Developing an Archaeological Specific Geodatabase to Chronicle Historical Perspectives at Bethsaida, Israel

by

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Dedication

This thesis is dedicated to my husband, Jim Schilling, my mom, Miriam Burrows, my children, Alyssa and Ryan, and all of my incredibly supportive family members and friends for their patience and encouragement throughout this process. Special thanks to Anton and Lenny for their willingness to lay by my side for hours on end while receiving little more than occasional belly rubs and treats.

Table of Contents

List of Figures

List of Tables

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List of Abbreviations

BCE	Before Common Era
CAD	Computer-aided design
CE	Common Era
ERD	Entity relationship diagram
GIS	Geographic information system
GCS	Geographic Coordinate System
GPS	Global Positioning System
MS	Microsoft
PDF	Portable document format
PDOP	Position Dilution of Precision
SSCI	Spatial Science
USC	University of Southern California
UTM	Universal Transverse Mercator
WGS	World Geodetic System

Abstract

Annual fieldwork at the Bethsaida, Israel archaeological excavation project yields an unwieldy amount of data that have historically been processed and managed via paper-based means and have no associated spatial data. There has been little adoption of modern technology applications to manage this data, even in recent years. The programming objective of this project involved designing and implementing an intra-site, archaeological specific, spatial database for collecting and managing excavation artifacts. A project-based approach was taken toward improved digital data management, tracking, mapping, and visualization in the examination of temporal and spatial archaeological data, thus facilitating the ability for archaeologists to gain new and otherwise undetected insights through spatial pattern analysis. Legacy data, along with data collected via a handheld Global Position System (GPS) device in 2015, aided in establishing the dataset parameters, feature classes, attributes, and domains of the database. This excavation site offered a unique opportunity to explore the space-time continuum through numerous human settlements evidenced by the vertical archaeological record representing the 10^{th} century before Common Era (BCE) through the 1^{st} century Common Era (CE). Visualization of the distribution, concentrations, and spatial relationships of material culture to settlement groups potentially illustrates social trends and cultural practices over the centuries. Data recording will become more consistent and efficient through structured, predefined categories and attributes, bringing greater organization via ontological and semantical consistency. Field collection will be further streamlined and enhanced by the adoption of handheld devices working congruently as an extension of the new geodatabase, collecting artifact information and spatial data, including stratification, in real time. Ongoing research and global collaborative opportunities become possible with the geodatabase, and greater cohesion amongst the diverse excavation team is

enhanced. Archaeologists are further able to forecast areas for future excavation based on the visualizations.

Chapter 1: Introduction

This project involves the creation of a project-specific archaeological artifact spatial database for a Geographic Information Systems (GIS) application to a site case study at Bethsaida, Israel. The study area encompasses a twenty-six-acre extent and reaches back in time to the tenth century BCE, chronicling several periods of human settlement in the vertical record. Objectives included designing, building, populating, and testing the database as well as introducing a handheld device field collection method as a companion to the database. The application was then reviewed and presented to archaeologists for their feedback and recommended changes. The resulting logic, time, and space representation satisfies an underlying void within the field of archaeology.

As a result of this project, archaeologists can gain a better understanding of and visualize the distribution, concentrations, and spatial relationships of artifacts to settlement groups that have inhabited this site from the 10th century BCE through the 1st century CE. Hyde, et al. (2012) discuss the benefits and enhancements GIS brought to work at the San Diego Presidio Chapel, especially in regards to synthesizing and analyzing intra-site data and reassembling past cultural practices in order to draw conclusions about social trends. Similarly, Bethsaida researchers will have improved abilities to target critical grids of archaeological interest within each of the stratification layers, and to identify correlations and trends associated with specific periods of inhabited time. This also serves as a tool in establishing direction for future seasonal excavation work. Stratigraphic sequences introduce a new level of complexity when compared with traditional GIS visualizations. Because Bethsaida was settled on numerous occasions over the centuries, it offered a unique opportunity to introduce and exploit GIS capabilities. González-Tennant (2009) concluded that GIS expands upon and creates new and superior visualization opportunities in archaeology beyond the traditional section-style drawing.

In section 1.1 the project background is discussed. Section 1.2 reviews the motivational factors that inspired the development of this geodatabase. Section 1.3 provides a brief methods overview, and Section 1.4 introduces the remaining structure of this thesis.

1.1 Study Area and Project Background

This section is broken down into subsections that will explore the project background. Subsection 1.1.1 provides relevant information about the geographic area of this case study. Subsection 1.1.2 examines the Bethsaida Excavation Project history.

1.1.1 Study Area

The survey area for this case study consists of a 26-acre parcel in Israel. Figure 1 provides reference to site location. Bethsaida is more specifically located on the eastern bank of the Jordan River at the northernmost end of the Sea of Galilee, in the larger region known as the Golan Heights.

Figure 1. Geographic location of the ancient city of Bethsaida, Israel (BibleHistory.com [last accessed 21 April 2014]).

Various selected areas at the excavation site are of primary focus each season when the dig occurs, and recent activity (2012 – 2015) has been in the areas commonly known as Area A, Area T, Area C, and Area B. These areas vary in size but are usually approximately 10 meters by 10 meters square. These terms for the various areas will be used throughout this paper to describe and refer to the intra-site location. Figure 2 provides general proximity of these areas of interest.

Figure 2. Current areas of interest within the Bethsaida Excavation Project.

1.1.2 Bethsaida Excavation Project History

Bethsaida was discovered in 1987 by archaeologist Dr. Rami Arav of the University of Nebraska, Omaha. This ancient city was the capital city of the kingdom of Geshur in the 11th century BCE, and later, in the 1st century, became the city of Bethsaida, which is mentioned several times in the New Testament of the Bible. Bethsaida is said to have been home to several of the apostles (Peter, Andrew, Philip, James, and John), and according to scripture is where

Jesus performed notable miracles (feeding the multitudes, healing the blind man). Geshur was home to the Armenian King, Talmai, whose daughter Maacah, became the wife of King David (Laub 2016, Bethsaida Excavations 2016, Arav and Freund 2004). In fact, the royal palace ruins are a significant part of what has been uncovered thus far at the excavation, as is a recently discovered access tunnel behind the palace near the city gate.

As the significance of this discovery spread to the academic and religious communities, it became the focus of great interest. Under Dr. Arav's direction, excavation gets under way in late May each year and lasts only six weeks in duration annually. Numerous basalt stone structures, Roman roads, Iron Age floors and valuable artifacts have been uncovered, and several civilizations are known to have inhabited the area based on the cultural materials left behind. The current asset inventory of the digital artifact database contains nearly 40,000 items of varying classifications (ceramic, glass, stone, bone, fishing, etc.), items associated with eleven centuries of inhabited time, and collection dates ranging from 1989 to 2014.

The Consortium of the Bethsaida Excavations Project (hereafter known as the Consortium, the major beneficiary of this project) and its university affiliates work under the oversight of Dr. Rami Arav of the University of Nebraska, Omaha. Together with volunteers, the Consortium annually excavates this ancient city. Today the ruins draw the attention of visitors from around the world as a premier site to visit in northern Israel. Rondelli (2008) cites the importance of settlement analysis and the need for understanding the spatial distribution of artifacts and human adaptations in synthesizing the actions of past settlement systems. Eight strata, or layers, have thus far been identified and currently represent historic time periods of activity at Bethsaida. Tripcevish and Wenke (2010) further conclude that although stratigraphic analysis remains one of the biggest problems faced in moving toward a digital environment, it is also the area that stands to gain the most from it.

Prior to this project getting under way, data management was heavily paper-based and the archaeologists were eager to move toward digital management of tracking, site mapping, and visualization. González-Tennant (2009) has noticed that although the gains to be seen by archaeologists from GIS implementation are great, there are insufficient educational resources as they attempt to implement this new technology.

The data gathered from Bethsaida has been recorded using many different means over the years, primarily non-digital until the recent adoption of a database software program housed on a local laptop computer (Microsoft Access (MS) version 2013 database). At the end of each excavation day, artifacts of significance are catalogued and data is entered, but the spatial data was lacking. Further, the consistency of data recording was identified as an overarching problem that could be vastly improved by establishing ontological and semantical consistency. Classifications for each artifact category were further broken down into distinct types that are known to the area, and this geodatabase provides and limits the available options for data input, rather than allowing open-ended entry. Tennant (2007) examined in depth the benefits a geodatabase can bring to site analysis when carefully designed feature sets with properly established relationships and domains are included. Data entry efficiency and accuracy can be greatly improved due to limited choices offered, eliminating invalid entries. Digital cataloging establishes data consistency, and may serve as a model for other ancient sites in the region with similar artifact find catalogues.

The entry of the vast amount of data owned by the Consortium is seen as a future or ongoing project for excavation volunteers or grad students at one of the participating Consortium universities, but was not a part of this project.

1.2 Motivation

This section examines the various motivational factors that inspired this project, including the author's personal connection to this excavation and reasons for investing in its development. A system to manage, analyze, and visualize large volumes of data was needed. With this system, greater collaborative research in the off-season could also be facilitated and the potential for heightened understanding of the data could be realized. The ability to explore the vertical measurement of the stratification layers was a unique opportunity as was the ability make the workflow in the field more efficient.

The Bethsaida Excavation Project was first introduced to me during my work in Israel on an unrelated archaeology research project in 2012. Since then, I have volunteered with the annual summer excavation team in 2013, 2014, and 2015. My expertise in the field of technology combined with my strong interest and undergraduate degree in anthropology and archaeology afforded a unique opportunity to explore, introduce, and blend digital systems into existing processes to expand collaboration potential and create more efficient site documentation. While working alongside archaeologists out in the field, it became evident that much information was being lost due to lack of immediate, detailed, and consistent recording, and that GIS capabilities could join forces with the Consortium to ease not only the burden of their post-excavation documentation analyses, but also to increase the level of accuracy and detail of the data collected. In short, many problems with the existing workflow and processing of information could be mitigated through the development and adoption of a well-designed geospatial database and the resulting analyses could be greatly enhanced.

Excavations yield a great volume of data each season, and while the data is entered into the MS Access database on a daily basis, that data is rarely processed promptly, catalogued accurately, or in a manner laymen can comprehend. As experienced at Bethsaida, and as Tripcevich and Wernke (2010) conclude, traditional fieldwork and reliance on paper and pencil techniques has hindered the adoption of new technologies. Additionally, GIS spatial databases, mapping, and visualization have not been frequently implemented on large-scale, intra-site excavation projects, and there is great potential for discovering untapped trends amongst the data. New techniques offer opportunities for creating greater organization amongst the existing chaos. Clearly defined categories of common artifact types and features combined with the ability to associate a time period and spatial data with an artifact creates an entirely new way to query information for visual consumption and analysis.

One objective of this project was to greatly improve the temporal and spatial examination of the archaeological record of the Bethsaida excavation site. This geodatabase establishes a consistent reference for the excavation grid and site monuments, thoroughly and consistently documents artifacts collected, associates finds with specific strata and spatial information, and provides researchers with a tool to aid in understanding the historical land use and cultural trends.

Geodatabases can be accessed remotely online by researchers worldwide. This means potentially expanded collaborative research opportunities in the future. A server-based spatial database facilitates year-round access and provides worldwide research opportunities, in contrast to the Bethsaida data, which is available only on-site during the active excavation season. Hyde et al. (2012) cite the research potential and analysis variety that GIS could yield during the post-excavation period. This is a key point, given that the excavation season is limited to six weeks each year during the summer months. Research progress goes unhindered by time constraints given this implementation allowing expanded access for numerous studies.

Representing excavation data via visualization and illustrative techniques on maps and models helps us to gain new insights through spatial analysis. It may be possible to establish patterns through visualization that go undetected otherwise. González-Tennant (2009) believes that the power introduced to archaeologists by GIS will allow them to more easily gauge spatial relationships in a complex environment. Because of the complexity of this particular excavation, significant value may be realized. Infographics are powerful depictions of raw data and can be understood by non-experts in the field of archaeology, including students, visitors to the site, and others with strong interests in the field. Density, clustering, proximity, and orientation pattern analysis can be powerfully communicated through visual renderings. One goal of this project was to accommodate the specific needs of the Bethsaida excavation data and types of artifacts contained therein, offering the ability to query and visualize data that has been collected over the years in a robust environment.

Numerous artifacts have been recovered from this historically significant site. This excavation offered a study area where many settlements have resided over time and are evidenced by the artifact record. GIS analytics provide the ability to spatially relate the six strata to one another and to visualize materials from each inhabited era while also keeping them in context with one another. Subsequent and previous settlement patterns can also be easily visualized and compared. Hyde et al. (2012) emphasize the benefit of using 3D and other visualization techniques to represent stratigraphy for a more thorough examination of the aspects (horizontal and vertical) of the material culture at the Presidio.

The data described and tested herein creates a new and exciting blend of information that has not come together in the past. Archaeologists and Consortium members that work at this excavation site tend to focus their attention primarily on their own specific area of interest and not on the project as a whole. Experts have specializations in osteology, pottery/ceramics, ancient coins, Iron Age, biblical history, theology, and more. Therefore, the types of data collected over the years may vary greatly, with different features and attributes recorded.

Data collection techniques via the use of handheld instruments with a high degree of accuracy can facilitate the uniform collection and recording of finds in the field. González-Tennant (2009) believes that data accuracy can be improved in the field by implementing a workflow that includes handheld devices loaded with a data entry form that restricts users to choosing from specific values. This improves the spatial context of the objects and provenience by attaching precise latitude (x) and longitude (y) coordinates at the time of the find. Point data collected in this manner in 2015 serves as an example of an enhanced and efficient workflow and was amongst the sample data entered during the testing phase of the geodatabase. An extension of this project and geodatabase is a data dictionary for handheld devices that can collect the data in real time out in the field going forward.

1.3 Methods Overview

The existing database was critically examined and journal articles were investigated to establish a foundation for the necessary range of entities, attributes, and relationships to be considered for inclusion in this database as well as potential problems that may be encountered.

Most influential were Tennant (2007), Gonzalez-Tennant (2009), Katsianis et al (2008), Zeiler and Murphy (2010, and Yeung and Hall (2007).

A needs assessment of the existing Microsoft MS Access database revealed a number of entities that were not in use and not needed as well as an unnecessary number of relationships and redundancies that could be reduced by a more streamlined design and incorporation of foreign keys. Based on this assessment a list of database entities and tables including attributes were assembled.

The scope then advanced to designing the entity relationship diagram (ERD) where the relationships between the tables and key fields were established. Since the ERD is the essence and blueprint of this geodatabase, careful design at this stage was critical to the success of the project.

The preexisting database did not account for the stratification, or vertical/depth measurements, so it was necessary to incorporate a means of categorizing depth for each of the stratum. A schema was developed to serve the purpose for this model, and a suitable categorization strategy was created for incorporation into this project. Note that actual elevation readings are a part of the legacy data in the Loci table. However, those readings do not carry over to each artifact individually.

The model was vetted for errors and completeness, and the approved ERD moved forward to the construction phase of the database using ArcGIS. The ERD was translated into a working model that was used for data entry.

A fishnet was used in ArcGIS to create a new master grid on a reference map. This grid acts as an overarching framework and constant point of reference when measuring distances and elevations in the field. This schema was created to serve as a substitute in this model since the actual, and original, data was not available and had not been properly maintained over time.

High definition aerial photography was georeferenced and used as the basemap for this project, which provides the foundational layer for subsequent analysis and adds visual interest. Detailed computer-aided design (CAD) drawings were manually digitized and used for referencing points and monuments and was compared to data collected in 2015. These drawings were originally created in AutoCAD, however these data were provided in PDF format for this thesis.

Tabular data exported from the MS Access database was formatted and edited in MS Excel version 2013 to include spatial references and additional fields as necessary and then imported to ArcGIS for visualization. This was a major amount of work. Data collected in 2015 was uploaded to the geodatabase for testing purposes and serves as an example of improved workflow through mobile device integration in the field. This data was compared to the georeferenced aerial imagery and the excavation grid to establish degree of error to previous processes and documentation. This dataset consists of point and polygon shapefiles (feature classes) with domains exhibiting the power of limited input options.

1.4 Thesis Structure

This thesis is broken down into five chapters. Following this introductory chapter, Chapter 2, Background and Literature Review, examines other similar works and validates a void in the field of archaeology that this project aimed to fill. Chapter 3, Methodology, provides an in-depth look at the way in which this project came to fruition technically. Chapter 4, Results, discusses the outcomes and analytical benefits gained through the development of this geodatabase. Chapter 5, Conclusions, is a reflection of the lessons learned, successes and obstacles encountered during this project creation.

Chapter 2: Background and Literature Review

This chapter explores some of the problems encountered during excavation periods, and reviews relevant literature for the development of this archaeological geodatabase. The literature consists of articles from leading anthropology and archaeology journals, volumes of published research on Bethsaida, publications from GIS journals, and Esri publications. Section 2.1 provides an in-depth look at literatures addressing similar problems as those faced at Bethsaida and substantiates field-related needs. Section 2.2 reviews geodatabase designs, components, and features that influenced specific needs of this project, as well as general best-practices in spatial database design.

2.1 Literature Review

Many in the field of archaeology share overarching difficulties, but as trends toward digital techniques and analysis become more prevalent, powerful, and efficient, technically skilled individuals entering the field find numerous opportunities for improvement, as evidenced by the literatures cited here. Section 2.2.1 explores the need for adoption of digital technologies in the field of archaeology. Section 2.2.2 discusses how digital enhancements can increase collaborative research. Section 2.2.3 validates the use of GIS on a large-scale project. Section 2.2.4 highlights the unique opportunity to model and analyze an archaeological excavation's stratification contents. Section 2.2.5 recognizes the value in adopting a field strategy that incorporates handheld devices that can be synchronized with the geodatabase.

2.1.1 The Need to Move Toward Digital Analysis

Consistency is one of the overarching problems with the data reporting at Bethsaida. There were no limited options or selections to choose from during data entry, everything currently was open ended so queries did not return accurate or complete results. Brovelli and

Maurino (2000) present a concept for structuring archaeological data in the context of a GIS environment and XML format model. The development of ARCHEOGIS, a web-based geodatabase application, aims to improve access and entry of excavation data remotely. In doing so, they present a thoughtfully considered hierarchical structure for a site and metadata model which was referred to during this project development. They address the difficulty presented by the lack of computer fluent professionals in the archaeology field and stress the need for consistency in data reporting, and for standardized models for site and metadata.

At an excavation site in Peru, Tricevich and Wernke (2010) use a GIS data-gathering system to digitize and accelerate the gathering of artifacts and structural feature information at an excavation site in order to improve recording and analysis. The authors highlight the benefit of having an entry method, or mobile form, which is foolproof in gathering accurate spatial provenience in the field, moving away from handwritten recording, emphasizing the need for a complex artifact attribute collection. This is a byproduct of a well-designed spatial database. Examples of data dictionaries and the manner in which the stratigraphy is recorded are also discussed and addressed. This type of system eliminates typographic errors and increases efficiency of data entry through the use of drop-down selections, radio button choices, and check boxes whether data is collected in the field or post excavation.

2.1.2 Potential for Increasing Collaborative Research

One of the primary difficulties experienced in post-excavation analysis is the physical distance between the Consortium members, which include: University of Nebraska Omaha, University of Hartford, Wartburg College, University of San Diego, University of Tulsa, Sacred Heart Seminary and School of Theology, St. Francis Theological College, College of Idaho, Truman State University, and Drew University (Bethsaida Excavations, 2016). Hyde et al.

(2012) illustrate in their study at the San Diego Presidio Chapel, that the implementation of GIS enabled a higher degree of synthesis and collaboration in the analysis of their study, and concurred that post-excavation research and collaboration benefitted and was facilitated by its adoption. The Consortium was eager to have a process that was more inclusive of the members during the off-season, one that would increase and improve communication and analytical processes.

Reed et al. (2015) stress the need for collaborative research environments in spatial databases in *Digital Data Collection in Paleoanthropology*. They emphasize the need for sharing in order to advance research in the scientific field of paleoanthropology and introduce a model for a web-based structure to facilitate this type of collaboration. Research, documentation, and publication at Bethsaida all benefit from the ability to share data and work in greater unity and less in silo operations. Additionally, the authors endorse the need for mobile recording adoption and effective database design to improve workflows dramatically over previously used (paper) methods.

2.1.3 Working with GIS in a Microcosm

The small geographic context that is the subject for analysis of this project is one of the unusual aspects introduced here. Bethsaida is a 26-acre parcel, and active grid squares within that area may be only 100 square meters in size. Because equipment today has much greater capacity for accuracy than in the past, recording finds can be accurate to the nearest centimeter in some cases. One challenge in conducting this literature review was to find other studies that had effectively implemented GIS strategies on a large-scale project. And while the geographic extent itself has little bearing on the geodatabase design, the resulting analyses will benefit greatly from use of equipment with centimeter level accuracy. In *Memories of a world crisis: The* *archaeology of a former Soviet nuclear missile site in Cuba,* author Burstrom (2009) discusses the investigation by archaeologists and GIS professionals into the Cuban Missile Crisis in the Cuban town of Santa Cruz de Los Pinos. Their goal is to identify and document remaining evidence of missile sites using GIS, resulting in many untold stories from the area. This study being so similar to that of an archaeological excavation documents success of a GIS study in a microcosm environment, or small geographic area, and also establishes the relevance of the ability to accurately detect, record, and document objects in a small geographic environment.

Similarly, researchers document select Inuit settlement details with a high degree of accuracy by implementing GIS to catalog and map archaeological monuments and settlement patterns in the Kazan River region, most specifically, caribou crossing, intending to tie oral tradition to the archaeological record. Authors Stewart et al. (2000) discuss the process and needs in developing feature classes and a spatial database to support the use of GIS in a small geographic area (500 by 500 meters).

Kacey Pham's (2015) master's thesis work is very similar in nature to the project proposed here. And I did, in fact, work closely with Pham on her prototype spatial database in SSCI-582, which was further modified and applied to her thesis work. While Pham's work relates specifically to a paleontological application at the La Brea Tar Pits, the database proposed here will bear a similar foundational structure resulting from the work done in partnership in the Spatial Databases class. Her work in a very small geographical context speaks to the ability of GIS to be precise and thorough in the documentation and handling of archaeological finds and to exploit the depth, or vertical nature of time and the law of superposition.

2.1.4 Visualizing the Space-Time Continuum

One of the greatest challenges to overcome with the Bethsaida project was designing and accommodating the z, or depth, data. Researchers from San Diego State University used existing data from the San Diego Presidio Chapel excavation in their case study and performed spatial analysis on burials at the site to reconstruct the ruins using 3D models and GIS technology. Hyde et al. (2012) explain how visualization, data management, and analysis were incorporated in this successful project, which illustrated the space-time continuum by plotting the z coordinate, or stratification/vertical depth measurement. Their study has much in common with the proposed project, specifically the visualization elements, and the inclusion of the vertical measurement to represent the stratification. In addition to Pham's (2015) study, this exemplifies the incorporation of the z measurement for study of the vertical record.

Katsianis et al. (2007) discuss the challenges in visualizing the spatiotemporal nature of stratification in archaeology. The authors point out that an artifact can have "multiple temporal values" in that it could have been manufactured at one time, used at another, deposited in the archaeological record at yet another. They discuss the problem presented by stratigraphy, cite the need for spatial databases to accommodate the complex nature of an object, and propose a solution that is "object-space-time" conscious. Examples of their entity relationship diagram proved to be extremely helpful in the development of this project. Figure 3 shows the data handling in their Temporal Class Diagram.

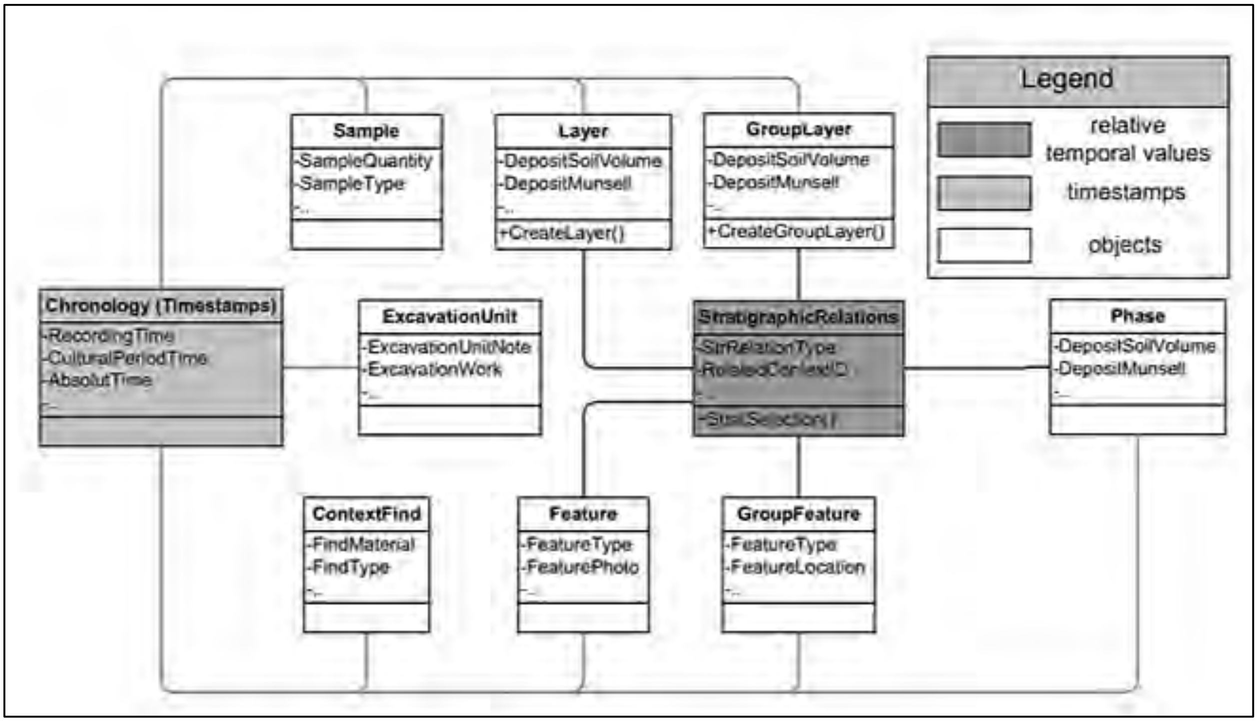


Figure 3. Katsianis et al. (2007) Temporal Class Diagram.

Birkenfeld et al. (2015) conclude “the application of precision piece plotting (point provenance) of finds to obtain their precise x, y, and z coordinates continues to be sporadic.” In their approach to work at Wonderwerk Cave, they employ a “reverse stratigraphic construction” technique. They present a very methodical and logical approach to solving the complexity of stratigraphy in GIS.

Anderson and Burke (2008) document the difficulty that can be presented with complex stratigraphy in an intra-site archaeological analysis and cite the gains to be made through analysis of the vertical, third, or z, dimension, distribution of artifacts. They argue that stratification cannot be arbitrarily determined and does not remain consistent, that considerations have to be made for interruptions in the stratigraphy by human or other means.

2.1.5 The Case for Adoption of Handheld Devices in the Field

Data collection and entry for the Bethsaida Excavation can be vastly improved through the adoption of handheld devices in the field as demonstrated by the workflow introduced in this project and collection methods used in 2015. Newhard et al. (2013) highlight two archaeological case study surveys in Anatolia and conclude that the adoption of handheld devices in the field allowed for the rapid gathering of data and fast processing time for further analysis using new GIS techniques. They found that although the data collection process can become more cumbersome in the field, the reduced post-processing time greatly improved productivity and workflow efficiency, citing increased accuracy of point placement within the excavation survey area, which was favorable to visualizing a general or random distribution of point density. They accurately illustrate and replicate actual artifact concentrations.

Reed et al. (2015) outline the benefits and strategy for using mobile devices in the collection of field data, citing the affordable nature of GPS devices today along with dependable integrated workflows to spatial databases, which presumably ease the level of difficulty in implementation and offers a wider availability of tools and software applications that can be employed. Tripcevich and Wernke (2010) concur and acknowledge that the workflow and efficient capture of data are great benefits realized by the adoption of a digital field strategy at the excavation site.

2.2 Spatial Database Design

This section addresses some of the unique needs of an archaeological specific geodatabase. Section 2.2.1 discusses the need for ontological and semantical consistency in order to classify objects according to a structure that is adhered to. Section 2.2.2 references actual geodatabases that have been designed for similar implementation. Section 2.2.3 reviews best practices in geodatabase design.

2.2.1 Ontological and Semantical Consistency

As previously mentioned, inconsistent data entry presents numerous problems in analysis and query results. Sharon, Degan, and Tzionit (2004) cite similar findings to Newhard et al. (2013), highlighting the value in implementing GIS technology at an archaeological survey project in Ramat Beit Shemesh, Israel. They find that handheld data capture revolutionized the ability to quantify spatial information gathered at the site. This study is extremely relevant and in close geographic proximity as well. They also point out the significance and stress the need for an extremely well organized data collection system and well-defined ontology as necessary foundations for successful outcomes, arguing that archaeologists in general should begin to move toward GIS since other data sources and documentation are moving in that direction. The authors had several objectives including the need for a database that was unified in all aspects of collection, analysis, and output, citing that lack of a common format amongst the data was a critical hindrance to the collaborative work.

Rondelli et al. (2008) address the need for improvement of artifact classification at archaeological sites. The interpretation and consistency of reporting currently varies from location to location and the authors propose semantic and ontological standards for analytical purposes and deeper analytical discovery. They further argue that large repositories of information could be greatly enhanced and more effectively queried with the proposed standardization. Pre-defined choices, well thought out entities, attributes, domains, and relationships are critical to the success of the geodatabase.

2.2.2 An Archaeological Project-Specific Database

Many database designs were investigated before proceeding with development, and it became clear that each and every archaeological excavation needs a customized entity relationship diagram as a foundation. González-Tennant (2009) determined the needs for and implemented a GIS model of data acquisition and presentation through hands-on fieldwork at four gold mining locations in New Zealand, citing improved accuracy over traditional methods with continuously improving equipment and software. The diagram and discussion of the geodatabase that resulted from their work is similar to this project. The need to organize, filter, and visualize data from these sites drove the development of a predictive GIS model. The author argues that digital technologies are continuously improving as equipment and software become increasingly more precise and accurate.

Tennant (2007) chronicles theoretical collection of excavation data using GIS and proposes a design for and implementation of a geodatabase complete with detailed breakdown of feature classes, attributes and relationships. Figure 4 is an example of how ceramics and relationships might be handled in a geospatial database according to Tennant.

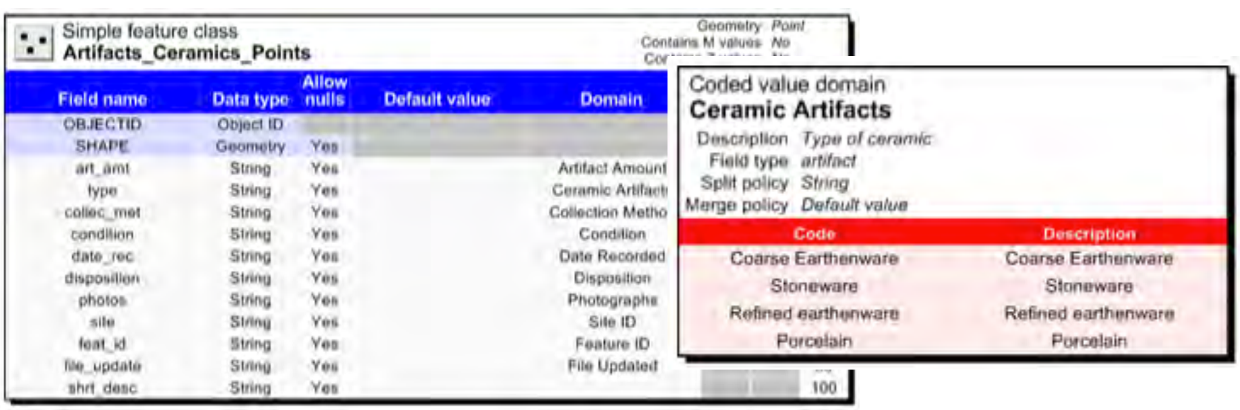


Figure 4. Tennant's tables of ceramic in a geodatabase.

This sound model and categories for feature classes was most useful during project development, however, Tennant does not account for stratification. Instructions for testing and downloading sample data to determine the soundness of the database before to implementation are also included. Because of the potential for great variability amongst cultural materials and assemblages present at an archaeological site, the author stresses the importance of project/site-specific database design to suit the environment, confirming earlier thoughts during the review of the artifact catalog. Because sites vary greatly from one area and time period to another, it is highly desirable to design a project-specific geodatabase to manage relationships and feature classes.

2.2.3 Best Practices in Geodatabase Design

The Esri publication by Arctur and Zeiler (2004) provided sound recommendations for planning the design and construction of the geodatabase. Their advice was to adopt an existing database schema template as the starting point, then to modify the template to suit the specific project needs. While that would have been highly desirable, a template could not be identified with closely aligned qualities needed for this project. The model proposed by Tennant (2007), discussed above, provided the nearest basis for comparison. In addition, Arctur and Zeiler suggest recommendations for a workflow, which was followed in the development of this geodatabase. It provides for continuous improvement and testing through a six step process: 1) obtain or develop a design, 2) modify the design, 3) load data, 4) build topological relationships, 5) test the model, and 6) revise the model. Each of these major steps was further broken down into a logical progression of small tasks required to bring the project to fruition. Careful analysis of the data, layers, feature classes, feature datasets, topology, domains, and relationships created a foundation upon which to build.

Chapter 3: Methodology

This chapter discusses the rationale and methodology behind the development plans for the Bethsaida Excavation spatial database project. Section 3.1 provides a general methods overview. Section 3.2 looks at the data requirements, equipment and software needed. Section 3.3 investigates each of the data sets, their contents, and how each was prepared and processed for use. Section 3.4 reviews the geodatabase programming needs, and section 3.5 includes a detailed project timetable with dependencies and expected completion dates.

3.1 Overview of Methodology

This section discusses the types of data that were needed and the field expertise required of individuals who were the intended end users of this application. A previous project in the SSCI-582 Spatial Databases class under the oversight of Dr. Jordan Hastings served as inspiration for this approach.

Data from an archaeological excavation comes in a wide variety of formats, sources, and in varying degrees of accuracy. One of the goals here was to unite those sources into a single cohesive structure to improve the quality of the data and demonstrate that the data sets can be combined spatially to produce robust visualizations based on a well-organized framework and classification system.

Much of the data received from the Consortium was in tabular format and required some cleanup, preparation and reestablishing relationships before it could be imported into Esri ArcMap version 10.4. MS Access database tables, Excel spreadsheets, Portable Document Format (PDF) documents, and high-resolution imagery are examples of the types of data that all needed to come together. Spatial data consists of point and polygon shapefiles. The process for completing this task is outlined in Section 3.3.1.

Two datasets that were identified as necessary early on could not be obtained (the elevation [stratification] data, and the excavation master grid [point] data). This did not hinder the development of the project, however, as it was possible to create schemas to substitute for the actual measurements and points that have been used historically in the field by the archaeologists.

Frequent communication, mostly via email, with several of the Consortium archaeologists has been instrumental in shaping the needs of this project. They form a core group of advisors during the development of this application. Key individuals participating in this process were Dr. Rami Arav (University of Nebraska, Omaha), Dr. Carl Savage (Drew University), Dr. Jerome Hall (University of San Diego), Dr. Harry Jol (University of Wisconsin – Eau Claire), and Dr. Nicolae Roddy (Creighton University).

3.2 Research Design

Existing archaeological geodatabases were examined for features and entities, relationships and domains, feature classes and fields, and then were compared to the pre-existing (non-spatial, MS Access) database during needs analysis. Based on the literature examined, there were many ideas that contributed to the final research design. The closest comparable project was found in Kacey Pham’s USC thesis paper, the result of which stemmed from a common group project in the SSCI-582 Database class. The original concept for this database was a collaborative effort by Kacey Pham, Jennifer Titus, and myself.

3.2.1 Equipment and Software Used

Equipment used includes a MacBook Pro laptop running O/S X Yosemite (10.10.4) and also running Windows 8 on a dual boot system. A Trimble GeoXH 3000 (running ArcPad software 10.0, GPS Controller 2.22, and Windows Mobile 6.1) was used for field collection in

2015. ArcGIS (10.4) and MS Office 2011 and 2013 were instrumental in the development of this database. Lucidchart was also employed to diagram the relationships and entities during the design phase.

3.2.2 Data Description, Requirements, and Quality

All data sets (except those that were self-gathered) are the property of the Bethsaida Consortium, and the quality varies. Unfortunately, there are no alternative sources as the data sets are unique to the excavation and largely legacy data, ranging in date from 1989 to 2014. Also note that much of the data is gathered by volunteers or untrained amateur archaeologists, and therefore often inaccurate in original descriptions.

Table 1 below succinctly summarizes the data involved in this project. It includes the data description, the spatial or non-spatial nature of the data, data sources, formats and types of data, project requirements, and quality.

Table 1. Data Description, Sources, Requirements, and Quality

Data Description	**Data Type & Requirements**	**Data Quality**
Tabular data – artifact information *Source: Bethsaida Consortium* *Non-Spatial*	*Type:* MS Access database on local computer *Requirements:* Must be able to export from MS Access to Excel Must have sufficient detailed information to categorize data	Cannot be assessed – quality of content depends greatly on data entry and knowledge of the individual assessing each find. Legacy data must be assumed to be correct due to these limitations.
Stratification data *Non-spatial - categorical assignment*	Type: MS Excel spreadsheet *Requirements:* Must have sufficient information for applying breaks to strata. Stratification categories apply site-wide as blanket coverage	A schema was designed to accommodate stratification classification in lieu of actual elevation measurements.

Data Description	Data Type & Requirements	Data Quality
CAD drawing *Source: Bethsaida Consortium* *Non-spatial (prior to georeferencing)*	*Type:* Adobe PDF format *Requirements:* High resolution/print quality document that when scanned and imported to ArcGIS renders clear imagery	Successful geocoding revealed that the accuracy of the CAD drawing has sufficient resolution.
Excavation grid *Non-spatial (prior to georeferencing)*	*Type:* Created vis Fishnet Tool in ArcMap. *Requirements:* None	A schema was designed to replace data that was unavailable and inaccurate/incomplete. This serves as a reference grid covering the entire 26-acre site.
Aerial Photography – high resolution imagery *Source: Bethsaida Consortium* *Non-spatial (prior to georeferencing)*	*Type:* JPEG format *Requirements:* High-resolution imagery to meet the needs of large-scale visualization. Provides sufficient visual detail to 5 meters	Excellent resolution (360 dpi) with only a small area of non-coverage, which does not lie within an active area.
Point and polygon data *Source: Field collection* *Spatial*	*Type:* Shapefiles – point and polygon *Requirements:* Points to include significant monuments, structures, roads. Polygons to include active areas	Meter level accuracy based on visual inspection and configuration

3.3 Data Narrative

The following sections describe each of the data sets that were incorporated into the resulting final project. Section 3.3.1 reviews the MS Access database. Section 3.3.2 is an overview of the stratification data's role. Section 3.3.3 discusses the CAD drawings, what and how they are used here. Section 3.3.4 examines the excavation grid. Section 3.3.5 looks at the aerial imagery. Section 3.3.6 investigates the point and polygon data collected in the field.

3.3.1 Tabular Data

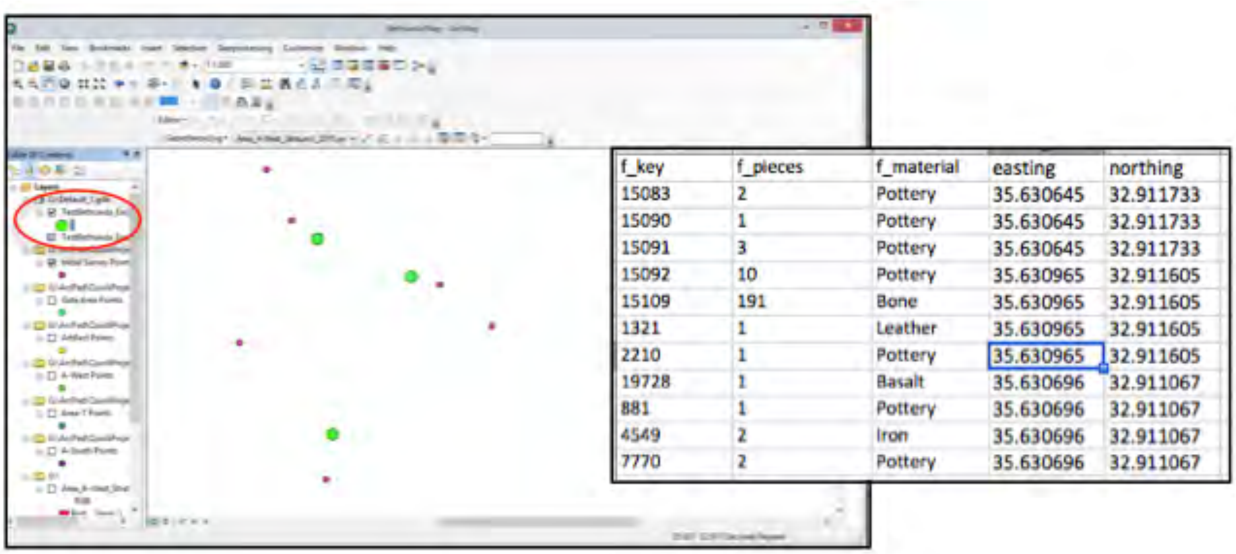
Data from the MS Access database tables was easily exported into Excel spreadsheets. Subsequently there were a number of challenges involved in getting the tables formatted properly and accepted into ArcMap. Figure 5 below provides an example of the data, including errors, that was exported from the MS Access database (shown here is a portion of the Finds table). Typical errors that needed to be corrected manually included things like Roman Nails that were categorized as Pottery or Bronze and Silver Coins that were categorized as Pottery or Bone that was classified as Stone, etc. A total of 40,147 Finds and 31,999 Baskets were recorded within the pre-existing relational database. Other entities (tables) were recreated during the programming phase.

1	f_key	f_pieces	f_state	f_notes	f_material
39132	15083	2	-	:-)	Pottery
39133	15090	1	-	:-)	Pottery
39134	15091	3	-	:-)	Pottery
39135	15092	10	-	:-)	Pottery
39136	15109	191	-	:-) Because Carl said so	Bone
39137	1321	1	+	?	Leather
39138	2210	1	+	1	Pottery
39139	19728	1	+	104gm	Basalt
39140	881	1	+	2 lines	Pottery
39141	4549	2	+	2 pieces - 1 piece two twisted strands	Iron
39142	7770	2	+	2 roman nails	Pottery
39143	1476	1	+	3 groove green bowl	Pottery
39144	19678	1	+	398gm	Basalt
39145	17953	1	+	7 cm	Iron
39146	18923	1	+	9 cm	Iron
39147	12117	1	+	A coin of Philip Gerod	Bronze
39148	15707	1	+	a handle of a jar with + mark on it.	Pottery
39149	15748	1	+	A hipo jar, notice the impact places.	Pottery
39150	11891	1	+	agate	Pottery
39151	18602	1	+	Alexander Jannaeus, bronze, IAA#143576, 104-76 BCE, W.	Pottery
39152	2682	4	-	also had plaster	Pottery
39153	2688	1	+	also had plaster	Pottery
39154	12173	1	+	an intact iron axehead. The second find of this type in this area.	Iron
39155	16642	1	-	animal teeth	Bone
39156	12178	1	+	Antiochus III 198 - 187 BCE	Bronze
39157	18920	1	+	Antiochus III bronze coin, minted in Ptolemais, 198 - 187 BCE,	Bronze
39158	12157	1	+	Antoninius Pius	Pottery
39159	12156	1	+	Antoninius Pius 153-154 CE (?)	Bronze
39160	14387	1	+	Antoninus Pius gold dinarius.	Pottery
39161	17369	1	+	Antoninus Pius Rome 145-161	Silver

Figure 5. A portion of the Finds table exported from MS Access into Excel spreadsheet. The data was often irrelevant, incomplete, or nonsensical, as evidenced here.

The process outlined here for formatting the Excel tables was complex and time consuming. The MS Access information, when exported to Excel, became static and relationships between fields and attributes no longer existed. Excel was chosen as the desired software to reestablish those relationships because of its ability to associate cells with one another by using the formula building feature, specifically VLOOKUP. A new Excel workbook was created and all relevant columns from the multiple MS Access tables were added to a single master worksheet with corresponding header labels. New worksheets, one for each entity, or table, were created to mirror the design of the ERD for loading into ArcMap. The Finds_ID was the single unique identifier that could be tied back to, and associated with, all other tables. Finds were sorted by type, then copied and pasted into the five sheets representing the five Finds entities. For example, all of the Find_ID's for Pottery were pasted into the Ceramic sheet. It was then necessary to find the Basket_ID, Basket_No, Loci_ID, Loci_No, Area_ID, and Strata_ID that corresponded to each unique Finds_ID. By using the VLOOKUP feature, this was accomplished and all relevant information related to each Finds_ID was restored on the master worksheet, resulting in a complete record for each artifact.

A total of 65 pairs of Easting and Northing coordinates from point data collected in the field were entered into the Excel spreadsheets (for testing purposes only) prior to importing a small sample of data into ArcMap, resulting in the desired spatial rendering as seen in Figure 6 below. Plotted points represent each record after importing to ArcMap.



f_key	f_pieces	f_material	easting	northing
15083	2	Pottery	35.630645	32.911733
15090	1	Pottery	35.630645	32.911733
15091	3	Pottery	35.630645	32.911733
15092	10	Pottery	35.630965	32.911605
15109	191	Bone	35.630965	32.911605
1321	1	Leather	35.630965	32.911605
2210	1	Pottery	35.630965	32.911605
19728	1	Basalt	35.630696	32.911067
881	1	Pottery	35.630696	32.911067
4549	2	Iron	35.630696	32.911067
7770	2	Pottery	35.630696	32.911067

Figure 6. Sample legacy data (right) successfully imported to ArcMap with resulting points (left).

3.3.2 Stratification Data

A schema for stratification data was created for this project in order to accommodate depth. One column in the Excel spreadsheet handles the z measurement in a categorized manner, associating each database record (when known) as belonging to one of 8 different strata; 1 being closest to the surface, and 8 currently being the deepest. This eliminates the need for elevation readings for each artifact record, although actual elevation readings are included as a part of each Loci record for reference in legacy data as well as new collections.

3.3.3 CAD Drawing

Detailed CAD drawings of 4 active excavation squares were obtained from the Consortium in PDF format. These were used to further confirm accuracy of reference points and monuments. Each was digitizing into JPG format, imported to ArcMap as a data layer, and georeferenced using field collection data points via the Georeferencing tool in ArcMap. Figure 7 shows one of the CAD drawings after import and with 3 georeferenced points visible.

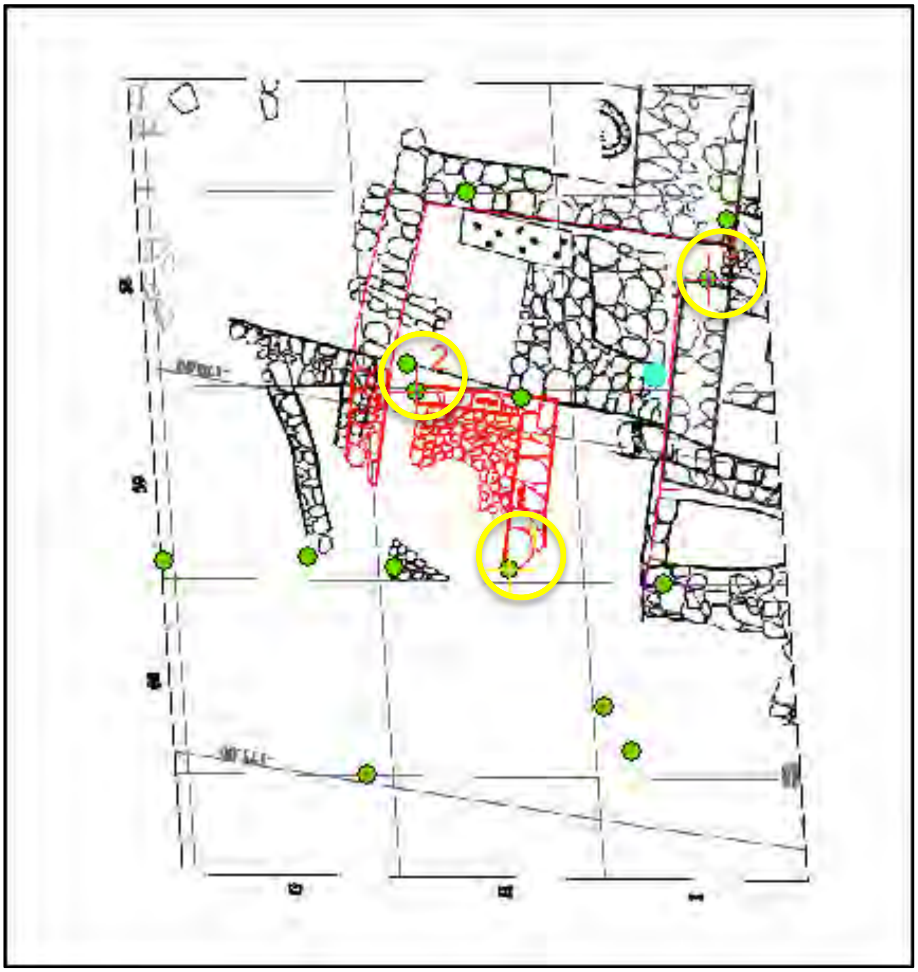


Figure 7. Imported CAD drawing with 3 georeferenced points.

3.3.4 Excavation Grid

It would have been highly desirable to geolocate the original excavation grid onto the basemap, however, that information was not available during the course of this project development and it was noted that many of the site markers are missing, have been moved, or have been vandalized over time, thus rendering it inaccurate. The grid acts as an overarching framework at the site to provide “constant” reference points when measuring distances and elevations in the field. It also provides historical monument information and assists in confirming geolocation accuracy of new data. Since this data was deemed a loss, a fishnet was applied in

ArcMap as a suitable substitute strategy in order to establish consistent reference points in the digital environment. These new reference points do not have any similar absolute or relative locations to the original on-site markers, but the new digital schema can actually be considered a more reliable and consistent source than the old, on-site markers due to significant disruption in the field. Figure 8 below shows the fishnet applied over a data layer.

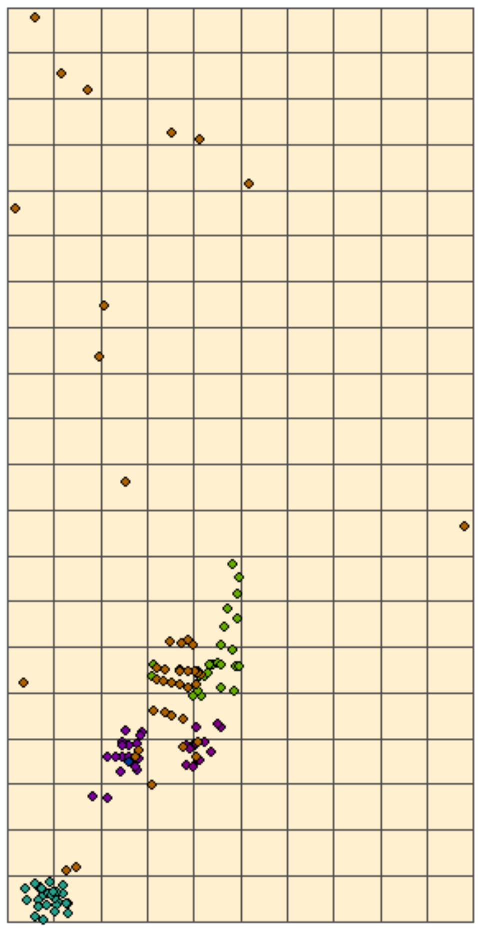


Figure 8. Fishnet polygons applied in ArcMap.

3.3.5 Aerial Photography

High-resolution aerial photography of the excavation was obtained from the Consortium and added to ArcMap as a data layer. This layer became the basemap for the project. The imagery of this part of the world is not readily available via web services to an extent needed to carry out this project, so it was necessary to procure photography with a high level of detail. The Consortium had made special arrangements for this photography in 2014 in the hopes that it would enhance ongoing research opportunities. Point data collected in the field was added to the map as layers, which were then used to georeference the imagery using the Georeferencing tool in ArcMap. Figure 9 shows the aerial imagery after import to ArcMap and with some georeferencing points in place.

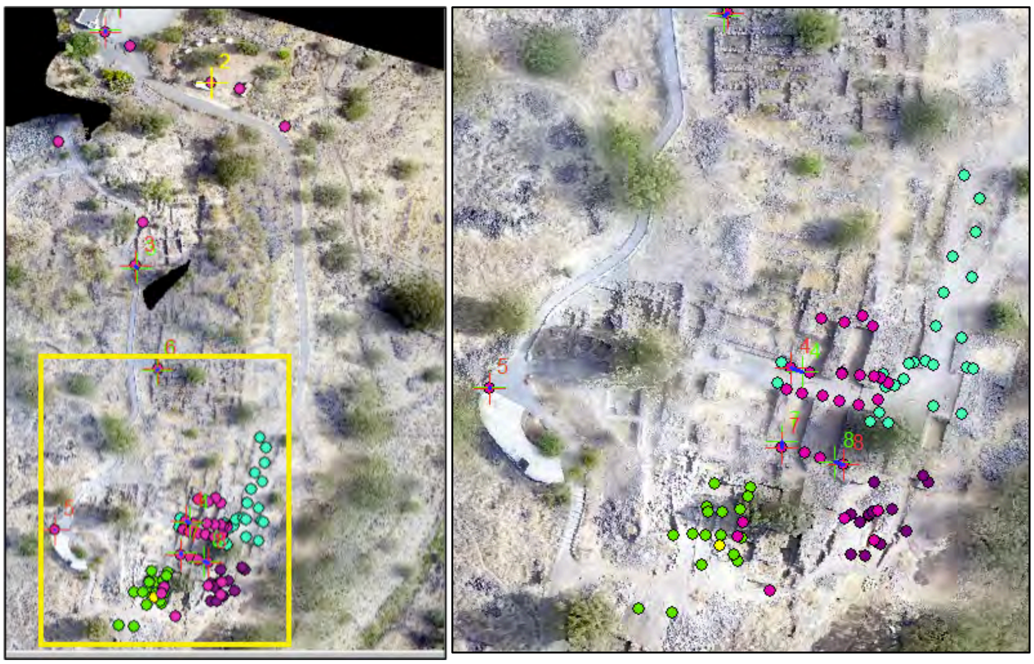


Figure 9. Entire excavation overview after georeferencing (left), and southern end of excavation shown in more detail (right).

3.3.6 Point/Polygon Field Data

Several sets of point data were collected in late June and early July of 2015 on-site at the excavation. The collection was executed using Trimble GeoXH-3000 running ArcPad 10.0 and GPS Controller 2.22 software on a Windows Mobile 6.1 operating system. GPS Controller and ArcPad software were configured to require a maximum Position Dilution of Precision (PDOP) tolerance of 6, and a minimum satellite configuration number of 5, at a minimum of 15 degrees above the horizon, settings recommended as striking a nice balance between precision and productivity (Texas Tech University, 2012). Data was collected in the Geographic Coordinate System (GCS) World Geodetic System (WGS) 1984, and projected in Universal Transverse Mercator (UTM) zone 36N (See Figure 10 below for geographic coverage) in ArcMap. Real time satellite coverage diagrams for precise location information can be found in Appendix A for each of dates June 28 through July 1, 2015.

Figure 10. UTM zone 36N, region of study site (image from SpatialReference.org [last accessed 30 May 2016]).

Various data sets include greater site monuments (for reference, objects that are not likely to change or move), individual active square corners, grid stakes (master grid) and parameters, and significant structures (walls, roads, city gate area). Each was then added to ArcMap in individual layers. Figure 11 shows what the data looks like during the collection process on the handheld Trimble device.

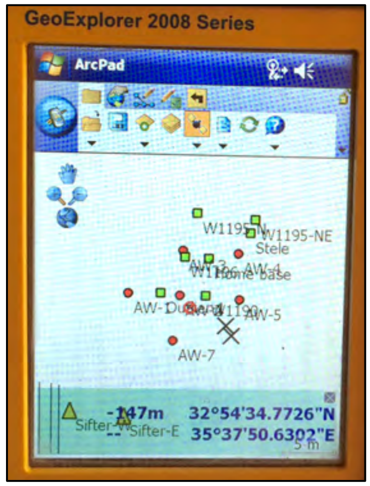


Figure 11. Trimble during data collection in Bethsaida, Israel, 2015.

Figure 12 shows the various points and layers that were then added to ArcMap as the Initial Survey Points layer. Some difficulty was encountered with the import of the data to ArcMap due to unfamiliarity with the workflow, however, once the proper files were associated and indexed in the layer properties it became clear as to what data storage structure requirement functionality was needed for this workflow. Post processing data correction was not accomplished or possible, as the GPS log files were not captured during the collection process due to an oversight during device configuration. Based on the large-scale nature of the project and the ability to overlay the points onto the high-resolution photography, combined with the PDOP and satellite restrictions that were in place during the collection process, it is believed that the evidence for data accuracy is quite reliable. Visual inspection of the plotted data aligns as expected and according to detailed notes taken during the collection process. In addition, the geographic location is nearly free of canopy cover and obstructions, and the Trimble GeoXH 3000 provides 1 to 3-meter accuracy, which can be further enhanced to subfoot accuracy with real time or post-processing (Trimble, 2012).

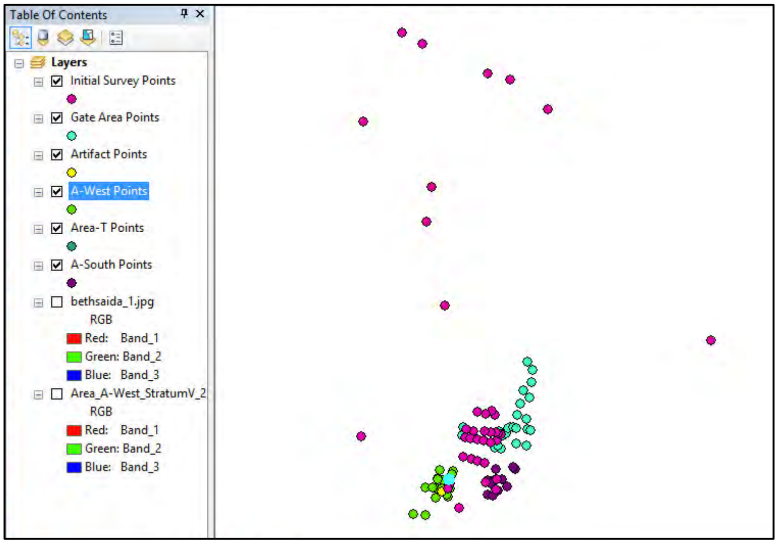


Figure 12. Data collected in the field using ArcPad via Windows Mobile operating system on Trimble GeoXH-3000 brought from ArcPad into ArcMap and visualized in layers.

The Initial Survey Points layer acts as a foundational layer for the overarching site georeferencing. Points were taken throughout the 26-acre site in order to work with the aerial photography and gain better accuracy when working within a single collection square, a smaller geographic unit, often about 10 x 10 meters in size. The handheld collection also served as an example of improved workflow through mobile device integration in the field. Point and polygon shapefiles (feature classes) with domains exhibit the power of limited input options.

3.4 Geodatabase Development Rationale

Many other databases and articles were consulted in the design phase of the new entity relationship diagram (ERD). It was essential to develop a keen sense for the necessary range of materials and attributes to be considered for inclusion in this database as well as potential problems that might be encountered. It was also necessary to keep it as simple as possible. This research involved gaining as much insight as possible from the archaeologists and directors of the Consortium. Early on, the local MS Access database was evaluated for suitability and flaws, and a resulting list of database tables including datasets, entities, feature classes, and attributes emerged. See Appendix A for all database tables.

Section 3.4.1 reviews the structure of the MS Access database. Section 3.4.2 provides an overview of the redesigned spatial database. Section 3.4.3 illustrates examples of simple queries for testing purposes.

3.4.1 Preexisting Entity Relationship Diagram

The diagram from the existing MS Access database is shown in Figure 13 below. It was much more complex than what was needed and contained entities that were omitted in the development of this project. Entities circled in yellow were selected for revised inclusion and were deemed necessary for the desired visualization. Basket and artifact photos will be collected in the field concurrently with artifact information on the handheld devices; however, the photographs are not stored in the geodatabase during this phase of the project, just referenced there. Licensing entities were also eliminated as they were not currently in use or needed. Notes are now handled as an inclusive field within each of the remaining entities rather than having Notes as an entity of its own. Stratum used to be handled as a field within the Baskets entity but will become an entity/table itself in the new design. Domains will be added as drop-down menu choices for data entry to aid in the ontological and semantical consistency desired vs. open ended data entry.

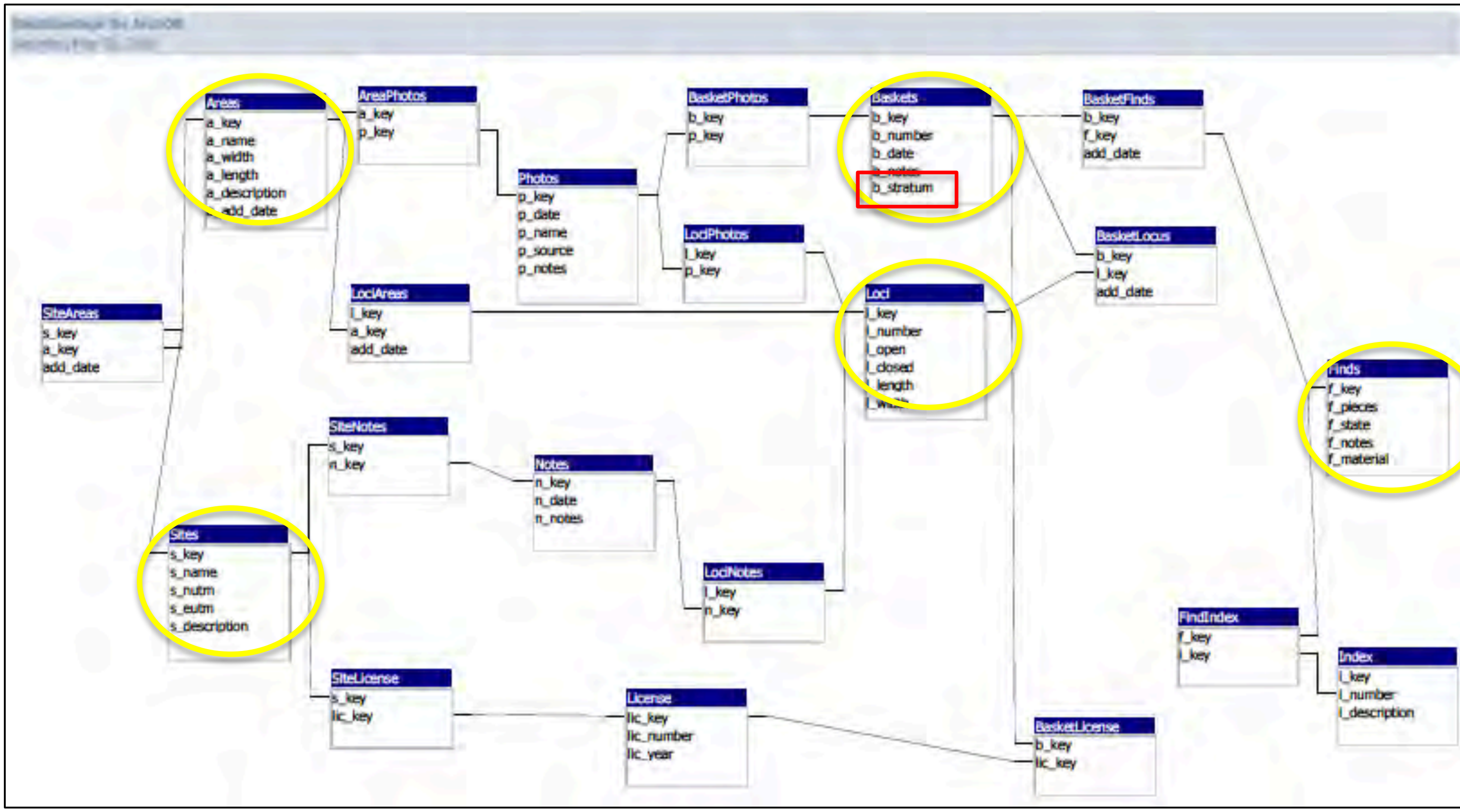


Figure 13. Existing ERD, yellow circles indicate entities that have been translated into the new geodatabase.

3.4.2 The Redesigned Entity Relationship Diagram

Once the elements to be included in the database had been determined, the scope advanced to designing the Entity Relationship Diagram (ERD) where the relationships between the tables and key fields were established. Multiple revisions of the ERD resulted in this final design. It is the essence and blueprint of this geodatabase. Careful design at this stage was critical to the success of the project and USC faculty thesis advisors and Consortium members were asked to contribute their feedback, expertise, and suggestions for programming and improvement. Figure 14 below depicts the basic ERD conceptual diagram that was settled on for development.

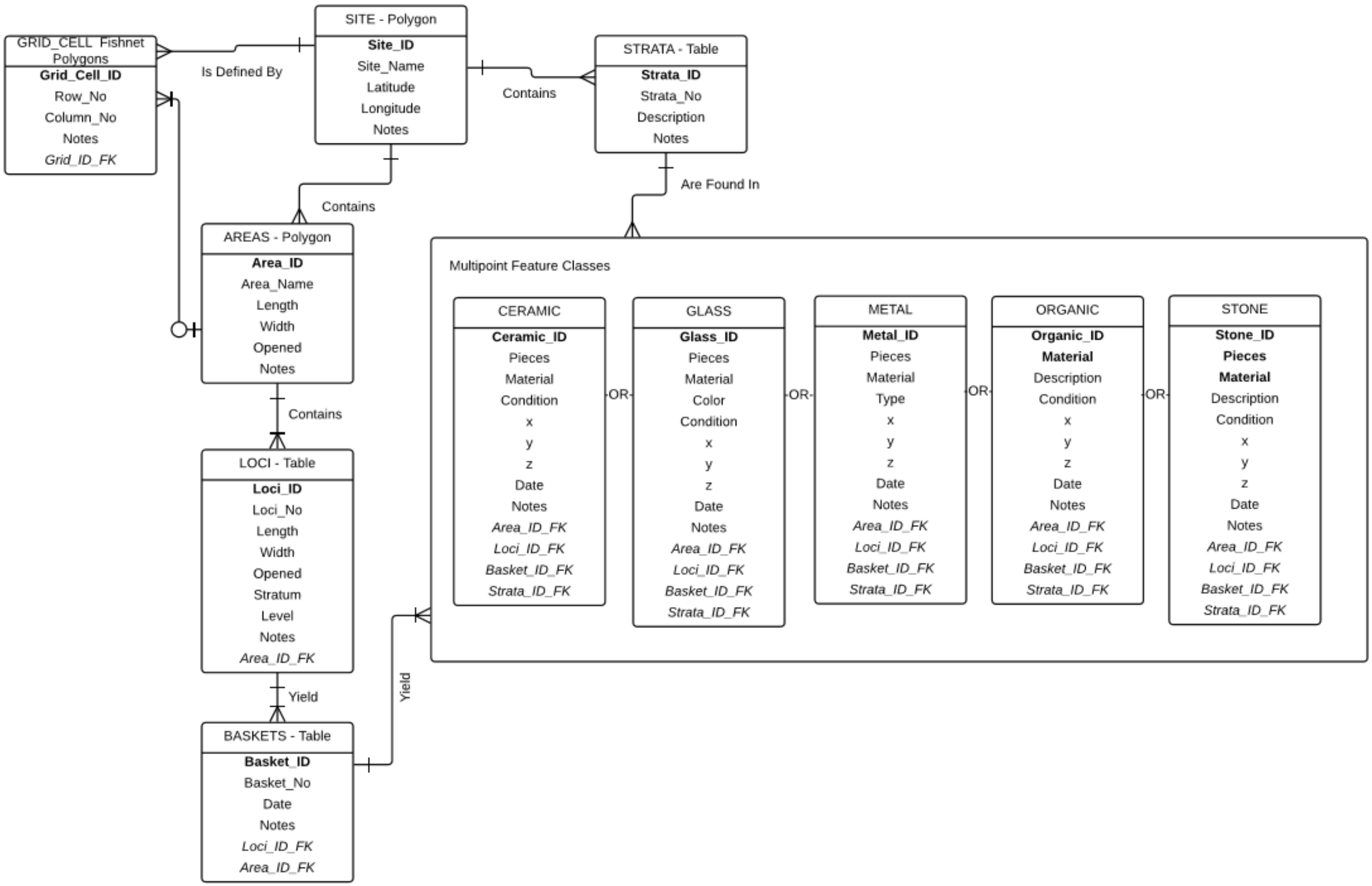


Figure 14. Finalized concept for the new spatial database, the Entity-Relationship Diagram.

The inclusion of Coded Value domains in the geodatabase infrastructure will ensure that proper categorization during the collection process aids in querying the data during the analysis phase. Coded Values also ensure that typographical errors do not influence data input and that only relevant options present themselves for selection within each entity. This reinforces the ontological and semantical consistency that was lacking in the MS Access database. Table 2 describes some of the Coded Value domains that were included in this design to create an efficient analysis environment.

Table 2. Coded Value Domains

Entity	Domain Name	Domain Selections
Ceramic Glass	Condition	Whole Fragment Scatter
Glass	Color	Clear Green Blue Yellow Red Other
Metal	Material	Bronze Gold Iron Lead Silver
Metal	Type	Coin Jewelry Tool
Organic	Material	Bone Leather Textile Wood
Stone	Material	Basalt Flint Limestone Stone

It was also necessary to identify and classify each of the strata. A domain schema was developed which will allow users to select a strata from a drop-down menu during the data entry process and the schema has been applied site-wide as a blanket approach at this time.

Once the model was thoroughly vetted for errors and completeness, the actual construction phase of the database in ArcGIS began. The ERD was translated into a working model that was used for data entry.

3.4.3 Testing and Sample Queries

A large sampling of legacy data from the MS Access database (ranging in date potentially from 1989 to 2014) was selected according to category and uploaded into the system to test the degree of compatibility and accuracy, and to aid in understanding any additional programming needs. The resulting visualizations of various layers were added to the basemap. Layers included a variety of artifact types in addition to vertical stratification categories in order to demonstrate the power of the z spatial component in the output. Sample queries were run and included spatial, temporal, and attribute field data input. Table 3 provides examples of queries that were used to assess the general functionality and complexity possible.

Table 3. Sample Test Queries

Test Queries	
Query 1	Query the Stone attribute table Find all of the Flint records in the Stone entity that were excavated from Strata 6
Query 2	Query the Organics attribute table Find all of the Bone records in the Organic entity that were excavated on a specific date
Query 3	Query the Metal attribute table Find all of the Bronze records in the Metals entity that are classified as Coin and were excavated from Strata 2
Query 4	Query the Glass attribute table Find all of the Blue records in the Glass entity that are classified as Fragment
Query 5	Query the Ceramics attribute table Find all of the pottery from the Ceramic entity that are classified as Whole and that were found in Area A and also were excavated from Strata 6
Query 6	Query the Ceramics attribute table Find all of the pottery from the Ceramics entity that are classified as Whole and comprised of less than six pieces
Query 7	Query the Organic attribute table Find all of the Bone in the Organic entity that was excavated within a specific range of dates

Chapter 4: Results

This chapter provides an overview of the results that were achieved in the development of this geodatabase. Section 4.1 discusses the final design and relationships included in the model. Section 4.2 describes population of the spatial database. Section 4.3 summarizes query results during the testing phase, and section 4.4 illustrates data visualization. Section 4.5 summarizes the results herein.

4.1 Geodatabase Design and Relationships

The ERD discussed in Chapter 3 and pictured in Figure 14 was translated and built in ArcMap without further revision. The simplicity of the final design combined with the ability to perform complex queries resulted in a system that will prove useful in performing the most common and typically needed functions. As mentioned in Chapter 3, many entities were omitted from the MS Access legacy database in order to streamline data entry both in the field and when working on a desktop system. Figure 15 provides a closer look at the relationships between the entities. The foreign keys associated with the Finds feature classes are directly responsible for and provide the power to carry out various and specific queries.

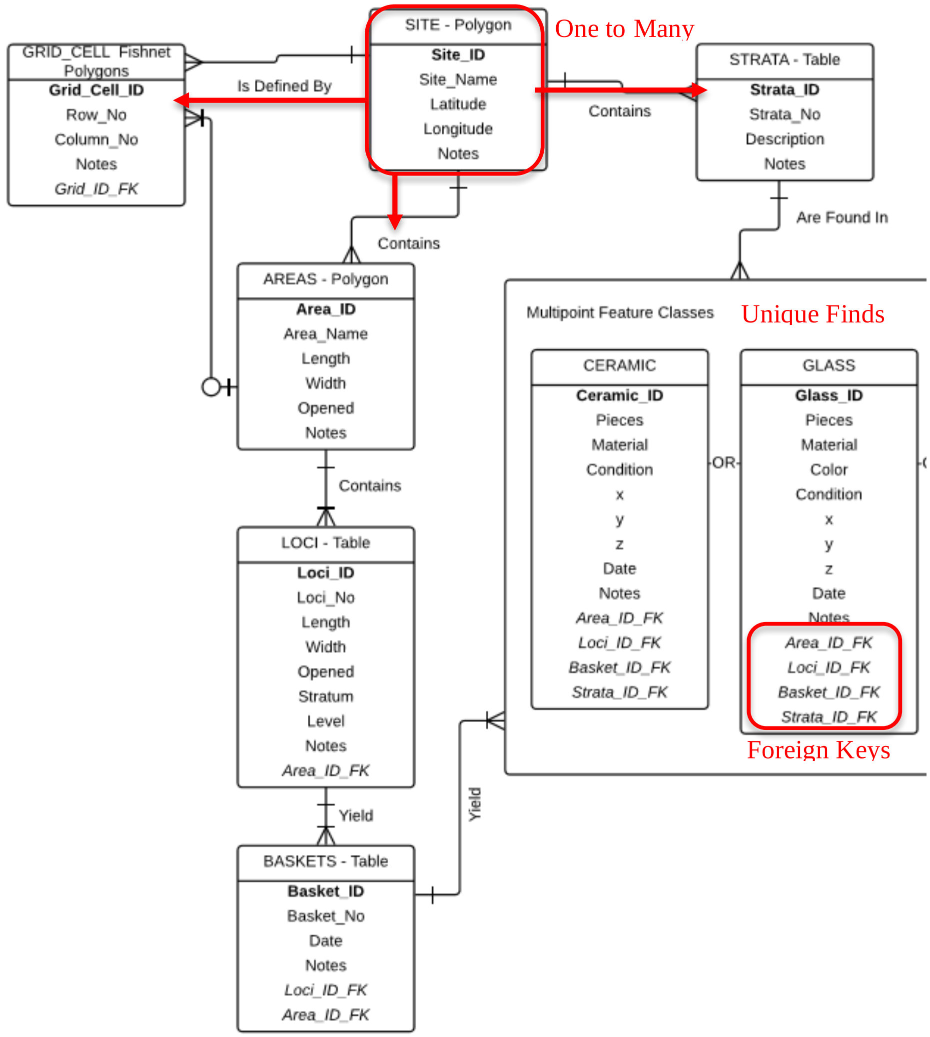


Figure 15. Relationships within the ERD

Grid Cell entities are strictly for referencing field activity and provide a consistent location association with all parts of the greater site. They are numbered from 1 to 200 beginning in the upper left of the fishnet. Area is the entity used to associate artifacts, baskets, and loci to an active excavation pit. The Site, the overarching highest level entity, has a one to many relationship with the Grid Cells, Areas, and Strata. The Areas have a one to many relationship with the Loci, Baskets, and Artifacts. Likewise each Loci can only belong to a single area, but may result in multiple baskets and artifacts. A Basket can only be associated with a single Loci, but again, many artifacts may be contents within a single basket. An artifact (anything included in one of the 5 Finds feature classes) can only belong to one Basket, one Loci, one Area, and one Strata. Finds do not have relationships with one another. The Find records are the core of the database, each having a single and unique record entry.

The ERD was translated into a working model in ArcMap and resulted in the structure shown in Figure 16. Feature classes, shapefiles, tables, relationships and topology are illustrated here along with some resulting layers and imagery, basemap and CAD drawings.

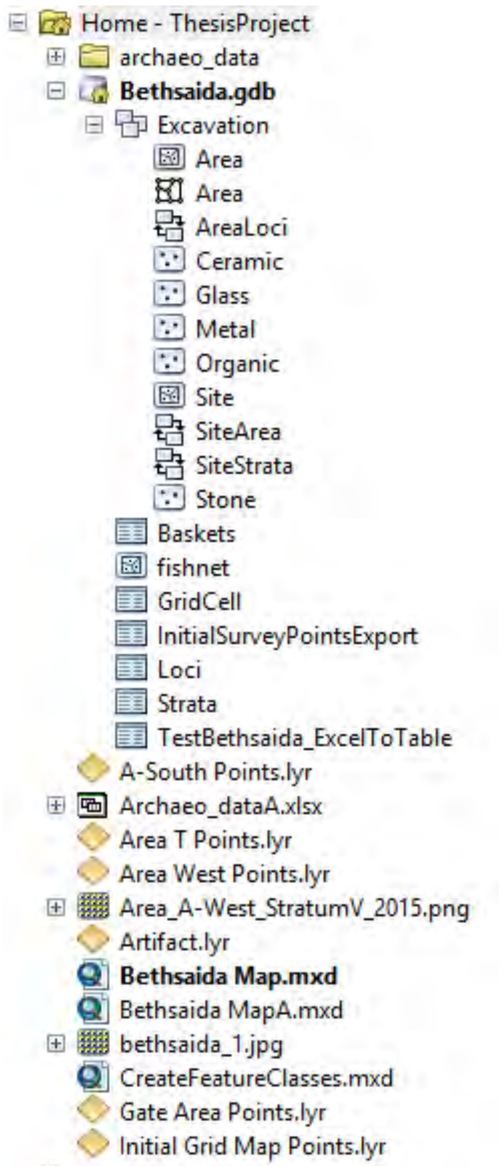


Figure 16. Geodatabase contents as viewed in ArcMap

4.2 Populating the Database

It was originally hoped and planned to enter approximately 200 legacy records into the database along with field data collected in 2015 - enough to visualize, query, and thoroughly test the design. After extensive time was spent on the tabular data formatting and master spreadsheet creation outlined in Chapter 3, it was possible to load a total of 25,427 records into the new geodatabase. These records did not include any spatial information, however, so 65 sets of coordinates were used to load into the majority of these records for testing purposes only, covering Areas A and T. This provided ample opportunity to demonstrate the power of the x and y coordinates. In addition, the categorized schema for stratification attaches a depth classification to each artifact record (which is assumed to be accurate and was included in the legacy data) making it possible to return specific results as to which artifacts have been excavated from each level, and in each area. Figure 17 is an example of the tabular data including test spatial coordinates, ready for loading into ArcMap. Notice that the ‘z’ coordinate column remains empty, but that the Strata_ID_FK gives each record a depth classification.

1	Metal_ID	Pieces	Material	Type	x	y	z	Date	Notes	Area_ID_FK	Loci_ID_FK	Basket_ID_FK	Strata_ID_FK
92	17348	1	Bronze		35.631074	32.909772		5/25/2012		0	1147	11228	6
93	17355	1	Bronze	Coin	35.630957	32.909709		5/25/2012	Autonomus Tyros bronze coin, date	0	1147	11228	6
94	17357	1	Bronze	Coin	35.630973	32.909694		5/25/2012	Hasmonean coin, minted at JErusale	0	1147	11228	6
95	17360	1	Bronze		35.630958	32.909643		6/6/2012		0	2241	23479	1
96	17362	1	Bronze	Coin	35.63098	32.909641		6/6/2012	Autonomous Tyros, bronze	0	2241	23479	1
97	17367	1	Bronze	Coin	35.631001	32.90966		6/6/2012	Bronze coin, Ptolemy I, Alexandria,	0	2241	23479	1
98	17358	1	Bronze	Coin	35.631005	32.909661		6/6/2012	Caracalla, Tyros, Bronze, 198 - 217 C	0	2241	23479	1
99	17366	1	Bronze	Coin	35.631046	32.90968		6/6/2012	Demetrius II, Tyros, Bronze, 144 - 14	0	2241	23479	1
100	17365	1	Bronze	Coin	35.630987	32.909707		6/6/2012	Ptolemy III, Tyros, Bronze, 246 - 222	0	2241	23479	1
101	17364	1	Bronze	Coin	35.630987	32.90971		6/6/2012	Roman provicial coin, Antioch (Syri	0	2241	23479	1
102	17361	1	Bronze	Coin	35.630995	32.909712		6/6/2012	Severus Alexander, Orthosia, Bronz	0	2241	23479	1
103	17359	1	Bronze	Coin	35.631022	32.909721		6/6/2012	unidentified coin	0	2241	23479	1
104	17356	1	Bronze	Coin	35.63061	32.909553		6/18/2010	Mark Antony and Cleopatra VII, min	0	1123	11091	1

Figure 17. Excel data, the Metal entity, prepared for loading into ArcMap

A summary of the data that was used to populate the geodatabase follows. Table 5 breaks down the categories of data into shapefiles and tables generated, along with the complete number of records each contains.

Table 4. Records Used to Populate Database

Name of Entity	Type of Entity	Number of Records Added
Site	Polygon Feature Class	1
Area	Polygon Feature Class	7
Grid Cell	Polygon Feature Class	200
Strata	Table	7
Baskets	Table	3,340
Loci	Table	998

Name of Entity	Type of Entity	Number of Records Added
Ceramic	Multipoint Feature Class	17,721
Glass	Multipoint Feature Class	310
Metal	Multipoint Feature Class	423
Organic	Multipoint Feature Class	1,422
Stone	Multipoint Feature Class	998

The basemap was imported as a .jpg file and georeferenced using 5 points of field data in ArcMap. The results depict quite accurate placement of the points, usually within a foot or two of the actual reading location. Figure 18 gives a site-wide overview and scope of the points that were captured in the field for georeferencing purposes, while Figure 19 shows which points were used to georeferenced the image. Figure 20 provides a close-up view of the Iron Age city gate area and resulting accuracy of the data collection in most cases. Note the rectangular structural formations, the granary bins, and where the point locations fall at the corners.

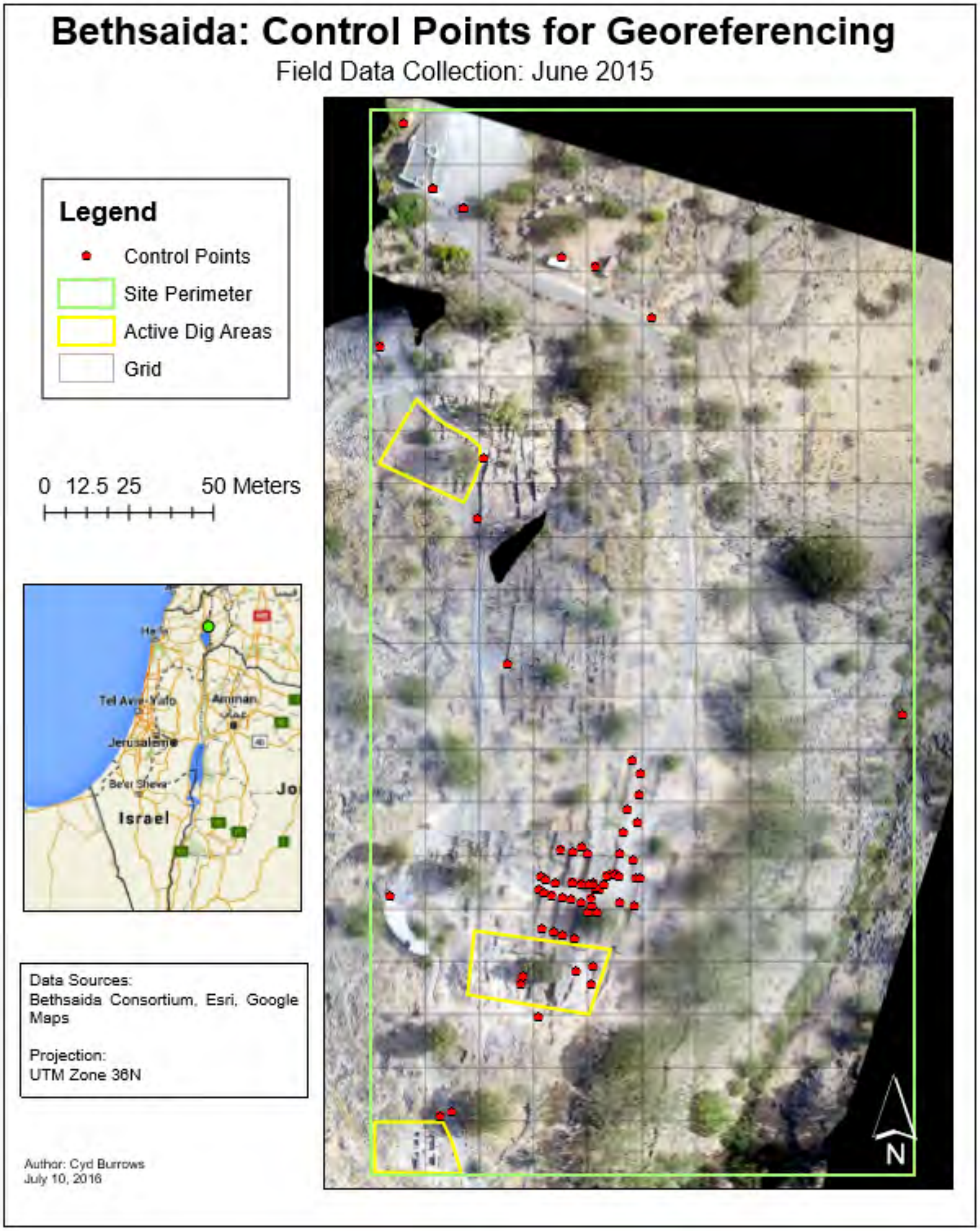


Figure 18. Points captured site wide in the field for georeferencing purposes

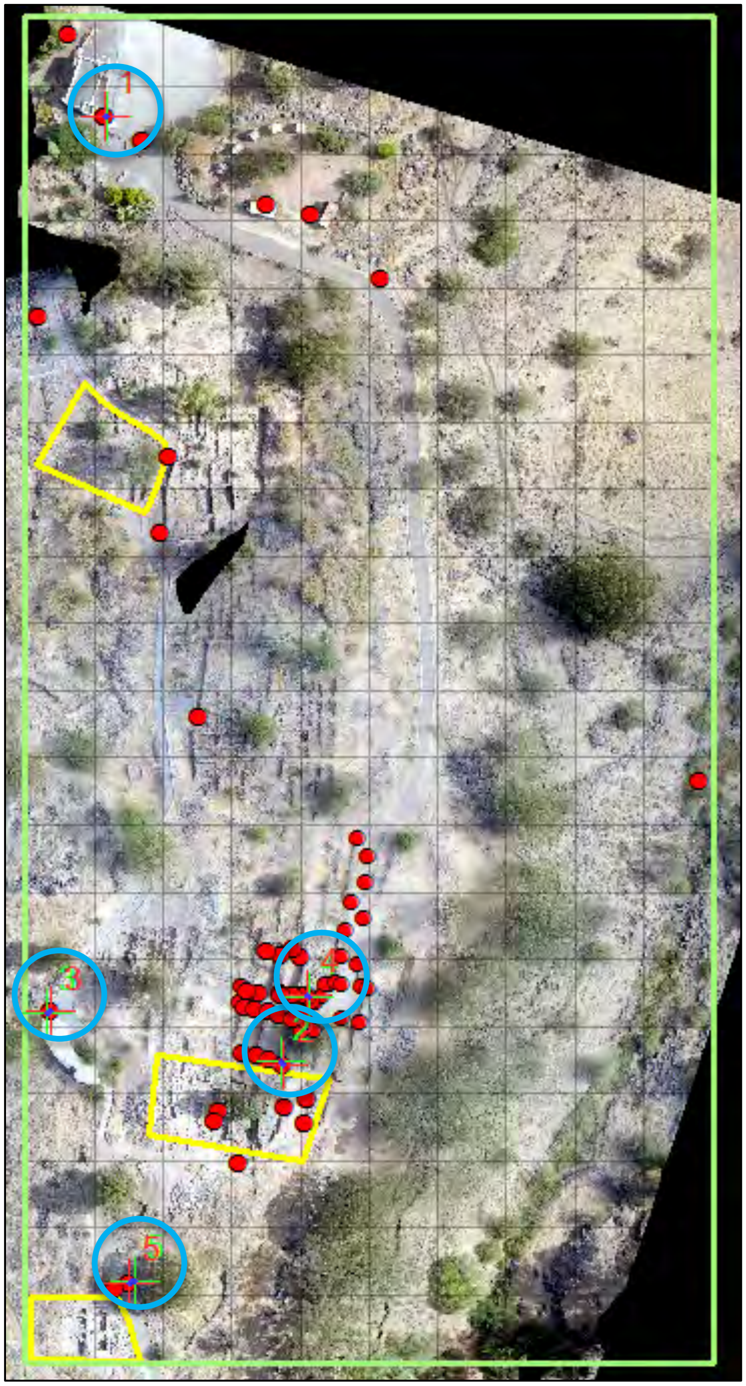


Figure 19. The five points used for georeferencing purposes indicated with blue circles

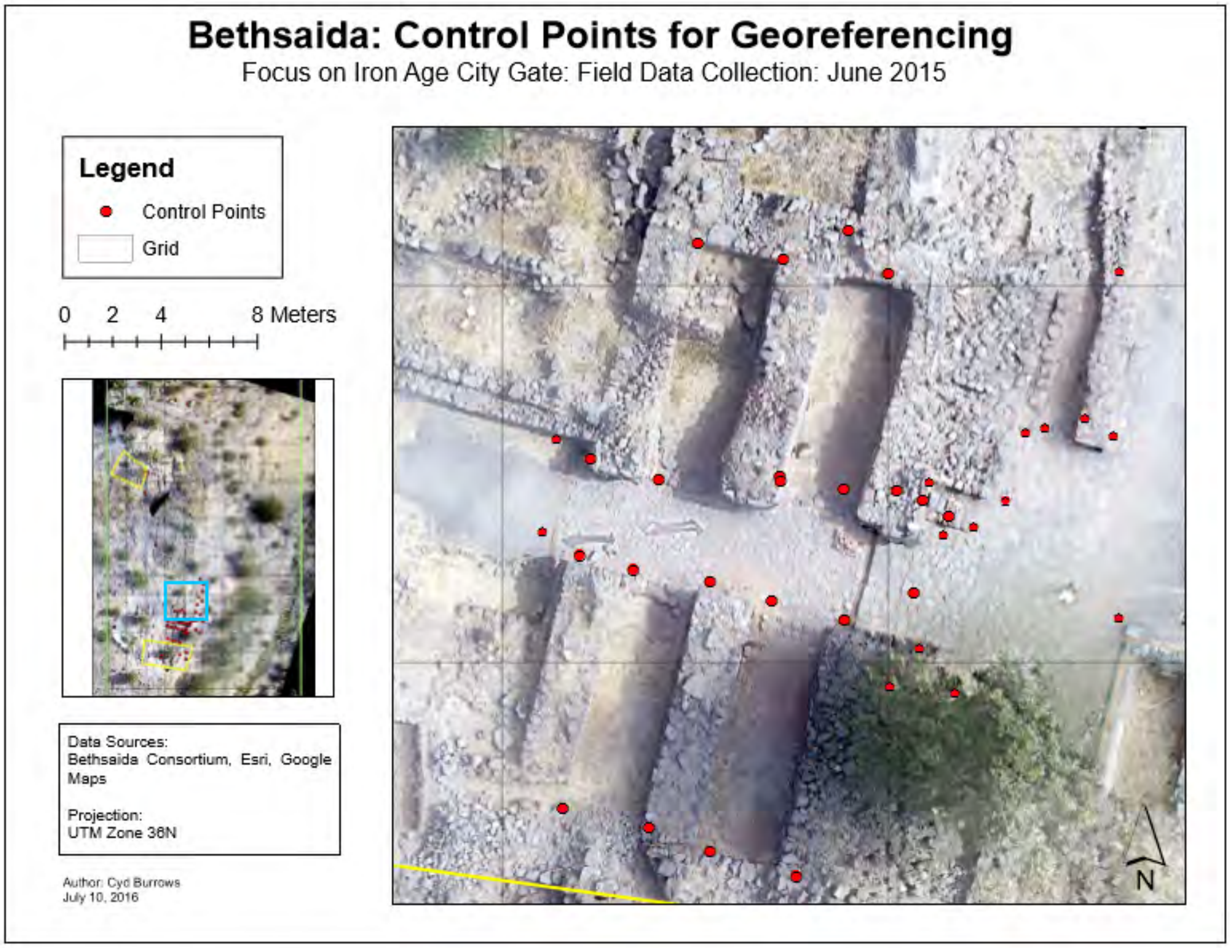


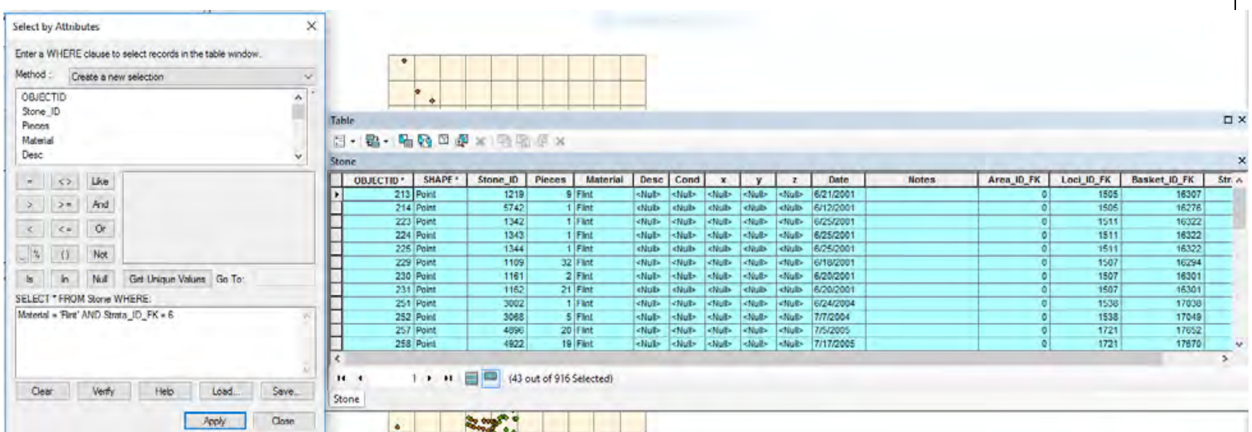
Figure 20. Close up of georeferencing points and resulting accuracy at city gate area. Inset blue rectangle depicts the area of focus. Note the scale.

4.3 Query Results

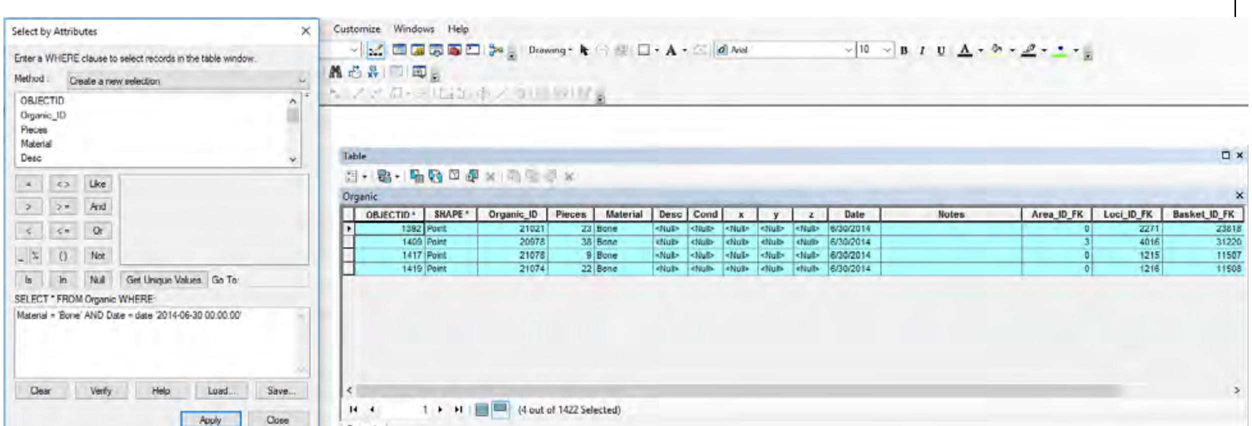
Chapter 3 outlined several queries that would be run to test the effectiveness and thoroughness of the geodatabase. These queries represent typical use case scenarios, questions similar to what might frequently be asked by, and of, the archaeologists. Using the Select by Attribute feature in ArcMap records meeting only designated criteria were easily sorted for mapping. Quick turnaround time on these types of inquiries has not been possible in the past. Tables 6 provides a look at the results of those queries.

Table 5. Query Results

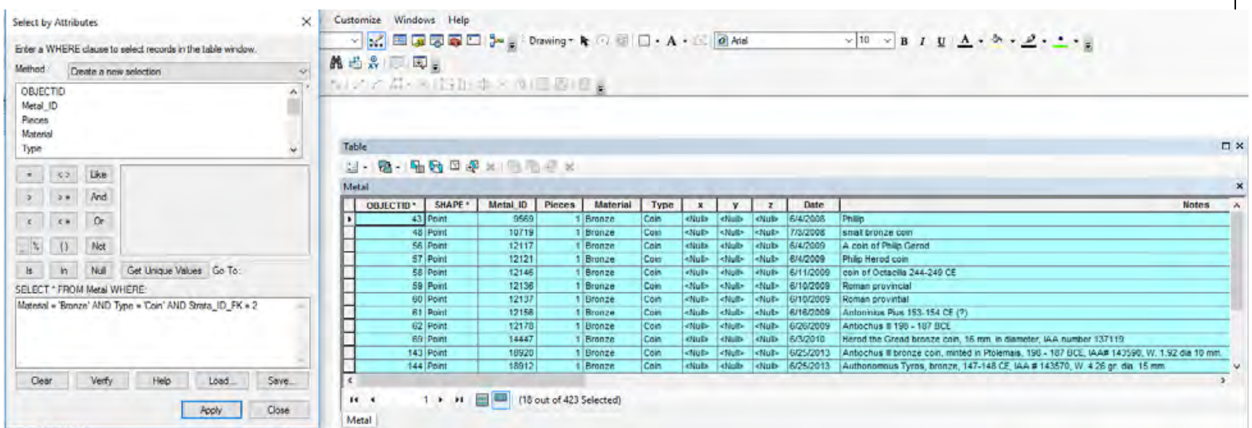
Query Results	
Query 1	Query the Stone attribute table
Goal	Find all of the Flint records in the Stone entity that were excavated from Strata 6 Query: Material = ‘Flint’ AND Strata_ID_FK = 6
Results	Returned 43 out of 916 records



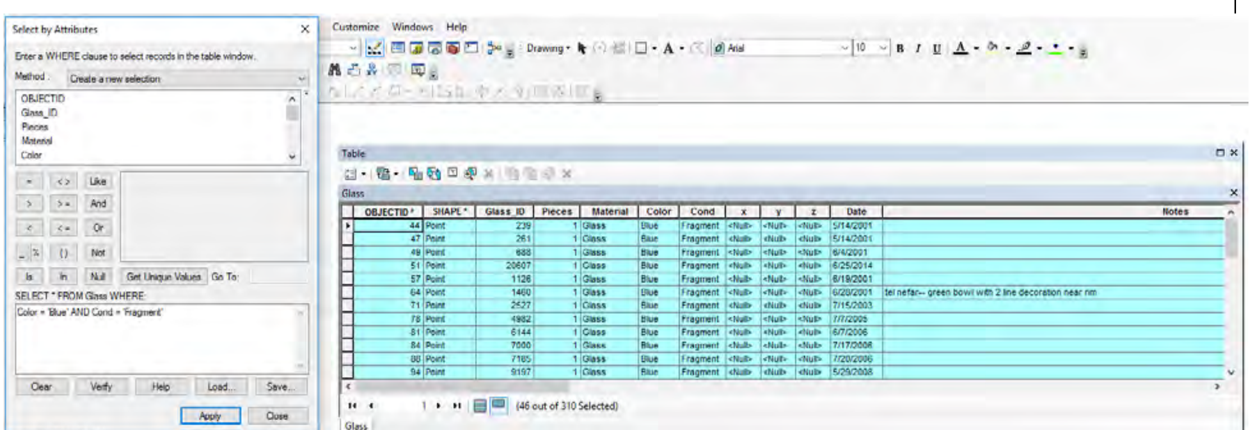
Query 2	Query the Organics attribute table
Goal	Find all of the Bone records in the Organic entity that were excavated on a specific date Query: Material = ‘Bone’ AND Date = date ‘2014-06-30 00:00:00’
Results	Returned 4 out of 1422 records



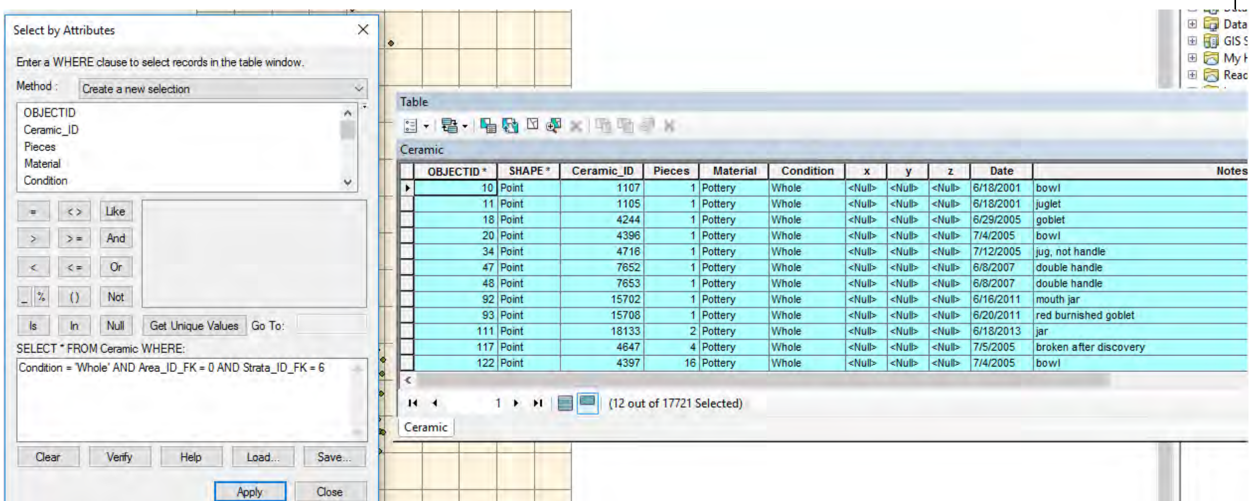
Query 3	Query the Metal attribute table
Goal	Find all of the Bronze records in the Metals entity that are classified as Coin and were excavated from Strata 2 Query: Material = ‘Bronze’ AND Type = ‘Coin’ AND Strata_ID_FK = 2
Results	Returned 18 out of 423 records



Query 4	Query the Glass attribute table
Goal	Find all of the Blue records in the Glass entity that are classified as Fragment Query: Color = ‘Blue’ AND Cond = ‘Fragment’
Results	Returned 46 out of 310 records

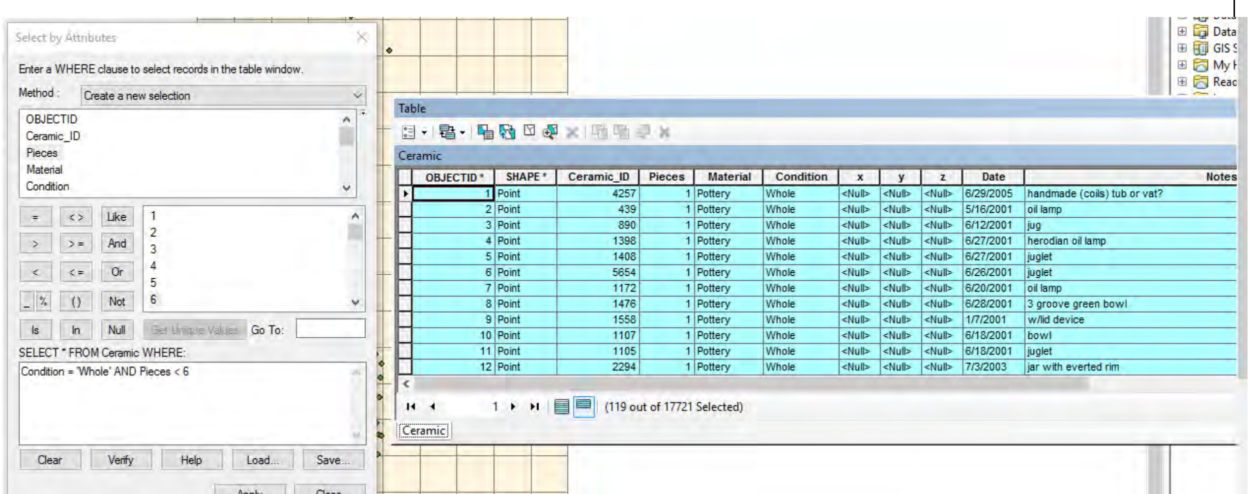


Query 5	Query the Ceramics attribute table
Goal	Find all of the pottery from the Ceramic entity that are classified as Whole and that were found in Area A and also were excavated from Strata 6 Query: Condition = ‘Whole’ AND Area _ID_FK = 0 AND Strata_ID_FK = 6
Results	Returned 12 out of 17721 records



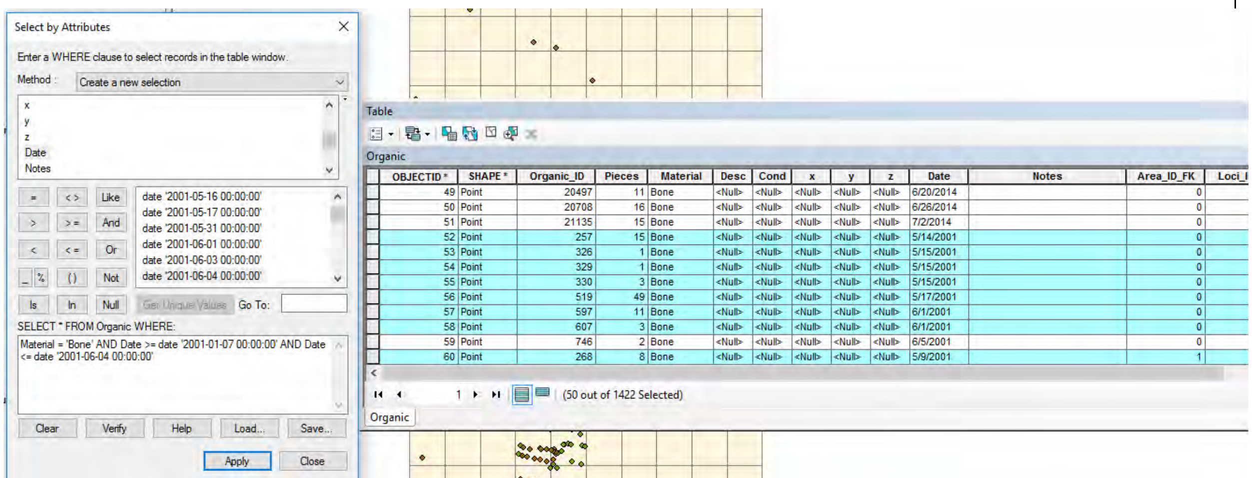
OBJECTID *	SHAPE *	Ceramic_ID	Pieces	Material	Condition	x	y	z	Date	Notes
10	Point	1107	1	Pottery	Whole	<Null>	<Null>	<Null>	6/18/2001	bowl
11	Point	1105	1	Pottery	Whole	<Null>	<Null>	<Null>	6/18/2001	juglet
18	Point	4244	1	Pottery	Whole	<Null>	<Null>	<Null>	6/29/2005	goblet
20	Point	4396	1	Pottery	Whole	<Null>	<Null>	<Null>	7/4/2005	bowl
34	Point	4716	1	Pottery	Whole	<Null>	<Null>	<Null>	7/12/2005	jug, not handle
47	Point	7652	1	Pottery	Whole	<Null>	<Null>	<Null>	6/8/2007	double handle
48	Point	7653	1	Pottery	Whole	<Null>	<Null>	<Null>	6/8/2007	double handle
92	Point	15702	1	Pottery	Whole	<Null>	<Null>	<Null>	6/16/2011	mouth jar
93	Point	15708	1	Pottery	Whole	<Null>	<Null>	<Null>	6/20/2011	red burnished goblet
111	Point	18133	2	Pottery	Whole	<Null>	<Null>	<Null>	6/18/2013	jar
117	Point	4647	4	Pottery	Whole	<Null>	<Null>	<Null>	7/5/2005	broken after discovery
122	Point	4397	16	Pottery	Whole	<Null>	<Null>	<Null>	7/4/2005	bowl

Query 6	Query the Ceramics attribute table
Goal	Find all of the pottery from the Ceramics entity that are classified as Whole and comprised of less than 6 pieces Query: Condition = ‘Whole’ AND Pieces <6
Results	Returned 119 out of 17721 records



OBJECTID *	SHAPE *	Ceramic_ID	Pieces	Material	Condition	x	y	z	Date	Notes
1	Point	4257	1	Pottery	Whole	<Null>	<Null>	<Null>	6/29/2005	handmade (coils) tub or vat?
2	Point	439	1	Pottery	Whole	<Null>	<Null>	<Null>	5/16/2001	oil lamp
3	Point	890	1	Pottery	Whole	<Null>	<Null>	<Null>	6/12/2001	jug
4	Point	1398	1	Pottery	Whole	<Null>	<Null>	<Null>	6/27/2001	herodian oil lamp
5	Point	1408	1	Pottery	Whole	<Null>	<Null>	<Null>	6/27/2001	juglet
6	Point	5654	1	Pottery	Whole	<Null>	<Null>	<Null>	6/26/2001	juglet
7	Point	1172	1	Pottery	Whole	<Null>	<Null>	<Null>	6/20/2001	oil lamp
8	Point	1476	1	Pottery	Whole	<Null>	<Null>	<Null>	6/28/2001	3 groove green bowl
9	Point	1558	1	Pottery	Whole	<Null>	<Null>	<Null>	1/7/2001	w/lid device
10	Point	1107	1	Pottery	Whole	<Null>	<Null>	<Null>	6/18/2001	bowl
11	Point	1105	1	Pottery	Whole	<Null>	<Null>	<Null>	6/18/2001	juglet
12	Point	2294	1	Pottery	Whole	<Null>	<Null>	<Null>	7/3/2003	jar with everted rim

Query 7	Query the Organic attribute table
Goal	Find all of the Bone in the Organic entity that was excavated within a specific range of dates Query: Material = ‘Bone’ AND Date >= date ‘2001-01-07 00:00:00’ AND Date <= date ‘2001-06-04 00:00:00’
Results	Returned 50 out of 1422 records



4.4 Visualizing the Data

The ability to target and combine elements in a query greatly improves the ability to visualize specific elements. The following maps demonstrate the data output as a visual representation.

One of the goals of this project was to be able to use the CAD drawings in a spatial context. Figure 20 provides an example of a CAD drawing that was imported and georeferenced using field data. The accuracy provides archaeologists with the ability to see the changes of the excavation areas over time. As each dig year passes, the active areas change considerably so this can provide a powerful means of reconstructing what has been removed from the ground in prior years.

Figure 21. CAD drawing overlay in ArcMap at 40% transparency - Area A (South). Note the accuracy in the alignment of the corners of the granary bins at the top of the map

The ability to geographically show artifact find locations, distributions and concentrations is another frequently needed function. In the following examples (Figures 21 through 24) various artifacts have been added to maps using differing criteria. Using ArcMap, an archaeologist can get a complete and detailed listing of these objects by opening the attribute table. Once again, the spatial data was added for purposes of this demonstration only. Artifacts do indeed belong to the areas in which they are shown, however, the exact spatial coordinates were unknown.

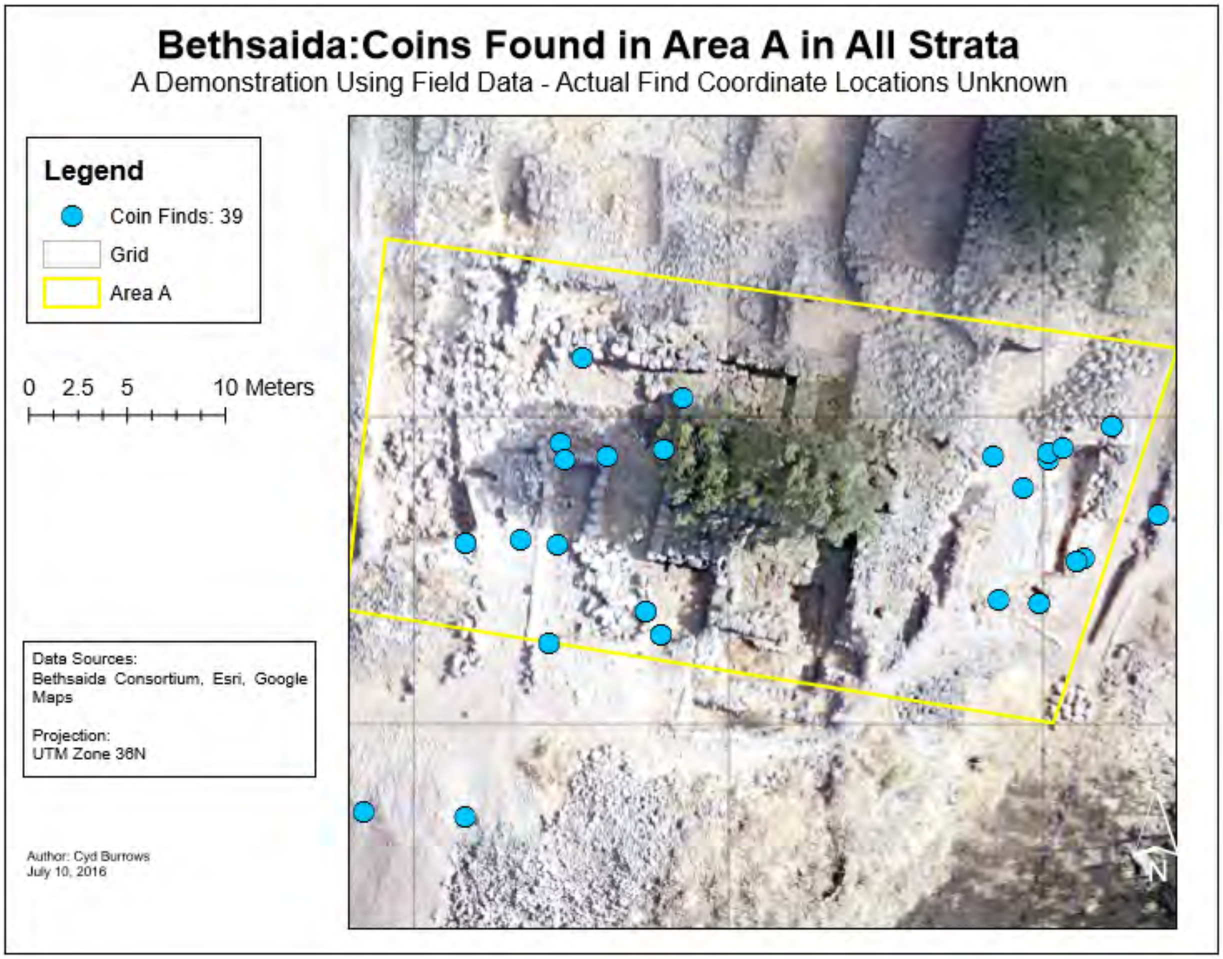


Figure 22. Example visualization of coin data

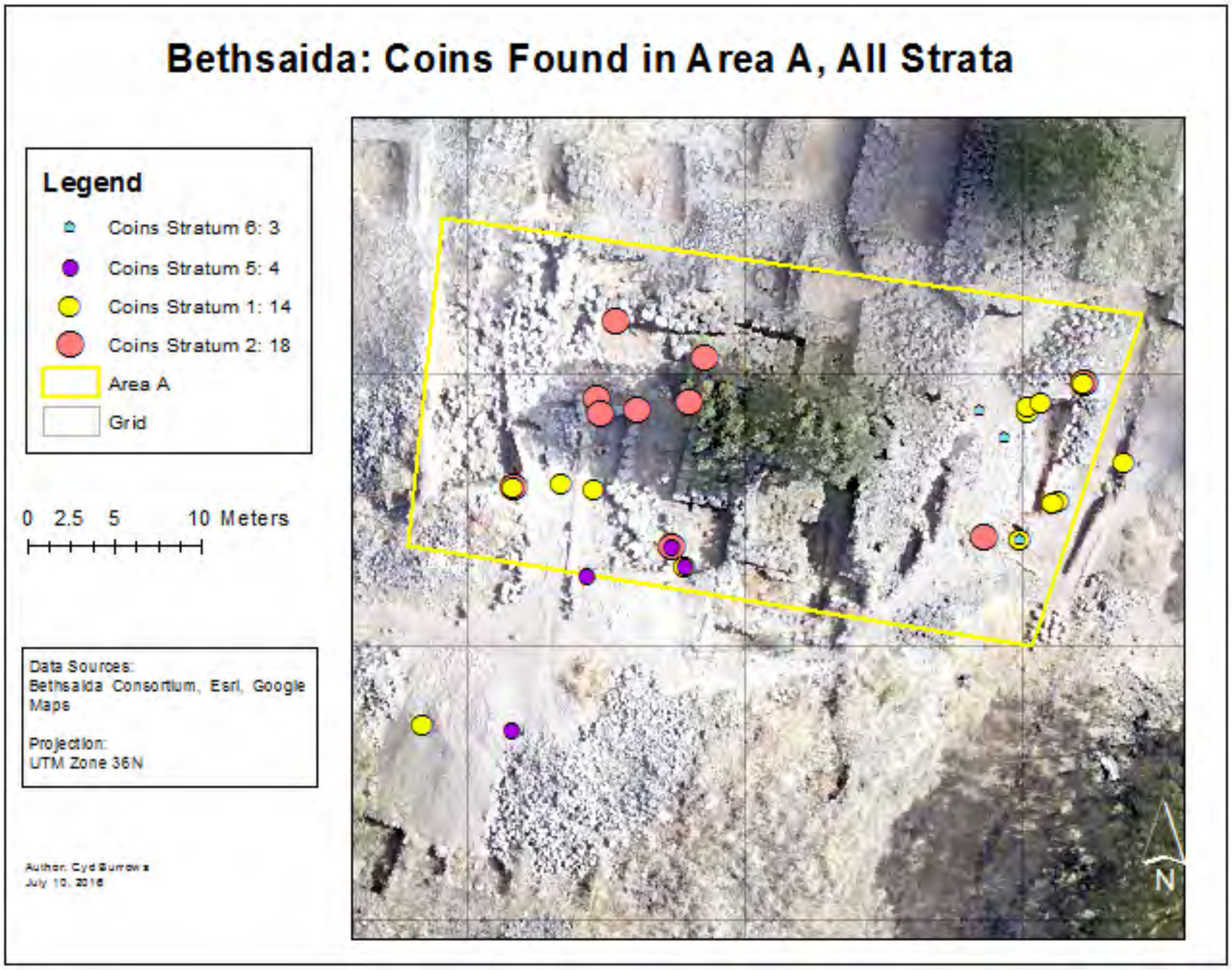


Figure 23. Variation of visualization of coin data

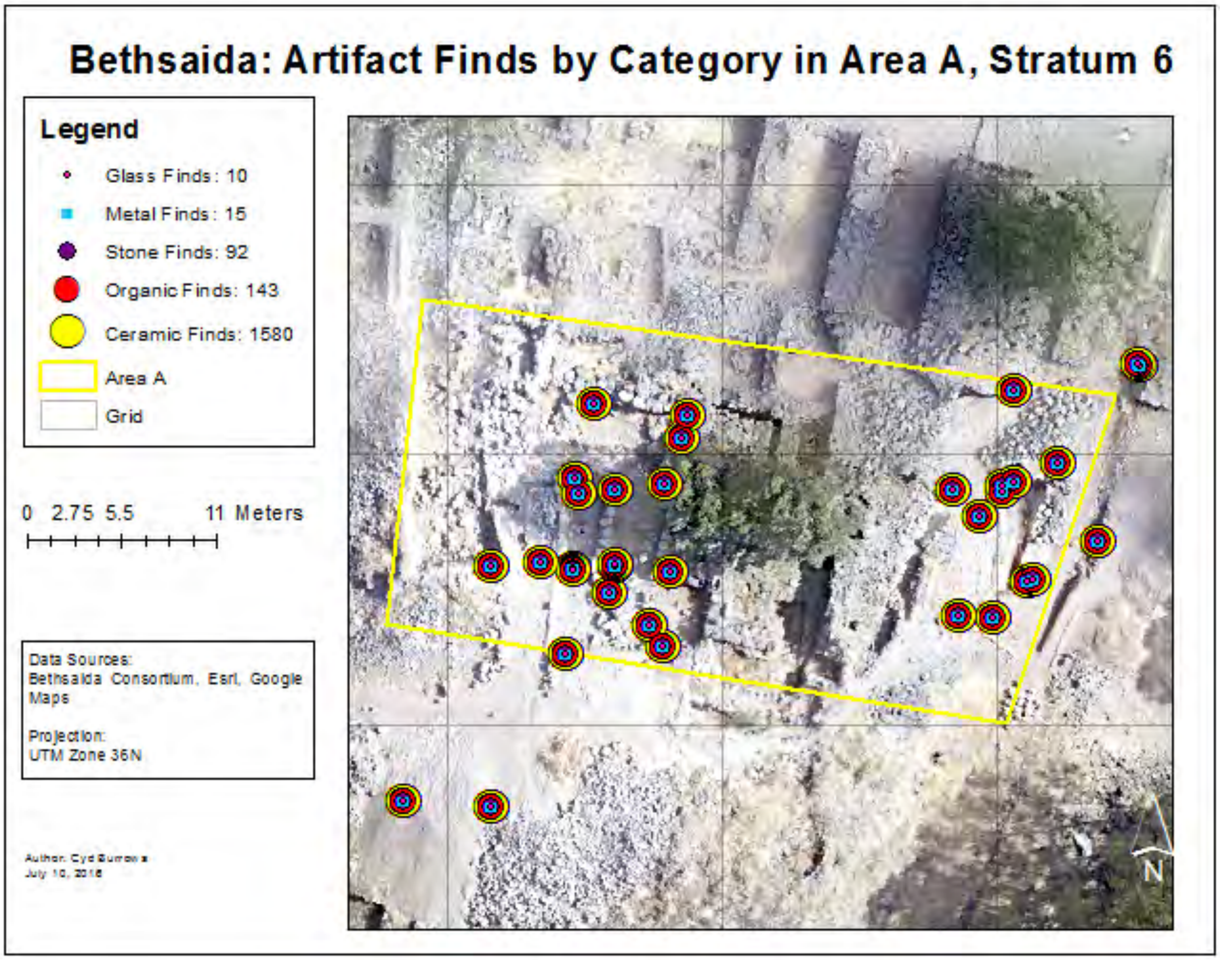


Figure 24. Example visualization of varying categories of finds in an area

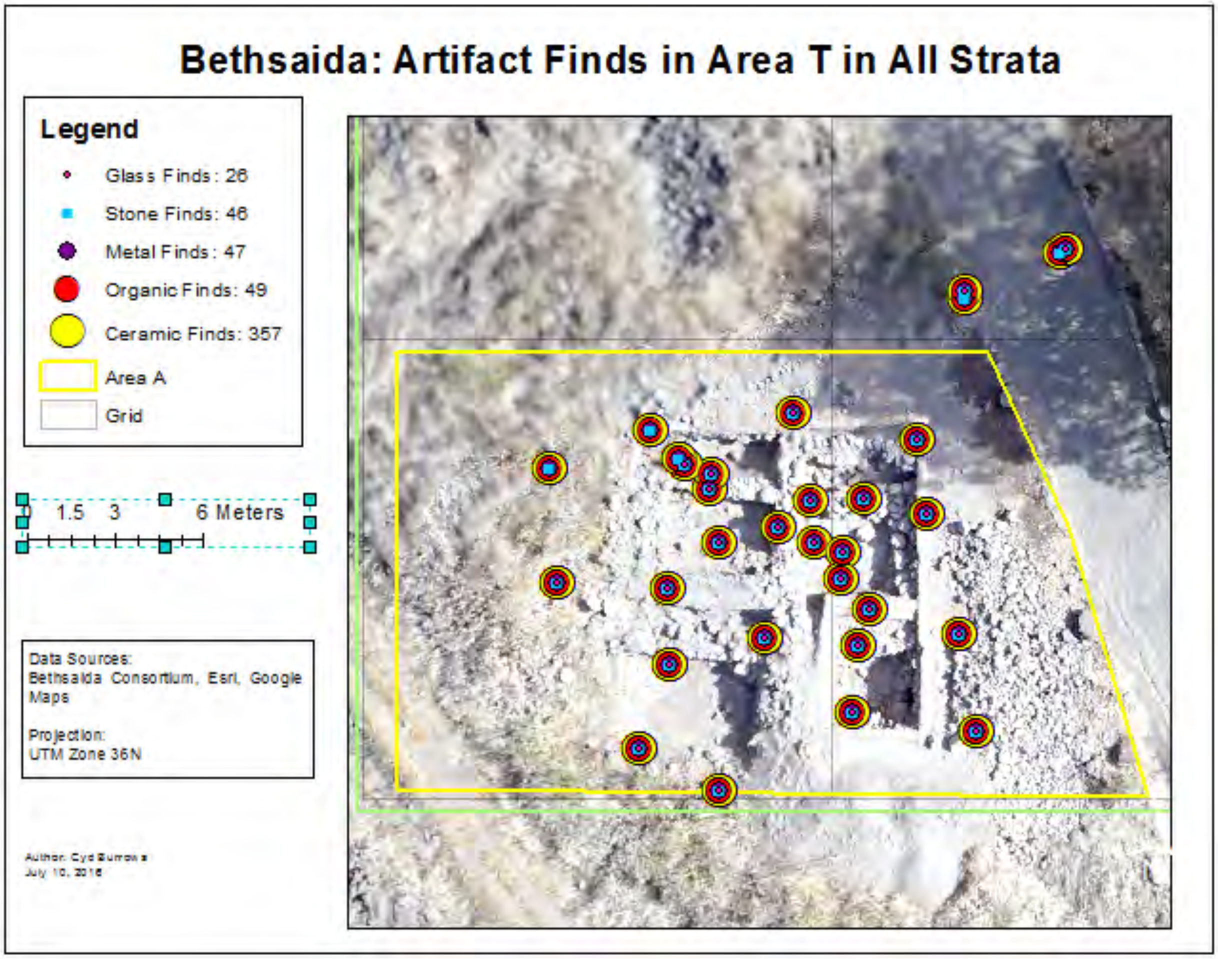


Figure 25. Example visualization of varying categories of finds in an area

4.5 Summary

The results described in this chapter confirm and demonstrate the completion of the project objectives including the conceptualization, design, creation, testing and implementation of a spatial database for specific use at the archaeological excavation in Bethsaida, Israel. Lessons learned and considerations for possible future work and development are discussed in Chapter 5.

Chapter 5: Conclusions

Final thoughts and discussion are presented in this chapter as are ideas for continued work and enhancement of this project. Section 5.1 reviews what went well and what did not, lessons learned. Section 5.2 covers plans for sharing the database with the Consortium and getting individuals trained on simple data entry techniques and how to run queries. Section 5.3 summarizes the importance of the investment in mobile field collection devices for accurate data gathering, and section 5.4 provides thoughts on future work and development.

5.1 Lessons Learned

The redesigned database resulted in a much simpler and more streamlined data flow. All entities have a purpose and the relationships are through the use of foreign keys and not separate entities as existed previously. The time invested on numerous ERD revisions seemed endless but proved to be well spent once the testing phase got under way and queries were returned smoothly and with a great deal of accuracy and complexity.

One of the greatest concerns initially was data acquisition, which admittedly, could have stopped the project in its tracks. It was known going into the final phase of the database construction that little, if any, communication with the Consortium would be possible as members would be out in the field during the months of May, June, and July. Fortunately, communication was started very early on, and all of the necessary requirements were obtained. The aerial imagery was especially helpful in bringing life to the subject area and creating a sense of the topography in the region.

Data preparation was another series of complex tasks that consumed a lot of time. Data from the MS Access database, when exported to Excel tables, required enormous amounts of manual cleanup. Many additional hours still need to be spent combing through the Finds and properly categorizing the records. Having more in-depth working knowledge of MS Excel would have been of great benefit. During the query testing phase, inconsistencies were noted such as some metal objects were classified as pottery, and bone as stone. Coin records did seem to have the necessary details included (although some were also discovered as improperly categorized), which is important as they are the only objects found in the archaeological record that contain dates (mint dates), helping to establish the historical time period of other objects nearby. Due to the rare nature of some of these finds (many are now in museums), it is extremely important to be able to show the exact extraction point location in order to validate surrounding finds. This will be a specific point for presentation to the Consortium and a justification for investing in handheld field collection devices going forward. It was noted that most other artifact records contained little or no description at all, making many records somewhat useless except to act as an item counted.

ArcPad software was new to the author, and the workflow into ArcMap was a bit of a challenge. Once the ArcPad files were properly associated with the various layers, the .mxd files rendered the captures as expected, which was extremely gratifying given that this process could not be tested in the field. It was noted during the data testing phase that GPS logging had not been enabled on the Trimble during collection. Thus no satellite data was recorded during the data gathering process, something to be aware of in the future when setting up the systems. See Appendix A for satellite coverage during hours of data collection for evidence that a minimum of 5 satellites were in place.

A much broader understanding of the excavation as a whole was achieved during the development of this project. The many components, various responsibilities, and workflows that have to be maintained both in the field and in the research process require skilled and experienced individuals with a keen attention to detail. Future seasons in the field will be seen from a different perspective and with a renewed appreciation for all of the mechanisms that work together.

5.2 Onboarding Consortium Archaeologists

It is anticipated that Consortium archaeologists will be introduced to the new spatial database in November 2016, when they gather for a common conference. Due to the fact that many live in remote locations, it may be possible to set up a webinar style overview sooner. If possible, meetings will be set to work with individual(s) that are local to the San Diego area prior to November, where they will be shown the process from start to finish. A basic tutorial can be screen captured, recorded, and distributed via YouTube or web link. The likelihood that grad students and other volunteers will be doing much of the data input is high, and therefore a short recording highlighting the importance of steps in the workflow could be very useful. The author will continue to be involved with maintenance for the immediate future until server based access is achieved.

5.3 Recommendations for Field Collection

One of the most significant outcomes of this project is the justification for handheld field collection devices. The demonstrations in Chapter 4 reveal the power of spatial placement in the archaeological record using test data, but to have extraction points that are nearly exact would emphasize concentrations and distribution of artifacts visually, creating complete scenes within specific time periods. The data can then be further queried to show only artifacts that were gathered during a particular dig season, or to reveal all artifacts belonging to a specific historical time period. Furthermore, the added feature of the Coded Value Domains ensures that entries are properly and consistently catalogued for ontological and semantical accuracy.

The Trimble GeoXH 3000 that was used for this project was an affordable piece of equipment (purchased for $1500 USD in 2015) and easy to travel with and configure. This device is extremely rugged and durable, has a long battery life and submeter accuracy which could be further improved with the adoption of a range finder antenna. Rotating new field roles for volunteers who gather data could be established and would allow students as well as archaeologists to become experienced in the process. It is recommended that one device is dedicated to each active area for the duration of the season annually.

Field collection also easily captures and exploits the value of the z-coordinate, which could replace, or be used in addition to, the strata categorization technique that is currently in use. The Trimble is also capable of capturing a photograph as a part of each point, line, or polygon, creating an all-inclusive and well-documented object in just a moment’s time.

One of the greatest impacts introduced by the use of the mobile field collection devices is the accuracy to be gained in the description process. The Coded Value domains that are programmed into the database allow users a list of choices rather than open ended entry in blank fields. The potential for increased consistency in data reporting is worth the investment all on its own.

5.4 Future Development

Currently the application is a desktop application, but collaborative research would be greatly enhanced via a ArcMap installation on a shared server. This project could then be accessed by all individuals that are participants of the research team, and could allow data entry year round. This will be a recommendation that will be passed on to the Consortium members for consideration.

A web application for sharing the Bethsaida excavation data with academics and archaeology enthusiasts worldwide would serve the purpose of promoting the excavation to volunteer workers and as a platform for gaining support for continued work at the site. The Bethsaida web site (on the University of Nebraska, Omaha site) might be able to draw larger audiences and increase interest through the inclusion of a web map browser-based and accompanying mobile app highlighting the artifacts.

There are numerous historical CAD drawings that could be digitized, georeferenced, and added to a catalog in ArcMap. This may be a project for future graduate students and could also be done year round.

Each of the legacy Finds records has an associated photograph, which could be added to the record and called up in ArcMap. This would be an arduous process, but could again be an ongoing part of work completed by graduate students or volunteers interested in learning more about the objects that have been excavated from this site.

The very nature of this project suggests that continued improvements will be suggested as it is put to use. It is hoped that other students of GIS who volunteer at this excavation will show interest in contributing to the continued development and expansion of this project.

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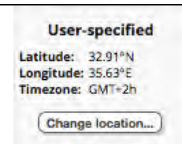
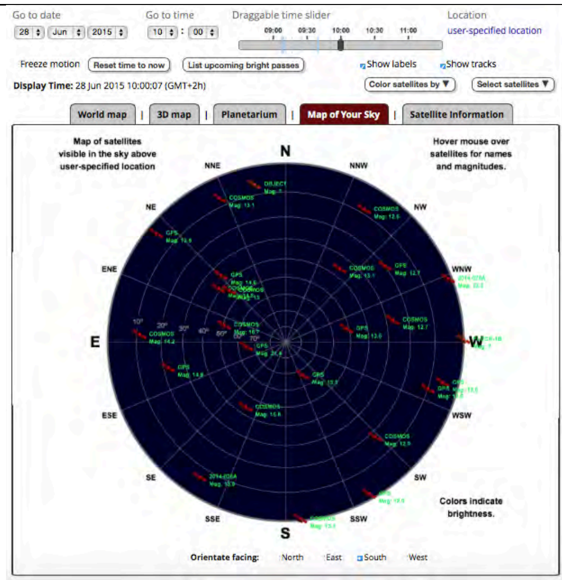
Appendix A: Satellite Coverage in the Field

Satellite Coverage for Field Collection Dates

Data retrieved from the web site InTheSky.org: https://in-the-sky.org/index.php

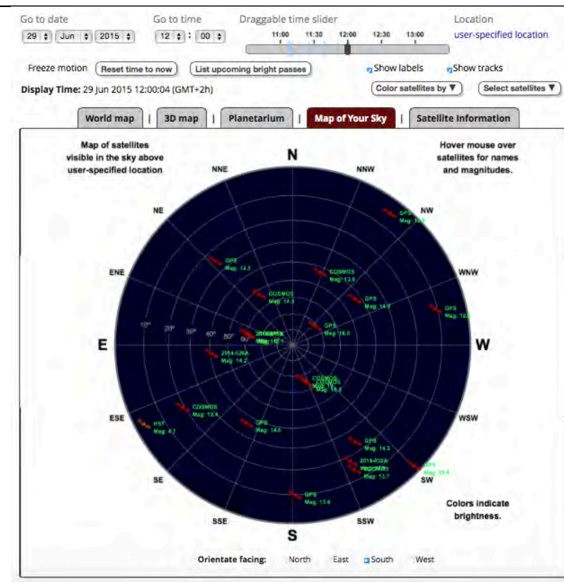




June 28, 2015 – 10:00am

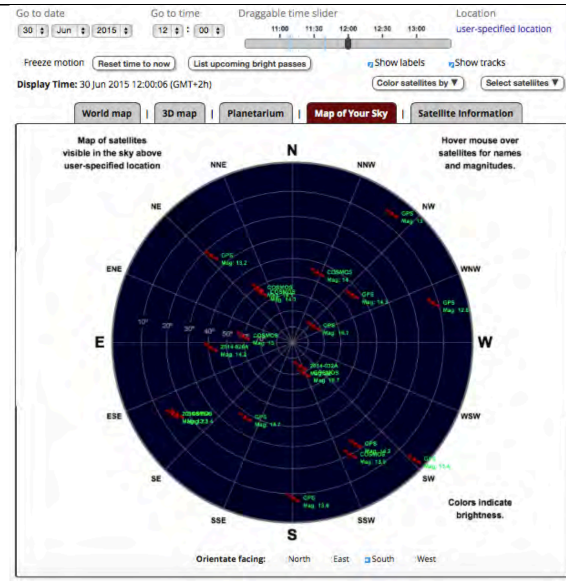
June 28, 2015 – 12:00pm

June 29, 2015 – 10:00am

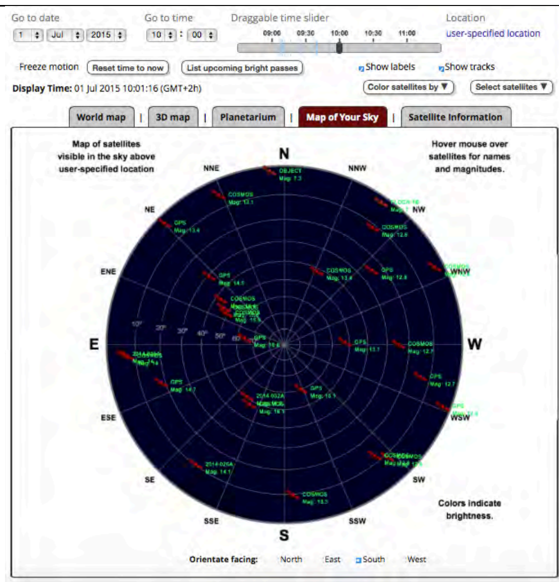


June 29, 2015 – 12:00pm

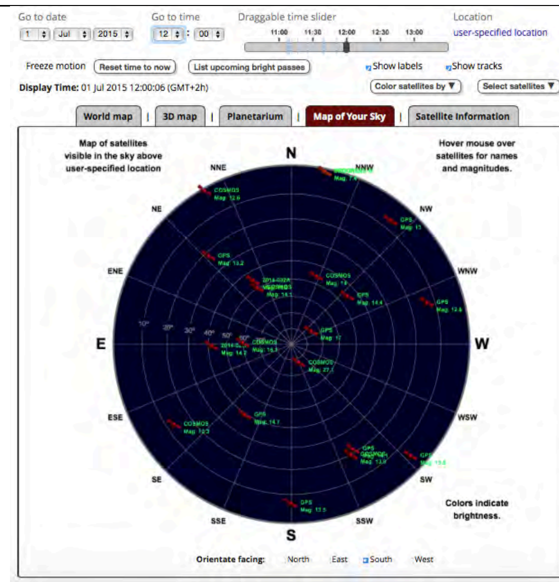
June 30, 2015 – 10:00am



June 30, 2015 – 12:00pm



July 1, 2015 – 10:00am



July 1, 2015 – 12:00pm

Appendix B: Geodatabase Tables

Table 6. Topology

Topology		
Entity	Rule	Description
Grid_Cell	Must not overlap	Grid cells must not overlap

Table 7. Relationship Classes

Relationship Classes			
Entity/Attribute	Entity/Attribute	Relationship	Comments
Site_ID	Area_ID	One-to-many	One Site contains many Areas
Site_ID	Strata_ID	One-to-many	One Site contains many Strata
Area_ID	Loci_ID	One-to-many	One Area may contain many Loci
Loci_ID	Basket_ID	One-to-many	One Loci may contain many Baskets

Table 8. Domains

Domains				
Entity	Domain Name	Domain Type	Domain Values	Description
Ceramic/Glass	Condition	Coded Value	Whole Fragment Scatter	Condition of artifact found
Glass	Color	Coded Value	Clear Green Blue Yellow Red Other	Color of glass found
Metal	Material	Coded Value	Copper Bronze Silver Gold Iron Lead	Type of metal found

Domains				
Entity	Domain Name	Domain Type	Domain Values	Description
Metal	Type	Coded Value	Coin Jewelry Tool Other	Object's intended use
Stone	Material	Coded Value	Basalt Flint Limestone Stone	Type of stone found
Strata	Strata_No	Coded Values	1, 2, 3, 4, 5, 6, 7, 8	Sediment layer representing a distinct period of time
Area	Area_Name	Coded Values	0, 1, 2, 3, 4, 5	Active dig areas

Table 9. Site Entity

Site - Polygon					
Field Name	Description	Data Type	Null Values	Unique	Keys
Site_ID	Site ID	Text	NotNull	Unique	Primary
Site_Name	Site Name	Text	NotNull		
Latitude	Latitude	Long Int.	Null		
Longitude	Longitude	Long Int.	Null		
Notes	Notes	Text	Null		

Table 10. Grid Cell Entity

Grid Cell - Polygon					
Field Name	Description	Data Type	Null Values	Unique	Keys
Grid_Cell_ID	Grid Cell ID	Text	NotNull	Unique	Primary
Grid_Cell_No	Grid Cell Number	Short Int.	NotNull		
Notes	Notes	Text	Null		

Table 11. Area Entity

Area - Polygon					
Field Name	Description	Data Type	Null Values	Unique	Keys
Area_ID	Area ID	Text	NotNull	Unique	Primary
Area_Name	Area Name	Text	NotNull		
Length	Length in Meters	Short Int.	Null		
Width	Width in Meters	Short Int.	Null		
Opened	Date Opened	Date	Null		
Notes	Notes	Text	Null		

Table 12. Loci Entity

Loci - Table					
Field Name	Description	Data Type	Null Values	Unique	Keys
Loci_ID	Loci ID	Text	NotNull	Unique	Primary
Loci_No	Loci Number	Text	NotNull		
Length	Length in Meters	Short Int.	Null		
Width	Width in Meters	Short Int.	Null		
Opened	Date Opened	Date	Null		
Stratum	Stratum No.	Short Int.	Null		
Level	Elevation Reading	Short Int.	Null		
Notes	Notes	Text	Null		
Area_ID_FK	Area ID	Text	NotNull		Foreign

Table 13. Basket Entity

Basket - Table					
Field Name	Description	Data Type	Null Values	Unique	Keys
Basket_ID	Basket ID	Text	NotNull	Unique	Primary
Basket_No	Basket Number	Text	NotNull		
Date	Date Collected	Date	Null		
Notes	Notes	Text	Null		
Loci_ID_FK	Loci ID	Text	NotNull		Foreign
Area_ID_FK	Area ID	Text	NotNull		Foreign

Table 14. Strata Entity

Strata - Table					
Field Name	Description	Data Type	Null Values	Unique	Keys
Strata_ID	Strata ID	Text	NotNull	Unique	Primary
Strata_No	Strata Number	Text	NotNull		
Description	Description	Text	Null		
Notes	Notes	Text	Null		

Table 15. Ceramic Entity

Ceramic – Point/Multipoint Feature Class					
Field Name	Description	Data Type	Null Values	Unique	Keys
Ceramic_ID	Ceramic ID	Text	NotNull	Unique	Primary
Cond	Condition	Coded Value	Null		
Pieces	No. Pieces Found	Text	NotNull		
x	X coordinate	Long Int.	Null		
y	Y Coordinate	Long Int.	Null		
z	Z Coordinate	Long Int.	Null		
Date	Date Found	Date	Null		
Notes	Notes	Text	Null		
Area_ID_FK	Area ID	Text	Null		
Loci_ID_FK	Loci ID	Text	Null		
Basket_ID_FK	Basket ID	Text	Null		
Strata_ID_FK	Strata ID	Text	Null		

Table 16. Glass Entity

Glass – Point/Multipoint Feature Class					
Field Name	Description	Data Type	Null Values	Unique	Keys
Glass_ID	Glass ID	Text	NotNull	Unique	Primary
Pieces	No. Pieces Found	Text	NotNull		
Material	Material	Text	Null		
Color	Color	Coded Value	Null		

Glass – Point/Multipoint Feature Class					
Field Name	Description	Data Type	Null Values	Unique	Keys
Cond	Condition	Coded Value	Null		
x	X coordinate	Long Int.	Null		
y	Y Coordinate	Long Int.	Null		
z	Z Coordinate	Long Int.	Null		
Date	Date Found	Date	Null		
Notes	Notes	Text	Null		
Area_ID_FK	Area ID	Text	Null		
Loci_ID_FK	Loci ID	Text	Null		
Basket_ID_FK	Basket ID	Text	Null		
Strata_ID_FK	Strata ID	Text	Null		

Table 17. Metal Entity

Metal – Point/Multipoint Feature Class					
Field Name	Description	Data Type	Null Values	Unique	Keys
Metal_ID	Metal ID	Text	NotNull	Unique	Primary
Material	Material	Coded Value	NotNull		
Type	Type	Coded Value	Null		
x	X coordinate	Long Int.	Null		
y	Y Coordinate	Long Int.	Null		
z	Z Coordinate	Long Int.	Null		
Date	Date Found	Date	Null		
Notes	Notes	Text	Null		
Area_ID_FK	Area ID	Text	Null		
Loci_ID_FK	Loci ID	Text	Null		
Basket_ID_FK	Basket ID	Text	Null		
Strata_ID_FK	Strata ID	Text	Null		

Table 18. Organic Entity

Organic – Point/Multipoint Feature Class					
Field Name	Description	Data Type	Null Values	Unique	Keys
Organic_ID	Organic ID	Text	NotNull	Unique	Primary
Desc	Description	Text	Null		
Cond	Condition	Text	Null		
x	X coordinate	Long Int.	Null		
y	Y Coordinate	Long Int.	Null		
z	Z Coordinate	Long Int.	Null		
Date	Date Found	Date	Null		
Notes	Notes	Text	Null		
Area_ID_FK	Area ID	Text	Null		
Loci_ID_FK	Loci ID	Text	Null		
Basket_ID_FK	Basket ID	Text	Null		
Strata_ID_FK	Strata ID	Text	Null		

Table 19. Stone Entity

Stone – Point/Multipoint Feature Class					
Field Name	Description	Data Type	Null Values	Unique	Keys
Stone_ID	Stone ID	Text	NotNull	Unique	Primary
Pieces	No. Pieces Found	Text	NotNull		
Material	Material	Coded Value	Null		
Desc	Description	Text	Null		
Cond	Condition	Text	Null		
x	X coordinate	Long Int.	Null		
y	Y Coordinate	Long Int.	Null		
z	Z Coordinate	Long Int.	Null		
Date	Date Found	Date	Null		
Notes	Notes	Text	Null		
Area_ID_FK	Area ID	Text	Null		
Loci_ID_FK	Loci ID	Text	Null		
Basket_ID_FK	Basket ID	Text	Null		
Strata_ID_FK	Strata ID	Text	Null		