Cultural Resource Management and GIS

A Course Project

Written by

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Introduction

It is the professional responsibility of the cultural resource manager to direct archaeological efforts in areas defined by political boundaries. In addition, it is the ethical responsibility of an archaeologist to analyze and publish accurate data concerning ancient inhabitants who occupied the landscape. As a result, it is important that site formation processes are not only understood but also evaluated so that accurate, chronological information can be extracted. With the help of GIS, cultural resource managers can work closely with archaeologists and direct excavation efforts to well preserved archaeological sites that are threatened by development. Cultural resource managers and city planners have the daunting task of protecting archaeological remains in the midst of rapid population growth and development. There are several laws that protect archaeological resources yet with at least 12,000 years of human occupation in North America it is difficult to know precisely where to begin. To a certain extent sites of proposed development are surveyed but this process is lengthy, arduous and often randomly conducted. Implementation of a GIS model would help pinpoint specific areas for detecting "in situ" sites and/or "high risk" areas in order to promote preservation, excavation and analysis in a more efficient manner.

Site Formation Processes

Archaeologists excavate archaeological remains for the purpose of extracting information in order to reconstruct the past and develop theories that explain ancient behaviors. With this objective in mind it is crucial to consider the accuracy of the data from which these theories are being built upon. A multitude of techniques have been developed through time in order to extract as much information as possible from archaeological sites. Unfortunately site formation processes can create an obscured picture that may lead to the development of erroneous theories. Wood and Johnson (1978: 315-316) point out that archaeologists have often operated under the assumption that past human activities are "reflected" (Childe, 1956: 1) and even "fossilized" (Binford, 1964: 424) in the "highly patterned" distribution of "all"

archaeological remains (Thompson and Longacre, 1966: 270). By 1968, archaeologists such as Ascher, followed by Krause and Thorne in 1971, and Schiffer in 1972 began to shift attention to the effects of site formation processes on the archaeological record. Over the past 30 years a tremendous amount of literature has been dedicated to the study of site formation processes. To my knowledge there is not any literature that addresses predicting site disturbance prior to excavation for the purposes of cultural resource management in the context of salvage archaeology. Furthermore, as of yet, no GIS applications address site formation processes and potential for disturbance once the site has been excavated.   If site formation processes can be identified prior to excavation it will save a lot of time and lead to greater accuracy in the archaeological record.

<div align="center">Predicting "Archaeological Sensitive" Areas</div>

Predictive models have been widely criticized in the archaeological community.   Ebert (2000) argues that inductive predictive modelling methods are inefficient in terms of detecting a lack of homogeneity in one's data and criticizes the translation of maps into variables. He claims that it focuses on sites rather than systems and attempts to relate location to environmental variables do not have a "theoretical basis" to be effective predictors. According to Warren and Asch (2000: 6) most archaeological predictive models rest the assumptions that settlement choices made by ancient people were strongly influenced by characteristics of the natural environment and that these factors are accurately depicted on modern maps. Woodman and Woodword have noted that "case control" studies are often used in predictive modelling. Procedures such as logistic regression assume a linear relationship between dependent and independent variables, which can take the form of correlation, confounding or interaction. In one case study 46 known prehistoric sites in an area, known as the Aberdeen Proving Ground (APG), helped facilitate an effective way to locate the variable potential of other archaeological sites in the area. The investigators decided to study a database containing 572 prehistoric sites located in areas of Upper Chesapeake Bay (UCB) that most closely resembled the environment

of the APG. The researchers utilized a deductive approach and divided the sites from the UCB into shell midden and lithic scatter categories. Their basic assumption was that the different sites would be located in different circumstances with respect to soil, soil drainage, proximity to water, topographic setting, slope and aspect. These characteristics were recorded from the UCB database along with a comparative background sample of 500 random locations taken from within the APG. To decide which variables to use in the construction of their specific predictive model the authors utilized an inductive procedure based upon the generation of a series of frequency tables for the site and random background locations with respect to each of the environmental variables and combinations of variables. This enabled them to eliminate the variables that were not relative to site prediction. They narrowed their variables down to proximity to water, water type, elevation range, and topographic setting. The authors chose to create weightings for particular combinations of classes possible between the four predictors. Construction of the predictive model involved combining the four variables and allocating each cell its appropriate potential classification dependent upon the unique combination of variables. The accuracy of the model was initially evaluated by comparing the known 46 prehistoric site locations within the APG to it. A more formal assessment of the overall performance of this model was performed by calculating Kvamme's simple gain statistic: Gain=1-(% of total area covered by model % of total sites within model area). This is based on the assumption that if the high potential area is small relative to the overall study area and the number of sites found within it is large in relation to the total for the entire study area then it is a fairly good model (Kvamme 1988: 329). This is only one example of the many case studies that have been conducted to construct archaeological site prediction models.
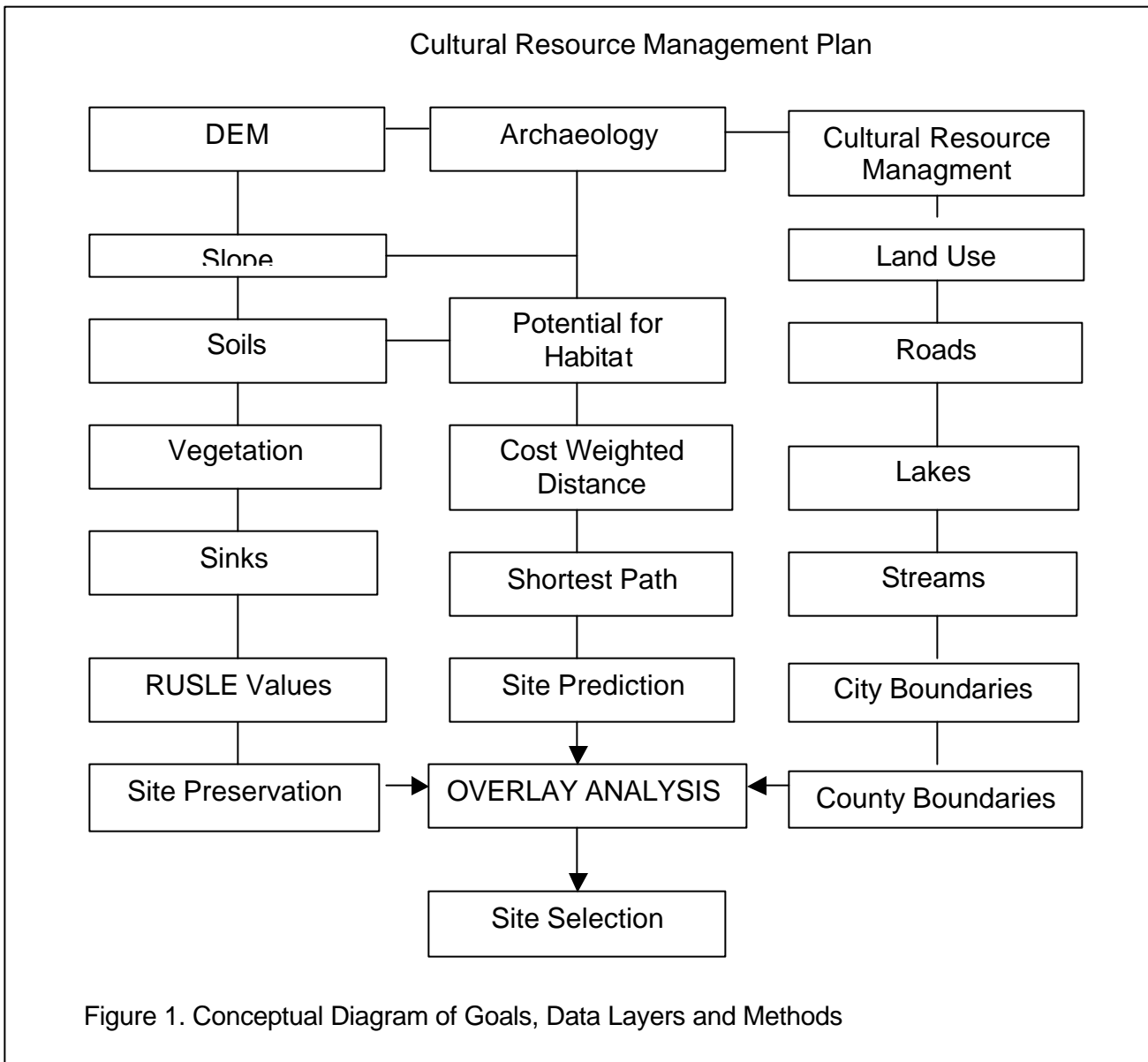
Research Goals

Geographic Information System Software has been utilized in a variety of archaeological studies. Most of the data that archaeologists recover is spatial in character. As a result, GIS has excellent potential for analyses, planning, and management of archaeological resources.

For the purposes of this research paper I focused on the organization or archaeological data, prediction of sites and planning for cultural resource management survey. First I will organize and integrate spatial and descriptive archaeological information into a geodatabase. Then, I will utilize GIS to determine where to survey and maximize recovery or protection of "in situ" archaeological sites. In addition, I make an effort to explain the location of sites and their relative preservation. My ultimate goal is to apply GIS as a mechanism to create a series of analytical archaeological resource maps that will facilitate efficient and effective cultural resource management, planning, mitigation, preservation, excavation and analysis.

Methodology

The purpose of this research is to build a GIS model that will organize previously documented archaeological information, predict probable archaeological site locales, explain known site locations, evaluate relative site formation processes and select areas for archaeological survey. As a result, this project consists of a research design that encompasses calculating the revised universal soil loss equation, computing cost weighted distance, least cost pathways, and overlay analysis. These facets are analyzed individually and then juxtaposed in order to maximize data retrieval. First, the revised universal soil loss equation is calculated in ArcView 8.0 Spatial Analyst 'Raster Calculator' to determine the potential for soil erosion and located areas of increased sedimentation. Next, least cost pathways based on weighted distance and shortest paths were also calculated in the Spatial Analyst Extension to establish "archaeologically sensitive" areas. The shortest paths that were calculated between three source sites and a sample of 150 other sites were given a buffer of 100 meters. These pathways were then clipped based on the city and lake boundaries to provide more detail. Finally, an 'Overlay Analysis' facilitated by the 'Geo-Processing Tools' in ArcView 8.0 was conducted in order to make the final selection of three site areas that would be suitable locations for archaeological survey. The Conceptual Diagram illustrated in Figure 1 provides a view of the general initial process required to achieve these goals.

Cultural Resource Management Plan

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┌─────────────┐   ┌──────────────┐   ┌──────────────────┐
│     DEM     │───│  Archaeology │───│ Cultural Resource│
└─────────────┘   └──────────────┘   │    Managment     │
       │                 │           └──────────────────┘
┌─────────────┐          │                    │
│    Slope    │──────┐   │           ┌──────────────────┐
└─────────────┘      │   │           │    Land Use      │
       │             │   │           └──────────────────┘
┌─────────────┐   ┌──────────────┐            │
│    Soils    │───│ Potential for│   ┌──────────────────┐
└─────────────┘   │   Habitat    │   │     Roads        │
       │          └──────────────┘   └──────────────────┘
┌─────────────┐          │                    │
│ Vegetation  │   ┌──────────────┐   ┌──────────────────┐
└─────────────┘   │ Cost Weighted│   │     Lakes        │
       │          │   Distance   │   └──────────────────┘
┌─────────────┐   └──────────────┘            │
│    Sinks    │          │           ┌──────────────────┐
└─────────────┘   ┌──────────────┐   │    Streams       │
       │          │ Shortest Path│   └──────────────────┘
┌─────────────┐   └──────────────┘            │
│ RUSLE Values│          │           ┌──────────────────┐
└─────────────┘   ┌──────────────┐   │  City Boundaries │
       │          │Site Prediction│  └──────────────────┘
┌─────────────┐   └──────────────┘            │
│Site         │         │            ┌──────────────────┐
│Preservation │──▶ OVERLAY ANALYSIS ◀─│ County Boundaries│
└─────────────┘         │            └──────────────────┘
                        ▼
                 ┌──────────────┐
                 │Site Selection│
                 └──────────────┘
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Figure 1. Conceptual Diagram of Goals, Data Layers and Methods

Data Layer Management

Data layers required for this case study included archaeological spatial coordinates, Digital Elevation Model (DEM) files, soils, vegetation, landuse, roads, lakes, streams, city, and county boundaries. I acquired my base data layers or base information from ESRI, TNRIS, North Central Texas Council of Governments, and the Texas Archaeological Resource Laboratory in Austin. The archaeological data required conversion from excel .dbf files to shape files. It was necessary to define the projection parameters for all of the data layers and then

project the all of the data layers to the same coordinate system. I chose UTM NAD 1927 Zone

14N to match the coordinate origination of the archaeological sites.   The procedure that I

followed to manage the data layers required the following steps:

- ?? Data acquisition: ESRI, TNRIS, DFWINFO, TARL
- ?? Conversion from database files to shape files.
- ?? Defining projection parameters for all data layers.
- ?? Projection of all data layers to same coordinate system (UTM NAD 1927 Zone 14N).
- ?? Creation of Geo-databases to manage data analysis.

The final step prior to analysis was to create a Geodatabase to manage the volume of

data collected during this study. Figure 2 illustrates the Geodatabase design that I constructed.

I created a Personal Geodatabase with Feature Datasets that contained numerous Feature

Classes as you can see here. The only data layers that I could not include in my Geodatabase

were the raster files that I had to file in folders separately.
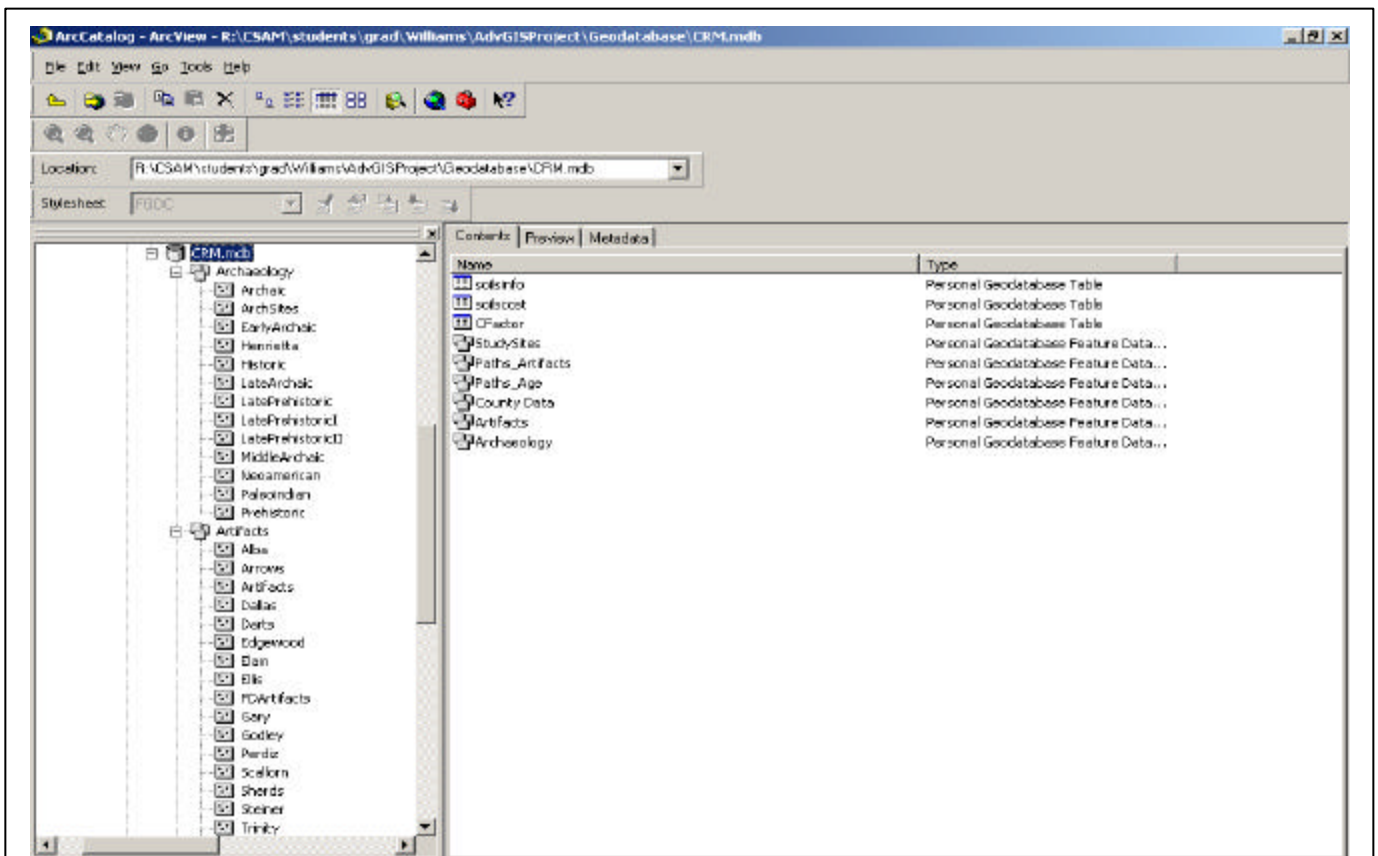
Figure 2. Geodatabase Design

Study Area

Denton and Wise Counties, situated in North Texas, are ideal settings for conducting archaeological research of this nature. These areas encompass two major environmental zones, the Western Cross Timbers and the Grand Prairie. The sites in Wise County are located primarily in pastures near minor tributaries whereas the sites in Denton County were situated near the Trinity River before the impoundment of Lewisville Lake. The parameters of the study area established in these counties are expressed by the DEM in figure 3. The location of the Lewisville Lake sites are beneficial with respect to providing information to cultural resource managers that is related to the effects of reservoirs on peripheral sites. Knowing the potential for future site disturbance is important for cultural resource management purposes. Being aware of past site formation processes is pertinent in terms of the accuracy of archaeological excavations and benefits both fields. Site Catchment areas will be developed based on the location of specific test units within known sites in Wise and Denton Counties. These known sites will provide specific variables that will establish the specific character of the microenvironment of each area. Following excavation, and prior to intensive archaeological analysis, it should be first determined which specific test units have been disturbed and which specific units are chronologically stratified. Beyond detecting mere presence of site disturbance, it is necessary to ascertain the degree of disturbance in certain locations so that further excavation can be directed to locations that are more likely to be undisturbed. These "in situ" areas will provide accurate, meaningful data that has the capacity to contribute to the archaeological record. Once the "in situ" units or areas are pinpointed, the general character of occupations (who they were, when they lived, what they did) can be determined, relative cultural ecological systems (how they related to the landscape) examined, and variables surrounding specific site location evaluated. Based on comparative data between sites, the validity of a GIS model, built to predict and explain the location of "in situ" versus disturbed sites, will be tested with other known site locations or in the field.

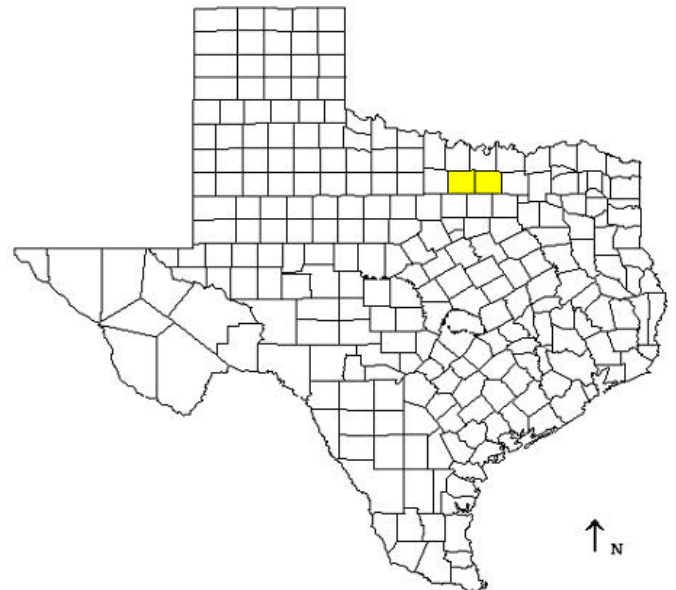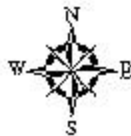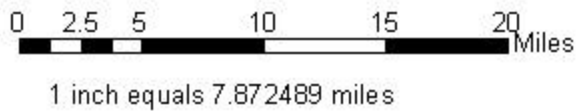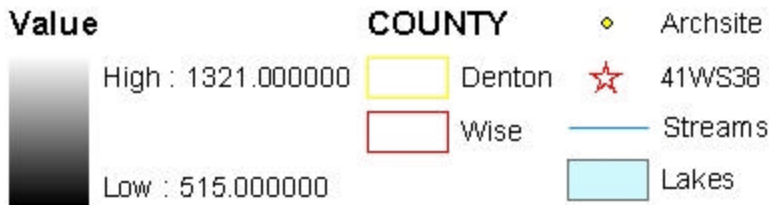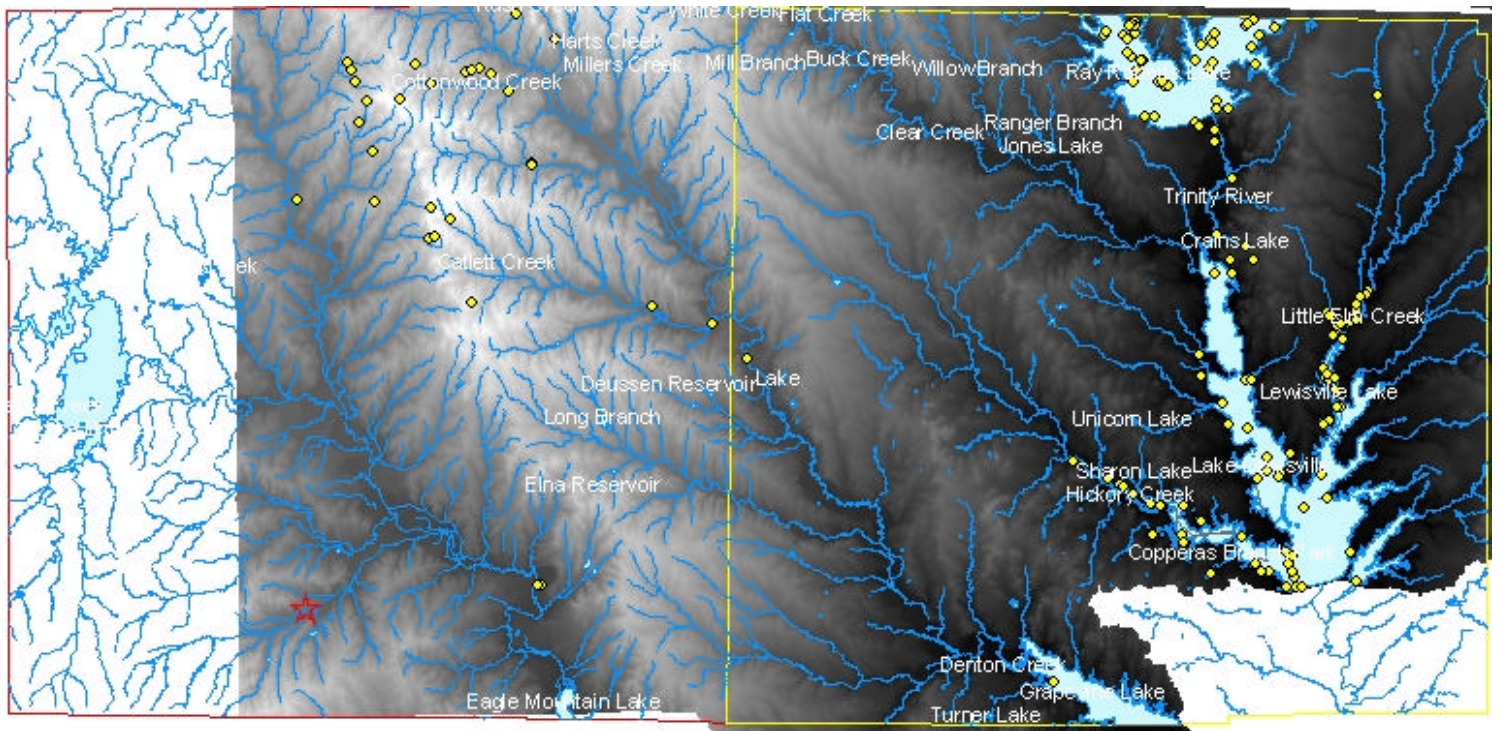# Study Area: Denton and Wise Counties

Figure 3. Study Area (represented by extent of DEM within Denton and Wise Counties)

Differential Preservation: Revised Universal Soil Loss Equation

Calculation of RUSLE is incorporated in order estimate past and future erosion potential at the archaeological site locations. It is also utilized as a mechanism to pinpoint areas that are susceptible to erosion or sedimentation. In order to get a handle on relative Site preservation I calculated the Revised Universal Soil Loss Equation on the study area with intentions to:

- ?? Identify areas susceptible to erosion.
- ?? Identify areas receiving sedimentation.
- ?? Evaluate how these areas correspond with existing archaeology.
- ?? Seek explanations for disturbed versus stratified sites and try to establish areas that have the appropriate conditions for stratification.
- ?? Prioritize Cultural Resource Mitigation.

Figure 4 provides a definition for the parts of the RUSLE equation but does not include preliminary steps of DEM preparation, the C-Factor (figure 5) or the P-Factor equal to 1.

Calculate Slope on DEM and Convert Soils to raster based on K factor=30

Raster Calculator (RUSLE/MUSLE) A = R * K * LS* C * P

A=potential soil loss in tons per year

R=erosivity of the rainfall (EI-index) Denton County R factor is scalar=280 (Greiner, 1979)Wise County R Factor (unknown at this point).

K=erodibility of the soil (unknown at this point).

LS=a component of the Universal Soil Loss Equation to account for the effects of topography on erosion. Expressed in Map Algebra:

LS= 1.4 * pow ((AS/22.13), 0.4)* pow((sin(SL)/0.0896),1.3)

Where, LS, AS and SL are grids. To calculate AS Raster Calculator input=

Original AS=FlowAccumulation(FlowDirection([DEM]))*30

Masked AS=Con([Original AS]< 101, [Original AS])

To calculate SL Convert Slope from degrees to Radians where, [Slope]*3.1416/180

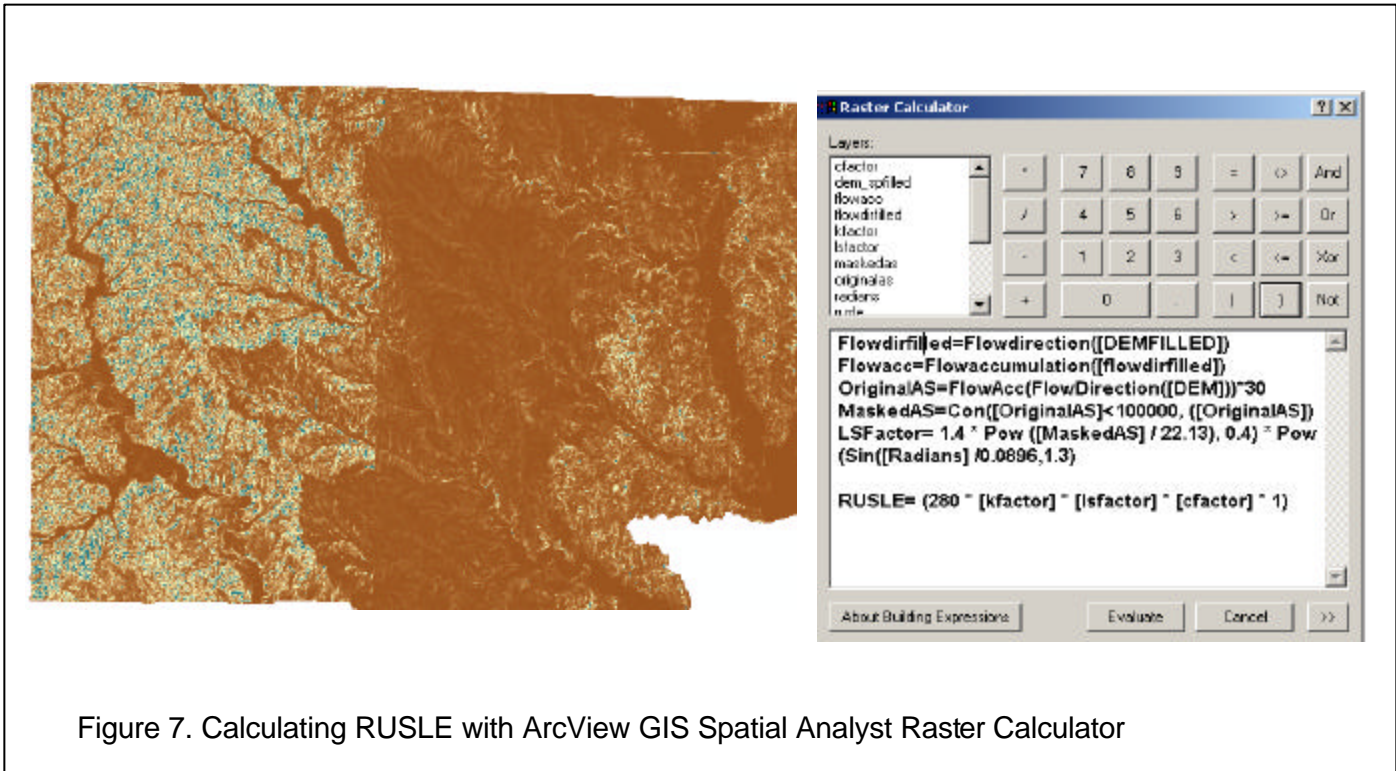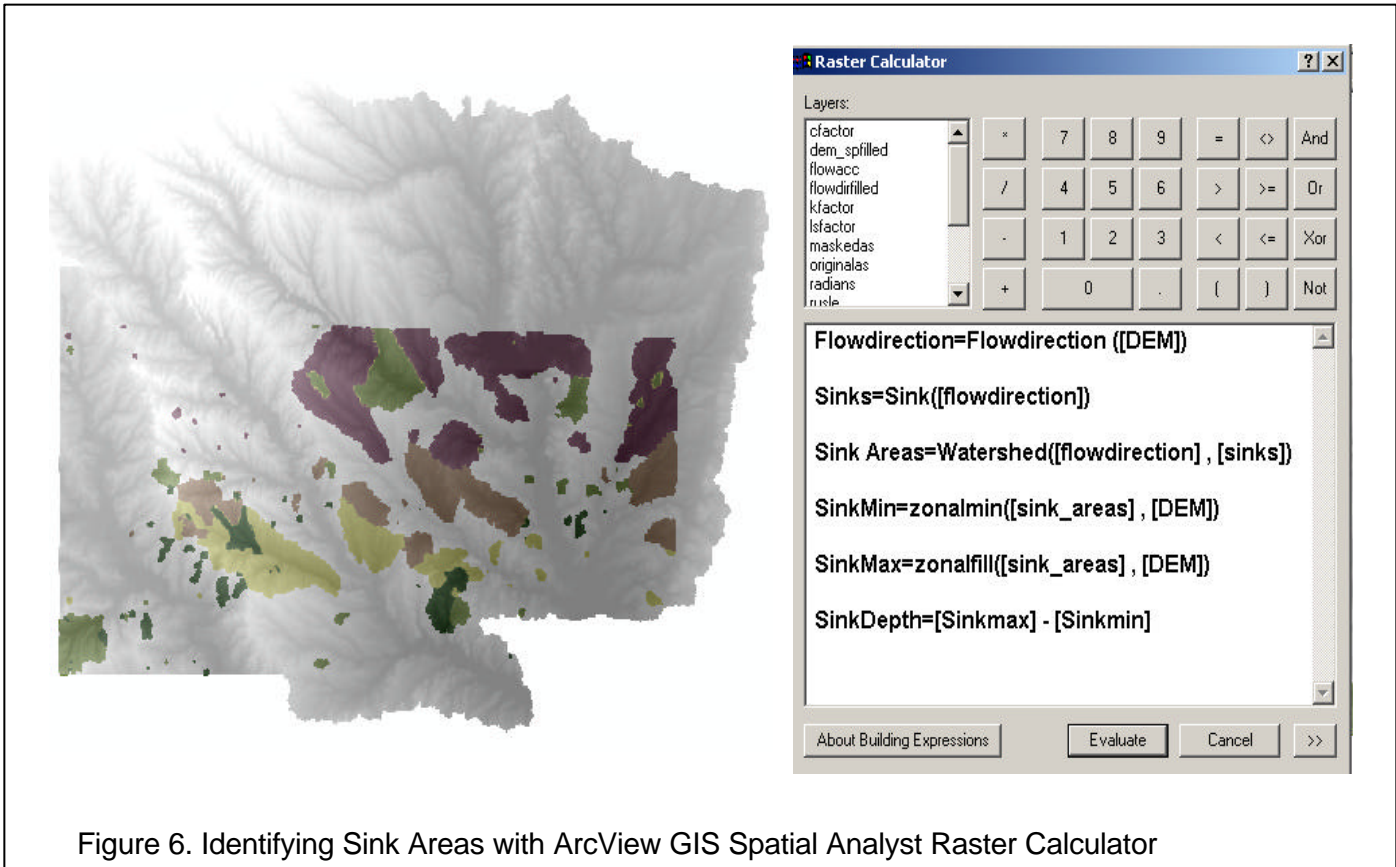Finally, LS Factor calculated using Raster Calculator on Slope Layer as:

1.4 *pow((Masked AS)/22.13), 0.4)* pow((Sin([Slope])/0.0896), 1.3)

Figure 4. Summary of procedure to calculate Universal Soil Loss Equation

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C-Factor Data					
Value	Type	C	Value	Type	C
1	Open Water	0.0	8	Highly maintained vegetation	0.1
2	Forest/riparian forest	0.1	9	Urban-highly vegetated	0.01
3	Herbaceous Rangeland	0.15	10	Urban-sparsely vegetated	0.01
4	Shrub/brush Rangeland	0.10	11	Bare Ground	0.63
5	Mixed Rangeland	0.12	12	Urban-sparsely vegetated	0.01
6	Crops/Pasture	0.28	13	Wetland	0.01
7	Transitional Crops and Pasture	0.35			

Figure 5. "C Factor" where C=cultivation parameter: a function of land use/cover types

Preliminary steps must be taken to prepare the DEM for this analysis such as identifying and filling "sinks".   This process smoothes out the surface for the analysis and helps identify sink areas where sediments are delivered. Figure 6 illustrates the procedure and preliminary results of sink identification. Identifying sinks is helpful from an archaeological perspective because these areas receive increased sedimentation that leads to increased preservation of archaeological remains.   The final steps of the RUSLE equation and initial results are illustrated in Figure 7. The soil loss equation ultimately calculates areas and provides values where increased erosion is likely to occur based on the characteristics of the landscape in question. If a site is disturbed there is a higher probability of cultural palimpsest rendering the information at the site almost meaningless in terms of chronological archaeological analysis. The best-case scenario would be recovery of "in situ" sites at locations that are being surveyed for future land development. However, knowing that there is disturbance can be revealing and it is possible to gain insight on specific site formation processes at the site that can be helpful in detangling the web of information available at archaeological site locations.

Figure 6. Identifying Sink Areas with ArcView GIS Spatial Analyst Raster Calculator

Figure 7. Calculating RUSLE with ArcView GIS Spatial Analyst Raster Calculator

Calculating the soil loss equation and projecting the archaeological sites allowed for several additional observations beyond what I had initially anticipated. In order to get a clear picture of what is going on it is necessary to look at the interaction of the Archaeology and the landscape from several different perspectives. Figure 8 shows all of the sites in relation to relative soil loss. At this scale and resolution it is difficult to see precisely what is happening between the sites and the areas that demonstrate increased erosion values.

Figure 8. Wise and Denton County Archaeological Sites, Streams, and Soil Loss
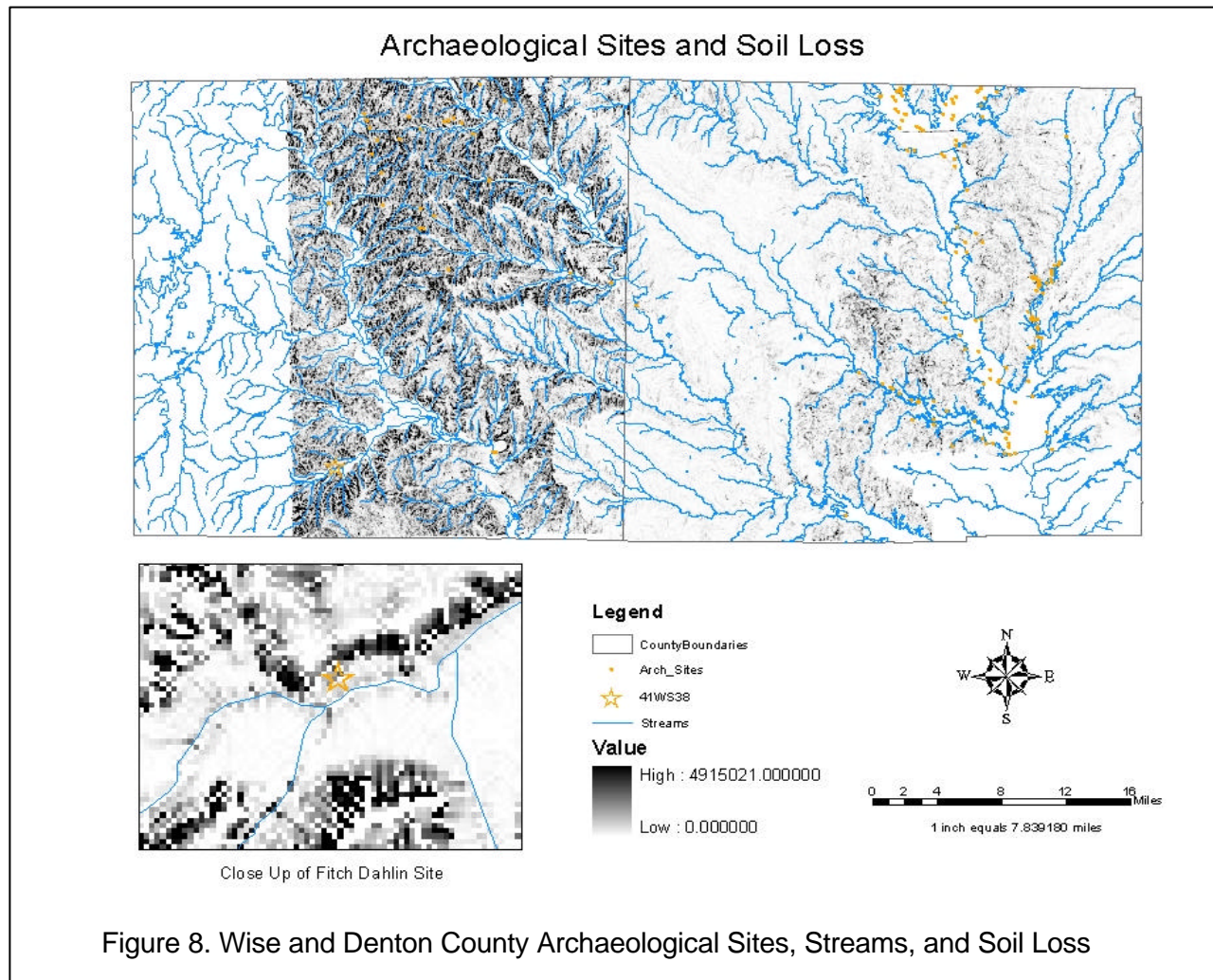
When the sites are considered in relation to soil erosion, with regard to the specific time period, it is possible to get more of a feel of where certain time periods are located in respect to areas of increased erosion. However, I feel that this sample is biased for a couple of reasons. First, alot of contract work has been done in Denton County and there are over 500

archaeological sites. As a result, the only historical sites that are represented in Denton County were a component of a site that contained more than one time period. Wise County on the other hand contains only 57 recorded sites and most of these sites are. There are several sites that have yet to be reported to TARL but it is an interesting question especially in light of the increased soil erosion in Wise County as to why there are not as many sites. One factor could be the lack of reservoir construction but there are also plenty of amateur archaeologists and private landowners who have uncovered archeological remains. It is possible to conclude that there is a correlation between soil erosion and site presence due to the much steeper slopes in Wise County but other factors should be kept in mind as well.

When Sinks are brought into the picture some interesting patterns emerge. Figure 9 is a map of the overall relation of archaeological sites to soil loss and sinks.

Figure 9 Wise and Denton County Archaeological Sites, Streams, and Sink Areas
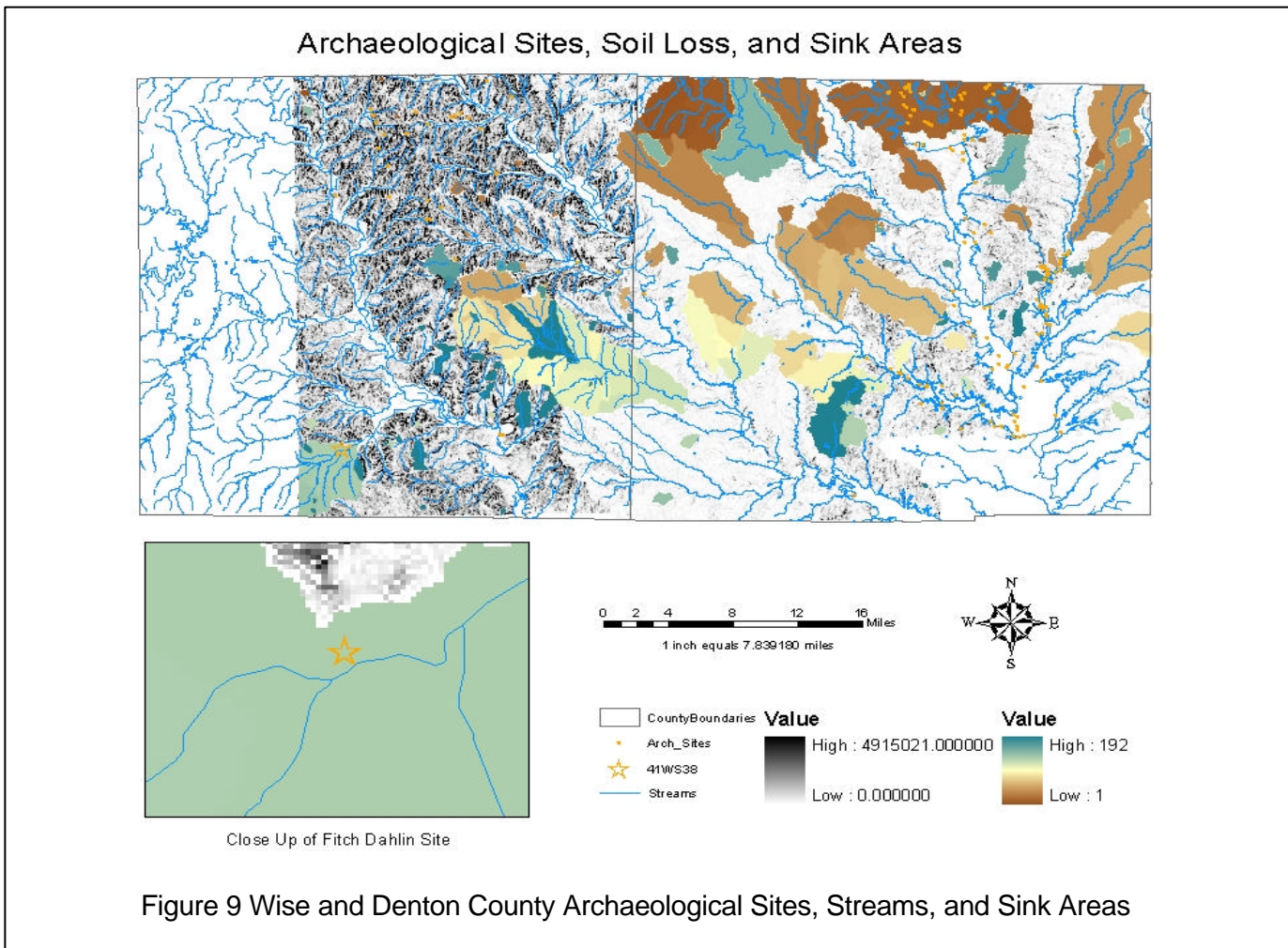
The maps that illustrate the archaeological sites with respect to time period provide more of a chronological view of the relationships between sites, sinks, and soil loss that may help explain differential preservation. The Archaic and Prehistoric sites tend to be heavily distributed in sink areas. For the sake of space and to illustrate my point I am only going to include the map of the prehistoric sites in relation to sink areas and soil loss (figure 10). The correlation is not very strong once we reach the Late Prehistoric time period and the relationship has almost disappeared by the historic times. It could be concluded that this is partially due to the increase in agriculture and the evolution of the landscape through time.   However, since the sample size of archaeological sites in Wise County is small it would be prudent to expand the study area.
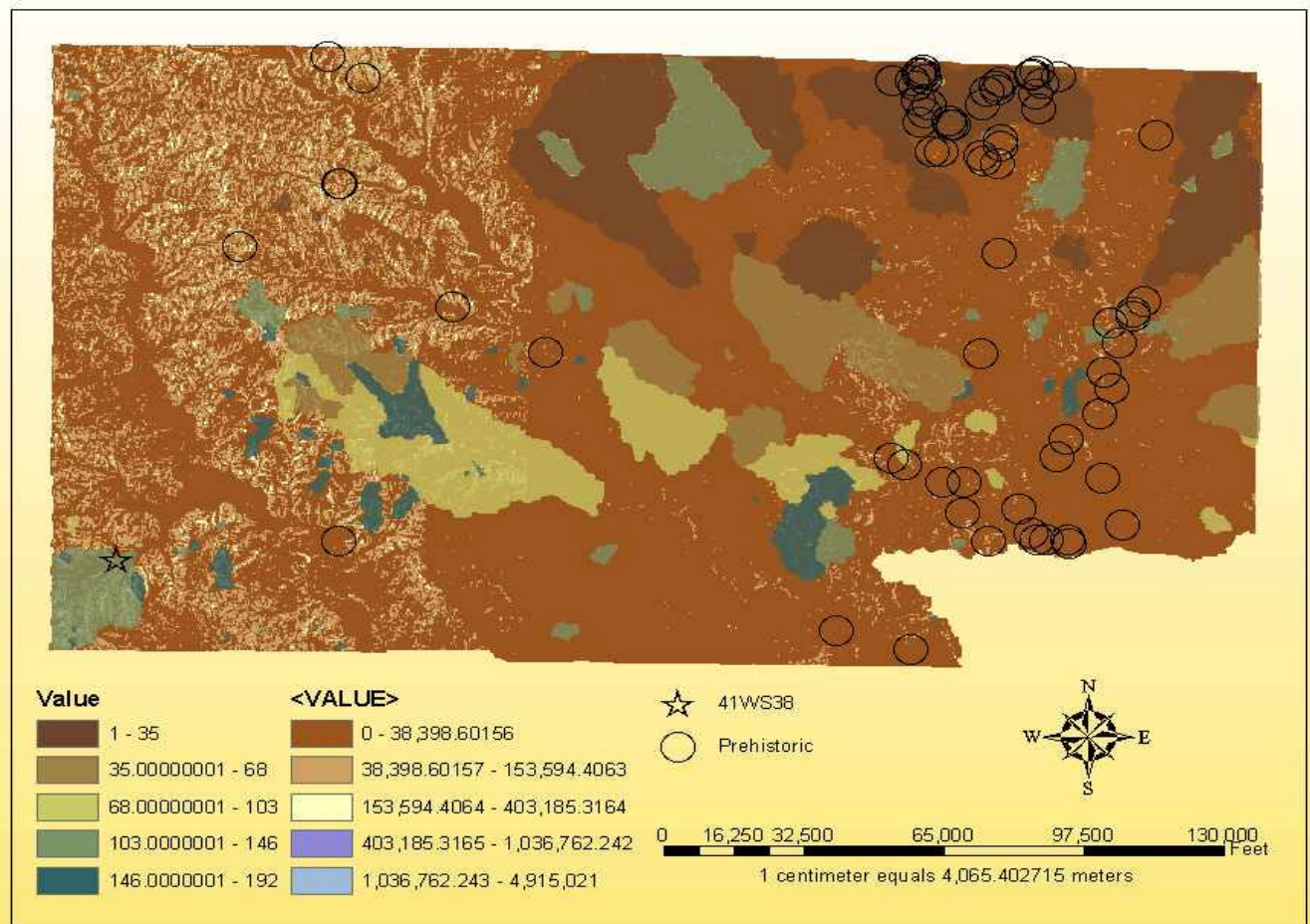
Figure 10 Wise and Denton County Prehistoric Sites, Soil Loss and Sink Areas

After examining the sinks and soil loss from a variety of perspectives I still had more questions about relative preservation and so I looked at the sites in terms of whether or not they had one, two, three, or more than four components. A component refers to the number of time periods represented at a particular site. This is something that becomes more important when considering site preservation, sedimentation, and stratification. Figure 11 is a map of all the sites in relation to elevation. Several other maps that were presented walk you through the different components with a changing background of elevation, slope, soil loss, and sinks in order to view how the different site types relate to the surrounding landscape. Overall, there seems to be a correlation that merits further study.
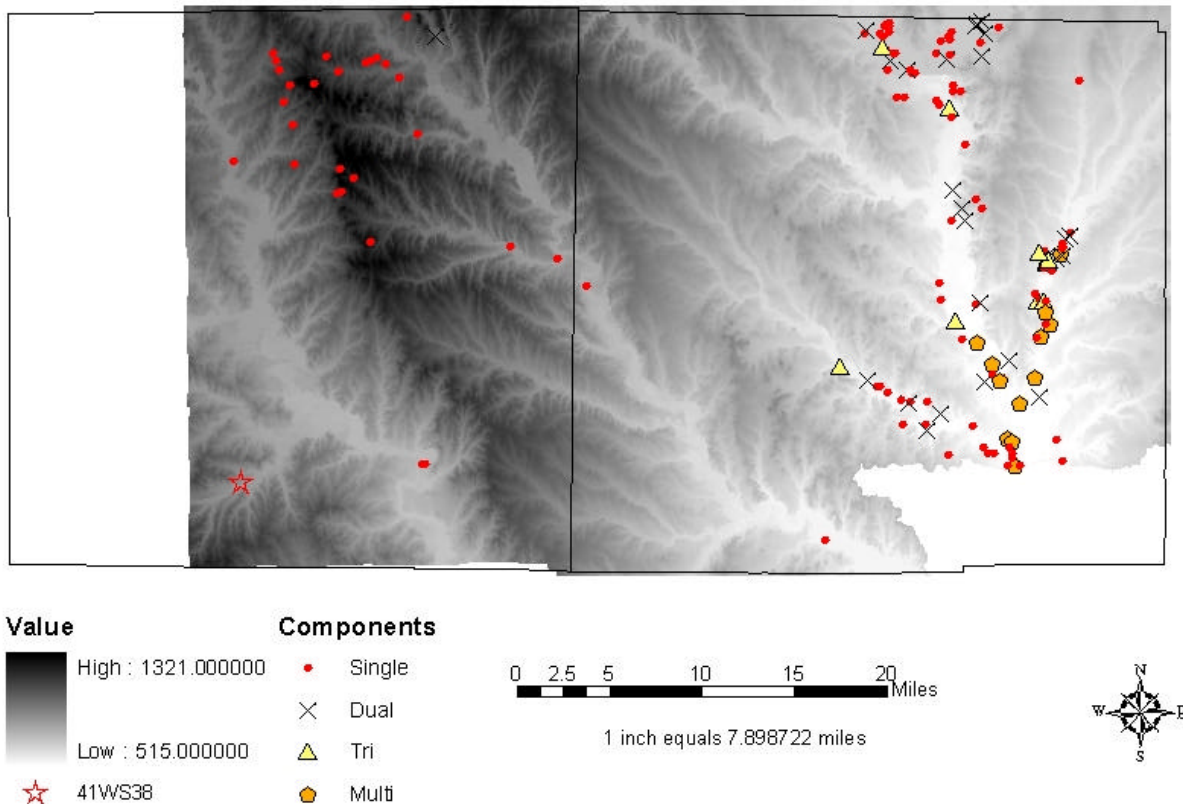

Figure 11 Wise and Denton County Site Components and Elevation

It is clear that soil erosion is more pronounced in the western part of the study area due to steeper slopes related to deeper stream incision. There appears to be a correlation between site age, erosion values, and sink presence. It will require further study to determine if there is a correlation between "in situ" sites and sink presence. Erosion in the western part of the study area may contribute to the scarcity of sites but it also could be attributed to bias in the record. As a result of this analysis I feel encouraged to do further study. Elevation, slope, sinks and soil loss are all important variables that factor into the site formation processes equation. When the site component facet enters the equation more information emerges. For future studies, with the perspective of aspect the sites should be looked at on a micro-scale to evaluate site formation processes on a site level. Also, the study area should be expanded to view a larger sample size and provide a larger variety to select good case study locales.

<div align="center">Site Prediction</div>

The site prediction model formulated for this case study is based on methods utilized in the past by other archaeologists, with a few additions, that will fulfill the research goals of this project. Several articles have been written regarding location models and prediction in the discovery of archaeological resources. Based on previous case studies, as well as, assumed relationships between humans and their surrounding eco-system that have been formulated on the basis of the contents found at local archaeological sites, several core environmental factors can be employed as variables. However, for the purposes of this study I chiefly considered slope and soil potential for openland and rangeland habitat to develop least cost pathways between sites that represented similar time periods or contained similar artifacts.

The central goal of this part of the analysis is to recreate probable "Least Cost" Pathways that establish parameters to predict "Archaeological Sensitive Areas" and meet the following conditions:

?? Pathways that would have been most advantageous for ancient humans.
?? Pathways between contemporaneous sites.
?? Pathways between sites containing similar artifacts.

GIS has the ability to generate cost surfaces. These surfaces take into consideration not only proximity or natural resources to the site but also the character of the terrain over which the proximity is measured. In order to build 'cost surfaces', obstructions, barriers, and differences in the quality of space that may have influenced transportation costs or even perception of the landscape have been evaluated in other investigations. In this case study 'cost surface' is calculated, based on slope and potential for soils to support vegetation that sustains openland or rangeland habitat. I chose to use soil potential for two types of habitat based on the types of animals that were present during prehistoric times and the lack of agriculture. I opted for soils that have the potential to produce vegetation and suitable habitat for rangeland wildlife and openland wildlife. These areas would have provided high calorie food for human and animal population in prehistoric times. The soil data was extracted from the Wise County Soil Survey. Four categories: high, medium, low, and very low were utilized by soil scientists to classify the potential for specific soils to support vegetation, that would sustain specific wildlife in the study area. Since there were not many 'very low' classifications, I grouped 'low' and 'very low' into one group. I built a database in excel based on the Soil Survey Designation of soil potential for openland and rangeland wildlife. The Soil Survey Ratings were High, Medium, Low and Very Low. The next step was to create weights for the variables. First, the soils that were considered to have a "High" suitability for each type of habitat were given a cost value of 0.07. The soil types with "medium" potential were given a cost value of 0.29 and the soils with "low" potential were given a cost value of 0.64. The process is illustrated below in Figure 12.

			Rank Sum	Rank Reciprocal		Rank Reciprocal	
SOIL SUITABILITY	RANK	Weight	Normalized Weight	Reciprocal Weight	Normalized Weight	Weight	Normalized Weight
		$(n-rj+1)$	Weight/Total Weight	$(1/rj)$		$(n-rj+1)p, p=2$	
HIGH	1	3	0.50	1.00	0.55	9	0.64
MEDIUM	2	2	0.33	0.50	0.27	4	0.29
LOW	3	1	0.17	0.33	0.18	1	0.07
Total		6	1.00	1.83	1.00	14	1

Figure 12. Soil Variable Weighting

These weights were derived by "Ranking Procedures" on page 180 of GIS and Multicriteria Decision Analysis by Malczewski. In this continuous format, the cost of the soils could be meaningfully combined with the slope values derived from the DEM of the study area. After further deliberation and examination of the procedure for calculating Least Cost Path I chose to rank my variables with whole numbers for the sake of simplicity and to save time. I plan to choose continuous values for future studies but for the time being I decided to rank, reclassify, and weight the variables to formulate the cost surface. As a result, soils with 'high' potential to support the wildlife groups that I chose were given the lowest cost value of 1 and the 'low' potential areas were given the highest cost value of 3. Also, based on the fact that slopes are not very steep in this region I grouped 'slope impedance' into three groups as well: steep, medium and slight. Slopes were measured in degrees and based on the topography of this area the slopes were classified into three groups according to Jenks natural breaks and then reclassified with the steepest slopes given a cost value of '3', the mid range values '2', and the lowest values a cost value of '1'. After all of the layers were in this format, the openland soil raster was multiplied by 0.4, the rangeland soil raster was multiplied by 0.4, and the slope raster was multiplied by 0.2 in the Spatial Analyst Raster Calculator. Then, also using the Raster Calculator, the three rasters were added together to calculate the 'combinedcostsurface'. The results from this process are illustrated in figure 13. Before I could proceed I had to develop source sites. I chose three study sites that represented several time periods and contained a variety of artifacts from my selected sample group. The first site is my thesis site in Wise County and the other two are from Denton County. The source sites are illustrated by the table in figure 14. CostDistance and CostDirection (figure 15) were then calculated in relation to the source location that was the Fitch-Dahlin archaeological site in Wise County. With these data layers and the destination data layer (figure 16) containing the other archaeological sites, the shortest path function was calculated and resulted in the various pathways between sites that contain similar artifacts and sites that are from similar time periods.
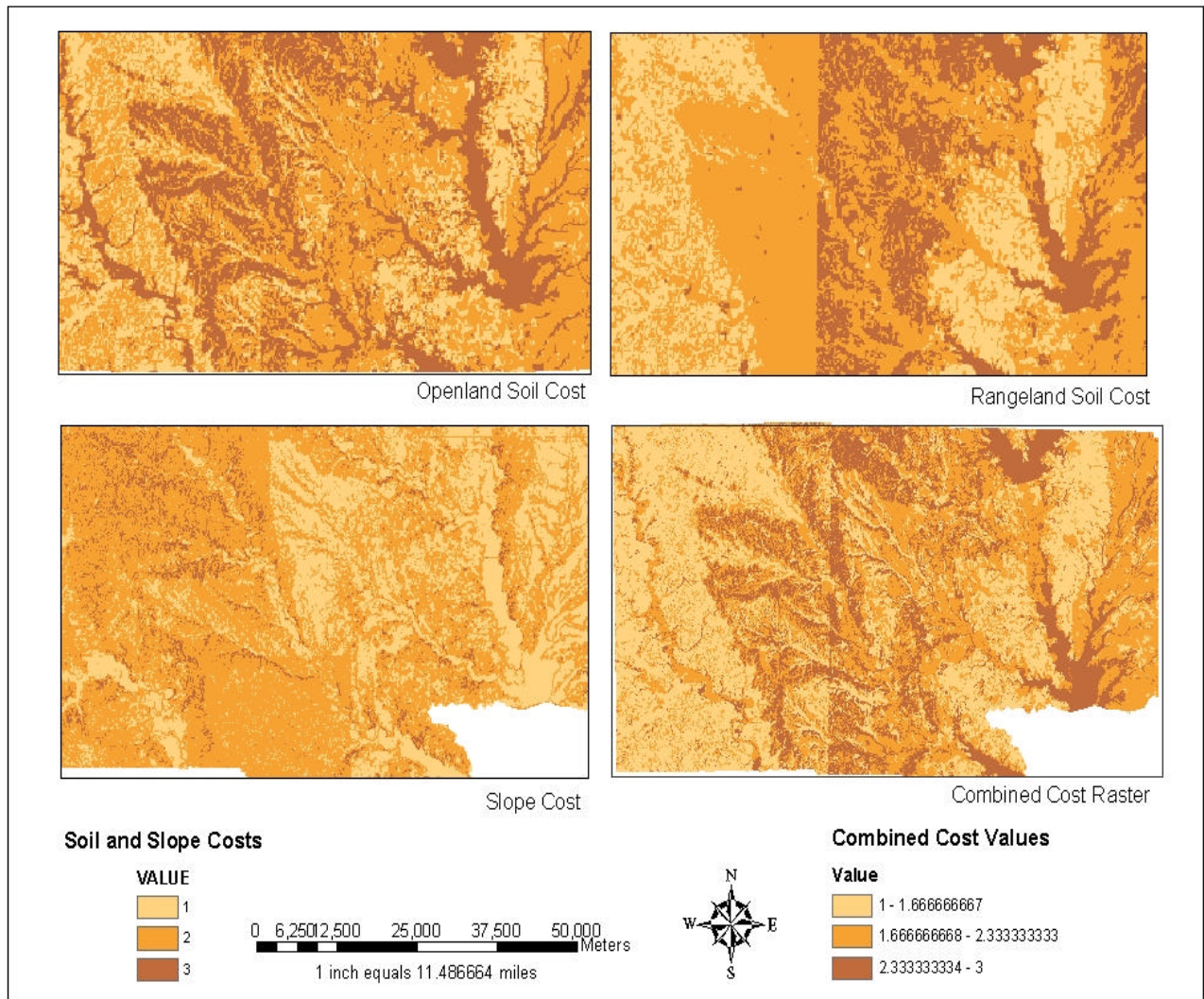
Cost Rasters for Least Cost Path Analysis

Openland Soil Cost

Rangeland Soil Cost

Slope Cost

Combined Cost Raster

Soil and Slope Costs

VALUE
1
2
3

0 6,2502,500 25,000 37,500 50,000
Meters
1 inch equals 11.486664 miles

Combined Cost Values

Value
1 - 1.666666667
1.666666668 - 2.333333333
2.333333334 - 3

N
W   E
S

Figure 13. Cost Rasters for Least Cost Path Analysis

41WS38 (Wise County)	41DN57 (Denton County)	41DN354(Denton County)
Alba	Alba	Alba
Elam	Edgewood	Dallas
Gary	Ellis	Ellis
Perdiz	Gary	Gary
Scallorn	Perdiz	Godley
Steiner	Scallorn	Scallorn
Sherds	Sherds	Sherds
Arrows	Trinity	Arrows
Darts	Yarborough	Darts

Figure 14. Archaeological Source Sites (sample size=3)
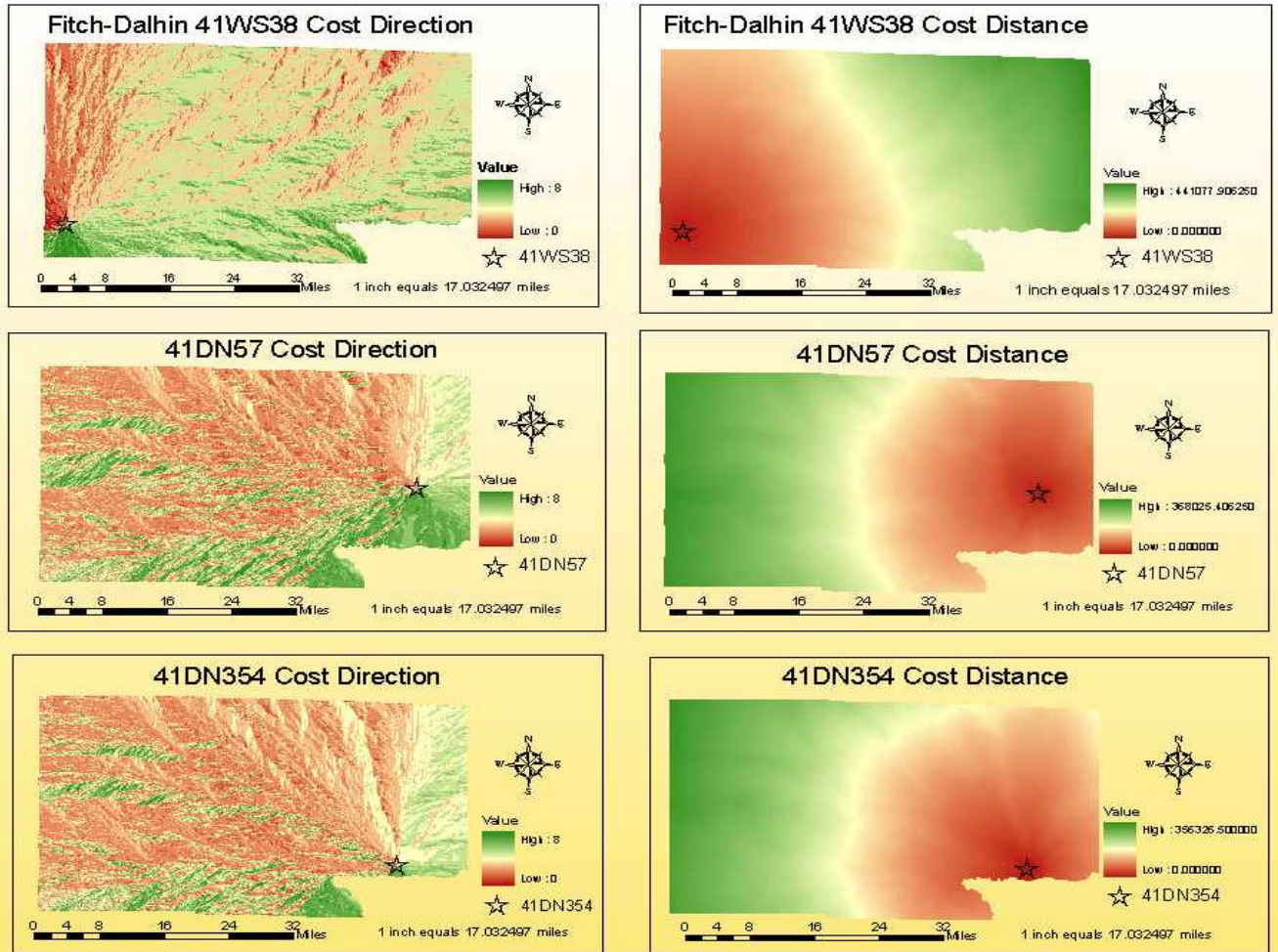
Figure 15. Cost Direction and Cost Distance Rasters for Archaeological Source Sites

Time Period	Artifact Type
Paleoindian	Alba
Archaic	Early Archaic
Middle Archaic	Late Archaic
Prehistoric	Dallas
Edgewood	Elam
Ellis	Gary
Late Prehistoric	Late Prehistoric I
Late Prehistoric II	Henrietta
Neo-American	Historic
Godley	Perdiz
Scallorn/Steiner	Trinity
Yarborough	Arrows/Darts/Sherds

Figure 16. Archaeological Destination Sites (sample size=195)

A combined view of the pathways and the three source archeological sites juxtaposed against the cost surface of 41WS38, is provided in figure 17, as a sample of the results from the shortest path function, calculated in 'Spatial Analyst'. It is based on the combined cost raster.
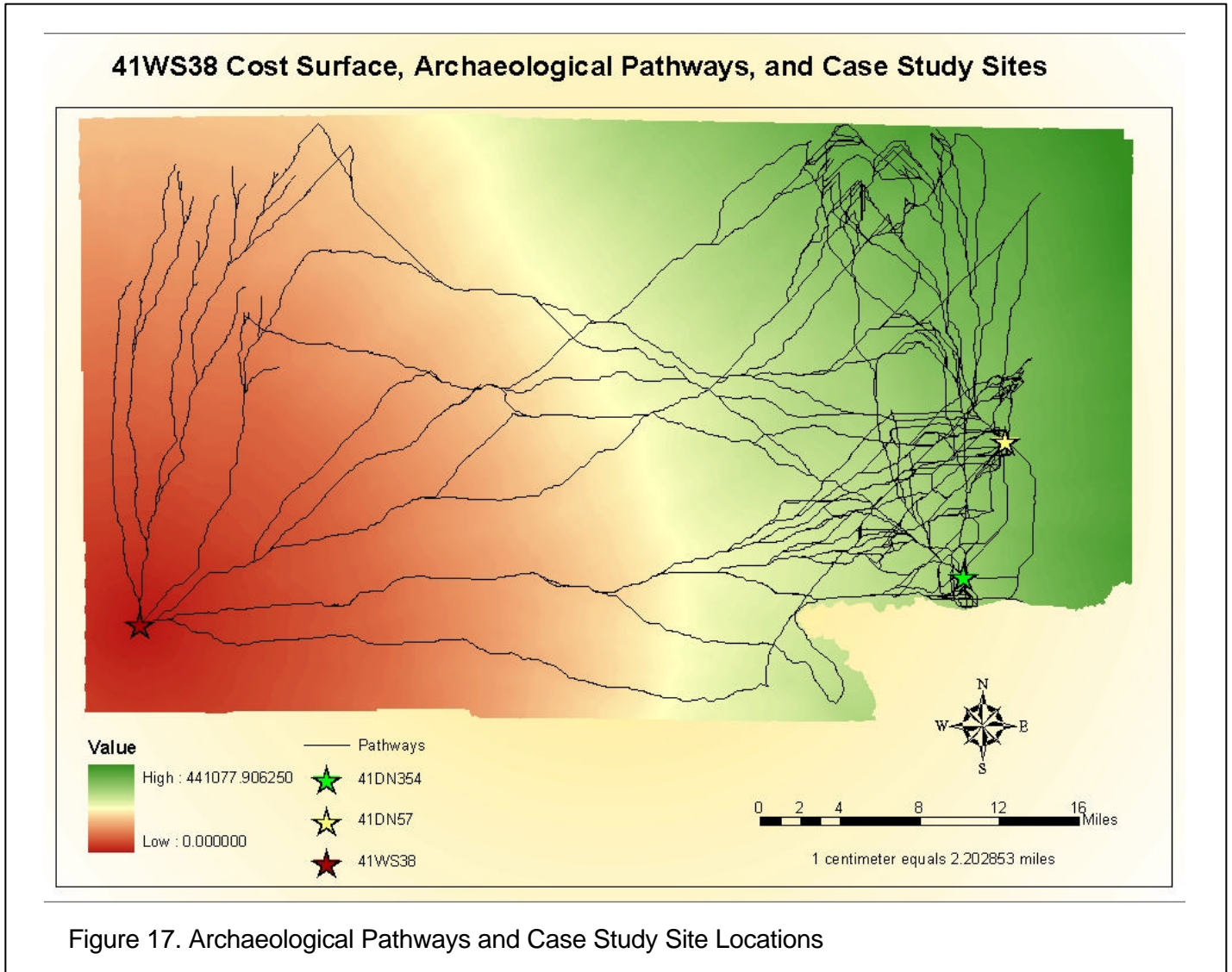
Figure 17. Archaeological Pathways and Case Study Site Locations

Development of "Least Cost" Pathways between sites of the same time periods and with similar point types provided:

- ?? A picture of probable cultural interaction per time period and per artifact typology.
- ?? A view of possible secondary cultural movement of artifacts
- ?? "Archaeologically Sensitive Areas"

Several maps were built for analytical purposed in order to view this aspect in relation to time, site distribution and the possibility of site interaction when sites contained the same artifacts or were inhabited during the same time periods. Prehistoric sites have the largest distribution with "intermediate" sites along the pathways. Once again, as with the RUSLE portion of the analysis, the sample size seems to be distorting the picture.

Preliminary results suggest that there are strong correlations that merit further study and refinement of this procedure. This study suggests that variables that created least cost pathways facilitated reuse of specific site areas. Further study in developing site catchments, and expanding the study area would be helpful in defining repeated occupation based on the results of this analysis. In addition, travel-time between sites and within site catchment should be factored into the equation. Beyond creating a more refined model, testing in the field is necessary to evaluate the validity of pathways developed for this study and for future studies.

Site Selection: Overlay Analysis

In order to establish recommendations for CRM purposes I observed the interaction of past and present cultures in combination with the character of the landscape. Overlay analysis consisted of combining these data. The following goals were established for site selection:

?? Buffer Pathway Results by 100 meters.
?? Union all Pathway layers together and select pathways within city limits to be clipped.
?? Select "Archaeologically Sensitive" Zones based on Buffered Pathway Results.
?? Overlay city limits, land use, land cover, lakes, rivers, streams, and roads.
?? Determine why known sites are preserved to base selection of future "in situ" site areas.
?? Prioritize mitigation according to RUSLE Soil Erosion, Sinks, Pathways and Land Use.

Several of the goals were met but a few minor adjustments were made due to time factors. Three "archaeologically sensitive" areas were chosen for preliminary cultural resource management investigation. The primary selection criterion for site selection was pathway density in relation to sinks and city limits. Figures 18 through 20 illustrate the areas selected for cultural resource management survey and testing.
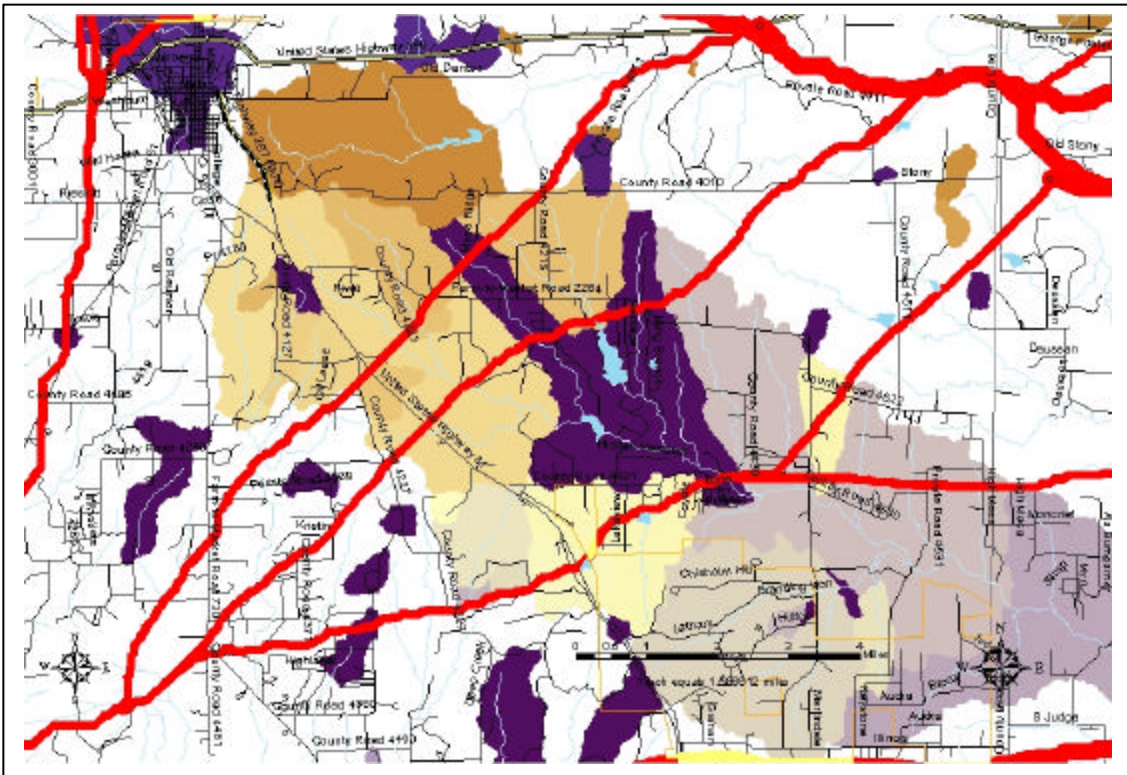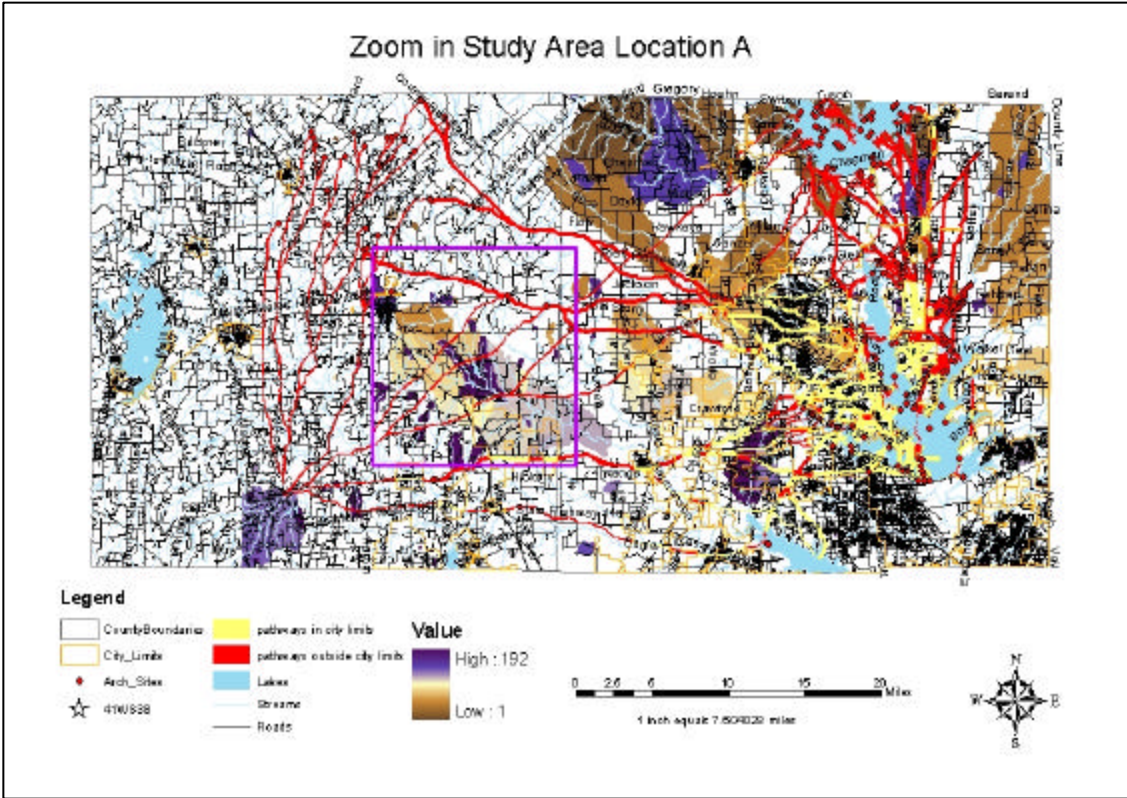
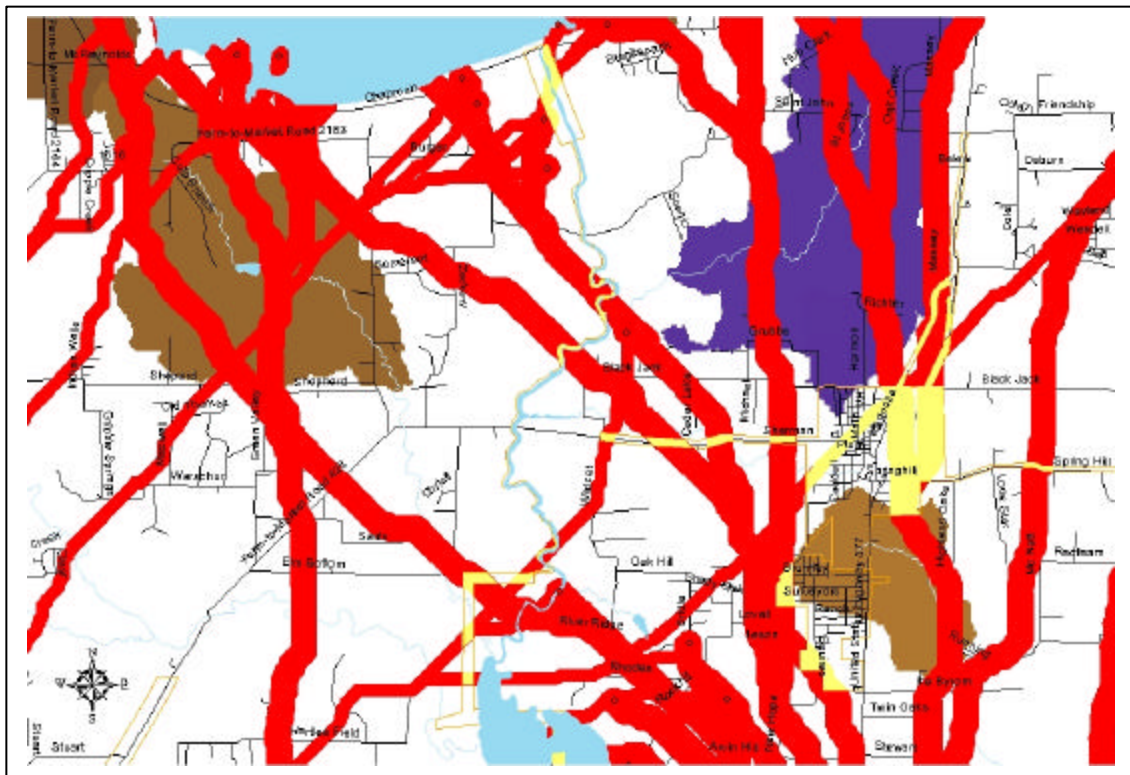Figure 18. Archaeological Pathways, Sinks, Roads and Case Study Site Location 'A'
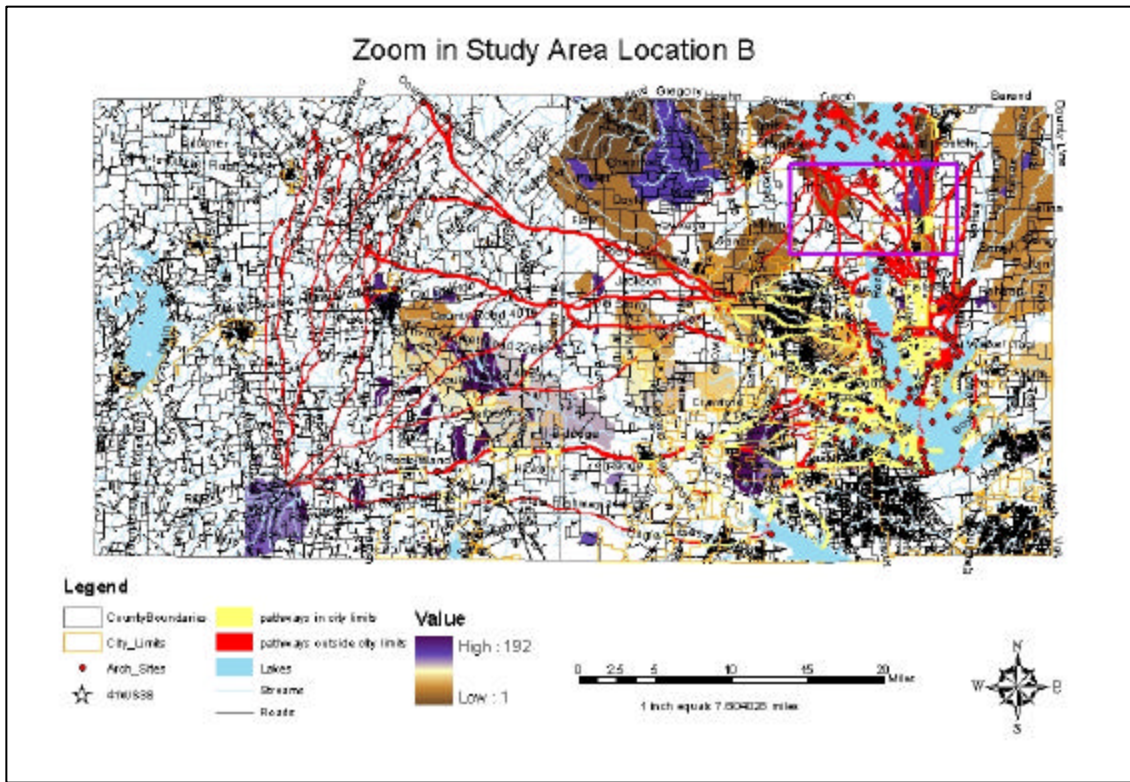
Figure 19. Archaeological Pathways, Sinks, Roads and Case Study Site Location 'B'
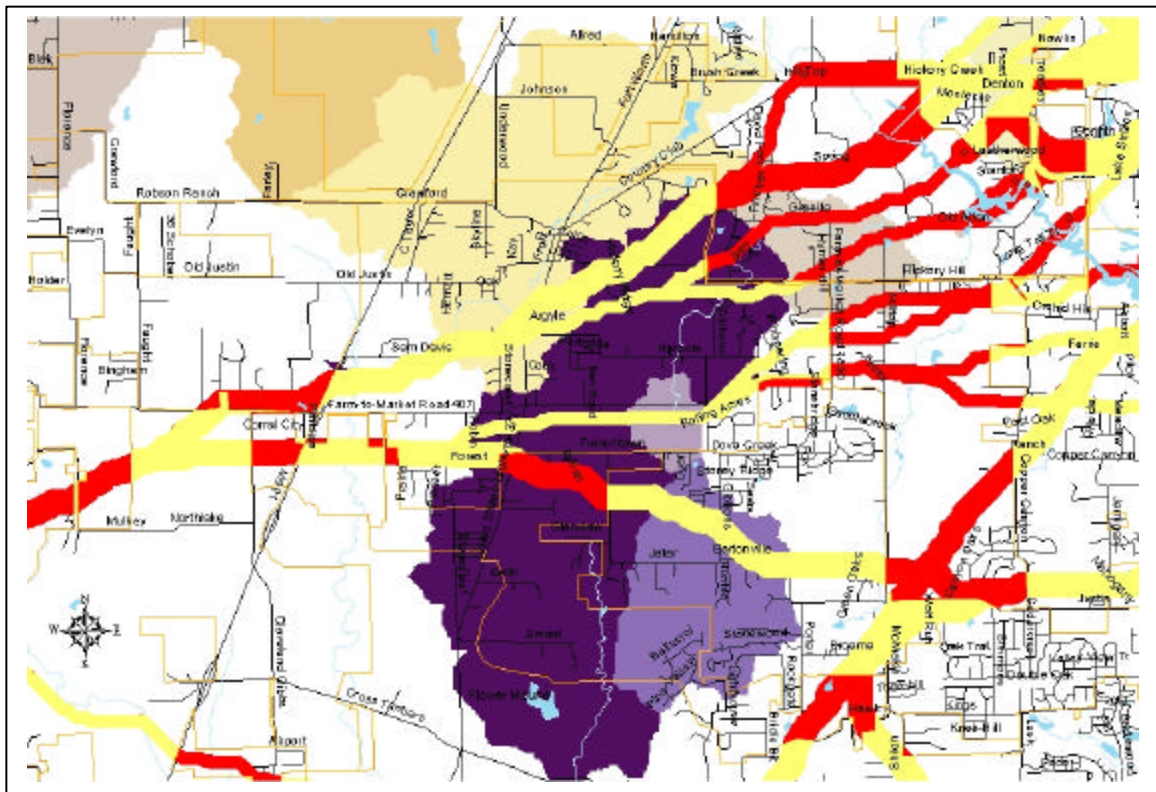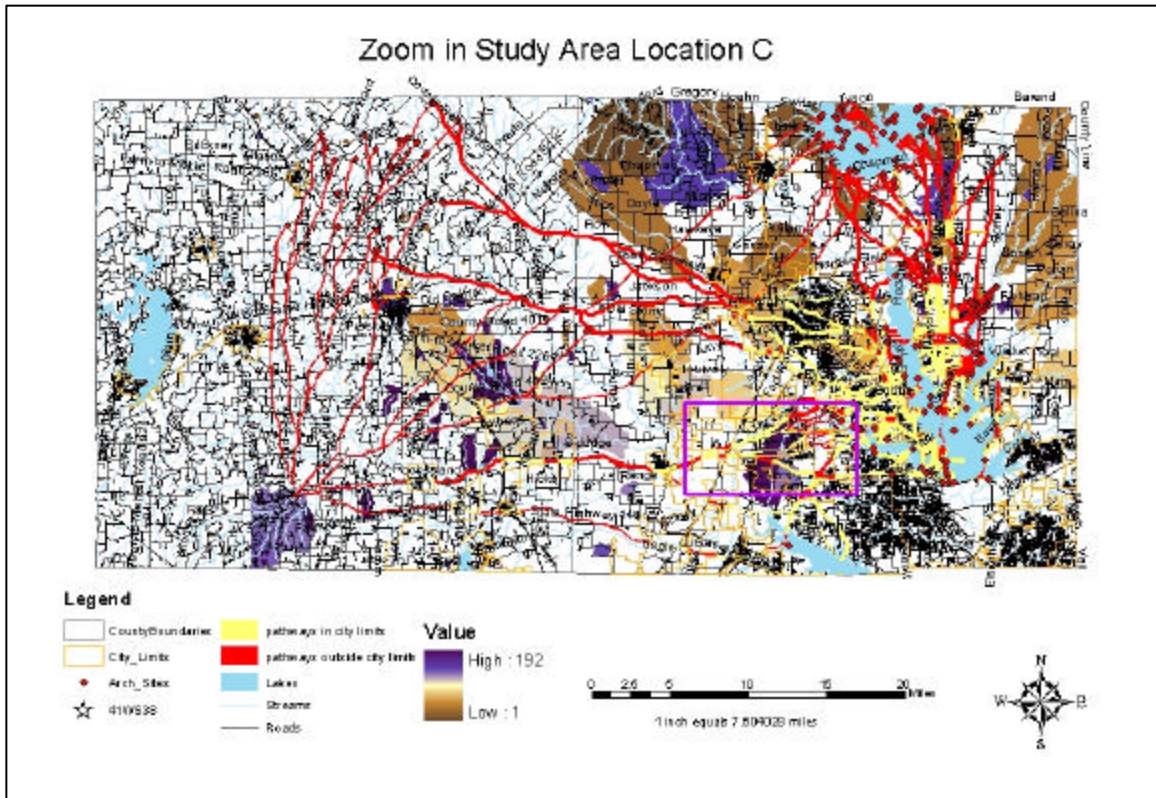
Figure 20. Archaeological Pathways, Sinks, Roads and Case Study Site Location 'C'

Once the areas are chosen, further inquiries can be made on a smaller scale with a GIS such as selection of depth to bedrock, erosion values, aspect to observe the direction of sedimentation flow, and variable sink depth to provide a game plan at a site level. The RUSLE calculation provided information regarding areas of soil loss and increased sedimentation. The "Least Cost Pathway" component of the analysis helped explain ancient behavioral choices in terms of site location selection and facilitated the construction of 'archaeological sensitive areas'. Overlay analysis permitted observation of the interplay between these various components.

Conclusions

As a result of conducting this analysis it becomes more evident how GIS can benefit the archaeological community and cultural resource managers. GIS, in the 'Information Age' is becoming essential for cultural resource managers as an organizing mechanism as well as, for identifying areas that may contain archaeological information for future planning and preservation efforts. The combination of GIS techniques employed in this model appears to have organizational potency, strong analytical utility, and predictive power. However, it needs to be refined and pushed further in order to be more effective and attain greater accuracy. Regional archaeological models, with predictive power could provide extremely useful tools to governmental agencies responsible for the management and protection of archaeological resources on public lands. Such models could be used for planning purposes, to indicate archaeological sensitive regions where development or disturbance should be avoided, and regions most likely lacking archaeological remains, where land alteration or development would have less of an impact on the resource. Parker 1986 emphasizes the positive contribution archaeological predictive modeling can make to resource management, through GIS, by reducing costs and increasing the quality and efficiency of management. Moving a proposed road alignment from a region predicted to be archaeologically sensitive, to one of less predicted sensitivity, can lower the costs of mitigation of impacts, for example. Due to the fact that cultural resource managers and government workers are often in charge of planning for and funding

archaeological resource recovery improvement of this GIS model would help maximize the efficiency of the process of survey, excavation, preservation, and site selection for future development.

Future Studies

Due to the scope of this analysis the need for further study is pronounced. In a cultural resource management situation an additional layer of land parcel status would be very beneficial so for future studies I would add that dimension. Prioritization, in that case would be focused first on areas inside city limits that contain vacant parcels, sink areas, and pathways, then outside city limits on areas that contain vacant parcels sink areas, and pathways, and finally in areas where sinks and pathways overlap. ArcIMS would be a good mechanism for communicating between entities and interacting with the data.   In order to reach maximum accuracy it would be necessary to include all of the sites recorded on file in the county. Also, a site catchment analysis on these areas would provide more specific variables on which to construct new pathways for greater accuracy. Other goals established for future research are included as follows:

- ?? Develop datasets for county level archaeological studies to be distributed to city planners and cultural resource management agencies.
- ?? Overlay land parcels, determine how sites, site catchment areas and probable pathways relate to specific land parcels, wetlands, and water bodies.
- ?? Carry out field survey and excavations prior to completion of building permit process and construct new datasets in Excel Format to be submitted to archaeological "parent" agency.
- ?? Model needs refinement in variables and weights and travel time computations.
- ?? Develop "site catchment" profiles for sites.
- ?? On micro-scale, the arrangement of the archaeology within the site matrix needs more attention.
- ?? On a meso-scale cultural resource managers need to be able to determine how the sites relate to one another and to future development.
- ?? On a macro-scale there is a necessity to refine cultural resource management techniques and facilitate comparisons between similar sites and environments.

In order to improve the models explored in this case study, and to enhance archaeological analysis, I have proposed the addition of 'Site Catchment Analysis', for future

studies. Site Catchment Analysis is a technique that has been employed to analyze the locations of archaeological sites with respect to the economic resources available to them. Site Catchment Analysis derives from optimal foraging theory. The basic principle behind this method is that the further from the base site the resources are, the greater the economic cost of exploiting them. Eventually there is a point at which the cost of exploitation surpasses the return. At this point an economic boundary can be defined to define the exploitation territory of a site. The ability of GIS to extract a variety of information about the environment and perform both geometric and statistical operations has led to its utility for the application of Site Catchment Analysis in archaeology. In seeking explanations for the spatial patterning of cultural remains archaeologists have concentrated on the distribution of sites and typically settlement sites. As a result, a number of theoretical approaches have developed through time. A prominent approach has been gravity models (Hodder and Orton 1976: 187-195). An economic model of settlement structure was proposed by von Thunen in 1966. "Central Place" theories of settlement hierarchy have been published in papers by Christaller (1935, 1966) and Grant (1986a). Butzer's (1982) ecologically-based resource concentration models are also effective explanatory mechanisms.

For the purposes of future research one of the central concerns will be "return to base" cost and "accessibility" cost of site locations. In order to calculate site catchment areas in terms of seasonal hunting and gathering behavior, the "return to base" cost will be derived by implementation of the isotropic function. According to Wheatley and Gillings (2002),

> "for the simplest case of isotropic cost surface calculation, the algorithm requires two inputs: a file containing the location of the features from which cost distance will be calculated (often referred to as seed locations) and a file that contains the cost of travel across each landscape unit is usually called a friction surface."

Slope, elevation, soil type and distance from specific natural resources should serve as the most significant variables in terms of accessibility for generating friction surface. In addition, this model will determine the pathways that incur the least cost and contain the least amount of

obstacles as a parameter for site selection. Friction data will be derived from generating slope surface from an elevation map and then performing the selected transformation of slope surface according to a proposed relationship between slope and time taken. In a case study, conducted by Wheatley and Gillings (2002) F=1/log (slope+1) was used for illustration and then the cost distance layer was reclassified according to the equation to identify zones that were within 2 hours walk. 'Return to base', Accessibility, and 'Distance' functions can help provide explanations for why a site was visited on one occasion or repeatedly over a long period of time.

Based on a combination of the aforementioned methods, a more refined approach, tailored to this area, for defining "catchment" areas, should be formulated, in future studies. Site Catchment can be evaluated based on the character of the landscape that surrounds the site locations. This type of analysis would help determine the variables that ancient inhabitants would have considered the most advantageous. It would also provide strong base data that can be weighted and utilized in the 'Weighted Distance', 'Shortest Path' and 'PATHDISTANCE' GIS functions.

There are many answers to archaeological questions contained within GIS analytical capacity, and ability to integrate data. GIS has been incorporated for handling and generating vast amounts of spatial data, for performing analyses, developing, and testing locational models, and for producing cartographic output in the form of archaeological predictive and other maps over wide regions. (Marozas and Zack 1987; Warren et. al. 1987; Kvamme and Jochim 1989) This study was successful in terms of a 'pilot study' and developing methodology. I feel like I have touched the 'tip of the iceberg' and it has created a sense of enthusiasm to make a better model and retest. I plan to improve and evaluate this model in relation to my thesis to help establish an explanatory mechanism for site location and examine the inter-site relationships between sites in North Central Texas. The possibilities of expansion with respect to this model, discovered during this analysis, provide a basis and increased confidence for the success of future studies.

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