses indicated the tool was not easy to run and one expressed concern regarding the waterway alternative contributing area calculation.

In general, the cumulative survey summary appears to indicate a slight improvement in model acceptance and use, compared to the verbal responses provided during the training session. This change can be attributed to several different occurrences. For example, an incomplete list of settings that would positively change their opinions are:

1. Not having all 18 participants filling out the survey
2. Individuals have now spent more time to become familiar with NTT, and that reduces the apprehension associated in general regarding using new tools

Individuals have now spent more time with NTT which allowed for a wider range of test scenarios that an individual uses to base their judgments upon.





# Appendix D: ODNR Evaluation of NTT

Hamilton, Rob (Ohio DNR) Review of NTT for Miami Conservancy District, OH.  
Paid for under USEPA Targeted Watersheds Grant #WS-00E74201-0, Great

Miami River Watershed Water Quality Credit Trading Program Implementation Project.



## Ohio Department of Natural Resources

TED STRICKLAND, GOVERNOR

SEAN D. LOGAN, DIRECTOR

### Division of Soil & Water Resources

4383 Fountain Square Drive - Bldg. B-3

Columbus, OH 43224-1362

September 16, 2010

Dusty Hall  
Miami Conservancy District  
38 E. Monument Avenue  
Dayton, Ohio

RE: **Evaluation of the Nutrient Trading Tool for  
Great Miami Watershed**

Dear Dusty:

As part of our contractual agreement with the Miami Conservancy District, I want to provide you with a preliminary report on the Nutrient Trading Tool (NTT). Since the initial NTT training at the Ohio Farm Bureau Federation office on August 26, 2010 I have had the opportunity to use NTT and share it with a few local SWCD staff involved with the Great Miami River Watershed Water Quality Credit Trading Program. Overall, the initial impression and reaction to NTT has been quite positive by those who have viewed or used the program. However, I believe that more analysis will be needed before I could recommend to fully use NTT in the Great Miami River Watershed Water Quality Credit Trading Program. I do think that NTT is a step in the right direction for nutrient trading

as the program has several features and updates that will help conservation districts, farmers and landowners evaluate the benefits of conservation practices and changes in agricultural management systems.

In this letter below I have include initial comments and reactions regarding NTT. Hopefully, you will find these comments helpful in understanding the need for further review the NTT with the current load reduction model that we are using currently in the Great Miami River Water Quality Credit Trading Program. The comments below are primarily organized by the individual tabs found in the NTT program.

### **General Comments about NTT**

The overall program is user friendly. The tabs are easy to use and walk users through the steps to use the program. The conservation agency staff that used the program needed only minimal instruction to get started. The help button seemed very useful in providing information when the next step was unknown. The pull down menus were also easy to use and the program was relatively fast when saving and updating. For one user, it did seem to take longer to calculate baseline and alternative scenarios; however, this could be the system that they were using.

## Soils

The soils section of NTT linked to web soil survey is very helpful. This allows users to quickly access soils information that the NTT program uses. Regarding Web Soil Survey (WSS) it is difficult to draw an exact field boundary. I attribute this primarily to the line thickness that WSS uses. For the purpose of trading programs recognize that WSS field acreages may vary from actual field acreages. From what we experienced more accurate field measurements can be achieved using ArcGIS. In the Miami watershed all maps and field acreages are being calculated using ArcGIS or an equivalent program.

One particular scenario that was used involved a field that was located in two counties. While WSS calculated the acreage and soils in both counties, we somehow lost the acreage and soils information for one of the counties when the information was imported into NTT.

## Management

The management section again is user friendly. The soils information in this section provides a good check to make sure you are working with the right field. Under the existing management scenarios, the cropping system needs expand to include wheat at a minimum. Other crops to include for our area would be hay and pasture. In some of our evaluations it would have also been useful to have a soybeans-corn scenario instead of a corn-soybean scenario. Recognize that these changes can be done by users when choosing the modify option; however, having these options as existing suggested management scenarios would be helpful. For Ohio, fertilizer recommendations should be based on tri-state fertilizer recommendations if it is not already.

### Management (Modify section)

The modify feature in the management section does allow you to try different scenarios. While we recognize that this program is set up to cover the United States it would be helpful if the choices were more region specific instead of the longer lists for the whole U.S. For example, the options for peanuts are probably not needed for Ohio. Having shorter lists makes it easier for the user. For the crop choices, there are other crops that could be added as well for Ohio.

For the fertilizer input section, 28% Nitrogen is not listed as a choice. Also it would be helpful to explain the

amount- Is this lbs of product applied per acre or actual lbs. of nutrient amount applied per acre?

It is good to see that manure is included as an option. Again the amount needs some clarification. Few producers using liquid manure will be able to tell you how many pounds per acre of liquid manure that is applied. They will know how many gallons were applied and some may even have a manure analysis. It might be good to allow the user to enter in their own fertilizer blend or manure analysis.

The feature that allows you to duplicate an operation from baseline to alternative works well. Overall, this section is the most difficult for users, but perhaps just some further training and guidance is needed on how to enter the data.

## Verify

The verify section does not show modified scenarios when you start with an existing scenario and then modify it. For example, I used a corn-soybean rotation existing scenario for baseline and alternative. I then modified it by adding wheat to the alternative scenario. This modification did not show up in the verify section.

## Reports

The reports section is possibly the most difficult to understand. One scenario we used corn-soybean (baseline) and corn -soybean-wheat (alternative) with no additional fertilizer showed very low sediment and phosphorus changes. Overall, most of the different scenarios we tried showed surprisingly low changes and reductions when compared with the U.S. EPA region 5 model.

Another scenario we tried was entering the exact information for both baseline and alternative. The yields showed up slightly different even though there were no changes in management. One recommendation would be to change the reduction% column to say %change, because results may increase instead of decrease. Also, we did not understand what flow/in. actually means in this section. As you know, cover crops are becoming a more widely used practice by many farmers in the Miami watershed. NTT does not seem to give much credit for sediment, nitrogen, or phosphorus when cover crops are applied.

## Structural Conservation Practices

The list of structural practices is good as it represents most of the primary conservation practices applied in Ohio. One practice that could possibly be added is drainage water management. Based on Midwest research, when tile drainage flow is managed meaning that tile flow is restricted during the non-growing seasons and is managed during the growing season a 40% reduction in flow can be achieved resulting in significant nitrogen and phosphorus reductions.

One scenario that we used for structural conservation practices was for a grass waterway. The results for sediment were much lower than expected, <2 tons per acre. On average, the area evaluated in this scenario generates a gully 3feet wide, 1 foot deep, and approximately 1,500 ft. long every year. Our estimates would be in excess of a 100 tons of soil loss for this same scenario.

## Summary and Recommendations

The NTT program has some really nice features and is relatively user friendly. Based on my experience users struggle the most with modifying management and interpreting results. Results seem much lower than we would expect based on experiences applying conservation practices. Further validation of the results is needed to see if they are representative of what is actually happening in the field.

Regarding the Great Miami River Watershed Water Quality Credit Trading Program, further comparison with current models will be necessary. As discussed and as part of our agreement, I will continue to work with our SWCDs on different practice scenarios over the next couple of months to help further determine if NTT is applicable to the Great Miami River Water Quality Credit Trading Program.

I hope that you find this preliminary report helpful. If you have any questions feel free to contact me at (614) 562-0738 or [rob.hamilton@dnr.state.oh.us](mailto:rob.hamilton@dnr.state.oh.us).

Sincerely,

Rob Hamilton, Administrator  
ODNR Division of Soil and Water Resources

Cc: John Kessler, ODNR Division of Soil and Water Resources



# Appendix E: WARMF Watershed Scale Model

This Appendix was prepared in its entirety by the University of California at Santa Barbara, under contract with EPRI.

## Introduction

The current project was designed to evaluate how field scale models, such as NTT, can be used in combination with watershed scale models, such as WARMF, to inform the Water Quality Trading credit estimation process. WARMF can serve to determine the potential benefits of different trades, and WARMF results can be used to provide insights with regards to identified river reaches that potentially are not meeting water quality objectives. The model can also be used to evaluate the potential benefits of implementing particular Best Management Practices (BMPs) at a large scale (i.e. in many farms) to accelerate water quality attainment.

WARMF is a state-of-the-art, dynamic watershed model that links catchments, river segments, and other water bodies to form a seamless watershed model that computes hydrology (water flows) and water quality based on physical, chemical and biological processes. WARMF (Watershed Analysis Risk Management Framework) was developed by Systech Engineering for EPRI (EPRI 2000) as a decision support system for water quality applications, and is now being utilized for broader water quality applications by USEPA and other users, since it is in the public domain.

Site-specific adaptation of the WARMF model version 6.2 to the Upper Big Walnut Creek (UBWC) watershed required input data, parameter estimation and calibration, and analysis in order to estimate hydrologic and water quality conditions throughout the basin. The current project team implemented the

WARMF model for the Upper Big Walnut Creek subwatershed (UBWC), which is part of the Scioto River watershed within the Ohio River Basin. The WARMF model was employed to establish a baseline of spatially-explicit surface water quality conditions in the UBWC watershed in order to assess the quantity and timing of point source and non-point source loads in a pilot trading area. In addition to simulating flow, the water quality constituents simulated in detail were nutrients (phosphorus and nitrogen species). While other water quality parameters can also be simulated, they have not been calibrated due to insufficient water quality data. The WARMF model of the UBWC watershed will be used to better understand the effectiveness of different agricultural BMPs in achieving water quality objectives in the watershed, and to develop the fate and transport attenuation factors for the nutrients within the UBWC watershed.

## Study Area

The Upper Big Walnut Creek (UBWC) Watershed in central Ohio comprises 190 mi<sup>2</sup> or 121,600 acres (493 km<sup>2</sup> or 49,300 hectares). It contains land area in portions of Delaware County, Morrow County, Licking County, Knox County, and Franklin County (Figure E-1), with the greatest portion of the UBWC falling within Delaware County (66%). Several studies have reported 290 miles length of total intermittent and perennial streams draining the UBWC watershed. The climate of the UBWC is characterized by continental, humid, and hot summers and snowy, wet winters. The UBWC contains approximately 45,100 acres of cropland (37 percent).

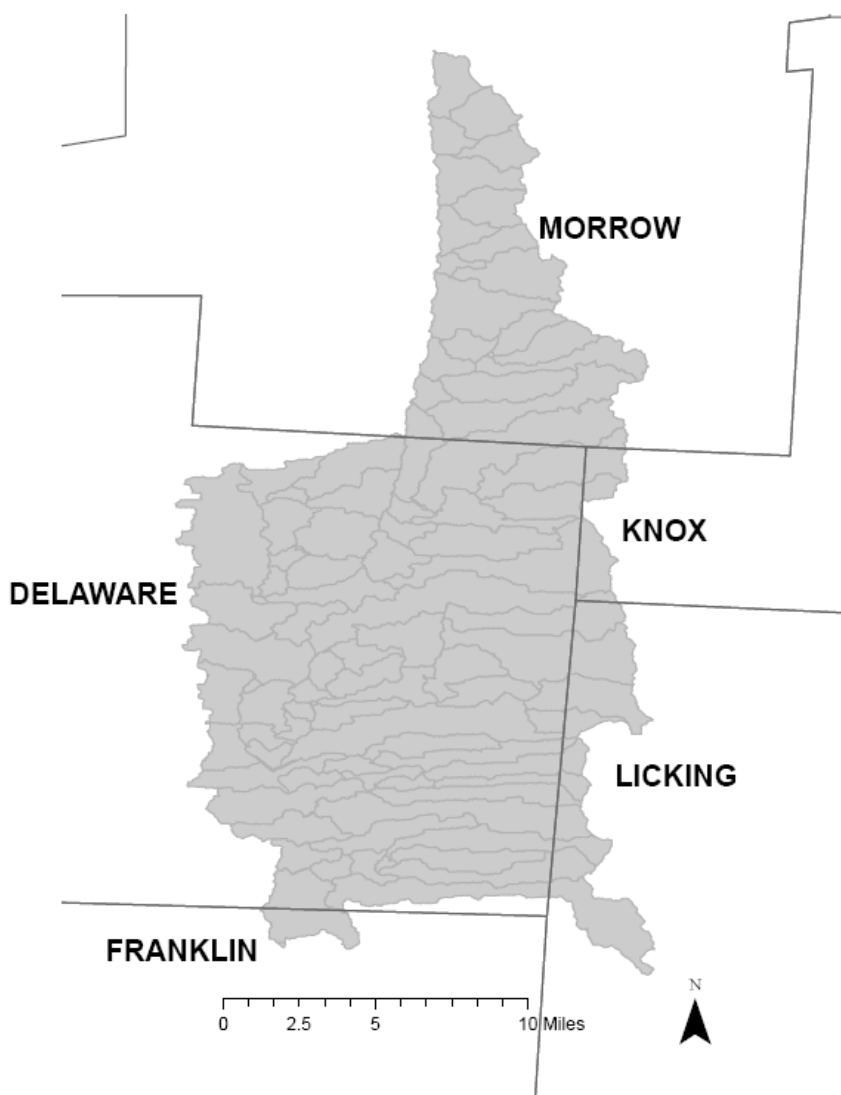


Figure E-1  
Location of Upper Big Walnut Creek watershed within the Ohio counties.

## Methodology

### WARMF Model

In the WARMF model (Chen et al. 1996; Chen et al., 1998; Chen et al., 2000), water from precipitation, as rainfall or snowfall, is routed through the canopy, land surface, shallow subsurface flow and deep groundwater flow, to the receiving water bodies, namely streams, rivers or lakes, with losses due to evapotranspiration, irrigation and other extractive uses which do not return it to the system. Chemical mass budgets are based on the amount of chemicals that are (1) in the system initially (e.g. nitrogen in vegetation, groundwater and/or soil minerals); (2) applied to the land surface (e.g.

fertilization, irrigation water, atmospheric deposition, septic system discharge, animal waste), and/or (3) are discharged directly into a waterbody (e.g. discharge of treated effluent). Assimilation and transformation among nitrogen (N) compounds is simulated, on the soil surface or in the various water compartments. The model considers the simultaneous uptake of phosphorus (P) by biota during assimilation, and the release of N and P during decomposition and mineralization.

Formulations of WARMF have been documented and updated (Chen et al. 2001). The model has been peer reviewed by independent experts (Keller 2000 and 2001). Several publications have documented the decision support capabilities of WARMF (Chen et al., 1998, Chen et al., 2000a, Chen et al., 2000b,

Weintraub et al., 2001, Herr et al., 2002, Keller et al., 2004, Keller and Zheng, 2005).

The Engineering module of WARMF contains a dynamic watershed simulation model that calculates daily surface runoff, ground water flow, non-point source loads, hydrology, and water quality of river segments and stratified reservoirs. The land surface is characterized by its land uses and cover, which may include forested areas, agriculture lands, or urbanized cities. In WARMF, a watershed is divided into a network of land catchments, river segments, and reservoir layers. Land catchments are further divided into land surface and soil layers. These watershed compartments are seamlessly connected for hydrologic and water quality simulations. . Daily precipitation, which includes rain and snow, is deposited on the land catchments. WARMF performs daily simulations of snow and soil hydrology to calculate surface runoff and groundwater accretion to river segments. The water is then routed from one river segment to the next downstream river segment until it reaches the terminus

of the watershed. The associated point and non-point loads are also routed through the system. Heat budget and mass balance calculations are performed to calculate the temperature and concentrations of various water quality constituents in each soil layer and river segment.

### **Model Implementation**

Several of the datasets used to develop the UBWC model were prepared and pre-processed using BASINS 4.0, a non-proprietary framework available through the USEPA. BASINS 4.0 includes a web data extractor and was used to download data from several national datasets, including USEPA, USGS, USDA and other agencies. The basic GIS databases needed for the BASINS/WARMF framework are the digital elevation model data (NED), hydrography, land use, soil, weather station locations, and associated observed data (Table E-1).

*Table E-1  
Datasets used for setting up WARMF*

<b>File Name</b>	<b>Description</b>	<b>Source</b>
National Elevation Dataset (NED)	Topography	USGS
SSURGO	Soils Data	NRCS
2001 National Land Cover Dataset 2008 Ohio Cropland Data Layer	Land Use	USDA, National Agricultural Statistics Service
Meteorology	Precipitation and other weather parameters	NOAA (NCDC)
Air quality	Atmospheric deposition	USEPA (NADP & CASTNET)
Gage stations	Observed hydrology	USGS
Water quality stations	Observed water quality	USEPA, USDA
Point source data	Flow and discharges	Ohio EPA
Non-point source data	Land Management Practices	USDA
Census	Urban Areas, Households	U.S. Census Bureau

### **Delineation**

The delineation tool in BASINS 4.0 (<http://www.epa.gov/waterscience/BASINS/>) was used to determine the catchments that comprise the

UBWC watershed, for modeling within WARMF. The Watershed Delineation module of BASINS relies on the National Elevation Dataset (topography) and the hydrologic extent (watershed boundary) of the UBWC study area. The UBWC watershed is defined by the U.S. Geological Survey as an 11-digit Hydrologic Unit

Code (HUC) region (Seaber et al., 1987), draining into the Hoover Reservoir at the southern-most extent of the basin. The underlying principle in the catchment delineation process is that the movement of water across the landscape is driven by topography. The delineation process generates two files that are imported into WARMF: the UBWC Watershed Delineation containing 97 catchments and the corresponding River Network.

River Network values, such as river length, mean width, mean depth, and mean slope, were calculated automatically by the delineation. Within the WARMF Engineering module, each of these 97 contains a distinct river segment and is further divided into land

surface and soil layers. These compartments are seamlessly connected for hydrologic and water quality simulations. The soils are characterized by area, thickness, depth, and soils types, and the land surface is characterized by its land uses and cover, which may include forested areas, agriculture lands, or urbanized cities. The UBWC watershed drains into Hoover Reservoir (Figure E-2). However, the scope of the project did not include modeling the reservoir explicitly. Thus, it was considered as part of the river network, as shown in Figure E-2b. Thus, the results in this lower part of UBWC are only illustrative and may not reflect actual flows or concentrations in the reservoir.

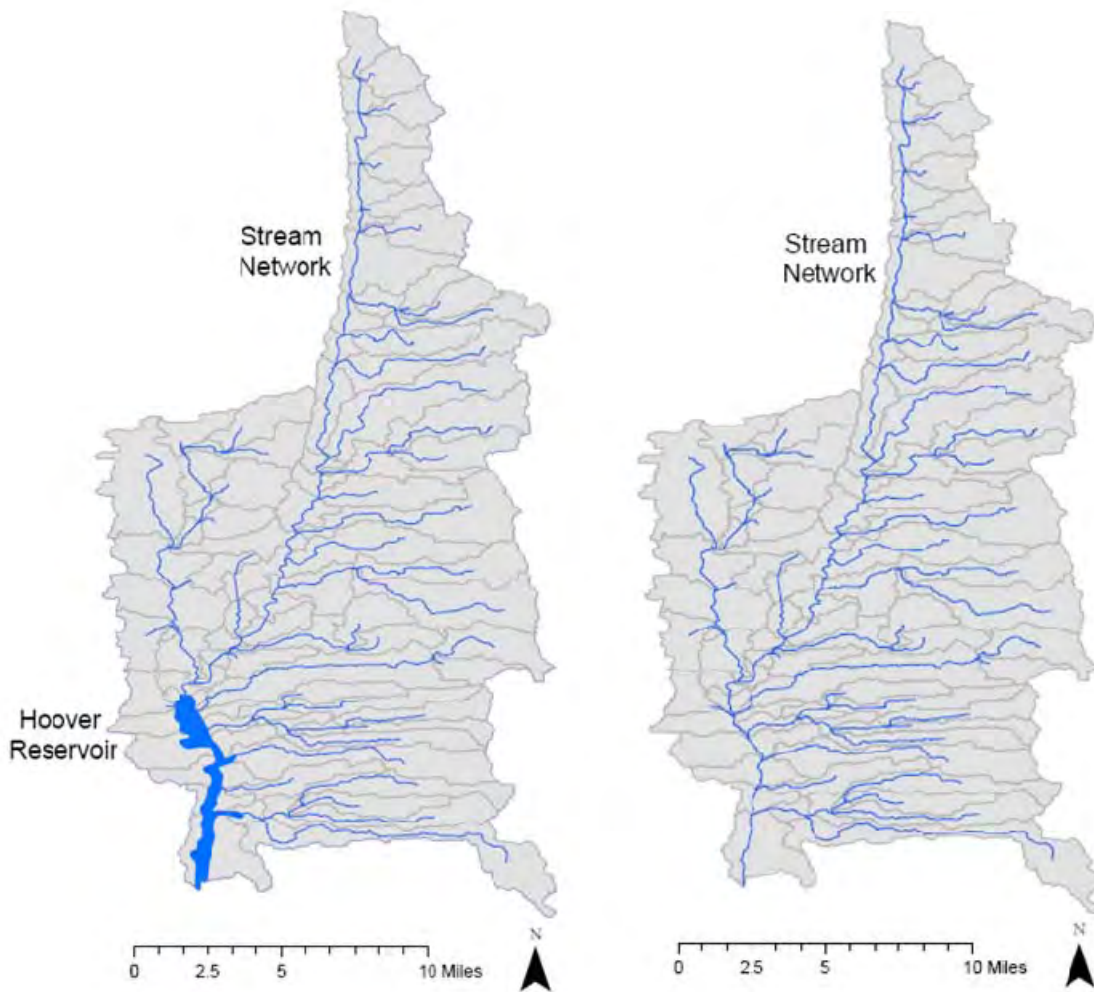


Figure E-2  
UBWC Stream Network and watershed delineation: (a) with; and (b) without Hoover Reservoir.



## **Soils**

The Soil Survey Geographic database (SSURGO) is used to characterize the soils. It is the most detailed level of electronically available soil mapping data done by the Natural Resources Conservation Service (NRCS).

SSURGO provides fine resolution data which can be aggregated to the spatial scale and depth of interest. The soil profile was subdivided into four layers. One reason for delineating the UBWC watershed into 97 catchments is to better represent the soils. However, even at this scale, a certain amount of spatial averaging is required. Saturated conductivity, for example, is an important soil property for infiltration and runoff predictions, and estimation of a single parameter value is difficult since it can vary spatially by orders of magnitude over relatively short distances (Arnold et. al. 1998).

Spatial analysis was performed on the SSURGO soils data, capturing the most representative soils parameter values for each catchment. Aggregation methods consisted of using a GIS-based framework to overlay the watershed delineation with SSURGO soils data. Though the SSURGO soils data has fine resolution, the properties of soils within the UBWC appear to show some homogeneity within Soil Layer 1 across several parameters. For this reason, we selected Soil Layer 2 for grouping homogenous soil areas, as it exhibited the

greatest range of values for conductivity, water field capacity, and saturated moisture content.

Baseline soils values were estimated by extracting the most frequently occurring value (by area) within each of the 4 soil layers of each catchment for the following SSURGO attributes:

- Thickness
- Horizontal hydraulic conductivity
- Vertical hydraulic conductivity
- Field Capacity (0.33 bar)
- Porosity and Saturated Moisture Content

These values were assumed to be the most spatially representative for that catchment and entered into the WARMF model as the baseline parameter values characterizing soils prior to calibration. The hydrologic calibration in WARMF will be discussed in greater detail below, but it is important to note that the process of calibration does result in adjustments to the SSURGO-aggregated parameters.

Spatial representation of three soil properties (thickness, horizontal hydraulic conductivity and field capacity) is presented in Figure E-3. The maps are presented in the units used in the WARMF model, for ease of comparison with the model.

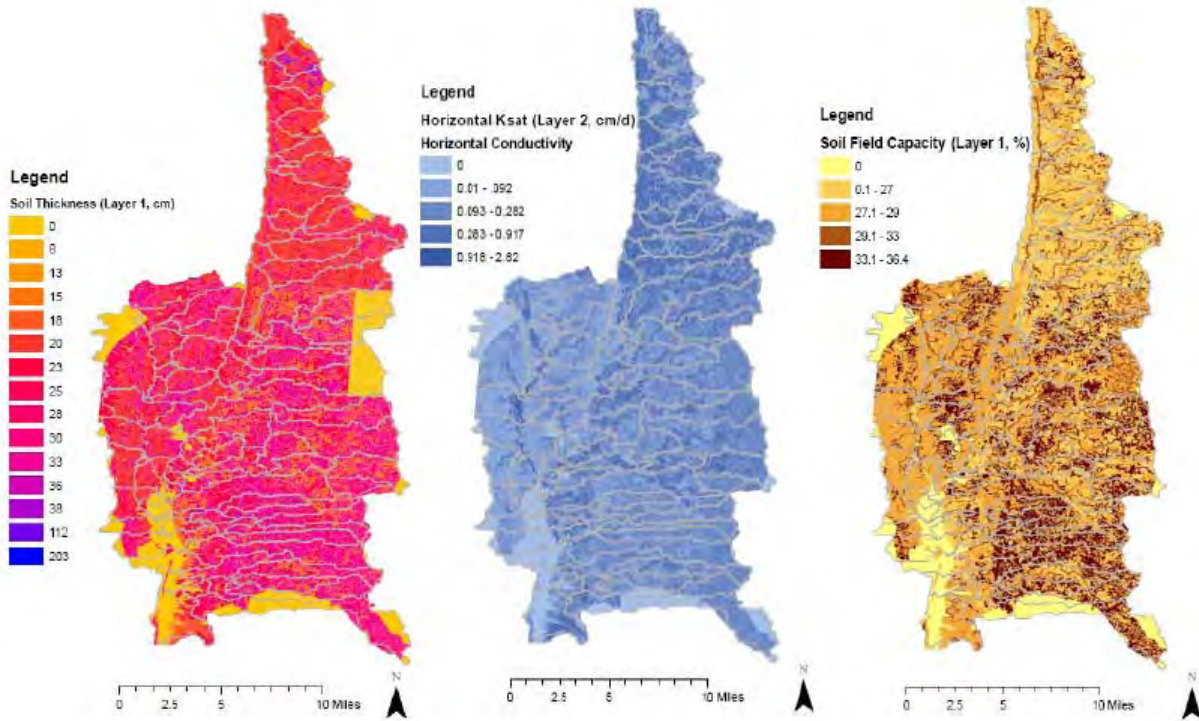


Figure E-3  
Soil properties in the UBWC: (a) thickness; (b) horizontal hydraulic conductivity; and (c) field capacity.

### Land Use

The USDA's Cropland Data Layer (CDL) is a crop-specific land cover data layer with a resolution of 56 meters. The CDL is produced using satellite imagery from the Indian Remote Sensing RESOURCESAT-1 (IRS-P6) Advanced Wide Field Sensor (AWiFS) collected during the 2009 growing season. The UBWC Cropland Data Layer contains ancillary classification inputs including the United States Geological Survey (USGS) National Elevation Dataset (NED) and the USGS National Land Cover Dataset 2001 (NLCD 2001). Figure E-4 presents the UBWC watershed's land use based on this information. To highlight the crops, Figure E-5 presents the land use without the non-agricultural land uses.

The WARMF framework is capable of modeling up to 35 distinct land use classes. However, it is common to reclassify the land use information to a smaller set of land uses, since some represent only a very small fraction of the land, and in some cases the parameter values associated with a land use are similar to another land use (e.g. corn and popcorn). Land uses are defined by the user depending on the land use dataset. For the UBWC, the WARMF model was based on the land use classes defined in the USDA NASS Cropland dataset and considers the 20 land use classes listed in Table E-2. The parameter values associated with each crop in the WARMF model are presented in Attachment A.

Table E-2

Landuses considered in WARMF for UBWC.

1	Corn
2	Soybean
3	Winter Wheat
4	Corn/Soybean
5	Winter Wheat/Soybean
6	Corn/Soybean/Wheat
7	Alfalfa
8	Grass, Pasture, Hay
9	Idle Cropland
10	Developed (Low)
11	Developed (Medium)
12	Developed (High)
13	Open Space
14	Deciduous
15	Evergreen
16	Mixed Forest
17	Shrubland
18	Wetlands
19	Barren
20	Water

### Legend

- Corn
- Popcorn
- Soybeans
- Winter Wheat
- Winter Wheat/Soybeans
- Oats
- Alfalfa
- Clover/Wildflowers
- Seed/Sod
- Pasture/Hay
- Idle Cropland
- Grass/Pasture
- Developed Open Space
- Developed Low
- Developed Medium
- Developed High
- Barren
- Forest - Deciduous
- Forest - Evergreen
- Forest - Mixed
- Shrubland
- Grassland
- Wetlands
- Wetland - Woody
- Wetland - Herbaceous
- Water



Figure E-4  
UBWC Land Use/Land Cover based on 2009 USDA/NASS Cropland Data Layer

### Legend

#### Agricultural Crops

-  Corn
-  Popcorn
-  Soybeans
-  Winter Wheat
-  Winter Wheat/Soybeans
-  Oats
-  Alfalfa
-  Clover/Wildflowers
-  Seed/Sod

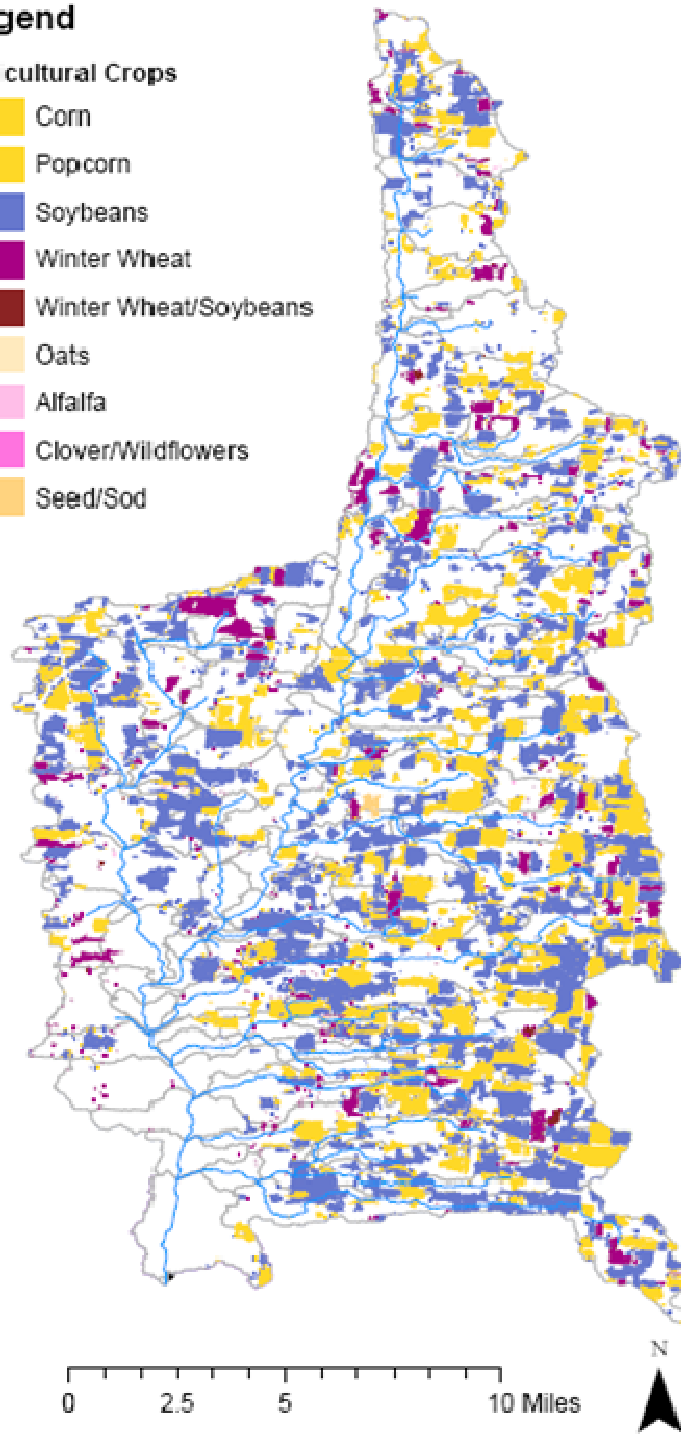


Figure E-5  
UBWC Agricultural land uses based on 2009 USDA/NASS Cropland Data Layer

## Land Application

The WARMF model contains several parameters associated with Land Application. The land application can be fertilization, animal waste, and atmospheric deposition of particles containing nitrogen or phosphorus. For the UBWC, we considered the fertilizer load per unit surface area as provided by Dr. Ali Saleh, so that the loading rate would be consistent with the NTT model. These are presented in Table E-3.

Of the 122,000 acres (49,300 hectares) that comprise the land area of the UBWC, 45,500 acres (18,400

hectares) are classified as croplands consisting of corn, soybean, winter wheat, soybean/winter wheat, oats, alfalfa, sod, grass, pasture, and hay (2009 Ohio Cropland Data Layer, USDA/NASS CDL). In order to estimate the total annual fertilizer load to each catchment in the UBWC WARMF model, the total area of each crop type was added and multiplied by the total N and total P applied as fertilizer per year as indicated in Table E-3. The results are shown in Figure E-6. An estimated 6,070,000 lb (2,760,000 kg) per year of Total N and 4,620,000 lb (2,100,000 kg) per year of Phosphate as P are applied to croplands within the UBWC watershed.

Table E-3

N and P loading (lb/acre) considered in WARMF for the various crops.

	<b>J</b>	<b>F</b>	<b>M</b>	<b>A</b>	<b>M</b>	<b>J</b>	<b>J</b>	<b>A</b>	<b>S</b>	<b>O</b>	<b>N</b>	<b>D</b>
Corn												
N	0	0	0	0	150	0	0	0	0	0	0	0
P	0	0	0	0	60	0	0	0	0	0	0	0
Soybean												
N	0	0	0	0	15	0	0	0	0	0	0	0
P	0	0	0	0	40	0	0	0	0	0	0	0
Winter Wheat												
N	0	0	0	60	0	0	0	0	0	25	0	0
P	0	0	0	50	0	0	0	0	0	50	0	0
Corn/Soybean												
N	0	0	0	0	165	0	0	0	0	0	0	0
P	0	0	0	0	100	0	0	0	0	0	0	0
Soybean/Winter Wheat												
N	0	0	0	60	15	0	0	0	0	25	0	0
P	0	0	0	50	40	0	0	0	0	50	0	0
Corn/Soybean/Winter Wheat												
N	0	0	0	60	165	0	0	0	0	25	0	0
P	0	0	0	50	100	0	0	0	0	50	0	0
Alfalfa												
N	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	37	0	0	0	0	0	0	0
Hay												
N	0	0	0	0	65	0	0	0	0	0	0	0
P	0	0	0	0	18	0	0	0	0	0	0	0

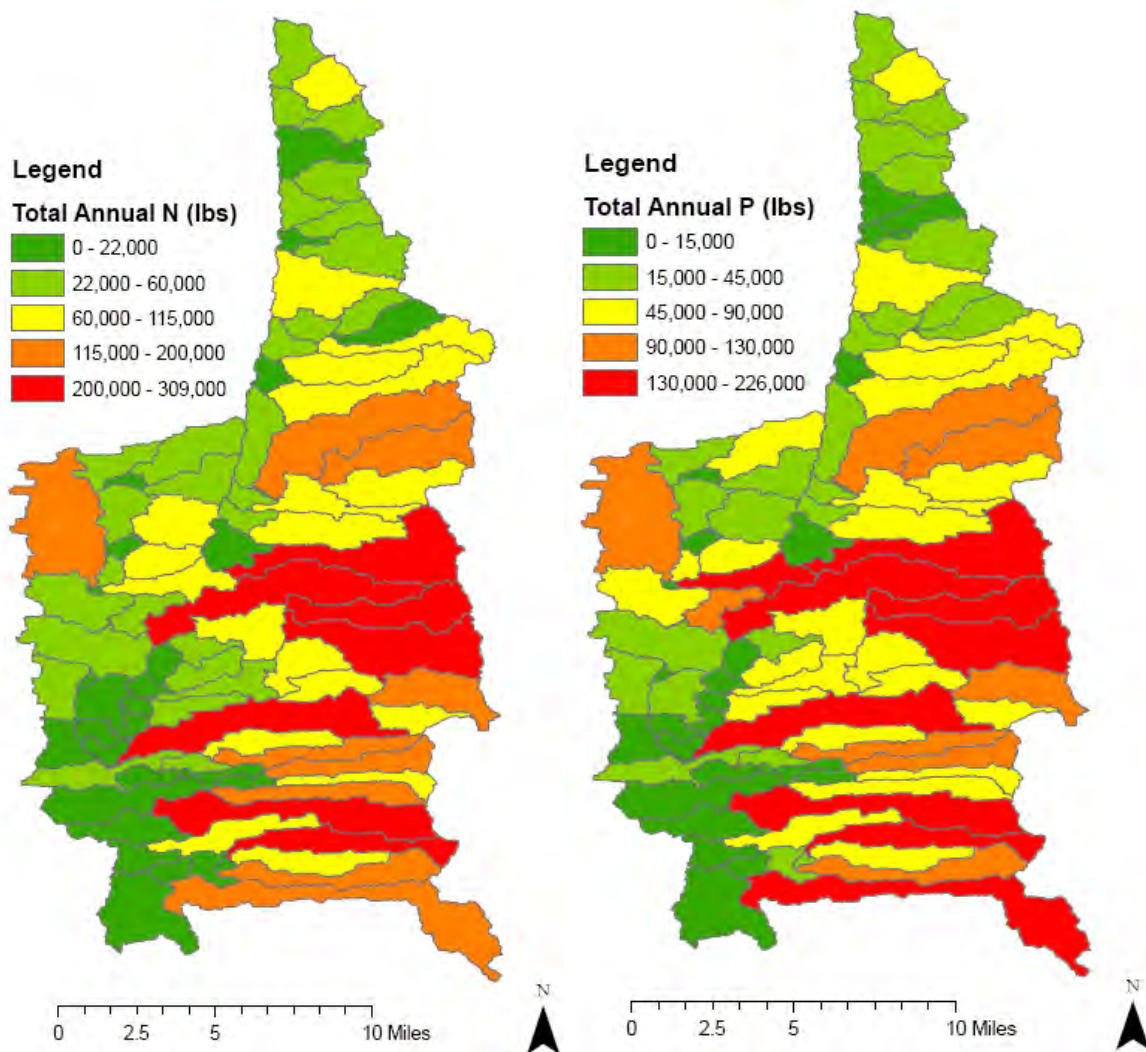


Figure E-6  
 Total N and P fertilizer applied in the various catchments of UBWC.

**Observed data**

Observed streamflow, water quality and point source data was assigned to their location in geographic coordinates along the WARMF stream network. Observed meteorology and air quality were assigned to the location of the monitoring station; WARMF then assigned the meteorology for a given catchment based on its distance to the meteorological station. BASINS-generated stream reaches may differ slightly from the National Hydrography Dataset, particularly in the UBWC watershed where topography is relatively flat and low-order streams may be intermittent and/or

perennial in nature. Thus, we verified the correct location of the observed data (Table E-4).

Observed water quality data at high resolution was available from a study by the Conservation Effects Assessment Program (CEAP) within the UBWC (King et al, 2008) for 4 catchments within the UBWC. This data was used to calibrate the WARMF model as detailed below. The location of the observed hydrology, water quality and point sources within UBWC is presented in Figure E-7.

Table E-4  
Observed data used in UBWC-WARMF model implementation

File Name	Station Name	Latitude, Longitude	Period of record
<b>Observed Hydrology</b>			
03228300	Big Walnut Creek at Sunbury	40.2362, -82.8513	01/89 – 11/09
03228500	Big Walnut Creek at Central College	40.113, -82.8815	01/40 - 04/10
<b>Observed Point Sources</b>			
4PS00016	Country View of Sunbury	40.2631, -82.7919	03/99 – 11/09
OH0053881	Village of Marengo/Morrow	40.4004, -82.8065	03/98 – 11/09
OH0114171	Village of Galena	40.2237, -82.8867	11/95 – 11/09
OH0055093	Village of Sunbury	40.2330, -82.863	05/95 – 11/09
<b>Observed Meteorology</b>			
OH 724280	Columbus Airport	39.991 -82.881	06/73 – 12/09
OH 724288	Ohio State Univ	40.078, -83.078	12/97 – 12/09
OH 724294	LancasterFairfield	40.000, -82.65	04/97 – 12/09
<b>Observed Air Quality</b>			
Lykens	Crawford County, Ohio	40.5502, -82.9982	11/99 – 03/09
<b>Observed Water Quality</b>			
USDA/CEAP A	Duncan Run	40.151, -82.8152	01/05 – 12/06
USDA/CEAP B	Rattlesnake Creek	40.1964, -82.8803	01/05 – 12/06
USDA/CEAP C	Long Run	40.320, -82.8152	01/05 – 12/06
USDA/CEAP D	Sugar Creek	40.3227, -82.7876	01/05 – 12/06



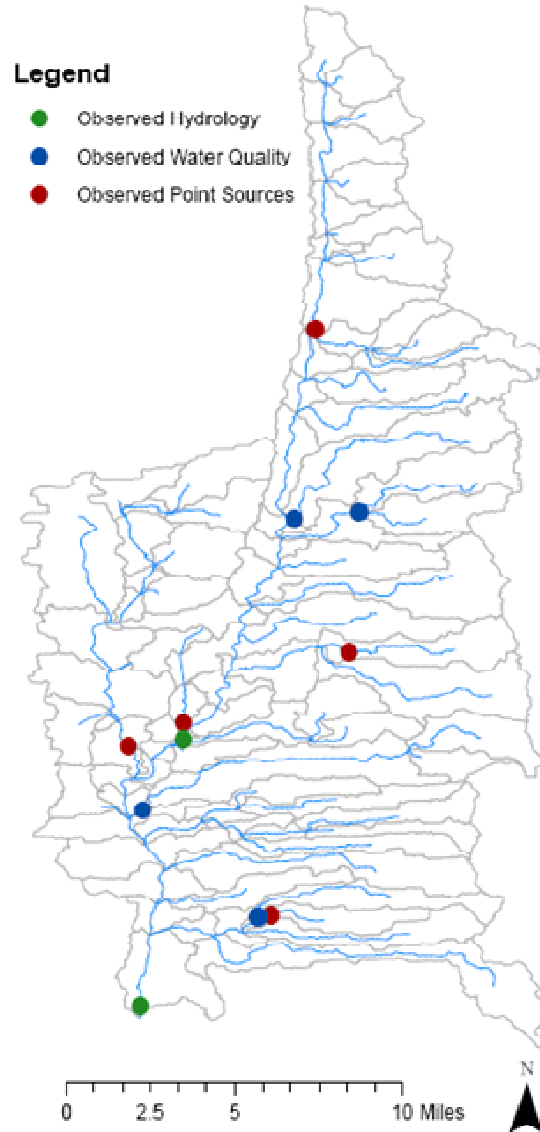


Figure E-7  
 UBWC catchments with observed hydrology (USGS), water quality (USDA/CEAP) and point source data used for calibration of the WARMF model

### Point Sources

Four major point sources were considered in the UBWC, based on Ohio EPA information. The data file for each point source was generated based on their

NPDES records. Discharge information, including flow and effluent concentrations for ammonium, nitrate and in phosphate, were available for the four point sources. Some characteristics of the point sources are presented in Table E-5.

Table E-5

Mean flow and nutrient loads from the four point sources in UBWC

	<b>Flow (acre-ft/d)</b>	<b>Ammonia (lb/day as N)</b>	<b>Nitrate (lb/day as N)</b>	<b>Phosphate (lb/day as P)</b>
Country View of Sunbury	0.02	0.05	No data	No data
Village of Marengo	0.08	0.65	No data	No data
Village of Galena	0.08	0.24	No data	0.14
Village of Sunbury	1.67	7.09	42.25	12.45

### Septic Systems

Onsite sewage treatment (septic) systems were characterized for the Upper Big Walnut Creek watershed using data provided by the 1990 U.S. Census, which is the most recent census with septic system data. Onsite sewage treatment systems are installed for treating waste emanating from a household plumbing fixture or water treatment unit. The UBWC WARMF model was implemented with a septic tank loading unique to each catchment based on the population estimated to use septic systems in each catchment. Figure E-8 presents the estimated number of persons that use septic systems within each catchment of the UBWC. Within the entire UBWC watershed, there

were approximately 36,000 persons served by septic systems in 1990. Of the 97 catchments modeled in WARMF, the population size served by septic systems ranged from 0 to approximately 4,000. Because the U.S. Census discontinued collection of these data during the 2000 and 2010 census, estimates used in the WARMF model were based on the population within each catchment as reported in the 2000 census. It is possible that some of these households have connected to one of the wastewater treatment plants in the UBWC since 1990, but there was no readily available information to adjust the estimate. Coefficient values were based on typical septic tank effluent flow and qualities obtained from Kirkland (2001), and are presented in Table E-6.

Table E-6

Septic System Parameters used in WARMF

Flow (gal/capita-day)	43.6
Ammonia (mg/L)	58.0
Phosphate (mg/L)	9.8
BOD (mg/L)	170.0

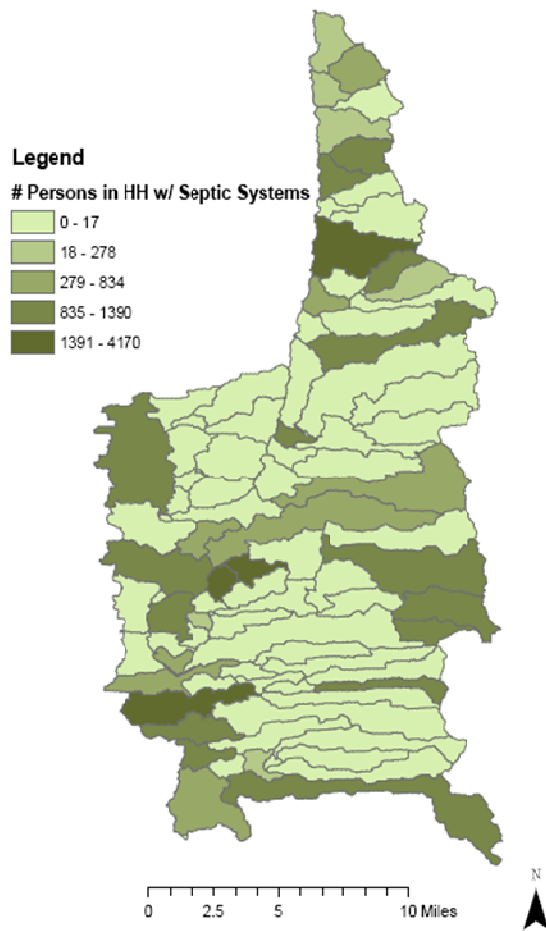


Figure E-8  
 Estimated population using septic systems in UBWC catchments. HH = household.

### Calibration

To simulate the processes related to hydrology and nutrient fate and transport, more than 100 parameters are needed for each single catchment and reach combination. The estimation and calibration of parameters is performed in a stepwise process. First the hydrologic response is calibrated using the observed hydrology. Then the water chemistry is calibrated, simultaneously adjusting parameter values for phosphorus and nitrogen compounds.

### Hydrologic Calibration

The Hydrologic Autocalibration tool in WARMF was used to simulate the surface water runoff, groundwater flow and the transport of surface water to the stream network. Observed streamflow records were available from the USGS and the USDA/CEAP study for six of the 97 catchments within the UBWC watershed

delineation. These five gauged catchments provided the baseline measurements for predicting streamflow in the model.

- The only catchment upstream of Hoover Reservoir containing continuous, gauged USGS streamflow measurements is Big Walnut Creek at Sunbury, Ohio. Big Walnut Creek at Sunbury was calibrated for years 2000–2009.
- The Big Walnut Creek gauge located at Central College, OH, which monitors the discharge of Hoover Reservoir, was only used to compare the overall flow out of the watershed with observed data, as a water balance check.
- The four catchments containing measured streamflow for the years 2005–2006 are Long Run, Sugar Creek, South and East Fork Rattlesnake Creek, and Duncan Run (USDA CEAP). It is important to note that the area of the four USDA

CEAP catchments was different than the catchment area in the WARMF model.

The hydrologic autocalibration tool adjusted the soils parameter values to better match the observed hydrologic response. Based on the spatial analysis of SSURGO soils properties, we assigned each of the 97

catchments to one of nine soil groups. The nine groupings were based on vertical conductivity values for soil layer 1 and 2 based on SSURGO. The parameters were constrained to the range of parameter values in Table E-7. The final hydrologic parameter values after calibration for the nine soil groups considered (Figure E-9) are presented in Table E-8.

*Table E-7*

*Range of parameter values for the parameters used for the hydrologic autocalibration for the nine soil groups considered in WARMF.*

	<b>Minimum</b>	<b>Maximum</b>
Detention Storage (%)	0	15
Horizontal Hydraulic Conductivity (cm/d)	1	300
Vertical Hydraulic Conductivity (cm/d)	1	200
Thickness of soil layer (cm)	1	150
Field Capacity (-)	0.1	0.4
Soil Moisture at Saturation (-)	0.2	0.6

Table E-8

Final parameter values by soil group used in WARMF model

Soil Group	Soil Layer	Soil Thickness	Initial Moisture	Field Capacity	Water Saturation	Horiz. Hydr. Conduct.	Vert. Hydr. Conduct.
		(cm)	(-)	(-)	(-)	(cm/d)	(cm/d)
1	1	1.0	0.425	0.303	0.425	288	79
	2	1.0	0.395	0.300	0.350	58	129
	3	1.0	0.355	0.293	0.340	52	1
	4	94.0	0.260	0.205	0.270	2	24
2	1	13.0	0.280	0.288	0.420	58	129
	2	112.0	0.350	0.343	0.350	1	8
	3	5.0	0.300	0.250	0.301	1	1
	4	5.0	0.200	0.100	0.200	1	1
3	1	1.0	0.350	0.238	0.480	1	79
	2	5.0	0.359	0.300	0.400	52	24
	3	5.0	0.310	0.251	0.301	52	24
	4	5.0	0.260	0.100	0.150	50	0
4	1	23.0	0.500	0.200	0.600	8	79
	2	5.0	0.400	0.200	0.500	8	79
	3	5.0	0.300	0.100	0.400	1	1
	4	5.0	0.200	0.100	0.300	1	1
5	1	1.1	0.600	0.063	0.600	1	84
	2	29.3	0.200	0.305	0.348	29	79
	3	1.0	0.312	0.307	0.321	43	24
	4	26.0	0.201	0.050	0.202	1	1
6	1	1.0	0.259	0.173	0.524	110	50
	2	25.3	0.203	0.250	0.283	79	2
	3	7.5	0.204	0.179	0.317	126	24
	4	1.0	0.201	0.198	0.248	21	1
7	1	4.2	0.299	0.353	0.399	150	79
	2	4.8	0.305	0.295	0.343	97	79
	3	6.1	0.306	0.279	0.306	134	24
	4	17.2	0.203	0.154	0.288	1	24
8	1	30.0	0.200	0.100	0.200	114	79
	2	200.0	0.207	0.267	0.280	150	1
	3	8.8	0.338	0.100	0.528	60	1
	4	4.1	0.200	0.233	0.240	93	1
9	1	1.0	0.425	0.303	0.425	258	79
	2	1.0	0.395	0.300	0.350	58	129
	3	1.0	0.355	0.293	0.340	52	1
	4	94.0	0.260	0.205	0.270	2	24

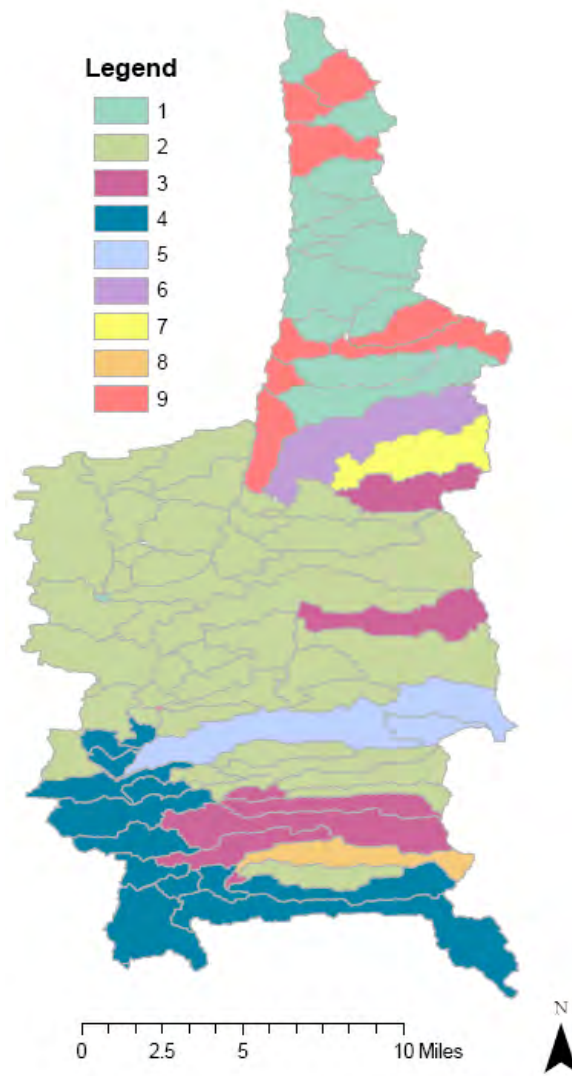


Figure E-9  
Soil groups used in WARMF model

The results of the hydrologic parameter calibration based on the USGS gage at Sunbury are shown in Figure E-10. The charts present the daily flow as well as the cumulative flow. These provide two different perspectives. The model is able to capture most of the observed peak flows, as well as the base flow conditions between storms. The cumulative flow comparison provides an indication of goodness of fit for the water balance (Figure E-10b). The cumulative flow reflects more accurately the match between model simulation and observations for both baseflow and stormflow. As can be seen, the model with the adjusted parameters is able to simulate very well the flow in the section of UBWC above Hoover Reservoir. The Nash-Sutcliffe

coefficient is 0.42. With additional flow gauges to adjust more accurately the parameter values of each major soil group, a better fit could be obtained.

The simulation results for Catchment 97, which is at the discharge of the UBWC watershed, are presented in Figure E-11. Because Hoover Reservoir has a managed flow, the predicted timing of the peaks and low flows does not always correspond to those observed over the 2000-2009 simulation. The cumulative flow (Figure 11b) indicates that the WARMF model accurately predicts the total flow exiting the UBWC watershed.

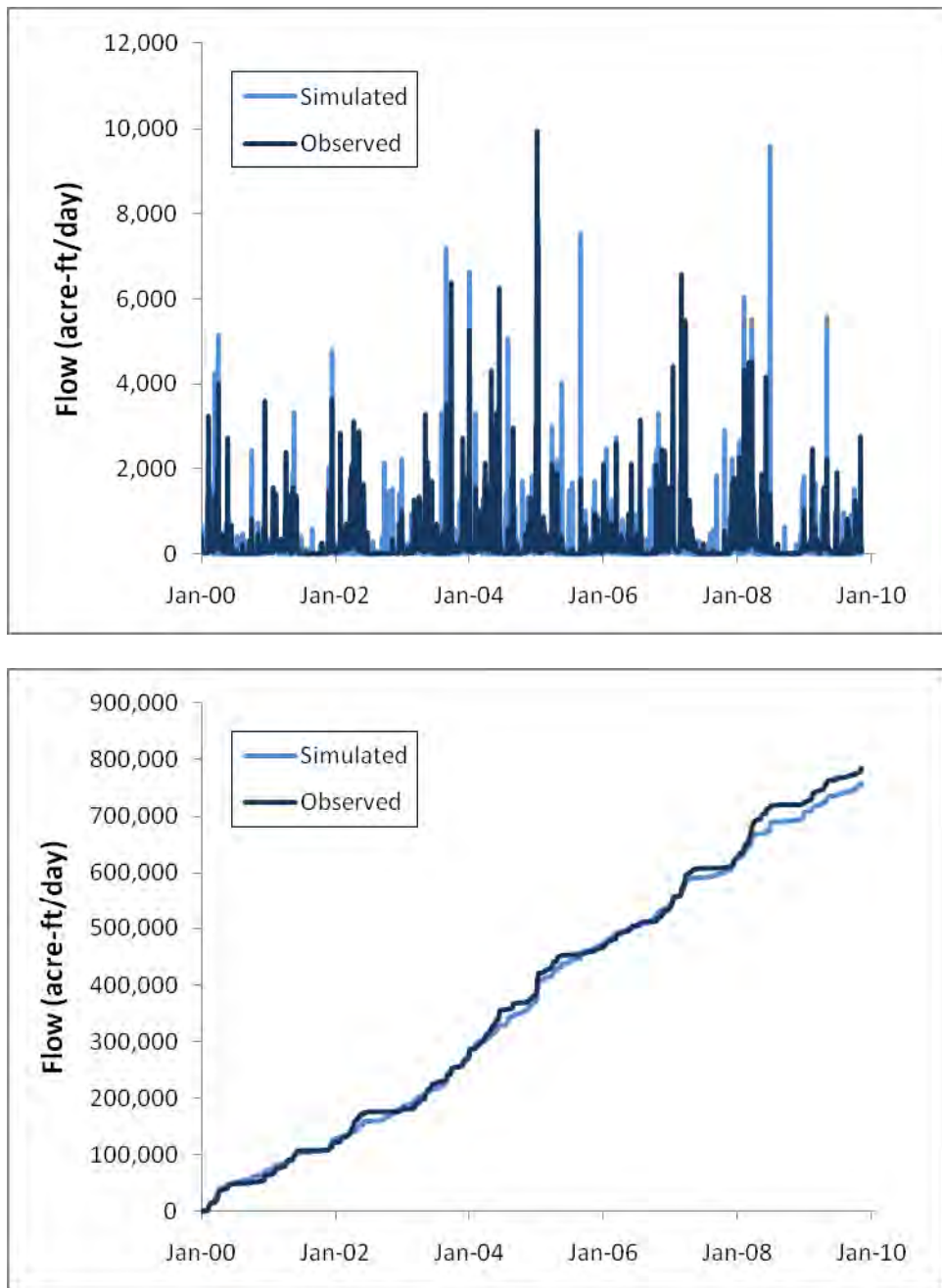


Figure E-10  
Comparison between observed and simulated (a) daily flow; and (b) cumulative flow, at Sunbury, Ohio.

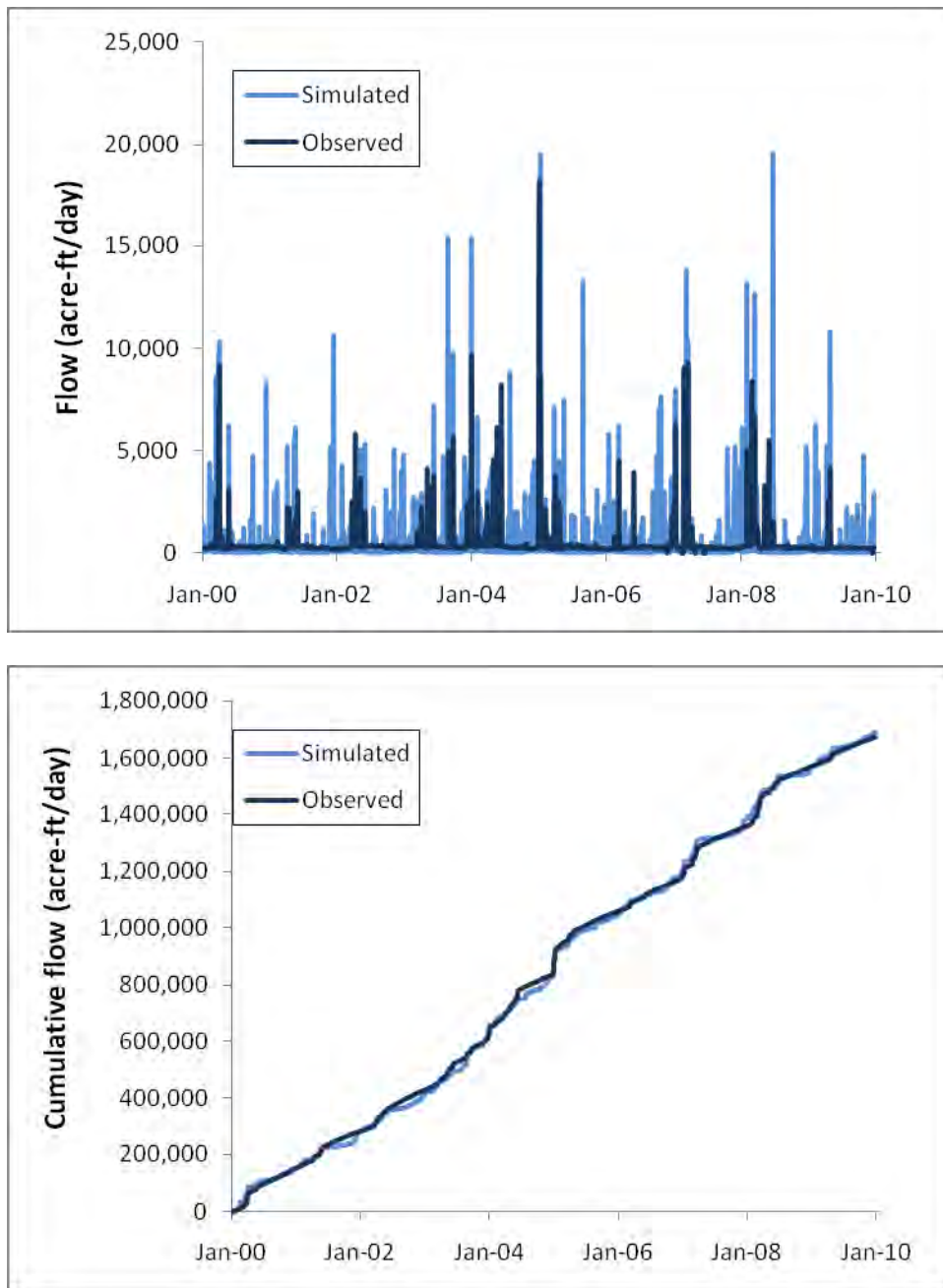


Figure E-11  
 Comparison between observed and simulated (a) daily flow; and (b) cumulative flow, at Central College, Ohio (discharge of Hoover Reservoir).

### Calibration of Water Quality

Calibration of water quality for the nutrients (N and P) relied on the data from the USDA CEAP study for four small catchments located in various regions around UBWC. There are three major classes of parameters that can be adjusted to better represent the water quality, namely the initial concentrations (in the soils, river water column and sediments), the adsorption

coefficients for the soils and sediments, and the reaction rates in soils, water column and sediments.

The initial concentrations set the overall initial mass in the particular compartment (soil, sediments, and water) and generally should be around the mean value of the observed data. The adsorption coefficients control the storage of chemicals (nutrients) in the soils and sediments. In general it is observed that nitrate is weakly



adsorbed, while ammonium and phosphate are more strongly adsorbed. The reaction rates control the transformation of ammonium to nitrate (nitrification) and then nitrate to nitrous oxide and nitrogen gas (denitrification). These reactions are a function of the redox conditions in the soils and sediments. A dissolved oxygen threshold of 2 mg/L was used in the UBWC, above which nitrification is the dominant reaction and below which denitrification is the dominant reaction. The final parameter values for the four locations are presented in Table E-9.

The results of the calibration are presented in Figures E.12-15. The combination of autocalibration parameter values and manual iterative changes based on knowledge of realistic input values resulted in best-fit predictions. The mean concentrations for the 2005-6 period are matched well for most of the parameters in 3 out of the 4 catchments. Rattlesnake Creek exhibited different behavior in part because a significant amount of the load in this catchment is from septic systems.

The temporal patterns presented in Figures E.12-15 indicate that there are some differences in temporal correspondence between the observed peaks and valleys of the flow and concentration profiles. While the overall temporal pattern of flow is reasonably well represented for Sugar Creek and Long Run, there is a peak flow in July 2005 for Rattlesnake Creek and Duncan Run (both towards the southern part of UBWC) which is not predicted by the model. The available meteorological data does not reflect a high storm during that period, and thus the model does not predict these high flows. The parameters that are adjusted for the calibration do not influence the timing of the observed highs and lows, which are controlled by hydrologic events such as snow melt, strong storms and low flows. In addition, although the available observed water quality data is of high quality, it is possible that an observed high concentration (e.g. ammonium peak of 1.7 mg/L in July 2005 for Sugar Creek, Figure E-12) may be real, or may be due to an analytical error, or particles not filtered out completely.

Figure E-12 presents the results of simulated daily values for flow and water quality, compared to the observed values for Long Run. With regards to flow, the calibrated model matches the (groundwater derived) baseflow between storms well, and in several cases the magnitude of the storm events, but there are a number of predicted storms that are not captured by the observations. This may reflect several issues: (1) flow data may have not collected during or immediately after a storm, so there is no record in the observed data; (2) the meteorological data from the NOAA stations used for the model does not adequately reflect the local meteorology. In particular it seems that a number of storms events observed at the meteorological station did not pass through this catchment. For ammonium, the simulation and observed data both indicate rather low values; the differences in the lowest values may reflect the detection limit of the observed data. The match for Total N and Total P in terms of the baseflow and peak values is reasonable, although the timing is influenced by the issues mentioned for the flow calibration.

The calibration results for Sugar Creek (Figure E-13) are similar to those of Long Run. The overall hydrologic behavior is reasonably matched, except that a number of storms predicted by the meteorological data appear not to have passed by this catchment. This reflects the challenge of using easily available meteorological data, which may not reflect local events. For ammonium, most of the simulated and observed values are within similar ranges, except for a few relatively high observed values, which cannot be predicted based on the current loading information. For Total N and Total P, the model simulations fall within the range of observed values. Although on average the model predicts higher peak Total N values, the difference may reflect that the observed values are captured only at few points between peaks and valleys.

Table E-9

Final parameter values after calibration.

	<b>Parameter</b>		<b>Rattlesnake Creek</b>	<b>Duncan Run</b>	<b>Long Run</b>	<b>Sugar Creek</b>
Catchment	Thickness, Layer 1	cm	11.1	8.9	1.0	4.7
	Thickness, Layer 2	cm	2.0	106.9	25.3	4.9
	Thickness, Layer 3	cm	20.0	15.8	7.5	9.5
	Thickness, Layer 4	cm	6.0	7.6	5.0	11.5
	Horiz. Hydr. Conduct., Layer 1	cm/d	6.0	110.3	150.0	94.4
	Horiz. Hydr. Conduct., Layer 2	cm/d	8.3	84.0	78.8	119.1
	Horiz. Hydr. Conduct., Layer 3	cm/d	53.6	60.5	35.0	107.0
	Horiz. Hydr. Conduct., Layer 4	cm/d	1.0	58.0	21.0	40.5
	Saturation Moisture, Layer 1	-	0.50	0.25	0.32	0.41
	Saturation Moisture, Layer 2	-	0.32	0.28	0.38	0.39
	Saturation Moisture, Layer 3	-	0.42	0.52	0.26	0.38
	Saturation Moisture, Layer 4	-	0.28	0.35	0.25	0.35
	Field Capacity, Layer 1	-	0.25	0.25	0.17	0.30
	Field Capacity, Layer 2	-	0.25	0.24	0.25	0.29
	Field Capacity, Layer 3	-	0.25	0.24	0.18	0.26
	Field Capacity, Layer 4	-	0.25	0.24	0.18	0.25
	Initial Moisture, Layer 1	-	0.33	0.24	0.26	0.27
	Initial Moisture, Layer 2	-	0.32	0.26	0.20	0.28
	Initial Moisture, Layer 3	-	0.34	0.24	0.20	0.28
	Initial Moisture, Layer 4	-	0.20	0.29	0.20	0.24
	Adsorption NO <sub>3</sub> , Layer 1	L/kg	6.0	6.3	5.0	5.8
	Adsorption NO <sub>3</sub> , Layer 2	L/kg	7.0	2.8	5.0	6.3
	Adsorption NO <sub>3</sub> , Layer 3	L/kg	8.0	4.7	5.0	6.7
	Adsorption NO <sub>3</sub> , Layer 4	L/kg	5.0	5.8	6.0	1.8
	Adsorption PO <sub>4</sub> , Layer 1	L/kg	70	650	500	44
	Adsorption PO <sub>4</sub> , Layer 2	L/kg	80	300	100	44
	Adsorption PO <sub>4</sub> , Layer 3	L/kg	70	200	200	40
	Adsorption PO <sub>4</sub> , Layer 4	L/kg	80	200	250	37
	Initial Concentrations NO <sub>3</sub> , Layer 1	mg/L	2.50	2.82	0.50	0.41
	Initial Concentrations NO <sub>3</sub> , Layer 2	mg/L	2.40	0.30	0.50	0.40
	Initial Concentrations NO <sub>3</sub> , Layer 3	mg/L	2.40	1.60	0.50	0.36
	Initial Concentrations NO <sub>3</sub> , Layer 4	mg/L	2.00	1.90	0.50	0.36

Table E-9 (continued)  
 Final parameter values after calibration.

	<b>Parameter</b>		<b>Rattlesnake Creek</b>	<b>Duncan Run</b>	<b>Long Run</b>	<b>Sugar Creek</b>
	Initial Concentrations PO4, Layer 1	mg/L	0.13	0.23	0.04	0.10
	Initial Concentrations PO4, Layer 2	mg/L	0.12	0.14	0.05	0.26
	Initial Concentrations PO4, Layer 3	mg/L	0.12	0.15	0.04	0.11
	Initial Concentrations PO4, Layer 4	mg/L	0.11	0.12	0.04	0.30
	Evaporation Magnitude	-	0.60	0.60	0.60	0.60
	Evaporation Skewness	-	0.61	0.61	0.61	0.61
	Precipitation Weighting factor	-	1.24	1.30	1.13	1.17
	Soil erosivity factor	-	0.22	0.08	0.05	0.07
River	Initial Water Depth	m	1.0	1.0	1.5	2.5
	Initial sediment depth	m	1.0	0.5	1.5	1.5
	Sediment diffusion rate	m <sup>2</sup> /d	0.0001	0.00029	0.0001 7	0.00007 1
	Initial Nitrate Concentration (Sediment)	mg/kg	3.00	0.86	0.16	0.24
	Initial Nitrate Concentration (Water)	mg/L	2.40	2.50	0.78	0.26
	Initial Phosphate Concentration (Sediment)	mg/kg	0.12	0.12	0.10	0.26
	Initial Phosphate Concentration (Water)	mg/L	0.10	0.36	0.13	0.40
	Adsorption, Nitrate, Sediment	L/kg	15.0	6.3	2.5	3.3
	Adsorption, Nitrate, Water	L/kg	5.0	6.5	5.0	9.8
	Adsorption, Phosphate, Sediment	L/kg	15000	15000	16000	7000
Adsorption, Phosphate, Water	L/kg	15000	15000	16000	7000	

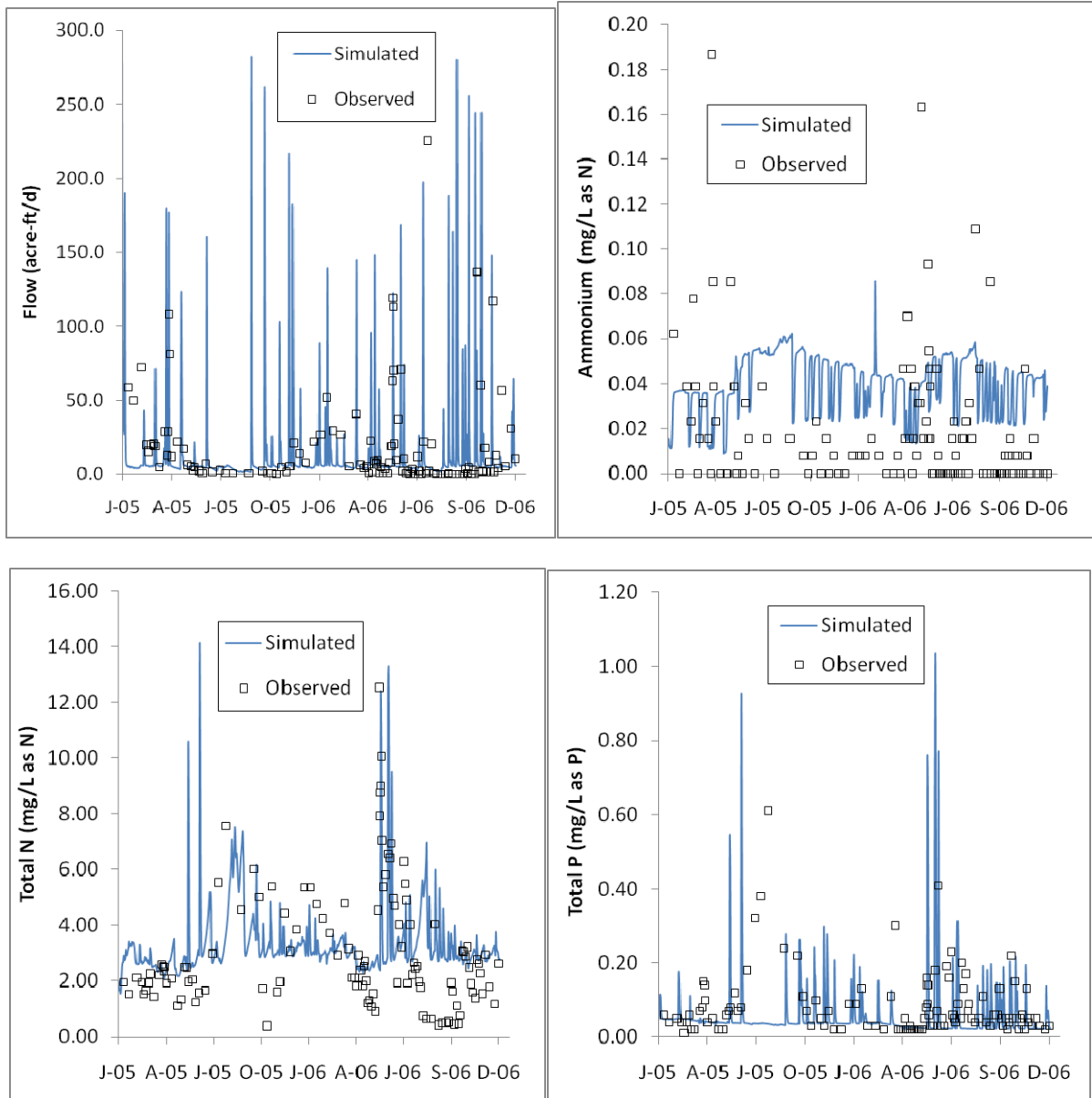


Figure E-12  
 Calibration results for Long Run

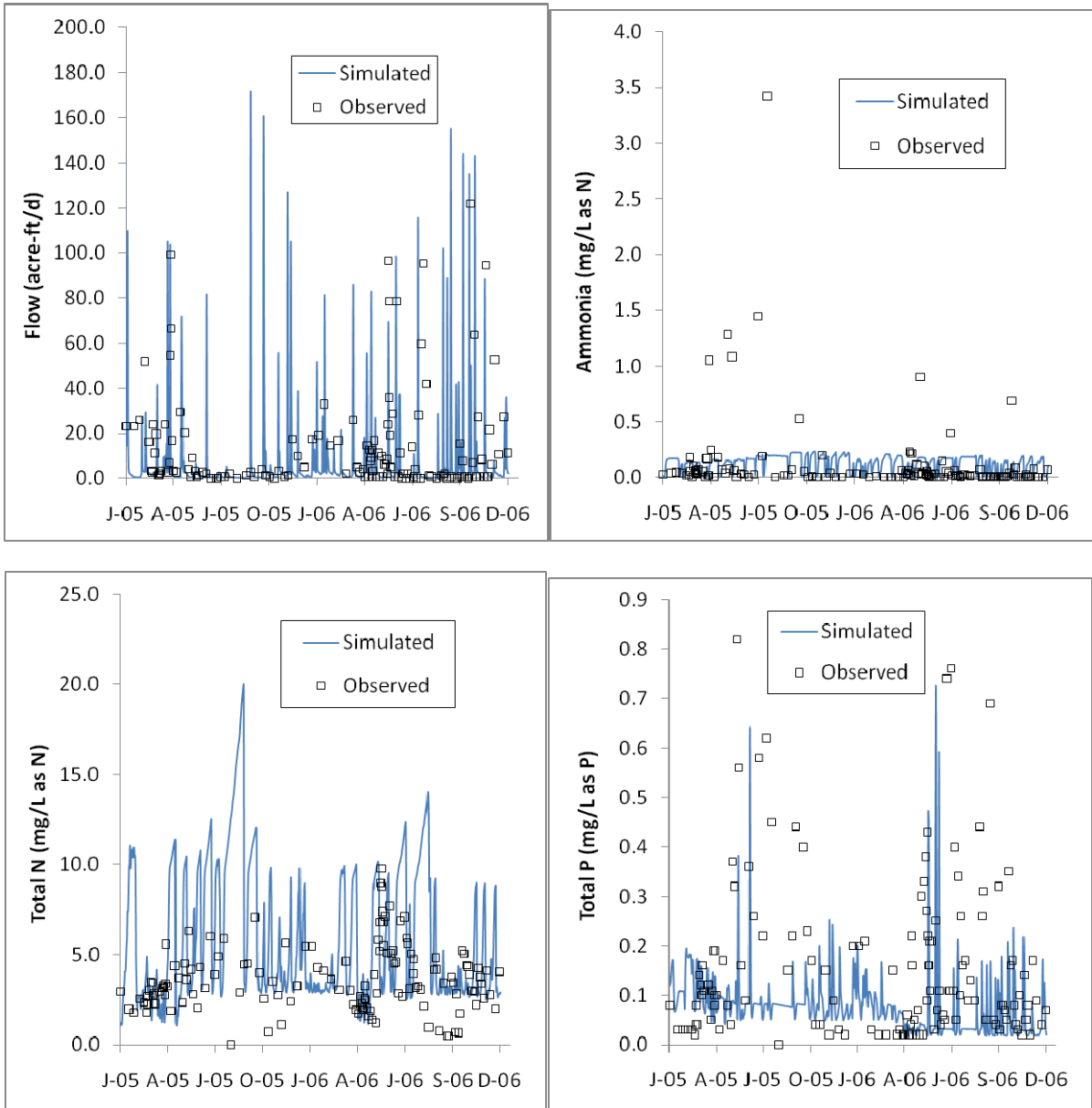


Figure E-13  
 Calibration results for Sugar Creek

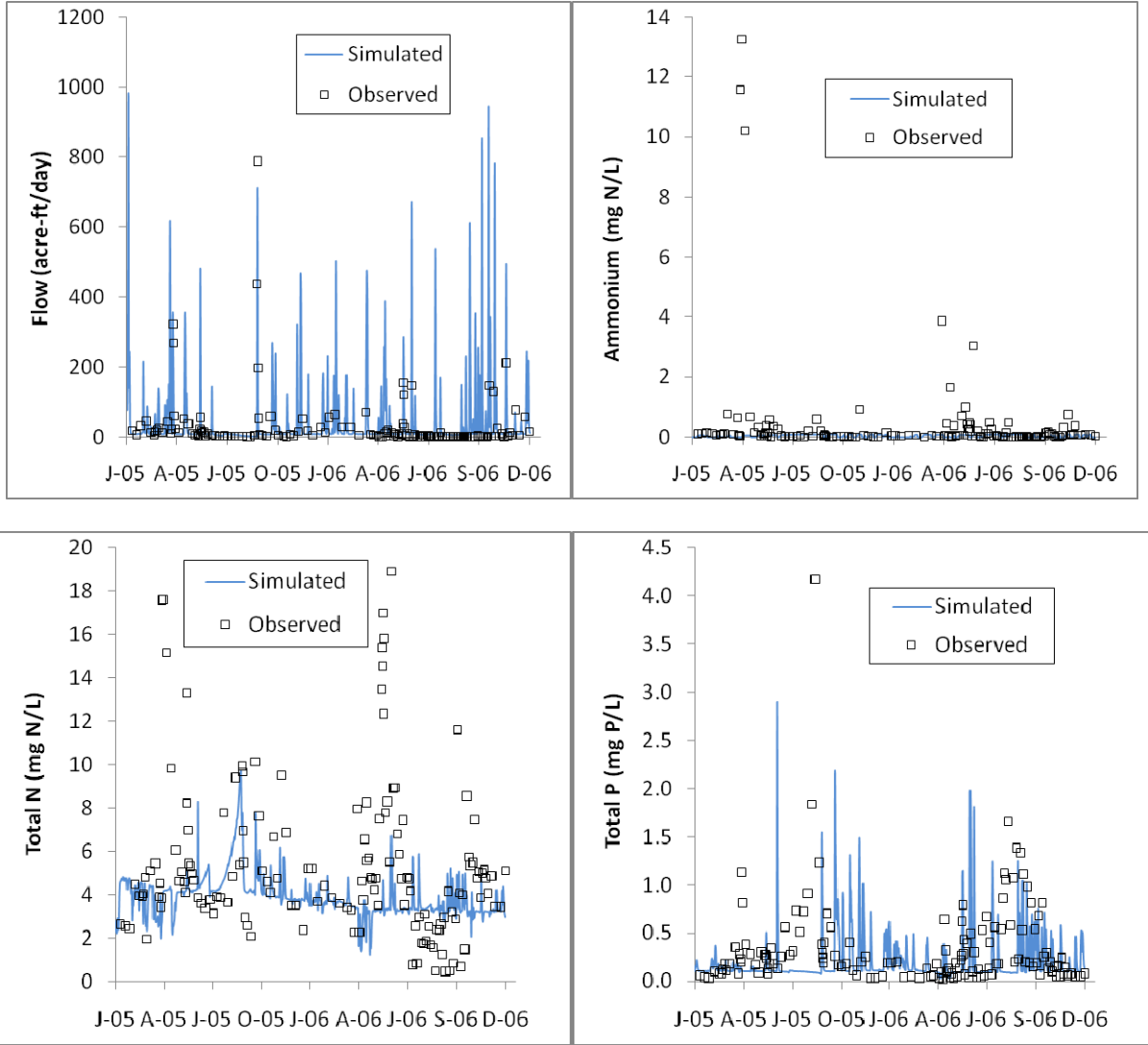


Figure E-14  
 Calibration results for Rattlesnake Creek

Rattlesnake Creek presents some important differences to the previous creeks, since it has a significant number of septic systems that discharge in the headwaters of the creek, thus increasing the nutrient load in the groundwater that eventually discharges to the creek. The flow calibration resulted in a comparable baseflow with the observed values, and several of the simulated storm events had peaks of similar magnitude as the observed values, although based on the meteorology there should have been additional storm events. The low ammonium concentrations were predicted well by the model, although there were a few very high

observed values, possible discharges from retention ponds, that were not predicted. This was similar to the simulation of Total N, which predicted well the baseflow concentration, but did not predict two major high events in August of 2005 and 2006. The range of Total P concentrations were matched well, although the timing was different between the model and the observed values, due mostly to the mismatch in storm event timing.

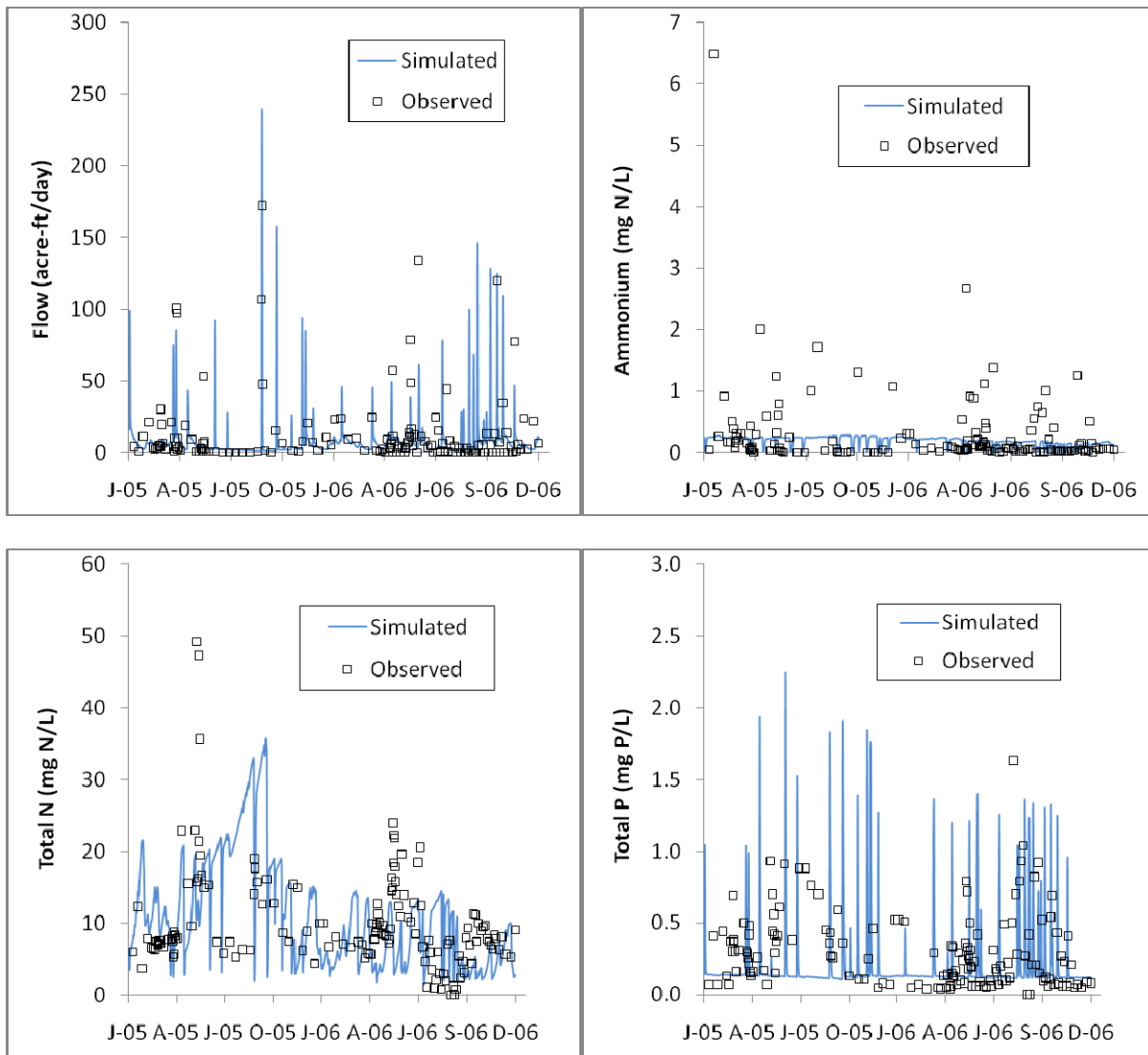


Figure E-15  
Calibration results for Duncan Run

The calibration of Duncan Run produced a reasonable match for the hydrology, adequately predicting most of the major storms and the baseflow. As with the other catchments, there were some storms predicted by the model based on the meteorological information which did not result in significant observed flow. Although for the most part observed ammonium concentrations were low and within the simulated values, there were a number of observed values which were considerably higher, perhaps due to discharges from stagnant ponds/pools or other sources of ammonium within the streams. The Total N and Total P levels were generally matched reasonably well, although there were two events in the spring of 2005 and 2006 that resulted in higher Total N than predicted based on the model input

data. The model also tends to over predict the peak Total P concentrations in this catchment, which was not the case for the other CEAP catchments.

### **Modeling the UBWC watershed response using WARMF**

Once the hydrologic and water quality calibration was completed, the parameter values were applied to the rest of the watershed. The model was then run to evaluate the response for various catchments within the watershed. Since the hydrologic and water quality response is different for the mainstem of the UBWC and the tributaries, these are generally described separately below. In addition, catchment numbering is

done automatically by the BASINS delineation; for clarity the numbering is presented in Figure E-16. As expected, flow increases progressively going from the headwaters, down the mainstem, and to the outlet of the UBWC watershed (Figure E-17). Since the reservoir was not explicitly modeled, the flows below catchment 60 in the mainstem are only for illustration, and do not necessarily reflect the movement of water within the reservoir. The flow in the tributaries is a function of their size, thus ranged from 1 to 225 acre-ft/day. Some tributaries were large enough to have continuous flow throughout the year, while others were ephemeral, with no flow conditions in parts of the year.

Water quality along the mainstem of the UBWC reflected a different pattern than flow (Figure E-18).

Total Nitrogen (TP) concentrations increase from upstream to downstream; TN increases are most rapid in the headwaters, and stabilize at high concentrations mid-stream at the confluence with Little Walnut Creek. Nitrate concentrations exhibit the same trend and parallel TN. Total Phosphorus (TP) and ammonium ( $\text{NH}_4^+$ ) concentrations increase only slightly from the headwaters to the Hoover Reservoir. We attribute slow increases of TP to the fact that phosphate concentrations are strongly controlled by the ability of benthic sediments to adsorb dissolved phosphate from the water column. Because ammonium oxidizes rapidly to nitrate under aerobic conditions, concentrations remain low.

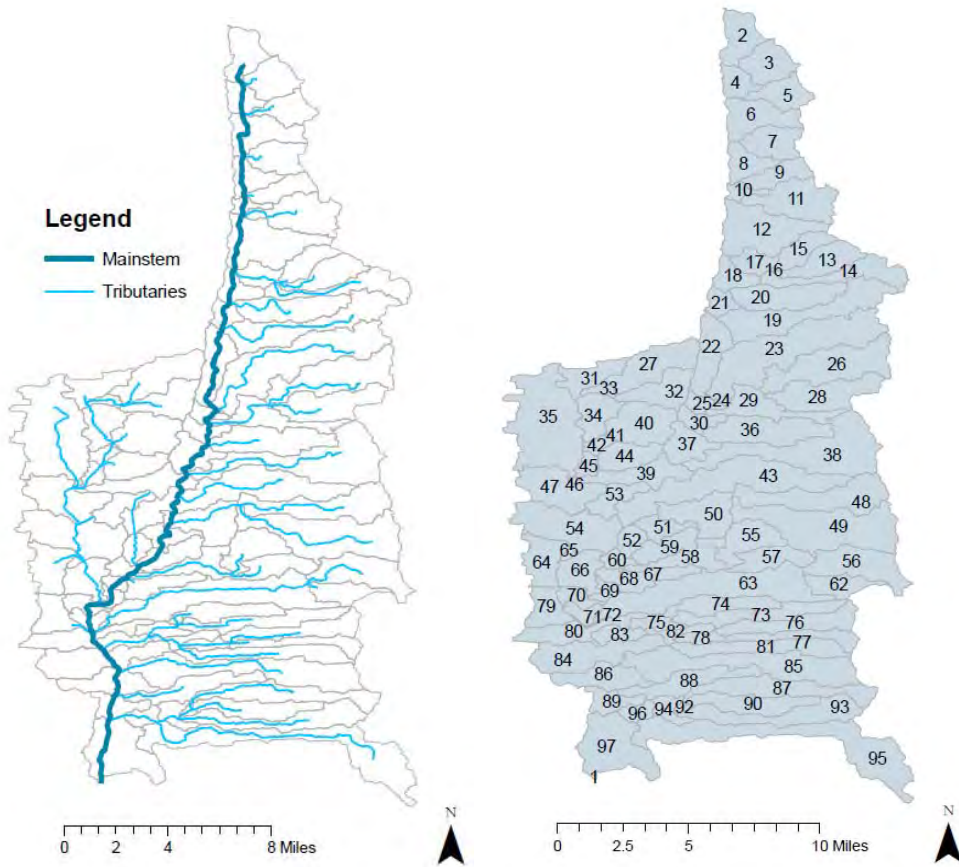


Figure E-16  
 Definition of UBWC mainstem and tributaries, and catchment numbering in WARMF model, based on BASINS delineation



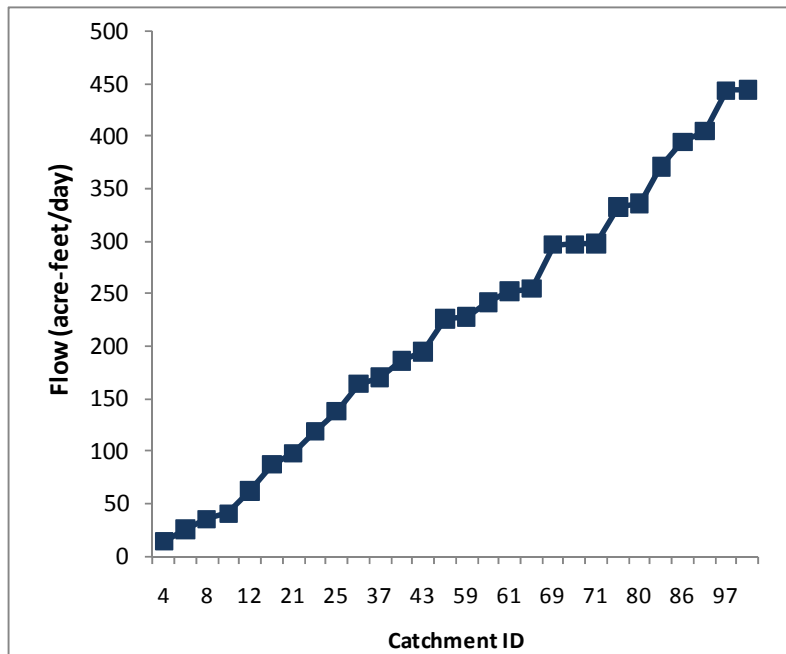


Figure E-17  
Flow by catchment within the mainstem of the UBWC.

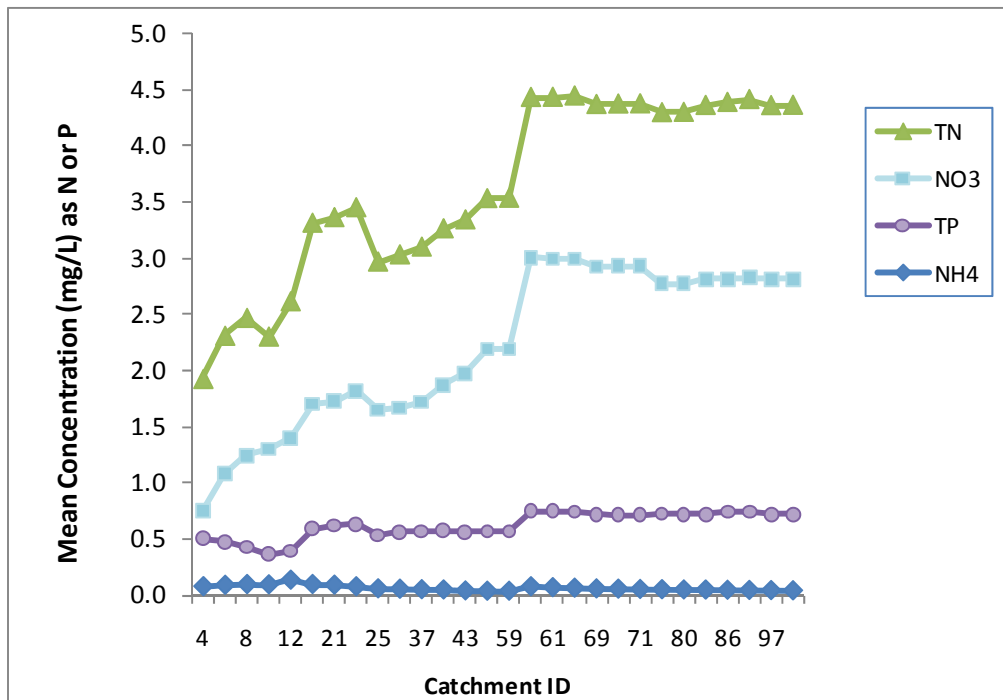


Figure E-18  
Mean nutrient concentrations in the mainstem of UBWC

Figure E-19 presents the mean TN and TP concentrations in various catchments of UBWC, illustrating those regions that are expected to have low, medium and higher concentrations. The thresholds

were set arbitrarily, as there are no specific water quality objectives for TN and TP in this region. This information can be used to determine potential “hot spots” (reaches with high concentrations), to be included in a monitoring program, and which are more

likely to benefit from a nutrient trading program and the implementation of BMPs. As with flow, the simulated concentrations in the reservoir in the lower portion of UBWC are only illustrative, and may not reflect the actual concentration levels in the reservoir.

The mean nutrient load increases consistently from the headwaters to the discharge of the mainstem of the UBWC (Figure E-20), for both TN and TP. The step

increase in catchment 60 is due to the load delivered by the Little Walnut Creek.

As indicated in Table E-10, the nutrient concentrations were lower in the tributaries than in the mainstem, and generally lower for the western tributaries compared to the eastern ones, reflecting the differences in streamflow and fertilizer application for the different regions.

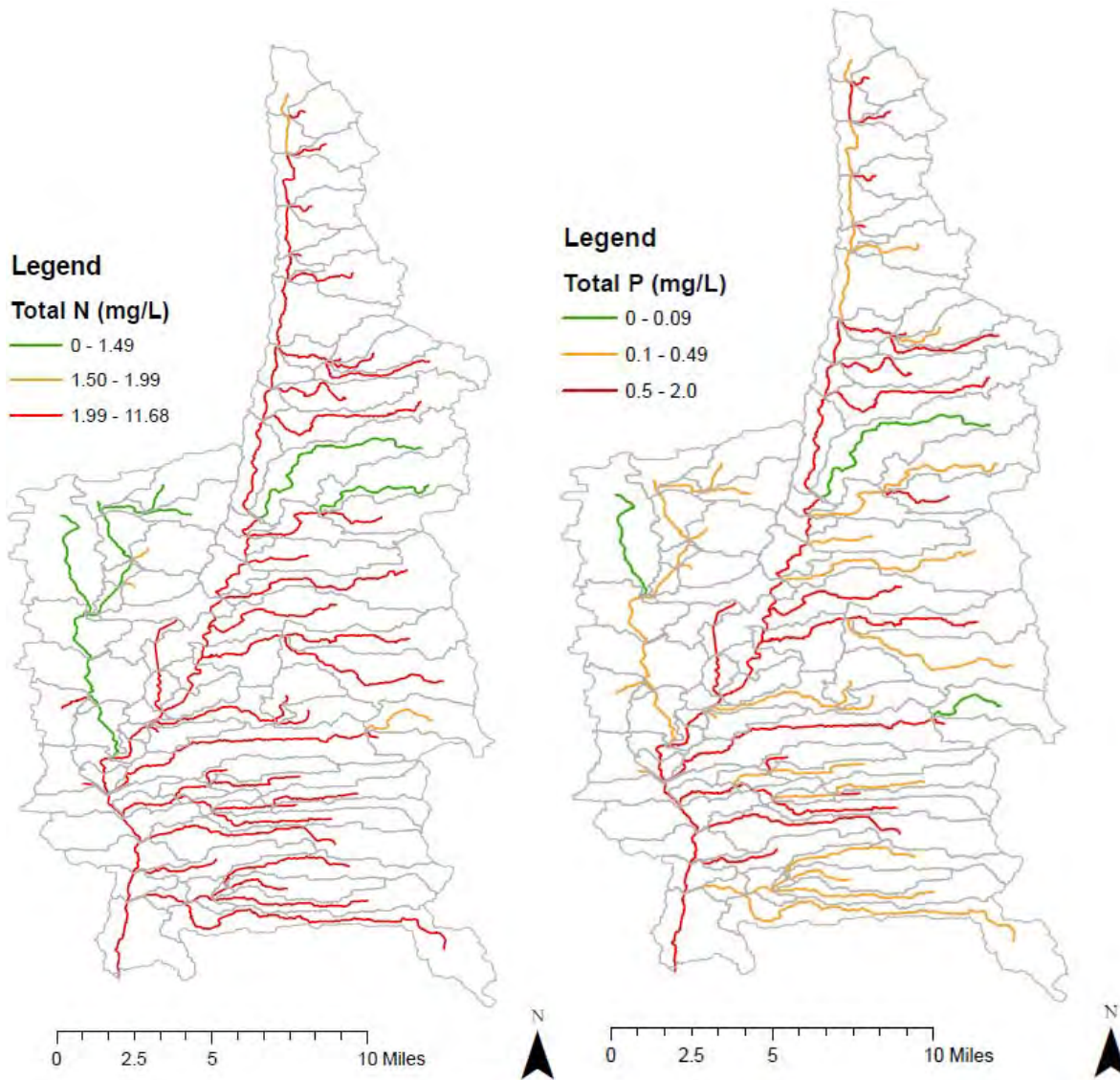


Figure E-19  
 Mean nutrient concentrations in the UBWC, as predicted by WARMF.

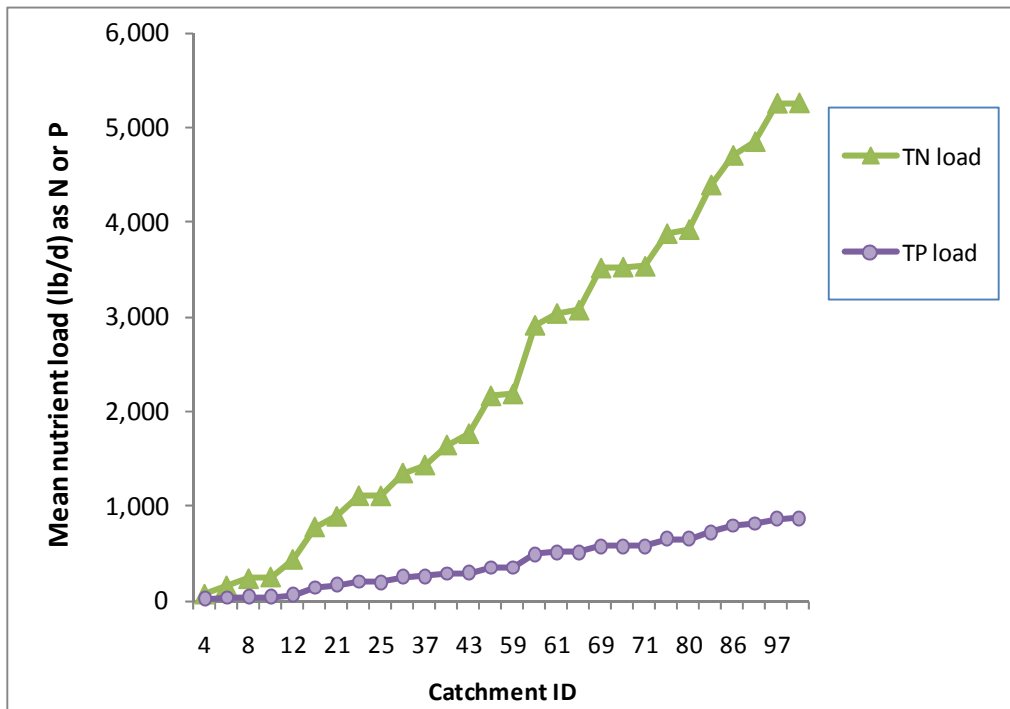


Figure E-20  
Mean nutrient load (lb/day) in the mainstem of UBWC

Table E-10  
Mean nutrient concentrations in different sections of UBWC (mg/L as N or P).

	NH <sub>4</sub>	NO <sub>3</sub>	TN	TP
Eastern Tributaries				
average	0.14	1.64	2.81	0.45
std. dev.	0.05	0.63	0.97	0.29
Western Tributaries				
average	0.12	0.76	1.23	0.14
std. dev.	0.03	0.28	0.40	0.08
Mainstem UBWC				
average	0.07	2.20	3.62	0.62
std. dev.	0.02	0.70	0.81	0.12

### Modeling of BMPs using WARMF

The following BMPs were modeled using the WARMF model: Nutrient Management, No Till,

Cover Crops, Row Cropping conversion to Alfalfa, Convert to Corn/Soybean/Winter Wheat rotation and Tile Drainage. WARMF parameter values were adjusted as indicated below to obtain reductions that are similar to those observed with the NTT model (Table

E-11) at the farm level for different soils and crops within UBWC. Since each catchment in the WARMF model has its own mix of crops and soils, the results

cannot be compared directly between the two models, but can be used to determine whether the simulated reductions are reasonable.

Table E-11

Average TN and TP reductions simulated by NTT for different crops and soils in UBWC.

	TN reduction	TP reduction
No till	19%	42%
Cover Crop	30%	41%
Alfalfa	95%	92%
Tile Drainage	22%	2%

### Nutrient Management BMP

For Nutrient Management, the WARMF model was used to explore a 25% decrease or increase in fertilizer application from the recommended values presented in Table E-3. This allowed us to predict a response to a fertilizer load increase or decrease for each catchment, since the response is mostly linear within this range. A separate response was developed for TN and for TP. These responses can then be used to evaluate a different percentage of load reduction, within the range evaluated. The slope of the response, which reflects the sensitivity of the concentrations in a given catchment to a percent change in nutrient load, increases from headwaters to discharge of the UBWC (Figure E-21). This indicates that nutrient management within the watershed has a much greater impact on the concentrations at the outlet than in the upper reaches of the watershed. The y-intercept for TN is strongly dependent on the location on the mainstem, increasing rapidly from headwaters to outlet, while the y-intercept

for TP was much less dependent on location on the mainstem (Figure E-22). This reflects the increasing load for TN as it leaches out from the soils into the streams and into UBWC, while TP is more strongly retained by the soils and sediments due to adsorption.

The nutrient response of the tributaries was not as significant as for the mainstem, with TN slopes for the eastern tributaries of 15 and 1.7 (mg/L %) for the western tributaries, and TP slopes of 6.4 and 0.7 (mg/L %) for the eastern and western tributaries, respectively. However, there is a significant difference between tributaries. Thus, the nutrient concentrations in some of the catchments will respond much more strongly to nutrient management than others. It is generally the rule that catchments in UBWC with higher loading have a stronger response to nutrient management. Some exceptions may occur when there are other sources of nutrient loads, such as a high number of septic systems in a given catchment.

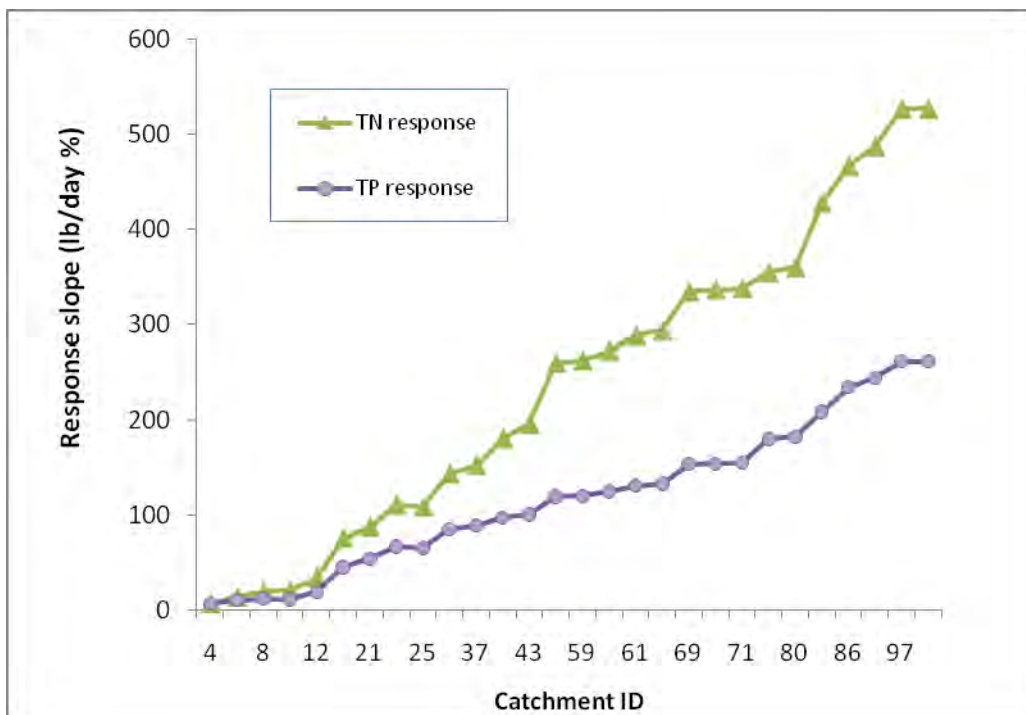


Figure E-21  
 Response slope of the concentrations to percent changes in nutrient application, in the mainstem of UBWC

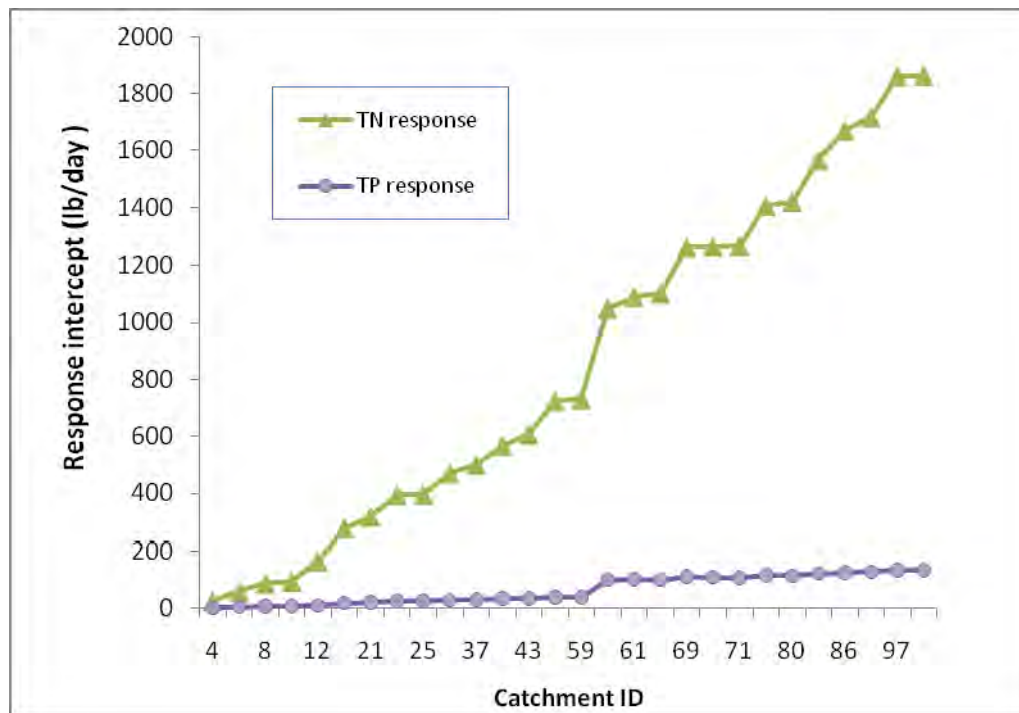


Figure E-22  
 Response intercept of the concentrations to percent changes in nutrient application, in the mainstem of UBWC

## No Till BMP

No Till was modeled by reducing the soil erosion parameters that are specific to each land use, specifically the Rainfall Detachment Factor and the Flow Detachment Factor. The values were reduced to 0.01 and 0.1, respectively, for corn, soybean and winter wheat uses, as well as the combinations of these land uses. This results in a noticeable decrease in sediment export, and thus a decrease in the associated TP export (Table E-12). There is a reduction of around 25% in TP export from the tributaries, and 12 % in the mainstem of UBWC. This BMP had a much lower

effect on TN, with a decrease of 5-15% in the tributaries, and actually a net increase in net TN export in the mainstem of around 6%. This net increase is likely due to less assimilation of the TN load in the water column by algae, due to the decrease in TP. However, there is significant variance for this net increase, and it would be advisable to confirm this response with water quality monitoring. In conclusion, No Till appears to be more effective in reducing TP export than TN export, and is more effective in reducing the TN loads in the tributary streams than in the mainstem of UBWC.

Table E-12

Effect of different BMPs on TN and TP for the tributaries and mainstem of UBWC.

	TN				TP			
	No Till	Cover Crop	Alfalfa	C/S/W *	No Till	Cover Crop	Alfalfa	C/S/W *
<b>Eastern Tributaries</b>								
average	5%	26%	47%	14%	24%	40%	34%	28%
std. dev.	11%	19%	18%	24%	15%	21%	33%	23%
<b>Western Tributaries</b>								
average	15%	42%	52%	34%	25%	42%	21%	39%
std. dev.	6%	6%	11%	12%	9%	13%	12%	13%
<b>Mainstem UBWC</b>								
average	-6%	3%	31%	-6%	12%	15%	29%	4%
std. dev.	5%	4%	5%	3%	5%	8%	10%	5%

\* Corn/Soybean/Wheat rotation

## Cover Crop BMP

Cover crop was modeled considering that the soils that normally are left uncovered after harvesting corn or soybean are covered in the winter, and that the Rainfall Detachment and Flow Detachment Factors were reduced to 0.025 and 0.1. In addition, the Leaf Area Index for the fall and winter months was kept at 3, and the Productivity at 4 kg/m<sup>2</sup>-yr. Thus, the net effect was to reduce sediment export, and there is an increase in the uptake of nitrogen as well due to the increased productivity. TP export in the tributary catchments decreased by an average of 40-42 %, with some variation, while TN export decreases by 26 to 42%, depending on the loads applied to each catchment. However, the overall impact on the mainstem of UBWC was reduced to a decrease of around 15% in TP export and 3% in TN export. In conclusion, cover crops can effectively reduce TP and TN loads in the tributary streams and to a lesser extent in the mainstem.

## Conversion to Alfalfa BMP

The conversion of current crops to alfalfa was modeled simply by considering the same values for all crops as for alfalfa, which means no nitrogen application, and although there is less productivity, the crop grows for a longer period of the year, with the soil covered by a crop throughout the fall and winter. Thus, it shows a strong net decrease in TN and TP, of around 30% for each at the outlet of UBWC. Different catchments exhibit a stronger response, depending on the level of fertilizer application they would receive if the normal crops (corn, soybean, wheat) were grown. While it is highly unlikely that all this cropland would be converted to alfalfa, mostly for economic reasons, this hypothetical scenario shows that cropland that is converted to alfalfa can result in a much lower nutrient export.

The more plausible conversion to a corn/soybean/winter wheat practice would also result in a decrease in TP export of around 4%. It could result in a net TN export of around 6%. As before, these numbers have a significant amount of variance associated with them, and it would require careful monitoring of water quality in a region predominantly using this rotation to determine more accurate parameter values for the WARMF model. In conclusion, conversion of a cropland to alfalfa can result in the greatest reduction in TN and TP, with greater reductions in the loads of the tributary streams than the mainstem.

## Tile Drainage BMP

Tile Drainage was simulated in WARMF by considering taking out shallow groundwater (using the pumping function) and discharging it into a drainage channel that connects directly to the stream segment in that catchment (a diversion into the stream). Tile drainage is assumed to be in operation during the high traffic periods, namely April-May and August-September. The model will drain the shallow groundwater at a constant rate until either the specified drainage rate is met for the day, or the groundwater layers are dry. This drainage extracts the groundwater with the nutrients that have accumulated in the pore water. For the simulations, a total removal of groundwater via tile drainage of 0.5 inches/day was considered. The amount needed for each catchment was calculated considering the number of cropland acres in that area. A tile drainage system was then considered for each catchment, and the individual catchment and aggregate response were simulated.

Overall the flow increased by around 5-6%, with a higher increase for the western tributaries (around 15%) than for the other catchments. For the upper eastern tributary streams, there was a typical decrease in TN loads from around 6 to 23 %, respectively. However, there were a number of catchments where the net effect was to increase the TN load in the creeks, resulting in a higher loading. The model predicts that at the beginning tile drainage results in a decrease in the TN load export, but that as time progresses, there are some high peaks of TN discharged into the creeks which result in a net average increased load. Further fine tuning of the tile drainage simulation (and actual conditions) will be needed to determine whether it is possible to always have a net decrease in TN loads in every catchment, and the conditions that lead to this desired outcome. For the mainstem reaches, initially there was a decrease in TN loading, since they reflected the lower loads in the upper eastern tributaries. However, as the loads of the western tributaries and the lower eastern tributaries increased, eventually the gains were eliminated and the net effect was an increased export of TN load at the outlet of the watershed of around 10%. In the case of TP, there was also a net decrease in the upper eastern tributaries, but the western tributaries in general had a net TP load increase under tile drainage. The net effect in terms of TP export out of the watershed was an increase of around 6%.

These examples of the implementation of simulated BMPs in the UBWC watershed are meant to illustrate the capability of the model to represent these operations. While efforts were made to generate reasonable results, in terms of the trends and magnitudes of the changes, it will be necessary to obtain monitoring data at a high level of temporal detail (e.g. daily or weekly) to calibrate the WARMF model more precisely. This would be necessary for any model. We can use NTT to provide guidance on the magnitude of the effect of the BMPs on nutrient loads at the edge of the field, but to model them at the large watershed scale requires water quality data at that scale.

### **Fate & Transport Attenuation Factors**

One key objective of the nutrient trading program is to determine the “trading ratios” that will be used to provide credits for nutrient load reductions. This requires an evaluation of the “fate and transport attenuation” that occurs as nutrient loads that are added or removed at one location in the watershed are assimilated by the biota along the transport pathways. For example, nutrients are taken up by algae and other aquatic plants in the river reaches, which reduces the overall load. Nitrogen that enters the river as ammonia can be oxidized (nitrified) to nitrate. Under anaerobic conditions in the sediments, nitrate can be reduced (denitrified) to either nitrous oxide gas or nitrogen gas, which bubble up and leave the catchment into the atmosphere. On the other hand, nitrogen and phosphorus that are taken up by vegetation and aquatic life and then are released as organic N and P, which can be further decomposed into other forms of N and P. These processes take time, so attenuation is a function of travel time along a particular pathway, and the nature of the pathway.

To determine the response of a nutrient load applied to one catchment to the nutrient concentrations and loads in other catchments, we simulated a hypothetical point source release at a rate of 2.2 lb/day (1 kg/d) of N and P. For N, we assumed that 50% of the release was in the form of ammonium and 50% as nitrate, while for P we assumed it was 100% as phosphate. The hypothetical point source was moved from catchment to catchment, and then the response of the downstream catchments was observed. Since there are 97 catchments in the

WARMF model of the UBWC, this was done for all 97 catchments. The resulting matrix of Fate & Transport Attenuation Factors is presented in 97 x 97 table of results, for each water quality constituent. At present, the matrices for TN and TP were developed. The attenuation factors are based on the change in mean load (as opposed to the change in concentration) at a given location, since that reflects best the impact of a load reduction or increase. The changes are all normalized to the change in the catchment in which the load is applied. Thus, the change for the catchment where the load is applied is 0%. A positive attenuation factor indicates that the load has decreased by a given % as it travels downstream. A negative attenuation factor indicates an increase in load; this can result since the capacity to attenuate the load may be minimal during very low flow conditions, and thus it actually increases the load in a few downstream reaches. This was typically observed for catchments where there were low or no flow conditions frequently.

The entire 97 x 97 matrices for TN and TP are presented in Appendix B. For illustration, Figure E-23 presents the attenuation factors for TN in four different catchments within UBWC. Due to the numbering algorithm in BASINS during the delineation, Catchment 2 is at the beginning of the watershed and Catchment 1 is at the outlet. However, the progression is mostly linear from Catchment 2 to 97, progressing downstream from the headwaters. TN attenuation is higher if the load is reduced in the headwaters (Catchment 2) but generally decreases as one proceeds to catchments downstream (e.g. 11 and 18). Attenuation is also a function of the size of a catchment, since a larger catchment will collect more rainwater and thus the impact of the load locally and downstream will be lower.

The attenuation factors can be interpreted as indicating the percent attenuation of a load increase or decrease. Thus, the location of the load reductions within a catchment are very important for calculating the credits that can be given, as well as the distance between a load reduction and the location of the buyer of the credit. While a similar trend is observed in the TP attenuation factors (Figure E-24), there are noticeable differences, based on the important differences in the biogeochemistry of N and P.



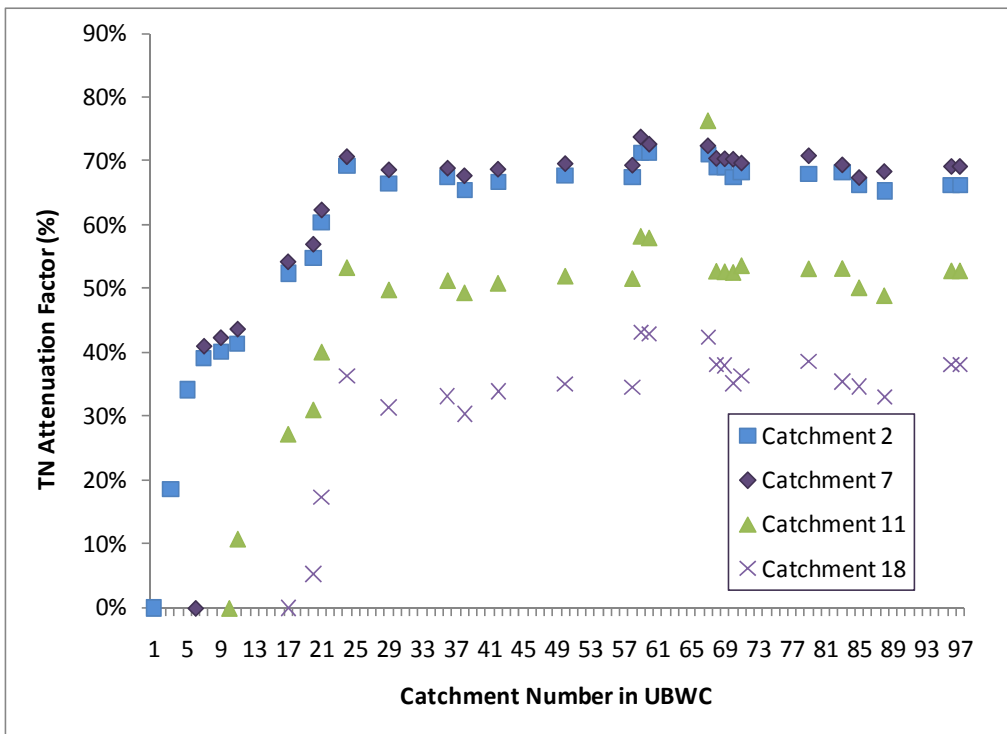


Figure E-23  
Examples of TN attenuation factors along the UBWC

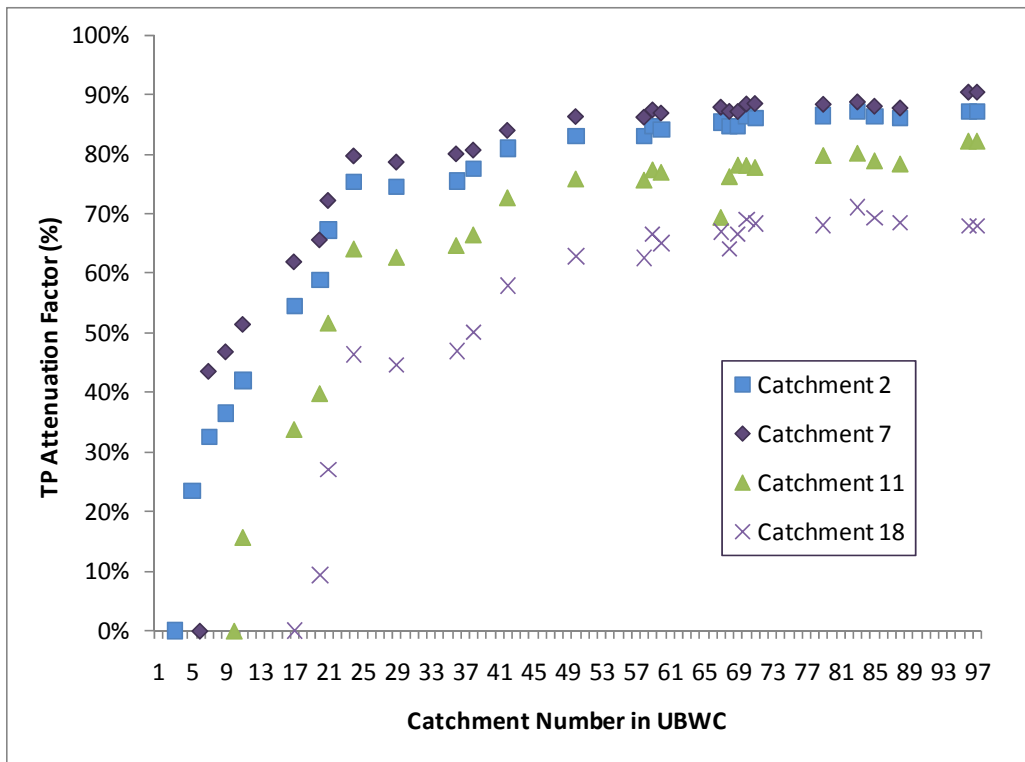


Figure E-24  
Examples of TP attenuation factors along the UBWC

To evaluate whether the magnitude and direction (increase or decrease) would affect the attenuation factors, a study was conducted with Catchment 2. If the hypothetical source load is increased by a factor of 10, the attenuation factors are essentially the same (Figure E-25). However, when the hypothetical point source is negative (i.e. instead of releasing 2.2 lb/day, the source extracts 2.2 lb/day of N and P from the river), there are

some small but noticeable differences in the attenuation factors (Figure E-25), which tend to increase slightly with distance down gradient from the catchment where the change was made. Note that for these catchments far away from the increase or decrease, the changes in concentration are quite small, and rounding errors may affect the calculation of the attenuation factors.

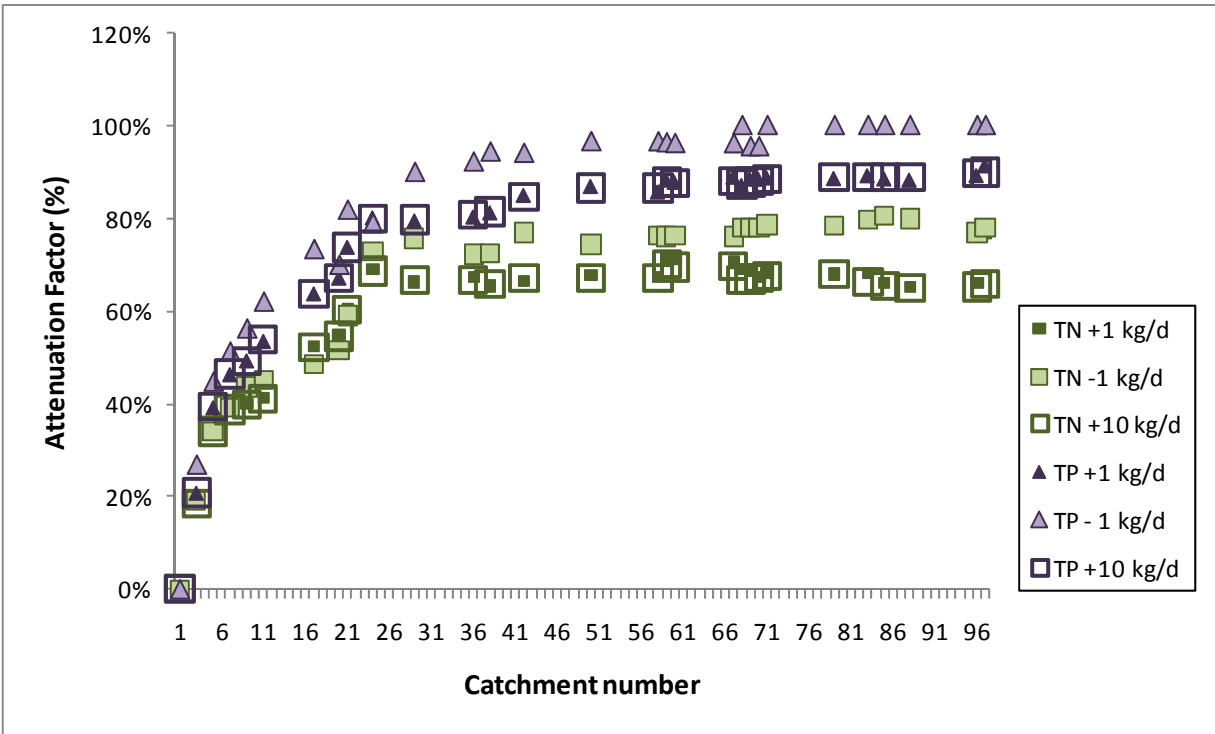


Figure E-25  
Sensitivity of TN and TP attenuation factors for Catchment 2 to different loads.

### Sensitivity Analysis

A sensitivity analysis was performed for all the WARMF model parameters that directly or indirectly influence hydrologic and nutrient processes, to determine which parameters would be most important for determine the model output (flow and concentrations in the tributaries and mainstem of UBWC). Since this process is rather time-intensive, we used one of the calibrated catchments, Sugar Creek, as the basis for the analysis. The information resulting

from the sensitivity analysis can be used to further refine the calibration of the watershed.

The sensitivity analysis was done on a single-parameter at a time basis, varying a parameter by +50% and -50% of its calibrated value, or +/- 50% of the range of literature values for the parameter. The simulation output for flow, ammonium, nitrate, total nitrogen and total phosphorus was then collected and compared to the original output. The effect of the change (directly or inversely correlated) is also noted.

Table E-13

Sensitivity analysis for flow in Sugar Creek catchment, UBWC.Units per WARMF.

Process	Parameter	Original value	Range	Δ50%	Effect on Flow
Catchment Specific Coefficients					
Storage	Detention	0.00	0-25	10	<b>0.0</b>
Water velocity	Manning's coefficient	0.10	0.01-0.4	0.2	<b>-0.6</b>
Meteorology	Precipitation Weighting	1.12		0.56	<b>257.4</b>
Groundwater transport Layer 1	thickness	4.30	1-100	10	<b>-33.6</b>
	initial moisture	0.30	0.2-0.6	0.1	<b>0.2</b>
	field capacity	0.35	0.1-0.4	0.398-0.353	<b>11.4</b>
	saturated moisture	0.40	0.2-0.6	0.15	<b>-8.6</b>
Groundwater transport Layer 2	horizontal conductivity	180	1-200	100	<b>0.0</b>
	vertical conductivity	79	1-100	50	<b>0.0</b>
	thickness	4.80	1-100	10	<b>-8.0</b>
	initial moisture	0.31	0.2-0.6	0.1	<b>0.2</b>
Groundwater transport Layer 3	field capacity	0.30	0.1-0.4	0.342-0.295	<b>9.8</b>
	saturated moisture	0.34	0.2-0.6	0.15	<b>-5.4</b>
	horizontal conductivity	119	1-200	100	<b>0.1</b>
	vertical conductivity	79	1-100	50	<b>0.0</b>
Groundwater transport Layer 4	thickness	6.09	1-100	10	<b>-5.4</b>
	initial moisture	0.31	0.2-0.6	0.1	<b>0.0</b>
	field capacity	0.28	0.1-0.4	0.305-0.279	<b>5.3</b>
	saturated moisture	0.31	0.2-0.6	0.15	<b>-3.7</b>
Groundwater transport Layer 4	horizontal conductivity	164	1-200	100	<b>0.2</b>
	vertical conductivity	24	1-100	50	<b>0.0</b>
	thickness	16.56	1-100	10	<b>-1.0</b>
	initial moisture	0.20	0.2-0.6	0.1	<b>2.3</b>
Groundwater transport Layer 4	field capacity	0.15	0.1-0.4	0.287-0.154	<b>0.8</b>
	saturated moisture	0.29	0.2-0.6	0.15	<b>-5.5</b>
	horizontal conductivity	1	1-200	100	<b>13.9</b>
	vertical conductivity	24	1-100	50	<b>0.0</b>
Watershed-wide (system) Coefficients					
Snow/Ice Melting Rate	Open Area	0.08		0.04	<b>0.5</b>
	Forested Area	0.08		0.04	<b>0.1</b>
Evaporation Coefficients	Magnitude	1.00		0.50	<b>-24.1</b>
	Skewness	1.00		0.50	<b>6.9</b>

The results of the sensitivity of flow in Sugar Creek to variations in catchment and watershed-wide parameters are presented in Table E-13. The model is most sensitive to precipitation weighting, which is a parameter that assigns a weight to the precipitation from the meteorological station, to increase or decrease the amount of water received. Clearly, this parameter plays a major role in the total amount of water that flows through the catchment and into the creek. Other parameters that play an important role are the magnitude and skewness of the evaporation coefficients, which are negatively correlated, meaning that an increase in evaporation will result in less flow, as expected. Similarly, the thickness of the soil layers is very important, and is negatively correlated, since an increase in soil thickness of a layer results in more water stored in groundwater, reducing flow in the creek. Also important are the saturated moisture and horizontal hydraulic conductivity. An increase in saturated moisture (capacity) results in more water storage in groundwater, leading to reduced flows. An increase in horizontal hydraulic conductivity results in more flow out of the soil layer into the creek, so it is positively correlated. The other parameters don't play a significant role in predicting flow in this catchment. A similar behavior would be expected for other catchments.

The results of the sensitivity of the four water quality parameters (ammonium, nitrate, total nitrogen and total phosphorus) for Sugar Creek are presented in Table E-17 in Attachment C. Of paramount importance are five parameters that are related to hydrology, namely precipitation, evaporation coefficients (magnitude and skewness), soil layer thickness, soil saturated moisture and the soil hydraulic conductivity. These model parameters have a significant effect on almost all of the concentrations of nutrients, with total nitrogen and nitrate exhibiting the higher sensitivity. Other soil parameters that influence total nitrogen and nitrate concentrations in the river are soil erosivity, ammonium and nitrate adsorption coefficient, soil cation exchange capacity, and the initial concentration of nitrate in the soil. Land use (crop) specific factors that influence total nitrogen and nitrate concentrations in the river are the flow detachment factor, cropping factor, long-term growth factor, leaf growth factor, crop productivity, annual nutrient uptake distribution, and plant composition.

The information obtained from these sensitivity analyses can be used to perform an uncertainty analyses

for the attenuation factors and for the performance of the BMPs. These uncertainty analyses were beyond the scope of the current project. To perform these uncertainty analyses, it would be best to select a catchment with observed data (such as Sugar Creek) and perform a stochastic simulation, i.e. running the WARMF model for this catchment for several thousand runs, varying the sensitive parameters randomly and then evaluating the impact on the output. While it may seem daunting to run thousands of simulations, each run for a single catchment takes about 8 sec in a state-of-the-art personal computer, thus it is quite feasible. A limitation at this point is the software tools to collect and analyze the output of thousands of simulations, specific for this catchment.

Based on the results of the study of attenuation factors, it appears that for most catchments the load decrease or increase would be attenuated within a few reaches. The highest uncertainty would be associated with the nearer attenuation factors, where the change in load has only been attenuated by 20 or 40%. These attenuation factors are likely to have a +/- 10% uncertainty associated with them. For attenuation factors further from the location where the change was made, where attenuation is 80, 90 or 99%, the uncertainty is smaller, and likely to be only 1-5%.

### **Application of results to Ohio River Basin Water Quality Trading Program**

The intention of this project was to evaluate the combined use of WARMF and NTT for modeling the fate and transport of fertilizer loads from the farm field to the rest of the watershed, and eventually to the entire Ohio River Basin. More important to the water quality trading program is modeling the potential impacts of different BMPs on water quality improvements, and the Fate and Transport (F&T) Attenuation Factors that should be applied to a particular load reduction or increase in a given section of a watershed. Using NTT results at the farm level for conventional practices and BMPs, the WARMF model was able to evaluate the larger scale impact of these practices. It should be noted that since we did not have available site-specific information on current practices (i.e. whether some of the BMPs considered here, or others, are being applied), the model results presented in this study do not take this into consideration. The F&T Attenuation Factors suggest rapid attenuation of load reductions or increases, within a few reaches of the location where the change was implemented. These results are directly

applicable to the Ohio River Basin water quality trading program.

In addition, the WARMF model can be used to predict “hot spots” and thus identify areas that may be of higher priority for the water quality trading program, as well as for monitoring. The model can also be used to assess 1) the scale and type of BMPs which must be adopted to result in reductions of specific nutrients, and 2) the downstream distance at which load reductions will be effective. For example, the model can be used to determine how an increase in the load discharged from an existing point source can be offset by implementing BMPs in the surrounding area.

As was clear during the calibration of the WARMF model, additional monitoring data will certainly be useful to make better predictions, particularly with regards to the effectiveness of the various BMPs. The longer these datasets are, the better the calibration, since it provides a broader range of conditions. The datasets should include not only flow and water quality information, but also information on the specific crops and BMPs that have been practiced within the study area. As additional data become available, it is recommended that recalibration of the WARMF model is done at least every two years. The effort to recalibrate the model is relatively minor, and the benefits could be substantial in terms of reducing the uncertainty in the predictions, and providing validity to the results.

## Conclusions and Recommendations

The WARMF model was implemented for the Upper Big Walnut Creek watershed, using available information. Local flow and water quality data is rather limited, which placed some challenges for calibrating the model. Nevertheless, some important conclusions can be drawn:

- Nutrient concentrations are lower in most of the tributaries compared to the mainstem of UBWC;
- TN loads increase relatively rapidly and constantly from the headwaters to the discharge of UBWC, while TP loads increase much more slowly;
- Nutrient management within the watershed has a much greater impact on the concentrations at the outlet than in the upper reaches of the watershed;
- Within a range of +/- 25% in the increase or decrease of nutrient loads from the recommended values, the UBWC WARMF model predicts a

linear response, which simplifies the evaluation of nutrient management activities;

- Catchments with higher current nutrient loading have a stronger response to nutrient management. Some exceptions may occur when there are other sources of nutrient loads, such as a high number of septic systems in a given catchment;
- WARMF is capable of modeling the BMPs that were selected for this study, and the results are in a similar range as NTT predictions for tributary catchments;
- The effect of the BMPs is attenuated in the mainstem with lower reductions in nutrient concentrations than in the tributaries;
- In general the BMPs are more effective in reducing TP than TN, except for substituting alfalfa for corn, soybeans or winter wheat;
- One way to produce WQT location factors is described in this report. The Fate and Transport Attenuation Factors given here are specific for each catchment;
- Attenuation of a change in loading, considering a small load of discharged nutrients, occurs relatively rapidly down gradient from the location where the change is made;
- There are some differences in the attenuation factors for TN and TP, although the pattern of attenuation is the same;
- Predictions of flow and nutrient concentrations are most sensitive in the UBWC to hydrologic parameters, which indicates that the calibration could be improved if it is conducted simultaneously for all of these output parameters, rather than in the traditional stepwise approach;
- The uncertainty in the calculation of the attenuation factors is expected to be greater for locations nearer to the location where the change is made than for locations farther away.

The WARMF model can thus be used to support the Ohio River Basin water quality trading program, both in its development and in its ongoing improvement, as new data becomes available.

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## Attachment A.

Table E-14  
Crop parameter values used in WARMF for the UBWC watershed

<b>Crop (Landuse) Parameter</b>	<b>Units</b>	<b>Corn</b>	<b>Soy bean</b>	<b>Winter Wheat</b>	<b>Corn/ Soybean</b>	<b>Winter Wheat/ Soybean</b>	<b>Corn/ Soybean/ Wheat</b>	<b>Alfalfa</b>	<b>Grass Pasture Hay</b>
Open in Winter	unitless	0.9	0.9	0.2	0.9	0.2	0.2	0.2	0.5
Cropping Factor	unitless	0.35	0.36	0.15	0.35	0.1	0.22	0.1	0.05
Rainfall Detachment Factor	g/cm <sup>3</sup>	0.108	0.108	0.108	0.108	0.108	0.05	0.05	0
Flow Detachment Factor	kg/m <sup>4</sup>	0.9	0.9	0.9	0.9	0.9	0.5	0.1	0.9
Fraction Impervious	unitless	0	0	0	0	0	0	0	0
Interception Storage	cm	0.25	0.2	0.1	0.25	0.15	0.25	0.1	0.1
Long-term Growth	unitless	1	1	1	1	1	1	1	0.1
Leaf Growth Factor	unitless	1	1	1	1	1	1	1	1
Productivity	kg/m <sup>2</sup> /yr	3	3	3	3	3	3	2	1.5
Active Respiration rate of growth	day <sup>-1</sup>	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07	1E-07
Maintenance Respiration	day <sup>-1</sup>	5.8E-08	5.8E-08	5.8E-08	5.8E-08	5.8E-08	5.8E-08	5.8E-08	5.8E-08
Dry Collection Efficiency	unitless	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Wet Collection Efficiency	unitless	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Leaf Weight-Area Ratio	g/cm <sup>2</sup>	0.01	0.005	0.006	0.01	0.006	0.01	0.005	0.005
Canopy Height	m	2	0.8	1	2	1	2	0.5	0.8
Stomatal Resistance	s/cm	1.43	1.43	1.43	1.43	1.43	1.43	1	1.43
Leaf Area Index for May (monthly)	unitless	1	0.5	3	1	3	3	3	1.5



Table E-14 (continued)

Crop parameter values used in WARMF for the UBWC watershed

<b>Crop (Landuse) Parameter</b>	<b>Units</b>	<b>Corn</b>	<b>Soy bean</b>	<b>Winter Wheat</b>	<b>Corn/ Soybean</b>	<b>Winter Wheat/ Soybean</b>	<b>Corn/ Soybean/ Wheat</b>	<b>Alfalfa</b>	<b>Grass Pasture Hay</b>
Annual Uptake Distrib. for May (monthly)	unitless	0.3	0.3	0.3	0.3	0.3	0.083	0.2	0.3
Litter Fall Rate	kg/m <sup>2</sup> - month	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00001	0.00001
Exudation Rate for May (monthly)	day <sup>-1</sup>	0.0001	0.00015	0.00005	0.0001	0.00015	0.0001	0.0001	0.0001
Leaf Composition NH <sub>4</sub>	mg N/g dry weight	12.8	33.1	17.2	12.8	24.04	24.04	30.8	12.8
Leaf Composition PO <sub>4</sub>	mg P/g dry weight	5.51	10.7	5.82	5.51	5.82	5.52	5.82	2.45
Trunk CompositionN H4	mg N/g dry weight	12.8	33.2	17.2	12.8	24.0	24.0	30.8	12.8
Trunk Composition PO4	mg P/g dry weight	5.51	10.7	5.82	5.52	5.82	5.52	5.82	2.45





## Attachment C.

Table E-17  
Model parameters included in the N and P sensitivity analysis

		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
<b>Catchment Specific Coefficients</b>								
Sediment	soilerosivity factor	0.2		0.1	0.0	<b>2.1</b>	<b>10.0</b>	0.3
Meteorology	precip. weighting	1.12		0.56	<b>6.0</b>	<b>169.2</b>	<b>392.9</b>	<b>3.6</b>
Soil Layer 1	thickness	4.30	1-100	10	<b>18.2</b>	<b>-126.9</b>	<b>238.1</b>	<b>-2.0</b>
	initial moisture	0.30	0.2-0.6	0.1	0.0	0.0	0.0	0.0
	field capacity	0.35	0.1-0.4	0.398-0.353	<b>-4.6</b>	<b>152.0</b>	<b>234.9</b>	<b>-2.4</b>
	saturated moisture	0.40	0.2-0.6	0.15	<b>2.8</b>	<b>26.4</b>	<b>53.4</b>	0.5
	horiz. hydr. conduct.	180	1-200	100	0.0	0.2	-0.3	0.0
	vert. hydr. conduct.	79	1-100	50	0.0	0.0	0.0	0.0
	Soil Layer 2	thickness	4.80	1-100	10	-1.9	<b>-57.5</b>	-
							<b>108.5</b>	
initial moisture		0.31	0.2-0.6	0.1	0.0	0.0	0.1	0.0
field capacity		0.30	0.1-0.4	0.342-0.295	<b>-4.5</b>	<b>76.3</b>	<b>120.8</b>	-1.5
saturated moisture		0.34	0.2-0.6	0.15	4.0	<b>25.3</b>	<b>56.2</b>	1.0
horiz. hydr. conduct.		119	1-200	100	-0.1	-1.4	<b>-2.5</b>	0.0
Soil Layer 3	vert. hydr. conduct.	79	1-100	50	0.0	0.0	0.0	0.0
	thickness	6.09	1-100	10	<b>-2.6</b>	<b>-59.0</b>	-	-1.3
							<b>113.5</b>	
	initial moisture	0.31	0.2-0.6	0.1	0.0	0.0	0.2	0.0
	field capacity	0.28	0.1-0.4	0.30-0.279	1.7	<b>5.9</b>	<b>11.9</b>	-0.2
	saturated moisture	0.31	0.2-0.6	0.15	<b>5.7</b>	<b>9.7</b>	<b>29.3</b>	0.4
horiz. hydr. conduct.	164	1-200	100	0.5	<b>-3.9</b>	<b>-7.5</b>	-0.1	
vert. hydr. conduct.	24	1-100	50	0.0	0.0	0.0	0.0	

		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
Soil Layer 4	thickness	16.56	1-100	10	0.2	<b>-8.9</b>	<b>-18.7</b>	0.2
	initial moisture	0.20	0.2-0.6	0.1	0.2	0.1	0.6	0.0
	field capacity	0.15	0.1-0.4	0.287-0.154	<b>-2.4</b>	<b>-3.5</b>	<b>-12.4</b>	-0.7
	saturated moisture	0.29	0.2-0.6	0.15	0.5	<b>10.3</b>	<b>-26.6</b>	-0.8
	horiz. hydr. conduct.	1	1-200	100	<b>-5.8</b>	<b>-78.5</b>	-	-1.8
	vert. hydr. conduct.	24	1-100	50	0.0	0.0	0.0	0.0
Init. conc. Layer 1	NH4	0.28 mg/l		0.14	0.0	0.0	0.1	0.0
	NO3	0.3 mg/l		0.15	0.0	0.2	0.3	0.0
	PO4	0.163 mg/l		0.082	0.0	0.0	0.0	0.0
Soil Layer 2	NH4	0.28 mg/l		0.14	1	0.0	0.0	0.0
	NO3	0.3 mg/l		0.15	0.0	0.1	0.2	0.0
	PO4	0.163 mg/l		0.082	0.0	0.0	0.0	0.0
Soil Layer 3	NH4	0.28 mg/l		0.14	1	0.0	0.0	0.0
	NO3	0.3 mg/l		0.15	0.0	1.0	1.2	0.0
	PO4	0.163 mg/l		0.082	0.0	0.0	0.0	0.0
Soil Layer 4	NH4	0.28 mg/l		0.14	1	0.0	0.4	0.0
	NO3	0.3 mg/l		0.15	0.2	<b>5.1</b>	<b>7.0</b>	0.0
	PO4	0.163 mg/l		0.082	0.0	0.0	0.0	0.0
Water	NH4	0.1 mg/l		0.05	1		0.0	
	NO3	0.4 mg/l		0.2	0.0	0.1	0.1	0.0
	PO4	0.001		0.0005	0.0	0.0	0.0	0.0
Sediment	NH4	0.1-0.3		0.15	0.0	0.0	0.0	0.0
	NO3	0.035-1.492		0.7	0.0	0.0	0.0	0.0
	PO4	0.001		0.0005	0.0	0.0	0.0	0.0
Reactions Soil	Nitrification (d <sup>-1</sup> )	0.01		0.005	0.0	0.1	0.2	0.0

		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
	Denitrification (d <sup>-1</sup> )	0.01		0.005	0.0	0.0	0.0	0.0
Surface	Nitrification (d <sup>-1</sup> )	0		0.005	0.0	0.0	0.0	0.0
	Denitrification (d <sup>-1</sup> )	0		0.005	0.0	0.0	0.0	0.0
Canopy	Nitrification (d <sup>-1</sup> )	0.05		0.025	0.1	1.1	1.2	0.0
	Denitrification (d <sup>-1</sup> )	0		0.005	0.0	0.0	0.0	0.0
Biozone	Nitrification (d <sup>-1</sup> )	0.05		0.025	0.0	0.0	0.0	0.0
	Denitrification (d <sup>-1</sup> )	0		0.005	0.0	0.0	0.0	0.0
Water	Nitrification (d <sup>-1</sup> )	0.1		0.05	0.0	0.0	0.0	0.0
	Denitrification (d <sup>-1</sup> )	0		0.005	0.0	0.0	0.0	0.0
Sediment	Nitrification (d <sup>-1</sup> )	0		0.05	0.0	0.0	0.0	0.0
	Denitrification (d <sup>-1</sup> )	0.01		0.005	0.0	0.0	0.0	0.0
Cation Exchange Capacity	layer 1	36.68		18.34	1.1	0.9	<b>10.8</b>	0.0
	layer 2	12.22		6.11	0.4	0.5	1.9	0.0
	layer 3	9.31		4.655	0.3	0.5	1.7	0.0
	layer 4	2.16		1.08	0.6	-0.4	1.6	0.0
Adsorp. layer 1	NH4 (% of CEC)	1		0.5	0.7	0.6	<b>10.9</b>	0.0
	NO3 (L/kg)	15		7.5	0.0	<b>-4.2</b>	<b>-4.6</b>	0.0
	PO4(L/kg)	80		40	0.0	0.0	0.0	0.4
layer 2	NH4 (% of CEC)	1		0.5	0.4	0.2	1.4	0.0
	NO3 (L/kg)	15		7.5	0.0	0.1	0.1	0.0
	PO4(L/kg)	80		40	0.0	0.0	0.0	0.0
layer 3	NH4 (% of CEC)	1		0.5	0.2	0.2	0.8	0.0
	NO3 (L/kg)	15		7.5	0.1	0.1	0.3	0.0
	PO4(L/kg)	80		40	0.0	0.0	0.0	0.1
layer 4	NH4 (% of CEC)	1		0.5	0.4	0.1	0.8	0.0
	NO3 (L/kg)	15		7.5	0.0	0.1	0.2	0.0

		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
Water	PO4(L/kg)	80		40	0.0	0.0	0.0	0.4
	NH4	6234		3100	0.0	0.0	0.0	0.0
	NO3	0		7.5	0.0	<b>-9.7</b>	-0.2	0.0
Sediment	PO4 (L/kg)	15000		7500	0.0	0.0	0.0	0.0
	NH4 (L/kg)	6234		3100	0.0	0.0	0.0	0.0
	NO3 (L/kg)	0		7.5	0.0	0.0	0.0	0.0
Sediment	PO4 (L/kg)	15000		7500	0.0	0.0	0.0	0.0
	depth	0.5		0.25	0.0	0.0	0.0	0.0
<b>Watershed-wide (system) Coefficients</b>								
Snow/Ice	Open Area	0.08		0.04	-0.1	<b>-1.5</b>	<b>-5.8</b>	-0.1
Melting rates	Forested Area	0.08		0.04	0.0	-0.2	-0.5	0.0
Evap. Coeff.	Magnitude	1		0.5	<b>3.3</b>	<b>-63.1</b>	-	-1.3
						<b>118.7</b>		
	Skewness	1		0.5	-1.6	<b>31.7</b>	<b>57.6</b>	-0.7
Open in Winter	Corn	0.9		0.45	0.0	0.0	0.0	0.0
	Soybean	0.9		0.45	0.0	0.0	0.0	0.0
	Winter Wheat	0.2		0.1	0.0	0.0	0.0	0.0
	Grass, Pasture, Hay	0.5		0.25	0.0	0.0	0.0	0.0
Rainfall detach.	Corn	0.108		0.054	0.0	0.0	0.0	0.0
	Soybean	0.108		0.054	0.0	0.0	0.0	0.0
	Winter Wheat	0.108		0.054	0.0	0.0	0.0	0.0
	Grass, Pasture, Hay	0		0.054	0.0	0.0	0.0	0.0
Flow detach.	Corn	0.9		0.45	0.1	-0.8	<b>-3.7</b>	-0.1
	Soybean	0.9		0.45	0.0	0.5	<b>1.9</b>	0.0
	Winter Wheat	0.9		0.45	0.0	0.0	0.0	0.0
	Grass, Pasture, Hay	0.9		0.45	0.0	0.0	0.2	0.0
Cropping Factor	Corn	0.35		0.175	0.0	-0.8	<b>-3.0</b>	-0.1

		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
	Soybean	0.36		0.18	0.0	-0.6	<b>1.7</b>	0.1
	Winter Wheat	0.15		0.075	0.0	-0.2	-0.4	0.0
	Grass, Pasture, Hay	0.05		0.025	0.0	-0.1	-0.4	0.0
Fraction Imperv.	Low	0.3	0 - 1	0.3	0.0	-0.2	-0.4	0.0
	Med	1	0 - 1	0.5	0.0	-0.2	-0.4	0.0
	High	1	0 - 1	0.5	0.0	-0.2	-0.4	0.0
Intercept. Stor.	Corn	0.25		0.125	0.0	-0.2	-0.5	0.0
	Soybean	0.2		0.1	0.0	-0.2	-0.5	0.0
	Winter Wheat	0.1		0.05	0.0	-0.2	-0.5	0.0
	Grass, Pasture, Hay	0.1		0.05	0.0	-0.2	-0.6	0.0
Long-term Growth	Corn	1		0.5	-0.9	<b>-19.7</b>	<b>-44.1</b>	-0.7
	Soybean	1		0.5	-1.0	<b>-21.6</b>	<b>-48.6</b>	-0.5
	Winter Wheat	1		0.5	0.0	-1.5	<b>-3.7</b>	-0.1
	Grass, Pasture, Hay	0.1		0.05	0.0	-0.2	-0.5	0.0
Leaf Growth Factor	Corn	1		0.5	0.2	<b>4.0</b>	<b>5.3</b>	0.0
	Soybean	1		0.5	0.0	0.5	0.8	0.0
	Winter Wheat	1		0.5	0.0	0.2	0.5	0.0
	Grass, Pasture, Hay	1		0.5	0.1	0.7	1.0	0.0
Productivity	Corn	3		1.5	-0.4	<b>-7.3</b>	<b>-18.0</b>	-0.4
	Soybean	3		1.5	-0.9	<b>-16.1</b>	<b>-38.0</b>	-0.4
	Winter Wheat	3		1.5	0.1	-0.5	-1.4	0.0
	Grass, Pasture, Hay	0.1		0.05	0.0	-0.2	-0.5	0.0
Dry collection efficiency	Corn	0.6		0.3	0.0	-1.0	-1.9	0.0
	Soybean	0.6		0.3	0.0	0.5	1.0	0.0
	Winter Wheat	0.6		0.3	0.0	0.2	0.6	0.0



		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
Wet Collection Efficiency	Grass, Pasture, Hay	0.6		0.3	0.0	0.7	1.5	0.0
	Corn	0.9		0.45	0.0	0.7	1.5	0.0
	Soybean	0.9		0.45	-0.1	0.6	1.3	0.0
	Winter Wheat	0.9		0.45	-0.1	0.5	1.1	0.0
Leaf Weight/area	Grass, Pasture, Hay	0.9		0.45	0.0	0.5	1.2	0.0
	Corn	0.01		0.005	0.0	0.4	0.9	0.0
	Soybean	0.005		0.0025	0.0	-0.4	-0.9	0.0
	Winter Wheat	0.006		0.003	0.0	-0.4	-0.9	0.0
Canopy Height	Grass, Pasture, Hay	0.005		0.0025	0.0	-0.5	-1.0	0.0
	Corn	2		1	0.0	-0.5	-1.0	0.0
	Soybean	0.8		0.4	0.0	-0.5	-1.0	0.0
	Winter Wheat	1		0.5	0.0	-0.5	-1.0	0.0
Leaf Area Index	Grass, Pasture, Hay	0.8		0.4	0.0	-0.5	-1.0	0.0
	Corn				0.0	0.4	0.7	0.0
	Soybean				0.0	-0.2	-0.5	0.0
	Winter Wheat				0.0	-0.4	-0.8	0.0
Annual Uptake Distribution	Grass, Pasture, Hay				0.0	-0.2	-0.5	0.0
	Corn				-0.4	<b>-8.7</b>	<b>-20.5</b>	-0.4
	Soybean				-1.2	<b>-18.0</b>	<b>-41.9</b>	-0.4
	Winter Wheat				0.0	-0.9	<b>-2.1</b>	0.0
Exudation Rate	Grass, Pasture, Hay				0.0	-0.5	-1.0	0.0
	Corn				0.0	-0.5	-1.0	0.0
	Soybean				0.0	-0.5	-1.0	0.0
	Winter Wheat				0.0	-0.5	-1.0	0.0
	Grass, Pasture, Hay				0.0	-0.5	-1.0	0.0

		Original Value	Range	$\Delta=50\%$	NH4	NO3	TN	TP
Litter Fall rate	Corn				0.0	-0.5	-1.0	0.0
	Soybean				0.0	-0.5	-1.0	0.0
	Winter Wheat				0.0	-0.5	-1.0	0.0
	Grass, Pasture				0.0	-0.5	-1.0	0.0
Leaf Composition	Corn			0.4	0.0	-0.5	-1.0	0.0
	Soybean			0.4	0.0	-0.5	-1.0	0.0
	Winter Wheat			0.4	0.0	-0.5	-1.0	0.0
	Grass, Pasture, Hay			0.4	0.0	-0.5	-1.0	0.0
Trunk Compos.	Corn				-0.2	<b>-5.8</b>	<b>-13.7</b>	-0.3
	Soybean				-0.4	<b>-12.7</b>	<b>-29.3</b>	-0.3
	Winter Wheat				-0.1	-0.9	<b>-2.1</b>	0.0
	Grass, Pasture, Hay				0.0	-0.5	-1.0	0.0
Litter Decay Rate	Litter Decay Rate	1		0.5	0.0	-0.5	-1.0	0.0
	Fine Litter	0.06		0.03	0.0	-0.5	-1.0	0.0
	Humus	0.005		0.0025	0.0	-0.5	-1.0	0.0
Fraction of Leachable Ions	Litter	0.1		0.3	0.0	-0.5	-0.9	0.0
	Fine Litter	0.25		0.3	0.0	-0.5	-1.0	0.0
	Humus	0.7		0.3	0.0	-0.5	-1.0	0.0
	Nonstructural	0.05		0.2	0.1	-0.5	-1.1	0.0

# Appendix F: Economic Evaluation of Conservation Practices

This appendix was prepared in its entirety by Tarleton University, under contract with EPRI.

## F.1. Introduction

NTT's role in water quality trading is focused on providing estimates of the changes in nutrient and sediment losses that result from implementation of conservation practices. NTT does not directly estimate water quality credits. In addition, the scope of NTT excludes any estimation of the costs to farmers of conservation practice implementation or any other associated economic impacts. The limitations of the scope of NTT imply that any additional tools needed for a WQT program (besides edge-of-field pollution reductions) must be developed outside of the NTT tool. In addition to tools that estimate conservation practice costs, these include tools or watershed models that estimate adjustment factors needed to calculate water quality credits, and implement credit registries, and other market infrastructure.

The focus of this chapter is on how to integrate economic evaluation of conservation practices as an additional piece of information farmers can use to make informed decisions in a WQT program. Besides the number of WQT credits they can sell, the cost implications of conservation practice implementation are by far the most important information – from the farmer's point of view – in a WQT program. This chapter outlines the types of economic models or tools available and how the appropriate tools can be integrated into a WQT platform to inform producers.

## F.2. Role of Economics

The concept of WQT is itself an economic phenomenon. For many decades, economists have advocated emissions trading as a means by which regulated entities can achieve pollutant reduction targets at lower cost. However, it was not until the past decade that WQT has been embraced in a significant way in the agricultural sector. Point sources of pollution, on the

other hand, have been involved in WQT programs for several decades. The rationale of WQT is based on the marginal principle that underlies the profitability of all business enterprises. Essentially, if regulated entities are allowed to trade pollutants, then those who can reduce levels of the pollutant at lower marginal cost will tend to offer greater reductions, some of which they can sell at profit to those entities that have much higher abatement costs. This way both trading parties gain – the firm with lower abatement costs will gain by selling the WQT credits at a price higher than their marginal abatement costs, and the firm with higher abatement costs will buy the credits at a price lower than their marginal abatement cost. This is the traditional win-win scenario that drives WQT. If there are concerns about pollutant distribution and the spatial and temporal ramifications, some allowances or buffers can be established, which will reduce the arbitrage opportunities, but nonetheless, will not eliminate entirely the gains from credit trading. Notwithstanding the significant role of economic principles in the foundation of WQT programs in themselves, economic tools are also critical from the farmer's point of view. Critical information gaps exist as to the cost entailed in (or more broadly the economic implications of) implementing conservation practices as credit generating investments. Land owners would like to ensure that the cost of the conservation practice over its useful economic life does not exceed the income that accrues from the sale of the credits generated by the practice. Farm economic models can fill this information gap by providing producers with reasonable estimates of the farm-level economic impacts of alternative conservation practices. Thus economic models can serve as a guide to aid farmers in selecting the most appropriate conservation practices.

## F.3. Types of Economic Models

Economists have developed a wide variety of models and tools for evaluating the costs and benefits of policies, practices, and other scenarios related to agriculture. The types of applications of economic models range from farm or field level budgeting to price, demand, supply, and production forecasting at the

global scale. There are models that evaluate the total economic benefits of a policy or practice of interest, while others look solely at the cost to regulated entities. In short, there are a variety of economic models for assessing any kinds of problems or issues related to agriculture (see for example, Bosch et al., 2008 for a review of economic models for TMDL assessment). For the purposes of evaluating costs of conservation practices and determining preferred practices for water quality trading, there are two main types of economic models based on design – simulation models and optimization models. The following gives a brief overview of both kinds of economic models.

### **F.3.1. Economic Simulation Models**

Economic simulation models are models that are designed to mimic the observed practices and behaviors of the farms or other entities being modeled with no regard to what is the preferred behavioral response. That is, simulation models do not seek to improve or optimize the economic situation. They simply mimic what is going on, or what would prevail under the scenario of interest. Examples of simulation models are Farm Level Income and Policy Simulation Model (FLIPSIM; Richardson and Nixon, 1981; Richardson et al., 1993; AFPC, 2005), Farm-level Economic Model (FEM; Osei et al., 2000a, 2000b, 2000c; Gassman et al., 2002), and Agricultural Drainage and Pesticide Transport (ADAPT; Westra et al., 2004). In actual practice, there are numerous economic simulation models that are employed to evaluate agricultural practices and policies on a daily basis, but most of these models are of site specific application and do not enjoy a wide range of application. Simulation models have the advantage of providing relevant information on the current economic situation (profits, costs, revenues, etc.) or the situation that would exist under a given scenario of interest. Due to the complexities inherent in many systems, certain assessments can only be evaluated by simulation models since optimization algorithms may not truly converge to an optimal solution in certain cases.

### **F.3.2. Economic Optimization Models**

Economic optimization models are models that seek to maximize or minimize some objective function, such as profits or costs, subject to various constraints. For instance, a farm optimization model may be designed to maximize farm profits subject to constraints on land availability, prices of inputs and outputs, and constraints

on crop yields or livestock production. Optimization models seldom reflect the prevailing situation in practice, but rather focus on determining the optimal (“best”) outcome in a given situation. For instance, an optimization model could be used to determine the most cost-effective implementation of conservation practices in a WQT program, not necessarily what farmers actually implement.

The traditional framework of a farm optimization model entails the choice of input levels to maximize farm profits  $\pi$ , subject to traditional input resource constraints, natural limits on crop and livestock production rates, and a host of other constraints. Profits are defined as total revenue (R) minus total costs (C), both functions of the output level, Q:

$$\pi(Q) = R(Q) - C(Q)$$

Since output depends on input levels choice of input values determines the output level and consequently profits. In a WQT program farmers do not only have to deal with the choice of nutrient application rates, seed, herbicides, and other farm inputs; they also have to decide what conservation practices would be implemented, and all these choices impact revenues and costs. An economic optimization model can be used to determine the optimal conservation practice that will be consistent with the farmer’s overall production objectives. In many applications, it may be most beneficial to integrate a suite of simulation and optimization tools. Simulation models can provide much needed data on the cost functions underlying complex farm situations. Output from simulation models can then be used in an optimization program to determine the optimal practice implementation profile for a given situation. Furthermore, some economic simulation models such as FEM (Osei et al, 2000a), include optimization submodules in order to mimic optimizations that are routinely performed on some farms.

### **F.4. Components of Farm Economic Models**

Farm economic models are designed to simulate the implications of farm decisions on farm-level economic indicators. While farm profits are the primary indicator of interest, economic models provide estimates of various cost and returns indicators as well. To adequately assess the full impacts of farm decisions on farm profits, costs and returns, holistic models that capture all relevant components of a farm enterprise are

preferred. However, in some situations partial budget analyses will suffice. The following is a categorization of the major components of a farm enterprise. Every component of a farm enterprise has implications for conservation practice implementation and the generation of water quality credits. A brief outline of each category is given below.

1. Cropping systems
2. Livestock systems
3. Manure and waste management
4. Facilities, structures and equipment
5. Land areas and characteristics
6. Farm energy generation and use
7. Exogenous factors.

### **F.4.1. Cropping Systems**

Virtually all farms have fields that are used to grow some crops. The cropping systems category includes all aspects of the farm that deal with crop rotations – crop, forage, or pasture management. For crop farms without livestock, the cropping systems category is the main aspect of the farm, and includes crop yields or forage growth, nutrient requirements, field operations, and use of raised feed and grain.

#### **F.4.1.1. Crop Yields and Forage Growth**

Crop yields are key aspects of farms that need to be captured in any economic model. While most economic models do not estimate crop yields, production functions exist that can be incorporated into economic models for yield estimation, or the yield data can be imported into economic models from other tools such as NTT. Crop yield information is crucial for evaluating various conservation practices. For instance, when a producer puts in a filter strip, it takes land out of production. The opportunity cost of implementing the filter strip is proportional to the per acre yield of the crop that was originally grown on the portion of the field where the filter strip is being implemented.

#### **F.4.1.2. Crop Nutrient Requirements**

Crop nutrient or agronomic requirements are a function of yield. Once yields are determined, agronomic requirements of nitrogen, phosphorus and other crop nutrients can be estimated. Nutrient requirements of crops are key factors in implementing a nutrient

management practice. In general, the higher the per-acre nutrient requirements, the greater the amount of nutrients that can be applied on each acre of land.

#### **F.4.1.3. Crop Operations**

Field operations for each crop refer to the specific tillage, planting, harvesting, and other operations that are performed during the growing season of the crop. Economic models estimate the costs of crop operations, and these estimates have a bearing on the relative profitability of many conservation practices. For instance, the relative profitability of no-till versus conventional tillage depends highly on the costs of tillage operations, costs of herbicide applications – which are often higher with no-till – as well as the costs of the other field operations that differ between the two tillage alternatives. Most of the crop operating costs are estimated in economic models using widely approved engineering coefficients and standards (ASAE 1995a; 1995b).

#### **F.4.1.4. On-Farm Crop or Forage Use**

Crop or forage output grown on-farm is either fed to livestock on the farm or sold. The behavioral assumptions underlying a farmer's decision to either feed the crop to livestock or to sell the crop can be crucial to on-farm nutrient cycling, and also impact the profitability of the farm enterprise.

#### **F.4.1.5. Crop or Forage Sales**

On crop farms, virtually all raised grain or forage is sold. On livestock farms, a portion is fed to livestock and the remainder is sold. The sale of crop accrues revenues with some offsetting costs, which often reflect marketing expenses and on-farm waste. Many farmers are now using sophisticated marketing techniques to enhance their farm profits.

### **F.4.2. Livestock Systems**

This category includes all livestock husbandry components, with the exception of manure handling. Manure handling is given special attention in a later section due to its critical role in water quality and other environmental issues. Livestock husbandry includes livestock inventory and product considerations, livestock husbandry operations, and livestock nutrition.

#### F.4.2.1. Livestock Inventory and Products

Most livestock operations consist of multiple livestock types of the same species (e.g., dairy calves, heifers, lactating cows, dry cows, and bulls) or even of different species. The types of livestock on a farm impact all other aspects of livestock management. Livestock inventory specifications detail the kinds of livestock on the farm, which impact inventory values, feed costs, and other economic indicators. Key livestock inventory information includes ranges and typical values for ages and weights, as well as the number of each species on the farm. Livestock products simply refer to all the livestock and milk, eggs, or other livestock products sold as well as any livestock purchased. Death and cull losses also affect livestock inventories. Sales and purchases of livestock and livestock products impact revenues and costs directly.

#### F.4.2.2. Livestock Husbandry Operations

Livestock operations include feeding, sick care, breeding, livestock moving on pasture, watering, and milking, among others. On smaller livestock enterprises, husbandry operations account for a greater share of livestock costs than on larger more capital-intensive farms. Some conservation practices such as intensive rotational grazing may entail significant changes in livestock husbandry operations.

#### F.4.2.3. Livestock Nutrition

Livestock feed accounts for a greater share of production costs than any other component of farm costs on most animal feeding operations. The livestock nutrition component includes farm decisions about ration choice and associated costs. On most livestock farms, feed rations are determined via a cost minimization process. Producers either solely or with the help of nutritionists or feed consultants, estimate how much of various feed items should be combined in the diet of each livestock species on the farm. Typically, desired yields or weight gains are predetermined and the ration is calculated subject to those targets. Because feed costs typically account for about half of operating costs on livestock farms either directly or indirectly, this component is of prime importance. Feed prices, livestock nutrient requirements, and feed nutrient composition are the three primary determinants of livestock rations. Conservation practices such as reduced phosphorus diets or phytase supplementation of the

diets of monogastric animals have impact on livestock ration choice.

#### F.4.2.4 Feed

Feeds refer to all the substances used as food for livestock. This includes grains, animal and plant byproducts, additives or supplements, and forages. The number of feed stuffs used in rations differs significantly depending on the type of livestock and the management practices used on the farm. On large animal feeding operations, feeds are the primary avenue of nutrient import into a farm.

#### F.4.2.5 Nutrient Content of Feeds

Given the nutrient requirements of livestock species, the amount of nutrients and the price per unit of a given feed stuff are two key determinants of ration composition. Nutrient contents are documented in National Research Council (NRC) publications and other nutrition references. Formulas for estimating nutrient requirements of livestock species as well as tabulated values are provided in the National Research Council's reference publications. Nutrient requirements can be calculated for the entire farm based on the distribution of the livestock species on the farm. For dairy cattle in lactation, nutrient requirements are a function of milk production levels, and to a lesser degree, maintenance and body weight gain. For other livestock species, nutrient requirements are primarily a function of body weight gain and to a lesser degree, other livestock byproducts. In addition to the nutrient requirements, most livestock operations determine rations based on certain upper bounds or tolerance limits on nutrient levels as well as other constraints on the intake of various feeds and total daily dry matter intake for all livestock species raised on the farm.

### **F.4.3. Manure and Waste Management**

Manure production and handling represents the most environmentally sensitive aspect of livestock operations. Changes to manure management practices can have significant impact on costs and returns of any livestock operation. Appropriate economic models for WQT programs should account for these aspects of livestock operations.

#### F.4.3.1. Manure and Manure Nutrient Production

Nutrient content and volume of manure is directly related to the number and types of livestock on the farm, as outlined in a previous section. Average values of manure production characteristics are tabulated in ASABE standards. These coefficients are multiplied by the corresponding number of livestock species to obtain total manure production characteristics for the farm. However, more farm-specific data are preferred if these are available. Manure characteristics of interest include the following:

- Total manure wet weight
- Total manure density
- Total urine weight
- Manure total solids
- Nitrogen (Total Kjeldahl Nitrogen – TKN)
- Ammonia nitrogen
- Phosphorus
- Orthophosphorus
- Potassium

The ASABE data (ASABE, 2005) provide means and standard deviations of these and other manure characteristics. In some cases, it might be necessary to use the mean plus one standard deviation, rather than just the mean, in order to obtain a more conservative estimate of the compositions of manure produced on the farm. Livestock manure also contains bacteria, which if not properly managed, can be a pollution concern in downstream waters. Once manure is produced, its economic impact on the farm depends on how it is handled and utilized or disposed of.

#### F.4.3.2. Manure Handling and Storage

Manure is handled in three main forms: solid manure, liquid manure (or slurry), and direct deposition of manure on pasture or cropland. Various handling options affect the characteristics of the manure in different ways, and consequently its impact on the environment and farm profitability.

##### *Solid Manure*

This refers to manure, high in organic content and dry solids, which is scraped from barns, buildings or open lot areas, or otherwise collected and handled in solid

form. Manure handled in this fashion is typically stored or hauled off and applied on land or processed through other means such as composting.

##### *Liquid Manure or Slurry*

This component of manure results from cleaning or flushing operations within farm buildings or from rain runoff that is captured in a containment structure such as a storage pond or lagoon. Liquid manure usually has a relatively high inorganic fraction, particularly inorganic nitrogen, due to mineralization. Liquid manure is often of very low total solids composition, and is typically applied on fields that lie closest to the confinement areas via irrigation or use of spreaders.

##### *Direct Deposition*

Direct deposition accounts for manure that is not collected and is chiefly deposited on pasture or cropland by grazing livestock. It is usually in solid form and is not subjected to the pre-land application losses that are characteristic of other manure handling options. Appropriate manure handling and storage requires the use of special structures and facilities and entails some regular operations not directly related to livestock production. The choice of storage or handling methods has an important bearing on the financial performance of the farm. For instance, totally enclosed manure storage structures are often very expensive but have the advantage of eliminating nearly all nutrient losses prior to land application.

#### F.4.3.3. Storage and Handling Losses

Various changes in chemical composition occur before collected manure is applied on land. These transformations lead to nitrogen losses and other changes that affect overall manure quality and the ability of plants to use it. The changes in manure nutrient content during handling and storage also impact the ratio of crop nutrients in the manure, affecting its usefulness as a balanced fertilizer for crop needs.

#### F.4.3.4. Manure Application Or Disposal

Manure application methods vary depending upon the form of manure. Solid manure is applied using spreaders or dump trucks. Liquid manure is typically irrigated but may also be applied using a spreader. All application methods entail costs to producers; however, judicious

accounting for manure nutrients could lead to fertilizer cost reductions that may outweigh the cost of manure application. Accuracy of economic model estimates regarding the economic impact of manure handling depends on how well these nutrient accounting features and operations are captured. Costs depend on the characteristics of the equipment used, form of manure, and the acreage required for application.

#### F.4.3.5. Losses During and After Land Application

The following manure application losses or adjustments need to be considered in an effective evaluation of manure nutrient management.

Manure nitrogen volatilization occurs when nitrogen is lost from the soil profile to the atmosphere. When solid manure is incorporated or liquid manure injected, these losses are minimized substantially.

Some portions of manure nutrients, primarily nitrogen, are not readily available for plant uptake. The portion readily available for plant uptake is referred to as the plant available portion. From an agronomic rather than an environmental perspective, it may be necessary to make adjustments in manure application rates to account for this component of manure nutrients particularly during the first few years after a change in manure application rates.

#### F.4.3.6. Supplemental Fertilizer Applications

When manure applications are pegged to crop agronomic rates, it may also be necessary to apply commercial fertilizer to maintain the agronomic ratios. Supplemental fertilizer needs are based on the difference between crop needs and manure nutrient application rates.

### **F.4.4 Facilities, Structures, and Equipment**

This component of farm modeling accounts for all the facilities, structures, machinery and equipment investment on the farm. Since these items usually account for the majority of fixed capital outlay required for the farm operation, it is relevant for all agricultural operations.

Facilities include all farm buildings. Structures include all land enhancements and installations made for specific use such as liquid-solid separation or waste storage. They may also include some structural

conservation practices such as berms, terraces, and grassed waterways. A fixed economic life in years is normally assumed for facilities and structures.

#### F.4.4.1 Financing of Facilities and Structures

As with other farm investments, farm buildings may be financed by owner's equity or by means of debt. Borrowing terms directly affect debt payment for facilities and structures. Similarly, characteristics such as the economic life of buildings can be used to determine the opportunity cost of equity capital.

#### F.4.4.2. Farm Machinery and Equipment

Economic models account for all the machinery used for field operations and for livestock feeding and hauling, as well as all equipment installed in farm buildings, such as milking equipment in the parlor. Machinery characteristics of relevance in farm economic modeling include price, terms of financing (length of loan and interest rate), proportion financed by owner's equity, useful life in hours, among others. The more frequently a machine is used, the sooner it needs to be replaced. Most economic models assume a fixed economic life, while others are more sophisticated and base economic life of the equipment largely on the rate of use.

Machinery borrowing terms determine to a large degree the fixed costs involved in machinery ownership. For the proportion of an equipment cost that is financed by debt, the terms of debt payment determine how much is paid annually and for how long. The payment period or number of payment years is not necessarily the same as the economic life in years of the equipment. Thus it is possible to have a machine that has been paid off and is still being used, or one that has been used up and is no longer useful, but has not been paid off.

### **F.4.5 Land Areas and Characteristics**

As with NTT and other tools, economic models account for the fields farmed by the producer. Economic models distinguish between land of different types and uses. Typical types of fields are cropland, hay land, improved pasture, unimproved pasture, and woodland. Typical uses are solid manure application, liquid manure application, livestock grazing, conservation reserve, and buffer or filter strips. Furthermore, unlike most environmental models, economic models also distinguish between land ownership types because land ownership has economic



implications and can also determine the extent to which a producer can implement a conservation practice.

The size of land area available to a livestock operation often plays a significant role in how they manage manure nutrients and the cost of conservation practices (Osei and Keplinger, 2008). Farms with lower animal units per acre tend to utilize manure more as a resource, whereas farms with higher confined animal units per acre often face higher manure utilization costs and tend to dispose of manure as a waste. The willingness of neighboring land owners to accept manure is also a key factor in the cost of manure nutrient management.

#### **F.4.6 Farm energy generation and use**

On-farm energy generation is playing an increasing role in U.S. farm and energy policies. Land owners have greater opportunities now than ever before to manage their resources to generate income streams in addition to their main livestock and crop production enterprises. Furthermore, byproducts such as livestock manure and crop residue can now be used to generate energy. By selling renewable energy to power generation companies, farmers can clearly play a role in reducing the carbon footprint while earning additional revenues to enhance their profits.

#### **F.4.7. Other Exogenous Factors**

Exogenous factors are parameters that are outside the control of an individual farmer. They include, among others, input and output prices, government policy instruments, and biophysical parameters.

##### **F.4.7.1. Input and output prices**

Despite the growth of corporate farms and multi-million acre cash crop production operations, farms are generally price takers. Input and output prices are exogenous to the decisions of any one farmer, and yet they are the primary determinant of farm profits that is outside of their control, and dictate what crops or livestock many producers would raise. In WQT, the dollar value of a nutrient credit will be an additional exogenous factor that will influence farmers' decisions about what practices they should implement.

##### **F.4.7.2. Government Policy**

Federal, state, or local government policy variables such as taxes or constraints on land use affect profitability of

farm enterprises. Government policy is often among the most predictable of the exogenous factors of interest to farmers because of the time it takes to formulate and pass legislation. However, the implications of these policies may be quite complicated and it may be years before producers learn to adjust to a given policy.

##### **F.4.7.3. Biophysical Parameters**

Some physical characteristics of the study area also affect the costs and returns associated with scenarios. Major examples include soil type and topography, spatial distribution of creeks and rivers, and climate distribution. Whereas average levels of most of these parameters might be reflected in farm specifications, their distributions impose different relative risks that impact choice among scenarios.<sup>5</sup> Integrating economic models into WQT programs

NTT has been designed to provide field scale nutrient loading data in a WQT program. An economic simulation model can be integrated into the WQT framework to provide reasonable estimates of the costs or other economic impacts of conservation practice implementation. An economic optimization model can also be integrated into the WQT framework to help determine the optimal profile of conservation practices to implement. As discussed earlier, data from an economic simulation model can serve as input into the economic optimization tool. The following are the key steps necessary to integrate economic models into WQT programs. These steps apply to economic simulation and optimization models, but certainly the former.<sup>5.1</sup> Determine the roles of the economic model(s)

The first step involved in integrating economic evaluation into WQT programs is to determine what roles these models would play. Economic models may be needed only to provide estimates of conservation practice costs, or they may be needed to provide the farmer or other user with readily available information on which practices are optimal or most profitable for their farms. They may also be needed to help determine which practices provide the greatest number of credits for a given amount of implementation cost. The roles of the economic model(s) need to be determined before the most appropriate model can be selected.<sup>5.2</sup> Select the required economic model(s)

The second step to incorporate economic evaluation into a WQT platform is to select the most appropriate

economic model(s). If the primary objective is to provide users with a tool for estimating costs of alternative conservation practices, then a comprehensive economic simulation model will do. If, on the other hand, the primary objective is to enable them to determine rapidly the most cost-effective or optimal conservation practices to implement, then an optimization model is required. In the latter case, an economic simulation model would still be useful as a key source of cost and returns information for the optimization model.

#### **F.4.8 Criteria for selection of economic model(s)**

The following criteria will serve as a useful guide to selecting the most appropriate economic models for WQT programs.

##### **F.4.8.1 Ease of use**

WQT programs involving agriculture will likely draw in farmers and their technical support personnel as the primary users of the models. Consequently, all the tools and models integrated in a trading platform need to be user friendly. Economic models may need to be simplified or an appropriate user interface may be needed in order make them accessible to non-sophisticated users.

##### **F.4.8.2 Reliability of estimates**

Most users are familiar with the fact that cost and returns estimates for any agricultural enterprises or practices will vary very widely depending on market conditions and a host of other factors exogenous to the producer. Thus any cost and returns estimates provided in a WQT platform for a specific situation need to be viewed as the best estimates given the constraints of the data available and the model's ability to capture the real world situation. A critical feature in the economic component as well as other components of WQT programs should be clearly stated disclaimers that indicate the limitations of the numbers provided.

Notwithstanding the user of disclaimers, the economic model(s) selected must be ones that produce very reliable estimates of the costs and/or returns associated with the practices being evaluated. There are a variety of sources of cost and returns data that can be compared with the output of the economic model(s) to determine

which ones are reliable enough to be included in the trading platform.

##### **F.4.8.3 Comprehensiveness**

In order to estimate the costs or economic impacts of conservation practice implementation on farms, the economic model(s) chosen must be comprehensive. A comprehensive model will include the relevant components of farm economic models as outlined in the previous section. For instance, if the conservation practice to be evaluated is comprehensive nutrient management, it may be crucial for the model to have a livestock ration component in order to capture the changes in manure nutrients that result from changes in livestock feed rations, such as using phytase to reduce manure phosphorus content in a swine or poultry operation. The appropriate model should also include manure application components that determine the rate at which manure can be applied on fields, and how much manure may need to be hauled off the farm and at what cost. Similarly, if it is of interest to evaluate filter strips installed on the downslope edge of a field, the model should capture the size of the filter strip area that is taken out of production, the impact of the reduced production on livestock rations if any, the impact on feed, grain or forage sales, as well as the cost of installing and maintaining the filter strip.

##### **F.4.8.4 Good track history**

It is desirable that the economic model(s) selected have a good track record of providing reasonable estimates of conservation practice costs at the farm level. Published records of use of the models can form the basis for evaluating its reliability.

##### **F.4.8.5 Plan for model upkeep and maintenance**

The model(s) selected should be ones that are being maintained by an institution that has the reputation of model development and upkeep. This is necessary because new features may be required by users and it is important to select models that are being updated on a regular basis. Regular maintenance will also ensure that any bugs or other issues that need to be addressed will be dealt with promptly.

#### F.4.8.6 Can be interfaced with other components of WQT program

The appropriate model(s) must also be compatible with the other tools within the WQT platform. Preferably, it should be possible to establish a physical interface between the economic model(s) and other tools such as NTT.

#### **F.4.9 Validate the model(s)**

Once the appropriate models have been selected the next step would be to validate it for use in the WQT program. Validation may simply entail a detailed review of the results of the model by professionals, as compared to their experience regarding the costs of the practices of interest. Validation may also include a comparison of the model output to actual cost and returns data from selected farms that have already implemented various practices. Model output may also be compared with cooperative extension and USDA publications to gauge their validity.

#### **F.4.10. Integrate within the Trading Platform**

The last step in the process is the physical process of actually integrating the model within the WQT platform. This step is primarily a programming exercise

that depends on the objectives of the trading program. Once the model has been integrated within the trading platform it is useful to perform some test runs with potential users prior to rolling it out in an actual trading program.

#### 6. Summary/Conclusions

Economic models can provide very useful information to support a WQT program involving agriculture. While the emphasis in trading programs is the calculation of credits, it is important to realize that producer participation will be primarily contingent on the costs of the practices being implemented as compared to any income from nutrient credit sales. Carefully selected and integrated economic models will provide reasonable estimates of the costs or returns associated with conservation practices. This cost information will help farmers avoid unprofitable trades (trades where the practice costs more than the revenue from credit sales), and can also help them choose between two profitable options for trade. While it is clear that there are limitations to the use of cost and returns estimates from economic models, these estimates can nonetheless prove very useful to farmers as a guide to their decisions regarding choice of conservation practices in a WQT program. Economic model output can be used in conjunction with data from other tools within the trading platform and must always be accompanied by an appropriate disclaimer, regardless of how reliable the estimates may be.

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# Appendix G: Nutrient Trading Tool (NTT) User Guide

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## **G.1 General Information**

### **G.1.1 Introduction**

This publication provides a brief overview of the steps needed to effectively operate the Nutrient Trading Tool (NTT). NTT is a web-based field model that was developed to assist producers, their technical service providers, and others to calculate nutrient and sediment loss reductions which can be credited in a water quality trading program. NTT estimates the nonpoint source nutrient load reductions resulting from various conservation practices. Since NTT provides nutrient reduction estimates for a wide array of practices and scenarios, the tool can be used for conservation practice evaluations, as well as a number of other applications in addition to estimating reductions for water quality trading credits.

### **G.1.2 Scope of NTT applications**

NTT can be used to evaluate a wide variety of conservation practices, including the following (USDA-NRCS conservation practice codes are indicated in parentheses):

- Alternative cropping systems (e.g., corn-soybeans versus continuous corn)
- Filter and buffer strips (386)
- Tillage/Residue Management (329, 345, 346)
- Contour farming (330)
- Fencing (382)

- Prescribed grazing (528A)
- Forage harvest management (511)
- Riparian zone management
- Heavy Use Area Protection (561)
- Pasture & Hayland planting (521E)
- Cover crops (340)

NTT results are edge-of-field estimates, meaning estimates of the nutrient and sediment runoff from the down-slope edge of the field being evaluated. NTT results are combined with other factors in order to calculate the number of water quality credits that may be sold as part of a water quality trading program. Factors that need to be considered to convert NTT estimates into water quality credits include differences in downstream impacts, watershed specific characteristics, variability in nutrient assimilation capacity, and other ecological and trading program issues. Your water quality trading program will provide the equations used in addressing the adjustment factors for your setting.

### **G.1.3 Procedure for NTT use**

NTT has been designed to be easy to use by agricultural professionals familiar with farm procedures and conservation practices. The detailed procedures for use of NTT will be described at the second section of this document. There are three basic steps to using NTT (Figure G-1):

- A. Define area of interest (AOI)
- B. Define baseline and alternative scenarios
- C. Run NTT's calculation tool and review the results



Figure G-1  
Steps involved in using NTT

When you first access the NTT home page (<http://ntt.tarleton.edu/nttwebars>), you are presented with a welcome screen (Figure G-2). If you already have an existing NTT project you would like to load, you may click the third button on the welcome screen labeled “Upload Existing Project” to locate the project file and import it into the current session. Otherwise, follow the steps outlined below to start your new NTT project.

**A** Define AOI

The first step in using NTT is to define the field or specific area that is the subject of interest. There are two ways to define a field in NTT. One is to use the web soil survey. The USDA-NRCS web soil survey (WSS) is an external web-based application that allows you to zoom into and select an area of interest. The other is to select the state, county, and weather station of interest, and then specify the dominant soil type and field size.

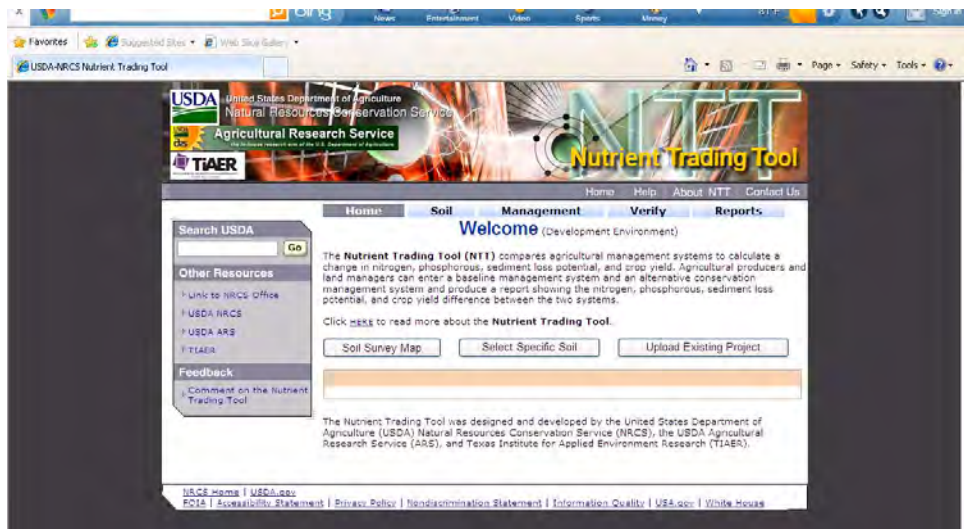


Figure G-2  
NTT Welcome Screen

In practice it is likely that users will face situations where using one dominant soil is not appropriate. In such situations, the web soil survey may be the only appropriate option to use. Please refer to section G.2.1.1 for detailed procedures for using the web soil survey.

**B** Define management scenarios

Users need to define two management scenarios before running NTT’s calculation tool. The first scenario will determine the reference point from which nutrient reductions will be calculated. The second scenario will

be the BMP or conservation practice that will be installed. Using these two scenarios, the user will estimate the nutrient load resulting from the anticipated BMP. If you are using NTT to estimate nutrient reductions for water quality trading, you will need to contact your trading program to determine the reference point, or “baseline”, from which nutrient reductions can be estimated (to obtain water quality credits, the farmer or landowner must implement a conservation practice that reduces nutrient and/or sediment losses beyond a pre-defined baseline).

In NTT the baseline and alternative scenario details are presented side by side in one screen for user convenience. Several management scenarios are preloaded into each NTT session to make it easier for you to define your baseline and alternative scenarios.

Illustrative examples on how to define scenarios are provided in Section G.2 of this user guide. Once you have selected the cropping systems, crop cultural practices (management information), and structural conservation practices of interest, you have completed scenario definition (under the management information

tab) and are ready for the last step in the NTT application.

**C** Run NTT’s calculation tool and review results

The last step in the NTT application process is simply to click “Next” after defining the scenarios. A “Verify Information” screen is presented that allows you to verify that you made the selections you actually intended to make. Once you click “Next” in the “Verify Information” screen, NTT’s calculation tool runs and returns the results for the baseline and alternative scenarios in a new screen (Figure G-3).

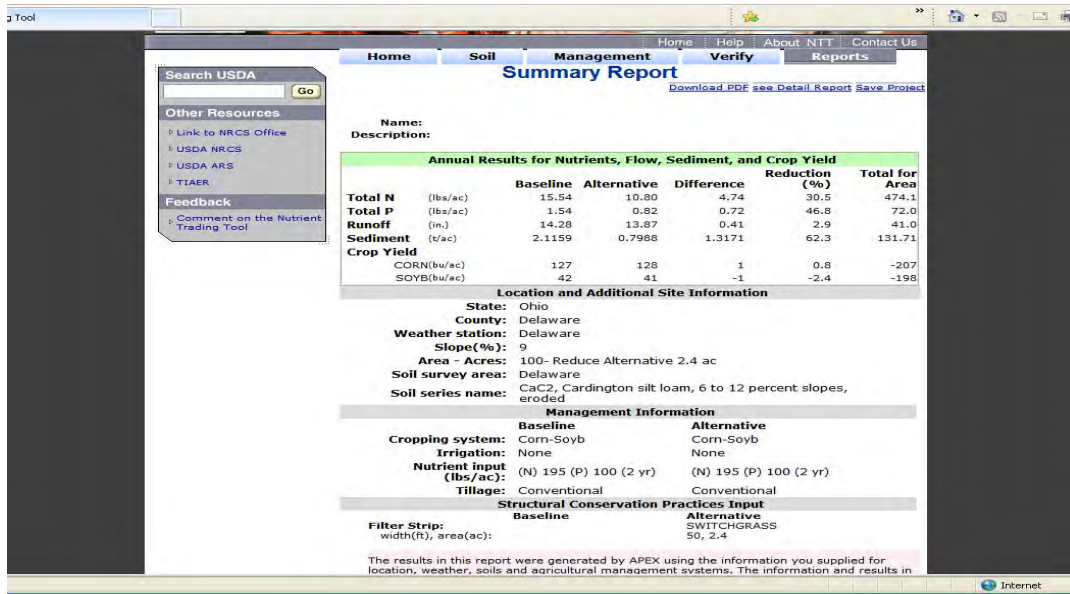


Figure G-3  
An example of NTT summary results screen showing filter strip impacts

### G.1.4 Interpretation of NTT output

NTT simulates the conditions on the area or interest over a number of years of weather information using a daily time step. After the simulations have been completed, NTT presents only the calculated annual averages for each of the indicators selected by the user and presents them in the results screen (Figure G-3). NTT results are therefore based upon long-term averages (last 12 years) and may not reflect the results for any given year. Consequently farmers and others should use the NTT results with this limitation in mind. Nonetheless, NTT provides reasonable estimates of the changes you can expect in the alternative management scenario when altered from the baseline scenario.

In the results screen, NTT presents nutrient losses in lbs/acre, sediment losses in tons/acre, runoff volumes (flow) in inches, and crop yields in the relevant yield unit on a per acre basis. The results are shown for the baseline and the alternative scenarios in separate columns. Then the simple difference between the two scenarios is also shown for each indicator. Finally, the last column displays what results when that difference is multiplied by the field size in acres.

The “Summary Results” screen also presents a summary of the management information that was defined by the user and used as input in the calculations presented in the screen. You can also see more detailed results by clicking on the “see Detail Report” link (please refer to G.2.2.6 for more information). It is important to note

that NTT allows simulation of multi-management scenarios at the same time. For instance one can use NTT to evaluate the effects of both nutrient reduction and filter strip on water quality at the same time.

As previously mentioned, the user is able to save their project using the Save function available in NTT (Figure G-4). Simply click the “Save Project” button on the Verify Information screen and follow the instructions to save the current project to a file on your computer.

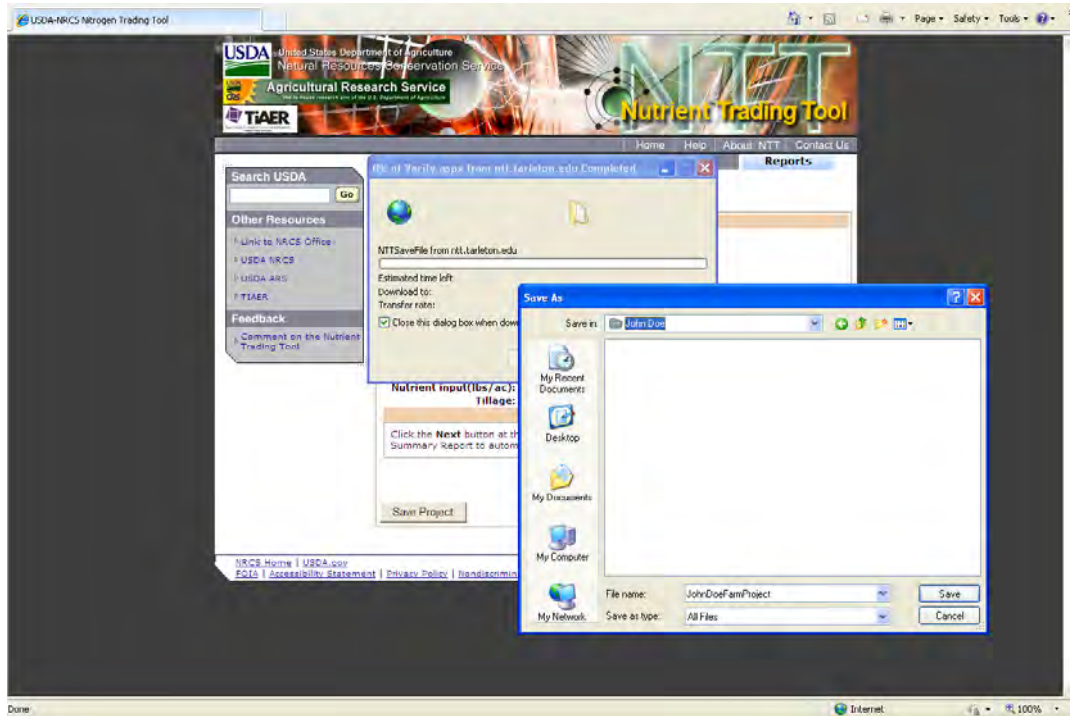


Figure G-4  
“Save Project” function in NTT

## G.2 Illustrative Cases

The following illustrative cases are presented to give you an idea of how to use NTT in specific situations. *All illustrations included below are purely hypothetical, and do not necessarily represent the situation on an actual farm. In addition, the numbers used in these illustrations are meant only to illustrate NTT use and do not constitute approved recommendations by USDA-NRCS or any other applicable state or local agency.* Finally the illustrations shown here use pre-existing crop operations that have been customized for the State of Ohio.

### G.2.1. CASE 1: A change in tillage practice

**Background information:** *A corn-soybean farmer in Delaware County is currently using conventional tillage practices on a 150 acre field. The farmer is considering no-till corn following no-till soybeans as an alternative practice*

*for which she may also qualify for water quality credits in an ongoing water quality trading program.*

**NTT implementation:** As mentioned in section G.1.3 above, users have two options to query field information (including soil, weather, and area): 1. the WSS option using the USDA-NRCS WSS program, and 2. the dominant soil option where you select the state, county and a single soil type of interest. Thus, to address this farmer’s situation, you can define the 150-acre AOI using the WSS program or by simply selecting “Ohio” as the State value and “Delaware” as the County value. For this and the following illustrations we will place more emphasis on the WSS program; however, both options are presented.



### G.2.1.1. Option 1. Define AOI using the USDA-NRCS web soil survey

This option will allow you to include multiple soils in your NTT project, and is generally more accurate than the other option that focuses on the dominant soil. Once selected, the AOI information will be subsequently imported into NTT, along with its field size information, soils and weather data (daily rainfall and temperature). To access the WSS application, click on the button labeled “Soil Survey Map” in the NTT welcome screen (Figure G-2). A new window is opened, which presents the initial screen of the WSS application (Figure G-5).

Click on the circular button labeled “START WSS” to start the WSS application and select your field or area

of interest. Once you have made your selection you will get back to this screen and click “Capture” to transform the AOI information into NTT format.

When you click the “START WSS” button a new window or browser panel appears (Figure G-6), which is the main page of the USDA-NRCS Web Soil Survey. You may need to temporarily enable pop-ups in order for this to work properly if popup blockers have been installed and enabled on your computer. When the *Web Soil Survey* map first appears, the continental United States is shown in full extent on the right panel (Figure G-6). The left panel of the screen displays several tabs that you can use to navigate to your specific area of interest.

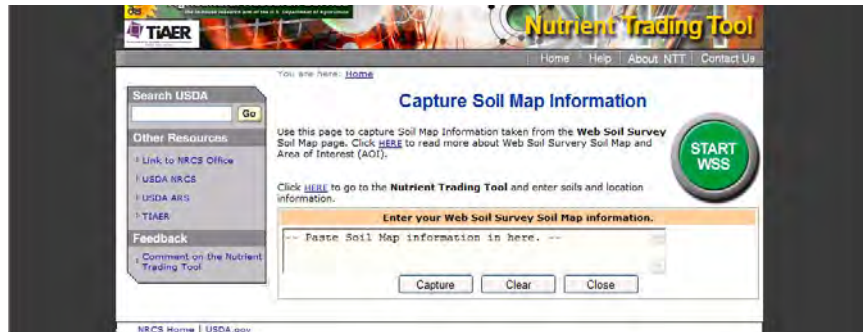


Figure G-5  
Option 1: Capture Soil Map screen to start WSS from within NTT

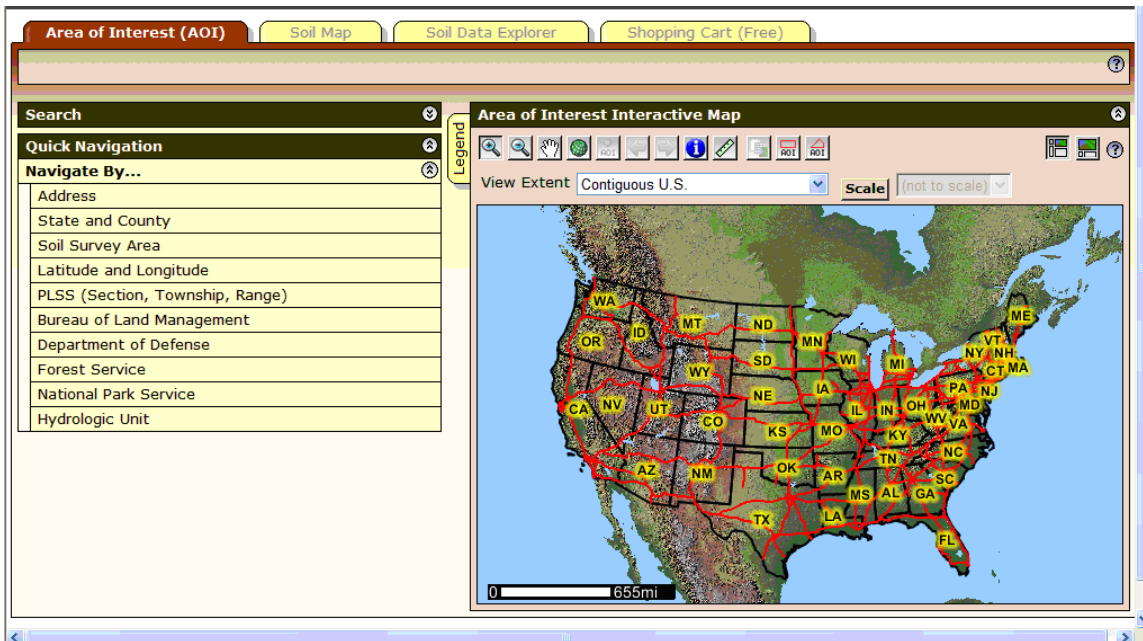


Figure G-6  
Initial screen in the WSS program prior to area selection

You can begin to navigate to your AOI by choosing from the State and County list, or alternatively by selecting from the Soil Survey Area list. For the example illustrated here select **State and County** and choose Ohio from the **State** drop-down box and

Delaware from the **County** drop-down box (Figure 7). Once you click “View” the WSS application will zoom in to Delaware County, Ohio, as displayed in Figure G-7. Allow enough time for the map to zoom in to the county-level view.

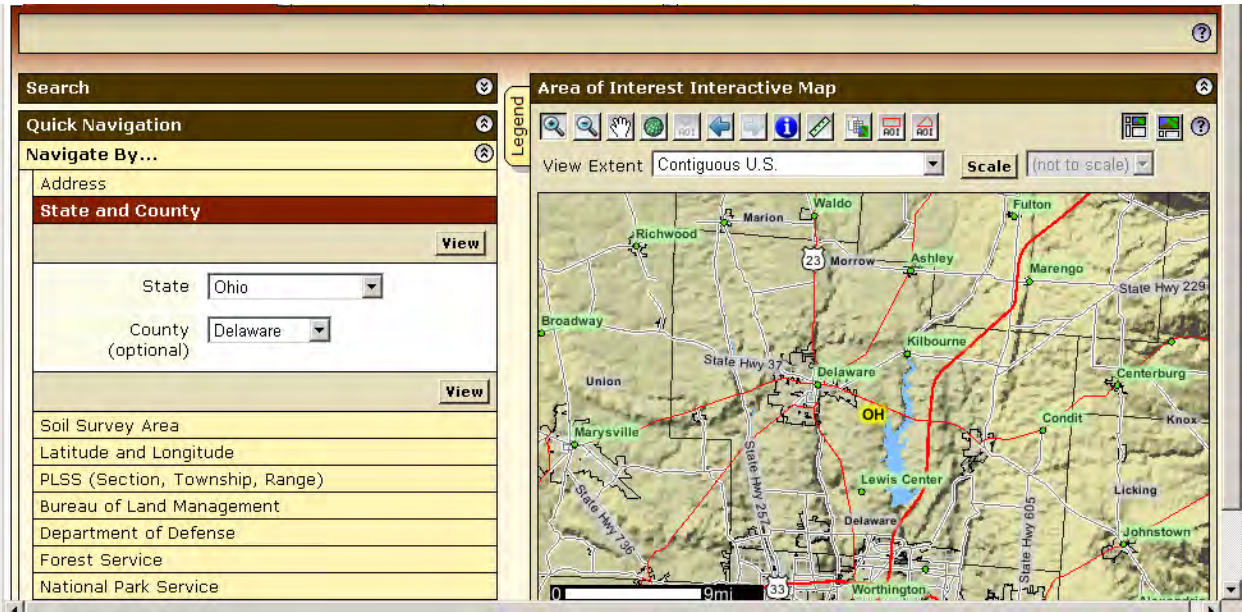


Figure G-7  
WSS screen after selecting state and county of interest

Next navigate to the specific AOI by progressively selecting rectangular areas with the zoom-in feature as the active selection tool. To ensure that the zoom-in selection tool is active, you must ensure that the zoom-in button right below the “Area of Interest Interactive Map” title bar is the enabled button. The zoom-in button is typically the leftmost button on the toolbar right below the “Area of Interest Interactive Map” title bar.

Once the zoom-in selection tool is active, you can select any rectangular area, making sure that you are within the vicinity of your area of interest – in this case Delaware County, Ohio. After an area has been selected, the map zooms in to that area (Figure G-8). The next zoom level would show street and field features more prominently.

Once a reasonable scale has been reached allowing selection of the AOI, use an AOI selection tool. One AOI selection tool displays a rectangle with “AOI” right below that rectangle. The other AOI selection tool just to its right displays an irregular shape, which you can use to select fields that are not rectangular in shape. Click on one of the AOI selection buttons to be sure it is enabled. Select an area that corresponds approximately to the field or area to evaluate (Figure G-9). It goes without saying that users need to pay particular attention to the AOI selection process and make sure the boundaries of the AOI coincide as closely as possible to the actual field boundaries they intend to include in the credit calculation. If necessary, you may need to zoom in to a more detailed view in order to enhance the accuracy of the AOI selection process.

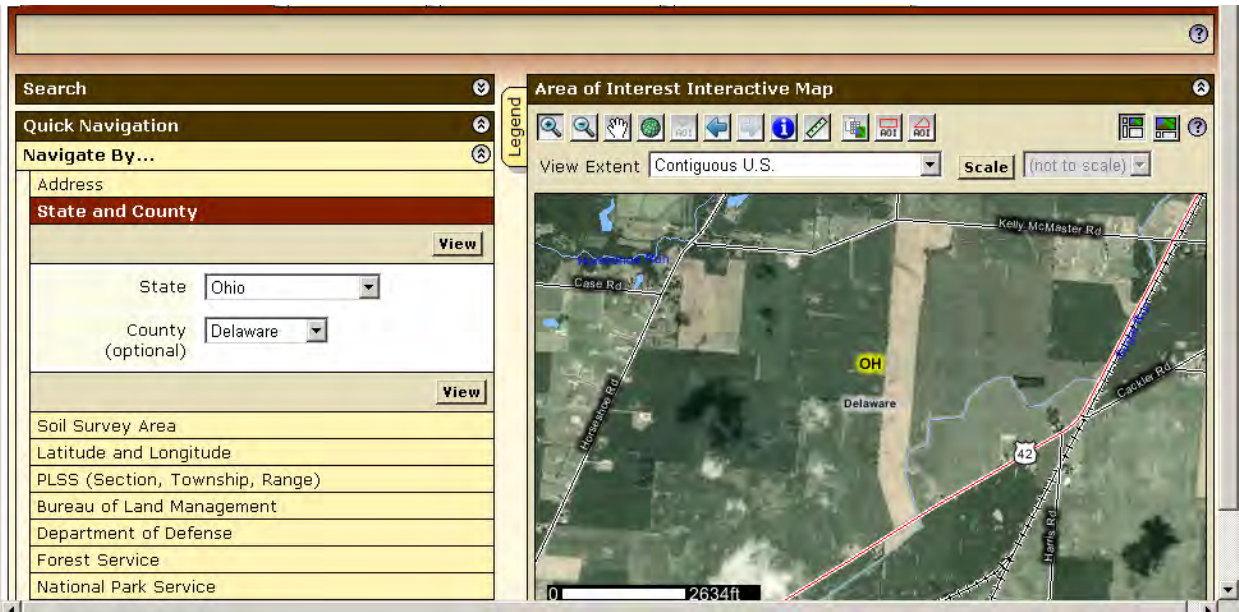


Figure G-8  
WSS screen after zooming into Delaware County, Ohio to select a field

A message “Creating AOI...” appears on the map, indicating that the AOI is being selected (Figure G-9) along with its soil information. Once the AOI has been selected, summary soil information for the AOI will be displayed in the left pane. If the soil information is not visible, click the “Soil Map” tab (Figure G-10).

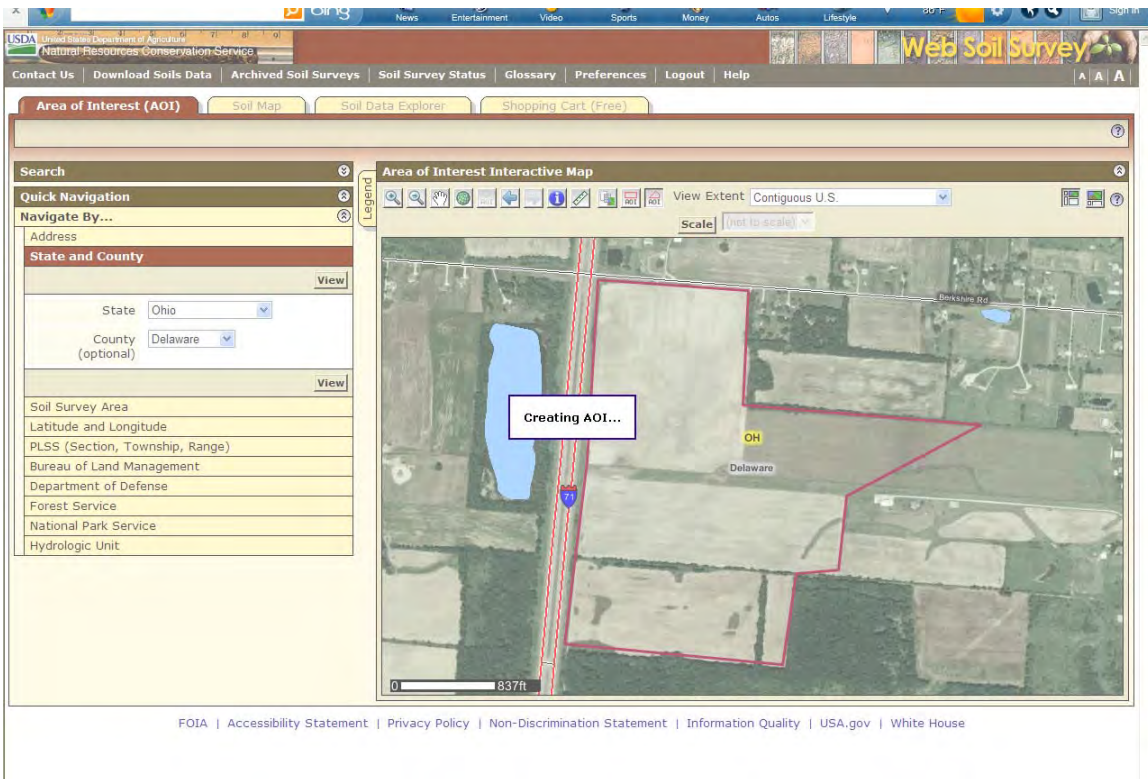


Figure G-9  
WSS screen showing AOI creation after selecting area of interest

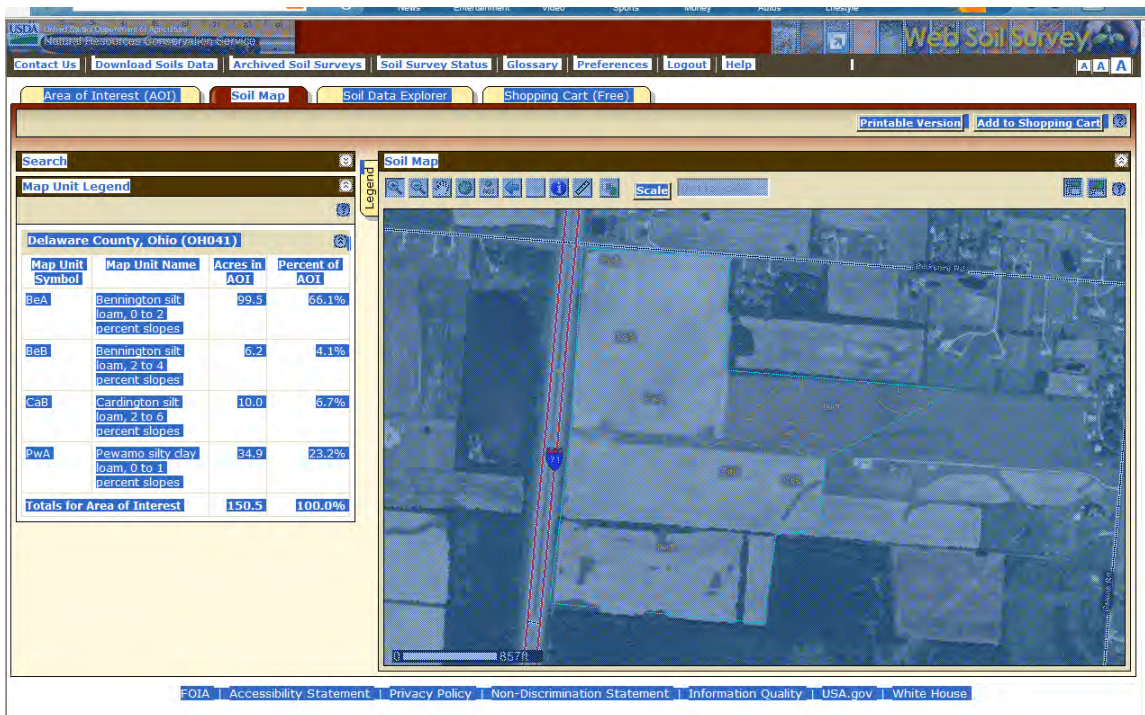


Figure G-10  
WSS screen after selecting all contents prior to copying into NTT

To export the soil information to NTT, go to the **Edit** menu tab of the browser and click on “Select All” (or press ctrl-A) and then “Copy” from the **Edit** menu tab of the browser (or press ctrl-C) (Figure G-10).

Next, move to the main *Capture Soil Map Information* screen, click on the “Clear” button, place the cursor in textbox under the **Enter your Web Soil survey Map information** title, paste (ctrl-V) the information copied from the soil map in the area provided, and click the **“Capture”** button so that the soil information is

recognized by the program and formatted in the display, as shown in Figure G-11. Then click **“Save”** to export the data to NTT. The data exported to NTT appears in the NTT window as displayed in Figure G-12. You will notice that in this case the AOI selected by the user is 150 acres in size and includes three soil types with varying slopes (Figure G-12). Along with importing the soil information, weather data, including 24 years of daily precipitation and temperature for the selected field is also uploaded.

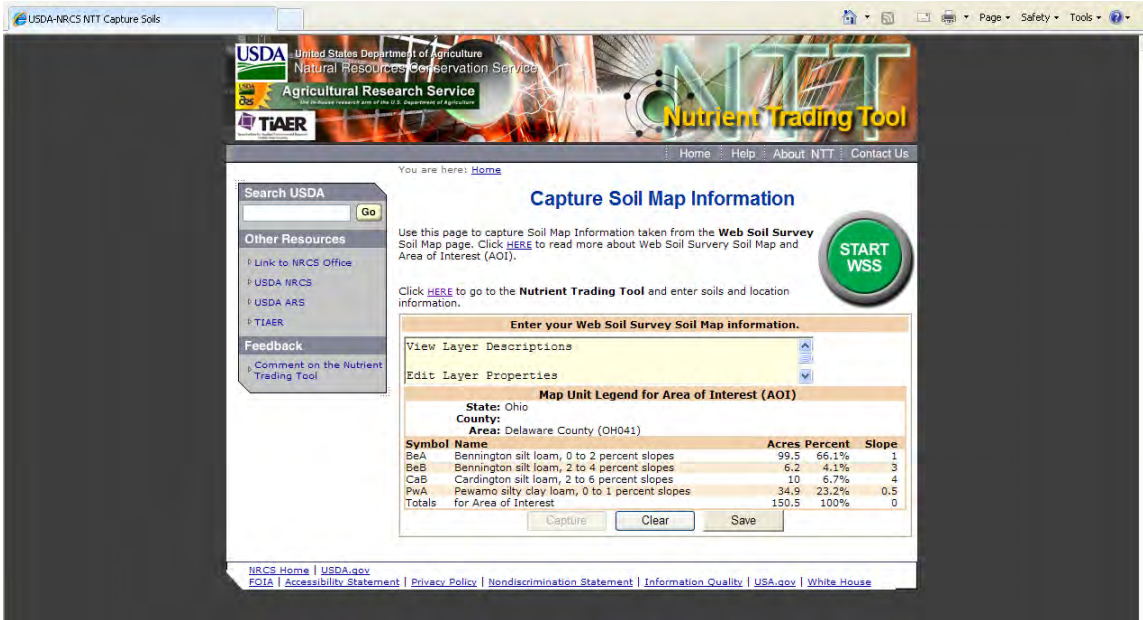


Figure G-11  
 NTT program after capturing selected soil information from WSS

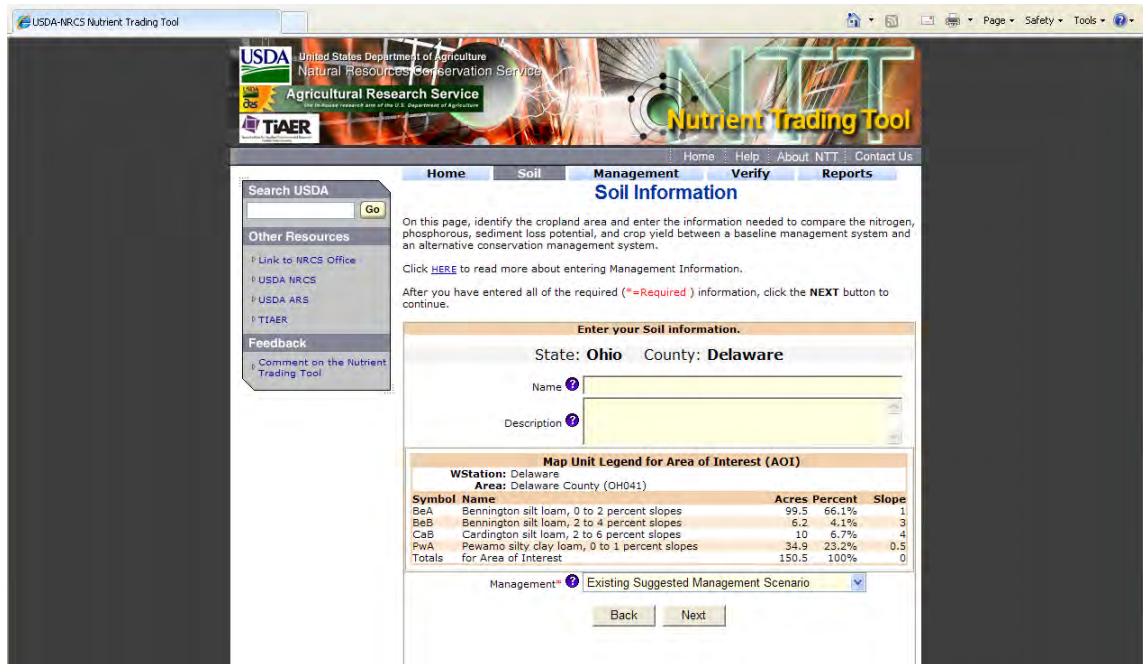


Figure G-12  
 NTT program after saving (importing) soil information from WSS

NTT allows you to name your project and record a project description if you so desire. Once this is done, or if you've selected to omit this information, click the "Next" button. You have now completed defining your area of interest and are ready to define your scenarios by selecting the "A. - Select From Existing Management

Scenarios” or the “B. - Upload/Create/Modify management Operation File” link.

### G.2.1.2 Option 2. Define AOI by selecting State and County on NTT screen

To use this option, click on the “Select Specific Soil” button on the NTT welcome screen. This will allow you to define your area of interest by choosing the State and County where your field is located and then a specific soil, preferably the dominant soil on your field. Once you click that button, the screen is expanded to display a lower pane where you can select your State and then County and then Weather station in that order (Figure G-13). At this point you can also select the indicators you wish to include in the current NTT session. By

default, all the available indicators (nitrogen, phosphorus, flow, sediment, and crop yield) are selected.

Once you have made your selections, click “Next” to go to the next screen (Figure G-14) where you can select the soil type applicable to your field and specify the field size. This screen permits you to select only one soil type, unlike the WSS program where multiple soil types are captured and exported to the NTT session. Along with importing the soil information, weather data, including 24 years of daily precipitation and temperature for the selected field is also uploaded.

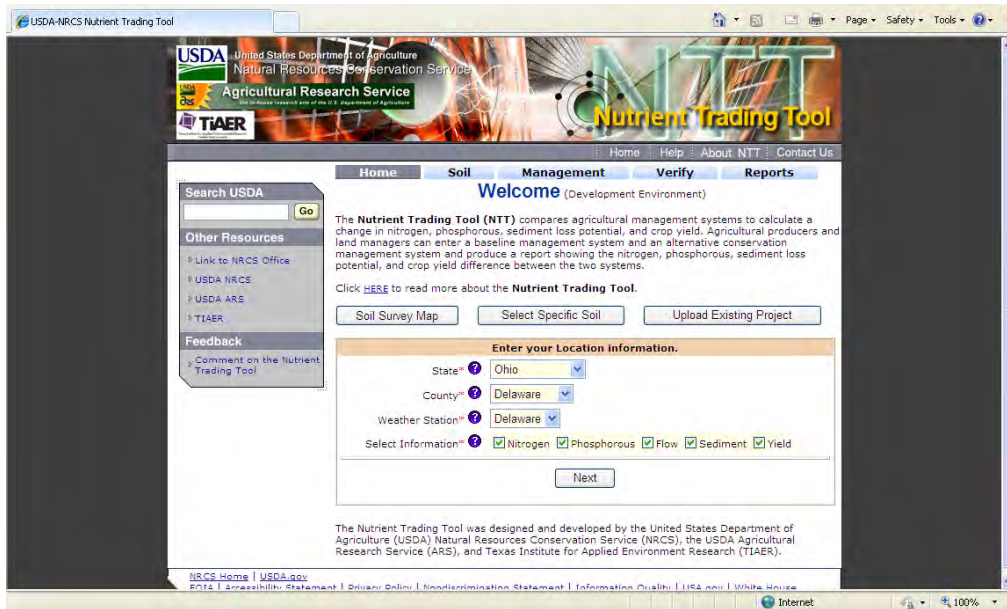


Figure G-13  
Option 2: Selection of State, County, and Weather station of interest

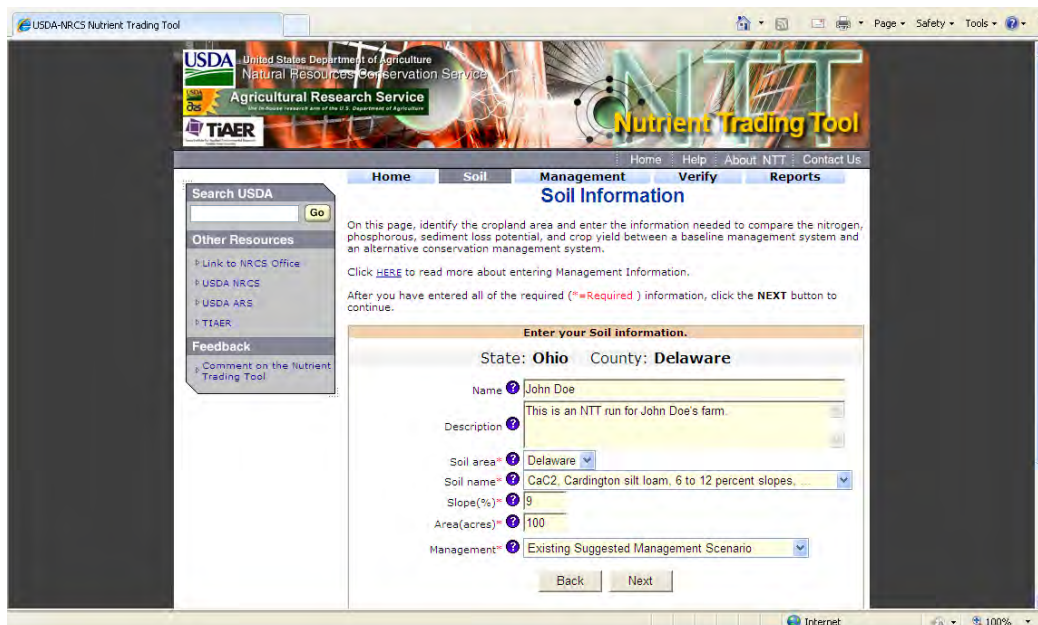


Figure G-14  
Option 2: Soil and field size specification screen

Your AOI definition is now complete and you can proceed to the next step to define the baseline and alternative scenarios by selecting either “Existing Suggested Management Scenario” or “Upload/Create/Modify management Operation File”.

## G.2.2 Management information input

At the bottom of the soil information screen, a drop down menu allows you to select “Existing Suggested Management Scenario” or “Upload/Create/Modify Management Operation File”. Select the “Existing Suggested Management Scenario” and click “Next” to get preloaded information. You can still modify the preloaded management information by clicking “Modify” at the bottom of the Management Information screen. Alternatively, you may upload a saved management file or create new scenarios from scratch by selecting the “Upload/Create/Modify management Operation File” option at the bottom of the Soil Information screen. The following five subsections provide more information about each option available for defining management information in NTT.

1. Selecting pre-loaded management scenarios
2. Uploading existing management files
3. Creating new management information
4. Modifying existing management information

### 5. Selecting structural conservation practices

#### G.2.2.1. Selecting pre-loaded management scenarios

The easiest way to define scenarios in NTT is to select from the list of pre-loaded management information. After the information has been selected users still have the option of making changes via the “Modify” button.

To access the list of pre-loaded management scenarios, simply select “Existing Suggested Management Scenario” from the Soil Information screen (Figure G-12). This brings you to a screen that displays drop down buttons for the baseline and alternative scenarios. Each drop down button contains a list of items that can be selected to define each scenario – cropping system, irrigation type, nutrient input, and tillage options. Once you have selected the relevant items to define your scenarios, you can click “Next” to proceed to the NTT calculation phase.

For this illustrative case, you can proceed to define the “conventional” and “no-till” tillage options for the corn-soybeans cropping system from “Management Information” screen, as shown in Figure G-15. In Figure G-15, we have already selected the cropping systems (corn-soybean), nutrient input, and the tillage types for both the baseline and alternative scenarios. Click “Next” to run NTT’s calculation tool.

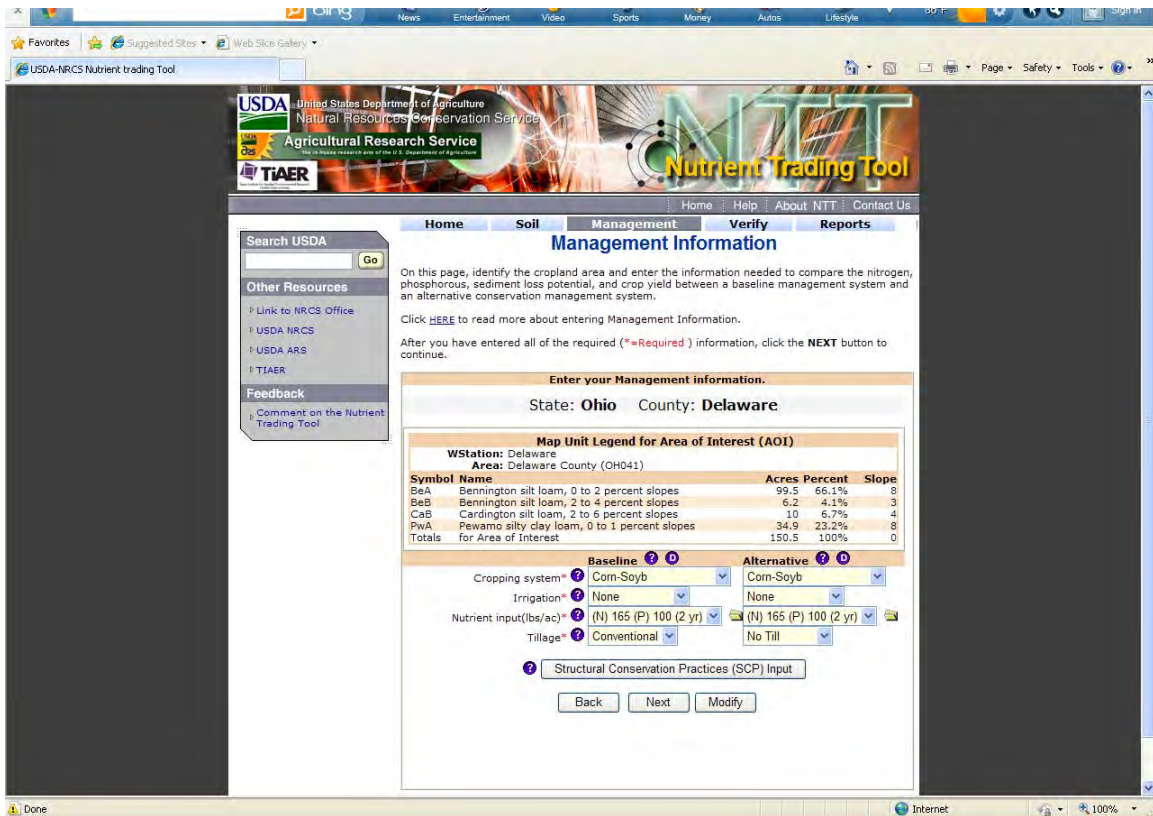


Figure G-15  
Defining baseline and alternative tillage for a corn-soybean field

#### G.2.2.2. Uploading existing management files

If you saved management information to a file in a previous NTT session, you can upload that file by selecting the “Upload/Create/Modify management Operation File” option from the soil information page. A new screen appears, which offers multiple options – to modify existing management information, to upload an existing management file, or to create new

management information (Figure G-16). To upload management information from an existing file, enter the full path and filename of the file in the text box to the left of the “Browse” button, or simply click “Browse” to navigate to the location of the file. Once the full path and file name has been specified in the text box, click the “Upload” button to load the file into the existing NTT session. Click “Next” to run NTT’s calculation tool.



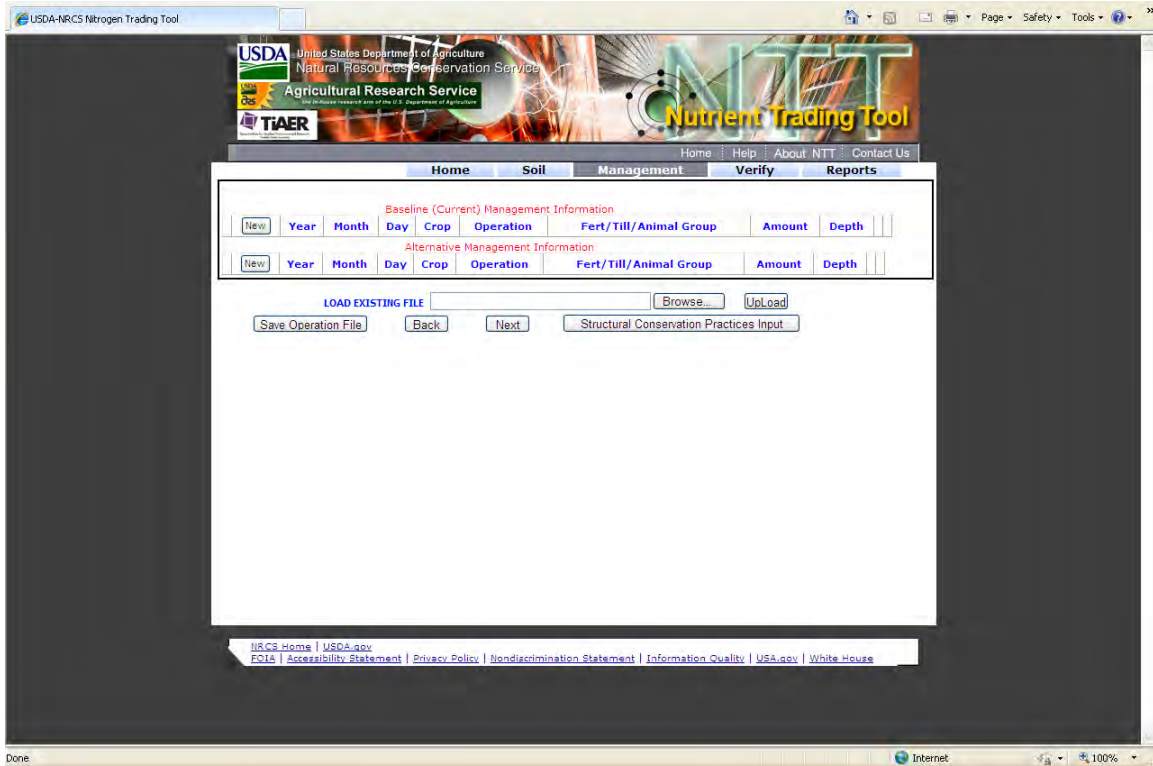


Figure G-16  
Management screen with options to upload or create field operations

### G.2.2.3. Modifying existing management information

You can modify existing management information that was uploaded from a previous session, or even pre-loaded management information. To modify

management information that exists in a file on your computer, simply upload that file as described above. The management information would be displayed on your screen as shown in Figure G-17. You can then use the options available on that screen to edit, copy, or delete specific lines of management operations.

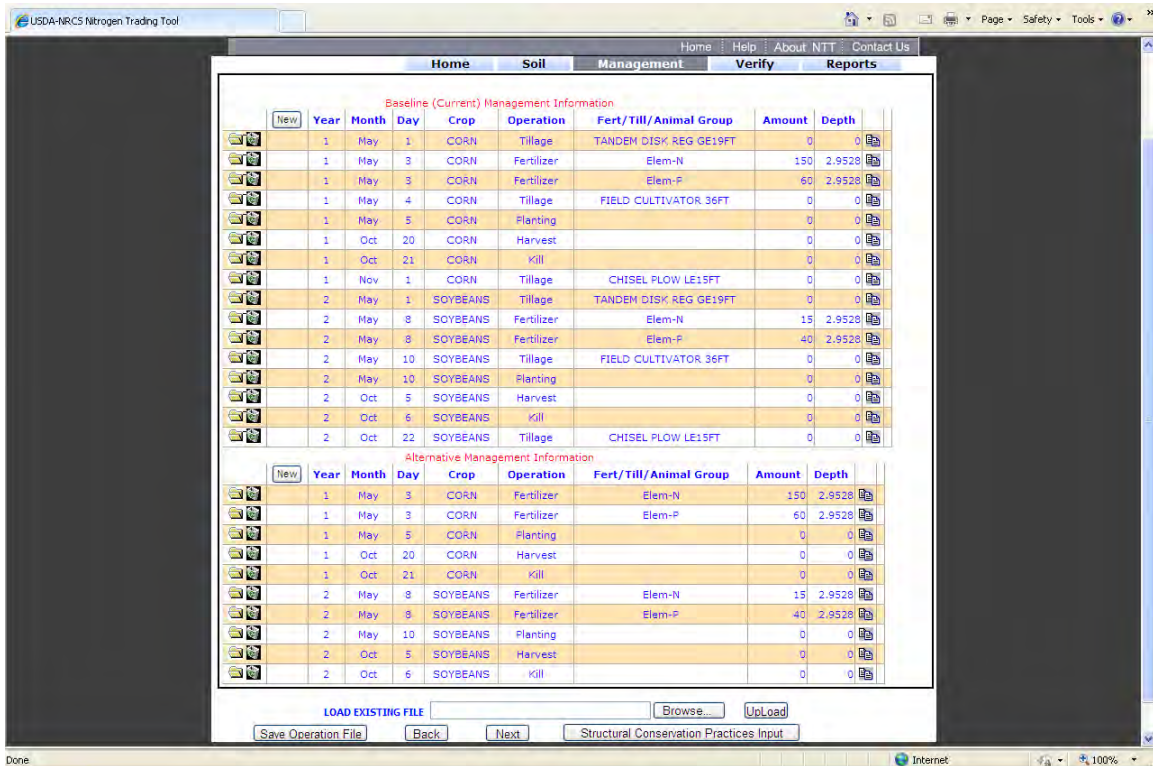


Figure G-17  
Management screen with editing/modification options

To delete an operation, simply click on the “Delete” button – the button with the trash can icon (🗑️) – to the left of that row. A dialog box appears asking for confirmation to delete that operation (Figure G-18). Click on the “OK” button to delete that operation. To edit an operation, click on the “Open” button – the button with the “file open” icon (📁) – to the left of that row. To copy an operation to the other scenario, click on the “Copy” button to the right of that row – the button with the Copy icon (📄). This action copies the

specific operation from the active scenario to the other scenario.

When you open an operation for editing, two additional buttons are displayed beside that operation: the “Save” button (💾) and the “Cancel” button (↶). Use the save button to save the changes made and exit editing mode. Use the cancel button to discard the changes made and exit editing mode (Figure G-19).

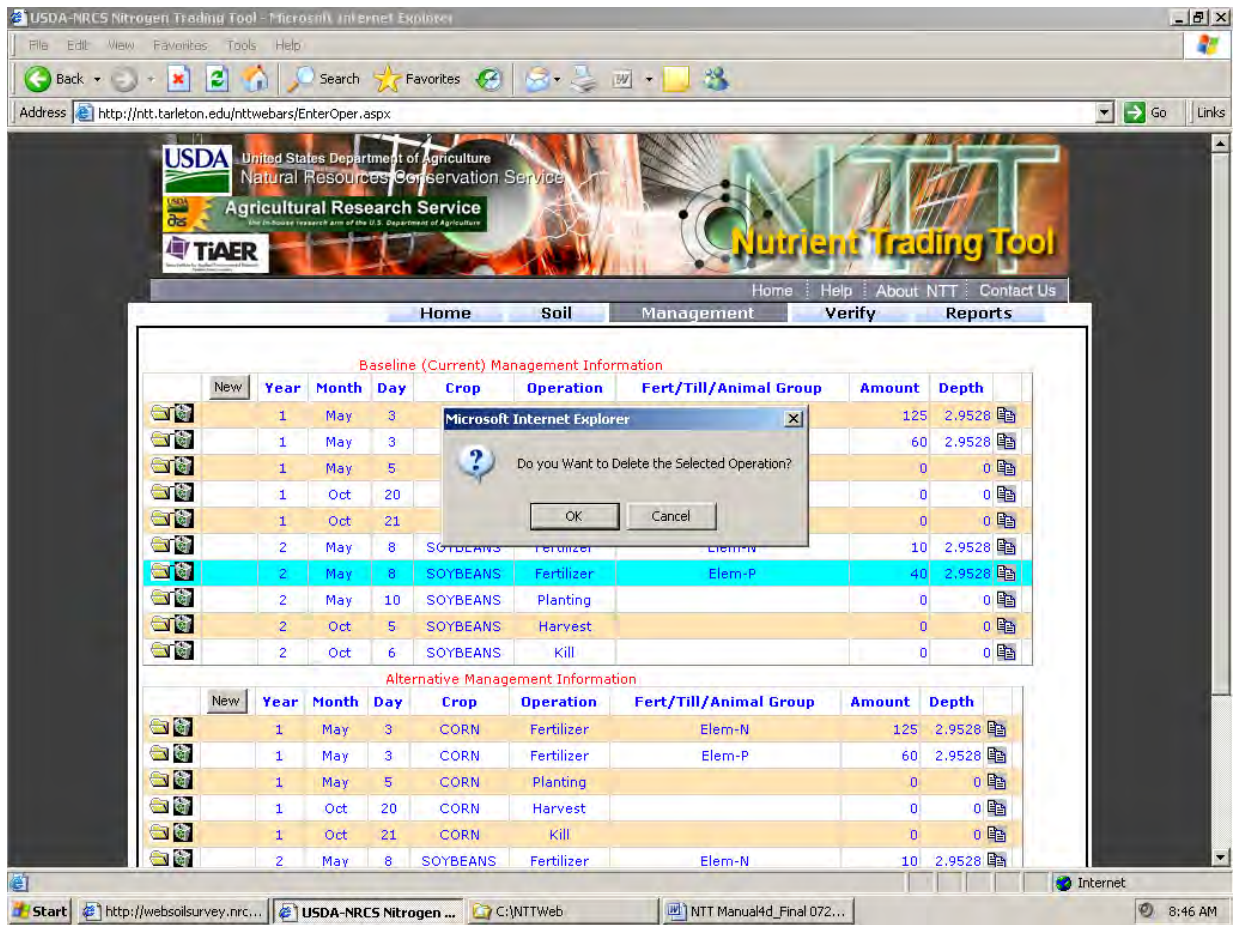


Figure G-18  
Detailed Management screen asking user to confirm operation deletion

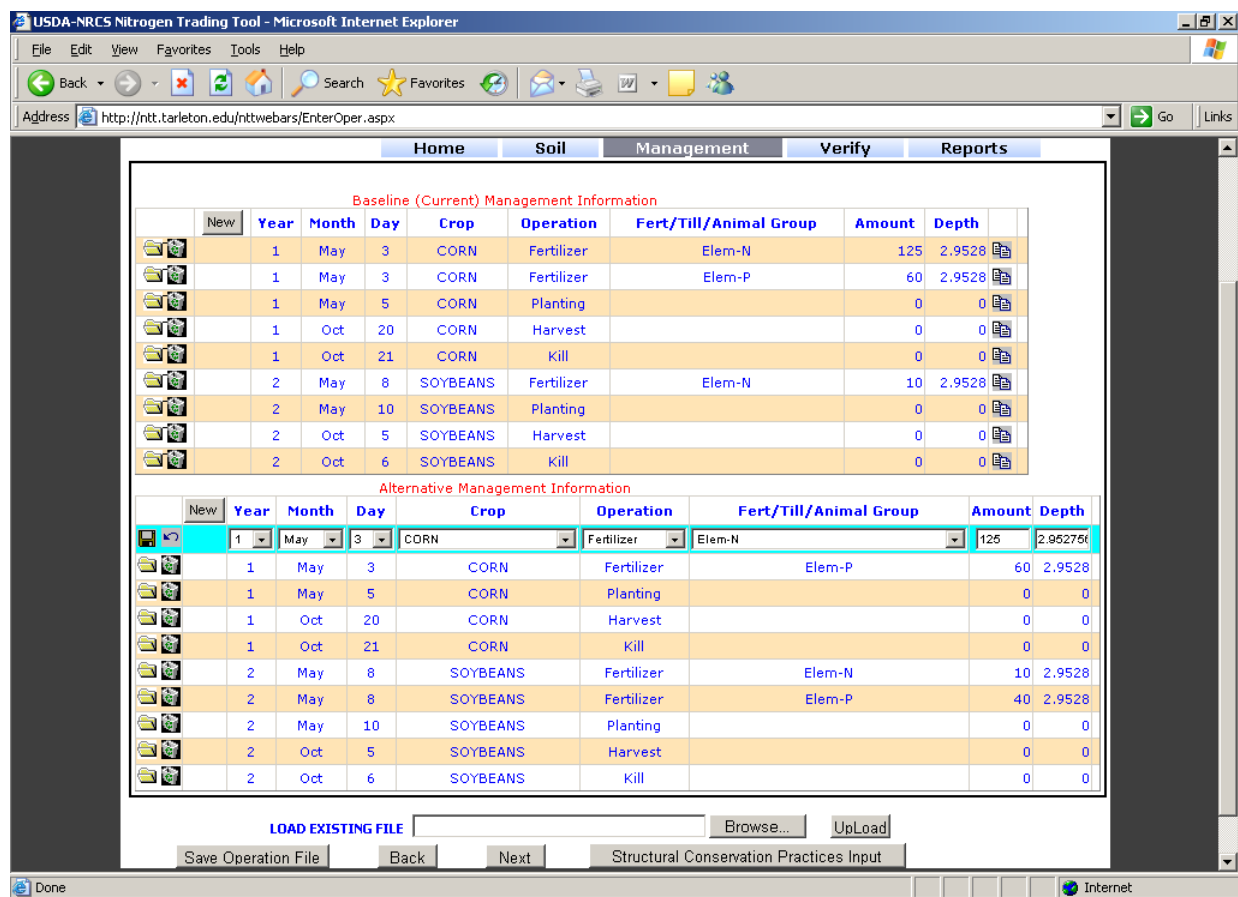


Figure G-19  
Detailed Management screen showing user editing of a specific operation

The same management modification options are available to you if you select a pre-loaded management scenario and wish to modify it. Simply select the pre-loaded management information that is closest to your desired specifications and click “Modify” (Figure G-15). The “Modify” screen appears, as in Figure G-18, displaying the pre-loaded management information details, with all the editing options as discussed in this subsection. Click “Next” to run NTT’s calculation tool.

#### G.2.2.4 Creating new management information

You can create new management information by selecting the “Upload/Create/Modify management Operation File” option as in the foregoing illustration. In the screen that is presented (Figure G-16), you enter a new management operation by clicking on the “New” button for the baseline or alternative scenario, as needed. Once you have finished entering all the management information required, you can click “Next” to proceed to the next phase of running and reviewing the NTT results. Note also that on this screen, you can

save the management information entered here to an external file on your computer by clicking on the “Save Operation File” button (Figure G-19). Click “Next” to run NTT’s calculation tool.

#### G.2.2.5 Running NTT program

In Figure G-20, we have already selected the cropping systems (corn-soybean), nutrient input, and the tillage types for both the baseline and alternative scenarios (using the procedures described in sections G.2.1.1 and G.2.2.1). Click “Next” to run NTT’s calculation tool. To view or edit the specific field operations included in each tillage option, you can use the “Modify” button as described in an earlier section.. Once you click “Next” a screen is presented that allows you to verify your selections before the calculation tool runs (Figure G-21).



Figure G-20  
Defining baseline and alternative tillage for a corn-soybean field

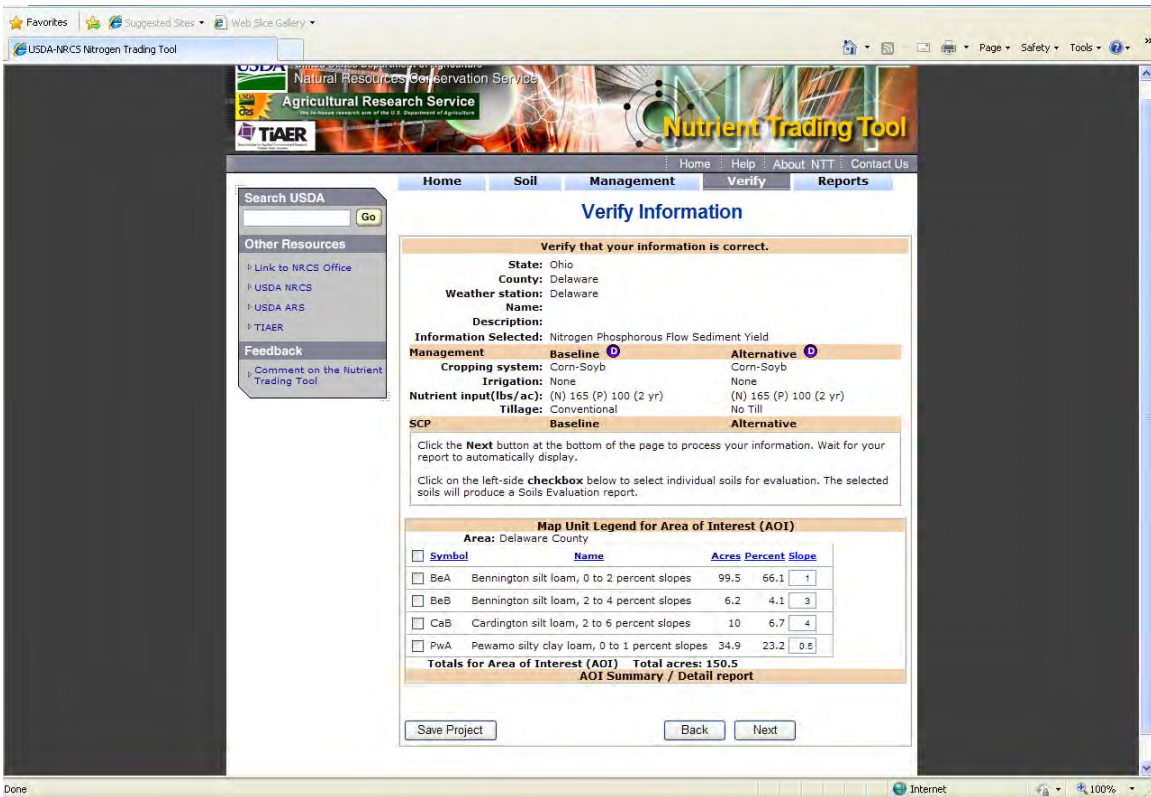


Figure G-21  
Verify Information screen allowing user to review information

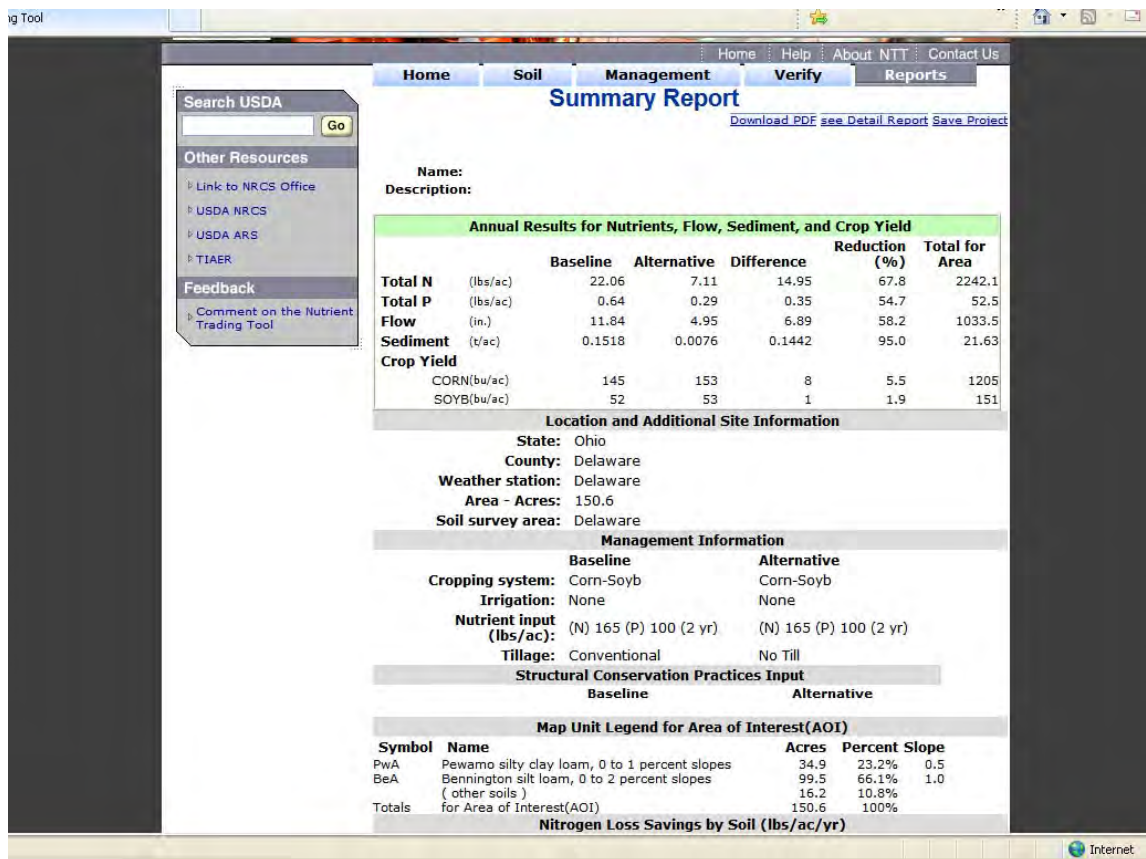


Figure G-22  
NTT results screen showing summary impact of no-till

Once you click “Next” on the “Verify Information” screen (Figure G-21), NTT’s calculation tool runs and presents the results (Figure G-22) for the two scenarios (baseline and alternative). The results displayed in the screen indicate that the only downside to the alternative scenario (no-till) is that soybean yields may be somewhat lower. However, many advantages are indicated. Corn yields are projected to go up while all nutrient and sediment losses decline significantly.

NTT’s calculation tool indicates that nitrogen losses decline by almost 15 lb/acre or 2,200 lbs for the 150-acre field. If nitrogen is the relevant nutrient for the water quality trading program, then the farmer can multiply the load reduction (2,200 lbs) by the program-designated adjustment factors for the field, to arrive at the total number of nitrogen credits that are generated. If phosphorus is the indicator of interest, then the load reduction value that will be used in the credit calculation is 53 lbs. In addition, as expected the no-till scenario significantly reduced soil erosion (by about 95%). Ancillary benefits such as reductions in sediment

loading may also be tracked by the water quality trading program.

### G.2.3 CASE 2: Filter strip

**Background information:** *The same farmer is interested in putting in a 50-foot wide filter strip at the edge of his 150-acre corn-soybean field. Both corn and soybeans are conventionally tilled on this field. He wants to know the potential water quality credits from this scenario.*

**NTT implementation:** NTT will provide reasonable estimates of the nutrient and sediment load reductions associated with the 50-foot filter strip. These estimates can then be used along with water quality program-specific information to calculate the nutrient credits for this farm.

The first step is to select the corn-soybean rotation for each scenario and then select “165 lb/acre nitrogen, 100 lb/acre phosphorus” as the nutrient application rates for the baseline and alternative scenarios (Figure G-23).

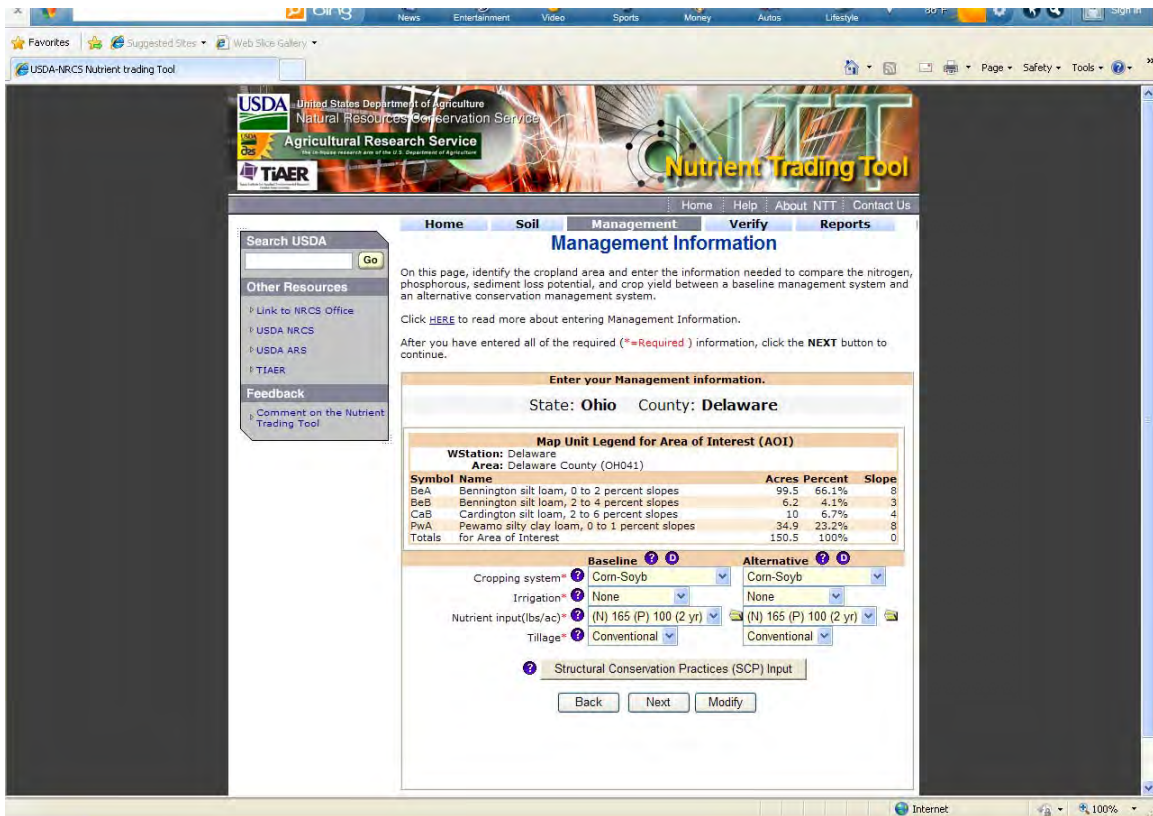


Figure G-23  
Management screen showing selection of nutrient and tillage options

### G.2.3.1. Selecting structural conservation practices

NTT provides the opportunity to evaluate a number of structural conservation practices such as filter strips and tile drainage. To access the structural conservation practices menu, click on the “Structural Conservation Practices (SCP) Input” button that is located near the bottom of the management information screen (Figure G-15). A new window is displayed (Figure G-24) that allows you to select the structural conservation practices

of interest and specify the required information. To select a given structural conservation practice, simply click the check box immediately to the left of its name. Once the practice has been selected, additional options appear that can be used to detail its design specifications. For instance, in the case of filter strips, once you click on the check box to select “Filter Strips (Grassed Buffer)”, two new options appear, one for specifying the type of vegetation on the strip, and the other for specifying the width of the filter strip.



Figure G-24  
Structural conservation practice screen prior to making selections

In the Structural Conservation Practices screen, select the filter strip option and specify 50 feet as the filter strip width (Figure G-25). Then, select “Switch grass” as the crop growing in the selected filter strip field. Finally, click “Next” to proceed to run NTT and obtain the results for this scenario.

The summary results screen will be displayed showing the impacts of the filter strip on the 150-acre field

(Figure G-26). The results indicate substantial reductions in nutrient and sediment losses. Crop yields are also reduced because land is taken out of production for installation of the filter strip. Thus the farmer is confronted with a trade-off situation – lower nutrient and sediment losses with some water quality credits, along with lower crop production for the entire farm, due to land taken out of production.

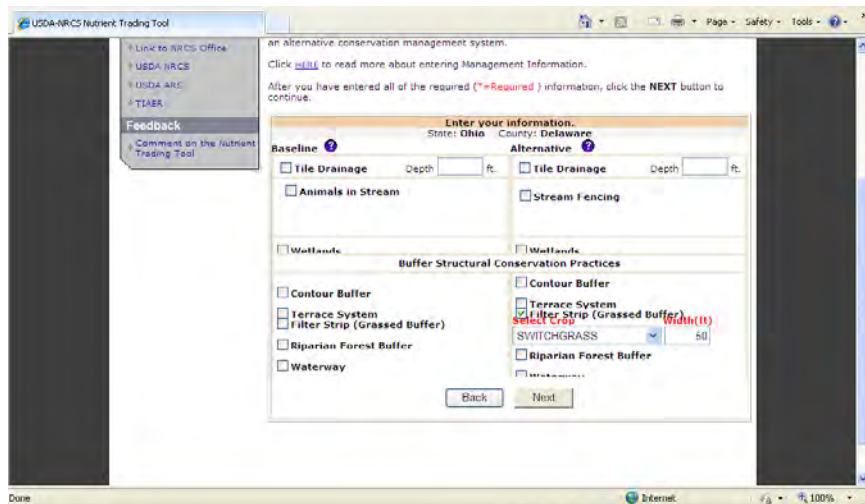


Figure G-25  
Addition of 50-foot filter strip to field for alternative scenario



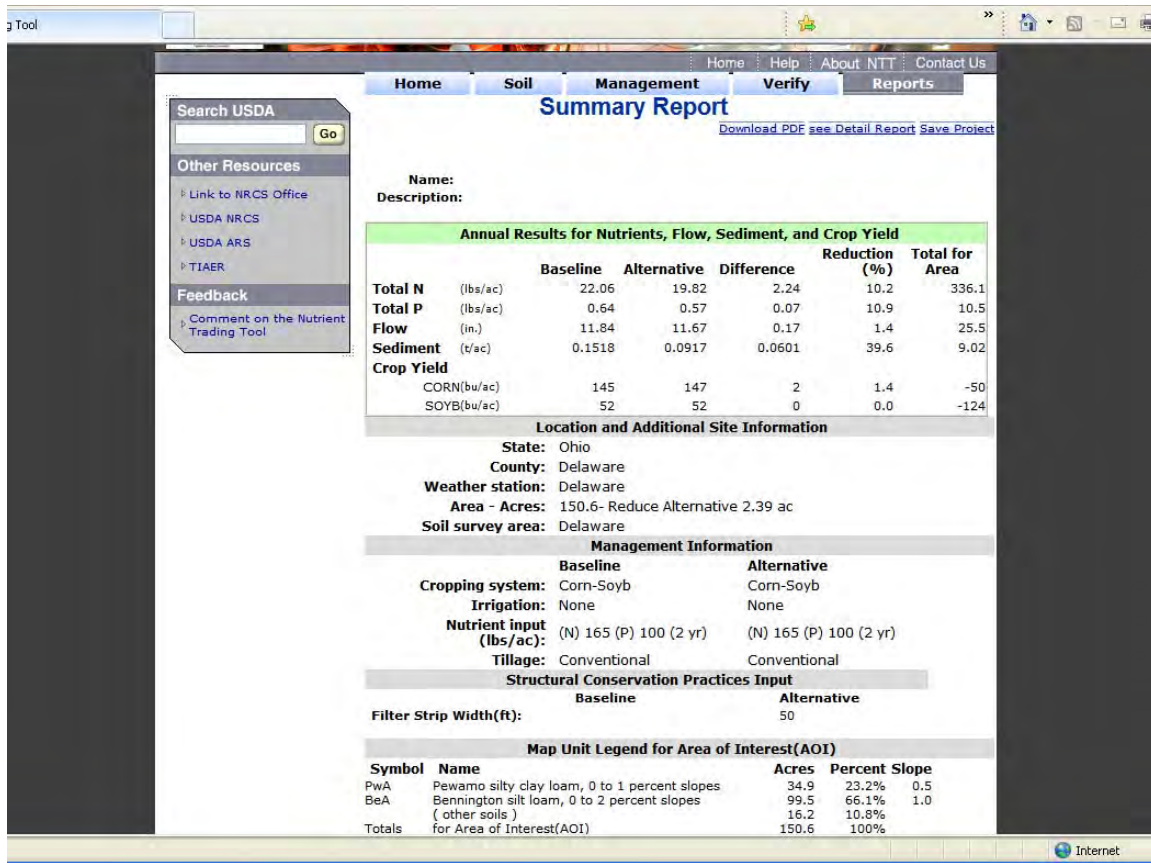


Figure G-26  
NTT results screen showing impact of 50-foot filter strip

### G.2.4. CASE 3: Multiple-practice scenario: no-till and filter strip

**Background information:** *The same farmer currently grows a corn-soybean rotation on a 150-acre field. Both corn and soybeans are conventionally tilled on this field and the total nutrient application rate is 165 lb/acre nitrogen and 100 lb/acre phosphate. He is considering switching completely to no-till production on this field. He is also interested in placing a 50-foot wide filter strip at the bottom edge of this field. He wants to know the potential water quality credits from this combined scenario.*

**NTT implementation:** NTT will provide reasonable estimates of the nutrient and sediment load reductions

associated with this combined scenario. These estimates can then be used along with water quality program-specific information to calculate the nutrient credits for this farm.

After defining the AOI, the next step is to select corn-soybean rotation for each scenario and “165 lb/acre nitrogen, 100 lb/acre phosphorus” as the nutrient input, also for each scenario. Then select conventional as the baseline tillage option and no-till as the alternative scenario tillage option (Figure G-27). Finally click on the “Structural Conservation Practices (SCP) Input” button to add the filter strip to the alternative scenario (Figure G-28).

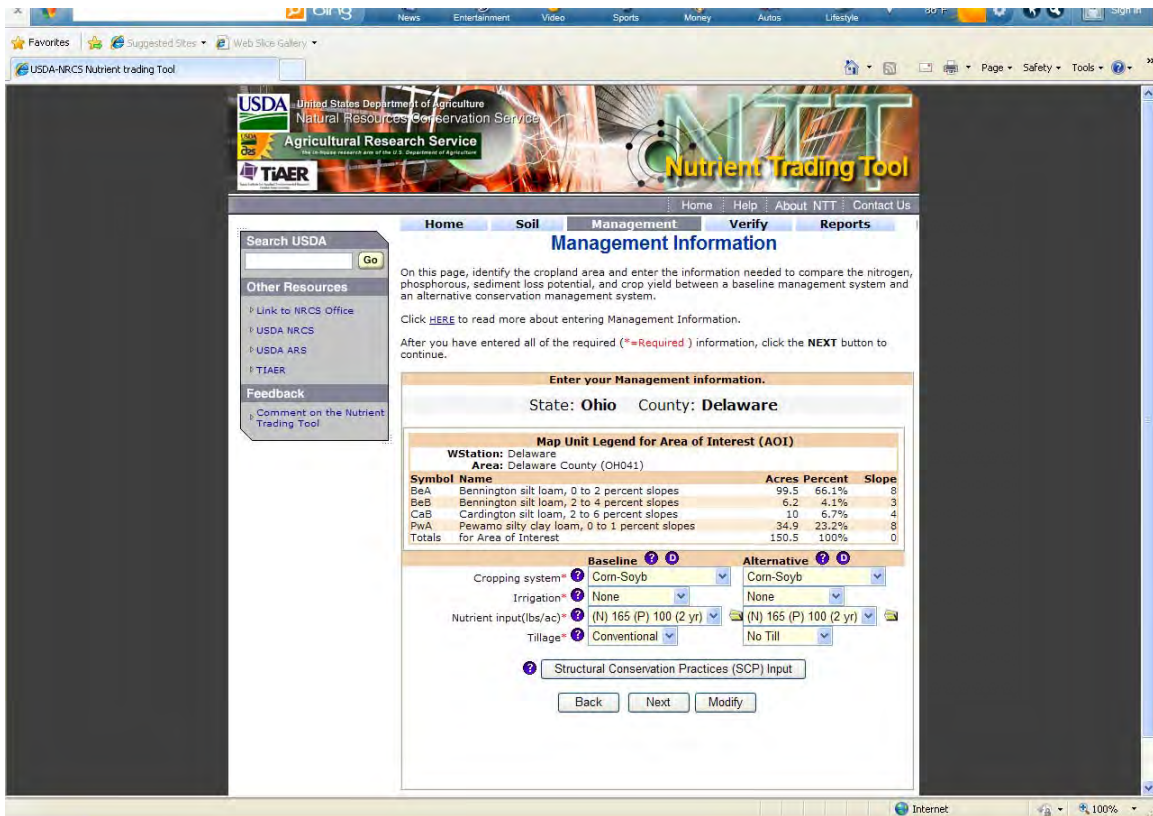


Figure G-27  
Selection of no-till for alternative scenario

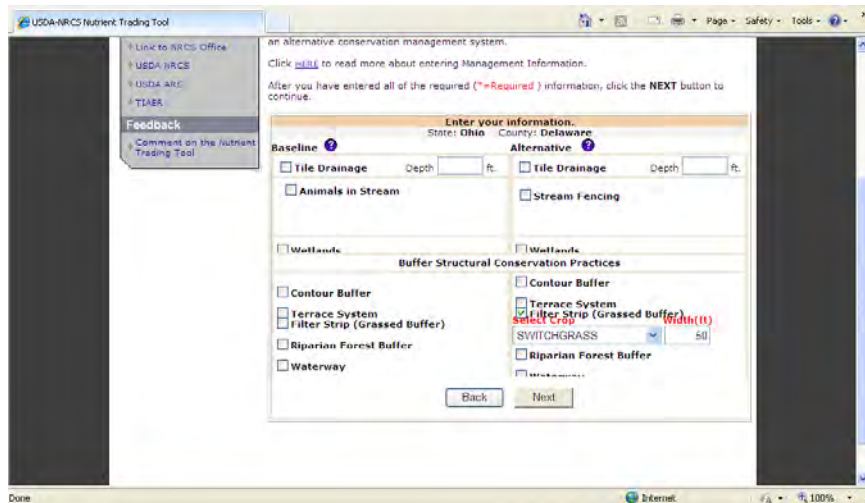


Figure G-28  
Addition of 50-foot filter strip to field for alternative scenario

In the Structural Conservation Practices screen, select the filter strip option and specify 50 feet as the filter strip width (Figure G-28). Then click “Next” to proceed to run NTT and obtain the results for the combined scenario. The summary results screen will be displayed showing the impacts of no-till and the filter strip on the

150-acre field (Figure G-29). The results indicate substantial reductions in nutrient and sediment losses. Whereas a portion of land is taken out of production, in this particular situation, the NTT results indicate some increase in overall corn and soybean production from this 150-acre field.

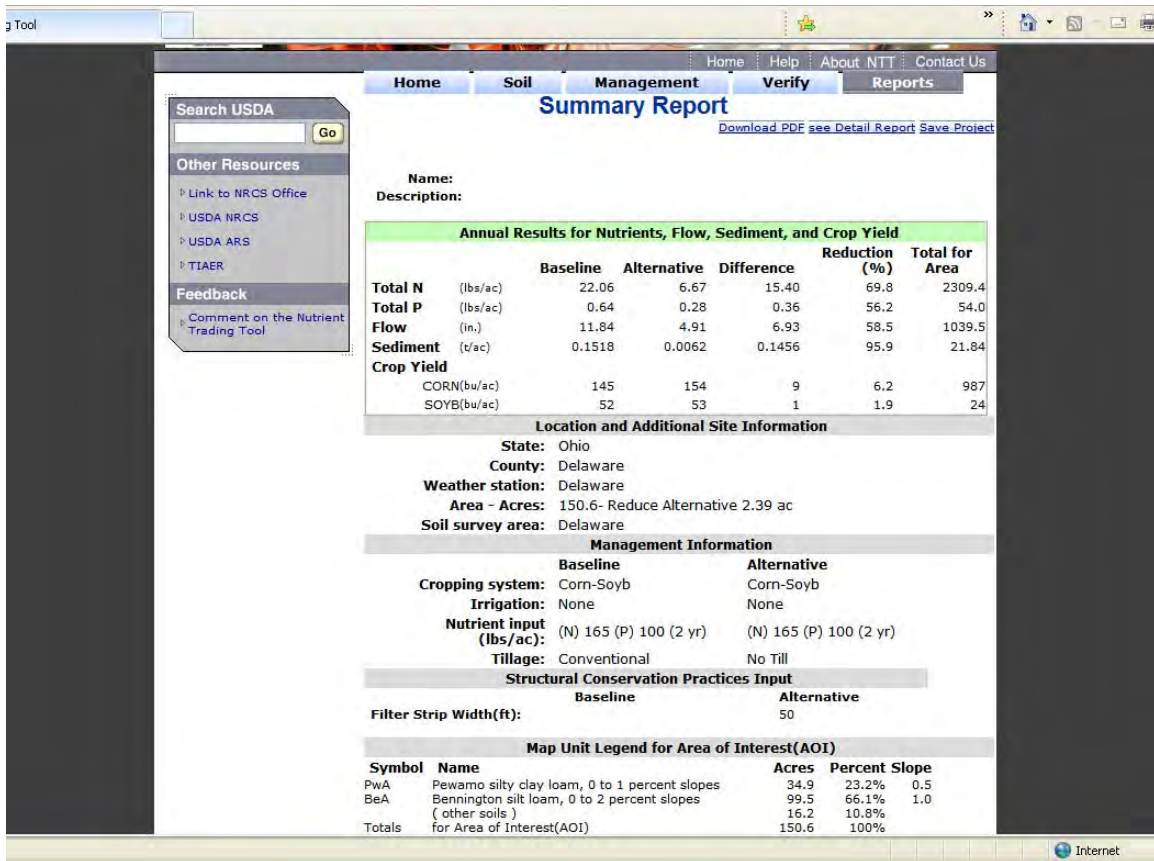


Figure G-29  
NTT results screen showing combined impact of filter strip and no-till

### G.3 Where to go for additional help

For additional help or to find out more about NTT, please contact

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### G.4 References

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Williams, J. R., R. C. Izaurralde, and E. M. Steglich. 2008. Agricultural Policy/Environmental eXtender Model: Theoretical documentation version 0604. BREC Report # 2008-17. Temple, TX: Texas AgriLIFE Research, Texas A&M University, Blackland Research and Extension Center. Available at: <http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx>. Accessed July 27, 2010.





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