Leon River Watershed Protection Plan Modeling
TSSWCB Project 06-12

Revision #0

Prepared by
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In cooperation with

Texas State Soil and Water Conservation Board
and
U.S. Environmental Protection Agency

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A1 APPROVAL PAGE

Quality Assurance Project Plan for the Leon River Watershed Protection Plan Modeling.

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LIST OF ACRONYMS

ARS	USDA – Agricultural Research Service
BMP	Best Management Practice
BRA	Brazos River Authority
CAR	Corrective Action Report
CEAP	Conservation Effects Assessment Project
CWA	Clean Water Act
DQO	Data Quality Objective
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program – Fortran
JMA	James Miertschin and Associates, Inc.
NLCD	National Land Cover Dataset
NPS	Nonpoint Source
QA	Quality Assurance
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
TCEQ	Texas Commission on Environmental Quality
TPDES	Texas Pollution Discharge Elimination System
TMDL	Total Maximum Daily Load
TSSWCB	Texas State Soil and Water Conservation Board
USGS	United States Geological Survey
WPP	Watershed Protection Plan

A3 DISTRIBUTION LIST

Parsons will provide copies of this quality assurance project plan (QAPP) and any amendments or appendices to each person on this list. Parsons will document distribution of the QAPP and any amendments and appendices, maintain this documentation as part of the project's quality assurance records, and will be available for review.

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A4 PROJECT/TASK ORGANIZATION

The following is a list of organizations and individuals participating in the development of the Leon River Watershed Protection Plan (WPP) project and their specific roles and responsibilities.

U.S. Environmental Protection Agency (EPA) Region 6

Randall Rush, EPA Project Officer

Responsible for managing the Clean Water Act (CWA) §319(h) funded grant on the behalf of EPA. Assists the TSSWCB in approving projects that are consistent with the management goals designated under the State's NPS management program and meet federal guidance. Coordinates the review of the project work plans, QAPPs, draft deliverables, and works with the TSSWCB in making these items approvable. Meets with the State at least annually to evaluate the progress of each project and when conditions permit, participate in a site visit on the project. Fosters communication within EPA by updating management and others.

Texas State Soil and Water Conservation Board (TSSWCB)

Pamela Casebolt, TSSWCB Project Manager

Maintains a thorough knowledge of work activities, commitments, deliverables, and time frames associated with project. Develops lines of communication and working relationships between BRA, TSSWCB, and EPA. Tracks deliverables to ensure that tasks are completed as specified in the contract. Responsible for ensuring that the project deliverables are submitted on time and are of acceptable quality and quantity to achieve project objectives. Participates in the development, approval, implementation, and maintenance of the QAPP. Responsible for verifying that the QAPP is followed by the BRA. Notifies the TSSWCB Quality Assurance Officer (QAO) of particular circumstances that may adversely affect the quality of data derived from the collection and analysis of samples. Enforces corrective action.

Donna Long, TSSWCB Quality Assurance Officer

Reviews and approves QAPP and any amendments or revisions and ensures distribution of approved/revised QAPPs to TSSWCB and EPA participants. Responsible for verifying that the QAPP is followed by project participants. Determines that the project meets the requirements of planning, quality assurance/quality control (QA/QC), and reporting under the CWA §319(h) program. Monitors implementation of corrective actions. Coordinates or conducts audits of field and laboratory systems and procedures.

Brazos River Authority (BRA)

Jay Bragg, BRA Project Manager

The BRA Project Manager is responsible for ensuring that tasks and other requirements in the contract are executed on time and with the QA/QC requirements in the system as defined by the contract and in the QAPP; assessing the quality of contractor work; and submitting accurate and timely deliverables to the TSSWCB Project Manager. Responsible for ensuring adequate supervision of all project tasks as defined by the contract. Responsible for ensuring that the project delivers data of known quality, quantity, and type on schedule to achieve project objectives.

Kay Barnes, BRA Quality Assurance Officer

The BRA QAO reviews and approves QAPP and any amendments or revisions and ensures distribution of approved/revised QAPPs to project participants. Assists the BRA Project Manager on QA-related issues. Coordinates reviews and approvals of QAPPs and amendments or revisions. Conveys QA problems to appropriate project management. Monitors implementation of corrective actions. Coordinates and conducts audits and is responsible for ensuring that tasks and other requirements in the contract are executed on time and with the QA/QC requirements in the system as defined by the contract and in the QAPP.

Parsons

Mel Vargas, Project Manager

The Parsons Project Manager is responsible for ensuring that tasks and other requirements in the contract are executed on time and with the QA/QC requirements in the system as defined by the contract and in the project QAPP; assessing the quality of subcontractor/participant work; and submitting accurate and timely deliverables to the BRA Project Manager. Responsible for ensuring adequate supervision of all project tasks as defined by the contract. Responsible for ensuring that the project delivers data of known quality, quantity, and type on schedule to achieve project objectives. Responsible for coordination, development, and delivery of quarterly reports and the final project report.

Jim Patek, Project Quality Assurance Officer

Responsible for coordinating development and implementation of the Parsons' QA program. Responsible for maintaining the QAPP and monitoring its implementation. Responsible for maintaining records of QAPP distribution, including appendices and amendments. Ensures modeling system used for the project is of known and acceptable quality and adheres to the specifications of the QAPP. Responsible for identifying, receiving, and maintaining project QA records. Responsible for coordinating with the TSSWCB to resolve QA-related issues. Notifies the Parsons Project Manager, BRA Project Manager, and TSSWCB Project Manager of particular circumstances which may adversely affect the quality of the modeling system and products. Coordinates the research and review of technical QA material and existing data related to model system design and analytical techniques. Implements or ensures implementation of corrective actions needed to resolve nonconformance noted during assessments. Provides copies of QAPP and any amendments or revisions to each project participant. Documents receipt of the plan by participants and maintains this documentation as part of the project's QA records.

Marcel Dulay, Lead Modeler

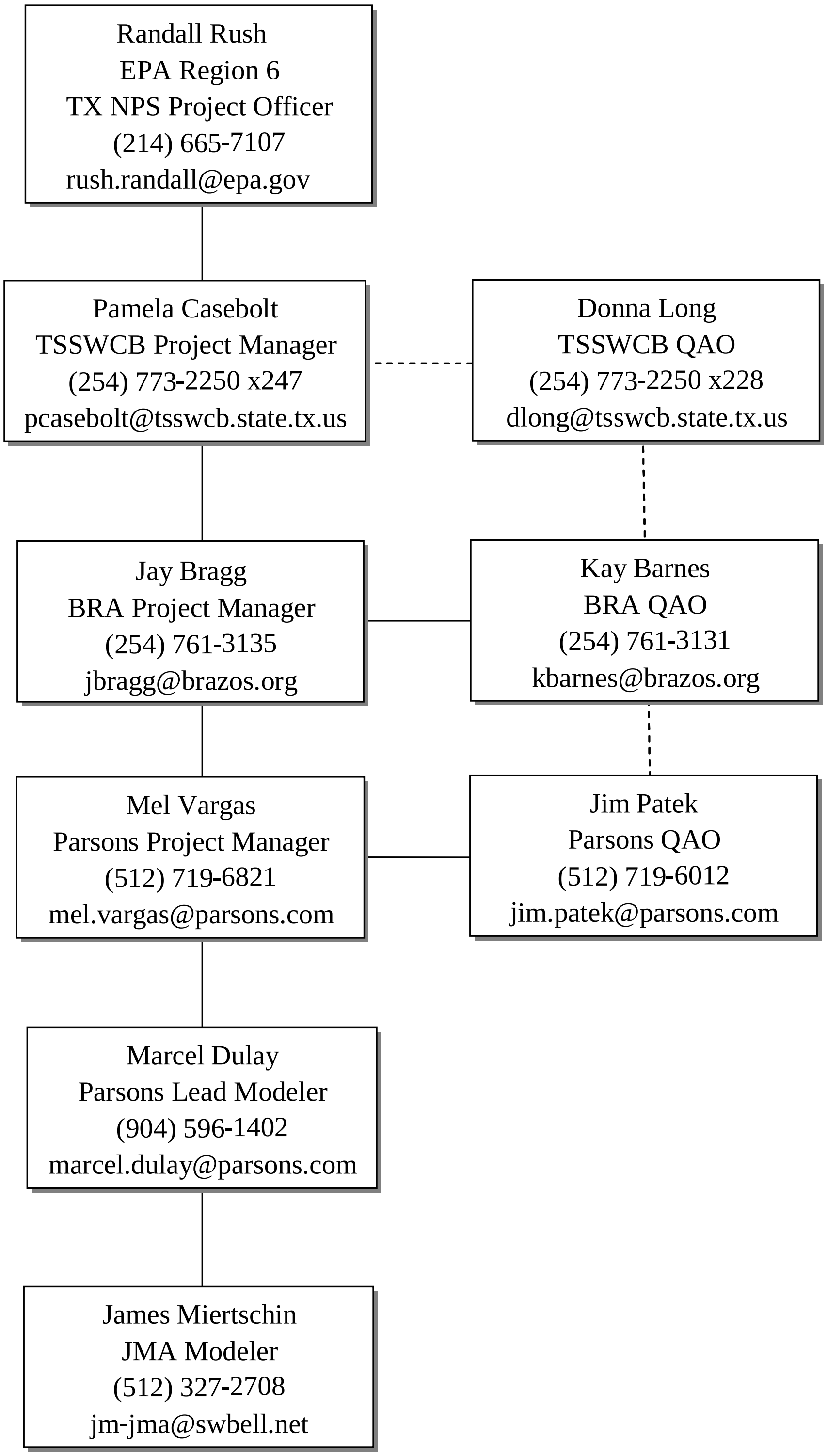
The Parsons Lead Modeler is responsible for water quality modeling using an existing watershed loading model, analysis of existing data, and reporting tasks for the project including development of data quality objectives (DQOs) and a QAPP. Responsible for the acquisition and application of the model and subsequent explanations of model inputs and outputs to the stakeholders, BRA and TSSWCB Project Managers. Oversees data management and all modeling activities for the project. Responsible for overseeing the operation of the model and reporting on the robustness and accuracy of model prediction based on its current data and level of calibration. Responsible for assuring stakeholders are involved during modeling, and that scenarios reflect their interests. Responsible for producing outputs for use during presentations, meetings, and reports on schedule to achieve project objectives.

James Miertschin and Associates, Inc. (JMA)

James Miertschin, Modeler

Responsible for refining and providing the existing watershed loading model to support and achieve the project objectives. Responsible for assisting project team with all aspects of operating the model as needed to support the production of the WPP. Informs other members of the project team when issues arise that may compromise the quality and usefulness of the model. Assist the Parsons Lead Modeler and Project Manager with resolving any issues related to operating the model, adjusting decision variables and interpreting outputs.

Figure A4.1 Organization Chart



A5 PROBLEM DEFINITION/BACKGROUND

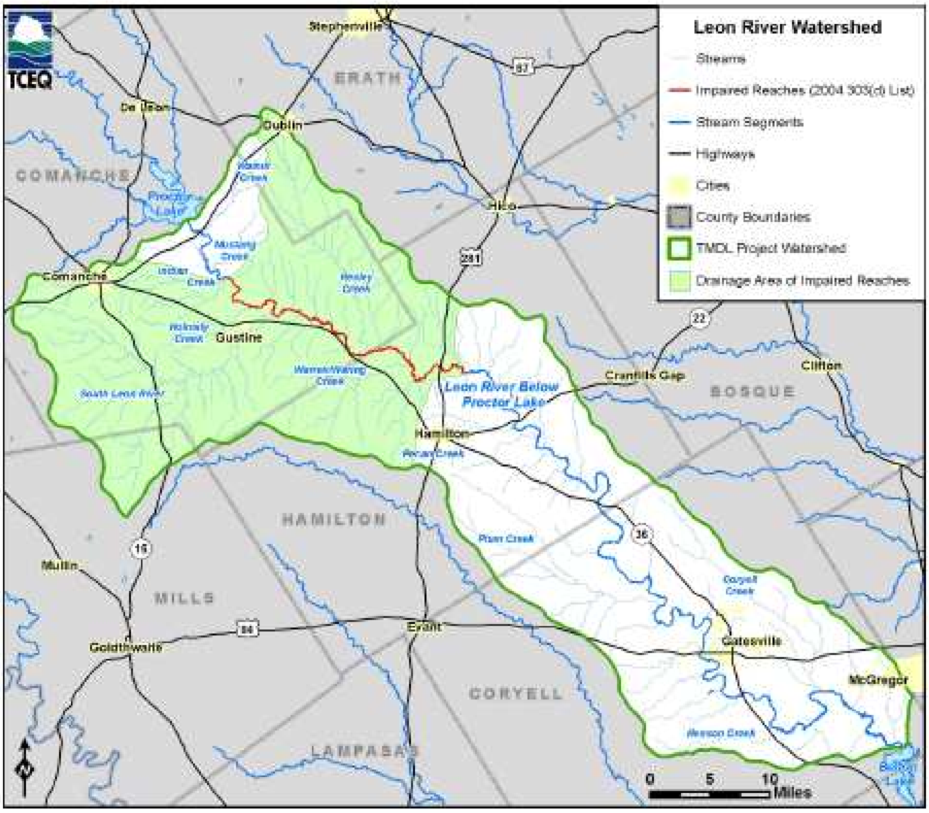
The study area displayed in Figure A5.1 is the Leon River watershed between Proctor Lake and Belton Lake (which is approximately 1,375 square miles). Segment 1221 of the Leon River starts at Proctor Lake dam and is 173 miles long with numerous tributaries that reside within Comanche, Erath, Hamilton, and Coryell Counties before it reaches Belton Lake (Segment 1220). Parts of Segment 1221 were initially placed on the State of Texas CWA §303(d) List in 1996 for having bacteria levels that "sometimes exceed water quality standards." Table A5.1 provides the most recent summary of water quality impairments and concerns identified in the *2008 Texas Water Quality Inventory and 303(d) List* for river and creek segments in the Leon River watershed. As summarized in Table A5.1, specific waterbodies are impaired as a result of high levels of bacteria and Resley Creek is also considered impaired because of low dissolved oxygen levels. Water quality concerns for low dissolved oxygen, chlorophyll *a*, bacteria, and some nutrients (orthophosphorus and nitrate) have also been identified in several segments.

Placement of the Leon River on the §303(d) List triggered the Texas Commission on Environmental Quality's (TCEQ) regulatory process of developing a total maximum daily load (TMDL), a legal requirement of the federal CWA. TCEQ initiated the TMDL process for bacteria in the Leon River upstream of Highway 281 in January 2002. Based on extensive data collection efforts, data analysis and modeling, and a series of stakeholder meetings, a draft TMDL titled *One Total Maximum Daily Load for Bacteria in the Leon River Below Proctor Lake, For Segment 1221* was prepared by TCEQ and released for public comment in April 2008. In September 2008, the TCEQ delayed final adoption of the draft bacteria TMDL for the Leon River; proposed revisions to the Texas Surface Water Quality Standards may affect future decisions to recommence with development of this TMDL.

The draft TMDL, as published by TCEQ, concluded that existing fecal coliform average daily loadings were 4,292,969 x 10^6 cfu split between point sources (36,921 x 10^6 cfu) and nonpoint sources (4,256,048 x 10^6 cfu). Based on the analysis conducted by TCEQ a 21% reduction in NPS loading and a 74% reduction in point source loading would be needed to meet current water quality standards (geometric mean of 126 cfu/100mL).

It must be noted that the TMDL is limited in geographic scope to only about a third of the watershed and only to a portion of the mainstem segment of the Leon River. "…only a portion of the river segment (highlighted in red) was found to be impaired, based on the 2004 303(d) List. The impaired reaches extend from just below U.S. Highway 281 near Hamilton upstream to the confluence with Indian Creek, just above FM 1476 near Gustine. In total, 44 miles of the Leon River have been designated as impaired." (draft TMDL) The WPP, and therefore this QAPP, is holistic in both geographic and topical scope (the entire watershed and other pollutant sources including nutrients). Bacteria loads and reductions from the draft TMDL are fundamentally only applicable at the "pour point" of the impaired reach, i.e., monitoring station 11932 (Leon River at US 281). This is further described in Appendix A – Excerpt from Section 5 of the *Final Modeling Report for Fecal Coliform TMDL Development for Leon River below Proctor Lake, Segment 1221*, (November 2006).

Figure A5.1 Impaired Reach of Leon River Watershed from draft TMDL



As described in Appendix A – Excerpt from Section 5 of the *Final Modeling Report for Fecal Coliform TMDL Development for Leon River below Proctor Lake, Segment 1221*, (November 2006), for the draft TMDL HSPF model, Segment 1221 of the Leon River watershed was subdivided into several subwatersheds to adequately represent the spatial variation in fecal coliform sources, watershed characteristics, hydrology, and the location of water quality monitoring and streamflow gaging stations. The watershed was subdivided into 15 subwatersheds, including distinct subwatersheds for the tributaries such as Walnut, Resley, and Plum Creeks along with the South Leon River. Modifications to the subwatershed delineation are described in §A6 of this QAPP.

In October 2006, the TSSWCB provided a grant to BRA to develop a stakeholder driven WPP that defines a comprehensive, watershed-based approach to water quality in the Leon River. The WPP is the detailed documentation of the regulatory and voluntary management strategies that stakeholders support to improve water quality in the Leon River watershed.

The purpose of the Leon River WPP is to establish implementation strategies for watershed protection/restoration activities that are supported by stakeholders. These implementation strategies guide the various activities over time that would reduce bacteria, in addition to other pollutant loads in creeks and rivers within the Leon River watershed. To accomplish this, the watershed stakeholders, BRA, and TSSWCB need to be able to estimate load reductions that can be achieved from the implementation of various watershed protection/restoration activities. These activities may include but are not limited to education for citizens, landowners, ranchers and farmers; construction of structural best management practices (BMPs), enactment of policies, enforcement of rules, and oversight of municipal, commercial and industrial activities. For this QAPP all of the aforementioned will be denoted as "strategies" when considered generically or as "activities" when specific implementation is considered. For the purposes of this project, existing computer models, geographic information systems (GIS), and other analysis tools will be used to understand the effects of applying strategies for reducing bacteria and nutrient loadings in the study area.

The primary modeling objective of the Leon River WPP is to indicate the degree to which the implementation of various strategies can reduce bacteria loads in the Leon River as compared to current and proposed water quality standards. Implementation strategies will be modeled such that scenarios are designed to achieve the load reductions in the draft TMDL report. The scientific underpinnings of the draft bacteria TMDL are derived from a wide array of data sources and the public domain watershed loading model known as Hydrologic Simulation Program – Fortran (HSPF) developed under a contract between TCEQ and James Miertschin and Associates, Inc. (JMA). As such, the TCEQ draft bacteria TMDL report and the technical support document prepared by JMA titled *Final Modeling Report for Fecal Coliform TMDL Development for Leon River below Proctor Lake, Segment 1221* (November 2006) demonstrates the data quality achieved for the existing HSPF model that will be used as part of this project to estimate reductions in bacteria loads. The combination of these two reports is denoted herein as the draft bacteria TMDL. The existing HSPF model is a valid and cost-effective tool, which has gone through technical review, for assessing water quality for parts of the Leon River; the draft TMDL only provides water quality reduction goals for a portion of the watershed. Therefore, it is the tool that will be used to support and advance the objectives of the Leon River WPP.

A secondary modeling objective of the Leon River WPP is to estimate the general reductions in nutrient loads that could be achieved by implementing strategies that address bacteria loads. Nutrients were not considered during the development and application of the HSPF model. However, a complementary approach that makes the best use of existing resources will be used so that reductions in nutrients can also be evaluated. Although not to the same degree as bacteria, it will be possible to identify nutrient sources and provide some basis for providing a qualitative assessment of the effectiveness of management strategies at reducing nutrient sources by subwatershed.

Table A5.1 Water Quality Impairments and Concerns within the Leon River Watershed (Segment 1221)

Segment	Area	Category	First Listed
	Bacteria Impairments - Texas 303(d) Listings		
1221	**Leon River Below Proctor Lake**		
1221_01	*Directly upstream of Lake Belton*	5a	1996
1221_04	*From the confluence with Plum Creek, upstream to the confluence with Pecan Creek*	5a	1996
1221_05	*From confluence with Pecan Creek, upstream to confluence with South Leon Creek*	5a	1996
1221_06	*From confluence with South Leon Creek upstream to confluence with Walnut Creek*	5a	1996
1221_07	*From the confluence with Walnut Creek upstream to Lake Proctor*	5a	1996
1221A	**Resley Creek (unclassified waterbody)**		
1221A_01	*Downstream portion, from confluence with Leon River upstream to conf. with unnamed tributary, approx. 1.0 mile N. of Comanche County Line*	5c (Bacteria, Dissolved Oxygen)	2004
1221A_02	*From confluence with unnamed tributary, upstream to end of waterbody, approx. 1.0 mile north west of Dublin*	5c	2004
1221B_01	**South Leon River (unclassified waterbody)** *Entire waterbody*	5c	2006
1221C_01	**Pecan Creek (unclassified waterbody)** *Entire waterbody*	5c	2006
1221D	**Indian Creek (unclassified waterbody)**		
1221D_01	*From confluence with Leon River, upstream to confluence with Armstrong Creek*	5c	2006
1221D_02	*From confluence with Armstrong Creek upstream to headwaters of waterbody*	5c	2006
1221F_01	**Walnut Creek (unclassified waterbody)** *Entire waterbody*	5c	2006

Segment	Area	Parameter	Concern
	Concerns - Texas Water Quality Inventory		
1221	**Leon River Below Proctor Lake**		
1221_01	*Directly upstream of Lake Belton*	DO	CS
		Chl-*a*	CS
1221_04	*From the confluence with Plum Creek, upstream to the confluence with Pecan Ck.*	B	CN
1221_05	*From confluence w/ Pecan Creek, upstream to confluence with South Leon Creek*	DO	CS
		Chl-*a*	CS
1221_06	*From confluence w/ South Leon Creek upstream to confluence with Walnut Creek*	Chl-*a*	CS
1221_07	*From the confluence with Walnut Creek upstream to Lake Proctor*	DO	CS
		Chl-*a*	CS
1221A	**Resley Creek (unclassified waterbody)**		
1221A_01	*Downstream portion, from confluence with Leon River upstream to conf. with unnamed tributary,*	B	CN
	approx. 1.0 mile N. of Comanche County Line	Chl-*a*	CS
1221A_02	*From confluence with unnamed tributary, upstream to end of waterbody, approx. 1.0 mile north*	OP	CS
	west of Dublin	NO3	CS
1221B_01	**South Leon River (unclassified waterbody)** *Entire waterbody*	DO	CS
1221D	**Indian Creek (unclassified waterbody)**		
1221D_01	*From confluence with Leon River, upstream to confluence with Armstrong Creek*	DO	CN
1221D_02	*From confluence with Armstrong Creek upstream to headwaters of waterbody*	OP	CS
		NO3	CS

Source: Texas Commission on Environmental Quality, 2008 *Texas Water Quality Inventory and 303(d) List.* http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/08twqi/twqi08.html
5a = A TMDL is underway, scheduled.
5c = Additional data and information will be collected before a TMDL is scheduled.
DO = depressed dissolved oxygen
Chl-*a* = chlorophyll-a
B = bacteria
OP = orthophosphorus
NO3=nitrate
CN - Concern for near-nonattainment of the Water Quality Standards
CS - Concern for water quality based on screening levels

Although the existing HSPF model has not been prepared for evaluating nutrients, it can be used to estimate nutrients loads by subwatershed and indicate where there will be added benefit of nutrient reductions by implementing strategies that address bacteria. Two steps are needed to make predictions of nutrient load reductions: 1) loading factors for different land use categories would need to be entered into the existing HSPF model and, 2) the HSPF model would have to be calibrated based on local water quality data. To maximize resources available for the WPP, only the first step will be performed because it may not be necessary to complete the second. The first step provides information of where nutrient sources are located and allows for a ranking of priority subwatersheds based on nutrient loadings. Since it is acceptable to assume that the implementation strategies to reduce bacteria would likely result in nutrient reduction, then it is practical to accept that the implementation of management strategies targeted at bacteria sources will result in net reductions of nutrient loads.

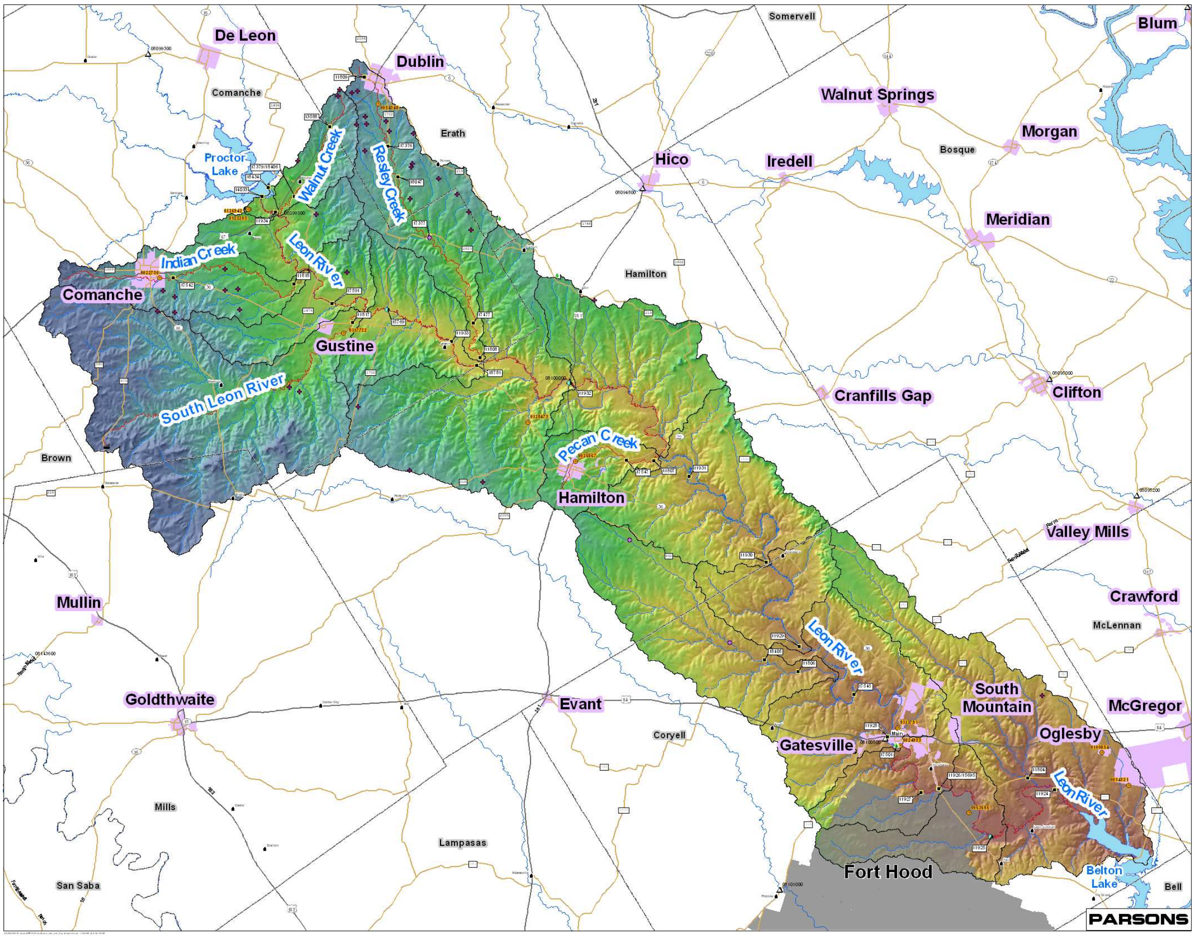
While there is a desire to go to the second step and complete the calibration to specify the degree of nutrient reductions, given the limited data and resources available, for the purposes of this project qualitative inferences of nutrient reductions are considered sufficient. A lack of model calibration can be compensated for by establishing a monitoring plan to evaluate whether the implementation of management strategies are effective at reducing instream bacteria and nutrient concentrations. The objectives, metrics and frequency of the monitoring plan will be further defined in Elements I, H, and G of the nine elements of a WPP.

The HSPF model will be used in its current form which is based on historical fecal coliform data. Additional water quality samples for Escherichia coli (*E. coli)* have been collected since the completion of the model but those data will not be integrated into the data set used by the model. Even though fecal coliform data is no longer being collected throughout the watershed, the model in its current form is fully capable of advancing the DQOs of this project and can help stakeholders move toward prioritizing the implementation of management strategies that enhance water quality. To overcome the limitation of new data and the mismatch between model outputs and current standards, the fecal coliform model outputs may be converted to *E. coli* by applying a ratio. Parsons will work with existing data, literature values and other information to derive an appropriate ratio to convert fecal coliform model outputs to *E. coli*.

In summary, two complementary approaches will be defined in this QAPP to support three goals: 1) the identification of pollutant loads by subwatershed, 2) the identification of load reductions needed to achieve water quality goals by subwatershed, and 3) the quantitative and qualitative assessment of the effectiveness of management strategies at reducing bacteria and nutrient sources. The first approach will rely on the existing HSPF model and geospatial data compiled using GIS to summarize bacteria and nutrient sources and estimate loads and reductions needed by subwatershed. The second approach will rely on the existing HSPF model to provide quantitative estimates of bacteria reductions to be achieved by implementing a suite of bacteria management strategies with a qualitative summary of the corollary benefits at reducing nutrient loads. A ratio will be applied to the HSPF fecal coliform outputs so that pollutant reductions can be evaluated against *E. coli* which is the prescribed bacterial indicator of the Texas water quality standards for freshwater streams. These approaches apply the appropriate level of analysis based on availability of data, existing tools, and the severity of the parameters of concern to establish a

WPP that can address both bacteria and nutrients.

Figure A5.2 Leon River Watershed



A6 PROJECT/TASK DESCRIPTION

This QAPP addresses the elements of the Leon River WPP that are part of the engineering services, especially as they pertain to hydrologic modeling and other engineering procedures provided by Parsons to BRA. As a CWA §319 grant funded project, this project will advance the goals and objectives of the Leon River WPP which includes attainment of water quality standards for contact recreation by reducing pollutant loads in the Leon River and its tributaries. The objectives in using the model to prepare the Leon River WPP are:

- Make use of available data and existing tools to estimate the bacteria load reductions expected for the strategies identified for the WPP which is one of the nine key elements fundamental to WPPs.
- Utilize available data and a cost effective method to indicate where nutrient load reductions are likely to occur based on implementation of the aforementioned strategies at the subwatershed scale.
- Prioritize subwatersheds which warrant greatest levels of bacteria reduction.
- Provide sufficient technical information to the decision-making process to promote, support and justify action by stakeholders.
- Demonstrate the degree to which existing contact recreation standards are attainable at the subwatershed scale for current water quality standards.

The fundamental purpose of this project is to provide stakeholders with a better understanding of the effectiveness and general costs that a variety of management strategies will have on reducing bacteria and nutrient loads in parts of the Leon River. This project involves preparation of a WPP, which includes figures, charts, graphics, tables, and maps based on modeling outputs that document the sources and estimated reductions in bacteria and nutrient loading by subwatershed in the Leon River Watershed. Parsons will use available data, develop a GIS, and apply a previously developed public domain HSPF model for this project. GIS and water quality data will be used to identify sources of bacteria and nutrients. The modeling tasks will consist of using HSPF to simulate reductions in bacteria loading and a combination of HSPF, GIS, and literature values to identify where there are likely to be nutrient reductions in priority areas. Parsons will use the modeling outputs to make inferences on how the applicability, relevance, and impact of the various strategies recommended for the Leon River watershed can lead to attainment of current water quality standards over time, as well as the proposed standards revisions being evaluated by TCEQ. The collection of additional water quality sampling data is not part of this project; therefore no new data will be added to the model. JMA will support Parsons during the model simulations. Throughout the WPP process stakeholders will be involved where they will have opportunities to provide valuable local knowledge, guide WPP development, and review reports.

Water Quality Data Description

Various sources of existing water quality data will be used throughout the development of the WPP. The first is from the TCEQ Surface Water Quality Monitoring Information System. This database contains physicochemical and biological data for several monitoring stations in the study area starting in 1993. These data are collected by the TCEQ, contributing river authorities, cities, and other local, state, and federal agencies and is maintained by TCEQ. This database serves as a repository for Texas' surface water quality data. These data are collected using TCEQ's *Surface Water Quality Monitoring Program and Water Quality Assessment Program Quality Assurance Project Plan*. As such, it is believed to be the most reliable set of data from which to perform water quality analyses and modeling.

Other water quality data being used to support the assessment of water quality conditions in the Leon River watershed are those derived from ambient water quality analyses at local stations in the study area performed by the United States Department of Agriculture – Agricultural Research Service (ARS) and Texas AgriLife Research. Both agencies are conducting in-depth studies that will help to validate physical-process models used for the National Assessment component of the Conservation Effects Assessment Project (CEAP). Texas AgriLife Research is also collecting water quality data in the Leon River watershed to support a landscape management project aimed at studying the effects of juniper removal. Both ARS and Texas AgriLife Research have been conducting research for a considerable period of time and anticipate that research and assessments in these watersheds will continue over many years. These studies adhere to EPA protocols where applicable, and use laboratories that are EPA certified. CEAP data includes edge of field studies along tributaries to the Leon River while the Texas AgriLife Research data includes ambient water quality analyses along the Leon River mainstem. Data from these two agencies are valuable as they include results for fecal coliform, *E. coli*, and nutrients.

GIS Data Description

Spatial and analytical data will be collected for each of the watersheds. Watersheds are delineated using the USGS National Elevation Dataset at 30 meter resolution and the highest available resolution National Hydrography Dataset Stream network. Data used for watershed characterization include the 30 meter resolution 2001 National Land Cover Dataset (NLCD) and the USDA SSURGO database. 1990 and 2000 Census data are utilized for watershed population estimates including households, pets, humans, and septic systems. The 2002 USDA Agricultural Census is used for estimating livestock counts in the watersheds.

GIS data obtained from TCEQ includes the water quality monitoring stations, Texas Pollutant Discharge Elimination System (TPDES) outfalls, and Texas Land Application Permit data.

HSPF Model Description

HSPF is an industry accepted public domain, hydrologic and water quality simulation model for extended periods of time on pervious and impervious land surfaces and in streams and well-mixed impoundments. Originally developed in the early 1960s as a hydrologic model, it has been enhanced by EPA, United States Geological Survey (USGS), and others to be more user-friendly, include water quality, have pre-and post-processing functions, and contains capabilities that make it one of the most used software packages for water quality modeling. HSPF uses continuous rainfall and other meteorologic records to compute streamflow hydrographs. HSPF can simulate many aspects of water in the environment, as well the ambient water quality. It is particularly valid as it is able to simulate fecal coliform in rivers and streams. The model can simulate one or many pervious or impervious unit areas discharging to one or many river reaches or reservoirs. The simulation can be done for as little as 1-minute to 1-day where periods from a few minutes to hundreds of years may be simulated. HSPF can be used to assess the effects of land-use change, reservoir operations, point or nonpoint source treatment alternatives, flow diversions, etc.

Table A6.1 Project Plan Milestones

Task	Project Milestones	Agency	Start	End
5	Develop QAPP	Parsons, JMA	07/08	02/09
6	Model Application	Parsons, BRA	02/09	03/09
6.1	Scenario Development and Ranking	Parsons, BRA	03/08	04/09
7	Final Scenarios	Parsons, BRA	05/09	07/09

Task Descriptions

Task 5 – QAPP: Preparation of this document serves as a guide for QA/QC of the various elements of the project (presented information, deliverables, and reports). Each year there will be an annual review to make any corrective actions to assure QA or enhance procedures to improve overall quality.

Task 6 – Model Application: This task involves the analysis, transfer, and modification of existing data to support the use of an existing HSPF model. Existing water quality data from the sources described above for nutrients, fecal coliform, and *E. coli* have been analyzed and reported using tables and figures to show stakeholder current trends in water quality and identify priority areas. Existing data will be assessed to derive an appropriate ratio that will be used when comparing fecal coliform modeling results to *E. coli* water quality criteria. The existing HSPF model, used for the draft bacteria TMDL, will be adopted for this project. This requires obtaining the original files used by JMA, which will be uploaded and tested. The computer model is currently only set up to handle bacteria parameters and is capable of providing outputs for bacteria loads at a watershed level.

The watershed delineation of the current model will have to be modified so that the recently impaired segments can be modeled. This will require subdividing at least two subwatersheds currently defined in the HSPF model. The other modification that is needed is the inclusion of nutrient parameters. Loading coefficients will be entered to determine nutrient loads at the subwatershed scale. Because the model will not be calibrated for nutrients, reductions in nutrient loads will not be modeled.

The model will be operated by reducing point and nonpoint source loads that reflect the implementation of strategies. This task will also respond to the specific implementation strategies identified through a series of stakeholder meetings. The goal is to evaluate individual strategies and determine the marginal reduction in bacteria loads. Model results at critical monitoring stations for individual strategies will be stored for use in scenario development and ranking.

Task 6.1 – Scenario Development and Ranking: The WPP public participation process seeks to continue and expand involvement of the public by incorporating local knowledge from stakeholders, providing a transparent process for developing strategies. The WPP process has broadened the list of stakeholder participants and has structured a series of meetings that will be used to facilitate the local process of selecting and ranking the BMP implementation scenarios in high priority watersheds. The desired outcome is a set of water quality attainment strategies that reflect the wishes of stakeholders in the study area. Scenarios are combinations of strategies implemented over time that stakeholders are willing to consider. As the effects of each strategy are understood throughout the watershed in combination with other strategies, a scenario takes form. The end result is to have strategies stakeholders are willing to implement in the Leon River watershed. The primary function of this task is to change decision variables in the model and provide outputs to stakeholder that can be understood. It is expected that several scenarios will be generated throughout the project.

Scenarios will be ranked based on bacteria based performance measures. A typical cost-benefit analysis will be determined: marginal change in bacteria loads to project costs. Parsons will configure a method to provide stakeholders easy access points to decision parameters that are likely to be manipulated during the development of the WPP. The decision parameters will be identified during stakeholder meetings. The range of strategies applied will reflect stakeholder input. Graphs will be provided to demonstrate the performance measures on how water quality may change as strategies are implemented in relation to existing and proposed bacteria water quality criteria. Graphs and tables will show the effect of various degrees of strategy implementation as decision support tools for deciding which strategies to recommend in the WPP.

Task 7 – WPP Final Scenarios: Based on modeling results derived from Task 2, input from stakeholders, BRA, Parsons, and TSSWCB will be obtained to reach support or acceptance for the final suite of strategies that can effectively reduce bacteria loads in each subwatershed. The modeling outputs, including pollutant load reduction estimates, will be used to organize the final suite of strategies by subwatershed and responsible party. A qualitative summary will be provided that addresses where there is likely to be added benefits of nutrient reductions in high priority areas. The outcomes obtained from the integration of modeling outputs and stakeholder input will be summarized in the WPP. The final scenarios will be presented in relationship to the pollutant load reduction goal of the draft bacteria TMDL (April 2008) as well as existing and proposed TCEQ water quality criteria for contact recreation.

A7 QUALITY OBJECTIVES AND CRITERIA

Quality Objectives

The objective of the water quality modeling for this project is to use the existing HSFP model to produce a time series of average daily flow (in cubic feet per second), bacteria loadings (in geometric mean of fecal coliform cfu/100 mL), and nutrient loadings (in milligrams per liter mg/L) at various points along the main stem of the Leon River and at major tributaries associated with impaired subwatersheds downstream of Proctor Lake to Lake Belton. Comparisons of simulated bacteria water quality before and after strategies are implemented are conducted to estimate the investment and level of effort needed to attain water quality standards for bacteria. Nutrient load reductions will be evaluated in terms of whether or not nutrient reductions are likely to occur as result of project implementation. Three major technical aspects of this project are to: (1) make predictions on bacteria load reductions by subwatershed, (2) indicate where nutrient reductions are likely to occur in the watershed, and (3) make correlations between fecal coliform and *E. coli* data.

The capacity to simulate water quality for bacteria was achieved by JMA with the HSFP model during the initial development of the draft bacteria TMDL. The draft bacteria TMDL documents the quality of the data, the calibration process, and reports sensitivity of key parameters [see Appendix A – Excerpt from Section 5 of the *Final Modeling Report for Fecal Coliform TMDL Development for Leon River below Proctor Lake, Segment 1221*, (November 2006)]. The appendix presents the development of representative linkages between the sources and the instream bacteria concentrations in the Leon River watershed, and how model parameters were adjusted to accurately represent hydrology and streamflow as well as fecal coliform bacteria loading and instream concentrations. Hydrologic parameters in the TMDL development model were set and adjusted based upon available soils, land use, and topographic data. Bacteria loading parameters in the model were based upon the linkages with the various explicit and implicit sources of bacteria.

The draft TMDL report provides calibration statistics and criteria for the HSPF Leon River model in various tables for hydraulic and water quality parameters. The results indicate that the calibration generally demonstrates compliance with desired criteria and the hydrologic calibration was achieved. The model's largest percent error is associated with the category of summer storm volume. This is understandable, because under summer conditions the prevalence of widely varying scattered thunderstorms is common, and this precipitation is what drives the hydrologic response. Hydrologic calibration was performed by comparing simulated flows to available field data consisting of continuous records of mean daily streamflow. By contrast, water quality calibration usually has to proceed with limited sets of observed data, and the data that is available typically consists of sporadically collected grab samples that represent single points in time. The bacteria simulated results display good visual agreement with the available fecal coliform data. Although the simulated fecal coliform values are for mean daily concentrations, plotted observed concentrations are for the most part instantaneous grab measurements. The calibration results shown in the various tables indicate that the modeled concentrations closely correspond to the observed fecal coliform values.

Sensitivity analyses were conducted to demonstrate the effects of variability in key modeling parameters. This type of analysis provides an indication of the impacts of various assumptions and calibration parameters. The parameters simulated were the bacterial areal loading rate to land surfaces, maximum accumulation of bacteria on the land surfaces, first-order decay rate for bacteria, rate of surface runoff required to remove 90% of the bacteria accumulated on the land surfaces, contributions of bacteria directly to the receiving stream from wildlife, livestock, and leaking septic systems, and bacteria loading from the reservoir. Each of the preceding parameters was analyzed individually at a level of plus or minus 50% of the base value. The results indicated that first-order decay rate for bacteria were the most sensitive (see parameter FSTDEC in Appendix A).

With regard to understanding nutrients, the HSPF model will only be used to summarize loading since it will be not be possible to make predictions on the degree of nutrient reductions. The model will be modified to include factors for different types of land uses that correspond to the amount of nutrients that are discharged for a unit of time. These values are typically based on empirical data that are adjusted during the calibration process based on localized field studies; however, this model will only be used to summarize nutrient loading so the factors will be based on published values that have been peer reviewed and attempts will be made to use factors that are indicative of the study area. These values will not be adjusted because there will be no calibration process as part of this project. Additionally, the application of the graded approach to QA/QC allows a less stringent strategy to dealing with nutrients in the Leon River WPP as nutrients are only a water quality concern, opposed to the bacteria impairment (i.e., relative severity of water quality issues).

The ability to draw a reasonable correlation between two parameters is based on the number of samples and nature of the data. Parsons will assemble available fecal coliform and *E. coli* data for the study area and perform statistical calculations to develop a ratio of fecal coliform to *E. coli*. Parsons will use various statistical methods to determine the strength of the correlation (e.g., T-statistics) to determine if the ratio has sufficient significance. There are several degrees of significance for avoiding errors used in scientific fields (10%, 5% or even 1% error) that are acceptable. Parsons will report the degree of significance of the ratio, and through discussion with the QA officers determine whether a reasonable power was achieved. A ratio will be used to transform fecal coliform model outputs into *E. coli* values. A band of uncertainty will be displayed in the WPP to indicate the variance of simulated values.

The second quality element relates to manipulation of decision variables in the model in order to make predictions of how water quality will change. Quality of the outputs can be associated to the quality of the calibration so long as the simulations are within the range of data used during the calibration. The project team will operate the model within its reasonable range of accuracy. The project team will inform BRA and TSSWCB on how the model was operated to show that decision variables were set to within an acceptable range. Stakeholders will be made aware of limitations. In the event it is necessary to go beyond the reasonable limit, QAOs from all parties will be made aware and the report will indicate that the results must be carefully considered. This course will only be taken if deemed necessary and after consultation with the project team and QAOs.

Quality Criteria

The project team will make sure the model is in the most updated form used by TCEQ in the draft bacteria TMDL. Details of the model calibration are provided in the draft bacteria TMDL report *One Total Maximum Daily Load for Bacteria in the Leon River Below Proctor Lake* which can be accessed from the TCEQ website. Model calibration is defined as how well the model is able to reproduce current observed flow rates and in-stream measurements of bacteria concentration for the period of 2000-2004. For the Leon River, continuous streamflow records are available at the USGS monitoring station 08100500, located at Hwy 84 in Gatesville, near the lower end of the stream segment. Mean daily streamflow records for this station were obtained for application to the modeling analysis. The hydrologic calibration for the Leon River focused upon quantitative comparison between simulated streamflow and observed streamflow at the location of the Hwy 84 USGS gaging station. The following criterion was considered acceptable model calibration: Total flow - 10%, Highest 10% of flows - 15%, Error in storm peaks - 15%, Summer volume - 25%, Winter volume - 25%, Summer storm flow - 50%, and Winter storm flow - 50%.

The water quality calibration for the Leon River was conducted using available fecal coliform data for the Leon River study area for the period 2001-2004. Most of the available data originated from routine monitoring programs. Additional monitoring of bacteria concentrations was conducted in 2003 and 2004. The available data sets were examined closely for input to the model calibration process. The primary calibration benchmark was the achievement of a reasonable visual conformance between simulated and observed fecal coliform values.

The model operation quality criterion is that it be used within its operation range where results are deemed reasonable. This is important so the model is operated within the range from where it is valid to make inferences on water quality improvement. To help the team understand the range of operation the sensitivity analysis prepared as part of the draft bacteria TMDL will be used, to inform the team of parameters with high uncertainty, error, or high variability. If a variable has high variability it indicates that it would be difficult to distinguish a difference between scenarios.

For nutrients the only quality criteria is that coefficients used are those that are published, peer reviewed, or based on local field work. The quality criteria for the bacteria ratio are that either TCEQ data or locally collected data be used for the analysis and that the WPP report the risk of error.

The Parsons QAO will work with JMA, TSSWCB and EPA to assure that the most updated model is being used in its valid range of operation. Appropriate use of the model will allow BRA and the TSSWCB to provide stakeholders valuable information for decision-making on how best to restore water quality in the Leon River and its tributaries.

A8 SPECIAL TRAINING/CERTIFICATION

All personnel contributing to the tasks associated with model calibration, validation, and development have received the appropriate education and training required to adequately perform their duties. No special certifications are required.

A9 DOCUMENTS AND RECORDS

The area where errors can occur is the version control of different models. Parsons and JMA will take precautions to assure strict labeling of files, records, and other mechanisms to assure accurate records and updated files are kept. The document and records that describe, specify, report, or certify activities, requirements, procedures, or results for this project and the items and materials that furnish objective evidence of the quality of items or activities are listed below.

Table A9.1 Project Documents and Records

Document/Record	Location	Retention[1]	Form
QAPP, amendments, and appendices	Parsons	5 years	Paper/Electronic
QAPP distribution documentation	Parsons	5 years	Paper/Electronic
Corrective Action Reports (CARs)	Parsons	5 years	Paper
Stakeholder Interest Summaries/Strategies	Parsons	5 years	Paper
Modeler notebooks	Parsons	5 years	Paper
Model Scenario Development Documents	Parsons	5 years	Electronic
Model Final Run Documents	Parsons	5 years	Paper/Electronic
Progress reports/final report	Parsons/BRA	3 years	Paper/Electronic

[1] after close of project

BRA or the TSSWCB may elect to take possession of records at the conclusion of the specified retention period. The Parsons Project Manager is responsible for retaining project documents and records and will do so to the extent practical both in electronic and hardcopy formats.

QAPP Revision

Until the work described is completed, this QAPP shall be revised as necessary and reissued annually on the anniversary date, or revised and reissued within 120 days of significant changes, whichever is sooner. The last approved versions of QAPPs shall remain in effect until revised versions have been fully approved. If the entire QAPP is current, valid, and accurately reflects the project goals and the organization's policy, the annual re-issuance may be done by a certification that the QAPP is current. This can be accomplished by submitting a cover letter stating the status of the QAPP and a copy of new, signed approval pages for the QAPP.

Amendments

Amendments to the QAPP may be necessary to reflect changes in project organization, tasks, schedules, objectives and methods; address deficiencies and nonconformances; improve operational efficiency; and/or accommodate unique or unanticipated circumstances. Requests for amendments are directed from the Parsons Project Manager to the BRA and TSSWCB Project Manager in writing. The changes are effective immediately upon approval by the TSSWCB Project Manager and QAO, or their designees, and the EPA Project Officer. Amendments to the QAPP and the reasons for the changes will be documented, and copies of the approved QAPP Expedited Amendment form will be distributed to all individuals on the QAPP distribution list by the Parsons QAO. Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process.

B1 SAMPLING PROCESS DESIGN

Not relevant.

B2 SAMPLING METHODS

Not relevant.

B3 SAMPLE HANDLING AND CUSTODY

Not relevant.

B4 ANALYTICAL METHODS

Not relevant.

B5 QUALITY CONTROL

Not relevant.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION AND MAINTENANCE

Not relevant.

B7 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

The HSPF model is fully calibrated and validated. The HSPF model was set up and calibrated using measured flow and in-stream measurements of fecal coliform. The period selected for hydrologic calibration encompassed the years 2000 through 2004. Application of a five-year hydrologic calibration period is generally recommended for application of the HSPF model. This modeling period has good availability of streamflow data, and it incorporates numerous wet, dry, and average flow conditions that typically occur in the study area. The study period selected for water quality calibration was 2001 through 2004. This simulation period incorporates a full range of seasonal and hydrologic conditions in the study area. A sensitivity analyses was conducted to demonstrate the effects of variability in key modeling parameters. This type of analysis provides an indication of the impacts of various assumptions and calibration parameters. See Appendix A for details on the calibration process. This calibrated model will be manipulated to reflect the implementation of management strategies.

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Not relevant.

B9 NON-DIRECT MEASUREMENTS

As discussed above, the development of the WPP relies on manipulating decision variables and using ratios. Because much of the historical data listed below was collected by federal, state and local agencies and has already been subjected to QA/QC procedures, the numeric values of the data used in the HSPF model and empirical work are accepted at face value. This WPP considers that these data were of high quality and the best available for the development of the HSPF model for the draft bacteria TMDL.

Meteorological, in-stream flow, wastewater flow and loading, GIS and measured water quality data were collected as raw data. The following are descriptions of the non-direct measurement data sources to be used in the WPP:

- Stream reaches characteristics related to flow rate, surface area, depth, volume, a unique length, slope, and Manning's "n" were obtained from digital elevation records based upon 7.5 minute USGS topographic maps, literature values, hydraulic function tables (F-tables) used in HSPF, available physical data from USGS streamflow gaging records, and Proctor Lake flow releases from U.S. Army Corps of Engineers.
- Precipitation data were obtained from the National Weather Service. Records of daily rainfall for the National Weather Service co-op stations in Dublin, Hamilton, and Hurst Springs and records of hourly rainfall for the National Weather Service co-op stations in Flat and Proctor were the primary source of data for modeling. The daily rainfall stations were disaggregated using the hourly rainfall data from either the Flat or Proctor stations.
- Land use data for the watersheds are based on the 2001 NLCD. Derived from the early to mid-1990s Landsat Thematic Mapper satellite data, the NLCD is a 21-class land cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 meters and mapped in the Albers Conic Equal Area projection, NAD 83.
- Fecal coliform, *E. coli* and nutrient data have been collected by various entities, including the BRA, ARS, Texas AgriLife Research and TCEQ, at several monitoring stations on the Leon River and its tributaries. Supplemental data were collected in 2003 and 2004 as part of the TMDL development and ARS and Texas AgriLife Research continue collecting *E. coli* and nutrient data at select stations in the watershed.
- Point sources, such as municipal wastewater treatment facilities, can contribute fecal coliform bacteria loads to surface water streams through effluent discharges. These point sources are permitted through the TPDES program that is managed by the TCEQ.
- The number of septic systems in the study area was estimated using information from the 1990 U.S. Census, which included a question regarding the means of household sewage disposal. Unfortunately, this question was not posed in the 2000 Census. Based on the 1990 data, the number of septic systems in the study area was estimated by intersecting the geographic census blocks with the study area watershed.
- Livestock population estimates were based upon the 2002 Agricultural Census, TCEQ concentrated animal feeding operation permits, and TSSWCB water quality management plan records. The types of livestock explicitly included in the present analysis included cattle, horses/donkeys, sheep/goats, hogs, and chickens. Dairy cattle numbers were estimated based upon numbers for each subwatershed provided by TCEQ and TSSWCB.

- The predominant wildlife species to be included in the modeling analysis were determined by wildlife biologists, literature values, site visits, and data from Texas Parks and Wildlife Department.
- Data regarding fecal production rates and fecal coliform density were based upon values reported in the EPA Fecal Coliform Loading Estimation Tool.

The HSPF model was set up and calibrated using measured flow and in-stream measurements of fecal coliform. The period selected for hydrologic calibration encompassed the years 2000 through 2004. Application of a five-year hydrologic calibration period is generally recommended for application of the HSPF model. This modeling period has good availability of streamflow data, and it incorporates numerous wet, dry, and average flow conditions that typically occur in the study area. The study period selected for water quality calibration was 2001 through 2004. This simulation period incorporates a full range of seasonal and hydrologic conditions in the study area. A sensitivity analyses was conducted to demonstrate the effects of variability in key modeling parameters. This type of analysis provides an indication of the impacts of various assumptions and calibration parameters.

B10 DATA MANAGEMENT

Systems Design

Parsons uses laptop personal computers and desktop personal computers. The Parsons computer network runs on a Windows operating system. The current version of HSPF operates in the Windows environment. Model inputs and outputs are compatible with the following databases including Microsoft® Excel, Microsoft® Access, and spatial data in ESRI® ArcView 9.2.

Backup and Disaster Recovery

Parsons has a reliable network server and offsite backed up system that performs daily, weekly, and monthly backups to a tape drive. In the event of a catastrophic systems failure, the tapes can be used to restore the data in hours. The backup facility is located offsite which protects from fire, theft, and other localized disasters. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

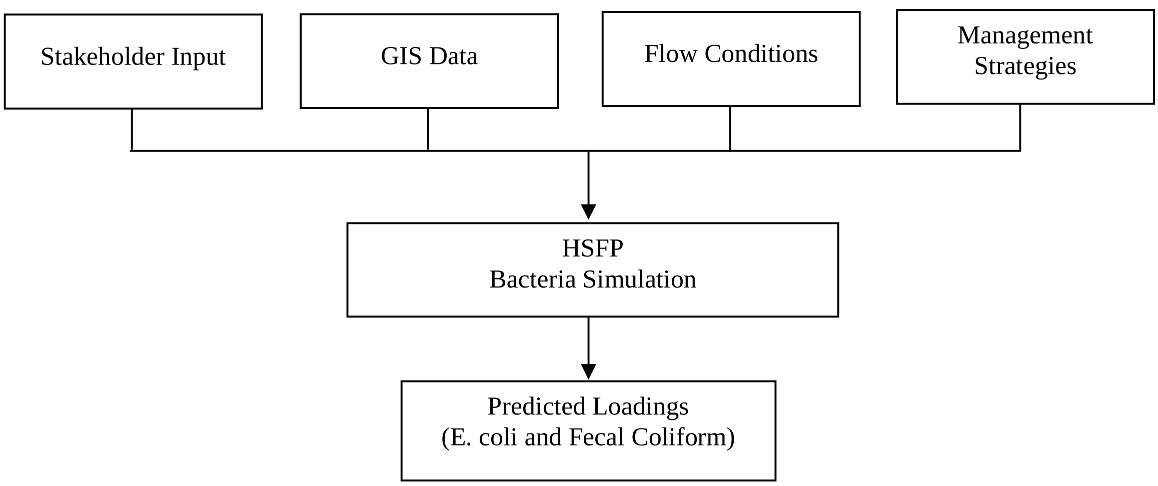
Archives and Data Retention

Electronic and paper file data will be stored in accordance with the retention times listed in Table A9.1. As Parsons has sufficient electronic storage space, all electronic data will be stored on servers. Original material provided over the course of the WPP will be stored on CDs and DVDs in a climate controlled room at the Parsons Austin, TX, office.

Information Dissemination

Information exchange will occur between the project team, stakeholders, and various government agencies. The model will be operated to reflect stakeholder interest, changes in loading estimates at a subwatershed scale, various flow conditions, and implementation of management strategies. Figure B10.1 is simple schematic of the flow information.

Figure B10.1 Information Dissemination Diagram



Relevant project information will be provided by Parsons to the BRA Project Manager and made available to stakeholders at periodic meetings. BRA will provide relevant project information through their website. In some cases transmission of large electronic files may be disseminated from Parsons to BRA or TSSWCB through the Parsons FTP site. Instructions will be provided, by Parsons, to allow secure access of files.

C1 ASSESSMENTS AND RESPONSE ACTIONS

Project staff will evaluate model use according to criteria discussed in Section A7 and will follow-up with any concerns that may arise. Results will be reported to the Parsons Project Manager in the format provided in Section A9. If desired level of quality is not met, corrective action will be recommended by Parsons QAO and Project Manager to assure the model is being used properly. If model outputs continue to conflict with model inputs, the Parsons QAO will work with BRA and TSSWCB to define implications to the project scope and schedule and arrive at an agreeable compromise.

The Parsons Project Manager is responsible for implementing and tracking corrective action procedures as a result of audit findings. Records of audit findings and corrective actions are maintained by the TSSWCB Project Manager, the BRA QAO and Parsons QAO. Corrective action documentation will be submitted to the TSSWCB Project Manager with quarterly progress reports.

If the procedures and guidelines established in this QAPP are not successful, corrective action is required to ensure that conditions adverse to quality data are identified and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem(s). CARs will be filled out to document the problems and the remedial action taken. Copies of CARs will be included with quarterly progress reports. The CARs and quarterly progress reports will discuss any problems encountered and solutions made. These reports are the responsibility of the Parsons QAO and Project Manager and are available for review upon request.

C2 REPORTS TO MANAGEMENT

Quarterly progress reports will note activities conducted in connection with this water quality modeling project, items or areas identified as potential problems, and any variations or supplements to the QAPP. CARs will be utilized when necessary (Appendix B). CARs will be maintained in an accessible location for reference at Parsons. CARs that result in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in an update or amendment to the QAPP.

D1 DATA REVIEW, VERIFICATION AND VALIDATION

The data review, verification, and validation process identifies whether the final data package for the Leon River WPP modeling conforms to the quality standards of the TSSWB and EPA. Only those data that are supported by appropriate QC data will be considered acceptable for use in model validation. Validation and verification criteria for the modeling, as defined by this QAPP, are the standards that are used to determine whether the modeling results are sufficient for drawing conclusions related to the DQOs in Section A7.

D2 VERIFICATION AND VALIDATION METHODS

The HSPF model is the core decision support tool used to advance the development of the WPP. The original calibration process included a verification and validation processes. Since HSPF model was calibrated during the development of the draft bacteria TMDL it will not be re-calibrated. The draft TMDL report indicates that, for an independent set of data, the model performed satisfactorily. Parsons will upload the existing model, make slight modifications, and validate the model using the same set of validation data.

Parsons will adopt the model and upload it to the Parsons server. The Parson QAO will verify that the most updated model is uploaded. Some spreadsheets or database interfaces may be developed to interact with decision variables and outputs from the model. The development of these auxiliary devices will be verified to assure that they are interacting with the appropriate model parameter. The model results obtained when using these devices will be validated against known results of the calibrated model. A verified and valid result would be one that would closely mimic the results of the latest draft bacteria TMDL results. These results will be provided as described in Section A9.

As described in Section A7, Parsons will verify that the most updated model is uploaded and once modified, verify that the model produces expected results. The validation and verification process will be conducted by the Parsons Lead Modeler.

D3 RECONCILIATION WITH USER REQUIREMENTS

The WPP process is a series of iterations to:

- understand stakeholder interests (i.e., implementation strategies they support);
- adjust the model to reflect those specific strategies;
- disseminate the results so that a WPP can be prepared that conforms to the nine key elements; and
- restore water quality in the Leon River watershed.

The principal users of the HSPF model are not modelers but rather stakeholders. As such, either through Parsons staff or via direct interaction with the model, stakeholders will be provided a way to access to the model. Decision variables will be set according to stakeholder preferences in order to provide the TSSWCB, and local stakeholder groups with information that pertains to watershed characteristics and the reductions achieved over time as a result of committed efforts.

The Leon River flow and watershed loadings, as determined by HSPF, will be provided to stakeholders, BRA, and TSSWCB for review in a clear and concise format. Simple graphs and tables will be used to represent integration. Simple values, such as reduction percentages, normalized concentrations, and achievement of goal percentages, will be used to facilitate stakeholder comprehension of water quality attainment. Outputs will also include a time series of average daily flow and bacteria loadings at points along the Leon River and its tributaries.

APPENDIX A

Excerpt from Section 5 of the *Final Modeling Report for Fecal Coliform TMDL Development for Leon River below Proctor Lake, Segment 1221* (November 2006)

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5.0 WATERSHED MODELING

Establishing the relationship between instream water quality targets and the source loadings of bacteria is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. The link can be established through a variety of techniques, ranging from qualitative assumptions based on scientific principles to sophisticated mathematical modeling techniques. In the development of a TMDL for the impaired reach of the Leon River, the relationship was defined through computer modeling based upon data collected throughout the watershed. Monitored flow and water quality data were used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, setup, and model application are discussed.

5.1 MODELING FRAMEWORK SELECTION

The US EPA Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) system Version 3.1 (EPA, 2004) and the Hydrologic Simulation Program - Fortran (HSPF) water quality model were selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. BASINS is a multipurpose environmental analysis system for use in performing watershed and water quality-based studies in a wide variety of areas. BASINS includes a geographic information system (GIS) for integration of landscape information, including land uses, monitoring stations, point source locations, and watershed delineation. The HSPF model is a continuous simulation model for watershed hydrology and water quality. The model can account for both point source loadings and non-point source loadings in the watershed. HSPF includes simulation of the receiving stream that receives mass loadings from the watershed. The features of HSPF that led to its selection are summarized below:

- Full capabilities for long-term simulation of hydrologic response
- Full capabilities for simulation of dynamic mass transport from the watershed surface
- Adaptability to urban and non-urban land uses
- Built-in receiving water module with instream source/sink terms
- Successful application to bacteria TMDLs demonstrated throughout the country.

The HSPF model is comprehensive in its treatment of the watershed. Land surfaces are simulated as either pervious or impervious land segments, labeled as PERLNDs and IMPLNDs, respectively. The model is driven by input of precipitation data. Runoff in response to rainfall is generated on the surfaces of the PERLNDs and IMPLNDs. Pollutant mass is also generated on these land surfaces and is available to be washed off by the runoff. The runoff volume and the pollutant mass volume are transported to the nearest channel, referred to as a RCHRES. Segmentation of the receiving stream is constructed as a series of RCHRES segments, with each transporting flow and mass to the next downstream segment, in the same configuration as the real stream segments in the physical world.

5.2 MODEL SETUP

Segment 1221 of the Leon River watershed was subdivided into several subwatersheds to adequately represent the spatial variation in fecal coliform sources, watershed characteristics, hydrology, and the location of water quality monitoring and streamflow gaging stations. Since Proctor Reservoir lies at the upstream end of segment 1221, boundary conditions for flow and fecal coliform concentration were created from dam release time series obtained from the US Corps of Engineers.

BASINS provides standard 8-digit Hydrologic Unit Code (HUC) boundaries developed by the USGS. The Leon River watershed boundary exists within HUC #12070201. This watershed was segmented to delineate the hydrologically connected subwatershed boundaries. These subwatersheds were delineated by using topographical data contained in a Digital Elevation Model (DEM), along with published USGS topographical mapping.

BASINS provides a processed DEM with a resolution of 90 meters. In order to get a better resolution in the subwatershed boundaries, a DEM from TNRIS with a resolution of 30 meters was used. This improved resolution provided more accurate topography of the study area.

Segment 1221 of the Leon River watershed was subdivided into 15 subwatersheds, including distinct subwatersheds for the tributaries such as Walnut, Resley, and Plum Creeks along with the South Leon River, as shown in Figure 5-1. The spatial division of the watershed into subwatersheds allows for a more refined representation of pollutant sources and a more realistic description of hydrologic factors in the watershed. The schematic of the subwatershed network developed in BASINS is shown in Figure 5-2. Each of the 15 subwatersheds has associated with it a defined stream reach (RCHRES segment). The numbering of the RCHRES segments and subwatersheds followed the pattern 10, 20, 30, …through 150 in an upstream to downstream sequence.

As the work was underway, an additional RCHRES segment was incorporated. RCHRES 41 was added as a hydraulic segment downstream of RCHRES 30. As a hydraulic segment, RCHRES 41 does not have a watershed assigned to it; however, flow and mass from two other segments enter and flow through it. It was provided to better reflect concentrations at FM 1702, one of the key water quality accounting points in the model formulation.

The stream reach that has been designated as impaired by bacteria constitutes only a portion of the complete watershed of segment 1221 of the Leon River. According to TCEQ, the impaired reach extends from just below Hwy 281 near Hamilton upstream to the confluence with Indian Creek, just above FM 1476 near Gustine, a distance of approximately 44 miles. In the model, this impaired reach is represented by the series RCHRES 30, 41, 50, and 70 on the mainstem of the Leon. Addition of the contributing headwater reach and tributary reaches pulls in RCHRES 10, 20, and 40. Therefore, the complete impairment zone is represented by the composite watershed of RCHRES 10 through 70, which constitutes roughly the upper half of the Segment 1221 watershed.

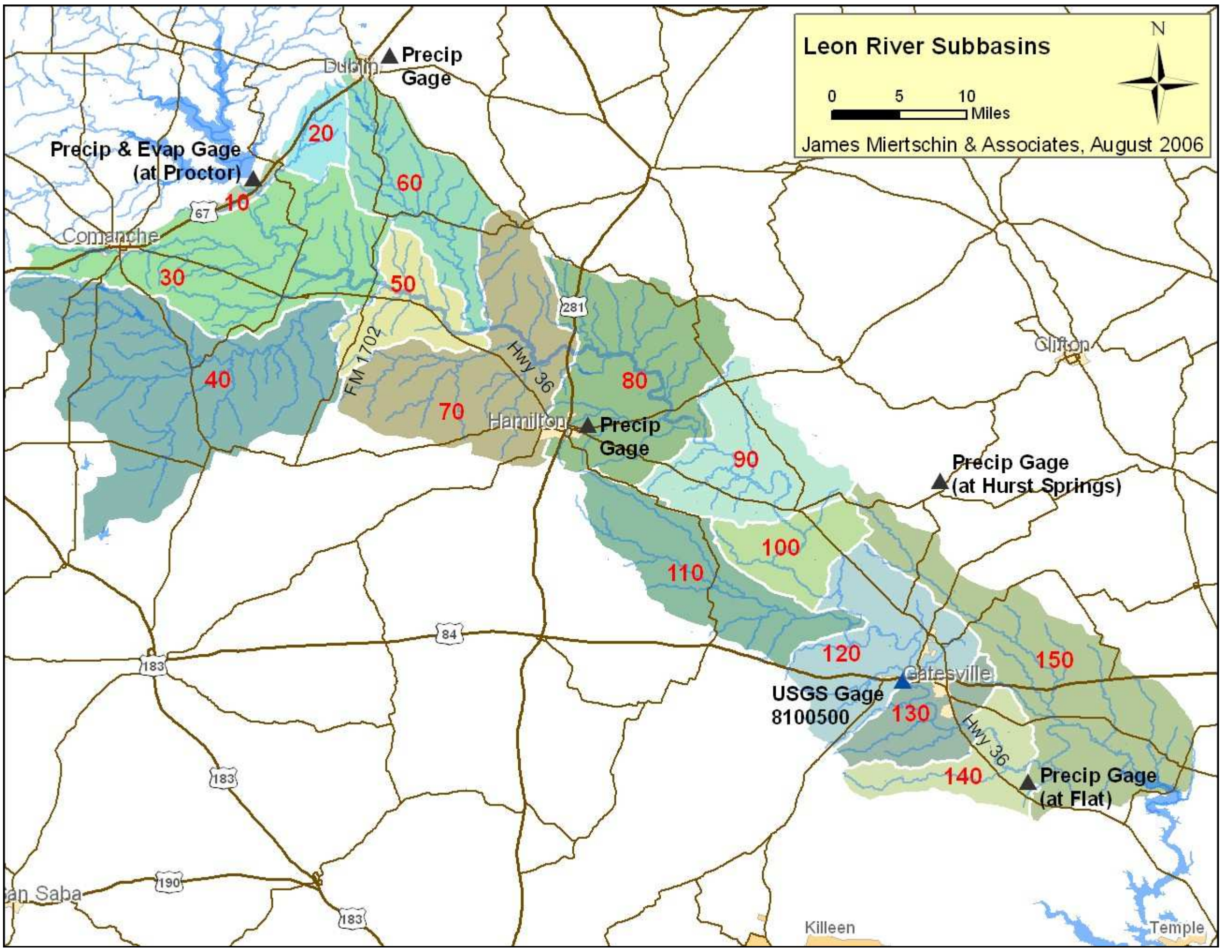

Figure 5-1 Leon River Subwatersheds

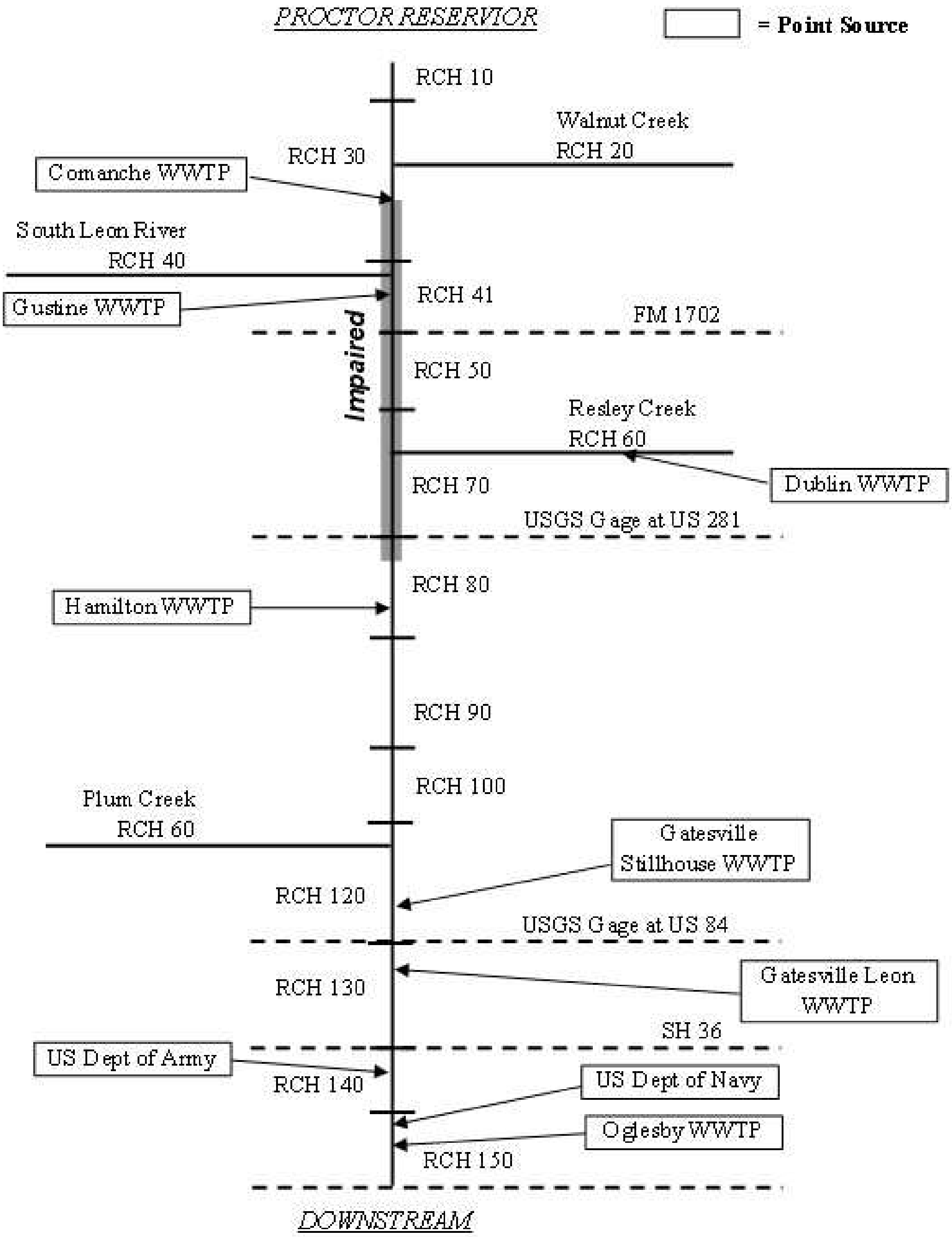

Figure 5-2 Schematic of Leon River

Land use data for the watersheds were based on the USGS National Land Cover Dataset (NLCD) found in BASINS. Derived from the early to mid-1990s Landsat Thematic Mapper satellite data, the National Land Cover Data (NLCD) is a land cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 meters. Table 5-1 shows land use coverages provided by NLCD and the consolidated land use list employed in the present study.

Table 5-1 Land Use Coverages used in Model

Consolidated Land Uses	BASINS Land Uses
Residential	Low Intensity Residential
	High Intensity Residential
Commercial/Industrial	Commercial/Industrial/Transportation
	Quarries/Strip Mines/Gravel Pits
Rangeland	Bare Rock/Sand/Clay
	Deciduous Shrubland
	Grassland/Herbaceous
	Pasture/Hay
	Other Grasses (Urban/recreational)
	Emergent Herbaceous Wetlands
Forest	Deciduous Forest
	Evergreen Forest
	Mixed Forest
	Woody Wetlands
Crop	Planted/Cultivated (orchards, vineyards, groves)
	Row Crops
	Small Grains

Multiple land use types were represented in the model. The five fundamental land use types included rangeland, forested land, crop/pastureland, residential land, and commercial/industrial land. Each land use type could have both PERLND and IMPLND segments. With each PERLND and IMPLND type were associated specific hydrologic and mass loading parameters. Some of the parameters were developed from site-specific data sources, while others were developed via the calibration of the model. An inventory of the various land use types and the area of each type within each subwatershed is displayed in Table 5-2 for the Leon River watershed.

Table 5-2 Various Land Use Types and Areas for Leon River Watershed

Land Use Type	Area (acres)	% of Total
Pervious:		
Forest	144,029	16.3%
Crop/Pastureland	87,813	10.0%
Rangeland	627,906	71.2%
Residential	3,886	0.4%
Comm/Ind	2,731	0.3%
WAF1	6,159	0.7%
WAF2	7,344	0.8%
Impervious:		
Residential	686	0.1%
Comm/Ind	1,821	0.2%
Total	882,375	100%

5.3 SOURCE REPRESENTATION

Both point and nonpoint sources were represented in the model. Point sources were added to the model as time-series of pollutant (bacteria) and flow inputs to the stream. Land-based nonpoint sources were represented in the model through an accumulation of pollutant mass on the land surface, where some portion is available for washoff and transport with runoff. The amount of accumulation and availability for transport vary with land use type. The model allows for a maximum accumulation to be specified.

Some nonpoint sources, rather than being land-based, were represented in the model as being deposited directly to the receiving stream, for example defecation by animals directly to a stream. These sources were labeled as “direct sources” in the model, and they were modeled in a manner similar to point sources. As such, they do not require a runoff event for delivery to the stream.

5.3.1 Point Sources

Existing point sources were explicitly included in the model. In the Leon River watershed, these point sources consisted of several municipal wastewater treatment facilities. Records for discharges from these outfalls during the simulation period were obtained from the TCEQ and the municipalities. The wastewater treatment facilities that include disinfection process units are generally not required to monitor fecal coliform concentrations, so the daily discharge of fecal coliform was estimated to be relatively low for these facilities. One of the wastewater treatment facilities uses facultative lagoons and is currently required to monitor fecal coliform concentrations five times per week and report their monthly averages to TCEQ. A time series for daily discharge flow and fecal coliform concentration was included for each municipal point source.

In addition, a time series was developed for each municipal discharger in the impaired reach to represent potential overflows under wet weather conditions. These time series represent the relatively uncontrolled phenomena that can and do occur with municipal wastewater systems: passage of peak flows through the treatment facility with diminished disinfection, overflows from lift stations, breaks in sewer lines, and exfiltration from sewer lines. The concept of the overflow loading was developed after review of TCEQ compliance reports and data for the municipal systems. The available information indicated that occasional discharges of raw sewage or effluent with relatively high bacteria concentrations do occur, but there is no documentation to define at what frequency, magnitude, and duration the events occur.

These overflow time series were calculated only for the days receiving more than 0.5 inch of precipitation. The flow rate of the overflow scenario was taken to be 3 times the reported daily flow rate on the assigned day of the overflow. This peak flow for the wastewater treatment plant was assumed to persist over a 6 hour period. The fecal coliform concentration during these overflow events was assumed to be 30,000 org/100 mL. This concentration should be a reasonable approximation of high-flow bypasses from either the treatment plant itself or from a lift station or collection system source; though the fecal coliform concentration could be substantially greater if raw sewage is released. There are many uncertainties regarding this overflow assumption, but the present formulation does accomplish the objective of incorporating a mechanism for simulation of high-flow releases from the municipal point source sector.

5.3.2 Failing Septic Systems

Septic systems provide the potential to deliver bacteria loadings to receiving streams via two mechanisms. First, drainfield failures or overloading could result in uncontrolled, direct discharges to the streams. Such failures would not be expected to be common in the study watershed, but they could occur in reaches with older homes located near a watercourse or in remote areas. As a second mechanism, an overloaded drainfield could experience surfacing of effluent, and the pollutants would then be available for surface accumulation and washoff.

The total number of septic systems in the watershed was estimated from available US Census data. A nominal assumed failure rate of 8 - 12% was applied, as discussed in Section 4.2.1. For this analysis, only the potential direct discharges from failing septic systems were considered in the model. Fecal coliform loadings were calculated based upon the fecal density of septic effluent and the flow from a household assuming a population of 3.0 persons per household.

The approach represents a method to incorporate explicitly bacteria loadings from failing septic systems into the modeling analysis. The precise number of actual failures and their loadings within the study area is unknown, and no data base is available to accurately quantity this mechanism. Instead, the present approach provided an input to the model, which could be adjusted via the calibration process, to account for some measure of loadings from this particular potential source of bacteria.

5.3.3 Livestock

Fecal coliform bacteria produced by livestock can enter surface waters through several pathways: washoff of waste deposited on the land surface, washoff of concentrated waste from land application sites, direct deposition of waste material in the stream, and potential discharges from animal confinement areas or waste handling systems. Each of these pathways can be accounted for in the model. The population of each livestock species considered in the modeling analysis was distributed among subwatersheds based upon the total area of forest and rangeland in each subwatershed. This livestock inventory was shown in Table 4-3.

Grazing animals contribute fecal coliform bacteria to the land surface that is subsequently available for washoff to surface waters during storm events. The mechanism for the contribution was shown schematically in Figure 4-3. The inventory of livestock animals and their waste loadings was analyzed using a modification of the EPA's Fecal Tool spreadsheet (EPA, 2000). This spreadsheet tool includes the necessary specifications of waste generation, fecal coliform density, and bacteria counts per animal unit for calculation of loads. It enables calculation of loading parameters for direct input into the modeling analysis, specifically, fecal coliform accumulation rates (in count/acre/day) and the maximum accumulation (in count/acre).

Dairy cattle populations for each subwatershed were estimated from data provided by the TCEQ and TSSWCB. There is no information available describing what fraction of the cattle population sends manure as a solid for land application versus as a liquid for sprinkler application. Another complication is the fact that some portion of the manure generated in the watershed is hauled out of the watershed for composting. For the present study, it was initially assumed that the cattle population was divided evenly between the two forms of disposal. Two disposal area categories were established in the model, namely, WAF1 and WAF2. WAF1 represents land surfaces that receive solid manure application. WAF2 represents land surfaces that receive sprinkler waste application. Theoretically, the number of cattle that contribute waste to WAF1 or WAF2 could be used to determine distinct bacteria loading factors for the two types of land use in each subwatershed. For the present analysis, in recognition of the many uncertainties regarding the number of cattle, their manure generation rate, the bacterial content of the manure, and the ultimate disposal location, it was assumed that the two WAF categories would be assigned similar bacterial loading rates for application in the modeling analysis. The two WAF categories will remain in the modeling formulation as a feature that could potentially be differentiated in future work.

Direct contributions from livestock were also included as inputs in the modeling analysis. It was assumed that grazing cattle and horses spent a small fraction of their time directly in the stream and therefore the potential exists for direct deposition. Other livestock, sheep/goats and hogs, were assumed to deposit all feces on pasture and forested areas. The potential direct contribution was estimated for each subwatershed using the parameters contained in the Fecal Tool spreadsheet. Results from this analysis were provided in terms of direct bacteria loadings (in counts/day) per stream segment. The analysis also enables calculation of the associated flow rate from these direct animal contributions, but this flow rate was not included in the hydrologic balance of the present analysis because of its extremely small size.

5.3.4 Wildlife

Wildlife species explicitly included in the modeling analysis included deer, raccoons, opossums, feral hogs, and ducks/geese. The population of each wildlife species was developed using estimated population densities per square mile of habitat and the total area of suitable habitat available in each subwatershed. This wildlife inventory was shown in Table 4-6. As with livestock, there are two mechanisms considered for bacteria loadings from wildlife to be transported to the stream segment. First, wildlife deposit waste on land surfaces that accumulates and is subsequently available for washoff with runoff. Second, wildlife may deposit waste directly into the stream.

Wildlife loadings were calculated within the framework of the modified EPA Fecal Tool spreadsheet (EPA, 2000), in a manner analogous to that applied for livestock. For specification of the number of animals that may be engaged in direct deposition to the stream, the area of a riparian habitat corridor approximately 300 feet in width was calculated, and the prescribed animal density was applied to this riparian area in order to provide an initial estimate of the near-stream populations. Then, a small fraction of this population was assumed to directly deposit waste in the stream. A seasonal component for the frequency of wildlife visitation to the stream was developed as a function of mean ambient water temperature, with the assumption that water visitation would be more likely under warm-weather conditions.

5.3.5 Urban Loadings

Some of the study area is comprised of the urban landscape of residential, commercial, and industrial areas. While the initial estimates of bacteria mass loadings for non-urban land use areas were developed based upon an inventory of septic systems, livestock, and wildlife, the myriad of sources in the urban areas were represented by typical loading rates from literature sources (EPA, 2000). These loading rates provided an initial estimate, and the final specification of loading parameters was derived via calibration exercises. These generalized urban loading rates thus represent bacteria loadings that may be derived from urban wildlife, pets, septic system failures, sewer system leaks, discharges of varied nature and composition, and any other sources that may be present.

5.3.6 Proctor Lake Releases

At the upstream boundary of the simulated reach in the model, flow and bacteria enter the river through releases from Proctor Lake. Flows were based on historical reservoir release data provided by the United States Army Corps of Engineers (USACE). Bacteria levels were based on historical monitoring data for bacteria at the dam floodgate (TCEQ monitoring station #11935). Since bacteria concentrations at the dam are only monitored on certain days, unmonitored days were assigned bacteria concentrations based on the closest available sample in the temporal record.

5.3.7 Incorporation of Sources in the Model

The preceding representations of bacteria sources were incorporated in various ways into the modeling framework. There were five fundamental categories of loads in the analysis:

- Point source loads
- Septic loads
- Direct source loads
- Land-based washoff loads
- Upstream loads

Point Source Loads

The category of point source loads is represented in the model in a straightforward manner. A time series of daily flow and bacteria for each point source was developed and these sources are then input directly into the specific RCHRES where each is situated. The bacteria loading time series is provided in units of org/day, and is input into the model in units of 10^6 org/hr. This source is a continuously discharging source of bacteria that occurs on a daily basis. As described previously, the point source component consists of a routine daily discharge load along with a synthesized overflow load. The routine point source load occurs daily with no association with rainfall runoff; therefore it is a source of bacteria under all stream flow conditions. Conversely, the overflow point source load occurs sporadically under conditions of high rainfall only.

Septic Loads

The category of septic loads is represented in the model as a continuous daily discharge of bacteria in each reach, similar to the point source mechanism. Because the flow contribution is negligibly small, only the bacteria contribution is represented in a time series. The septic loading time series is provided in units of org/day. The septic load category discharges with no association with rainfall runoff events; therefore it is a source of bacteria under all stream flow conditions.

Direct Source Loads

The direct source category captures bacteria loadings that are discharged to the stream on a continuous basis, with no association with rainfall runoff. The loading time series was provided in units of org/day. A time series for direct source bacteria discharge was developed for each reach, based upon assumptions described previously for direct wildlife and livestock deposition to the stream. Because the flow contribution is negligibly small, only the bacteria contribution was represented in a time series. These time series values were applied as initial estimates only and factors were applied to adjust the direct source values up or down in the calibration process. The direct source category was the primary source variable that was adjusted in the model calibration process to achieve an acceptable water quality calibration under baseflow conditions in the receiving stream. With this procedure, the initial estimates based upon presumed animal populations were not critical to the analysis. Even though the initial estimates were developed based upon presumed direct animal defecation, this category of direct source loads would also capture any other continuous daily releases of bacteria that may be occurring in the stream but that are difficult to quantify. For example, in some locations, leaking sewer mains could contribute a steady source of bacteria to the stream that would constitute a direct source component.

Land-Based Washoff Loads

The land-based washoff loads are expected to be the source of the largest quantity of bacteria. As the category name implies, these loads represent bacteria that are deposited on the land surface and are subsequently washed off the land surface to the receiving stream under conditions of rainfall runoff. As such, loads from this category exert an influence on instream bacteria concentrations primarily under runoff and high flow conditions, and they would not be expected to be a substantial contributor to instream bacteria on a daily basis.

The land-based washoff loads are formulated as loading rates of bacteria to the land surface on a daily basis, along with a limit on the total amount of bacteria that can be stored on the land surface at any point in time. Initial estimates (starting values) for these loading rates were developed based upon assumptions related to wildlife and livestock populations that were described previously. However, these loading rates were ultimately set based upon adjustments during the model calibration process. Therefore, the initial assumptions regarding animal populations were not critical to the process, serving only to establish a hypothetical loading rate based upon assumed population numbers.

Upstream Loads

The releases from Proctor Lake were input into the modeling analysis as time series for flow and bacteria. This category is a continuous source of bacteria, operative on a daily basis.

5.4 STREAM CHARACTERISTICS

Application of the HSPF model requires that stream reaches be represented by constant characteristics that relate flow rate, surface area, depth, and volume. Each reach also is described by a unique length, slope, and Manning's "n" coefficient for resistance to flow. The length and slope were obtained from digital elevation records based upon 7.5 minute USGS topographic maps, as well as from observations from paper copies of the same maps. Manning's *n* was estimated based upon literature values.

The hydraulic function tables (F-tables) used in HSPF describe the relationship among flow rate, surface area, depth, and volume in each stream reach. The flow and geometry relationships were developed based upon available physical data from USGS streamflow gaging records. These records were analyzed to develop a typical cross section and relationships at the gaging station location, then the data were extrapolated upstream and downstream to provide coverage of the entire reach. This extrapolation was based on the overall slope of the stream channel in each subwatershed, but the F-tables were modified on a reach-by-reach basis in recognition of other available data, such as field measurements of cross sections and observations of channel characteristics.

5.5 SELECTION OF REPRESENTATIVE MODELING PERIOD

The selection of a representative modeling period was based upon the availability of stream flow and water quality data and the need to represent critical hydrological conditions. With respect to streamflow data, records for the Leon River at Gatesville were available from October 1950 to the present. The most comprehensive time period for reported fecal coliform concentrations consists of the period from 2001 to the present. Some data are available prior to that time; however, it was assumed that the more recent data would be more representative of current water quality conditions. The period selected for hydrologic calibration encompassed the years 2000 through 2004. Application of a five-year hydrologic calibration period is generally recommended for application of the HSPF model. This modeling period has good availability of streamflow data, and it incorporates numerous wet, dry, and average flow conditions that typically occur in the study area. The period selected for water quality calibration was 2001 through 2004. This simulation period incorporates a full range of seasonal and hydrologic conditions in the study area.

5.6 MODEL CALIBRATION PROCESS

In order to develop a representative linkage between the sources and the instream water quality response in the Leon River watershed, model parameters were adjusted to accurately represent hydrology and streamflow as well as fecal coliform bacteria loading and instream concentrations. Hydrologic parameters in the model were set and adjusted based upon available soils, land use, and topographic data. Bacteria loading parameters in the model were based upon the linkages with the various explicit and implicit sources described previously.

5.6.1 Hydrologic Calibration

Hydrologic calibration entails adjustment of pertinent model parameters in order to achieve agreement between simulated streamflow rates and observed streamflow rates. Ideally, a stream to be modeled will have one or more continuous streamflow gaging stations with long-term records available. These records would supply the data base of observed flows for a specific location within the stream segment.

There were several model parameters that were adjusted to achieve hydrologic calibration. Key parameters included the following:

LZETP - evapotranspiration from the root zone
AGWRC - recession rate for groundwater
IRC - recession rate for interflow
LSUR - length of overland flow plane
UZSN - soil moisture storage in the upper zone
LZSN - soil moisture storage in the lower zone

CEPSC - interception storage on pervious surfaces
INFILT - infiltration capacity of the soil
INTFW - soil water contributing to interflow
DEEPFRC - loss to lower groundwater storage
RETSC - interception storage on impervious surfaces

For the Leon River, continuous streamflow records are available at the USGS monitoring station no. 08100500, located at Hwy 84 at Gatesville, near the lower end of the stream study segment. Mean daily streamflow records for this station were obtained for application to the modeling analysis.

The hydrologic calibration for the Leon River focused upon quantitative comparison between simulated streamflow and observed streamflow at the location of the Hwy 84 USGS gaging station. In the Leon River model, this location corresponds to RCHRES 120. For the present analysis, the calibration period encompassed the years 2000 through 2004. Results for the entire calibration period are displayed in Figure 5-3. This figure shows simulated flow and observed flow as a function of time.

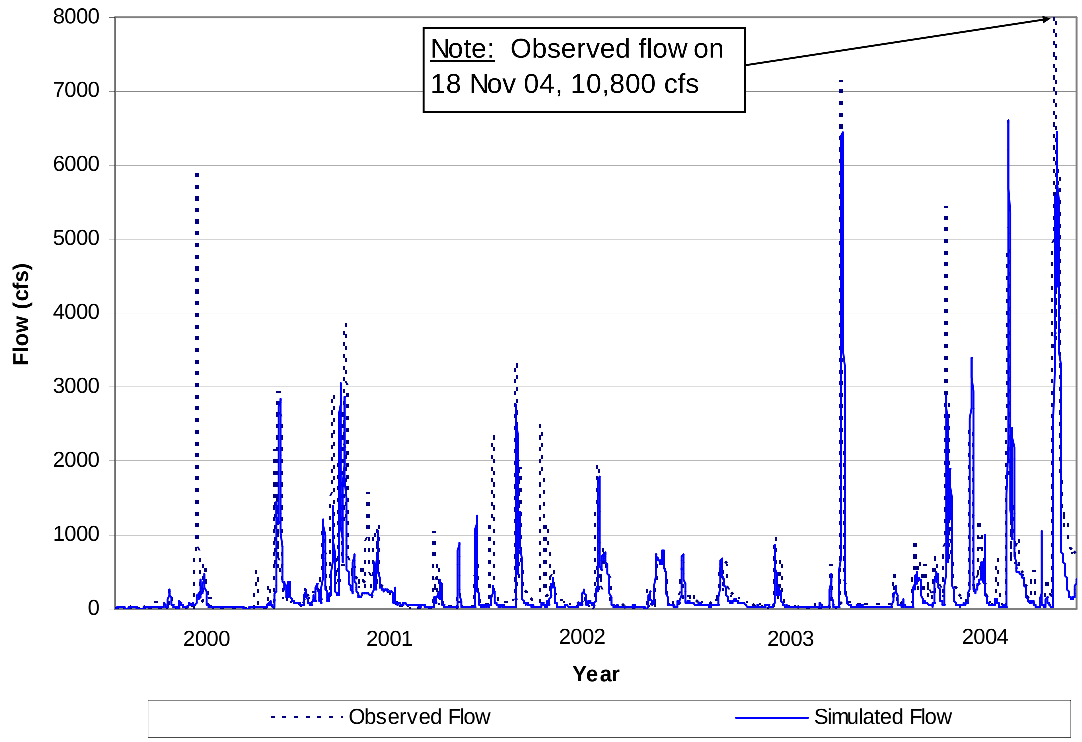

Figure 5-3 Hydrologic Calibration Results for Leon River at Hwy 84, 2000-2004

To provide some additional visual resolution, results are also presented for each individual simulation year in Figures 5-4 through 5-8. Precipitation records for the gage at Flat (see Figure 5-1) are also shown in these figures.

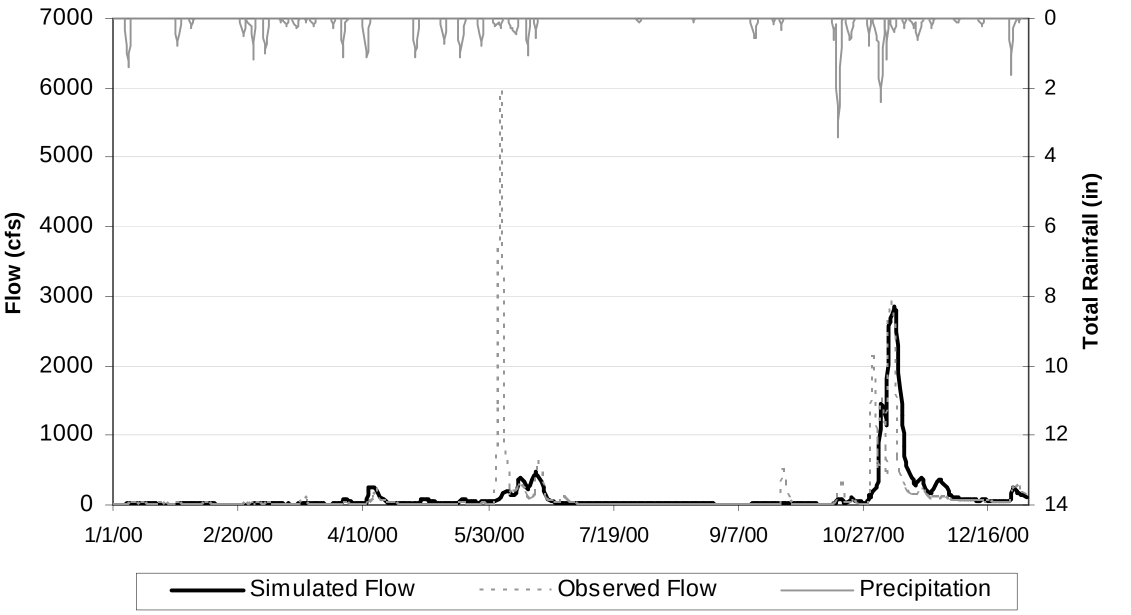

Figure 5-4 Hydrologic Calibration Results for Leon River at Hwy 84, 2000

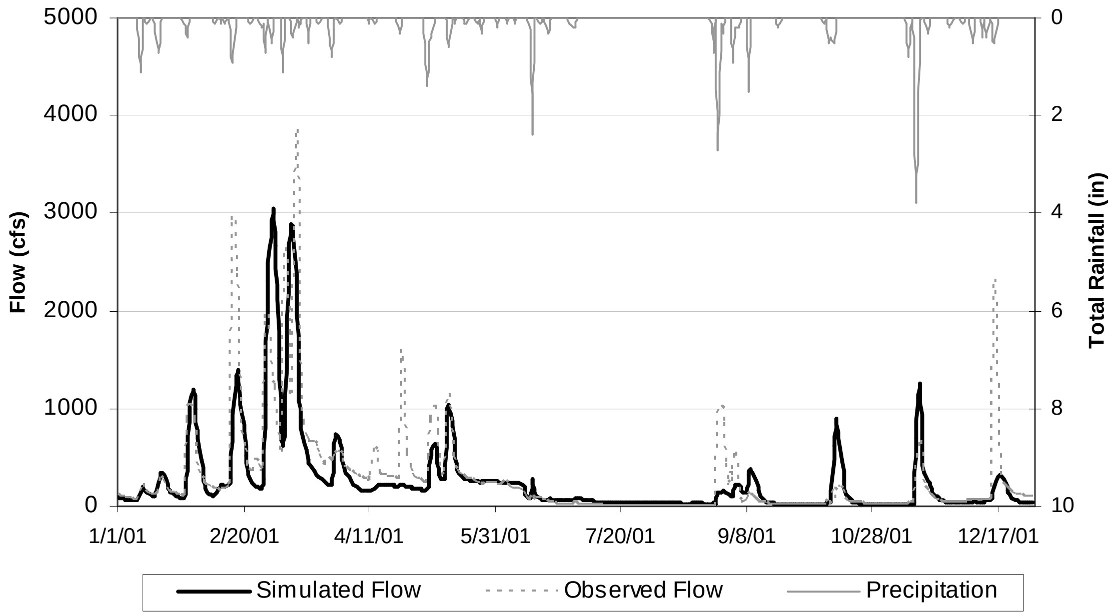

Figure 5-5 Hydrologic Calibration Results for Leon River at Hwy 84, 2001

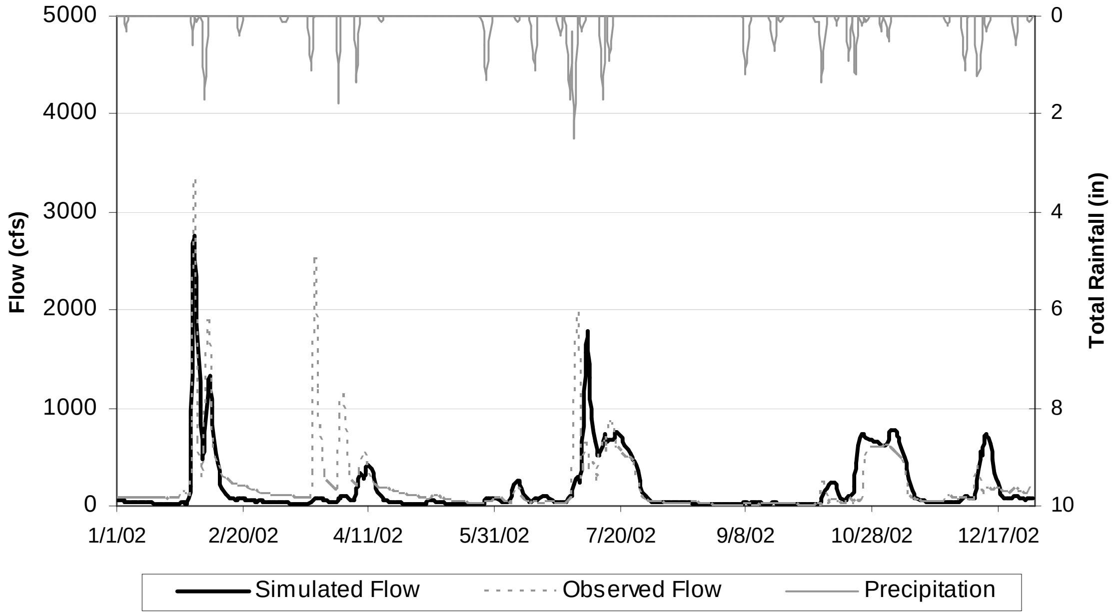

Figure 5-6 Hydrologic Calibration Results for Leon River at Hwy 84, 2002

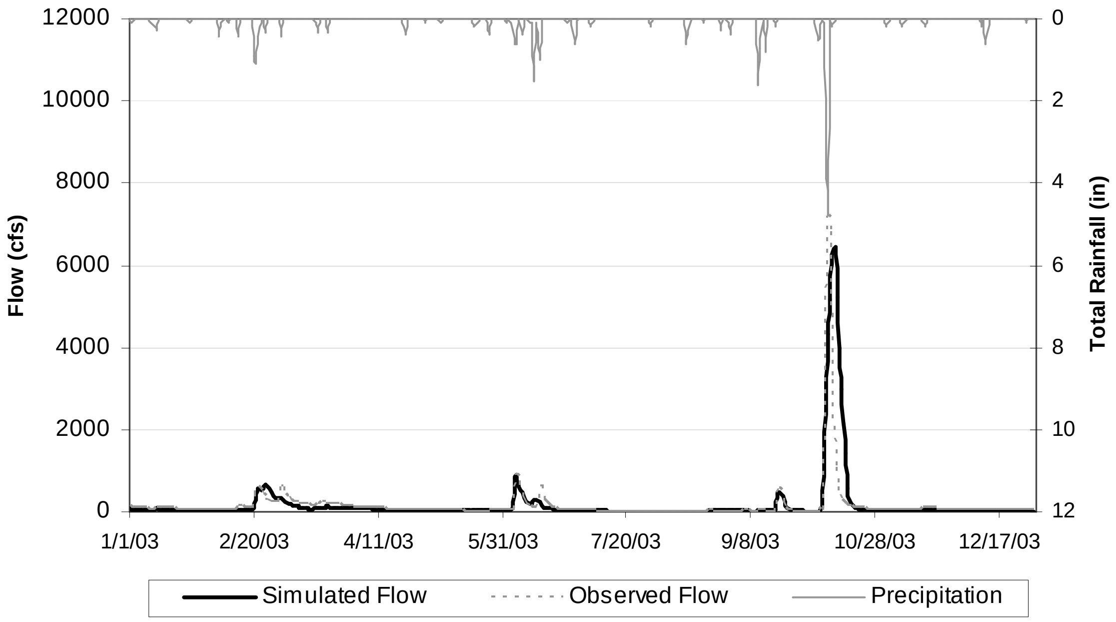

Figure 5-7 Hydrologic Calibration Results for Leon River at Hwy 84, 2003

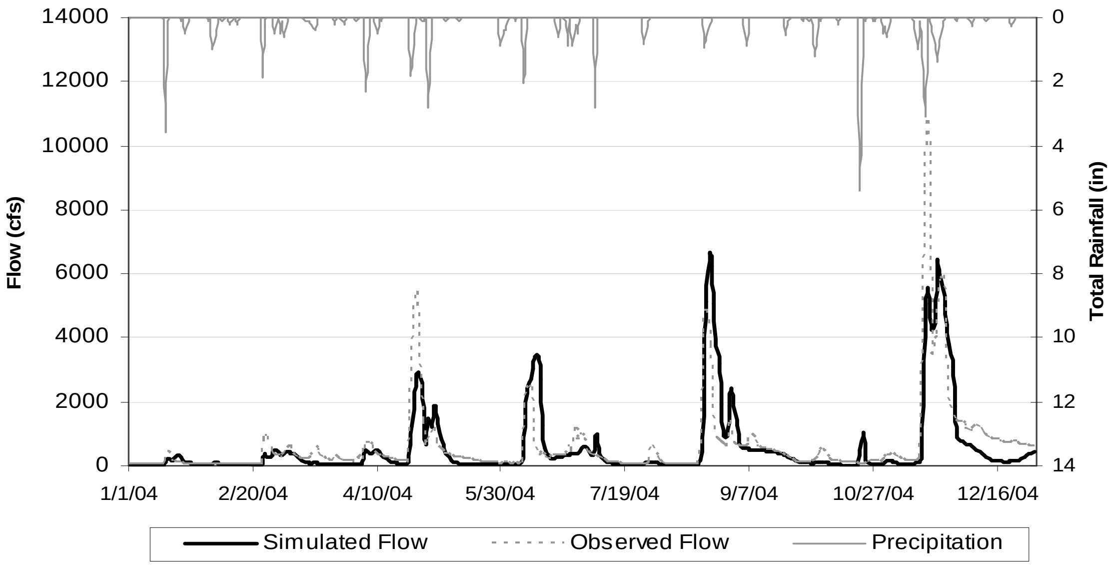

Figure 5-8 Hydrologic Calibration Results for Leon River at Hwy 84, 2004

Calibration statistics and their acceptable or desired ranges are summarized in Table 5-3 for the Leon River. The results indicate that the hydrologic calibration has been successfully achieved. The calibration generally demonstrates compliance with desired criteria. The model's largest percent error is associated with the category of summer storm volume, but it is still very near the criterion. This is understandable, because under summer conditions the prevalence of widely varying scattered thunderstorms is common, and this precipitation is what drives the hydrologic response. A flow duration curve for the Leon River is shown in Figure 5-9. A comparison of the observed and simulated average monthly runoff at RCHRES 120 is presented in Figure 5-10.

Table 5-3 Hydrologic Calibration Statistics for Leon River at Hwy 84, 2000-2004

Annual Averages	Simulated	Observed
Total flow (in/yr)	3.11	3.15
Highest 10% of flows (in/yr)	2.08	1.92
Storm flow (in/yr)	1.44	1.29
Storm peaks (cfs)	2877.1	3800.5
Summer flow (in/yr)	0.92	0.74
Winter flow (in/yr)	1.16	1.3
Summer storm flow (in/yr)	0.92	0.74
Winter storm flow (in/yr)	0.53	0.58

	% Error	Criteria
Total flow	-1.33	10%
Highest 10% of flows	8.49	15%
Error in storm peaks	-24.3	15%
Summer volume	24.01	25%
Winter volume	-11.23	25%
Summer storm flow	51.34	50%
Winter storm flow	-9.0	50%

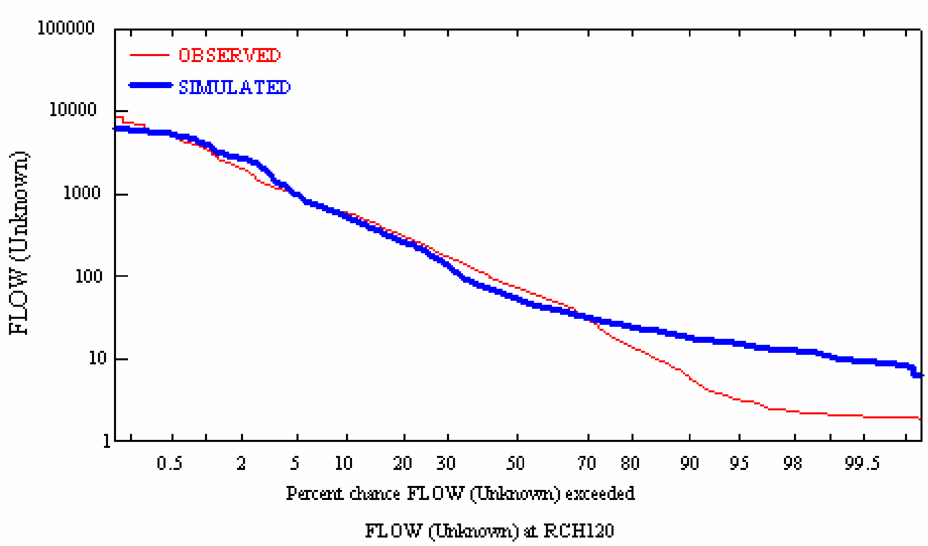

Figure 5-9 Flow Duration plot for Leon River at Hwy 84, 2000-2004

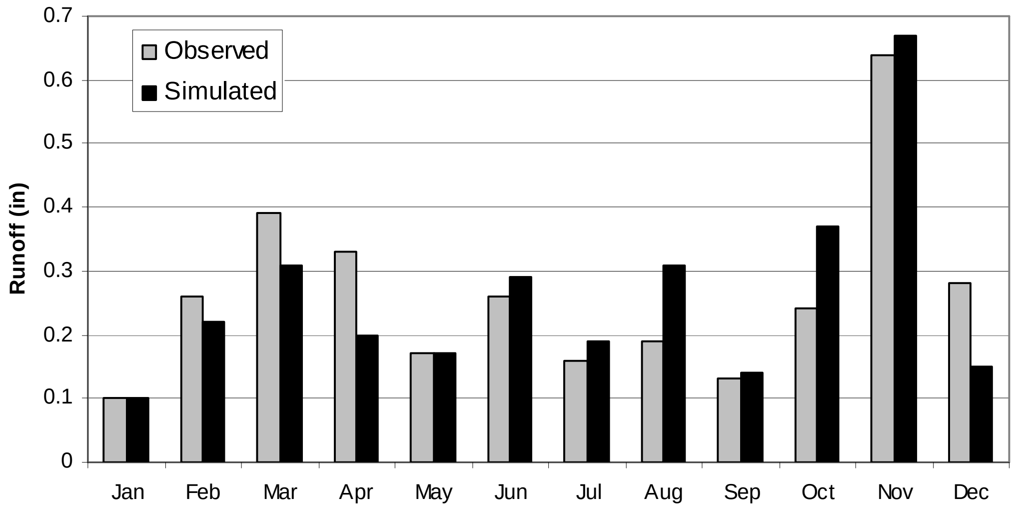

Figure 5-10 Comparison of Average Monthly Runoff for Leon River

5.6.2 Water Quality Calibration

Compared to the hydrologic calibration, water quality calibration is considerably more challenging. For hydrologic calibration, ample observed data is often available for the stream segment, typically consisting of continuous records of mean daily streamflow. By contrast, water quality calibration usually has to proceed with limited sets of observed data, and the data that is available typically consists of sporadically collected grab samples that each represent a single point in time.

For the present evaluation, the available water quality data set is somewhat limited. There are a few water quality monitoring stations with available fecal coliform data in the study reach, so the spatial extent of data is acceptable. The frequency of data collection at several sites has historically been steady. And as is the case with almost all bacteria data bases, the available fecal coliform data set consists of grab samples that provide an instantaneous measurement of instream concentration, rather than a daily mean or an event mean concentration. Fecal coliform measurements exhibit a high degree of variability and an acceptable laboratory precision test may encompass as much as 1-log of variability (ten times greater to one-tenth of actual value). Despite these potential difficulties, the available bacteria data set for the study area is sufficient to accomplish the study objectives and it is comparable to data sets that have been successfully employed in other TMDL determinations.

The water quality calibration for the Leon River was conducted using available fecal coliform data for the Leon River study area for the period 2001-2004. Most of the available data originated from routine agency monitoring programs. Additional monitoring of bacteria concentrations was conducted in 2003 and 2004 in conjunction with the present study. The available data sets were examined closely for input to the model calibration process. This available water quality data base represents the site-specific data that is available for calibration of the model. Many of the bacterial loading parameters and variables in the modeling analysis are based upon assumptions and best professional judgment, but the measured values of fecal coliform bacteria concentrations within the Leon River provide the test for the validity of the multiple assumptions.

The population of available fecal coliform measurements at each monitoring station was analyzed to provide information that might establish approximate calibration targets for the stream. At any one monitoring station, the available data set typically consists of a set of grab samples that were collected under a range of streamflow conditions and that exhibit a substantial range of values. There is typically no direct correlation of streamflow rate and concentration. However, intuition would suggest and observations do indicate that there is some correspondence of higher bacteria concentrations with elevated streamflow rates. This correspondence was analyzed in detail for the bacteria data set at three key monitoring stations located on the Leon River study segment. Attendant streamflow and antecedent streamflow was analyzed for individual data points and each point was classified as either baseflow or runoff related. Statistical analysis of the baseflow and runoff data sets was conducted to define median values and 99 percent confidence intervals for each population. While these statistics on the limited historical data base provided guidance, the primary calibration benchmark was the achievement of a reasonable visual conformance between simulated and observed fecal coliform values.

Calibration of the Leon River model entailed adjustment of bacteria-related parameters to achieve agreement of the simulated model results with observed fecal coliform measurements. Several parameters were available for adjustment in the model. To achieve calibration under baseflow conditions, adjustment was made to parameters that represent continuous discharges and are not dependent upon transport via runoff mechanisms. For the present analysis, the primary parameter that was adjusted was the magnitude of loading derived from the category of direct sources. The direct sources category nominally includes contributions of fecal coliform from direct deposition from wildlife or livestock, but this type of continuous source could also include contributions of fecal coliform from failing septic systems and leaking wastewater collection system infrastructure. This direct source category could also represent other mechanisms that are difficult to quantify explicitly, including resuspension of bacteria associated with sediment and illicit discharges.

Calibration under runoff conditions was achieved through adjustment of parameters that relate to washoff of bacteria from land surfaces. The accumulation rate of bacteria on land surfaces (ACQOP) and the maximum accumulation (SQOLIM) were adjusted to render either more or less bacterial mass available for washoff. These bacterial accumulation rates represent the contributions from wildlife, livestock, and general urban loadings to the land surfaces in the watershed. The rate of surface runoff that will remove 90% of stored fecal coliform (WSQOP) was adjusted, which effects the proclivity for washoff to occur. These key model parameters were adjusted based upon the site-specific bacteria concentration data collected in the Leon River.

The final values for ACQOP and SQOLIM established in the calibration are shown in Table 5-4. Uniform values of ACQOP and SQOLIM were applied to all of the land use categories in the subwatersheds in the present study.

Table 5-4 ACQOP and SQOLIM Loading Rates

Description	ACQOP (10^6 counts/ac/d)	SQOLIM (10^6 counts/ac)
Forest	600	1,800
Cropland	300	900
Rangeland	600	1,800
Residential	5,000	15,000
Comm/Ind	3,000	9,000
Res. Impervious	2,500	7,500
Comm/Ind Imp.	1,500	4,500
WAF1	2,000	6,000
WAF2	2,000	6,000

Figure 5-11 shows the results of the calibration as simulated fecal coliform at US 281. The simulated results display good visual agreement with the available fecal coliform data. Note that the simulated fecal coliform values are mean daily concentrations, while plotted observed concentrations are for the most part instantaneous grab measurements. It would be unrealistic to expect simulated mean daily fecal coliform concentrations to match precisely observed grab sample concentrations. The degree of correspondence between simulated and observed values is similar to standards of performance exhibited in other TMDL determinations for bacteria. Comparison of baseflow and runoff population median concentrations for simulated results versus observations is summarized in Table 5-5. The calibration results shown in Table 5-5 indicate that the modeled concentrations closely correspond to the observed fecal coliform values.

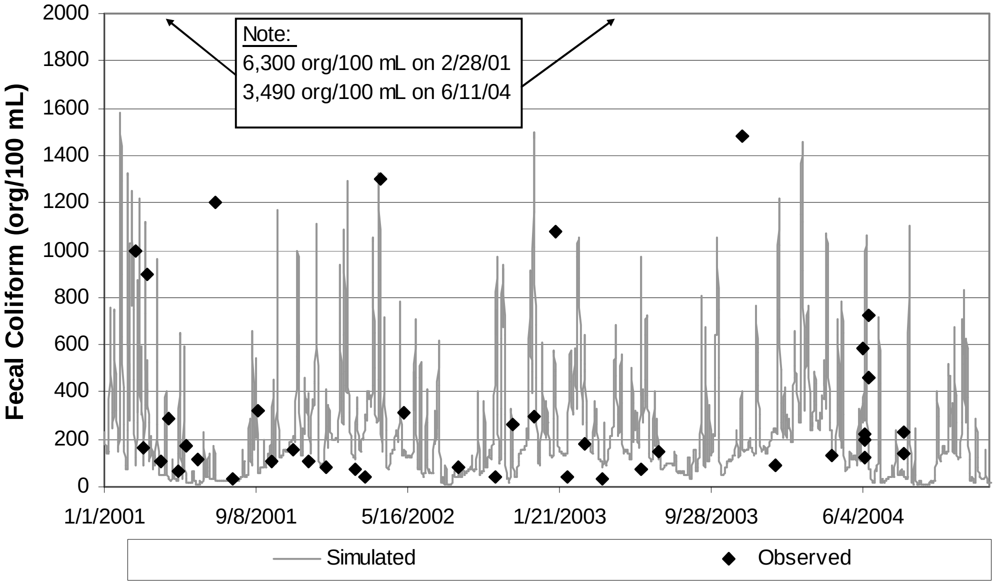

Figure 5-11 Water Quality Calibration for Leon River at US 281, 2001-2004

Table 5-5 Comparison of Observed and Simulated Fecal Coliform Concentrations

	Observed Concentration		Simulated Concentration
	Median	99% Confidence Range	Median
Key Mainstem Stations			
FM 1702 - RCH 41			
Baseflow	173	98 - 246	95
Runoff	820	535 - 1882	558
US 281- RCH 70			
Baseflow	113	73 - 169	63
Runoff	900	281 - 1397	488
SH 36 - RCH 130			
Baseflow	100	70 - 193	75
Runoff	1200	608 - 2643	522
Additional Stations			
US 377 - RCH 10			
Baseflow	113		112
FM 1476 - RCH 20			
Baseflow	308		358
CR 394 - RCH 60			
Baseflow	215		251

One additional check of the reasonableness of the water quality calibration was performed. A specific reach was selected and the model simulated bacterial loads emanating from each land use category were inventoried. These loads were then applied to the annual runoff volume emanating from each land use category in order to calculate an average annual runoff concentration. Reach 60 was selected for this analysis in the present study. The typical annual average runoff fecal coliform concentrations that were simulated in the modeling analysis for Reach 60 are displayed in Table 5-6. These simulated concentrations appear reasonable based upon best professional judgment. To obtain an additional perspective, the simulated values can be compared to ranges of typical concentrations reported in the literature, as shown in Table 5-7. It is apparent for this comparison that the fecal coliform concentrations simulated in the model are within the range of values reported from other studies.

Table 5-6 Typical Fecal Coliform Washoff Concentrations in Model (Reach 60)

Land Use	Concentration (org/100 mL)
Forest	2,800
Cropland	962
Rangeland	1,751
Residential	13,429
Comm/Ind	8,193
WAF1	5,431
WAF2	5,430
Residential Imp.	5,319
Comm/Ind Imp.	3,195

Table 5-7 Typical Fecal Coliform Washoff Concentrations in Other Studies

Land Use	Concentration (org/100 mL)
Forest	200 - 50,000
Cropland	200 - 10,000
Rangeland	200 - 50,000
Residential	5,000 - 50,000
Comm/Ind	5,000 - 50,000
WAF1	10,000 - 100,000
WAF2	10,000 - 100,000
Residential Imp.	5,000 - 50,000
Comm/Ind Imp.	5,000 - 50,000

The typical bacteria concentration ranges reported in Table 5-7 were derived from a variety of sources. The concentrations characteristic of urban land uses were based largely upon available bacteria data collected in two Texas cities, Austin and San Antonio, along with national-level data (Glick, 2005; Miller, 2005; EPA, 1986). Bacteria data for agricultural related land uses were derived from numerous available reports and studies from across the country that investigated bacteria concentrations in runoff from specific land use types (see for example, Baxter-Potter and Gilliland, 1988; Buckhouse and Gifford, 1976; Doran and Linn, 1979; Drapcho and Hubbs, 2003; Edwards, et al, 2000; Edwards, et al, 1997; Inamdar, et al, 2002; Kress and Gifford, 1984;

Mau and Pope, 1999; Moore, et al, 1989; Ockerman, 2002; Robbins, et al, 1972; Selvakumar and Borst, 2004; Smith and Douglas, 1973; Thelin and Gifford, 1983; Weidner, et al, 1969). Most of these studies examined bacteria runoff from grazed pastures and agricultural operations and the effects of factors such as loading rate, time, rainfall intensity, and distance. Though these various agricultural studies were located at various places throughout the country, it is expected that bacteria transport and processes resident within the Leon River watershed would be generally similar.

In many water quality modeling studies, calibration exercises are followed by a validation exercise, which typically entails exercise of the calibrated model and comparison to an independent set of observed measurements. This type of exercise is particularly valuable when two distinct set of observed conditions are present, for example, when simulating a dissolved oxygen sag below a wastewater discharge under first warm-weather, then cold-weather conditions, or under two distinctly different streamflow regimes. For the present analysis of bacteria concentrations, there does not exist a distinct set of observed data that reflect conditions that are not already embodied within the calibration data set. It was more important to apply the complete contemporary available bacteria data set to the calibration exercise, in order to have the greatest confidence in the calibration results.

The bacterial loads associated with the model calibration can be readily examined in terms of load originating from the land use categories and point sources embodied in the analysis. The simulated loads for the impaired reach of the Leon River (Reaches 10 through 70) are compared graphically in Figure 5-12 and are tabulated in the subsequent Table 6-2. The loads presented are the total annual average loads that enter the impaired stream, contributed by the various sources. The loads do not account for decay that occurs as the bacteria travel downstream.

For the study reach, it is apparent that the largest presumed source of fecal coliform bacteria is rangeland. This is attributable to the fact that rangeland is the largest land use category in terms of acreage, and it is the recipient of bacterial deposition from wildlife and livestock. The next largest contribution is estimated to be urban land uses, and the third largest source is shown to be the category of direct sources. The urban areas and WAFs have relatively small acreages but their assumed loading parameters are relatively large.

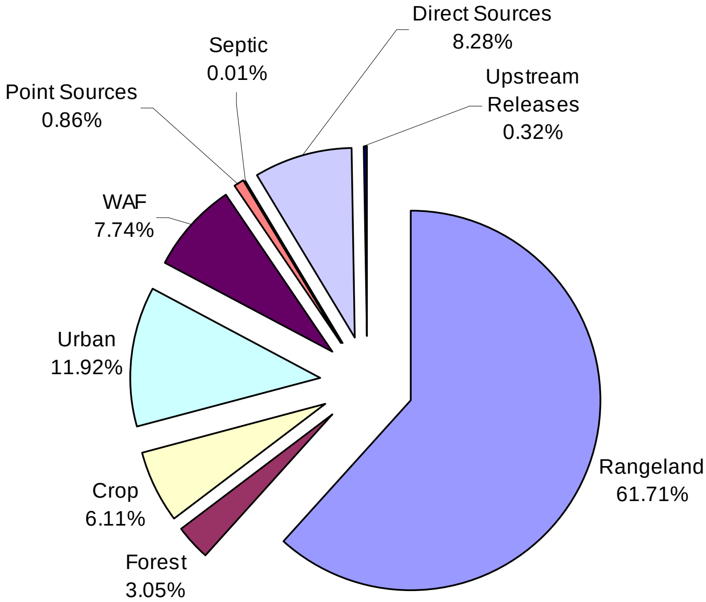

Figure 5-12 Comparison of Fecal Coliform Sources for the Leon River

Now that the calibration of the water quality model is complete, it may be instructive to put in perspective some of the initial assumptions. Preceding sections described the development of initial estimates of livestock and wildlife populations by subwatershed. This was followed by calculation of the potential fecal coliform contributions from each source based upon application of literature values for mass of fecal material and bacterial density. These source representations were employed to develop initial values of ACQOP and SQOLIM for input into the modeling analysis. These initial values should be considered to represent the potential loading parameter values that are based upon numerous assumptions. The initial values of ACQOP and SQOLIM underwent substantial adjustment during the process of model calibration. Typically, the initial values to establish loading parameters were reduced substantially to achieve model calibration, typically arriving at values that were 1-10% of the initial theoretical value. The exception to this trend was the adjustment of urban land use contributions. These areal loading rates were increased substantially in the calibration process. So, this discussion should illustrate that the model calibration is not directly related to the initial assumptions on animal counts. Even if the initial counts were substantially revised, it would not necessarily affect the ultimate calibration of the model.

5.7 SENSITIVITY ANALYSIS

Sensitivity analyses were conducted to demonstrate the effects of variability in key modeling parameters. This type of analysis provides an indication of the impacts of various assumptions and calibration parameters.

The following parameters were selected for the sensitivity analysis:

ACQOP - the bacterial areal loading rate to land surfaces, in units of 10^6 org/acre/day. This is a key calibration parameter for washoff of bacteria from land surfaces during runoff conditions. It represents the cumulative daily loading of bacteria from a variety of potential sources, including wildlife and livestock, which is deposited on the land surface and subsequently available for washoff by runoff. Calibration values for ACQOP were developed for each land use category empirically during the calibration exercises. Values range from approximately 400 – 9000 10^6 org/acre/day in the model (see Table 5-4 for loading rates). Larger ACQOPs would represent larger numbers of bacteria deposited daily.

SQOLIM - the maximum accumulation of bacteria on the land surfaces, in units of 10^6 org/acre. This is a key calibration parameter that affects the washoff of bacteria from land surfaces during runoff conditions. It accounts for the decay of bacteria deposited on the land surface by establishing a maximum value that can be in place, available for washoff. Calibration values for SQOLIM were developed for each land use category empirically during the calibration exercises, and were set at three times the ACQOP. In effect, this limits the amount of bacteria available for washoff to three days of accumulation. A larger SQOLIM would mean that more bacteria are allowed to accumulate on the land surfaces.

FSTDEC - the first-order decay rate for bacteria, in units of 1/day. This is a key calibration parameter that effects bacteria numbers within the watercourse. It accounts for the decrease in bacteria numbers, or die-off, as they are transported downstream. The value used in calibration was 0.7 / day in the impaired reach. A larger decay rate would mean that bacteria die-off more rapidly.

WSQOP - the rate of surface runoff required to remove 90% of the bacteria accumulated on the land surfaces, in units of inches/hour. This is a key calibration parameter that affects the ability of deposited bacteria to be washed off the land surfaces during runoff conditions. It specifies the runoff rate and relates it to the ease with which bacteria are removed from the land surfaces. Two values for WSQOP were used in the calibration; a rate of 1.8 inches/hour was specified for PERLND (pervious) land surfaces, while a rate of 1.0 inches hour was specified for IMPLND (impervious) land surfaces. A larger WSQOP would mean that a larger runoff rate is needed to remove bacteria, in effect making it more difficult for the bacteria to wash off the surface.

Direct Nonpoint Sources - the contributions of bacteria directly to the receiving stream from wildlife, livestock, and leaking septic systems, in units of 10^6 org/day. This is a key source loading of bacteria in the modeling analysis under lower flow conditions, since this mechanism is not related to runoff. It was developed empirically during the calibration exercises. A larger value for direct nonpoint source would mean a larger contribution from the various potential sources that contribute directly to the stream.

Proctor Lake Boundary Condition - the bacteria loading from the reservoir, in units of 10^6 org/day. This is a significant source loading of bacteria in the modeling analysis, particularly under lower flow conditions. It was based upon data for releases from the reservoir provided by the USACE and historical monitoring data for bacteria at the dam floodgate (TCEQ monitoring station #11935). A larger value would represent a higher concentration and therefore higher load from the reservoir.

Each of the preceding parameters was analyzed individually at a level of plus or minus 50% of the base value. In this parlance, the base value is the calibrated set of model coefficients and parameter values. The ACQOP and SQOLIM were analyzed individually and, in addition, as a paired set of values where the inter-parameter ratio employed in the model was maintained. In other words, when ACQOP was varied by plus or minus 50%, the SQOLIM was varied accordingly, consistent with the fundamental assumption in the base case.

For each sensitivity condition, the model was rerun and results obtained as simulated daily bacteria concentrations for the period 2001 - 2004. To facilitate comparison of the results, the daily bacteria concentrations simulated at Hwy 281 (RCHRES 70) were transformed to moving 91-day geometric mean values. Plots for each parameter are displayed in Figures 5-13 through 5-19. In these plots, only the geometric mean values for the year 2004 are presented in order to amplify the results.

In Figure 5-13 are shown the results for the sensitivity analysis on ACQOP. Variation of this parameter individually demonstrated relatively small differences in the results. The range of plus or minus 50% represents a reasonable range for ACQOP, but actual values could be much higher.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
ACQOP	10^6 org/ac/d	Bacterial areal loading rate	400-9000, depending on land use category	Relatively small differences in results; simulated instream bacteria concentration change less than 10% of the geometric mean	Relates to bacteria washoff during runoff; cumulative loading of bacteria from wildlife, livestock to the land surface; +/- 50% could relate to total number of animals in the watershed

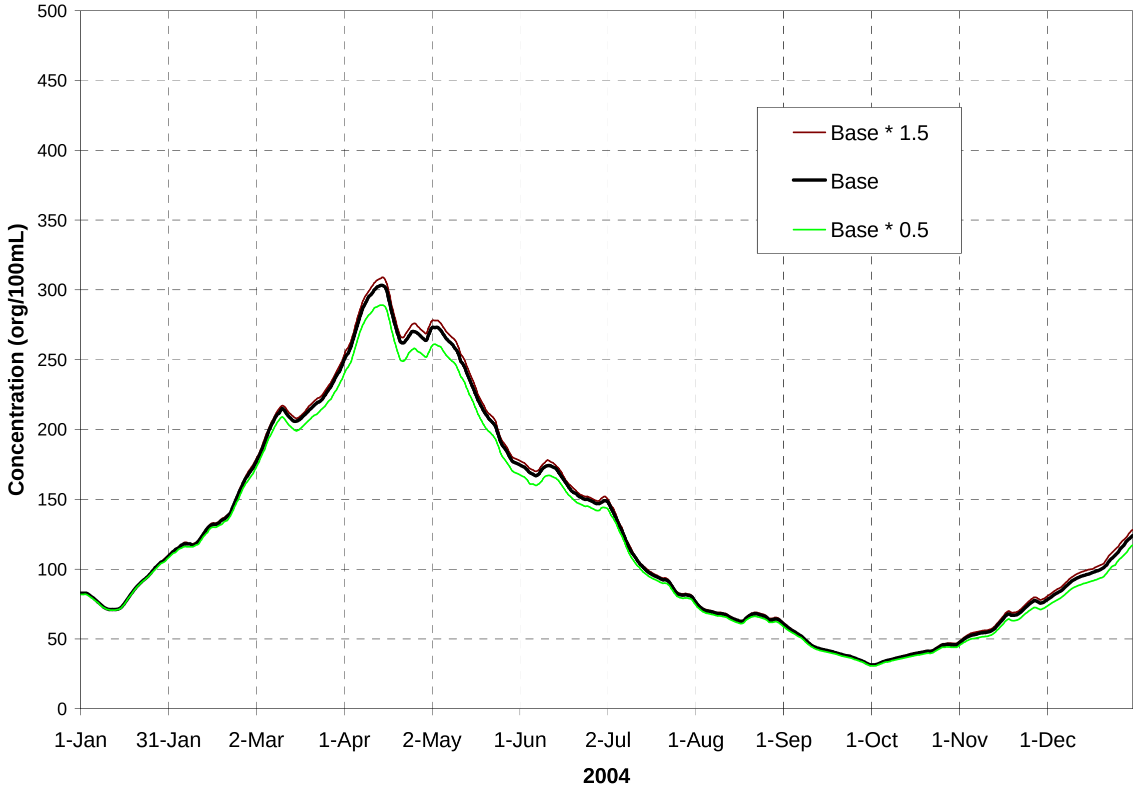

Figure 5-13 ACQOP Sensitivity Analysis, 91-Day Geometric Mean

The sensitivity analysis on SQOLIM is shown in Figure 5-14. Variation of this parameter individually showed a moderate amount of differences in the results, compared to the base case. The range of plus or minus 50% represents a reasonable range for SQOLIM, but actual values could be much higher.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
SQOLIM	10^6 org/ac	Bacteria maximum accumulation	1200-27000, depending on land use category	Moderate differences in results; simulated instream bacteria concentration change 15-25% of the geometric mean	Relates to bacteria washoff during runoff; maximum loading of bacteria from wildlife, livestock to the land surface that can accumulate; 3 days of accumulation base, so sensitivity looked at 1.5 – 4.5 days

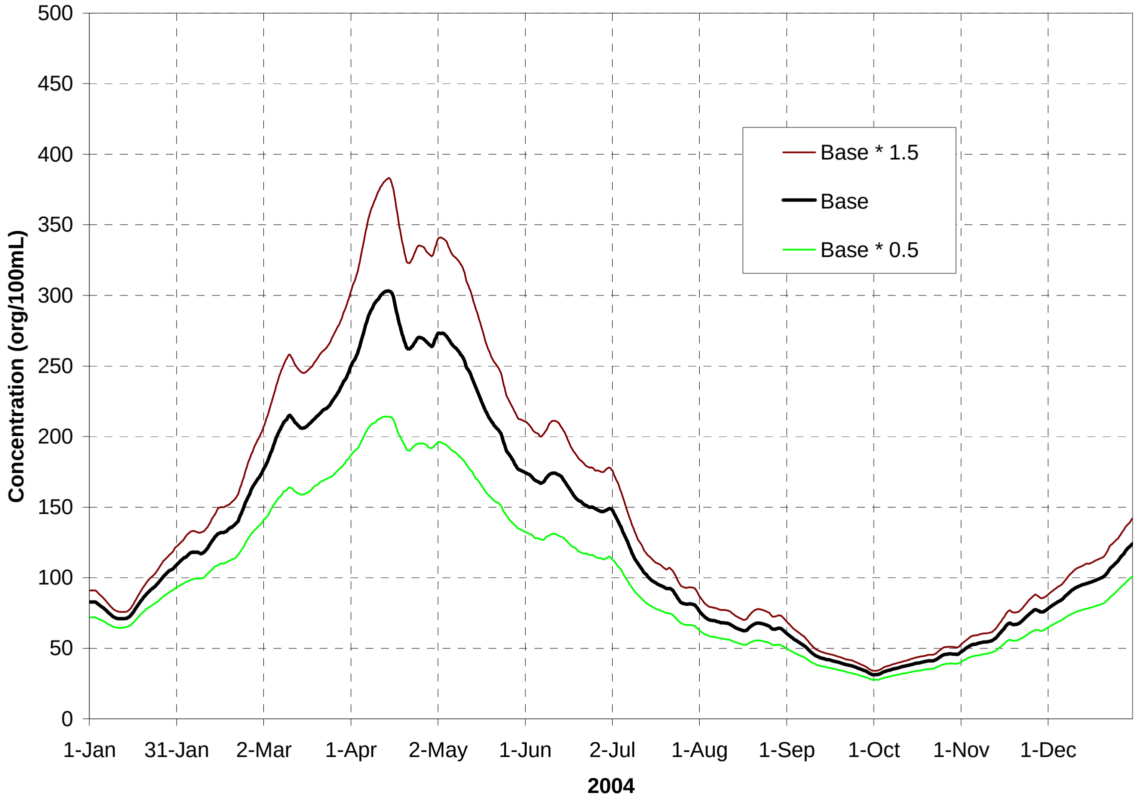

Figure 5-14 SQOLIM Sensitivity Analysis, 91-Day Geometric Mean

The sensitivity analysis on the paired combination of ACQOP and SQOLIM is shown in Figure 5-15. A moderate difference in results was demonstrated by variation of the paired parameters.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
ACQOP & SQOLIM pair	10^6 org/ac/d and 10^6 org/ac	Bacterial areal loading rate and maximum accumulation	ACQOP at 400-9000; SQOLIM at 1200–27000 depending on land use category	Moderate differences in results; simulated instream bacteria concentration change 15-30% of the geometric mean	Relates to bacteria washoff during runoff; cumulative loading of bacteria from wildlife, livestock to the land surface and maximum accumulation; +/- 50% change in the paired combination of the loading parameters

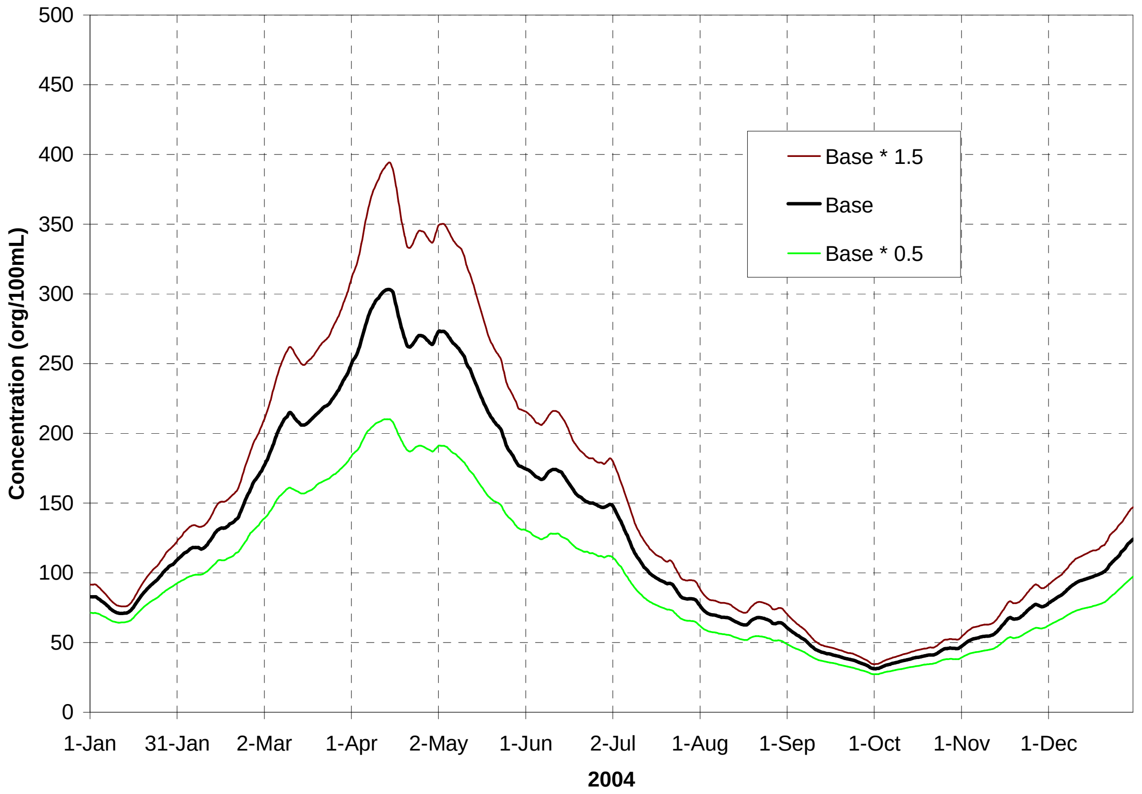

Figure 5-15 ACQOP & SQOLIM Sensitivity Analysis, 91-Day Geometric Mean

In Figure 5-16 are displayed the sensitivity results for FSTDEC. Variation of this parameter over a range of plus or minus 50% had a relatively large effect on the simulation results. The range of plus or minus 50% represents a reasonable range for the first-order decay coefficient in watercourses.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
FSTDEC	1/day	Bacterial decay rate	0.7/day	Large differences in results; simulated instream bacteria concentration change 30-50% of the geometric mean	Rate at which bacteria die off in the stream, after they are introduced by point or nonpoint sources; at rate of 0.7/d approx half die in one day

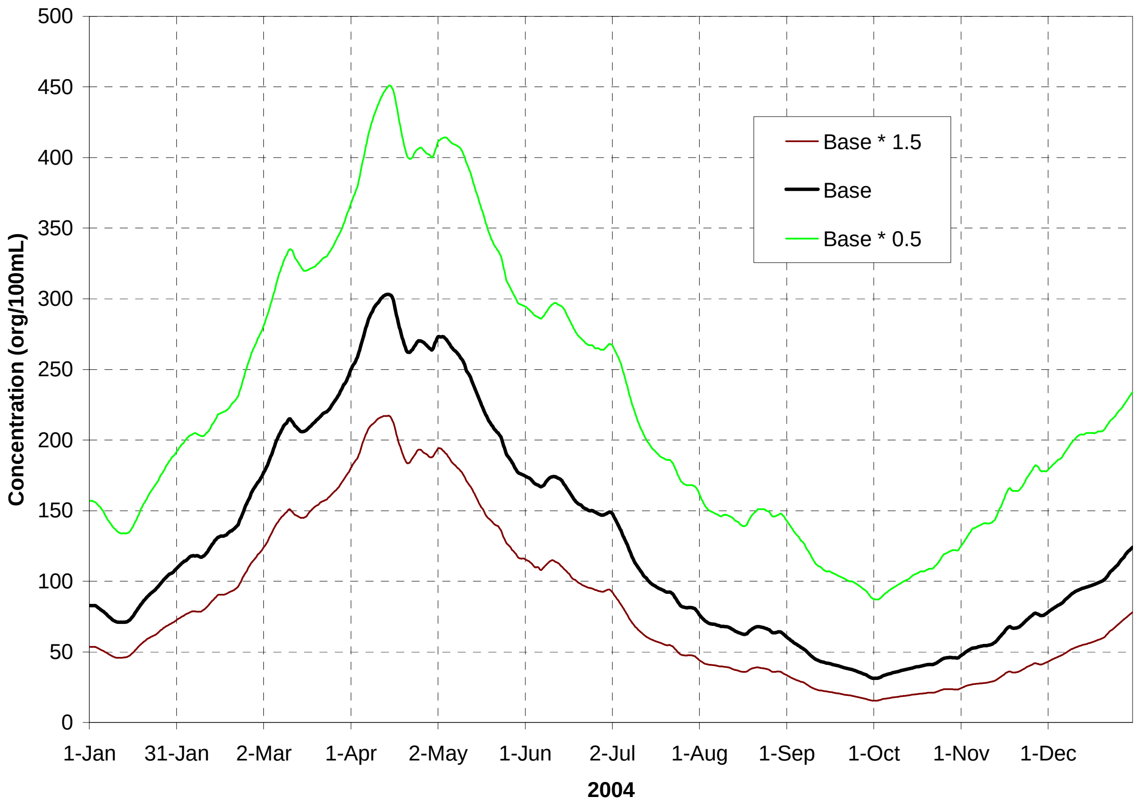

Figure 5-16 FSTDEC Sensitivity Analysis, 91-Day Geometric Mean

Figure 5-17 shows the results of the sensitivity analysis for WSQOP. Differences from variation of this parameter are relatively small to large in magnitude. The range of plus or minus 50% represents a reasonable range for the runoff rate.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
WSQOP	In/hr	Surface runoff rate required to wash off 90% of bacteria mass	1.8 for pervious, 1.0 for impervious surfaces	Small to large differences in results; simulated instream bacteria concentration change 0-40% of the geometric mean	Effects washoff of bacteria during runoff; larger WSQOP means that larger runoff rate is needed to wash off bacteria; the runoff rate in the model is usually low

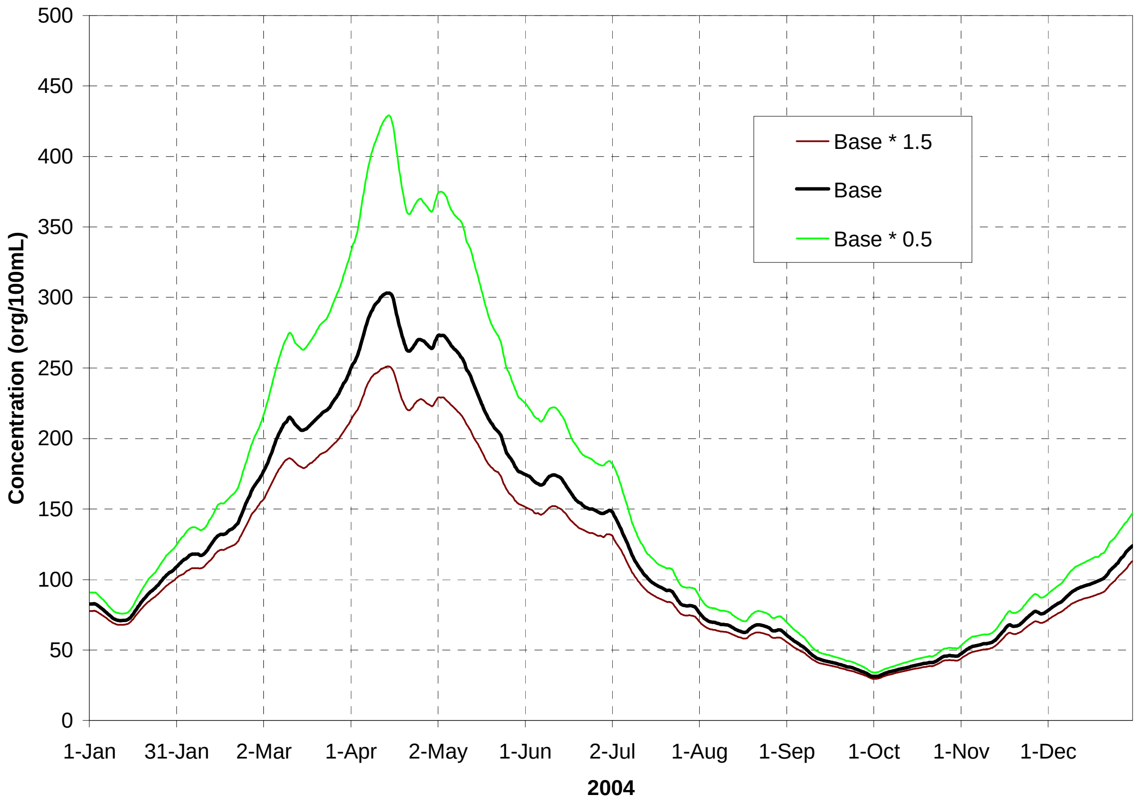

Figure 5-17 WSQOP Sensitivity Analysis, 91-Day Geometric Mean

Sensitivity to variation of direct nonpoint sources is illustrated in Figure 5-18. The observed effects of variation are relatively small. Actual values of direct nonpoint sources could vary by more than the tested range of plus or minus 50%, with potential values much higher.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
Direct nonpoint sources	10^6 org/d	Direct bacteria concentrations to the stream	12000-144000 10^6 org/d, depending on reach	Relatively small differences in results; simulated instream bacteria concentration change 5-10% of the geometric mean	Related to direct input of bacteria to stream from wildlife, livestock, septic systems, or sewage collection systems; not related to runoff

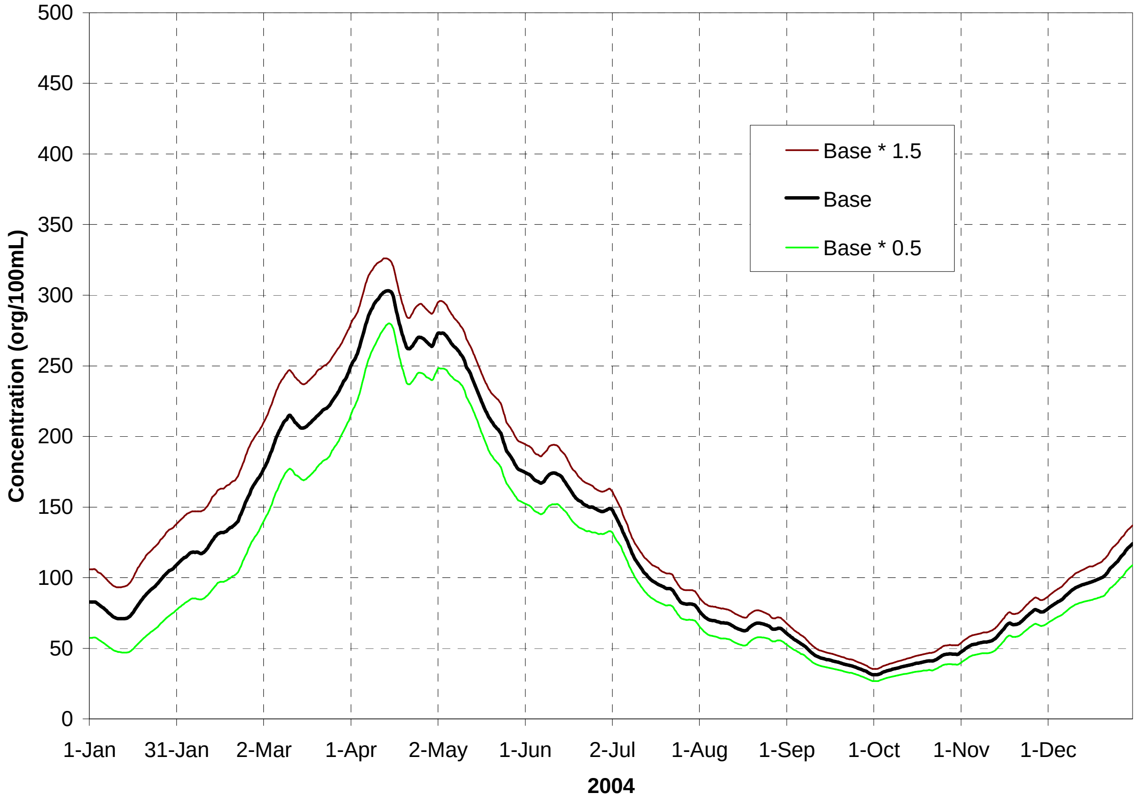

Figure 5-18 Direct NPS Sensitivity Analysis, 91-Day Geometric Mean

Effects of variation of the bacteria loading from Proctor Lake are shown in Figure 5-19. Variation of this parameter demonstrated a relatively small difference in results. The range of plus or minus 50% is probably a reasonable range for this source, though for short term releases values could be substantially higher.

PARAMETER	UNITS	DEFINITION	VALUE IN CALIBRATION	RESULTS OF +/- 50% SENSITIVITY	INTERPRETATION
Proctor Lake input	10^6 org/d	Bacteria contribution from lake releases	Average 260000 10^6 org/d	Relatively small differences in results; simulated instream bacteria concentration change 0-15% of the geometric mean	Bacteria in releases from lake; +/- 50% has relatively small effect; input directly into stream

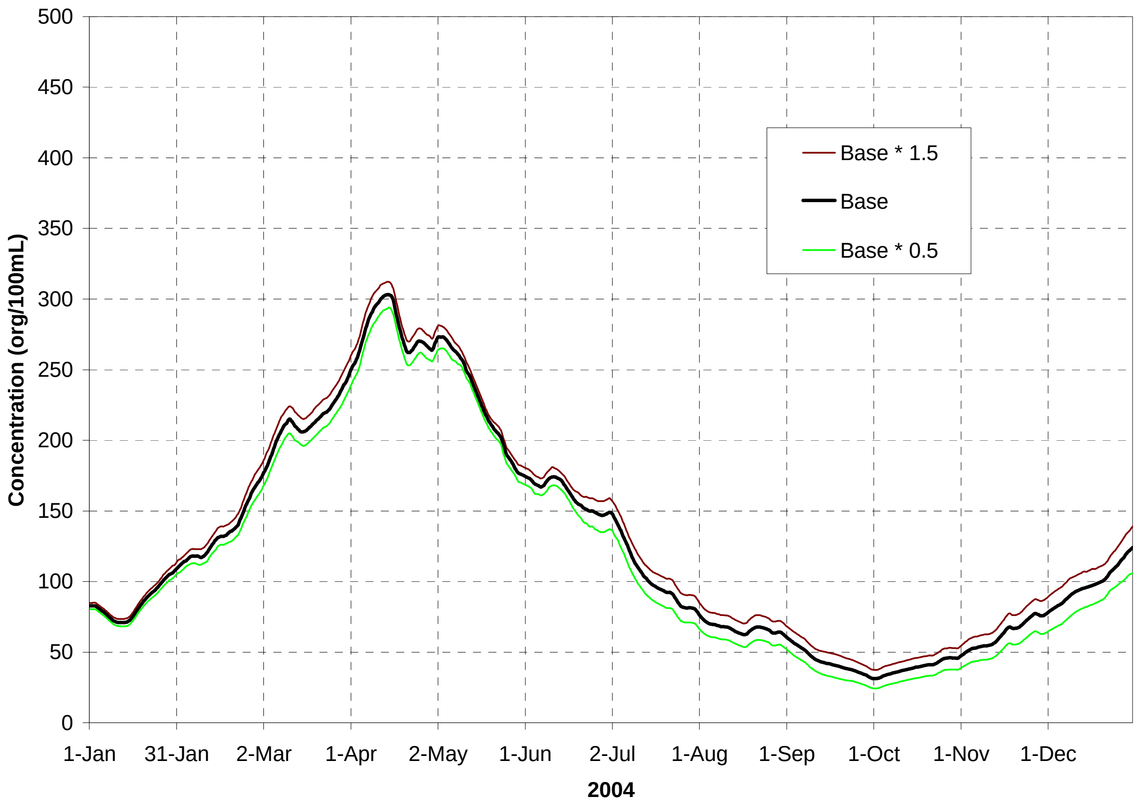

Figure 5-19 Proctor Lake Loading Sensitivity Analysis, 91-Day Geometric Mean

APPENDIX B

CORRECTIVE ACTION REPORT

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Corrective Action Report

SOP-QA-001
CAR #: _______________

Date: ____________________ Area/Location: _____________________

Reported by: ____________________ Activity: __________________________

State the nature of the problem, nonconformance or out-of-control situation:

____
____
____
____

Possible causes:

____
____
____

Recommended Corrective Actions:

____
____
____

CAR routed to: ________________________________

Received by: __________________________________

Corrective Actions taken:

____
____
____
____

Has problem been corrected? YES NO

Immediate Supervisor: ______________________________

Program Manager: ______________________________

Quality Assurance Officer: ______________________________

TSSWCB QAO: ______________________________