Texas State Soil and Water Conservation Board
Total Maximum Daily Load Program Project

Classification of Current Land Use/Land Cover for Certain Watersheds Where Total Maximum Daily Loads or Watershed Protection Plans Are In Development

Quality Assurance Project Plan (Project # 08-52)

Texas State Soil and Water Conservation Board

Revision 0

prepared by

Texas A&M AgriLife

Texas Water Resources Institute

and

Spatial Sciences Laboratory

Effective Period: March 2008 to March 2009

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Section A1: Title and Approval Sheet

Quality Assurance Project Plan for *Classification of Current Land Use/Land Cover for Certain Watersheds Where Total Maximum Daily Loads or Watershed Protection Plans Are In Development.*

Texas State Soil and Water Conservation Board (TSSWCB)

Name: ~~Aaron Wendt~~ Pamela Casebolt
Title: TSSWCB Project Manager

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Name: Donna Long
Title: TSSWCB Quality Assurance Officer

Signature: Donna K. LutLong Date: 5/13/08

Texas A&M AgriLife, Texas Water Resources Institute (TWRI)

Name: C. Allan Jones
Title: TWRI Project Lead

Signature: Charles Allan Jones Date: 04/24/08

Name: Kevin Wagner
Title: TWRI Quality Assurance Officer (QAO)

Signature: Kevin Wagner Date: 4-24-08

Texas A&M AgriLife, Spatial Sciences Lab (SSL)

Name: Raghavan Srinivasan
Title: Spatial Sciences Lab Director; Project Manager

Signature: R. S— Date: ____________

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List of Acronyms and Abbreviations

CAR	Corrective action report
CD	Compact Disc
CWA	Clean Water Act
DOQQS	Digital ortho quarter quads
DQO	Data quality objectives
DTED	Digital terrain elevation data
ESRI	Environmental Systems Research Institute
GIS	Geographic information system
GPS	Global positioning system
GSD	Ground sample distance
LULC	Land use / land cover
NAD	North American Datum
NAIP	National Agriculture Imagery Program
NDOP	National Digital Orthophoto Program
NLCD	USGS national land cover data set
PM	Project Manager
QA	Quality assurance
QC	Quality control
QAO	Quality Assurance Officer
QAPP	quality assurance project plan
SOP	Standard operating procedures
SSL	Spatial Sciences Laboratory
SWAT	Surface water assessment tool
TCEQ	Texas Commission on Environmental Quality
TM	Landsat Thematic Mapper
TMDL	Total maximum daily load
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
USDA-NRCS	U.S. Department of Agriculture-Natural Resources Conservation Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
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:

- Texas State Soil and Water Conservation Board (TSSWCB)

  Name: Pamela Casebolt
  Title: TSSWCB Project Manager

  Name: Donna Long
  Title: TSSWCB Quality Assurance Officer

- Texas A&M AgriLife, Texas Water Resources Institute (TWRI)

  Name: Kevin Wagner
  Title: TWRI Quality Assurance Officer

- Texas A&M AgriLife, Spatial Sciences Lab (SSL)

  Name: Raghavan Srinivasan
  Title: Spatial Sciences Lab Director

Section A4: Project/Task Organization

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

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

Pamela Casebolt, TSSWCB Project Manager

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 participants.

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. 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 TSSWCB Total Maximum Daily Load Program.

TWRI - Texas A&M AgriLife, Texas Water Resources Institute (TWRI), College Station, Texas. Responsible for reporting and development of data quality objectives (DQOs) and a quality assurance project plan (QAPP).

C. Allan Jones, Project Lead

The TWRI Project Lead is responsible for ensuring that tasks and other requirements in the contract are executed on time and with the quality assurance/quality control 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 TSSWCB Project Manager.

Kevin Wagner, Quality Assurance Officer

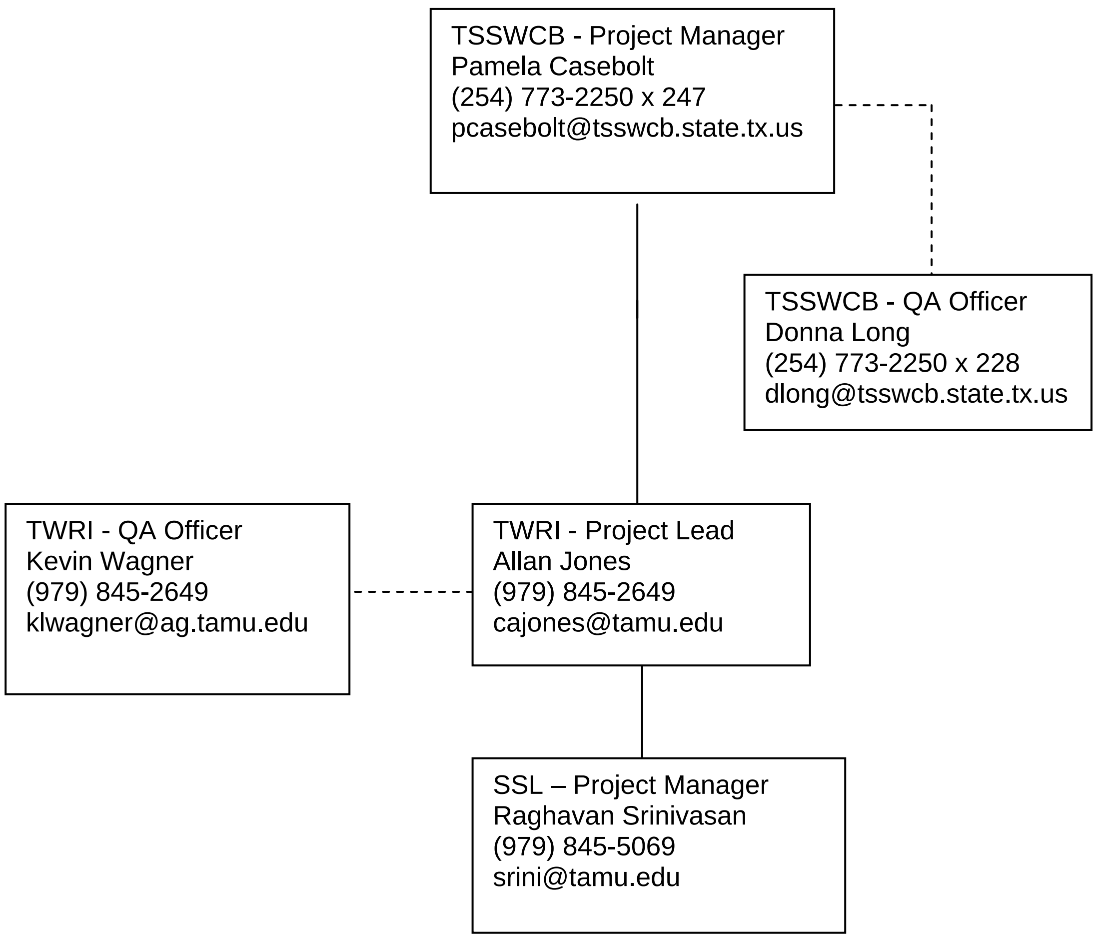
Responsible for project reporting and determining that the Quality Assurance Project Plan (QAPP) meets the requirements for planning, quality control, and quality assessment. Conducts audits of field and laboratory systems and procedures. Responsible for maintaining the official, approved QAPP, as well as conducting Quality Assurance audits in conjunction with TSSWCB personnel.

SSL - Texas A&M AgriLife, Spatial Sciences Lab (SSL), College Station, Texas. Responsible for classifying land use and land cover in the Big Cypress Creek, middle Brazos River, Navasota River, Lake Granger, and Buck Creek watersheds for use in TMDL and WPP development.

Raghavan Srinivasan, Spatial Sciences Laboratory Director; Project Manager

Responsible for coordinating and supervising land use and land cover classification activities. Responsible for ensuring that personnel have adequate training and a thorough knowledge of standard operating procedures specific to the classification of land use and land cover. Responsible for oversight of all Spatial Sciences Laboratory operations and ensuring that all quality assurance/quality control requirements are met. Enforces corrective action, as required.

Figure A4.1 Project Organization Chart

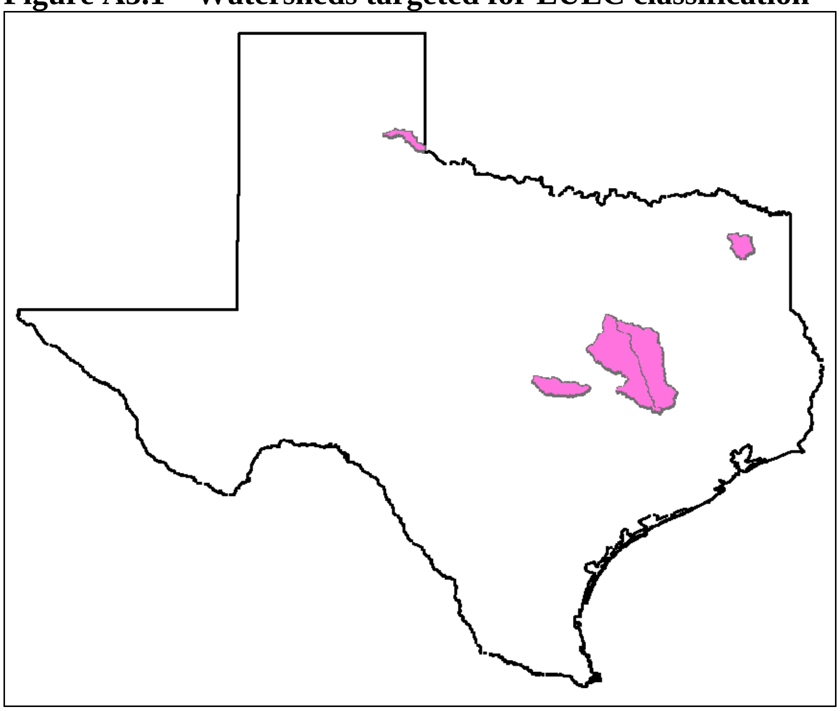


Section A5: Problem Definition/Background

An important component to any watershed assessment is having up to date land use data. LULC data describe the vegetation, water, natural surface, and cultural features on the land surface LULC data is used to understand potential pollutant sources and to target pollutant abatement/remediation efforts. LULC data is a fundamental building block in sophisticated watershed models, such as SWAT.

To address pollutant source assessment needs, SSL will classify the current land use for the Big Cypress Creek, Middle Brazos River, Navasota River, Lake Granger, and Buck Creek watersheds. The results of this effort will be used in the decision-making processes as a part of the TMDL or WPP development in these watersheds.

Figure A5.1 Watersheds targeted for LULC classification



The Big Cypress Creek watershed contains Segment 0404 and its unclassified tributaries. A bacteria TMDL project is being initiated for this watershed (TSSWCB funding). This is also the contributing watershed for Lake O' the Pines, for which a dissolved oxygen TMDL has been adopted.

The middle Brazos River watershed contains Segment 1242 and its unclassified tributaries. Numerous waterbodies are impaired for bacteria and a TMDL project is being initiated for five of those impaired streams (TSSWCB funding).

The Navasota River watershed contains Segments 1209, 1210, 1252, 1253 and their unclassified tributaries. Numerous waterbodies are impaired for bacteria and a TMDL project is being initiated for one of those impaired streams (TCEQ funding).

The Lake Granger watershed contains Segments 1247, 1248, 1249, 1250, 1251 and their unclassified tributaries. A WPP project is currently underway (TSSWCB CWA §319(h) project 05-09) focusing on sediment and nutrient concerns and bacteria impairments.

The Buck Creek watershed contains Segment 0207A and its tributaries. A WPP project is currently underway (TSSWCB CWA §319(h) project 06-11) focusing on nutrient concerns and a bacteria impairment.

Section A6: Project/Task Description

The project will classify current land use for the Big Cypress Creek, Middle Brazos River, Navasota River, Lake Granger, and Buck Creek watersheds through a combination of satellite based image classification schemes and where needed "heads-up digitizing" of aerial photos. 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% 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% 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% 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 80-100% 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% of total vegetation cover.
- Near Riparian Forested Land – Areas dominated by trees generally greater than 5 meters tall, and greater than 50% of total vegetation cover. These areas are found following in near proximity (within 30-60 m) to streams, creeks and/or rivers.
- Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% but less than 50% 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% of total vegetation.
- Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

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 classify the land use / land cover in the Big Cypress Creek, Middle Brazos River, Navasota River, Lake Granger, and Buck Creek watersheds

Table A6.1. Project Plan Milestones

TASK	PROJECT MILESTONES	AGENCY	START	END
1.1	Develop QAPP	TWRI	Feb 08	Mar 08
1.2	Provide revisions and necessary amendments to the QAPP	TWRI	Mar 08	Aug 08
1.3	Prepare electronic quarterly progress reports	TWRI	Feb 08	Aug 08
1.4	Perform accounting functions for project funds	TWRI	Feb 08	Aug 08
2.1	Perform satellite image classification & heads-up digitizing of aerial photos of the Big Cypress Creek watershed	SSL	Mar 08	Aug 08
2.2	Identify LULC classes in the Big Cypress Creek watershed & delineate them in shapefile or ArcGIS grid format	SSL	Mar 08	Aug 08
2.3	Verify Big Cypress Creek watershed LULC thru field sampling	SSL	Mar 08	Aug 08
3.1	Perform satellite image classification & heads-up digitizing of aerial photos of the middle Brazos River watershed	SSL	Mar 08	Aug 08
3.2	Identify LULC classes in the middle Brazos River watershed & delineate them in shapefile or ArcGIS grid format	SSL	Mar 08	Aug 08
3.3	Verify middle Brazos River watershed LULC thru field sampling	SSL	Mar 08	Aug 08
4.1	Perform satellite image classification & heads-up digitizing of aerial photos of the Navasota River watershed	SSL	Mar 08	Aug 08
4.2	Identify LULC classes in the Navasota River watershed & delineate them in shapefile or ArcGIS grid format	SSL	Mar 08	Aug 08
4.3	Verify Navasota River watershed LULC thru field sampling	SSL	Mar 08	Aug 08
5.1	Perform satellite image classification & heads-up digitizing of aerial photos of the Lake Granger watershed	SSL	Mar 08	Aug 08
5.2	Identify LULC classes in the Lake Granger watershed & delineate them in shapefile or ArcGIS grid format	SSL	Mar 08	Aug 08
5.3	Verify Lake Granger watershed LULC thru field sampling	SSL	Mar 08	Aug 08
6.1	Perform satellite image classification & heads-up digitizing of aerial photos of the Buck Creek watershed	SSL	Mar 08	Aug 08
6.2	Identify LULC classes in the Buck Creek watershed & delineate them in shapefile or ArcGIS grid format	SSL	Mar 08	Aug 08
6.3	Verify Buck Creek watershed LULC thru field sampling	SSL	Mar 08	Aug 08

Section A7: Data Quality Objectives and Criteria

The objectives for this project are as follows:

1) Develop and obtain approval for a QAPP
2) Classify current land use / land cover for the Big Cypress Creek, middle Brazos River, Navasota River, Lake Granger, and Buck Creek watersheds for use in TMDL and WPP development.

A combination of satellite based image (2004-2006) classification schemes and where needed "heads-up digitizing" of the 2004-2006 National Agriculture Imagery Program (NAIP) aerial photos of the area in ESRI's ArcGIS 9.x software will be used to classify the current land use / land cover. 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 Orthophoto 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, 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.

To achieve the needed precision and accuracy, the land use / land cover classification scheme to be used in this delineation will include at a minimum the twelve classifications discussed in A6. Individual LULC classes will be identified and delineated with a minimum mapping unit of 2 acres on screen.

Representativeness will be addressed by collecting ground control points for at least ten locations per land use type per watershed. This GPS survey will utilize the Trimble GeoExplorer 3 Global Positioning System Receiver in the WGS84 (World Geodetic System of 1984) Mode to obtain control point latitude/longitude values within 10 meters of true locations at the 95% confidence level. This level of accuracy is consistent with Tier 3 described in the EPA National Geospatial Data Policy. The Trimble GeoExplorer 3 will be set to capture data provided that at least four satellites are in view and the Position Dilution of Precision (PDOP) value remains at 6 or below. The receiver will be set to provide audible or visual warnings when the quality settings are exceeded. Sample interval and time on station will be consistent with Trimble GeoExplorer 3 Manual recommendations. Post-processing the GPS data will be accomplished using the vendor's software package operating on a local workstation. The higher end software package will perform statistical analyses on the point data downloaded from the GPS receiver. For 10-meter data accuracy, any data points with a standard deviation of 3 meters or more will be a basis to exclude that data point from the collection. Ideally, the standard deviation for 10-meter accuracy data should be 1 meter or less at the 95% confidence level.

Once the ground control points are collected as outlined in the previous paragraph, the individual LULC classes will be verified through comparison with the ground control points to ensure an accuracy of 80% or greater. This will be complemented with aerial photographs and other ancillary data that is available (See section B).

Comparability will be addressed by collecting, analyzing, and reporting the data as described in section B of this document.

A completeness goal of 100% is needed for the project. Valid data is required for each land use / land cover class mapped in order to complete the cover maps for each watershed.

Section A8: Special Training/Certification

No special certifications are required. However, all personnel involved in classification of land use and land cover will have the appropriate education and training required to adequately perform their duties. GIS technicians will be experienced or trained in using Trimble GeoExplorer 3 GPS Receivers, (ESRI) ARCINFO and ARCVIEW.

Section A9: Documentation and Records

Digital files of land cover data for each watershed will be produced in shapefile or ArcGIS grid format and stored on CD-ROM disks. Multi-color hard copy maps of land cover can be produced at various geographic scales from these digital files. SSL plans to produce hard copy land cover maps for all five watersheds. Other products will be produced as required by the TSSWCB, cooperators and other data users.

Metadata documentation will be developed and will document data sources, processing techniques, accuracy assessment, and other pertinent information.

Appendix B represents the field data collection form used for this project. Other records and documentation to be developed for this project include the following: digital files of spatial data, field data, and scanned photographs.

Records of field data, original aerial photos, digital files used for classifying LULC and accuracy assessment, and corrective action reports (CARs) will be maintained and archived by SSL for at least five years.

All electronic data are backed up on an external hard drive monthly, compact disks weekly, and is simultaneously saved in an external network folder and the computer's hard drive. A blank CAR form is presented in Appendix A.

Quarterly progress reports disseminated to the individuals listed in section A3 will note activities conducted, items or areas identified as potential problems, and any variations or supplements to the QAPP. CARs will be utilized when necessary. 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. All quarterly progress reports and QAPP revisions will be distributed to personnel listed in Section A3.

The TSSWCB may elect to take possession of records at the conclusion of the specified retention period.

QAPP Revision and Amendments

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; the revision must be submitted to the TSSWCB for approval before the last approved version has expired. 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 plan is current. This will be accomplished by submitting a cover letter stating the status of the QAPP and a copy of new, signed approval pages for the QAPP.

QAPP amendments 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. Written requests for amendments are directed from the TWRI Project Leader to the TSSWCB PM and are effective immediately upon approval by the TSSWCB PM and QAO. Amendments to the QAPP and the reasons for the changes will be documented and distributed to all individuals on the QAPP distribution list by the TWRI Project Leader or designee. Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process.

Section B1: Collection Process/Field Survey Design

The production of a land cover map is an iterative process based on data from satellite imagery, aerial photography, existing maps and field reconnaissance. Satellite imagery consisting of summer and winter scenes in 2004-2006 covering the five watersheds has been purchased. Land use / land cover will be assigned to twelve categories according to the category descriptions provided in Section A6.

Ground reference data must be collected to train the computer software to recognize the spectral reflectance of various land cover categories represented in the NAIP imagery. Since ground reference data generally cannot be collected for the entire project area, representative samples will be used.

SSL staff will collect or acquire at least ten actual ground locations per land use type in each watershed for use in mapping land cover. These locations will be used to conduct supervised classifications of remote sensing data from satellite imagery. This data will also be used for accuracy assessment as outlined in Section B5.

Field data will be collected according to standard protocols. The SSL Project Manager will review field data and assign appropriate classification prior to digitizing the data for GIS analysis. Descriptions of land use / land cover that cannot be assigned a class corresponding to the scheme used in labeling classes on the land cover map will be rejected.

Types and numbers of samples required: SSL will acquire 10 representative ground locations for each land cover class labeled on the land cover map.

Sampling Locations and frequencies: SSL has a goal of 600 field sites statewide with a minimum of 10 sites for each land use / land cover class. Data are being acquired from all five watersheds to provide a representative sample.

Section B2: Data Collection Methods

Phase 1 Acquisition:

Ancillary data will be used to classify the satellite based images into classes. The SSL is using existing aerial photos, topo maps and field data from the Natural Resource Conservation Service (NRCS) as sources to define LULC polygons. The geographic location of the polygons is known and is matched to the same location on the imagery.

Phase 2 Acquisition:

Field sampling will be used to verify individual LULC classes identified and delineated. Ground control points used in the field sampling will be collected for at least ten locations per land use type per watershed using GPS units with an accuracy of 1-10 m.

LULC categories are identified in the field by an observer who is knowledgeable about LULC identification and classification standards. Observed LULC classifications are recorded on data forms provided by the SSL (Appendix B). No specialized equipment is used to collect the sample data.

Ancillary data will be used to supplement the sample data gathered by the field personnel. These sources include color infrared, black and white and color aerial photography of the same time period as the imagery and other sources that become available during the classification process.

All ancillary data that arrives in the GIS lab in non-digital form will be inspected for accuracy and appropriateness by the SSL Project Manager and then digitized for use in the GIS classification process. Where applicable, aerial photos will be scanned on a flatbed scanner and the resultant images will be geo-rectified using a specialized software program. The rectified image will be viewed in a GIS application and the necessary data from the image will be traced. Attribute information will be attached to each traced polygon and saved as a file. Where data can be matched visually from a paper copy to a digital source it will be digitized directly on the screen without scanning.

Documentation of Field Sampling Activities

Field sampling activities are documented in field notebooks. For all visits, site identification, date, time, personnel, and conditions at the site are recorded.

Recording Data

All field and Spatial Sciences Laboratory personnel follow the basic rules for recording information including: (1) writing legibly in indelible, waterproof ink with no modifications, write-overs or cross-outs; (2) correcting errors with a single line followed by an initial and date; and (3) closing-out incomplete pages with an initialed and dated diagonal line.

Deviations from Sampling Method Requirements or Sample Design, and Corrective Action

Examples of deviations from sampling method requirements or sample design include but are not limited to such things as inadequate sample volume due to spillage or container leaks, failure to preserve samples appropriately, contamination of a sample bottle during collection, storage temperature and holding time exceedance, sampling at the wrong site, etc. Any deviations will invalidate resulting data and may require corrective action. Corrective action may include for samples to be discarded and re-collected. It is the responsibility of the TWRI Project Lead and QAO to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP. In addition, these actions and resolutions will be conveyed to the TSSWCB Project Manager both verbally and in writing in the project progress reports and by completion of a corrective action report (CAR).

Corrective Action Reports (CARs) document: root cause(s); programmatic impact(s); specific corrective action(s) to address any deviations; action(s) to prevent recurrence; individual(s) responsible for each action; the timetable for completion of each action; and the means by which completion of each corrective action will be documented. CARs will be included with project progress reports. In addition, significant conditions (i.e., situations which, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the TSSWCB immediately both verbally and in writing.

Section B3: Data Handling and Custody

Field data forms provided by SSL are hand delivered or mailed back to the SSL Lab via business reply envelopes. All ancillary data sources are filed by watershed in the SSL Lab. When hardcopy data is digitized or otherwise entered into the computer, backups of the digital files to removable media will be made to ensure no loss of data due to machine failure.

Section B4: Analytical Methods

Phase 1 Classification:

The SSL is using summer and winter satellite images and a combination of satellite based image classification schemes and heads-up digitizing of NAIP aerial photos of the area to conduct the land cover inventory of the watersheds. NAIP quarter quads are rectified to the UTM coordinate system, NAD 83 and cast into a single predetermined UTM zone.

The spectral classes from each scene covering the watersheds are first labeled into the twelve LULC categories using whatever ground information was available, including aerial photos, topo maps and data from the NRCS. The land use classification scheme to be used is described in Section A6. Individual LULC classes will be identified and delineated in shapefile or ArcGIS grid format with a minimum mapping unit of 2 acres on screen. Ground truth sample polygons are then divided into two randomly selected groups, one for image labeling and the other for classification accuracy testing.

Phase 2 Classification:

ESRI ArcGIS software will be used to classify images in Phase 2. Classification will be done using the geographic extents of one scene. The product of the Phase 1 classification will be used as input to the supervised classification process. One category will be selected as the focus of a classification operation. Appropriate ground samples and ancillary polygons containing LULC data, located and labeled by SSL personnel, will be matched with corresponding areas on the original satellite images and the image polygons will be classified using on-screen interpretive techniques to an accuracy of 80% or greater. The process will be repeated for each LULC category using field samples and other ancillary data.

As a point of comparison, 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.

A detailed account of data processing techniques will be documented in metadata according to the established standards. ESRI ArcCatalog software will be used to record the metadata for this project.

Section B5: Quality Control

Assessing the accuracy of land cover mapping products is an elusive and challenging problem that calls for continuing research and development within GIS and remote sensing technology. The criteria for accuracy assessment reflect the need to balance the requirements for rigor and defensibility with practical limitations of cost and time. The assessment methods must be scientifically sound and economically feasible.

The basic unit of the land cover mapping process is a polygon of 2 acres that represents a land use / land cover class with a relatively homogenous composition. An accuracy assessment will be conducted by selecting a sample of locations (e.g., centroids of mapped polygons) from the final version of the land cover map and determining the true land cover classification at these locations. These data are frequently called the reference data set. Properly executing an accuracy assessment involves knowing the nature of the created map, identifying the field methods for obtaining the reference data, designing a sound method for selecting reference data, actually collecting the data, conducting statistical analyses, and reporting the results.

This project has a goal of mapping land cover with 80% accuracy. We will attempt to measure thematic accuracy as a percentage of the land cover map classified correctly overall and by cover type with a standard error no greater than 8%.

Summary of steps and standards used in Accuracy Assessment:

1. Produce a final land cover map, classification, and description of land cover classes that will be assessed.
2. Identify the methods for obtaining reference data.
3. Design a sampling protocol that meets the desired statistical precision.
4. Collect the reference data, test their reliability, and archive the database.
5. Compare the reference data to the map, conduct analyses, and report the results.

Step 1: A final version of a land cover map will be produced as described in section B4. We anticipate having at least 12 cover classes that can be delineated on the satellite imagery. Because classification will be done in phases, one scene at a time, it will not be necessary to wait until the mapping is completed for all watersheds to begin accuracy assessment. Knowledge of the characteristics of the map to be assessed is important in determining the sampling frame (number, size, and classification of polygons). The methodology used to collect the reference data will match the classification system of the cover map.

Step 2: We plan to use field collected data as the primary source of reference data to assess the quality of the final cover map. Ground-truthing involves physically visiting the site in question to determine its true land cover type and will require substantial cooperator support and coordination. The SSL Project Manager and SSL personnel will develop a field sampling plan that will guarantee consistency between reference data and the needs of the assessment project and future remapping, (i. e., the method of collecting the field data will enable the land cover to be identified at the same level of detail as the land cover map). Quality Control will be achieved by assuring that the GPS receiver performance criteria under section A.5 above are met at all times. Statistical checks will be performed on the data during the post-processing phase and the data will be compared to known map coordinates and features using USGS topographic maps and other appropriate map sources of known quality.

The design of the assessment study will be stratified by, and only by, land cover types present in the final land cover map. The protocol for selecting field sampling sites will be based on the final number of land cover classes, the number of polygons within each class, and the number of samples needed to accomplish statistical precision.

With a minimum mapping unit of 2 acres, we anticipate that the occurrence of other unmapped cover types (inclusions) within a polygon will cause few problems in collecting field data. Nevertheless, the SSL Project Manager will develop field protocols to ensure that each mapped cover type can be correctly identified in the field. The characteristics of land cover types that may affect these protocols are: polygon sizes (small, medium, large), polygon shapes (linear or non-linear), and heterogeneity of the land cover (degree of patchiness and size of inclusion patches).

An individual measurement will result in a decision as to whether or not the field reference point agrees with the land cover map's label of that polygon. Accuracy is the statistical reduction of many samples into a statement of percent agreement.

Step 3: Sampling units are defined here as all areas within the project area geographically contiguous and of homogenous primary attribute, that is, vector polygons or contiguous raster clusters of the same primary land cover type code. Land cover maps are based on algorithmic clustering of TM pixels with the resultant categories being spectrally similar. Therefore, pixels are probably not independent of each other. Although polygon boundaries are not precise, they are believed to represent real patterns on the the ground and the polygon is the defined feature that should be assessed. Therefore, the sampling unit is defined as a mapped polygon. The sample frame is the list of all polygons that comprise the final land cover map.

The sampling protocol for accuracy assessment will be designed to meet the statistical precision needed to accomplish the stated objectives for accuracy and standard error. Field sites will be selected through a stratified, two-stage probability sample. Accuracy assessment field data will be recorded on forms and returned to the SSL lab for analysis (see Appendix B). Probability sampling, as opposed to purposive selection of "representative" elements or haphazard selection of convenient elements, is now a standard scientific tool since it guards against selection biases and it leads to objective statistical inferences. Stratification will ensure good geographic spread of the sample across the state and will provide a representative sample of alliances.

Two stages of sampling will be employed. In the first stage, large tracts of land (e.g. counties, Landsat scenes, or some other convenient unit) will be selected in a stratified sample. In the second stage, sampling points within the large tracts will be selected. The reason for sampling in two stages, as opposed to sampling sites directly, is that direct sampling of sites would lead to a widely-scattered sample with high logistical costs.

Because cost of collecting field data could be limiting, consideration will be given to stratifying according to the relative cost or effort required to measure the sampling site.

Step 4. GIS methods will be used to select sampling units from the sampling frame which consists of all the polygons in a vector map.

Field surveys will use methods similar to those used to collect data for classification purposes (Appendix B). However, reference data will be collected by 2 or 3 well-trained field observers who have no knowledge of the primary attribute given by the land cover map for the sampling unit. This will involve providing each observer with coordinates and a map showing the polygon to be sampled but without the associated land cover type label. The field maps will typically have base information such as roads, streams, and locational grids such as UTM coordinates.

Observers will be trained and field tested in the typical techniques used for land use inventories. They will also be given training in the classification scheme employed in the land cover mapping process. They will be provided written guidelines and other materials to assure that consistent, repeatable results are obtained (Appendix B).

The field data for each sampling unit will be assigned a pointer that identifies its location on the land cover map. Reference data will be compiled as a GIS coverage containing both the locations of samples and their attributes. Metadata will include a description of the method used by the analyst to determine agreement between the map and reference data and a measure of observer reliability in order to replicate the published analysis. Field forms will be archived and GIS data managed in accordance with procedures outlined in this document.

Step 5. Measurements from field sampling units will be compared with labeled polygons on the land cover map. As a first step in statistical analysis, agreements, or lack thereof, will be tabulated in a matrix whose rows represent mapped categories and columns represent observed cover types. The resulting error matrix is a contingency table which represents the probabilities of every possible correct or incorrect classification.

Statistical analyses of the measurements from the assessment sample need to recognize that the data arise from a complex sample. It is not valid to analyze these data as if they are independent and identically distributed. Analyzing data from a stratified two-stage sample as if they were independent and identically distributed will typically lead to confidence intervals which are unrealistically narrow and hypothesis tests which reject too easily. That is, the precision of the analysis is overstated. Proper methods for dealing with data from stratified two-stage samples will be employed in this study.

Limitations and Constraints: In planning accuracy assessments, three general constraints (technology, logistics, and cost) must be considered because of the limitations they place on our ability to obtain ideal data sets.

Technological constraints: This category of constraints includes measurement errors relating to aquiring field observations. Error in determining the true location of the sampling unit in the field should not be a major problem in Texas because the terrain is moderate and bisected by an elaborate system of roads and highways. Sampling units will be outlined in advance on topographic maps, county road maps, and aerial photos (if available) and provided to field observers. Also, field observers will usually be able to survey entire sampling units, thereby reducing error caused by inadequate integration of all attributes of a unit.

Logistical constraints: Most sampling units will be located in close proximity of a road and can be visited without great expense. Few locations will be inaccessible due to dangerous terrain. If sampling measurements cannot be made at a site due to inaccessibility, then these sites will be dropped from the sampling scheme and replaced with more accessible ones.

Financial constraints: We will conduct an accuracy assessment that is a reasonable balance between available funding and scientific soundness.

Failures in Quality Control and Corrective Action

All incidents requiring corrective action will be documented through use of CARs (Appendix A). Corrective action will involve identification of the possible cause (where possible) of the QC failure. Any QC failure that has potential to compromise data validity will invalidate the data. The resolution of QC failures will be reported to the TSSWCB in the quarterly progress report. CARs will be maintained by the Project Leader and the TSSWCB PM.

Section B6: Instrument/Equipment Testing, Inspection, and Maintenance

Equipment testing will be accomplished by the GPS Operator prior to, during and after field use. Built-in equipment diagnostics and functionality checks will be utilized in accordance with the operation manuals. Results will be reported in pre-survey, field and post-processing logs. Issues will be documented with the GPS Coordinator or equipment owner.

Section B7: Instrument/Equipment Calibration and Frequency

GPS receivers cannot be calibrated. However, a number of settings can be changed (maximum PDOP, signal-to-noise ratio, filter coefficient, etc.) which will affect operation of the unit. In general, manufacturer default settings will be employed for optimum data accuracy.

Section B8: Inspection/Acceptance for Supplies and Consumables

The primary consumables for GPS operations are batteries. During the equipment testing, inspection and maintenance periods, batteries will be examined by the GPS Operator for functionality, charge and compatibility with manufacturer's specifications. Fully charged, backup batteries will be taken to the field for use when recharging is not an option.

Supplies used in the SSL Lab will be inspected upon receipt by the SSL Project Manager for visible signs of damage. All data will be backed up on removable storage media so that failure of primary storage media will not result in data loss. Supplies will be purchased from reputable vendors to ensure quality.

Section B9: Non-direct Measurements/Secondary Data Use

The display of GPS ground points will be accomplished by overlaying the collected points on map features of comparable quality. This provides a road network, topographic features and other map elements that can place the collected points in the context of real-world features. This is an additional quality check, since large deviations from expected locations would cause the data and processing methods to be rechecked. Standards map products of known quality will be used.

Landsat Thematic Mapper (TM) digital satellite imagery will be the primary data source for constructing base maps of LULC. Ancillary information will be drawn from other imagery where applicable.

Summer and winter coverages of Landsat TM imagery from 2004-2006, have been obtained. It is desirable to base land cover mapping upon multi-season data since multiple seasons allow the use of information about vegetation phenology in the classification process.

The Landsat TM data are received in digital format on a CD. The images have been pre-processed to correct missing information and other problems inherent in satellite-gathered imagery. The images obtained were also geo-referenced to real-world coordinates and clustered into 240 spectrally distinct classes prior to receipt.

National Agriculture Imagery Program (NAIP) aerial photos of the area will also be used. 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 Orthophoto 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.

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

Field Collection

Field staff will visit each watershed to collect ground control points for at least ten locations per land use type using Trimble GeoExplorer 3 GPS Receivers with an accuracy of 10 m. Site identification, date, time, personnel, and conditions at the site are noted in the field notebook.

All field observations will be manually entered into an electronic spreadsheet. The electronic spreadsheet will be created in Microsoft Excel software on an IBM-compatible microcomputer with a Windows XP Operating System. The project spreadsheet will be maintained on the computer's hard drive, which is also simultaneously saved in a network folder. All pertinent data files will be backed up monthly on an external hard drive. Current data files will be backed up on r/w CD's weekly and stored in separate area away from the computer.

Original data recorded on paper files will be stored for at least five years. Electronic data files will be archived to CD after approximately one year, and then stored with the paper files for the remaining 4 years.

Spatial Sciences Laboratory Data

Landsat TM imagery arrives in the SSL lab on CD. It is stored on CD until processing time when it is copied to the hard drive of a workstation. Data forms with field information arrive via hand-delivery or the US mail and are stored in raw form in the lab. Data from the forms are digitized and stored on the hard drive of a computer in the lab. Backup copies of all digital data are made to removable media. All data forms are checked prior to digitizing for accuracy and then after digitizing to assure correspondence to the original form. All necessary data from ancillary sources are digitized or copied to the hard drive of a computer in the SSL lab and then backup copies are made of the digital data. Where ancillary data have been digitized, the SSL Project Manager checks that the original data correspond correctly to the digitized data.

A combination of IBM compatible microcomputers with a Windows XP Operating System and workstations using the UNIX operating system will be used to process the data. An effort was made to purchase machines with the most memory, largest hard drives and fastest processing speeds that were available at the time. Additional hard drive space and random access memory will be purchased as project needs require. A suite of software will be used to process the data. All software packages are industry standard and represent the best application available for each processing function.

All GIS and LULC data will be backed up on r/w CD's weekly and stored in separate area away from the computer. At least 10% of all data manually entered in the database will be reviewed for accuracy by the Project Manager to ensure that there are no transcription errors. Hard copies of data will be printed and housed in the Spatial Sciences Laboratory for a period of five years.

Data Validation

Following LULC classification and delineation, LULC data will be validated and verified with field sampling ground control points to an accuracy of 80% or greater. Any LULC that does not meet this will be re-classified until an accuracy of 80% is achieved. No LULC that does not achieve 80% accuracy will be submitted to the TSSWCB.

Metadata Preparation

Metadata preparation will be accomplished by the GPS Operator upon conclusion of the data processing phase using the EPA, *Geospatial Metadata Technical Specification v. 1.0*, November 2007.

Data Dissemination

As classification of each watershed is completed, the Project Manager will provide a copy of the shapefile or ArcGIS grid format of the LULC via recordable CD media to the TSSWCB PM.

Section C1: Assessments and Response Actions

The following table presents types of assessments and response actions for data collection 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	Continuous	SSL, TWRI	1. Monitor project status & records to ensure requirements are being fulfilled. 2. Monitor and review performance & data quality.	Report to TSSWCB Project Manager in Quarterly Report
Equipment Testing	As needed	GPS Operator	1. Pass / Fail Equipment Testing	Repair or Replace
Data Completeness	As needed	Project Manager	1. Assess Stations Sampled vs. Planned Sampling	Revisit Site or Amend Project Objectives
Data Quality Objectives	As needed	GPS Operator	1. Evaluate if Data Meets / Does Not Meet DQO	Exclude Questionable Data Points
Performance Criteria	As needed	GPS Operator	1. Evaluate if Data Met / Did Not Meet Performance Criteria	Exclude Questionable Data Points
Statistical Quality Checks	As needed	GPS Operator	1. Evaluate if Data Met / Did Not Meet Standard Deviation	Exclude Questionable Data Points
Map Overlay Against Known Locations	As needed	GPS Operator	1. Assess if Data Points are Good / Poor Fit Against Known Locations	Recheck Acquisition and Processing Steps
Technical Systems Audit	As needed	TSSWCB QAO	1. Assess compliance with the QAPP. 2. Review facility & data management as they relate to the project.	30 days to respond in writing to TSSWCB QAO to address corrective actions

The SSL Project Manager will conduct in-house audits of data quality and staff performance to assure that work is being performed according to standards. Audits will be documented in a written laboratory journal and initialed by the SSL PM. If audits show that the work is not being performed according to standards, immediate corrective action will be implemented and documented in the laboratory journal.

The TSSWCB QAO (or designee) may conduct an audit of the field or technical systems activities for this project as needed. The SSL Project Manager will have the responsibility for initiating and implementing response actions associated with findings identified during the on-site audit. Once the response actions have been implemented, the TSSWCB QAO (or designee) may perform a follow-up audit to verify and document that the response actions were implemented effectively. Records of audit findings and corrective actions are maintained by the TSSWCB Project Manager and TWRI QAO. Corrective action documentation will be submitted to the TSSWCB Project Manager with the progress report. If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements or contracts between participating organizations.

Section C2: Reports to Management

Quarterly progress reports will be generated by TWRI personnel and will note activities conducted in connection with the LULC classification, items or areas identified as potential problems, and any variation or supplement to the QAPP.

Preliminary versions of land cover maps will be made available for inspection by the TSSWCB Project Manager as they become available.

Once the LULC map for a watershed is complete, the SSL Project Manager will submit the GIS land cover map, metadata, and a report of accuracy assessment activities as outlined in section B to the TSSWCB.

CAR forms will be utilized when necessary (Appendix A) and will be maintained in an accessible location for reference at TWRI. The CARs that result in changes or variations from the QAPP will be made known to pertinent project personnel, documented in an update or amendment to the QAPP and distributed to personnel listed in Section A3. Following any audit performed, a report of findings, recommendations and responses are sent to the TSSWCB Project Manager in the quarterly progress report.

Section D1: Data Review, Verification and Validation

In summary, this project will use summer and winter scenes of Landsat Thematic Mapper imagery to conduct a general land cover inventory for each watershed. Ancillary data consisting of field surveys, available photography and existing vegetation maps will be used to classify vegetation and label distinct spectrally clustered polygons on the imagery. LULC classification will follow the methods and quality control standards outlined in this QAPP (Section A7). The project has a goal of achieving 80 percent accuracy in the overall classification of LULC. The coverage will include 5 watersheds in Texas with a minimum mapping unit of two acres. An independent set of ground reconnaissance data will be obtained to conduce the accuracy assessment analysis. Ground reconnaissance data will be reviewed and validated as outlined in Table D1.1.

Table D1.1. Ground Control Point Data Review, Validation, and Verification Criteria

Data Element	Reviewed By	Validation Criteria
Coordinate Data	Project Manager	Consistent with Sampling Process Design
Coordinate Data	GPS Operator	GPS Mode Matches Field Log & GPS Internal Data
Coordinate Data	GPS Operator	Default Settings Match GPS Internal Data
Coordinate Data	GPS Operator	Standard Deviation below 3 Meters for Acceptance
Coordinate Data	GPS Operator	Good Fit when Data Plotted against Known Locations
Coordinate Data	GPS Operator	Meets National Map Accuracy Standards
Metadata	Project Manager	Meets EPA Guidelines for Metadata Documentation

Because of inherent technological, logistical, and financial constraints (Section B6), it is possible that the accuracy goal may not be achieved for all LULC classes. However, accuracy assessment will be essential for validating the final LULC map and providing the user with a measure of reliability. 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. The Spatial Sciences Laboratory Project Manager is responsible for ensuring that data are properly reviewed, verified, and submitted in the required format for the project. Finally, the TWRI QAO is responsible for validating that all data collected meet the data quality objectives of the project and are suitable for reporting.

Section D2: Verification and Validation Methods

All field and laboratory data will be reviewed, verified and validated to ensure they conform to project specifications and meet the conditions of end use as described in Section A7. The SSL Project Manager is responsible for the integrity, validation and verification of the data each task generates or handles throughout each process. The field and laboratory tasks ensure the verification of all raw data and electronically generated data. The field data will be verified and validated as described in Table D2.1.

Table D2.1. Field Data Verification and Validation Methods

Data Element	Validation Method
Coordinate Data	Compare Sampling Process vs. Field Log and Internal GPS Log
Coordinate Data	Compare GPS Planned Mode vs. Field Log and Internal GPS Log
Coordinate Data	Compare Manufacturer Default Settings vs. Internal GPS Log
Coordinate Data	95% of Coordinate Points fall within National Map Accuracy Standards when overlaid on known quality map features of similar accuracy

Verification, validation and integrity review of LULC data will be performed using self-assessments and peer review, as appropriate to the project task, followed by technical review by the SSL Project Manager. The LULC data generated are evaluated against ground control points and project specifications and are checked for errors. Potential outliers are identified by examination for unreasonable data. If a question arises or an error or potential outlier is identified, then issues will be resolved through mutual consultation between the SSL Project Manager, TWRI QAO, and TSSWCB Project Manager. Issues which can be corrected are corrected and documented electronically or by initialing and dating the associated paperwork. If an issue cannot be corrected, the SSL Project Manager consults with the TWRI Project Lead to establish the appropriate course of action.

The final versions of the land cover maps and the accuracy assessment report will be peer reviewed prior to its release to the TSSWCB and the public. Prior to release, the SSL Project Manager has responsibility for reviewing all data and verifying that final products achieved QAPP-defined goals for accuracy, completeness and acceptance criteria. The final version of each land cover map will be conveyed to users as digital GIS files in ARC/INFO format on CD-ROM disks. Hard copy maps will also be provided free to the TSSWCB as needed.

The final element of the validation process is consideration of any findings identified during assessments or audits conducted by the TWRI or TSSWCB QAO. Any issues requiring corrective action must be addressed, and the potential impact of these issues on previously collected data will be assessed. Finally, the SSL Project Manager in coordination with the TWRI QAO validates that the data meet the data quality objectives of the project and are suitable for reporting to the TSSWCB.

Section D3: Reconciliation with User Requirements

The GPS Reconnaissance Survey results and products will be evaluated against the Data Quality Objectives established and user requirements to determine if any reconciliation is needed. Reconciliation concerning the quality, quantity or usability of the data will be reconciled with the user during the data acceptance process. Types of reconciliation may include reduction in the scope of the project in terms quality or quantity of data produced in meeting partial user requirements.

Once the final version of each Land Use / Land Cover Map is produced, the TSSWCB Project Manager will review the product and the accuracy assessment report to determine if they fall within the acceptance limits as defined in this QAPP. Completeness will also be evaluated to determine if the completeness goal for this project has been met. If data quality indicators do not meet the project's requirements as outlined in this QAPP the data may be returned for revisions.

These data, and data collected by other organizations, will subsequently be analyzed and used for watershed assessment, TMDL and watershed plan development, and modeling activities. Thus, data which do not meet requirements will not be submitted to the TSSWCB nor will be considered appropriate for any of the uses noted above.

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:________________________________

Project Manager:___________________________________

TWRI Quality Assurance Officer:______________________________

TSSWCB Quality Assurance Officer:____________________________

FIELD SURVEY FORM

Date: _______________

Name: ________________________________

Agency: _______________________________

Watershed: ___________________________

Site Name: ____________________________

Point No.: _______

UTM Coordinates: _____________________________

OR

Latitude/Longitude: ____________________________

Land Use / Land Cover: Use description in Section A5 to determine LULC for this point:

Developed Open Space_____
Developed Low Intensity_____
Developed Medium Intensity_____
Developed High Intensity_____
Open Water_____
Barren Land_____

Forested Land_____
Near Riparian Forested Land_____
Mixed Forest_____
Rangeland_____
Pasture/Hay_____
Cultivated Crops_____

How confident are you of your assessment?
_____ High confidence _____ Medium confidence _____ Low confidence

Comments: