Work Plan and Schedule for North Bosque River TMDL Modeling System

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Introduction

Total maximum daily loads (TMDLs) for soluble reactive phosphorus have been approved by the Texas Commission on Environmental Quality (TCEQ) and the U.S. Environmental Protection Agency (EPA) for the North Bosque River and the Upper North Bosque River, Segments 1226 and 1255 respectively (TNRCC, 2001). The implementation plan has recently been approved by both the TCEQ and Texas State Soil and Water Conservation Board (TCEQ and TSSWCB, 2002). The development of the two TMDLs was based in part on applications of the Soil & Water Assessment Tool (SWAT). Public concerns regarding the modeling efforts for the TMDL development included:

- Lack of spatial resolution in the definition of subbasins.
- Exclusion of the 40 PL-566 flood retardation reservoirs in the watershed.
- Contributions of discharges associated with dairy lagoons and wastewater storage ponds.

The purpose of the project is to refine the TMDL modeling, while incorporating new data and knowledge regarding model-simulation activities and features, and to then reanalyze the TMDL allocation. This project deliverable provides the work plan and schedule, which will be used to guide execution of the overall project.

Work Plan

A major task of the work plan is based on model refinements and supporting data collection described in a project report to TCEQ entitled *Initial Recommendations for Refinements to North Bosque River TMDL Modeling System* (Hauck, Saleh, and Ward, 2003) and a subsequent advisory group meeting held March 31, 2003 wherein comments were received on this report. In addition, the work plan incorporates tasks necessary to take the refined modeling system to final applications for reanalysis of TMDL phosphorus load allocations. Work plan activities will be performed by the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University, as the lead, with the Center for Water Resources Research (CRWR) at The University of Texas at Austin in a subcontract role.

Task 1. Stakeholder Involvement

TIAER and CRWR will conduct public meetings of the project's advisory group on a sufficiently frequent basis to keep group members apprised of project developments and to allow opportunities for public comment on the refinement, validation, and application of the modeling system. These public meetings will be held no more frequently than quarterly and at such times that there are substantive topics warranting a meeting. On the occasions when relatively minor issues arise requiring advisory group comments, group e-mail communication will be used to convey information and solicit comments.

TIAER will follow the TMDL public participation guidance and adhere to the requirements of HR 2912, Section 1.10. TIAER will provide meeting notice and agenda information to TCEQ sufficiently early to allow web site posting at least two weeks prior to the meeting. TIAER will provide within three weeks of each meeting hardcopies of all informational materials used at each meeting and concise meeting minutes for posting on the TCEQ web site.

Task 2. Modeling System Refinements and Supporting Data Collection

TIAER and CRWR will provide a modeling system for the North Bosque River TMDL that incorporates refinements presented in the project's initial recommendations report and comments received at the March 31, 2003 public meeting. The Soil & Water Assessment Tool (SWAT), which was the model used to perform the TMDL, will provide

the framework of the refined modeling system. This task is for convenience divided into two subtasks – one for the modeling system refinements and the other supporting data collection.

Subtask 2.1 Refining Components of Modeling System (June 2003—Nov. 2005)

The four work effort components to refine the modeling system and the entity taking the lead in performing each component are as follows:

A. Watershed and landscape loading (TIAER),
B. Representation of point sources (TIAER),
C. Improved characterization of dairies (TIAER), and
D. Instream fate and transport (CRWR).

Supporting data collection efforts are described below in Subtask 2.2.

A. Watershed and Landscape Loading:

TIAER will refine the watershed and landscape loading components of SWAT. Within this component two of the three public concerns regarding the previous modeling effort will be addressed—lack of spatial resolution in definition of subbasins and exclusion of PL-566 reservoirs in the model. Several activities are involved in this component.

1. TIAER will improve spatial resolution through a delineation process by defining additional subbasins within SWAT, which in turn will provide hydrologic response unit (HRU) of all major soil and land use and land covers (land use/cover) combinations within a subbasin. Land use/land covers will include specific crops on dairy waste application fields (WAFs), specification of liquid or solid application as the dominant waste, range land, wooded, urban, and improved pasture and row crops not associated with dairy waste disposal. Abandoned and active WAFs will be accounted for within HRUs. Sensitivity testing will be performed by TIAER to determine implications of subbasin resolution on SWAT results.

2. Under Subtask 2.2 Activity 1, TIAER or a subcontractor will develop an updated land use/cover to reflect "most recent" conditions—most likely 2002 or 2003. The performance of the modeling system with the new GIS land use/cover layer will be initially tested within this activity; however, more exacting testing will occur under Task 3 (Modeling System Validation).

3. PL-566 flood retardation reservoirs will be included in SWAT for hydrologic routing and water quality fate and transport. Portions of this TIAER refinement activity will overlap with and be coordinated with efforts involving the improved spatial resolution (discussed above) and CRWR's efforts on instream fate and transport (Subtask 2.1, Component D).

4. TIAER will seek and evaluate appropriate algorithms to improve the landscape phosphorus processes within SWAT, since such algorithms are known to be in

development at various research institutions across the country. If an algorithm with substantive improvement in soil phosphorus kinetics is located that is compatible with SWAT data requirements, the algorithm will replace the current one in SWAT. The new algorithm will be tested against existing data sets in the North Bosque River watershed. The data sets to be used for algorithm testing will be developed from completed field plot research conducted by TIAER on WAFs.

5. TIAER will verify SWAT's characterization of sediment and nutrient losses from major land use/covers of the watershed including WAFs, improved pasture, wooded, urban, and range lands. Because range and wooded lands often transition one into the other on the landscape, TIAER plans to verify losses from these land covers together. The modeling system will simulate each land use/cover to validate SWAT's predictions against existing TIAER data sets for small watersheds and field plots of the North Bosque River watershed. To evaluate the modeling system's performance for improved pasture receiving commercial fertilizer and different manure application rates, data collection activities will occur under Subtask 2.2, Activity 5.

B. Representation of Point Sources:

TIAER will include within the modeling system the effects of the seven permitted municipal wastewater treatment plants (WWTPs) in the watershed (Clifton, Cransfill Gap, Hico, Iredell, Meridian, Stephenville, and Valley Mills). Self-reporting data and TIAER effluent monitoring data will be used to characterize each WWTP. An algorithm will be developed to provide for simulation of unauthorized WWTP discharges in the modeling system.

C. Improved Characterization of Dairies:

TIAER will refine SWAT's capabilities to simulate dairy waste storage facilities and waste treatment lagoons, hereafter referred to collectively as lagoons, and liquid and solid WAFs. Through these refinements, the final public concern of the previous TMDL modeling—contributions of discharges from lagoons—will be addressed.

1. To include authorized and unauthorized lagoon discharges, TIAER will develop a new algorithm that will allow simulation of authorized and unauthorized lagoon discharges. The algorithm will either be standalone and produce compatible output of discharge quantity and quality to be used as input to SWAT or preferably directly integrated into SWAT. This new algorithm will consider individual lagoon physical characteristics (e.g., multiple sequential lagoons, design volumes, contributing process and stormwater), various operating conditions, and water quality characteristics.

2. TIAER will use existing data to improve representation of nutrient concentrations in soils and dairy manure and lagoons that are used as input data to SWAT. Data collection efforts discussed under Subtask 2.2 (Activities 11 & 12) are critical to this activity. The characterization of SWAT input for soil nutrients will include the soils of WAFs and, also, the other land uses/covers of the watershed.

3. Through ongoing research funded by EPA, TIAER will provide algorithms to improve SWAT's capabilities to simulate dairy WAFs and management practices. TIAER is enhancing the SWAT model through this EPA project to 1) allow liquid and solid dairy waste application rates to be based on simulated soil test phosphorus concentration of each field and 2) adjust the number of WAFs receiving waste in response to a fixed supply of manure nutrients and time variable application rates. Additional work efforts will be required under the present project to use this SWAT enhancement. Particularly, the GIS land use/cover layer will need to be revised by TIAER to include specification of crop type and method of application (liquid or solid) for WAFs.

D. Instream Fate and Transport:

CRWR with assistance from TIAER will enhance the modeling system to allow delineation of stream hydraulics and transport terms under dynamic (storm) conditions, formulation of better kinetic processes, and implementation of these improved numerical solutions as part of the structure of SWAT. The desire is to take full advantage of the current instream fate and transport component of SWAT, which remains essentially untested. However, should technical obstacles arise with achieving an analytically satisfactory and numerically accurate solution within SWAT, then it may become necessary to implement a separate model and address separately the manner of conjunctive operation with SWAT. Data collections under Subtask 2.2 Activities 3 and 14–19 will support this refinement effort.

1. The project team will rigorously evaluate the present instream fate and transport component of SWAT to determine its acceptability to overall project needs.

2. The modeling system will be enhanced to allow delineation of stream hydraulics and transport terms under dynamic conditions. This will be preceded by a review of the probable significance of such dynamic processes to water quality impairment in the Bosque, so as to appropriately focus the study effort.

3. Enhanced formulations of kinetic processes for receiving waters (PL-566 reservoirs and streams) will be added to the modeling system.

4. Improved numerical solutions will be implemented in the modeling system.

Subtask 2.2 Supporting Data Collection (Sept. 2003 – Feb. 2006)

The success of the refinement and subsequent validation and application of the modeling system depends on supporting data collection. All primary data collection will occur under an approved quality assurance project plan (QAPP) developed specifically for this project. Secondary, or existing data, to be used by the project will be specified in appropriate sections of the QAPP. The completion of most Subtask 2.1 (Refining Components of Modeling System) requires supporting data collection including primary and secondary data. The linkage of supporting data collection to the specific work efforts and activities of Subtask 2.1 are provided in Table 1. More details on the data collection activities are provided immediately below.

Table 1. Supporting data collection linkages to modeling system refinement components.

Refining Components of Modeling System	Corresponding Data Collection Activities
A. Watershed and landscape loading	
1. Improved spatial resolution	None
2. Update land uses/covers	1. Develop land uses/covers from satellite imagery 2. Obtain information on WAFs, corresponding crops, and application methods from public information.
3. Include PL-566 reservoirs	3. Evaluate and synthesize historical TIAER water quality and quantity data on inflows and outflows to two PL-566 reservoirs monitored intensively in the mid-1990s 4. Synthesize morphometric, hypsographic, and outlet discharge rating information for 40 PL-566 reservoirs
4. Improve landscape phosphorus algorithms	None
5. Validate SWAT's predictive capabilities for sediment and nutrient losses from major land uses/covers	5. Operate three (3) side-by-side field plots, first receiving commercial fertilizer; later one remaining as a control and others receiving different manure application rates
B. Representation of Point Sources	6. Collect self-reporting data and investigate TCEQ records for operational problems 7. Collect routine (bi-weekly) effluent samples from selected WWTPs, unless permit requires such reporting
C. Improve Characterization of Dairies	
1. Include authorized and unauthorized lagoon discharges	8. Collect and analyze available data on capacity of lagoon systems on diaries 9. Collect and analyze available information on reported discharges 10. Collect and analyze information on operation of lagoons from inspection reports and other sources
2. Improve modeling system representation of nutrients in soils and dairy manure and lagoons	11. Collect and analyze available information on soil nutrients in WAFs and other major land uses; evaluate need for supplemental data collection. 12. Collect and analyze information on water quality in dairy manure and lagoons; evaluate need for supplemental data collection.

Table 1. Supporting data collection linkages to modeling system refinement components.

3. Improve SWAT's simulation capabilities for dairy WAFs and management practices	13. Information on management of dairy solid and liquid wastes will be garnered from knowledgeable sources.
D. Instream Fate and Transport	14. Conduct time of travel studies 15. Conduct seasonal assessment of periphyton and macrophyte extent 16. Conduct seasonal dose response assays 17. Conduct phosphorus mass budget on headwater stream reach with significant interflow component 18. Conduct phosphorus mass budget on stream reach with significant accumulations of organic and cohesive sediments

1. An updated GIS land use/cover layer will be developed for the watershed. Appropriate Landsat Thematic Mapper image(s) or comparable satellite imagery will be purchased from year 2002 or 2003 overflights. The image will be analyzed to determine major land uses/covers, with an emphasis on those needed by the landscape portion of SWAT (e.g., range, wooded, improved pasture, row crop, urban, water, etc.). The GIS-based land use/cover layer will be groundtruthed to substantiate an acceptable level of accuracy. The resulting GIS land use/cover layer will be ArcView compatible. An additional subcontract arrangement will be necessary for performance of some aspects of this activity. Efforts to be performed by TIAER involve incorporating into the existing 1996 land use/cover specific information on active and abandoned WAFs based on 1999/2000 dairy information. (This information reflects the data used in the original TMDL development.) The more recent land use/cover developed under this work effort will incorporate active and abandoned WAFs based on 2002/2003 dairy operation information from activity 2 immediately below.

2. TIAER will evaluate information on WAFs to update and refine its existing GIS layers and spreadsheets on this information. TIAER presently has spreadsheets that reflect the WAFs of dairy operations in 1995 and spreadsheets and GIS layers for WAFs that existed in late 1999-early 2000. Each known application field will be specified as active or abandoned. For active fields, crops grown and dominate method of waste application (liquid or solid) will be indicated based on information supplied in dairy permits, permit applications, and other public information sources. A new GIS layer of active and abandoned dairies will be developed based on 2002/2003 dairy information. Drive-by surveys and any other methods readily available will be used to ascertain the type and level of management occurring on a representative sampling of abandoned WAFs, which will be used to guide management definition for abandoned WAFs in the modeling system.

3. TIAER will evaluate historical data of the mid-1990s for two catchments that included PL-566 reservoirs to develop data sets for testing performance of the model system refinement that adds these reservoirs to the modeling system. Water, sediment, and nutrient mass balance approaches and statistical measures will be used to ascertain changes in stream water quality manifested by these reservoirs. This information and analyses will be used to evaluate the performance of the inclusion of PL-566 reservoirs in the modeling system.

4. TIAER will obtain plans and specifications and design memoranda from the USDA-Natural Resources Conservation Service (NRCS) for each of the 40 PL-566 reservoirs in the North Bosque River watershed. The morphometric, hypsographic, and discharge rating data for each of the 40 PL-566 reservoirs will be synthesized into the necessary input data to allow accurate specification of these reservoirs' characteristics in the modeling system.

5. TIAER will operate under this project three side-by-side field plots, each about 0.5 acre in size, to provide additional data sets for establishing nutrient contributions from specific land uses and management practices. These field plots of improved pasture (Coastal bermudagrass) will first be managed to receive agronomic application of commercial fertilizers for a period of approximately one year. In subsequent years, one plot will remain as a control. One of the remaining two plots will be managed for manure application according to NRCS Field Office Technical Guide 590 and the other according to allowable rates in typical TCEQ dairy permits. Note that the data collected from these plots are in addition to existing TIAER data for other major land uses in the watershed.

6. TIAER will collect self-reporting data (1995-2004) for permitted municipal WWTPs within the study area. These data will be used to categorize discharge from these WWTPs for input into the modeling system. TCEQ permit files will be reviewed to determine occurrences of operational difficulties to provide the basis of quantifying unauthorized discharges or persistence of effluent quality outside of permit limits.

7. At selected WWTPs, TIAER will conduct focused effluent monitoring for nutrients over a 12-month period. The effort required under this activity will be contingent on findings of monitoring needs from item 6 immediately above.

8. TIAER will collect and organize information on the size and configuration of lagoon systems for operating dairies in the watershed. Public information from TCEQ permit files will be the primary source of information. Other information sources such as the Agricultural Producer Certification Option (APCO) program will be investigated. Data confidentiality issues, however, will present obstacles to use of this information source.

9. All available information regarding recent lagoon discharges, water quality of the discharges (if available), and conditions causing the discharges will be obtained from TCEQ, Texas Parks and Wildlife Department, and anecdotal sources.

10. Information on lagoon system operation will be obtained and synthesized from recent TCEQ dairy inspection reports and other reliable sources that can be located.

11. Existing soil nutrient concentrations will be obtained for dominant land uses in the watershed. While the focus will be on WAFs, soil nutrients of other land uses, such as improved pasture, wooded, urban lawns, and range, will be included in the data search. Data sources to be considered will include dairy self-reporting data at TCEQ, other TCEQ data, soils testing results available at the Texas A&M Soils, Water and Forage Testing Laboratory, and various research studies conducted by Texas A&M University and Tarleton State University. If existing soil nutrient data are inadequate for specification of conditions in the modeling system, additional soil testing will be required within this project to the degree resources and access allow.

12. Existing data on lagoon and manure nutrient content will be obtained from dairy self-reporting data provided to TCEQ and known research studies. These data will be synthesized to provide specification of conditions required by the modeling system. If data are found to be insufficient, additional sampling will be required within this project to the degree resources and access allow.

13. TIAER will contact cooperating dairy operators, NRCS, and Texas Cooperative Extension to obtain information on typical management practices and waste application rates used on WAFs. This information will be used to supplement and update the crop management practices used in the modeling for TMDL development.

14. In a few critical reaches of the North Bosque River, TIAER will perform time-of-travel studies under two different base flow conditions using dye injection and tracking.

15. TIAER will assess on a seasonal basis (winter, spring, summer, fall) over a two-year period, the extent of periphytic algae and macrophytes at a number of accessible locations along the North Bosque River and its major tributaries (Green Creek, Duffau Creek, Meridian Creek, and Neils Creek). The number of locations selected for sampling will be sufficient to reasonably characterize conditions of the North Bosque River and the lower reaches of major tributaries. Quantitative or semi-quantitative methods will be used.

16. Seasonal (winter, spring, summer, fall) nutrient dose response assays for suspended algae will be conducted at no more than five (5) locations along the North Bosque River. The locations will be picked to depict the decreasing nutrient gradient along the river. The assays will be performed over two years.

17. Phosphorus and water mass budget studies will be conducted on a headwater stream reach exhibiting a significant base flow component that originates from interflow. The first phase of this monitoring effort will be selection of an appropriate stream reach with cooperating landowners or public access for conducting detailed reconnaissance. Assuming an appropriate reach can be located, information from the reconnaissance will be used to design the monitoring components that will be performed in this activity.

18. Phosphorus and water mass budget studies will be conducted on a stream reach exhibiting significant accumulations of sediment in pool areas. The first phase of this monitoring effort is selection of an appropriate stream reach and conducting a detailed reconnaissance. Assuming an appropriate reach can be located with cooperating landowners or public access, information from the reconnaissance will be used to design the monitoring components. A priority will be given to finding a stream reach that can also be one of the reaches used for time-of-travel studies, nutrient dose response assays, and evaluation of extent of periphytic algae and macrophytes.

Task 3. Modeling System Validation (Sept. 2005 – Mar. 2006)

Under this task, the project team will validate the modeling system to the project watershed using available water quantity and quality data for the Bosque River watershed and applying appropriate statistical measures to evaluate performance. Under Task 2.1, Refining Components of the Modeling System, focused model testing and validation of various components of the modeling system will have already occurred. This task represents validation of the integrated modeling system to the Bosque watershed.

1. Calibration of the modeling system will be the first work effort under this task. Hydrologic calibration will first occur using a two-step process. First, long-term streamflow records at U.S. Geological Survey gauging stations will be used to calibrate the hydrologic response. As the second step, shorter duration streamflow records from TIAER monitoring stations, which occur over a much greater number of small watersheds and catchments, will be divided into two periods—one period for calibration and the other for verification. The model hydrologic response will be refined to streamflow data for the calibration period. The modeling system predictive capabilities for sediment, nutrients, and algae will be calibrated against the water quality data of the same period. Appropriate visual and statistical measures of predicted response to observational data will be employed, including, but not limited to, Nash-Sutcliffe E values, scattergrams (or bivariate plots), time-series plots, and ordinary least squares regression.

2. Verification of the hydrologic and water quality response of the modeling system will occur against the second period of intensive monitoring surveys. The same visual and statistical measures of model performance used in calibration will be employed for verification.

3. Sensitivity testing of the modeling system will be performed to determine response of predictions to uncertainty of key input parameters. The list of input parameters will be determined as the project progresses, but parameters of interest include size of subbasins, soils, and important kinetic rates. Because of its dominating importance to subsequent modeling efforts, sensitivity to subbasin size will need to be investigated very early in the

project under Subtask 2.1 Component A (Watershed and Landscape Loading), specifically Activity 1 that is to improve spatial resolution.

The modeling system validation process will occur using the GIS land use/cover layer developed from a June 1996 Landsat Thematic Mapper image with 1999/2000 dairy information. This land use/cover represents conditions occurring during the most intensive TIAER monitoring efforts of 1993 through 2000 and also a time of relatively stable dairy cow numbers in the watershed. Point sources will be defined based on self-reporting data for the two periods and water quality characterization from historical TIAER sampling of the municipal wastewater treatment plants.

4. The validated modeling system will be operated with the new land use/cover and dairy operation condition developed in a previous project task and new point source definitions (e.g., Cransfill Gap WWTP should be operational by then), which are to be developed under Task 2.1, to ensure that model response seems reasonable with the land use/cover that will be used in Task 4 (Modeling System Application). The modeling system with the new land use/cover will be operated with the same subbasins used in the validation process discussed above, though HRU definition might be altered because of changes in land use.

Task 4. Modeling System Application (Nov. 2005 – Aug. 2006)

The refined modeling system will be applied to reanalyze the TMDL allocation. The exact nature of the scenarios to be defined by TCEQ and interested parties can not be defined at this time, and this definition will be a crucial part of this task. Work efforts to be performed by the project team include:

1. TIAER will solicit from TCEQ and stakeholder interests the definition of scenarios to be simulated by the Bosque River watershed modeling system. The scenarios will include one or more baselines (e.g., present conditions of point and nonpoint source contributors, fully permitted conditions of contributors) and various phosphorus control strategies.

2. The TIAER project team will operate the modeling system for each defined scenario and provide these results at a minimum: 1) as annual loadings and annual average concentrations at the five index stations used in the TMDL implementation plan, and 2) as percent contribution by major sources (e.g., municipal WWTPs, urban runoff, WAFs, dairy lagoon discharges, range/woodland, and improved pasture and row crop). Model results will be evaluated in the context of the desired reanalysis of TMDL allocations and desired concentration and load reductions.

Schedule

The overall project schedule is considered as two separate efforts—1) refining and applying the modeling system and 2) supporting data collection. This separation recognizes that the project funding occurs from two sources; each source funding one of these efforts. The milestones for the effort to refine components of the modeling system are provided in Table 2 and the milestones for the supporting data collection effort are provided in Table 3. The refinement and application of the modeling system will occur from approximately June 2003 through August 2006. Support data collection will occur from approximately June 2003 through August 2005 with a final report completed by February 2006. No primary data collection will occur prior to QAPP approval, though secondary (existing) data collection will not be held to this constraint.

Table 2. Time Schedule of Tasks and Deliverables
Refinement and Application of the North Bosque River TMDL Modeling System

DELIVERABLE	DATE DUE
Quarterly and monthly progress reports (Administrative)	as required
Advisory group meetings (Task 1)	as required, no more often than quarterly
Map of improved spatial resolution (Task 2.1)	Sept. 30, 2003
Memorandum on approach for instream fate and transport modeling component (Task 2.1)	Nov. 21, 2003
Memorandum on modeling lagoon discharges (Task 2.1)	February 27, 2004
Memorandum on modeling PL-566 reservoirs (Task 2.1)	February 28, 2005
Draft report on refinements to modeling system (Task 2.1)	August 31, 2005
Final report on refinement to modeling system (Task 2.1)	October 31, 2005
Draft report on validation and sensitivity testing of modeling system (Task 3)	January 31, 2006
Memorandum on initial scenario definition (Task 4)	January 31, 2006
Final report on validation and sensitivity testing of modeling system (Task 3)	March 31, 2006
Draft report on scenario application and reanalysis of allocation (Task 4)	July 17, 2006
Final report on scenario application and reanalysis of allocation (Task 4)	August 31, 2006

Table 3. Time Schedule and Tasks and Deliverables
Monitoring to Support North Bosque River TMDL Modeling Refinements
(Does not include tasks and deliverables in existing Work Order #10)

DELIVERABLE	DATE DUE
Quarterly and monthly progress reports (administrative)	as required
GIS layer of TMDL (1996) land use/cover with active and abandoned WAFs (Subtask 2.2.2)	September 30, 2003
Annual briefing report on monitoring support status (Subtask 2.2)	August 16, 2004
Annual briefing report on monitoring support status (Subtask 2.2)	August 16, 2005
GIS layer with new land use/cover (Subtask 2.2.1)	August 31, 2005
Draft report on support monitoring	December 16, 2005
Final report on support monitoring	February 15, 2006

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