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Darkmold Archaeological Site Analysis: Three Dimensional Surface Modeling and Data Compilation

A Major Individual Project submitted in partial satisfaction of the requirements
for the degree of Master of Science in Geographic Information Systems

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December 2006

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Three Dimensional Surface Modeling and Data Compilation

The report of Kristen Diane Waldvogel is approved.

Robert Booth

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December 2006

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ABSTRACT

Darkmold Archaeological Site Analysis:
Three Dimensional Surface Modeling and Data Assemblage

By
Kristen Diane Waldvogel

Archaeology is a spatial discipline, which is why using Geographic Information Systems (GIS) analysis is a powerful tool for archaeological applications. In the past, the use of GIS by archaeologists consisted of site location prediction, or related applications covering large areas. This project is concentrated on a single site in southwestern Colorado, known as the Darkmold Site. The purpose of this project is to amass data collected from the site, convert it to digital format to be used in the ArcGIS software made by ESRI, and return it to the client in a form that can be updated and maintained through future field seasons. Converting the data is no small task because in the field data is recorded on paper forms and collected using a Total Station. However, neither of these collection methods imports easily into the software. The data assemblage of this project involves the creation of a personal geodatabase to store the data, and manipulation and conversion of files into accepted formats. The three dimensional surface models are the results of interpolating the ground surface elevation of the site after each year of excavation. Briefly, the methodology for creating the surface models involves creating Triangulated Irregular Network (TIN) surfaces from point and line data, and converting the TIN to a raster surface. This project also includes a discussion on relating data of spatial tables to standalone tables, which is basic to GIS, to allow for simultaneous querying of the data in the GIS. The importance of this project to the use of GIS in archaeology is not only in the methods, but in the realization of what is required to build a successful GIS application. For GIS analysis to be successful at the site level, excavation methods must incorporate data collection for the goals of the GIS.

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List of Acronyms

3D	Three Dimensional
DBF	Database Table File
ESRI	Environmental Systems Research Institute, Inc.
FLC	Fort Lewis College
FS	Field Specimen
GIS	Geographic Information Systems
GPS	Global Positioning Systems
IDW	Inverse Distance Weighted
OID	Object Identification Number
TIN	Triangulated Irregular Network
UTM	Universal Transverse Mercator

1. Project Introduction

The Darkmold Site, given number 5LP4991 by the state of Colorado, was discovered in September 1998, about six miles north of Durango, Colorado. It is located on the west side of the Animas River valley on a glacial kame terrace, where the landowner began excavation for a single family home. Initial excavations consisted of blading the surface to create a flat area to build on (see Figures 1 and 2), before digging foundation trenches. These trench excavations led to the discovery of the site. Prehistoric human remains were uncovered in the trenches, and Colorado State law required proper removal of any human remains before construction could continue (Discovery of Human Remains, Colorado Statutes). Archaeologists from Fort Lewis College (FLC) were contracted to remove the human remains and construction resumed; however, after multiple subsequent discoveries of human remains, the landowner turned the site over to FLC Archaeological Field School for archaeological training and excavation. Initial funding for this project was secured by the director of the FLC Archaeological Field School through a grant from the Colorado Historical Society, State Historic Fund.

Figure 1. The Darkmold Site, looking east.

Figure 2. The Darkmold Site, looking northwest.

The Darkmold Site is a Basketmaker II[1] and Pueblo I[2] habitation site that was occupied sporadically between about 200 B.C. and A.D. 750 (Charles, 2005). Since the site was resettled over the course of its use, many features within the site were compromised by the intrusion of later occupations. These multiple occupations (the exact number of occupations is unknown), coupled with the blading completed by the landowner, severely compromised the Darkmold Site and make it very difficult to interpret (Charles, 2005).

The location information at the Darkmold Site was captured using a Total Station[3]. Attribute information was recorded on paper field forms. In the lab, spatial data captured by the Total Station was loaded into AutoCAD to create maps. Attribute information was entered into a Microsoft Access database from the paper field forms.

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[1] Basketmaker II culture is characterized "as having elongated (un-deformed) skulls, intricate textiles, atlatls [spear-throwing tool] and darts, distinctive rock art, and copious amounts of corn. They notably lacked pottery and the bow-and-arrow, which occurred among later groups" (Charles, 2005, p. 1).

[2] According to Mona Charles (personal communication, December 12, 2006) Pueblo I culture is characterized "by distinctive pottery, aggregation into villages with hamlets consisting of a series of surface rooms (roomblock) made of wattle and daub with an associated pitstructure usually south of the roomblock. Ceramics consist of jars, bowls, and ladles. Much of the ceramic pieces from the Durango area are characterized by a lead-glaze paint. Turkeys and dogs were domesticated by this time and the main food base seems to be corn agriculture".

[3] A TopCon brand Total Station with a rod and reflector were used.

1.1. Client Introduction

The client is Mona Charles, Director of the Archaeological Field School at Fort Lewis College. Ms. Charles has extensive background in archaeology and geology, and has been Director of the FLC Archaeological Field since 1999. She is responsible for all excavation, lab work, and documentation of the Darkmold Site. Each field season she leads a group of up to 16 students to excavate the site and complete all lab work. Ms. Charles will publish a final report on her findings at the Darkmold site once the Field School is finished at the site. The analyst excavated at the Darkmold Site under Mona Charles, and has first-hand knowledge of all the excavation of Feature 78, a highly compromised burial, as well as an understanding of the field excavation, recording, and laboratory techniques.

Ms. Charles expects to benefit from this project through the ability to put all data together, and explore relationships between features[4] and artifacts[5] through their attributes and spatial relationships. She would like to have the model cover the entire site, but is willing to focus on certain features if the entire site cannot be completed. These outcomes will allow for a more detailed analysis and, therefore, more meaningful interpretations about the site.

The client wishes to see all spatial data for the site viewed in 3D, using a Geographic Information System (GIS). This will display artifacts as they layed in the ground. Attributes such as artifact or feature type, age, material, quantity, and perceived use will be included to help further differentiate aspects of the site and allow for more meaningful queries.

1.2. Needs Analysis

Archaeology as a discipline is primarily concerned with spatial data, and the data that archaeologists record and analyze is 3D in nature (Wheatley & Gillings, 2002). The data that are recorded include location information and detailed attribute information on all site components. This information is extremely important because once an excavation is complete the archaeologists' records are all that is left (Hester, Heizer, & Graham, 1975). Through excavation, archaeologists learn about a site, but excavation ultimately destroys the site, which is why such detailed field records are needed.

The main problem at the Darkmold Site relates to this field information. Excavation, to date, is complete; records have been taken to the lab, but as of now all data have not been displayed together. Therefore, it is difficult to interpret the site through its various occupations, or use the attributes for comparison. For example, the site has instances of roasting pit features that were re-used as burial pits that were later compromised by the landowner's blading (Charles, 2005). Changes to features through time occurred over the entire site and these physical and temporal relationships are not

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[4] "Features are discrete occurrences within a site or locus that represent an event and that cannot be removed without destroying (or disturbing) their overall integrity and relationship" (Sutton & Arkush, 1996, p. 7). Examples of features common at the Darkmold Site are roasting pits, storage cists, and bell shaped pits.

[5] An artifact is a portable object that retains and shows evidence of having been made or used by humans (personal communication, Mona Charles, December 2, 2006). Examples of artifacts common at the Darkmold Site are projectile points, bone awls, and gaming pieces.

completely understood. Of the information recorded, a major concern of this project is vertical locations because they can be used to explain the temporal changes at the site. The law of superposition states that a stratigraphic layer is younger than those below it, and related to archaeology, a feature is younger than the feature it cuts into (Waters, 1992). It would help the archaeologists to be able to see the locations of features and artifacts not only based on their planar positions, but also by their depths below the surface.

2. Project Background and Proposed Solution

This section demonstrates where the problem faced at the Darkmold Site fits into the domain of archaeology, specifically archaeology utilizing GIS. GIS has been utilized in archaeological analysis since the early 1980s (Mazoras & Zack, 1987), although this use was mostly limited to site suitability studies at the landscape level (Biswell, Cropper, Evans, Gaffney & Leach, 1995). More recently, archaeologists started looking to GIS as an analytical method for site level analysis (Christopherson, Fish, Fish, Chamblee & Leckman, 2005; Wust, Nebiker & Landolt, 2004). At the University of Arizona, the archaeological field school incorporates a geodatabase with Global Positioning System (GPS), and GIS into their basic training (Christopherson et al., 2005). This technical knowledge was well received by the University of Arizona staff and students alike because, even though they had a short field season, their progress was augmented by the technology (Christopherson et al., 2005). This technology allowed them to more efficiently record the surface remains and survey the study area than would have been possible through standard field methods. However, this methodology will not work as well as traditional methods at the Darkmold Site, because the ultimate goals are education and excavation, not survey.

Specifically, the techniques used during excavation diverge from those used in survey because different information is required from each type of investigation (Colorado Historical Society, 2005). For this project, the concern lies with the location of artifacts and features. A feature is an archaeological entity that has a place within the natural stratigraphy of the earth that has been located through archaeological investigation (Arroyo-Bishop & Zarzosa, 1995). Examples of features at the Darkmold Site include storage cists, hearths, roasting pits, and refuse pits. Sites are usually arbitrarily divided by grids, often 1 m x 1 m, superimposed over the entire area (Hester et al., 1975). Before excavation begins, a Total Station[6] is used to locate the excavation units to the superimposed grid system. The x and y locations as well as the elevation (z) are recorded for each level excavated, all tied to the site grid.

The Darkmold Site was excavated mostly in arbitrary 10cm levels. This means the starting elevations of the unit were excavated down 10cm then a level form was completed and a planar map was drawn, then another 10cm level was excavated and this process continued until a feature floor was reached (Hester et al., 1975). These methodologies are standard in archaeology (Hester et al., 1975) and were used with only minor modifications to fit the specific situation at the Darkmold Site.

Artifacts recovered from the Darkmold Site were labeled with a field specimen (FS) number and entered into the field database. A FS number is assigned to each level of a unit's excavation and the FS is further distinguished by artifact type[7]. For a single artifact found in-situ, its location is recorded with a Total Station (called Point Provenience). Other field specimens that contain "bulk" materials (such as bone or

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[6] At the Darkmold Site, the Total Station was placed at the same location each day, and a back site was performed to a known benchmark after each set up. The Total Station used a data logger to capture all x, y and z locations, which were also recorded in a hard-copy log book.

[7] For example, *FS109 Lithic Tool* is Field Specimen 109, which was found in structure 1 layer 3, profile 4 and contains a lithic tool artifact.

lithics) are artifacts found in the feature fill out of context or in the screen, so their location is not exactly known but a count of bulk artifacts is related to a unit level. This bulk FS count is valuable for understanding what occurred throughout the site. For example, an area with a large amount of bulk lithics could have been an area of the site used for lithic reduction, which is the creation of stone tools and projectile points.

The artifact and feature distribution over a site is indicative of its organization during occupation; this information allows archaeologists to infer the past physical and social relationships to some degree (Gargett & Hayden, 1991). Although it cannot be absolutely determined why features were placed where they were within a site, all were placed consciously by the site's occupants and the relationships are important to understanding the site and its culture (Gargett & Hayden, 1991). A map or a three dimensional model is the ideal way to visualize spatial data, such as is found on an archaeological site, and the visualization can prove to be a powerful decision making tool (Berry, 1993). Archaeologists realize the benefits of using GIS analysis, but in the past ten years they have realized the limitations of using a 2D abstraction to model a 3D reality (Wheatley & Gillings, 2002). New hardware and software developments offer alternatives to the 2D abstraction, and the growing pains of utilizing new methods can be lessened with the support of other users.

On the Environmental Systems Research, Inc. (ESRI) support website for GIS users, there is an entire forum devoted to archaeologists and their GIS endeavors.[8] This forum for questions and support is very important because there are reasons to believe that applications of GIS for intrasite analysis are not quite "straightforward" (Biswell et al., 1995, p. 270). Biswell et al., (1995) specifically cite a lack of funding as the reason behind this claim, while others in the field have technical considerations as well. A few archaeologists wrote of specific goals and questions about utilizing 3D models, and a knowledge base can help advance these methods by allowing users to bring their ideas together.

Brad Santos (2002) writes that he is utilizing ArcMap's 3D Analyst to reconstruct a pit house feature that has been excavated. The problems Santos (2002) faces are how to get his field data into GIS and how to represent something that covers such a small area. Bob Booth (2002), the ESRI Archaeology Interest Group Coordinator, suggests bringing the x, y data into GIS in tabular format and digitizing features from site maps. Another user is concerned with setting up the map at a large scale and viewing the associated elevation data in 3D (Macaulay, 2004). The responder suggests using the site datum to georeference the information to a wider coordinate system, UTM in this case, and enter elevation values in a database field to use for visualization in ArcScene (Booth, 2004). Another responder, with GIS experience in site level analysis, suggests making a shapefile for each feature or artifact type and using ArcGIS to show it three dimensionally based on a z value field in the database (Phillips, 2004). Yet another suggestion to Macaulay (2004) is to overlay multiple layers, each containing all features and artifacts in one excavation level as shown in Figure 3 (Booth, 2005). Other current uses of 3D analysis at the site level are to reconstruct historic buildings and objects

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[8] ESRI Archaeology user forum website: http://forums.esri.com/forums.asp?c=87

(Wust, Nebiker, & Landolt, 2004), to determine structure volume and site area statistics (Hill, 2004), and to show artifact density within a site (Craig, 2002).

There is a great deal of information that goes into building a 3D model, which has made the research for this project difficult. Every site has its own particular challenges, such as the bladed surface at the Darkmold Site. With the many differences between sites, the methodology for creating a 3D model differs among projects, but methods from different projects can be combined usefully.

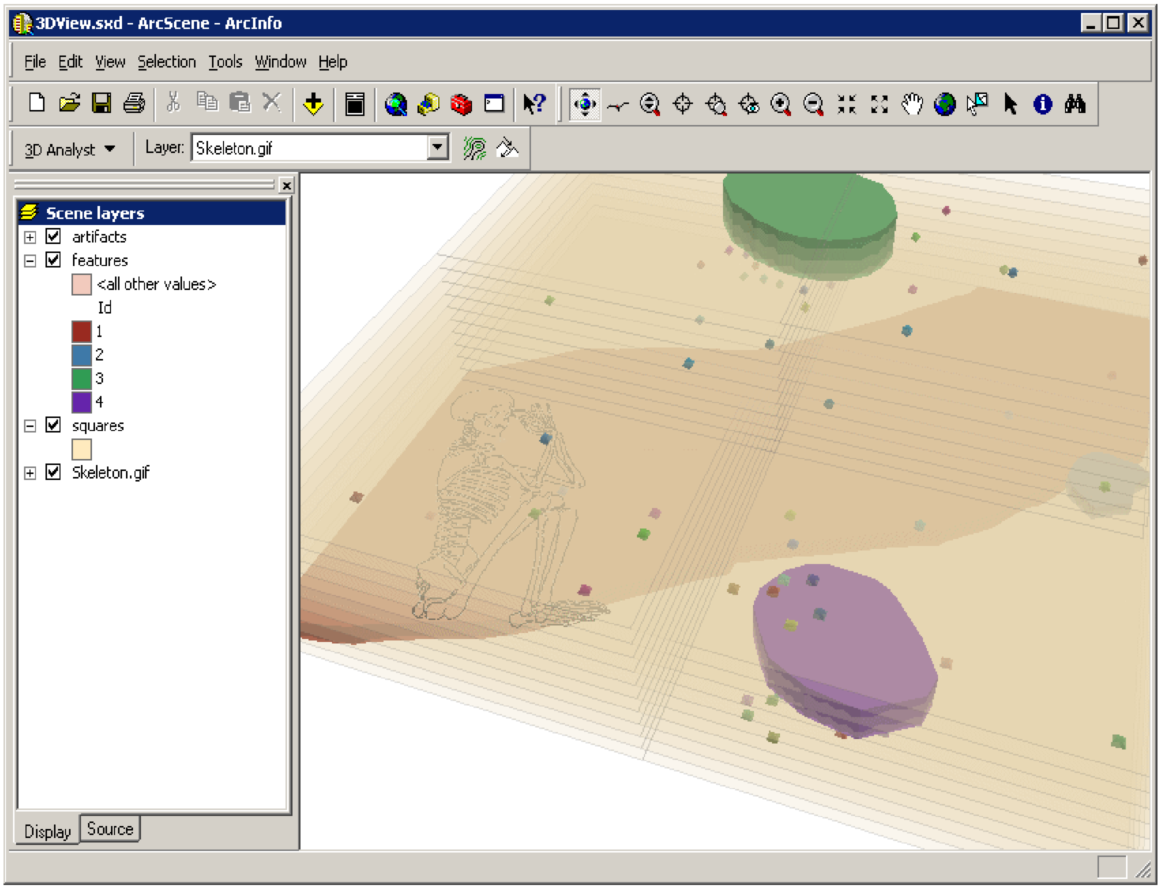


Figure 3. 3D view of an archaeological site, based on excavation levels (Booth, 2005).

First, all methodologies begin with data. To build a practical 3D model x, y, and z coordinates are required for objects and features, as well as detailed attribute information (Mazoras & Zack, 1987). The consensus for generating quality data is to start by considering the data collection techniques.

Suggestions for collecting data for use in 3D modeling include using a scale that is appropriate for the desired final product, collecting data in a device that can be transferred to the desired end medium, and collecting attribute information digitally where applicable (University of California Santa Barbara, n.d. a). These suggestions are designed to make data collection and processing as precise and accurate as possible. At the University of California Santa Barbara, archaeologists created these data capture suggestions and used them to complete a 3D visualization of a site, shown in Figure 4 (UCSB, n.d. b). This 3D model is similar to the surface model proposed for this project so the methodology behind the data collection is similar. With a good data collection methodology in place, a geodatabase can be built from field data that will facilitate creation of a 3D site model.

Figure 4. 3D model of an archaeological site (UCSB, n.d. b).

In the future, the use of GIS in archaeology will continue to increase. According to Wheatley and Gillings (2002), this growth can only occur if the applications of GIS are shaped around a specific research question. Using GIS analysis for a specific question will tie the analysis to an archaeological framework, making it more understandable and accepted in the archaeological community. This will be an improvement over past practices of just completing routine analyses that were not based on the research goals (Wheatley & Gillings, 2002).

The analyst proposes to complete a 3D analysis of the Darkmold Site to show where features, artifacts, and other archaeological entities were once located. Before beginning a 3D analysis, the analyst will have to organize the existing data to make sure all needed components are present and in the proper formats. The current data from the site consists of AutoCAD site overview drawings from each year of excavation (1999-2005). The AutoCAD drawings were created from the Total Station points taken in the field. Although the drawings only show x and y locations, z locations were also recorded by hand on the Total Station log sheets and in the Total Station data collector. Attribute data are currently stored in an Access database and may be referenced by FS numbers.

To complete this 3D application the analyst will create a geodatabase for the storage of x, y, and z values of artifacts, features, and excavation units because all location information (especially the elevation data) may not be available in the AutoCAD maps. In addition to 3D modeling, the project proposes to allow the user to query multiple tables using relates between tables.

3. Data

A major initiative of this project is to take the many different data types that exist for the site and make them compatible for concurrent display. All data coordinates and elevations are measured in meters since that is the standard adopted at the site, which is also the standard measurement unit in archaeology.

3.1. Data Types

The data types that were combined for this project are as follows. Raw Total Station point data (in the form of Excel spreadsheets) including x, y, and z positions collected at the site, as well as descriptions of the point. CAD polyline, point and annotation layers, with x and y locations attached, were created from Total Station point data and planview maps created in the field. An Access database containing attribute information for artifacts collected during excavation. Various Excel spreadsheets containing specific feature or burial information, results from radiocarbon dates tested, and detailed elevation values along the trenches excavated by the landowner. Finally, detailed attribute and positional data were also recorded on hardcopy site forms. The methods for utilizing this data are discussed in further detail in section 3.4.

One issue that continuously presented itself regarding the many different types of data being used was differing data types for the same item. For example, a feature number may have been recorded in an excel file as a text field. While in another excel file the corresponding feature number may have been recorded as a double number type. In order to link the two excel files those two data types must be the same, so even between data of the same format there are discrepancies.

3.2. Data Source

The data used for this project was provided by Mona Charles of the FLC Department of Anthropology. All data was collected by the students of the FLC Archaeological Field school during the field seasons from 1999-2006. The excavation and data collection were completed by the students under the supervision of Mona Charles. The duration of excavations ranged from two to four weeks each season. Archaeology field school begins with a full week of in-class lectures regarding the techniques of excavation, mapping, data collection, the basics of stratigraphy and geology, artifact recognition, the moral and legal implications surrounding archaeology, and documentation. Starting the second week of field school the students are at the site. Students are divided into crews of roughly four to five members each, with one teaching assistant per two crews. Based on the research plan developed in the off season, Mona Charles determines where each crew will begin. Each day the main site datum (a single point to which the entire site is referenced) is located with the Total Station. For each new feature or burial a separate sub-datum is located with the Total Station (a sub-datum is also commonly referred to as a “mapping datum”) and subsequent mapping of the feature or burial is done by hand using the sub-datum as a point of reference. The location of any artifact found in place is also located, or point provenienced, with the Total Station.

Since the students completing the excavation and data collection are learning and are new to the procedures, one can expect some errors. However, this is not overly apparent in the data since great care was taken with collecting and storing the data. Teaching assistants and Ms. Charles double check the site forms and data at the end of each day to make sure there are no obvious errors. This ensures the highest quality data collection and that there is the opportunity to fix a mistake if one is caught. Also, the terms and methods of recording the data are standardized at the site, so if one understands the procedures and naming conventions in use, the data can be understood regardless of the data type or whether the analyst was present at the site when the specific data were collected.

3.3. Data Accuracy

The accuracy of the data collected in archaeology is very important since it is the only record that will remain after excavation. The majority of the data from the Darkmold Site was collected using the Total Station. The Total Station is a survey grade instrument that collects point locations with sub-millimeter precision. The field school students are new to using a Total Station, thus the rod may not always be positioned correctly or the Total Station sight can be slightly off, so the data is actually collected to centimeter accuracy. Thus, all x, y, and z values are precise to the nearest tenth of a millimeter, and centimeter accuracy. Data obtained from CAD files were created from the Total Station data, so the accuracy is also to the centimeter. Data in Excel files were entered by hand or converted from Total Station points, usually by Field School students. Through the process of manipulation and preparation of the data, some discrepancies were located that were most likely due to human entry error. When data may contain human-induced errors it is difficult to determine the overall accuracy of the dataset; however, the errors that were located were fixed, so unless other errors are detected it then shifts to the judgment of the analyst as to whether the data have sufficient accuracy for the project. The analyst believes that all the data for this project maintains the necessary accuracy.

While it is important to have data accurate enough to perform the task, this task did not require the very high accuracy recorded at the site. Nevertheless, the accuracy of the original data were maintained throughout this project. The data collected at the Darkmold Site was not collected with the intention of creating a GIS application. The intention was to explore what the excavation would yield, use the site as a teaching venue, and salvage and record the findings with as much accuracy and detail as possible in order to write a report of the findings. Instead of a three dimensional view of the surface of the site created in a GIS, a photo is how the surface is remembered. The data used in the project are highly accurate; however, it was intended for a purpose other than this GIS analysis, which presents entirely different concerns (for discussion see section 9.2).

3.4. Data Manipulation and Preparation

In order to use the Total Station data that were received in the form of Microsoft Excel spreadsheets, their format needed to be changed to a database table file (DBF). The methodology for this conversion is as follows. First, the data type of each field was checked to make sure the data type and precision required in the geodatabase was being used. Second, the Excel file was saved as a database table file, which can be loaded directly into in ArcMap. The data is then loaded into a feature class, and the steps required to load the data into a geodatabase feature classes are detailed in section 4.2.

The CAD data that include point, annotation, polygon and polyline information from the site is read by the ArcGIS software without any manipulation. Features are divided for display based on data type (point versus line or polygon) with attributes that divide the features as they were differentiated by the initial creator of the dataset. The only manipulation that was required was to separate information from the CAD files as detailed in section 4.2, none was required to simply display the data.

The attribute data that was in the form of Excel spreadsheet tables required formatting to a DBF table before it could be added to an ArcMap document. Data in this form included elevation values for the trenches, detailed information on all burials and features, and the results of radiocarbon dating on samples from the site. This information is not spatial in nature; however, it has ties to the existing spatial data. This makes it valuable for querying so the goal was to make it available to queries and other tables in ArcMap. With the Excel tables the analyst must first make sure the fields are formatted to the type of data that will be needed in ArcMap. For example, the burial number column in the Burials feature class is a text field because there are burials that contain numeric as well as alphanumeric designations, thus the field in the Excel sheet cannot be integer or the values will not be equivalent when they are brought into ArcMap. Once the data types are correct the file is saved as a DBF type, so they can be imported into ArcMap or the Access database. This latter process is described in detail in section 7.1.

The final data manipulation was to bring the Access tables into ArcMap. These tables were from the Field database, designed to hold the detailed artifact catalog for the site. All that needed to be done was to add the tables to ArcMap, and they are displayed as DBF tables with no spatial data. This allows the data to be queried as with the converted Excel sheets, which can be used to relate the attribute information to its spatial counterpart.

4. Geodatabase

A personal geodatabase was created to contain the data for this project. The overall purpose of this geodatabase is to contain all data collected at the site in a way that is efficient for the use, display, and update of the data.

4.1. Geodatabase Design

The geodatabase design remains intentionally simple to allow the client to add data from future excavations. In line with the goals of housing the data and making them usable, the design utilizes multiple domains acting on a single feature class. For display purposes, layer files were created from this feature class to safeguard the actual data and improve performance. Other related ancillary data are stored as feature classes in feature datasets or within the database.

The database contains two feature datasets and many feature classes. The feature datasets are named "Original Data" and "Surface Points". The Original Data feature dataset contains the Total Station point data collected for each year at the site. The master feature class is also housed in this feature dataset (called "Master") and contains all years of excavation merged into a single feature class. The Surface Points feature dataset contains point data from the Total Station data that was deemed useful for interpolating the site's surface. This data and methodology is detailed in sections 5.1 and 5.2, respectively. Feature classes containing ancillary site data are stored separately from the feature datasets, much of which was gleaned from CAD maps, as discussed in section 3.4.

This section will discuss the coded value domains that were created for the Total Station point data. The purpose of the coded domains was to organize the data and allow a definition query to be easily constructed that would differentiate between the types of points and offer more information about features, burials, and artifacts specifically. The coded values were taken from the Access database of attribute data and the Total Station log sheets provided by the client. Not all codes are used currently, but all have been included in this database so they can be used in the future. The domains were created with a hierarchical structure. At the highest level, each point is assigned a value in the Point_Type domain (see Table 1). Every point at the site will have a value from this domain. The next level down through the hierarchy are the Artifact_Type (see Table 2), Burial_Type (see Table 3), and Feature_Type (see Table 4) domains. Only those points that are artifacts will have a value from the Artifact_Type domain, while burial points will have values for the Burial_Type domain, and features will have values for the Feature_Type domain. All other points that do not fall into the burial, artifact, or feature domains are only identified by the high-level Point_Type domain.

To create the coded domains in the feature class, the coded values and descriptions were entered into an Excel spreadsheet and saved as a DBF table. The "Table to Domain" tool in ArcToolbox was used to create a coded value domain from values in a DBF table. The analyst specified input table, code field, description field, workspace where the domain is to be created, and the name of the new domain. This was completed with each table for coded value domains, until each domain was created. An example of a portion of the main data table with domains is shown in Figure 5.

Table 1. Coded values for Point_Type domain.

Code	Description	Code	Description
1	Artifact	14	Mapping Datum
2	Auger Test	15	Other
3	Bedrock	16	Pollen Sample
4	Burial	17	Profile
5	Check	18	Radiocarbon Sample
6	Cutbank	19	Rock Wall
7	Datum	20	Shed
8	Dendro Sample	21	Test Shot
9	Driveway	22	Test Unit
10	Feature	23	Trail
11	Ground Surface	24	Trench
12	Grid	25	True North
13	Line Level		

Table 2. Coded values for Artifact_Type domain.

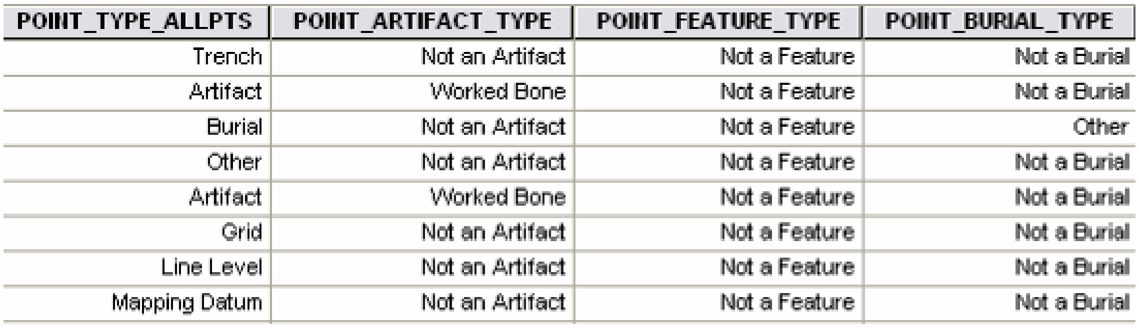
Code	Description	Code	Description
1	Not an Artifact	23	Gizzard Stone
2	Abrader	24	Hammerstone
3	Adobe	25	Human Bone
4	Animal Bone	26	Jacal
5	Antler	27	Lithic Tool
6	Biface	28	Mano
7	Bone Awl	29	Manuport
8	Bone Bead	30	Metate
9	Bone Scraper	31	Notched Bone
10	Bone Tool	32	Other
11	Burned Bone	33	Pendant
12	Ceramic Handle	34	Pipe
13	Ceramic Pipe	35	Projectile Point
14	Ceramic Vessel	36	Shell
15	Chopper	37	Shell Bead
16	Core	38	Stone Bead
17	Corncob	39	Human Teeth
18	Corn Kernels	40	Unfired Ceramic
19	Drill	41	Worked Bone
20	Effigy	42	Worked Sherd
21	Eggshell	43	Worked Stone
22	Gaming Piece		

Table 3. Coded values for Burial_Type domain.

Code	Description	Code	Description
1	Not a Burial	5	Oblong Pit
2	Bell-Shaped Pit	6	Other
3	Burial Pit	7	Oval Pit
4	Not Complete		

Table 4. Coded values for Feature_Type domain.

Code	Description	Code	Description
1	Not a Feature	16	Oval Hearth
2	Arc	17	Oval Pit
3	Bell-Shaped Cist	18	Pit Structure
5	Bell-Shaped Roasting Pit	19	Pit-Unknown
6	Bench	20	Plaster Floor
7	Burned Earth	21	Post Hole
8	Circular Pit	22	Refuse Pit
9	Cist	23	Rock Wall
10	Floor	24	Round Cist
11	Hearth	26	Shallow Oval Pit
12	Historic Perk Test	27	Slab-lined Cist
13	Large Roasting Pit	28	Slab-lined Pit
14	Not Complete	29	Slab-lined Roasting Pit
15	Other	30	Bell-Shaped Storage Cist



POINT_TYPE_ALLPTS	POINT_ARTIFACT_TYPE	POINT_FEATURE_TYPE	POINT_BURIAL_TYPE
Trench	Not an Artifact	Not a Feature	Not a Burial
Artifact	Worked Bone	Not a Feature	Not a Burial
Burial	Not an Artifact	Not a Feature	Other
Other	Not an Artifact	Not a Feature	Not a Burial
Artifact	Worked Bone	Not a Feature	Not a Burial
Grid	Not an Artifact	Not a Feature	Not a Burial
Line Level	Not an Artifact	Not a Feature	Not a Burial
Mapping Datum	Not an Artifact	Not a Feature	Not a Burial

Figure 5. Example of domain values in main data table.

4.2. Geodatabase Population

The main source of data is Total Station points containing x, y, and z location values. The points were given to the analyst as Excel spreadsheet files with a separate Excel file for each year of excavation. The methodology for converting the data in order to populate the points into a geodatabase feature class is as follows and each Excel file was processed in the same way. Each DBF table (converted from Excel spreadsheets as discussed in section 3.4) was added to ArcMap and displayed using the “Add X Y data” tool. This takes the x and y values from the table and displays them spatially. Then, the x y spatial data were exported as a shapefile. Finally, a new empty feature class was created in the geodatabase with the required fields, precision, and ability to contain elevation values. The “Append” tool was used to append the existing point shapefile to the existing geodatabase feature class. Each year of Total Station point data is then stored in a separate feature class; however, the main data table contains the data from all years. A year field was created in each feature class and this was populated with the year the data were collected, so once the data were combined it could still be differentiated by year. The feature classes for each year of excavation were then merged into a single feature class. It is the hope of the analyst that data in future years can go through this same process and be appended to the main feature class after future excavations (see section 4.3).

Once the main feature class was created, there was little to distinguish one point from another even though they represent distinct aspects and locations at the site. It was the suggestion of Mark Kumler (personal communication, August 26, 2006) to utilize coded domain values to differentiate each point and add additional information to certain point types (detailed in section 4.1). To accomplish this, four new fields were created and the domains discussed in section 4.1 were applied: Point_Type_Allpts (Point_Type domain), Point_Artifact_Type (Artifact_Type domain), Point_Feature_Type (Feature_Type domain), and Point_Burial_Type (Burial_Type domain). The analyst populated each of these fields with the appropriate domain value by hand. The values given to each point were based on point information recorded on the Total Station log sheets.

In order to show the detail that was captured for each feature and burial at the site, the CAD polyline data were used. The points representing features and burials in the Total Station data simply represent a datum used for mapping or the center of a feature or burial. The CAD lines were digitized by Field School students based on the Total Station data and planview maps drawn in the field. The CAD polylines show the size, shape, and location of all bones, rocks, and walls that make up burials or features (see Figure 6). In order to transfer the CAD polylines into the geodatabase, the analyst selected individually those polylines from the CAD files that were either features or burials. Each set of polylines was exported to a separate feature class within the geodatabase. When the features and burials were digitized in CAD, many single part features were created, so in the newly created feature classes there were multiple entries per feature or burial. The analyst required that there be only one entry per feature or burial in the feature class. To accomplish this each feature was first dissolved into a separate feature class using the "Dissolve" tool in the Data Management toolbox. This was required because ArcMap would not allow so many polylines to be merged at once using the "Merge" command on the Editor toolbar (in many cases there were more than 60 polylines that represented one

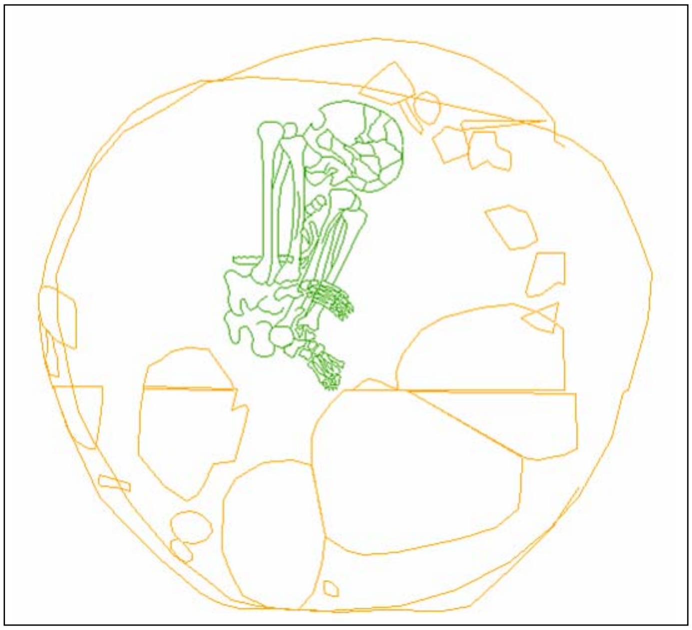


Figure 6. Burial (green) within a feature (orange) as polylines created from CAD files.

feature or burial). Once each feature or burial was dissolved to separate feature classes, all feature classes of the same type were merged together using the “Merge” tool.

4.3. Future Updates

It is the hope of the analyst that the database will be updated with each additional year of Total Station data. This will allow the client to have a method of storing the data and easily compare new data to previous years. Another benefit is the ability to update the attribute as well as the spatial data so comparisons between the two are possible where previously the spatial and non-spatial data have not been combined.

To update the spatial data the methodology is as follows. First, the new Total Station data will have to be converted from an Excel file into a DBF table. The DBF table can be brought into ArcMap to make sure the data types are correct before proceeding. Second, use the “Add X Y Data” tool to add the Total Station points to the data view. Third, export the Total Station points to their own feature class. Fourth, use the Append tool in the Data Management toolbox (General toolset) to combine the two datasets. The new feature class of points will be the input features, while the output features will be the existing main point dataset, named “Master”. The schema type does not need to be tested because the user will populate the point type fields once the datasets are combined. A training video shows this process in a step-by-step fashion; see details in section 8.2.1.

The feature classes based on the CAD files (burial and feature polylines discussed in section 4.3) should also be updated each year. The methodology is similar to the above; however, the data are added directly into ArcMap and a query of the attributes will be used to select features in the CAD files that need to be appended. Subsequently the “Append” tool is used in the same fashion to append the burials to the Burials feature class, and the features to the Features feature class.

It is important to keep this database and GIS application updated because it is easiest to fix errors or collect more data before the field season is over. By displaying all the data types together, both spatial and non-spatial, it can help show where there are an abundance of data or where more work may be needed. The excavation organization of the Field School work in the field is followed by lab work to process the artifacts and samples collected, digitize the field maps, and create the CAD files. This needs to apply to the GIS application as well because, as the analyst learned from this process, sifting through years worth of data after the fact creates many suggestions for future data collection techniques (see discussion Chapter 9), keeping data up to date will support a more accurate and useful GIS application.

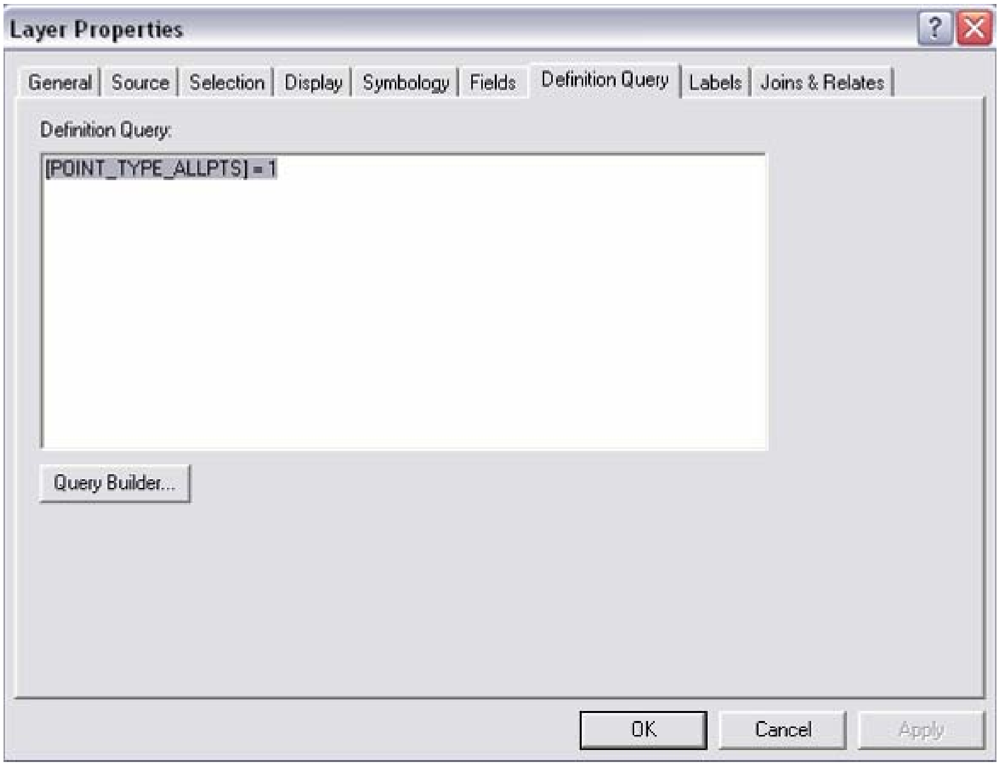
5. Two Dimensional Display

The two dimensional display for this project is important because currently it is the form of map communication that is most widely used in archaeology. Site forms and reports always include a planview, or two dimensional, map to show location, detail, shape, and placement. The map series at the end of this chapter utilized the following components and methods for map creation and display.

5.1. Layer Files

The layer file is the basis of the data displayed on the maps in this series. A layer file stores the symbology, definition query, and names that the main dataset had when the layer file was created. Thus, the layer file references the data in the parent dataset, but it can have different symbols and definition query for that data. This was the way the analyst decided to display the Total Station point data for the map series and in future two dimensional displays because all the point data are in one large feature class. Using layer files allows the changes mentioned above to be completed without loading many copies of the same large dataset into one ArcMap document.

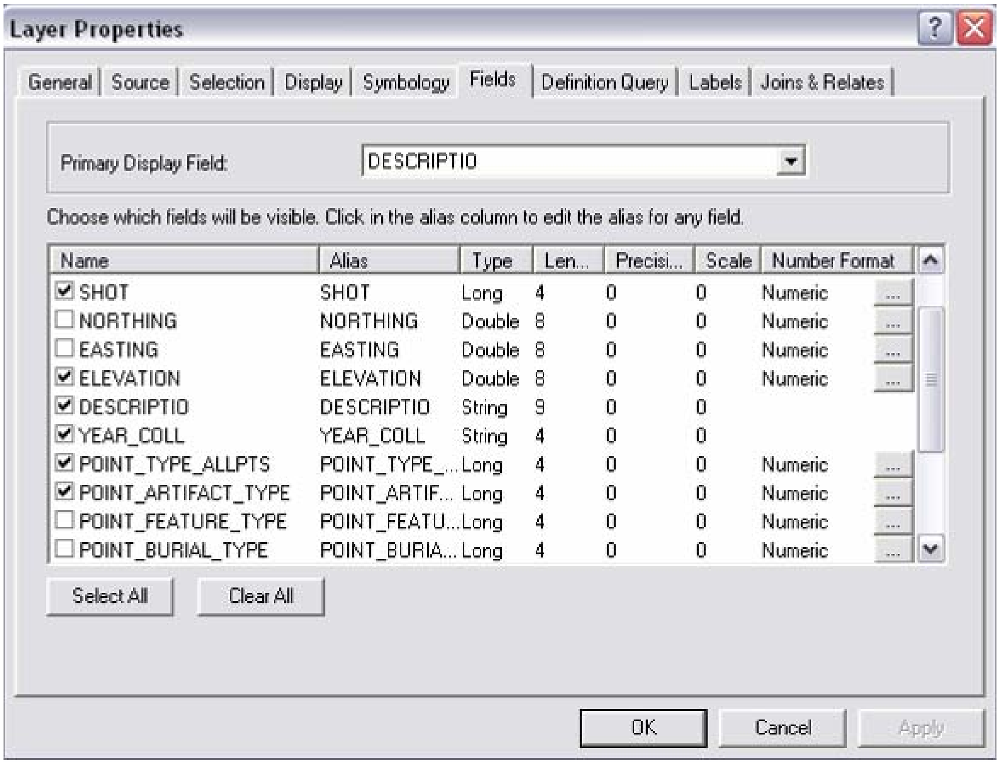
Creation of the layer files begins with the main feature class. To create the layer for the artifacts shown in the map series, a definition query is created to only show the artifact points from the main feature class. The definition query stated: [POINT_TYPE_ALLPTS] = 1 (see Figure 7), signifying that the only points that will be shown are those where the value in the Point_Type_Allpts field is equal to one (see



[POINT_TYPE_ALLPTS] = 1

Figure 7. Definition query for artifact points.

coded domain in Table 1), meaning that the point is an artifact. In addition to the definition query, the analyst chose to limit the fields shown in the layer attribute table (see Figure 8). For instance, the Point_Burial_Type is hidden from view in the artifact layer because the burial information is not relevant. This only hides the field, because the data in the hidden field can still be used in queries or viewed if the box to hide the field is un-checked. Once the definition query is set, the symbology can be changed to suit the points in the definition query, in this case the artifact symbols are used (discussed in the following section). Once the definition query and symbols are set, the layer name should be renamed in the table of contents to reflect the layer, so in this case it is named "Artifacts". The layer file is created by right clicking on the dataset name in the table of contents and choosing "Save as Layer File". The layer file is not saved within the database. The layer file references the feature class, so the analyst can choose to create a separate folder at the same level as the geodatabase to store layer files. As long as the layer file is located in the same relative location from its main file, it can reference the data. With layer files, it is important that all symbology, naming, and definition queries are set when the layer is created because any changes made to the layer are not saved. When the layer is opened in another document, it will revert to the original settings, thus any necessary data changes must be made to the original dataset then a new layer can be created. However, when new data are added to the main dataset, it will automatically be included in the layer file with the previously defined symbology and visible fields if the new data fits the current definition query.



Layer Properties

Primary Display Field: DESCRIPTIO

Choose which fields will be visible. Click in the alias column to edit the alias for any field.

Name	Alias	Type	Len...	Precisi...	Scale	Number Format
☑ SHOT	SHOT	Long	4	0	0	Numeric
☐ NORTHING	NORTHING	Double	8	0	0	Numeric
☐ EASTING	EASTING	Double	8	0	0	Numeric
☑ ELEVATION	ELEVATION	Double	8	0	0	Numeric
☑ DESCRIPTIO	DESCRIPTIO	String	9	0	0	
☑ YEAR_COLL	YEAR_COLL	String	4	0	0	
☑ POINT_TYPE_ALLPTS	POINT_TYPE_...	Long	4	0	0	Numeric
☑ POINT_ARTIFACT_TYPE	POINT_ARTIF...	Long	4	0	0	Numeric
☐ POINT_FEATURE_TYPE	POINT_FEATU...	Long	4	0	0	Numeric
☐ POINT_BURIAL_TYPE	POINT_BURIA...	Long	4	0	0	Numeric

Figure 8. Selecting field visibility for artifact points.

Layer files were created for the following points at the site: artifacts, auger test, bedrock, burials, datum, dendro sample, driveway, features, site grid, other point, pollen sample, radiocarbon sample, rock wall, test unit, and trench. Each point has a different layer file, symbology, and definition query based on the domain for the point type of interest.

5.2. Symbology

There are other fields of study that utilize GIS analysis that have standardized symbol sets. Transportation applications, for instance, may use the same symbols for stop signs that one expects to see on the road. However, archaeology does not have a standardized symbol set. At each site there may be a set of symbols that is used for consistency and clarity, but that is not overarching in the discipline. For the map series in this project, the focus of the symbol creation was on artifact point features. Since the attribute table for the Artifacts layer already contained a field that differentiated Point_Artifact_Type, the symbols were created to match the artifact type. Initially the analyst tried to create mimetic symbols for the artifacts, or symbols that mimic the thing they represent (Slocum, McMaster, Kessler, & Howard, 2004). In this case, there were too many similar looking artifact types, such as a biface, chopper, hammerstone, and lithic tool. An archaeologist holding the artifact could distinguish between the four types, but a user looking at a paper map at the scale required to show all the artifacts could not.

To solve this problem, the analyst settled on geometric symbols, which are distinguished by shape, hue, or other distinguishing mark such as a label. This allowed the artifacts to be divided into categories first based on whether the artifact was a tool, whether it was made of bone, or whether it was another good. Each category was uniquely symbolized by shape: tools are symbolized as triangles, goods are symbolized as circles, and bone is symbolized by squares. Then the tools and goods categories were further subdivided by hue. Tools were divided by material type into stone and bone. Goods were divided by artifact type into beads, ceramics, and gaming pieces. Finally each symbol has an identifying letter to make it unique within its family of symbols. The final results are shown in Figure 9. A casing was used behind each symbol to allow the

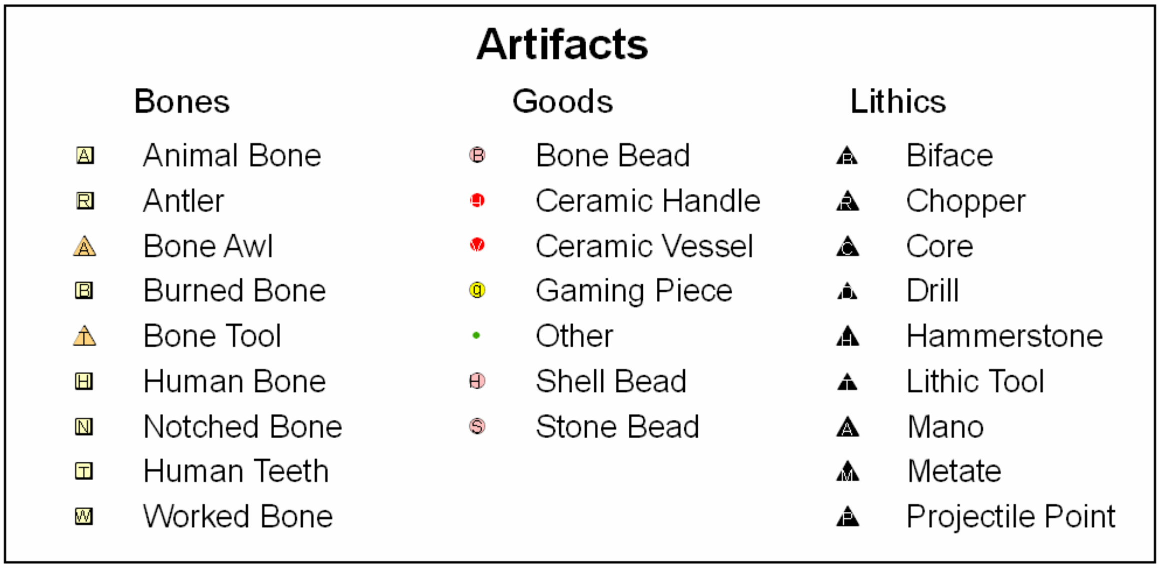


Figure 9. Artifact point symbols created for the site.

reader to differentiate between symbols in the event of overlap, and to distinguish the symbol from the map background. This solution to the symbols for artifacts at the site is simple for the reader to understand, and the grouping of the symbols allows information such as material type or use to be seen easily.

To date, there are no formal symbol sets for archaeology; however, ESRI is working to create some. Bob Booth, the Archaeology Users Group coordinator for ESRI, has been working (with the input of willing archaeologists) to create a simple symbol set that can be used for archaeological applications (see Figure 10). Mr. Booth acknowledges that the set is a rough draft and may be most useful to North American sites (personal communication, November 6, 2006). Creating a symbol set is a step in the right direction in terms of creating GIS components for archaeology; however, the variation between sites, excavation and collection methodology, standards, and goals make it difficult to create something useful for all. Although, if a symbol set is created, archaeologists can modify it to meet their needs instead of starting from the beginning. Working to create tools useful to the archaeologist using GIS may increase the future use of GIS in archaeology.

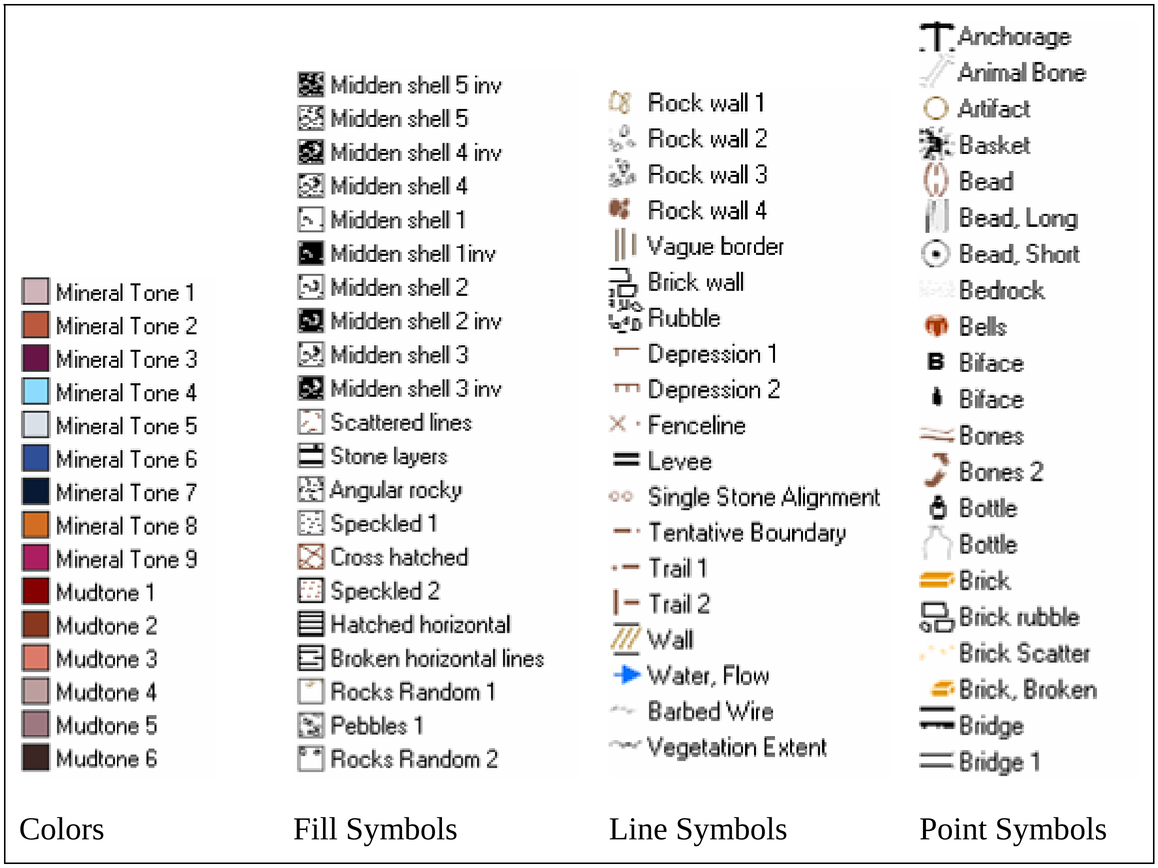
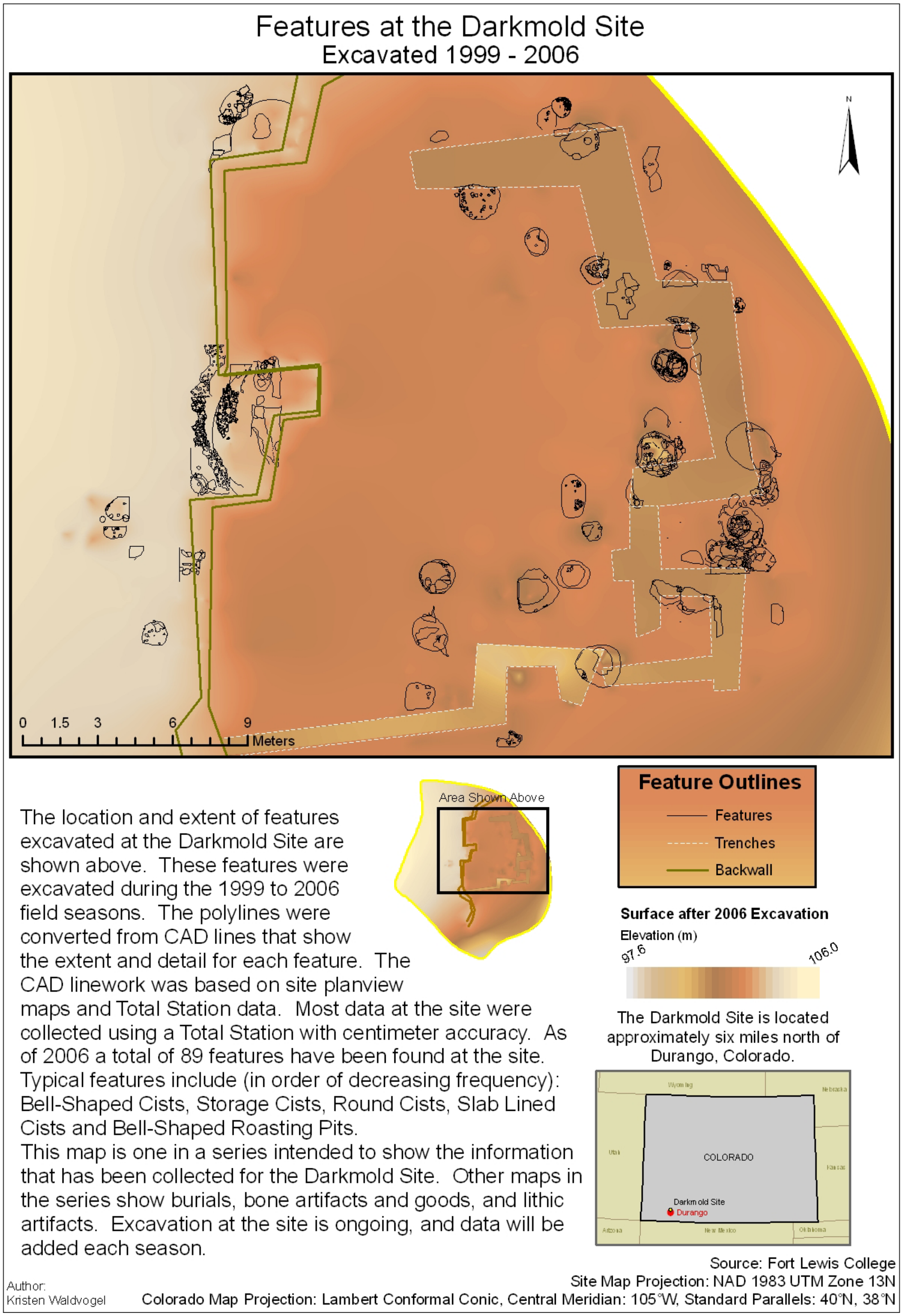


Figure 10. Sample symbology for archaeology, created by B. Booth, ESRI.

5.3. Map Series

A map series was created to show the information that is available for the Darkmold Site. There are four maps in the series because the area of the site is small, which makes it difficult to display the great amount of data at once. The first map in the series shows the Features at the site (Figure 11). The second map in the series shows the Burials at the site (Figure 12). The third through sixth maps show artifacts and goods at the site; however, they had to be divided into four maps because there were too many artifacts found to show all at once. The third map shows bone artifacts and other goods (Figure 13), while the fourth map shows detailed views of some of the bone artifacts and goods (Figure 14). The fifth map shows lithic artifacts at the site (Figure 15), while the sixth map shows detailed views of some of the lithic artifacts (Figure 16). The symbology discussed in section 5.2 was utilized in all maps of the series.



The location and extent of features excavated at the Darkmold Site are shown above. These features were excavated during the 1999 to 2006 field seasons. The polylines were converted from CAD lines that show the extent and detail for each feature. The CAD linework was based on site planview maps and Total Station data. Most data at the site were collected using a Total Station with centimeter accuracy. As of 2006 a total of 89 features have been found at the site. Typical features include (in order of decreasing frequency): Bell-Shaped Cists, Storage Cists, Round Cists, Slab Lined Cists and Bell-Shaped Roasting Pits.

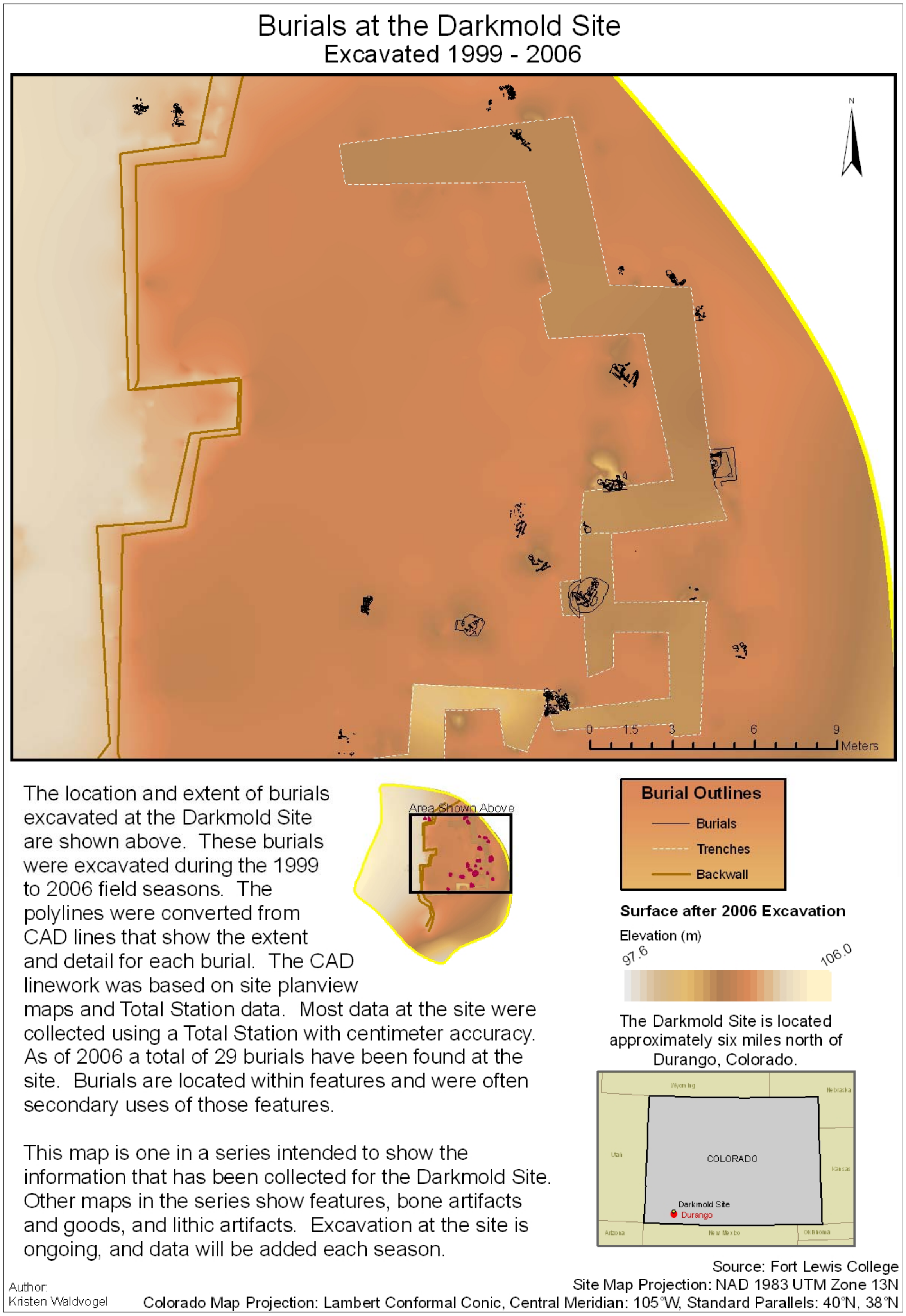
This map is one in a series intended to show the information that has been collected for the Darkmold Site. Other maps in the series show burials, bone artifacts and goods, and lithic artifacts. Excavation at the site is ongoing, and data will be added each season.

The Darkmold Site is located approximately six miles north of Durango, Colorado.

Source: Fort Lewis College
Site Map Projection: NAD 1983 UTM Zone 13N
Colorado Map Projection: Lambert Conformal Conic, Central Meridian: 105°W, Standard Parallels: 40°N, 38°N

Author:
Kristen Waldvogel

Figure 11. Features at the Darkmold Site.



The location and extent of burials excavated at the Darkmold Site are shown above. These burials were excavated during the 1999 to 2006 field seasons. The polylines were converted from CAD lines that show the extent and detail for each burial. The CAD linework was based on site planview maps and Total Station data. Most data at the site were collected using a Total Station with centimeter accuracy. As of 2006 a total of 29 burials have been found at the site. Burials are located within features and were often secondary uses of those features.

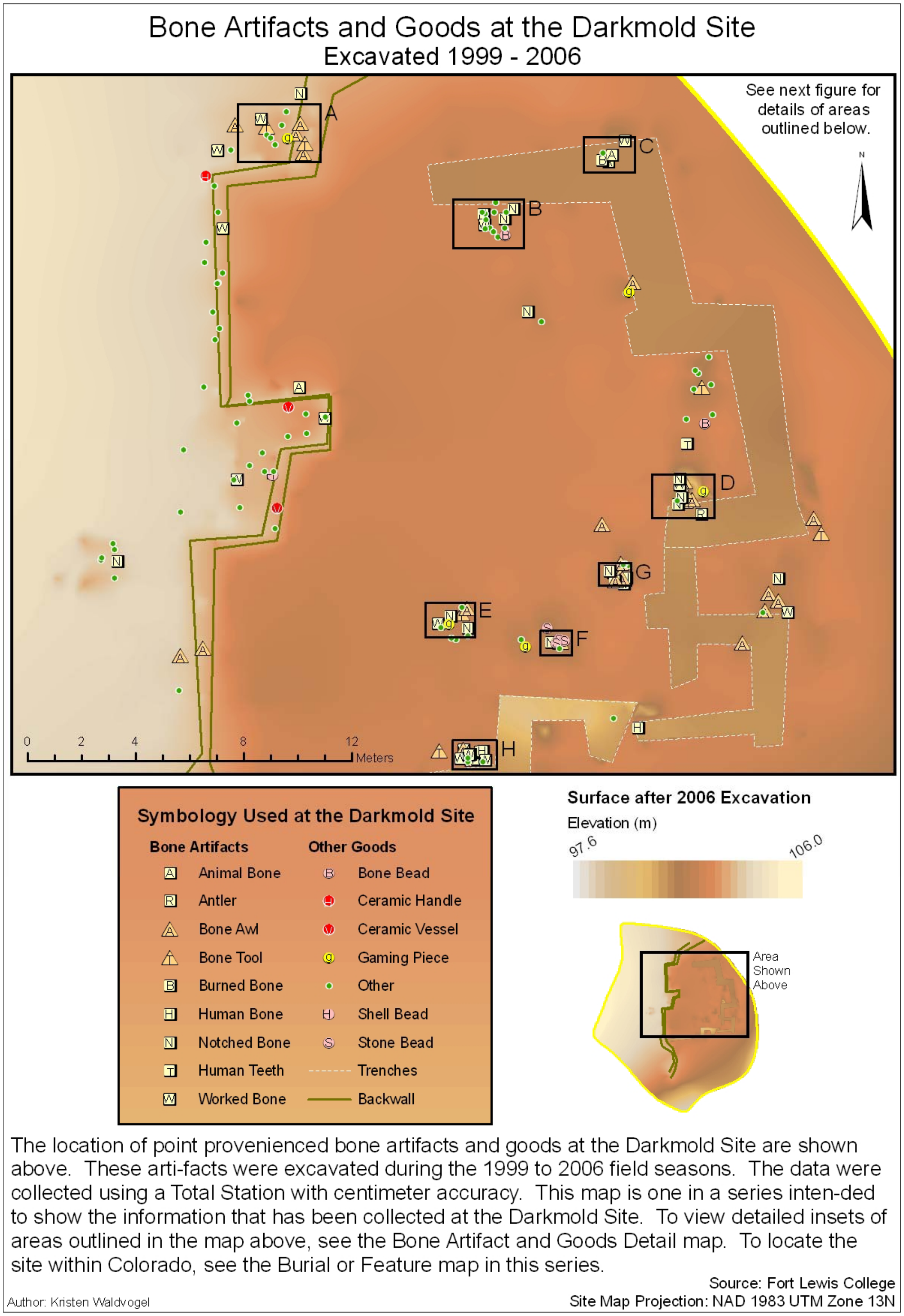
This map is one in a series intended to show the information that has been collected for the Darkmold Site. Other maps in the series show features, bone artifacts and goods, and lithic artifacts. Excavation at the site is ongoing, and data will be added each season.

The Darkmold Site is located approximately six miles north of Durango, Colorado.

Source: Fort Lewis College
Site Map Projection: NAD 1983 UTM Zone 13N
Colorado Map Projection: Lambert Conformal Conic, Central Meridian: 105°W, Standard Parallels: 40°N, 38°N

Author:
Kristen Waldvogel

Figure 12. Burials at the Darkmold Site.



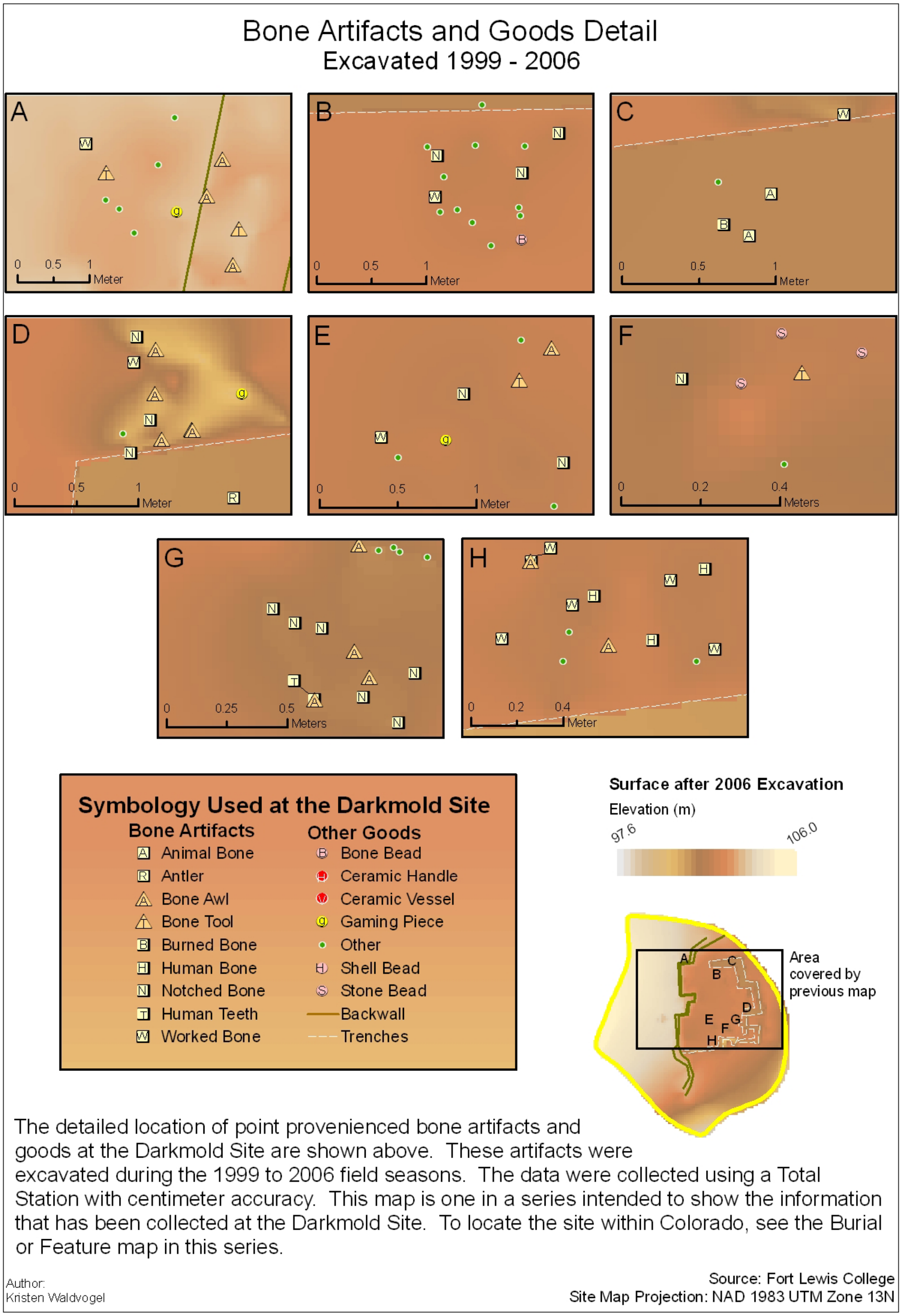
The location of point provenienced bone artifacts and goods at the Darkmold Site are shown above. These arti-facts were excavated during the 1999 to 2006 field seasons. The data were collected using a Total Station with centimeter accuracy. This map is one in a series inten-ded to show the information that has been collected at the Darkmold Site. To view detailed insets of areas outlined in the map above, see the Bone Artifact and Goods Detail map. To locate the site within Colorado, see the Burial or Feature map in this series.

Source: Fort Lewis College

Author: Kristen Waldvogel

Site Map Projection: NAD 1983 UTM Zone 13N

Figure 13. Bone Artifacts and Other Goods at the Darkmold Site.

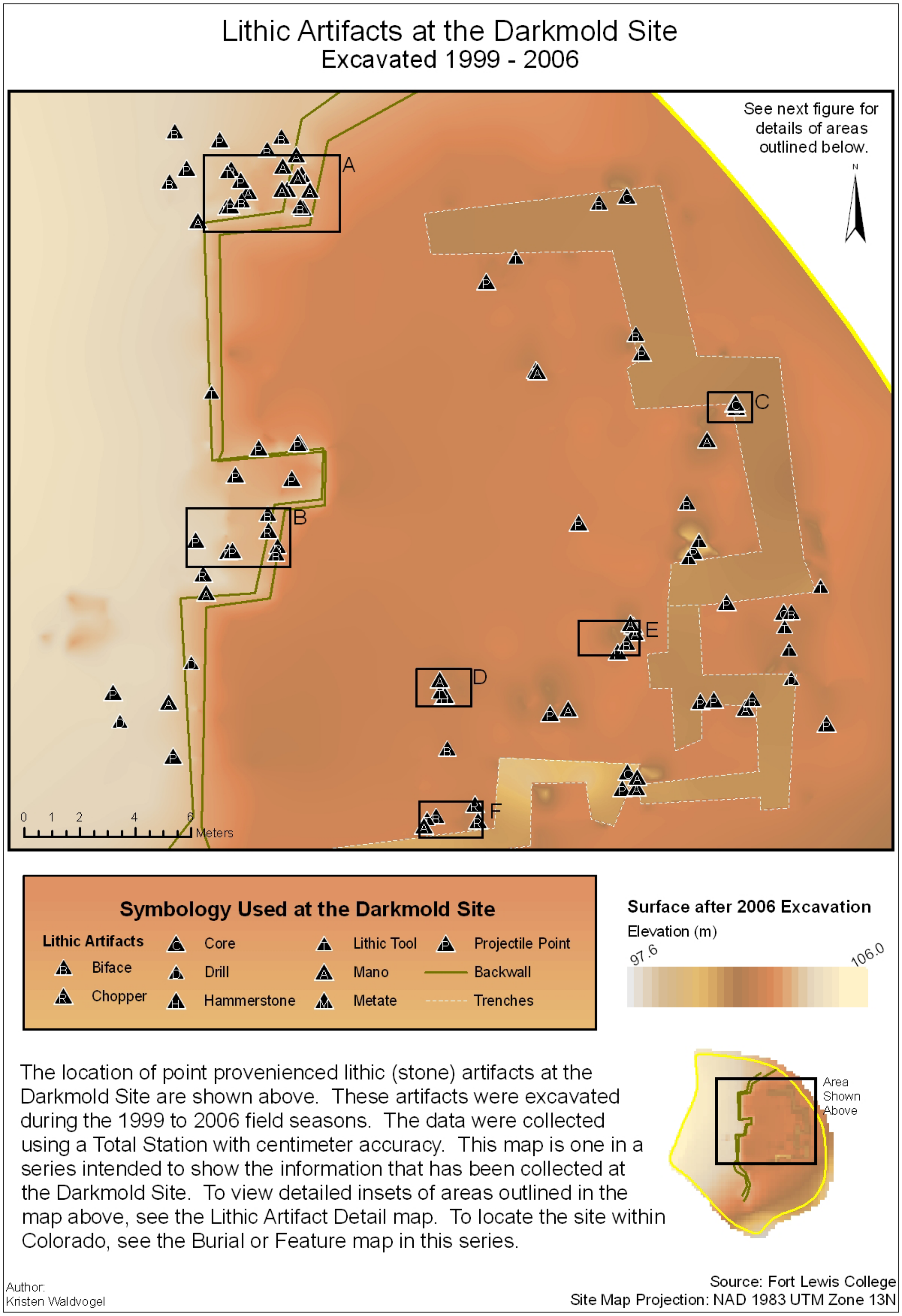


The detailed location of point provenienced bone artifacts and goods at the Darkmold Site are shown above. These artifacts were excavated during the 1999 to 2006 field seasons. The data were collected using a Total Station with centimeter accuracy. This map is one in a series intended to show the information that has been collected at the Darkmold Site. To locate the site within Colorado, see the Burial or Feature map in this series.

Author:
Kristen Waldvogel

Source: Fort Lewis College
Site Map Projection: NAD 1983 UTM Zone 13N

Figure 14. Detail of Bone Artifacts and Other Goods.

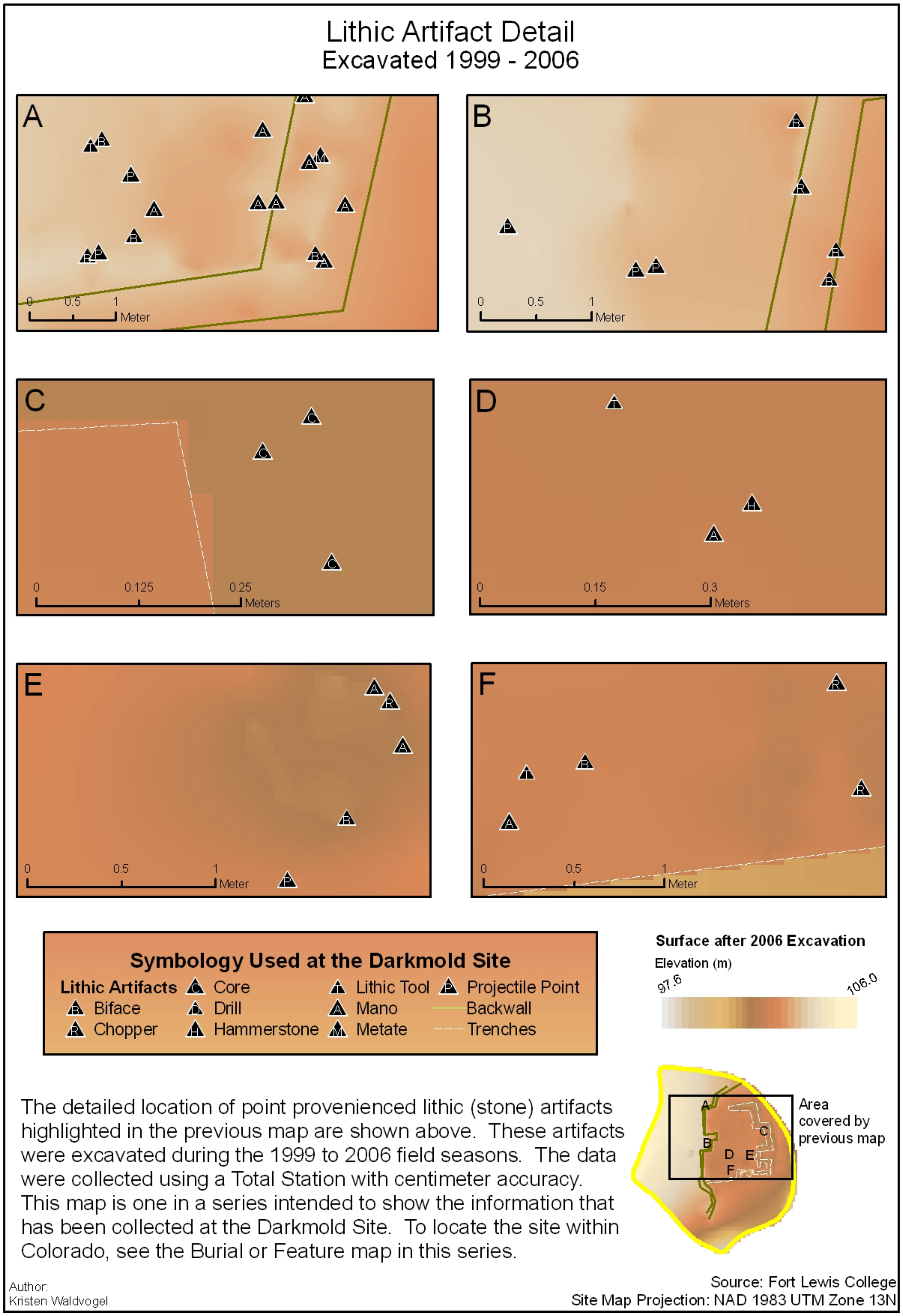


The location of point provenienced lithic (stone) artifacts at the Darkmold Site are shown above. These artifacts were excavated during the 1999 to 2006 field seasons. The data were collected using a Total Station with centimeter accuracy. This map is one in a series intended to show the information that has been collected at the Darkmold Site. To view detailed insets of areas outlined in the map above, see the Lithic Artifact Detail map. To locate the site within Colorado, see the Burial or Feature map in this series.

Author:
Kristen Waldvogel

Source: Fort Lewis College
Site Map Projection: NAD 1983 UTM Zone 13N

Figure 15. Lithic Artifacts at the Darkmold Site.



The detailed location of point provenienced lithic (stone) artifacts highlighted in the previous map are shown above. These artifacts were excavated during the 1999 to 2006 field seasons. The data were collected using a Total Station with centimeter accuracy. This map is one in a series intended to show the information that has been collected at the Darkmold Site. To locate the site within Colorado, see the Burial or Feature map in this series.

Figure 16. Detail of Lithic Artifacts.

6. Three Dimensional Surface Models

The goal of the three dimensional surface models is to create a model that most accurately represents the ground surface of the site. A separate model is created for each year of excavation. The final methodology, as discussed below, resulted from using Total Station points as well as CAD linework as the input to a Triangulated Irregular Network (TIN). A TIN was chosen because of the amount of control the analyst has over the inputs and the interpolation of the surface. Ultimately the TIN was converted to a raster, and the final result of the three dimensional surface models is eight raster grids representing the elevation surfaces at the site after each year of excavation. Throughout this discussion the analyst refers to “previous year” as data from any year before the year being examined, and “current year” as the data for the year currently being examined.

6.1. Data

The data utilized to create three dimensional surfaces of the site are from Total Station points and CAD linework. The Total Station points are the artifacts, test unit corner points, sub-datums, and all other points collected at the site. The CAD linework includes the lines demarcating the back wall and trenches at the site. To begin with, all data were considered, but it was quickly apparent that not all points from the Total Station were useful in creating surface models. Each point was given a point type, as discussed in Chapter 4. Points called “Profile”, “Line Level”, “Test Shot”, and “True North” do not represent a location on the ground surface. A point designated “Profile” is one used to locate a stratigraphic profile map and could denote any elevation along the profile of a wall. A point designated “Line Level” is one that is taken at the location a line level is stretched to map a feature, burial, profile, or other aspect of the site. This is a datum for mapping a specific feature and is not necessarily at the ground surface level. As with points designated test shot or true north, they may not have been tied to the ground surface either, so they do not have a use in creating a model of the ground surface.

For the CAD linework, the trench outlines were used as line features and no attribution was assigned; however, the lines were used to create data. In order to create the almost vertical walls of the trenches, a trench floor line was created from the CAD trench top lines to force the interpolators to calculate the trench floor, walls, and top separately. A buffer was created two centimeters inside the original trench line to represent the trench floor line. The analyst received detailed elevation values for the top and floor of each trench, but the exact location of those values within each trench was unknown. To utilize this data, the analyst decided to use the average top and floor elevation for each trench in the corners of the trench only. Where two trenches connected, the average of the two averaged corner values was used. The points had to be created to apply the elevation values to, so the “Feature to Line” tool was used to convert the trench top and floor lines to polygon features. Then the “Line to Feature Vertices” tool was used on the polygons to create points at the corners of the trench top and floor lines. The elevation values discussed above were then attributed by hand for these points. In addition to the points at the corners of the trench top and floor, the analyst discovered that elevations along the trench lines would be required to create an appropriate surface.

Since elevations along the trench lines were not available, they had to be created. To do this two surfaces were created. The first surface was an Inverse Distance Weighted (IDW) raster surface created using the trench floor corner points only, interpolating using each point compared to its two nearest neighboring points. This showed the variation of a surface between those points. The second surface was an IDW raster surface based on the trench top corner points. For each of these surfaces the “Features to 3D” tool was used to give the trench line feature classes the elevation values of the IDW surface. Then the “Divide” tool was used on each of the line feature classes. The “Divide” tool added points every half meter along each trench line and each point added has the elevation value from the line at that point. These points can be used to create the surface model for the site.

The back wall lines were attributed with the elevation of the lines because they fall along contour lines, thus the back wall lines happen to have a constant elevation that was used to create the surface models.

In order to create a surface that models the ground as accurately as possible, only the points thought to represent the elevation at the ground surface were used. The Total Station points that were usable to create a surface (as discussed previously) were selected from the main feature class and exported to a separate feature class. From this new feature class of usable surface points, eight feature classes were created; one for each year of excavation. The reason for separating the points by year was because they could be introduced into the surface creation methodology separately, thus giving the analyst more control over the inputs to the surface. The concern with using the points from the previous years in addition to those of the current year surface was that some of those points still hold valid surface elevations, while some were removed while excavation continued under where that point had been located. To remedy this, the analyst compared the data from previous years with the current years data to determine if there were any overlaps, or areas that had been excavated further in the current year. To choose the points that were duplicates, or not valid for the current year, a “Select by Location” query was used. The analyst selected points from previous years that were within ten centimeters of a point in the current year. By looking at the attribute table and comparing the type of point, the analyst determined whether the point from the previous year was also valid for the surface elevation of the current year. For example if the current year is 2000, the points from 1999 will be examined to locate any duplicates. If there is a point in the 1999 data that is within 10cm of a point in the 2000 data and that point is an artifact, that artifact point will not be used to create the 2000 surface; because the artifact would have been removed and excavation most likely continued. Once the point data from previous years was determined to be useful, it was appended to the surface point feature class for the current year. This methodology was also applied to the points on the contour lines, and none were found to be erroneous. This methodology allowed the analyst to amass more point data for later years where the elevation value continued to represent the ground surface. After the feature classes of usable surface points were created, they were further divided into feature classes of surface points falling only outside the top of the trench versus points falling in the trench floor. Again, separating the points gives the analyst more control over the inputs for interpolation.

Once the analyst began experimenting with interpolating a surface, it became apparent that the coverage of the points was too minimal and the surface would not be an accurate representation. Mark Kumler suggested using points along the contour lines as mass points in the TIN (personal communication, September 26, 2006). These points were extracted using the “TIN to Features” tool, which turned the TIN nodes into points. This created points along the contour lines that could be used as additional input to create the surfaces. The only problem with the points along the contour lines was the density of the points, there were too many. Every interpolator tried became overloaded with the number of points along the line, so the analyst thinned out the points so there was a point only every two meters along the contour line. Once the points were thinned out the analyst checked them to make sure no later excavation occurred underneath the contour points; this was completed using the same methodology as for the surface points.

6.2. Methodology

Surfaces in the ArcGIS software can be in the form of a TIN or a raster dataset. Each has advantages and disadvantages in every situation so the analyst used the ESRI help documentation (ArcGIS, 2005) to determine which would be best to use in this situation. The analyst determined that, based on the data available, it is best to create a TIN, then convert the TIN to a raster dataset. With a TIN the analyst has the ability to utilize many point datasets to interpolate the surface elevation, as well as multiple line and polygon features to determine which points are related or the area of interpolation. Of the raster interpolators, the IDW method is the only interpolant that allows the use of breaklines to determine which points are related during interpolation (ESRI, 2005); however, only one feature class containing breaklines can be used and this project requires three to four breaklines. The “Edit TIN” dialog is shown in Figure 17, which shows the variables that must be identified for each feature class used. The two variables this project is most concerned with is the height source, meaning which field in the

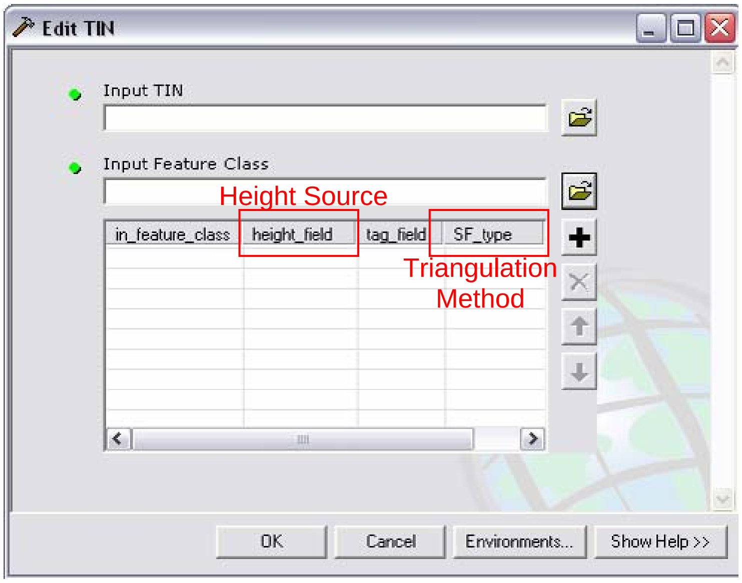


Figure 17. Edit TIN dialog with variables of interest highlighted.

feature class contains elevation information, and the triangulation method, which designates how the features are used in the interpolation.

Although deciding to use a TIN to interpolate the surface was fairly straightforward, determining how to create that TIN was a challenge. Four methods for creating a TIN grew from the trials, and all but one failed to produce a surface that the analyst felt accurately models the ground surface at the site. The failed methods will be introduced, followed by a detailed discussion of the successful method.

The first method involved using surface points as mass points for triangulation type with the elevation field as the height source for the points. This method was attempted before the points along the trench lines were created, so those points were not included. The points along the contour lines were used as mass points with the elevation field as the height source. The back wall lines were used as hard breaklines with no height source. The trench top line was used as a soft breakline with no height source assigned. The resulting TIN was modified to use the site boundary polygon as a hard clip to limit the area covered by the TIN. No height source was used for the site boundary. The TIN was converted to a raster using the "Convert TIN to Raster" tool. The raster surface that resulted from this methodology is shown in Figure 18. The trenches lack definition because the trench lines were used as soft breaklines, which tries to account for all elevations smoothly from the floor to the top of the trench. Soft breaklines only force edges to be created along that line, they do not change which points are included in interpolation. Also, the points at the top and floor corners of the trench were not created and were not used in this method. These elevation points, in addition to hard breaklines

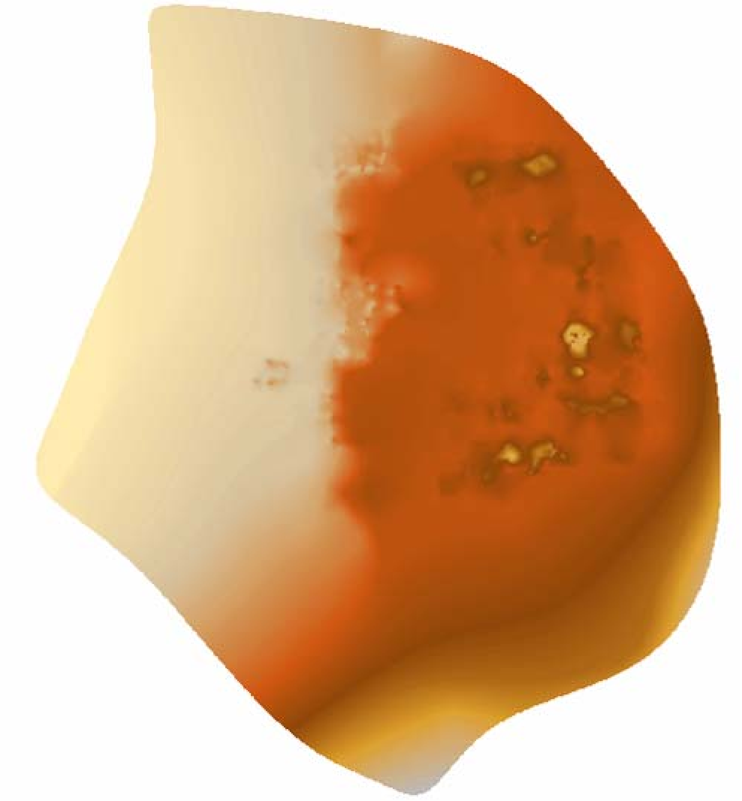


Figure 18. Surface resulting from first methodology.

and elevation as the height source for the back wall, would improve this method. In reality the trench wall is vertical so the breaklines should not allow the points outside the trench as well as inside the trench to be compared.

The second method is similar to the first method but with the addition of the points along the trench lines, as well as top and floor trench corner points. The surface points and the points along the contour lines were used as mass points and the height source for each was the elevation field. The points along the trench top and floor lines were used as mass points with the height field stored in the z-values. The points at the corners of the trench top and floor were used as mass points with the elevation field as the height source. The back wall lines were used as hard breaklines with the elevation field as the height source. The trench top and floor lines were used as hard breaklines with no height source. The resulting TIN was converted to a raster dataset. The result of this methodology is shown in Figure 19. The trenches are well defined; however, the floor of the trench has inaccurate high points showing as darker brown areas. The floor of the trench is slightly variable but it never reaches an elevation so near to the elevation of the trench top as the darker brown areas indicate. After this result, the analyst decided to create three separate TIN surfaces, convert each to raster, then mosaic the rasters together to create one raster surface in hopes of better approximating the trench floor as well as the trench top.

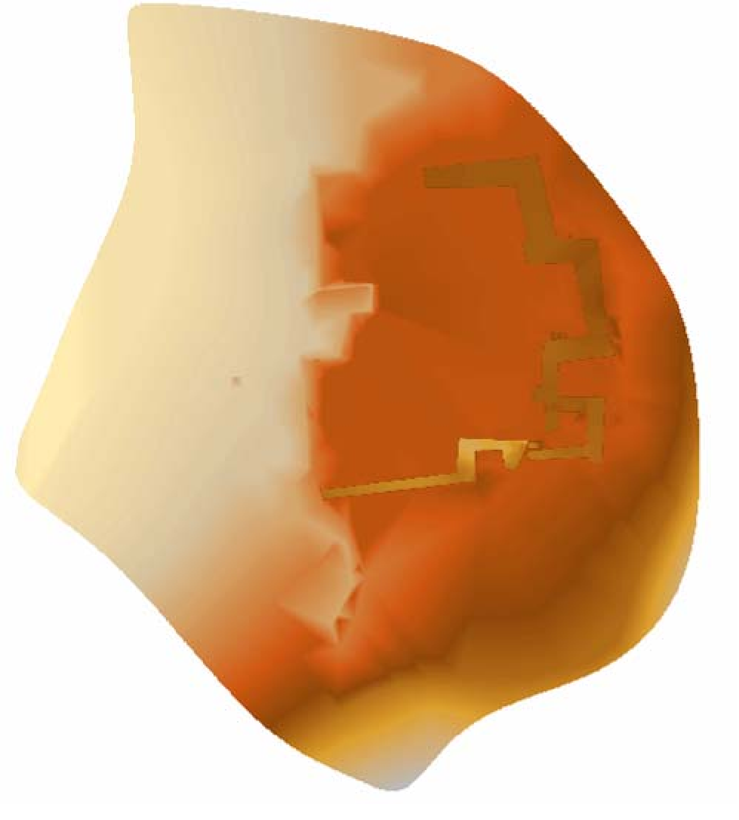


Figure 19. Surface resulting from second methodology.

The third method involved creating three separate TIN surfaces (one for the top of the trench, the trench wall, and the trench floor) and merging them in order to create a surface with a vertical trench wall. This methodology was attempted before the points along the trench top and floor or the trench top and floor corners were created, so those were not used. The surface points and the points along the contour lines were used as mass points with the elevation field for the height source. The back wall lines were used as hard breaklines with the elevation field as the height source. The trench top and floor polygons were used as hard clip or hard erase with no height source. The top TIN was created using the trench top as a hard clip, meaning the TIN was created except for within the trench polygon. The trench floor TIN was created using the trench floor polygon as a hard erase, which only creates the TIN for areas within that polygon and "erases" any portion of the TIN outside the polygon. To create the wall TIN the trench top polygon was used as a hard clip and the trench floor polygon was used as a hard erase, so clipping to the top of the trench and clipping out the inside of the trench. Each TIN was converted to a separate raster and all three raster datasets were mosaicked together. The surface resulting from this methodology is shown in Figure 20. The trenches are not as defined as in the second method, and the trench floor had the same elevation inaccuracies as the second method. Additionally, when zoomed in to the trenches, partial pixels with no data values can be seen. This is the result of converting the TIN surfaces to raster. Since the raster surface is a square cell-based surface and the TIN is not, the raster surface left gaps where the TIN surfaces curved. After testing this methodology the analyst created the points along the trench lines as discussed in section 6.1. This methodology gave the most control over the interpolation so far and with more complete data coverage this

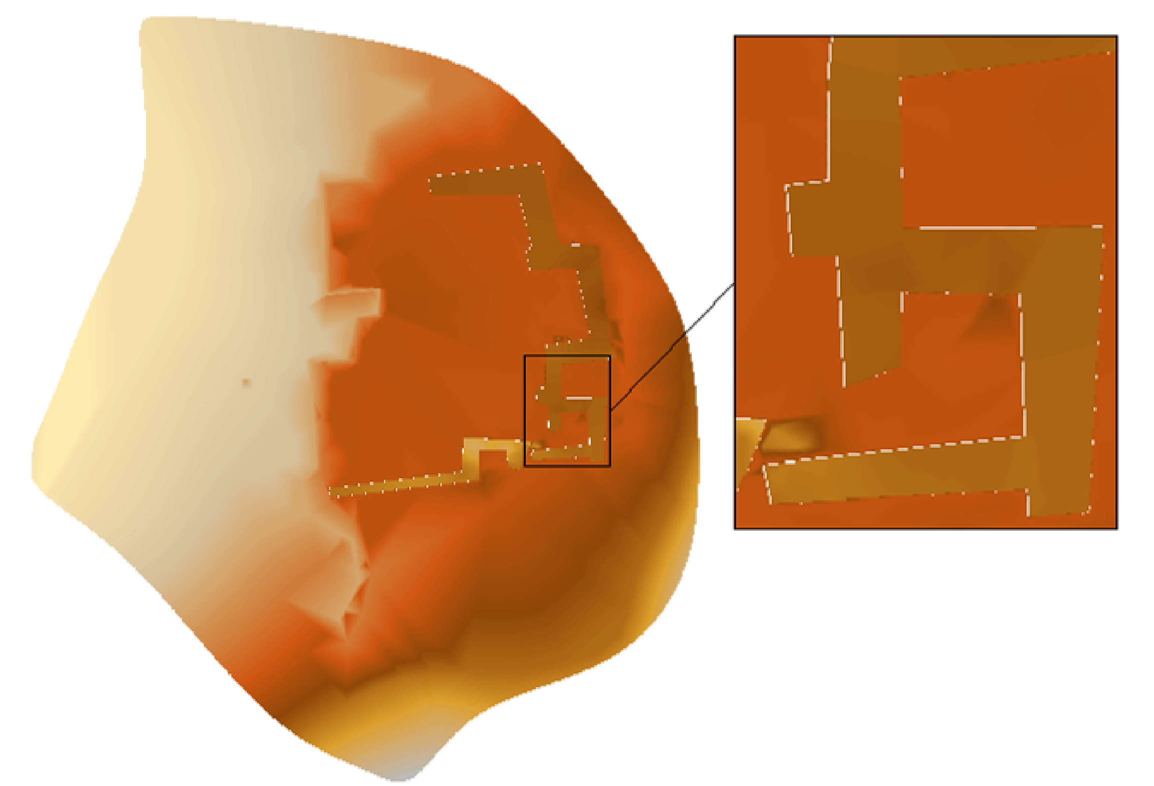
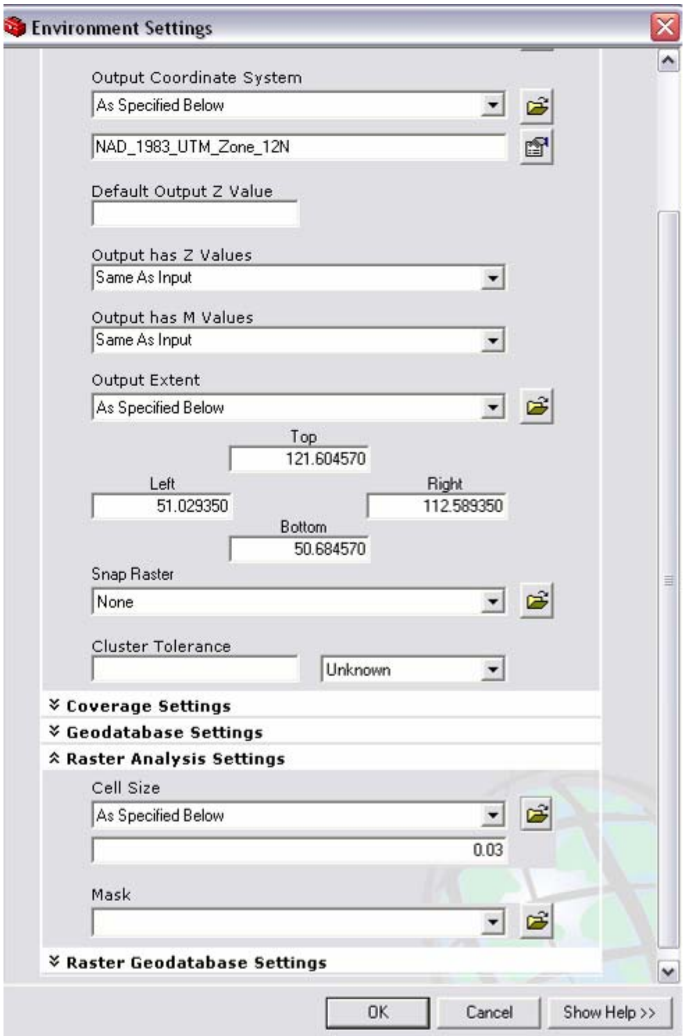


Figure 20. Surface resulting from third methodology, inset shows no data pixels.

methodology was altered to become the final methodology used to create the surface models for the site.

The final methodology for surface creation, much like the third method, involves creating three separate TIN surfaces. Each surface is converted to raster and mosaicked together. The most unique aspect of the successful method is the use of ArcToolbox tools instead of the 3D Analyst toolbar tools used in previous methods. The environment settings shown in Figure 21 are only honored by ArcToolbox. Setting the extent for analysis as shown in Figure 21 fixed the problem of partial pixel slivers noted in the previous method. In addition, the analyst set the data frame projection prior to analysis (so it would not "project on the fly") as shown in Figure 22, which was also necessary to negate the partial pixel slivers. The datasets used in the final methodology of surface creation are listed in Table 5. There was no additional data for the floor of the trench after 1999 so only one trench floor surface was created and the 1999 trench floor is used in all later surfaces. Similarly, only one wall TIN will be created since there is no data to indicate a change in the wall through the years of excavation.



Environment Settings

Output Coordinate System: As Specified Below

NAD_1983_UTM_Zone_12N

Default Output Z Value:

Output has Z Values: Same As Input

Output has M Values: Same As Input

Output Extent: As Specified Below

Top: 121.604570

Left: 51.029350

Right: 112.589350

Bottom: 50.684570

Snap Raster: None

Cluster Tolerance: Unknown

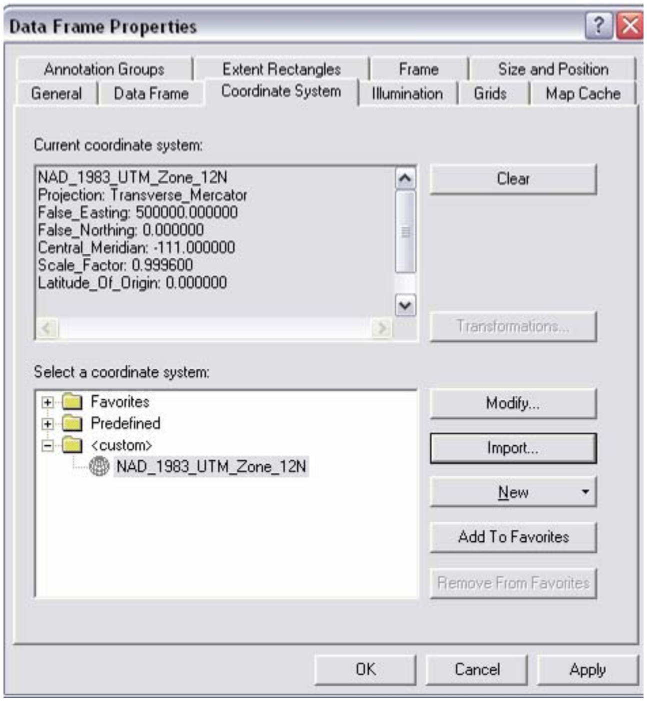
Raster Analysis Settings

Cell Size: As Specified Below

0.03

Mask:

Figure 21. Environment settings dialog.



Current coordinate system:

NAD_1983_UTM_Zone_12N
Projection: Transverse_Mercator
False_Easting: 500000.000000
False_Northing: 0.000000
Central_Meridian: -111.000000
Scale_Factor: 0.999600
Latitude_Of_Origin: 0.000000

Select a coordinate system:

- Favorites
- Predefined
- <custom>
  - NAD_1983_UTM_Zone_12N

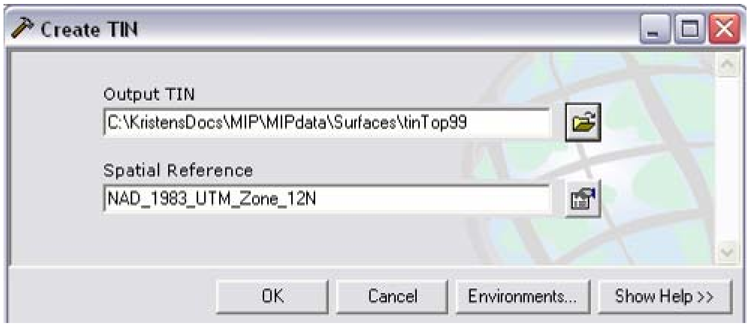
Figure 22. Setting coordinate system prior to surface creation.

Table 5. Datasets used in creation of TIN using final methodology.

			TIN Using Data		
Dataset Name	**Description**	**Data Type**	**Top**	**Wall**	**Floor**
trTopPts_Dens	Points along top trench line created using divide tool	Point	x		
trFloorPts_Dens	Points along floor trench line created using divide tool	Point			x
Art**Fl	Surface points used to interpolate the floor of the trench	Point			x
TopSurfPts**	Surface points used to interpolate the top of the trench	Point	x		
Contours_2m	Points along the contour lines	Point	x		
trptsgt99p5	Top points at trench corners	Point	x	x	
trptslt99p5	Floor points at trench corners	Point		x	x
Backwall	Lines denoting the back wall of the site	Polyline	x		
TrenchTop	Polygon created from the CAD trench lines, denotes top of trench	Polygon	x	x	
TrenchFloor	Polygon created from buffer of CAD trench line, denotes floor of trench	Polygon		x	x

* This symbol is replaced with numbers of the year for which the current surface is being created

Step One: Create an empty TIN (Figure 23) for the top of the trench using the “Create TIN” tool in the 3D Analyst toolbox. Save the TIN in an appropriate location and name it tinTop**. Make sure the spatial reference is correct (this is automatically taken from the environment settings).

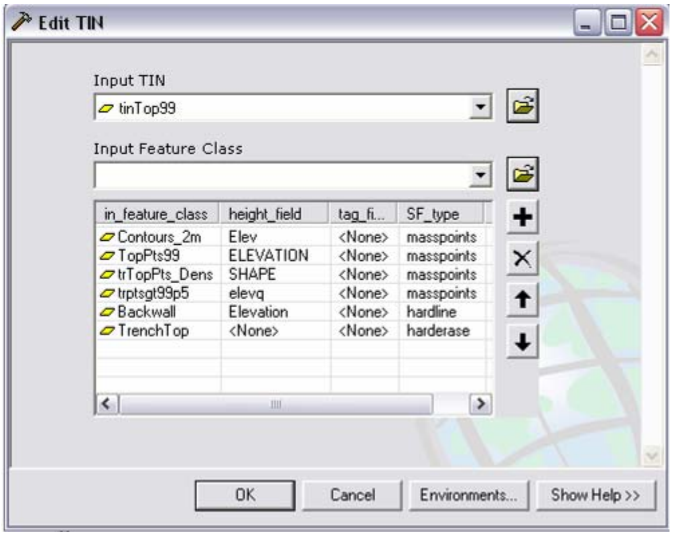


Output TIN
C:\KristensDocs\MIP\MIPdata\Surfaces\tinTop99

Spatial Reference
NAD_1983_UTM_Zone_12N

Figure 23. Create TIN dialog.

Step Two: Edit the empty TIN (using the "Edit TIN" tool in the 3D Analyst toolbox shown in Figure 24) for the top of the trench using points along the contour lines, the surface points for the current year, and the points at the top trench corners as mass points with the elevation field as the height source. The points along the top trench line are mass points with the height source in the z-values. The back wall lines are used as hard breaklines with the elevation field as the height source. Finally the trench top polygon is used as a hard erase with no height source. The resulting TIN is shown in Figure 25.



Input TIN
tinTop99

Input Feature Class

in_feature_class	height_field	tag_fi...	SF_type
Contours_2m	Elev	<None>	masspoints
TopPts99	ELEVATION	<None>	masspoints
trTopPts_Dens	SHAPE	<None>	masspoints
trptsgt99p5	elevq	<None>	masspoints
Backwall	Elevation	<None>	hardline
TrenchTop	<None>	<None>	harderase

Figure 24. Dialog to edit top TIN.

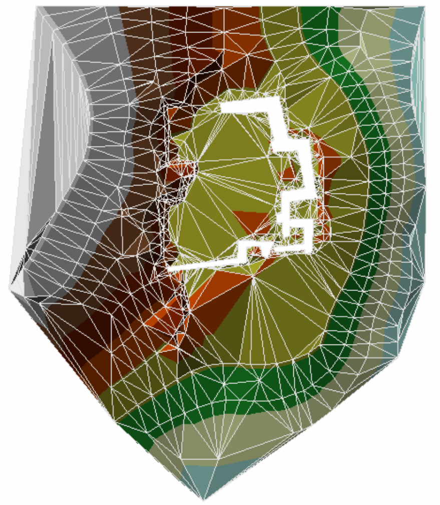
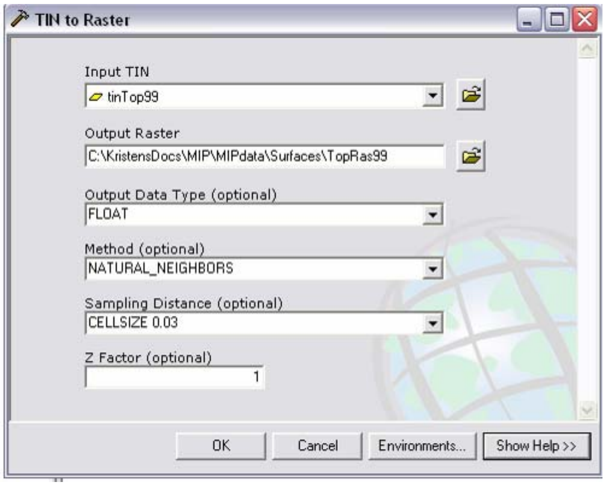


Figure 25. Top TIN result.

Step Three: Convert the top TIN to a raster dataset (using the "TIN to Raster" tool in the 3D Analyst toolbox shown in Figure 26). Use the top TIN as input, set the cell size to 0.03m and save the output raster as rasTop**. Set the method to Natural Neighbors. This method was chosen because according to the ArcGIS Desktop Help (2005), the natural neighbors method "is particularly useful if you have breaklines or an irregularly shaped data area". This method can also handle large point datasets easily. The resulting raster is shown in Figure 27.



Input TIN
tinTop99

Output Raster
C:\KristensDocs\MIP\MIPdata\Surfaces\TopRas99

Output Data Type (optional)
FLOAT

Method (optional)
NATURAL_NEIGHBORS

Sampling Distance (optional)
CELLSIZE 0.03

Z Factor (optional)
1

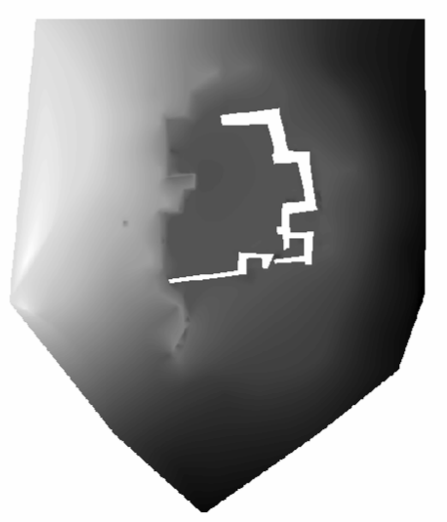
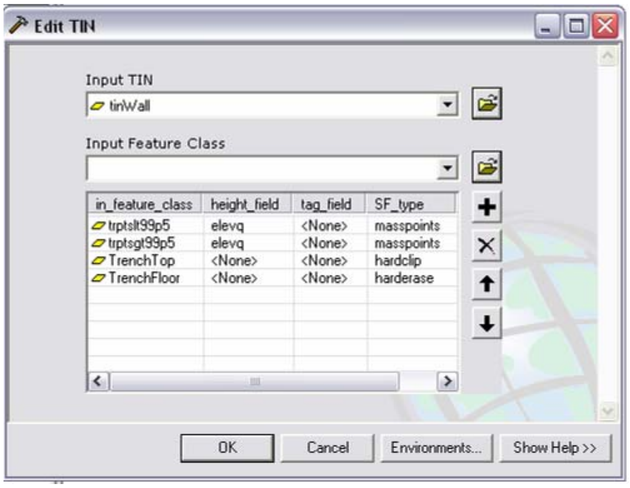


Figure 26. Dialog to convert TIN to raster.

Figure 27. Top raster result.

Step Four: Create another empty TIN for the trench wall using the same method and tool as in step two. Name the empty TIN tinWall.

Step Five: Edit the empty TIN for the trench wall. This wall surface will be used in the surface for each remaining year. Use the “Edit TIN” tool (Figure 28) to input the necessary datasets. The trench top and floor corner points are used as mass points with the height source coming from the elevation field. The trench top and trench floor polygons are used as hard clip and hard erase respectively with no height source. The resulting wall TIN is shown in Figure 29.



Input TIN
tinWall

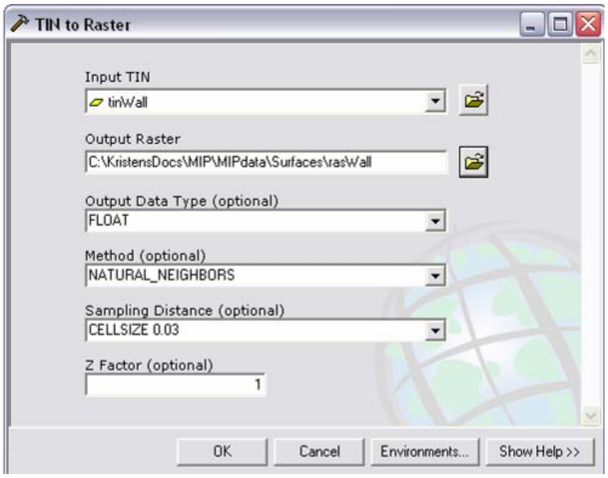
Input Feature Class

in_feature_class	height_field	tag_field	SF_type
trptslt99p5	elevq	<None>	masspoints
trptsgt99p5	elevq	<None>	masspoints
TrenchTop	<None>	<None>	hardclip
TrenchFloor	<None>	<None>	harderase

Figure 28. Dialog to create wall TIN.

Figure 29. Wall TIN result.

Step Six: Convert the wall TIN to raster (Figure 30) with a cell size of 0.03m. Set the method to nearest neighbor. Save the raster as rasWall. The resulting raster is shown in Figure 31.


TIN to Raster

Input TIN
tinWall

Output Raster
C:\KristensDocs\MIP\MIPdata\Surfaces\rasWall

Output Data Type (optional)
FLOAT

Method (optional)
NATURAL_NEIGHBORS

Sampling Distance (optional)
CELLSIZE 0.03

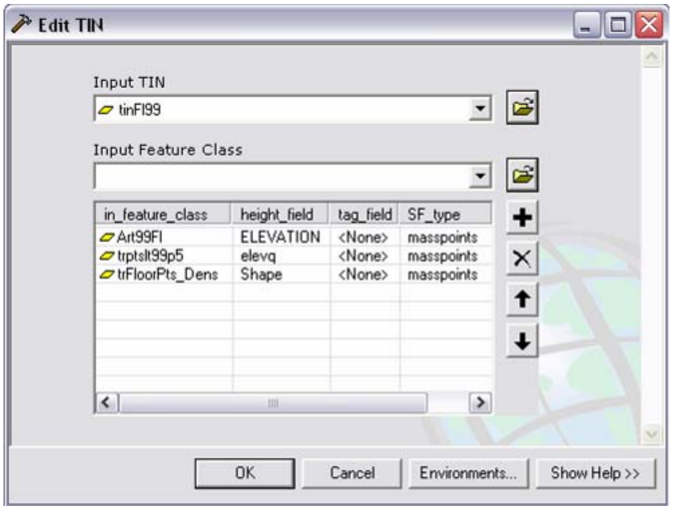
Z Factor (optional)
1

Figure 30. Dialog to convert wall TIN to raster.

Figure 31. Wall raster result.

Step Seven: Create another empty TIN for the trench floor using the same method and tool as in steps two and four. Name the empty TIN tinFl.

Step Eight: Edit the empty TIN for the trench floor. Use the “Edit TIN” dialog (Figure 32) to input the necessary datasets. The surface points within the trench floor for 1999 and the points at the trench floor corners are mass points with the elevation field as the height source. The points along the floor trench line are mass points with the z-values as the height source. The trench floor polygon is not used in this case because the surface created while not restricting the points used is more accurate. To create a raster surface of the trench floor will require one more step using the “Extract by Mask” tool. The resulting TIN is shown in Figure 33.


Edit TIN

Input TIN
tinFl99

Input Feature Class

in_feature_class	height_field	tag_field	SF_type
Art99Fl	ELEVATION	<None>	masspoints
trptslt99p5	elevq	<None>	masspoints
trFloorPts_Dens	Shape	<None>	masspoints

Figure 32. Dialog to edit floor TIN.

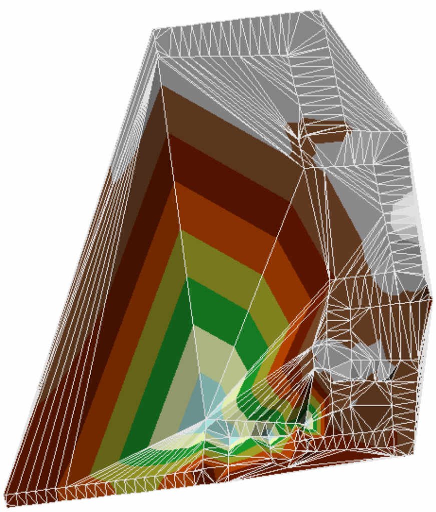
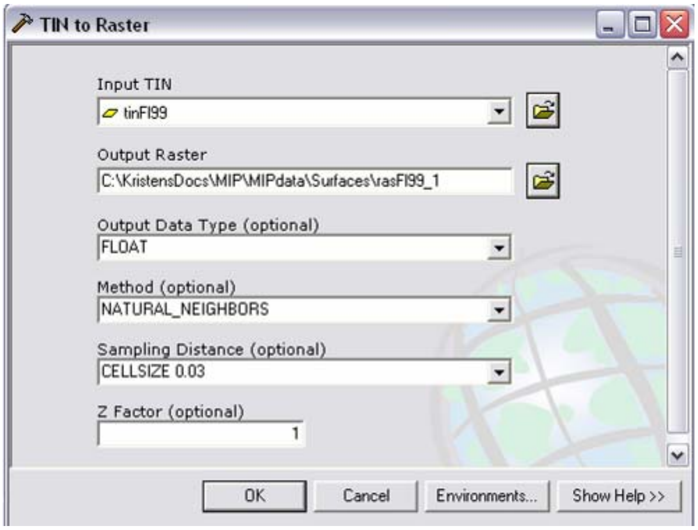


Figure 33. Floor TIN before extract.

Step Nine: Convert the floor TIN to raster (Figure 34) using a 0.03m cell size and the natural neighbors method. Name the raster rasFl_1. The resulting raster is shown in Figure 35.



TIN to Raster

Input TIN: tinFl99

Output Raster: C:\KristensDocs\MIP\MIPdata\Surfaces\rasFl99_1

Output Data Type (optional): FLOAT

Method (optional): NATURAL_NEIGHBORS

Sampling Distance (optional): CELLSIZE 0.03

Z Factor (optional): 1

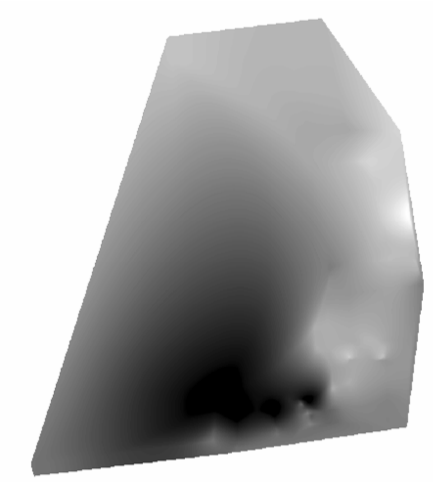
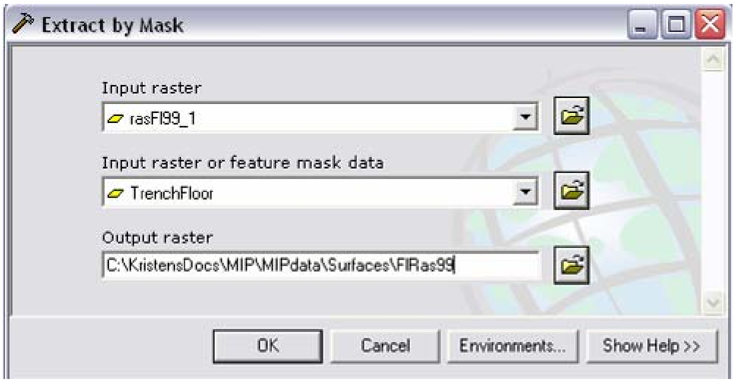


Figure 34. Dialog to convert floor TIN to raster.

Figure 35. Floor raster before extract.

Step Ten: Extract the floor raster using the “Extract by Mask” tool in the Spatial Analyst toolbox (Figure 36). This uses the trench floor polygon as a mask to extract only the portion of the floor raster within that polygon. Name the raster rFloor. The resulting raster is shown in Figure 37.



Extract by Mask

Input raster: rasFl99_1

Input raster or feature mask data: TrenchFloor

Output raster: C:\KristensDocs\MIP\MIPdata\Surfaces\FlRas99

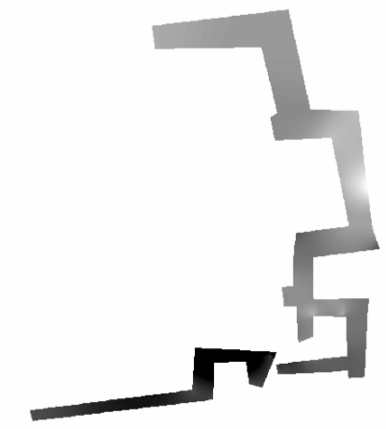
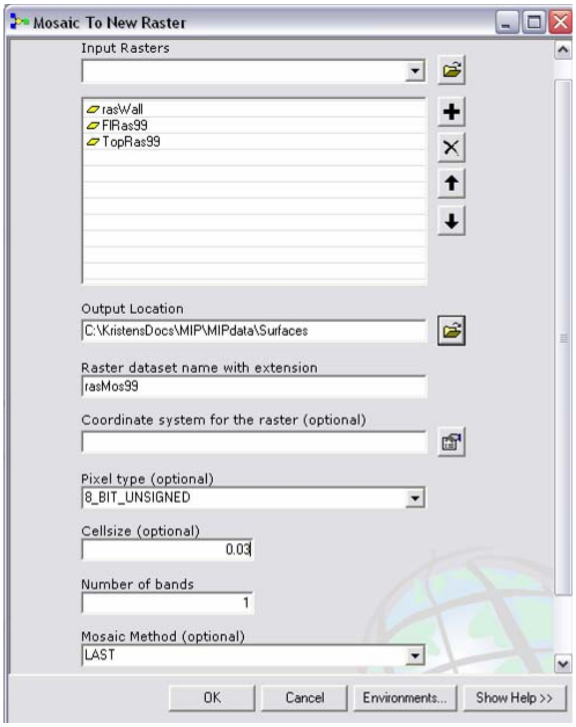


Figure 36. Dialog for extract by mask for floor raster.

Figure 37. Floor raster result.

Step Eleven: Mosaic the three raster datasets to create one raster using the “Mosaic to New Raster” tool in the Data Management Tools toolbox (Figure 38). All three raster datasets are input so they appear in the following order in the list: wall, floor, top. The order is important because the default mosaic method is last, which gives the raster last in the list priority for any overlapping cells. This can be changed but the user must be aware of the order of the datasets in the list when setting this option. The cell size is set to 0.03m and the output dataset is named rasMos**. The resulting raster is shown in Figure 39.



Input Rasters

rasWall
FlRas99
TopRas99

Output Location: C:\KristensDocs\MIP\MIPdata\Surfaces

Raster dataset name with extension: rasMos99

Coordinate system for the raster (optional):

Pixel type (optional): 8_BIT_UNSIGNED

Cellsize (optional): 0.03

Number of bands: 1

Mosaic Method (optional): LAST

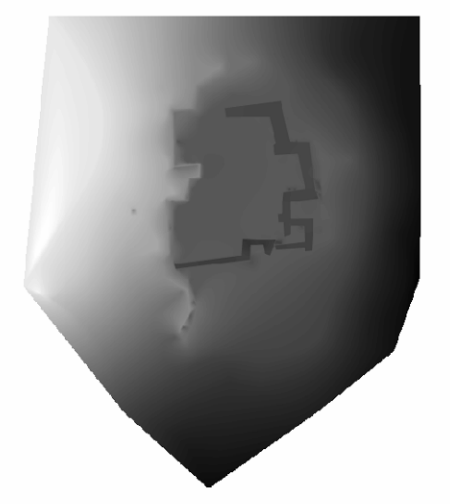
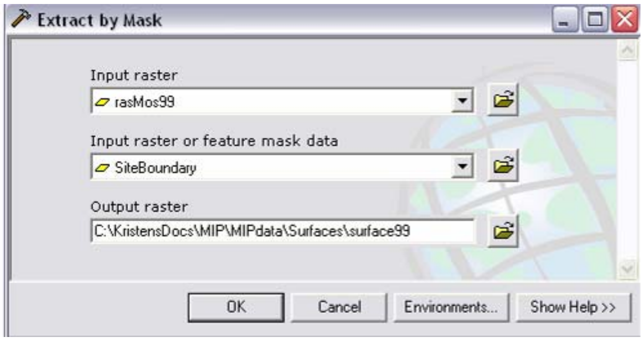


Figure 38. Dialog for mosaic to new raster.

Figure 39. Mosaicked raster result.

Step Twelve: Extract only the portion of the raster within the site boundary using the “Extract by Mask” tool in the Spatial Analyst Tools toolbox (Figure 40). This will clip the surface to the area the client is interested in, which is the area within the site boundary. Input the mosaicked dataset, use the Site Boundary as the mask, and name the output dataset surface**. The resulting raster (Figure 41) is the final raster surface for the current year.



Input raster: rasMos99

Input raster or feature mask data: SiteBoundary

Output raster: C:\KristensDocs\MIP\MIPdata\Surfaces\surface99

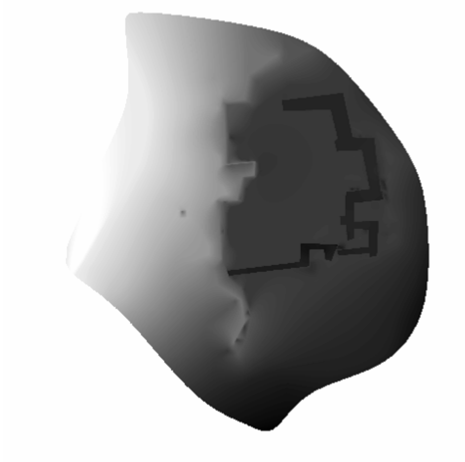


Figure 40. Dialog for filter tool.

Figure 41. Final surface result.

Step Thirteen: The final step is to apply the color ramp created for the site (see Figures 42 and 43), which is discussed in section 6.3.

Figure 42. Final surface with color ramp.

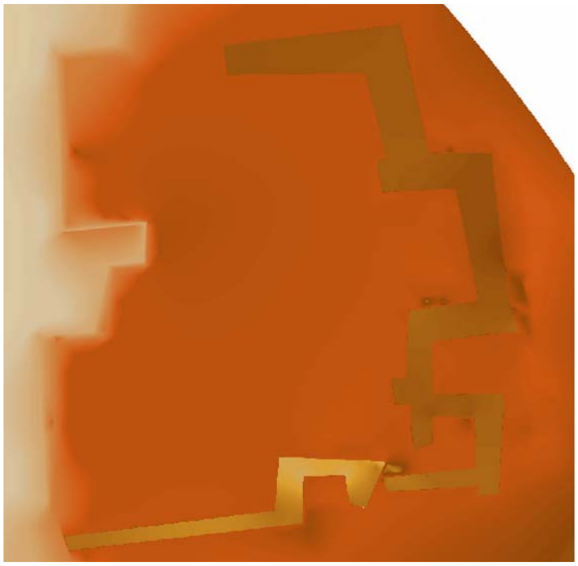
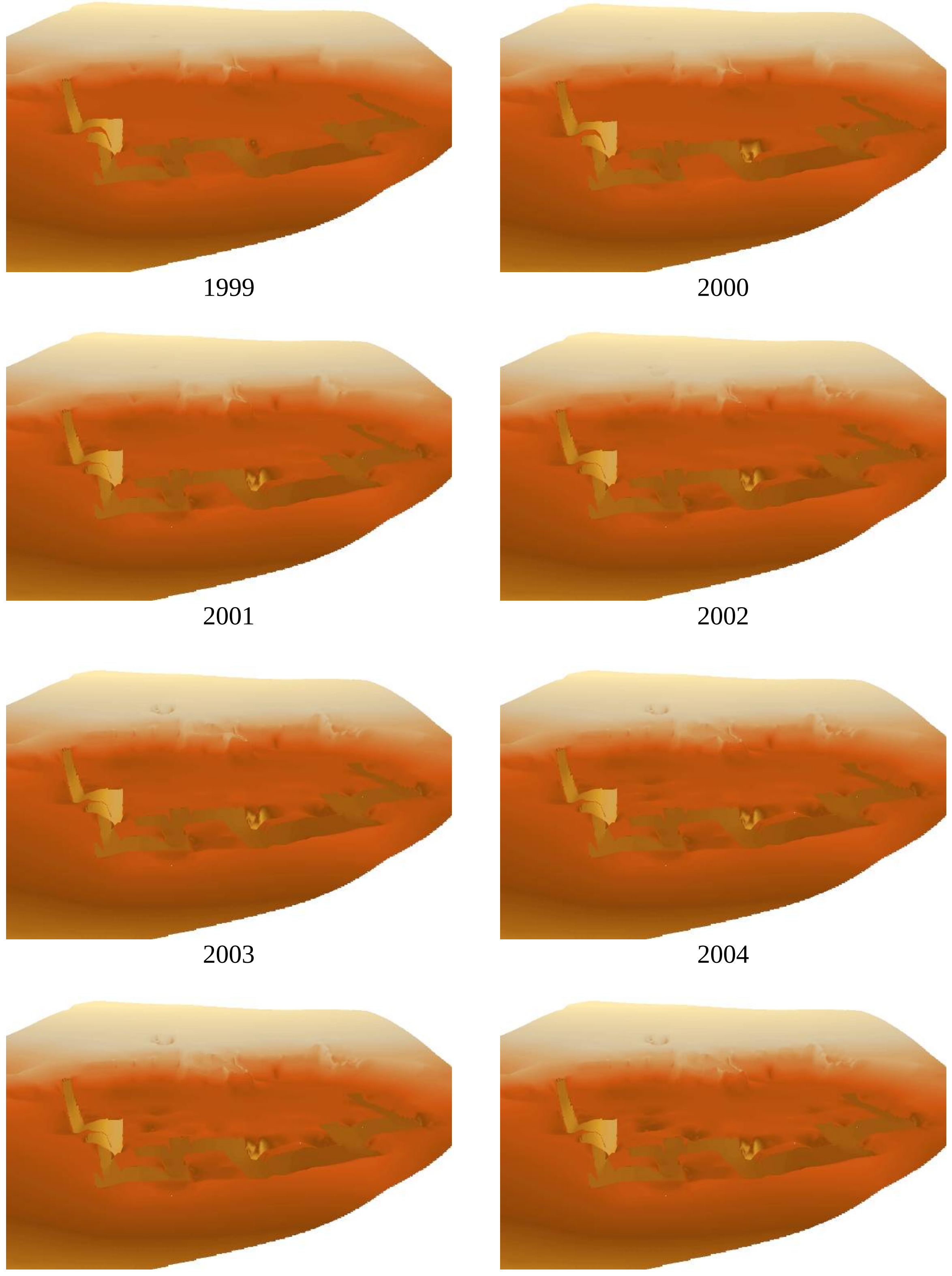


Figure 43. Detail of trenches in final surface with color ramp.

All final surfaces created for each year of excavation are shown in 3D in Figure 44. The same color ramp symbolizing elevation is used on each surface. The 3D views were created by exporting the 3D surfaces from ArcScene to a two dimensional image.



1999 2000

2001 2002

2003 2004

2005 2006

Figure 44. Final surfaces for each year.

6.3. Symbology

A custom color ramp was created by the analyst to display the elevation of the surface models. This was completed using the tools in the style manager in ArcMap (see Figure 45). The analyst hoped to create a color ramp that approximated the colors of the ground surface of the site. However, in order to create a color ramp that is effective, other colors had to be introduced to the ramp because the ground surface at the site itself shows little color change. The ramp is a multi-part color ramp that is created by adding nine algorithmic color ramps together. Each algorithmic color ramp consists of two colors, one at each end of the ramp. The intermediate colors are blended based on either the CIE Lab or Lab LCh blending algorithm. To connect all nine ramps into one continuous ramp, the color at the end of one ramp is the same as the color at the beginning of the next ramp. In this way a ramp is created that smoothly transitions through all the colors of each component ramp. The final ramp used at the Darkmold site (Figure 46) progresses from grey through tan, dark brown, and red, to end with a cream

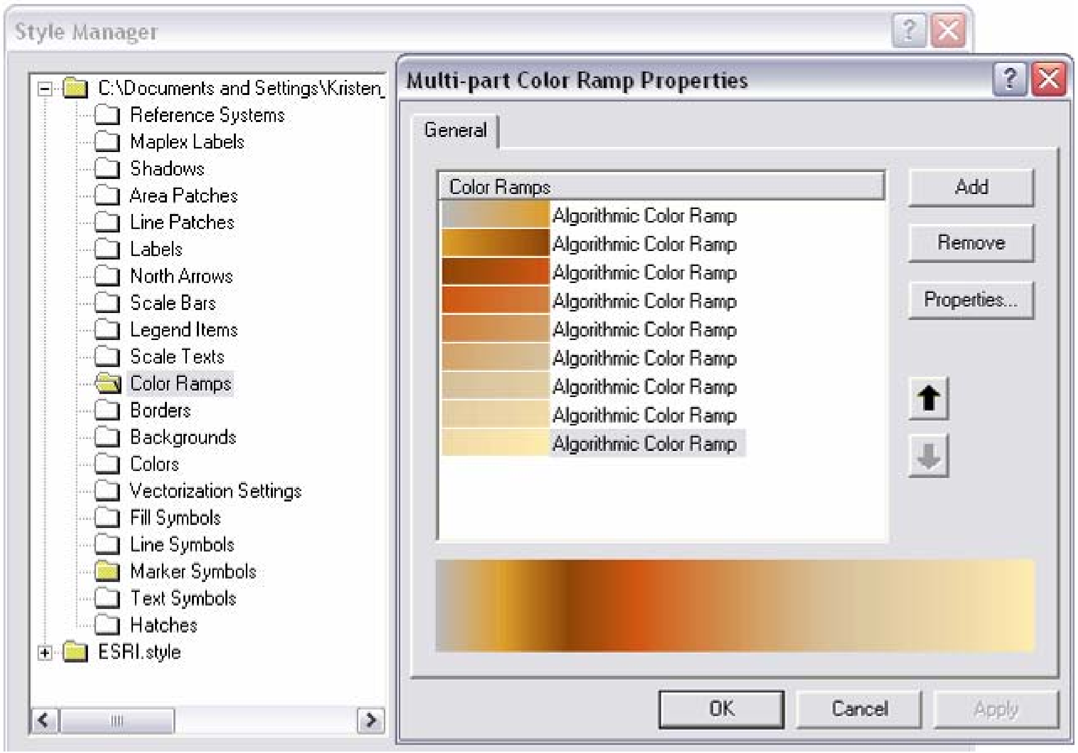


Figure 45. Style manager showing multi-part color ramp created for site.

Figure 46. Final color ramp for surface models.

color. The reason for including the light colors at the right end of the ramp is to ensure the area of interest of the site (the trenches, flat excavation area, and back wall) is symbolized with the tan, brown and red colors that can be seen and distinguished easily. By adding the light colors at the high end of the ramp, the other colors are pushed to cover more of the elevation values of interest for the surface. See this difference in Figure 47. The colors used to highlight the areas of interest were shifted to the lower elevations with each subsequent color ramp until the proper elevation span was covered.

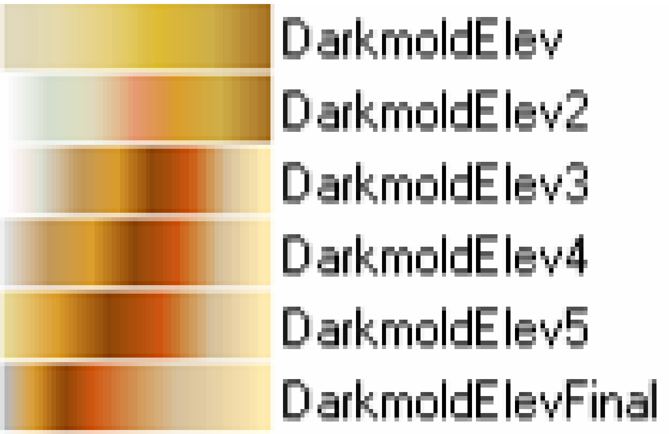
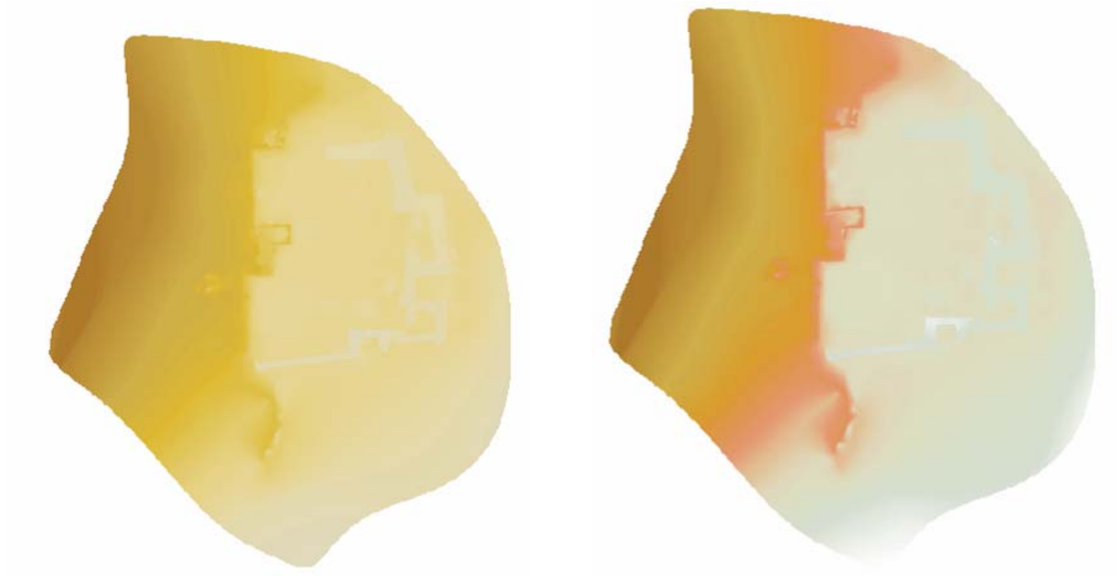


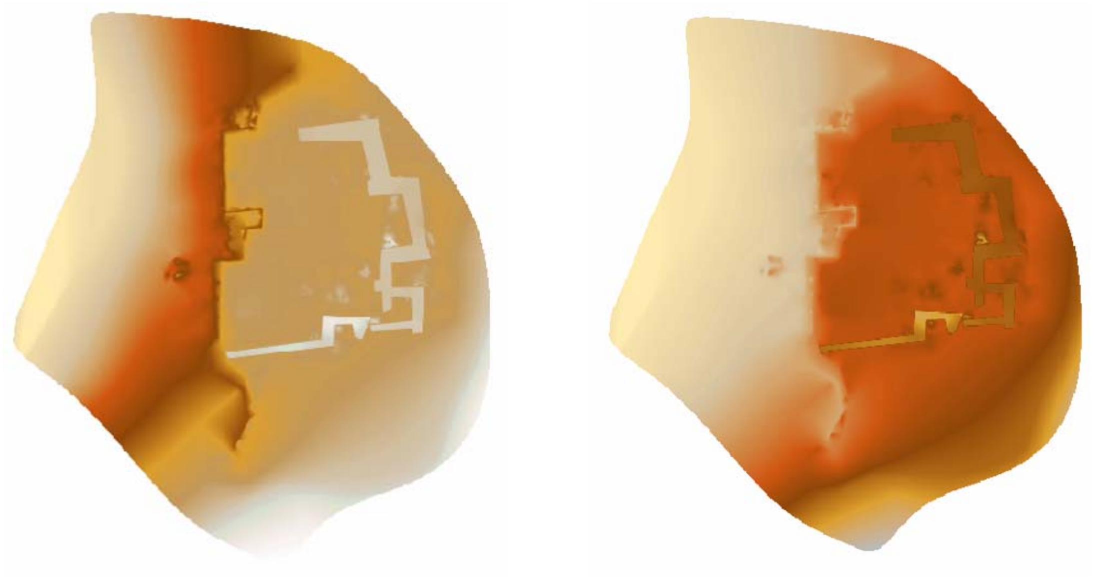
Figure 47. Working versions of color ramps.

The surface is symbolized with working versions of the color ramp for the site, then finally with the final ramp (Figure 48) to show the differences between color ramps graphically. The reader will notice that portions of the site are mostly obscured by some of the early color ramps. As surfaces were created for the site the ramps were stretched over different elevations, so one ramp may look best if stretched over a larger range of elevations or vice versa. As the surfaces being displayed changed (discussed in Chapter 6), the color ramps also had to change.



Color Ramp 1 (DarkmoldElev)

Color Ramp 2 (DarkmoldElev2)



Color Ramp 3 (DarkmoldElev3)

Final Color Ramp (DarkmoldElevFinal)

Figure 48. Color ramps created for Darkmold site.

7. Relating Data for Querying

The ability to query data is an important part of this project. Bringing all types of data together for display is an accomplishment; however, being able to ask further questions of the data is where the real value of GIS lies. Since all the data types have not been together previously, there are questions that may not have been answered or even been apparent to ask. By relating the different data types this can be done. Initially the project had proposed to create a custom query tool to allow the user to query data through a user interface that is more friendly than the standard ArcMap “Query by Attributes” tool; however, the analyst determined that creating custom tools would limit the query options of the user. When new data are added to the application, the custom tools would most likely need re-coding, causing more work for the client. Also, it is doubtful that the client would have access to someone who could make the necessary code edits. The analyst felt that by including a training demonstration to show how to use the ArcMap query tools (see section 8.2.3) that ultimately the user would be more successful.

7.1. Data Preparation

The data preparation required for allowing the different data types to relate is similar to that required to display the data spatially. However, the original organization of the tables is important in this case. The data used for querying in this project are Excel files of detailed burial and feature information, the existing Access attribute database, and the main point feature class. The Field database, as it is named, was created to house artifact data for the site. This contains little information about the artifacts that can be queried in ArcMap. However, the client agreed that the Field database is a good place to store the information currently in Excel files regarding feature and burial information.

The ultimate goal was to get the Excel tables into ArcMap. In order to do this the Excel files needed to be converted to DBF tables. However, they needed some reformatting before they could be used in this capacity. The problem with the tables was that an entry for a single burial or feature took up many lines, as shown in Figure 49, with burials as an example. Thus, there were many blank cells that would not be accepted in DBF format.

BURIAL_NUM	FEATURE_NU	CONTEXT	SEX	AGE	COMPLETENE	BURIAL_GOO	BODY
Burial 5	Feature 11	Primary	Female	35+ yr	Incomplete	None	Indeterminate
Burial 6A	Feature 6	Primary	Male	35-39 yr	Incomplete	1 Cholrite Schist Pipe	Supine-flexed
						1 Cholrite Schist Pendant	
						1 Bone Bead	
						1 Bone Awl	
Burial 6B	Feature 6	Secondary	Male	30+ yr	Incomplete	None	Supine-flexed

Figure 49. Excel burial table before reformatting.

Not only would the DBF file not accept the file formatted as it was, querying on the data would also fail because those burial goods were not effectively linked to a burial or feature number. To alleviate this problem, the analyst reformatted the Excel file so each burial or feature was a single row entry, as shown with burials as an example in Figure 50. Once the tables were formatted properly, they were saved as DBF tables and

BURIAL_NUM	FEATURE_NU	CONTEXT	SEX	AGE	COMPLETENE	BURIAL_GOO	BODY_POSIT
1A	1	Secondary	Male	40+ yr	Incomplete	None	Indeterminate
1B	1	Secondary	Indeterminat	4 yr	Incomplete	None	Indeterminate
2	2	Primary	Indeterminat	7 yr	Incomplete	67 Olivella Beads (+5-12 in	Supine-flexed
3	9	Primary	Female	50+ yr	Incomplete	None	Supine-flexed
4	10	Primary	Male	35-50 yr	Complete	None	Supine-flexed
5	11	Primary	Female	35+ yr	Incomplete	None	Indeterminate
6A	6	Primary	Male	35-39 yr	Incomplete	1 Cholrite Schist Pipe, 1 C	Supine-flexed
6B	6	Secondary	Male	30+ yr	Incomplete	None	Supine-flexed
6C	6	Secondary	Female	Unknown	Incomplete	None	Supine-flexed

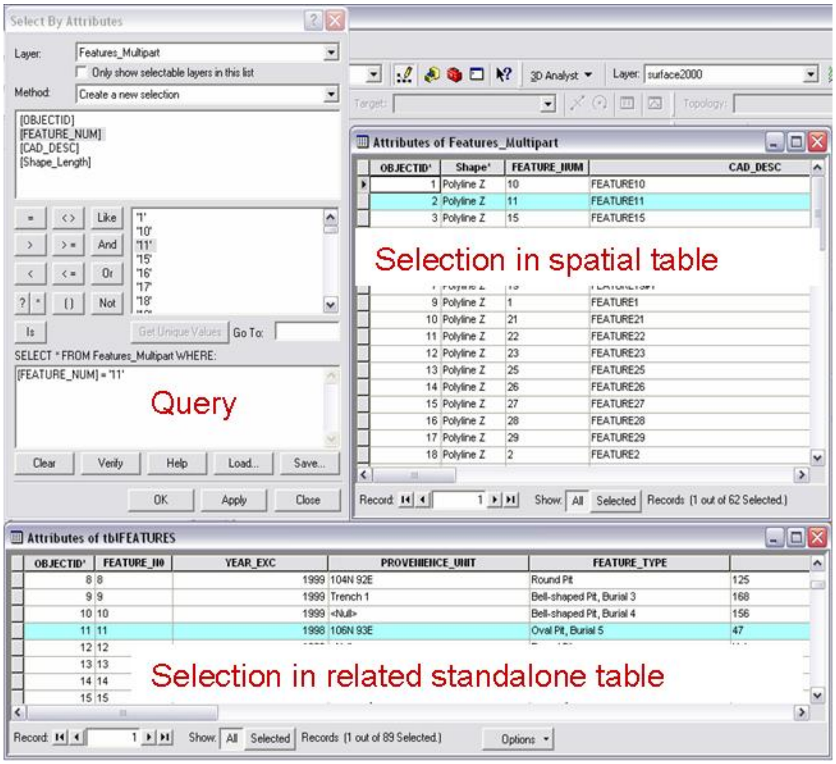
Figure 50. Excel burial table after reformatting.

imported into the Field database. From the Field database the tables were then added into ArcMap as standalone DBF tables. The final step was to create an object identification number (OID) for the entries in each table because without an OID field, ArcMap will not allow the relates to work between tables (Rorke, 2004). To create the OID, each table was exported from ArcMap into the Field database as a feature class. ArcMap automatically created the OID field when the tables were exported. Now the new feature classes for burials and features (named tblBURIALS and tblFEATURES, respectively) can be updated in future field seasons and will be relatable to the other data layers in ArcMap.

Once the standalone tables were formatted properly and imported into ArcMap, the spatial features were prepared. In the main point feature class, three fields were added to store FS number, burial number, and feature number. These were populated using the information in the burials and features DBF tables in the Field database (described above). Since the spatial data and tabular data have related fields they can be queried as a unit, which will reveal the related information throughout all tables using a single query. The relations set up in this project are described fully in the following section.

7.2. Data Relates

Relates were set up between the tables and feature classes in ArcMap. Relates automatically highlight rows matching the query in each table participating in the relate. For example, if the user queries for Feature 11, any points in the main feature class with a feature number equal to 11 are highlighted, as well as the record for Feature 11 in the related feature data standalone table (see Figure 51). The user can move between the related tables and view the information for the selected records. This method was chosen instead of a join because joining the data adds the values of one table to the other by adding fields containing all the data from the joined table. The analyst determined that to establish joins between five datasets would result in tables that were too large and cumbersome to use.



Layer: Features_Multipart

☐ Only show selectable layers in this list

Method: Create a new selection

[OBJECTID]
[FEATURE_NUM]
[CAD_DESC]
[Shape_Length]

'1'
'10'
'11'
'15'
'16'
'17'
'18'

SELECT * FROM Features_Multipart WHERE:

```
[FEATURE_NUM] = '11'
```

Layer: surface2000

OBJECTID*	Shape*	FEATURE_NUM	CAD_DESC
1	Polyline Z	10	FEATURE10
2	Polyline Z	11	FEATURE11
3	Polyline Z	15	FEATURE15
9	Polyline Z	1	FEATURE1
10	Polyline Z	21	FEATURE21
11	Polyline Z	22	FEATURE22
12	Polyline Z	23	FEATURE23
13	Polyline Z	25	FEATURE25
14	Polyline Z	26	FEATURE26
15	Polyline Z	27	FEATURE27
16	Polyline Z	28	FEATURE28
17	Polyline Z	29	FEATURE29
18	Polyline Z	2	FEATURE2

Record: 1 Records (1 out of 62 Selected.)

OBJECTID*	FEATURE_NO	YEAR_EXC	PROVENIENCE_UNIT	FEATURE_TYPE	
8	8	1999	104N 92E	Round Pit	125
9	9	1999	Trench 1	Bell-shaped Pit, Burial 3	168
10	10	1999	<Null>	Bell-shaped Pit, Burial 4	156
11	11	1998	106N 93E	Oval Pit, Burial 5	47
12	12				
13	13				
14	14				
15	15				

Record: 1 Records (1 out of 89 Selected.)

Figure 51. Example of query result with related tables.

The five relates created in the application are as follows. The first relates the Artifacts point feature class to the Burials standalone table based on FS number. The second relates the Burials line feature class to the Burials standalone table on burial number. The third relates the Features line feature class to the Features standalone table on feature number. The fourth relates the Burials standalone table to the Features standalone table on feature number. Finally, the fifth relates the Artifacts point feature class to the Features standalone table on FS number.

8. Training Demonstrations

The training demonstration videos are located on the MIP data compact disc in the “TrainingDemos” folder. They can be viewed by opening the folder and double clicking on a demonstration.

8.1. Introduction and Purpose

The training demonstrations were created using the trial version of the Captivate software by Adobe (see http://www.adobe.com/uk/products/captivate for more information). The program captures the screen shots, mouse movement, and mouse clicks as the creator moves through an action. Once the video is produced, the creator can edit the video and add textual information that gives the viewer more information of options that could be chosen or reasons why the parameters in the video were used. When users view the video, not only will they see what the creator was doing on the screen, but how the creator moved through the process and what parameters were used. The client wished to have training demonstration videos rather than traditional written training documentation.

The purpose of the training demonstrations is to show how to use some of the functionalities of ArcMap that will be of use for analysis at the Darkmold site. Since all the data types are available for display and query, there is much that can be gleaned if the user knows how. Video training was encouraged by the client in lieu of traditional hardcopy training manuals because of the possibility that more people may be able to utilize the videos and more easily learn to use some of the basic functions necessary. Also, the client has increasing knowledge of the operation of the ArcGIS software and determined that a gentle reminder on methods in the form of training videos would be more useful than paper manuals.

8.2. Abstracts of Training Demonstration Files

8.2.1. Appending New Data to Master Feature Class

This demonstration shows how to organize new Total Station point data from the site and add it to the existing dataset. This allows the user to add the data collected during the current season to the master point data feature class. This demonstration also illustrates how to properly attribute the new features with the correct coded domain values once they are added to the Master feature class.

8.2.2. Creating a Layer File

This demonstration illustrates how to create a layer file from the main feature class. Layer files are used to display symbology and limit the features being shown; such is the case with artifacts, auger tests, and other points at the site. This demonstration covers how to prepare the Master dataset before creating the layer file. This includes: giving the layer a useful name, limiting the data visible using a definition query, limiting the fields shown in the attribute table, and assigning the correct symbology. Layer files currently exist for the following points: artifacts, auger tests, bedrock, burials, datums (both the main site datum and sub-datums), dendro samples, driveway, features, grids, other, pollen samples, radiocarbon samples, rockwall, test units, and trench points. The user must remember that layer files simply store the symbology, definition query, and visible fields. The layer file references the original dataset, so no data is actually stored within a layer file. Any data changes must be made in the master feature class.

8.2.3. Select by Attributes

This demonstration illustrates how to use the “Select by Attributes” dialog to complete queries. The “Select by Attributes” dialog allows the user to select from data within the map document based on a query statement. An example is to query artifacts that are projectile points. Every projectile point is selected and the user examines the attribute table to discover more information about those projectile points, if available.

8.2.4. Utilize Related Feature Classes and Tables

This demonstration illustrates how to create relates and access related tables once a query has been performed. Once a relate is created between two tables, the related data is accessed through the attribute table. This demonstration also covers managing relates, and how to work with selection sets (for example, how to switch the selection set).

8.2.5. Working with Coded Value Domains

This demonstration illustrates how to manage, create, and edit coded value domains within a personal geodatabase. Specifically, this includes how to add a new coded value, how to delete an existing coded value (assuming any data given the value to be deleted have been reassigned to a different value before the code is deleted), and how to change or update an existing coded value.

8.2.6. Loading and Saving Definition Queries

This demonstration illustrates how to load existing definition queries from a file and save definition queries. The definition queries in this project are primarily used to create layer files, and saved definition queries can be easily used from a file. This allows the user to load, rather than create, queries when a layer file is needed, as well as have an example to look to if it is necessary to create a different query.

8.2.7. ArcScene

This demonstration illustrates how to display data in 3D in ArcScene. This includes setting the base height of the layer, changing the symbology, and using the base height of another layer to display data that does not have z values.

9. Conclusions and Recommendations

9.1. Results

The final result of this project is the culmination of the goals it set out to accomplish. Although the methods for accomplishing these goals may have changed through the process, ultimately the goals were met. The main goals were to bring together many different data types in a way that would allow all data to be used together, to allow the user to query the data, and to model the surface of the site. This was accomplished by manipulating and converting data into types that could be used together, such as feature classes and organizing the data in a geodatabase. By setting up relates between the feature class attribute tables and the Access standalone tables, queries can be completed on all tables at once. This allows the user to create one query and see all resulting information in related tables. The site surface models were completed for each year of excavation. As discussed in chapter six, the analyst believes the results were as accurate as can be achieved using the data available. The surfaces can be used to view the changes at the site over time. Creating the surface models is one step toward being able to recreate a site and use GIS to record, digitally and in great detail, all that is excavated from a site. This idea will be discussed further in section 9.3. Finally, the analyst found little supporting research to show GIS being utilized in a small area for archaeology. With the success of this project through surface creation and data compilation, this illustrates how GIS is as valuable for mapping an area as small as the Darkmold site as it is for mapping larger portions of the world.

9.2. Data Problems

The major hurdle of this project was the data itself. In archaeology it is unlikely that one would be faced with a lack of data. On the contrary, large amounts of highly detailed spatial data are collected for most archaeological excavations. The problem is making sure the data are usable. The first data hurdle that was encountered involved the Total Station data. Initially the digital data were not available so the task was to manually import almost 1,400 point records from a Total Station hardcopy log to a digital format. This would have involved entering every x, y, and z value by hand, which had the possibility of introducing a great deal of human error into the project. The client was able to locate the Total Station data in digital format, so this was used for the project; however, the digital data arrived about five months into the project. Receiving the digital Total Station data did not fix all data problems. Within the Excel files for each year there were duplications of data. The data for 2001 was incomplete, and the data files for 2003, 2004, and 2005 were actually duplicates of the incomplete 2001 data. This data error was found seven months into the project and the client provided the new data within ten days of realization of the error. Most likely when the data were converted from the raw Total Station format to Excel, file names were overwritten without the user's knowledge. This error was caught, but if the project had proceeded with poor data, that error would have been propagated throughout the entire analysis.

Data storage methods for ancillary data were a recurring problem for this project. The bulk of the information from the site is in paper format because that is what is recorded in the field. The Total Station data are the only digital data currently being collected at the Darkmold site during excavation. Thus, much of the detailed attribute information that would make a GIS application data rich is not in digital format, and therefore could not be used in this project. In order to make the data usable it would have to be collected from various site forms and input and organized digitally. This type of data creation and entry is outside the scope of this project but will most likely be an important part of the use of GIS in archaeology in the future. One area where not having digital data was a problem to this project was the trench elevation values. Extremely detailed elevation data was made available in Excel format; however, there was not enough information included to tie the elevation points to a specific location within each trench. The trench number with a coded location value was given; however, the map that locates the coded location values to the trenches was not available. In order to use the elevation values for the trenches, the elevation values were averaged and used over the entire trench segment, rather than at the exact locations at which the values were measured.

The final problem with the data is the fact that the Total Station points used to create the surface model were not collected with the intention of using them to create a surface model. As mentioned in Chapter 6, the points were the location of artifacts or other objects at the ground surface. This data are obviously concentrated around features and burials, while unexcavated or partially excavated areas of the site have little to no coverage of digital data. The better the coverage of digital elevation points across the site and the more detailed the points in areas of importance, such as features and burials, the better an interpolator can perform to create a surface model.

9.3. Value of Methods to Archaeology

It is the opinion of the analyst that this project could provide some ideas to the archaeological community. As discussed in Chapter 2, GIS is becoming more widely used in archaeology; however, little has been published on the use of GIS for site level analysis. The strength of this project is in the data compilation. Bringing as many data types together from the site as possible gives the ability to view all data together, allowing for more powerful analysis than shuffling through paper forms. There is much more data available to this project than were used, and the limiting factor for the amount of data used was time. If archaeologists convert as much information as possible from paper site forms into a digital format, future projects would focus on analysis rather than data compilation. Another positive outcome from converting paper records to digital for use in a GIS is the preservation of the site information. Not only can a GIS store the spatial and tabular information, it can also store and utilize images, for example. The point is to have as much information available for use in the GIS as possible because once excavation is completed the records are all that is left. The power of the GIS is the ability to visually see the location of objects across the site, just as they lay in the ground. This could prove to be a valuable way to analyze and “preserve” a site in the future. GIS applications also lend themselves to sharing better than hardcopy records. Anyone with the proper software or a free reader version can share and utilize the data, thus making the information more readily available to interested parties.

9.4. Future Recommendations for Darkmold Site

Based on the data used, the surfaces are the most accurate representation of the ground at the site. However, the surfaces are not *the* most accurate representation of the ground surface. The reason the surface models can be the most accurate with the given data, but not the most accurate representation of the surface, is related to the data used to create the surfaces. The data input into the TIN to create the surfaces, as discussed in section 6.1, are points that represent locations of artifacts, auger test points, and other objects at the site. It is the opinion of the analyst that to create a much more accurate surface of the site, points should be collected (or converted to a digital format from hardcopy site forms) with the creation of a surface as the goal. The points used were spread across the site, but as discussed, there were not enough points available along the trenches in a digital format to create a very accurate model of the trench floor. The same can be noted for features and burials excavated. Often the only point collected digitally for a feature or burial is a mapping datum, which serves the purpose for archaeological records; however, points collected to capture the extents and elevation changes of a feature, burial, or the trenches, would create a more detailed surface. The analyst recommends tasking a future field crew with collecting detailed point data across the site, or converting hardcopy data to digital data, for the purpose of making a surface model.

With the issues of data continuing throughout the entire project, the main recommendation is regarding that data. As with any GIS application, the goals should be clearly identified before collecting data, to ensure the data will enable the analyst to meet those goals. To create the surface models, many methods were tried and many failed because the data were not what the methods required. If the data were collected with the intent of interpolating the ground surface, different methods of interpolation might apply and there is little doubt that the process would be much easier. If an accurate surface is to be created of the site, the analyst suggests collecting data with the intention of creating that surface. Once a “mesh” of points is created across the site and more detailed information is collected for the areas of interest, updates in future years would only have to include areas that were newly excavated. Another key to the ongoing success of this GIS application for the Darkmold Site is to keep the data updated. Each field season new data should be added, preferably before the season ends to ensure that quality data have been collected. By keeping the data updated after each season the client can avoid the bulk of the data problems faced in this project. Since the goal of the Field School is primarily education, rather than completing large excavations, there is not a great deal of new data each year, so keeping the database current should be possible.

Suggestions that fall outside the scope of this project are to make the data and maps available on an ArcIMS site or through an ArcReader file. Both would make the information available to interested parties, possibly even sooner than the reports may be completed. The ArcReader application would run on the free ArcReader software to allow the application to be shared with those who do not have the ArcGIS software. As with the ArcIMS website, the interested party would only require internet access to view the data. Another suggestion is regarding the display of the trench walls. Photos, a different color scheme, or portions of the fence diagram (see Appendix A) could be displayed over the current surface trench walls, giving a more detailed or realistic view of the trench walls. The more archaeology uses GIS the more the data collection will naturally align itself to the needs of the GIS. With the abundance of information, especially spatial information collected by archaeologists, GIS is a perfect match. It is the hope of the analyst that GIS and archaeology continue to partner, and that this project completed for the Darkmold Site provides one more impetus to fuel that partnership.

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11. Appendix A. Fence Diagram

This fence diagram of the Darkmold Site was created using ArcGIS 3.2 software. This was the first use of GIS at the site to document the natural strata and features in the trenches and back wall of the site. The analyst does not know the methodology used to create the diagram.

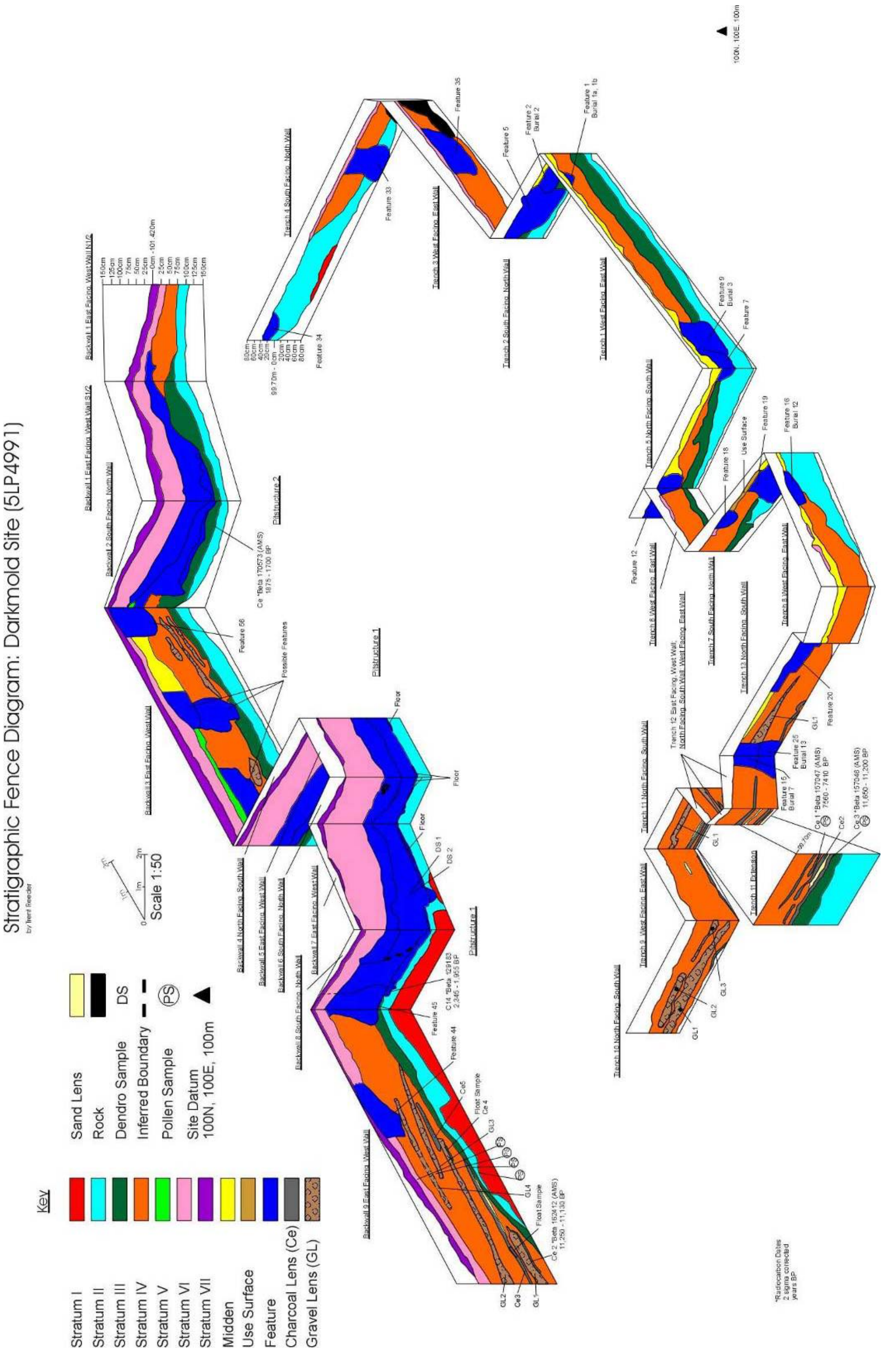

Figure 52. Diagram of back wall and trenches created using GIS.

12. Appendix B. Radiocarbon Dating

Radiocarbon dates were obtained from charcoal or corn samples found at the site. Radiocarbon dating obtains a date by measuring the residual radioactivity of a sample. The rate of decay of the carbon radioactivity of an object or sample is constant through time, thus it can be measured and a date can be calculated (detailed information available online at www.c14dating.com). Dates presented in the charts below (Figure 53) are in corrected years before present (B.P.). The scale of years B.P. aligns with the A.D. and B.C. scales more commonly recognized. The relationship is: 0 B.C. or A.D. 0 is equal to 1950 B.P., which is the convention that was established by Willard F. Libby when he developed the technique in 1949 (Highman, 1999). The charts show the range of dates returned by the radiocarbon samples as vertical bars and the middle date (intercept) of those is shown as a red square with black outline. This gives the range of B.P. dates returned, and the intercept that is the most likely single date to apply to that sample. The

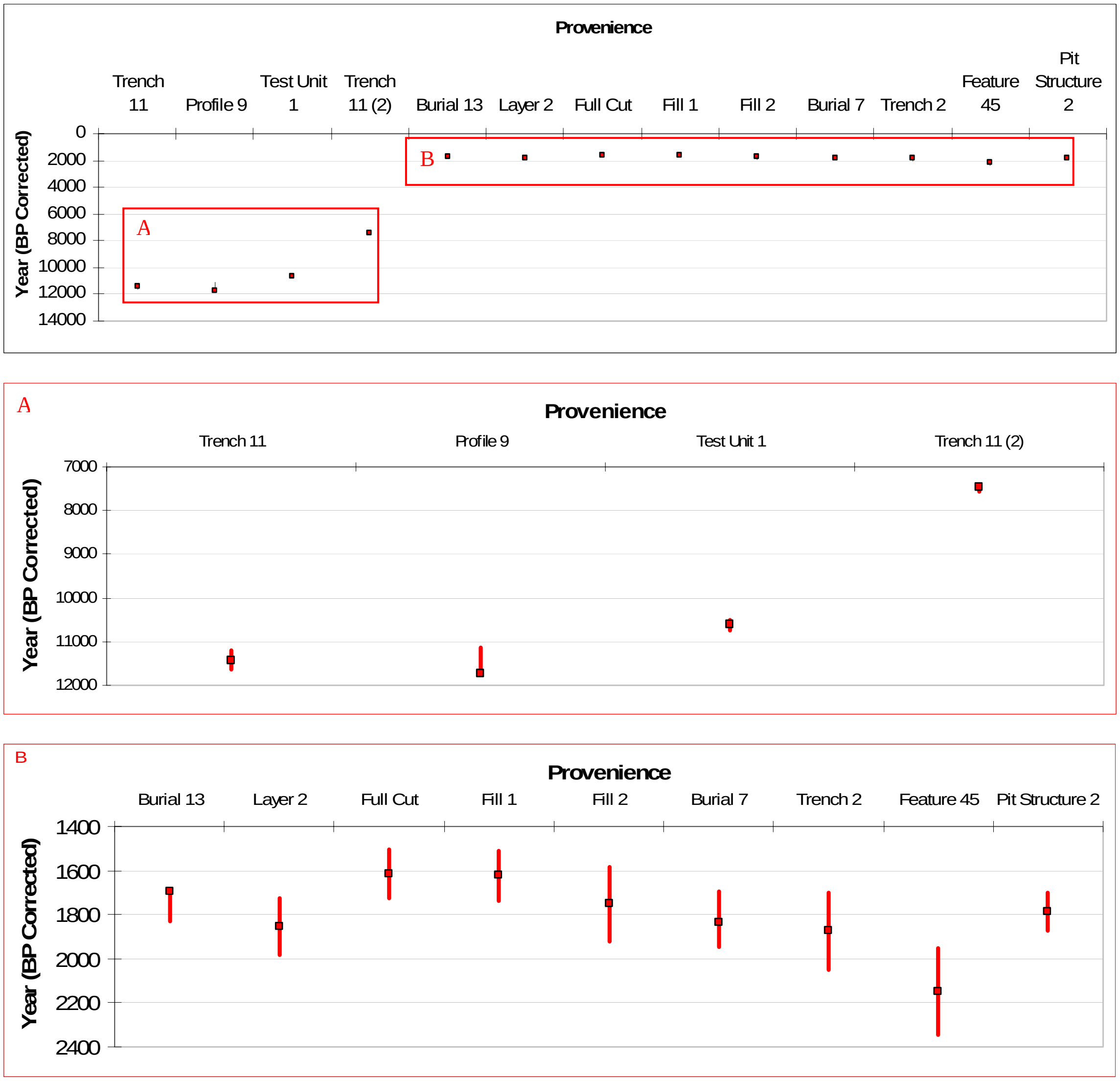

Figure 53. Graphs showing radiocarbon dates taken from samples collected at the site.

samples on the left are older than those to the right on the main chart. The inset charts offer a detailed view of the two sections of samples, those between 11,650 B.P. to 7,410 B.P. and 2,345 B.P. to 1,505 B.P. The gap between 7,410 B.P. and 2,345 B.P. could have three possible explanations. First, that the site was not occupied during that time span; second, that there were no samples collected to represent that time span; or third, that none of the samples collected that could fall in that time span were viable for radiocarbon dating.

13. Appendix C. Metadata

Feature Class Name	Abstract	Date	Spatial Accuracy
Backwall	Total Station points taken at the back wall of the site.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
Burials_Multipart	Multipart line showing Burial details. Dataset was created from a CAD polyline dataset.	11/20/06	Based on Total Station points with centimeter accuracy.
Elev_ContoursCAD	One meter elevation contours created from CAD polylines.	11/20/06	Based on Total Station points with centimeter accuracy.
Features_Multipart	Multipart line showing Feature details. Dataset was created from a CAD polyline dataset.	11/20/06	Based on Total Station points with centimeter accuracy.
Grid_CAD	Lines showing the 2m grid superimposed over the site. Dataset was created from a CAD polyline dataset.	11/20/06	Based on Total Station points with centimeter accuracy.
SiteBoundary	Polygon of the official site area. Dataset was created from CAD polygon dataset.	11/20/06	Based on Total Station points with centimeter accuracy.
TrenchFloor	Polygon covering trench floors, created by buffering CAD trench polylines.	11/20/06	Arbitrarily buffered 2cm inside CAD trench outlines, which are accurate to centimeter.
TrenchTop	Polygon covering trench top, created from a CAD polyline dataset.	11/20/06	Based on Total Station points with centimeter accuracy.
trFLine_z	Polyline outlining trench floors with elevation values for the lines. Created from CAD polylines, elevation from IDW of trench top corner points.	11/20/06	Horizontal: Based on Total Station points with centimeter accuracy. Vertical: Based on IDW created from trench corner points, which are averages of elevation values.
trptsgt99p5	Points at the top trench vertices, elevation values averaged from known elevations of trench top.	11/20/06	Horizontal: Placed on vertices of CAD trench polylines. Vertical: Averaged known elevation values for each trench, collected with

			Total Station or by hand in reference to a mapping datum.
trptslt99p5	Points at the floor trench vertices, elevation values averaged from known elevations of trench floor.	11/20/06	Horizontal: Placed on vertices of TrenchFloor polylines. Vertical: Averaged known elevation values for each trench, collected with Total Station or by hand in reference to a mapping datum.
trTopLine_z	Polyline outlining trench top with elevation values for the lines. Created from CAD polylines, elevation from IDW of trench floor corner points.	11/20/06	Horizontal: Based on Total Station points with sub-centimeter accuracy. Vertical: Based on IDW created from trench corner points, which are averages of elevation values.
dm1999	Point data collected at the site in 1999.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2000_2	Point data collected at the site in 2000	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2001_2	Point data collected at the site in 2001.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2002_2	Point data collected at the site in 2002.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2003_2	Point data collected at the site in 2003.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2004_2	Point data collected at the site in 2004.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2005_2	Point data collected at the site in 2005.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dm2006_2	Point data collected at the site in 2006.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
dmPoints_to2006	All point data for the site through the 2006	11/20/06	Collected with Total Station maintaining

	excavation.		centimeter accuracy.
Art00Fl	Surface points from 2000 from the trench floors.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
Art99Fl	Surface points from 1999 from the trench floors.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
Contours_2m	Points along the contour lines, spaced at an interval of 2m.	11/20/06	Horizontal: Created from TIN vertices along the contour lines and thinned to a 2m interval. Vertical: Created from CAD contour lines.
TopSurfPts99	Points from 1999 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
TopSurfPts00	Points from 2000 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
TopSurfPts01	Points from 2001 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
TopSurfPts02	Points from 2002 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
TopSurfPts03	Points from 2003 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
TopSurfPts04	Points from 2004 outside the trenches, with valid surface elevations.	11/20/06	Collected with Total Station maintaining centimeter accuracy.

	Extracted from dmPoints_to2006 feature class.		
TopSurfPts05	Points from 2005 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
TopSurfPts06	Points from 2006 outside the trenches, with valid surface elevations. Extracted from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
trFloorPts_Dens	Points along the trench floor line created from adding points along the line at half meter intervals and assigning the elevation from the line at that point.	11/20/06	Created from trFLine_z feature class.
trTopPts_Dens	Points along the trench top line created from adding points along the line at half meter intervals and assigning the elevation from the line at that point.	11/20/06	Created from trTopLine_z feature class.

Layer Name	Abstract	Date	Spatial Accuracy
Artifacts.lyr	Artifacts found at the site. Created from dmPoints_to2006 feature class.	11/20/06	Collected with Total Station maintaining centimeter accuracy.
AugerTest.lyr	Auger Test holes at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Bedrock.lyr	Points of Bedrock at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Burials.lyr	Burial points at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Datum.lyr	Site datum or mapping	11/21/06	Collected with Total

	datums. Created from dmPoints_to2006 feature class.		Station maintaining centimeter accuracy.
DendroSample.lyr	Collected dendro samples. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Driveway.lyr	Points along the driveway to the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Features.lyr	Feature points at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Grid.lyr	Points along the grid over the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Other.lyr	Other points collected at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
PollenSample.lyr	Collected pollen samples. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
RadiocarbonSample.lyr	Collected radiocarbon samples. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
RockWall.lyr	Points along the rock wall at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
TestUnit.lyr	Points at the corners of test units at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy.
Trench.lyr	Points along the trenches at the site. Created from dmPoints_to2006 feature class.	11/21/06	Collected with Total Station maintaining centimeter accuracy. Some from trench slump.

Surface Name	**Abstract**	**Date**	**Spatial Accuracy**
surface99	Ground surface model for 1999.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface00	Ground surface model for 2000.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface01	Ground surface model for 2001.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface02	Ground surface model for 2002.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface03	Ground surface model for 2003.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface04	Ground surface model for 2004.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface05	Ground surface model for 2005.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.
surface06	Ground surface model for 2006.	11/21/06	Created using surface points and lines input into a TIN. Points collected at centimeter accuracy, lines were created from these points. Raster has a cell size of 0.03m.