FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task D

Quality Assurance Project Plan

Draft Report

March 2010

44237-001

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES COLORADO 1874

AET
Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK D
DRAFT REPORT

Quality Assurance Project Plan

Prepared for:

Florida Department of Health
Division of Environmental Health
Bureau of Onsite Sewage Programs
4042 Bald Cypress Way Bin #A-08
Tallahassee, FL 32399-1713

FDOH Contract CORCL

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Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

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SCHOOL OF MINES
1874
COLORADO

Table of Contents

List of Figures

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Section 1.0 Introduction

1.1 Background

Nitrogen transport in the subsurface is a complex process, especially when considering the nitrogen inputs from onsite sewage treatment and disposal systems (OSTDS). Figure 1-1 summarizes the conceptual understanding of the inputs of nitrogen and the transformative, advective, and dispersive processes that lead to measureable nitrogen concentrations groundwater. The dominant transformation processes in ground-water include advection, dispersion (due to heterogeneities) and denitrification (conversion of nitrate to nitrogen gas).

Additional discussion regarding modeling the fate and transport of nitrogen and its movement and distribution in groundwater related to OSTDS was presented in the Task D Literature Review (submitted previously).

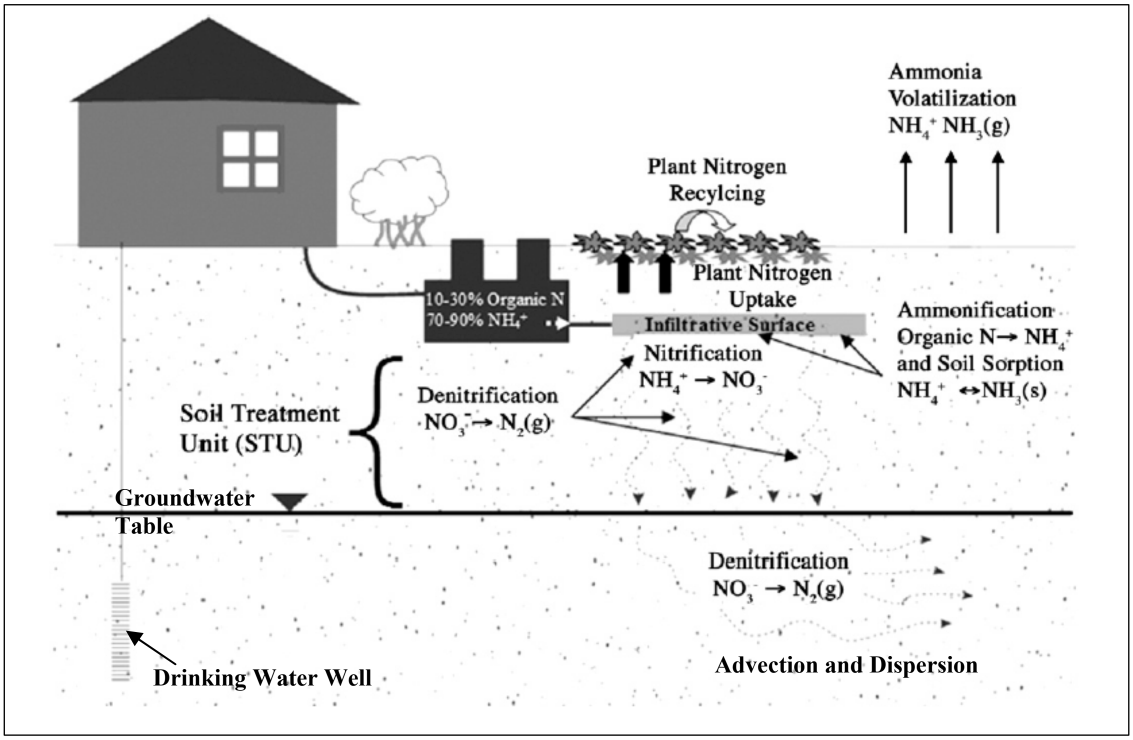

Figure 1-1: Nitrogen Processes Occurring in a Typical OSTDS (after Heatwole and McCray, 2007)

1.2 Project Scope and Purpose

For Task D of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS), Colorado School of Mines (CSM) will develop a simple modeling tool to evaluate the fate and transport of nitrogen in groundwater related to the use of OSTDS. The model development will include the model conceptualization, design, and model-performance evaluation.

The goal of Task D is develop a user-friendly modeling-tool that can be used to simulate nitrogen transport and transformation in groundwater, and to predict spatial and temporal nitrogen concentrations and fluxes, for a robust set of conditions relevant to OSTDS. Conditions that are important in Florida include seasonal loading from OSTDS, seasonal precipitation patterns, a spatial distribution of OSTDS, soil treatment, ground water transformation and transport, the ability to produce output concentrations and a reasonable plume shape, and to provide information on mass flux at a downstream boundary.

The project organization is described in the next section, and the technical approach is described in detail in Section 2.0.

1.3 Project Organization

Task D is comprised of the following activities over 5 years:

1) Literature review,
2) Plan development,
3) Development or selection of a simple tool that calculates or estimates the spatially averaged nitrogen removal in different soil types in Florida for input into the groundwater modeling tool,
4) Development of an analytical modeling tool that can be used to predict temporal and spatial concentrations and fluxes of nitrate in groundwater,
5) Selection of existing site data (including from Task C) for model-performance evaluation,
6) Performance evaluation of the model,
7) Develop methodology for determining model input parameters,
8) Develop a risk-based framework to use the model in decision making,
9) Develop a framework to evaluate when use of analytical model is appropriate, or when more complex modeling is warranted,
10) Integration of a process-based unsaturated soil treatment module with the groundwater analytical modeling framework in Task D.3,
11) Incorporate spatially variable OSTDS inputs with the unsaturated soil treatment module,
12) Evaluate the performance of the soil-treatment module with data collected from Task C,
13) Selection of existing site data for integrated soil-aquifer model-performance evaluation,
14) Develop methodology for determining integrated soil-aquifer model input parameters,

15) Performance evaluation of the integrated soil-aquifer model,

16) Develop a risk-based framework to use the integrated model in decision making,

17) Develop a framework to evaluate when use of analytical model is appropriate, or when more complex modeling is warranted,

18) Reporting.

The literature review has been previously submitted to the Florida Department of Health (FDOH) and the Research Review and Advisory Committee (RRAC) for review (Task D.1). This Quality Assurance Project Plan (QAPP) describes the proposed modeling-tool development, implementation, and testing, each building off of the existing knowledge of OSTDS performance and modeling techniques.

The work described in this QAPP encompasses the entire scope of the 5-year project. We anticipate that items 1 through 6 above and associated reporting will be completed in the forthcoming year, and this QAPP primarily details these items. The remaining items would be completed in the duration of the 5-year project. However, efforts to be completed in subsequent years will build off of the previous findings from field and modeling studies (Tasks C and D) using the observational method.

Hazen and Sawyer will provide top-level management, task oversight, and direct reporting to the Florida Department of Health (FDOH). Professor John McCray (Colorado School of Mines) is the principal technical manager for Task D. Ms. Kathryn Lowe (CSM) serves as the liaison to Hazen and Sawyer as well as coordinating Task C efforts with Task D needs. Dr. Mengistu Geza (CSM) is the lead technical expert providing model development and model-performance evaluation. Additionally, modeling projects are often dynamic by nature and frequently experience changes in conceptual and technical design as the development or model-performance evaluation progresses. Thus, the contractors will be responsible for update reports that indicate needed changes in the project schedule, objectives, and path forward.

Section 2.0
Task D Description

The first phase of Task D will include development of a user-friendly analytical modeling tool that that can be used to simulate nitrogen transport and transformation in groundwater, and to predict spatial and temporal nitrogen concentrations and fluxes, for a relevant set of conditions relevant to OSTDS.

The sophistication of the modeling tool is to be directed at the expertise level of an OSTDS technical practitioner (e.g., a soil-scientist, hydrologist, civil or environmental engineer, chemist, etc) who is not an expert in mathematical modeling.

Conditions that are important in Florida include seasonal loading from OSTDS, seasonal precipitation patterns, a spatial distribution of OSTDS, soil treatment, ground water transformation and transport, and the ability to produce output concentrations and a reasonable plume shape, and to provide information on mass flux at a downstream boundary. In this first phase, the research will focus on the following sub-tasks:

2.1 Description of Activities

The work scope described in this section is consistent with the scope of work and deliverables in the FOSNRS contract. The following description of activities provides detail related to the design and implementation of the ground-water modeling tool, selection of site data for model-performance valuation, computer file handling, and numerical data handling.

2.1.1 Development/Selection of a Simple Tool That Calculates Spatially Averaged Nitrogen Removal in Florida Soils

The main goal of this project is to develop a simple tool that can enable users to simulate groundwater plumes of nitrogen. Thus, we move directly toward this goal by first identifying a simple tool that can calculate or estimate the spatially averaged nitrogen removal in different soil types in Florida for input into the groundwater nitrogen-modeling tool. Most nitrogen modeling tools used by states assume no treatment in the unsaturated soil. This approach is highly conservative and is usually not realistic or appropriate because significant treatment of nitrogen in most unsaturated soils has been rigorously documented (e.g., McCray et al., 2010). Thus, we will use a simple model that can provide realistic estimates of this treatment. Later in the project, we plan to incorporate a more robust soil-treatment module that can account for spatially variant OSTDS. However that is a complex process that would delay completion of the ground water modeling tool. Nonetheless, the groundwater nitrogen-modeling tool requires input from OSTDS. Thus, a simple soil-treatment module is used initially.

We intend to incorporate information from existing soil-treatment approaches that calculate or estimate treatment based on specific soil types that exist in Florida. We will evaluate the approach developed by Ayres and Associates (specifically for Florida soils) to estimate soil reduction of nitrogen in the vadose zone to determine nitrogen loading to the aquifer. We will also evaluate the approach used by McCray et al. 2010, which enables a prediction of nitrogen removal and vadose zone pore-water concentrations for each soil type among the 12 from the USDA soil triangle. This module will enable an estimate of percent nitrogen reduction between the OSTDS and an aquifer water table. This concentration or loading will be used as a source term for the groundwater nitrogen-modeling tool.

The performance of this module will be evaluated using soils data collected from Task C when/if this data becomes available. We will also use any existing available soil-treatment data provided by FDOH, Hazen and Sawyer, or Colorado School of Mines.

2.1.2 Development of an Analytical Modeling Tool that can be Used to Predict Temporal and Spatial Concentrations and Fluxes of Nitrate in Groundwater

Results of the literature review (Task D.1) suggested the use of the Horizontal Plane Source (HPS) model as the basis for the groundwater nitrogen-plume modeling tool. The model solution assumes a horizontal-plane contaminant source zone (Figure 2-1). Figure 2-1 shows a single OSTDS but the plane source could also represent an averaged input for a development. The HPS model is based on the analytical solution developed by Carslaw and Jaeger (1959) for the transport of heat in solids. Galya (1987) adapted this analytical model for contaminant transport in groundwater. Heatwole and McCray (2006) used this model for OWS applications assuming spatially and temporally averaged inputs to the aquifer with no soil treatment.

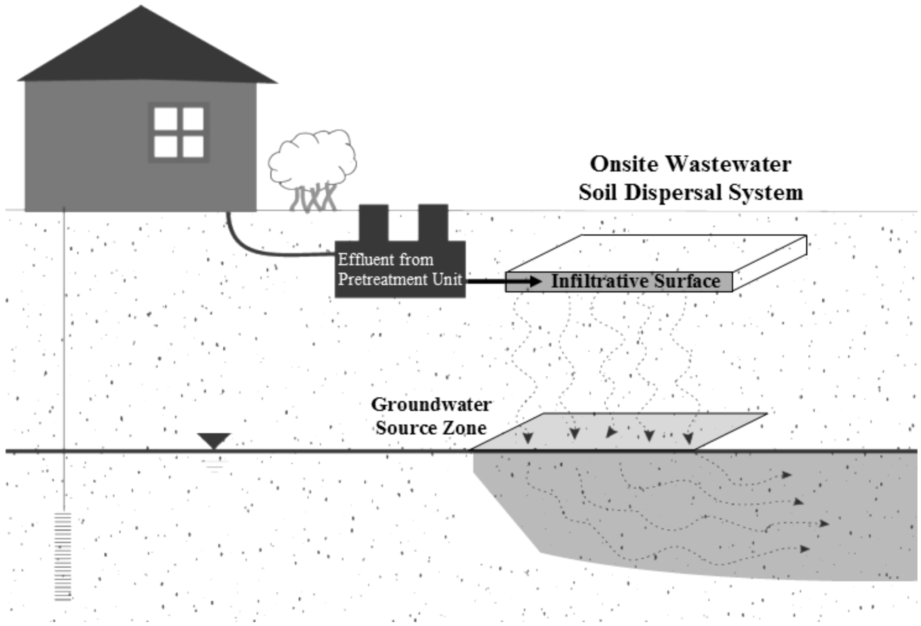

Figure 2-1: Conceptual Model for OSTDS Contamination of Groundwater Including the Contaminant Horizontal Plan Source (HPS) to the Aquifer

The HPS model is a transient, three-dimensional analytical model capable of simulating advective-dispersive transport and first order degradation (e.g., from denitrification) in a homogeneous aquifer with uniform horizontal flow. Assumptions of homogeneous media are required to develop the user-friendly model that is the goal of this research. Detailed heterogeneity can only be accounted for with the use of numerical models and a considerable amount of site data. However, successful models can be developed for heterogeneous media using our proposed modeling tool by accounting for aquifer heterogeneity through a macro-dispersion model-input parameter. To illustrate this concept, Figures 2-2 depicts a plume calculated by the HPS model, while Figures 2-3 and 2-4 illustrate measured plumes below OSTDS at Florida sites. Note that the HPS model captures the dominant features of the nitrogen plume: a relatively shallow plume below the water table, with considerable longitudinal spreading. The model could also produce a "rounder" lateral plume similar to that shown in Figure 2-3 by decreasing the ratio of longitudinal to transverse dispersivity. The figures depict 2-D plumes, but the HPS model can calculate concentrations in three dimensions in an aquifer.

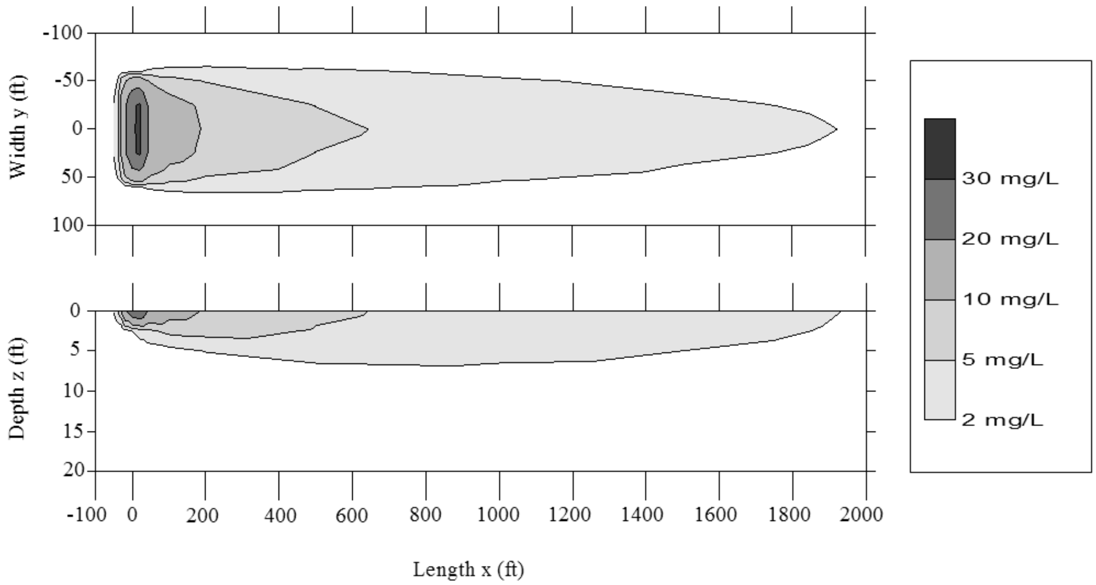

Figure 2-2: Plume Illustration Showing Aerial (Top) and Cross-sectional (Bottom) Views of a Nitrate Plume Generated by the HPS Model

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Figure 2-3: Plume Illustration Showing a Plot of Measured Concentrations for Aerial Views of a Nitrate Plume in Lake County, Florida

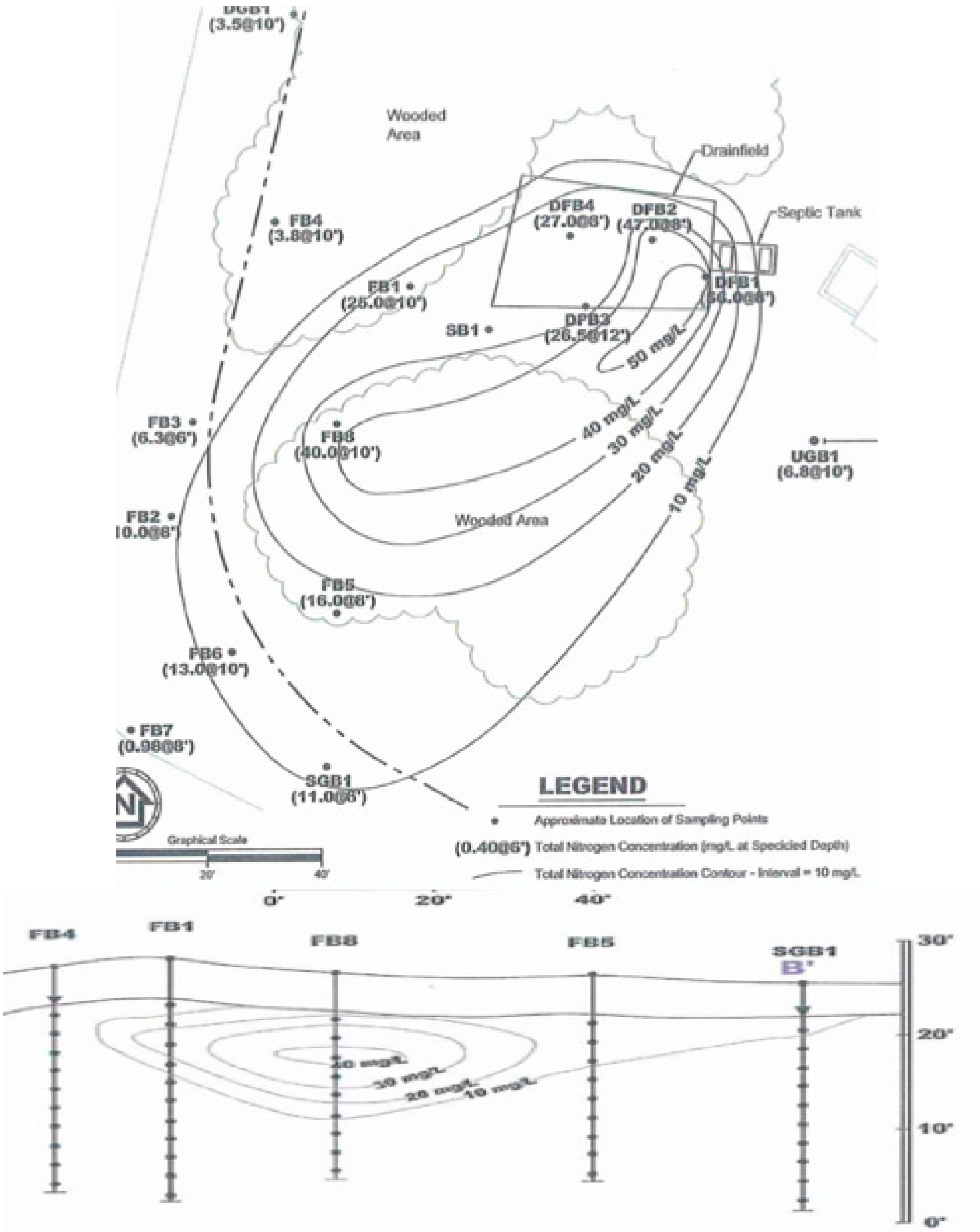

Figure 2-4: Plume Illustration Showing a Plot of Measured Concentrations for Aerial (Top) and Cross-sectional (Bottom) Views of a Nitrate Plume in Seminole County, Florida

The HPS approach is capable of simulating aquifer impacts from single or multiple OWS through the law of superposition (Task 11 in Section 1.3), but the modeling procedure becomes more complex and computationally demanding. Thus, the simplest approach for using this model is when the source zone is the same area as the footprint of the development or OWS source. Then, the input to the vadose zone must consider the average loading per unit area.

The HPS model can consider a time-varying source rate and generates output for a transient, three-dimensional aquifer solute concentration in relation to the source zone. The time variable mass input is given by:

$$\dot{m} = i_r L W c_0 \qquad \text{(eqn. 1)}$$

The variable, *m*, is the temporally variable nitrogen mass loading rate, *L* and *W* are the dimensions of the source zone horizontal plane source "footprint", *i* is the time variable infiltration rate and c_o is the time variable concentration in the total infiltrating water reaching the water table. The infiltration can include that from climate inputs as well as from OSTDS, and c_o may include the effects of rainfall dilution. The mass of the nitrogen input does not change with dilution, but the time-dependent temporal strength of the horizontal plane source would vary, as would the aquifer dilution relative to ground-water flow.

The analytical solution calculated groundwater concentrations in space and time, $C_p(x,y,z,t)$, given by:

$$c_p(x,y,z,t) = \int_0^t \dot{m}\, c_s(x,y,z,t) \qquad \text{(eqn. 2)}$$

and

$$c_s(x,y,z,t) = \frac{e^{-kt}}{4nRLWb}\left(erf\left(\left(\frac{x - v't + L/2}{\sqrt{4D_{xx}'t}}\right)\right) - erf\left(\frac{x - v't - L/2}{\sqrt{4D_{xx}'t}}\right)\right)$$
$$\times\left(erf\left(\frac{y + W/2}{\sqrt{4D_{yy}'t}}\right) - erf\left(\frac{y - W/2}{\sqrt{4D_{yy}'t}}\right)\right) \times \left(1 + 2\sum_{j=1}^{\infty} \exp\left(-\frac{j^2\pi^2 D_{zz}'t}{b^2}\right)\cos\left(\frac{j\pi z}{b}\right)\right)$$

(eqn. 3)

Where $c_p(x, y, z, t)$ are calculated ground-water concentrations, *v'* is the contaminant velocity [L/T], *D'* are the dispersion coefficients in the *x*, *y*, and *z* directions including any effects of contaminant retardation [L^2/T], *b* is the aquifer thickness [L], *k* is a first-order degradation rate constant (e.g., for denitrification) [T^{-1}].

The solution to the above equations requires integration, but can be solved through numerical approximation using Simpson's rule. The analytical solution can thus be implemented in a Java application and compiled to create an executable file capable of calculating multiple space-time inputs, and can likely be achieved with a spreadsheet program.

A sensitivity analysis was conducted to evaluate the importance of input parameters for the HPS model (Heatwole and McCray, 2006). These are input parameters that have the most impact on model output, and must be carefully considered when developing model input. The most sensitive parameters were vertical dispersivity, velocity, porosity, the ratio of source zone length to width, solute infiltration rate, OWS nitrate concentration, and denitrification rates have significant sensitivities and these parameters. For example, aquifers with faster groundwater velocities will be much better equipped to attenuate nitrate inputs from typical OWS. Thus, these parameters will be critically important to obtain when parameterizing the model.

2.1.3 Selection of Existing Site Data (Including from Task C) for Model-Performance Evaluation

Actual data from OSTDS sites will be used to evaluate the performance of the groundwater nitrogen-modeling tool. The details on the performance evaluation are provided in the next section. At a minimum the site data should include spatial nitrogen concentrations in ground water, fundamental hydrogeology parameters (especially the ones the model is most sensitive to, as described in the previous section), and information on the OSTDS loading. The primary source of this data will be the controlled pilot-scale testing to be conducted at the GCREC to characterize nitrogen fate and transport under a variety of typical operating conditions (described in the Task C QAPP). Other sites were also identified as described in the Task D.3 report submitted previously, and will be evaluated for use in model-performance evaluation:

- Primary Candidate Studies
  1) Wekiva Nitrogen Source Study, described by Briggs et al., (2007) and Roeder (2008).
  2) St. George Island study, described by Corbett and Iverson (1999) and Corbett et al., (2002).

- Alternate Candidate Studies
  1) Florida Keys, described by LaPointe et al (1990)
  2) Lake Okeechobee described by ESE (1993)

2.1.4 Performance Evaluation of the Model

The performance of the model will be evaluated based on whether or not it adequately simulates site data, and whether model calibration is required to produce an acceptable modeled representation of site data. The first test is qualitative, based on whether or not the model can simulate the most important attributes of the plume (e.g., plume shape, length, maximum concentrations, etc).

The second test is quantitative. Model performance is quantitatively evaluated by comparing simulated parameter values to the corresponding measured values. These parameters are called calibration targets. Calibration targets for this work will include nitrogen concentrations (weighted equally in space), the mass of contaminant in the plume, and plume dimensions. Because concentration calibration targets are spatially and temporally variable, the goodness of calibration, or overall model performance, is assessed by some average or representative measure of performance that incorporates or summarizes the "match" of measured to simulated data for all locations in the hydrogeologic domain.

Measures of model performance are classified into difference measures and correlation measures. Root Mean Square Error (RMSE) is perhaps the most common measure. Other difference measures include the mean bias error (MBE), the index of agreement (d), and the Nash-Sutcliffe efficiency (NSE). Correlation measures and graphical techniques are also useful for evaluating model performance.

Moriasi et al. (2007) reviewed several model-evaluation techniques, including statistical measures and graphical techniques. They reported ranges of values and corresponding performance ratings for each recommended statistic and gave recommendations for acceptable criteria for each statistic. Based on this analysis, they recommend use of three quantitative statistics and a graphical technique. The statistical measures were the NSE, NMB, and RSR. Thus, we will use multiple methods for evaluating the model performance. By using multiple methods, the model-performance and calibration evaluation is not unduly hindered by the specific limitations of a single calibration statistic. These are described in the next section.

2.2 Performance Assessment

The model-performance assessment will be conducted by using model-evaluation statistics (i.e., acceptance criteria) to determine whether the model can appropriately simulate the observed data. The following performance metrics are used.

Root Mean Square Error-observations standard deviation ratio (ROSR, also called RSR). Singh et al. (2004) developed the RSR which can account for the bias due to variability in the data set. RSR standardizes RMSE using the observations' standard deviation. RSR is calculated as the ratio of the RMSE and SD of measured data:

$$RSR = \frac{RMSE}{STDEV_{obs}} = \frac{\sqrt{\sum_{i}^{n}(o_i - p_i)^2}}{\sqrt{\sum_{i}^{n}(o_i - o_{mean})^2}} \quad \text{(eqn. 4)}$$

where p_i is simulated parameter value, o_i is observed (or measured) value, n is the number of observations, and o_{mean}, is the mean of the observed values. The smaller the RSR value for a given hydrogeologic model, the better the calibration. A RMSE value closer to zero indicates a better fit to observed values. The denominator in the RSR serves to minimize the influence of a few observations that have very large or small values relative to the observations as a whole. RSR varies from the optimal value of 0, which indicates zero RMSE or residual variation and therefore perfect model simulation, to a large positive value. The lower RSR, the lower the RMSE, and the better the model simulation performance. Moriasi et (2007) conducted a detailed study of model-calibration-evaluation measures and recommended the following criteria for RSR: 0 to 0.5 is considered to be very good, 0.50 to 0.60 is good, 0.60 to 0.70 is satisfactory and greater than 0.70 is unsatisfactory.

The index of agreement (d): The index of agreement (d) developed by Willmott (1981) is another measure of a standardized measure of the degree of model prediction error. It is calculated as:

$$d = 1.0 - \frac{\sum_{i=1}^{N}|o_i - p_i|}{\sum_{i=1}^{N}|p_i - \overline{o_i}| + |o_i - \overline{o_i}|} \quad \text{(eqn. 5)}$$

where o_i = measured value, p_i = simulated value and $\overline{o_i}$ is mean of measured values. The d value varies between 0 and 1. A value of 1 indicates a perfect agreement between the measured and predicted values, and 0 indicates no agreement at all (Willmott,

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1981). This method is similar in concept to the RSR. Additional literature review is required to develop standardized acceptance criteria for this statistic.

Nash-Sutcliffe Efficiency (NSE): The Nash-Sutcliffe Efficiency (NSE) (Nash and Sutcliffe, 1970) determines the model efficiency as a fraction of the measured value variance that is reproduced by the model. The underlying concepts justifying this statistic are similar to the RSR. NSE is given is calculated as:

$$NSE = 1 - \frac{\sum (o_i - p_i)^2}{\sum (o_i - \overline{o_i})^2} \qquad \text{(eqn. 6)}$$

where: $\overline{o_i}$ is mean of measured values. The closer the NSE value to 1.0 the better is the model estimation. NSE ≥ 0.75 is considered to be an excellent estimate, and NSE between 0.75 and 0.36, is regarded to be satisfactory (Motovilov et al., 1999).

Normalized mean bias (NMB): Normalized mean bias (NMB) measures the average tendency of the simulated data to be larger or smaller than their observed values (Gupta et al., 1999). This statistic normalizes the difference (model - observed) over the sum of observed values. NMB is defined as:

$$NMB = \frac{\sum_1^n (p_i - o_i)}{\sum_1^n (o_i)} * 100 \qquad \text{(eqn. 7)}$$

Positive values indicate that simulated values tend to be greater than observed values, while negative values indicate that simulated values tend to be smaller than observed values. A value of zero indicates no bias. Additional literature review is required to develop standardized acceptance criteria for this statistic.

Correlation measures: The relationship between measured and observed data such as covariation and correlation can be useful to evaluate model performance and “calibration goodness”. The correlation coefficient, R, or the coefficient of determination (R^2) is typically used. R^2 describes the degree of co-linearity between simulated and measured data. R^2 ranges from 0 to 1, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Santhi, et al., 2001, Van Liew et al., 2003). Indeed, in hydrogeologic modeling, an R^2 value greater than 0.7 is considered excellent. However, R^2 is oversensitive to high extreme values (outliers) and insensitive to additive and proportional differences between model predictions and measured data (Legates and McCabe, 1999). That means it is possible to obtain a good R^2 value as long simulation results capture the trend in observed values even when the ab-

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solute differences are large. For example, it is possible to achieve a very high R^2 value even if a simulated hydraulic head-vs-time data series is visually offset (does not overlap) with the observed head-vs-time series, provided that the shape (or trend) of the two series was the same. Thus, while this value is a good measure of model goodness, it cannot be used alone.

<u>Graphical techniques</u>: Graphical techniques such as comparative time series plots, bar graphs comparing measured to simulated values, box plots showing the overall difference (including high and low ranges for the errors), can also be helpful. In particular, plots that can illustrate the spatial or temporal variation in measured-vs-simulated differences are helpful to understand how the model is performing in different geographic locations or through time. An example of a plot that can aid in spatial analysis is a "dot plot" where the size of the dot represents the difference in simulated vs. observed values. The dot plot can help place the model results in geographic context, or suggest areas where additional data collection or more careful data scrutiny is warranted. Graphical methods enable the modeler to insert professional judgment and "common sense" into the task of model-performance evaluations.

<u>Model Uniqueness</u>: During model calibration, it is often impossible to converge on a unique solution when estimating many parameters (Geza et al. 2009). That is, a similar model calibration can be achieved for different input-parameter values. This fundamentally suggests a non-physical model, or that the model is not likely to be effective for simulating conditions outside the calibration conditions. Consequently, one needs to pose a tractable calibration problem by limiting the number of parameters for which values will be estimated (i.e., simplifying the model to one that represents important aspects of the system (Hill, 1998)). This is accomplished by identifying the most sensitive, uncorrelated parameters. (Poeter et al., 2005; Saltelli et al., 2004), and evaluating whether input parameters are correlated. Accepted USGS guidance (Poeter et al. 2005) will be used for this purpose.

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Section 3.0
Quality Assurance

3.1 Data Quality Objectives (DQOs)

The general quality assurance (QA) objectives for Task D are provided below:

1) Document the model theory.

2) Document the model development process.

3) Document model revisions.

4) Back-up the model software and associated electronic files.

5) Verify that the theory and mathematics used in the model area accurately implemented.

6) Evaluate model performance using measureable acceptance criteria.

7) Provide guidance on how to use the model.

8) Identify and track QA documentation.

The process used to meet each DQO is described in more detail below.

3.2. Process to Meet Data Quality Objectives (DQOs)

3.2.1 Document the Model Theory

The model theory will be documented in detail as part of a written User's Manual. A technical expert who was not involved with the model theory selection or development will review the document for appropriateness and correctness, and sign a written statement indicating that the document was reviewed and providing the date of the review.

3.2.2 Document the Model Development Process and Theory

The model development process (software used, methods used to develop the software, mathematics used to implement functions) will be documented in an electronic document and updated monthly. A signature sheet will be implemented that documents the developers acknowledgement that the electronic document has been updated.

3.2.3 Document the Model Revisions

Significant revisions to the model software will be documented in an electronic document and updated monthly. A signature sheet will be implemented that documents the developer's acknowledgement that these revisions have been documented.

3.2.4 Back-Up the Model Software and Associated Electronic Files

The most recent version of the software will be saved and backed up daily on electronic storage media located in a separate physical location at CSM from the computer used to implement the changes. An electronic version of the software will be saved at the end of each month and all these monthly versions will be kept until the end of the project. An electronic document that is updated monthly will document the name of the file and the significant changes to the document.

The file name will include a model identifier, developer initials, and date. For example, if the software is implemented in an XLS file:

Nmodel-MG-31Mar10.XLS

where "Nmodel" is the name of the model, MG is the developer initials (e.g., Mengistu Geza) and the date is March 31, 2010.

If software is used that requires separate input or output files, then designators of "in" and "out" will be used in the filename. An example of a Fortran input file is given below:

Nmodel-MG-31Mar10.in

3.2.5 Verify That the Theory and Mathematics in the Model are Accurately Implemented

Correct implementation of the theory and mathematics will be verified using two methods.

1) Hand calculations to verify selected model calculations. The verification will be conducted by a technical expert who has not been directly involved with the model development.

2) Benchmarking the model against a tested software package where the initial, boundary, and run-time conditions are manipulated to be the same for both models.

These verification methods and outcomes will be documented in a short report to the sponsor.

3.2.6 Evaluate the Model Performance Using Measurable Acceptance Criteria

The model performance will be evaluated as described in Section 2.2. These verification methods and outcomes will be documented in a short report. Numerical statistical measures will be used to assess how well the model simulates measured field data. The statistics calculated for measured versus observed data will be compared to accepted values published in the peer-reviewed literature. While the "goodness" of a model is necessarily subjective, the use of numerical acceptance criteria provides a transparent means of documenting the model performance. Finally, the model's performance in simulating measured data will also be tested for non-uniqueness and input parameter correlation (recall Section 2.2), in accordance with the guidance provided in the USGS document written by Poeter et al. (2005).

3.2.7 Provide Guidance on How to Use the Model

A written guidance document will be provided that describes how to use the model. A technical expert not directly associated with model development will review the document. The reviewer will sign a written statement indicating that the document was reviewed and providing the date of the review.

3.2.8 Identify and Track QA Documentation

A written list and short description of all the documents associated with DQO's defined in sections 3.2.1 through 3.2.8 will be maintained in a file titled "QA-Documentation.doc" and will be provided to the sponsor within the relevant report. This will enable the QA system to be fully auditable.

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Section 4.0
Health and Safety

Work associated with Task D is conducted in an office setting. Thus, only routine health and safety measures required (ground fault circuit interrupts, clutter around electrical connections not permitted, etc.).

Section 5.0 References

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