Clean Water Act Section 319(h) Nonpoint Source Pollution Control Program Project

Lampasas River Watershed Assessment and Protection Plan

TSSWCB Project Number 07-11

Revision #0

Quality Assurance Project Plan

Texas State Soil and Water Conservation Board

prepared by

Texas AgriLife Research

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Texas A&M University Spatial Sciences Laboratory

Effective Period: Upon EPA Approval through September 30, 2010,
with annual updates required

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Section A1 Approval Sheet

Quality Assurance Project Plan for "*Lampasas River Watershed Assessment and Protection Plan.*"

United States Environmental Protection Agency (USEPA), Region VI

Name: Donna Miller
Title: USEPA Chief; State/Tribal Programs Section

Signature:___________________________________Date:______________

Name: Ellen Caldwell
Title: USEPA Texas Nonpoint Source Project Manager

Signature:___________________________________Date:______________

Texas State Soil and Water Conservation Board (TSSWCB)

Name: Pamela Casebolt
Title: TSSWCB Project Manager

Signature:___________________________________Date:_____________

Name: Donna Long
Title: TSSWCB Quality Assurance Officer

Signature:___________________________________Date:_____________

Texas AgriLife Research at Blackland Research and Extension Center (BREC)

Name: Dennis Hoffman, Ph.D.
Title: Senior Research Scientist; Project Manager

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Name: Raghavan Srinivasan, Ph.D.
Title: Spatial Sciences Lab Director

Signature:________________________________Date:____________

Name: Steven Potter
Title: Watershed Coordinator

Signature:________________________________Date:____________

Name: Jason McAlister
Title: BREC—Water Quality Group Quality Assurance Officer

Signature:________________________________Date:____________

Section A2: Table of Contents

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List of Acronyms and Abbreviations

AgriLife Extension	Texas AgriLife Extension Service
CAR	Corrective Action Report
CBMS	Computer Based Mapping System
CWA	Clean Water Act
DEM	Digital Elevation Model
DQO	Data Quality Objectives
BRA	Brazos River Authority
BREC	Texas AgriLife Research at Blackland Research & Extension Center
GIS	Geographic Information System
LDC	Load Duration Curve
NLCD	National Land Cover Data Set
NPS	Nonpoint Source
PM	Project Manager
QA	Quality Assurance
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
Research	Texas AgriLife Research
SAS	Statistical Analysis System
SOP	Standard Operating Procedures
SSL	Spatial Sciences Laboratory
SSURGO	Soil Survey Geographic
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SPARROW	SPAtially Referenced Regressions On Watershed attributes
SSL	Texas A&M University-Spatial Sciences Laboratory
USDA-ARS	United States Department of Agriculture-Agricultural Research Service
USDA-NRCS	United States Department of Agriculture-Natural Resources Conservation Service
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WPP	Watershed Protection Plan

Section A3: Distribution List

Organizations, and individuals within, which will receive copies of the approved QAPP and any subsequent revisions include:

- United States Environmental Protection Agency, Region VI

  Name: Donna Miller
  Title: USEPA Chief; State/Tribal Programs Section

  Name: Ellen Caldwell
  Title: USEPA Texas Nonpoint Source Project Manager

- Texas State Soil and Water Conservation Board

  Name: Pamela Casebolt
  Title: TSSWCB Project Manager

  Name: Donna Long
  Title: TSSWCB Quality Assurance Officer

- Texas AgriLife Research at Blackland Research and Extension Center

  Name: Dennis Hoffman, Ph.D.
  Title: Senior Research Scientist

  Name: Raghavan Srinivasan, Ph.D.
  Title: TAMU Spatial Sciences Lab Director

  Name: Steven Potter
  Title: Watershed Coordinator

  Name: Jason McAlister
  Title: BREC—Water Quality Group Quality Assurance Officer

Section A4: Project/Task Organization

The following is a list of individuals and organizations participating in the project with their specific roles and responsibilities:

USEPA – United States Environmental Protection Agency, Region VI, Dallas, Texas. Provides project overview at the Federal level.

Ellen Caldwell, USEPA Texas Nonpoint Source Project Manager
Responsible for overall performance and direction of the project at the Federal level. Ensures that the project assists in achieving the goals of the federal Clean Water Act (CWA). Reviews and approves the quality assurance project plan (QAPP), QAPP amendments, project progress, and deliverables.

TSSWCB –Texas State Soil and Water Conservation Board, Temple, Texas. Provides project overview at the State level.

Pamela Casebolt, TSSWCB Project Manager
Provides the primary point of contact between the Texas State Soil and Water Conservation Board (TSSWCB) and BREC. Responsible for ensuring that the project delivers data of known quality, quantity, and type on schedule to achieve project objectives. Tracks and reviews deliverables to ensure that tasks in the work plan are completed as specified. Reviews and approves QAPP and any amendments or revisions and ensures distribution of approved/revised QAPPs to TSSWCB and USEPA participants. Notifies the TSSWCB Quality Assurance Officer (QAO) of significant project nonconformances and corrective actions taken.

Donna Long, TSSWCB Quality Assurance Officer
Reviews and approves QAPP and any amendments or revisions. Responsible for verifying that the QAPP is followed by project participants. Assists the TSSWCB Project Manager on QA-related issues. Monitors implementation of corrective actions. Coordinates or conducts audits of field and laboratory systems and procedures. Determines that the project meets the requirements for planning, quality assessment (QA), quality control (QC), and reporting under the CWA Section 319(h) NPS Grant Program.

BREC – Texas AgriLife Research at Blackland Research and Extension Center, Temple, Texas. Responsible for development of data quality objectives (DQOs) and a quality assurance project plan (QAPP). Responsible for modeling activities associated with SELECT and Statistical Modeling.

Dennis Hoffman, Project Manager
Responsible for submitting accurate and timely data analyses and contributions for progress and final reports to the TSSWCB PM. 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 work plan and in the QAPP; Responsible for assessing the quality of work by staff; submitting accurate and timely deliverables to the TSSWCB PM, for verifying that the QAPP is followed by the BREC water quality staff, and that the data produced is of known and acceptable quality.

Raghavan Srinivasan, Spatial Sciences Laboratory Director

Responsible for oversight of modeling activities associated with SELECT and statistical modeling assurance/quality control requirements are met. Enforces corrective action, as required.

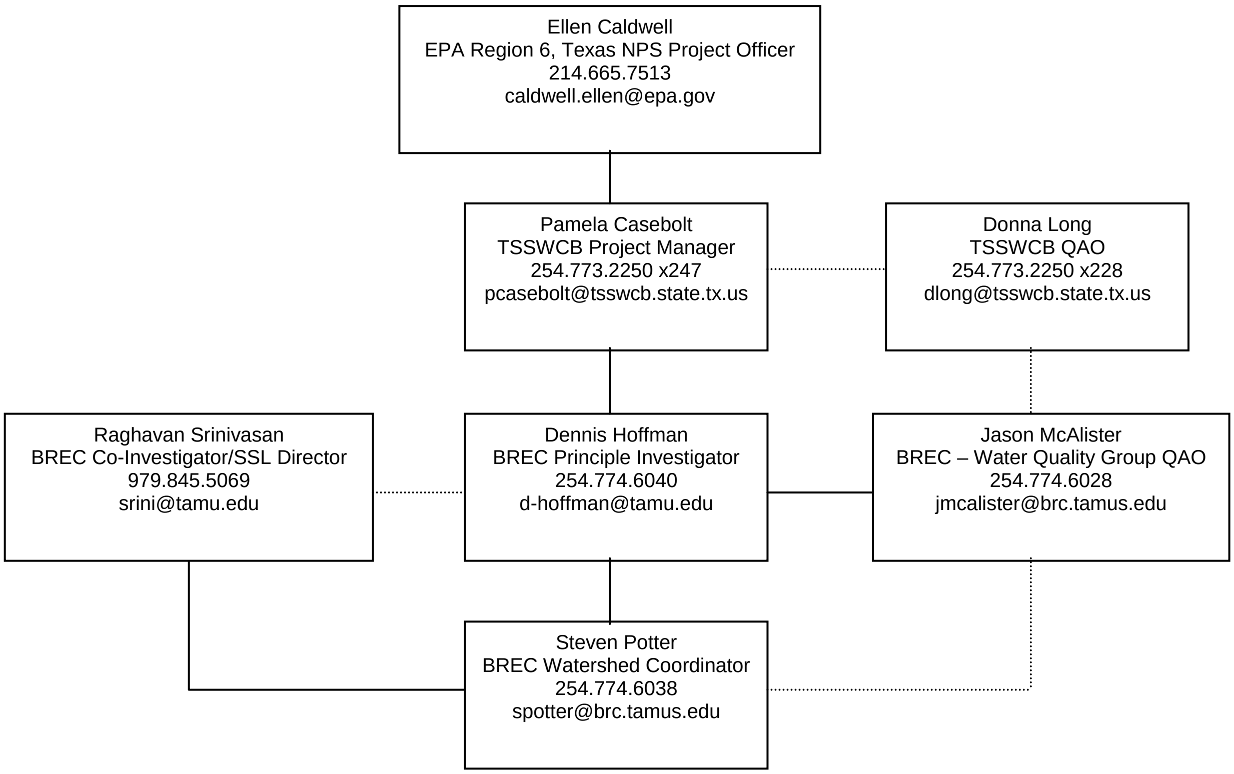
Steven Potter; Watershed Coordinator

Responsible for the Lampasas Watershed load duration curve development and SELECT modeling. Responsible for water quality modeling support via statistical models. Responsible for verifying that the data used for modeling efforts are of known and acceptable quality. Responsible for coordinating and organizing a stakeholder group that serves an advisory role in Watershed Protection Plan (WPP) development, developing a WPP with assistance from stakeholders and submitting it to TSSWCB and EPA.

Jason McAlister; BREC—Water Quality Group Quality Assurance Officer

Responsible for determining that the Quality Assurance Project Plan (QAPP) meets the requirements for planning, quality control, and quality assessment. Responsible for maintaining the official, approved QAPP, as well as the facilitation of Quality Assurance audits in conjunction with TSSWCB and EPA personnel, and the implementation, documentation, verification, and reporting of corrective actions.

Figure A4-1. Project Organization Chart
Dashed lines indicate communication only



Section A5: Problem Definition/Background

The Lampasas River (segment 1217 in the Brazos River Basin), rises in western Hamilton County 16 miles west of Hamilton and flows southeast for 75 miles, passing through Lampasas, Burnet, and Bell counties. In Bell County the river turns northeast and is dammed five miles southwest of Belton to form Stillhouse Hollow Lake (segment 1216). Below Stillhouse Hollow Lake, the Lampasas River flows to its confluence with Salado Creek and the Leon River to form the Little River.

The Lampasas River is characterized by relatively low water levels most of the time and is situated within a predominantly rural and agricultural landscape. Land use within the watershed is mostly rural, with grasslands and row crops.. Major agricultural interests include beef cattle on rangeland, in addition to hay, wheat, oats, sorghum, corn, cotton, peanut, and pecan operations.

During periods of rainfall, bacteria (*E. coli*) originating from birds and mammals, livestock, inadequately treated sewage, and/or failing septic systems may be washed into the Lampasas River and its tributaries and have the potential to contribute to elevated bacteria densities; consequently, impairing recreational use of the waterbody. *E. coli* may remain in the streams at levels exceeding established criteria, measured well after a rain event has occurred. These organisms are normally found in wastes of warm-blooded animals and are generally not harmful to human health, but may indicate the presence of pathogens.

The Lampasas River above Stillhouse Hollow Lake is on the *2006 303(d) List* for elevated bacteria levels. Water quality monitoring data also indicate nutrient enrichment in isolated areas within the watershed. The State requires water quality in the Lampasas River be suitable for contact recreation, a healthy aquatic ecosystem, fish consumption and general use.

The data used to assess current bacterial concentrations in the Lampasas River are the result of sampling conducted through the Texas Commission on Environmental Quality (TCEQ) Clean Rivers Program. Fecal coliform samples have been taken at 5 designated sampling sites along the Lampasas River. It has been observed that, in the past five years, two of the five sampling sites indicated a use concern or non-support of contact recreation. Although routine sampling indicates the presence of elevated bacteria levels in the Lampasas River, the contaminant source is unclear.

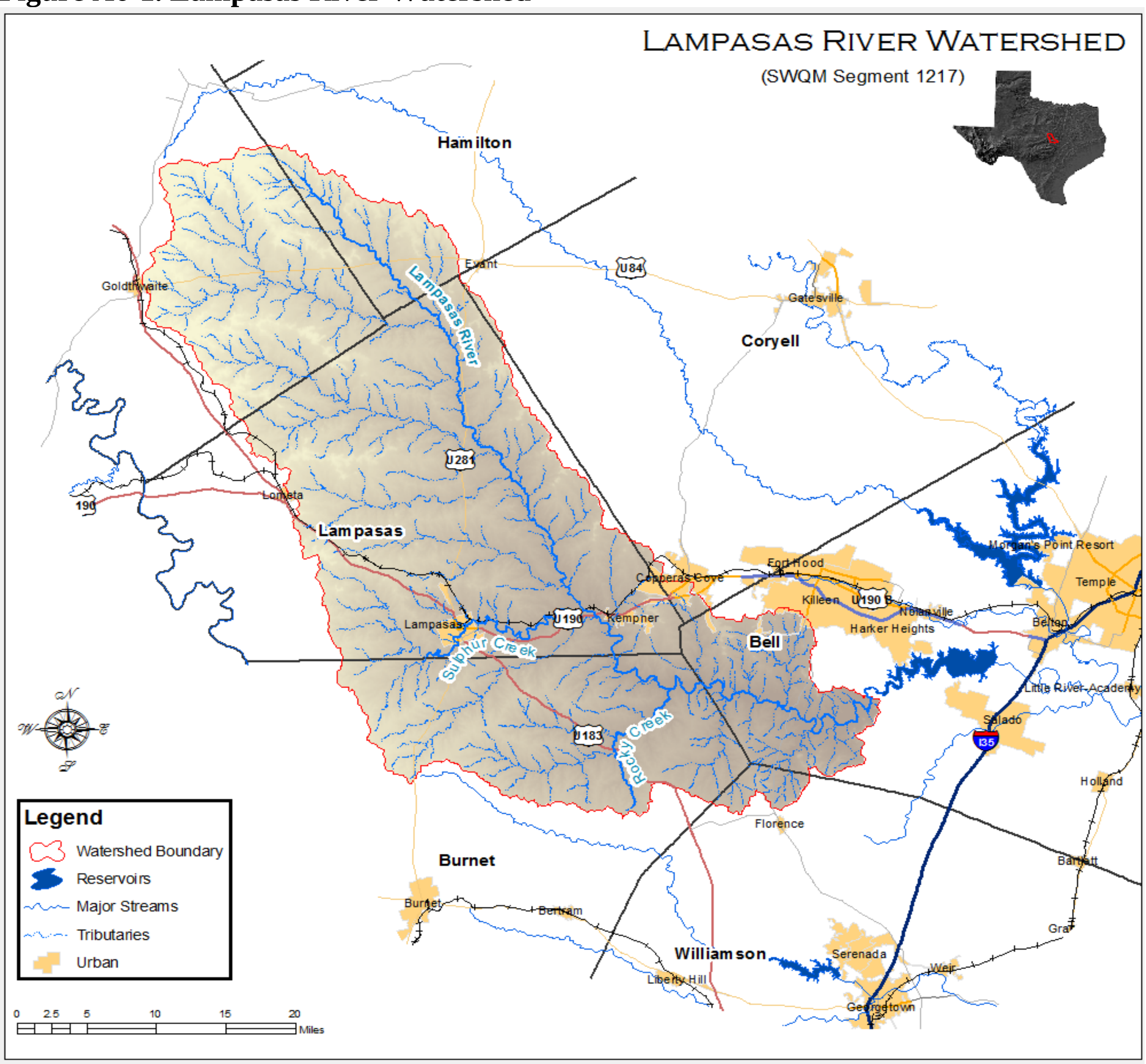
There is a clear need to 1) further assess bacterial contamination to the Lampasas River, as well as the potential for other pollution within the watershed; 2) update classification of land use distribution and influencing processes related to water quality and overall watershed health; 3) develop Load Duration Curves (LDC) for the Lampasas River to characterize contaminant loads across flow conditions; 4) use spatially explicit modeling to rank and estimate the potential fate and transport of pollutants; and 5) facilitate and encourage public education, involvement, and/or awareness of all water quality issues within the Lampasas River Watershed through a stakeholder driven water quality implementation and management strategy.

These tasks will be accomplished through development of a comprehensive watershed protection plan (WPP). With this approach, planners stand a better chance of effectively addressing the Lampasas River water quality impairment by first gathering the required information, while reaching out to facilitate stakeholder involvement and awareness of water quality issues within the watershed.

Section A6: Project Goals and Task Description

The purpose of this project is to work in concert with federal, state and local partners to coordinate a stakeholder-driven process for the development of a WPP in the Lampasas River Watershed (see figure A6-1) that is consistent with EPA's nine essential elements of a WPP. Project partners include TSSWCB, TCEQ, Texas AgriLife Extension, Brazos River Authority, Soil and Water Conservation Districts (506, 508, 509, 534, 554), Groundwater Conservation Districts (Clearwater UWCD, Central Texas GCD, Fox Crossing Water District, Saratoga UWCD), U.S. Army Corps of Engineers, USGS, Texas Water Development Board, Central Texas Streamteam, municipal and county governments including the Central Texas Concil of Governments (COG), Lake Stillhouse Hollow Cleanwater Steering Committee, Inc., and the Friends of Sulphur Creek.

Figure A6-1. Lampasas River Watershed



In order to fully develop an effective WPP for the Lampasas River, current land uses and the biophysical processes occurring on the landscape will be identified and assessed in a spatial and temporal context. This identification and assessment process will serve to quantify pollutant origin, transport mechanisms, and fate. Geographic analysis of the watershed will further refine a current land use / land cover dataset, based on available National Land Cover Dataset (NLCD 2001). The most current USDA National Agriculture Imagery Program (NAIP) aerial photography will be utilized to review, validate and/or correct anomalous land use characterization as appropriate. Supporting this effort will be the utilization of municipal and census data (among others). Final digitization of land use will be verified by ground-truthing and other verifiable data.

Inventory of potential watershed contributors of bacterial and other NPS pollution will be undertaken. For example, inventory of agricultural use is required to assess the potential for agricultural NPS contamination. In addition, inventory of groundwater use, residential/commercial development, municipal wastewater treatment, on-site wastewater treatment (septic systems), wildlife habitat, livestock, and other relevant watershed characteristic data will be compiled and analyzed. A comprehensive geo-database will be developed for analysis, providing for management strategy identification and prioritization.

Watershed assessment focus will then be directed toward development of load duration curves. This will allow watershed planners to allocate bacteria loadings to categories of potential point and nonpoint sources. The load duration curve method has found wide acceptance across the country for bacteria TMDLs and satisfies recommendations of the Bacteria TMDL Task Force Report (TWRI, 2007).

An assessment to rank the sources of bacteria loads and estimate the fate and transport of *E. coli*, nutrients (N and P), salinity, and sediment within the watershed will be undertaken using a spatially explicit Geographic Information System (GIS) methodology. For this approach, the watershed will be divided into subwatersheds and pollutant loads from various sources, i.e. agriculture, urban, and wildlife, will be identified and quantified for each. From this information, total pollutant loading for the watershed can be calculated and contributing components will be ranked based on percentage and estimated production. In addition to the GIS methodology, the hybrid statistical and process-based approach of SPARROW (SPAtially Referenced Regressions On Watershed attributes) will be used to estimate the fate and transport of pollutants within the watershed. The SPARROW approach allows users to statistically analyze uncertainty in model parameters and predictions.

Concurrent with assessment activities, an information, education, and holistic communication program will be implemented to foster partnerships, identify and recruit stakeholders, organize workgroups, and facilitate coordination towards the development of the WPP. This project will enhance partner, stakeholder and public understanding of watershed processes, facilitate reduction of NPS pollution potential associated with land use, aid in the development and utilization of the WPP as a living document and water quality planning tool, and encourage stewardship.

Project success will be measured through the amount of public participation in the planning process, quality and quantity of Lampasas River watershed assessment data compiled and modeled, number and participation in educational outreach activities, and implementation of a Lampasas River WPP. Additionally, success will be measured by the project's ability to satisfy the nine key elements of a WPP.

The purpose of this QAPP is to clearly delineate the QA policy, management structure, and procedures, which will be used to implement the QA requirements necessary to model bacteria impairments and their sources.

Table A6-1. Project Plan Milestones

TASK	PROJECT MILESTONES	AGENCY	START	END
1.1	Conduct quarterly meetings, or as appropriate, with project participants, and other interested parties to discuss project schedule, lines of responsibility, communication needs, and other requirements.	Texas AgriLife Research at Blackland Research & Extension Center (BREC)	Jan 08	Sept 10
1.2	Identify and recruit key stakeholders through public education and outreach. Organize stakeholder group. Prepare and distribute semi-annual newsletter to stakeholders. Develop and host watershed website.	BREC	Jan 08	Sept 10
1.3	Organize workgroups based on stakeholder recommendations	BREC	Jan 08	Sept 10
1.4	Conduct stakeholder meetings as appropriate (stakeholder/community driven), and conduct workgroup meetings according to project demands	BREC	Jan 08	Sept 10
1.5	Prepare stakeholder and workgroup educational programs as requested	BREC/AgriLife Extension	Jan 08	Sept 10
1.6	Develop Lampasas River WPP	BREC	Jan 08	Sept 10
2.1	Develop flow duration curves using historical stream-flow data.	BREC	Oct 08	Jan 09
2.2	Develop LDCs to characterize pollutant loadings in the Lampasas River Watershed for all parameters of concern. Determine if and under what conditions bacteria levels exceed water quality standards.	BREC	Oct 08	Jan 09
2.3	Calculate the load reductions necessary to meet water quality standards.	BREC	Oct 08	Jan 09

TASK	PROJECT MILESTONES	AGENCY	START	END
3.1	In order to develop and implement DQOs and QA/QC activities necessary to ensure environmental data of known and acceptable quality is generated through this project, a QAPP for Tasks 2-4 will be developed that is consistent with *EPA Requirements for Quality Assurance Project Plans (QA/R-5)* and the *Environmental Data Quality Management Plan for the TSSWCB*	BREC	Mar 08	Aug 08
3.2	Classify current land use for the watershed using existing land use/land cover data utilizing most current imagery available	BREC	Nov 08	April 09
3.3	Verify classification of land use through ground-truthing of sub-sampled land units, and collection of available data	BREC	Nov 08	April 09
3.4	Delineate the Lampasas River Watershed into catchments using highest resolution digital elevation model available	BREC	Nov 08	April 09
3.5	Compile all of feature class, raster, and tabular data into a comprehensive geo-database reflecting existing watershed conditions	BREC	Nov 08	April 09
4.1	Compile and estimate the contribution of potential sources of *E. coli* and other parameters within the watershed	BREC	May 09	Dec 09
4.2	Allocate numbers of each potential source category, in a spatial context according to land use classification using GIS	BREC	May 09	Dec 09
4.3	Identify potential pollutant sources across the landscape based on proximity to hydrology, land use, and other factors using SELECT analysis	BREC	May 09	Dec 09
4.4	Utilize the hybrid statistical and process-based approach of SPARROW (SPAtially Referenced Regressions on Watershed Attributes) to quantify uncertainty in SELECT parameters	BREC	May 09	Dec 09
5.1	Work with stakeholders and workgroups to prioritize implementation activities based on consensus and continual watershed assessment and awareness	BREC	June 09	Sept 10
5.2	Assist stakeholders in identification and acquisition of resources necessary to precede with watershed implementation and protection strategies, and in anticipation of future watershed needs.	BREC	June 09	Sept 10
5.3	Identify metrics or other indicators which will be used to evaluate successful implementation or improvement of watershed health over time	BREC	June 09	Sept 10

Model Descriptions

Statistical Models

1. Spatially Explicit Load Enrichment Calculation Tool (SELECT)
2. Load duration curve

3. SPARROW

Spatially Explicit Load Enrichment Calculation Tool (SELECT)

The Center for TMDL and Watershed Studies at Virginia Tech has been involved in TMDL development for bacteria impairments. The Center personnel developed a systematic process for source characterization that includes the following steps:

- inventorying bacterial sources (including livestock, wildlife, humans, and pets);
- distributing estimated loads to the land as a function of land use and source type; and
- generating bacterial load input parameters for watershed-scale simulation models.

This process provides a consistent approach that is necessary to develop comprehensive bacteria TMDLs. The Center personnel developed a software tool, the Bacteria Source Load Calculator (BSLC), to assist with the bacterial source characterization process and to automate the creation of input files for water quality modeling (Zeckoski, et al., 2005). But BSLC does not spatially reference the sources. A spatially-explicit tool, Spatially Explicit Load Enrichment Calculation Tool (SELECT) is being developed by Spatial Sciences Laboratory and Biological and Agricultural Engineering, to calculate contaminant-loads resulting from various sources in a watershed. SELECT spatially references the sources, and is being developed under ArcGIS 9 environment. SELECT will calculate and allocate pathogen loading to a stream from various sources in a watershed. All loads will be spatially referenced. In order to allocate the *E. coli* load throughout the watershed, estimations of the source contributions will be made. This in turn allows the sources and locations to be ranked according to their potential contribution. The populations of agricultural animals, wildlife, and domestic pets will be calculated and distributed throughout the watershed according to appropriate land use. Furthermore, point sources such as Waste Water Treatment Plants will be identified and their contribution quantified based on flow and outflow concentration. Septic system contribution will also be estimated based on criteria including distance to a stream, soil type, failure rate, and age of system. Once the watershed profile is developed for each potential source, the information can be aggregated to the sub-watershed level to identify the top contributing areas.

Load duration Curve

The duration curve framework provides a simple-yet-powerful graphical analysis method for examining relationships between flow and a water body's loading capacity when correlations between water quality impairments and flow conditions are suspected. Load duration curves (LDC) characterize water quality monitoring data at different stream flow regimes and accounts for how flow patterns affect changes in water quality over the course of a year (USEPA, 2007). LDCs show targeted loads across all flow regimes along with the magnitude and frequency of water quality standard exceedances in each regime. The basis of the LDC is the flow duration curve (FDC) (Figure A6-2) which uses the hydrograph of the observed stream flows to calculate and depict the percentage of time the flows are equaled or exceeded.

Development and analysis of LDCs help identify loading capacities, load allocations, margins of safety, and seasonal variations. Duration curves also provide a means to link water quality concerns with key watershed processes that may be important considerations in watershed protection plans and TMDL development (USEPA). Used with knowledge of hydrologic principles, LDCs can help identify the relative importance of watershed characteristics and factors such as water storage or storm events, which subsequently affect water quality. In large watersheds like the Lampasas, multiple LDCs developed at different points along a stream can aid in isolating and identifying impairment sources. Ambient water quality data, taken with some measure or estimate of flow at the time of sampling, can be used to compute an instantaneous load at each point.

Using the relative percent exceedance from the flow duration curve that corresponds to the stream discharge at the time the water quality sample was taken, the computed load is plotted in a duration curve format (Figure A6-3). Graphing loads calculated from water quality data and the daily average flow on the date of the sample, characteristic patterns develop which help describe the nature of the water quality impairment. As indicated in Figure A6-3, loads that plot above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show compliance.

Examining the pattern for occurrence across all flow conditions, high flow events only, or low flows only, helps identify whether the impairment is due to a point or nonpoint source. Impairments observed in the low flow area generally indicate the influence of point sources, while those further left in high flow and moist conditions tend to reflect potential nonpoint source contributions. Data may also be separated by season (e.g., spring runoff versus summer base flow). For example, Figure A6-3 uses a "+" to identify those samples collected from March to October.

The utility of duration curve zones for pattern analysis can be further enhanced to characterize wet-weather concerns (USEPA). Since flow is used to develop the duration curves stream discharge measurements on days preceding collection of the water quality sample may also be examined by comparing the flow on the day the sample was collected with the flow on the preceding day. Any one-day increase in flow (above the designated threshold) is assumed to be the result of a surface runoff event. In Figure A6-3, these samples are identified with a red shaded diamond.

Figure A6-2. Flow Duration Curve (FDC) for streamflow conditions at USGS monitoring station 08104100 on the Lampasas River, near Belton, TX.

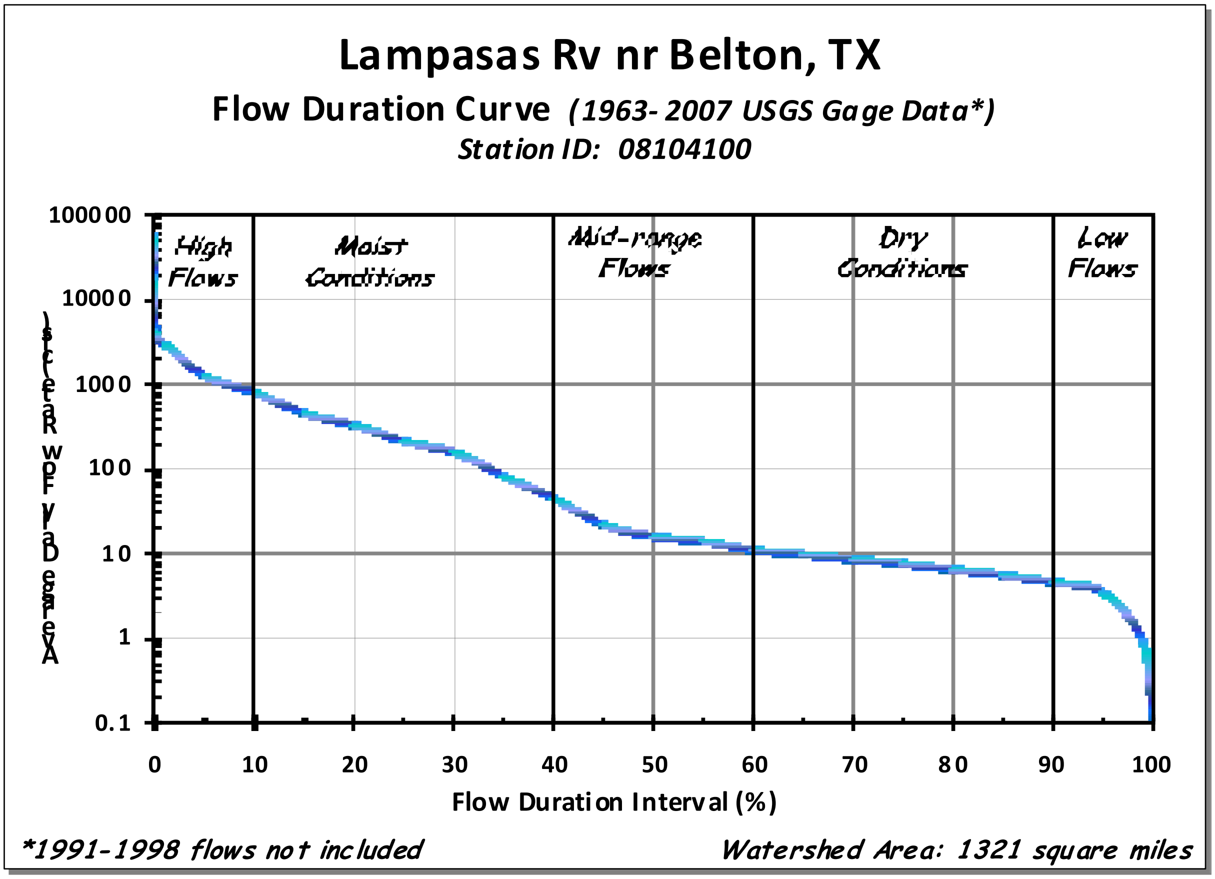
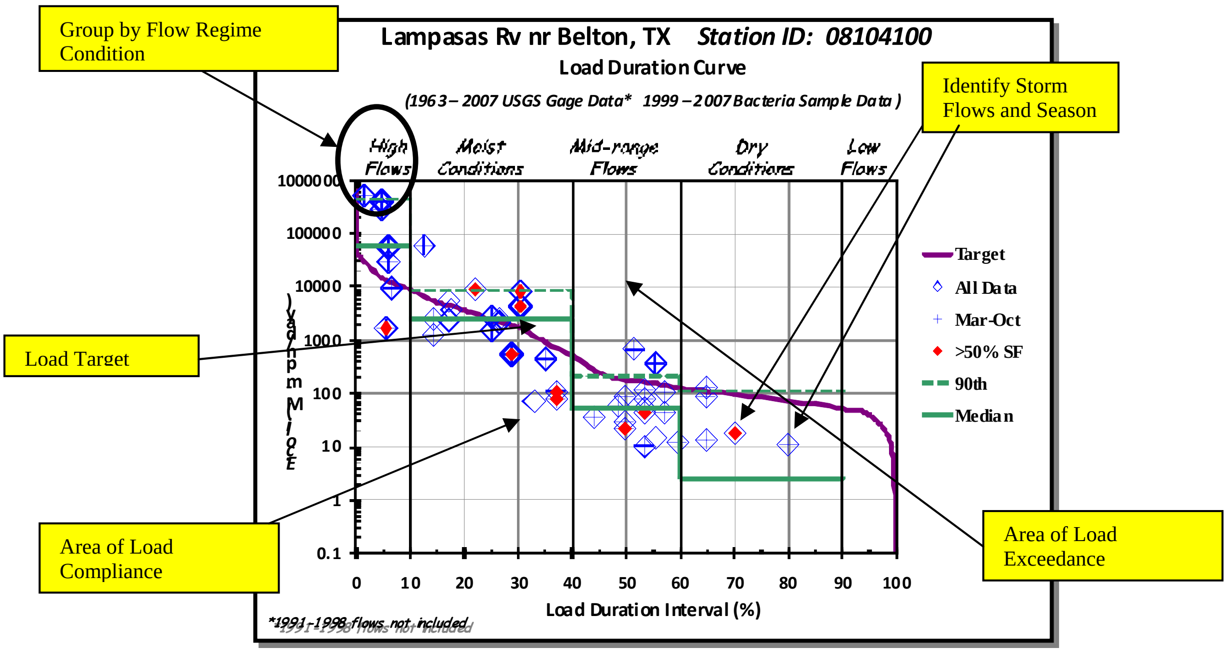


Figure A6-3. Load Duration Curve (LDC) for *E. coli* at BRA monitoring station 11897 on the Lampasas River. Flow data were obtained from the USGS gage station 8172400.



SPARROW (SPAtially Referenced Regressions On Watershed attributes)

SPARROW (SPAtially Referenced Regressions On Watershed attributes) is a hybrid statistical/deterministic regional water quality assessment model that uses mechanistic functions with spatially distributed components for pollutant predictions (Smith et al., 1997). The model spatially references various watershed components, such as stream monitoring data, pollutant sources, etc., to surface water flow paths that are defined by a digital drainage network. It then imposes mass-balance constraints to empirically estimate terrestrial and aquatic rates of pollutant flux. Applications of SPARROW include estimation of the spatial distributions of pollutant yields, pollutant sources, and the potential for delivery of those yields to receiving waters. This information can be used to (1) predict ranges in pollutant levels in surface waters, (2) identify the environmental variables that are significantly correlated to the pollutant levels in streams, (3) evaluate monitoring efforts for better determination of pollutant loads, and (4) evaluate various management options for reducing pollutant loads to achieve water-quality goals. SPARROW has been used previously to estimate the quantities of nutrients delivered to streams and watershed outlets from point and diffuse sources over a range of watershed sizes (Alexander et al., 2001, 2000; Preston and Brakebill, 1999; Smith et al.,1997). This approach will be utilized for this work because it not only uses process-based models to simulate transport of pollutants, but it also uses the actual historical monitoring data and known predictor variables to predict the various model input parameters. In this manner, a more realistic model can be developed that closely describes the conditions of the particular watershed (Schwarz, et al., 2006).

Section A7: Quality Objectives and Criteria for Model Inputs / Outputs

BREC, in coordination with TAMU Spatial Sciences Laboratory (SSL) faculty will conduct watershed assessment modeling to develop pollutant source and loading information for the Lampasas Watershed Protection Plan based on watershed data collected and assembled in a geodatabase. The objectives of the watershed modeling for this project are as follows:

1) Develop and obtain approval for a QAPP for spatial modeling (SELECT modeling) and spatial/temporal analysis (SPARROW/load duration curves) for the Lampasas River Watershed.
2) Obtain current landuse/landcover classification through extraction of information contained in the 2001 National Land Use Land Cover Inventory, and verify current land use through aerial photo interpretation of the 2004-2005 National Agriculture Imagery Program (NAIP) imagery, and ground-truthing as necessary.
3) Spatially characterize and rank sources of bacteria, nutrients (N and P), salinity (TDS, SO_4, Cl), and sediment within the watershed using SELECT, a spatially-explicit Geographic Information System (GIS) methodology. Divide the area into sub-watersheds and identify, quantify and rank pollutant loads from various sources, i.e. agriculture, urban, and wildlife. For each monitoring location in Lampasas River Watershed, obtain Load Duration Curve (LDC) to analyze the temporal trends in the observed water quantity and quality data. Obtain an interpolated model to simulate the trends of the monitored data. Evaluate the exceedances and the required load-reductions for different flow-rate regimes (low, medium, and high flow) using LDC and interpolated model. Utilize the hybrid statistical and process-based approach of SPARROW (SPAtially Referenced Regressions) to analyze the spatial load distribution from various sources based on monitoring data.

Land Use/Land Cover (LULC) Classification and Verification

The initial phase of the project will consist of classifying the current land use for the watershed. This will be done through extraction and development of the 2001National Land Cover Database (NLCD) (Homer et al., 2004) currently available at from Multi-Resolution Land Characteristics Consortium website at http://www.mrlc.gov/index.asp**.** This data will further be refined by verification and/or correction as determined by aerial photo interpretation. NLCD datasets will be reviewed for consistency with 2004-2005 National Agriculture Imagery Program (NAIP) aerial photography. Coverage of the LULC inventory will be interpreted and validated within ESRI's ArcGIS 9.x software. Individual land use/cover classes corrections will be identified and delineated in shapefile format with a minimum mapping unit of 0.5 ac on screen and verified through field sampling to an accuracy of 80% or greater. Ground control points used in the field sampling will be collected for at least ten locations per land use type using GPS units with an accuracy of 1-10 m.

NAIP provides two main products: 1 meter ground sample distance (GSD) ortho imagery rectified to a horizontal accuracy of within +/- 3 meters of reference digital ortho quarter quads (DOQQS) from the National Digital Ortho Program (NDOP) (2004 imagery); and, 2 meter GSD ortho imagery rectified to within +/- 20 meters of reference DOQQs (2005 imagery). The tiling format of NAIP imagery is based on a 3.75' x 3.75' quarter quadrangle with a 360 meter buffer on all four sides. NAIP quarter quads are rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone.

As a point of comparison, the USGS National Land Cover Data (NLCD) is created with Landsat Thematic Mapper images. Each image is precision terrain-corrected using 3-arc-second digital terrain elevation data (DTED), and georegistered using ground control points. The resulting root mean square registration error is less than 1 pixel, or 30 meters.

The land use classification scheme to be used in this delineation will include:

- Developed Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

- Developed Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

- Developed Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

- Developed High Intensity- Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

- Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.

- Barren Land - (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover and includes transitional areas.

- Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than 50 percent of total vegetation cover.

- Near Riparian Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than 50 percent of total vegetation cover. These areas are found following in near proximity to streams, creeks and/or rivers.

- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent but less than 50 percent of total vegetation cover.

- Rangeland – Areas of unmanaged shrubs, grasses, or shrub-grass mixtures.

- Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

Load Duration Curves

The LDC approach has been utilized in several TMDL projects as an initial screening-tool to evaluate the actual temporal load trends in streams (USEPA, 2007; Cleland, 2003;). In cases of violations, it is necessary to determine the required load-reduction in that region near the monitoring station. The load-reductions should be calculated for all flow-regimes of the stream. In order to do this continuous monitoring data will be estimated by regressing the water quality monitoring sample data. Uncertainty of the model will be estimated via residual error analysis. The straight line passing through residual error plot should have a slope of zero.

SELECT Modeling

SELECT was developed by faculty at the SSL and the Department of Biological and Agricultural Engineering at Texas A&M. It is similar to BSCL (Zeckoski, et al. 2005) in TMDL development. High quality spatial data (Landuse data, SSURGO soils data, the National Hydrography Dataset (NHD), etc) will be processed and utilized in SELECT approach. Distributions for input parameters for SELECT will be created based on literature values and expert knowledge.

SPARROW – “employs a statistically estimated nonlinear regression model with contaminant supply and process components, including surface-water flow paths, non-conservative transport processes, and mass-balance constraints. Parameters of the regression equation are estimated by correlating generally available stream water-quality records, such as those from State and Federal monitoring programs, with GIS (Geographic Information System) data on pollutant sources (e.g., atmospheric deposition, fertilizers, human and animal wastes) and climatic and hydrogeologic properties (e.g., precipitation, topography, vegetation, soils, water routing) that affect contaminant transport. The statistical estimation of parameters in SPARROW provides measures of uncertainty in model coefficients and water-quality predictions” (Schwarz, et al., 2006). Validation and calibration of SPARROW will be followed as described in Schwarz et al., 2006.

Model calibration inputs ands outputs

The following criteria have been established for this project as acceptable model calibration inputs and outputs, respectively:

- Simple and multiple linear regressions with a $r^2 > 0.8$ will be enforced with regard to the SELECT model,
- The straight line passing through residual error plot of the LCD should have a slope of zero,
- Validation and calibration of SPARROW will be followed as described in Schwarz et al., 2006,

If the standards are not obtained, a corrective action report will be submitted to TSSWCB with the following quarterly report. If these steps do not bring predicted values within calibration standards, the Quality Assurance Officer will work with TSSWCB and EPA to arrive at an agreeable compromise.

Section A8: Special Training Requirements/Certification

All personnel involved in model calibration, validation, and development will have the appropriate education and training required to adequately perform their duties. No special certifications are required.

Section A9: Documentation and Records

All records, including modeler’s notebooks and electronic files, will be archived at BREC, located in Temple and at Texas A&M University in College Station for at least five years. These records will document model testing, calibration, and evaluation and will include record of code verification (hand-calculation checks, comparison to other models), source of historical data, and source of new theory, calibration and sensitivity analyses results, and documentation of adjustments to parameter values due to calibration. Electronic data on the desktop and network server are backed up daily to a tape drive. In the event of a catastrophic systems failure, the tapes can be used to restore the data in less than one day’s time. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

Quarterly progress reports disseminated to TSSWCB and project cooperators will note activities conducted in connection with the water quality modeling project, potential problems, and any variations or supplements to the QAPP. Final reports on LULC derivation, SELECT, LDC and SPARROW will be generated. Outcomes and stakeholder decisions based on these reports will be documented in the project final deliverable, the Lampasas River WPP.

Corrective Action Reports (CAR) will be utilized as necessary (Appendix A). CARs will be maintained for reference in an accessible location by BREC and disseminated to the individuals listed in section A3. CARs resulting in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in updates or amendments to the QAPP.

Section B1: Sampling Process Design (Experimental Design)

Not relevant.

Section B2: Sampling Method Requirements

Not relevant.

Section B3: Sample Handling and Custody Requirements

Not relevant.

Section B4: Analytical Methods Requirements

The initial phase of the project will consist of classifying the current land use for the watershed. This will be done through extraction and development of the 2001 NLCD currently available from Multi-Resolution Land Characteristics Consortium website at http://www.mrlc.gov/index.asp. This data will further be refined by verification and/or correction as determined by aerial photo interpretation. LULC datasets will be reviewed for consistency with 2004-2005 National Agriculture Imagery Program (NAIP) aerial photography. Coverage of the LULC inventory will be interpreted and validated within ESRI's ArcGIS 9.x software. Individual land use/cover classes corrections will be identified and delineated in shapefile format with a minimum mapping unit of 0.5 ac on screen and verified through field sampling to an accuracy of 80% or greater. Ground control points used in the field sampling will be collected for at least ten locations per land use type using GPS units with an accuracy of 1-10 m.

NAIP provides two main products: 1 meter ground sample distance (GSD) ortho imagery rectified to a horizontal accuracy of within +/- 3 meters of reference digital ortho quarter quads (DOQQS) from the National Digital Ortho Program (NDOP) (2004 imagery); and, 2 meter GSD ortho imagery rectified to within +/- 20 meters of reference DOQQs (2005 imagery). The tiling format of NAIP imagery is based on a 3.75' x 3.75' quarter quadrangle with a 360 meter buffer on all four sides. NAIP quarter quads are rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone.

As a point of comparison, the USGS National Land Cover Data (NLCD) is created with Landsat Thematic Mapper images. Each image is precision terrain-corrected using 3-arc-second digital terrain elevation data (DTED), and georegistered using ground control points. The resulting root mean square registration error is less than 1 pixel, or 30 meters.

The land use classification scheme to be used in this delineation will include:

- Developed Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

- Developed Low Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

- Developed Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

- Developed High Intensity- Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

- Open Water - All areas of open water, generally with less than 25% cover of vegetation or soil.

- Barren Land - (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover and includes transitional areas.

- Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than fifty percent of total vegetation cover.

- Near Riparian Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than fifty percent of total vegetation cover. These areas are found following in near proximity to streams, creeks and/or rivers.

- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent to 50 percent of total vegetation cover.

- Rangeland – Areas of unmanaged shrubs, grasses, or shrub-grass mixtures

- Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

Not relevant for LDC development and SELECT modeling

Section B5: Quality Control Requirements

The initial phase of the project will consist of classifying the current land use for the watershed. This will be done through extraction and development of the 2001 Land Use Land Cover Dataset. This data will further be refined by verification and/or correction as determined by aerial photo interpretation. LULC datasets will be reviewed and adjusted where necessary for consistency with 2004-2005 National Agriculture Imagery Program (NAIP) aerial photography. Coverage of the LULC inventory will be interpreted and validated within ESRI's ArcGIS 9.x software. Individual land use/cover classes corrections will be identified and delineated in shapefile format with a minimum mapping unit of 0.5 ac on screen and verified through field sampling to an accuracy of 80% or greater. Ground control points used in the field sampling will be collected for at least ten locations per land use type using GPS units with an accuracy of 1-10m.

Not relevant for LDC development and SELECT modeling

Section B6: Equipment Testing, Inspection, & Maintenance Requirements

Not relevant.

Section B7: Instrument Calibration and Frequency

Not Relevant.

Section B8: Inspection/Acceptance Requirements for Supplies and Consumables

Not relevant.

Section B9: Data Acquisition Requirements (Non-direct Measurements)

The BRA is a partner in the Clean Rivers Program for the state of Texas. As such, they collect data on a regular basis for routine water quality assessment as part of the state's mandate for CWA §305(b) – Water Quality Inventory Report. These data also are used by Texas for consideration of water bodies to be added to their list of impaired water body segments, as described in CWA §303(d). Additional data obtained from the Texas Commission on Environmental Quality are from the TRACS database.

All data used in the modeling procedures for this project are collected in accordance with approved quality assurance measures under the state's Clean Rivers Program, Texas Commission on Environmental Quality, Texas Water Development Board, USDA, National Weather Service, or USGS. Future data collection supported by CWA §319(h) funds through TSSWCB will be incorporated into the modeling process as the data become available. Any subsequent targeted monitoring data as recommended through the WPP process will be collected under a separate QAPP.

GIS data to be used are 2004 and 2005 NAIP (National Agricultural Imagery Program) aerial photos, SSURGO (Soil Survey Geographic) and CBMS (Computer Based Mapping System) soils, USGS NLCD (National Land Cover Dataset) landuse, National Hydrography Dataset (NHD), Census data (2000), Agricultural Census data from USDA-NASS (2002), and the USGS 30-meter resolution digital elevation model (DEM). Quality assured stream flow measurements will be collected from USGS stream gage stations (08103800 and 0810410000).

Because most historical data is of known and acceptable quality and were collected and analyzed in a manner comparable and consistent with needs for this project, no limitations will be placed on their use, except where known deviations have occurred.

Section B10: Data Management

Systems Design

BREC uses laptop personal computers and desktop personal computers. The computers run the Windows operating system. Databases include Microsoft® Excel, Microsoft® Access, ESRI file geodatabase, and a SAS database management system.

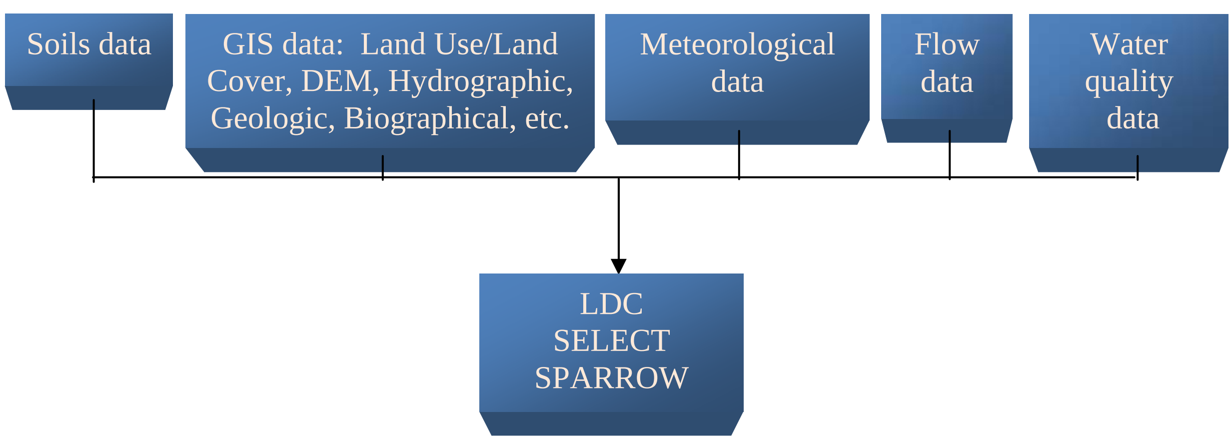
Backup and Disaster Recovery

The personal computer drives are backed up on a daily basis to an offsite server for storage in a secure secondary location. In the event of a catastrophic systems failure, the server backup can be used to restore the data in less than one day's time. 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

Original data recorded on paper files are stored for at least five years. Data in electronic format are stored on backup server in at a separate location on the BREC campus

Figure B10-1. Information Dissemination Diagram



Section C1: Assessments and Response Actions

Table C1.1 presents the types of assessments and response actions for activities applicable to the QAPP.

Table C1.1 Assessments and Response Actions

Assessment Activity	Approximate Schedule	Responsible Party(ies)	Scope	Response Requirements
Status Monitoring Oversight, etc.	Continuous	BREC	Monitoring of the project status and records to ensure requirements are being fulfilled. Monitoring and review of performance and data quality.	Report to project lead in Quarterly Report
Technical Systems Audit	Minimum of one during the course of this project.	TSSWCB QAO	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP. Facility review and data management as they relate to the project.	30 days to respond in writing to the TSSWCB QAO to address corrective actions

In addition to those listed above, the following assessment and response actions will be applied to modeling activities. As described in Section B9 (Non-direct Measurements), modeling staff will evaluate data to be used as model input according to criteria discussed in Section A7 (Quality Objectives and Criteria for Model Inputs/Outputs Data) and will follow-up with the various data sources on any concerns that may arise.

The model calibration procedure is discussed in Section D2 (Validation and Verification Methods), and criteria for acceptable outcomes are provided in Section A7 (Quality Objectives and Criteria for Model Inputs/Outputs).

Results will be reported to the project QA officer in the format provided in Section A9. If agreement is not achieved between the calibration standards and the predictive values, corrective action will be taken by the Project Manager to assure that the correct files are read appropriately and the test is repeated to document compliance. Corrective action is required to ensure that conditions adverse to quality data are identified promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. Corrective Action Reports (Appendix A) will be filled out to document the problems and the remedial action taken. Copies of Corrective action reports will be included with BREC—Water Quality Group's most current quarterly progress report. The quarterly progress report will discuss any problems encountered and solutions made. These reports are the responsibility of the Quality Assurance Officer and the Project Manager and will be disseminated to the TSSWCB PM and project cooperators. If the predicted value cannot be brought within calibration standards, the Quality Assurance Officer will work with TSSWCB to arrive at an agreeable compromise.

Software requirements, software design, or code are examined to detect faults, programming errors, violations of development standards, or other problems. All errors found are recorded at the time of inspection, with later verification that all errors found have been successfully corrected. Software used to compute model predictions are tested to assess its performance relative to specific response times, computer processing usage, run time, convergence to solution, stability of the solution algorithms, the absence of terminal failures, and other quantitative aspects of computer operation.

Checks are made to ensure that the computer code for each module is computing module outputs accurately and within any specific time constraints. The full model framework is tested as the ultimate level of integration testing to verify that all project-specific requirements have been implemented as intended. All testing performed on the original version of the module or linked modules is repeated to detect new “bugs” introduced by changes made in the code to correct a model.

Section C2: Reports to Management

Quarterly progress reports developed by the Project Manager will note activities conducted in connection with the water quality modeling project, items or areas identified as potential problems, and any variations or supplements to the QAPP. Corrective action report forms will be utilized when necessary (Appendix A). CARs will be maintained in an accessible location for reference at BREC and disseminated to individuals listed in section A3. 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.

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 promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. Corrective Action Reports will be filled out to document the problems and the remedial action taken. Copies of Corrective action reports will be included with the BREC—Water Quality Group's most current quarterly progress report. The quarterly progress report will discuss any problems encountered and solutions made. These QA reports are the responsibility of the Quality Assurance Officer and the Project Manager and will be disseminated to the TSSWCB PM and project cooperators.

Section D1: Data Review, Validation and Verification

All data obtained will be reviewed, validated, and verified against the data quality objects outlined in Section A7, “Quality Objectives and Criteria for Model Inputs / Outputs.” Only those data that are supported by appropriate quality control will be considered acceptable for use.

The procedures for verification and validation are described in Section D2, below. BREC—Water Quality Group’s Project Manager is responsible for ensuring that data are properly reviewed, verified, and submitted in the required format for the project database. Finally, the BREC—Water Quality Group’s QAO is responsible for validating that all data collected meet the data quality objectives of the project and are suitable for reporting.

Section D2: Validation Methods

There is no validation and calibration for the SELECT model or LDC as they are data processors. Validation and calibration methodology for SPARROW is documented in Schwartz et al., 2006 and will be strictly followed.

Calibration is the process where the model input parameters are adjusted until the simulated data from the model match with observed data. Model parameters related to watershed/landscape processes will be adjusted to match the measured and simulated flow, sediment, nutrients and bacteria at key locations in the watershed. During the calibration process, all model parameters will be adjusted within literature recommended ranges. Calibration will be done to represent normal, wet and dry years. Time series plots (between simulated and observed data) and statistical measures such as mean, standard deviation, coefficient of determination and Nash-Suttcliffe simulation efficiency (Nash and Suttcliffe, 1970) will be used to evaluate the prediction (performance) of the model during calibration. Coefficient of determination indicates the strength of relationship between the observed and simulated values. Nash-Suttcliffe simulation efficiency indicates how well the plot of observed versus simulated value fits the 1:1 line. If the values for these two measures are less than or very close to zero, the model prediction is considered ‘unacceptable or poor’. If the values are one, then the model prediction is ‘perfect’. Calibration is done systematically, first for flow, then for sediment and followed by organic and mineral nutrients (Santhi et al., 2002).

Model parameters related to subwatersheds and landscape processes will be adjusted to match measured and simulated flow and water quality trends at key locations in the watershed. All model parameters will be adjusted within ranges recommended in published literature. Then the model will be validated without adjusting any parameters. Depending on the monitoring data available, calibration and validation periods will be chosen. Time series plots and standard statistical measures will be used to evaluate the performance of models during calibration and validation.

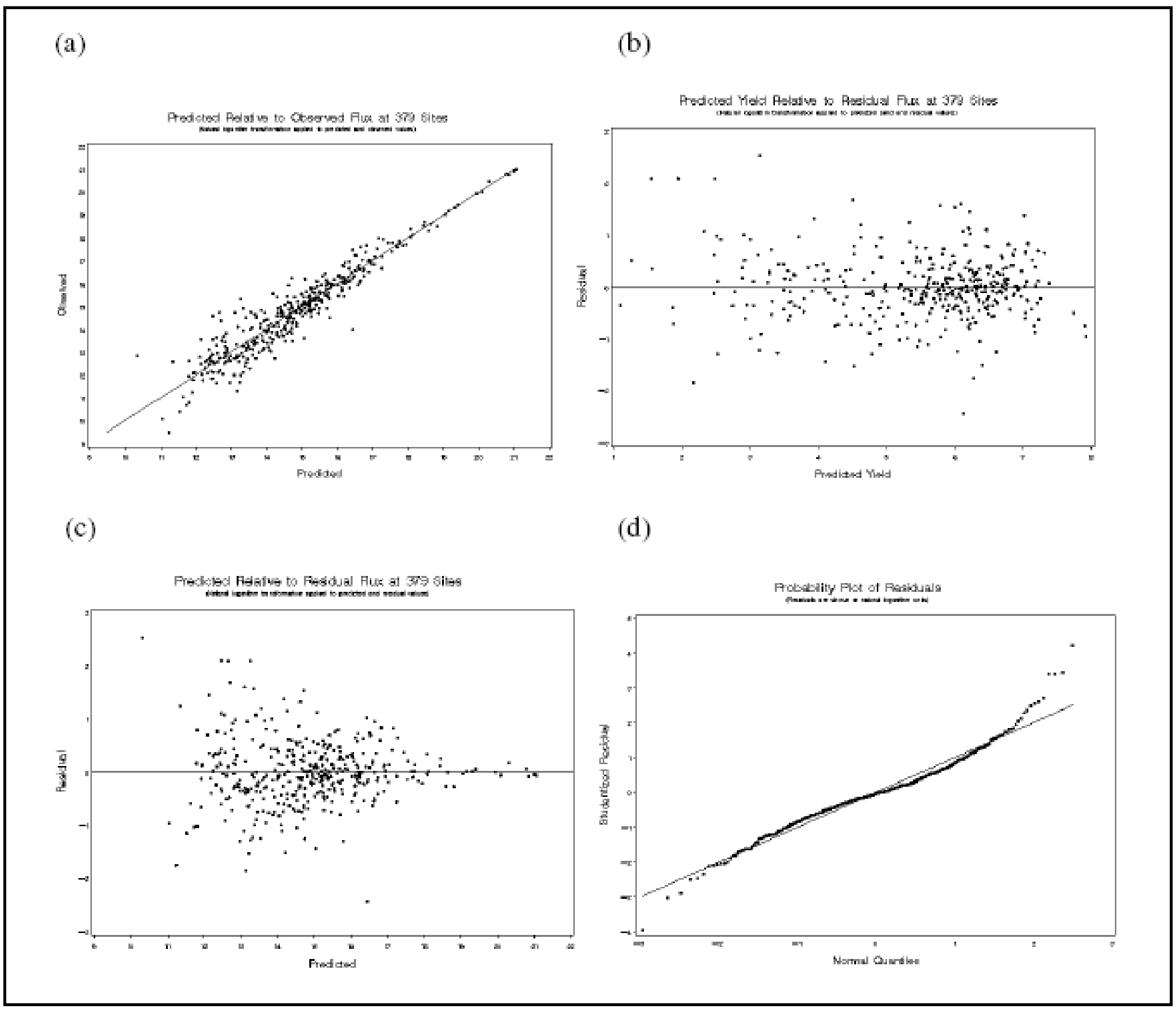
Heteroscedasticity

The estimated residuals from the model contain a great deal of information for evaluating model specification. When using the statistical techniques, such as least squares, inherent in SPARROW, a number of assumptions are typically made. One of these is that the error term has a constant varience. This will be true if the observations of the error term are assumed to be drawn from identical distributions. Heteroscedasticity is a violation of this assumption.

The assumptions of the model require the weighted residuals to be identically distributed (homoscedastic), independent across observations, and uncorrelated with the explanatory variables. Several procedures detailed by Schwartz et al. (2006) will be used to evaluate the reasonableness of these assumptions when for SPARROW model applications.

Evidence of problems related to heteroscedasticity can be obtained primarily by inspection of a set of four diagnostic graphs shown in figure D2-1. The first plot is of the observed versus predicted flux in log units (figure D2-1a). The graphed points should exhibit an even spread about the one-to-one line (the straight line in figure D2-1a) with no outliers. A common pattern expressed in this graph for SPARROW nutrient models is the tendency for larger scatter among observations with smaller predicted flux—a pattern of heteroscedasticity. One possible cause for this pattern is greater error in the measurement of flux in small basins due to greater variability in flow or to greater relative inhomogeneity of contaminant sources within small basins. If the heteroscedasticity is caused by measurement error, then appropriate assignment of weights reflecting the relative measurement error in each observation (plus an additional common model error) can improve the coefficient estimates and correct the inference of coefficient error.

Figure D2-10. Diagnostic plots for evaluating SPARROW model errors and adherence of the residuals to the model assumptions: (a) predicted and observed flux; (b) residuals and predicted yield; (c) residuals and predicted flux; and (d) a probability plot of residuals.



The pattern of predicted versus observed logarithm of flux may also indicate systematic bias in the model. A significant deviation of the plotted points from the one-to-one line in a particular region of the graph indicates the model is structurally biased. Structural bias of this kind implies the residuals of the model are likely to be correlated with the predictors (another example of failure of the third assumption that residuals are independent of predictors) and may result in biased coefficient estimates. Such bias is generally not eliminated by including additional observations; rather, it is likely that an important predictor—one associated with basin scale—is absent from the model. Identifying such a predictor will usually correct the problem and remove the region-specific bias of residuals from the one-to-one line.

The plot of log residuals versus predicted yield (i.e., mass per unit of drainage area), as shown in figure D2-1b, is also useful for validating the model fit. The graphed points once again should exhibit an even spread about the one-to-one line, with no outliers. The graph is useful for identifying and diagnosing bias and heteroscedasticity in much the same way as the graph of predicted versus observed log of flux (fig. D2-1a). The conversion to yield units, however, tends to remove scale effects, such as those related to drainage area. Deviations from the one-to-one line in this graph are indicative of a systematic bias or misspecification of the model at the watershed scale related to specific land-to-water or in-stream processes, such as reservoir attenuation. In this case, including an additional process or modifying the functional form of an existing process may solve the problem.

A plot of log residuals versus predicted flux, as shown in figure D2-1c, provides a third check of whether residuals meet the assumptions of the least squares methodology: the residuals should not vary systematically either in terms of spread or bias with the predictions. Under heteroscedasticity, unweighted residuals may exhibit varying levels of spread across the range of predictions. If a proper weighting of the observations has been applied, so that the heteroscedasticity is removed, the residuals in figure D2-1c will show a common spread that is centered near zero throughout the range of predictions (homoscedasticity). Various assignments of weights may be tested by comparing figures D2-1a and D2-1c: weights are optimal if the systematic pattern of heteroscedasticity in figure D2-1a is absent from figure D2-1c

A fourth type of graph that is indicative of cases of heteroscedasticity, but is most commonly used to identify non-normally distributed residuals, is a probability plot of the model residuals, as shown in figure D2-1d. The probability plot depicts the relation between the empirical distribution of the residuals and the normal distribution: specifically, it is the scatter plot relating the ordered standardized weighted residuals, and the quantiles of the adjusted ranks.

The empirical distribution will plot along the reference line in figure D2-1d if the standardized weighted residuals are normally distributed. Conversely, if the empirical distribution plot is a convex shape (that is, the steepness of the graph is greater than the one-to-one line for the lower portion and less than one-to-one for the upper portion), then the residuals are skewed to the left (negative skew), implying there are more small residuals and fewer large residuals compared to a normal distribution. If the empirical distribution is a concave shape (that is, the steepness of the graph is less than the one-to-one line for the lower portion and greater than one-to-one for the upper portion), then the residuals are skewed to the right (positive skew), implying there are more large residuals and fewer small residuals compared to a normal distribution. If the empirical distribution generally plots along the one-to-one line in the middle section of the graph but the tails of the figure show points consistently above or below the line, then there is more or less probability in the tails as compared to a normal distribution. For example, a group of points falling below the one-to-one line at the low end of the graph is indicative of an empirical distribution having a fatter left tail than the normal distribution. A group of points lying above the one-to-one line on the upper end of the graph is indicative of an empirical distribution that is fatter than the normal distribution in the right tail.

Because departure of the residuals distribution from normality does not necessarily invalidate the SPARROW model results, departures of the empirical distribution from the one-to-one line is not necessarily of concern. Failure to meet the three assumptions of the nonlinear least squares methodology (that residuals are mutually independent, identically distributed, and independent of the predictor variables) is, however, sometimes associated with deviations from the one-to-one line in the normal probability plot. For example, heteroscedasticity of the residuals (failure of the second assumption) causes the tails of the empirical distribution to be fatter than the normal distribution, which is expressed on the probability plot as points at the low end of the probability plot lying below the one-to-one line and points at the high end lying above the one-to-one line (as is the case for the residuals of the example nitrogen model shown in figure D2-1d). It is stressed, however, that heteroscedasticity represents a problem for model estimation and interpretation only if the heteroscedasticity is caused by failure of the third assumption, that is, if the residuals are related to the predictors (i.e., gradients). This particular cause of heteroscedasticity can be detected by interpreting the graph of predicted and observed flux in figure D2-1a.

A formal test of the normality assumption is provided by the Shapiro-Wilk's test statistic (W). The W statistic is essentially the squared value of the correlation coefficient between the residuals and the expected values of the normal order statistics. W is a measure of the straightness of the normal probability plot. Probability values for evaluating the statistical significance of W are numerically estimated in SPARROW.

The standard SPARROW output includes the normal distribution probability plot correlation coefficient, the Shapiro-Wilks normality test statistic, and the probability value of the Shapiro-Wilks test statistic. The probability plot correlation coefficient provides a measure of the linear correlation between the ordered, standardized weighted residuals, obtained from the estimated parametric model, and the quantiles of the standard normal distribution. A value of the correlation coefficient near one is evidence that the residuals are from a normal distribution, whereas a value below 0.98 is generally indicative of non-normal residuals.

Section D3: Reconciliation with User Requirements

The modeling framework developed for this project will be used to evaluate water quality issues in streams within the Lampasas River Watershed. It will provide the Lampasas River Watershed cooperators and stakeholders, through the Steering Committee and Work Groups, with optimum information pertaining to watershed characteristics and to the prediction of possible pollution, the sources of this pollution and will assist in identifying optimum placement of BMPs to prevent pollution loading in area streams. This, in turn, will enable their decision-making efforts as part of a comprehensive Watershed Protection Plan process.

The final data will be reviewed to ensure that it meets the requirements as described in this QAPP. Corrective Action Reports will be initiated in cases where invalid or incorrect data have been detected. Data that have been reviewed, verified, and validated will be summarized for their ability to meet the data quality objectives of the project and the informational needs of water quality agency decision-makers. These summaries, along with a description of any limitations on data use, will be included in the final 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:___________________________________

TWRI Quality Assurance Officer:______________________________

TSSWCB Quality Assurance Officer:____________________________