SWAT Modeling Quality Assurance Project Plan

Support for Developing the Northern Canadian Watershed Based Plan:
Targeting Critical Source Areas of N and P and Modeling Lake Overholser

Submitted To The

Oklahoma Conservation Commission

For The

U.S. Environmental Protection Agency

Submitted by:

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This Quality Assurance Project Plan has been prepared according to *Guidance for Quality Assurance Project Plans for Modeling*, EPA QA/G-5M, EPA/240/R-02/007, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, D.C., December 2002. This Document is used to ensure that the modeling is scientifically sound and defensible, and that the modeling input and output are of the quality required for the intended purpose of this project. Portions of this document were taken from the Quality Assurance Project Plan titled *Modeling Quality Assurance Project Plan for TMDL Development for Dissolved Oxygen and Nutrients for Subsegment 020401 (Bayou Lafourche) in the Barataria Basin*, EPA Contract # 68-C-02-109, Task Order 0003, September 3, 2003.

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SECTION A: PROJECT MANAGEMENT

A1. QUALITY ASSURANCE PROJECT PLAN APPROVAL PAGE

Support for Developing the Northern Canadian Watershed Based Plan: Targeting Critical Source Areas of N and P and Modeling Lake Overholser

August 4, 2006

Plan Prepared by:

_____
Daniel E. Storm, Professor, Oklahoma State University Date

Investigator Approval:

_____
Daniel E. Storm, Professor, Oklahoma State University Date

Conservation Commission Approval:

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Dan Butler, Director, Water Quality Division Date

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Shannon Phillips, Assistant Director, Water Quality Division Date

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Greg Kloxin, QAPP Officer, Water Quality Division Date

Office of the Secretary of Environment Approval:

_____
Jennifer Myers Wasinger, Environment Programs Manager Date

EPA Approval:

_____
USEPA Region VI Office of Water Quality - Project Officer Date

_____
USEPA Region VI Office of Water Quality - Approving Officer Date

A2. DISTRIBUTION LIST

This document will be distributed to the following people:

Daniel E. Storm	Professor Biosystems and Agricultural Engineering Department Oklahoma State University
Michael J. White	Research Engineer Biosystems and Agricultural Engineering Department Oklahoma State University
Phillip R. Busteed	Research Engineer Biosystems and Agricultural Engineering Department Oklahoma State University
Scott Stoodley	Senior Program Director of Water Resources AMEC Earth and Environmental Sciences
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Shannon Phillips	Assistant Director, Water Quality Division Oklahoma Conservation Commission
Greg Kloxin	QAPP Officer, Senior Technical Writer Oklahoma Conservation Commission
Jennifer Myers Wasinger	Environment Programs Manager Office of the Secretary of Environment
USEPA QAPP Officer	USEPA Region VI, Office of Water Quality

A3. PROJECT/TASK ORGANIZATION

A3.1 Purpose/Background

Project organization provides the necessary information for the involved parties to understand their role in the project and identifies lines of authority and reporting for the project.

A3.2 Roles and Responsibilities

This section describes the overall organization of the modeling program that will be conducted by Oklahoma State University and its subcontractors for EPA Region VI. The project management, quality program, and modeling activities are included in this modeling quality assurance project plan (QAPP). Duties and responsibilities of personnel for various aspects of the modeling and reporting process are also described. The organizational aspects of the program provide the framework for conducting specific tasks. The organizational structure and function can also facilitate project performance and adherence to quality control (QC) procedures and quality assurance (QA) requirements. Key project roles are filled by those persons responsible for overseeing the modeling and ensuring that it is technically sound and scientifically defensible, as well as the persons responsible for approving and accepting final products and deliverables. The program organizational chart is presented in Figure A-1 and includes relationships and lines of communication among participants. The responsibilities of these persons are described in Table A-1.

A4. PROBLEM DEFINITION/BACKGROUND

The North Canadian River Basin is located in the west central portion of Oklahoma. Headwaters of the North Canadian River originate in Union County, New Mexico. The river flows east through the Oklahoma panhandle to Fort Supply Lake in Woodward County, and then in a southeasterly direction to Canton Lake and towards Oklahoma City. This project focuses on the North Canadian River downstream of Canton Lake to outlet of Lake Overholser, which has a drainage area of approximately 197,000 ha.

The objectives of this project are to 1) identify areas in the Northern Canadian River basin that likely contribute disproportionate amounts of nitrogen and phosphorus to Lake Overholser, 2) determine the endpoint for Lake Overholser necessary to meet Oklahoma Water Quality Standards, and 3) determine possible agricultural practices that may be implemented to meet this endpoint.

This Modeling QAPP will only cover Objectives 1 and 3. A separate QAPP will be submitted for the lake modeling in Objective 2.

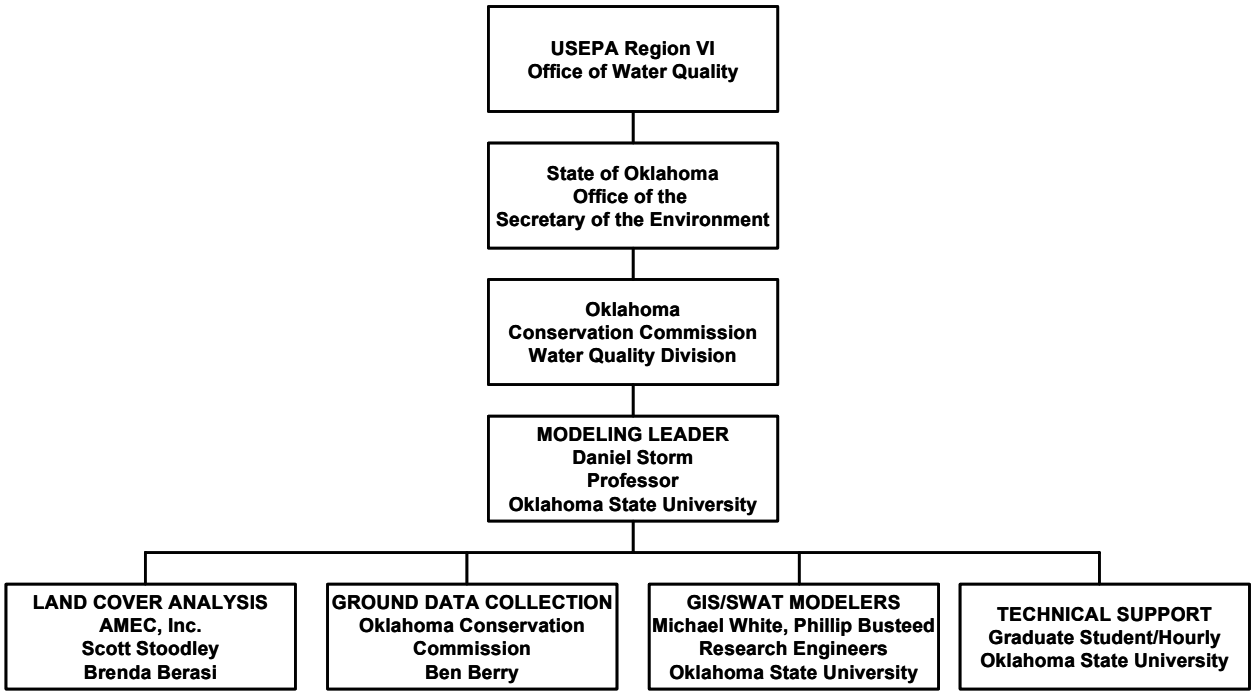

Figure A-1. Northern Canadian Targeting Critical Source Areas of N and P and Modeling Lake Overholser Organizational Chart.

Table A-1. Key Positions and Areas of Responsibilities.

Title	Description of Duties/Responsibilities
USEPA Region VI, Office of Water Quality	Approves the requirements for the project and reviews project deliverables to ensure standards have been met.
Oklahoma Office of the Secretary of the Environment	Recipient and administrator of Federal Clean Water Act funds, e.g. Section 319(h) funds.
Oklahoma Conservation Commission	Oversees work performed by the subcontractor for the project to meet EPA requirements.
Modeling Leader	Supervise project personnel and coordinate activities related to the project including but not limited to QAPP development and implementation, reporting, budgets, providing guidance and technical advise, assuring accurate and appropriate model input data and output interpretation, setup, calibration, and validation, and ensure that project goals are met.
Land Cover Analysis	Development of land cover for the modeling effort, and to ensure that the product is accurate and appropriate to meet project goals.
Ground Data Collection	Collection of ground truth data required to develop the land cover.
GIS/SWAT Modelers	Perform all aspects of the watershed modeling necessary to meet project objectives.
Technical Support	Support work performed by GIS/SWAT modeler.

A5. PROJECT/TASK DESCRIPTION

A5.1 Purpose/Background

The North Canadian River Basin is located in the west central portion of Oklahoma. Headwaters of the North Canadian River originate in Union County, New Mexico. The river flows east through the Oklahoma panhandle to Fort Supply Lake in Woodward County, and then in a southeasterly direction to Canton Lake and towards Oklahoma City. This project focuses on the North Canadian River downstream of Canton Lake to outlet of Lake Overholser, which has a drainage area of approximately 197,000 ha.

Nutrients and sediment are the primary pollutants in Oklahoma's surface waters. Nutrient and soil loss from upland and riparian areas can be reduced by best management practice (BMP) implementation. Funding for BMP implementation is provided by Section 319 of the Clean Water Act. Section 319(h) establishes funds to help states and tribal nations address nonpoint source water pollution (EPA, 2003). Through this program, the Oklahoma Conservation Commission (OCC) has finite funding available to implement BMPs throughout Oklahoma watersheds. To most efficiently use these funds, it is necessary for the OCC to quantitatively target areas with the highest potential for water quality improvement.

The SWAT 2000 model will be used to estimate total N and total P loading from the upland areas as well as targeting critical source areas. SWAT 2000 is a distributed parameter basin scale model developed by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas. SWAT 2000 is included in the Environmental Protection Agency's (EPA) latest release of Better Assessment Science Integrating Point and Nonpoint Sources (BASINS). An ArcView GIS interface is available to generate model inputs from commonly available GIS data.

A5.2 Description of Work to be Performed

A5.2.1 Data Compilation

Historical flow and water quality data from streams will be compiled from numerous sources. Historical GIS data will also be compiled, i.e. soils, topography, digital areal photography, streams, and ponds. Other historical data to be assembled include point source discharges (flow and nutrients), precipitation, temperature, and soil nutrient status.

A5.2.2 Pollutant Load Estimation

If adequate flow and water quality data are available, nitrogen and phosphorus loads will be estimated using the USGS LOADEST2 program. These load estimates will be used to calibrate the SWAT model.

A5.2.3 Land Cover Analysis

A digital land cover database for use in the watershed modeling will be developed from 30 meter, multi-spectral Landsat Thematic Mapper satellite imagery. Imagery will be acquired

covering the spatial extent of the watershed. For this project, a traditional classification method will be used where pixels are selected that represent patterns or land cover features that can be recognized or identified with help from other sources, such as ground data, aerial sources (photography, orthophoto quads) or maps. Knowledge of the types of information desired in the end product is required prior to the onset of classification. By identifying patterns, the software is trained to identify pixels with similar characteristics. AMEC Earth & Environmental Sciences will rely on the Oklahoma Conservation Commission to assist in collection of georeferenced ground truth data to ensure the best potential accuracy of the final products.

A5.2.4 Model Development

The SWAT model will be configured using available GIS and tabular data. The level of detail simulated is defined in the initial model development, and will be adequate to accomplish the goals of the project.

A5.2.5 Model Calibration

If there are adequate flow and water quality data, the SWAT model will be calibrated (see Section B.1) to reduce the uncertainty in the model predictions.

A5.2.6 Targeting Critical Source Areas

From the calibrated SWAT model, subbasin estimates by hydrologic response unit (HRU) for annual phosphorus loads will be documented. These loads will then be used to target potential critical source areas of phosphorus from upland areas. Graphical basin maps will be produced to show the results of the targeting methodology with the highest phosphorus contributing areas shaded by severity.

A5.2.7 Evaluating BMPs to Meet Water Quality Standards

The SWAT model will also be used to evaluate scenarios to estimate the potential reduction in phosphorus and nitrogen loads resulting from the implementing Best Management Practices (BMPs) to meet water quality standards in Lake Overholser.

A5.2.8 Documentation

The documentation task will consist of compiling all applicable historical and supporting data, and develop summary tables for the final report that will be submitted to USEPA. The report will also include a summary of model assumptions, model calibration, model projections, and targeting results.

A6. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

A6.1 Purpose/Background

The purpose of this element is to document the data quality objectives (DQOs) of the project and to establish performance criteria for the measurement system that will be

employed in generating these data. For this modeling QAPP, these data being generated are the water quality model predictions from SWAT.

A6.2 Data Quality Objectives

Targeting critical source areas of pollutants from upland areas is an important component to implementing technical assistance and cost share programs in areas that will potentially provide the greatest improvement in water quality with limited funds. Therefore, the SWAT model should appropriately represent the physical, chemical, and biological processes occurring with the watershed so that the runoff volume, sediment yield, and nutrient loads can be accurately qualified.

Model calibration reduces the uncertainty in the model predictions. We begin the process by calibrating the SWAT model for flow, then sediment, and finally for nutrients. Assessment of calibration performance may be determined using statistical measures (mean, standard deviation, relative error, Nash-Sutcliffe Efficiency, and Coefficient of Determination) as well as graphical techniques (observed vs predicted and time series graphs).

It is important to note that a properly calibrated model will never perfectly match observed data since a hydrologic/water quality model is by definition a simplification of complex real world processes. In addition, there are inherent errors in the observed flow and water quality data. Therefore, rather than trying to match each observed data point, we try to model appropriately the relevant watershed processes. The ultimate acceptability of the model calibration will be determined based on whether or not the model predictions are believed to accurately represent the watershed processes for this specific targeting application.

A7. SPECIAL TRAINING CERTIFICATION

Personnel performing modeling for this task order will be familiar with the requirements of this QAPP and will have previous experience in applying the SWAT model for targeting purposes. No special training or certifications are necessary for this modeling task.

A8. DOCUMENTS AND RECORDS

A8.1 Purpose/Background

This element describes the following:

- Process for ensuring that appropriate project personnel have the most current approved version of the QAPP.
- Information and records to be included in the report package.
- Other records and reports that will be produced.
- Requirements for final disposition of records and documents.

A8.2 QAPP Distribution

Upon approval of the QAPP by the USEPA Quality Assurance Officer and the Oklahoma Conservation Commission, the QAPP will be distributed to the Modeling Leader, the Land Cover Analysis group, the Ground Data Collection personnel, the GIS/SWAT Modeler, and the Technical Support personnel. If any revisions to the QAPP are required after the approval, a memorandum detailing the changes will be distributed to all participants after obtaining proper approval(s).

A8.3 Information in Targeting Report Package

As discussed in section A.5.2.6, the report will consist of summary tables for historical and supporting data, as well as summaries for the model assumptions, model calibration, model projections, and targeting results. The report will also include summaries for model input and output, and plots of predicted and observed flow, sediment, and nutrient loads (when applicable). Large color printouts of the watershed showing targeted areas and a GIS layer of targeted areas will also be provided.

A8.4 Documentation Control and Management

A majority of internal documentation and record transfer within the project team while the project is ongoing will be done electronically. Hard copy reports will be made to USEPA Region VI and the Oklahoma Conservation Commission. The Project Leader will be responsible for final electronic and hard copy documentation version control, updates, storage, tracking, and distribution. Because existing software will be used for all phases of this project, there is no need to develop any new file types or protocols. While the project is ongoing, the GIS/Modeler will backup all electronic documentation and data on local hard drives with weekly full backups and daily incremental backups. The backup data will be archived using two separate hard drives, one for daily backups and the other for weekly backups. In addition, any documentation and data received by the Modeling Leader from anyone on the project team will be archived using a similar daily and weekly backup scheme.

A8.5 Disposition of Records and Documents

At the end of the project, all documentation, data (GIS, water quality data, etc.), and SWAT model files will be archived on DVDs. These DVDs will be archived and stored by the Modeling Leader, and if requested will be provided to the USEPA Region VI and/or the Oklahoma Conservation Commission.

SECTION B: DATA GENERATION AND ACQUISITION

B1. DATA SOURCES AND SELECTION

Basin scale hydrologic modeling requires a vast amount of data with many of these data coming from non-direct measurements, such as other modeling studies, model user manuals, and published literature. The modeling report will contain all data sources and

references. These data come from a variety of sources with some of the sources given in Table B-1. Often there are several data sets available from which to choose for a particular modeling task. These data are evaluated based on the criteria described below.

Table B-1. Potential data sources for the SWAT model.

Data Name	Data class	Data Type	Data Source
30 m DEM	GIS	Elevation	US Geological Survey
MIADS	GIS	Soils	Oklahoma Natural Resource Conservation Commission
Landsat imagery	Image	Multi-spectral	Satellite Imaging
Ground truth	Tabular		Oklahoma Conservation Commission Personnel
STATSGO database	Tabular	Soils	Soil and Water Assessment Tool
NEXRAD precipitation	Tabular	Weather	Arkansas-Red Basin Forecast Center
NOAA Cooperative Observer Network	Tabular	Weather	National Oceanic & Atmospheric Administration
Soil test phosphorous	Tabular	Soil test Phosphorus	Oklahoma State University Soil, Water & Forage Analytical Laboratory
Management operations	Tabular	Management	Cooperative Extension Publications

B1.1. GIS Data Detail

GIS data come in a variety of detail levels, which may be expressed as a resolution or map scale. White (2001) found that the detail of input GIS data has a significant impact on SWAT model output.

B1.2. Age of Data

Some data are more time sensitive than others. For example, land cover may change dramatically over the span of a decade, where as soils typically change only over geologic time.

B1.3. Accuracy

When accuracy information is not available, the data must be assessed by professional judgement.

B1.4. Temporal Continuity

Temporal continuity is of great importance when selecting weather, streamflow, or water quality data. Weather and streamflow should ideally be continuous on a daily basis, although it is possible to estimate missing days based on other data. These data are seldom continuous for long periods of time, thus continuity is a common criterion for data selection.

B1.5. Spatial Consistency

Spatial consistency is often sacrificed to use the most current data available. Most data sets cover only a limited area such as a state or county. A basin is typically not limited to those same boundaries, and often cross both state and county lines. This leads to the use of multiple GIS data sets to define a single model input layer and may create a lack of consistency across the basin.

B2. QUALITY AND LIMITATIONS OF SWAT MODEL DATA

It is not currently possible to comprehensively quantify the error in SWAT model predictions, thus there are no quantitative data quality requirements. It is possible, however, to list model limitations. Model limitations may be the result of data used in the model, inadequacies in the model, or using the model to simulate situations for which it was not designed. Hydrologic models will always have limitations, because the science behind the model is neither perfect nor complete. A model by definition is a simplification of the real world. The following is a list of notable SWAT model limitations:

B2.1 Weather

Weather is the driving force for any hydrologic model. Data collected at a few points are applied to an area of thousands of square miles. Rainfall can be quite variable, especially in the spring when convective thunderstorms produce precipitation with a high degree of spatial variability. It may rain heavily at a weather station, but may be dry a short distance away. On an average annual or average monthly basis, these errors may cancel. This limitation among others, cautions us against using daily model output.

B2.2 Radical Parameter Changes

Scenarios involving radical changes to the basin result in greater uncertainty. The SWAT model is calibrated using estimates of what is presently occurring in the basin. Large departures from calibration conditions raise the level of uncertainty in model predictions.

B2.3 Small Land Covers

Land uses that cover very small areas are not represented in the SWAT model. Land uses that occupy limited areas such as unpaved roads, bare areas, construction sites, and some row crops may not be simulated. In addition, most of these features may not be depicted in the available land cover. Some of these small areas may contribute many times more sediment on a per unit area basis than rangeland. Although significant, they may not be able to be simulated with the currently available data.

B2.4 Hydrologic Response Unit (HRU) Characteristics

Each HRU is assumed to have the uniform characteristics by the SWAT model. An HRU is a unique combination of soil and land cover within a subbasin. Each portion of the HRU has the same characteristics regardless of its location within that HRU. Local factors such as slope are not considered variable within an HRU, even though slope is a important factor in both sediment and nutrient contributions.

B.2.5 Management Uncertainty

There is a great deal of uncertainty associated with management. In reality, management varies significantly from field to field. It is not possible to easily determine what is happening where, or to simulate all these activities in the model. Therefore, categories are

created to cover reasonable managements choices only.

B2.6 Instream Process

SWAT models in-stream processes are based, in large part, on unvalidated assumptions of channel and stream-bank properties. Therefore, these processes will be turned off and not utilized.

B3. MODEL CALIBRATION

The first step in the SWAT calibration process is evaluating if there are enough flow and water quality data available to calibrate the model. Generally speaking, for flow we would like to have 10 years of daily flow to properly calibrate the SWAT model, assuming that the data reflect a range of wet to dry precipitation years. In order to calibrate the SWAT model for sediment and/or nutrients, we typically develop flow vs concentration relationships using a nonlinear regression program, like the US Geologic Survey program LOADEST2 (Crawford, 1996), and use the relationship to estimate daily loads. Typically these regressions require, at a minimum, approximately 40 data points at one location taken over a wide range of flows. A less desirable method to calibrate for sediment and/or nutrients is to use the observed concentration data directly. However, this requires calibrating the SWAT model on a daily time step, which is more difficult and has a higher level of uncertainty compared to a monthly or annual calibration. It should be noted that the minimum number of water quality data and years of daily flow data is project specific.

The next step in the calibration process is to perform the initial model setup and configuration. The model is then calibrated in the following order (Figure B-1): 1) annual flow calibration, 2) monthly and/or daily flow calibration, 3) sediment calibration, and 4) nutrient calibration. Calibration is an iterative procedure that progresses from one model component to another and from course to fine parameter modifications. Block diagrams of these procedures are shown in Figures B-1 to B-4. These block diagrams are general, since it is not possible to represent all the specific details or decisions made by a modeler. Many of the blocks actually represent many highly specific decisions based on many aspects of the model predications and observed data comparisons.

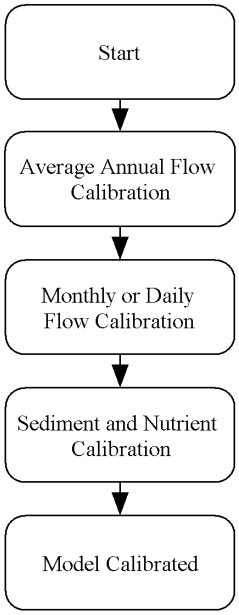

Figure B-1. General SWAT model calibration procedure.

The calibration process requires goodness-of-fit statistics to be used in describing the model's performance relative to the observed data. The ASCE Task Committee (1993) recommended graphical and statistical methods useful for evaluating model performance. In most instances, both visual comparisons of predicted and observed data as well as goodness-of-fit statistics should be used. Plotting of predicted results and observed results along with the 1:1 line can be helpful in identifying model bias. The percent deviation of predicted values from observed values is one numerical goodness-of-fit criterion. A second basic goodness-of-fit criterion recommended by the ASCE Task Committee (1993) is the Nash-Sutcliffe coefficient or coefficient of simulation efficiency. Legates and McCabe (1999) evaluated various goodness-of-fit measures for hydrologic model validation and suggested that correlation and correlation-based measures (e.g., the coefficient of determination) are oversensitive to extreme values and are insensitive to additive and proportional differences between model estimates and observed values. Thus, correlation-based measures can indicate that a model is a good predictor, even when it is not. Legates and McCabe (1999) concluded that measures such as the Nash-Sutcliffe coefficient of efficiency and the index of agreement are better measures for hydrologic model assessment than correlation-based measures. Legates and McCabe (1999) suggested a modified Nash-Sutcliffe coefficient that is less sensitive to extreme values may be appropriate in some instances. They also suggested additional evaluation measures such as summary statistics and absolute error measures (observed and modeled means and standard deviations, MAE and RMSE) should be reported for model results.

There are no standards or a range of values for goodness-of-fit statistical parameters that will adjudge the model performance as acceptable (Loague and Green, 1991). Ramanarayanan et al. (1997) suggested values of goodness-of-fit statistics for determining the acceptable performance of the APEX model. They indicated that values close to zero for the correlation coefficient and/or the Nash-Sutcliffe coefficient indicated the model

performance was unacceptable or poor. They judged the model performance as satisfactory if the correlation coefficient was greater than 0.5 and the Nash-Sutcliffe coefficient was greater than 0.4. Santhi et al. (2001) assumed a Nash-Sutcliffe coefficient greater than 0.5 and a Coefficient of Determination (R^2) greater than 0.6 indicated acceptable model performance when calibrating SWAT. However, acceptable statistical measures are project specific.

In this study, we will use both the graphical and statistical goodness of fit techniques discussed above. For monthly and annual calibrations we will attempt to calibrate within a relative error of 3, 25, and 25 percent for flow, sediment, and nutrients, respectively. Note that the model will only be calibrated for components that have an adequate amount of data available. If the model is not calibrated, the results are still valid and useful. However, they will contain a higher degree of uncertainty compared to a calibrated model.

B4. HARDWARE AND SOFTWARE CONFIGURATION

No special hardware is necessary for the modeling in this task order. The software to be used for the modeling is SWAT 2005 running under Microsoft Windows XP, which has been well tested and needs no modification for use in this project.

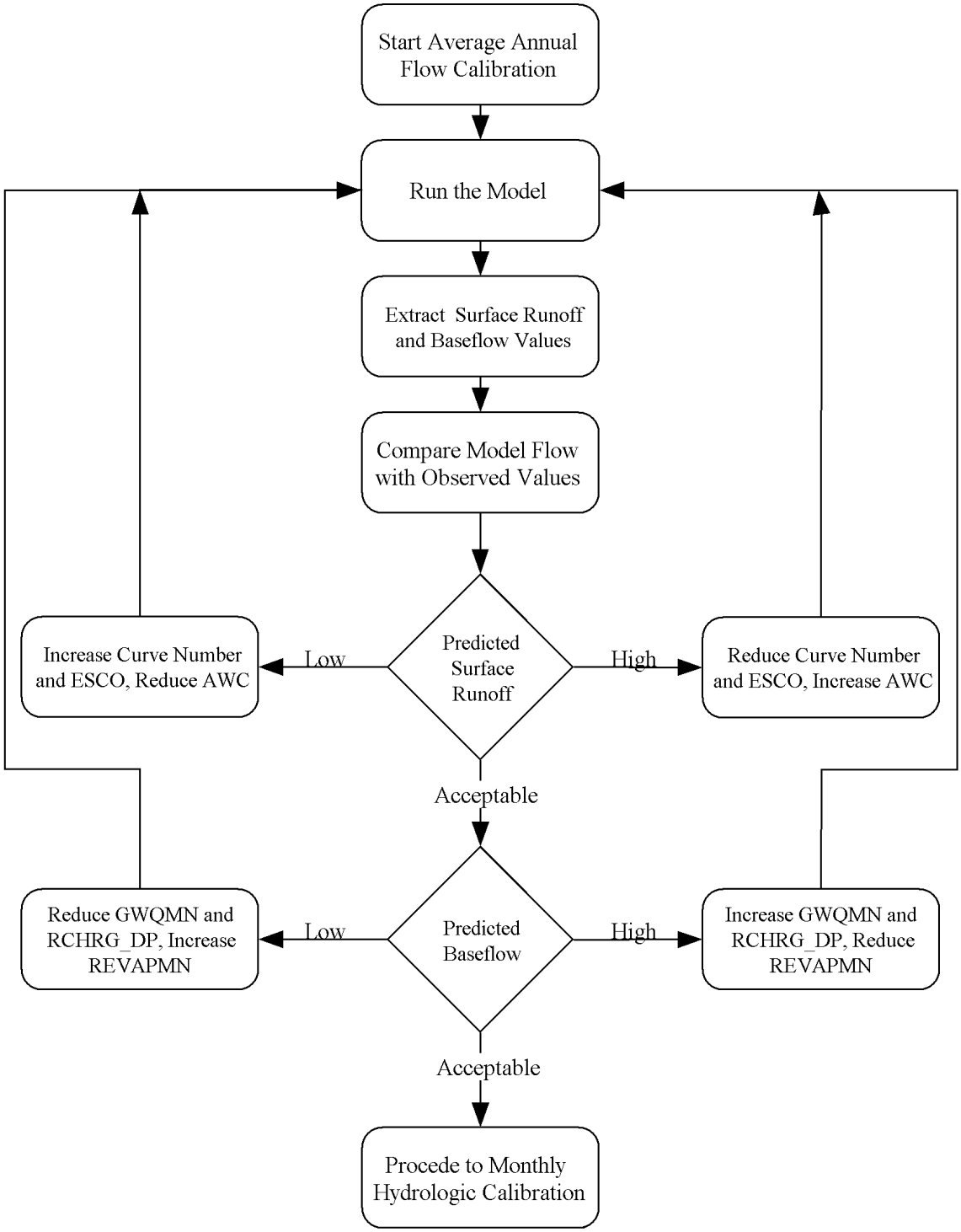

Figure B-2. Average annual flow calibration procedure used for the SWAT model.

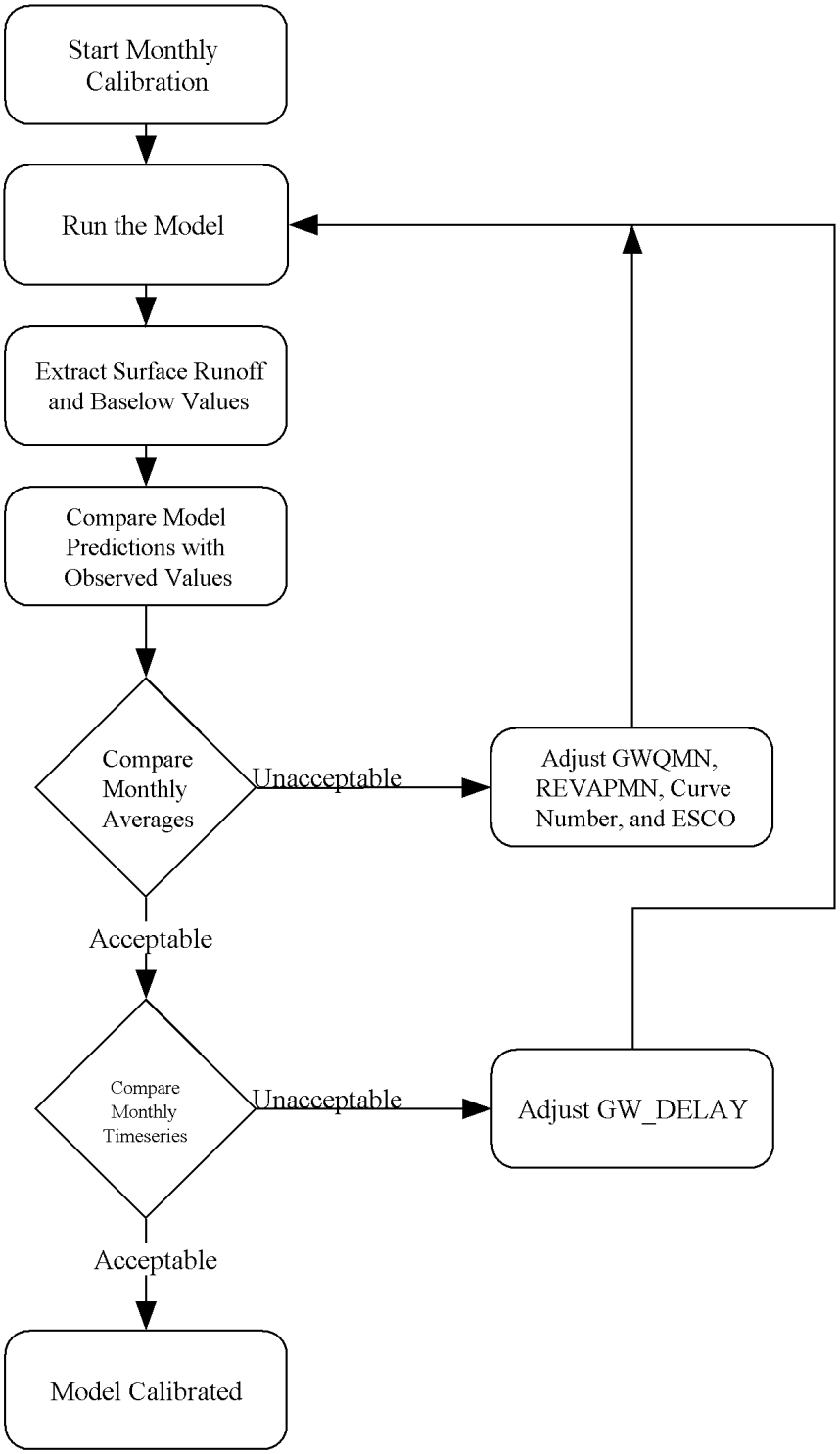

Figure B-3. Monthly flow calibration procedure used for the SWAT model.

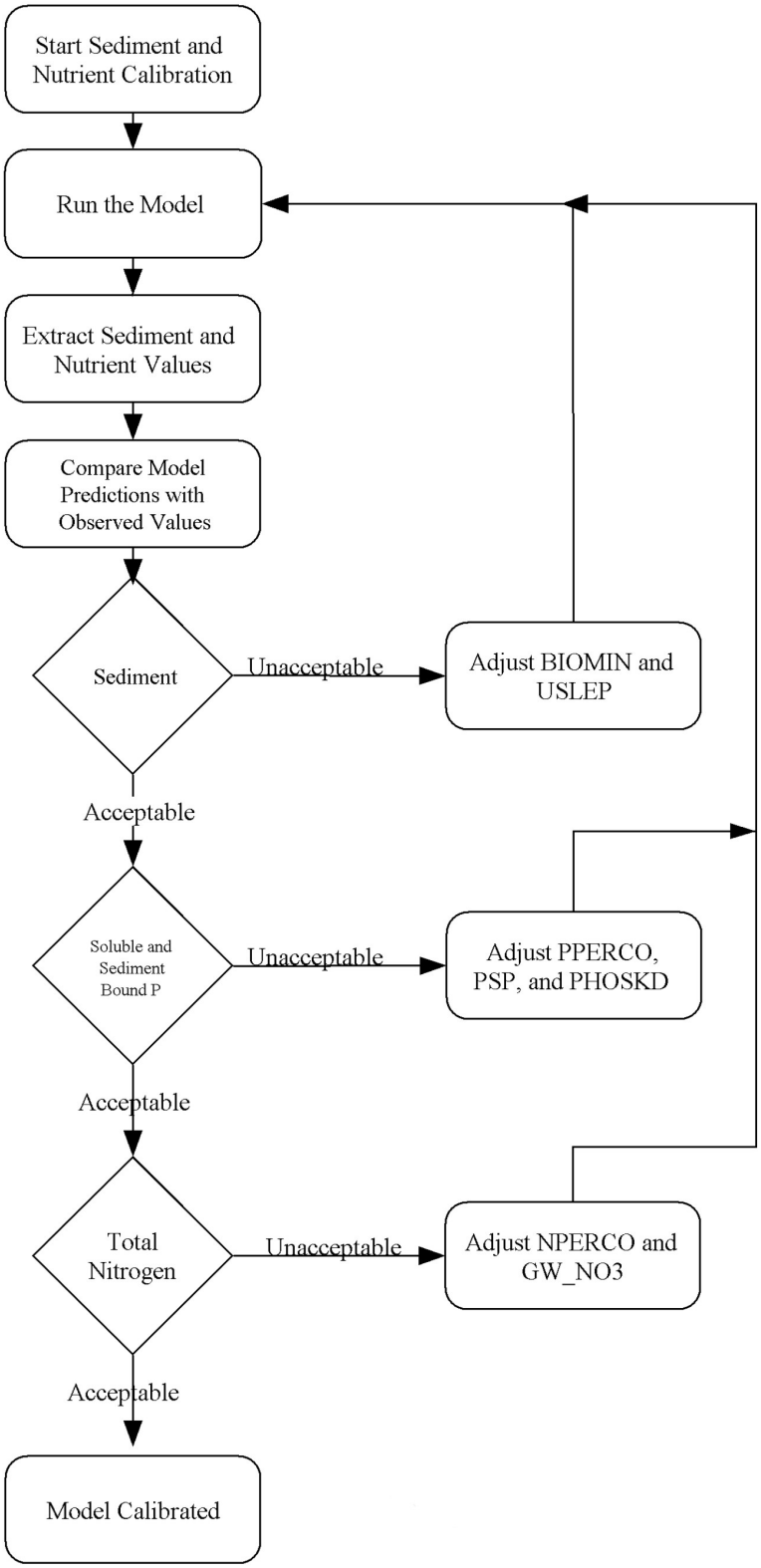

Figure B-4. Sediment and Nutrient calibration procedure used for the SWAT model.

SECTION C: ASSESSMENT AND OVERSIGHT

C1. ASSESSMENT AND RESPONSE ACTIONS

C1.1 Purpose/Evaluation

The purpose of this element is to describe internal and external checks that ensure that:

- All elements of the QAPP are correctly implemented as prescribed.
- The quality of the data generated by implementation of the QAPP is adequate.
- Corrective actions, when needed, are implemented in a timely manner and their effectiveness is documented.

C1.2 Assessment and Project Activities

No external audits will be conducted for the modeling. Internal checking of model results will be performed by the Modeling Leader and through reviews by the Oklahoma Conservation Commission and the US EPA Region VI. This internal checking will go on throughout the model application process, not just at the end. The purpose of this self-assessment will be to verify that appropriate input values are being used and proper calibration procedures are being followed. The Modeling Leader will be responsible for the final product before it is submitted to the Oklahoma Conservation Commission and the US EPA Region VI.

C1.3 Reporting and Resolution of Issues

Findings of practices and procedures that do not conform to this modeling QAPP will be reported by the Modeling Leader to the Oklahoma Conservation Commission QAPP Officer. These findings as well as deficiencies discovered will be reported to the Modeling Leader as soon as they are discovered. Appropriate corrective action, including that already in place, will be discussed. Corrective action will then be initiated or modified as needed. Corrective action will be documented through preparation and submittal of memoranda to the Modeling Leader. The Task Order Leader and the QA Coordinators will be notified, as necessary, of any deficiency that might compromise the quality of the data or adversely affect the health of personnel resulting in a stop-work situation.

C2. REPORTS TO MANAGEMENT

Modeling results and associated documentation will be compiled by the Modeling Leader and submitted to the Oklahoma Conservation Commission and US EPA Region VI after internal checking. Results of QC checks will be presented to the Modeling Leader. After all QAQC activities and appropriate corrective actions have been identified, implemented, and evaluated, the Modeling Leader will prepare a memorandum describing the results of QAQC activities, and corrective actions with appended documentation, as necessary.

SECTION D: DATA VALIDATION AND USABILITY

D1. DEPARTURES FROM VALIDATION CRITERIA

The purpose of this element is to state the criteria for deciding the degree to which each data item has met its quality specifications as described in Group A. This decision will be based on the investigator's estimate of the effect that each deviation from the QAPP will have on the usability of the associated data item, its contribution to the quality of the reduced and analyzed data, and its effect on the decision. Quantitative criteria for acceptance of the calibration were listed in Section B.3. The model calibration results will be evaluated against these criteria by the Modeling Leader.

D2. VALIDATION METHODS

Validation is the process of verifying the ability of a calibrated model to make predictions outside the calibration period. A portion of the available data is withheld during calibration and later used to validate the model. The SWAT model will not be validated unless sufficient data exist.

D3. RECONCILIATION WITH USER REQUIREMENTS

Modeling will be reviewed by the Modeling Leader to assess the usability of the model results, in light of any QAQC issues identified, for the intended purpose (e.g. targeting). In general, model results that are generated such that acceptance criteria are met will be deemed useable for the intended purpose. If data quality indicators (performance criteria) do not meet the project's requirements for DQOs as outlined in this QAPP, these data may be discarded. The Task Order Manager will evaluate the cause of the failure (if possible) and make the decision to discard the modeling and re-generate it.

SECTION E: REFERENCES CITED

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