Summer 7-8-2010

Design of a Comprehensive Geographic Information System for the Administration of El Camino Real De Los Tejas National Historic Trail

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DESIGN OF A COMPREHENSIVE GEOGRAPHIC INFORMATION SYSTEM FOR THE ADMINISTRATION OF *EL CAMINO REAL DE LOS TEJAS* NATIONAL HISTORIC TRAIL.

Final Report for

Cooperative Agreement No. H5000 02 A271

Gulf Coast Cooperative Ecosystem Studies Unit

Texas AgriLife Research

National Historic Trails System-Intermountain Region

National Park Service

U.S. Department of the Interior

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Stephen F. Austin State University

Nacogdoches, Texas

July 2010

CONTENTS PAGE

EXECUTIVE SUMMARY

Stephen F. Austin State University's (SFASU) Arthur Temple College of Forestry and Agriculture's (ATCOFA) Geographic Information System's (GIS) Laboratory were engaged by the National Park Service (NPS) National Trails System-Intermountain Region to provided GIS services supporting the NPS's development of a Comprehensive Management Plan (CMP) for *El Camino Real de los Tejas* National Historic Trail (ELTE). This scope of work was completed under Cooperative Agreement No. H5000 02 A271 of the Gulf Coast Cooperative Ecosystem Studies Unit (CESU) sponsored by the Texas AgriLife Research Program at Texas A&M University, College Station, Texas. ATCOFA assisted the NPS in the coordination of local landowner and other local stakeholder contacts, conducted archival research of NPS specific questions, developed high-resolution GIS maps of landscapes encompassing potential Trail resources, evaluated Trail resource landscapes and archaeological records for potential inclusion of sites/segments, developed web based interactive mapping applications for collaborative research of potential Trail resources, as well as provided logistical support and transportation for the investigation, evaluation, and determination of ELTE's High-Potential Sites and Segments across Texas, Louisiana, and Mexico. ATCOFA's development of a comprehensive GIS design for archeological and historic resources associated with ELTE Trail resources, as presented in the web based mapping applications, facilitates the management, preservation, and interpretive needs of the Trail while also providing a common platform for historians, Trail advocates and partners, archaeologists, and the public to collaborate on complex ELTE Trail mapping issues. Route verification and the development of a Trails geodatabase by ATCOFA aided the NPS's Trails research and facilitated the preparation of ELTE's Comprehensive Management Plan.

PROJECT DESCRIPTION

Researchers at Stephen F. Austin State University's (SFASU) Arthur Temple College of Forestry and Agriculture's (ATCOFA) Geographic Information System's (GIS) Laboratory were engaged by the National Park Service (NPS) National Trails System-Intermountain Region staff to provided value added GIS services supporting the NPS's development of a Comprehensive Management Plan (CMP) for *El Camino Real de los Tejas* National Historic Trail (ELTE). This scope of work included the development of a comprehensive GIS of Trail resources and was completed under Cooperative Agreement No. H5000 02 A271 of the Gulf Coast Cooperative Ecosystem Studies Unit (CESU) sponsored by the Texas AgriLife Research Program at Texas A&M University, College Station, Texas.

While in close consultation with the NPS staff and taking into account already established NPS GIS data standards and protocols, ATCOFA provided the technical support needed to develop the plans and procedures necessary to accomplish the required services. ATCOFA assisted the NPS in the coordination of local landowner and other local stakeholder contacts as well as provided logistical support and transportation for evaluation and determination of ELTE's High-Potential Sites and Segments across Texas, Louisiana, and Mexico. ATCOFA also provided historic aerial photography, high-resolution datasets of aerial photography, satellite imagery, and LiDAR to aid in the physical inventory of ELTE's High-Potential Sites and Segments (APPENDIX A).

PROJECT JUSTIFICATION

The development of a comprehensive GIS design for archeological and historic resources associated with ELTE facilitates the management, preservation, and interpretive needs of the trail while also providing a common platform for historians, trail advocates and partners, archaeologists, and the public to collaborate on complex ELTE mapping issues. Utilizing the geospatial technologies of remote sensing and GPS combined with pedestrian archaeological surveys of existing trail resources, an inclusive and robust GIS research design added structure to the consistency of approach in the collection, storing, and validating of ELTE's historic and existing trail resources. Route verification and the development of a geodatabase facilitated the preparation of the Comprehensive Management Plan for the trail and will assist with the protection of trail resources.

PROJECT OBJECTIVES

The project assisted the NPS with the preparation of the Comprehensive Management Plan for ELTE. It also developed an all-inclusive GIS managed inventory of ELTE's existing trail resources while documenting the development and use of a geodatabase design framework for ELTE that incorporated remote sensing data, physical landscape data, historical research, and archaeological evidence of trail resources. The development of the GIS geodatabase, the remote sensing strategies, and the pedestrian archaeological methodology was accomplished through active collaboration with the NPS, historians, and trail partners, providing an inter-disciplinary approach to ELTE's GIS development.

PROJECT COLLABORATION

Cooperative Agreement No. H5000 02 A271 required substantial involvement and collaboration between ATCOFA and the NPS National Trails System-Intermountain Region staff. ATCOFA agreed to assist the NPS with the development of ELTE's CMP through the creation of an overall route verification strategy, design of a comprehensive geodatabase of known trail resources, preparation of maps and mapping related products illustrating the development and the procedures for including high-resolution data, and the design of test cases for utilizing geospatial technologies in a comprehensive GIS research design. The NPS agreed to assist ATCOFA through the preparation of written guidelines for route verification, the identification of routes that needed verification and ground-truthing, the review of map products, comments on guidelines for data capture and the use of high-resolution data, and collaboration in the development of an overall GIS research design for ELTE that in the future could be used in other historic trails. The NPS also offered suggestions and feedback as the project evolved (APPENDIX A).

PROJECT COMPLETION

The following Sections indentify how ATCOFA provided GIS services and assisted the NPS in locating and evaluating ELTE Trail resources in Texas and how ATCOFA provided GIS services and assisted the NPS in preparation of ELTE’s CMP and associated documentation. ATCOFA assisted the NPS by:

<u>SECTION</u>

A. coordinating local landowner and other local stakeholder contacts,
B. conducting archival research of NPS specific questions,
C. developing high-resolution GIS maps of Trail resource landscapes,
D. evaluating Trail resource landscapes with archaeological records for site selection,
E. developing an interactive GIS mapping web application for collaborative Trails research,
F. providing logistical support / transportation for the selection of High-Potential locations,
G. identifying ELTE resource test case locations for application of geospatial technologies,
H. applying appropriate geospatial technologies for evaluation high-potential landscapes,
I. developing a comprehensive GIS design for archeological/historic ELTE Trail resources,
J. developing an ELTE Trails resources GIS geodatabase for preparation of ELTE’s CMP.

SECTIONS A, B, & C

ATCOFA responded to the NPS needs for coordination with landowners and other interested partners and stakeholders for gaining access to properties, locating the properties, and for the verification of questionable routes by acting as a liaison between Texas landowners and the NPS.

ATCOFA also responded to the NPS needs for coordination with partners and stakeholders through public outreach and education by presenting current NPS collaborative GIS Trails research (APPENDIX C). At each presentation or educational outreach event, new local landowner contacts were made as well as new Trail resource leads were found. The making of local contacts of knowledgeable Trails researchers would greatly aid the locating of High-Potential Sites and Segments. ATCOFA assisted the NPS through the use of archival research of historic documents and other resources not generally available to the NPS in Santa Fe. ATCOFA responded to NPS needs for specific research questions by conducting archival research and spatial analysis and by responding to the NPS's request through written comments, printed materials, and/or maps. APPENDIX E contains an example of a written comment ATCOFA submitted to the NPS in response to a specific inquiry from the NPS and a request for written information (APPENDIX A).

Cited by the NPS has having unique ELTE Trails resource knowledge, the Principal Investigator was asked by the NPS to provide critical editorial review of CMP chapters as they became available and was also asked to review the draft CMP document for factual errors prior to in-house NPS review. It is not clear if the corrections and editorial comments provided to the NPS were incorporated into the draft CMP prior to the in-house NPS review. The Principal Investigator was additionally asked to review High-Potential Site or Segment locational accuracy as well as provide critical review of developing NPS spreadsheet entries and editorial review of other NPS contractor written materials. The NPS routinely referred Trail related questions from interested Trail enthusiasts, Trail partners, and other Trail stakeholders to the Principal

Investigator, and utilized the Principal Investigator as a resource in helping communities along ELTE to develop Challenge Cost Share Grant ideas. The NPS also included the Principal Investigator, as a regional Trails expert, in meetings with County and State officials, and often referred specific Trails related questions to the Investigator (APPENDIX A).

ATCOFA aided the development of ELTE's CMP by preparing GIS maps and mapping related products with supporting data for completion of data gaps in NPS files. ATCOFA and also provided editorial and critical review of maps and documents; supplying additional digital data where needed for NPS's review. See APPENDIX A for specific data, question, and/or work request received from the NPS along with the date of the request and the dates and nature of the written, produced, researched, or created ATCOFA response. For example, the NPS requested that the Principal Investigator review a site identified by the NPS for possible examination by the site review team that had been described to the NPS as one of two crossings of the Guadalupe River used in the 1700s. ATCOFA's image analysis along with applied ancillary historical data determined that the Salt Creek Swales in DeWitt County are right on the NPS route line displayed on NPS map sheet #9, and that it runs between the confluence of Cibolo Creek and the San Antonio River just below *El Fuerte del Cibolo* and the crossings of the Guadalupe River at Cuero; northwest of Yorktown in western DeWitt County, near the community of Davy (APPENDIX A).

ATCOFA also provided high-resolution GIS maps for field research by both ATCOFA and the NPS, as well as provided extensive ground-truthing of questionable routes, sites, and locations provided by the NPS. Collaboration between the Principal Investigator and the NPS in identifying, defining, and developing strategies for addressing these issues for the CMP allowed for substantial progress in the completion of the plan for ELTE (APPENDIX A).

SECTION D

ATCOFA evaluated possible ELTE Trail resource locations and resource physical landscape settings combined with archaeological records by incorporating a spreadsheet of known Trail resources, created by another NPS contract investigator, into a comprehensive and spatially enabled GIS geodatabase of ELTE Trail resources across Texas. The spatial analysis techniques for utilizing the spatially enable spreadsheet (database) of Trail related archaeological resources is presented in APPENDIX F and is illustrated in Figures 5, 6, and 7. The spatially enabled ELTE Trail resources spreadsheet (converted to GIS file geodatabase) was made available to the NPS in mid-November of 2008 through a web based mapping application developed for delivery of high-resolution spatial datasets for use in collaborative Trails research developed specifically for NPS CMP research and document preparation (Figure 4).

SECTION E

ATCOFA developed an interactive GIS mapping web application for collaborative Trails research and assisted the NPS with the development of ELTE's CMP by helping to define a route verification strategy through aiding in the identification and verification of questionable routes utilizing spatial analysis and archival research. The development of a route verification strategy was an ongoing and iterative process that was continually refined throughout the life of the project through the collaboration between the Principal Investigator and the NPS researchers (APPENDIX A). To accomplish this goal, the Principal Investigator coordinated with regulatory state entities, historical societies, local landowners and stakeholders, and the ELTE Trail Association before traveling to the National Trail Systems-Intermountain Region's office in Santa Fe in November of 2008 to address long-term strategies for verification, mapping, and monitoring of historic trail routes as well as to address short-term issues associated the preparation of the CMP, such as mapping, route verification, and identification of tentatively selected High-Potential Sites and Segments.

While at the Regional office in Santa Fe, the Principal Investigator delivered to the NPS, explained the development and creation of, and demonstrated the use of an ArcGIS Server Web Mapping Application service for ELTE trail resources developed for dissemination of collaborative research pertaining to ELTE's CMP and related Trail resources (Figure 1). ATCOFA detailed the use of the dataset, outline some of the limitations of the dataset, and explained the benefits of its use as a collaborative Trails research tool. As an example of the usability of the web service for Trails research, Figure 2 shows the web service displaying the NPS documented routes across eastern Texas in red, and in stark contrast, the ATCOFA verified routes from georeferenced 1936 historic aerial photography in light blue. Additionally, Figure 3 shows a close up of the historic aerial photography with the contrasting trail route lines.

The web service was made available to the NPS throughout the contract period and was utilized by ATCOFA throughout the physical inventory, evaluation, and analysis of the ELTE High-

Potential Sites and Segments (Figure 4). The ELTE web service was discontinued at the end of the contract period at the end of September 2009, and a counter attached to the web service only registered 153 visits other than ATCOFA GIS analysts and researchers. Evaluation of Internet address usage statistics indicated that the web service was a valuable tool for collaboration between ATCOFA's GIS researchers and other Texas state agencies, Trail researchers, and Trail stakeholders; however, it was not considered by the Principal Investigator, to be a useful tool for the dissemination of information or use by the NPS as demonstrated by only 2 NPS visits to the web service in almost a calendar year, as well as a lack of NPS feedback on the usability of the web resource and the presented data format.

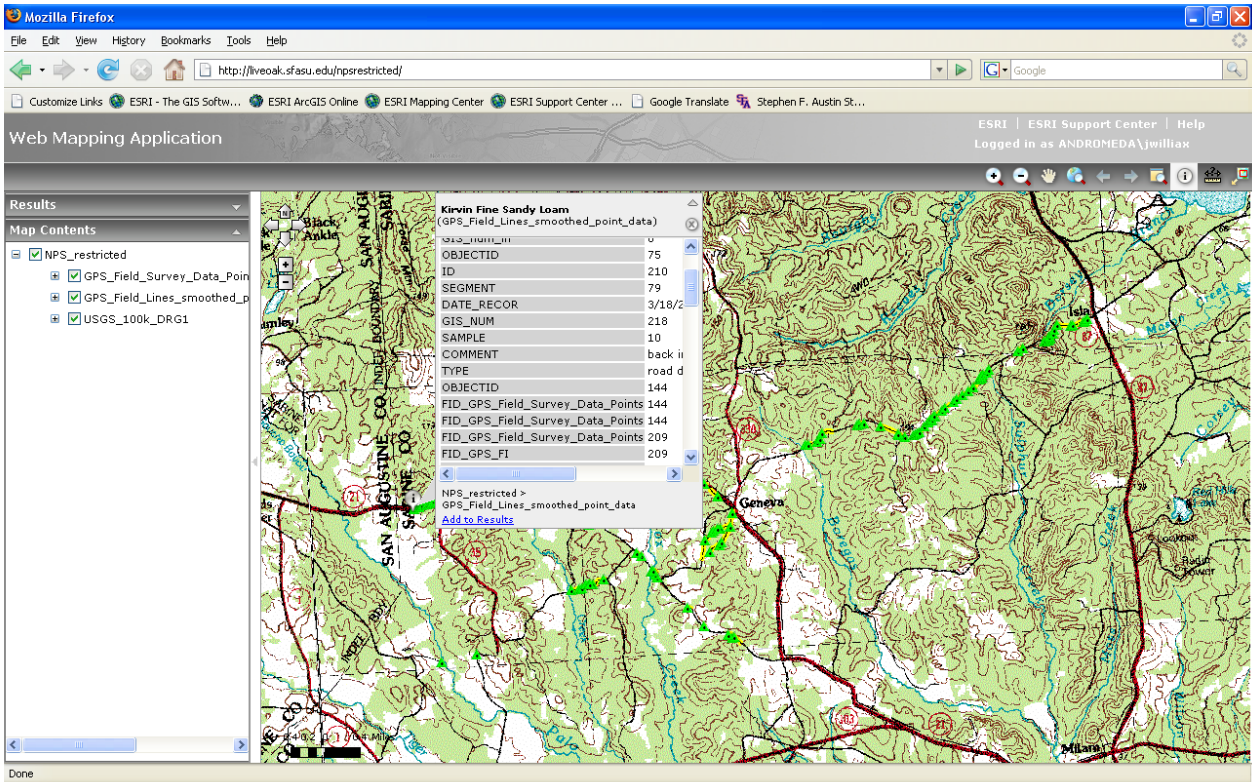

Figure 1. ArcGIS Server Web Mapping Application of ELTE Trail Resources developed for collaborative Trails research.

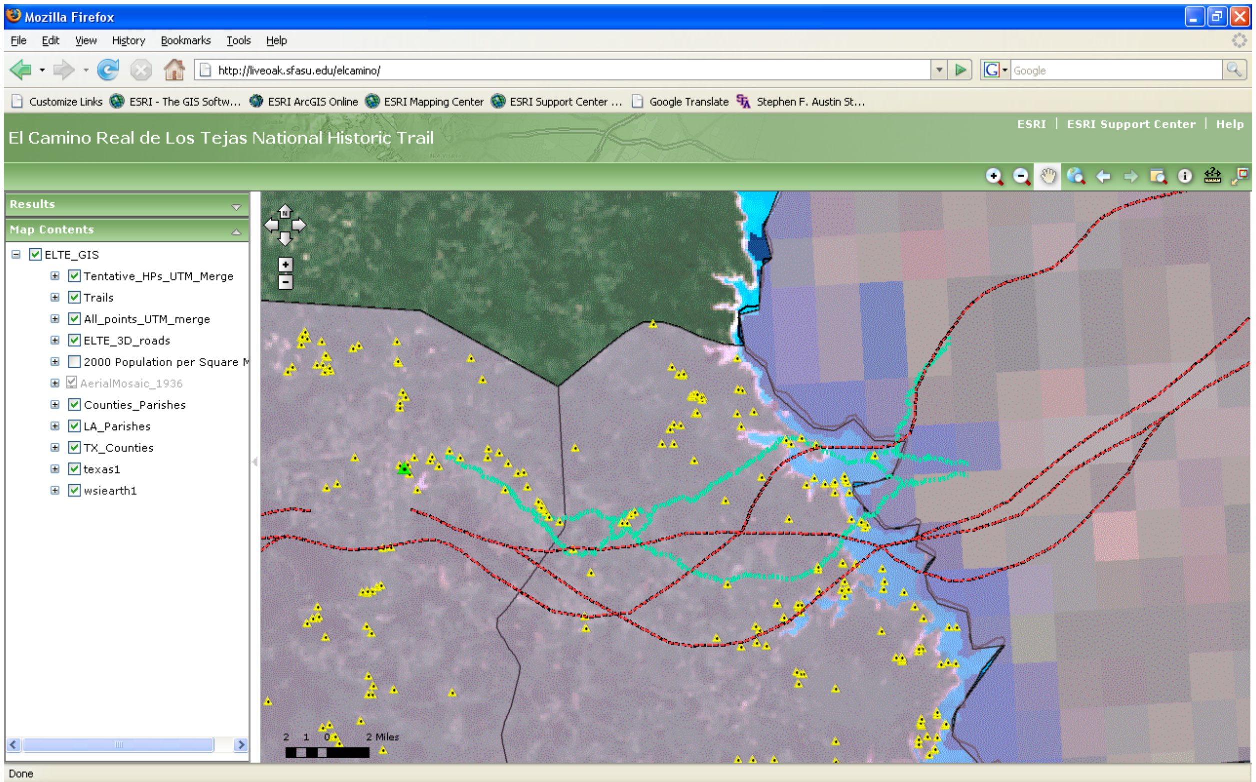

Figure 2. ArcGIS Server Web Mapping Application of ELTE Trail Resources showing contrast between NPS documented routes in red and ATCOFA verified Trail resources in light blue (evaluated archaeological sites are in yellow).

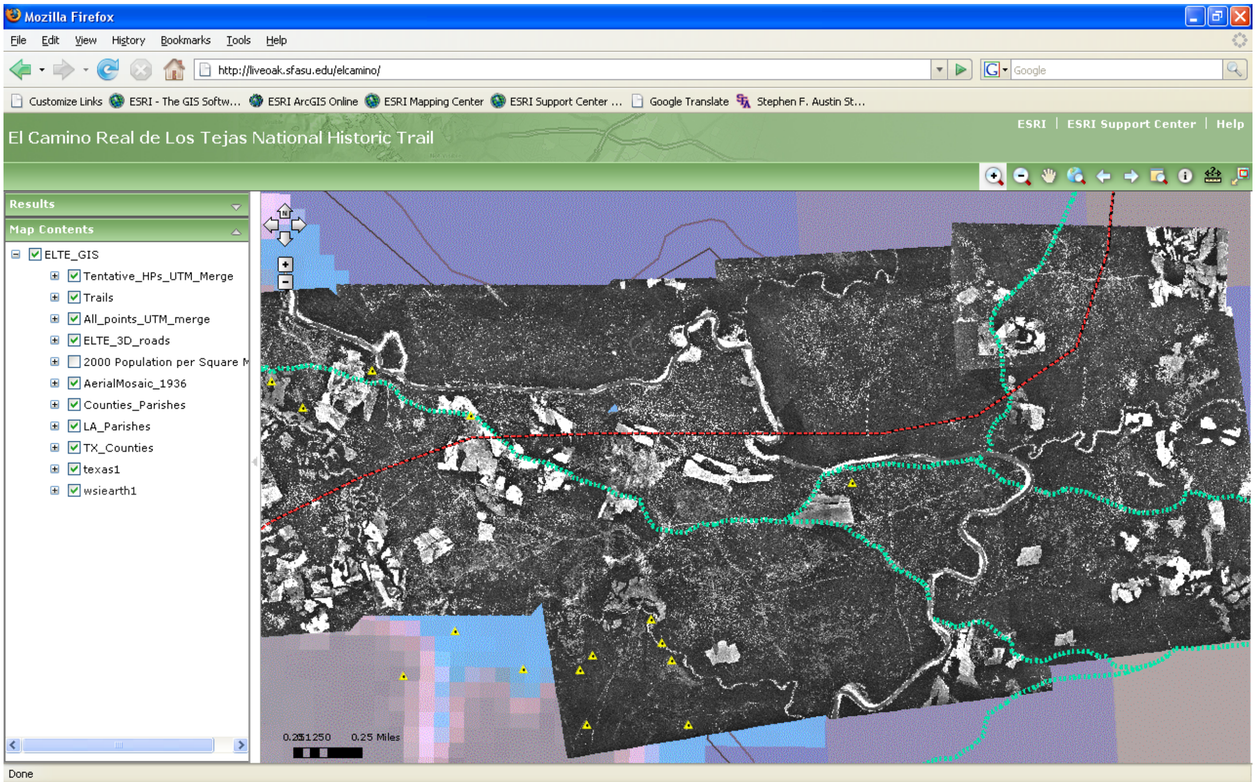

Figure 3. ArcGIS Server Web Mapping Application of ELTE Trail Resources showing close up of 1936 historic aerial photography with contrasting NPS documented routes in red and ATCOFA verified Trail resources in light blue.

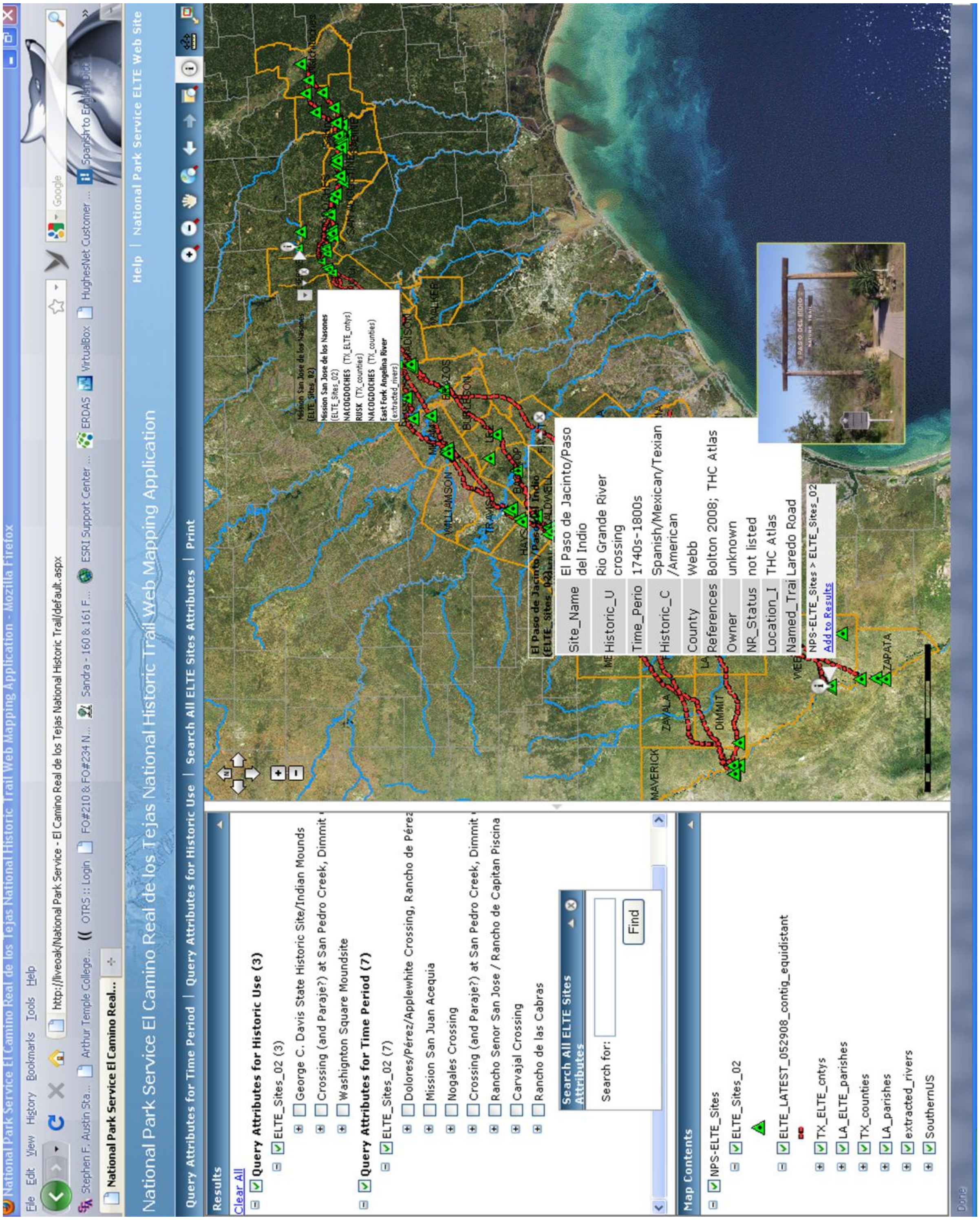

Figure 4. ArcGIS Web Mapping Application of ELTE Trail Resources Developed for the NPS.

SECTION F

ATCOFA provided logistical support and transportation for the investigation, evaluation, and determination of ELTE's High-Potential Sites and Segments across Texas, Louisiana, and Mexico. ATCOFA participated with the NPS as a part of a small site assessment team composed of NPS staff, the Texas Historical Commission's Director of State Archaeology, a Texas Department of Transportation Archaeologist experienced in ELTE Trail resources, and ATCOFA's Principal Investigator. The site assessment team traveled through the State, Louisiana, and Mexico for determination and inventory of potential ELTE High-Potential Sites and Segments. ATCOFA assisted the NPS by aiding in the coordinating and planning of field visits as well as coordinating contact with landowners, historical societies members, and other Trail resource knowledgeable individuals, partners, and stakeholders (APPENDIX A).

ATCOFA provided logistical support and transportation for three separate NPS trips to ground-truth and evaluate potential ELTE High-Potential Sites and Segments. Two one week long trips in January and February of 2009 and one three day trip in June of 2009 required the coordination of local landowners and other local stakeholders across twenty-eight counties of Texas. SFASU through ATCOFA provided the transportation and transportation costs associated with the NPS evaluation visits. At least 3 additional times NPS staff was escorted across ELTE Trail resources using ATCOFA transportation and experienced GIS Trail researchers as guides and as introductions to local landowner contacts (APPENDIX A).

SECTION G

Substantial collaboration between ATCOFA and the NPS on the development of a comprehensive GIS research design for ELTE included the creation of test cases for utilizing geospatial technologies in the evaluation of ELTE's High-Potential Sites and Segments (APPENDIX A). ATCOFA provided historic aerial photography, high-resolution datasets of aerial photography, satellite imagery, and LiDAR via the ArcGIS Server Web Mapping Application for these test cases. The test case locations were chosen based on their Trail resource uniqueness as well as ease of accessibility and were used to illustrate the usability and value of a specific and appropriate geospatial technology for aiding in the inventory of ELTE's Trail resources. The test cases were added to the ELTE web mapping application along with their respective datasets as they were selected for analysis. Figure 5 shows a close up of the web mapping application with archaeological sites, associated with ELTE Trail resources, which were evaluated for selection as test cases. Figure 6 shows a close up of East Texas counties and the archaeological sites evaluated for selection as test cases. Figure 7 shows the locations of identified potential ELTE Trail resource test cases.

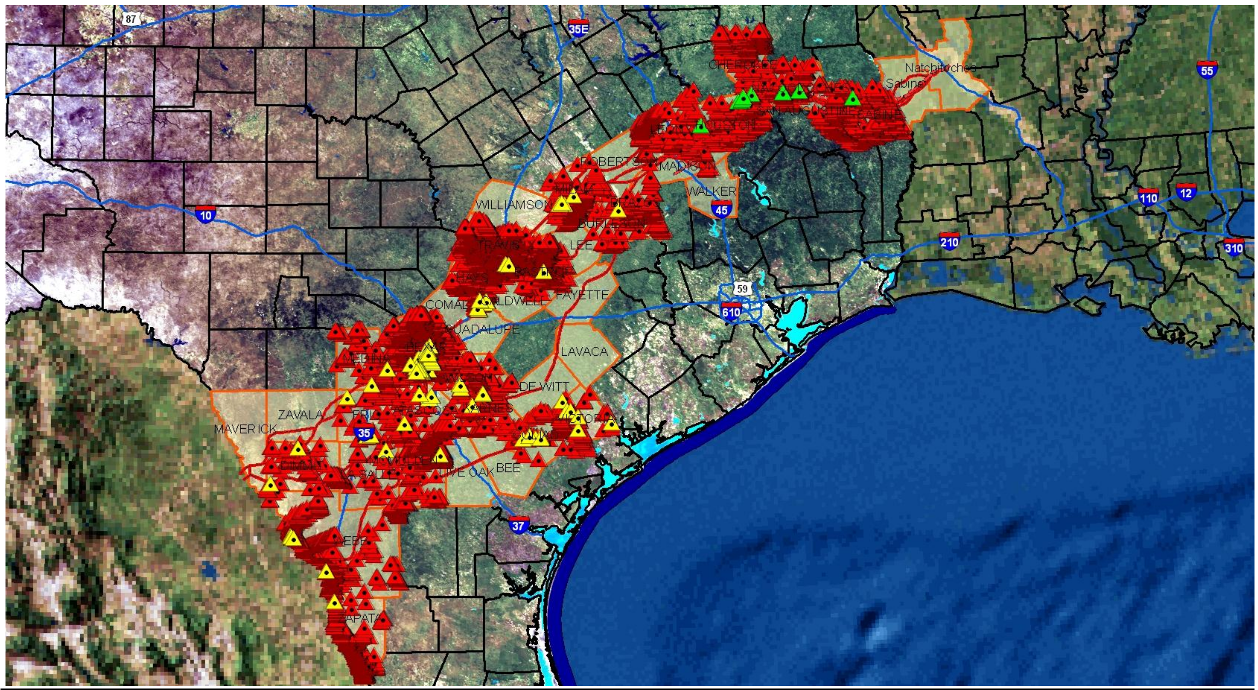

Figure 5. Close up of ELTE Web Mapping Application with archaeological sites evaluated for selection as a test case.

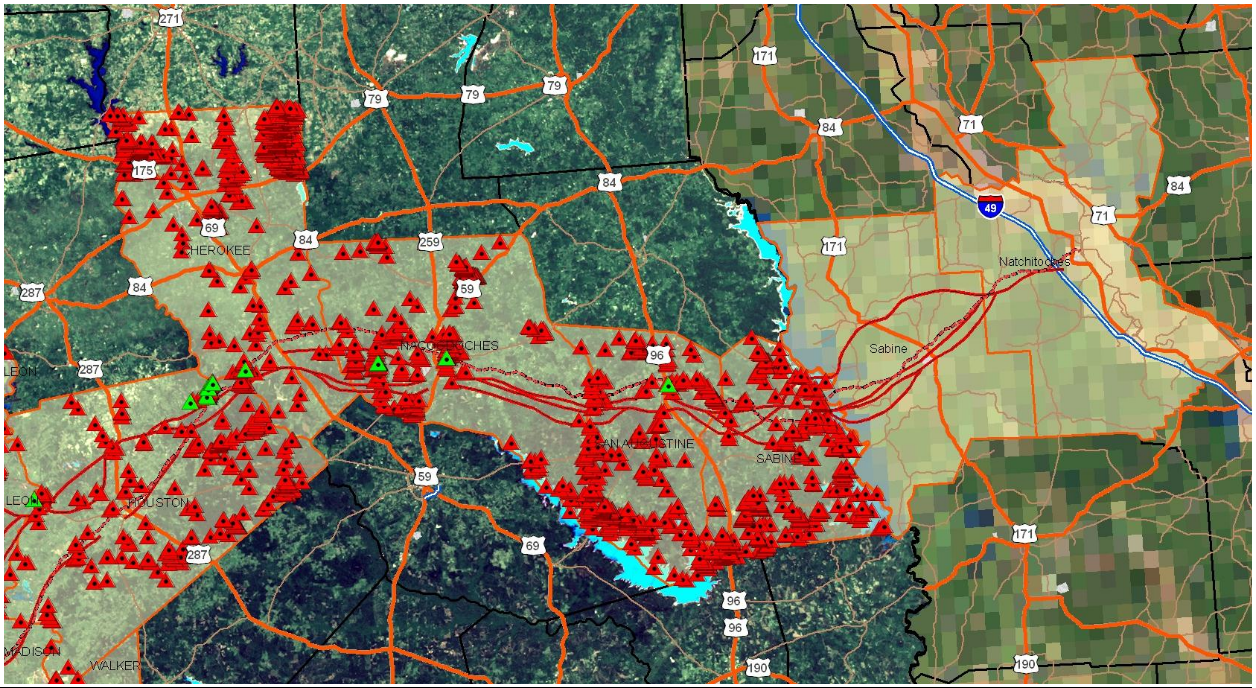

Figure 6. Close up of ELTE Web Mapping Application of East Texas counties and the archaeological sites evaluated for selection as a test case.

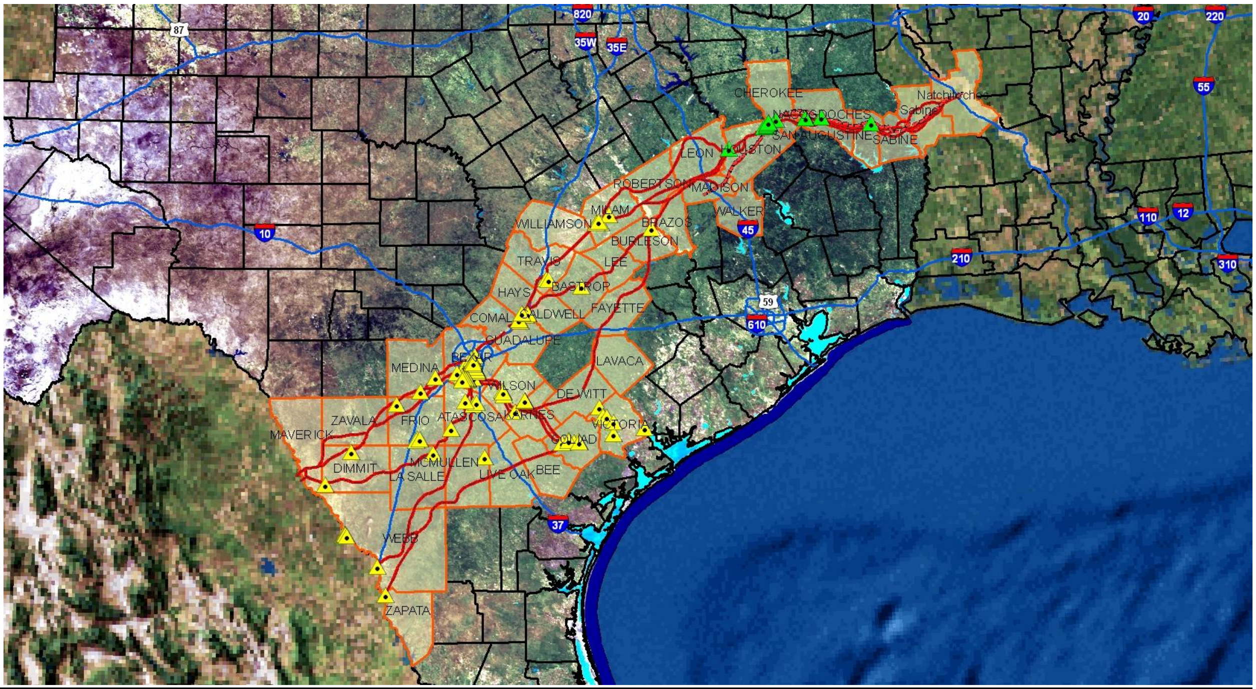

Figure 7. ELTE Web Mapping Application of locations identified as possible ELTE Trail resource test cases.

Three locations were initially chosen as test cases based on their unique Trail resources. The first was Conquista Crossing in Karnes County, a historic crossing on the lower San Antonio River. Local informants and Trail partners identified Conquista Crossing as a significant Trail resource; however, no known documentation for the crossing exists. Access was granted to the north side of the property where deep swales were found leading to the river crossing; the south side was not accessible at the time of initial NPS sites evaluation team visit. Permission was later granted to the Principal Investigator to access the south side of the crossing where additional Trails resources were located. Due to the unique vegetation differences on both sides of the crossing and due to the fact that the south side is mostly covered in ground-obscuring prickly pear cactus and chaparral shrubs, this location was chosen as a candidate for use of high-resolution imagery from both aerial photography and satellite images (Figure 8).

The second location chosen was the Navasota Swales on the county line of Robertson County's southern border and Brazos County's northern border. The Navasota Swales are 0.4-kilometer (0.25-mile) west of the Navasota River; south of and adjacent to the OSR. It is not clear which county the swales are in and consultation with the Brazos County Judge and the County Surveyor have, as yet, not clarified the swales ownership. Henry Mayo, Trails partner and Brazos County surveyor, states that there are existing documents referring to this general area as an early Texas Republic settlement called Tinenville. This location was selected for its large size, its intact Trails resources, and that it had previously been identified in 1915 for placement of a granite Daughters of the American Revolution (DAR) Old San Antonio Road marker (Figure 9).

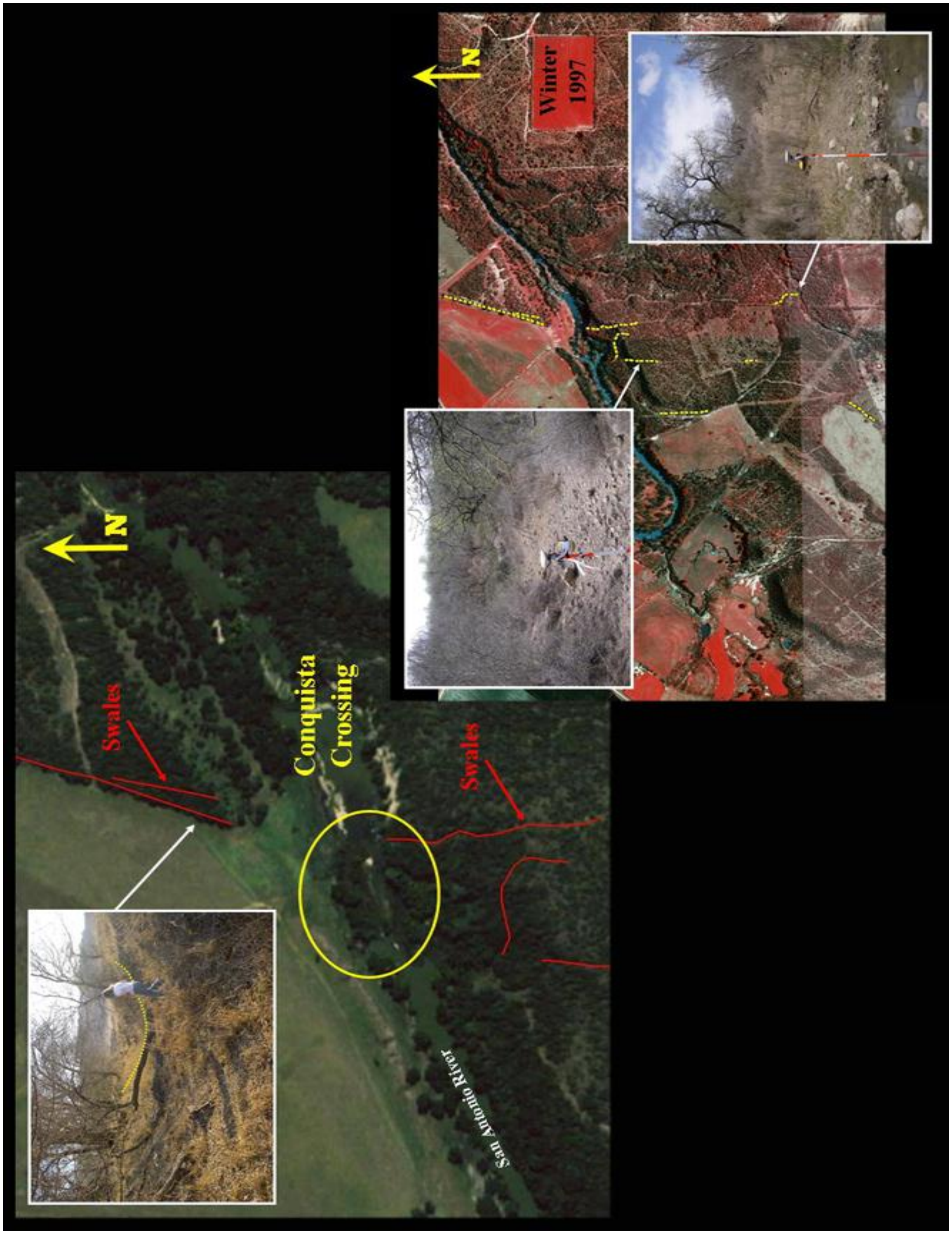

Figure 8. Example of High-Resolution Image GIS Maps for Trail Resource Evaluation.

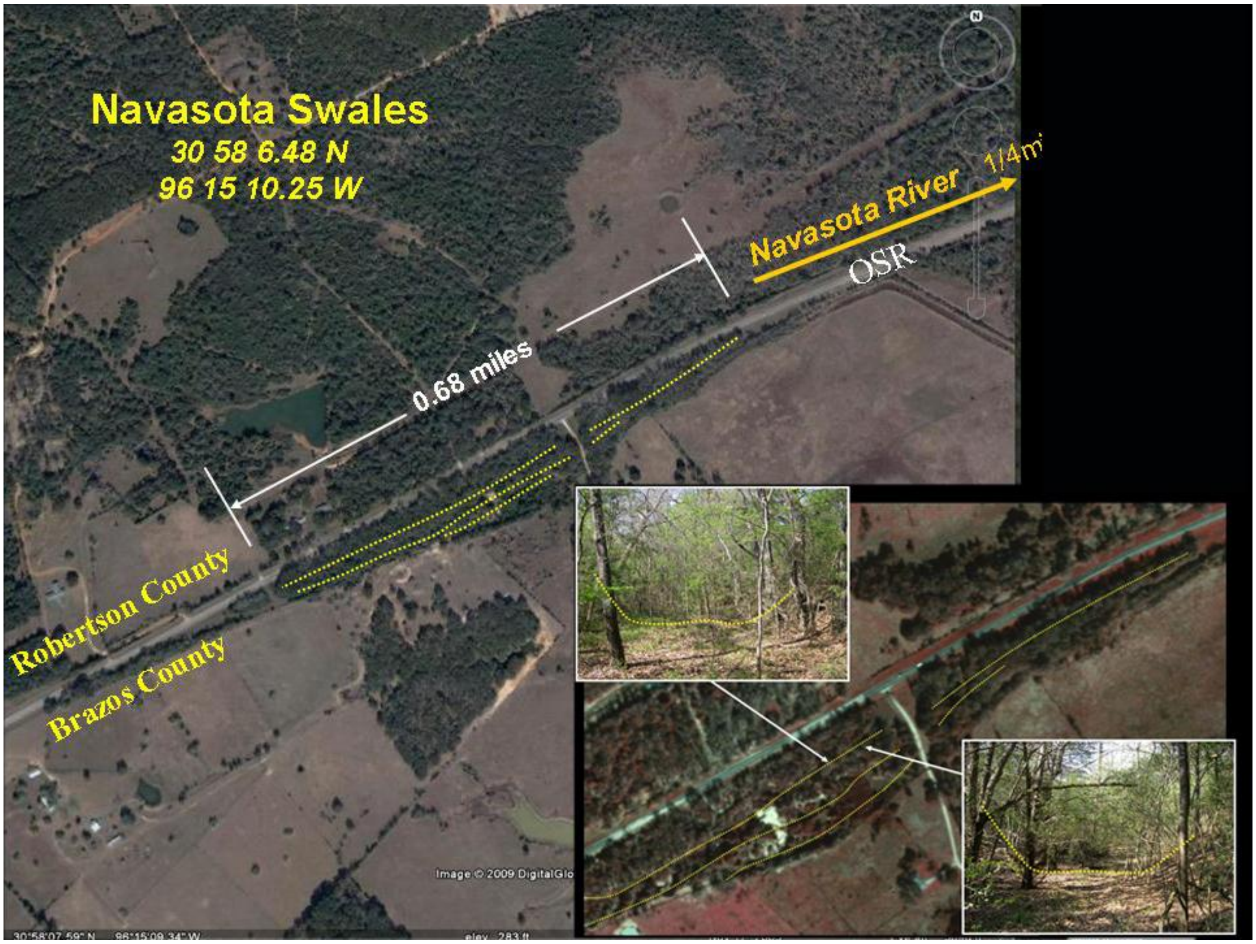

Figure 9. Example of High-Resolution Imagery Used in Web Mapping Application for Evaluation of Targeted ELTE Trail Resources for inclusion as test cases.

The last location chosen as a test case was the Legg Plantation Swales in western Nacogdoches County near the Angelina River (Figure 10). These swales were identified using LiDAR technology in an area that is well documented as having an early segment of ELTE Trail resources. A subsequent field survey identified existing ELTE Trail resources that have since become threatened by a new pipeline coming through Nacogdoches County from Canada. The Keystone XL pipeline construction has the potential to severely impact existing ELTE resources and will cross both the upper and lower (earlier) ELTE trail alignments.

The Legg Plantation Swales area has been archaeologically surveyed resulting in identification of numerous trail resources including road swales, river crossings, and historic home sites with Spanish period artifacts. Caddo artifacts are also plentiful indicating a large and continual occupation in this area. There are several known and excavated Caddo villages in this area as well as the estimated location for the principle Hasinai village (where the word tejas came from) and the estimated locations for Mission *Nuestra Señora de La Purísima Concepción* and *Nuestra Señora de los Dolores de los Tejas Presidio* founded in 1716.

The Legg Plantation Swale location was chosen as a test case because the swales were identified using LiDAR technology before a subsequent field survey identified existing ELTE Trail resources on the ground thus demonstrating that it is economically feasible to use geospatial technology coupled with historic research and archaeological surveys for inventory of existing Trail features (APPENDIX F).

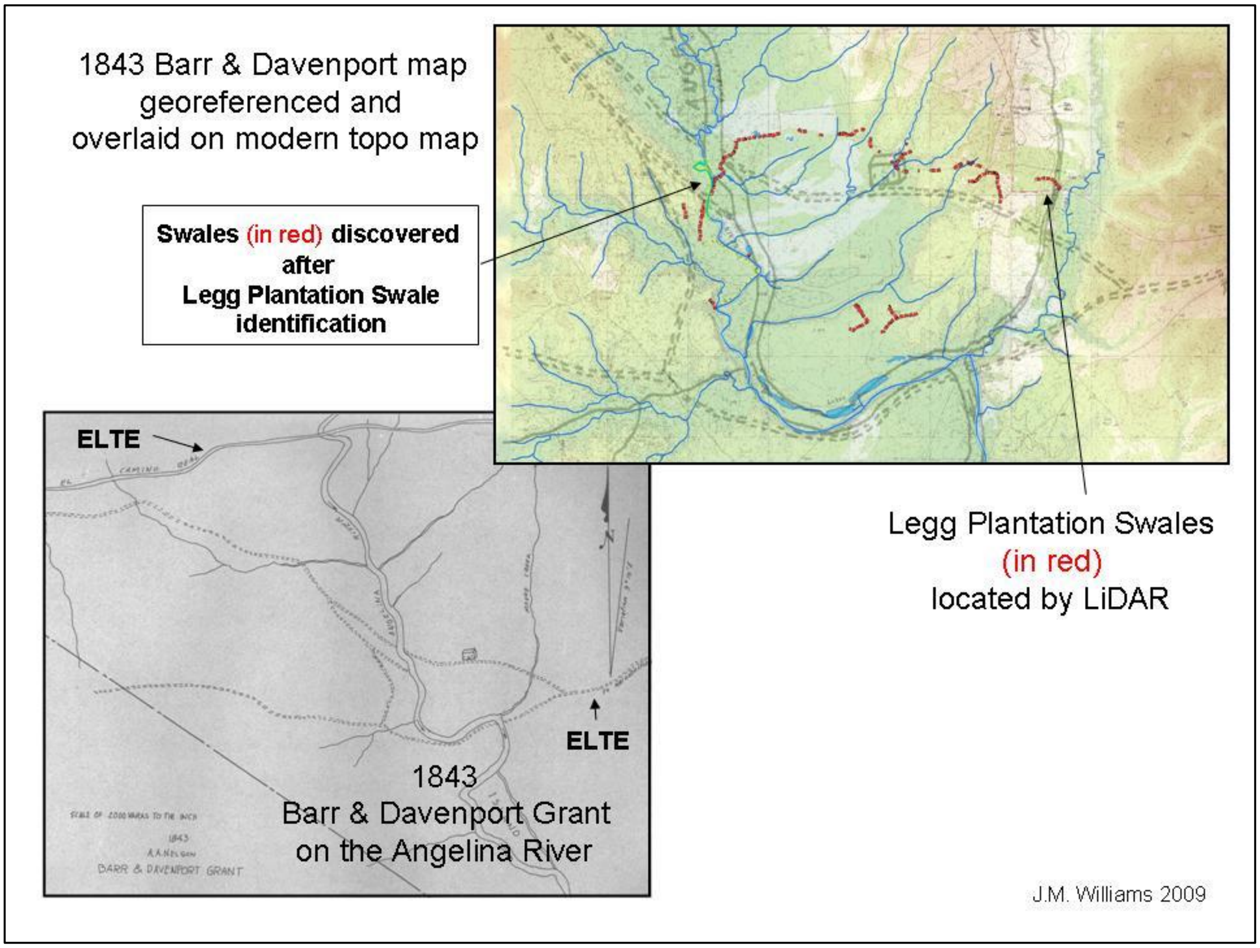

Figure 10. Legg Plantation Swales in western Nacogdoches County near the Angelina River.

SECTION H

ATCOFA evaluated, tested, and applied appropriate geospatial technologies for the test case High-Potential landscapes including the use of satellite imagery, aerial photography, and LiDAR. However, due to budgetary constraints and the limited timeframe allotted, only the Legg Plantation Swales and surrounding area was examined with LiDAR.

LiDAR (Light Detection and Ranging) is a remote sensing technology very similar to radar. Instead of radio waves, LiDAR uses near-infrared laser light as energy source. A laser emitter sends out a pulse of light that reflects off of a surface and back to a sensor. Distance is calculated from the time between emission and return. This technology has been mounted to aircraft (both fixed wing and rotary aircraft) and linked with a GPS (Global Positioning System) unit and an Inertial Navigation System, and can now record the geographic coordinates and elevation of reflecting surfaces, generating 2,000 to 50,000 pulses per second with a surface footprint of approximately 20-centimeters in diameter creating 6 to 7 LiDAR footprints per 1 square meter. A rotating mirror deflects the laser to either side of the flight line allowing for a wide area to be scanned. The resulting data is a 3-dimensional, geo-referenced 'point cloud,' consisting of numerous points with the x, y coordinates for each as well as the elevation of the point (Dhananjay and Madhav 2008).

During ATCOFA's investigations of the Legg Plantation area, a U.S. Department of State (DOS) proposed pipeline, the Keystone XL project, threatened to cross existing ELTE Trail resources along both the upper road (early to mid-nineteenth century) and the lower but much earlier road in the area of Mission Concepcion and Presidio Dolores as well as the Concepcion Crossing of the Angelina River adjacent to and perhaps leading to the Legg Plantation Swales. Potential impacts of the pipeline to the cultural resources associated with *El Camino Real de los Tejas* in western Nacogdoches County could be significant, and it is highly probable that artifacts (material culture) of Caddo or 17th to 18th century European (Spanish) origin will be encountered (Figure 11). ATCOFA had been in the process of ground-truthing and more accurately inventorying the Trail resources in the area when the proposed Keystone XL pipeline's location became known. The NPS asked the Principal Investigator to take the lead in representing ELTE's Trail resources on the ground, provide the DOS and their archaeological contractors with the needed locational data, and help the NPS collect the information the NPS requires relating to the area of potential impact from the proposed Keystone XL project (APPENDIX A).

At the suggestion of the NPS, ATCOFA agreed to host a meeting in Nacogdoches at the ATCOFA facilities between the DOS and their archaeological subcontractors, the Keystone pipeline company, representatives of the THC, and a NPS representative, who attended the meeting through a conference call, for the purpose of discussing potential impacts to Trail resources and mitigation measures to minimize the potential impacts from pipeline construction. The NPS representative stated to the assembled group that the ATCOFA Principal Investigator would be representing the Trails resource for the NPS in the vicinity of the proposed pipeline project. Additionally, ATCOFA not only provided transportation to the site, but also escorted the DOS representatives and took them to view where the Keystone XL ROW would cross the existing trail resources. A few weeks later, ATCOFA took the NPS Historian out to the site to evaluate the affected Trail resources and their proximity to the Keystone XL project. At a field visit and meeting arranged by the NPS in November of 2009 to view the pipeline project area, ATCOFA met with, provided maps for, and provided guide services for the NPS, the DOS, and pipeline personnel. ATCOFA provided value added services for the NPS, outside the scope of this contract, by agreeing to represent the NPS, on the ground, in this process (APPENDIX A).

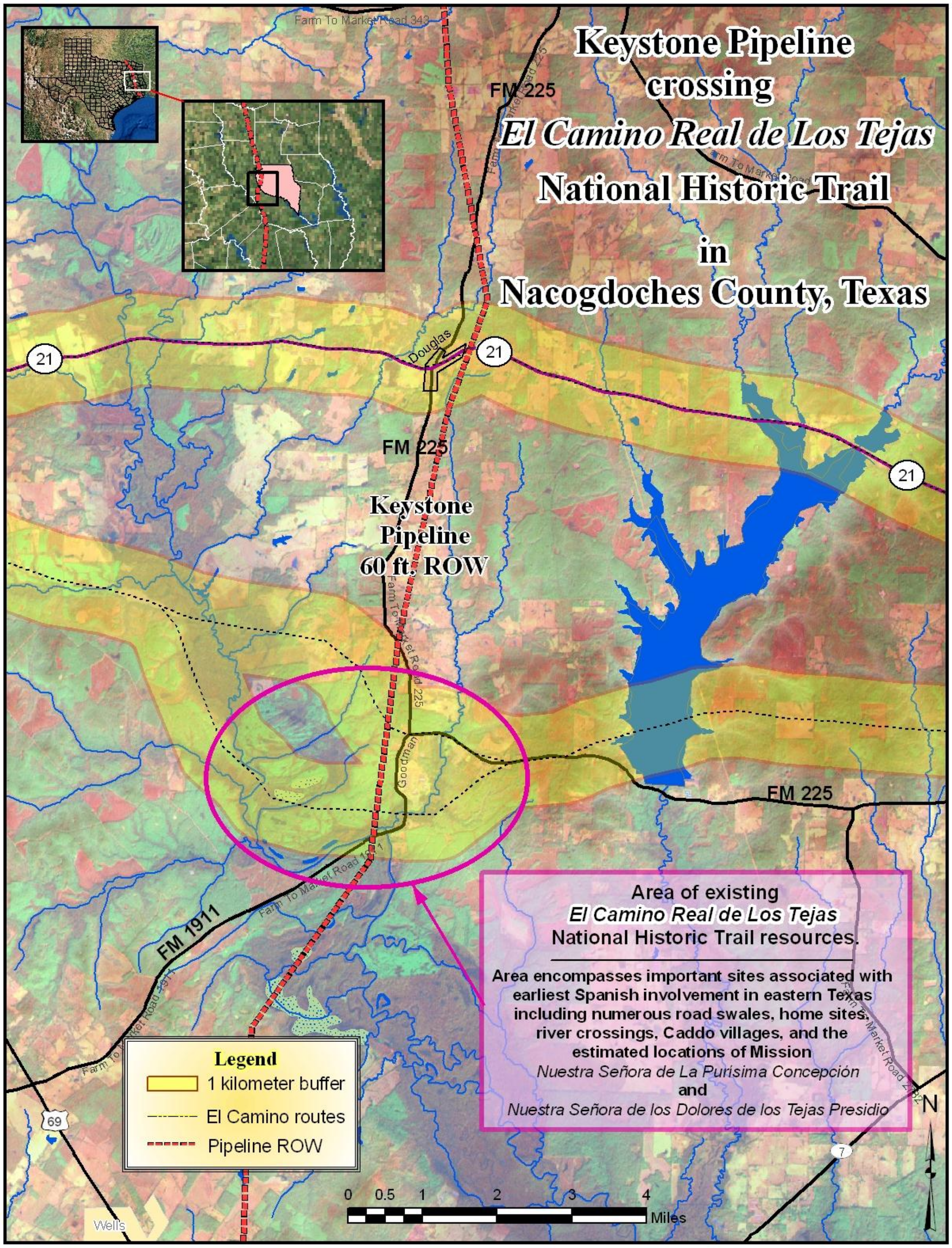

Figure 11. The proposed Keystone XL pipeline's potential impacts to ELTE Trail resources.

In April of 2009, the NPS Trails Administrator out of Santa Fe, requested through the NPS Historian, that ATCOFA share the LiDAR dataset of the Legg Plantation area with the NPS's other CESU GIS contactor at the University of Utah so that they could aid in my analysis. However, ATCOFA's LiDAR dataset was provided to ATCOFA before this contractual agreement with the NPS was negotiated and signed, and absolutely no NPS funds were used in its acquisition. This dataset is copywrited and protected under several pending developmental patents. As a result, ATCOFA was not at liberty to provide this data to other NPS contractors (APPENDIX A).

Also in April of 2009, the NPS asked ATCOFA about using LiDAR on a road segment in Louisiana, but ATCOFA determined that the publicly available LiDAR data for Louisiana does not cover their area of interest, and that the cost of acquiring new LiDAR for the NPS was well beyond the costs associated with this scope of work and that the NPS could not afford to purchase the datasets (APPENDIX A).

The LiDAR dataset that ATCOFA used is a raw four return product provided by SURDEX, a commercial LiDAR company, directly to ATCOFA for research and development of forest related commercial data products. This was a joint venture between ATCOFA and SURDEX for research advancement and expansion of applied LiDAR forest products in areas accessible to ATCOFA for field verification. SURDEX was contacted to pose the question of the NPS's request for data sharing, and ATCOFA was reminded that this is proprietary research data, and that ATCOFA is only allowed to provide derivative products such as documentation, maps, or slides to the NPS. However, SURDEX assured me that if the NPS wished to purchase the LiDAR dataset as a commercial product, the cost would be reduced to $33,000.00 for the 13 square mile (8,320 acres) area provided to ATCOFA (Figure 12). For this project, no NPS funds were allocated or used to acquire the LiDAR dataset (APPENDIX A).

Due to ATCOFA's archaeological experience working with LiDAR data, the LiDAR dataset was provided to ATCOFA, prior to ATCOFA's involvement with the NPS, that encompassed the known locations of existing ELTE Trail resources including swales and ruts, creek and river crossings, the known location of the 18th century *Rancho D'Ortolan*, the hypothetical locations of *Mission Conception* and *Presidio Dolores*, as well as the principle Hasini (Caddo) village. This is the area imperiled by the proposed KeystoneXL pipeline project.

Dr. I-Kuai Hung (ATCOFA Faculty) and a Graduate Student refined and tested automatic extraction algorithms for working with this LiDAR, and utilized an area within our LiDAR dataset (SFA's Experimental Forest) where there was unlimited access for ground-truthing the data. Ground-truthing is essential for understanding the nature of what is being reflected by the LiDAR and is required to be able to use LiDAR effectively. The development of automated data extraction techniques was also be critical to ATCOFA's cost effective use of this type of remote sensing.

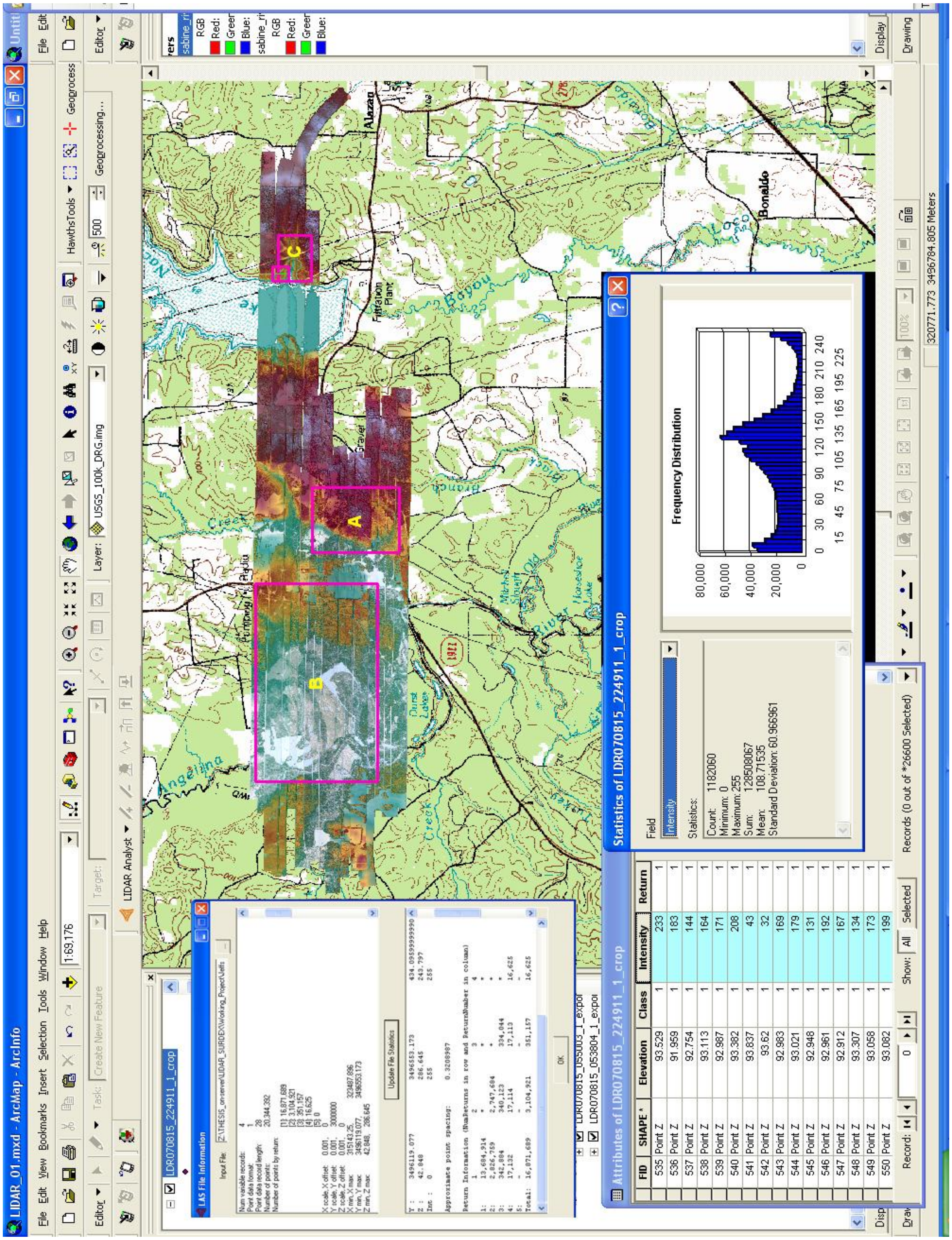

Figure 12. LiDAR dataset used by ATCOFA in their analysis of ELTE Trail resources.

LiDAR applications in Forestry were originally used in generating Digital Elevation Models (DEM) of difficult to navigate areas, like forests or mountains. Because of the small beam and the ability to receive multiple returns from a single pulse, LiDAR can penetrate vegetation and reach the ground. At first, any vegetation returns were considered noise, but foresters have realized that these returns displayed a 3-D model of the forest. In the past two decades, research has been conducted to realize LiDAR's potential as a remote sensing tool. Studies have used this technology to generate canopy height models, individual tree delineation, above-ground biomass, and even species classification (Lim *et. al.* 2003).

The research for this project focused on utilizing current software programs: TiFFS (Toolbox for LiDAR data Filtering and Forest Studies) and LiDAR Analyst for ArcGIS 9.3. These programs are designed for analyzing LiDAR point clouds to generate DEMs, CHM (Canopy Height Model), and individual tree properties such as geographic coordinates, tree height, and crown diameter. Although the programs are commercially available, there is little assessment of their accuracy and reliability. The purpose of the Graduate Student's research was to assess the accuracy of forest measurements derived from LiDAR data using commercial software programs in comparison to in-situ field measurement data. This research has a direct but binary relationship with LiDAR's application to archaeology (Figure 13).

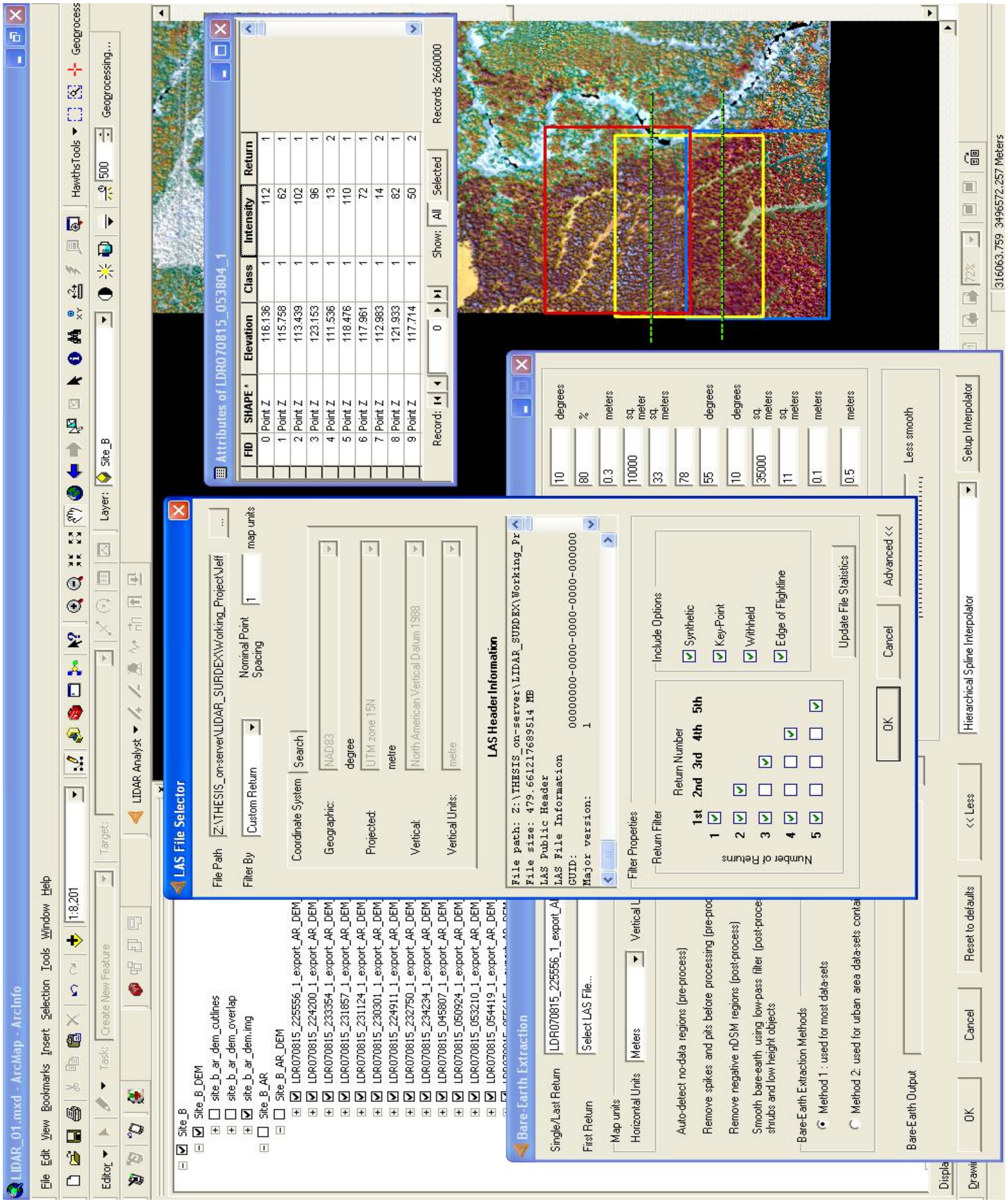

Figure 13. LiDAR data extraction and processing of 3D terrain surface.

The original LiDAR data of the study area was acquired in August 2007. This dataset was analyzed with TiFFS for tree location, individual tree height, and crown diameter. A DEM and a CHM were also produced for the entire forested area. The data was analyzed with LiDAR Analyst for comparison as well and preliminary results indicated that these were both effective in removing the tree cover and revealing the bare-ground surface. In order to provide an accuracy assessment of the dataset, the root mean square error at the plot and subplot levels for tree height and crown diameter was calculated, as well as the correlation coefficient (*r*) in order to see if there is any correlation between the LiDAR derived data and the field measured data. The results showed that there is little to no correlation in crown diameter. However, tree height has an *r* value of .8123 at the plot level, which proved to be very promising. It would appear that TiFFS software tends to underestimate the crown diameter, but overestimates the total number of trees. Additional research is ongoing to see if these discrepancies cancel each other out in the calculation of timber volume and the removal of the vegetative cover (Figure 14).

The field data was collected, and the TiFFS processing was completed before utilizing LiDAR Analyst for calculating timber volume; a VBA (Visual Basic for Applications) program was developed in order to speed up the process. Geospatial archaeology using LiDAR for hidden feature identification of *El Camino Real de los Tejas* National Historic Trail Resources is based on the premise that many generations of indigenous trails through the forests of eastern Texas were utilized by early European explorers, and that these early trails became modified through heavy use and the expansions and improvements needed to accommodate easy passage of European horses and carts and finally the heavy wagons of Anglo-American settlers.

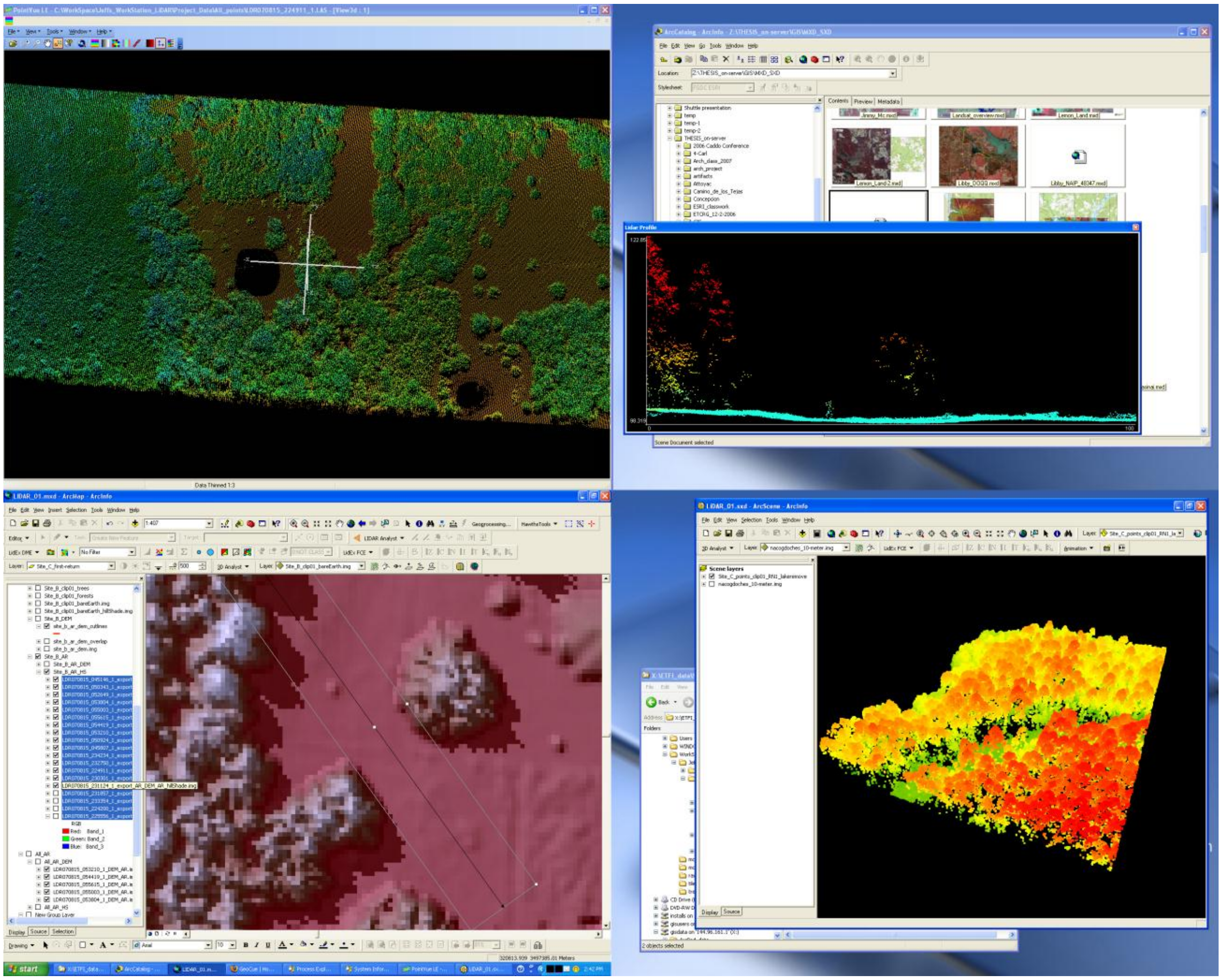

Figure 14. Elevation colored LiDAR point cloud within the Legg Plantation Swales area.

Composed of physical disturbances, the archaeological record at the landscape level is at best an incomplete catalog of the interactions of human activity and the natural world. A forested environment obscures surface features of the archaeological record; however, the capture and subsequent analysis of LiDAR is a cost effective method of reducing an area of interest. Additionally, a GIS geodatabase model design framework for managing archaeological data with physical landscape data was created to aid in the identification of hidden archaeological features. When combined with the analysis of LiDAR point clouds, before the removal of the biomass for a bare earth product, a robust dataset for evaluating the landscape offered a unique spatially responsive perspective allowing for an integrated study of the landscape forces influencing the selection of preferred 17th and 18th century Spanish road locations within the Legg Plantation area (Figure 15 and 16).

ATCOFA evaluated, through the identification of all significant natural, historical, and cultural resources of the Trail by applying geospatial technology for integration of historical documents, empirical archaeological surveys, and located trail attributes into a GIS geodatabase design that has proven that the landscape forces influencing the selection of a preferred Spanish road location can be concluded, resulting in the identification of additional existing trail segments (APPENDIX F).

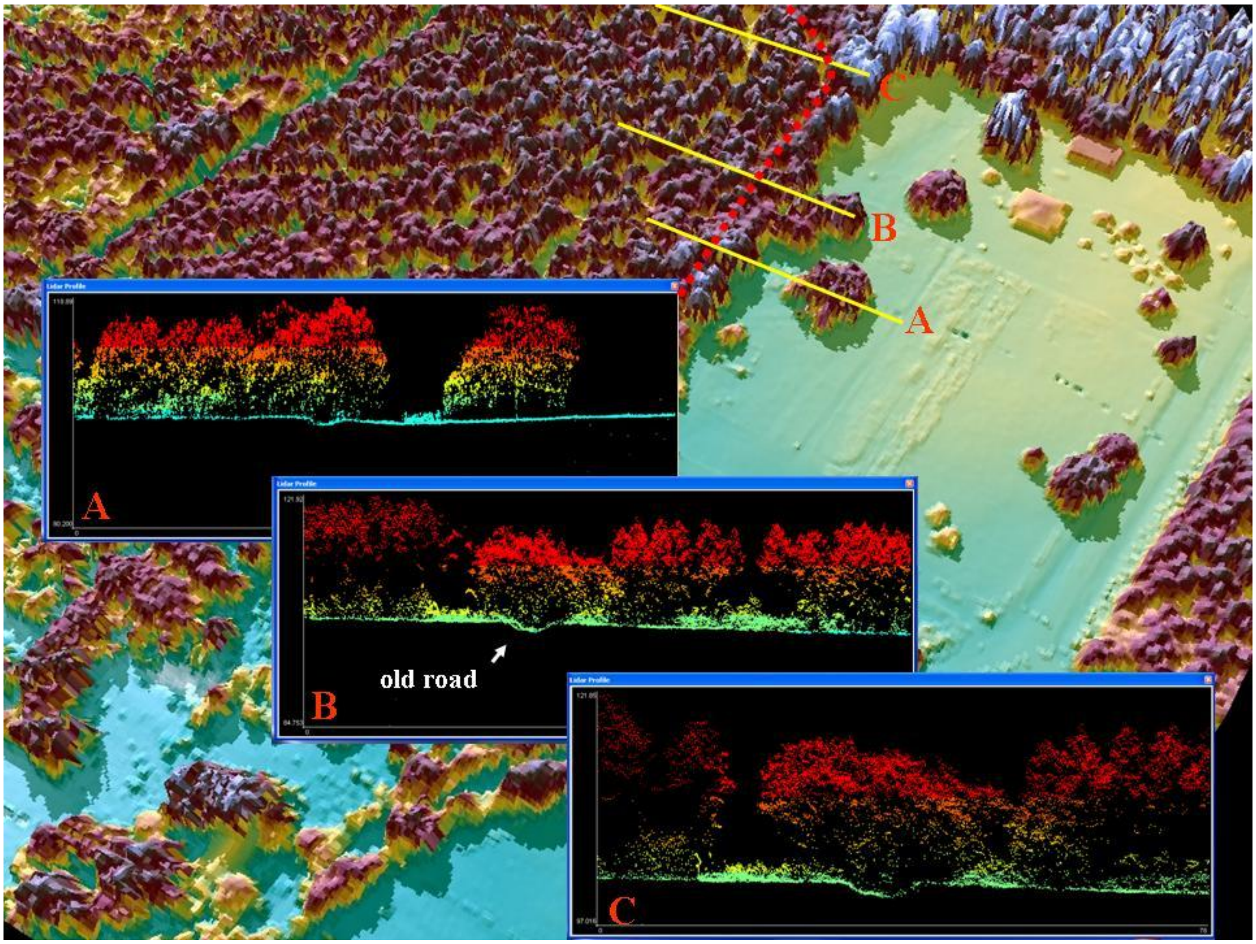

Figure 15. LiDAR of road segments of the Legg Plantation Swales.

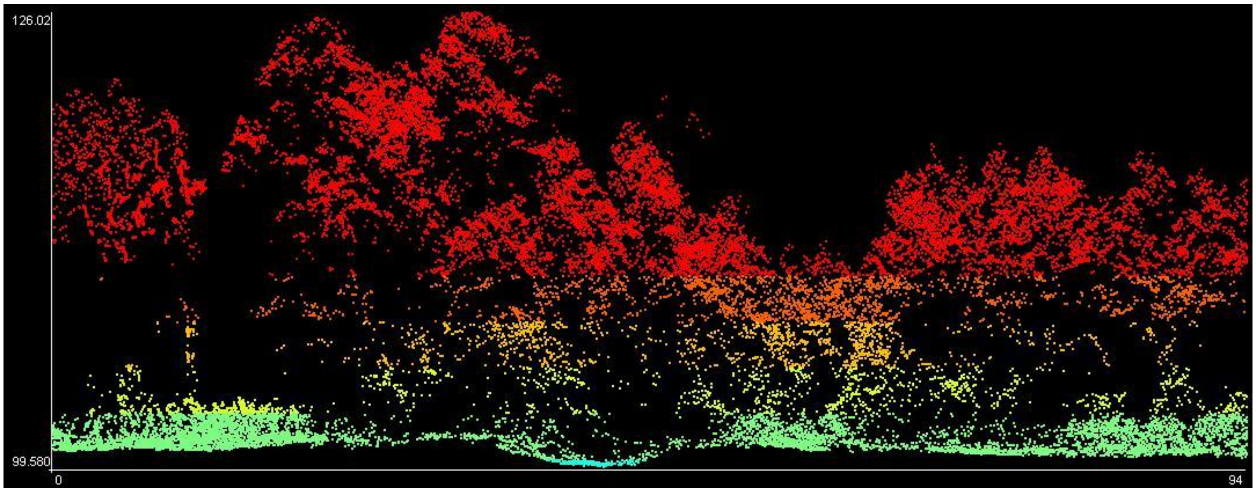

Figure 16. LiDAR close up of a road segment near the Legg Plantation area.

Using the techniques developed for utilizing LiDAR technology for ELTE Trails research, additional swales leading to the crossings of the Angelina River were discovered. The ELTE swales, identified from the application of LiDAR at this location, have been confirmed on the ground which provided a much broader landscape understanding of the area. This area has the same aesthetic potential and landscape quality as many other sites across ELTE that the High-Potental Sites and Segments team evaluated across the entire ELTE Trail. But this landscape has something that no other site on ELTE has; through the demonstrated use and application of cost saving technology such as LiDAR, this landscape has a much higher probability of yielding significant information on Spanish and Caddo interactions and the connections between these historic interactions along existing ELTE Trail resources (Figures 17 and 18).

In June of 2009, ATCOFA provided the NPS with a georeferenced 1843 landownership map illustrating a clear relationship with the newly identified Legg Plantation Swales as well as the Conception Crossing of the Angelina River. The map supported the assessment that the Legg Plantation Swales are indeed a part of ELTE Trail resources and that this specific location is a High-Potential Segment (APPENDIX A).

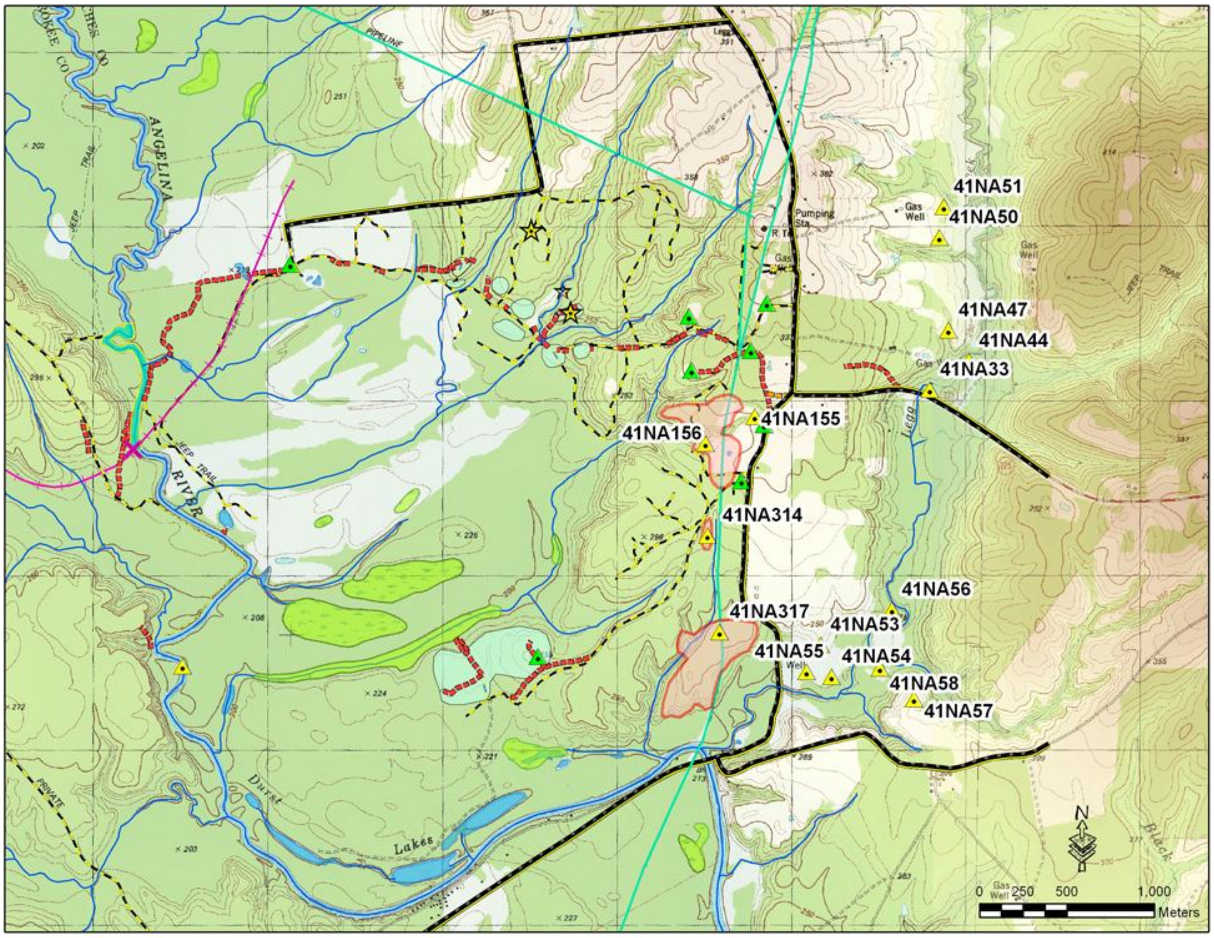

Figure 17. GIS map of the Angelina River crossing (Conception Crossing) near the Legg Plantation area.

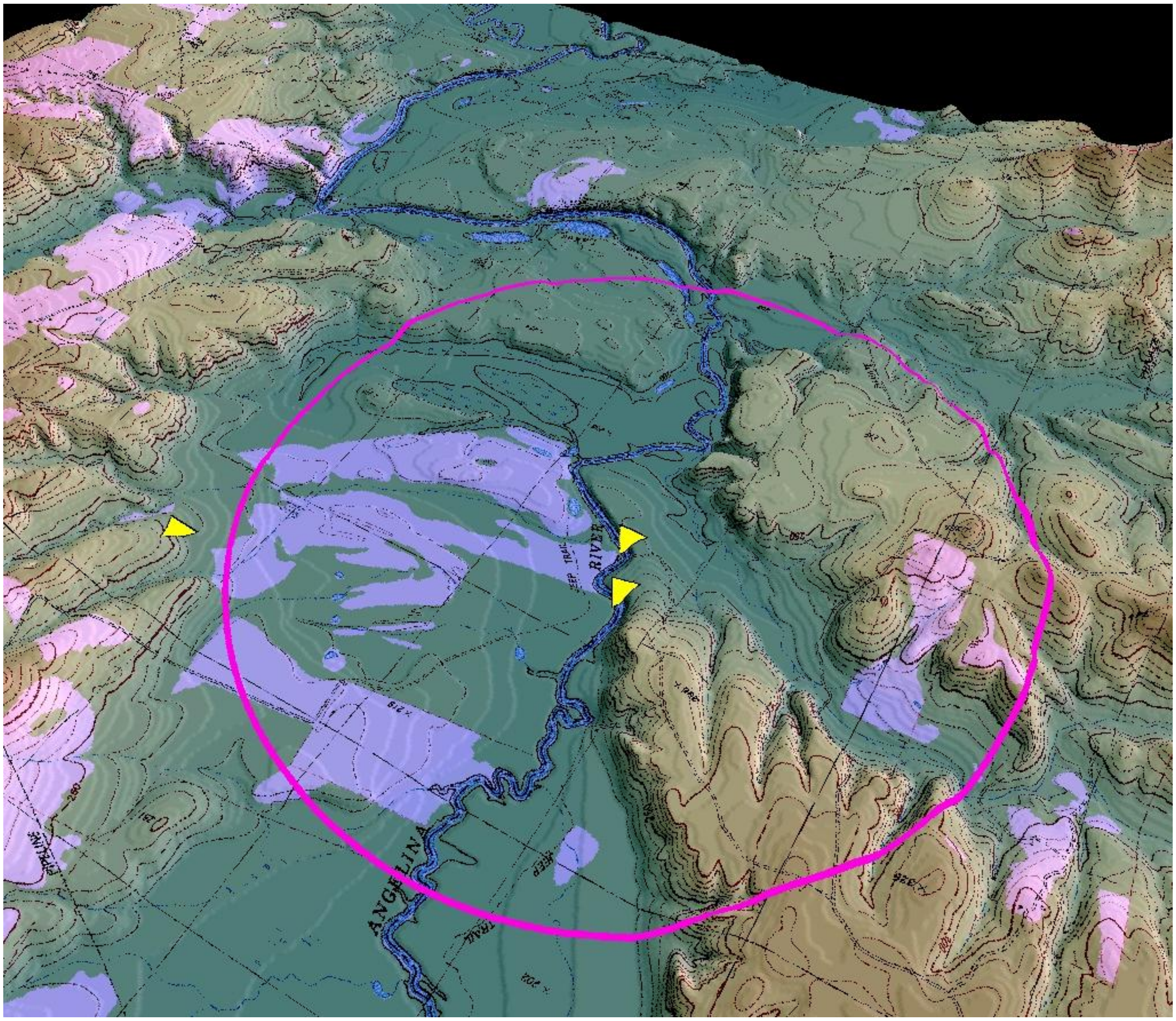

Figure 18. DEM of archaeological survey area in the Legg Plantation Swales vicinity.

ATCOFA has proven and demonstrated that the use of LiDAR for archaeological research is a cost-effective means of working in dense forested areas (Figure 19). The analysis of LiDAR data is also cost-effective in reducing large areas into smaller more targeted areas for inventorying ELTE's Trail resources; however, it is the Principal Investigators opinion that the use of LiDAR and its subsequent data processing and analysis is beyond the financial scope of the NPS for inventory of Trail recourses. Also bare earth (i.e., DEM) products displaying below nominal ground related archaeological features (i.e., roads) requires state-of-the-science technology, specialized knowledge, and high-end computing power that when coupled with historic research databases and archaeological pedestrian surveys is beyond the NPS's abilities to use for Trails inventories. Additionally, it is the Principal Investigators opinion that the use of raw LiDAR data is beyond the NPS's ability to process or utilize effectively, and it is not clear whether the NPS has the ability to effectively utilize derived LiDAR products such as DEMs of bare earth or high-resolution Trails data extracted from LiDAR (Figure 20).

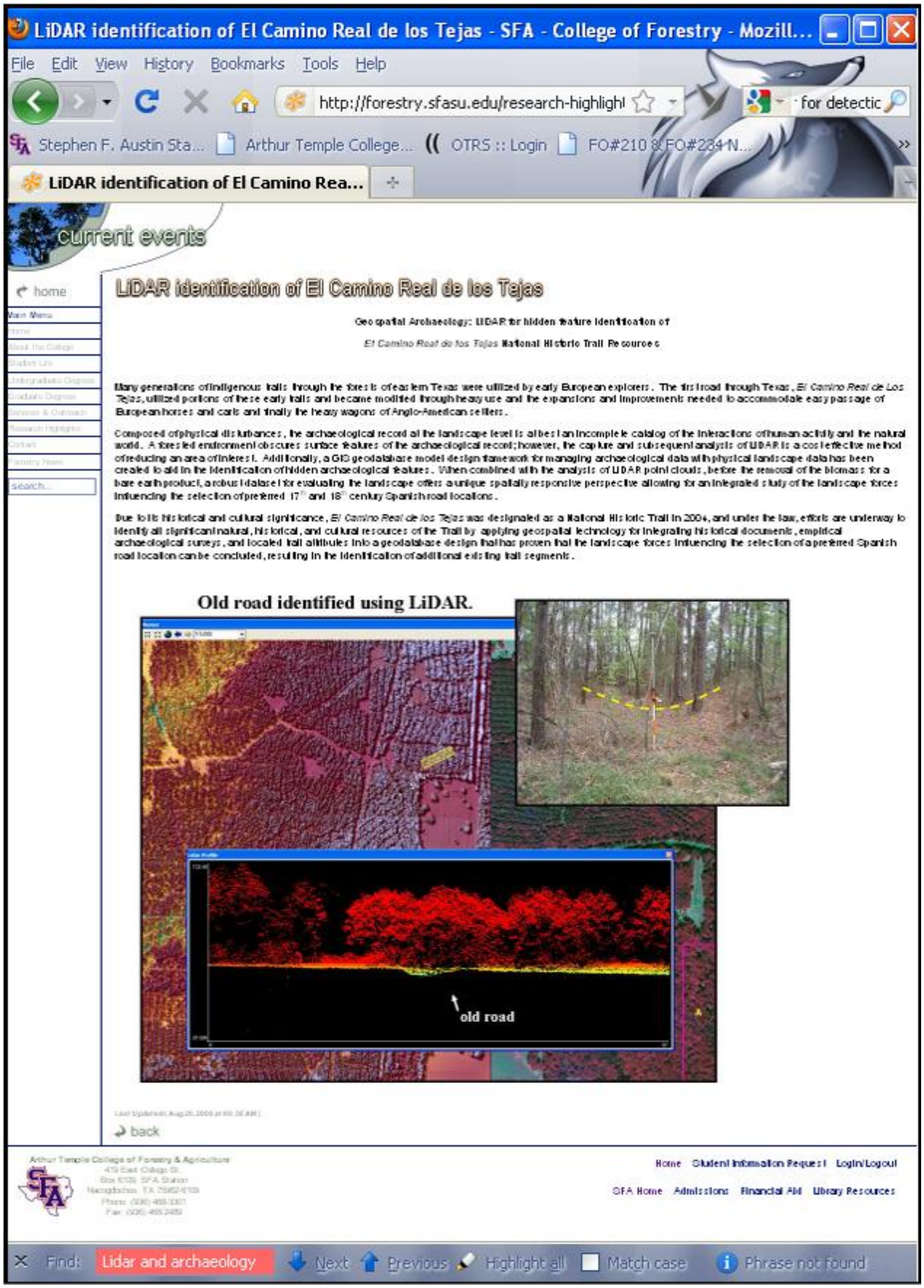

Figure 19. http://forestry.sfasu.edu/research-highlights/lidar-identification-of-el-camino-real-de-los-tejas.html

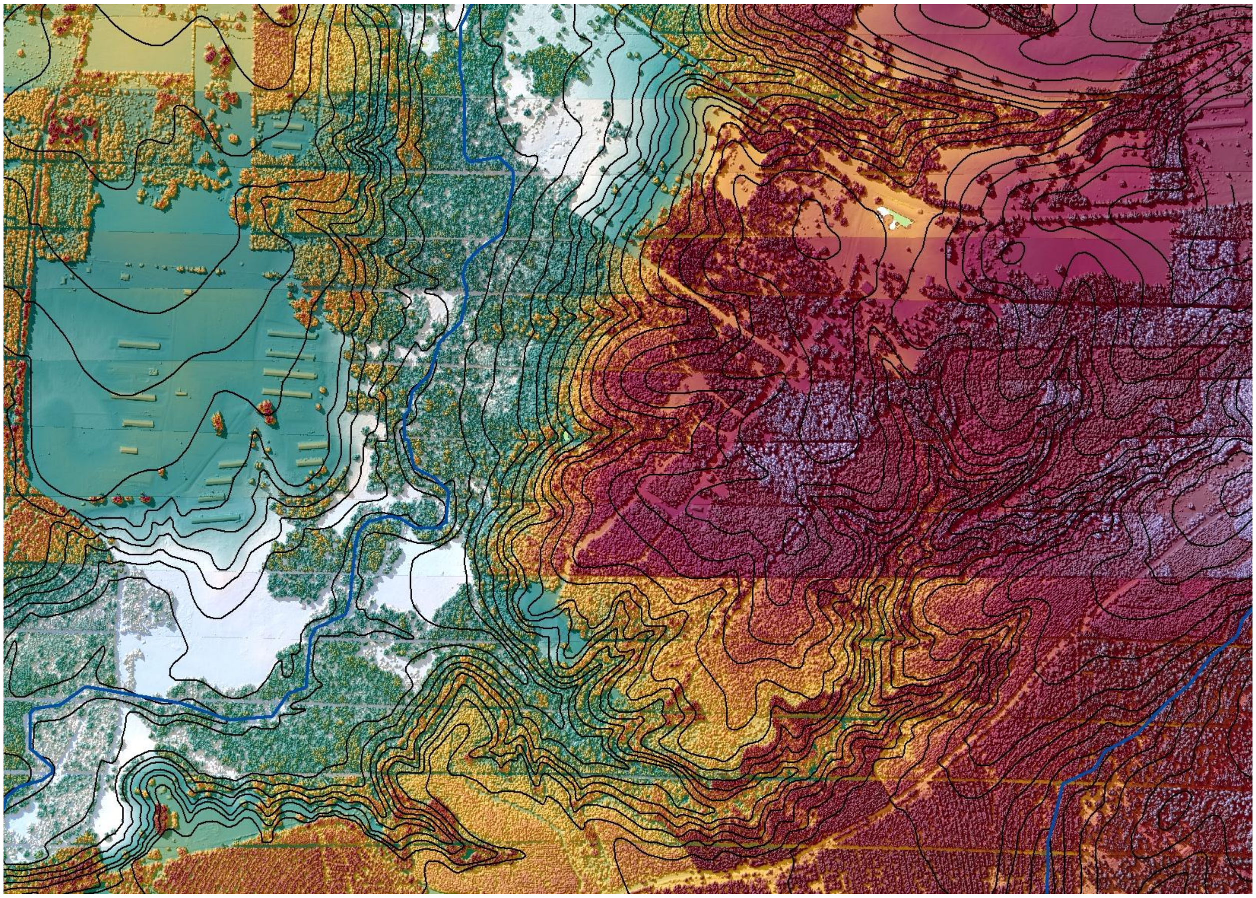

Figure 20. Composite image of over 3.5-million 3D LiDAR data points colored by elevation and LiDAR derived 1-meter contour lines in the Legg Plantation Swales area.

SECTIONS I & J

ATCOFA developed the strategy and the procedures for including high-resolution data (aerial photography, satellite imagery, and LiDAR datasets) to aid in the inventory of ELTE's High-Potential Sites and Segments. APPENDIX F provides an example of how to apply these procedures and strategies and Figure # and # show usage of the high-resolution imagery. ATCOFA created, tested, and verified a GIS geodatabase utilizing high-resolution satellite imagery coupled with precision Global Positioning Systems (GPS) data of site locations and combined them with historic Trail resources data to provide the NPS with a spatial dataset of ELTE Trail resources in both an ArcGIS 9.3 file based geodatabase format as well as a complete transportable Google Earth KMZ file (Figure 21).

ATCOFA provided basic GIS services to the NPS including editing and correcting the NPS GIS geodatabase that was reprojected from the NPS's High-Potential Sites spreadsheet coordinate system of decimal degrees into the Texas Statewide Mapping System (TSMS) which is the best projection for showing spatial data across the entire state. The projection will also work as far east as to encompass Natchitoches, Louisiana. TSMS uses the GRS 1980 spheroid and is a projected coordinate system for the State using Lambert's Conformal Conic projection. The corrected GIS TSMS based map showed that quite a few of NPS's High-Potential Sites spreadsheet were incorrectly positioned. The data was double checked and corrected against the 1-meter resolution 2004 Texas Digital OrthoQuarter Quadrangles (TxDOQQ) with WGS-84 as the datum. The incorrectly positioned data points were due to the level of accuracy of the GPS unit used by the NPS.

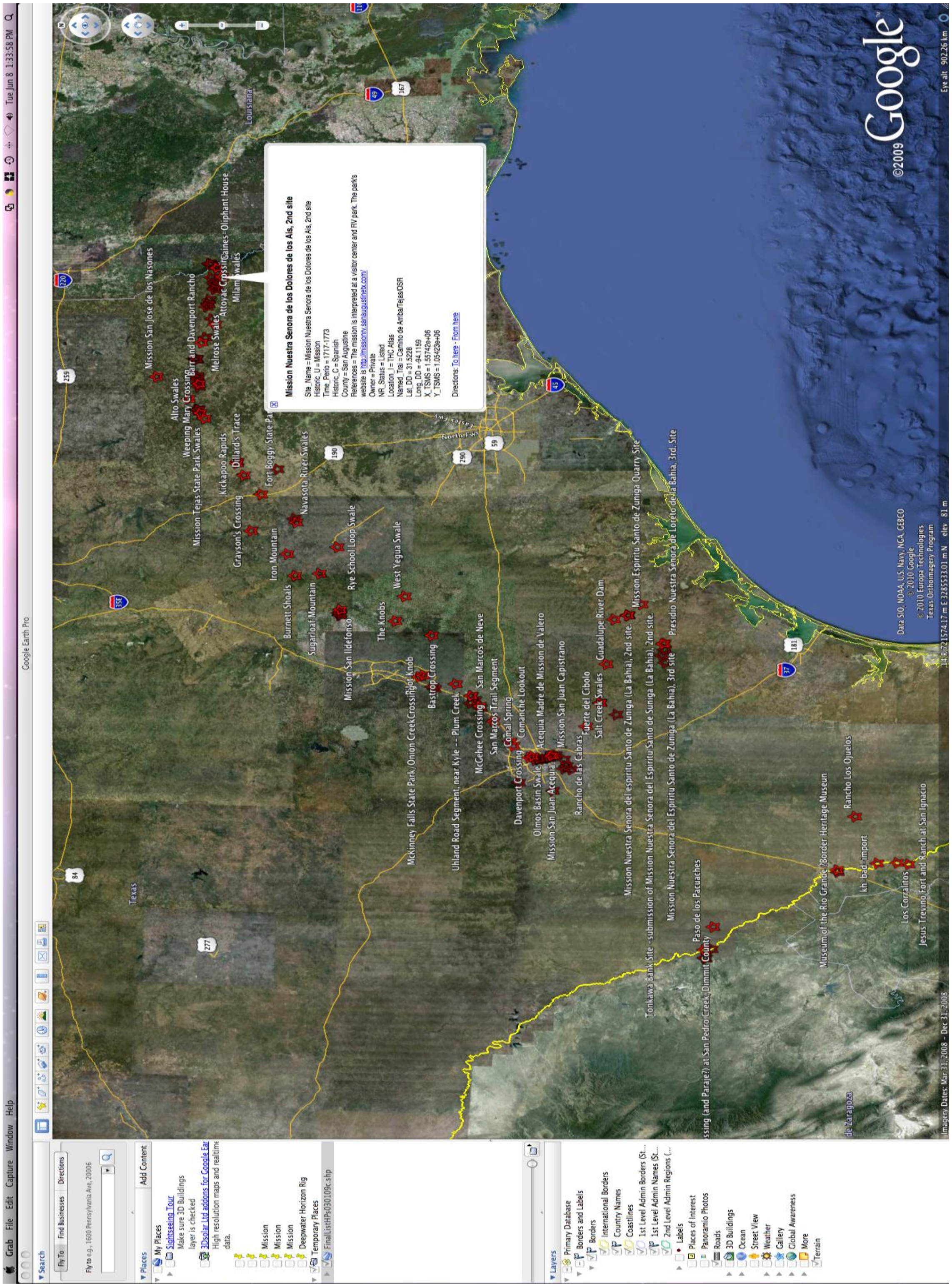

Figure 21. Google Earth KMZ file of High-Potential Sites and Segments with database.

Several of the NPS's High-Potential Sites can be seen on the imagery (including El Nacimiento swales in Coahuila, Mexico) and were located to an accuracy of 1:12,000 (TxDOQQ scale). This also includes all of the NPS's High-Potential Sites north and east of Austin (Brazos and Crossroads regions). Additionally, Salt Creek Swales in DeWitt County can be seen in the aerial photography and were added to the dataset because there are existing swales at this site that the NPS visited in the spring of 2008, and it is right on the NPS route line on NPS map sheet #9 that runs between the confluence of Cibolo Creek and the San Antonio River just below *El Fuerte del Cibolo* and the crossings of the Guadalupe River at Cuero.

An additional thirty-six High-Potential Sites were added from East Texas. The evaluation team did not have time to visit these sites, but they should be included in the NPS's High-Potential Sites list. The data records for Kickapoo Rapids and Hurricane Shoals were divided into 2 individual sites because they are separated by almost 0.8-kilometer (0.5 mile). *Paso de Francia, Paso de Los Islas*, and *Paso de los Pacuaches* have been divided into individual sites because they are separated by several kilometers. All of these Rio Grande crossings are visible on Google Earth (the individual crossings of the Rio Grande and the deep swales leading to the crossings on both sides of the border).

Two CD sets of the ELTE Trails resource GIS database products were provided to NPS Historian Dr. Susan Boyle and NPS GIS Specialist John Cannella the week of May 29th, 2009. An ArcGIS MXD document file was also included and Layer file definitions were included so that the map document could be rebuilt if needed. The data on the CD included the edited High-

Potential Sites spreadsheet, a GIS Trails resource GIS geodatabase containing high-resolution base data and the High-Potential Sites point Feature class, and a final edit of a Google Earth KMZ export file with the respective file names of

1) FinalListHPs030109_JMW_edits.xls,
2) ELTE_TX_HPsites.gdb, and
3) FinalListHPs030109_JMW_edits.shp.kmz.

Other than acknowledging receipt of the datasets, the NPS's only comments related to submittal of the ELTE GIS dataset was that they had an opportunity to discussed, in detail, the use and value of ELTE's Trail resource GIS dataset with ELTE's NPS Superintendant, Aaron Mahr, and that the GIS Specialist was going to develop a demonstration of the usability of the dataset for the entire NPS staff. However, after several months of absolutely no feedback, no editorial comments, and no requested changes from the NPS Historian or NPS GIS Specialist, these spatial datasets of ELTE Trail resources, provided to the NPS on May 29th, 2009, were considered by ATCOFA to be adequate and acceptable to the NPS (APPENDIX A). Figure 22 is a screen capture of the ELTE Trails dataset being queried in an ArcGIS environment during spatial analysis of patterns and trends of differing Trail resource types.

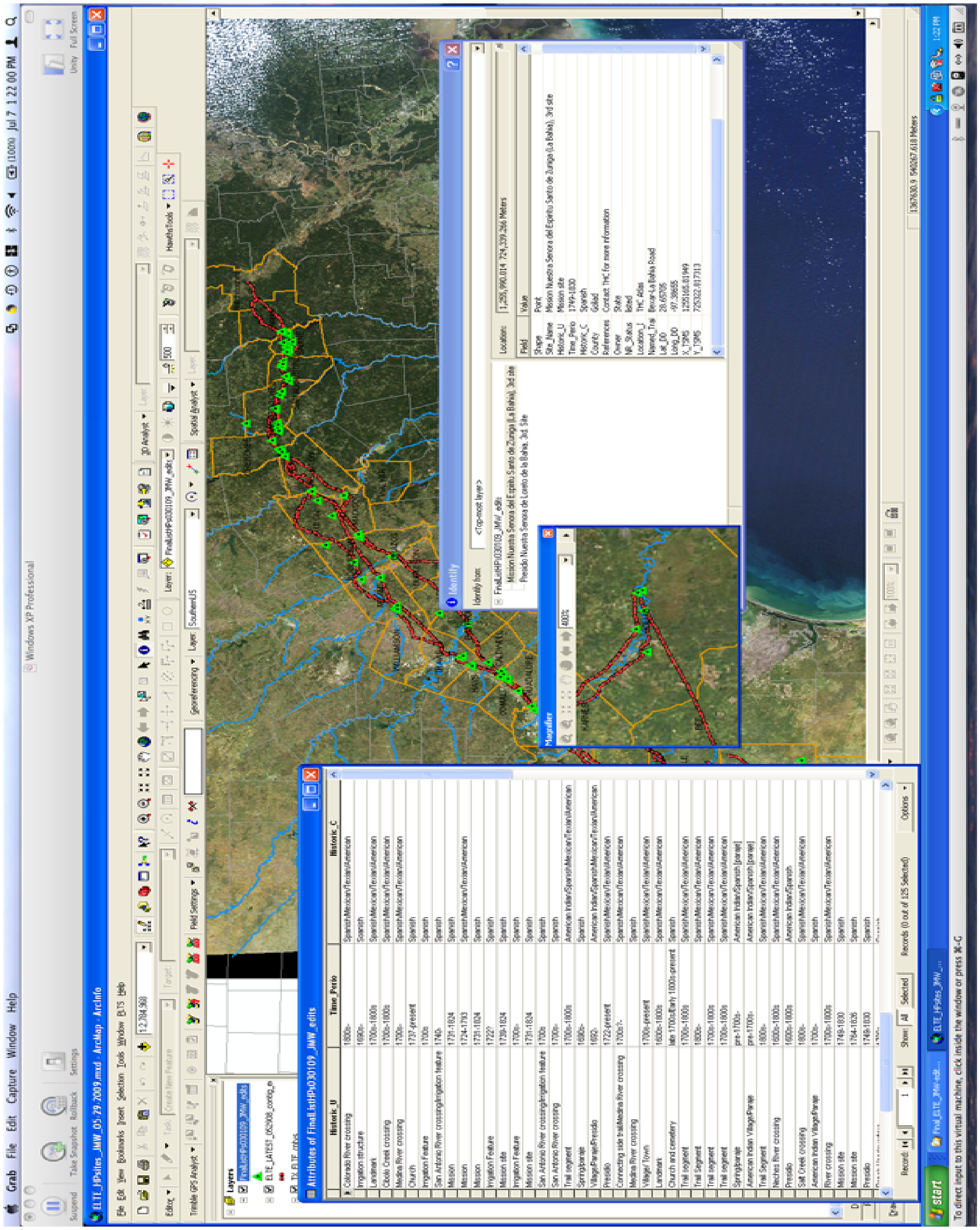

Figure 22. Screen capture of the ELTE Trails dataset being queried in ArcGIS during spatial analysis of patterns and trends associated with differing types of Trails resources.

The NPS contracted with ATCOFA to provide various GIS related services to assist them with the locating and evaluation of ELTE High-Potential Sites and Segments and to aid them with collecting supporting documentation (i.e., GIS maps) and to aid in document preparation of ELTE's CMP. The various GIS services provided to the NPS required the use of ATCOFA's GIS Laboratory and "state-of-the-science" technology including ATCOFA's GIS Servers, GIS WorkStations, large format plotters, large format scanners, data storage devices, survey grade GPS units, specialty GIS and remote sensing software, State and local high-resolution datasets including airborne and satellite imagery and LiDAR, as well as GIS Laboratory time. ATCOFA bills all GIS research contracts at the federally excepted rate of $100.00 per hour of GIS Laboratory time; not including professional GIS analyst hourly time. APPENDIX B details the ATCOFA GIS Laboratory time used to contractually provide the GIS services to the NPS under Cooperative Agreement No. H5000 02 A271.

ATCOFA's GIS Laboratory provided 492-hours of GIS services to the NPS, not including the hundreds of hours used by the Graduate Student hired to process the projects LiDAR data. At the federally excepted billable hourly rate, ATCOFA's GIS Laboratory provided $49,200.00 worth of GIS services of which the NPS budgeted $20,000.00 for the GIS services. Therefore SFASU, through ATCOFA's value added GIS services, subsidized the NPS's requirements for GIS services for the ELTE's CMP by $29,200.00 at no additional cost or expense to the NPS (APPENDIX B).

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APPENDIX A

Work Requests

(ELTE Email Log)

Date of Request	Requesting/ Receiving Agency	Contact	ATCoFA Task and / or Response	Date Completed
07/02/08	THC	Jim Bruseth	Provided information regarding cooperative agreement between the NPS and SFA re: El Camino Real de los Tejas GIS Project; also regarding Lobanillo Cuts and Sabine County officials	07/02/08
09/29/08	NPS	Susan Boyle	Asked to evaluate "Working draft spatial data standards for cultural resources managed within NPS"; responded with request for empty geodatabase for evaluation.	09/29/08
10/03/08	NPS	Susan Boyle	Requested to contact Salt Lake City office regarding mapping.	10/08/08
10/18/08	NPS	Susan Boyle	Given information on trails workshop in Socorro, NM.	10/18/08
10/20/08	NPS	Susan Boyle	Asked to add and/or modify the potential attributes or sites and segments of El Camino Real de los Tejas; file based on Rediscovery Project for the Santa Fe Trail	10/21/08
10/21/08	NPS	Susan Boyle	Discussion of dates for NPS exploratory field trip	10/22/08
10/22/08	NPS	Susan Boyle	Discussion of dates & sites for NPS exploratory field trip; request to review table of potential visitor sites for the ELTE; request for contacts at Texas Parks & Wildlife	10/22/08
10/30/08	NPS	Susan Boyle	Requested THC contact information; also requested that Challenge Cost Share Grant information be disseminated	10/30/08
11/11/08	NPS	Susan Boyle	Requested feedback on Trails class; also information on trail classes, as well as feedback on ETLE field trip/	11/11/08
11/14/08	NPS	Susan Boyle	Provided edited version of Meeting Agenda w/Mapping	11/14/08
11/15/08	NPS	Susan Boyle	Asked to review final agenda.	11/15/08
11/24/08	NPS	Susan Boyle	Discussion of inclusion of additional sites and personnel in ELTE field trip (Brazos County – Henry Mayo, James Oliver – NPS).	11/24/08
11/25/08	NPS	Susan Boyle	Discussion of Brazos County site and updated High Potential Sites list.	11/25/09
11/26/09	ETCRG	Tom Middlebrook	Coordination of December ETCRG meeting including details relating to ELTE presentation.	11/26/09
11/27/08	NPS	Susan Boyle	Provided evaluation of Mariah Wade's South Texas road information.	12/02/08
11/27/08	NPS	Susan Boyle	Provided rational for ELTE period of significance of 1821-1845	12/02/08
12/07/08	NPS	Susan Boyle	Asked to review portions of the Ethno-history for the ELTE; asked for further comments on ELTE field trip itinerary; discussion of developing relationship with Nacimiento group.	12/08/08
12/10/08	NPS	Susan Boyle	Provided information on old Carter's Ferry cemetery for the Crow family; scheduled further update by phone for 12/11/08.	12/10/08
12/11/08	NPS	Susan Boyle	Discussion of Robertson County possible sites and additions to the field trip itinerary.	12/13/08
12/16/08	NPS	Susan Boyle	Asked for clarification of Henry Mayo's site; confirmed as driver on field trip, asked to follow up on Robert Hick's information.	12/16/08
12/18/08	NPS	Susan Boyle	Further discussion of January field trip, including Ft.	12/18/08

			Boggy, and April workshop; asked to begin tentative itinerary for February ELTE field trip; discussion of contact with TXDOT.	
12/20/08	Stakeholder	Randy Parten	Discussion of involvement in the ELTE process/	12/20/08
12/22/08	THC	Terry Colley	Notified THC of problem related to location of XL Keystone Pipeline across ELTE resources in Nacogdoches County.	12/21/09
12/23/08	NPS	Mike Taylor	Email exchange re: Keystone Pipeline forwarded to NPS between 12/20/09 and 12/23/09.	12/20/08
12/26/08	NPS	Susan Boyle	Copied on introduction to Andy Sansom, Trails Association Director	n/a
01/04/09	NPS	Susan Boyle	Copied on discussion with Cathy Lazurus, Chair of Robertson County Historical Commission regarding upcoming ELTE site visit to Robertson County.	n/a
01/05/09	NPS THC	Mike Taylor Jim Bruseth	Email exchange regarding NEPA and Keystone Pipeline	01/07/09
01/06/09	NPS	Susan Boyle	Final exchange of information regarding Brazos County site visit.	01/06/09
01/06/08	NPS	Susan Boyle	Provided abstract of article on the use of LIDAR in geospatial archaeology for use in ELTE document..	01/07/09
01/08/09	NPS	Susan Boyle	Asked to provide written description of work linked to 01/07/09 invoice.	01/08/09
01/08/09	NPS	Susan Boyle	Discussion of itinerary – Mission Tejas, and Caddo Mounds.	01/08/09
01/18/09	Robertson County	Robert Hicks	Discussion of possible ELTE sites in Robertson County	
01/19/09	Robertson Historical Commission	Maureen Winn	Discussion of possible location of Grayson Crossing in Robertson County.	01/19/09
01/20/09	Robertson County	Robert Hicks	Discussion of possible ELTE routes and objections to elimination of alternative routes.	
01/21/09	NPS	Susan Boyle	Asked to review information on Mission Tejas State Park and interpretation plans; also use of thesis by interested party.	01/21/09
01/21/09	NPS	Susan Boyle	Asked to examine High Potential Site - Guadalupe Crossing near Cuero; and to provide mapping for NPS exploratory field trip.	01/21/09
01/26/09	NPS	Susan Boyle	Discussion of Hays County sites added to list; asked to physically examine site in DeWitt County; further discussion on Mission Tejas, connection with Richard Santos, and Otis' investigating situation re: Caddo as stakeholders.	01/26/09
01/28/09	NPS	Susan Boyle	Addition to itinerary for second NPS filed trip – Jesus Trevino Ranch	01/28/09
01/29/09	NPS	Susan Boyle	Comments requested on Itinerary for NPS	01/29/09
02/09/09	THC	Jim Bruseth	Requested to attend XL Keystone Pipeline Meeting.	02/09/09
02/09/09	NPS	Susan Boyle	Info provided about possible Caddo Center w/ELTE interpretation.	n/a
02/09/09	NPS	Susan Boyle Mike Taylor	Discussion regarding NPS involvement in the Keystone pipeline process; asked to advise on types of testing.	02/09/09
02/10/09	THC	Jim Bruseth	Provided information regarding fieldwork at San Gabriel Mission.	02/10/09
02/10/09	NPS	Susan Boyle	Discussion of collaboration w/Rolanda Teal of Cane Rover regarding her CCS grant regarding the underground railroad through Los Adaes	02/10/09

02/12/09	TrAssoc.	Steven Gonzales	Requested all GIS Datasets for ELTE Association; request forwarded to Susan Boyle, NPS.	02/12/09
02/12/09	NPS	Susan Boyle	Asked to evaluate descriptions of 2 trail routes near Franklin.	02/12/09
02/12/09	NPS	Susan Boyle	Asked to critique Ethnographic material and Historical Background.	
02/17/09	NPS	Susan Boyle	Copied on discussion with Jim Bruseth of the THC regarding possible ELTE sites in Victoria County.	n/a
02/17/09	NPS	Susan Boyle	Requested references about migration into Texas along the OSR – diaries, personal accounts, historical documents, ethnic studies.	n/a
02/18/08	NPS	Susan Boyle	Provided report to NPS on Keystone pipeline meeting.	02/18/09
02/23/09		Willene Taylor	Discussion of need for additional historical documentation for Conquista Crossing.	02/23/09
02/24/09	NPS	Aaron Mahr	Discussion regarding the problems associated with providing ATCFA LiDAR data to CESU contractor in Utah for ELTE related analysis.	02/24/09
02/25/08	NPS THC	Susan Boyle Mike Taylor Jim Bruseth Bill Martin	Provided notes from Nancy Porter, AECOM Environment, and David Harvey, ENTRIX Inc., re: 02/18/09 Nacogdoches meeting regarding Keystone Pipeline and ELTE NHT	02/25/09
02/25/09	Goliad County Historical Commission	Patsy Light	Coordination of March 20th site visit to Conquista Crossing and marker dedication	02/25/09
03/02/09	NPS THC Brazos County	Susan Boyle Jere Krakow Jim Bruseth Henry Mayo	Provided email description & photos of Rye Loop Swales	03/02/09
03/02/09	NPS THC	Susan Boyle Jim Bruseth	Description provided of meeting with Association members on 2/27/09; also description of river crossing site examinations from Milam County to Leon County	03/02/09
03/04/09	Robertson County	Robert Hicks	Provided arguments against existence of trail through Rockdale; forwarded to Susan Boyle, NPS.	03/04/09
03/10/09	Louisiana Parks and Tourism	Raymond Berthelot	Coordination of meeting at Los Adaes regarding ELTE segments in the park; provision of historical and mapping resources.	03/10/09
03/17/09	NPS	Susan Boyle	Copied on discussion with Anne Boykin and Barbara Althaus regarding CCS grant project for Brazos County.	n/a
03/17/09	NPS	Susan Boyle	Asked to review description of process for route verification for the CMP alternatives; asked to provide input & discussion for the Mission Tejas CCS grant; asked to verify submission of Chris Talbot/SFASU CCS grant.	03/17/09
03/18/09	NPS	Susan Boyle	Copied on discussion with Cindy Brandimarte regarding CCS grant project for Mission Tejas and Jeff Williams' involvement in process.	n/a
03/24/09	NPS	Susan Boyle	Provided 1816 Darby Melish map and discussion of north south connector road.	03/24/09
03/29/09	NPS	Susan Boyle	Along w/a selection of Texas officials, asked to review Draft Comprehensive Management Plan Sections.	n/a
04/03/09	NPS	John Cannella	Asked to set up phone conference regarding GIS data available for the trail and what is currently being developed.	

04/08/09	TxDOT	Al McGraw	Requested to schedule phone conference to establish a protocol for reporting and informing TxDOT concerning identification of Camino Real(es) along or within TxDOT ROW	04/08/09
04/13/09	NPS	Susan Boyle	Discussion of next Trail Association Board Meeting agenda, Cooperative Agreements with THC and LA SHPO, and June 8th filed trip.	n/a
04/20/09	Cultural Lore	Rolanda Teal	Requested to review CCS grant application before submission to NPS.	04/22/09
04/20/09	NPS	Susan Boyle	Discussion of logistics of June 8th field trip, including Brazos County trail section and Rye School segment, and NPS expectations for the CESU.	n/a
04/22/09	NPS	Susan Boyle	Copied on discussion with Anne Boykin and Barbara Althaus regarding CCS grant project for Brazos County.	n/a
05/04/09	Tr. Association	Steven Gonzales	Discussion of payment for maps provided at Trail Association Board Meeting in Natchitoches Louisiana.	05/04/09
05/24/09	NPS	Susan Boyle	Asked to provide comments on inclusion of Robertson County site; discussed planning of June 8th site visit.	05/24/09
05/26/09	NPS	Susan Boyle	Further discussion of itinerary for June 8th site visit.	05/26/09
05/28/09	Milam County	Lucille Estell	Further discussion of itinerary for June 8th site visit.	05/28/09
05/29/09	NPS	Susan Boyle	Forwarded NPS GIS Specifications.	
05/29/09	NPS	Susan Boyle	Provided graphics for Salt Creek Swales in DeWitt County.	05/29/09
05/29/09	NPS	Susan Boyle	Provided graphics and narrative for Conquista Crossing in Karnes County.	05/29/09
05/29/09	NPS	Susan Boyle	Provided graphics for Navasota River Swales in Brazos County.	05/29/09
05/29/09	NPS	Susan Boyle John Cannella	Provided email description of information packet mailed to NPS office, including hardcopy edits for the CMP and several CDs of data , including the edited High Potential Sites spreadsheet, GIS geodatabase and the High Potential Sites point feature class, and a Google Earth KMZ file; work done for these items is explained in this email.	05/29/09
06/03/09	NPS	Susan Boyle Mike Taylor	Provided maps for NPS/THC exploratory field trip based on NPS itinerary	06/03/2009
06/01/09	NPS	Susan Boyle	Information given regarding management of trail, digit lab in Salt Lake, and final plan for June 8th field trip.	06/01/09
06/03/09	NPS	Susan Boyle	Provided finalized itinerary for June 8th field trip.	06/04/09
06/04/09	NPS	Aaron Mahr *et al*	Provided information regarding possible ELTE sites impacted by Toledo Bend Reservoir.	06/04/09
06/05/09	TPWD	John Ferguson	Asked to submit invoice for work at Mission Tejas 04/09/09; informed TPWD that work was part of ELTE work; email exchange continued through remainder of June,	06/05/09
06/07/09	Robertson County	Maureen Winn	Clarification provided regarding Burnett Shoals Crossing as discussed at Franklin meeting.	n/a
06/10/09	Brazos County	Barbara Althaus	Provided information about Tinnan's Crossing and requested confirmation.	06/10/09
06/11/09	NPS	Susan Boyle	Provided maps & images for Gonzales County site and artifact.	06/12/09
06/12/09	TPWD	John Ferguson	Asked to review Project Review Request, Mission Tejas, Caddo Village Meadow.	06/13/09
06/19/09	NPS	Susan Boyle	Discussion of inclusion of Louisiana sites in draft;	06/19/09

			discussion of comments and data set for draft; discussion of CCS grants.	
06/20/09	NPS	Susan Boyle	Asked to review and advise partner regarding forwarded correspondence concerning CCS grant for Brazos County.	06/19/09
06/20/09	NPS	Aaron Mahr	Asked to review and advise partner regarding forwarded correspondence concerning Robertson County route identification.	06/20/09
06/24/09	NPS	Aaron Mahr	Copied on discussion with Robert Hicks regarding possible ELTE sites though Robertson County	06/24/09
06/30/09	Milam County Robertson County	Lucille Estell Mary Graham Maureen Winn	Forwarded slides of swale types.	06/30/09
06/30/09	NPS	Susan Boyle	Asked to review and advise partner regarding forwarded correspondence concerning draft CCS grant for Brazos County.	06/30/09
07/01/09	Brazos County	Barbara Althaus	Discussed elimination of Navasota Swales from NPS list, necessity of land owner support, and CCS grant..	07/01/09
07/01/09	NPS	Susan Boyle Cc: ETLE board members	Received info concerning Robertson County sites; provided slides of swale types	07/01/09
07/01/09	Sabine County	John Minton	Email and phone exchange 07/01/09-07/06/09; provided information on Sabine County Sites.	07/02/09-07/06/09
07/02/09	NPS	Susan Boyle	Informed that additional detail is necessary for some of the East Texas ELTE High Potential Sites or most will be discounted. Additional detail and justification provided.	07/03/09
07/04/09	NPS	Susan Boyle	Suggested that additional material be added to the Google Earth file and Excel database that the NPS intends to use as a future resources; indicated that sites not considered now will be added to tentative list.	
07/06/09	Milam County	Lucille Estell	Asked for maps; forwarded contact information for Dan Utley; finalized details for Tejas Book Festival and the Nature Festival.	07/06/09/09
07/13/09	Tr. Association	Mary Waters	Asked to respond to request for information from Environmentex regarding proposed cell tower near ELTE. Advised Tr.Assoc. to forward request to THC.	07/13/09
07/23/09	NPS	Mike Taylor	Response to information provided on 07/23/09 regarding Keystone pipeline and report of NPS meeting with Keystone pipeline contractors. On 08/04/09	07/23/09
08/06/09	Tr.Association	Gary Dunnam	Description of concerns related to the omission of Victoria from the ELTE, including specific research; includes request for information – provided maps and background research assistance.	08/08/09
08/26/09	Cane River National Heritage Area	Katherine Johnson	Requested a meeting to discuss GIS project for ELTE in Louisiana; advised that NPS contract needed completion before additional work could be considered.	09/10/09
09/08/09	Tr.Association	Gary Dunnam	Requested information regarding Santa Cruz, south Texas military outpost;	09/16/09
09/29/09	Cane River National	Katherine Johnson	Reiterated interest in providing monetary assistance for a the research and development of a GIS project for ELTE	09/10/09

	Heritage Area		in Louisiana; advised that NPS contract needed completion before additional work could be considered.	
10/05/09	TPWD	Barbara Parmley	Confirmed arrangements for walk on the ELTE segment at Mission Tejas SP w/Mary Turner of the Texas Forest Trail, and Pat Stephens Williams and Chay Runnels of SFASU.	
10/05/09	Adais Nation of Louisiana	Rufus Davis	Request for “jump start presentation” to aid in the setting up of El Camino Real Chapter in Natchitoches.	10/06/09
10/06/09	Adais Nation of Louisiana	Rufus Davis	Continued discussion regarding the setting up of El Camino Real Chapter in Natchitoches, including members of the Cane River National Heritage Area Commission; reiterated that funding for research and mapping would be available.	10/06/09
10/12/09	NPS	Mike Taylor	Requested attendance at meeting of interested parties at site of XL Keystone Pipeline intersection with ELTE resources in November.	10/12/09
10/15/09	Madison County Historical Commission	Patrick and Nancy Page	Request for assistance or suggestions related to using remote sensing technology to locate the La Bahia Trail; provided contact names for historical researchers in their area, available research, and access to thesis.	10/16/09
10/19/09	Tr.Associati on	Gary Dunnam	Requested site visit to Victoria area in January to be followed by speaking engagement in February.	10/19/09
10/28/09	Ind. Researcher	Barry Harrin	Requesting information regarding crossings and trail segments in Karnes and Kennedy Counties.	10/30/09
11/16/09	Tr. Association	Joy Graham	Provided clarification of information on irrigation ditches near San Xavier Missions in Milam County.	11/18/09
11/30/09	NPS	Mike Taylor	Arranged appointment to discuss XL Keystone Pipeline.	11/30/09
12/03/09	THC	Greg Smith	Coordinated ELTE meeting in Austin.	12/03/09
12/07/09	Texas State University	Stephen Black	Requested review of rough draft of Mission Dolores exhibit for Texas Beyond History; asked to provide information on Dr. James Corbin’s work at Mission Dolores; asked to provide information on research, shovel testing, GIS and Camino Real segment as well as images and maps.	12/07/09
12/07/09	NPS	Mike Taylor	Requested suggestions for coordinating site visits in Nacogdoches.	12/07/09
01/29/10	Tr. Association	Lucille Estell	Coordinating final agenda for Tejas Book Festival.	01/29/10

APPENDIX B

GIS Laboratory Time Used

(ELTE Contract Hours Log)

2008 GIS Lab hours - ELTE GIS		**2009 GIS Lab hours - ELTE GIS**	
DATE	HOURS	DATE	HOURS
2-Sep	3	5-Jan	3
3-Sep	3	6-Jan	3
4-Sep	4	7-Jan	4
5-Sep	3	8-Jan	3
8-Sep	4	19-Jan	4
9-Sep	6	20-Jan	5
10-Sep	4	21-Jan	5
11-Sep	4	22-Jan	4
12-Sep	2	23-Jan	6
15-Sep	4	12-Feb	4
16-Sep	2	13-Feb	4
17-Sep	6		
18-Sep	2	16-Feb	4
19-Sep	8	17-Feb	4
22-Sep	4	23-Feb	2
23-Sep	4	24-Feb	4
24-Sep	6	25-Feb	4
25-Sep	6		
26-Sep	2	2-Mar	4
		3-Mar	4
29-Sep	4	4-Mar	4
30-Sep	4	5-Mar	4
1-Oct	2		
2-Oct	4	23-Mar	4
3-Oct	8	24-Mar	4
		25-Mar	3
6-Oct	4	26-Mar	4
7-Oct	4		
8-Oct	8	6-Apr	4
9-Oct	2	7-Apr	3
10-Oct	6	8-Apr	4
		9-Apr	3
13-Oct	4	10-Apr	4
14-Oct	4		
15-Oct	2	13-Apr	4
16-Oct	4	14-Apr	4
17-Oct	2	15-Apr	4
		16-Apr	5
20-Oct	4	17-Apr	4
21-Oct	2		
22-Oct	2	20-Apr	4
23-Oct	6	21-Apr	4
24-Oct	4	22-Apr	4
		23-Apr	5
27-Oct	6	24-Apr	5
28-Oct	5		
29-Oct	3	27-Apr	8
30-Oct	5		
31-Oct	5	4-May	6
		5-May	8
4-Nov	2	6-May	6
5-Nov	2	7-May	3
6-Nov	4		
		11-May	4
11-Nov	8	12-May	2
12-Nov	8	13-May	4
13-Nov	5	14-May	4
14-Nov	4	15-May	3
3-Dec	2	18-May	3
4-Dec	2	19-May	6
5-Dec	4		
		21-May	4
8-Dec	3	22-May	4
9-Dec	4		
10-Dec	4	26-May	8
11-Dec	3	27-May	8
		28-May	8
15-Dec	2	29-May	8
16-Dec	2		
Total	240	Total	252

Total GIS Laboratory Time in Hours: **492**

APPENDIX C

Presentations and Meetings

representing

ELTE Trail Resources

(Public Outreach Log)

Appendix C – Public Outreach Log

Date of Meeting or Presentation	Requesting/ Receiving Agency	Contact	Location	Task
09/08/07	NPS	John Conoboy	Duluth, MN	**Presentation** included description of GIS & archaeological techniques for identifying & mapping segments of the ELTE.
10/12/07	TxDot	Al McGraw	Austin, Texas	**Meeting** Discussion of methodology – identifying trail resources.
10/27/07	TAS		San Antonio, Texas	**Presentation** included description of GIS & archaeological techniques for identifying & mapping segments of the ELTE.
10/31/07	ECR Partners	John Conoboy	San Antonio, Texas	**Meeting** Discussion of methodology – identifying trail resources.
11/01/07	TxDot THC	Al McGraw Jim Bruseth	Austin, Texas	**Meeting** Coordination and development of partnerships for identifying trail resources.
11/07/07	East Texas GIS Conference		Nacogdoches, Texas	**Presentation** Description of GIS & archaeological techniques for identifying & mapping segments of the ELTE
12/13/07	THC	Jim Bruseth	Austin, Texas	**Meeting** Discussion of methodology – identifying trail resources.
05/06/08	ELTE Association		San Augustine, Texas	**Presentation** Description of GIS & archaeological techniques for identifying & mapping segments of the ELTE
10/13/08	TPWD/TARL		Austin, Texas	**Meeting** Coordination and development of partnerships for identifying trail resources.
10/14/08	THC TxDot	Jim Bruseth Al McGraw	Austin, Texas	**Meeting** Coordination and development of partnerships for identifying trail resources.
10/24/08	ELTE Association	Mary Waters	Bastrop, Texas	**Presentation** GIS Aided Archaeological Research for Locating & Identifying 18th Century Spanish Roads Through East Texas
10/25/08	TAS		Lubbock, Texas	**Presentation** GIS Aided Archaeological Research for Locating & Identifying 18th Century Spanish Roads Through East Texas
11/06/08 – 11/09/08	NPS		Socorro, NM	**Workshop** Mapping the National Historic Trails
11/19/08 – 11/20/08	NPS	Susan Boyle	Santa Fe, N.M.	**Presentation** & **Meeting** Design of a Comprehensive Geographic Information System for the Administration of El Camino Real de los Tejas NHT
01/05/09-01/11/09		Landowners	San Augustine & Sabine Counties	**Meetings** with landowners regarding trail segments and NPS site visit
01/12/09 – 01/16/09	NPS	Susan Boyle *et al*	Austin, Texas to Natchitoches, Louisiana	**Site Visits & Meetings** with Landowners /Stakeholders regarding ELTE resources and site identification
01/16/09	Robertson County	Robert Hicks	Austin, Texas	**Meeting** Discussion regarding Brazos Shoals
02/01/09 – 02/07/09	NPS	Susan Boyle *et al*	Austin, Texas to Laredo, Texas	**Site Visits & Meetings** with Landowners /Stakeholders regarding ELTE resources and site identification
02/11/09	DOS		Livingston, Texas	**Scoping Meeting** regarding Keystone Pipeline;

				spoke regarding ELTE resources which would be impacted by pipeline
02/18/09	Stakeholders		Nacogdoches, Texas	**Meeting** Stakeholders to discuss Keystone Pipeline and impact on ELTE resources
02/20/09			San Augustine and Sabine Counties	**Site Visits** Lobanillo Cuts and Mission Dolores
02/26/09			Cherokee,Houston & BrazosCounties	**Site Visits** Caddo Mounds, Alabama Crossing, Brazos Swales
02/27/09			Robertson et al Counties	**Site Visits** Apache Pass, Burnett Shoals, Port Sullivan Crossing, Iron Mountain
02/27/09			?? et al Counties	**Site Visits** Big Eddy, Hyde's Ferry, Los Crusas, Dillard's Ranch
03/05/09	Preserve America/SFA	Teresa Coble	Nacogdoches, Texas	**Presentation** 5 short presentations regarding the Camino Real as a part of the Preserve America grant kick off and the City of Nacogdoches Heritage Tourism Conference *Texas After Dark*
03/06/09		Gary Pinkerton	Nacogdoches & Rusk Counties	**Site Visit** Trammel's Trace
03/07/09	Stone Fort Museum	Carolyn Spears	*Nacogdoches, Texas	**Presentation** for ELTE Interpreters' Workshop Description of ongoing research on the Camino Real and the new mapping efforts related to identifying trail resources.
03/08/09	Stone Fort Museum	Carolyn Spears	San Augustine & Sabine Counties	**Site Visit** for ELTE Interpreters' Workshop Mission Dolores and Lobanillo Cuts
03/10/09	Milam County HC THC	Joy Graham Jim Bruseth Kathleen Gilmore	Milam County	**Site Visit** Mission Xavier Complex Meet with Dr. Kathleen Gilmore about ELTE
03/13/09	Caddo Conference	Organizing Committee	Norman, OK	**Presentation** An outline of ongoing research on the Camino Real and the new mapping efforts related to identifying trail resources.
03/20/09	ELTE Association	Patsy Light	Karnes County	**Site Visit** Conquista Crossing and Goliad
03/24/09	TxDot	Al McGraw	Caldwell, Texas	**Presentation** An outline of ongoing research on the Camino Real and the new mapping efforts related to identifying trail resources.
04/01/09 – 04/02/09	Los Adaes	Ray Berthold	Los Adaes SP Louisiana	**Site Visit** Los Adaes; meet with Ray Berthold and identify and map ELTE segments within the park
04/03/09	College Station	Anne Boykin	College Station, Texas	**Presentation** "The Brazos County Swales" Discussion of the identification and mapping of trail segments in Brazos County
04/08/09 – 04/09/09	Mission Tejas	John Ferguson	Mission Tejas SP	**Site Visit** Identify and map ELTE segments within the park
04/17/09	Fort Boggy		Fort Boggy SP	**Site Visit** Identify and map ELTE segments within the park
04/22/09	TxDot	Al McGraw	Austin, Texas	**Meeting** Discussion of procedures for identifying trail resources and notifying TxDot if within ROW.
04/28/09	Brazos	Lucille	Franklin, Texas	**Presentation** "Mapping the Land" Discussion of

	Region Chamber	Estell		techniques for identifying and mapping segments of the Camino Real
04/30/09	ELTE Association	Lucille Estell	Natchitoches, Louisiana	**Presentation** Description of ongoing research on the Camino Real and the new mapping efforts related to identifying trail resources.
05/01/09	ELTE Association	Lucille Estell	Sabine County	**Site Visit** Lobanillo Cuts
05/07/09	Stone Fort Museum	Carolyn Spears	*Chireno, Texas	**Presentation** An outline of ongoing research on the Camino Real and the new mapping efforts related to identifying trail resources.
05/08/09	Taylor Middle School	Lucille Estell	Apache Pass, Texas	**Presentation** Story of the Camino Real and the new mapping efforts related to identifying trail resources as appropriate for students.
05/28/09	San Augustine Historical Society	Sammi Johnson	San Augustine Texas	**Presentation** An outline of ongoing research on the Camino Real, including swales within San Augustine and surrounding counties.
05/30/09			Gonzales, Texas	**Site Visit** Explore possible ELTE sites in Gonzales County
06/08/09	NPS	Susan Boyle Mike Taylor	Austin to Nacogdoches	**Site Visits** San Xavier, Robertson and Brazos Counties, Caddo Mounds, Mission Tejas, and Fort Boggy
06/12/09	Stone Fort Museum	Carolyn Spears	*Crockett, Texas	**Presentation** Part of the celebration of the anniversary of the 1837 founding of Houston County;
07/04/09	Stone Fort Museum	Carolyn Spears	*Nacogdoches Texas	**Presentation** Joint presentation w/Photographer Christopher Talbot of SFA's School of Art who is documenting communities along the trail
07/08/09	Nacogdoches Historical Commission	Judge Cox	Nacogdoches, Texas	**Meeting** Discussion of historical documentation regarding trail resources
08/13/09	Stone Fort Museum	Carolyn Spears	*Caddo Mounds State Historic Site	**Presentation** Discussion of the significance of Caddo Mounds as a locus of trail activity and the identifying of trail resources along the road to the Caddo.
09/24/09	East Texas Historical Association	Jim Bruseth/ THC	Nacogdoches, Texas	**Presentation** An outline of ongoing research on the Camino Real, including swales within San Augustine and surrounding counties.
10/16/09	ELTE Trail Association Board Mtg	Lucille Estell	Castroville, Texas	**Presentation** Discussion of research areas, including the refining of routes through the counties along the trail. Draft CMP issues.
10/16/09	NPS	Aaron Mahr and Mike Taylor	Castroville, Texas	Discussed extending ATCoFA's work on ELTE and ATCoFA's help in determining National register Trails resources.
01/21/2010	NPS	Mike Taylor	Nacogdoches, Texas	NPS discussed why NPS was not renewing funding for ELTE research; ATCoFA explained why CCS will not work at ATCoFA.

APPENDIX D

LiDAR Research Articles

Number	Author's Last Name	Year	Title	Location
1	Alexander	2008	Extraction of vegetation for topographic mapping from full-waveform airborne laser scanning data	digital
2	Arroyo	2008	Integration of lidar and quickbird imagery for mapping riparian zones in australian tropical savannas	digital
3	Blair	1999	The laser vegetation imaging sensor: a medium-altitude airborne laser altimeter for mapping vegetation and topography	print
4	Boudreau	2008	Regional aboveground forest biomass using airborne and spaceborne lidar in quebec	print and digital
5	Breidenbach	2008	Estimation of bivariate diameter and height distributions using ALS	digital
6	Breidenbach	2008	Monitoring capercaillie habitat using ALS	digital
7	Brzank	2007	Supervised classification of water regions from lidar data in the wadden sea using a fuzzy logic concept	digital
8	Buddenbaum	2008	Characterization of forest stands using full waveform laser scanner and airborne hyperspectral data	digital
9	Chauve	2007	Processing full-waveform lidar data: modelling raw signals	digital
10	Chauve	2010	Advanced full-waveform lidar data echo detection: assessing quality of derived terrain and tree height models	digital
11	Chen	2006	Isolating individual trees in a savanna woodland using small footprint lidar data	digital
12	Chen	2005	Fusion of lidar data and high resolution images for forest canopy modeling	print
13	Chen	2007	Estimating basal area and stem volume for individual trees from lidar data	print
14	Chen	2007	Airborne lidar data processing and information extraction	print
15	Csanyl	2007	Improvement of lidar data accuracy using lidar-specific ground targets	digital
16	Dorigo	2008	A new automated approach for co-registration of national forest inventory and airborne laser scanning data	digital
17	Dubayah	2000	Land surface characterization using lidar remote sensing	digital
18	Dubayah	2000	Lidar remote sensing for forestry	print and digital
19	Evans	2009	Discrete return lidar in natural resources: recommendations for project planning, data processing, and deliverables	digital
20	Evans	2006	Lidar - a new tool for forest measurements?	print
21	Falkowski	2008	The influence of conifer forest canopy cover on the accuracy of two individual tree measurement algorithms using lidar data	digital
22	Fernandez	2007	An overview of lidar point cloud processing software	digital
23	Garcia	2008	Planimetric offset adjustment of multitemporal laser scanner data	digital
24	Garcia-Gutierrez	2008	Remote mining: from clustering to DTM	digital
25	Gaulton	2008	LiDAR mapping of canopy gaps in continuous cover forests; a comparison of canopy height model and point clouds	digital
26	Geerling	2006	Classification of floodplain vegetation by data-fusion of spectral (CASI) and lidar data	print
27	Goepfert	2008	Integration of intensity information and echo distribution in the filtering process of LIDAR data in vegetated areas	digital
28	Goerndt	2010	Comparison and analysis of small area estimation methods for improving estimates of selected forest attributes	digital

Number	Author's Last Name	Year	Title	Location
29	Goncalves	2008	Land cover classification of rural areas using LiDAR data: a comparative study in the context of fire risk	digital
30	Gonzalez	2008	Using lidar technology in forestry harvest planning	digital
31	Goodwin	2006	Assessment of forest structure with airborne lidar and the effects of platform altitude	digital
32	Griffin	2008	Using lidar and normalized difference vegetation index to remotely determine LAI and percent canopy cover	digital
33	Hancock	2008	Assessing the accuracy of forest height estimation with long pulse waveform lidar through monte-carlo ray tracing	digital
34	Harding	2004	Terrapoint lidar mapping instrumentation and methodology	print
35	Heinzel	2008	Full automatic detection of tree species based on delineated single tree crowns - a data fusion approach	digital
36	Hofle	2008	Area-based parameterization of forest structure using full-waveform airborne laser scanning data	digital
37	Hollaus	2009	Tree species classification based on full-waveform airborne laser scanning data	digital
38	Holmgren	2003	Estimation of tree height and stem volume on plots using airborne laser scanning	print (journal)
39	Holopainen	2008	Utilization of tree species stratum data in forest planning simulations	digital
40	Holopainen	2008	Performance of airborne laser scanning- and aerial photograph-based statistical and textural features in forest variable estimation	digital
41	Huang	2008	Micro-pulse lidar measurements of aerosol vertical structure over the loess plateau	digital
42	Hyde	2006	Mapping forest structure for wildlife habitat analysis using multi-sensor (lidar, SAR/InSAR, ETM+, quickbird) synergy	print
43	Hyyppa	2008	Algorithms and methods of airborne laser scanning for forest measurements	digital
44	Julian	2009	The use of local indicators of spatial association to improve LiDAR-derived predictions of potential amphibian breeding ponds	digital
45	Kaartinen	2008	Accuracy of automatic tree extraction using airborne laser scanner data	digital
46	Koetz	2005	Concept for forest parameter estimation based on combined imaging spectrometer and lidar data	print
47	Kwak	2007	Detection of individual trees and estimation of tree height using lidar data	print
48	Kwak	2007	Estimation of LAI using lidar remote sensing in forest	print and digital
49	Lang	2007	3D forest structure analysis from optical and lidar data	print
50	Leckie	2003	Combined high-density lidar and multispectral imagery for individual tree crown analysis	print
51	Lefksy	2007	Revised method for forest canopy height estimation from geoscience laser altimeter system waveforms	digital
52	Lefsky	1999	Surface lidar remote sensing of basal area and biomass in deciduous forests of eastern maryland, USA	digital
53	Lefsky	2002	Lidar remote sensing for ecosystem studies	print and digital
54	Lim	2003	Lidar remote sensing of forest structure	print
55	Lin	2008	Detection of weak and overlapping pulses from waveform airborne laser scanning data	digital
56	Lindberg	2008	Estimation of tree lists from airborne laser scanning data using a combination of analysis on single tree and raster cell level	digital

Number	Author's Last Name	Year	Title	Location
57	Lucas	2008	Advances in forest characterisation, mapping and monitoring through integration of lidar and other remote sensing datasets	digital
58	Mao	2008	Pure rotational raman lidar with fiber bragg grating for temperature profiling of the atmospheric boundary layer	digital
59	McCombs	2003	Influence of fusing lidar and multispectral imagery on remotely sensed estimates of stand density and mean tree height	print (journal)
60	Means	2000	Predicting forest stand characteristics with airborne scanning lidar	print and digital
61	Melkas	2008	Accuracy and efficiency of the laser-camera	digital
62	Mundt	2006	Mapping sagebrush distribution using fusion of hypersectral and lidar classifications	print
63	Naesset	2002	Predicting forest stand characteristics with airborne scanning laser using a practical two-stage procedure and field data	print and digital
64	Naesset	2004	Practical large-scale forest stand inventory using a small-footprint airborne scanning laser	print and digital
65	Nakajima	2008	An analysis of the relationships between tree growth and crown information derived from airborne lidar data	digital
66	Nelson	2008	Model Effects on GLAS-based regional estimates of forest biomass and carbon	digital
67	Nelson	2004	Measuring biomass and carbon in delaware using an airborne profiling lidar	print and digital
68	Nelson	2009	Estimating quebec provincial forest resources using ICESat/GLAS	print and digital
69	Olofsson	2008	A method for linking field-surveyed and aerial-detected single trees using cross correlation of position images	digital
70	Omasa	2006	3D lidar imaging for detecting and understanding plant responses and canopy structure	print
71	Oono	2008	An improved method of individual tree detection using airborne lidar	digital
72	Opitz	2006	Automated 3-d feature extraction from terrestrial and airborne lidar	print
73	Orka	2007	Utilizing airborne laser intensity for tree species classification	print
74	Pascual	2008	Mean height and variability of height derived from lidar data and landsat images relationship	digital
75	Pearson	2009	An analysis of the performance of the UFAM pulsed doppler lidar for observing the boundary layer	digital
76	Pesonen	2008	The comparison of airborne laser scanning-based probability layers as auxiliary information for assessing coarse woody debris	digital
77	Peterson	2007	Use of lidar for forest inventory and forest management application	digital
78	Pirotti	2008	Neural network and quad-tree approach to extract tree position and height from lidar data	digital
79	Popescu	2003	Measuring individual tree crown diameter with lidar and assessing its influence on estimating forest volume and biomass	digital
80	Popescu	2002	Estimating plot-level tree heights with lidar: local filtering with a canopy-height based variable window size	print
81	Popescu	2002	Estimating plot-level forest biophysical parameters using small-footprint airborne lidar measurements	print
82	Rahman	2008	Tree filtering for high density airborne lidar data	digital
83	Rahman	2009	Tree crown delineation from high resolution airborne lidar based on densities of high points	digital
84	Reitberger	2008	3D segmentation and classification of single trees with full waveform lidar data	digital
Number	Author's Last Name	Year	Title	Location
85	Reutebuch	2005	Light detection and ranging (lidar): an emerging tool for multiple resource inventory	print and digital
86	Roberts	2005	Estimating individual tree leaf area in loblolly pine plantations using lidar-derived measurements of height and crown dimensions	print
87	Rosette	2008	Representation of vegetation and topography within satellite lidar waveforms for a mixed temperate forest	digital

88	Rossmann	2007	Using airborne laser scanner data in forestry management: a novel approach to single tree delineation	print and digital
89	Roth	2007	On the potential for high-resolution lidar to improve rainfall interception estimates in forest ecosystems	digital
90	Russell	2002	An early history of the stephen f. austin experimental forest: utilizing interactive multimedia and oral histories	print and digital
91	Sexton	2009	A comparison of lidar, radar, and field measurements of canopy height in pine and hardwood forests of southeastern north america	digital
92	Simard	2003	Airborne lidar surveys - an economic technology for terrain data acquisition	print and digital
93	Slatton	2008	A primer for airborne lidar	digital
94	Spuler	2007	Raman shifter optimized for lidar at a 1.5 um wavelength	digital
95	St-Onge	2008	Methods for improving the quality of a true orthomosaic of vexcel ultracam images created using a lidar digital surface model	digital
96	Stephens	2008	Quality assurance and quality control procedures of airborne scanning lidar for a nation-wide carbon inventory of planted forests	digital
97	Straub	2008	Combining airborne laser scanning and GIS data to estimate timber volume of forest stands based on yield models	digital
98	Suarez	2005	Use of airborne lidar and aerial photography in the estimation of individual tree heights in forestry	digital
99	Takahashi	2008	Estimation of stand volume by fusing low laser-sampling density lidar data with quickbird panchromatic imagery	digital
100	Takahashi	2007	Assessment of lidar-derived tree heights estimated from different flight altitude data in mountainous forests	print
101	Trotter	1997	Estimation of timber volume in a coniferous plantation forest using landsat TM	digital
102	Valbuena	2008	Lidar and true-orthorectification of infrared aerial imagery of high pinus sylvestris forest in mountainous relief	digital
103	Vastaranta	2008	Comparison of different Laser-based methods to measure stem diameter	digital
104	Vauhkonen	2008	Estimating crown base height for scots pine by means of the 3D geometry of airborne laser scanning data	digital
105	Vernon	2008	A comparison of automated land cover/use classification methods for a texas bottomland hardwoodsystem using lidar	digital
106	Voss	2008	Seasonal effect on tree species classification in an urban environment using hyperspectral data and lidar	digital
107	Wehr	1999	Airborne laser scanning - an introduction and overview	print
108	Wezyk	2008	Describing the selected canopy layer parameters of the scots pine stands using ALS data	digital
109	Wynne	2006	Lidar remote sensing of forest resources at the scale of management	digital
110	Zhao	2007	Hierarchical watershed segmentation of canopy height model for multi-scale forest inventory	print

APPENDIX E

Rational for Extending ELTE's Period of Significance from 1821 to 1845.

Jeffrey M. Williams

Rational for extending ELTE's period of significance from 1821 to 1845.

I'm not sure that I am qualified to try and find a rational for extending the period of significance to 1845. Perhaps a Texas historian or sociologist could better identify the reasons. So that is why I sent you the video because if after you watch the last 15-minutes of the movie and you still don't recognize why the years between 1821 and 1845 are important, then not much I could say would make a difference.

I realize that ELTE is much more than a Texas resource, but I must focus on Texas because that is where my knowledge lies. I have struggled to isolate why this period is important (Corbin and I also grappled over this issue) and again I'm probably not the best person to be making this argument, but after giving it long and careful thought, I'm still going to try and articulate it, so here goes…….

It was during the period between 1821 and 1845 that the modern identity of what it means to be a Texan was born; at least in my own opinion and reflecting my association with East Texans rather than a broader cross section of all Texans.

So what is it that characterizes the Texas identity? Maybe its love of the land, family, God, and individual freedoms, but that doesn't really distinguish Texans from any other group of Americans. So what is it? Spanish or Mexican heritage? Still not enough. Intermixing with French or Native Americans? Not enough either. The American pioneering tradition of homesteading a new land, or could it be related to having a chance to start over or to reinvent ones self? Still not enough by itself. So what makes a Texan and why is the period between 1821 and 1845 important?

I personally think it is the blending of all of the above and much more, but most importantly I believe it is a shared cultural heritage of having been an independent country; a Republic won through strength of character, determination, and necessity. The blood and sacrifice of these early Texas pioneers set a stage where their descendants, still living on the same land carved with great hardship from the wilderness, could make direct connections with their ancestors and the traditional values of hard work, family, country, and personal opportunity while still maintaining a fierce independence.

But being a Texan or what it means to be a Texan is not the issue. It is the years between 1821 and 1845 that is of concern, but in my opinion the two can not be separated because what we know or perceive Texas to be is directly related to these intervening years. And it is the old road that connected and unified the land that was to become Texas. No matter what you call it, *El Camino Real de Los Tejas*, the Old Spanish Road or Old San Antonio Road (OSR), it is still the same thing in the minds and intellects of the descendants of these first Texans.

In an effort to be less subjective and to add substance to my argument, I have attempted to distill the importance of the period between 1821 and 1845 into historical events directly related to the OSR with examples as to why the road is critically important in understanding why there is an ELTE NHT at all.

In January of 1821 Moses Austin is granted the first empresario grant by the Spanish government with the northern border being El Camino Real. But before the land could be fully colonized by his son Stephen, Mexico had gained its independence in a long and bloody struggle.

Mexico's war for independence was also fought along the roads of Texas such as the battle of Medina where the Spanish killed everyone and hung hundreds in the trees as a warning along the road leading to San Antonio. Santa Anna, who was to return to Texas twenty-three later, was a young decorated Spanish officer during this bloody campaign to regain control of the northern provinces.

Stephen F. Austin's colonists for the most part became loyal Mexican citizens and swore allegiance to the Constitution of 1824. As the identity of the Northern provinces shifted from Spanish to Mexican, the road name also begins to change from the El Camino Real to the Old San Antonio Road or Old Spanish Road.

The Mexican period of identity in Texas starts in 1821 and reaches its zenith in Texas before the turbulent years following the election of Busamante in 1828. The land measurement system of leagues and varas, adopted by the Republic of Texas and that is still used in the eastern portion of Texas today, was formalized by the Mexican government who first encouraged American immigration by extending grants to over 25 empresarios and then attempted to restrict the flood of immigration in 1830 after trying to control slavery.

In 1833 while the Texan's prospered through cotton, horses, skins and hides, and other exports transported across the OSR, Santa Anna was dismantling the federalist Mexican government and establishing himself as the supreme authority. The political situation continued to be unstable in central Mexico leading to harsh and unjust policies that cumulated in the Mexican military clashing with Texan volunteers in 1835. The Texans, refusing to give up a cannon at Gonzales, raised the "come-and-take-it" flag and soundly beat the well trained Mexican forces beginning a long series of conflicts resulting in the original taking of the Alamo from Mexican forces.

Returning in 1836 (using the OSR), Santa Anna continued his policy of executing all rebels (at Goliad, Gonzales, and San Antonio), and when defeated by the Texas army at San Jacinto, Santa Anna signed away all lands north of the Rio Grande and agreed to recognize Texas' Independence in exchange for his life. While Santa Anna was sent back by sea, the defeated Mexican army was marched down the OSR on its return to Mexico. Although Mexico never officially recognized Texas as a sovereign republic, it was General Sam Houston's instance that Santa Anna be spared so that Texas could have a chance at international recognition. In fact it was this action that prompted several European countries to recognize Texas' independence and ignited the United States' fear that Great Britain would attempt to add Texas to its empire.

In 1836 the interim government of the Republic of Texas called for a presidential election in which Sam Houston easily won. Also during this election, Texas overwhelmingly voted to request annexation to the United States. Stephen F. Austin was appointed Secretary of State but died before he could be confirmed, and the rest of President Houston's appointments attempted to heal political wounds. Originally Houston had difficulties supporting as well as controlling the Texas Army who was composed of American volunteers who wanted to invade Mexico. Holding the army together with the promises of large land grants, Houston's greatest difficulties were Mexico's warlike attitude and Indian threats on frontier settlements linked by the OSR. The only real action involving the Texas Army was when President Houston, during his second term, sent them to the East Texas area to put down the infamous "Regulator/Moderator War." The army traveled the OSR to eastern Texas and proceeded to restore order in the communities springing up along newly opened cross roads.

Mirabeau Lamar, who succeeded Houston as President of the Texas Republic in 1838, developed several aggressive national policies including removal of all Indians from Texas. Uniting the troubled settlements along the OSR, he supported militias for local protection and the ensuing aggression resulted in the removal of all Indians including those who had befriended and supported the Texans during the war for the Republic. President Lamar, who opposed annexation, also ordered other national improvements including schools and universities with land grants to support his education initiatives. Known as the “Father of Texas Education,” Lamar spent close to five million dollars during his three-year term as President; greatly inflating the Texas national debt while President Houston had spent less than a half a million dollars during his first term.

In 1839 the Texas Congress authorizes the first improvements of the OSR as a national road and makes provisions for local counties to levy taxes for its maintenance and upkeep. Although no large scale statewide upgrades were made, local improvements greatly aided the immigration of settlers eager to plant cotton in the vast unexploited soils of Texas. The improved roads also facilitated the export of cotton to important shipping centers like New Orleans and Galveston. These settlers brought their southern traditions of plantation life centered on the economies of slavery to Texas; resulting in a huge migration of African-American slaves. Descendants of these first African-Americans still live in isolated communities of eastern Texas.

It wasn’t until 1840 that the western boundary of the United States and that of Louisiana was fixed on the Sabine River thus ending a hundred year boundary dispute that affected not only the political policies of sovereign countries (first Spain then Mexico and the United States) but also the safety and health of those trying to immigrate to Texas. The U. S./Texas Republic Boundary Commission was originally headquartered at Fort Jessup implying travel over the OSR in the execution of their official duties. In 1844, during President Sam Houston’s second term, annexation negotiations begin to center on President Houston’s insistence that the United States provide military protection along its southern border.

By early 1844, the United States had signed a treaty with the Republic of Texas for annexation as a territory with the provision that the U. S. provide military protection and that the U. S. would assume Texas’ debt. The U. S. Congress refused to ratify the treaty, and as a partial impact of Congress’ action, the annexation of Texas became a major issue affecting the presidential election politics of that year. After the election of U. S. President Polk in 1844, efforts by Texas to join the Union included writing a comprehensive constitution. The constitution was finally accepted by the U. S. Congress in late 1845 allowing Texas to join the Union as the 28th state. The convention to develop a constitution for statehood was held in Austin and the OSR was the main route of travel to the convention.

As a response to the annexation of Texas, Mexico declares a defensive war on the United States, and after the capture of Mexico City in 1845, the war with Mexico is over. The permanent international boundary between the United States and Mexico is then fixed at its present alignment. The OSR becomes the primary artery in diplomacy and commerce between these countries. In fact the U. S. Army improved the OSR both during and after the war for the movement of supplies and troops to fight the war and to defend the southern boundary.

While the original heritage of the Spanish is still alive in Texas and the El Camino Real was well formalized by the end of 1821, it is both the Mexican and Texas Republic periods that immediately follow that the majority Texan’s identify with. Many families in Texas still live on the land settled by their ancestors during this period, and the shared heritage of these folks who still live along and identify with the OSR is an important component of the current culture of Texas. Ending the ELTE NHT period of significance at 1821 would denying this heritage and would do an injustice to not only the old road as a resource linking the people who made up what was to become Texas but would also limit the inclusion of a Mexican international component in ELTE.

And one final note, just between you and me, ending the period of significance at 1821 would cause unbelievable grief for the NPS. The outpouring of resentment and stubborn independence would literally kill any good will that the NPS could ever possibly generate. Trust me I know…..it will become a tremendously huge headache for the NPS, it will become extremely costly in the terms of dollars and NPS time, and most likely will result in Congressional pressure on the NPS to rectify.

APPENDIX F

Excerpts:

GIS Aided Archaeological Research of *El Camino Real de Los Tejas* with Focus on the Landscape and River Crossings along *El Camino Carretera*.

Jeffrey M. Williams

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2007

Document available on Google Books.

Geospatial Technology and Archaeology

pp. 53 – 60.

By managing archaeological data in a landscape level GIS, an analysis and visualization tool is developed for combining disparate historical data with spatial data in a fashion that can be investigated and manipulated to produce useful research products. Current archaeological research theory recognizes the value of GIS for regional and landscape analysis. As an archaeological tool, the greatest potential use of GIS is as a research oriented landscape visualization system for studying the spatial relationships between humans and their cognitive environments. A GIS can manage archaeological data in a spatially responsive medium allowing for an integrated understanding of the landscape forces influencing the selection of preferred locations (Harris 2002:139-142; Wheatley and Gillings 2002:16-18).

A landscape level GIS can be used effectively with historic documents to create useful research tools for understanding the selection of one location over another based on landscape and cultural opportunities or limitations. The ability to visualize landscape change over time, the ability to visualize the character of the landscape in a 3D-environment, and the ability to incorporate multiple types of data, both historic and current, into a single analysis and visualization tool is a strength that GIS brings to the understanding of archaeology (Harris 2002:139-142; Wheatley and Gillings 2002:16-18).

Although an early limitation, technological advances have overcome some of the early usability issues of an integrated GIS, software advances have eased the strain of managing spatial databases, and state and federal agencies have adopted GIS standards for land use planning and monitoring resulting in volumes of easily accessible spatially enabled environmental data (Allen *et al.* 1990:382-386). In "The Archaeologist's Workbench: Integrating GIS, Remote Sensing, EDA, and Database Management," the authors conclude that technology is no longer the most significant issue but rather it is the possibility of arranging the technology [tools] in a manner that facilitates the exploratory investigation of perceived or unanticipated relationships (Farley *et al.* 1990:160-164).

In "Landscape: A Unifying Concept in Regional Analysis," Crumley and Marquardt develop the line of reasoning that landscape is the manifestation of the relationship and interaction of humans with the physical environment. Therefore, landscape is a dynamic spatial unifier where the definition of environmental relationships varies between specific scales and human centers of activity. The authors conclude that landscape provides the foundation for integrating ecology with historical factors, long used by archaeologists, to study and document social and material change (Crumley and Marquardt 1990:73-79). A landscape level context aware GIS, based on the assumption that humans are closely tied to the natural and cultural environments, can be used to examine the intricacies of the topographic setting with the environmental variables of known archaeological sites yielding quantifiable parameters of choices.

GIS has been used by the Arkansas Historic Preservation Program (AHPP) to integrate historic maps and documents for identifying segments of the Trail of Tears route through Arkansas. In 1830, the Cherokee Indians of the southeastern United States were forcibly marched to the Oklahoma Indian Territory. Resulting in thousands of deaths, the routes followed by the Cherokee became known as the Trail of Tears. Recognized as an important cultural heritage feature, the routes crossing nine states are administered by the NPS under the Trail of Tears National Historic Trails Act. Using modern geospatial technologies, AHPP has integrated the use of historic maps with remote sensing in a GIS for identifying unclear routes of the Trail of Tears. Once verified by field surveys, the data are submitted to the NPS for inclusion in their Long Distance Trails GIS (Files 2000:online).

Traditionally the integration of historic data from disparate sources, including landscape resource data, has been costly in terms of time and dollars. While GIS provides a cost effective yet simple structure for integrating and accessing data based on spatial location, at its core is the database that, when properly designed, can facilitate exploration of archival or historical data within the geography of its logical relationships. Complex queries of attribute information can be combined with geographical criteria for creation of data that can be geographically visualized; potentially leading to further composite questions. The resultant data can also be added back to the database creating additional complex relationships of behavior and interaction (Church *et al.* 2000:142-145; Gregory 2003:56-59; Wheatley and Gillings 2002:90-94).

By its very nature, archaeology is spatially oriented and therefore an ideal application for GIS. Nevertheless, the development of an archaeological geodatabase and the cultural observations contained within the datasets is a complex and intricate undertaking that many scholars believe is influenced by contemporary understanding of the events, and the meaning attached to the event, place, or thing (Kvamme 1989:139-203; Mitchell 1999:11-14; Oliver 2001:175-188).

Robust archaeological geodatabase designs have been developed over specific landscapes for the creation of archaeological site prediction models. The models have shown to be a cost effective method of reducing the area and the time needed for pedestrian archaeological surveys. These sorts of predictive models are based on the assumption that humans are closely tied to the natural and cultural environments, so the creation of an accurate digital representation of the landscape is absolutely necessary to avoid incorrect and ineffective models (Clement *et al.* 2001:online; Hageman and Bennett 2000:113-127). While predictive models focus on representations of the landscape as a resource to be exploited and utilized; thereby taking on value, they often under represent the value of the features linking the resources.

Therefore, a well thought out and well designed GIS database is a critical component for studying the relationships between spatial features and the attributes that characterize the feature. The Environmental Systems Research Institute (ESRI) geodatabase data model provides this structure in a customizable format that can be manipulated to model real world interactions and relationships. The geodatabase is an *object-oriented* data model that stores the geometry and attributes of spatial features in a single database. The

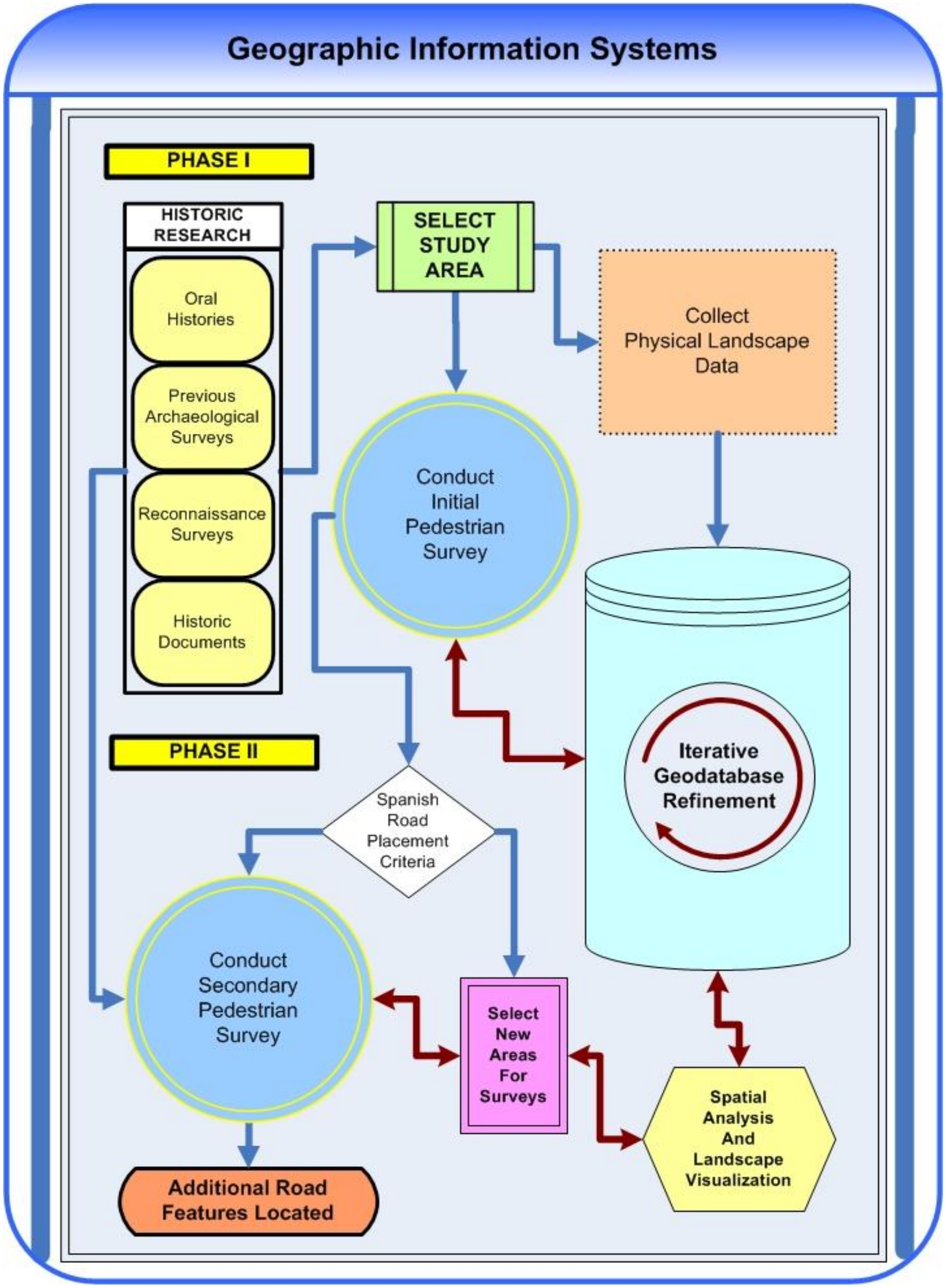


Figure 23. Flow of Research Processes.

geodatabase can incorporate general relationships among features along with the complex natural behaviors of those features in a design that can enforce the integrity of the behavior or relationship.

ESRI defines a well designed geodatabase data model as having a comprehensive architecture with all the necessary data to accommodate different users with similar needs. Thorough documentation of the processes and steps used to create the data model are considered by ESRI to be a crucial component of the geodatabase data model design (Zeiler 1999:182-184).

Geodatabase data models provide a template for sharing the "best practices" scientific methodology of data development and manipulation for a specific GIS application. Data models allow for better decision making, reduce costs by sharing successful GIS implementations, and provide a common framework for data standards (ESRI 2002:online).

The ESRI Press book "Modeling Our World: The ESRI Guide to Geodatabase Design" sums up the development of a geodatabase data model by stating that the purpose is to make "GIS datasets smarter by endowing them with natural behaviors, and to allow any sort of relationship to be defined among features." For archaeology, the geodatabase data model facilitates the inclusion of contextual data in a framework that expands the ability of the researcher to understand relationships and behaviors of data as it relates to the spatial extent under study (Zeiler 1999:5-8).

METHODOLOGY

pp. 60 – 105.

The basic objectives of the research outlined in this document were to demonstrate that a GIS managed archaeological landscape visualization model can be developed using an integrated geodatabase design framework and that this model can be used in an iterative process leading to the discovery and identification of additional remnants of Spanish road features in East Texas. To facilitate these objectives, the research methods were divided into two broad phases. Figure 23 illustrates the flow of the research processes used for this project.

Phase 1

Phase 1 consisted of historic research, selection of a study area, a field survey to locate existing Spanish roads, and the collection of physical landscape data. Historic research into Spanish activities in East Texas provided the archaeological context of the investigation. The examination of historic documents also helped identify travel preferences across the landscape and helped limit a geographical area for study.

Historic Research

Phase 1 included historic research of reputable translations of Spanish, French, and English colonial documents. Legal documents from the Republic and State of Texas pertaining to historic roads in eastern Texas were also examined. Using this information, temporal boundaries were selected and specific Spanish activity areas were targeted for inclusion in this study.

Within the last one-hundred years, many scholarly publications have documented these early accounts of exploration in Texas utilizing a variety of primary documents and period translations from the Latin American collections of the University of Texas, the Spanish archives at the National Library in Mexico City, as well as the *Archivo de las Indies* in Seville, Spain. These documents have aided in the development of a more complete understanding of the settlement patterns, the kinship associations, and the utilization of the natural landscape for subsistence by the first European explorers.

Although a complete understanding of this period in East Texas does not exist, many scholarly attempts have been made to provide a comprehensive picture of this time period. The one dominant historical premise that these research publications have in common is that they are centered on the exploration of early indigenous trails, later to become roads linking the northern Spanish empire with its Capital in Mexico City, 2,414 kilometers (1,500 miles) south.

As a place of value, the early road segment of *El Camino Real de los Tejas* known as *El Camino Carretera* (the cart road) is the first road mentioned by the Spanish that links the eastern most Spanish missions and *presidios*. Spanish references to the specific area of *El Camino Carretera* begin in 1727 with Brigadier General Pedro de Rivera's report to the Spanish Crown. In 1767 both the Marqués de Rubi and Nicolas de la Fora chronicle their trip across this area on their way to the Capital of the Province of Texas at *Los Adaes*. Using historical documents and maps as well as transcripts of oral interviews, this study focused on examining the evidence as it related to physical landscape features.

The Spanish network of roads through the lands of the Caddo was vital for communication with the frontier. Spanish efforts to curtail French interests in trade with Caddo settlements consumed volumes of correspondence that traveled over the roads by countless couriers to Spanish officials in San Antonio and beyond. Dr. James Corbin spent 30-years researching *El Camino de los Tejas* both as actual locations on the landscape and as mentioned in primary Spanish documentation. Dr. Corbin's notes and files were graciously made available for this research. The volumes of notes referencing specific locations provided an in-depth look at previously located Spanish road features, ranchos, missions, Caddo villages, and other specific locations mentioned in the Spanish correspondence as well as Spanish motivations for maintaining frontier defenses so far from their base of support.

East Texas road historian and Shelby County Archaeological Steward, Connie Hodges, has conducted many years of research along the old San Antonio road in Sabine

County and has contributed to many significant research projects and publications. Her research uncovered historic documentation relating to *El Camino Carretera*, and she has conducted oral interviews and land ownership research in the specific area of *El Camino Carretera.* Her extensive notes and GPS located historic features were also graciously made available to this study. Her research provided the foundation for identification, by Dr. Corbin, of an existing Spanish road system within the study area.

Scanned digital copies of historic maps from the ETRC were incorporated into the GIS as raster data. These historic maps included an 1863 San Augustine and Sabine County land ownership map (Figure 3) showing the surnames of landowners and an 1840 Republic of Texas and United States Boundary Commission map of the Sabine River (Figure 18) showing ferries, road crossings, and river port towns.

By examining historic maps and comparing them to the modern character of the landscape, the shared ideals and values of the countless generations of humans who have developed a sense of place here, is manifested as a distinctive community pattern. Wood and Fels (1992) suggest that, "maps are embedded in a history they help construct." They continue with the concept that the historical relationship of humans and the value of place are inherent in maps and that the maps themselves reveal these patterns (Wood and Fels 1992: 28-47).

With over four hundred years of historic documents relating to European travels in East Texas, it is easy to notice that the documents refer to the Tejas as being friendly and welcoming of the Europeans. In almost all cases, pathways or trails are mentioned in relation to traveling in the Tejas provinces, and in many cases the early explorers refer to these Tejas pathways as roads. Some Spanish references to roads of the Tejas refer to other well used roads, differing routes, and forested and open areas. With the Capital of the Province of Texas being at Los Adaes (Robeline, Louisiana), it is not hard to imagine the travel of dozens of couriers, solders, settlers, supply pack trains, and missionaries across the road from San Antonio to the Capital.

Field Survey

The delineation of a specific study area was the first step in locating and identifying existing Spanish road segments. By using historical data combined with archaeological field survey techniques, the actual locations of identified Spanish activities were examined.

Previous archaeological investigations within the study area were compared with 19^{th} century land ownership maps and studied for clues to road features. Custom field maps of the study area were prepared from digital copies of USGS 1:100,000 quadrangle maps obtained from the Texas Natural Resources Information System (TNRIS) and were included as the first raster datasets of the developing geodatabase model created in ESRI's ArcGIS 9.1 software (Figure 25).

Following a preliminary examination of the area, Dr. Corbin confirmed the identification of an old road system in the correct alignment with the local geography and in the correct location to be a Spanish road following the routes mentioned by Brigadier General Rivera in 1727, by the Marqués de Rubi in 1767, and again by Nicolas de la Fora in 1767.

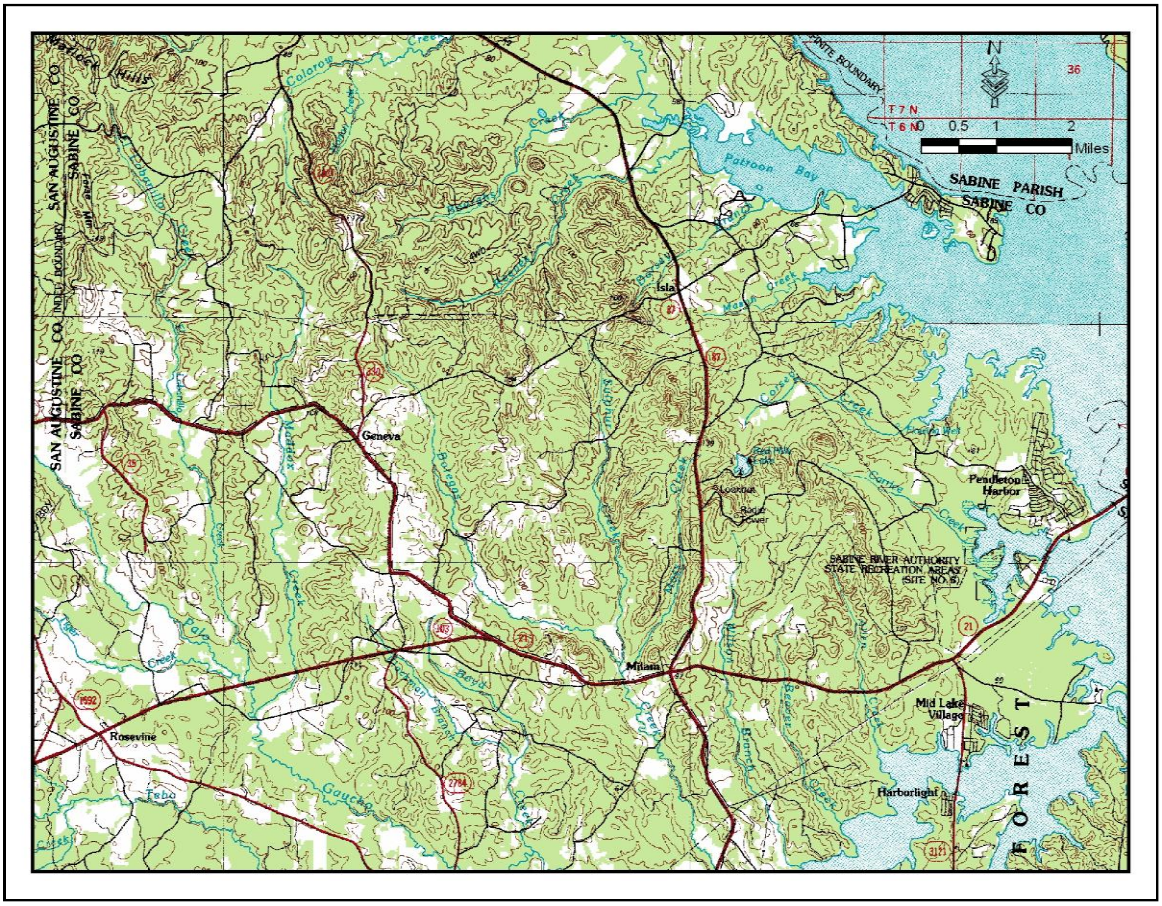


Figure 25. Preliminary field map using USGS 1:100,000 topographic quadrangle of study area (Williams 2007).

Recent archaeological surveys of old roads systems have identified early segments of *El Camino Real de Los Tejas*, and techniques have been developed for locating and recording these road networks. As Principal Investigator, Corbin describes the use of multiple routes of *El Camino Real* and writes in an “Archaeological Survey and Cultural Resource Assessment of Mission Tejas State Historical Park, Houston County, Texas," that a recently located linear depression has been identified as an old road segment that matches the general route shown on Walker's 1806 map of *El Camino Real* (Erickson and Corbin 1996:3-29).

A portion of a road network discovered during a cultural resource survey of Fort Boggy State Park in Leon County, Texas was potentially identified as a segment of a north-south road linking an upper and lower segment of *El Camino Real.* Eleven road segments located during the survey linked historic house sites and activity areas, and one very deep and wide segment spanned the entire length of the 809 hectare (2,000 acres) park. Specific field survey techniques were developed for locating and mapping road segments during this award winning cultural resource survey (Corbin *et al.* 1994:78-85).

Following Dr. Corbin's identification of a road system within the Sabine County study area, a pedestrian survey strategy was prepared and conducted using the cultural resource survey techniques developed by Dr. Corbin for locating and documenting old road networks.

The primary method used for identifying an old road segment was to find, within an undisturbed area of forest, a slight to extreme linear depression approximately 1 to 2 meters (3.3 to 6.6 feet) wide and follow it, looking for a reason or purpose for it being there. If the depression stayed consistent in width, the depth could be explained by the natural wearing of carts or wagons, oxen, mules, and foot traffic versus mechanical modification, and the depression could not be explained by natural processes such as erosion or by modern farming, hunting, logging, or forest management activities, then the depression was considered a historic road segment and was assigned a segment number (Filchner *et al.* 1957:44-54; Hester *et al.* 1975:13-36).

The linear integrity of the depression was also important in the selection criteria as an old road segment in that the depression must lead from some apparent specific place of origin in the general direction to be traveling to another specific place. In other words, the individual linear depression segments must connect to form a network leading to or through a previously defined activity space of Spanish origin.

The methods used to identify and survey an old road varied not only with ease of access, but also according to prevailing landscape conditions. In some areas, the steepness or lack of slope would dictate the technique while in other areas, the thickness of vegetation would dictate the techniques used. However once located, the primary method of identifying a linear depression as a road segment was to walk back and forth, in a zig-zag manner, across the feature in the general direction in which the linear feature is oriented. This method was used not only to define the spatial extent of the feature but also to identify any additional parallel road features. It was common practice to move the road up or down slope creating areas of parallel road segments when a road became impassible from erosion or heavy traffic (Dr. Corbin, personal files 2005).

The technique of documenting a linear road feature was consistent across the landscape surveyed. The most important factor considered, however, was that visibility through forested cover must be at least 20 to 30 meters (66 to 98 feet) to facilitate the identification of the depression as a linear road feature and to be able to see and document the physical characteristics of the depression. The vegetative ground cover of East Texas is at its minimum during the late winter months of January, February, and March; therefore, the optimum field survey time starts after hunting season in mid-January and lasts until the ground cover vegetation begins to leaf out in mid- to -late March or early April.

Once a road depression had been identified using the methods previously mentioned, a GPS point was taken at the survey's arbitrary starting location. The linear feature was then walked in each direction from the starting point using the GPS to capture either line or point features. A sample location was established at every major change in the road depression such as a bend or turn, an obvious change in slope, a width or depth change, a creek crossing, or road intersection (Figure 26). If long stretches of road depression had similar physical features, the sample locations were also chosen based on the location that best characterizes the physical parameters seen (Hester *et al.* 1975:13-36).

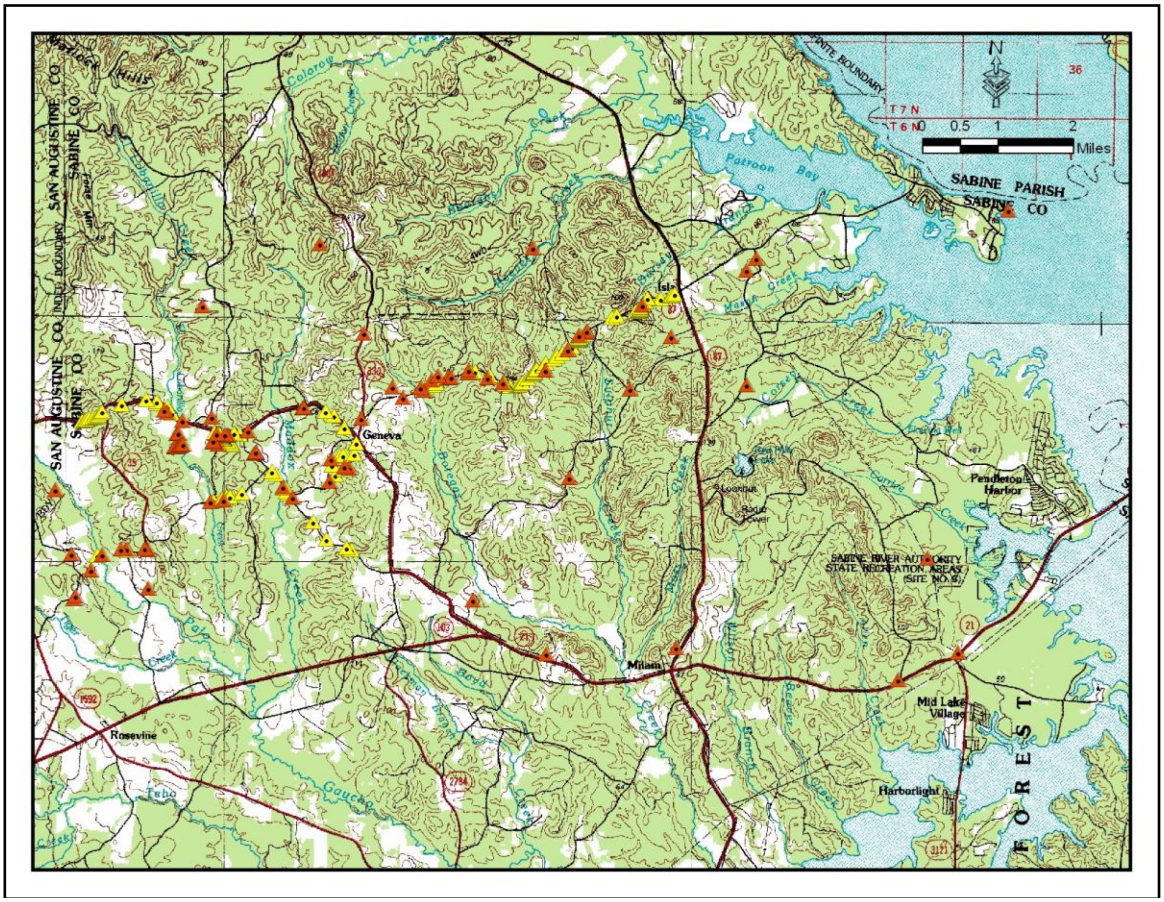


Figure 26. GPS point data collected during the field survey. Yellow triangles = First two years; Red triangles = Second two years (Williams 2007).

Detailed descriptions and measurements at each location were recorded with a focus on identifying physical characteristics of the road and landscape features at that location (Figure 27). Each sample location was documented by a globally unique identifier (GUID) number referencing the specific feature's location in the database. Each sample location also included attributes that incorporated the road segment and sample number.


Figure 27. The author recording road depression data during a field survey.

Since the direction of survey was based on convenience, the individual sample location numbers were not consecutive; the GUID number, however, remained unique and was associated with the individual road segment number (Figure 28).

At each sample location, data was collected using ESRI's ArcPad 7.0 field mapping application running on a GPS enabled handheld computer (Figure 29). A feature class (point, line, or polygon) created for ArcPad included, as attributes, the individual variables of the road depression.

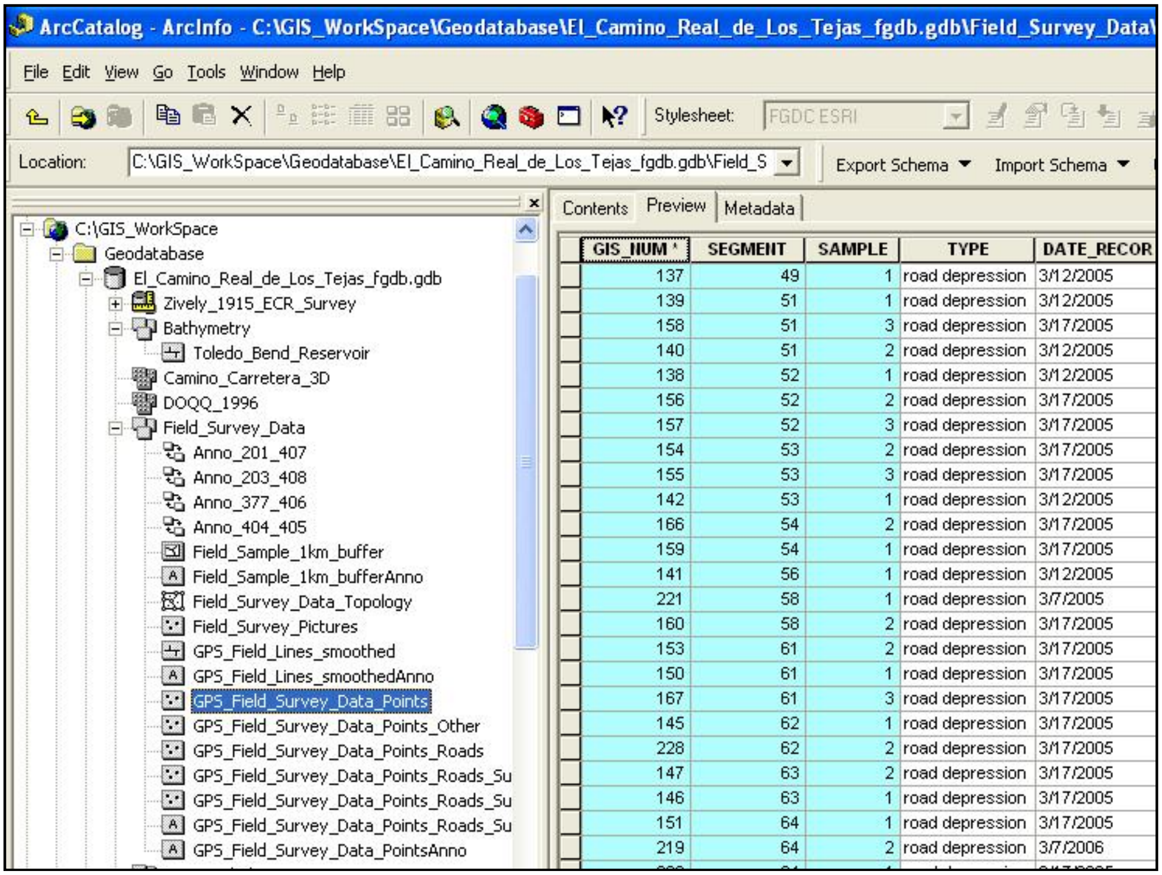


Figure 28. GIS globally unique identifier (GUID) number with individual segment and sample numbers.

The attributes were captured in customized forms created in ESRI's ArcPad Application Builder program. This program allowed for creation of easily managed field data entry forms that were constrained within defined data parameters (i.e., slope not to exceed 30 degrees).

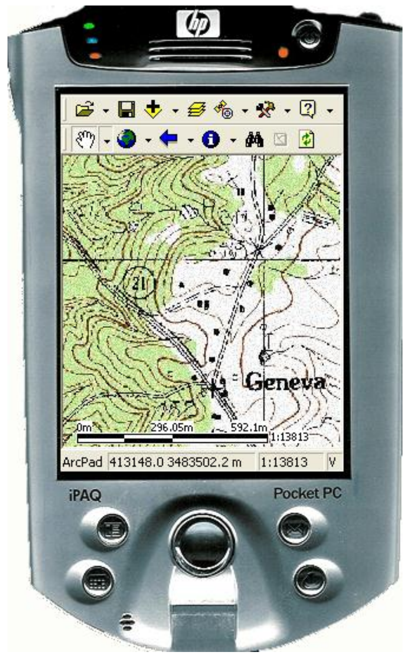


Figure 29. GPS enabled handheld computer running ArcPad 7.0.

In the laboratory, the field collected GPS positions (captured as feature classes) were post-processed using Trimble's Pathfinder software and the ArcGIS GPSCorrect application. Post-processing was used to differentially correct the GPS data by removing the combination of errors associated with delays of timed radio frequencies and a satellite's orbit and location in space. This results in greater horizontal positional accuracy. The data collected during the later seasons were collected using H-Star technology allowing for an even greater level of precision (Figure 30). The positional accuracy of features located during the later seasons was considered to be within a radius of 0.50 meters (1.6 feet) from the center of the mapped feature. The positional accuracy of located features prior to using the H-Star technology was considered to be 2 to 5 meters (6.6 to 16.4 feet) (Trimble 2005:2-9).

Figure 30. GPS data collection using a Trimble GeoXH GPS receiver with a high-gain Zepher antenna. Data was post-processed for differential correction using H-Star technology.

In the field, the width and depth of the depression were measured using a steel metric tape, and in certain areas a clinometer was used to determine the local slope or a soil probe was used to determine the surface soil characteristics. In addition to the data collected in the ArcPad application, a metric range pole was digitally photographed in the foreground with pictures looking down both directions of the depression. Also, a brief characterization of the location including topography, geology, hydrology, soils, vegetation, and landscape position was recorded. When processed, the point, line, or polygon file from each road segment included, in separate attribute fields, the spatial coordinates, the measured variables, the digital photographs, and the descriptive comments collected from the field survey (Figure 31).

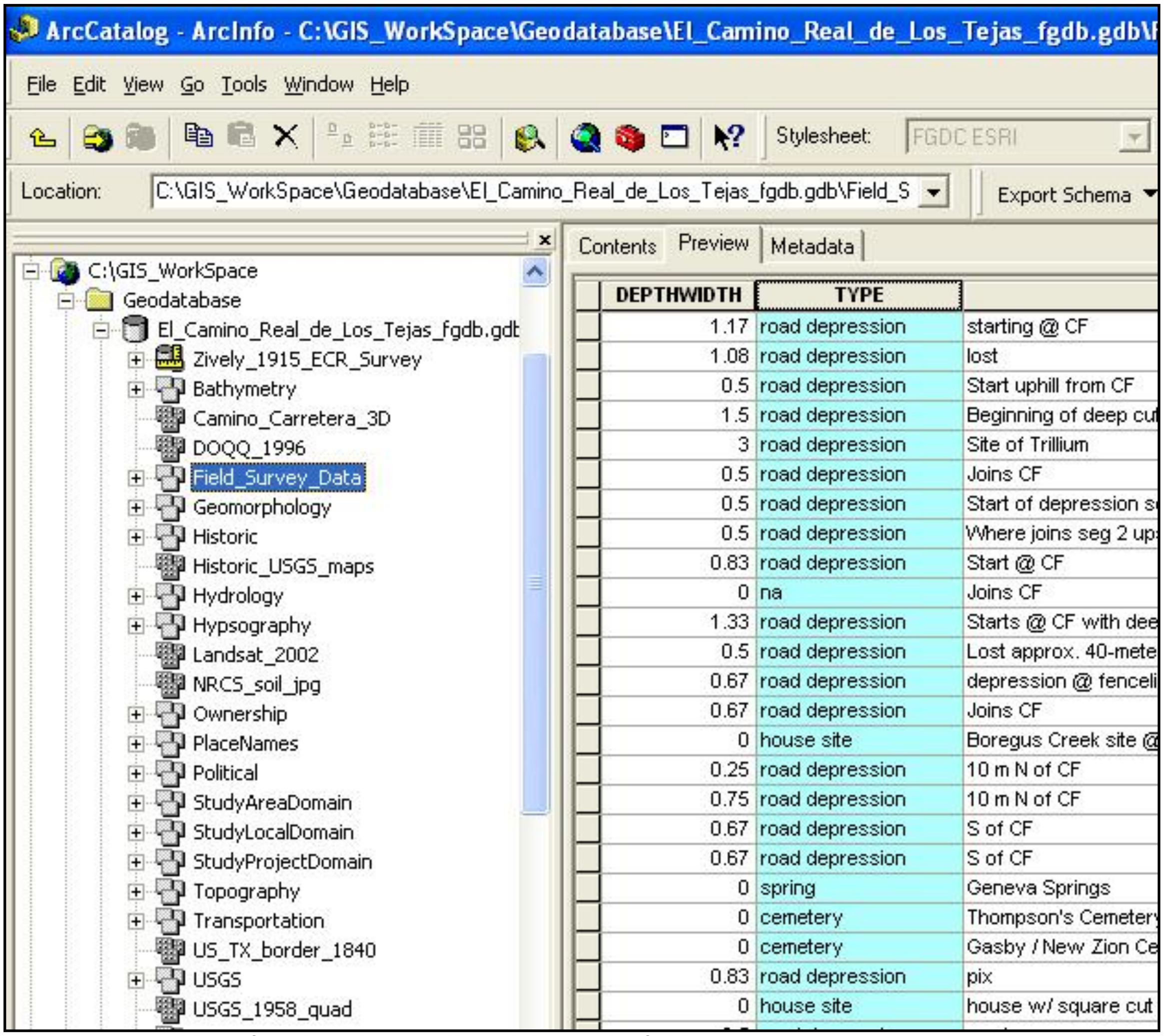


Figure 31. Partial list of road attributes collected during the field survey.

Additional cultural features located along the survey route were also recorded and photographed. It was expected that numerous indicators of previous settlement activities would be encountered. Previous historical research, oral histories, and first-hand accounts indicated that many homes were located close to or on the early roads of East Texas. These recorded features included but were not limited to lateral road depressions, the remains of houses or old home sites expressed by foundation stones, farm features such as cattle dip tanks or farm outbuildings, wells or well depressions, springs or other water sources, and cemeteries. Within the surveyed area, any depressions that were considered a road created by modern hunting, forestry, or agricultural activities were also documented by digital photographs creating a dataset of depressions with their physical characteristics considered not being of Spanish origin.

Due to the optimum field survey time for identifying road systems starting after hunting season in mid-January and only lasting until the ground cover vegetation greens up limiting visibility through the forest, the pedestrian survey of the study area was conducted over four field seasons beginning in 2003 and ending in 2006. The multi-year survey allowed for complex road areas to be visited over and over again during various seasons of the year and allowed for iterative development and use of the archaeological geodatabase model.

Landscape Data

Phase 1 also included creation of a GIS application for managing the data collected from the field survey and for inclusion of the physical landscape data of the study area. The GIS was created using, as a spatial reference standard, the Universal

Transverse Mercator (UTM) coordinate system for Zone 15 North with the 1983 North American Datum (NAD83).

Several maps of various scales published by the USGS were used to aid in developing a list of landscape variables encompassing the study area. Supplemented with additional ancillary data including map data from the NRCS and the Texas Bureau of Economic Geology (BEG), the comprehensive list of physical landscape data included existing digital data regardless of scale or lineage. Figure 32 shows the list of physical landscape data used in this study. The data was reprojected, with coordinate transformations where necessary, to the spatial reference standard outlined above. The GIS was used to create landscape variables not identified during the field survey or included in the collection of physical landscape data. Examples of GIS data creation include the derivation of slope and aspect from a Digital Terrain Model (DTM) or the calculation of distance from a cultural feature to perennial water.

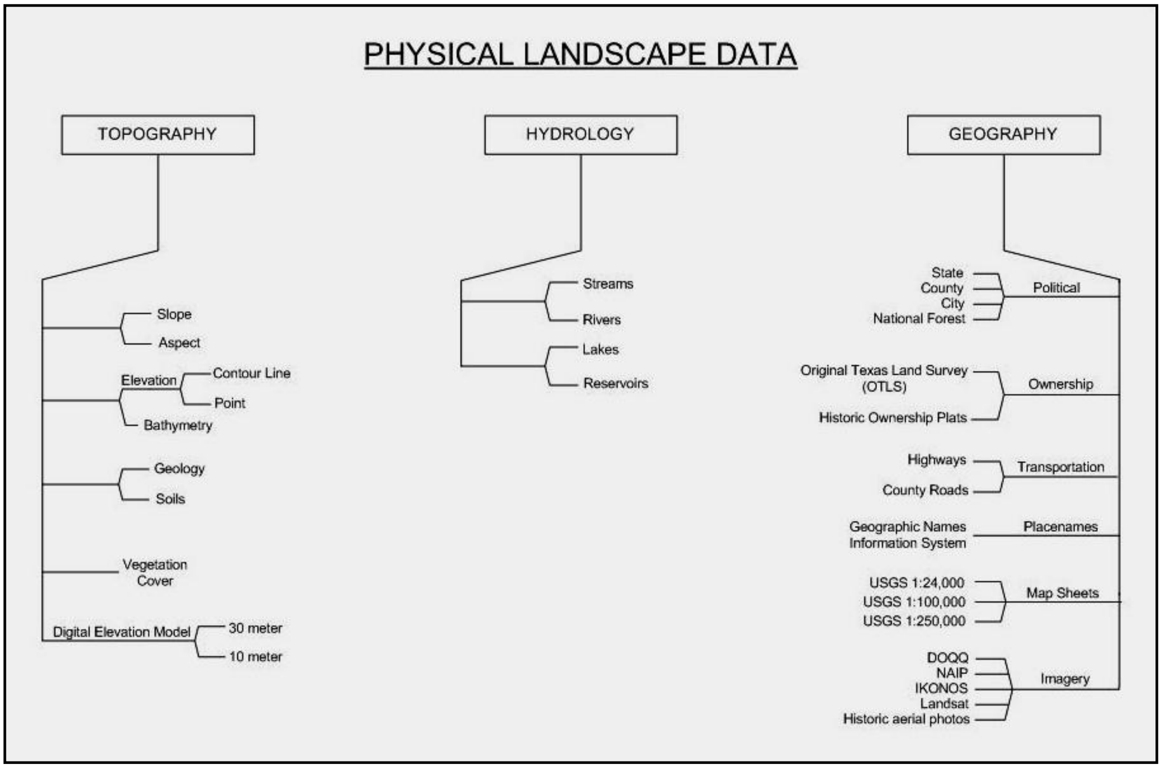


Figure 32. Physical landscape data used in study.

Vector data included the National Elevation Dataset (NED) contour lines and elevation points, National Hydrography Dataset (NHD) stream lines and water bodies, NRCS soils data, BEG surface geology, and Texas Department of Transportation (TxDOT) road and street data. Also a dataset of bathymetric contours for Toledo Bend Reservoir was included (Figure 33). The Original Texas Land Survey (OTLS), a vector dataset of original 1836 survey lines, from the Texas General Land Office (GLO) was included in the GIS.

Raster data included a 10 meter (32.8 feet) resolution Digital Elevation Model (DEM) from the USGS and 1 meter (3.3 feet) digital orthophoto quarter quadrangles (DOQQ) flown during the winter of 1996 [leaf-off] from TNRIS, as well as 1 meter (3.3 feet) color infrared (CIR) aerial photography from the U. S. Department of Agriculture's (USDA) Farm Services Agency (FSA) National Aerial Imagery Program

(NAIP) flown in the summer of 2004 [leaf-on]. Seamless Digital Raster Graphics (DRG) of USGS 1:250,000, 1:100,000 and 1:24,000 topographic quadrangles from a database connection with the Forest Resources Institute (FRI) Spatial Data Engine (SDE) were also used.

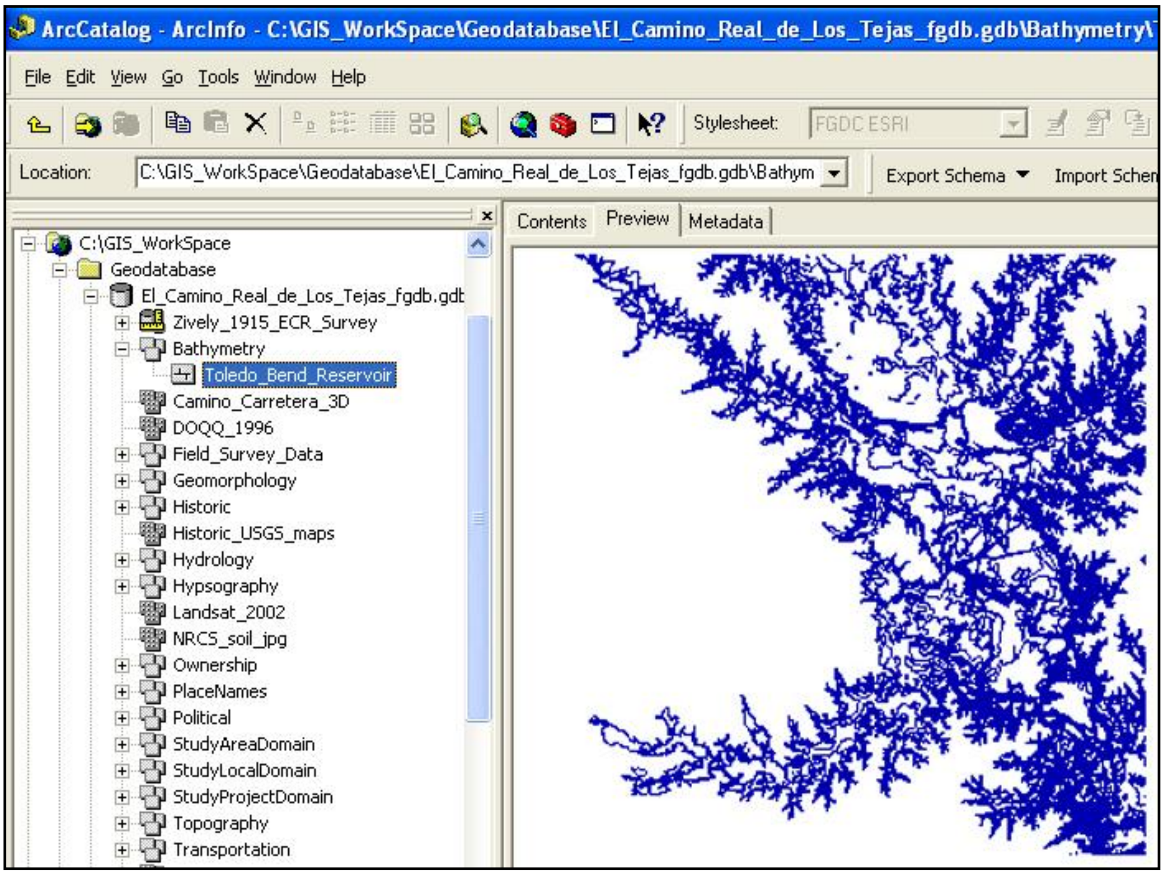


Figure 33. Bathymetric data for Toledo Bend Reservoir.

FRI was instrumental in aiding the search and recovery efforts of the Space Shuttle *Columbia* disaster by providing geospatial (GIS, GPS, and remote sensing) support in early February of 2003. The shuttle's debris path roughly paralleled Highway

21 across East Texas, and during the shuttle recovery effort, current high-resolution satellite imagery as well as historic aerial photography became available for the region encompassing the study area. High-resolution multispectral satellite imagery from Space Imaging's IKONOS satellite was provided to FRI and was panchromatic sharpened (resolution merged) providing a nominal resolution of 0.67 meters (2.2 feet) of the region encompassing the study area. The satellite imagery was obtained and used as a planning aid for the field surveys (Figure 34).

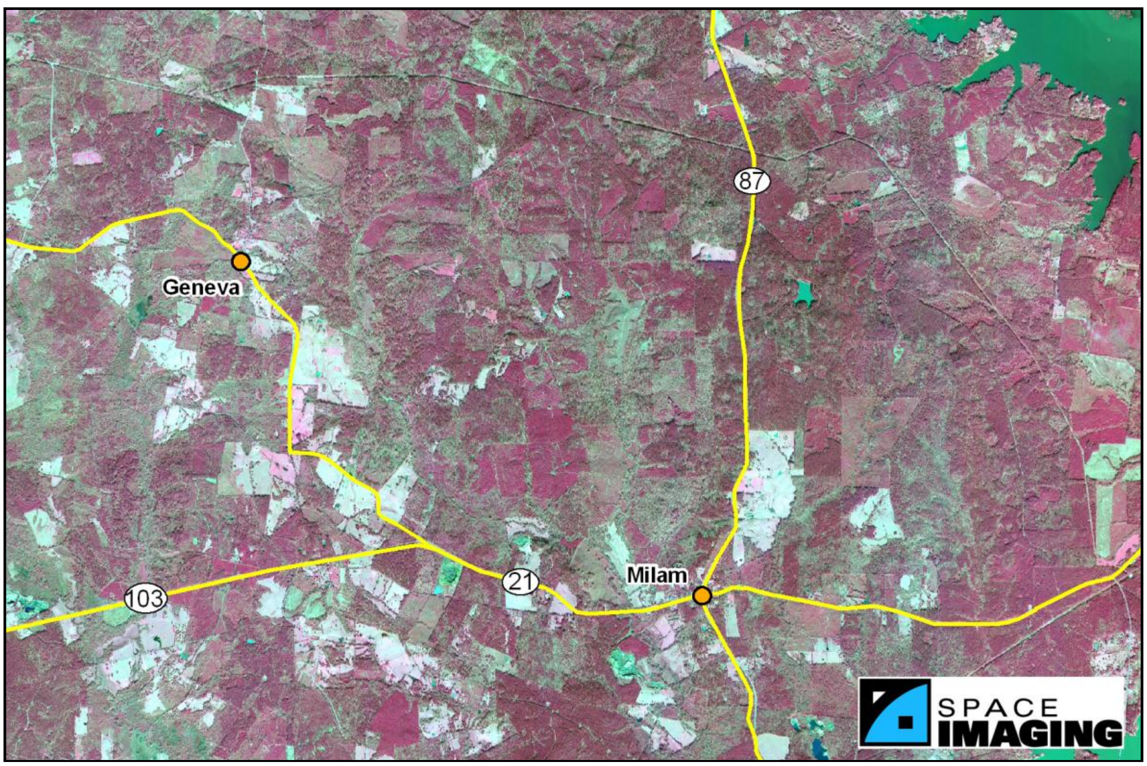


Figure 34. Space Imaging's IKONOS satellite image dated February 1, 2003 (Williams 2007).

Black and white aerial photographs from 1960 and 1968 of the Toledo Bend Reservoir region also became available during the shuttle recovery efforts. The aerial photographs encompass several historic road crossings, ferry locations, and drowned river port towns. TNRIS maintains the Texas State Aerial Photograph Archives which house these photographs. These archives were searched to determine the years of available coverage. Photographs encompassing the study area were located and digitized by scanning at 600 dpi before being georeferenced to 1996 DOQQs of the area using the Georeferencing application in ArcGIS. Aerial photography of the area encompassing historic ferries and early crossings of the Sabine River from 1936 and 1940 (pre-impoundment Toledo Bend Reservoir) were provided to this study by The University of Texas at Austin's Center for Space Research (CSR).

The georeferenced historic aerial photography was used to create feature classes within the flooded Sabine River valley of farm locations and connecting roads, logging tramways and river crossings (Figure 35). The vector feature classes were created by "heads-up" digitizing the visible physical features, and the attribute type field was populated with the type of feature created (i.e., road, river or stream crossing, farm, tramway, etc…).

The inclusion of georeferenced historic aerial photography in the GIS aided in the interpretation of the parameters affecting the selection of road or river crossing locations; and in places, the associated impacts of the physical positioning of historic features on the landscape and the resultant settlement patterns along these early roads could easily be seen. The historic photography added a temporal component to the research and contributed to the understanding of why certain areas were chosen over other locations.

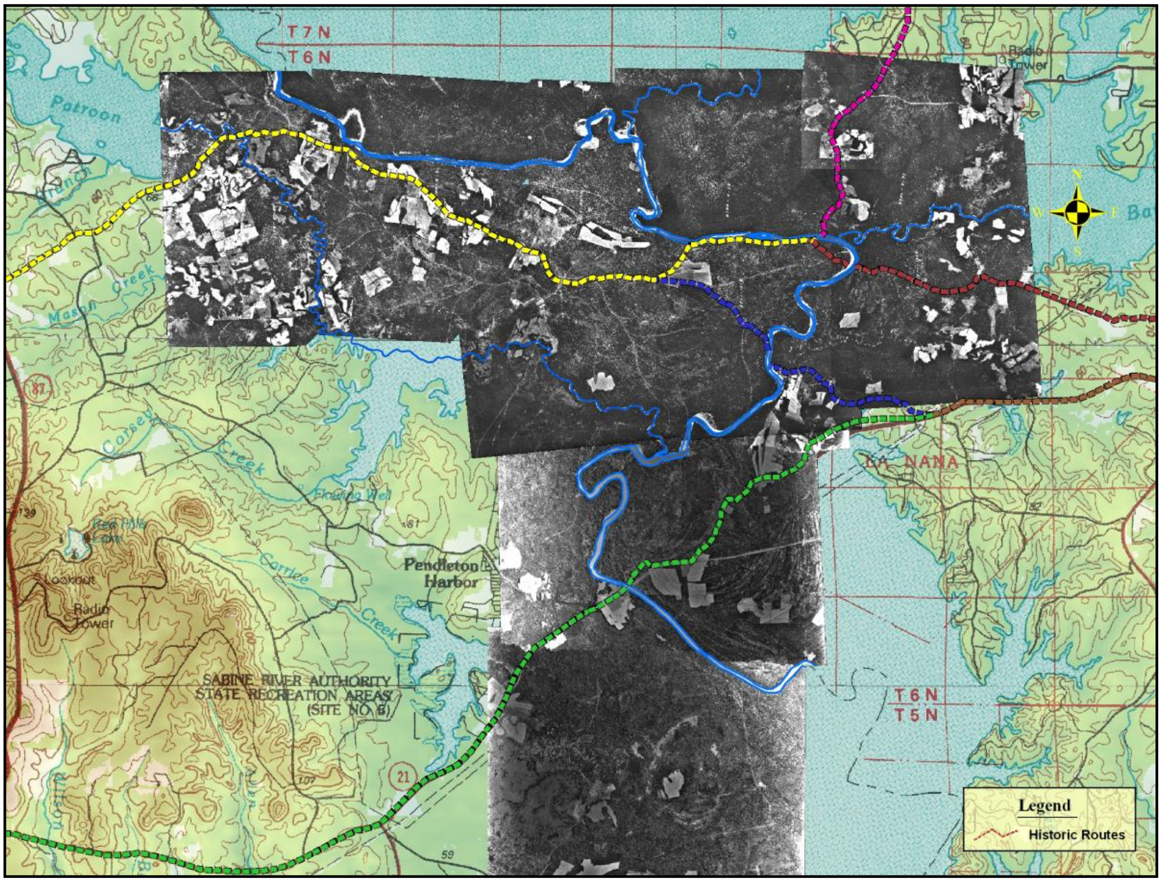


Figure 35. Georeferenced 1936 aerial photographs over a USGS 1:100,000 topographic quadrangle showing routes across the Sabine River (Williams 2007).

Additional raster data consisted of scanned digital copies of historic maps. These maps were used as references for physical features and although not drawn to adequate detail and scale, the maps provided valuable historical information for the study.

Phase 2

Phase 2 began with the creation of an archaeological geodatabase incorporating physical landscape attributes with surveyed road attributes. It also included developing a set of landscape criteria for Spanish road placement, and in addition to constructing the archaeological geodatabase; it included the development and documentation of an iterative process of archaeological landscape visualization and spatial analysis. Using the results of these processes, Phase 2 also included supplementary field surveys for locating additional road segments.

Archaeological Geodatabase

With the completion of Phase 1, the design of an archaeological geodatabase data model proceeded utilizing the information collected on the physical parameters that constitute a Spanish road. Conceptually, the process of creating an archaeological geodatabase design for this research necessitated that the physical variables of a Spanish road and the physical landscape variables crossed by the road be known. Figure 36 illustrates the conceptual progression where data are developed in an archaeological geodatabase, analyzed in a GIS, and returned to the geodatabase framework.

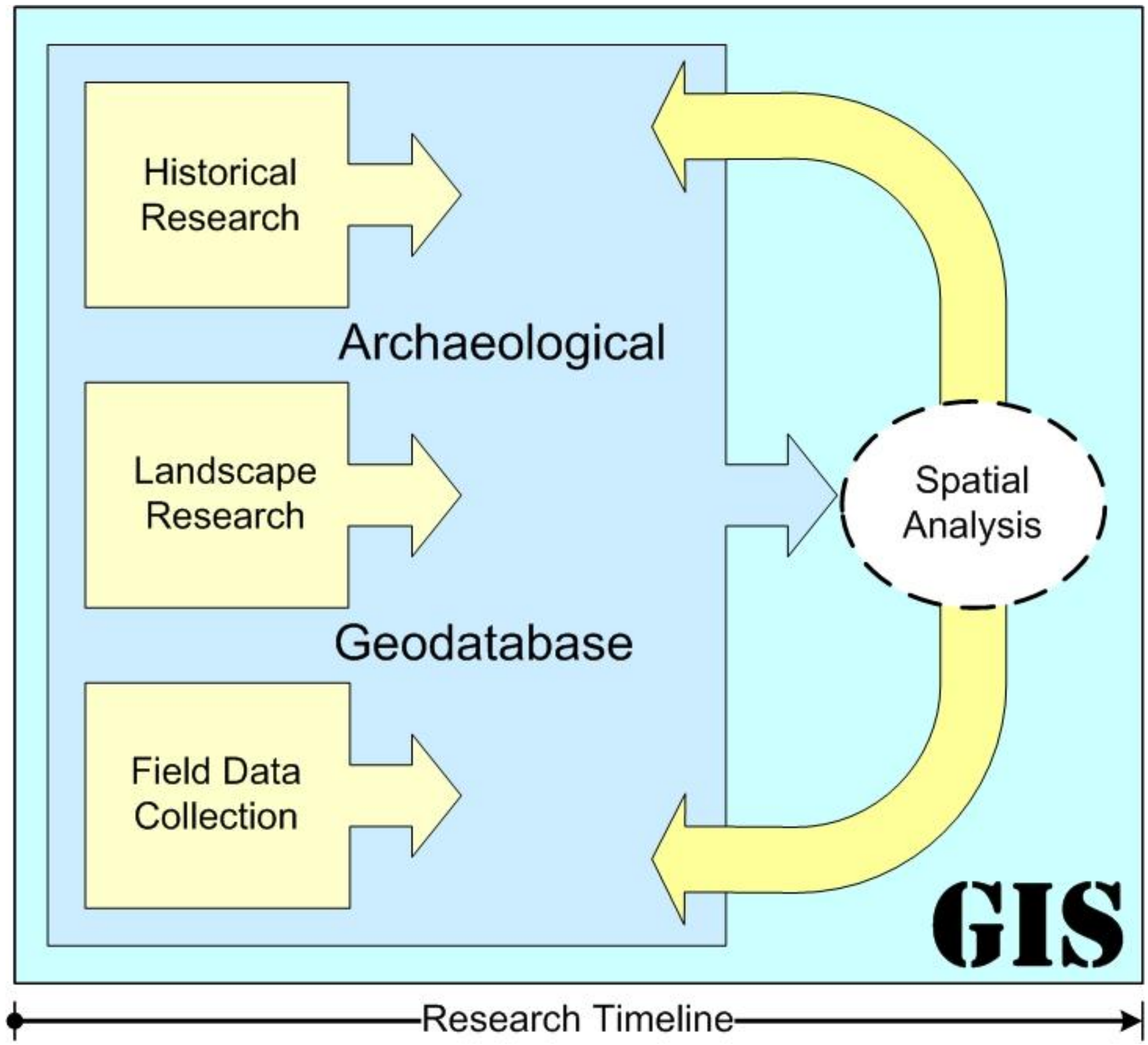


Figure 36. Conceptual data flow of the Archaeological Geodatabase Model.

This process created a robust system for handling complex spatial analysis where the resulting data were reintroduced into the archaeological geodatabase creating a dynamic model of archaeological landscape interaction. To accomplish this conceptualized data flow model, the design of the geodatabase was tested and revised until it met the requirements of the archaeological landscape visualization model.

ESRI's geodatabase data model is an object-oriented geographic model that represents a geographic feature as a relational object with a discrete spatial location. The relational object is stored in a single row of a table in a relational database management system (RDBMS). The geometry of the feature is stored in a field of type Shape while the attributes of the feature are stored where each field type represents a single attribute of the feature.

This research project originally created a personal geodatabase using ArcGIS 9.1. The personal geodatabase datasets are stored in Microsoft Access data files, but this had serious limitations due to reduced performance when the size exceeded 500 MB. The personal geodatabase has a maximum size limit of 2 GB; therefore, two personal geodatabases were created. One for vector files only and the other for raster files that quickly reached the 2 GB limit.

At the release of ESRI's ArcGIS 9.2 software, the inefficiency of the personal geodatabase was circumvented by the availability of a file geodatabase system where the datasets are stored as folders in a file system (Figure 37).

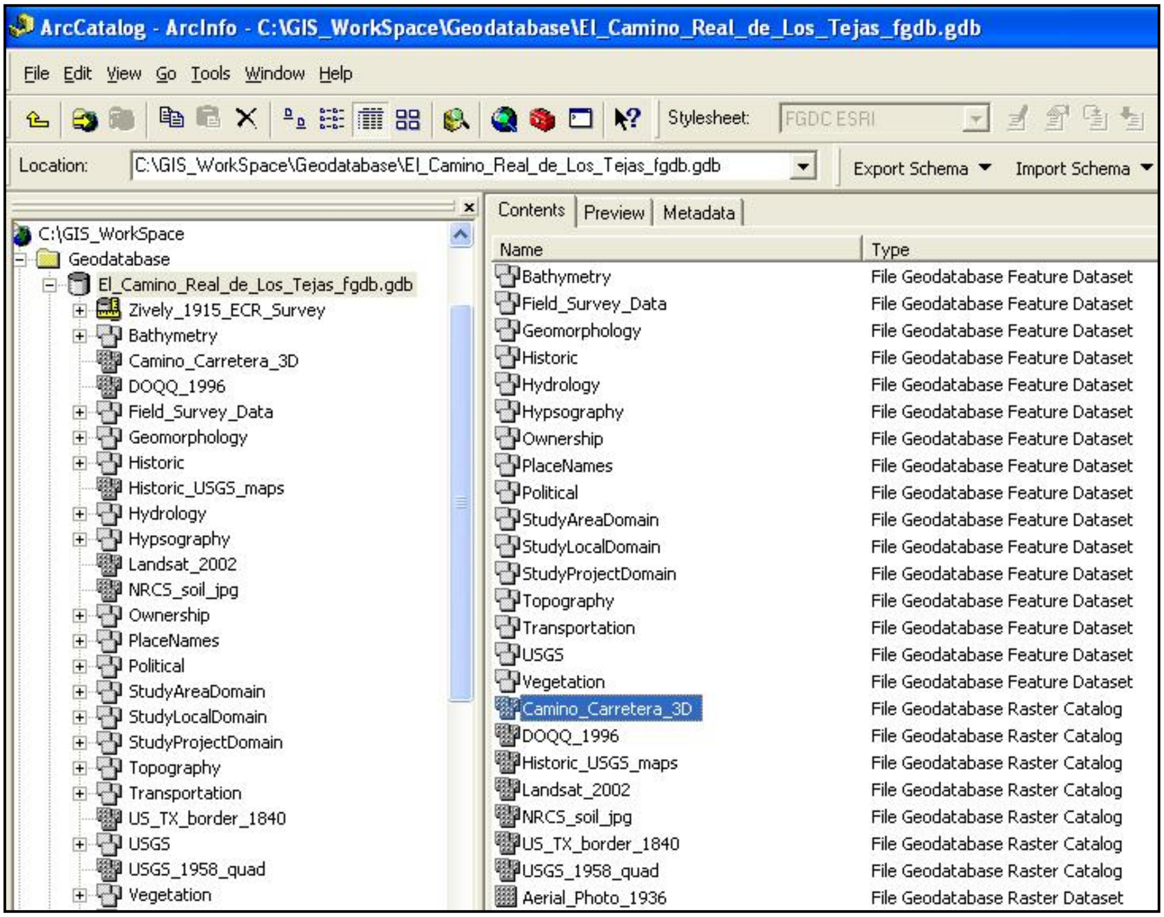


Figure 37. Structure of the file geodatabase developed for the archaeological visualization model.

There is no limit on the size of the file geodatabase and each dataset can hold up to 1 TB of data. Both the raster and vector personal geodatabases were migrated to a single ArcGIS 9.2 file geodatabase using the Export XML Workspace Document Wizard in ArcCatalog (Figure 38).

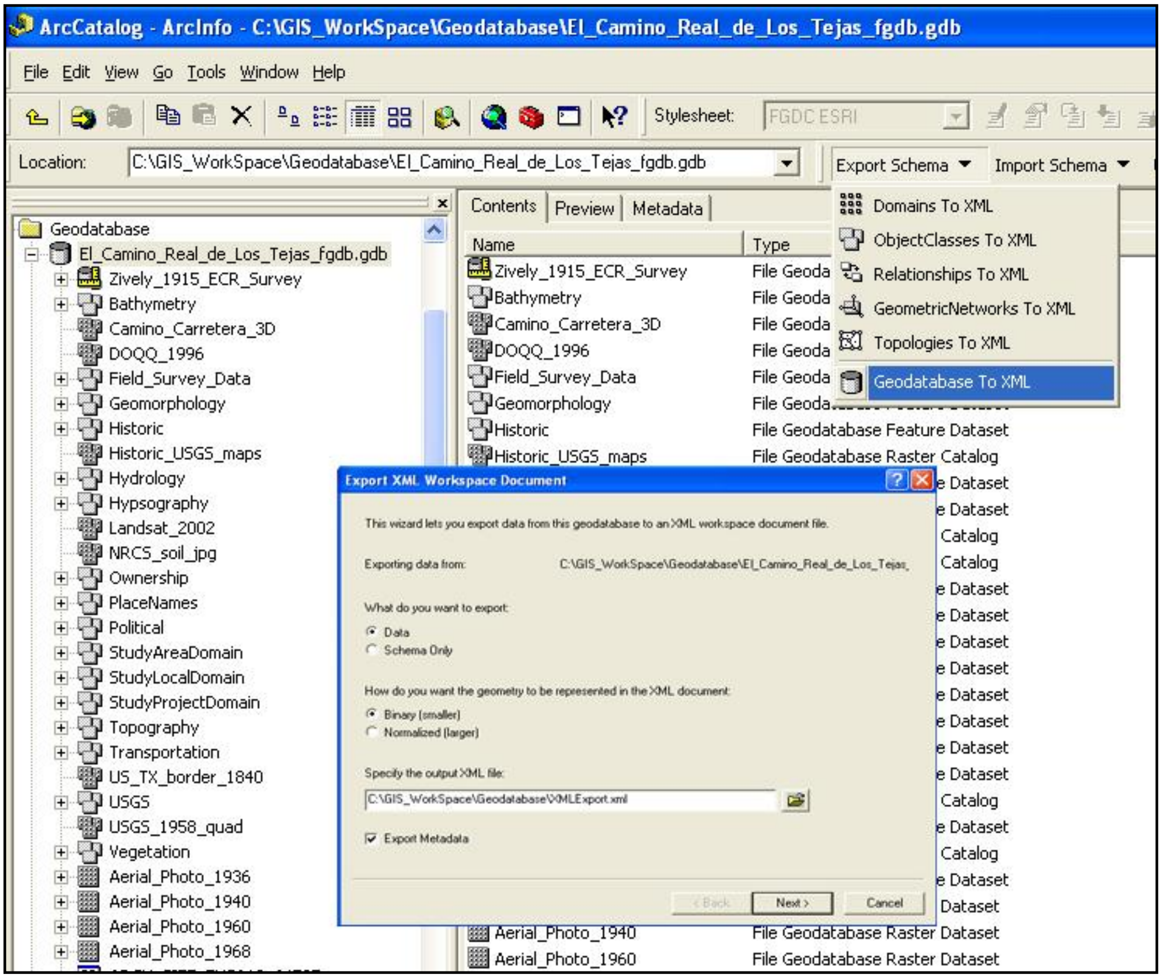


Figure 38. Exporting geodatabase using Export XML Workspace Document Wizard.

Within the geodatabase, feature datasets were created for the grouping of similar feature types sharing a common spatial reference and geographic area. Feature datasets included topography, hydrology, geomorphology, land ownership, political boundaries, and transportation. Within each feature dataset, feature classes were created for each specific data type. Feature classes included soil series and surface geology as polygons under the geomorphology feature dataset or rivers and streams as lines, lakes and reservoirs as polygons, and springs as points under the hydrology feature dataset (Figure 39).

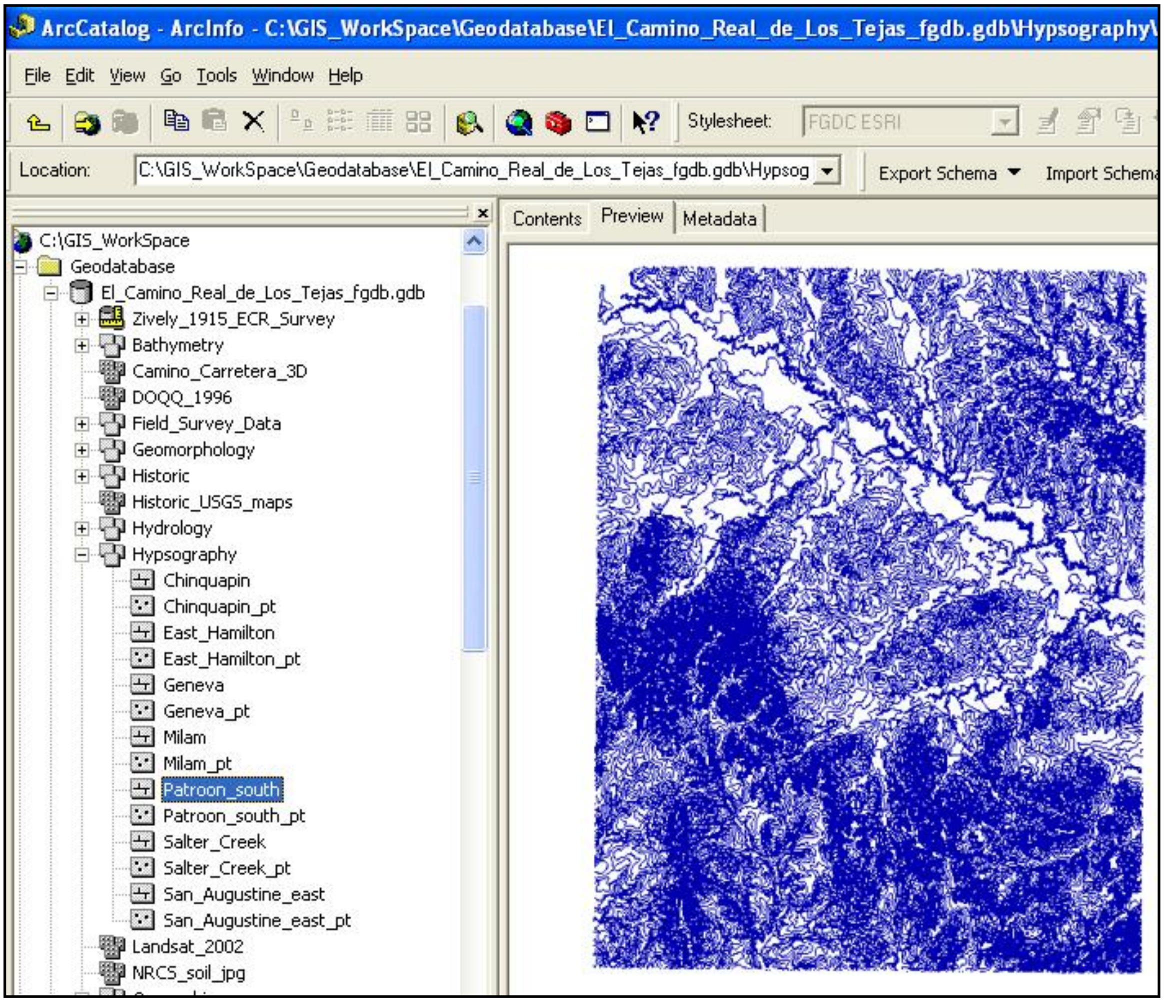


Figure 39. Contour line feature class within hypsography feature dataset.

Raster datasets and raster catalogs were created for the various rasters and were included in the file geodatabase for faster display at all scales. A raster dataset is a mosaic of two or more individual rasters while a raster catalog has a table where each record defines the individual raster dataset that is included in the catalog. Unlike the raster dataset, the raster catalog is displayed without mosaicing the imagery thereby reducing the computational overhead needed for display. Both the raster dataset and the raster catalog are managed by the geodatabase which means that rasters are stored and wholly contained within the file geodatabase rather than having a pointer to the raster files stored elsewhere (Figure 40).

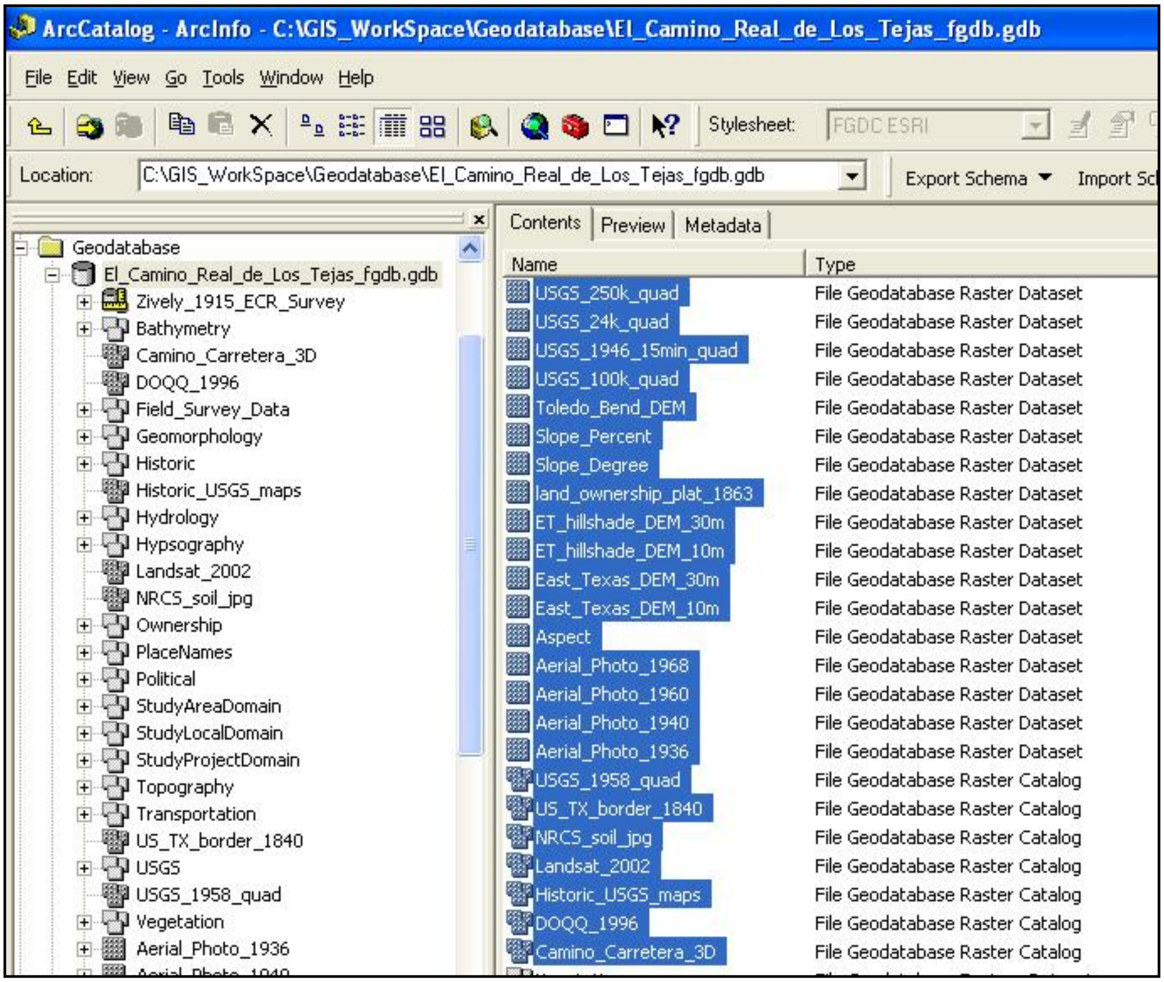


Figure 40. Raster catalogs and raster datasets for the project.

By allowing the geodatabase to manage the raster datasets and raster catalogs, faster display at various scales is achieved, and the geodatabase is more flexible in its portability because it contains all of the data.

Once the feature datasets and feature classes were defined, data collected from the field survey and from the various physical landscape data holders was imported into the feature classes. After the importation, the data was validated by visual inspection for correct alignment with the USGS 1:24,000 or 1:100,000 quadrangles. For the field survey data, validation included scrutinizing the attribute tables for duplicate segment, sample, or GUID numbers. To validate the linear features captured during the field survey, a topology was created with the rule that each line must be covered by a sample point before the line segment could inherit the physical properties collected at the point feature (Figure 41).

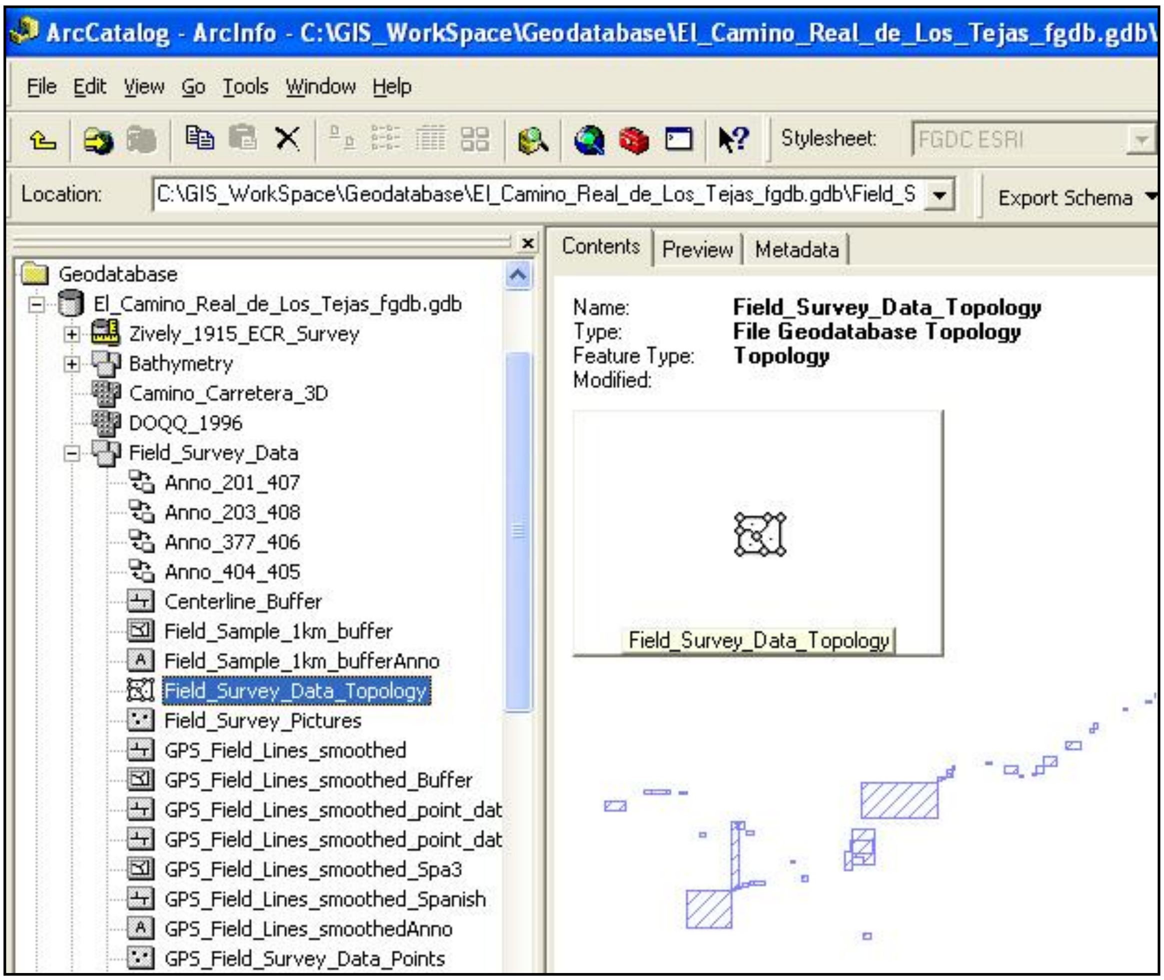


Figure 41. Topology rule that each linear feature must be covered by a sample point.

Additional data types included in the geodatabase were tables of ancillary data including conversion factors for Spanish length measurements, classification codes, copies of field notes, and previous archaeological surveys of the region. Annotation feature classes were also included in the geodatabase for labeling features. The Geographic Names Information System (GNIS) was used to extract the annotation feature class for the physical landscape of the study area (Figure 42).

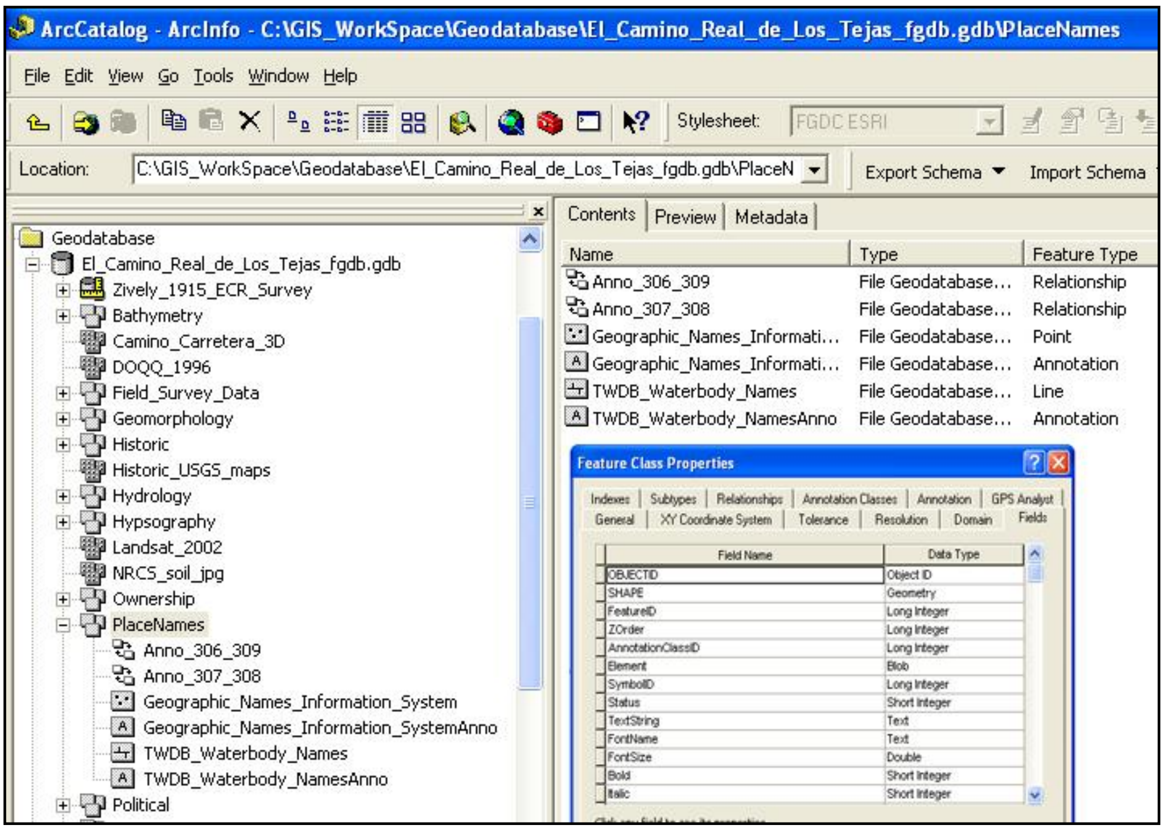


Figure 42. Annotation feature class from the Geographic Names Information System for Sabine County.

A new temporary data type called terrain has been introduced with the ArcGIS 9.2 geodatabase. Terrains are 3D Triangulated Irregular Network (TIN) based surfaces that reside in a feature dataset and reference the feature classes in that dataset. A terrain data type was created for this project in a feature dataset called Topography that included Toledo Bend Reservoir bathymetry, elevation contour lines, and elevation point feature classes (Figure 43).

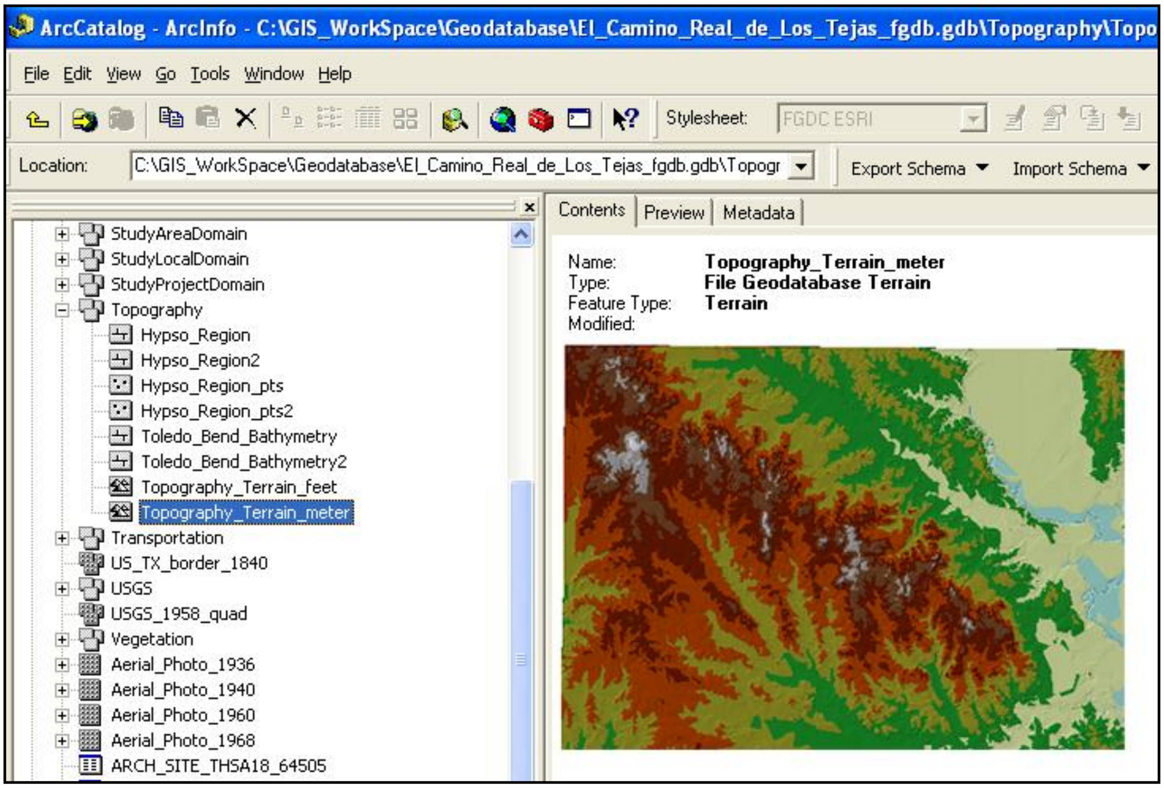


Figure 43. Terrain feature class built "on-the-fly" from the Topographic feature dataset.

Terrains can utilize very large point datasets but require the ArcGIS 3D Analyst extension for creation of the terrain surface "on-the-fly" in the geodatabase. Terrains were useful for quickly visualizing the 3D character of the landscape at any scale because they use pyramiding to improve performance. The pyramids only reference the data needed for a specific view and not the entire dataset for "on-the-fly" construction of a surface from feature class measurements.

Using ESRI's Geodatabase Designer (an add-in for ArcGIS) in ArcCatalog, documenting and exporting the geodatabase design or schema was easily accomplished. Geodatabase Designer captured the schema without difficulty so that it could be edited and then exported as an xml file (Figure 44).

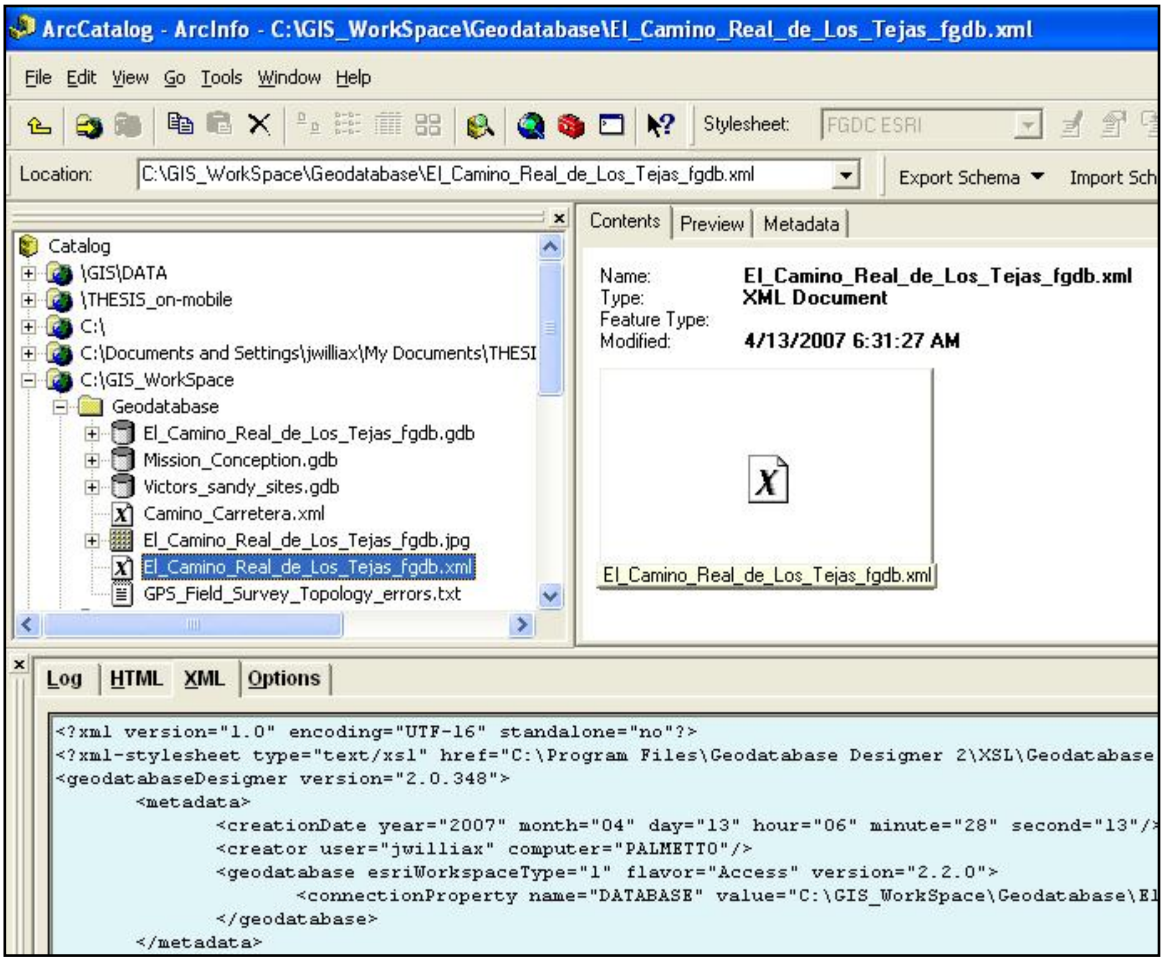


Figure 44. Exporting geodatabase using Export XML Workspace Document Wizard.

The xml file could be used in Geodatabase Designer or ESRI's ArcCatalog Geodatabase wizard to export or import the schema into a new geodatabase. The object-oriented design of the geodatabase supports the definition of custom feature datasets that incorporate feature classes; class attributes, attribute tables, and relationship classes that govern the spatial behaviors of features on the landscape. The design of a data schema that incorporated these custom properties allowed for repeated iterations of design testing where each iteration was refined for added functionality of the data schema (Figure 45).

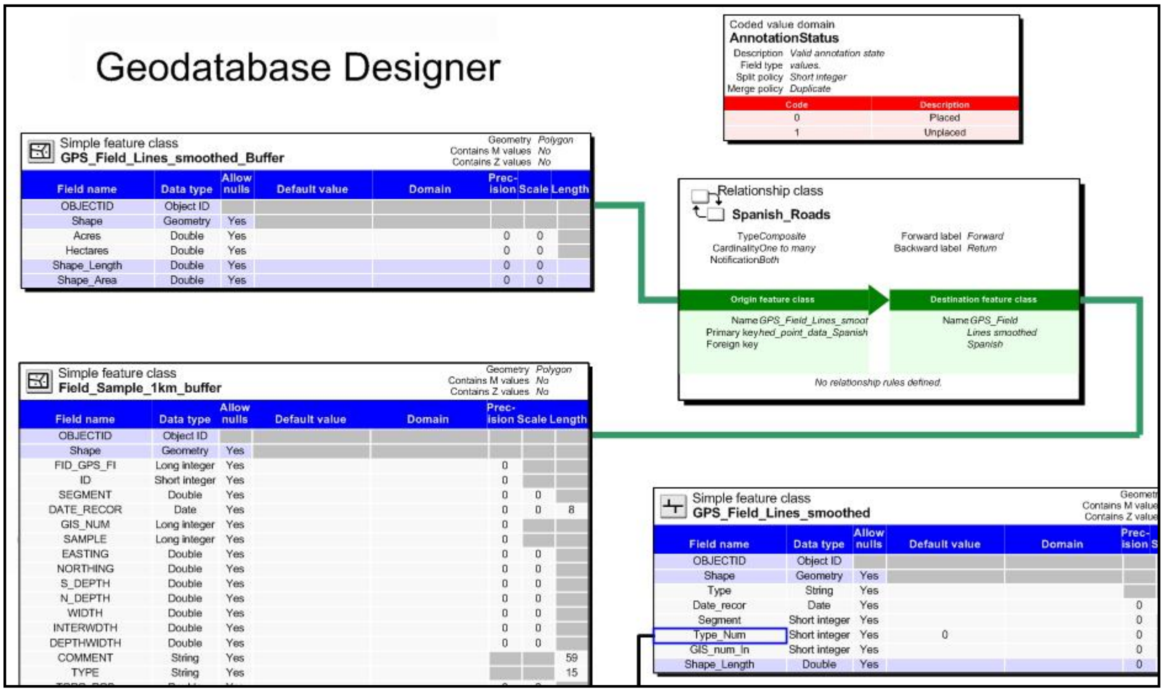


Figure 45. Geodatabase schema from ESRI's Geodatabase Designer.

Data Analysis

Landscape resources that were inherent in the selection and development of Spanish roads can be studied by careful observation of both historic patterns of settlement and road placement. To facilitate the examination of the natural resource influences on the locations of early Spanish roads however, a clear understanding must be developed of the physical properties associated with the remains of an existing Spanish road.

Therefore, a set of criteria for Spanish road placement was created by extracting the physical landscape variables at each sample location of the field survey (Figure 46).

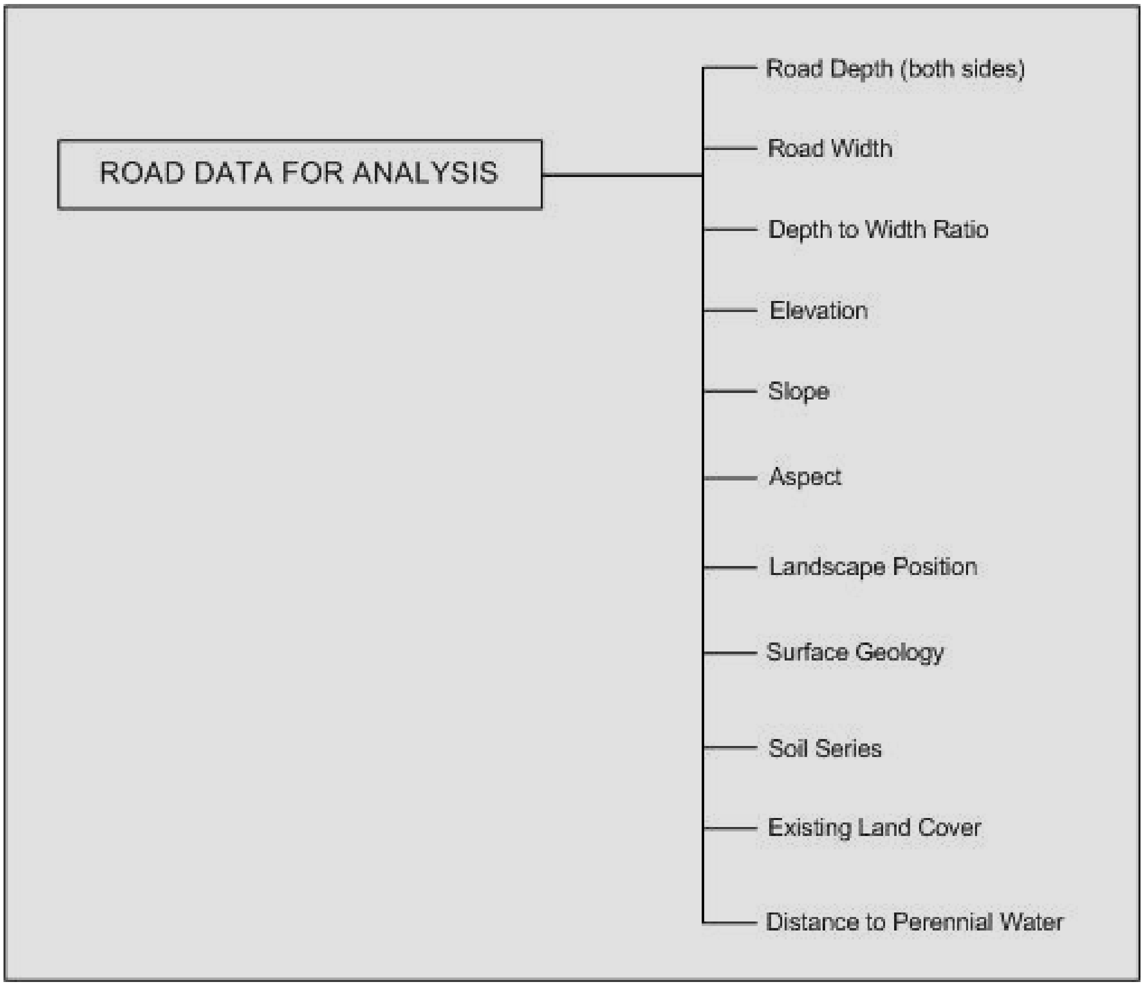


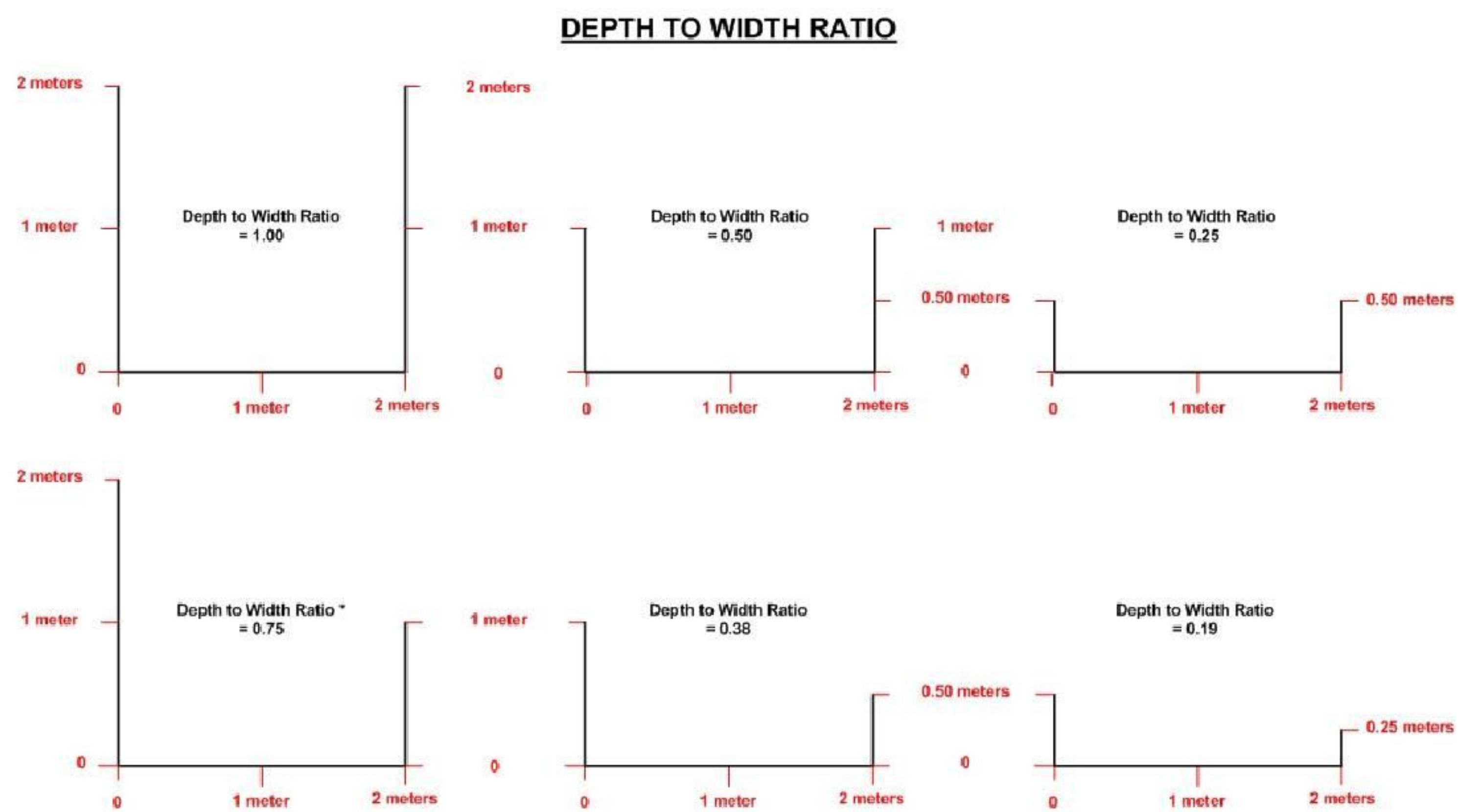
Figure 46. Data for determining the criteria for Spanish road placement.

Based on the assumptions that humans prefer certain physical locations for travel and that cultural features do not occur uniformly across the landscape, the arrangement of located Spanish roads was analyzed to help describe the physical aspects of a Spanish road. The attributes collected at each sample location along with extracted physical landscape variables were investigated, through spatial data analysis, for any hidden trends or patterns that could help define a Spanish road.

At the outset Exploratory Data Analysis (EDA) was used in conjunction with spatial analysis techniques including overlay and proximity relationship analysis. Analysis included using the point locations collected during the field survey to derive slope percent and degree from the DEM raster dataset as well as to extract surface geology and soil series polygon values. Elevation in feet and meters were calculated, topographic position was determined, and distance to perennial water was computed using the ArcGIS Near Tool of the Proximity Toolset.

In order to have a single numerical value of the impact of a Spanish road on the landscape, a simple ratio was calculated using measurements from the field survey. Exploration of the sample data revealed that to define the depth of a road feature at any given location, the depth data measured on both sides of the road depression must be combined for an averaged road depth variable [Intermediate Depth] before being used to calculate a depth-to-width ratio variable. The depth-to-width ratio variable was calculated by dividing the intermediate depth by the width at each sample location as a single measure of that sample point's archaeological impact on the physical environment at that location. The higher the depth-to-width ratio number, the greater the impact; and conversely with a lower depth-to-width ratio number, the impact on the archaeological record is much less. For example, a road depression that has a depth of 1 meter (3.3 feet) and a width of 2 meters (6.6 feet) has a depth-to-width ratio value of 0.50, while a road location that has a depth of 0.50 meters (1.6 feet) and a width of 2 meters (6.6 feet) has a depth-to-width ratio value of 0.25 (Figure 47).

The first set of Spanish road placement criteria data from the analysis was visualized in ArcMap and led to the selection of additional areas to be surveyed (Figure 48). For this project it was important that the data be explored freely without assumptions; thereby, allowing for a deeper understanding of the data relationships, data irregularities, and the overall data structure. The data itself revealed its inherent underlying structure through EDA and allowed an insight to develop in how best to approach interpreting the data. For archaeology, this is a method or philosophy as to how data analysis should be conducted by allowing the data to reveal its underlying structure without preconceived assumptions.



* (Depth 1) 2 meters + (Depth 2) 1 meter / 2 = (Intermediate Depth) $\frac{1.5 \text{ meters}}{(\text{Width}) \ 2.0 \text{ meters}}$ = 0.75 [Single variable of impact's expression in the archaeological record]

Figure 47. Depth-to-width ratio used for calculating impacts on the archaeological record.

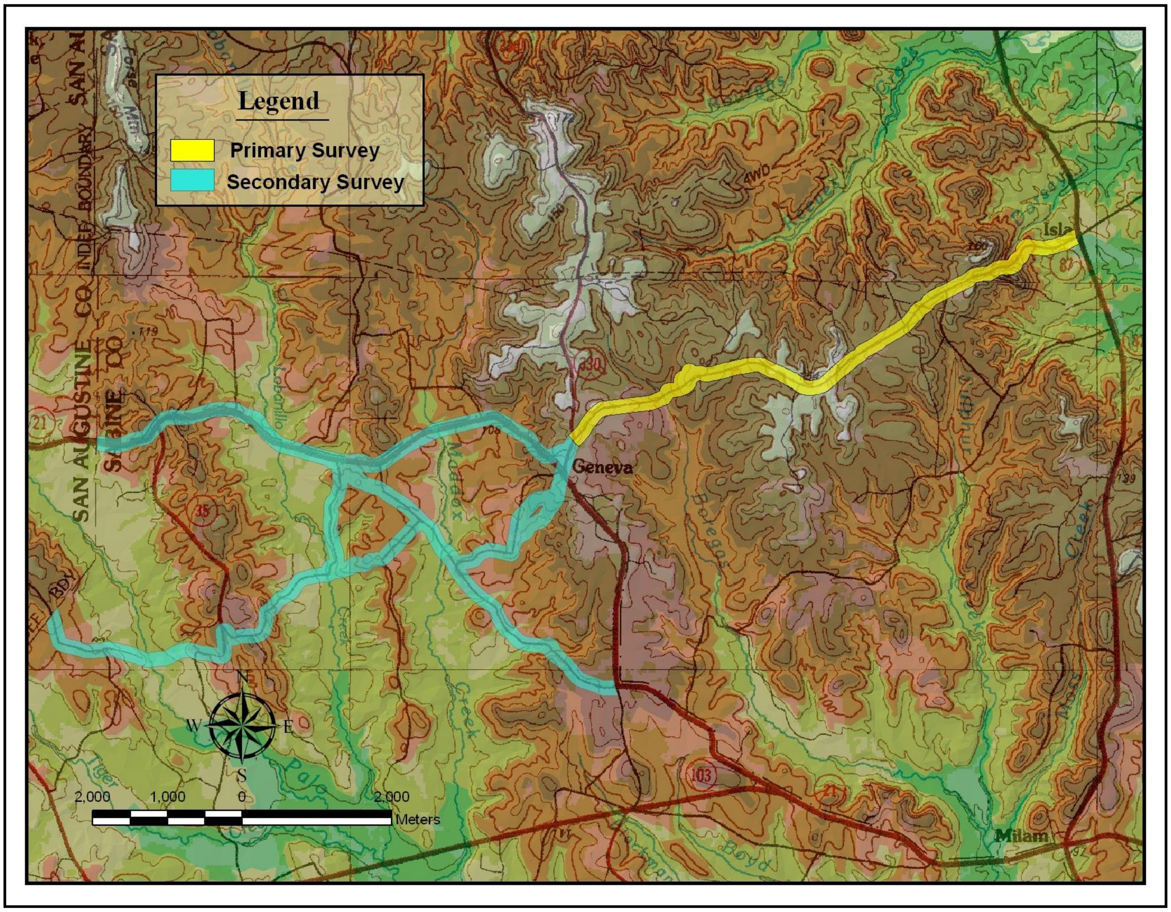


Figure 48. Additional area identified for secondary survey (Williams 2007).

<u>Archaeological Landscape Visualization Model</u>

A GIS managed archaeological landscape visualization model was developed for this study and utilized to visualize changing road criteria over time across the landscape as well as to visualize the character of the landscape in a 3D-environment. The ability to incorporate multiple types of data, both historic and current, into a single analysis and visualization tool is a strength that GIS brings to the understanding of the landscape forces influencing the selection of preferred Spanish road locations.

The archaeological landscape visualization model is a conceptual process model that provided the logical framework for an integrated dynamic flow of data capture, historic research, and spatial data analysis in a geodatabase data model design. Figure 49 illustrates this conceptual model. In the model, historic research, field surveys, and data analysis are happening concurrently. By mapping archaeological evidence in a landscape level GIS, a spatial analysis and integrated visualization tool was created through repeated iterations of refinement and was used to discover regional cultural landscape resources by limiting or confining the potential placement of Spanish road features on the landscape.

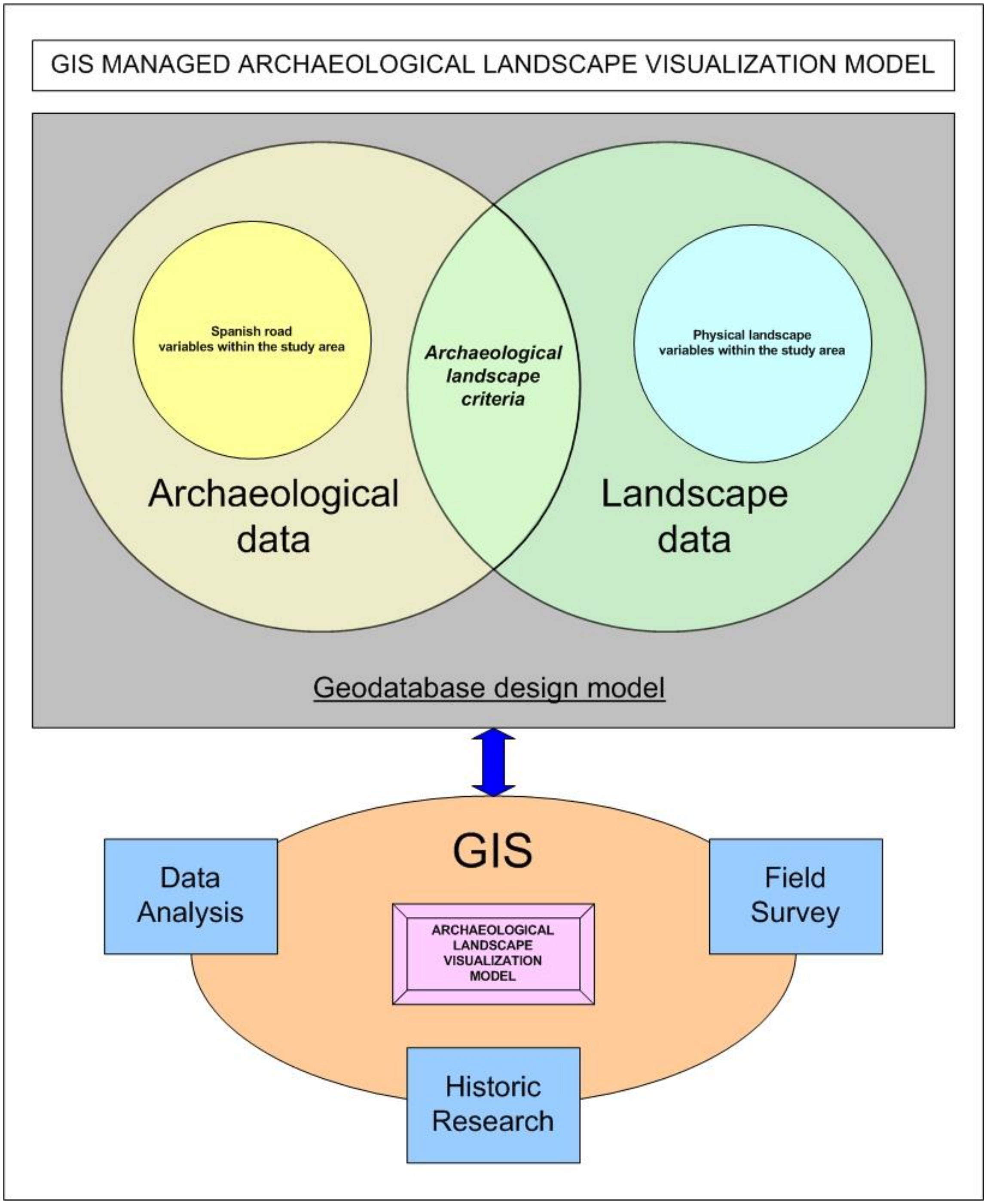


Figure 49. Conceptual design of the archaeological visualization model process.

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