EXHIBIT F2

MODELING QUALITY ASSURANCE PROJECT PLAN

Modeling Quality Assurance Project Plan

for

Lake Maumelle Watershed Planning Project

Contract No. PSA 6-22-05
Tt Account No. 16388

Prepared for:

Central Arkansas Water
221 East Capital Avenue
Little Rock, Arkansas 72202

Prepared by:

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Revision 1

This quality assurance project plan (QAPP) has been prepared according to guidance provided in *EPA Requirements for Quality Assurance Project Plans* (EPA QA/R-5, EPA/240/B-01/003, U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC, March 2001) and *EPA 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, DC, December 2002) to ensure that environmental and related data collected, compiled, and/or generated for this project are complete, accurate, and of the type, quantity, and quality required for their intended use. Tetra Tech will conduct the work in conformance with the quality assurance program described in the quality management plan for Tetra Tech's Fairfax Center and with the procedures detailed in this QAPP.

Approvals:

Leslie Shoemaker, Ph.D. Project Officer/QA Officer/PM Tetra Tech, Inc.	Date	Jonathan Butcher, Ph.D., P.H. Quality Assurance Officer Tetra Tech, Inc.	Date
Kimberly Brewer, A.I.C.P. Quality Control Officer Tetra Tech, Inc.	Date	John Riverson Quality Control Officer Tetra Tech, Inc.	Date

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Acronyms and Abbreviations

BMPs	best management practices
CAW	Central Arkansas Water
CE-QUAL-W2	U.S. Army Corps of Engineers' two-dimensional water quality model
CVS	concurrent version control system
DQI	data quality indicator
DQO	data quality objective
EFDC	Environmental Fluid Dynamics Code
EPA	U.S. Environmental Protection Agency
GBMM	Grid-based Mercury Model
GIS	Geographical Information System
HSPF	Hydrologic Simulation Program - FORTRAN
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RAM	random access memory
SET	Site Evaluation Tool
TM	Technical Monitor
TMDL	Total Maximum Daily Load
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WEPP	Water Erosion Prediction Project

Distribution

This document will be distributed to the following Central Arkansas Water and Tetra Tech, Inc., staff members who will be involved in this project.

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1 Project Management

1.1 PROJECT/TASK ORGANIZATION

Central Arkansas Water (CAW) has retained Tetra Tech, Inc. to provide consulting services toward the development of a comprehensive watershed management plan for Lake Maumelle. The lake is the primary water supply for the cities of Little Rock and North Little Rock, as well as 10 other municipalities and unincorporated communities. CAW aims to maintain the water quality of Lake Maumelle through appropriate watershed protection.

CAW has requested that services address several areas including watershed and lake analysis, establishment of management goals, evaluation of management options and risks, and recommendations for water quality program enhancement. As part of this work, Tetra Tech will develop a series of analytical tools. These will include several mathematical modeling analyses to address the sources, fate, and transport of water, sediment, and a variety of pollutants in Lake Maumelle and its watershed through use of watershed models, site-scale pollutant loading models, and lake response models. Additional analytical tools will be developed to address cost comparison of alternatives.

This QAPP provides a general description of the modeling and associated analytical work to be performed for the project, including data quality objectives and quality control procedures to ensure that the final product satisfies user requirements. This QAPP also addresses the use of secondary data (data collected for another purpose or collected by an organization or organizations not under the scope of this QAPP) to support Lake Maumelle Watershed Planning.

The organizational aspects of the program provide the framework for conducting tasks. The organizational structure and function can also facilitate task performance and adherence to quality control (QC) procedures and quality assurance (QA) requirements. Key task roles are filled by the persons who are leading the various technical phases of the project and the persons who are ultimately responsible for approving and accepting final products and deliverables. Figure 1, the program organization chart, shows the relationships and lines of communication among all participants and data users. The responsibilities of these persons are described below.

Mr. Bruno Kirsch, PE will provide overall project/program oversight for this study as the CAW Project Manager (PM). He will work with the Tetra Tech PM and Deputy PM to ensure that project objectives are attained. The CAW PM will also have the following responsibilities:

- Provide oversight for the assessment effort and ensure adherence to project objectives.
- Review and approve the project work plan, QAPP, and other materials developed by Tetra Tech to support the project.
- Coordinate with contractors, reviewers, and others to ensure technical quality and contract adherence.
- Provide final approval of task deliverables.

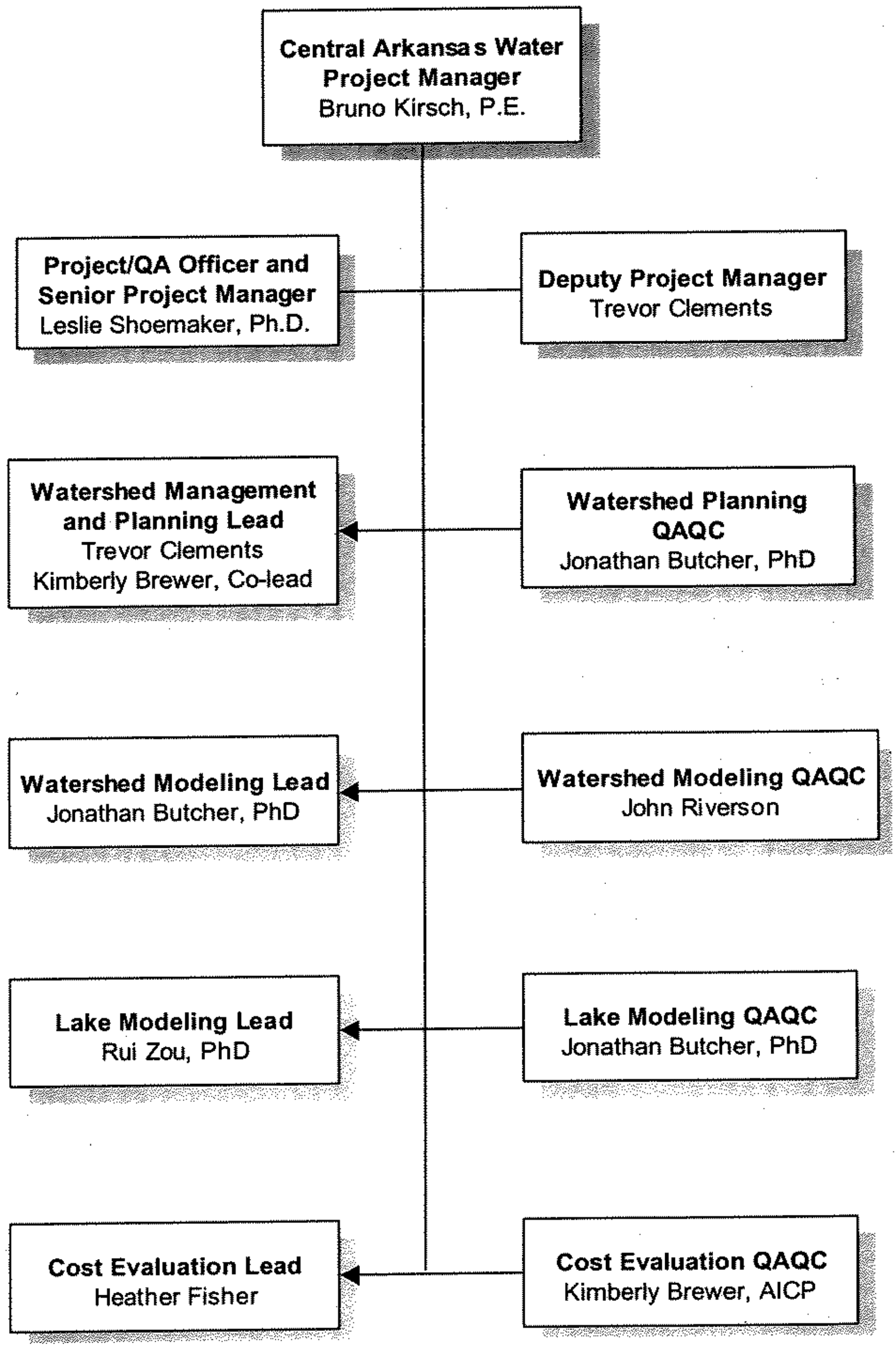

Figure 1. Organizational Structure of the Tetra Tech Team

The Tetra Tech Project Officer and Senior PM is Leslie Shoemaker, Ph.D., and the Deputy PM is Trevor Clements. Dr. Shoemaker and Mr. Clements will supervise the overall project, including study design and model application. Principal duties of the Tetra Tech PM and Deputy PM include the following:

- Coordinate task assignments, establish priorities, and schedule work.
- Ensure completion of high-quality deliverables within established budgets and time schedules.
- Provide guidance, technical advice, and performance evaluations to those assigned to the task.
- Implement corrective actions and provide professional advice to staff.
- Prepare or review preparation of task deliverables and other materials developed to support the task.
- Provide support to CAW in interacting with the task team, technical reviewers, and others to ensure that the technical quality requirements of the study design objectives are met.

Additionally, Dr. Shoemaker will be the Project QA Officer, responsible for reviewing and approving the QAPP and monitoring QC activities to determine conformance.

A core group of scientists, engineers, and planners will constitute the project integration team: Mr. Trevor Clements will lead the Watershed Management and Planning tasks in addition to his role as Deputy PM. Jonathan Butcher, Ph.D. will lead the Watershed Modeling Tasks and will act as Modeling QC Officer for the Watershed Management and Planning, and Reservoir Modeling Tasks. Rui Zou, Ph.D. will lead the Reservoir Modeling Tasks. John Riverson will act as Modeling QC Officer for the Watershed Modeling Tasks. Ms. Heather Fisher will lead the Cost Evaluation Tasks. Ms. Kimberly Brewer, A.I.C.P. will assist Mr. Clements in co-leading planning tasks, and she will act as the QC Officer for Cost Evaluation.

In their capacity as Modeling QC Officers, Drs. Butcher and Zou will be responsible for performing or overseeing evaluations to ensure that quality is maintained through the data collection and analysis process. Neither QC Officer will participate directly in the tasks that he checks. QC evaluations will include reviewing site-specific model equations and codes (when necessary), and providing written documentation of these reviews to ensure that the standards set forth in the QAPP and in other planning documents are met.

In her capacity as Cost Evaluation QC Officer, Ms. Brewer will be responsible for overseeing evaluations of the project resource economist conducting cost evaluations. She will check the methods being applied, sources of information for their appropriateness, results for their accuracy and reasonableness, and documentation for its content and accuracy.

Other QA/QC staff, including technical reviewers and technical editors, will be selected as needed and will provide oversight of the content of the work products and ensure that such work products comply with CAW's specifications.

1.2 Problem Definition/Background

1.2.1 Background

Central Arkansas Water (CAW) has retained Tetra Tech, Inc. to provide consulting services toward the development of a comprehensive watershed management plan for Lake Maumelle. The lake is the primary water supply for the cities of Little Rock and North Little Rock, as well as 10 other municipalities and unincorporated communities. CAW aims to maintain the water quality of Lake Maumelle through appropriate watershed protection.

CAW has requested that services address several areas including watershed and lake analysis, establishment of management goals, evaluation of management options and risks, and recommendations for water quality program enhancement. Throughout this planning process, Tetra Tech is working with CAW and stakeholders to ensure strong public participation and support for the final outcome. The approach is designed to be science-based and support informed decision-making by the CAW and the stakeholder community. To meet these needs, Tetra Tech is following a four-phased Scope of Work:

I. Project Organization and Preliminary Planning

II. Tool Development and Assessment

III. Management Plan Development

IV. Transition Support for Plan Implementation

Tetra Tech is currently in the process of completing Phase I, Project Organization and Preliminary Planning. Phase I includes the tasks shown in Table 1.

Phase I is nearing completion and provides a strong information foundation upon which to plan the remaining project phases. Under this first phase, Tetra Tech has helped CAW establish Policy and Technical Advisory Councils as the primary basis for coordinating stakeholder participation. Existing information has been compiled and briefly reviewed to develop a preliminary understanding of watershed and lake conditions, and issues that will need to be addressed by the watershed management plan. The Policy Advisory Council (PAC) has conditionally endorsed draft watershed management goals and objectives, and is considering preliminary targets for specific indicators established for the goals and objectives. The Technical Advisory Council has provided input to Tetra Tech on the selection of indicators, methods for quantifying and predicting the indicators, and the basis for preliminary targets. A three-scale, linked modeling network (site, watershed, and lake) has been selected, and completion of this quality assurance project plan (QAPP) is the final step to Phase 1 to guide model development, assessment and data management for the next two phases.

Table 1. Tetra Tech Lake Maumelle Project Phase 1 Task Summary

1.1	Stakeholder committee development and phase 1 outreach
A.	Assist in forming stakeholder committee (Policy and Technical Advisory Councils)
B.	Support Phase I Public Outreach
1.2	Conduct scoping analysis/update watershed information
A.	Conduct initial data management
B.	Review existing resource assessments and conduct interviews
C.	Conduct preliminary data analysis
D.	Summarize existing information
E.	Present results and facilitate stakeholder meetings
1.3	Set management plan overarching goals
A.	Develop strawman goals and objectives
B.	Facilitate stakeholder establishment of goals and objectives
1.4	Develop indicators and preliminary targets
A.	Develop strawman indicators and targets for management objectives
B.	Facilitate technical workgroup conference calls to refine indicators and targets
C.	Present recommended indicators and targets to Policy Advisory Council
1.5	Select appropriate models/assessment methods
A.	Conduct evaluation of candidate models
B.	Facilitate Technical Advisory Council meeting and calls to review and discuss model choices
C.	Present recommended models/assessment methods to Policy Advisory Council
1.6	Quality Assurance Program Plan (QAPP) Development
A.	Identify information gaps for proposed assessment tool development and application
B.	Develop DQOs, data collection and management plan, assessment protocols, model development plan, etc.

1.2.2 Problem Definition

The Lake Maumelle Watershed Assessment is being planned consistent with EPA's Data Quality Objectives Process. A key component of the Data Quality Objectives process is the identification and documentation of the decision context for the project (the principal study questions). Identification of decision needs commenced in Phase I through elicitation of Goals and Objectives with the project Policy Advisory Council. This process resulted in concurrence on the Draft Goals and Objectives presented in Table 2.

Table 2. Draft Goals and Objectives

Endorsed 10/20/05 by the Policy Advisory Council [Note that the PAC will review at their 12/8/05 meeting whether aesthetics should also be addressed in the objectives]

OVERARCHING GOALS OF THE WATERSHED MANAGEMENT PLAN

- Maintain long-term, abundant supply of high quality drinking water for present needs and continuing growth of the community.
- Provide an equitable sharing of costs and benefits for protecting Lake Maumelle.

OBJECTIVES

(Note: it will be assumed that only management options that comply with environmental regulations, such as water quality standards, will be considered.)

Minimize risks to public health from: • toxic spills • pesticide/herbicide runoff • bacteria/pathogens from failing septic/community systems and animal wastes • toxins from blue-green algae	(most important)
Minimize impacts on watershed property owners and residents including: • use restrictions • cost of BMPs	(most/more important)
Minimize water supply taste, odor, and color problems associated with: • algae • iron and manganese • turbidity	(more important)
Minimize impact on the water supply intake and water treatment facility operations such as: • intake/filter clogging • excess chemical additive requirements • increased operation and maintenance (O&M)	(more important)
Minimize rate increases from: • increased treatment costs • increased O&M • land acquisition/buffer easements	(more important)

Minimize loss of reservoir water supply storage capacity from sedimentation.	(important)
Minimize risk of impairment to tributary streams in the watershed for stream and lake protection from: • channel instability (erosion, sedimentation, scour) • pollution from runoff (sediment, nutrients, pesticides/herbicides, pathogens)	(important)
Allow limited recreation that reflects environmentally sound stewardship of the lake for: • fishing • sailing • boating • access (picnicking, hiking, visiting)	(important)
Meet other community values including: • Be economically competitive • Provide a strong tax base for communities in the region and minimize tax increases • Be administratively feasible	(important)

The Principal Study Questions for the project correspond directly to the Goals and Objectives. For each objective, there are two associated Principal Study Questions:

1) Is the objective likely to be achieved in the future under reasonably projected scenarios of development pressure with current management and regulations?
2) Are there feasible alternative management strategies that will increase the likelihood of achieving the objective?

The second step in the identification of decision needs is definition of the types of alternative actions that could be used to help ensure achievement of objectives. This is important to consider, because the analytical tools must be capable of representing the effects of such alternative actions on the objectives. Tetra Tech is currently developing a menu of the most promising management options from which to draw. This will enable Tetra Tech and the Policy Advisory Council to develop alternative management scenarios (or combinations of different management options). We will carry forward the most promising options based on technical, political, and administrative feasibility, as well as potential cost to the development community. While the identification of potential management options is not complete, it is clear that they are likely to include some or all of the following classes of options for consideration:

1) Restrictions on package wastewater disposal facilities.
2) Zoning, such as density limits for development.
3) Structural and nonstructural management practices/development guidelines or ordinance provisions for new development, including use of low-impact development techniques for onsite stormwater control and/or performance standards for the practices.
4) Adoption of forestry and agricultural best management practices (BMPs).
5) Purchase and retirement of development rights for sensitive tracts.

6) Performance standards for onsite wastewater disposal.
7) Maintenance of stream riparian corridors.
8) Restrictions on use and/or transport of toxic chemicals.
9) In-lake management techniques.

These management options encompass a variety of spatial scales, including site-level, watershed-level, and lake response. For this reason, the modeling tools must also be able to address multiple spatial scales. An appropriate modeling framework was therefore selected in conjunction with the Technical Advisory Council. The lake model will include CE-QUAL-W2 (an updated version of the tool than that previously used by USGS for Lake Maumelle) for 2-D general simulation of lake-wide response. It will also include EFDC for 3-D flow and transport to evaluate lateral variations and nearshore impacts.

The watershed model will be HSPF for watershed-scale simulation of flow, pollutant loads, and transport. The site scale models include the Site Evaluation Tool (for site scale development impacts and stormwater BMP evaluation) and the WEPP (for forestry practices and evaluation of impacts of unpaved roads).

1.3 Project/Task Description and Schedule

The tasks to be implemented in Phase II through Phase IV of the project are described in Statement of Work, reproduced below.

Phase II Tasks – Tool Development and Assessment

The emphasis in Phase II is on performing the analysis that will support the selection of final alternatives in Phase III. Phase II includes additional data compilation and collection, watershed model development, reservoir model application (and/or development), assessment tool development, and baseline application of the assessment tools.

Task 2.1 Data Compilation and Collection to Support Assessments

Additional data will be compiled from local agencies, regional studies, and other historic data sets as appropriate. This data compilation builds on previously collected and compiled data in Phase I; supplemental processing is needed for specific data sets required for modeling purposes. Other groups may support significant portions of the data gathering. Key data sets needed to support modeling tasks include:

- Precipitation (time series, spatial distribution)
- Temperature (time series, spatial distribution)
- Hydrography
- Flow gaging
- Water quality sampling
- Land use
- Imperviousness
- Soils
- Topography

- Reservoir bathymetry
- Reservoir operations (water supply withdrawal data and dam release data)
- Special features, existing management
- Results of experimental watershed studies conducted by the U.S. Forest Service (USFS) (and others, as appropriate) in similar areas of Arkansas.

Land use, soils, and topography data will be used as the basis for deriving watershed modeling simulation units (i.e., land use units).

Supplemental information may need to be gathered to support watershed, reservoir or specialized assessment techniques. Based on the results of Phase I scoping, channels in the Maumelle watershed possess limited amounts of mobile sediment. However, additional information is needed on stream morphology and first-order stream erosion processes. Initial geomorphological investigations suggest that erosion on Mountainburg soils in the watershed is limited by armoring, while most stream segments are likewise armored by cobbles, limiting bank erosion. Additional geomorphological assessment in the watershed is advisable, both to assess channel stability and to evaluate upland erosion. In addition, surveys should be conducted at Hot Springs Village to establish reference conditions for the long term effects of development in the Ouachita Mountains ecoregion, and conditions in the Alum Fork of the Saline River experimental watershed, where USFS has conducted a number of studies, should be examined for applicability to the Maumelle watershed.

Deliverables and Schedule:

1) Continued update of database, GIS coverages (developed throughout Phase II, electronic files delivered at project close-out).
2) Site visit for follow up field geomorphology surveys (between November 2005 and January 2006).
3) Technical memo on geomorphological investigations (by 3/9/06).

Task 2.2 Develop Watershed Modeling Tools

During Phase I, appropriate watershed modeling tools for the Maumelle watershed were established in consultation with the TAC. The basic watershed modeling tool will be the EPA-supported HSPF model, which will provide a representation of hydrology and pollutant loading throughout the watershed. The HSPF modeling application will be supplemented through the application of site-level models, which will provide more detailed simulation of site-specific management practices. Watershed model development, will include setup, testing, and application of the system to the Lake Maumelle watershed. The watershed modeling links activities on the land surface to responses in the streams and lake, and addresses hydrologic regime, sediment loading, and nutrient concentration/loading. The watershed model will be used to assess the effects of future development and the use of traditional and non-traditional best management practices. Related site-scale tools (2.2 C) will be used to fine-tune the watershed-scale model to accurately represent the localized impacts of development and potential benefits of management alternatives. Development of the watershed model is in two parts: hydrology and water quality.

A) Watershed Hydrology. The development of watershed models is based on good representation of the watershed hydrology. Hydrology is the dominant driver for the movement of pollutants from the land surface to the stream systems and lake. Hydrologic processes include rainfall-runoff relationships and in-stream water transport. The steps performed in setup and testing of the hydrologic application will consider the following:

- Selection of base land use/soils/weather categories.
- Delineation of subwatersheds (consistent with other planning activities).
- Initial model setup.
- Development of water balance by hydrologic unit.
- Testing and calibration of land use specific rainfall-runoff response as data allow.
- Testing and calibration to available subwatershed flow gaging.
- Sensitivity analysis.
- Validation with recent watershed monitoring data.

Deliverables and Schedule:

1) Technical memo on hydrologic watershed simulation documenting model setup, calibration and validation results (by 1/31/06).

B) Water Quality. Water quality will be simulated with HSPF for each land use category and aggregated at the subwatershed level. Outputs from the various subwatersheds will then be routed through the stream network. Pollutants of particular concern are likely to include dissolved and particulate phosphorus, nitrogen (nitrate, nitrite, ammonium, and organic nitrogen), pathogens, sediment, and organic carbon. The watershed model will also be set up to evaluate the movement of pesticides/herbicides and toxic chemicals from land applications and potential spills.

Water quality model testing will include the same sequence as the hydrologic modeling. Some differences will be dictated by the availability of data. Modeling steps include:

- Source inventory and delineation (NPS, Atmospheric Deposition)
- Monitoring data processing
- Setup and testing
- Land use specific testing (see also Task 4 below)
- Watershed calibration
- Sensitivity analysis
- Watershed validation using recent or newly available data
- Baseline application/scenarios
- Final application and data output.

The water quality modeling will be used to develop baseline simulations and a series of scenarios for evaluation using the lake model. Simulations will be used to establish contaminant loading thresholds associated with inlake concentration targets. Outputs will be automatically generated as graphs and maps. Various output metrics will be examined including local scale loading, watershed loading, and hydrologic changes (frequency of runoff, peak runoff).

Deliverables and Schedule:

1) Technical memo on the setup, calibration, and validation of the water quality portion of HSPF (by 2/28/06).

2) Electronic input and output files for the HSPF final calibration and validation modeling (provided with all modeling files at project close-out).

C) Site-Scale Models. HSPF provides a strong framework for evaluating loads from the watershed as a whole. Loads from individual land uses, however, need to be calibrated to accurately represent conditions and management practices at the site scale. One key area for analysis of future scenarios is pollutant loading from development, both with and without a variety of site-scale management practices. To evaluate pollutant loading and the effects of management practices at the development scale, Tetra Tech will employ the Site Evaluation Tool (SET). For site-scale analysis of forestry practices and unpaved roads, we will employ the WEPP model, building on work already undertaken by personnel at the Ouachita National Forest.

Deliverables and Schedule:

1) Technical memo on the setup of the SET and WEPP models for management option evaluation (by 2/28/06).

Task 2.3 Lake Modeling

Lake models will likely be used to evaluate the impacts of watershed conditions on in-lake indicators of water quality such as phosphorus concentration and chlorophyll *a*. The lake model needs to be sufficiently detailed to evaluate the localized effects of inputs on water quality in the vicinity of the water supply intake, but also needs to be developed on an aggressive schedule. A two-dimensional CE-QUAL-W2 model has already been developed for the lake. This model meets many, but not all, of the project objectives, and can be refined and updated quickly. The main disadvantage of CE-QUAL-W2 is that it does not simulate lateral variability, which is of particular concern for impacts from near-shore activities. During Phase I, use of the three-dimensional EFDC model was also evaluated. This would provide additional spatial resolution, but would require substantially more time and effort (including additional data collection) for full implementation. A compromise approach was therefore developed in consultation with the TAC, which incorporates full application of the CE-QUAL-W2 model coupled with implementation of the hydrodynamic portion of the three-dimensional EFDC model. The CE-QUAL-W2 application will enable rapid development to simulate lake-wide response of nutrients, algae, dissolved oxygen, and TOC. It can also be used to analyze risk of watershed loads of sediment, toxics (including mercury), and pathogens relative to water intake and in-lake concentrations. EFDC hydrodynamics and simple transport implementation (without full eutrophication simulation) can also proceed relatively quickly and in parallel with the CE-QUAL-W2 refinement. This will allow analysis of the significance of lateral variations in water quality, detailed evaluation of spill movement and transport of loads from shore areas, and will provide a basis for future development of a fully three-dimensional water quality model (with additional data collection) if needed.

Model development will include calibration and validation of the hydrodynamics and water quality parameters. Specific procedures and criteria for calibration and validation will be set forth in the Model Quality Assurance Project Plan.

Deliverables and Schedule:

1) Technical memo on lake model setup, calibration, and validation (by 2/28/06).

Task 2.4 Supplemental Assessment Techniques

Additional assessment techniques will be developed to evaluate and track the indicators identified in Phase I that are not readily modeled by using traditional watershed and lake modeling techniques. This includes both quantitative and qualitative estimates of costs and impacts on community values (tax base, economic competitiveness, etc.). These supplementary techniques will be used to help evaluate the full suite of indicators identified in Phase I. Unlike the water quality indicators, the assessment of these supplemental indicators will be based on a relative comparison between alternate management scenarios rather than measurement against targets and thresholds. For each method, the approach, development and testing will be documented. A baseline application will be developed that will be used as the point of comparison for future alternatives and scenarios.

Below are the proposed supplemental assessment techniques, including cost tools, a watershed visualization model, and stakeholder participation.

Task 2.4.1 Cost Tools

A.) Development of Site Evaluation Cost Tool (for Stormwater Management BMPs). Tetra Tech will develop a spreadsheet tool that estimates the watershed-wide cost of implementing stormwater management BMPs for each modeling scenario. Tetra Tech will use the cost estimates to illustrate the relative cost differences between the modeling scenarios. Research will be conducted to determine the best available information on BMP costs in the vicinity of Lake Maumelle. The effect of soils and other site constraints will be considered when determining appropriate cost estimates for the Lake Maumelle watershed. For each modeled land use, site examples will be designed with BMPs that meet the scenario performance requirements. Inputs to the spreadsheet tool will include BMP cost data, BMP dimensions, and area of each land use in the watershed. The spreadsheet tool will calculate cost per acre for each land use and will extrapolate each cost per acre to the entire watershed. Costs will include construction, design, engineering, and operation and maintenance.

Deliverables and Schedule:

1) Technical memo detailing tool development (by 3/31/06).

B) Forestry Best Management Practice Cost Tool. Tetra Tech will develop a spreadsheet tool that estimates the watershed-wide cost of implementing forestry BMPs for each modeling scenario. Tetra Tech will use the cost estimates to illustrate the relative cost differences between the modeling scenarios. Research will be conducted to determine the best available information on forestry BMP costs in the vicinity of Lake Maumelle. Cost data will be taken from published literature on the costs of forestry BMPs as well as information from National Forest Service staff, other government agents, and university researchers. The forestry BMPs will be defined as practices separate from harvesting techniques that reduce the impact of harvesting on Lake Maumelle and its tributary streams. Inputs to the spreadsheet tool will include BMP cost per acre harvested and acres harvested per year in the watershed. It will be developed so that multiple forestry BMPs can be included in one scenario. The spreadsheet tool will calculate cost per acre for each forestry land use and will extrapolate each cost per acre to the entire watershed.

Deliverables and Schedule:

1) Technical memo detailing tool development (by 3/31/06).

C) Methodology for Estimating CAW Utility Rate Costs. For each management scenario, Tetra Tech's lake water quality models will generate raw water quality for concentrations/levels of TOC, chlorophyll *a*, turbidity, etc. It is assumed that CAW will use this raw water data to estimate:

- Additional annual operational (e.g., chemical) and capital requirements for the period 2007-2037 triggered by the management scenario, not other regulatory requirements.
- Cost of the additional operational/capital requirements.

- Resulting utility rate increases.

For each management scenario, Tetra Tech will recommend the number of acres for CAW land acquisition. It is assumed that CAW will estimate:

- Cost of the land over the period 2007-2037.
- Resulting utility rate increases.

Finally, for each management scenario, Tetra Tech will provide data on the number of houses in the watershed at buildout, and a projected rate of growth through the year 2037. Based on this added population in the watershed, we would ask CAW to estimate the additional cost of lake security and the estimated resulting utility rate increase.
If CAW is not able to quantitatively estimate these potential impacts on utility rates, Tetra Tech will work with the CAW staff to develop qualitative or best-professional-judgment comparisons across management scenarios.

Deliverables and Schedule:

1) Parameters for raw water quality, land acquisition needs, and watershed housing units will be provided to CAW throughout Phase III. (CAW to use its Utility Rate Model to provide cost information.)

D) Methodology for Evaluating Administrative Costs. White papers and case studies will be used to help evaluate the administrative needs and feasibility associated with different watershed management approaches. Tetra Tech will research the level of staffing, funding, and expertise needed to implement different types of watershed plans in other areas. We will also draw on guidance from the American Water Works Association, Center for Watershed Protection, Association of County Officials, League of Municipalities, and others as appropriate.

Tetra Tech will work with the local planners to develop assumptions about the number of development applications per year that could be anticipated with different development scenarios. Building on research and case studies from other areas, Tetra Tech will next work with local planners to evaluate the number of staff needed to implement different types of zoning and/or development ordinances including conduct development plan review, site inspections and enforcement, inspection of best management practices, etc. Potential funding mechanisms will also be identified. This task is linked to the evaluation of feasibility criteria below.

Deliverables and Schedule:

1) White papers regarding watershed management administrative needs and funding options (by 3/31/06).

Task 2.4.2 Method for Evaluating "Other Community Values" and Feasibility Criteria

Indicators related to meeting other (non-water quality) community values can best be assessed by the Policy Advisory Committee. These values include providing a strong tax base, minimizing tax increases to businesses and residents, and being economically competitive. In addition, it is important for the Policy Advisory Committee to screen management options for their political feasibility. Finally, it is important to adopt a watershed plan that is administratively feasible to local governments, CAW, and other parties responsible for implementation and that is technically feasible for meeting plan objectives. Tetra Tech will use a variety of methods to evaluate these community values and feasibility criteria.

As a first step, Tetra Tech will complete a list of management option evaluation criteria related to community values and feasibility. This will include definition of the criteria, and how these criteria will be used to evaluate whether the management option or scenario is meeting, partially meeting, or not meeting the management plan objectives and targets.

To determine technical feasibility, in addition to the watershed, lake and site scale models proposed in Sections 2.2 and 2.3, Tetra Tech will develop white papers that will address the degree to which different management options are suitable for use in the Lake Maumelle watershed given soils, slopes, and other natural features or constraints. This is also linked to the Development of Management Options, Task 3.1, where white papers will be developed for evaluation and screening of management options to model.

As detailed above, white papers and case studies will be used to help evaluate the administrative needs and feasibility associated with different watershed management approaches. This information will be brought forward to the Policy Advisory Committee to evaluate whether resources could and would be made available to meet the administrative needs associated with the different management options. Overall administrative feasibility of each management scenario, as well as other community value impacts, will be evaluated using facilitated discussion with, and a survey of, the Policy Advisory Council (see below).

Tetra Tech will develop a survey for the Policy Advisory Council to elicit individual responses regarding each management scenario's positive or negative impact on the community values indicators. The survey will also ask the members to provide perceptions on each scenario's political and administrative feasibility. Once Tetra Tech has compiled the survey, we will present the results and lead a facilitated discussion to determine the group's preferred scenario in meeting community values and overall feasibility criteria. Tetra Tech will administer the survey during Phase II of the project.

Deliverables and Schedule:

1) Evaluation criteria related to community values and feasibility (by 1/30/06).
2) Survey Tool for Policy Advisory Council Scenario Evaluation (by 1/30/06).
3) White papers regarding technical feasibility of management options (provided to Councils between December 2005 and March 2006).

Task 2.5 Conduct Baseline Modeling Analyses

Using the framework developed and tested in Tasks 2.1-2.4, a set of baseline watershed and lake conditions will be evaluated to establish points of reference for development of management alternatives in Phase III. The baseline analyses will consider existing and future buildout conditions. Assessment results will be evaluated and the potential impacts evaluated on a subwatershed, regional, and lakewide basis. The assessment framework will allow for the assessment of the impacts at multiple scales and for multiple indicators. In addition, the analysis will consider the risk associated with delivery of pollutants to the lake and specifically the water supply intake.

A) Develop Baseline Modeling Existing and Future Buildout Land Use Assumptions. Existing land use conditions will be defined based on currently available GIS land use conditions (based on GIS and local tax parcel information) and, to the extent information is readily available, the management practices currently being used in the watershed. Tetra Tech will work with local planners and resource agencies to establish a likely buildout scenario under existing rules and regulations for the watershed. Assumptions will be made regarding the type of waste handling facilities used in the future (individual septic versus community onsite systems or package wastewater treatment plants), which will in turn influence the assumptions of future housing density. Assumptions will be reviewed with members of the Technical and Policy Advisory Council to provide them with the opportunity for feedback prior to completion of the baseline analyses.

B) Set Up Assessment Framework for Baseline Analyses. Working with the project planners, the modeling team will translate the baseline land use and scenario assumptions into modeling assumptions. Databases and model input will be set up for the site-scale, watershed, and lake models.

C) Apply Models, Interpret and Document Results. The models will be run for existing conditions and up to two future buildout scenarios. Results will be displayed for the key indicators in relation to the target values for those indicators. The project team will interpret the results, noting areas and levels of uncertainty, and prepare appropriate graphics and written documentation for communication of the results to CAW, the Councils, and other stakeholders.

D) Present Baseline Analyses Findings. Results of the baseline analysis will be presented to the public and Councils and used to support development of management scenarios (combinations of management options designed to meet management goals and objectives) as a part of Phase III activities.

Deliverables and Schedule:

1) Draft existing and buildout assumptions (by 1/12/06).
2) Facilitated discussion of existing and buildout assumptions (part of TAC and PAC meeting agendas [if needed] in January and February 2006).
3) Baseline modeling input and output files (part of final electronic files submittal).
4) Preliminary discussion of results with TAC (target first week in March 2006).
5) Powerpoint presentation to PAC (3/16/06).
6) Baseline analyses documentation (draft memo in April 2006; final within 15 business days of receipt of comments from TAC and CAW).

Phase III Tasks – Management Plan Development

Task 3.1 Develop Management Options

A) Evaluate/Screen for Promising Management Options and Strategies. Tetra Tech will draft white papers on alternative watershed management strategies for new development (e.g., targeted/prioritized land acquisition, large lot zoning/subdivision, stream buffer requirements, performance standards for new developments related to pollutant loading and hydrology impacts, low-impact development design, nutrient banking, etc.) and existing resource management issues (e.g., land management practices, lake use and management). (Note: white paper development and conceptual discussions will begin parallel to Phase II tasks.) Tetra Tech will present options to the Technical Advisory Council and Policy Advisory Council and work with them to screen for the most promising options to include in "scenarios" (i.e., combinations of options that together address the full suite of management objectives).

Deliverables and Schedule:

1) Preliminary white papers on alternative watershed management strategies (provided in support of December, January and February PAC meetings).
2) Up to four Technical Advisory Council conference calls to discuss technical feasibility and application assumptions (December 2005 through March 2006).
3) PowerPoint materials for presentation of options at Policy Advisory Council Meetings.

4) Options presentations at Policy Advisory Council Meetings (December 2005, and January and February 2006 meetings).

B) Present Promising Options to Watershed Landowners and Water Supply Users and Obtain Feedback. Tetra Tech will meet with watershed landowners and water supply users to present the draft list of promising options to address new development and existing resource management issues and get feedback on these options. Feedback will be solicited through surveys and discussion. Based on these meetings, Tetra Tech will revise the options or add additional options, as needed.

Deliverables and Schedule:

1) PowerPoint and other presentation materials for watershed community meetings (by 2/10/06).
2) Survey tool for community meetings (by 2/9/06).
3) Community meetings in the watershed: one community meeting in Little Rock; one community meeting in North Little Rock (February 2006).
4) Compilation of meeting comments and survey results (by 3/9/06).
5) Updated information on preferred management options (by 3/9/06).

C) Work with Stakeholder Committee to Develop Alternative Scenarios to Meet Targets (i.e., combining options). Based on the most promising options identified by stakeholders in subtasks 3.1.A and B, Tetra Tech will help the PAC craft scenarios that combine options in a way to achieve management goals and objectives. Tetra Tech will prepare two strawman scenarios that are distributed to the PAC for review and comment. These should include options that address existing and future potential issues. A PAC meeting will then be facilitated to refine the scenarios as needed to address comments and with due consideration to the goals and objectives.

Deliverables and Schedule:

1) Strawman scenarios (by 3/9/06).
2) Facilitated Technical Advisory Council conference call (March 2006).
3) Facilitated Policy Advisory Council Meetings (3/16/06).
4) Final scenarios to model (refinements based on 3/16/06 discussion documented by 4/1/06).

Task 3.2 Evaluate Management Options and Select Most Promising Solutions

A) Model Scenarios and Present Findings. Using the assessment framework developed for Phase II, Tetra Tech will test the ideas of alternative scenarios at the site and watershed scale. Management scenarios will be translated to modeling assumptions and model input databases will be developed. Model output will be formatted for indicator comparison. The evaluations should consider all management goals and indicators (e.g., cost to landowners, cost of development, cost to CAW, recreation, administrative feasibility, political feasibility, etc.). Results will be interpreted relative to targets, noting areas and levels of uncertainty. Presentation materials will be prepared and modeling results documented. Results will be communicated to the public at two meetings immediately preceding the second of two Policy Advisory Council meetings that will be scheduled to review results. Comments will be solicited using three basic questions to facilitate compilation of input: 1) What do you like about the proposed recommendations?; 2) What don't you like about the proposed recommendations?; and 3) For the things you don't like, how might they be changed so that they would be acceptable to you while still meeting the overall goals and objectives? Input will be compiled for submittal to CAW and the Policy Advisory Council.

Deliverables and Schedule:

1) Preliminary discussion of results with TAC (target conference calls for first week in May and first week in June 2006).
2) PowerPoint presentation to PAC of scenario evaluation results (initial modeling results 5/18/06; remaining indicator results 6/15/06).
3) Handout summarizing results and levels of uncertainty (6/8/06).
4) Facilitated public meetings (6/13/06; 6/14/06).
5) Compiled public input (initial results reported at 6/15/06 PAC meeting; follow up within next two weeks as needed).
6) Facilitated PAC meeting (6/15/06).
7) Model application documentation (draft technical memo by 7/13/06; revised version within 15 business days of receipt of TAC and CAW comments).

Scenario Refinement. Based on the comments received at the public and PAC meetings in June 2006, Tetra Tech will work with CAW and the PAC to select the preferred scenario or refine one of the scenarios as needed to better meet the goals and objectives. If refinement is required, Tetra Tech will present the proposed "refined scenario" to the PAC for discussion and approval. Detailed analysis of the "refined" scenario will be performed as needed. Subsequent findings will be presented to the PAC, addressing areas and levels of uncertainty and working toward consensus.

Deliverables and Schedule:

1) If required, a facilitated PAC meeting to review and approve refined scenario (target agreement on refinements at 6/15/06 meeting; if not, potentially convene conference call within two weeks of 6/15/06 meeting or just put on the agenda for the 7/20/06 meeting.
2) Handout summarizing refined scenario results (schedule to be determined).
3) PowerPoint presentation of detailed analysis for the refined scenario (schedule to be determined).
4) Updated documentation of detailed analysis (schedule to be determined).
5) Facilitated PAC meeting to review results from detailed analysis of the compromise scenarios.

Task 3.3 Watershed Plan Development

A) Develop Draft Watershed Plan Documentation. Tetra Tech will work with the TAC and PAC to fine-tune the implementation strategy, and will compile information on the recommended suite of management options, roles and responsibilities associated with the recommended provisions, costs and anticipated funding sources into a preliminary draft document (i.e., focus on these components, not technical appendices).

Deliverables and Schedule:

1) Facilitate up to 3 conference calls with the TAC to work on technical components of the watershed plan implementation strategy (July through August and potential early-September 2006).
2) Facilitate discussion of watershed plan implementation strategy development (7/20/05 and 8/17/05 PAC meetings).
3) Preliminary Draft Watershed Plan Document for public review (9/30/06).

B) Present Results to the Community. Tetra Tech will present the results of any refined scenario evaluations and the draft watershed plan recommendations to the community (including the CAW Board, land owners in the watershed, the general public, and local government boards). Comments will be solicited on areas such as what potential obstacles or key challenges to implementation do people see and do they have alternative suggestions. Input will be compiled for submittal to CAW and the Policy Advisory Council.

Deliverables and Schedule:

1) PowerPoint presentation and displays to communicate results to the community (September 2006).
2) Facilitated PAC meeting to discuss draft plan document and presentation to the community (9/21/06).
3) Meetings with watershed landowners (October 2006).
4) General public meetings (one in Little Rock, one in North Little Rock) (October 2006).
5) Local government board meetings (October 2006).
6) One CAW Board Meeting (October 2006).
7) Summary of compiled comments (November 2006).

C) Present Compiled Comments to Policy Advisory Council. Tetra Tech will bring back the public comments to the Policy Advisory Council, and work with CAW and the Council to revise recommendations as needed. If the changes are significant, then the detailed analysis will be updated to fully represent the changes.

Deliverables and Schedule:

1) Facilitated meeting to discuss public comments and refine the plan (November 2006).
2) If needed, update detailed analysis of the final plan (schedule to be determined).

D) Present Final Recommendations to the CAW Board and Local Boards. Tetra Tech will support presentation of the consensus recommended watershed management plan to the CAW Board and local boards as needed by CAW.

Deliverables and Schedule:

1) To be determined in conjunction with CAW at a future date.

E) Complete Watershed Management Plan Document. Portions of the plan (or materials to incorporate with the plan) will have been documented throughout Phases II and III. A final version will compile materials and reflect board decisions.

Deliverables and Schedule:

1) Final Plan Document (schedule to be determined based on time required).

Phase IV Tasks – Transition Support for Plan Implementation

Task 4.1 Support Implementation Transition to Operating Under the Adopted Plan

These activities will best be determined after the plan has been adopted. Examples of potential services that CAW may want from Tetra Tech for this phase of the project are provided below.

A) Develop monitoring and data management program to track effectiveness of the adopted watershed management plan.

B) Assist with ordinance and design manual development.

C) Provide developer tool kits and training.

D) Assist in developing and implementing a targeted land acquisition program.

E) Support planning and evaluation of development pilot projects.

1.4 Quality Objectives and Criteria for Model Inputs/Outputs

This section describes the quality objectives for the project and the general performance criteria to achieve those objectives. Specific quantitative tests are described further in Section 2.

EPA policy is to use a systematic planning process to define quality objectives and performance criteria. Systematic planning identifies the expected outcome of the modeling project, its technical goals, cost and schedule, and the criteria for determining whether the inputs and outputs of the various intermediate stages of the project, as well as the project's final product, are acceptable.

The Data Quality Objectives Process also requires definition of inputs to the decision. Most of the management objectives cannot be measured directly. Instead, an appropriate measurement endpoint or indicator must be selected as a basis for evaluation of progress toward the objective. Specific indicators associated with each objective were developed during Phase I in consultation with the Technical Advisory Council. The analysis questions, selected indicators and associated assessment tools are summarized in Table 3.

The general quality objectives for modeling are to provide information sufficient to answer each of the analysis questions contained in Table 3. These questions must be answered at a level of accuracy appropriate to decide (1) whether a significant risk to attaining objectives (as specified in Section 1.2.2) is presented under potential future land use conditions in the watershed, and (2) the performance of different management options in mitigating the risk.

The credibility and level of accuracy associated with model predictions will be established using a calibration and validation process. Specific quantitative tests are described in Section 2.1.

1.5 Documentation and Records

Thorough documentation of all modeling activities is necessary for the interpretation of study results. All records and documents relevant to the application, including electronic versions of data and input data sets, will be maintained at Tetra Tech's offices in the central file. The central repository for the lake response, watershed, site-level, and costing models will be Tetra Tech's Research Triangle Park, NC office. Tetra Tech will deliver a copy of the records and documents in the central file to CAW at the end of the task. Unless other arrangements are made, records will be maintained at Tetra Tech's offices for a maximum of 3 years following task completion.

Table 3. Study Questions, Indicators, and Assessment Tools

Threats	Sources	Analysis Questions	Indicators	Scales	Models/Methods
Toxics					
• Spills	Accidents at bridge crossings, roads, and storage areas Improper management at storage areas	• How long to reach WS intake? • How potent at intake? • How can management affect delivery or potency?	Time-of-travel Concentration - conservative - nonconservative	Watershed Lake Response	GBMM[1] & HSPF EFDC & CE-QUAL-W2
• Pesticides/herbicides	Applications (forestry, turf farms, golf courses, residential/commercial landscaping)	(Screen first to determine if potential for significant threat; if yes, same questions apply as for spills)	Time-of-travel Concentration - conservative - nonconservative	Watershed Lake Response	GBMM[1] & HSPF EFDC & CE-QUAL-W2
• Disinfection by-products	Reaction between disinfection chemicals and TOC in raw water (affected by algae)	• How much algae or TOC change must occur in the lake to affect THM production?	Total Organic Carbon (TOC)	Watershed Lake Response	HSPF CE-QUAL-W2
• Mercury (Hg)	Disturbed soils, atmospheric deposition, biomass burning	• What activities/mechanisms increase redox potential, DOC concentrations, and sulfate conc. to promote methylation and increase fish tissue concentrations? • How can management affect amount of Hg delivered and methylation to minimize the risk?	Hg load Sediment redox potential Sulfate concentrations	Watershed Lake Response	HSPF CE-QUAL-W2 w/ EFDC[2]
• Algal toxins	Produced by some forms of blue-green algae; related to nutrient enrichment; loading from developed areas, turf farms, golf courses; waste systems	• How much nutrient loading needed before lake productivity levels exceed threshold levels? • How can management affect amount and delivery of nutrients?	Chlorophyll *a* (productivity measure) Phosphorus & Nitrogen	Site-scale Watershed Lake Response	SET & HSPF HSPF CE-QUAL-W2 w/ EFDC[2]
Algae					
• Taste & odor, color • Impact treatment • Impact aesthetics • Impact DO/fishery	Excessive algae related to nutrient enrichment; loading from developed areas, turf farms, golf courses; waste systems	• How much nutrient loading needed before lake productivity levels exceed threshold levels? • How can management affect amount and delivery of nutrients?	Chlorophyll *a* (productivity measure) Phosphorus & Nitrogen Loads	Site-scale Watershed Lake Response	SET & HSPF HSPF CE-QUAL-W2 w/ EFDC[2]

Threats	Sources	Analysis Questions	Indicators	Scales	Models/Methods
Pathogens					
• Impact on WS • Impact on 2ndy recreation	Failing septic/community systems; direct discharge; animals (livestock, wildlife, pets)	• How much loading will threaten uses? • How can management affect amount and delivery of pathogens?	Fecal coliform/E-Coli (check w/ DEQ) Cryptosporidium/ Giardia	Site-scale Watershed Lake Response	SET & HSPF HSPF CE-QUAL-W2 w/ EFDC[2]
Sediment					
• Impacts on treatment • Impacts on storage • Impacts on water clarity • Impacts on tributary stability & habitat	Land disturbance (clear-cutting, tilling, construction, forest fires, off-road ATVs, post-construction runoff); Stream channel erosion	• How much loading before thresholds exceeded? • How can management affect amount and delivery of sediment	Sediment Load Channel Instability Turbidity/Secchi Depth	Site-scale Watershed Lake Response	SET & HSPF HSPF/WEPP[3] CE-QUAL-W2 w/ EFDC[2]
Land Use Restrictions/ Cost of Development	Provisions in watershed management plan	• How much restriction/cost is reasonable to protect water quality? • How can restrictions/costs be minimized while still achieving WS protection?	Per acre cost of development Per acre cost of key measure for forestry	Site-scale Jurisdictional or watershed-scale	SET Spreadsheet tabulation Evaluate restrictions qualitatively as well with input from stakeholders; tie to tax base, economic competitiveness
Rate Increases	Increased costs of treatment, operation and maintenance; land acquisition and conservation easement costs	• At what levels of lake response do additional treatment or O&M costs increase? • How does acquiring land through title or easement purchase affect water quality (cost/benefit)?	O&M costs Treatment system capital costs Land acquisition costs	WS system Watershed for land acquisition costs	Need to work with CAW to examine cost impact on rates; tie to being economically competitive with neighboring communities
Invasive Species	Import to the watershed via boats, motors, and boat trailers; migratory water fowl; aquarium content dumping	• What type of management is needed to prevent infestations?	Address management needs without indicator assessment	Lake	Emphasis will be on developing best management practices for marina area and boat owners

1 GBMM hydrology only is proposed to be implemented to yield spatial detail on overland time of travel from potential source areas.
2 Initial implementation of EFDC in 3-dimensions will address hydrodynamics and transport of pollutant tracers only. This will be used to support evaluation of spatial features and transport patterns associated with near-shore sources.
3 Geomorphology screening indicated that there was no need for selecting an additional method for augmenting HSPF to address tributary channel stability. However, selected applications of the WEPP model will be used to estimate runoff from unpaved roads to augment HSPF.

The Tetra Tech PM and designees will maintain files, as appropriate, as repositories for information and data used in models and for the preparation of reports and documents during the task. Electronic project files are maintained on network computers and are backed up weekly. The Tetra Tech PM will supervise the use of materials in the central files. The following information will be included in the hardcopy or electronic task files in the central file:

- Any reports and documents prepared.
- Contract and task order information.
- QAPP and draft and final versions of requirements and design documents.
- Electronic copies of models.
- Results of technical reviews, internal and external design tests, quality assessments of output data, and audits.
- Documentation of response actions during the task to correct problems.
- Input and test data sets.
- Communications (memoranda; internal notes; telephone conversation records; letters; meeting minutes; and all written correspondence among the task team personnel, suppliers, or others).
- Studies, reports, documents, and newspaper articles pertaining to the task.
- Special data compilations.

Records of receipt with information on source and description of documentation will be filed along with the original data sheets and files to ensure traceability. Records of actions and subsequent findings will be kept during additional data processing.

All data files, source codes, and executable versions of the computer software will be retained for internal peer review, auditing, or post-task reuse in the electronic task files in the administrative record. These materials include the following:

- Versions of the source and executable code used.
- Databases used for model input, as necessary.
- Key assumptions.
- Documentation of the model code and verification testing for newly developed codes or modifications to the existing model.

The Tetra Tech PM and other experienced technical staff will review the materials listed above during internal peer review of modified existing models or new codes or models. The designated QC Officers will perform QC checks on any modifications to the source code used in the design process. All new input and output files, together with existing files, records, codes, and data sets, will be saved for inspection and possible reuse.

Any changes in this QAPP required during the study will be documented in a memo sent to each person on the distribution list following approval by the appropriate persons. The memo will be attached to the revised QAPP.

2 Model Calibration and Supporting Data Acquisition and Management

2.1 MODEL CALIBRATION AND VALIDATION

2.1.1 Objectives of Model Calibration Activities

The principal study questions for this project address the response of Lake Maumelle and its watershed to future changes in land use and management practices (specific indicators associated with project objectives are summarized in Section 1.4). The general objective for model calibration is to create a reliable suite of predictive tools that can be used to evaluate such responses. To create reliable tools, all models will be subjected to an iterative process of calibration and validation.

Calibration consists of the process of adjusting model parameters to provide a match to observed conditions. Calibration is necessary because of the semi-empirical nature of water quality models. Although these models are formulated from mass balance principles, most of the kinetic descriptions in the models are empirically derived. These empirical derivations contain a number of coefficients that are usually determined by calibration to data collected in the waterbody of interest.

Calibration tunes the models to represent conditions appropriate to the waterbody and watershed under study. However, calibration alone is not sufficient to assess the predictive capability of the model, or to determine whether the model developed via calibration contains a valid representation of cause and effect relationships. To help determine the adequacy of the calibration and to evaluate the uncertainty associated with the calibration, the model is subjected to a validation step. In the validation step, the model is applied to a set of data independent from that used in calibration.

For Lake Maumelle, a substantial number of years of observed data are available. These data will be separated into a calibration period and a second validation period. This will help to ensure construction of a robust predictive tool.

While model developers will strive to achieve the highest quality of fit possible during calibration and validation, the decision purposes of the models must be kept in mind. Specifically, the models will be used to evaluate whether or not management objectives will be met under a variety of future conditions, and to provide a basis for comparison among management alternatives. As such, some degree of uncertainty in model predictions is acceptable; however, bias – a systematic deviation between model predictions and observations – should be avoided to the extent practicable.

2.1.2 Model Calibration/Validation Procedures

2.1.2.1 Calibration/Validation of Watershed Model (HSPF)

The HSPF watershed model contains components to address runoff and constituent loading from pervious land surfaces (PERLNDs), runoff and constituent loading from impervious land surfaces (IMPLNDs), and flow of water and transport/transformation of chemical constituents in stream reaches (RCHRESs). Primary external forcing is provided by the specification of meteorological time series. The model operates on a lumped basis within subwatersheds. Upland responses within a subwatershed are simulated on a per-acre basis and converted to net loads on linkage to stream reaches. Within each subwatershed, the upland areas are separated into multiple hydrologic response units (HRUs) defined by similar land use, soil, and cover characteristics.

The first step in developing an HSPF model is the assembly of relevant spatial coverages, identification of meteorological data, and the definition of model subbasins. Subwatersheds will be defined based on hydrography (NHD), location of monitoring stations, natural breaks in topography or soils, digital elevation models (DEMs), and existing quality-assured subbasin delineations. The NRCS Watershed Boundary Dataset (12-digit HUCs) has not yet been released for Arkansas, but may be available in near-final draft form. A 10-digit HUC coverage has been provided by the USFS, but full metadata have not been obtained at this time. These potential sources will be reviewed and used to define drainage divides where appropriate. Automated DEM processing will then be used to complete the subbasin delineation.

Calibration of the HSPF model is a sequential process, beginning with hydrology, followed by the movement of sediment, and chemical water quality. Hydrologic calibration will use the standard operating procedures for the model described in Donigian et al. (1984) and Lumb et al. (1994). The primary location for calibration will be the USGS gage 07263295 Maumelle River at Williams Junction, AR, which has been operational since August 10, 1989. Additional flow data are maintained for USGS 07263300, Maumelle River at Maumelle Dam, which can be used in conjunction with reservoir storage and release monitoring to ensure that a water balance is maintained for the entire watershed.

Development will begin by dividing the available flow record into separate calibration and validation periods. The validation period will be used to assess the precision of the model calibration.

Initial values of hydrologic parameters will be set to reflect the characteristics of site soils and cover types, following USEPA (1999). Parameters will be adjusted from this baseline within reasonable ranges to improve model fit.

Lack of fit between model and data for hydrologic simulation has two primary causes: Incorrect specification of parameter values, and errors introduced by the extrapolation of point measurements of rainfall and other meteorological forcing functions to an entire watershed. Calibration attempts to limit the first source of error, but some uncontrollable error typically remains due to meteorologic extrapolation. The precision targets for the hydrologic calibration, as recommended by Lumb et al. (1994), are summarized in Table 4. Hydrologic calibration will endeavor to meet or exceed these precision targets for both the calibration and validation periods. These targets are not themselves acceptance criteria; however, deviation from the targets will require corrective action in the form of an investigation and documentation of the reasons for deviation from the targets.

Table 4. USGS Recommended Precision Targets for HSPF Hydrologic Calibration (Daily Flows)

Relative Errors (Simulated-Observed)	Statistical Target
Error in total volume	± 10%
Error in 50% lowest flows	± 10%
Error in 10% highest flows	± 15%
Error in storm peaks	± 15%
Seasonal volume error	± 10%
Error in summer storm volumes	± 15%
Error in low flow recession	± 0.01

Additional statistics, such as the coefficient of model fit efficiency (Nash-Sutcliffe coefficient) will also be reported for the hydrologic calibration.

Hydrologic response itself is not a direct indicator associated with the principal study questions, but adequate hydrologic calibration provides the necessary basis for the water quality calibration. Indeed, the accuracy of the water quality simulation is to a large extent constrained to be no better than the accuracy of the hydrologic calibration.

Unlike flow, water quality parameters are not observed continuously. The calibration must therefore rely on comparison of continuous model output to point-in-time-and-space observations. This creates a situation in which it is not possible to fully separate error in the model from variability inherent in the observations. For example, a model could provide an accurate representation of an event mean or daily average concentration in a reach, but an individual observation at one time and one point in a reach itself may differ significantly from the average. For this reason, it is important to use statistical tests of equivalence that are relevant to the principal study questions in the evaluation of the water quality calibration.

Calibration for sediment will proceed sequentially after hydrologic calibration. Sediment calibration is complex, because instream observations represent a combination of upland loads and instream deposition/resuspension processes. It is therefore important to begin by constraining the upland loads to reasonable ranges. A starting point is provided by soil erodibility characteristics, such as are used in the Universal Soil Loss Equation (USLE). Indeed, a theoretical relationship can be established between several of the HSPF parameters and USLE parameters available in soils databases. An important source for constraining upland loads will be monitoring and modeling undertaken by the USFS and Oklahoma State University (e.g., OCES, 1994), as described further under Site-Level Models. Following the specification of upland load rates, calibration to instream TSS concentrations will proceed following the guidelines in Donigian and Love (2002), which describe sediment calibration as an iterative, weight-of-evidence approach.

Observed and simulated sediment concentrations will be compared both graphically and statistically and summarized in terms of means and relative absolute errors. Observed sediment concentrations can be highly variable and affected by local events, such as a bank failure or vehicle intrusion into a stream. For this reason, attempts will be made to minimize errors, but a specific precision target for relative absolute error will not be specified. Instead, a Student's *t*-test will be used to evaluate the consistency between paired simulated and observed concentration values. Consistency in long term loading simulation will also be evaluated by comparing model predictions to estimates of load obtained using the FLUX procedure (Walker, 1987) or equivalent approach. For model uses to answer study questions it is most important to control bias in the simulation. Bias relative to flow regime will be evaluated through the use of rating curve regressions (Donigian and Love, 2002) and logistic regressions on the load-duration curves.

Model development for other water quality constituents follows sediment (as transport of many pollutants is influenced by sediment transport), but will have many similarities to the sediment calibration process. As with sediment, calibration of the watershed models for nonpoint pollutant loading will begin with a pre-calibration step, designed to constrain the contributions of individual land uses to reasonable ranges. The pre-calibration step will make use of: (1) the results of application of site-scale models as described below, (2) recommendations on appropriate parameter values contained in the scientific literature, (3) model developers' experience with other, similar applications, and (4) national experience with the HSPF model, as summarized in Donigian et al. (1999).

Depending on the constituent and the location, up to eight tests of model fit (both qualitative and quantitative) are applied. These may be sorted into three functional groups, as follows:

Qualitative Assessment of Model Fit

Visual Comparison of Observed and Predicted Concentrations: This is the first step in the model calibration process. Visual comparisons are used for all constituents to assure that model predictions are in general agreement with observations.

Visual Comparison of Observed and Predicted Loads: Where sufficient data are available to compute a representative sample of load estimates from observed data, visual comparison is made between predicted and observed mass transport curves. These curves display load estimates against flow, and are typically shown as a log-log plot with a power function regression. Ideally, the predicted and observed mass transport curves should overlie one another. This comparison shows that the predicted distribution of loads across the flow regime is consistent with the distribution available in the sample data.

Tests for Equality of Long-Term Average Loads and Concentrations

T-tests on equality of Observed and Predicted Mean Concentrations: The *t*-test provides a basic statistical evaluation of the equality of means from two different time series. Even where discrepancies in timing of peaks and errors in the prediction of individual point-in-time concentrations are present, the model should be able to represent long-term averages. In general, water quality models of this type and scale should be able to predict the mean of an observed sample within about 20 percent of the sample mean. Therefore the *t*-test should show less than an 80 percent probability that the two means are not identical.

The two-sample *t* statistic on the difference in means is formed as follows:

$$t = \frac{\overline{x_1} - \overline{x_2}}{s_{x-y}}$$

where s_{x-y} is the pooled standard error of the two time series. The null hypothesis is that the difference in the means is less than some criterion, d. The resulting *t* statistic can then be compared to tabulated values.

This test can be misleading when the sampled data are not representative of the complete time series. For instance, if the sample for a given site does not include high flow events, the resulting mean may be biased relative to the complete data. To help guard against this possibility, paired-sample *t*-tests are performed on the days for which observations are available. In addition, the medians (50^{th} percentile values) of the observed and sample data are also compared. The median is a more robust measure that is less sensitive to biases caused by unrepresentative sampling or inclusion of outliers.

The *t*-tests are thus performed in two ways. First, a standard *t*-test examines the equality of the means of the two series. A paired *t*-test provides a more rigorous test by examining whether the mean discrepancy or residuals between the pairs of observed and simulated values is small.

T-tests on equality of Observed and Predicted Average Loads. This test is similar to the previous, but examines the equality of loads.

Comparison of Total Load Estimates. At the main USGS monitoring station in the Maumelle River, sufficient monitoring data are available to estimate total load series from flow and concentration data, using the USACOE FLUX program. In most cases, the best load estimates from FLUX (in the sense of minimum coefficient of variation) are obtained using a flow-stratified regression, in which separate regressions of concentration versus flow (or rating curves) are applied to the high and low flow regimes. Statistical tests may be performed to determine whether the FLUX estimate is equal to the simulated total load.

Equality of Transport Curve Slopes: Where the distribution of loads versus flows is represented by a power curve, the visual fit between observations and simulations can be tested quantitatively by comparing the equality of the exponent in the power curve regression of load on flow. For model uses to answer study questions it is most important to control bias in the simulation. Bias relative to flow regime will be evaluated through the use of rating curve regressions (Donigian and Love, 2002) and logistic regressions on the load-duration curves.

Tests of Individual Predictions versus Observations

Regression of Predicted on Observed Concentrations. This test and the subsequent one examine the model's ability to predict the series of observations, rather than just their average or distribution. As noted above, it was expected that the limitations of the model would reduce its ability to replicate individual concentrations, so the replication of individual observations may be weak for some parameters.

The basic linear model is

$$y = \alpha + \beta x$$

where y represents model predictions and x represents calibration observations. If the model provides a good fit, we would expect the slope of the regression, β, to be close to 1, while the intercept, α, should be zero. We could then test whether the values of α and β show a significant departure from these values: if the intercept is not equal to zero, this indicates a consistent bias, while if β is not equal to 1 this indicates that model error increases or decreases with the magnitude of the true value, suggesting inadequate calibration. However, as warned by Reckhow et al. (1990), interpretation of the usual regression model statistics (standard error and R^2) can lead to misleading results when applied to the model calibration problem.

To assess model goodness of fit, an ordinary least squares regression is usually performed between the measured and calculated values. Simple t-tests may then be performed to test whether the regression slope is significantly different from 1 or the regression intercept is significantly different from 0, indicating the presence of bias. Flavelle (1992) discusses the range of validity of this procedure, as well as the use of regression analysis in optimizing the calibration.

2.1.2.2 Calibration of GBMM

The GBMM (Grid-Based Mercury Model) is a tool currently under development by Tetra Tech for USEPA Office of Research and Development. The intention of the model is to provide a grid-based simulation of mercury transport using modern ArcGIS tools. Within the context of the Lake Maumelle project, the GBMM will not be used for detailed mercury simulation. Instead, it will serve as a convenient platform for the implementation of fine-scale, grid-based hydraulic time-of-travel estimates. This will provide relevant information on risk of transport of surface spills.

The GBMM modeling suite is currently undergoing peer review arranged by Dr. Robert Ambrose for USEPA ORD. The specific application to the Lake Maumelle watershed will not be calibrated, as the primary intent is only to provide information on relative times-of-travel. However, a senior QC Officer will review the application to ensure consistency of parameter specifications with the watershed-scale HSPF modeling application.

2.1.2.3 Calibration of WEPP

The Water Erosion Prediction Project (WEPP) model will be used to further inform site-level estimates of sediment yield from forest land and unpaved roads. The intention is to take existing implementations of WEPP for the Ouachita National Forest, which have been calibrated to experimental plot data, and apply them without additional calibration. However, a review will first be undertaken of any differences in soils or other conditions between the experimental plots and the Maumelle watersheds. If this review suggests the need for any parameter modifications, these will be developed in consultation with National Forest experts.

2.1.2.4 Calibration of Site Evaluation Tool

Tetra Tech's Site Evaluation Tool will be used to help refine estimates of site-level loading from developed land under different alternative management practices. The tool is a spreadsheet-based application that relies on pollutant event mean concentrations (EMCs) and literature values for removal rates for different types of BMPs. The tool is designed to predict average annual loads. Calibration is not recommended for the current application, although further refinement could be made in the future as part of pre- and post-construction sampling. While the model will not be strictly calibrated, it can be adjusted to better represent local conditions. Specifically, Tetra Tech will perform a search of national and local sources to determine appropriate values for EMCs and BMP removal efficiencies.

2.1.2.5 Calibration/Validation of Lake Model CE-QUAL-W2

CE-QUAL-W2 is a two-dimensional, longitudinal/vertical, hydrodynamic and water quality model. The model solves laterally averaged two-dimensional partial differential equations representing water circulation, thermal dynamics, mass balance and transport of dissolved and suspended particulate constituents, and fate and transport of water quality constituents including nutrients, algae, and dissolved oxygen. Due to its full hydrodynamic feature as well as its capability of simulating multiple arbitrary tracer constituents, CE-QUAL-W2 is readily usable for evaluating most of the major concerns for Lake Maumelle, such as the time-of-travel of spills, toxic concentration distribution resulting from one or multiple spills, pathogens, in addition to the response of algae to change in phosphorus loading. In addition, a numerical tag analysis can be implemented to identify the contribution from different sources to the water quality problem at a special location of concern.

The CE-QUAL-W2 model is a general modeling framework. To develop a site-specific representation, the general modeling framework of CE-QUAL-W2 needs to be customized to Lake Maumelle using the forcing data that characterize this system. The major forcing data include upstream flow, temperature, and water quality boundary conditions, lateral tributary flow, lateral distributed flow, lateral withdrawal boundary conditions, downstream outflow boundary conditions, and atmospheric boundary conditions. In this study, upstream, and lateral tributary/distributed boundary conditions will be provided by the calibrated HSPF watershed model. The lateral withdrawal and downstream outflow boundary conditions will be configured using observed data. The atmospheric boundary conditions will be configured using information obtained from adjacent meteorological stations.

The starting point for the CE-QUAL-W2 application to Lake Maumelle is the existing model implementation created by USGS (Green, 2001). This application was calibrated to 1991 and validated to 1992 data. The model is described as fitting temperature and DO "well" and nutrients and algae "reasonably well" – although there are problems with the algal fit. It is important to note, however, that this implementation was not linked to a watershed model, and inflows were estimated by prorating observed flows at the Maumelle River gage, which covers only about half the watershed. As a result, model hydrology showed significant deviations from observations (up to 10 percent volume error in fall 1991 and worse in spring 1992). Other hydrodynamic errors may have been associated with meteorological forcing. Linking the lake model to a watershed model is believed to provide a good chance for significant improvement in the performance of the lake model over that described by Green (2001).

The USGS application provides a starting point for the current implementation, although we will move the model to the updated version (3.2), which incorporates a number of improvements in process representation. All assumptions in the previous model – which was calibrated to only one year of data – will be carefully reviewed before proceeding. The CE-QUAL-W2 model for Lake Maumelle will be recalibrated and validated through a sequential process, beginning with hydrodynamics, followed by the water quality. Calibration and validation periods will be specified prior to beginning the process.

Hydrodynamic and water quality models are often evaluated through visual comparisons, which plot the simulated result against observed data for the same location and time, and visually judge if the model is able to mimic the trend and overall magnitude of the observed condition. If the model predicted results follow the general trend and reproduce the overall magnitude of the observed data, the model is said to represent the dynamics in the prototype well. The merit of this method is that it is straightforward, taking full advantage of the strength of human intelligence in pattern identification. This method works particularly well when data are limited in quantity and contain significant uncertainty. The limitation of this method is that it relies on the subjective judgment of modelers, and lacks quantitative measures to differentiate among sets of calibration results.

An alternative approach aimed at overcoming the limitations of the visual comparison method is to quantify the goodness of fit using a series of statistical measures. Ideally, if there is a large number of data and most of the data are accurate, a quantitative approach can be very reliable in judging a model's performance. However, in reality, the amount of water quality data is generally limited and the available data often contains errors and uncertainties. Therefore, the validity of the quantitative statistical method is often compromised by uncertainties in the observed data (Zou and Lung, 2004). In addition, there is no widely acceptable range of error statistics defined for water quality model calibration. One reason is that in a water quality model, the complex internal kinetic and transport processes make the cause-and-effect relationship between the external forcing and internal water quality response very complicated. Therefore, it is generally not expected that a water quality model can reproduce the exact timing of water quality in a dynamic system. For example, if a water quality model has mimicked the time variable feature in a lake very well, but with a 2-day shift in time, then poor error statistics can result. In this case the error statistic does not make any practical sense unless it is interpreted with the visual comparison of trend and magnitude.

In this study, a dual approach will be adopted to guide the calibration of the CE-QUAL-W2 model of Lake Maumelle. The dual approach will be implemented in a two-stage manner. For the first stage, the model calibration is guided through the visual comparison approach, which would allow the calibration effort to be led toward reproducing the trend and overall dynamics of the lake. The first stage is a global search process for a water quality calibration which prevents a calibration from being trapped at state spaces with good error statistics but incorrect overall representations. After the model has been calibrated to the trend and overall dynamics, the second stage would involve fine tuning the parameters and then calculating various error statistics in order to find the most appropriate calibration within the range of state spaces that were found in stage one. The second stage is thus a local search process for a water quality calibration. Constrained by the stage one global search, the error statistics can be interpreted together with the general fit to trend and magnitude.

After the model is calibrated, it will be applied to the validation period to further evaluate the degree of generalization of the model. Since there is no widely accepted range of error statistic measurement, the quality of calibration will be evaluated by comparison to published literature results of similar applications.

The first step to calibrate the Lake Maumelle model is to calibrate hydrodynamics. The data needed for hydrodynamic calibration and validation include water surface elevation, flow velocity (if available), temperature profile and time series, and other conservative constituents where data is available. These data will be divided into separate calibration and validation periods. Hydrodynamic calibration will be implemented following the standard routine as described in the model users' manual (Cole and Wells, 2003), in the order of elevation, velocity, and temperature. The dual approach as described above will be applied to implement the calibration. The key factors that would impact the hydrodynamic calibration include watershed inflow and temperature, accuracy of flow measurement, unaccounted for groundwater interaction, dam operation, meteorological condition representation, bottom roughness, and bathymetry. All these factors will be considered in the calibration process, and further communication with the watershed model components and review of available data will be conducted, roughness and bathymetry will be refined until a satisfactory calibration is achieved.

The second step is to calibrate the water quality dynamics. Water quality calibration is significantly more complicated than the hydrodynamic calibration. The major factors that need to be considered include the watershed model simulated loading, accuracy in data used to characterize the water quality input, potential groundwater interaction, complicated interaction between nutrients, algae, and dissolved oxygen (DO), and the exchange of nutrients and oxygen between bottom water and the benthic sediment layer. A large number of iterations will be conducted to achieve a satisfactory calibration of the model. The dual approach, as described above, will be used to guide the calibration process.

After both the hydrodynamic and water quality models are calibrated, they will be applied to the validation data set to further evaluate the model's capability of representing different conditions.

At minimum, the absolute mean error method will be used to compare model predictions and observations in the second calibration stage.

Absolute Mean Error Statistic. The absolute mean error between model predictions and observations is defined as

$$E_{abs} = \frac{\sum|(O-P)|}{n}$$

where:

E_{abs} = absolute mean error.

An absolute mean error of zero is ideal. The magnitude of the absolute mean error indicates the average deviation between model predictions and observed data. Unlike the mean error, the absolute mean error cannot give a false zero.

2.1.2.6 Calibration/Validation of Lake Model EFDC

EFDC is a three-dimensional full hydrodynamic and water quality model with the capability of simulating water circulation, transport of dissolved and suspended constituents, and complicated eutrophication and toxic dynamics. In this study, only the hydrodynamic module of EFDC will be used as a supplement to the CE-QUAL-W2 to characterize higher resolution transport behaviors of spills and near field conditions adjacent to any watershed development. The data requirements for configuring the EFDC hydrodynamic model are similar to those of the CE-QUAL-W2, except that the lake will be discretized into three dimensions to represent the lateral, longitudinal, and vertical variability. The hydrodynamic model will be calibrated with elevation, velocity (if available), and temperature using the method as described in the CE-QUAL-W2 section.

2.1.2.7 Calibration of Cost Tools

To address study questions regarding a variety of cost implications of different management scenarios, Tetra Tech will develop cost tools for stormwater BMPs, forestry BMPs, impacts on CAW utility rates and local government administrative costs.

Stormwater BMP Cost Tool. Research will be conducted to determine the best available information on stormwater BMP costs in the vicinity of Lake Maumelle. Regional BMP cost data will be used as available. When out-of-state or national costs are used, the costs will be converted to local prices with published conversion factors. The effect of soils and other site constraints will be considered when determining appropriate cost estimates for the Lake Maumelle watershed. Inputs to the spreadsheet tool will include BMP cost data, BMP dimensions, and area of each land use in the watershed. Costs will include construction, design, engineering, and operation and maintenance (O&M). A 30-year period will be used for O&M as the expected life of the BMP (i.e., before replacement or significant overhaul is required). Therefore, the O&M costs will reflect routine maintenance over that 30-year period. The spreadsheet tool will calculate cost per acre for each land use and will extrapolate each cost per acre to the entire watershed using standard Excel spreadsheet functions.

Forestry BMP Cost Tool. Research will be conducted to determine the best available information on forestry BMP costs in the vicinity of Lake Maumelle. Regional BMP cost data will be used as available. When out-of-state or national costs are used, the costs will be converted to local prices with published conversion factors. The forestry BMPs will be defined as practices separate from harvesting techniques that reduce the impact of harvesting on Lake Maumelle. Inputs to the spreadsheet tool will include BMP cost per acre harvested and acres harvested per year in the watershed. Acres harvested per year will be estimated according to the assumptions developed by Ouachita National Forest personnel for application of the WEPP model and available information on forestry practices in the watershed. The spreadsheet tool will be developed so that multiple forestry BMPs can be included in one scenario. The spreadsheet tool will calculate cost per acre for each forestry land use and will extrapolate each cost per acre to the entire watershed using standard Excel spreadsheet functions.

Estimating CAW Utility Rate Costs. One of two methods will be used to estimate utility rate increases. Under the first option, CAW will estimate utility rate increases for each management scenario based on modeling data and land acquisition estimates provided by Tetra Tech.

- CAW will use raw water concentrations from Tetra Tech's lake water quality models to estimate the additional annual operational (e.g., chemical) and capital requirements for the period 2007-2037 triggered by the management scenario, not other regulatory requirements. Note that the 30-year planning period was selected because it is consistent with the expected life of stormwater BMPs, and provides a reasonable long-term basis for evaluation. Then CAW will estimate the cost of the additional operational/capital requirements and the resulting utility rate increases.
- For each management scenario, Tetra Tech will recommend the number of acres for CAW land acquisition. CAW will estimate the cost of the land over the 30-year period (2007-2037) and the resulting utility rate increases.
- Finally, for each management scenario, Tetra Tech will provide data on the number of houses in the watershed through a 30-year planning period (2007-2037) based on a projected rate of growth through the year 2037. Based on this added population in the watershed, CAW will estimate the additional cost of lake security and the estimated resulting utility rate increase. The most up-to-date and available data on water supply costs, land prices, security costs, and local utility rates will be used. Regional data will be used as available.

Under the second option, if CAW is not able to quantitatively estimate the potential impacts on utility rates, Tetra Tech will work with the CAW staff to develop qualitative or best-professional-judgment comparisons across management scenarios.

Evaluation of Administrative Costs. Tetra Tech will research level of staffing, funding, and expertise needed to implement different types of watershed plans in other areas. Guidance will be obtained from the American Water Works Association, Center for Watershed Protection, Association of County Officials, League of Municipalities, and other respected sources as appropriate. Regional data will be used as available. Tetra Tech will work with the local planners to develop assumptions about the number of development applications per year that could be anticipated with different development scenarios. Building on research and case studies from other areas, Tetra Tech will work with local planners to evaluate the number of staff needed to implement different types of zoning and/or development ordinances including conducting a development plan review, site inspections and enforcement, inspection of best management practices, etc. Potential funding mechanisms will also be identified. White papers and case studies will be used to help evaluate the administrative needs and feasibility associated with different watershed management approaches.

2.1.2.8 Uncertainty Analysis for Calibrated Models

From a decision context, the primary function of the calibrated water quality models is to predict the response of selected indicators that can be used to assess attainment of management goals under various future scenarios. An important input to the decision-making process is information on the degree of uncertainty that is associated with model predictions. In some cases, the risks or "costs" of exceeding a target value may be substantially greater than the costs of over-protection, creating an asymmetric decision problem in which there is a strong motivation for risk avoidance. Further, if two scenarios produce equivalent predicted results, the scenario that has the smaller uncertainty is often preferable. Typical practice is to include a conservative margin of safety to minimize this risk. However, it is not possible to evaluate how much of a margin of safety is appropriate without information on the uncertainty associated with model predictions. Therefore, an uncertainty analysis of model predictions is essential.

A majority of the key water quality indicators represent output from the lake model, although these are strongly affected by the watershed model. As with any mathematical approximation of reality, a water quality model is subject to significant uncertainties. Some information on uncertainty in lake model predictions will arise directly from the calibration and validation process. However, a more formal analysis is likely to be appropriate.

The major sources of model uncertainty include the following:

- **Mathematical formulation**. A real water system is too complex for a mathematical model to represent all the dynamics, therefore, no matter how sophisticated a mathematical water quality model is, it is based on a simplified mathematical formulation. The simplifications in general neglect processes that are considered to be insignificant, thus the model can catch the general trend of the real system. In other words, a mathematical model is designed to represent the trend, rather than provide exact replication of the real system. Thus, uncertainty exists when those neglected factors start to play some detectable roles.
- **Data Uncertainty**. Site-specific data are the basis for developing a water quality model for a specific water body. A water quality model requires data from different sources and for a large number of parameters. Many of these data are subjected to either systematic or random errors. Also, data are always limited in both time and space, thus an interpolation method has to be used to represent continuous inputs. In most cases, monitoring data are not available for all the water

quality parameters; thus, they have to be derived based on some empirical method. All these can contribute to uncertainty in the model.

- **Parameter Specification**. In a water quality model, parameters quantify the relationships in the major dynamic processes. The values of parameters are generally obtained through the model calibration process while constrained by a range of reasonable values documented in literature. Due to the sparseness and uncertainty in data used to configure and calibrate a water quality model, the model parameter is also subjected to uncertainty. Actually, the parameter uncertainty can be considered as a direct reflection of the uncertainty from both mathematical formulation and data. In real world practice, while it is hard to quantify the uncertainty in model formulation and data, uncertainty analysis for model parameters becomes a key method for evaluating the overall uncertainty of model predictions.

The most widely applied parameter uncertainty analysis approach is sensitivity analysis. Sensitivity analysis is implemented by perturbing model parameter values one at a time and evaluating the model response. This method is useful in identifying key parameters and processes in a water quality system, and the interpretation of the result is straightforward and meaningful. Sensitivity analysis, however, is limited in that it cannot account for the compound uncertainty of multiple parameters since it is implemented by varying parameter values one at a time. In a water quality model, many, if not all, of the parameters interact with each other, hence their uncertainties often compound to form an overall parameter uncertainty, which ultimately represents the model uncertainty.

Generally, the evaluation of overall parameter uncertainty has been handled using the Monte Carlo method (Bobba et al. 1995; Duke et al. 1998; Yulianti et al. 1999; Zou et al, 2002). In the Monte Carlo simulation, the model parameters are assumed to be random variables that are represented by probability density functions (PDFs). However, the applicability of the Monte Carlo method in this study is restricted by the prohibitive computational requirements of full implementation for a complex pair of lake and water quality models. In addition, it is also unlikely that sufficient data are available to derive the probabilistic distribution through statistical analysis.

Another alternative is to apply fuzzy mathematics to evaluate the compound uncertainty in a water quality model since water quality parameters can often be perceived in terms of possibilities rather than probabilities in management context. For example, although it is hard to define a PDF for a water quality model parameter, it can often be expressed more vaguely as "the value of parameter X is about 0.25, and can vary between 0.1 to 0.4." This kind of linguistic judgment can be automatically transformed into mathematical language using fuzzy mathematical operations. The fuzzy approach has the advantage over the Monte Carlo method in that it directly handles the uncertainty in parameters caused by vagueness in definitions, and it does not require derivation of detailed PDFs (Dou et al., 1995; Zou and Lung, 2002). However, although the computational requirement for implementing a fuzzy approach can be lower than the Monte Carlo method, it can still be prohibitive because the solution of a series of non-linear optimization problems will be required given the complexity in transport and kinetics in the Lake Maumelle model.

The potentially most applicable method for analyzing the compound uncertainty in the Lake Maumelle model is to apply an interval parameter method, in which Tetra Tech will replace a few (less than 5) key single value parameters in the model with interval numbers which characterize the estimated range of the parameters, and then apply a simulation-based optimization algorithm to solve the minimization and maximization equations to obtain the possible range of model prediction based on the interval parameters. In doing so, the decision-maker can obtain information about the most optimistic and pessimistic consequences of the model prediction, which can then provide a range to use to make decisions on development and environmental management. It should be noted that this method, although subject to significantly lower computational burden than the fuzzy method, still needs complicated computer implementation and can be time consuming. Therefore, whether there is a need to implement this type of compound uncertainty analysis in addition to the sensitivity analysis will be determined based on data review, preliminary sensitivity analysis, and the availability of time and funding.

Tetra Tech will also evaluate uncertainty in cost estimation. Using available information, Tetra Tech will estimate ranges of uncertainty in BMP costs to account for variations in BMP design and site constraints. Tetra Tech will use the median of each range, or most representative estimate, to represent the BMP cost estimate.

Tetra Tech will use the median cost estimates to illustrate the relative cost differences between the modeling scenarios. By using the cost estimates for relative comparisons and not for budgetary purposes, Tetra Tech will account for the uncertainty of the cost estimates. When the cost estimates are used for comparison purposes only, the effect of error on the policy conclusions will be minimized.

To address uncertainty in utility rate and administrative costs, Tetra Tech will use the cost estimates to illustrate the relative cost differences between the modeling scenarios. By using the cost estimates for relative comparisons and for a planning level resource needs analysis, Tetra Tech will account for the uncertainty of the cost estimates. When the cost estimates are used for comparison and planning purposes only, the effect of error on the policy conclusions will be minimized. Annual operational and capital improvement plan budgets will still need to be developed by CAW.

2.1.3 Acceptance Criteria for Model Calibration

2.1.3.1 Acceptance Criteria for HSPF Watershed Model

Threat: Toxics/Spills

Analysis Questions: How long would it take to reach the water supply intake? How potent would it be at intake? How can management affect delivery or potency?

Indicators: Time of travel, potential concentration (conservative, non-conservative).

Acceptance Criteria for HSPF: The analysis questions address potential risk. The model cannot be directly calibrated for toxic spills as these have not been observed. The acceptance criteria for HSPF are therefore of a general nature related to the ability of the model to simulate time of travel and potential concentrations:

1) The model provides an acceptable representation of watershed hydrology by meeting the calibration targets specified in Section 2.1.2.1 or explaining why specific targets are not met due to uncontrollable contingencies such as unrepresentative meteorological data.
2) The model provides an acceptable representation of the transport of water quality constituents based on a general review of the calibration and validation statistics.

Threat: Pesticides/Herbicides

Analysis Questions: Use the model to screen first to determine if there is a potential for a significant threat. If yes, same analysis questions apply as for toxic spills.

Indicators: Time of travel, potential concentration (conservative, non-conservative).

Acceptance Criteria for HSPF: Same as for Toxics/Spills

Threat: Disinfection Byproducts

Analysis Questions: How much algae or TOC change must occur in the lake to affect THM production?

Indicators: Total Organic Carbon (TOC).

Acceptance Criteria: The analysis question will be addressed primarily through the lake model. For HSPF, the acceptance criteria are:

1) Acceptance criteria are met for algae (below).
2) Annual watershed loads of TOC predicted by the model and estimated from monitoring data are not statistically different from one another at the XX percent confidence level using a Student's *t*-test.

Threat: Mercury

Analysis Questions: How can management affect the amount of mercury delivered to the lake?

Indicators (watershed): Mercury load.

Acceptance Criteria: The watershed model needs to describe relative changes in mercury load associated with the erosion and delivery of mercury-bearing sediments. A full watershed mercury model will not be developed and calibrated at this stage. HSPF is acceptable for these purposes if the acceptance criteria for sediment (below) are met.

Threat: Algal Toxins

Analysis Questions: How much nutrient loading is needed before lake productivity levels exceed threshold levels for algal blooms? How can management affect amount and delivery of nutrients?

Indicators (watershed): Nitrogen and phosphorus loads.

Acceptance Criteria: The watershed model will be acceptable for these purposes if acceptance criteria for algae (in general) are met.

Threat: Algae (impacts on taste and odor, color, treatment, lake aesthetics, lake DO, fishery)

Analysis Questions : How much nutrient loading is needed before lake productivity levels exceed threshold levels for algal blooms? How can management affect amount and delivery of nutrients?

Indicators (watershed): Phosphorus and nitrogen loads.

Acceptance Criteria: The analysis questions will be addressed primarily via the lake model. The watershed model needs to provide an adequate representation of nutrient loading to support the lake model simulation.

1) Annual watershed loads of total inorganic nitrogen and total phosphorus predicted by the model and estimated from monitoring data are not statistically different from one another at the XX percent confidence level using a Student's *t*-test.
2) Load-duration analysis confirms lack of a significant bias in TN and TP load predictions relative to flow regime.
3) HSPF simulation of nutrient load response to management options is demonstrated to be consistent with predictions of the Site Evaluation Tool.

Threat: Pathogens

Analysis Questions: How much loading will threaten uses (water supply and secondary recreation)? How can management affect the amount and delivery of pathogens?

Indicators: Concentrations and loads of fecal coliform bacteria and Giardia/Cryptosporidium.

Acceptance Criteria: Monitoring data are available for fecal coliform bacteria; however, significant natural variability is expected in these results, due for instance to wildlife/wildfowl inputs. A natural log transformation is useful before performing statistical tests to reduce the effects of outliers. Numeric water quality standards in the streams and lake are relevant. In contrast, the protozoan pathogens Giardia and Cryptosporidium, while of concern, are infrequently monitored and rarely detected. They are evaluated as a potential risk relative to transport with fine sediment material.

1) The model should reproduce 80 percent of the observed instream monitoring data for fecal coliform bacteria in excess of 200 per 100 ml within 0.5 log units.
2) Load-duration analysis confirms lack of a significant bias in fecal coliform bacteria predictions relative to flow regime.
3) Model meets acceptance criteria for sediment (in support of protozoan pathogen simulation).

Threat: Sediment (impacts on treatment, storage volume, aesthetic impacts, impacts on tributary stability and stream habitat).

Analysis Questions: How much loading before thresholds (for indicators) are exceeded? How can management affect the amount and delivery of sediment?

Indicators: Sediment load, channel instability, turbidity/Secchi depth. The sediment load indicator will be predicted directly by the watershed model. The turbidity indicator will be interpreted based on model predictions of suspended fine sediment. The channel instability indicator will be assessed based on a geomorphic survey, for which model hydrodynamics may provide input; however, this indicator is not directly addressed by the watershed model.

Acceptance Criteria: Criteria are specified for both load and suspended sediment concentration. For sediment load:

1) Obtain consistency in long-term load estimates using Student's *t*-test.
2) Demonstrate minimal bias in load estimates relative to flow regime by use of rating curve regressions and logistic regressions on the load-duration curve.
3) Confirm that loading rate estimates from forest lands are consistent with predictions from WEPP site-level modeling.

For suspended sediment concentration, a weight-of-evidence approach will be used to establish model credibility, following Donigian and Love (2003), and specific quantitative targets are not imposed:

1) Use Student's *t*-test to evaluate consistency between paired simulated and observed concentration values. Report error statistics and provide discussion of uncertainty in model predictions for the turbidity endpoint.

2.1.3.2 Acceptance Criteria for GBMM Watershed Model

Threat: Toxics/Spills

Analysis Questions: How long would it take to reach the water supply intake? How potent would it be at intake? How can management affect delivery or potency?

Indicators: Time of travel, potential concentration (conservative, non-conservative).

Acceptance Criteria for GBMM: The GBMM, in the context of this project, will be used only to provide grid-based refinements of travel times of overland flow and will not be calibrated. The application will be deemed acceptable upon passing the internal QC review.

2.1.3.3 Acceptance Criteria for WEPP Model

Threat: Sediment (impacts on treatment, storage volume, aesthetic impacts, impacts on tributary stability and stream habitat).

Analysis Questions: How much loading before the thresholds (for indicators) are exceeded? How can management affect the amount and delivery of sediment?

Indicators relevant to WEPP: Sediment load.

Acceptance Criteria: The WEPP model application will use existing calibrations developed for the Ouachita National Forest. Any proposed modifications will be reviewed with appropriate Forest Service personnel. The model application will be deemed acceptable following successful review of documentation from the Forest Service.

2.1.3.4 Acceptance Criteria for Site Evaluation Tool

The Site Evaluation Tool will be a background component of the modeling, used to refine site-level estimates of pollutant loading for various developed land uses and management practices. The model application will be deemed acceptable once it is demonstrated that a thorough review has been undertaken to identify values of EMCs and removal efficiencies appropriate to the Lake Maumelle area.

2.1.3.5 Acceptance Criteria for CE-QUAL-W2 and EFDC Lake Models

Threat: Toxics/Spills

Analysis Questions: How long would it take to reach the water supply intake? How potent would it be at intake? How can management affect delivery or potency?

Indicators: Time of travel, potential concentration (conservative, non-conservative).

Acceptance Criteria for CE-QUAL-W2 and EFDC: The analysis questions address potential risk. The model cannot be directly calibrated for toxic spills as these have not been observed. However, the potential transport of toxics in the lake can be assumed to be well simulated if the hydrodynamic models are reasonably calibrated. The acceptance criteria for the hydrodynamic models are therefore of a general nature related to the ability of the model to simulate time of travel and potential concentration at the water supply intake:

1) Both the EFDC and CE-QUAL-W2 models provide an acceptable representation of the lake water circulation through the calibration processes described in Section 2.1 or an explanation of why specific targets are not met due to inaccuracy in bathymetric, meteorological, and flow boundary condition data.
2) Both the EFDC and CE-QUAL-W2 provide the capability of simulating different transport patterns during different times of the year, such as winter mixing and summer stratification, through the temperature calibration process.
3) The simulated time of travel by EFDC and CE-QUAL-W2 should agree over a large scale, and any disparity should be explainable based on the theory and spatial representation of the two models.

Threat: Pesticides/Herbicides

Analysis Questions: Use model to screen first to determine if there is a potential for a significant threat. If yes, the same analysis questions apply as for toxic spills.

Indicators: Time of travel, potential concentration (conservative, non-conservative).

Acceptance Criteria for lake models: Same as for Toxics/Spills.

Threat: Disinfection Byproducts

Analysis Questions: How much algae or TOC change must occur in the lake to affect THM production?

Indicators: Total Organic Carbon (TOC).

Acceptance Criteria: The lake model must be able to perform a mass balance of TOC, and, in particular, estimate what portion of the TOC concentration is due to inlake production by algae. For CE-QUAL-W2, the acceptance criteria are:

1) Acceptance criteria are met for algae through calibrating the nutrient and algal dynamics (below).
2) A satisfactory level of calibration for TOC concentrations in the lake can be obtained using the dual approach described in Section 2.1.2.5.

Threat: Algal Toxins

Analysis Questions: How much nutrient loading is needed before lake productivity levels exceed threshold levels for algal blooms? How can management affect the amount and delivery of nutrients?

Indicators (lake): Chlorophyll *a* concentration (including frequency of bloom concentrations); nitrogen and phosphorus concentrations.

Acceptance Criteria: The lake model will be acceptable for these purposes if acceptance criteria for algae (in general) are met.

Threat: Algae (impacts on taste and odor, color, treatment, lake aesthetics, lake DO, fishery)

Analysis Questions : How much nutrient loading is needed before lake productivity levels exceed threshold levels for algal blooms? How can management affect amount and delivery of nutrients?

Indicators (lake): Chlorophyll *a* concentration (including frequency of bloom concentrations); nitrogen and phosphorus concentrations.

Acceptance Criteria: Algal densities can vary widely on short timeframes and can be very sensitive to the interaction between sampling depth and mixing characteristics. As a result, significant discrepancies may occur between individual observations and model predictions. However, a properly calibrated model should, accurately represent trends in space and time. As noted in Section 2.1.2.5, specific quantitative accuracy targets will not be established for chlorophyll *a* simulation. Instead, qualitative acceptance criteria are established as follows:

1) The lake model reproduces inorganic nitrogen and inorganic phosphorus concentrations with a degree of accuracy comparable to that estimated for the watershed loading model.
2) A unified set of kinetic parameters provides a robust representation of chlorophyll *a* concentrations at multiple locations and times in the lake.
3) Root mean square errors are minimized to the extent practicable.
4) Growing season average concentrations are reproduced without significant bias.
5) The model is judged to do an adequate job of replicating the distribution as well as the central tendency of observed chlorophyll *a* concentrations.

Threat: Pathogens

Analysis Questions: How much loading will threaten uses (water supply and secondary recreation)? How can management affect the amount and delivery of pathogens?

Indicators: Concentrations and loads of fecal coliform bacteria and Giardia/Cryptosporidium.

Acceptance Criteria: Coliform bacteria concentrations in the lake are typically very low. When detectable concentrations are observed they are likely often related to local inputs from waterfowl. Concentrations of the protozoan pathogens Giardia and Cryptosporidium are infrequently monitored and rarely, if ever, detected. As a result, there are not believed to be data sufficient to calibrate a model of pathogens in the lake to observations. Instead, the model will primarily provide information on risk relative to potential increases in loads. Acceptance criteria for the lake model are:

1) The model is calibrated for hydrodynamics and provides an acceptable representation of transport patterns in the lake.
2) For conditions in which the watershed model predicts bacterial loads of sufficient magnitude to be detectable within the lake, the lake model provides a reasonable representation of observed concentrations when calibrated using the dual approach described in Section 2.1.2.5.
3) The model meets acceptance criteria for sediment (in support of protozoan pathogen simulation).

Threat: Sediment (impacts on treatment, storage volume, aesthetic impacts, impacts on tributary stability and stream habitat).

Analysis Questions: How much loading can occur before thresholds (for indicators) are exceeded? How can management affect the amount and delivery of sediment?

Indicators (lake): Sediment load, turbidity/Secchi depth (water clarity). The sediment load indicator will be predicted directly by the watershed and lake models. The watershed model determines the gross sediment loading, while the lake model determines rates of settling and removal. The water clarity indicator in the lake will be interpreted based on model predictions of suspended fine sediment after correcting for the contribution of algae and dissolved organic compounds. Determination of this indicator is also important for the algal simulation, as water clarity is an important controlling factor on algal growth potential.

Acceptance Criteria: Criteria are specified for both load and suspended sediment concentration. For sediment load in the lake model:

1) Over the long term, model predictions of sediment accumulation are consistent with the rate of loss of storage estimated from bathymetric surveys.

For water clarity in the lake:

2) During periods in which the watershed loading of sediment appears to be accurately simulated, observed and simulated suspended sediment concentrations and inorganic turbidity in the lake are in agreement when calibrated using the dual approach described in Section 2.1.2.5.
3) The model successfully represents spatial and seasonal trends in water clarity observed in the lake.

2.1.3.6 Acceptance Criteria for Cost Models

Threat: Land Use Restrictions/Cost of Development

Analysis Questions: How much restriction/cost is reasonable to protect water quality? How can restrictions/costs be minimized while still achieving WS protection?

Indicators: Per acre cost of development, per acre cost of key measure for forestry.

Acceptance Criteria: Tetra Tech will provide cost information to the PAC to aid in the evaluation of different management options. To address the analysis questions, the PAC will not use absolute cost targets. Instead, the PAC will compare the scenario cost estimates and will select the preferred management scenarios(s) based on the relative cost differences in conjunction with other management objectives. Regional BMP cost data will be used as available. By utilizing the most up-to-date and best available data, the cost tool will be assumed to be acceptable to provide a relative basis for comparison between management scenarios and effectively answer the analysis questions.

Threat: Rate Increases

Analysis Questions: At what levels of lake response do additional treatments or O&M costs increase? How does acquiring land through title or easement purchase affect water quality (cost/benefit)?

Indicators: O&M costs, treatment system costs, land acquisition costs.

Acceptance Criteria: Utility rate increases will be estimated by CAW using its Utility Rate Model. The Policy Advisory Council (PAC) will not use absolute cost targets. To answer the analysis questions, the PAC will compare the water quality benefits and cost estimates among the management scenarios and will select the preferred management scenario(s) based on the relative differences in conjunction with other management objectives. The utility rate cost tool will be judged acceptable for these purposes when the analysis is reviewed and approved by CAW.

2.1.4 Frequency of Model Calibration Activities

The current project will include calibration to observed data collected from the 1989-2005 monitoring records. This calibration will reflect existing land use and management in the watershed and current lake operations. As land use (and potentially lake operations) change over time, it may be necessary to undertake another iteration of model calibration. Such future activities are not, however, within the scope of the QAPP for the current project.

2.2 NONDIRECT MEASUREMENTS (SECONDARY DATA ACQUISITION REQUIREMENTS)

Nondirect measurements (also referred to as secondary data) are data previously collected under an effort outside this contract that are used for model development and calibration. Details regarding how relevant secondary data will be identified, acquired, and used for this task are provided below.

2.2.1 Meteorology

USGS operates two precipitation monitoring stations, results of which are reported to the NOAA Hydrologic Automated Data System (HADS). These stations correspond to the USGS flow gages: Lake Maumelle at Natural Steps (MAUA4, 16E9770E) and Maumelle River at Williams Junction (WLMA4, 16E9878A). A Cooperative Summary of the Day (SOD) weather station (034010) has been operated at Lake Maumelle Dam since December 1956, reporting precipitation only. Additional precipitation data appears to be available from the National Climatic Data Center (NCDC) for other nearby sites, including several sites with sub-daily precipitation (Figure 2). A thorough search will be made for quality controlled precipitation stations, which will be examined for applicability to the modeling effort.

The models will also require input of other meteorological variables, such as wind speed, air temperature, potential evapotranspiration, and solar radiation. A search for applicable data will be conducted and documented in a memorandum before use in the model.

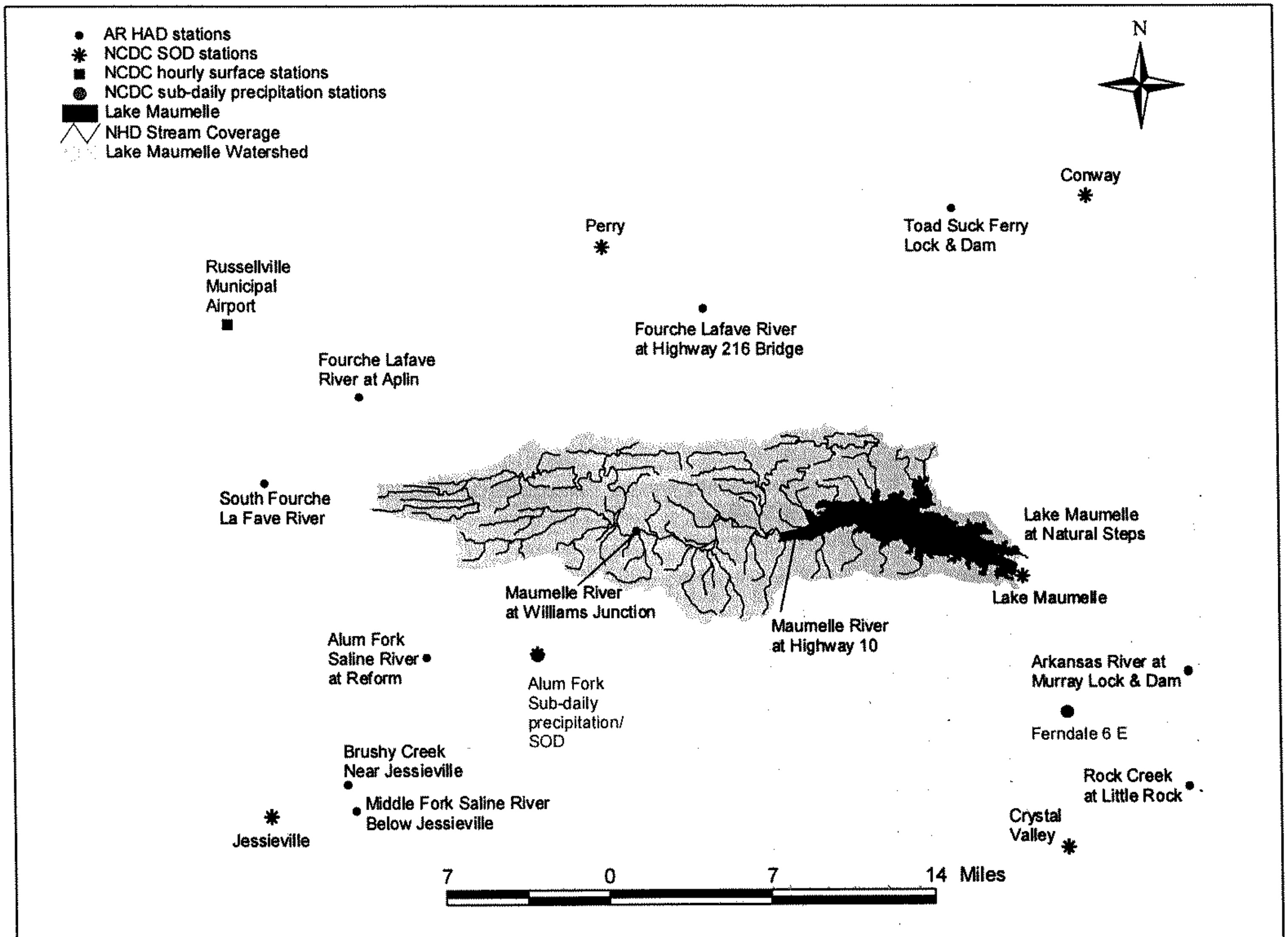

Figure 2. Meteorological Stations Active after 1991 in and near the Lake Maumelle Watershed

2.2.2 Land Use/Land Cover, Soils, and Topography

Several sources are available for current land use and land cover along with soils and a digital elevation model. Most of these coverages were obtained from quality assured government sources. Basic information on land cover is provided by the 1992 NLCD derived from Landsat imagery (the 2001 NLCD coverage is not yet available for Arkansas). The University of Arkansas Center for Advanced Spatial Technology (CAST) has also interpreted spring, summer, and fall 1999 Landsat imagery to produce land use/land cover maps. The 1999 coverage needs to be evaluated further for use in the project. Of particular concern may be the fact that Landsat interpretation typically under-represents rural residences. It may be appropriate to supplement the satellite land cover with other information on land uses, such as tax parcel data. Tetra Tech will analyze and combine these sources to create an appropriate unified coverage of current land use and land cover. Thorough documentation and metadata will be provided with the unified coverage.

Table 5. Sources of Land Use/Land Cover, Soils, and Elevation Information

Name	Date	Source
NLCD Land Cover	1992	USGS/ MRLC Consortium; http://www.mrlc.gov/mrlc2k_products.asp
CAST Land Cover	1999	Center for Advanced Spatial Technologies, University of Arkansas
Perry County Parcel Data	2005	Perry County, AR
Pulaski County Parcel Data	2005	Pulaski County, AR
Roads	2004	CAW
Digital OrthoPhotos	2004	Provided by CAW
SSURGO Soils (Pulaski, Perry, and Saline counties, AR)	2005	<http://www.ftw.nrcs.usda.gov/ssur_data.html
Digital Elevation Model		USGS, National Elevation Dataset

2.2.3 Hydrography and Bathymetry

Watershed hydrography is based on the National Hydrography Dataset coverage (http://nhd.usgs.gov/). Additional information on lake bathymetry was provided by CAW.

2.2.4 Flow

Flow monitoring is conducted by USGS, and all data are available from NWIS-WEB. A summary of continuous flow gages in the watershed is provided in Table 6.

Table 6. Continuous Flow Monitoring Gages

Agency	Site Number	Site Name	From	To
USGS	07263295	Maumelle River at Williams Junction, AR	1989-08-10	Present
USGS	072632966	Lake Maumelle at State Hwy 10 near Wye, AR	2002-10-01	Present
USGS	07263300	Maumelle River at Maumelle Dam at Natural Steps, AR	1989-08-17	Present

Additional instantaneous measurements of flow, stage, and other stream characteristics are available with the water quality observations. Gages have now been established at Bringle Creek near Crossroads (072632962), Young Creek near Martindale (072632971) and Reece Creek near Little Italy (072632982) to provide discharge data associated with automatic water quality samplers.

2.2.5 Water Quality Observations

Water quality within Lake Maumelle and its watershed has been monitored by USGS under contract with CAW. The USGS monitoring data has been provided by CAW. All data were collected under an approved QAPP and are believed to be fully usable for this modeling project.

Monitoring commenced in 1989 and continues to the present. USGS monitored water quality at four locations on the lake and four in-stream locations above the lake. The dataset contains 320 measured water quality parameters, including ambient nutrient concentrations, constituents of bed sediment, and concentrations of organic substances. The major stations sampled have under 100 sampling days per constituent, and minor stations have less than 30 sampling days per constituent. The current dataset contains over 50,000 separate observations. A summary of the data as reported on USGS NWIS-WEB is provided in Table 7. Additional provisional data are available after August 2004 and will be obtained from USGS. Spot-checks between the database and NWIS-WEB will be conducted to verify the quality of the data used in this project. Additional (newer) monitoring data will be provided to the project team via CAW.

The USGS water quality dataset will be archived in the original Excel files received from CAW in a local file server and on the project FTP site. Working copies will be maintained in a quality assured relational database.

Additional information on lake water quality is available from CAW operational monitoring, covering various parameters in the raw water supply.

Table 7. Water Quality Observations in the Maumelle Watershed Reported by USGS on NWIS-WEB

Agency	Site Number	Site Name	From	To	Count
USGS	07263292	Narrow Creek Near Williams Junction, AR	1968-06-26	1968-09-24	3
USGS	07263295	Maumelle River at Williams Junction, AR	1989-05-22	2004-08-02	95
USGS	07263296	Maumelle River Near Wye, AR	1989-05-23	1990-08-28	10
USGS	072632962	Bringle Creek at Martindale	1998-12-02	2004-05-14	11
USGS	072632964	Lake Maumelle South of Hwy. 10 at Cross Roads, AR	1998-12-02	2004-08-04	3
USGS	072632965	Lake Maumelle West of Hwy 10 Bridge Near Wye, AR	1991-07-08	2004-08-03	193
USGS	072632966	Lake Maumelle at State Hwy 10 Near Wye, AR	2001-07-02	2004-04-22	15
USGS	07263297	Lake Maumelle East of Hwy 10 Bridge Near Wye, AR	1989-05-25	2004-08-03	532
USGS	072632971	Yount Creek Near Martindale, AR	2002-02-15	2004-04-22	7
USGS	072632972	Lake Maumelle Ds from Yount Creek Near Wye, AR	1991-01-11	1996-08-13	539
USGS	072632977	Twin Creek at Nursery Pond Near Crossroad	1994-07-19	2000-08-23	192
USGS	072632978	Twin Creek Near Wye, AR	1990-04-04	1998-08-06	62
USGS	07263298	Lake Maumelle Ds from Twin Creek Near Wye, AR	1989-05-25	1998-08-06	1,812
USGS	072632982	Reece Creek at Little Italy, AR	1998-12-02	2004-04-22	8
USGS	07263299	Lake Maumelle Near Little Italy, AR	1989-05-26	2004-08-03	940
USGS	072632991	Lake Maumelle at Jolly Roger Marina Nr Little Italy	1998-08-26	2000-08-21	3
USGS	072632992	Lake Maumelle Near Pinnacle, AR	1991-01-11	1992-10-21	281
USGS	072632995	Lake Maumelle at Natural Steps	1989-05-26	2004-08-03	1,065
USGS	07263300	Maumelle River at Maumelle Dam at Natural Steps, AR	1971-03-12	1973-05-11	5

2.2.6 Cost Model Inputs

Research will be conducted to determine the best available information on stormwater and forestry BMP costs in the vicinity of Lake Maumelle. Cost data from the region will be used as available. For stormwater BMPs, cost data will be acquired for construction, design, engineering, and operation and maintenance costs from respected sources such as US EPA, research organizations, universities, and local agencies. For forestry BMPs, cost data will be obtained from respected sources such as National Forest Service staff, other government agents, and university researchers. Data on treatment costs, land prices, and other factors relevant to the estimation of utility rate costs will be provided directly by CAW. For administrative costs, the most up-to-date and reliable information on administrative requirements and costs will be used, developed in consultation with representatives of local governments. The inflation rate and conversion factor to local prices will also be specified from current, respected sources. If multiple sources publish different figures, Tetra Tech will select the figures that best represent the conditions in the Lake Maumelle watershed.

2.2.7 Quality Control for Nondirect Measurements

The majority of the nondirect measurements will be obtained from quality assured sources in federal or state agencies. Tetra Tech will assume that data obtained from USGS or EPA documents and databases have been screened and meet specified measurement performance criteria. These criteria might not be reported for the parameters of interest in the documents or databases. Tetra Tech will determine how much effort should be made to find reports or metadata that might contain that information. Tetra Tech will perform general quality checks on the transfer of data from any source databases to another database, spreadsheet, or document.

Where data are obtained from non-government sources without a clear QA trail, Tetra Tech will evaluate data quality of such secondary data before use. Additional methods that might be used to determine the quality of secondary data include:

- Verifying values and extracting statements of data quality from the raw data, metadata, or original final report.
- Comparing data to a checklist of required factors (e.g., analyzed by an approved laboratory, used a specific method, met specified DQOs, validated).

If it is determined that such searches are not necessary or that no quality requirements exist or can be established, however these data must be used in the task, Tetra Tech will add a disclaimer to the deliverable indicating that the quality of the secondary data is unknown.

A special note is appropriate regarding precipitation data. The precipitation data supplied by NCDC can vary widely in terms of QC, from carefully controlled observations at first-order weather stations, to data of uncertain quality reported by volunteer observers. Data from volunteer Cooperative Summary of the Day stations will be carefully evaluated for potential quality problems. An important issue for many precipitation series is attribution of missing data. Rainfall for model input will be processed using the MetADAPT weather data processing tool. The tool was developed with the Normal Ratio Method patching routine to fill gaps in rainfall records on an hourly basis.

The records will be reviewed to consider unreasonable or extreme values. This will be performed by inspection of the patched record against a regional record that has no impaired periods or a very small amount of impaired periods, such as an airport station. Furthermore, the patched record will be reviewed against the original record and the index stations.

2.3 Data Management and Hardware/Software Configuration

No sampling (primary data collection) will be conducted for this task. Secondary data collected as part of this task will be maintained as hard copy only, both hard copy and electronic, or electronic only, depending on their nature.

Software to be used for this project includes two types: tested and publicly available code and executables available from USEPA or USACOE, and spreadsheet analysis tools created for this or similar projects.

Table 8. Modeling Software

Model	Provider	Source
HSPF (WinHSPF) v. 12	USEPA	http:///www.epa.gov/waterscience/basinsv3.htm
CE-QUAL-W2 v 3.2	USACOE and Portland State University	http://www.ce.pdx.edu/~scott/w2/
EFDC-HYDRO	USEPA Region 4	http://www.epa.gov/athens/wwqtsc/html/efdc.html
GBMM	Tetra Tech	Tetra Tech (under development for USEPA ORD)
WEPP	USDA and USFS	http://topsoil.nserl.purdue.edu/nserlweb/weppmain/
Site Evaluation Tool	Tetra Tech	Tetra Tech (to be modified for this project)
Cost Tools	Tetra Tech	Tetra Tech (to be modified for this project)

The software used for the project operates on standard Pentium-class microcomputers under the Windows (2000/XP) operating system. The recommended hardware configuration varies depending on the complexity of the model. For HSPF, CE-QUAL-W2, and EFDC, minimum requirements are anticipated to include a 600-megahertz processor, 512-megabyte random access memory (RAM), 10-gigabyte disk drive, and compact disc (CD) reader.

Tetra Tech will provide the final version of the model input, output, and executables, to the client for archiving at the completion of the task. Electronic copies of the data, GIS, and other supporting documentation will be supplied to EPA with the final report. Tetra Tech will maintain copies in a task subdirectory (subject to regular system backups) and on disk for a maximum period of 3 years after task termination, unless otherwise directed by the client.

Most work conducted by Tetra Tech for this task requires the maintenance of computer resources. Tetra Tech's computers are either covered by on-site service agreements or serviced by in-house specialists. When a problem with a microcomputer occurs, in-house computer specialists diagnose the problem and correct it if possible. When outside assistance is necessary, the computer specialists call the appropriate vendor. For other computer equipment requiring outside repair and not currently covered by a service contract, local computer service companies are used on a time-and-materials basis. Routine maintenance of microcomputers is performed by in-house computer specialists. Electric power to each microcomputer flows through a surge suppressor to protect electronic components from potentially damaging voltage spikes. All computer users have been instructed on the importance of routinely archiving work assignment data files from hard drive to compact disc or floppy disk storage. The office network server is backed up on tape nightly during the week. Screening for viruses on electronic files loaded on microcomputers or the network is standard company policy. Automated screening systems have been placed on all of Tetra Tech's computer systems and are updated regularly to ensure that viruses are identified and destroyed. Annual maintenance of software will be performed to keep up with evolutionary changes in computer storage, media, and programs.

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3 Assessments and Response Actions

3.1 Assessment and Response Actions

The QA program under which this work assignment will operate includes surveillance and internal and external testing of the software application. The essential steps in the QA program are as follows:

- Identify and define the problem.
- Assign responsibility for investigating the problem.
- Investigate and determine the cause of the problem.
- Assign and accept responsibility for implementing appropriate corrective action.
- Establish the effectiveness of and implement the corrective action.
- Verify that the corrective action has eliminated the problem.

Many technical problems can be solved on the spot by the staff members involved; for example, by modifying the technical approach, correcting errors in input data, or correcting errors or deficiencies in documentation. Immediate corrective actions are part of normal operating procedures and are noted in records for the task. Problems not solved this way require formalized, long-term corrective action. If quality problems that require attention are identified, Tetra Tech will determine whether attaining acceptable quality requires short- or long-term actions. If a failure in an analytical system occurs (e.g., performance requirements are not met), the appropriate QC Officer will be responsible for corrective action and will immediately inform the Tetra Tech PM or QA Officer, as appropriate. Subsequent steps taken will depend on the nature and significance of the problem.

The Tetra Tech PM (or designee) has primary responsibility for monitoring the activities of this task and identifying or confirming any quality problems. Significant quality problems will also be brought to the attention of the Tetra Tech QA Officer, who will initiate the corrective action system described above, document the nature of the problem, and ensure that the recommended corrective action is carried out. The Tetra Tech QA Officer has the authority to stop work if problems affecting data quality that will require extensive effort to resolve are identified.

Corrective actions may include the following:

- Reemphasizing to staff the task objectives, the limitations in scope, the need to adhere to the agreed-upon schedule and procedures, and the need to document QC and QA activities.
- Securing additional commitment of staff time to devote to the task.
- Retaining outside consultants to review problems in specialized technical areas.
- Changing procedures.

The assigned QC Officers will perform or oversee the following qualitative and quantitative assessments of model performance to ensure that models are performing the required tasks while meeting the quality objectives:

- Data acquisition assessments.
- Secondary data quality assessments.
- Model testing studies.

- Model evaluations.
- Internal peer reviews.

3.1.1 Model Development Quality Assessment

This QAPP and other supporting materials will be distributed to all personnel involved in the work assignment. Designated QC Officers will ensure that all tasks described in the work plan are carried out in accordance with the QAPP. Tetra Tech will review staff performance throughout each development phase of each case study to ensure adherence to task protocols.

Quality assessment is defined as the process by which QC is implemented in the model development task. All modelers will conform to the following guidelines:

- All modeling activities including data interpretation, load calculations, or other related computational activities are subject to audit and/or peer review. Thus, the modelers are instructed to maintain careful written and electronic records for all aspects of model development.
- If historical data are used, a written record on where the data were obtained and any information on their quality will be documented in the final report. A written record on where this information is located on a computer or backup media will be maintained in the task files.
- If new theory is incorporated into the model framework, references for the theory and how it is implemented in any computer code will be documented.
- All modified computer codes will be documented, including internal documentation (e.g., revision notes in the source code), as well as external documentation (e.g., user's guides and technical memoranda supplements).

A QC Officer will periodically conduct surveillance of each modeler's work. Modelers will be asked to provide verbal status reports of their work at periodic internal modeling work group meetings. Detailed modeling documentation will be made available to members of the modeling work group as necessary.

3.1.2 Software Development Quality Assessment

QC Officers will also conduct surveillance on any needed software development activities to ensure that all tasks are carried out in accordance with the QAPP and satisfy user requirements. Staff performance will be reviewed throughout the life cycle to ensure adherence to task procedures and protocols. All task staff will conform to the following guidelines:

- All software development activities, including data compilation, processing, and analysis, are subject to audit or peer review. Thus, the programmers are instructed to maintain careful written and electronic records for all aspects of software development.
- As computer programs are modified, (e.g., hand calculation checks, checks against other models) the code will be checked and a written record made as to how the code is known to work.
- If historical data are used, a written record of where the data were obtained and any information on the quality of the data will be documented in the final report. A written record of where this information is located on a computer or backup medium will be maintained in the task files.
- All new and modified computer codes will be documented, including internal documentation (e.g., revision notes in the source code) as well as external documentation (e.g., user guides and technical memoranda supplements).

- The QC Officer or his designee will conduct periodic surveillance of each programmer's work. Programmers will also adhere to a variety of practices and protocols in addition to the guidelines listed above. Programmers will follow development practices and use a software testing plan that includes internal testing, error tracking, and external testing.

Depending on the scale of the software task, one or more developers might need to collaborate or concurrently work with the same software source code. In these situations, it is important that all changes to the code be tracked and easily reconstructed as the various versions are reassembled into the single, monolithic code base. To assist with version control and management, Tetra Tech uses a concurrent version control system (CVS) during development. CVS is a "source control" or "revision control" tool designed to keep track of source changes made by groups of developers working on the same files, allowing them to stay in sync. Version control and tracking also enables a particular "snapshot" of a development process to be recovered at some stage in the future (after the development has moved beyond the snapshot).

3.1.3 Surveillance of Project Activities

Internal peer reviews will be documented in the project file and QAPP file. Documentation will include the names, titles, and positions of the peer reviewers, their report findings, and the project management's documented responses to their findings. The Tetra Tech PM may replace a staff member if it is in the best interest of the task to do so.

Performance audits are quantitative checks on different segments of task activities. The Tetra Tech QC Officer or his designees will be responsible for overseeing work as it is performed and for periodically conducting internal assessments during the data entry and analysis phases of the task. The Tetra Tech PM will perform surveillance activities throughout the duration of the task to ensure that management and technical aspects are being properly implemented according to the schedule and quality requirements specified in the data review and technical approach documentation. These surveillance activities will include assessing how task milestones are achieved and documented, corrective actions are implemented, budgets are adhered to, peer reviews are performed, and data are managed, and whether computers, software, and data are acquired in a timely manner.

3.2 Reports to Management

The PM (or designee) will provide monthly progress reports to CAW. As appropriate, these reports will notify CAW of the following:

- adherence to project schedule and budget.
- deviations from approved QAPP, as determined from project assessment and oversight activities.
- the impact of these deviations on model application quality and uncertainty.
- the need for and results of response actions to correct the deviations.
- potential uncertainties in decisions based on model predictions and data.
- Data Quality Assessment findings regarding model input data and model outputs.

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4 Output Assessment and Model Usability

4.1 Departures from Validation Criteria

The models developed for the Lake Maumelle Watershed Planning project will be used to assess a series of study questions, as summarized in Table 3, associated with the project goals and objectives (Table 2). Acceptance criteria for each of the modeling components are described in Section 2.1.3.

Written documentation will be prepared under the direction of the relevant QC Officer addressing each calibrated model's ability to meet the specified acceptance criteria and provided to the PM and QA Officer for review. If a model does not meet acceptance criteria, the QC Officer will first direct efforts to bring the model into compliance. If, after such efforts, the model still fails to meet acceptance criteria, a thorough exposition of the problem and potential corrective actions (e.g., additional data collection or modification of model code) will be provided to CAW.

4.2 Validation Methods

The primary water quality models proposed for the Lake Maumelle Watershed Assessment will be rigorously validated using data separate from those used in model calibration, as described in Section 2.1. Results of model validation will be documented in writing and provided to CAW.

4.3 Reconciliation with User Requirements

Quality objectives for modeling are addressed in Section 1.4. Acceptance criteria for model calibration (Section 2.1.3) were selected to ensure achievement of the quality objectives. If there are unresolvable departures from validation criteria, the ability of the models to achieve quality objectives and provide answers to the principal study questions may be compromised. If such circumstances occur, Tetra Tech will consult with CAW (and the Policy Advisory Council and Technical Advisory Council, as appropriate) whether the levels of uncertainty present in the models can allow user requirements to be met, and, if not, the actions needed to address the issue.

A detailed evaluation of the ability of the modeling tools to meet user requirements will be provided in the Baseline Analyses Documentation memorandum.

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