Spatial 3D Analysis and Site Suitability for Fort Toulouse in Elmore County, Alabama

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Abstract:

Fort Toulouse represents the establishment and gradual expansion of European-originated culture and settlements in what is now the Southeastern United States of America. In the case of this Alabama post, founded in 1717, the French established a remote enclave deep within the native country to carry on trade with the Alabamas, Upper Creeks, and Choctaws and to militarily block English expansion in that district. As the result of colonizing the region, an advantage the French had over the English was that the social and political organization of indigenous populations began to weaken in the early eighteenth century, allowing the French to gain political and economic control. Later, the post became an established settlement of French farmers and independent traders, centered on Fort Toulouse. In this thesis, I use several GIS analytical techniques, including line of sight, renditions of the forts, degree of site visibility, and site suitability, to measure defensibility for the surrounding area of this fortified territory. Visualizations in 3D include a terrain model that incorporates elevations, a digital elevation model, environmental conditions, and topography. Moreover, using site suitability analysis, the GIS will attempt to delineate and specify key factors that influenced the French to erect a fort at this location. Hydrographic data will provide the means for analysis of the river networks to determine various degrees of visibility, particularly from the highest point at Fort Toulouse— the bastion. The product of this paper will contribute to preservation efforts at the site by the Alabama Historical Commission and will also provide an interactive, three-dimensional product, contributing to the public education on this historic site.

Chapter 1. Introduction

1.1 Historical, Cultural, and Archaeological Background at Fort Toulouse

The significance of Fort Toulouse as a historic site stems from its role in French settlement during colonization of North America, the impact of European invasion on native groups, and the revival of European-originated culture, including its goods and values (Waselkov 1982). The French occupation during the eighteenth century and later garrisoning of Fort Jackson by U.S. soldiers during the nineteenth century provides a historical perspective into the early foundations and development of the United States. Fort Toulouse was established in 1717, serving as an active trade center between indigenous groups and the French for forty-seven years (Waselkov 1982). Networks of Native American trading routes spread throughout the region, encouraging ties between native Alabamians and the French, which greatly enhanced French efforts to dominate trade negotiations and successfully defend the fortified site. Today, Fort Toulouse is maintained by the Alabama Historical Commission (AHC), where replicas of historic structures are accessible to the public (Figure 1).

The geographic location of Fort Toulouse provided an advantage for forming the keenest friendships amongst French and the Upper Creeks who occupied the area around the junction along the Coosa and the Tallapoosa Rivers (Figures 2 and 3) (Thomas 1989). The streams along these rivers are navigable, stretching several miles before reaching the area near present-day Wetumpka and continuing further upstream along the Alabama River to what is today the location of Rome, Georgia. Other native groups who interacted with the French were the Choctaws, Chickasaws, and the Cherokees. The Lower Creeks, amongst many others, became influential trading partners and lived along the Chattahoochee river whose villages consisted of dispersed households and small structures, maintained by a population of about 3,500 (Waselkov 1982). The French had an advantage over English colonists who weakened their alliance with the Lower Creeks by dishonest trading negotiations.

While the French constructed the original fort in 1717, environmental conditions led to rapid deterioration of the fort, leading to a series of renovations that increased the size of the garrison over time (Heldman 1973). Many members of the French garrison, often sharing extended family descent, arrived from areas throughout France, as well as from Louisiana and Canada where the Creole presence was growing. These variants of French culture helped to enrich the French-originated cultural heritage in North America (Waselkov 1982). Archaeological investigations have provided evidence about events, customs, the blending of cultures, and militant strategies that occurred during the French occupation of Fort Toulouse. In 1764, the French withdrew from the fort and it fell into disrepair (Heldman 1973; Brooms and Parker 1979). In 1812, American troops garrisoned the site and renamed the fort in honor of General Andrew Jackson (Lee 2011). Unlike the original fort, Fort Jackson was intended for defense against hostilities, particularly dealing with negotiations between unfriendly indigenous populations. During the War of 1812 and the Creek War of 1813-1814, Fort Jackson was regarded for its role in strengthening local militia and defeating the Creek nation (Thomas 1989).

Figure 1. Reconstruction of the fortified site; Fort Toulouse in Wetumpka, Elmore County Alabama.

1.2 French Settlement and Site Location

Historical literature describes the French's desire to capture the interests of native peoples who used vast trade networks nearby (Thomas 1989; Waselkov et al 1982). Because the French realized that an alliance with local Indians could be the key to successful occupation and colonization of what is now the Southeastern United States, Fort Toulouse was not conceived as a typical military outpost, but rather as a French enclave deep within the Alabamian wilderness, serving to pacify Creek Indians through trade and making the Coosa, Tallapoosa, and Alabama rivers safe for French trade and settlement (Heldman 1973).

In the early years of the eighteenth century, the Alibamus were aligned with the English who traded from the Carolinas.French relations were so poor that Lemoyne Suier de Bienville, Commandant at Mobile, led expeditions against the Alibamus where plans were approved for a military and trade center in Alibamu country in 1714. However, it was not until 1717 that action was taken to implement the plan (Thomas 1989). The first defensive works erected in 1717 were determined to be rather rudimentary in nature. The French would have desired a strong defensive position considering the hostilities with the indigenous population, but an imposing structure would possibly have worsened aggressions. The detached and exposed nature of the new post made "public relations" an important factor, and the structure that was erected is described as "a stockade of about one hundred yards square yards with four bastions" (Brooms and Parker 1979: 27). Francois Saucier, an engineer sent from Mobile to Fort Toulouse, reported that four years after the initial construction, repairs were needed due to a deteriorating condition (Brooks and Parker 1979). Therefore, a change from wooden to earthen construction was proposed at this time, but it is evident that this course of action was not taken by reports in 1733 that state the wooden stockade was again falling apart (Heldman 1973).

At this site, the French, Spanish, English, and native populations created a network of trade trails and Fort Toulouse developed into the center of active trade. During the early historic period, the French and multiple distinct native groups, including Creeks (Muskogees), Alabamus (Allibamons), Chickasaws, Choctaws, and Cherokees— developed a system of exchange for peace keeping and assurance of future negotiations (Waselkov et al 1982). Thirty years before the French left the site, inhabitants were experimenting with various crops and raising livestock due to the fertile soil of the land.

Figure 2. Diagram of early eighteenth century European settlements, showing the proximity of the Ft. Toulouse site to Creek occupation (Thomas 1989, pg.1).

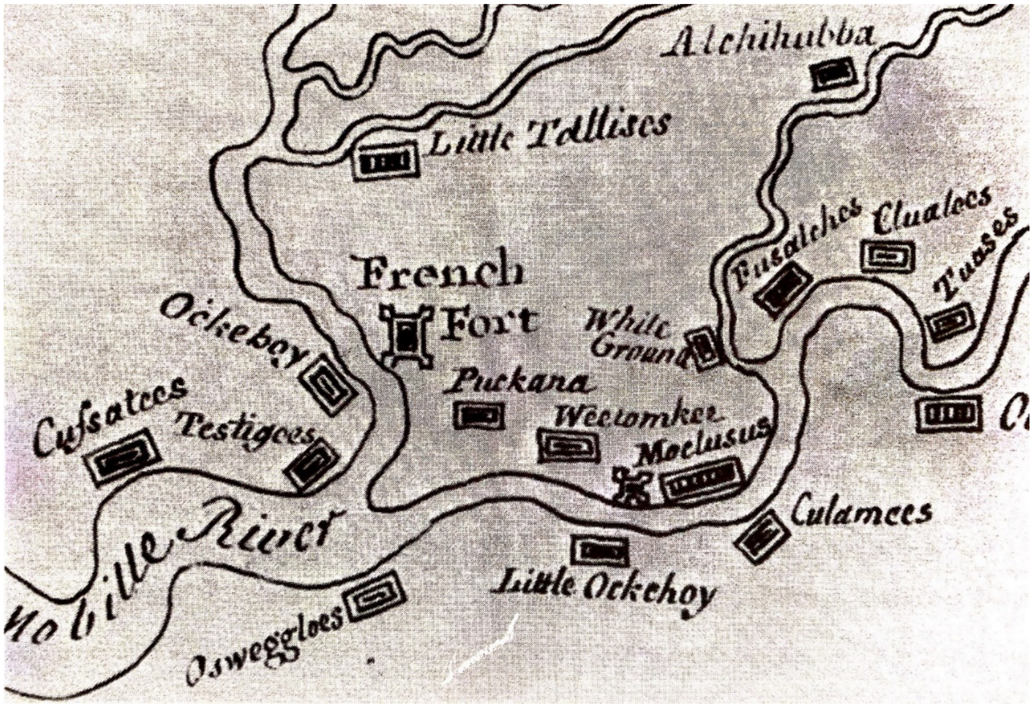

Figure 3. Diagram of Fort Toulouse and surrounding native settlements (Thomas 1989, pg.25).

Many French, Spanish, and English fortifications in the New World were more often referred by their location rather than their official name, and Fort Toulouse was also known as “Post aux Alibamons,” which translates to “Post of the Alibamus” (Lee 2011). The post was not a defensive site against the indigenous people, but against the English instead. The site was surrounded by nearly a dozen indigenous villages, where a sneak attack would have been quite successful against the French. The “Treaty of Friendship and Commerce” was drafted by Edmond Atkin, the Agent and Superintendent of Indian Affairs on the frontiers of Virginia, North and South Carolina, and Georgia and was the first treaty to be signed by Alabama natives, promising to live amongst them in peace (Thomas 1989).

The establishment of Fort Toulouse occurred during a pivotal time of French colonization throughout the Louisiana territory, which encompassed what is today the state of Alabama. Not only was its establishment used to deter English settlement in the surrounding area, but also to declare French presence amongst the indigenous and rival European settlers. The placement of Fort Toulouse where the juncture of the Coosa and Tallapoosa Rivers form the Alabama River made the garrison a prominent feature on the landscape. For the French, traveling upstream from Mobile to build Fort Toulouse proved to be a laborious process. Described by DeMarrais et al. (1996:18), the "materialization of ideology" is a concept that various forms of material culture, including manmade structures on the landscape, are used to express "unambiguous messages of power." This idea can be applied to the site selection for Fort Toulouse. Its prominent location on a high bluff overlooking two major waterways also served as an effective means of promoting French political, economic, and social power in the region. This materialization of French power and ideology had a tremendous influence on the region's trade networks, resource allocation, and French integration into the socioeconomic landscape. From positioning the fort strategically along the waterways, the French sought to make their presence known and influence the cooperation of outsiders who would not want conflict, which might arise by trading or conspiring with others against them. The fort served as a repository for various resources, such as weaponry, food, clothing, and materials. The French had access to European goods for trade, novelty items that intrigued the indigenous villages and further contributed to their control over trade negotiations. The concept of materialization of ideology was also used during Dr. Kimberly Pyszka's examination of the placement and orientation of Anglican churches in early colonial South Carolina (2013). Her findings concluded that one such church, the St. Paul's Parish Church— established in 1707 and located approximately 15 miles west of Charleston— was strategically located along the waterways to express English power and control of the colony to travelers who were passing by. Such landscape decisions made in the early eighteenth century certainly left their mark on the development and settlement patterns within the colony.

1.3 Brief Review of Archaeological Excavations and Reconstruction

No detailed plans of Fort Toulouse had ever been recovered and as a result, archaeology has provided many of the insights into the overall size and spatial layout of the French, and later American, posts. In 1971, the Fort Toulouse property, previously held by the Alabama Department of Conservation, was transferred to the AHC. In October of 1972, excavations to determine the exact location of Fort Toulouse and what would later become the location of Fort Jackson begun under the direction of Dr. Donald P. Heldman (Figure 5). In 1975, Dr. Heldman left the project and his assistant, Craig Ray continued the archaeological investigations led by the AHC. In August of 1976, Bascom McDonald Brooms began duties as Archaeological Director of the project and James W. Parker joined Mr. Brooms as historical archaeologist and field supervisor (Brooms and Parker, 1979).

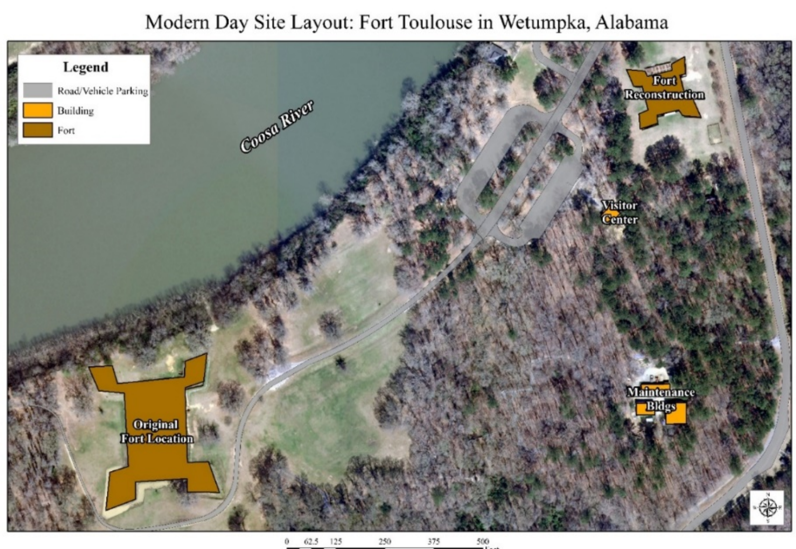

Figure 4. Modern day site layout at Fort Toulouse in Wetumpka, Alabama. Map shows original fort location, visitor center, maintenance buildings, and location of the fort reconstruction.

During the late twentieth century, Fort Toulouse was reconstructed approximately thirteen-hundred feet from the original site location (Figure 4).

Fort Toulouse faces the Coosa River, which merges with the Tallapoosa River to form the Alabama River 900 yards to the west of the site (Figure 7). At each of the four corners of the rectangular fort was a diamond shaped defense known as a bastion. This form of fortification architecture evolved from the Roman era and reached its most recognized configuration in the seventeenth and eighteenth centuries. The strong points located at the meeting of the curtain wall lines were aligned in such a manner that enfilading fire could be directed at attackers fronting the curtain (Brooms and Parker 1979).

In 1972-73, Heldman recorded the southwest bastion, most of the wall construction trenches along the western face and flank, and portions of the eastern face wall (Brooms and Parker 1979). An additional construction line, cut by the Jacksonian ditches and attributed to an earlier edifice, was located at that time. Within the northwest bastion, severe erosion had taken place that obliterated any remains. However, a powder magazine was determined to have existed in the center of the defense. Heldman also recorded that they revealed a 12-ft. earthen moat that surrounded the fortified area. The fortified boundary reached twelve feet in height with increased defensibility with the addition of impaled wooden spokes (Figure 8). The bastion re-erected at the original fort location depicts a height of roughly thirty feet above level ground. Documentation and excavations have uncovered that the moat surrounding Fort Toulouse, built in 1734, measured about 15 ½ feet wide and 7 ½ feet deep.

The southeast bastion had a similar armament as the northwest bastion. A magazine containing American armaments was excavated in the southeast bastion during earlier excavations by Heldman in 1972-73. Like its counterpart to the southwest, the defense at the northeast bastion contained wall lines and postmolds associated with a picket palisade (Brooms and Parker 1979). Flank walls on the east and on the west were found. The walls could not be delineated entirely, as erosion had removed the point of the bastion. Along the west flank wall, a depression contained European trade goods and aboriginal ceramics. Twentieth century trash, Creek War material, nineteenth century Euro-American remains, and historic and prehistoric aboriginal material comprise the assemblage from the northeast bastion. The wall ditch excavations of the east curtain could not discern a definite architectural association but did reveal burned wood residue lining the postmolds that suggested preservative charring of the posts (Brooms and Parker 1979).

Further confirmatory archaeological evidence of the fort's architecture was discovered during excavations made in 1977-1979, funded by the AHC and the Heritage Conservation and Recreation Service. In their report, Brooms and Parker drew conclusions about the French fort walls and five interior, northeast-southwest oriented buildings, and the American fort walls, oriented north-south and east-west. Auburn University at Montgomery conducted excavations during the summer of 1980, led by Dr. Craig Sheldon, Ned Jenkins, and Gregory Waselkov from the University of South Alabama. Excavation techniques varied due to the limited time and funds available that involved only undisturbed primary content cultural zones in the northeast and southwest bastions (Waselkov et al. 1982).

Excavations located along the curtain walls and parts of the four bastions largely determined the French fort's true configuration (Figure 6). Additional excavations traced the extent of the southwest bastion wall, exposing the entire northeast bastion. By doing so, it became possible to extrapolate the remaining palisade line by assuming that the other three bastions were shaped similarly to the northeast one (Waselkov et al.1982). Since nearly all of the French period artifacts found during these archaeological projects were in secondary contexts due to the American construction and activities at Fort Jackson, the artifact analysis was limited in scope.

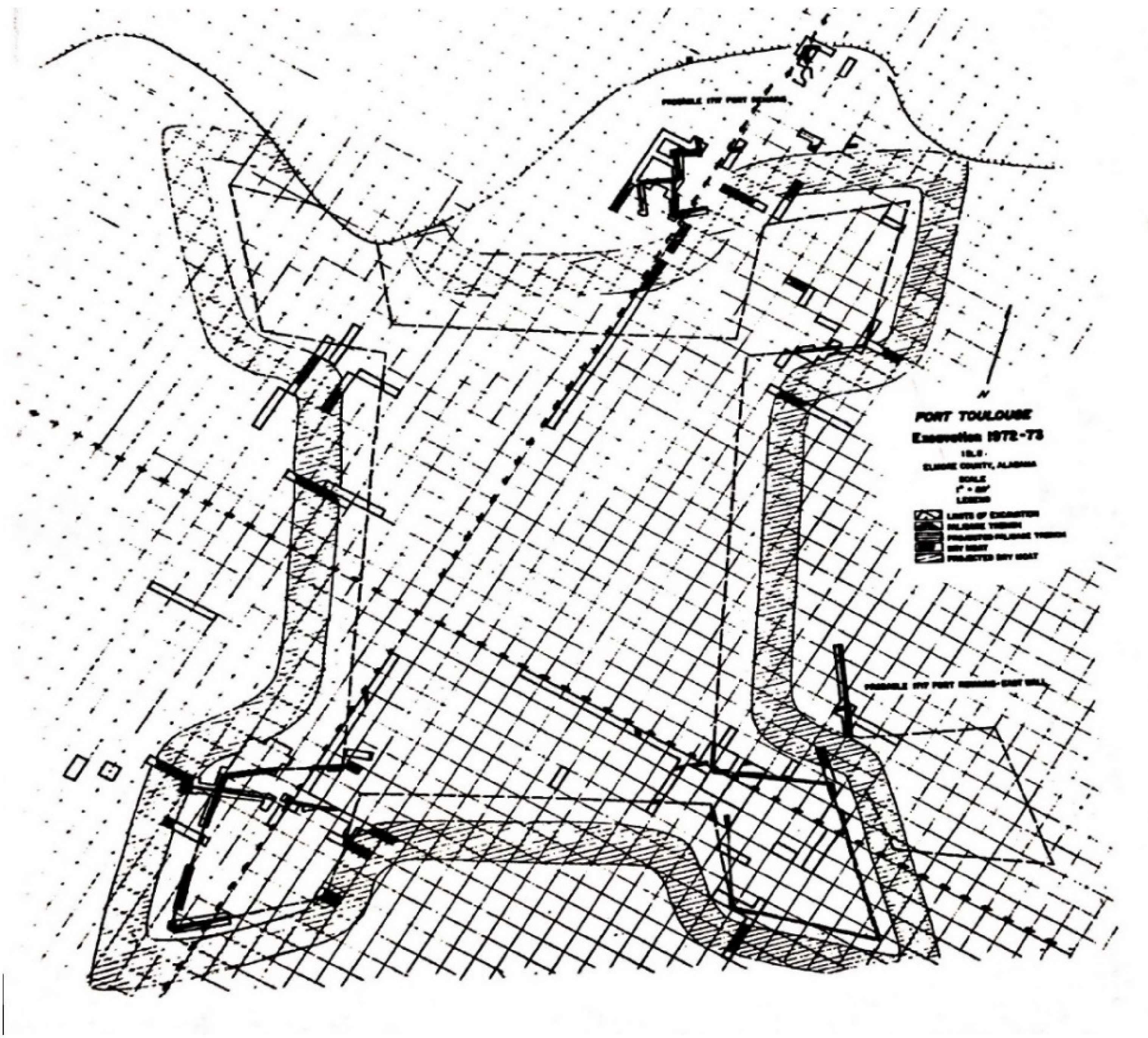

Figure 5. Birdseye view diagram of archaeological excavations during 1972-73 at Fort Toulouse (Thomas 1989).

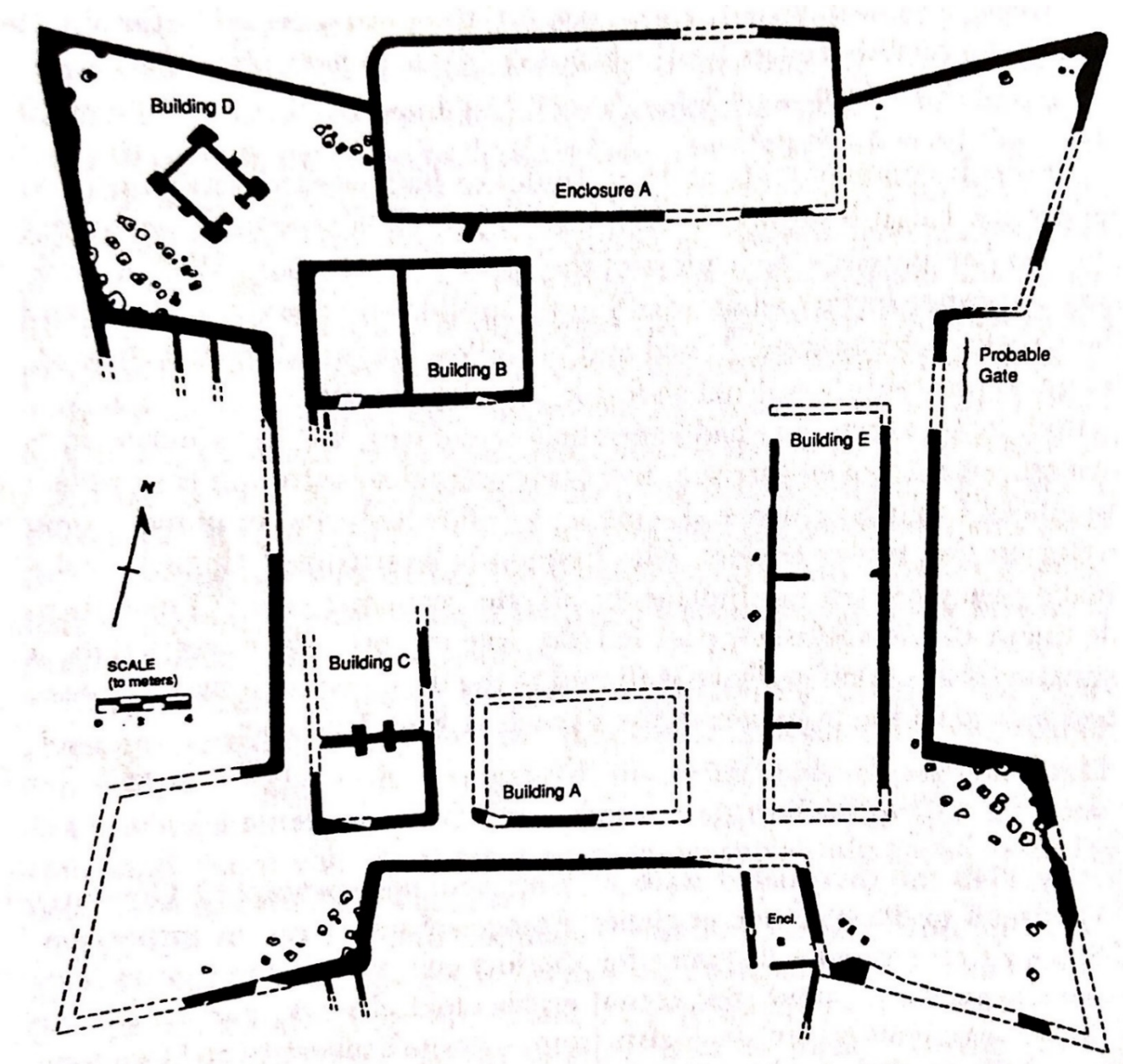

Figure 6. Diagram produced from excavations at Fort Toulouse (Waselkov et al. 1982).

Figure 7. Eastward view of Coosa River twenty yards from Fort Toulouse.

Figure 8. Fort Toulouse's reconstruction at the original location, the Southeast bastion. In this photograph, the impaled spokes are visible.

1.4 Objectives and Product of the Project

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Archaeological research is grounded in the spatial components of material culture and human behavior, and applications in GIS can simplify tedious, time-consuming tasks into more efficient and innovative mechanisms of research. Conducting terrain analysis offers visual aspects of distribution mapping and placement that can reveal complex patterns and relationships, improve management of datasets into a well-defined spectrum, and provide technologically advanced analyzation processes.

GIS applications are used throughout many studies to enhance satellite remote sensing imagery and aerial photography that aids the capability to reveal trends and patterns in the physical environment that are not exposed through traditional methods. Spatial data employed in GIS software can describe objects of historical significance in terms of their position in a coordinate system, include information about their non-spatial attributes, and can determine their spatial relation to one another. Modeling procedures used in GIS can provide information on the social and cultural significance of a landscape that is unique to a culture in a particular area, predict settlement patterns, increase complexity and accuracy of catchment data, calculate viewshed analysis, providing realistic depictions of areas used to examine human interactions. From this analysis, GIS allows researchers to publicly present findings, increasing preservation efforts, and provide a renewed interest in heritage culture.

For this project, GIS is used as a tool to examine how humans create social and environmental constructs across landscapes—through various barriers and boundaries—distinguished by clearly defined spatial practices and perceptions. The GIS employed by this research is used to examine systemic adaptions to natural, geographic conditions by framing the terrain and social and environmental landscape of Fort Toulouse. In regard to the spatial analysis performed for this project, the term *terrain analysis* refers to the physical attributes— topographic, geological, and man-made, of the site, and the term *landscape* refers to the associated cultural concepts through which experiences and environments are perceived. The term *viewshed analysis* refers to an econometric approach to assess how the visibility of an environment benefited the French by allowing them to monitor movement, oversee the surrounding area, maximize resource allocation, and successfully defend the fortified site. To understand Fort Toulouse in its entirety, it is important to consider the cultural choices that influenced the movement of French settlers and their experience within the environment. The results of these analyses in conjunction with site suitability analysis is hypothesized to show that site location and selection is the product of a systematic, decision-making process that aims to maximize the management and oversight of an area.

This thesis will provide a spatial, terrain, and visibility analysis to illustrate the visibility of the river network and surrounding area at Fort Toulouse. Future site development plans will benefit greatly from renditions made using GIS operations and will be accessible to the public. Further analyses will include the degree of site obscurity to better determine the level of defensibility at this fort. Furthermore, site suitability analysis will identify important environmental and topographical factors that determine locations of the fortified site and will demonstrate the potentially suitable areas to build forts using the Maxent approach. A three-dimensional visualization product will be provided to the Alabama Historical Commission to further enhance site development and public knowledge at this glimpse of Alabama's historic past of French colonization efforts.

Chapter 2. Literature Review

Methods of spatial, visibility, and site suitability analysis consist of various techniques that are dependent on the concepts, details, data sources, and needs of previous research. In this chapter, I review a number of case studies focusing on the various approaches that influenced thesis project. Each reference contributes to the research being studied by providing insightful ways to establish theories that could be developed from interpretations of the analysis results.

2.1 Literature Review on Terrain Analysis

Recent developments in GIS software have enhanced the capability in performing virtual 3D GIS studies for terrain modeling. Terrain modeling and analysis is the interpretation of topographic features such as slope, aspect, contour, viewshed, and elevation used to build a mathematical abstraction of a terrain surface to stratify landscapes and understand relationships between physical and non-physical features. A case study by Guney, et al. (2013) examines a variety of ways to perform integrated research based on multimedia applications for the Ottoman Fortresses on the Dardanelles. Because historical remains from the Ottoman era are being destroyed by natural and human interactions, performing a detailed, inclusive analysis for the fortresses of Seddulbahir and Kumkale in Turkey was imperative to the conservation of the site characteristics (Guney et al. 2013). For the detailed and inclusive analysis, they generated a Digital Terrain Model (DTM) using ArcGIS and AutoCAD software to provide isometric views and contour maps using a 3D interface (Guney et al. 2013). This type of digital, three-dimensional geospatial environment allows the user to fully navigate the site and select for additional information stored in attribute tables. The realism of the virtual environment provides a critical component to preservation efforts by documenting the scenery and preserving the cultural heritage of the sites. Renditions of structures can be detailed with as much complexity as desired.

Stine (2000) utilized Geographic Visualization (GVis), a technique in terrain analysis, in a case study to enhance the archaeological study of a nineteenth century blacksmith shop (31Ca29) in North Carolina. GVis is a research perspective that moves away from the conventional, two-dimensional use of maps to interactive, three-dimensional visualizations of spatial data (Stine 2000). GVis utilizes computer graphics to aid in data exploration. Investigations into the precise location of the forge through GVis were sponsored by the North Carolina Historic Sites commission and the Gold History Corporation. By using archaeological marker data in conjunction with GVis techniques, the researchers were able to discern the location of the forge, which has previously been undiscovered.

The location of the forge was situated in a roughly flat, lightly-wooded area that aided in defining the spatial extent of the area (Stine 2000). The GVis employed for Stine’s project was aided by historical documents, maps, oral histories, inferential statistics, and archaeological marker artifacts that determined the presence of particular features on the landscape (Stine 2000). The conclusions arrived by the researchers considered various lines of inquiry, and by focusing on the role that geographic visualization played in helping to determine the precise location of the forge, similarities can be found to the Fort Toulouse project. Software that aids in animation and multi-media were used to provide a virtual reality of the site and further exploration of existing datasets. Benefits of GVis to historical archaeological research efforts allow advanced demonstration of ideas and the enhanced presentation of geographic and spatial information from static objects to interactive models.

Using computer graphics to aid in data exploration, not only can patterns be identified but also hypotheses, questions, and insights can be formed as a result of spatial analysis through visualization of a particular landscape—whether that be political, social, environmental, or a combination of those. Vis methods result in "confirmatory statistics" (Stine 2000) that support theoretical assumptions and expose patterns within a dataset that may not have been not considered significant. The interpretation and presentation of spatial analysis using GIS enhances the spatial elements of a site and becomes a useful new method of inquiry into historical archaeological research. The goal of visualization techniques revolves around reconstructing the site in a spatial and temporal manner. Forte (1995) states that, "the principle aim of scientific visualization techniques is to process digital images to produce a simulation model thus increasing the information in the images." Similar to the Fort Toulouse project, Forte uses data from Digital Terrain Models (DTMs) and digital aerial photographs to reconstruct the site of S. Rosa Terramara in Italy (1995). Visualization techniques aim to determine the relationship between geophysical changes to a landscape and the anthropogenic processes associated with it (Stine 2000), which are intrinsically difficult to map. By applying this methodology, such information can be represented in an interpretive manner, the site can be understood as a whole, and particular questions can be answered about archaeological data.

2.2 Literature Review on Visibility Analysis

Visibility analysis is a subset of terrain analysis that can help to understand aspects of the physical environment in order to predict the choices for settlements, sites, or activities and can assist in the study of visibility from particular areas of interest, creating a line of sight and visibility by calculating a 360-degree circle around a particular location (Kvamme 1999; Ebert 2004).

Cumulative viewsheds create a value for a locational point that is visible from multiple locations, define a line of sight, and provide an understanding of particular social landscapes and can expose the relationship between visual dominance and territoriality.

Defensibility, being a qualitative term, exhibits consistent patterns of human selection based on elevation, hillside or slope, and distance to water, which all constitute a suitable location for a fortified structure. Visibility is a major factor in human use of certain landscapes for specific purposes. For fortified structures, visibility consistently becomes a significant component. Alblas (2012) sought to reduce the limitations of current visibility analyses by improving the DEM input that represents the terrain of an area of interest but excludes the manmade structures and vegetation in the surrounding landscape. Because these are important variables in determining the degree of visibility, this study converted vector data by rasterization that enhanced the research analysis by incorporating the density of vegetation as well as other environmental and social factors.

There are two primary types of geospatial data models utilized for this type of archaeological research—vector GIS and raster GIS. Vector GIS is a requirement where a precise location is significant for databases of cultural properties management, for example, or where accurate perimeters are essential. Within the database management software, text and numeric features may be linked to one another along with cartographic features, which is vital to queries and searches conducted within the map form (Kvamme 1999). In contrast, raster GIS can be used for less stringent perimeters where locations are less precise, resulting in numerical processing and modeling capabilities that are functional for map features and can be easily converted from one format to another. Raster GIS offers more complex visual abilities that are not available in more traditionally used vector-based CAD systems (Kvamme 1999). Using these applications, distance operations can be conducted that incorporate elevation changes, ground steepness, and other factors that would be more cumbersome to measure in the field. Although each of these applications is useful in itself, the most essential benefits are derived by combination— resulting in complex and detailed examinations of regions that are uniquely advantageous to researchers.

Researchers have used what are referred to as “fuzzy viewsheds” (Jones 2006; Ogburn 2006; McCoy 2009; Alblas 2012) that utilize what is referred to as a distance decay—a term for a visibility analysis that describes the effect of cultural or spatial interactions between two locations and the decline in visibility as distance increases. These methods enhance the accuracy of the visibility analysis from the point of observation, adding credit to research claims. The results indicate the degree of visibility based on the comparison of distances of viewpoints from lower visibility zones to alleviate uncertainties in the analytical results. Research suggests that even the slightest variation in elevation can greatly alter the results that are produced by the visibility procedure (Darnell et al. 2007). Using visibility analysis in conjunction with terrain modeling for site suitability analysis is the most comprehensive way to present conservation-based solutions for historic sites, like Fort Toulouse.

Smith and Cochrane (2011) analyzed defensive sites in the western islands of Fiji to determine site suitability based on several variables, highlighting the significance of visibility. This study determined that site elevation and range of view were positively correlated and fortified sites were placed inconspicuously within the landscape (Smith and Cochrane 2011). Three characteristics were provided by the visibility analysis: the land visible from each site, the amount of land form which the site itself was visible, and the content of those views. The study results demonstrated that both visibility of fertile land and site obscurity were important considerations when constructing fortified sites within the region. Because defensive sites seem so intimately linked to community agricultural resources, an ecological framework can explain the rise of fortified sites in areas that meet the specified criteria—the land visible from each site, the amount of land form which the site itself was visible, and the content of those views. The placement of defensive structures and fortified sites generally develops within a region where there is an increased competition for limited territory.

2.3 Site Suitability Analysis

Understanding the relationship between environmental and human interaction is a key part of determining best practices for land use and development. Topographic and terrain data can greatly contribute to the analysis of human-managed landscapes and applied, niche-based theory. The niche-based theory is a function of the environmental, topographic, and geographic conditions that influence land use decision-making processes and occurrences. Huemann et al. (2013) demonstrated "a novel method of understanding nonlinear relationships" that exist between human activity and space, involving factors that are difficult to quantify. Modelling land use suitability greatly consists of allocating land development and quantifying the activities that occur. Site suitability analysis quantifies ecological settings, land cultivation opportunities, geographical, sociological, and demographic conditions.

Huemann et al. (2013) describe the greatest challenge in modelling site suitability as "creating the rule sets that define (site suitability models)." Interactive and nonlinear data may exhibit various patterns when analyzing the area of interest. By applying machine-learning algorithms, a wide range of scientific difficulties around pattern recognition can be resolved. As a result, land-use models can be generated that expose the relatively likelihood compare to the entire landscape.

Maxent is a modelling software used for site suitability analysis, which is often conducted in wildlife habitat analysis and land use modeling. Ha et al. (2016) utilized this software to project potential conservation easement locations based on various environmental and socio-economic conditions at the current conservation easement locations. With the incentive to reach regional planning goals, understanding land use patterns and determining the relationship between environmental and social factors was imperative to apply this approach for expansion of easement locations. By doing so, Ha and his colleagues illustrate how future land use and development would impact different purposes of conservation easements including wildlife habitats and agricultural systems in Southeast Michigan. Furthermore, conservation easement distribution predictions were generated using Maxent, comparing both social and environmental factors and as a result, potential areas of expansion were determined (Ha et al., 2016). This research further contributes to our understanding of how the pattern-process of conservation easement allocation and the resulting conservation easement patterns are often complex involving spatial and non-spatial factors from both the human and physical environments. Decision-makers may benefit from considering the easements' geographic distance relative to underrepresented communities (Ha et al., 2016).Egeland et al. (2010) utilized the site suitability approach to target areas for paleoanthropological surveys. Using raster layers, an algorithm calculated a single path of raster cells that presented the cheapest cumulative route relative to cost. Based on the results, the cheapest route running across Syria and into eastern Turkey lines the northwestern border of Armenia. The distribution of known Lower Paleolithic occurrences in northern Armenia supported the presumption that the region was an important corridor for the movement of early hominid populations and exposed potential sites that had not been considered previous because of the lack of prior paleoanthropological research in the area. Egeland et al. used GIS to conduct a site suitability analysis for the areas of highest potential.

The site suitability analysis included the following variables: land cover type, aspect, slope, elevation, and proximity to rivers. The linear scale transformation values for each variable were summed using the raster calculator, averaging potential outliers, and assigned a suitability score that ranged from 0, or lowest suitability, to 100, or highest suitability (Egeland 2010). The calculated raster values were reclassified into three suitability categories: unsuitable, suitable, highly suitable. From these results of the analysis, it was evident that the northernmost stretch of the study area had the highest potential for paleoanthropological sites. A total of twenty-five new sites spanning the Lower Paleolithic through the Upper Paleolithic were identified from the site suitability analysis (Egeland 2010). The results of this study indicate that remote, predictive modeling can benefit paleoanthropological survey using the integration of environmental variables and GIS.

Chapter 3. Spatial 3D Analysis

3.1 Data and Method on Terrain Analysis

For terrain analysis, a variety of operations can be performed on spatial datasets that are used to conduct surface analysis. The product is a three-dimensional digital map that characterizes spatially relevant topographic and geological information into various layers. Raster-based spatial data is easily manipulated using various operational tools found in ArcToolbox (ESRI). While the complexity of a landscape presents challenges in digital representation, terrain analysis captures features that are significant to the study area, the spatial data are organized into layers that can be further analyzed.

For this project, a LiDAR point cloud available through the USGS EarthExplorer data gateway was used to create surface models of the study area for terrain analysis (Figure 9a). Light Detecting and Ranging (LiDAR) is an optical remote sensing technology that measures properties of scattered light to determine and define ranges of elevation, vegetation, and terrain for a particular landscape, which is capable of producing an accurate digital elevation model (DEM). LiDAR utilizes three technologies –lasers, Global Positioning Systems (GPS), and Inertial Navigation Systems—that are combined to allow a high degree of accuracy in the positioning of the footprint of a laser beam as it hits objects on the Earth's surface. The National Geospatial Center of Excellence (NGCE) has a partnership with USGS to promote the exchange of accurate digital land elevation data and establish standards and guidance that benefits all users, whether they are government agencies or within the public domain.

Given the known range of values from the LiDAR point cloud, interpolation was conducted to estimate the unknown values in order to create the digital terrain model (DTM), which is a vector dataset composed of regularly spaced points that represent the bare-earth terrain (Figure

9b). In addition, this interpolation method was carried out to create a digital surface model (DSM), which captures natural and built features on the Earth's surface (Figure 9c), as well as a digital elevation model (DEM), which is a bare-earth raster grid (Figure 9d). Spatial autocorrelation, or Tobler's First Law of Geography, helps understand how similar closer objects are to other nearby objects. The method of spatial autocorrelation used to convert the LiDAR point cloud into surface models for this project was Inverse Distance Weighting (IDW). IDW is a very flexible spatial interpolation method that utilizes the number of closest points to interpolate unknown elevation values. The formula for IDW, known as Shepard's algorithm, is as follows:

$$u(\mathbf{x}) = \begin{cases} \dfrac{\sum_{i=1}^{N} w_i(\mathbf{x}) u_i}{\sum_{i=1}^{N} w_i(\mathbf{x})}, & \text{if } d(\mathbf{x}, \mathbf{x}_i) \neq 0 \text{ for all } i, \\ u_i, & \text{if } d(\mathbf{x}, \mathbf{x}_i) = 0 \text{ for some } i, \end{cases}$$

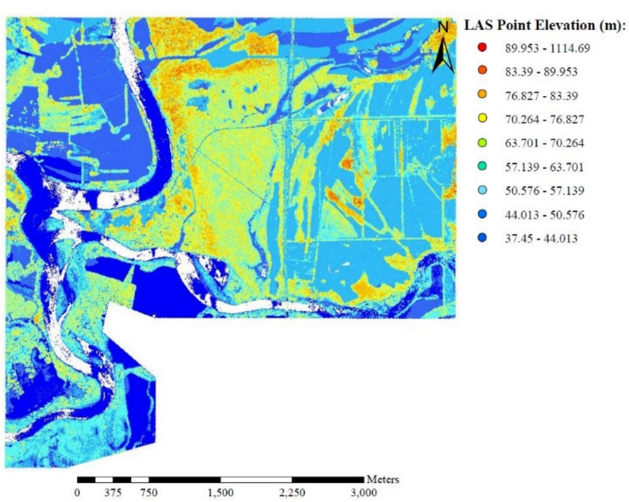
where

$$w_i(\mathbf{x}) = \frac{1}{d(\mathbf{x}, \mathbf{x}_i)^p}$$

The function above provides a general form of finding an interpolated value u at a given point x based on samples $u_i = u\ (x_i)$ for $_i = 1, 2, \ldots, N$. In this IDW weight function, x is an interpolating or known point, d is a given distance from the known point x, N is the total number of known points used in interpolation, where p is the positive number. As distance increases from the interpolated points, weight decreases. Greater values of p assign greater influence on values closest to the interpolated point (Shepard 1968). It is important to mention that for the data used in this project, the IDW method produced more well-defined results for geo-visualization techniques than that of the more popular Kriging method, which considers not only the total number of known points but the overall spatial arrangement of those points. This decision was due to the arrangement of points within the LiDAR las datasets and the higher degree of resolution, as the results from the IDW method produced a smoother, less-dense surface model than that of the Kriging method. The Kriging method would be more beneficial for datasets with less resolution and point density.

The LiDAR point cloud separates points into ground and non-ground classification. Ground points reflect the Earth's surface, while non-ground points reflect those of vegetation and manmade structures within the study area. Using ArcGIS 10.5.1, the LAS datasets—LAS, meaning data collected by LASer via aircraft— were converted to a multipoint feature class, which was then resampled, using interpolation, from an irregular data format to a regular grid for analysis and visualization. The optimum ground sampling distance (GSM) was found to be equal to the average point spacing and a nearest neighbor method was used for resampling. With this approach, a DSM grid was generated from both ground and non-ground classified points and a DTM was generated with only ground classified points, as shown in Figures 9b-c. DTMs are typically used interchangeably with DEMs, where both are raster grids representing the bare earth, built from non-ground LiDAR points and therefore void of manmade structures, like buildings or powerlines, and vegetation.

a)



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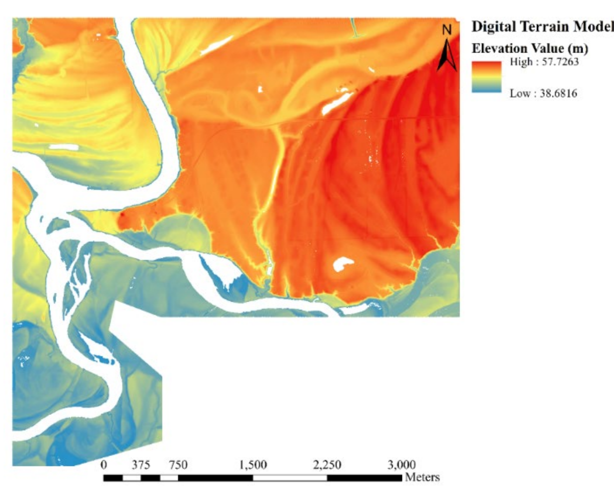


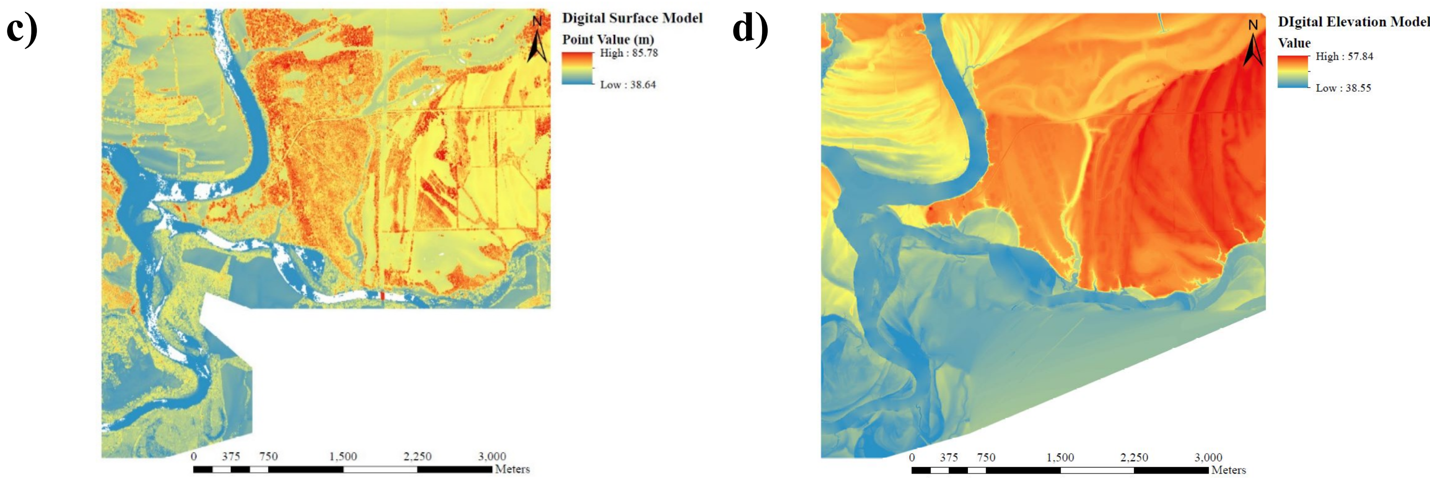


Figure 9. a) LiDAR point cloud for study area, b) Digital Terrain Model (DTM) generated by interpolating LiDAR ground point data using the IDW and nearest neighbor sampling methods, and c) Digital Surface Model (DSM) generated by interpolating both ground and non-ground LiDAR point data, and d) Digital Elevation Model (DEM) generated by creating a rasterized grid from a las dataset filtered for ground points.

After creating the DTM, a triangulated irregular network (TIN) was generated and used to display the topography as a bare earth model in a three-dimensional view, which demonstrates the degree of visibility from an observation point at the site to analyze the geographic advantage of Fort Toulouse's strategic location (Figures 10a-d). A vector data modelling approach was used to generate the above-ground analysis of the study area, meaning that features such as the surrounding vegetation and fort were digitized from satellite imagery and artistic renditions with heights created to fit the contours of the TIN, further resembling the environment. The resolution and scale of the digital landscape greatly impacts the quality of the model and by utilizing higher resolution spatial data, higher quality analysis can be derived.

Satellite imagery obtained from DigitalGlobe and USGS EROS Data Center for the study area then overlaid the TIN, adding to the realism of the rendition. Within the three-dimensional geo-workspace using ArcScene 10.5, the user can toggle through the environment in whichever direction desired. In addition to geo-visualization from terrain analysis, several mathematical variables such as slope gradient, aspect, and curvature are applicable values that can be generated with ArcGIS software and were utilized as potential variables for site suitability analysis.

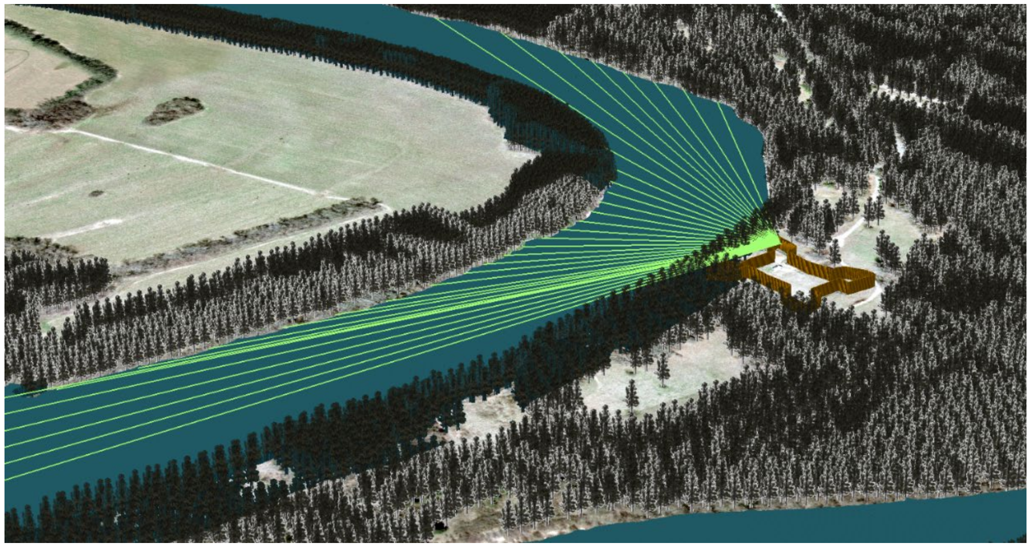
3.2 Analytical Results and Discussion on Terrain Analysis

Within the GIS database, a defined region of the study area with a specific coordinate base is focused on and data layers are spatially registered. These data layers exist in the form of digitized, or scanned paper maps and secondary layers may be satellite imagery or aerial photography used to enhance the primary data (Kvamme 1999). Images can be processed to enhance visibility and classification, allowing features to be spatially registered to the map. Digital elevation layers may also be interpolated systematically, creating a simulation used to visualize a study area and process terrain features that estimate ground steepness and drainage lines, creating line of sight visualizations throughout a specified region (Kvamme 1999; Ebert 2004).

Geovisualization techniques—visualization of geographic information—provide a unique, interactive approach that inextricably links the geographical information that resides beneath the renditions. The capabilities of the 3D GIS allow users to explore different layers of the map, zoom in and out, change the visual appearance of the map to fit specific environments, and represents further developments in cartography that take advantage of modern computer displays and graphics to render changes to a map in real time. The spatial analysis shows that the GIS provides an effective environment for simulating human activity patterns and site selection. The digital map demonstrates the landscape and geographically determinative features within the context of the social and political landscape of the region, being that Fort Toulouse was surrounded by several native Alabamian settlements. For this reason, the GIS software becomes a very powerful tool for this project.

The results of the analysis support the argument that the French strategically placed Fort Toulouse on the landscape for highly functional purposes, such as achieving optimal line-of-sight for monitoring water networks and trade routes. From the observation point where the Northeast bastion is located at Fort Toulouse, sight lines depict the degree of visibility to the east of the Coosa River where oncoming travelers may have first encountered the fort (Figure 10a). Visibility is also depicted to the west of the Coosa River, towards the junction of the Tallapoosa River, which eventually becomes the Alabama River (Figure 10b). Terrain analysis and geo-visualization techniques also provide a realistic representation of how the fort appeared during its French occupation throughout the eighteenth century (Figures 10c-d). The presence of the French fort sitting high on the bluff most certainly would have caught the attention of people as they traveled along the waterway. In addition to its function as a trading post, Fort Toulouse would have also showcased the French's social, economic, and political power in the region due to the fort's establishment.

a)



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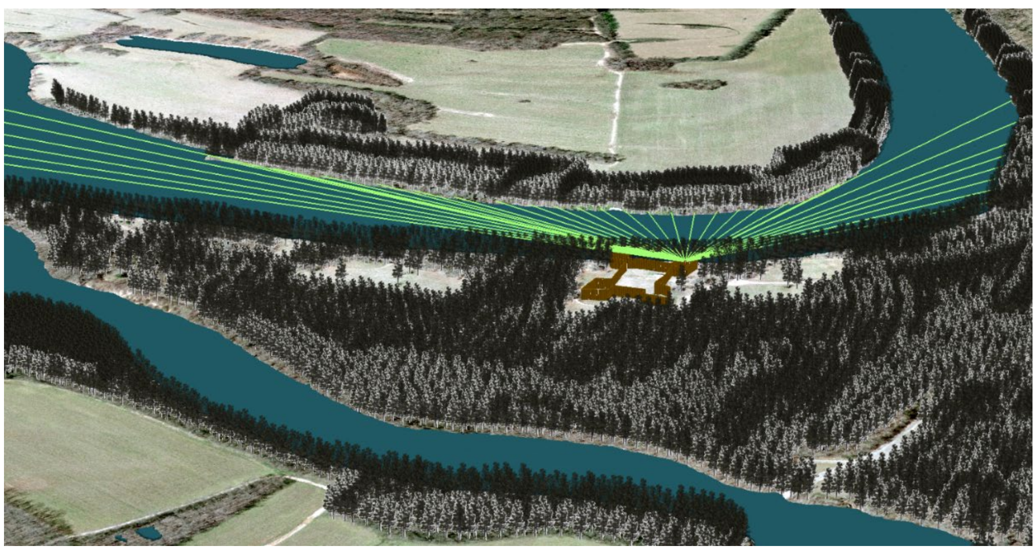

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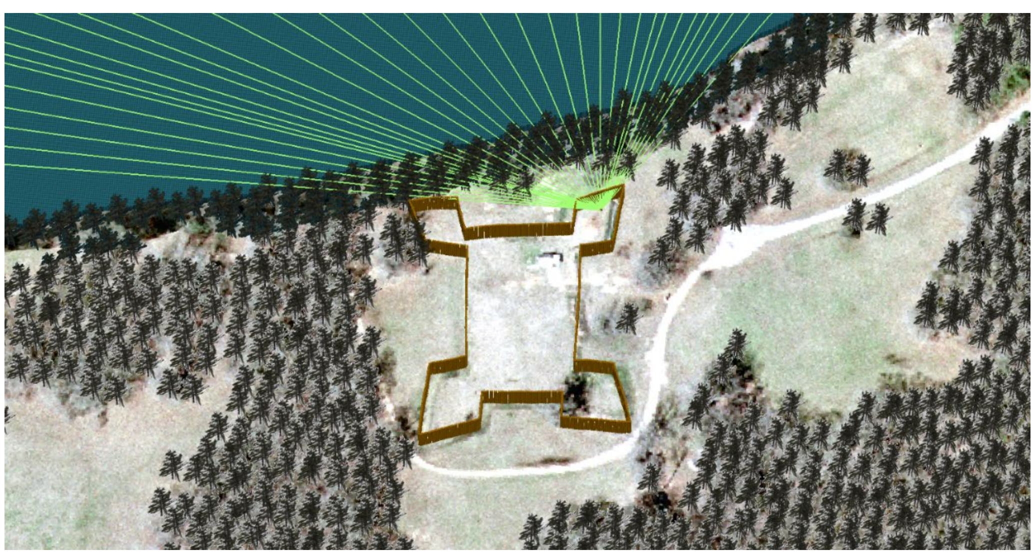

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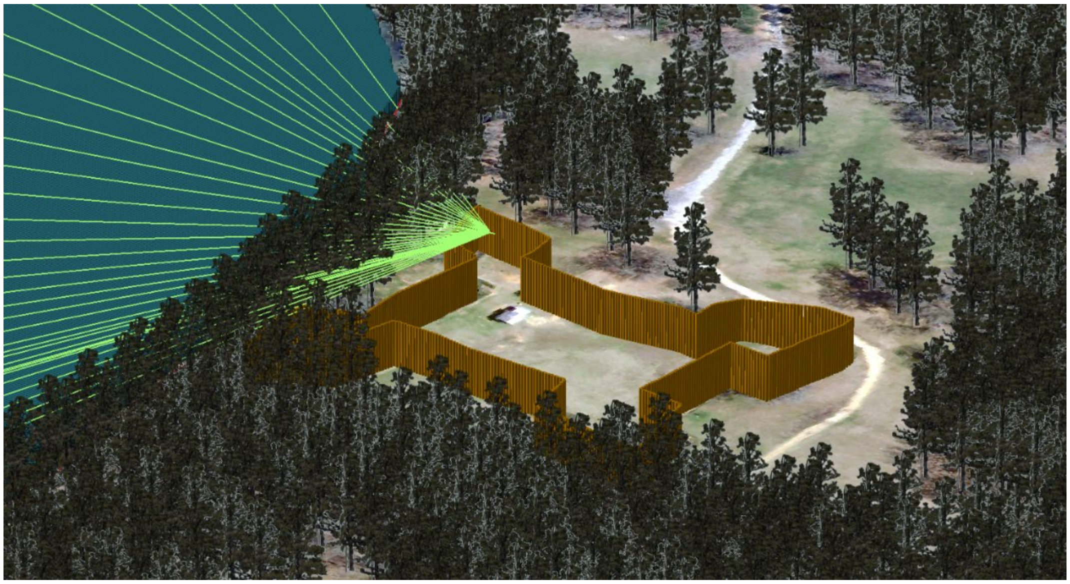


Figure 10. a) East northeastern view of terrain model showing the Coosa River to the East and West, b) North northwestern view of terrain model showing the Coosa River to the East and West c) Northern bird's eye view of Fort Toulouse rendition with sight lines and d) zoomed-in East northeastern bird's eye view of Fort Toulouse rendition with sight lines.

Because of the historical nature of Fort Toulouse, research efforts are reliant on textual, architectural, and archaeological evidence to support hypotheses about human activity at the site. Traditional, static maps have limited exploratory capabilities. Terrain analysis of the study area can allow researchers to visualize a representation of the landscape as it may have appeared during the historical period of interest. "GIS can analyze the information in traditional, historical texts describing places, and from other forms of historical geographical investigation, such as historical topography" (Alhasanat et al., 2010:351). Sites dedicated to defensibility and fortification such as Fort Toulouse often share environmental, geographic, and climatic aspects that prove to be advantageous for defensive measures. Chartering foreign land was a challenging endeavor for French explorers who came to the New World in search of prosperity and colonization. Predictably, the geographic location of Ft. Toulouse greatly contributed to the success of the

French defensive strategies that occurred at the site. Because of the preexisting native occupation in the surrounding area, French defenders were able to develop cordial relationships centered on trade agreements and peace negotiations. Occupying the area at the junction of two river systems also served as an advantage for the French, allowing visibility in multiple directions.

Terrain analysis using GIS capabilities creates a new dimension of research that facilitates historical archaeology and geographic studies. The results of the analysis show that the site of Fort Toulouse is carefully situated at routes of transhumance and hydrography. During a critical period of social-political movements amongst the Europeans and Native Americans, several important factors played into the site selection of Fort Toulouse by French settlers. It is hypothesized that this decision aided in efforts to monitor perennial water sources and established trade and courier routes (Alhasanat et al., 2010). From the spatial analysis and geo-visualization of the landscape, the proximity of Fort Toulouse to roads and water sources became potentially significant variables for site suitability analysis.

3.3 Data and Method on Visibility Analysis

Viewshed analysis, an important extension of 3D spatial analysis, is an algorithm-based method used to quantify the visibility of a landscape from a specified location. By using the elevation value of each cell in a DEM, visibility for any given point in the study area can be calculated. Every cell is initially treated as visible unless the topography creates points of obstruction, and in binary viewshed, its most basic form, a raster surface is produced that indicates visibility by the value of '1' and non-visibility by the value of '0'for each cell (Nutsford 2015). The visual significance of perceived terrain describes how influential visible terrain is to an observer's perception of the environment, which is reliant on the distance to the perceived object and the vertical dimension—slope, aspect, and curvature—of the terrain.

Line-of-Sight (LoS) is a procedure used to calculate the visibility of a terrain from along a straight line from one point to another point (Figure 11). This can be visualized by creating a ray or sight line in one direction from the observer point to the target point. Once the sight lines are created using a tool in ArcToolbox, a check for LoS determines obstruction points along the path results in values that and whether a cell along the sight line is visible or not. Undoubtedly, the most important feature across the landscape surrounding Fort Toulouse are the waterways—visible to the east and the west from the bastions of the fort. To quantify the visibility of target areas across the waterway, sightlines were constructed from the observer point.

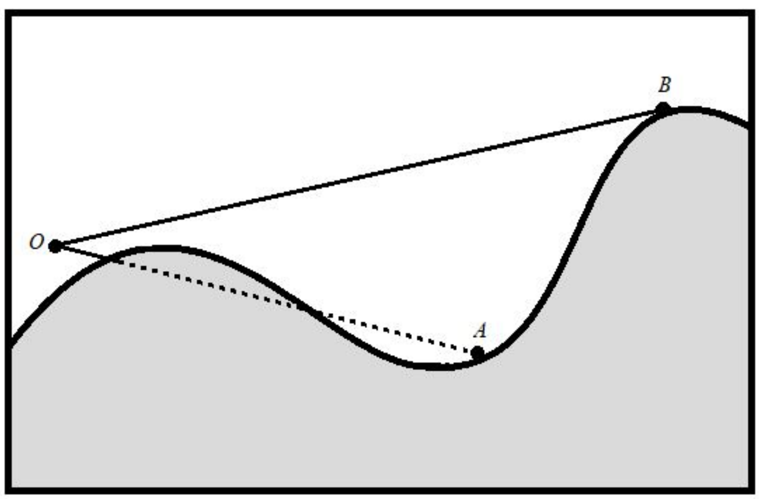
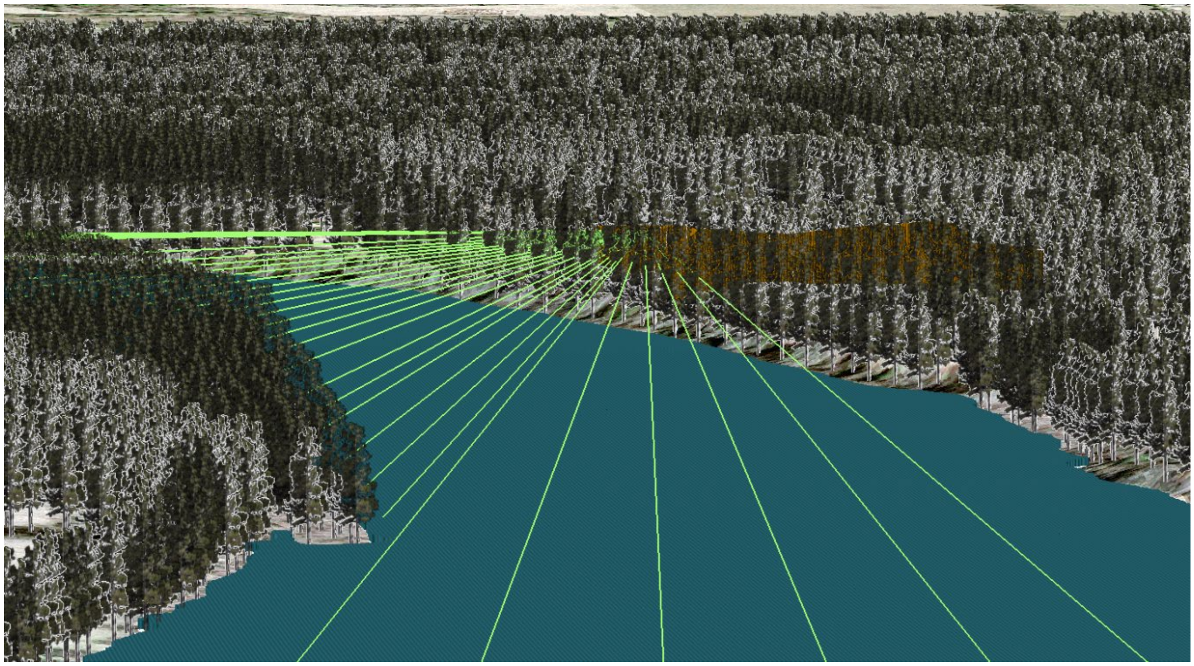


Figure 11. Side view of a sight line between observer O and points A and B. By conducting LoS (line-of-sight), Point A is found to not be visible as the sightline between O and A is obstructed by the hill located between the points, whereas Point A is visible as there is no part of the terrain between O and A that obstructs visibility.

a)



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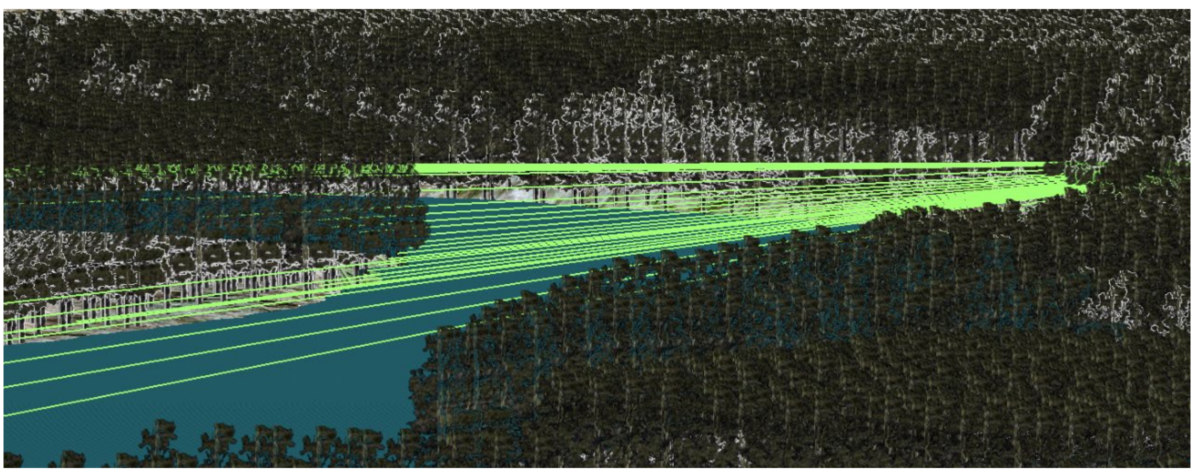


Figure 12. a) Three-dimensional view of the sight lines constructed from the Northeast bastion at Fort Toulouse to various points along the Coosa River bank, and b) three-dimensional, parallel view of sight lines from the Northeastern bastion at Fort Toulouse, showing the angle that is created when measuring from one elevation (at Fort Toulouse) to the next (along the riverbank).

Two types of quantitative approaches were used during visibility analysis—line of sight analysis, which determines whether two points in space are inter-visible, and a perspective approach that displays identified areas of visibility from a point of observation—the northeastern bastion of Fort Toulouse. The line-of-sight and viewshed analysis was conducted using ArcGIS

10.5 Spatial Analyst extension using the DTM generated during terrain analysis with a resolution of 1 meter. Sight lines for the study area were constructed to determine whether points along the Coosa River were visible from the fort's northeast bastion, what obstruction points, dependent on the elevation of the landscape, exist and how they affect the degree of visibility to those areas of interest (Figures 12a and 12b). Since the value stored in each cell of the raster represents the height of a subarea, it will not be the exact value for each physical point in a terrain. Therefore, the higher the resolution of the raster used for visibility analysis, the more accurate the representation of the area will be. When performing visibility analysis, it is important to consider the sampling method used by different input data because different methods will provide different results.

3.4 Analytical Results and Discussion on Visibility Analysis

Defensibility of a location is highly dependent on the visibility and relevant variables of the surroundings. Results showed that the French could successfully deter approaching parties from both directions on the Coosa River. The visibility of surroundings shown from the terrain analysis (Figure 13a) where the bastion, situated at the northeast corner of the fortified structure, provided the ability to monitor and defend the area with ease. Visibility analysis allows for researchers to understand the social dimensions related to visibility and patterns that are recognizable as accessible and unchanged, and the ways in which manmade structures were articulated on the landscape with specific intentions.

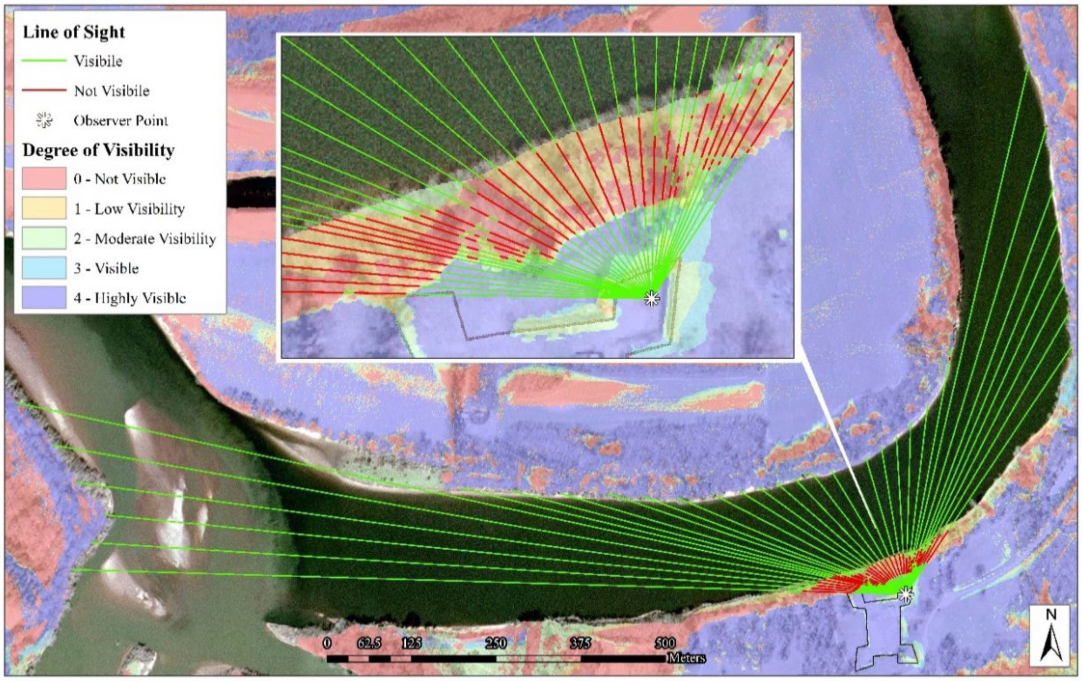
From an archaeological point of view, visibility analysis opens the prospect of investigating the material and physical conditions that were used to alter and structure the landscape and how those landscapes are constantly being modified and used. Frequently, the current spatial layout of a landscape will not correspond to a configuration that existed at one point in time, but one that spans many time periods and human generations (Llobera 2007). Patterns in visibility, and particularly inter-visibility patterns such as the junction of two rivers where Fort Toulouse was constructed, are linked to movement of humans and the subsequent transformation of the landscape by visibility analysis.

The results of visibility analysis help to understand and quantify how much land is visible around the fort and what impact that may have made on defensive measures while also identifying which features are most prominent across the landscape. The visibility analysis tool interpolates the DTM and provides the capability to determine visibility at a fine scale of ground-based locations (Etherington et al. 2008). The results allow for analysis by providing classification in five values, 0, being nonvisible, through 4, being highly visible, as shown in Figures 13a and 13b. The tool does so by calculating the visibility of each cell center by comparing the altitude angle to the cell center with the altitude angle to the local horizon, which is computed by considering the terrain that intervenes between the observer point and the cell center and categorized by the value that is returned by the tool calculations. By overlying the visibility analysis results on the TIN created for terrain analysis provides an added visualization for the degree of visibility from the observation point, as shown in Figure 13b.

One particular issue which has been identified with the visibility application and methodology to this data is that the landscape surrounding Fort Toulouse might have been considerably more wooded during the historical period than it is today. Based on the results of the research, I hypothesized that fortified sites tended to be constructed in clearer areas of the landscape or had been cleared for land use. Additionally, based on the evidence that indigenous peoples constructed a monumental mound two centuries beforehand just a few hundred meters away from the location of Fort Toulouse, the area had been used by humans for quite some time before the arrival of the French. However, there are no available reports on whether or not the land was continuously occupied from the time the mound was built until Fort Toulouse was established.

Theoretically, an observer can see any point that is located within the determined regions of visibility and these results may be interpreted as revealing the intentions of the French for constructing Fort Toulouse at this location because of the areas of high visibility. It is equally plausible that other variables, such as elevation, proximity to water, and ability to showcase their presence which are associated with the area of visibility being the causing factor. Therefore, the location of Fort Toulouse on higher ground may be interpreted as a side effect of the visibility rather than the alternative, that the visibility of the observer point, or northeast bastion at Fort Toulouse, is a side effect of the selection of high ground.

a)



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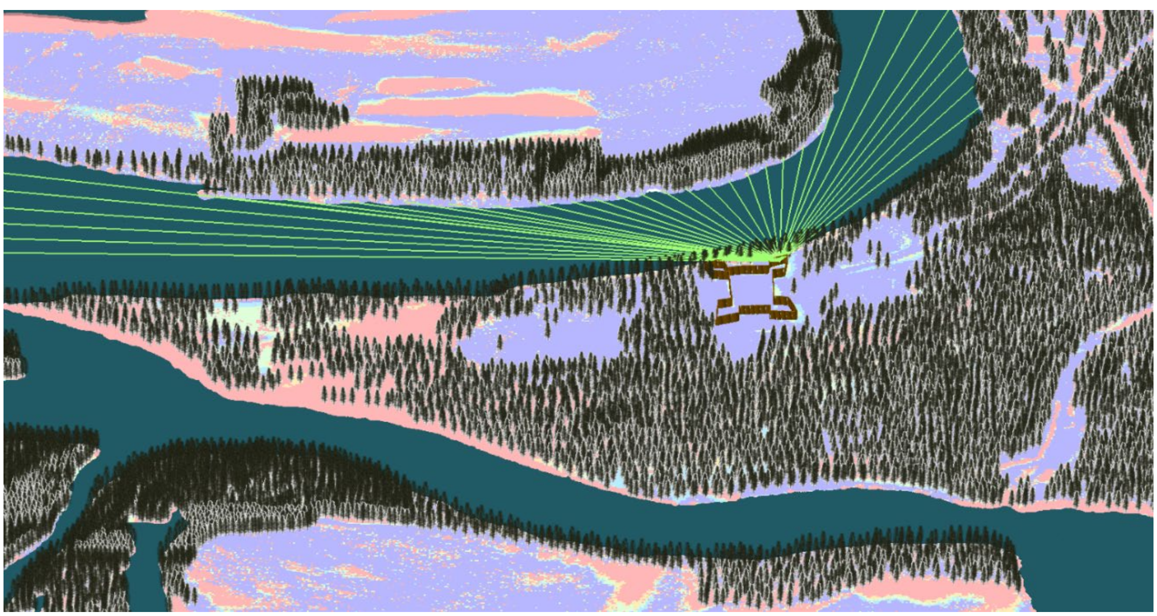

Figure 13. a) Viewshed analysis from the observer point, the Northeast bastion at Fort Toulouse, with Line of Sight analysis displayed. The results of the viewshed analysis depict four degrees of visibility ranging from non-visible (light red) to highly visible (light purple), and b) a three-dimensional view of Fort Toulouse with viewshed results overlaying the TIN surface, the Coosa River is to the North and the Tallapoosa River is South.

Chapter 4. Site Suitability Analysis

4.1 Data and Method on Site Suitability Analysis

Machine-learning algorithms have been applied to a wide range of scientific research questions regarding pattern recognition and likelihood of occurrences across landscapes (Huemann et al. 2011; Huemann et al. 2013; Ha et al. 2016). Models using machine-learning algorithms produce statistical results that are based on integrative calculations and define site suitability or the likelihood and patterns of habitation and land-use. Variables used in such models consist of presence-only data that is incorporated into the niche concept—finding patterns of habitation and substantial human impact across landscapes. This concept is a function of the environmental, topographic, and geographic conditions that influence land use decision-making processes and occurrences.

One of main objectives in this research is to understand what factors of the natural, built, and social environment correspond to human site selection for economic prosperity and defensibility, and the relative importance of those factors that contributed to the success of French settlement and occupation of Fort Toulouse. To address the main objective, the niche-based approach used by Maximum Entropy (MaxEnt) modelling is applied and the inputs use variables of environmental and geographic presence that are both continuous and categorical (Elith et al. 2006). When provided with consistent input parameters, MaxEnt is a deterministic model that combines data types using linear and nonlinear functions. Different functions can be hinged together to understand the significance and impact of each variable by providing useful model assessment tools in a user-friendly graphical interface for model prediction and analysis results. The results are based on validation using the receiver operating characteristic, AUC-ROC, which is a common classification statistic adapted to presence-only methodology. The AUC-ROC statistic was developed for binary presence-only classifications and compares the results against randomly-generated background data to distinguish patterns of land-use occurrence from the random environment and is best suited to be performed against small datasets (Huemann et al. 2011).

In this use of the MaxEnt model, the following assumptions have been made: First, areas with proximity to major waterways would be more suitable for French economic gain and survivability. Secondly, areas with proximity to waterways would be more advantageous for defensive efforts. Thirdly, land use decision-making is a process that is influenced by demographic considerations, socio-economic factors, and environmental settings and conditions. Lastly, because of the absence of demographic and consensus data for the time-period in which Fort Toulouse was first established, social and economic conditions are best represented by historic and modern-day road networks that were influenced by well-defined trade and transportation routes used by native populations long before the arrival of the French settlers.

A list of variables used in the MaxEnt model is provided in Table 1. Landsat data provided by the National Land Cover Database (NLCD) land cover collection, collected by USGS (U.S. Geological Survey, Department of the Interior), was accessed via the NRCS Data Gateway and selected for inclusion in this analysis and uses classification schemes such as topography, agricultural and census statistics, wetlands, and other land cover maps, which have been applied across the study area. A DEM at a spatial resolution of 30 meters was used to integrate the contours and spot elevations to obtain a finer level of detail. Polygon data for waterways and line features for road networks were processed using ESRI's ArcGIS 10.5 software to produce raster inputs used in conjunction with NLCD and DEM raster data for the MaxEnt model. Several other variables were tested for model selection that were excluded from the results due to high covariance with elevation, such as slope angle, slope aspect, and hillshade, which produced less than 0.5% significance to site suitability results.

Variable	Description	Year of Data
ROAD_DIST	Distance (km) of line features representing road networks from the site of Fort Toulouse	2014
HYDRO_DIST	Distance (km) of polygon features representing waterways surrounding the site of Fort Toulouse	2014
DEM	Digital elevation model (m) of the study area based on interpolated contour intervals collected and processed by U.S. Geological Survey, accessed through NRCS Gateway	2015
NLCD	National Land Cover Dataset land cover collection (m)	2015
Slope	Processed from the 30 m resolution DEM; gradient or steepness values for each cell of the raster.	2015
Aspect	Processed from the 30 m resolution DEM; identifies the compass direction that the downhill slope faces for each location.	2015
Hillshade	Shaded relief from a surface raster by considering the illumination source angle and shadows.	2015

Table 1. Variables used in MaxEnt model for site suitability analysis.

Initial testing of variables included a series of five-iteration runs that eliminated variables found to decrease the testing gain and those that contributed less than 0.5% to the model (Table 2). A jackknife analysis was applied for all environmental and land use variables to the models. Once the list of variables was reduced by level of significance, a more rigorous test of 100 iteration runs was conducted. Once the results were collected, the MaxEnt software generates a map of likelihood occurrence that was derived from all environmental and land use variables for potential fortified sites.

4.2 Analytical Results of Site Suitability

Variable contributions results are illustrated as standard line graphs (Figure 14a-d). The contribution of each variable varied, and the major contributors were distance to waterways (73.1%), elevation (19.6%), distance to road networks (6.2%) and land use data (0.6%). Distances to hydrography and waterways between roughly 0 - 2,000 m shows the most suitable areas and locations for potential fortresses (Figure 14a). Elevation between 30m and 50 meters provides the best condition for potential fortress location (Figure 14b). Distance from road networks around 4,000 meters show the most suitable areas for potential fortresses (Figure 14c). A less significant variable than the three previously mentioned was land use data, however, the results clearly showed that the likelihood of potential fortress placement tends to increase at land use type 11—open water—and 41—deciduous forest (Figure 14d). In other words, areas near by the open water and deciduous forest provide the most suitable condition to build fortresses.

The MaxEnt model produces a map of occurrence probabilities for the site average and tables detailing model selection of variables that have been tested with the datasets. The AUC-ROC can serve as a useful indicator of model fit. Figure 15 illustrates ROC curves of model sensitivity as a function of 1- specificity, calculated as fraction predicted area in the MaxEnt model (Heumann et al. 2013). In other words, if the mean of AUC value is close to 1, it indicates that a prediction of the model is significantly better than random instances (0.50). Specifically, conditions of fortress location, which are generally constrained to certain ranges of elevation and distance to waterways, has a relatively high AUC (0.750). The AUC value would be lower if potential fortress location is widespread distribution throughout the study area (close to the random instances). Figure 16 represents the likelihood of fortified sites for Elmore and Montgomery counties. Areas with relatively close proximity to waterways show moderate to high likelihood of occurrences for fortified site selection. Additionally, areas with elevation between 30m and 50m show similar likelihood patterns. The results provide a high correlation with assumptions made during the planning phase of the site suitability analysis.

Variable	Percent Contribution	Permutation Importance
Distance to Hydrography	73.1%	38.4
Elevation	19.6%	25.2
Distance to Roads	6.2%	35.7
NLCD	0.6%	0.2
Slope	*	*
Hillshade	*	*
Aspect	*	*

Notes: An asterisk (*) indicates variables excluded due to negligible contribution

Table 2. Site suitability variables, each with percent contribution and permutation importance.

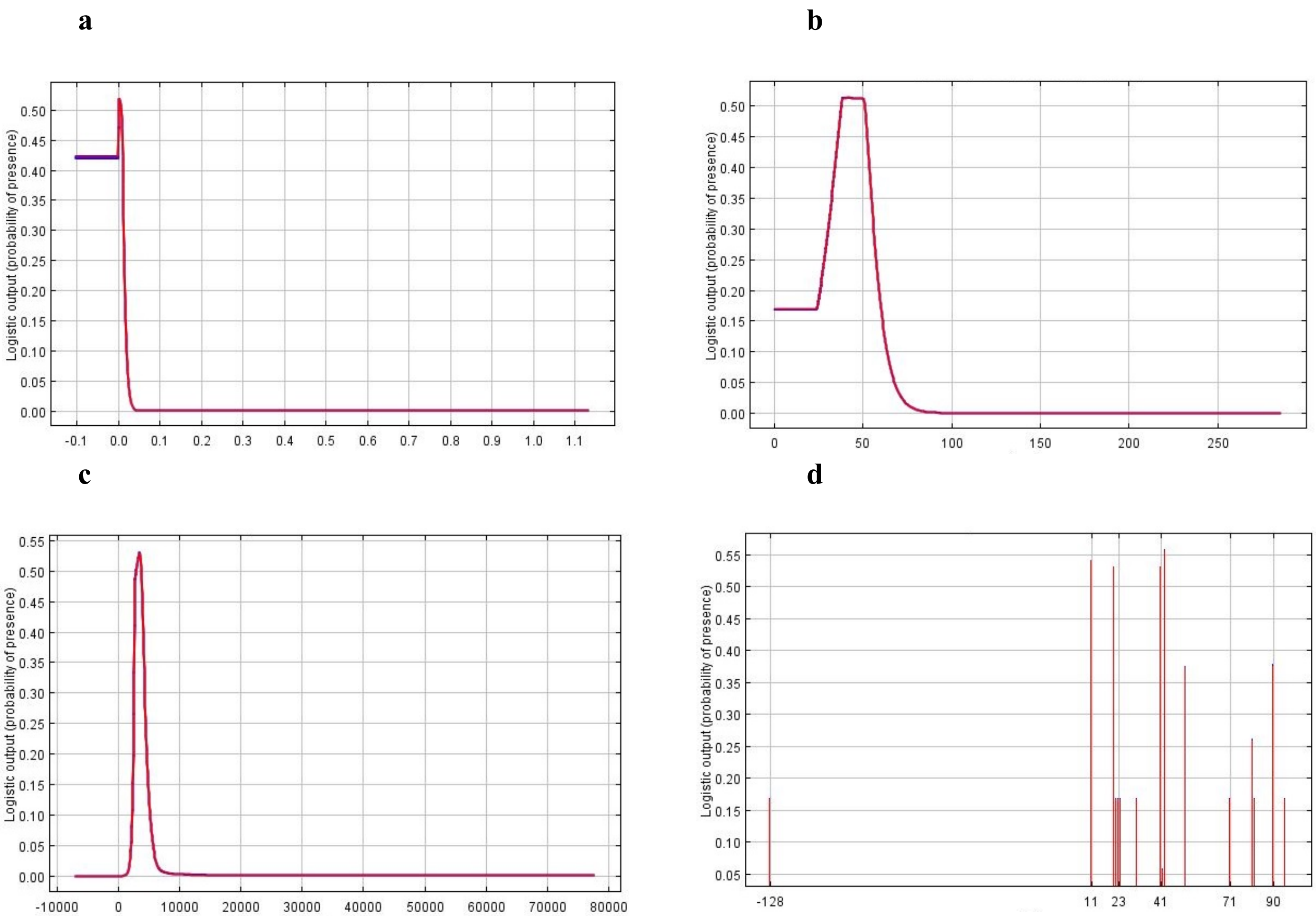

Figure 14. Response curves using environmental variables and human population for a) distance to hydrography (73.1%), b) elevation (19.6%), c) distance to road networks (6.2%), and d) land cover type (0.6%).

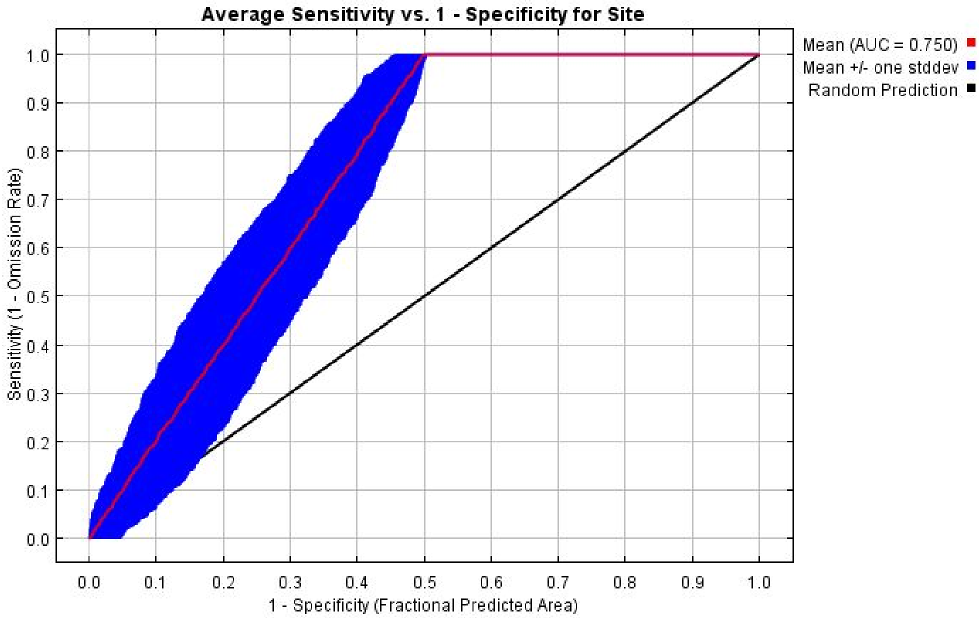

Figure 15. Receiver Operating Characteristic (ROC) value for model fitness. The median and standard deviation (AUC) value is listed.

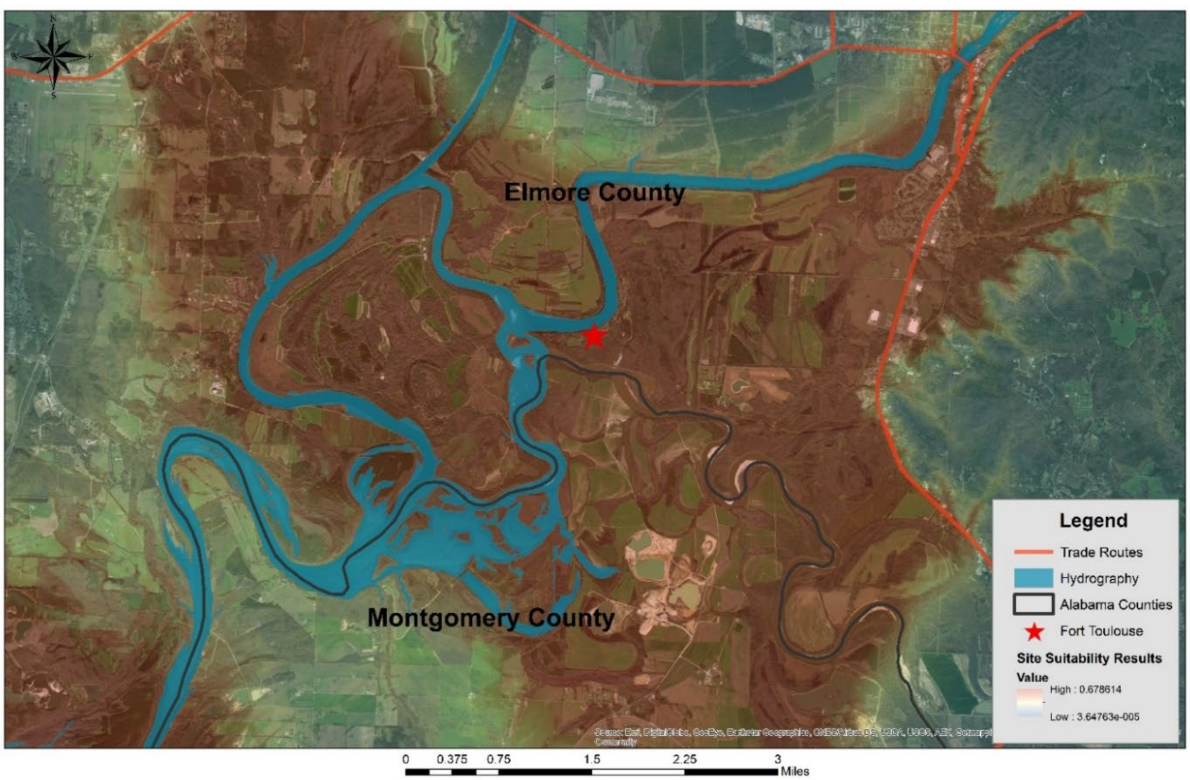

Figure 16. Site Suitability analysis in portions of Elmore and Montgomery counties.

For sites that are situated along riverways, relatively higher elevation is desired to avoid the repercussions of soil erosion near the river bank. However, for the site of Fort Toulouse, the river bank receded far more than the French initially anticipated, causing a series of reconstruction events over the course of one-hundred and fifty years (Waselkov et al. 1982). Elevation was a significant variable contributing to the suitability of site selection for defensive fortification. Proximity to waterways was the dominant factor in site suitability analysis and undoubtedly served the French in their effort to maintain control over the fort.

Chapter 5: Conclusion

GIS creates a new way to understand historical data, enhanced by better visualization of the GIS database, with easier data handling and greater uniformity, quality, and accuracy of historical information. The terrain analysis allows for a better understanding of how both the French and the indigenous peoples moved throughout the landscape for defensibility and along trade networks. The navigability of waterways surrounding Fort Toulouse served as an advantage for settlers and indigenous peoples who relied on the trade network for survival. The results of the visibility analysis suggest that there is an optimal degree of visibility that undoubtedly impacted the success of site as a defensive fortification. This evidence further suggests that the French utilized this location to gain political and economic control over the region, a concept known as materialization of ideology. However, error is inherent in all types of data, and errors in the DTM used in the model can result in the visibility map not accurately representing the actual visible area from a point on the landscape (Jones 2006). Quantization effects of rasterizing the elevation model and interpolation errors introduced by the algorithm used in ESRI's ArcGIS 10.5 software can also cause locational displacement of elevation values. Such errors may also propagate into secondary errors within the terrain analysis and attribute values that determine the visibility analysis results. Such errors have been investigated by Fisher (1992) who developed the concept of "fuzzy viewsheds" that incorporate a degree of uncertainty into the calculation of the visibility map. The fuzzy viewshed approach is beyond the scope of this thesis but would certainly offer a method of increasing the accuracy of results and incorporating estimated errors in methodology for future visibility analysis.

Another source of information concerning the accuracy of the visibility analysis may come from sensitivity studies where the height of the observer can be increased or decreased, and the experiment repeated to assess the accuracy and impact of observation placement on the experiment results. It has not been possible to conduct sensitivity analyses in this case, but it is encouraging that similar sensitivity studies have shown that an offset of four meters showed almost no variation in the patterns discerned by the analysis (Kvamme 1990). However, a genuinely reliable source for determining the level of accuracy from the visibility analysis results lies with field observation, and the author can report that an afternoon spent identifying features from the tested observation point provides a very good correlation with the theoretical visibility map conducted of the study area.

The data on modern landscape variables were relatively course-grained during the site suitability analysis and lack temporal dimension that reflects the historic period in which the site of Fort Toulouse was first selected and constructed. Historic data sources, particularly of census data and population size for neighboring native villages, could greatly enhance the accuracy of the model's outcome if ever to become available. Additionally, elevation was found to be a dominant factor, yet the resolution used for site suitability analysis was 30 m in order to maintain consistency in spatial resolution across all types of datasets used in the MaxEnt model. Only four variables of significance were used in this site suitability analysis. Having more fine-grained data would potentially affect the predicting modelling and are much needed, but data sources with higher resolution were unavailable for this study. Future analysis would benefit from the use of more potential variables. Finally, it must be recognized that remote GIS predictive modelling, while providing a useful guide for site selection and overall analysis, is no substitute for field observation, which could hypothetically produce drastically different results. Nevertheless, the results of the site suitability analysis indicate that site defensibility and fortification could benefit from predictive modelling using the integration of environmental and social variables using GIS, potentially becoming a modern-day solution.

This thesis has presented various methods of investigating the spatial components within the historic landscape of Fort Toulouse that certainly contributed to the success of the post and are rather easy to apply using relatively inexpensive GIS technology. By means of easily available data sources, the analysis techniques and procedures produced intriguing results that helped to develop theories about site selection based on visibility, elevation, proximity to water, and locational advantage. The interpretation of the results must remain tentative, as further evidence is needed in order to evaluate the accuracy of the outcome. Nonetheless, the results of this research indicate that historical archaeological surveys can benefit from predictive modeling using the integration of environmental variables with GIS procedures. It is hoped that this thesis has suggested that terrain modelling, visibility and site suitability analysis provide results that can be inferred from an archaeological perspective of historical sites such as Fort Toulouse.

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Spatial 3D Analysis and Site Suitability for Fort Toulouse in Elmore County, Alabama

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