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An Intra-Site Spatial Analysis of Fort St. Joseph (20BE23) in Niles, MI

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AN INTRA-SITE SPATIAL ANALYSIS OF FORT ST. JOSEPH (20BE23) IN NILES, MI

by

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In the field of archaeology, surveying and mapping have played key roles in documenting and analyzing site data. With the advancements in Geographic Information Systems (GIS), this integration of spatial data is made easier and better visualization can be attained for site layout and artifact distributions both horizontally, in space, and also vertically through a temporal component. The ongoing excavations at Fort St. Joseph (Smithsonian trinomial - 20BE23), near Niles, Michigan, makes it an excellent site for exploring the evolution of applied GIS methodology and the adjustment of among ongoing static database applications to new spatial methods of investigating site distributions. The fort was occupied from 1691 until 1781, over which time it was a mission, military garrison, and trading post. Excavations have taken place annually since 2002 with a hiatus in 2003, 2005, and 2014, providing 11 years of data for analysis. The purpose of this project is to use GIS to assess the ways in which the dynamic nature of long term archaeological digs, with data being added annually, changes the understanding of spatial and temporal patterns over time. Analysis will include measures of artifact densities, and relationships among spatial patterning of artifact classes, as well as predictions and interpretations of these densities and distributions. An additional outcome of this project will be an active and updatable, documented geodatabase that links artifact and site data with a geographic location, useable by those involved with research in the Fort St. Joseph Archaeological Project.

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TABLE OF CONTENTS

TABLE OF CONTENTS—Continued

LIST OF TABLES

LIST OF FIGURES

List of Figures—Continued

List of Figures—Continued

CHAPTER I
INTRODUCTION

Spatial technologies have become integral to how researchers collect, store, analyze, and visualize data. Even since the earliest methodological innovations, such as grid based excavations supported by aerial photography, thinking spatially has enhanced the ability to locate and preserve archaeological sites and preserve the large amounts of information necessary to interpret them. In recent years spatial technologies such as Geographic Information Systems (GIS), Global Positioning Systems (GPS), ground-based laser mapping, remote sensing, LiDAR, and geophysical survey have become common tools in archaeology. Many of these techniques provide a step away from the strict conformation of methods, but allow for a more exploratory approach to generate new insights and hypotheses. These methods also create new pathways for sharing and visualizing data, among individuals associated with a single project, but also enabling those farther afield to provide analysis and input. Spatial technology has become an indispensable tool for analysis in archaeology.

The ongoing archaeological excavation of Fort St. Joseph (FSJ) (20BE23) is located near Niles, Michigan. This site has been actively excavated on an annual basis since 2002, resulting in 11 years of systematic data collection (Nassaney et al. 2003). Mapping the activities of an excavated archeological site is the key to proper documentation and analysis of the site and accurate interpretation of found artifacts. The application of GIS to the sum of accumulated data at Fort St. Joseph will allow a more comprehensive view of the current extent of the site and the distribution of artifacts. Since Fort St. Joseph is an active and continuously excavated site, it is an excellent site to explore different methodologies that incorporate GIS, and use GIS for the interpretation of new data.

This study will include the development of visualization techniques for presenting artifact frequency and interpretation of spatial density among classes of artifacts. This project's purpose is to analyze how the perspective of the site can be altered, enhanced or refined with the support of GIS through the analysis of spatial deposition of artifacts and the patterns identified during excavations. Through comparison with previous outcomes and the utilization of new methodology, methods similar to Dimensional Analysis of Variance (DAV) can be employed as a logical method for grid-based spatial analysis in archaeology. All information obtained from this thesis will have the ability to be updated and available to all persons involved in the Fort St. Joseph Archaeological Project through a documented geodatabase.

Through this research, the following questions will be addressed:

1. Do perceptions of artifact distributions change with an increase of data?
2. Do different methodological approaches result in different quantifications of the spatial patterning of distributions? Are these methods suitable for spatial analysis in archaeology?
3. Can GIS- aided spatial analysis be used to interpret patterns of behaviors and spatial organization within an archaeological site?
4. How do results of this analysis compare to previous work at the FSJ site?

Spatial Analysis in Archaeology

Spatial analysis plays an important role in archaeology. It is based on the idea that location and relationship between artifacts and objects are a reflection of past activities, which assumes they have remained undisturbed or their redistribution can be accounted for (Anderson 2003). The evidence provided by this type of analysis offers insight into the behaviors of inhabitants over time and the organization of space in a historical context. However, archaeological sites are rarely found undisturbed and relationships and significance of patterns can be difficult to distinguish.

Analysis of spatial patterns in archaeology must make two main considerations. First, the spatial structure of the site deposit must be taken into account. Within this structure, it is necessary to establish whether or not the artifacts are clustered or evenly distributed. Once this is determined, clustering can be more closely evaluated to provide information about site disturbance and organization. Historic sites, such as Fort St. Joseph, tend to have a more formal layout and organization than many prehistoric sites. However, there is a lack of specific details of the layout of the Fort site in historic documents. Natural and human processes, since deposition, can have major effects on the distribution and characteristics of a site. Due to this, these processes should be identified and considered in the final interpretation of any spatial analysis related to archaeological research.

Geographic Information Systems in Archaeology

Geographic information science provides a method to further investigate the spatial and temporal distributions of artifacts and features at Fort St. Joseph. GIS is a database management tool that allows for the digital storage, manipulation, visualization, and integration of a wide variety of spatially referenced data. It is a branch of a larger set of technologies called Spatial Information Systems (Howard 2006). GIS is a quickly developing tool in archaeology, as well as other fields. Archaeological research focuses on space and time to record the past. GIS has influenced and changed how researchers record and measure these two dimensions by improving the methods available to analyze and interpret them. Mapping and statistical analysis once requiring many months if done by hand, can now be done in a matter of minutes (Chapman 2006). This offers researchers greater possibilities to address questions through the plethora of data collected through systematic archaeological survey.

The merging of GIS and archaeology makes sense. Archaeological excavations occur in a three-dimensional space and consist of horizontal stratigraphic units divided into levels. Traditionally, these levels are represented by a two-dimensional top plan, which due to the two-dimension nature of GIS is easily translatable. Each stratigraphic or temporal layer can be represented by its own digital data layer (Williamson and Nickens 2000). When looking at a single site, each excavation unit is used as a unit of analysis and the features and artifacts it contains are the subject of analysis. An exact 3D coordinate of each artifact is preferred for point-based analysis, however a grid-based analysis is common for sites with less precise artifact provenience. Aggregate artifact counts can be represented through vector data models after being separated into classes. Layers can then be superimposed for better analysis (Moyes 2002). For this project, distribution and spatial patterning of objects throughout the site is a primary goal and the quantitative analysis needed is a function of ESRI ArcGIS. An in-depth examination of the GIS methods that will be used to complete this project will be discussed in a later section. It is important to note that GIS allows for spatial relationships to be treated as any other variable when traditionally non-spatial techniques are implemented. It can also be used to increase the ease and effectiveness of spatial statistical techniques developed before computer-based GIS software was widely available.

Thesis Organization

The thesis will begin with a discussion of how spatial analysis has developed within the field of archaeology. This is followed by a brief discussion of spatial analytical methods and their potential utility for this research. It will also examine spatial studies and the role of Geographic Information Systems for use in archaeological applications. This will include a detailed introduction to GIS, including its strengths and weaknesses in archaeology. Analysis is supported dimensionally, with its graphic capabilities being combined with quantitative methods to aid in spatial interpretations.

Chapter three provides an introduction to the dataset. The Fort St. Joseph site (Niles, Michigan) is described, outlining the site's characteristics and its importance in the Great Lakes region and to the history and development of the French fur trade. This will be followed by an introduction to the methodological framework for this thesis. The focus will be on the development of the database and the methods employed for spatial analysis and statistical evaluation of the data. The final results of these methods and initial interpretation will be presented in chapter four.

Chapter five will provide a more detailed interpretation of the results identified in chapter six. This will include the evaluation of spatial patterns and any statistical significant clustering identified in the horizontal artifact distributions. These interpretations will then be discussed in relation to historic archaeology and the differential use of space at Fort St. Joseph. The last portion of this chapter concludes the thesis with an evaluation of the methods used and their suitability for spatial analysis in archaeology. Potential limitations of this research, as well as recommendations for improvement of future spatial studies in archaeology at FSJ are discussed.

CHAPTER II
LITERATURE REVIEW

Spatial Analysis in Archaeology

The use of spatial analysis in archaeology can provide valuable data about the regional setting and local relationships between any given space and the everyday life of those who occupied it. Spatial analysis considers the impact of everyday activates at a variety of scales. It identifies and creates a blueprint for patterns of use through the analysis of the distribution of archaeological materials. The activities that create these distributions are defined by certain factors, including the socio-economic conditions of the occupants, length and intensity of occupation, and the relationship of everyday tasks to the subsistence system (Anderson 2003). Since this information provides vital evidence about the behavior of past occupant groups of a site, spatial analysis is a very important part of archaeological studies.

The purpose of this review is to assess the methods available and how they have been used in previous studies. Spatial analysis is not new to the field of archaeology. However, the many possible methods and applications of spatial analysis have recently increased and each has its possibilities and limitations. Each site and time period has its own characteristics and distribution of artifacts and therefore requires a unique methodology (Wheatley 2004). It is not uncommon in spatial analysis for data to be forced to conform to a certain method, losing much of its valuable information (Zubrow 1990). In this chapter I will review potential spatial analysis tools and possible methods available for the field of archaeology. The focus of this project, based on the goals and available data is the analysis of the spatial distribution of artifacts at Fort St. Joseph, in Niles, MI.

What is Spatial Analysis in Archaeology?

Spatial analysis is the use of certain statistical techniques to analyze and describe spatial distribution of archaeological material over the landscape over time or within a single site. The value of spatial information is represented through the use of detailed plans and maps, as well as the careful recording of feature and artifact locations (Allen et al. 1990; Johnson 1984; Kintigh 1990). After analyzing the spatial patterns associated with artifacts, an archaeologist can interpret the behaviors and activities of the people inhabiting a site. This information can affect the portrayal and understanding of the occupants of any given space (Clark 1977; Green 1990).

At first, the use of spatial analysis in archaeology was focused on global (in the statistical sense) analysis methods such as nearest neighbor analysis (Whallon 1973), dimensional analysis of variance (Whallon 1974), and variance/mean ratios (Dacey, 1973). As the use of quantitative analysis advanced, scalable methods were developed. These include factor analysis (Cowgill, 1968), isopleth mapping (Banning 2002), local density analysis (Graham, 1980), Fisher's exact test (Spurling and Hayden 1984), Fourier methods (Carr 1987), and k-means cluster analysis (Kintigh and Ammerman 1982). Of these, isopleth mapping, variance-to-mean ratio, and dimensional analysis of variance are relevant to this study. These three methods are grid-based and have the most potential for applications consistent with the goals of this research. Contemporary studies have also focused on the consideration of site formation processes, such as geological influences, post-deposition human influences, and post-hoc animal disruption of sites (Kintigh 1990; Rigaud and Simek 1991). Some researchers have also used ethnographic studies to investigate spatial patterning and the activities that form those patterns (Moyes 2008).

Before the quantitative revolution, researchers relied only on visual identification and interpretation of spatial patterns. During the excavation process, stratigraphic layers are often easily defined, but also are often not the same throughout a site due to variable topography or due to the subjective interpretation of the excavator (Kintigh and Ammerman 1982; Wobst 2006). Visual interpretation of the layers can be affected in numerous ways. This includes the location and intensity of light, which effects how layers of the profile are recorded. This can cause limitations and challenges with representing the data accurately. If the stratigraphy is complex or hard to define, a profile should be considered as only an interpretation and not definitive of the entire site (Koetje 1992; Whallon 1973). Visual interpretation of artifact clusters can also be effective for generalizing artifact data, but statistical analyses provide a more objective method for interpretation.

The ongoing development of spatial analysis and an interest in modeling spatial distributions in archaeology has supported the development of methods for pattern recognition that are reinforced by statistical evidence. Quantitative methods are replicable and usually more objective than visual interpretation alone (Koetje 1992). This re-enforcement hinders the effects of a subjective researcher and focuses on the real spatial relationships between artifacts.

Intra-Site Spatial Analysis

The scale of spatial analysis can vary depending on the type and volume of data that is available or the research question. In the field of archaeology, spatial patterns can be explored at an inter-site (regional) level or intra-site (site based) level (Wobst 2006). Within intra-site analysis, there are two dimensions. The first is the inferential level and the second is the operational level. The inferential level derives information from the data to describe and reconstruct past activities and behaviors, factors or conditions that are not directly observable. The operational level searches for relationships between observable archaeological remains (Carr 1984). There are three specific steps that control the operational level of spatial analysis. To start, the distribution of artifacts is analyzed to determine relative arrangement across the site and whether spatial patterns such as clustering occur, or alternatively if the artifacts are randomly or uniformly scattered. Once a pattern in the distribution is identified, concentration areas are determined for each artifact type (Carr 1984; Whallon 1973). It is then possible to identify if different artifact types have a similar arrangement throughout the site. Frequency and spatial distribution then allows for inferential level analysis to reconstruct activities and behavior based on the observable patterns (Johnson 1984). This information can lead to estimations of population, social organization, site function, seasonal use, and many other characteristics of a sites use. This interpretation and reconstruction is the backbone of how archaeologists understand past peoples beyond merely cataloging the items they used.

Grid- Based Spatial Analysis

While point-based spatial analysis may be more detailed, previously recorded archaeological datasets lacking point-based artifact locations may only have enough information for grid-based analysis. Instead of defining densities by absolute coordinates, quadrants are used to represent the frequency of artifacts (Hietala and Stevens 1977; Johnson 1984). The major advantage of this type of analysis is that it accounts for some clustering of samples. Even data with coordinates can be generalized to quadrants (Banning 2002). One problem that arises from the use of spatial analysis in archaeology is limited correlation between the method used and the sample to which it is applied (Whallon 1973). Past researchers have criticized the fact that many research questions have been chosen for use with a particular method, rather than finding a method that will help answer the question (Zubrow 1990). This approach can cause biased results. Grid-based analysis provides a compromise and allows for analysis of multiple scales of data to answer questions.

One of the main benefits of grid-based spatial analysis is that it mirrors the data collection characteristic of most archaeological data (Koetje 1992). Similar to Fort St. Joseph, many archaeological excavations count artifacts per unit area, recording only the quadrant location. This avoids the chaos for recording X, Y, Z coordinates for hundreds of artifacts, thus saving time and money. The use of grid-based analysis is almost always suitable for answering research questions and utilizing the dataset.

Spatial Organization and Factors of Disturbance

The nature of archaeological deposits and the archaeological record in general is inherently varied. Each deposit was created through unique depositional processes. Some sites may have only been used sporadically, while some were relatively long-term occupation sites, such as Fort St. Joseph. Especially in the context of historical sites, many structures were permanent, but at the same time temporary structures may also have been present. With the presence of permanent structures, different periods of occupation are hard to distinguish. In this situation, occupation layers are overlapping and hard to differentiate (Straus 1979). This means a small group of people might have occupied a site for a long time or a large group occupied a site for a short time with the resulting artifact distribution almost the same. However, for many historical sites, input of other data sources can determine issues of context (Straus 1979). Written records and narrative can account for what factors of disturbance were caused by occupation. These same records can also describe post-occupational site disturbance such as agricultural land use, as is the case with Fort St. Joseph

Methods of Spatial Analysis

Spatial analysis advanced greatly in the mid-20th century. After the Second World War, a boom in technology turned many disciplines towards more quantitative approaches. In the 1970s, archaeology saw a major period of theoretical and methodological advances in spatial analysis (Barcelo and Pallares 1998; Zubrow 1990), many of which influenced other disciplines. Among the first major methods of archaeological spatial analysis were Dimensional Analysis of Variance (Schiffer, 1974; Whallon 1973) and Nearest Neighbor Analysis (Whallon 1974). These two methods both use quantitative tests that involve spatial coordinates or data counts. From here, spatial analysis followed two separate paths. The first path followed the development of formation processes and distribution patterns. The other path followed the growth of new and advancing methodologies (Blankholm 1991). The previously mentioned models were based on assumptions that enabled the models to reflect uniformity within and among sites no matter the time or culture that inhabited them. However, many archaeologists later realized the potential error of this assumption which discounts the natural variability of the archaeological landscape.

More recently, the development and advancement of traditional spatial analysis has led to new methods that address issues for specific sites and archaeological problems (Marble, 1990). Improvements in how methods are applied have also contributed to the variety of new methods that depend on requirements and goals of specific research (Blankholm 1991). Selection of an appropriate method is dependent on the requirements of the research and available data, as well as the strengths and weaknesses of the specific methods. The goal of this research is to identify spatial patterning of artifacts at Fort St. Joseph and compare predicted distributions of artifacts to those established in previous studies. Locations and content of artifact clusters will be identified and examined horizontally to identify potential activity areas within the fort site. Since artifacts in the fort database are limited to unit level data, the chosen method for this analysis will be grid based.

Isopleth Mapping

The goal of isopleth mapping is to model spatial distributions of artifact densities by modeling them along the lines of a topographic map (Banning, 2002). In the fields which this method originated, the data fits within the model in a somewhat organized manner. However, archaeological data is more chaotic and doesn't necessarily conform to natural boundaries. For example, topography and magnetic fields have a gradual change in values over space which allows for other values to be interpolated based on just a few points. However, archaeological data has peaks in variation over space (Banning 2002; Hietala and Stevens 1997). The data that is represented is objective, and varies depending on where and how measurements are taken, and the distance between measurements. Some of this variance can be generalized through a smoothing filter (Jermann and Dunnell 1979). This can be done by taking the average for a set of four quadrants. This method can drastically change the data based on the spatial size of the quadrants or the number of quadrants in a set. This is the biggest drawback of this method.

Variance-to-Mean Methods of Analysis

The grid-based method most similar to nearest neighbor is the variance-to-mean ratio. This method uses a count of archaeological material per grid unit and measures the mean density and the variance of the distribution about the mean (Dacey 1973; Silverman 1986). The ratio is a measure of how clustered or dispersed a set of data is compared to a standard 2D statistical model. Relying on a Poisson distribution, there is a random assignment of observations to each quadrant of space. If the projected ratio is close to 1, the pattern is random and the Poisson value and variance to mean ratio are equal. A high value would be an indication of clustering, and a lower value would indicate even distribution of the data across space (Dacey 1973). This method is also hindered by the size of quadrant used.

Dimensional Analysis of Variance

The last method to be discussed is the dimensional analysis of variance (DAV). This method is also used to identify clustering within a dataset; however, it uses the potential shortcomings of other methods, quadrant size, to its advantage (Schiffer 1974). Through this method, the researcher assesses how patterns change as quadrant size changes (Carr 1984, Wheatley 2004). Similar to the other grid-based methods, DAV doesn't require exact coordinates for each artifact. The output of DAV is a generalized analysis of the distribution of artifacts. DAV was originally introduced to archaeology by Whallon in 1973. It compares the distribution of multiple grid sizes to identify those containing the most significant clustering of artifacts. This allows for clustering based on actual artifact counts and distributions, rather than an objective grid unit (Schiffer 1974; Whallon 1973). In the DAV method, the restrictions placed on grid size and the use of grid units could cause problems when working with small sites or those in a non-regular setting (Carr 1984). In Whallon's application, the area being observed was a small cave floor, which made identifying patterns difficult. The site at Fort St. Joseph lies on a floodplain and stretches across the open landscape, and as such is not confined to spatial limits, such as those that might exist for a cave or rock shelter site.

Why Spatial Analysis?

Spatial analysis plays an important role in archaeological research and as such, has greatly increased the used of quantitative methods in the discipline. The information obtained from these methods aids in the interpretation of activities related to spatial occupation of any given site. Depositional and post depositional processes can have extensive effects resulting in a mixed assemblage that is hard to interpret (Anderson 2003; Johnson 1984). However, careful excavation and recording can aid in deciphering the stratigraphic record and the original distribution of artifacts horizontally across space (Straus 1979). The analysis of distributions must take into account the processes that have affected site formation up to the point of excavation.

After careful investigation of a variety of potential spatial analysis methods, dimensional analysis of variance has been chosen as the best method to meet the goals of this research and will be explored further in greater detail in chapter five. Limitations of previously recorded data make this grid-based method flexible and reliable for datasets similar to Fort St. Joseph. Through spatial analysis and GIS capabilities, it is possible to locate distributional patterns, as well as interpret the horizontal distribution of archaeological materials in the terms of activity areas and occupational time frame. This research also provides an opportunity to evaluate the use of dimensional analysis of variance for the analysis of historical occupation sites potentially demonstrating the value of this method in the field of archaeology.

Geographic Information Systems and Archaeology

The integration of Geographic Information Systems (GIS) has greatly expanded the role of maps and spatial display in the field of archaeology. Visualization and mapping methods, once time consuming and only for the meticulous, are now readily accessible and can be completed in a short amount of time. This thesis is intended to outline an effective method intended to visualize and identify the spatial distribution of archaeological materials. Spatial analysis used in combination with GIS has become a necessary component for archaeological research at all scales. The only limitation is the amount of data collected and the outputs that can be generated from that data (Kvamme 1999). With the introduction of GIS, came a broader range of what kinds of data could be created (Knoerl 1991). GIS is a group of powerful, computer-based mapping programs. They utilize the proficient storage, analysis, and representation of data based on its spatial reference.

Based on reviews of current literature, the main GIS applications in archaeology have been regional scale studies, which look at the relationship between sites and the landscape as discussed previously. The use of GIS so far has been somewhat limited, but there are many more possible uses in both regional and intra-site applications (Wheatley and Gillings 2002). The largest limitation is the lack of integration of GIS software due to software costs and necessary training (Fisher 1999). GIS software is relatively new and is continuously changing and adapting. There is a need for education and continued training among researchers to take full advantage of everything this technology can provide. Lastly, this section will discuss the use of GIS in quantifying data, as well as future developments.

What is GIS?

The post WWII development of computer aided technologies has had a major impact on many research fields. A significant increase in the accuracy and speed of data collection and analysis has changed the types of research that can be done and what questions can be answered. Geographic Information Systems, or GIS, was introduced in the 1960s, at the peak of the quantitative revolution (Ebert 2004; Fisher 1999: Knoerl 1991). During this time an onslaught of post war technology and interest in statistical modeling was contributing to numerous academic fields. Since GIS first came on the scene, it has made a significant contribution to the use of archaeological data (Allen et al. 1990; Marble 1990; Wheatley and Gillings 2002). It has made the input, storage, analysis, and output of data much more efficient.

Early uses of GIS were limited in their utility and application; however, GIS software has developed with continued advances in computer technologies. As the functionality of the software has increased it has become applicable to a wider range of research applications in the field of archaeology. GIS is generally defined in archaeology as computer databases that are spatially referenced and create links between spatial data (a point or feature) and non-spatial or attribute data, usually a record located within the database (Wheatley and Gillings 2002, Kvamme 1999). The user can define what attributes are available for each spatial object, which allows for visual and quantitative analysis of the dataset. Attribute data is defined as data about the objects whose locations and spatial location we have carefully recorded. It is usually found in inventories or field records and reports. GIS programs are also capable of statistical analysis and manipulation. They can also be used for the capture, retrieval, and display of any real-world data that is spatially referenced (Kvamme 1989).

Vector and Raster Based GIS

Two main types of GIS exist, vector-based and raster-based. Their use depends on what data are available and what questions are being answered. The different formats allow a user to manipulate the data in different ways (Kvamme 1999). Vector-based GIS makes use of polygons, lines, and points as a representation for spatial data and its related attribute data. The visualization of vector-based graphics is similar to traditional maps, making it efficient and a suitable way to manage and represent large data sets over large areas and containing a lot of attribute data. This makes them useful for studies of spatial distribution (Kvamme and Kohler 1988). The possible outputs created in vector-based GIS provide a functional visualization for analysis by researchers, however overall cost of this method can be its main limitation (Knoerl 1991). In the field of archaeology, analyses of continuous surfaces are common. This requires use of raster-based GIS in the form of topographic coverages and digital elevation models. Raster grids can have values for the entire surface (Kvamme 1989; Knoerl 1991; Ebert, 2004). However, vector-based analysis is preferred for representation of distribution frequencies and the general mapping of sites.

Raster-based data uses a system of regular grid cells. Each cell is assigned a value representative of a particular category of data (Knoerl 1991, Kvamme 1999). Its format is functional and simple to program and also allows for the creation of maps with a high quality, grid resolution (Wheatley and Gillings 2002). Variations of surfaces are readily identified by color variations and are a good form of representation for elevation models, topography, and soil maps. Each cell is given a unique or categorical value for each layer. This value represents a certain classification. Typical applications of analysis of raster data by archaeologists includes location modeling and cost surfaces, methods that are particularly useful in regional-scale studies (Knoerl 1991; Kvamme 1989). While raster-based analysis can be useful, the output, especially of large datasets, can consume storage space and can be costly over time. Grids with smaller cells require a larger amount of digital storage. Although somewhat problematic, larger cells cause a loss of information and overgeneralization of data (Ebert 2004). This results in over smoothing of features, which could hide some patterns. If multiple values are present in a cell, the dominant value will be the only one represented and inaccurately represent data boundaries (Kvamme 1989). This highlights the researcher's need for finding an appropriate grid cell size and number of data layers to use for a project.

Both formats, vector and raster, have their strengths and weaknesses. Surfaces are best represented through raster data. Analysis of attribute information is best represented through vector data (Ebert 2004; Fisher 1999). ArcGIS software allows for the use and analysis of both formats, leaving the choice of the best format up to the researcher. After a format is chosen, data can be collected, organized, and then analyzed. Individual layers are represented as a horizontal plane located on the same coordinate scale (Allen et al. 1990; Ebert 2004). Organization and manipulation of data is key in order to accurately compare layers.

Advantages for Archaeological Applications

A growing interest in GIS applications has occurred over the last decade. Many areas of study in archaeological research utilize GIS. These include spatial analysis, landscape archaeology, predictive modelling, and location modeling for Cultural Resource Management (Allen et al. 1990; Green 1990). These methods dramatically decrease survey and analysis time. Other advantages of GIS in archaeology include the digitization of archaeological sites (Wheatley 1992; Wheatley 1996). This allows for a connection of visual and analytic data to a spatial representation of site boundaries (Wheatley and Gillings 2002). As GIS continues to advance and data is collected, the breadth of analysis that can be completed is greatly increased.

The applications of GIS in archaeology provide new tools for the researcher. One of its key advantages is its functionality as a tool for the collection, combination and presentation of data. GIS is able to store and manage a large amount of data, which is then able to be retrieved and analyzed through statistical methods (Chapman 2006; Wheatley 1992). Artifacts and features can be represented as unique and individual spatial data structures within a geodatabase. A geodatabase is a collection of spatially referenced datasets that are collected into a single folder (ESRI 2015). Data concerning other archaeological information can also be geographically referenced and stored in a geodatabase, whether it is at an intra-site level or at a regional level (Kvamme 1999). Through this system, researchers can query unique archaeological data structures in the geodatabase and identify attribute data pertaining to that object (Wheatley 1996). This greatly increases the speed and efficiency of the research process.

Due to the nature of the archaeological process, vast amounts of data and materials are acquired and need to be stored in an accessible and appropriate form (Green 1990; McCoy and Ladefoged 2009). With GIS, a geodatabase has the capability to store and access multiple types of data in a single database. The data can also be used and manipulated in multiple contexts. Digital content is easy to access and update when necessary and new fields can also be added. Before the availability of computer databases, researchers were restricted to manual analysis of data (McCoy and Ladefoged 2009; Wheatley 1996). This process was time consuming and limiting in terms of what kind of analysis can be done. Manual methods also have an increased chance of error and variations of a sample (Kvamme and Kohler 1988). Given the challenges of non-computer based methods, the appeal of GIS databases and digital methods of analysis have grown.

Not only does GIS allow for new means of storage and data management, but it also combines a new level of graphics and display with the appeal of quantitative methods. These new display capabilities of display are an exceptional environment for spatial analysis (Chapman 2006; Ebert 2004). Researchers often take advantage of GIS to create effective visual displays and detailed maps. Spatial properties of archaeological data are valuable sources for the researcher. These data allow for the creation of landscape maps and the ability to identify unique relationships between the landscape and archaeological findings (Kvamme 1993; Ebert 2004). Multiple maps can be created quickly and incorporate color or shading, or enhanced 3D perspectives (Kvamme and Kohler 1988), all of which are difficult to produce for traditional paper- based maps. The addition of quality graphics and maps enhances any site report or publication, and increases the understanding of the publication's audience (Allen et al. 1990). An unlimited potential can be found in GIS, based on the skill of the user and the capabilities of the software (McCoy and Ladefoged 2009). While GIS is utilized for its functionality, the software can be limited to storage, management, and visualization of data (Williamson and Nickens 2000). While all methods of research are not always available in GIS software, high quality maps can be produced and effectively improve the visual interpretation of archaeological data.

Beyond the storage and visualization capabilities of GIS, this technology can be utilized as a research tool to map and evaluate cultural resources. The initial use of GIS emphasizes its functionality for database management, but archaeologists are beginning to explore the potential research properties of GIS software (Williamson and Nickens 2000). Development of new technologies in archaeology has provided new methods to answer research questions concerning organization of social structures, spatial clustering of artifacts and territoriality. This allows for an advancement of archaeology in the study of groups in relation to their physical and cultural environments (Anderson 2003; Kvamme 1993; Savage 1990). The growing development of GIS will eventually lead to an effective research methodology, heavily influenced by the application and capability of this software.

The accuracy and replicability of measurements in a short amount of time is greatly increased with the use of GIS. Large datasets are able to be fully analyzed in a short period of time, compared to manual selection and analysis of a single sample of data (Kvamme and Kohler 1988; Wheatley 1992). GIS software allows for various types of spatially referenced data to be queried and overlaid. This permits the manipulation of existing data and the creation of new information from that data, which can be time-saving and beneficial to projects with limited budgets (Anderson 2003). The time and labor-power needed to digitize information is cut drastically. Map algebra uses mathematical functions to create new data layers from raster data (Allen et al. 1990; Ebert 2004). This capability is a unique function of GIS software that is focused on answering specific research questions.

While GIS had an early following, its applications in archaeology have remained limited. So many functions of GIS software are yet to be utilized by archaeologists. This technology is not just a tool to aid in solving research problems, but it is also a method to address new problems and questions that have remained unanswerable (Allen et al. 1990; Anderson 2003; Green 1990). To use GIS to its fullest potential, archaeologists must explore new applications of the software and take full advantage of its analytical functions.

Potential Limitations for Archaeological Applications

Initially, the use of GIS in archaeology was limited by issues surrounding the debate between deductive and inductive research. GIS technology was hindered by problems that had been associated with inductive research methods (Gaffney and van Leusen 1995; Maschner 1996; Zubrow 1990). Deductive methods require data and information to be collected and leads to the evaluation of a prepared hypothesis or certain expectations. With inductive methods, such as modeling, the evidence creates new interpretations through analysis (Zubrow 1990). Those against this method called into question the accuracy and functionality of data obtained through inductive methods (Kincaid 1988). Archaeology has been historically driven by deductive, hypothesis-based research and has somewhat overlooked the use of inductive methods.

With the pressure towards a "new archaeology" in the 1960s, came a push towards the use of the scientific method and deductive research models, which make assumptions of the data. The main disadvantage of this approach is being able to validate any *a priori* statements or hypotheses (Kincaid 1988; Maschner 1996). The main focus of inductive research is quantitative methods, which can be a disadvantage to the unfamiliar researcher. In the end both deductive and inductive research models should be used in archaeological research; deductive models for their functionality in site interpretation, and inductive models for the accuracy of their statistical methods (Gaffney and van Leusen 1995).

Cost and User Knowledge

With advantages of new software, come limitations. Although GIS has an emphasized functionality for cultural resource management and conservation, it has weaknesses. With technology that requires a knowledgeable user, there is always a chance that the methodology defines the course of the research and how the data is analyzed (Gilbert 1991; McCoy and Ladefoged 2009). In order to make effective use of GIS, researchers must keep in mind the cost of software, equipment, and technical training to ensure quality of data input and output (Green 1990). It is only after these issues are taken into account that GIS can be used to its full extent.

One of the biggest drawbacks of GIS is the cost of software and equipment. Although GIS technology has demonstrated its utility in archaeological research, many organizations or individual users must compromise overall quality of GIS in order to obtain the software and equipment to successfully utilize the technology (Wansleeben 1988). Limited software is hindered by restricted functionality, leaving the full range of GIS technology to only be used by wealthier institutions. Limited availability and cost associated with database creation and management has also inhibited the technology's use, and forcing researchers to seek more cost effective methods and tools (McCoy and Ladefoged 2009). Another aspect of GIS technology is obtaining digital data. Often the collection and fine-tuning of data can be the costliest in regards to money, but also time (Williamson and Nickens 2000). One way to overcome this limitation is the open sharing of data and equipment. This can aid in the minimization of costs and increase of new information. Decreasing the overall costs of GIS technologies is important to increasing its access, especially in archaeology.

GIS is also limited by the training and skill required to use the technology to its fullest potential. Although some functions of GIS may appear simple, many of the functions require a sophisticated knowledge of the software (Wheatley 1996). The concepts used in GIS are often complex and require training to fully utilize the associated software. Developments and changes are continuously being made to many programs, requiring a need to maintain a detailed knowledge of how the technology is evolving (Ebert 2004). Without training, only a rudimentary understanding can be developed. In order to successfully use GIS as a research tool, training and practice are essential.

Quality of Data Analysis

GIS has the capability to create high quality graphical representations, however these displays can often lack analytical value. There are multiple factors that contribute to the quality of a GIS created map; skill of the user, how the data are collected in the field, and methods of manipulation within the database (Kincaid 1988; Wheatley and Gillings 2002). The importance of appropriate training as a source of error is discussed in the previous section. As data is collected in the field, certain errors can occur with collection. Often archaeological data is collected by field school students, volunteers, or technicians with limited previous field experience (Howard 2006). Error is also found as more archaeological collections are being digitized. Records can often be incomplete or inaccurate. Continual enhancements to data collection methods, storage, and analysis have been made with the aid of computer technology (Wheatley 1996). Even at the simplest level of visualization, placement errors can be identified and fixed. Original hard-copy records and databases typically do not have a spatial reference and errors often go unnoticed. Any results are then inaccurate (Wheatley 1992). It is therefore important to take into account the quality of data before analysis to accurately evaluate the outcome.

Another critique related to the quality of data analysis through the application of GIS technology is the application of environmental variables to describe human behavior, also referred to as determinism. It is suggested that archaeologists rely too much on environmental characteristics as a basis for site prediction and modeling, that the characteristics of human experience are left unaccounted (Kincaid 1988). This lack of a humanistic element goes hand-in-hand with Fisher's (1999) definition of environmental determinism, which he explains as "a theoretical approach to archaeology that regards past and present cultures as somehow functions of, or shaped by, environmental pressures" (Fisher 1999: 12; Gaffney and van Leusen 1995; Anderson 2003). The constraints of using environmental variables as the only characteristic contributing to the interpretation of archaeological materials ignores all aspects of human behavior that are vital to the creation and deposition of said materials (Kincaid 1988). To overcome the unintentional deterministic means applied to archaeological studies, research strategies must consider both the spatial and temporal relationships of an archaeological landscape, but to do so in a way that also incorporates the attributes of human experience and interaction (Allen et al. 1990; Anderson, 2003; Kincaid 1988). The models created through GIS can only be considered as part of the puzzle. Considering these additional elements will allow for a more humanistic archaeology and benefit from the use of more suitable site models.

Archaeology is often criticized for inheriting theory and methodologies from other disciplines without a detailed assessment. This leads to a structuring of research based on a particular method, letting it be the directive for research questions and analysis (Allen et al. 1990; Kincaid 1988; Wansleeben 1988). As GIS was not initially developed for use in archaeological applications, it has the possibility to fall victim to this critique. The qualification as a "borrowed" method could also be a factor in GIS's reduced utilization in the discipline (Chapman 2006; Ebert 2002). By critically assessing the best method for the data, rather than the best data for the method, researchers can recognize and account for possible issues (Kincaid 1988). The quick development and assimilation of GIS into archaeology is often identified as a reason for this critique. Moreover, that any limitations to the use of GIS, is not due to the technology, but rather the archaeologists' use of it (Ebert 2002). Research should not accommodate a methodology. Instead the theory and methods used for analysis should be adapted to accommodate the goals of the research.

GIS Applications in Archaeology

Over time, GIS technology has made great strides in advancing the types of analysis that are available in terms of both 2D and 3D spatial data. Spatial analysis and visualization have become essential to archaeological investigations and spatial studies (Kvamme 1993). GIS is a vital tool for creating graphics that present spatial data in an informative and logical manner (Kvamme 1995). Maps of artifact distributions spread throughout a site are just some examples. This kind of visualization provides representation of cluster analysis in a way that is easy to understand and quicker to read than an expansive table of numerical results, and places the data in context. GIS representation can also aid in further interpretation of other site characteristics, such as slope and arrangement of features (Kvamme 1995). Graphical display combined with statistical reinforcement provide the archaeologist with efficient support for spatial research.

While quantitative analysis has long been an accepted part of archaeological research, certain abilities for quantification through GIS are just now reaching a point of development that can be actively utilized. Until recently 3D data was extremely limited. In recent years, however, advancing technology and research have made 3D data such as LIDAR more obtainable (Wheatley and Gillings 2002). Advances in open source software have also made 3D modeling and digitalization of sites more accessible for projects with limited funding. That being said, applications of GIS technology have still been limited to mostly 2D applications, which is beneficial for horizontal spatial analysis at the single site level or for regional scale analysis (Ebert 2004).

Previous trials to use GIS for 3D analysis required researchers to look at a series of stacked 2D layers for analysis. This provided some temporal context, but was still inadequate in terms of a successful 3D representation of the data (Anderson 2003; Kvamme 1996). An accurate 3D analysis would result in a better temporal understanding of the structure and occupation of any site by identifying the interrelationships at play between stratigraphic layers, or the vertical distribution of the site. The future advancements of GIS in archaeology rely on further development of both 2D and 3D analysis (Kvamme 1993; 1995). While 3D analysis interprets both spatial and temporal characteristics of a site, it is difficult to complete with large scale data sets that do not include a 3D coordinate for location. The factor of scale limits many studies to the 2D level, as is the case with FSJ, which has an expansive collection of artifacts.

Future Developments

GIS technology is constantly evolving so as to possibly answer new questions and provide new possibilities. Although there are several factors limiting the future of the use of GIS technology in archaeology, many see a bright future ahead (Allen et al. 1990, Kvamme 1989). Archaeologists have only begun to utilize the capabilities of GIS. There is agreement in the discipline that although there are hindrances, the value of the results outweighs these challenges (Ebert 2004; Kvamme 1996; Wheatley 1996).

The issues encountered early on by researchers that limited functionality were often software bugs that have been fixed through continual development and refinement of the technology over time. As GIS software advances, its potential is slowly being realized (Wheatley and Gillings 2002). The future of archaeology will embrace the digital age. New research inspired by the use of GIS will occur and the suitability of the methodology and expanse of available information will continue to be critiqued (Fisher 1999). A major aspect that needs to be addressed is the technical development and research of GIS technology, an evaluation of how data is collected, and methods to reduce costs. The current limitation is lack of training. As technology continues to evolve, so must the researcher to maintain innovative approaches (Anderson 2003). With continued progress, GIS has the capability to become a common resource for landscape and spatial analysis, and a key tool for cultural resource management.

CHAPTER III
THE DATA SET AND METHODS

Fort St. Joseph

Fort St. Joseph played a key role in the European development of the Great Lakes region and the expansion of the fur trade. The FSJ site is one of several major historic archaeological sites in the state of Michigan, located on a floodplain along the St. Joseph River just south of present day Niles, Michigan. While part of the site is accessible to archaeologists, a majority lies underneath landfill deposits or is covered by increased water level of the St. Joseph River. Despite the limited access caused by these environmental conditions, the currently accessible portion of the Fort contains valuable information on the history of the Great Lakes region and study of the fur trade.

French Fur Trade, New France and Fort St. Joseph

With the first European contact in the Great Lakes, the hunt for Christian converts and precious furs began. As trade expanded in the region, so did the force of religion. French missionaries arrived, bringing bibles and Catholicism. In the 1680s French Jesuits constructed a mission along the St. Joseph River. Fur traders followed soon after and a fort was built on the site in 1691 to serve as a trading post for the French fur trade (Nassaney et al. 2003). The location was strategically chosen at the shortest overland portage from the St. Joseph to the Kankakee River (Figure 1), which eventually flows into the Gulf of Mexico by way of the Mississippi River (Nassaney et al. 2002-2004). This connected the fur trade to French territories in the South and the port of New Orleans. The Fort was also centrally located in the St. Joseph River Valley in proximity to Native American groups (Kohley 2013).

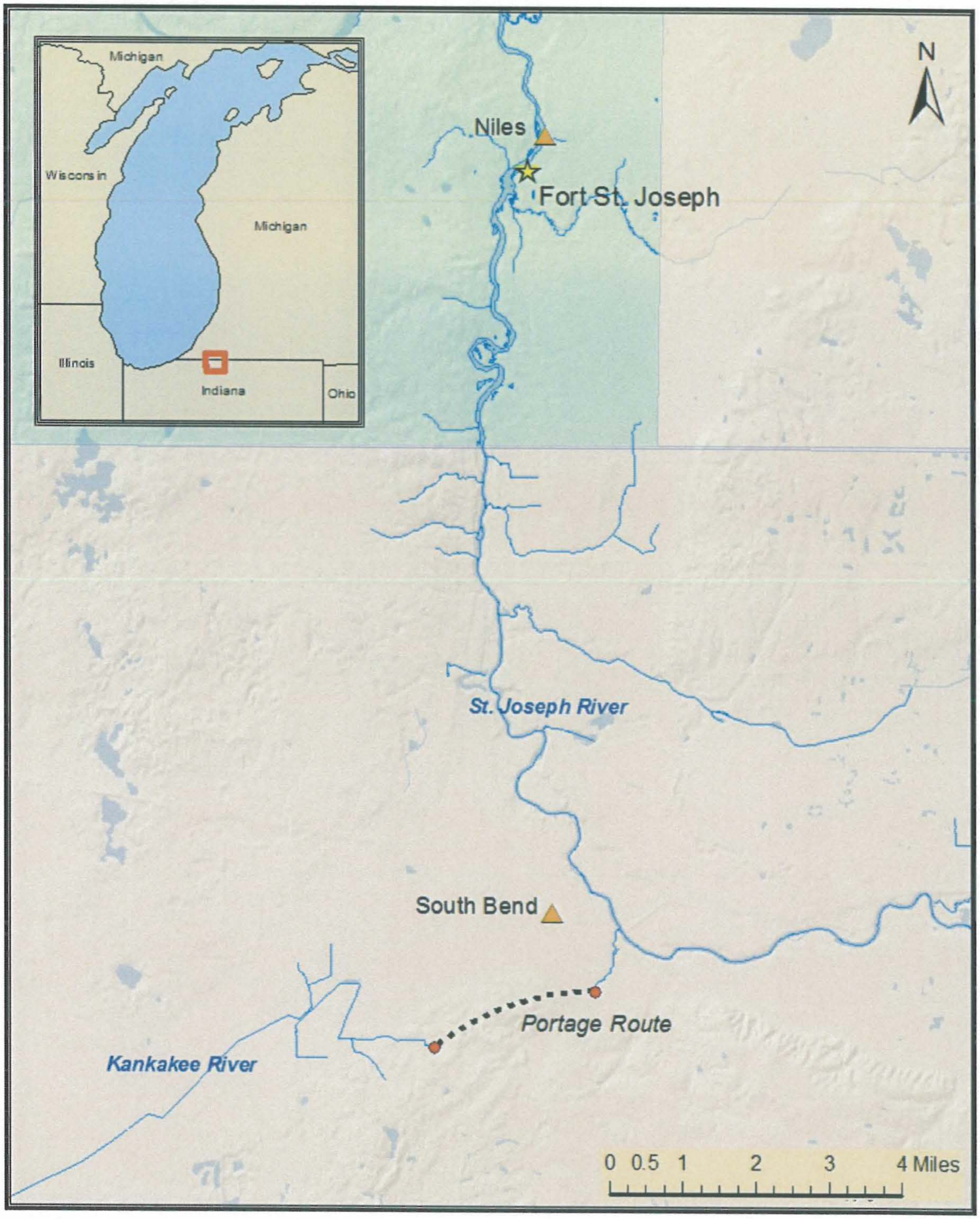


Figure 1 – Location of Fort St. Joseph and the St. Joseph / Kankakee River portage. Prepared by Katelyn Hillmeyer.

The Fort acted as a stronghold for the French until their loss of the fort during the French and Indian War (Nassaney et al. 2003). At that point it was taken over by the British and used as a supply depot during the American Revolution. For a short period, the fort was also taken over by a group of French and native raiders under the Spanish flag in 1781. It was quickly returned to the British, who soon abandoned it. With the signing of Jay's Treaty in 1795, the United States took control of the territory (Nassaney et al. 2003). When the British left, the fort was abandoned and left to ruin. Occupation of the Fort by the French, British, Spanish, and United States give the modern day City of Niles its nickname, the "City of Four Flags".

Little documentation survives to describe the structures and layout of Fort St. Joseph. Most documentation that mentions the Fort, is in the form of historical maps, most of which are at too broad a scale to focus on an individual fort, and look more at the Great Lakes region as a whole and depict major trade routes (Nassaney et al. 2002-2004). Other research has identified only two descriptions of the 18^{th} century fort. The first description dates from 1721 and the writings of Pierre-Francois-Xavier de Charlevoix (Benston 2010). His description is brief and does not provide description of many of the buildings known to exist at the fort. However, it does mention a mission, commandant's house, garrison, and some sort of palisade wall. (Interestingly, his description appears in the 1761 published English translation and not in the original French.) Overall, there is suspected to have been at least 20 structures. Among these were a chapel, missionary's quarters, commandant's house, stone and iron jail, military and storage buildings, and 15 houses (Benston 2010). While the presence of these structures is noted, there is no formal documentation of their location within the fort or arrangement.

After the British left, the structures began to decay. The area was turned to farmland. Collectors found numerous artifacts in the plowed fields (Beeson 1900), but the fort remained hidden. On July 4th, 1913 a large stone monument was placed and dedicated by the community of Niles to commemorate the Fort (Nassaney 2015). While the rock remains a continuous reminder of the Fort and the history of the region, local knowledge and interest in the Fort faded. In the 1930s the dam located downstream of the forgotten fort was raised in elevation creating a flood pool that submerged part of the fort (Nassaney et al. 2002-2004). A distance from the river, the remainder of the fort site was slowly covered with landfill deposits, which eventually turned to forest.

It wasn't until 1992, and the creation of a local group called "Support the Fort", that there was renewed interest in locating the remains of Fort St. Joseph. This led to an archaeological survey in 1998 (Nassaney et al. 2002-2004). Major excavations began in 2002 and have been ongoing as part of a field school conducted through Western Michigan University (Nassaney et al. 2003). Over the course of the FSJ project, countless artifacts and numerous features have been uncovered representative remains of those who once occupied the site. Among the artifacts are religious tokens, structural components, and clothing adornments. Features at the site consist of remains of stone foundations, fireplaces, and debris pits, identifying the structural remains of houses of people who lived and worked at Fort St. Joseph (Nassaney 2015).

Site Stratigraphy

Excavations at the site are laid out on an arbitrary one meter by one-meter grid pattern with the datum, N0 E0, located towards the southwest corner of the Fort site (20BE23) (Benston 2010). Units are marked on the grid and identified by the grid coordinate of their southwest corner (e.g., - N30 E8, or N22 W7). Most units are 1 x 1 meter with an area of 1 meter square or 2x1 meters and have an area of 2 meters square. Artifacts use the unit name as their location of recovery, and are rarely labeled with a more precise location unless recovered from undisturbed context. The horizontal distribution of the site extends to the northwest and southeast, where excavations are limited by the current river level and landfill. Some shovel test pit (STP) testing extending to the southwest has also shown presence of some 18th century artifacts, of which the extent is still unknown (Nassaney 2015). Field school excavations on the terrace above the floodplain at the Lyne site (20BE10) have also uncovered limited 18th century artifacts, indicating the extent of colonial activity in this area.

Vertical arrangement of the site consists of four basic soil layers; alluvium, plow zone, occupation, and sterile sand (Benston 2010; Nassaney, et al. 2002-2004). The alluvial zone is comprised mainly of rich, organic soils that are a result of seasonal flooding and an increase in water level after the construction of the dam. This layer extends to 25-30 centimeters below the current surface. The next layer is the plow zone, which begins at the extent of the alluvium and extends to 55-60 centimeters below the current surface. This layer contains artifacts relating to the Fort, but is characterized by churning caused by agricultural plowing before the installation of the dam. The occupation layer is undisturbed soil beginning just below the plow zone, and extending to various depths. This layer contains many of the 18th century artifacts and features. Below the occupation layer is a discontinuation of artifacts and features and the presence of sterile sand deposits.

The Dataset

The data for this thesis was collected from field notes and documentation, GPS field measurements, paper site maps, and excel databases of the artifact collections. These resources are maintained by the Fort St. Joseph Archaeological Project and the Western Michigan University Department of Anthropology. During the field school, students are required to take detailed notes of each layer within their unit during excavations. These notes describe the soil type, artifacts being recovered, and other details important for a permanent record. Several other documents are created and/or maintained during the field season, including a site map and feature list. These documents stay up to date on the units being excavated. During the 2015 field season, GPS measurements were collected for the site datum, the dewatering system, and the trees and stumps. Measurements were limited by consistent flooding of the site during an unusually wet field season. Artifacts from the site are bagged and tracked by unit and depth. After the field season they are cleaned, processed, and then logged into the database. This database contains an accession number, unit number, stratum, depth, material, function, specimen description, count, and weight for each artifact. The completed database, through 2014, was used to perform this analysis and provides necessary attribute information for the horizontal and vertical analysis of artifact distributions.

Previous Research

In 2009, a preliminary GIS analysis of the Fort St. Joseph project was completed (Benston 2010). Benston provided an exploratory view of excavations through the calculation of artifact densities and comparison of the relationships between certain recovery zones (Benston 2010). Through the initial creation of an ArcGIS database and spatial investigation of the Fort site, Benston was able to identify limited spatial patterning related to the horizontal distribution of artifacts. A majority of the density and cluster maps revealed little to no spatial patterns. Over all, the maps displayed a random distribution to the site. However, some patterning was present when artifacts classes were investigated individually (Benston 2010). For example, in the case of ceramics, it was noted that most of the collection was found towards the west half of the site. It was also noticed that cream ware specifically, appeared to be more closely related with a single house structure. Vertical distributions revealed only a loose relationship between the plow zone and artifacts found in the occupation zone (Benston 2010).

Benston's study also documented limitations associated with analysis at the Fort site. These include the limited locality of artifacts and the limited expansion of the site due to the landfill deposits and river. She concluded that further research and methods were necessary, and that her study was just the first step to employing GIS analysis at Fort St. Joseph.

Research Challenges

Several years of research at Fort St. Joseph have uncovered hundreds of artifacts spread throughout the site. However, analysis is limited by a lack of precise coordinates for each artifact. Most artifact locations are noted down to their 1 meter-square unit, or half of a 2 meter-square unit and have an approximate depth. In some cases, the most precise location lack the half of the 2 meter square unit and only have the location of the unit as a whole. Another problem faced is a non-continuous definition of site layers. Since the excavation are carried out as part of a field school, some measurements may not be accurate and vertical layers are roughly defined.

The use of spatial analysis can demonstrate potential use areas within the site. To do this, it is important to define a methodology to identify deposits related to daily life, military life, and religious habits. Spatial analysis in archaeology usually focuses on either the horizontal plane, or the vertical plane. As the horizontal distribution of artifacts provides useful information regarding the distribution of activities within individual cultural levels, it is necessary to be certain that the artifacts are associated with a single occupational phase contemporary with the level being analyzed. Therefore, any analysis of spatial patterning should consider first how the vertical dimension has influenced site formation process and the possible post-depositional movement of material.

Fort St. Joseph holds important information about the development of the fur trade and European settlement in the Great Lakes region. Characteristics and problems associated with the analysis of historical sites, such as the Fort, have been identified. The importance of spatial analysis within the study of archaeology has also been specified. It now becomes necessary to identify the possible limitations that come with the application of this spatial analysis and the capabilities provided through the use of GIS.

Methods

Within the field of archaeology, the use of spatial analysis can reveal important information regarding the organization and use of a particular site. The previous chapters have demonstrated the significance of spatial analysis, as well as the potential benefits of GIS as a visualization and database management tool in archaeology. This section describes the methodology developed for the spatial analysis of artifact distributions at Fort St. Joseph. The dataset was adjusted for use with ArcGIS software to initially examine the summation of artifacts by category. In addition, individual archaeologically defined levels were analyzed in order to identify clusters of finds that may signify possible activity areas within the site. This was accomplished through the utilization of ArcMap 10.3 to visualize the horizontal and vertical patterning based on dimensional distributions. Cluster analysis was then used to identify units producing similar artifacts and spatial organization. Finally, statistical analyses of cluster contents to identify potential activity areas.

Data Preparation

Before analysis could begin many of the data sources needed to be edited, updated, and formatted. This included adding new features and editing features in many of the shapefiles, making new shapefiles for data, sorting and "cleaning" up data tables, and projecting spatial data into an appropriate coordinate system.

The original database, created by Benston, contains a one meter by one meter fishnet grid. This grid provides a base for the unit map. The unit map acquired from the original database included only the units excavated thru 2009. There were also several units in the wrong location, and a unit excavated in 2007 that was left off the original layer. Student field notes, unit summaries, and a paper site map, were used to correct these issues. Using the original fishnet and unit map new units were added to update the layer. Information including the southwest corner coordinate, years excavated, area, associated features, orientation, and approximate depth were added or updated using the editor tools in ArcMap.

Based on information from the field notebooks for all previous excavations, a new feature layer was created. Included in the attributes for each polygon was the feature number, year(s) excavated, possible interpretation, associated units, and description. To represent the landmarks that bound the site, the "Landmarks" shapefile was imported from the original database. Derived from the GPS points taken for the river's edge and approximate landfill boundaries, the original shapefile was updated using the editor tool. A feature was added to represent the possible variations in water level along the river. Units closer to the river's edge can flood, even while the dewatering system is running. Planning for variations in the river's edge will assist with planning future excavations.

The artifact inventories, which catalog the artifacts retrieved from excavations, were compiled into a single sheet. Any recognizable errors, such as mistyped unit numbers, were corrected. The following fields of the inventory were maintained: Accession Number, Depth, Stratum, Unit Number, Material, Function, Specimen Description, Count, Weight and Reference (Table 1). Three fields were added to aid in summarizing the data and join it to the unit map; Year, Level, and Artifact Class. Year was added for easier identification once the inventories were joined. Level was created and contained 6 classes based on the Strata field, but generalized them and corrected differences in wording for the field. In the original inventories plow zone was listed as PZ, plowzone, PlowZone, Plow Zone, and PlowZ. Multiple variations of the same class made it difficult to summarize the data. The Artifact Class field was created for a similar purpose. It organized the artifacts into one of 16 classes to aid in summarizing the inventory. These classes were adapted from Benston (2010) and are identified in Table 2. Some artifacts were removed due to missing location information and item descriptions. The dataset was then summarized by count and weight for each assigned artifact class by unit. This table was then joined to the unit map and used in the visualization of artifact distributions across the site.

All imported spatial data layers were converted into a shapefile usable by ArcMap 10.3. These files were then projected in the same coordinate system, NAD 1983 State Plane Michigan South FIPS 2113, to provide the most accurate representation of the site. The original projection of the data from the Michigan Geographic Data Library was not used because it was designed to best represent the entire southern region of Michigan. However, it has a higher level of inaccuracy in the northeast and southwest corners. The city of Niles and the Fort site are located in the southwest corner of Michigan, making this projection unreliable (Benston 2010).

Table 1 - Inventory catalog fields created and standardized for the Fort St. Joseph archaeological geodatabase with the purpose of each field, adapted from Benston (2010).

Inventory Catalog Fields	Field Purpose
Accession Number	Individual number assigned to accession
Depth	Depth below datum of accession
Stratum	Stratigraphically defined layer of excavation
Unit Number	Unit of excavation
Material	Material
Function	Usage
Specimen Description	Detailed artifact description
Count	Number of associated artifacts for accession
Weight	Total weight in grams of accession
Reference	Additional notation not applicable to other fields
Year*	Excavation and accession year
Level*	Generalized stratigraphic layer for analysis
Artifact Class*	Generalized artifact category for analysis
*Fields added to catalog specifically for this thesis.	

Table 2 - Generalized artifact categories created and standardized for the Fort St. Joseph archaeological geodatabase with the function of each category, adapted from Benston (2010).

No.	Category Name	Typical Category Function (not an all-inclusive listing)	Functional Summarizing Field
1	Food Prep	Food remains, Tooth	Weight
2	Household	Awl, Cloth Seal, Buckle, Chisel, Clasp, Handle, Straight Pin, Thimble, Tool	Weight
3	Gun or weapon	Butt Plate, Gun Flint, Gun Part, Musket Ball, Projectile, Shot	Weight
4	Structural	Clay, Stone, Wood, Mortar, Other	Weight
5	Natural	Faunal, Fossil, Natural	Weight
6	Unknown	Unknown, Blank	Weight
7	Glass, not beads	Container, Window Pane	Weight
8	Nails	Nail	Count
9	Burnt Wood	Charcoal, Fuel	Weight
10	Bead	Bead	Count
11	Button	Button	Count
12	Adornment	Brooch, Crucifix, Finger Rings, Tinkling Cones	Count
13	Ceramics	Container, Tableware	Weight
14	Smoking Pipe	Smoking Pipe, Pipe Bowl, Pipe Stem	Weight
15	Metal or Coal	Clinker, Fragment, Residue, Scrap, Slag	Weight
16	Modern	Plastic, Post-Fort Items	Weight

Artifact Density Distributions

After the data was updated and formatted, analysis could proceed. The first step of this process was to map the distribution of artifacts by the general categories established in Table 2. This provides a visual representation of the general distribution of artifacts. To organize the data tables to join the data to the unit map, a summary was done of the complete artifact database to organize and sum the count and weight of each artifact category for each individual unit using the "Summarize Table" tool in ArcGIS 10.3. The output of this operation is a table that was then joined to the individual unit shapefile. The distribution of each category could then be visualized by weight or count and standardized by area. The newly created table was standardized and used for further analysis.

Statistical Methods

The application of statistical methods to aid in modelling artifact distribution provides a way to prove the significance of patterns and further establish models to assess artifact distribution across the entire site. Two different methods were used to investigate the distribution of artifacts at Fort St. Joseph in this research. First, cluster analysis was used to identify units that produced a similar artifact assemblage during excavations. Second, a modified version of Dimensional Analysis of Variance was used to identify patterning in distribution across changes in scale of analysis.

Cluster Analysis

Cluster analysis was used to identify similarities among units within the excavations of Fort St. Joseph. Rather than looking at the site in its entirety, each unit was looked at individually and compared with the others. This process identified units that have exposed the same types and amounts (count or weight) of materials. Major outliers were identified by using Spearman's R correlation matrices and then removed. Then a principle component analysis (PCA) was calculated to reduce material types into orthogonal components. The factor loadings from the PCA were saved and used to run a hierarchical cluster analysis and to determine the number of logical clusters for a K-Means cluster analysis. Three clear hierarchical levels of clustering were identified (5, 10, 15 clusters) and the groupings were added to the table and rejoined in ArcMap to be visualized. The results of the clustering analysis identified units that contain similar groupings and overall quantities of artifacts.

A Take on Dimensional Analysis of Variance

In the method for Dimensional Analysis of Variance as developed for archaeology by Robert Whallon (1974), the density of artifacts is examined through comparing patterns at various grid sizes using a variance to mean ratio. Analysis begins with the original grid size used at survey (1 meter^2) and increases by powers of 2 (2 x 2, 4 x 4, 8 x 8, 16 x 16 and so on). The variance and mean are calculated for each artifact class at each block size and the variance to mean ratio is graphed. Peaks in the graph represent block groups that have a high frequency of strong spatial patterning. Any peaks that do exist are also tested for significance within a 95% confidence interval.

Whallon's method has become somewhat outdated, being developed in the peak of the Quantitative Revolution (Djindjian 2015). The drawbacks and critical reviews of Whallon's method considered it too complicated and time consuming to calculate (Riley 1974; Schiffer 1974). However, the technology and methods available for statistical analysis have advanced immensely. With the help of visualization aids like ArcGIS and computer based statistical tools like Minitab, it is possible to use a similar, but more approachable and efficient method of analysis.

After summarizing the count and weight of each unit, the output table was joined with the individual units and the larger fishnet grids, associated with Whallon's power based size increases. This allowed each unit and its associated artifact count and weight to be merged into the larger grid sizes quickly and efficiently. A summary table was then calculated for each fishnet and exported for further analysis. While artifact location for Fort St. Joseph is only known to the 1-meter by 1-meter excavation unit for a majority of the artifacts, the unit grids were divided into quarters to add a .25 meter^2 grid to the analysis. The tables for all the grid sizes were merged into a single file, the preferred format for analysis by Minitab, and two additional fields were added ("New_Unit_Name" and "Grid_Size"). These new fields made identification of specific units easier in the new grids and added a field to group the data by size during analysis.

Once the new data was standardized and cleaned up, a one-way ANOVA assessed similarities and differences within each category. In the operations window in Minitab, the individual artifact categories were chosen as the response and the "Grid_Size" field was chosen as the factor. Equal variances were assumed and a 95% confidence interval was chosen. A Tukey post-hoc test was used with an output of groupings and an interval plot. Expanded result choices for each test also included descriptive statistics, model summary, an interval plot, and analysis of variance of means. Peaks in the interval plot show the grid sizes that are significant as far as patterning in the spatial distribution of artifacts. The Tukey post hoc test proves the statistical significance of the peaks.

Interpolation and Prediction

The final part of analysis looked at creating an interpolated surface to predict the densities of artifacts throughout the site. The excavation data from 2002 through 2014 was used to create a density surface map for each artifact category. Inverse Distance Weighting (IDW) was used to create the density maps based on the artifact distribution by area. This method is preferred for areas with a sparse density of points (Childs 2004). A separate raster was made for each category using the grid sizes that were considered significant by the ANOVA output. The relationship between the resulting raster layers were then used to predict potential density in areas that are yet to be excavated. The input in ArcGIS requires users to select a set number of points or a maximum distance from unknown values to the input dataset to create an interpolated surface. For sake of consistency, a set of parameters was established and used for each category and grid size. The output cell size was set to 1 meter to match the original excavation grid and interpolations were done using a maximum distance of 10 and a total of 24 points. The resulting density maps represent predicted density of unexcavated areas based on the accumulation of artifacts from previously excavated units.

CHAPTER IV
RESULTS AND INTERPRETATIONS

Introduction

This chapter will provide a detailed description of the results of both the K-means clustering and the application of Dimensional Analysis of Variance. The results of the statistical trial for both are presented, followed by the results of these methods with respect to individual artifact categories. The results of the significance testing will be described, as well as artifact categories with distributions that are considered statistically significant. The raster surfaces created through the application of Inverse Distance Weighting (IDW) will also be discussed.

Recreating the Fort St. Joseph Archaeology Project Database

The original FSJ database created by Benston (2010) was obtained from the author to act as a skeleton for the new database. Many of the layers, besides those that were site specific, were out of date. For this reason, the data was updated, categorized, and organized into a new geodatabase structure. Base layer data and shapefiles were obtained from the Michigan Geographic Data Library for Berrien County (State of Michigan 2002-2016). Data was collected to rebuild the basic framework of Berrien County and the City of Niles within the main database. While the main use of this database is the research at hand, a goal of this study was also to create a database for use with future research associated with the fort. Much of the basic framework of the database will not apply directly to this study, it may be of use in future research and conservation of the site. The framework includes a county base layer, hydrography, road networks, elevation points, aerial photography, and historic and modern land cover data.

To develop a framework specifically for the site, certain layers were taken from the original database and updated with new information obtained from more recent project field notes, artifact inventories, and field survey completed during the summer of 2015. Layers retrieved from the original database were the geophysical maps, the one meter by one meter fishnet grid, permanent site markers, and 2002 thru 2009 unit maps. Records and notes used to update these layers was obtained from student field notes and records kept by the Fort St. Joseph Archaeological Project in the WMU Department of Anthropology Lab. Field survey using GPS during the 2015 field season was used to verify the site datum. GPS was also used to collect locational points for the dewatering system. The original unit map was updated to include units excavated since 2009 and the artifact inventories were consolidated and joined to this layer. A geophysical survey was done as part of initial excavations in 2002. Investigations at Fort St. Joseph covered 2300 square meters using multiple techniques, including magnetometry (Benston 2010; Nassaney et. al. 2002-2004). The results of this geophysical survey were obtained from the original database.

During the 2015 field season, amid storms and high water, field measurements were obtained through the use of GPS. These measurements reaffirmed the site datum and permanent points. Measurements were also taken to locate and identify the well points of the site's dewatering system and trees that may impede future excavations. These measurements were recorded in a field notebook as well as by the handheld GPS receiver. After leaving the field the GPS points were converted to a shapefile and added to the database as an additional layer. The locations of known obstacles will aid in planning future excavations and aid in avoiding problems in the field. Several traverses were made to mark the boundaries of the current excavation. It should be noted that high waters caused by spring run-off effected the site during much of the 2015 field season. Based on the common flux of river level, a polygon was created to represent the variations in the river's edge. The boundary of the city landfill was maintained from the original database.

Cluster Analysis

As discussed in the previous chapter, cluster analysis was used to identify units that incorporate similar artifact compositions. Clusters was established at three different levels; 5, 10 and 15 groups. Each level of clustering shows a different pattern across the site. Groups correlate not only with the artifact composition of each unit, but also with the year the unit was excavated. Units that were extreme outliers, or were excavated in 2015, are separated from the regular groupings before analysis. Artifact data for the 2015 units was not yet available for analysis.

At 5 groups (Figure 2), a majority of the units were part of the same two groups. Units considered to be outliers had significantly high densities of a specific artifact category that put them into individual groups. The first group that should be noted is group 1 which includes units that are mainly on the eastern half of the site. The second significant group is group 5 which contains most of the units at the site, including almost all of the 1 meter^2 units. Although most of the units are within one main group, those that are separated into a second group and are located mostly on the eastern side of the site may represent a significant pattern in distribution.

When split into 10 groups (Figure 3), individual characteristics of central units began to appear. Group 1 and 10 correspond to units associated with suspected house foundations and fireplace features. Group 4 corresponds to units next to or containing trash pit features. Group 3 is associated with units that have a high density of food related artifacts such as processed bone.

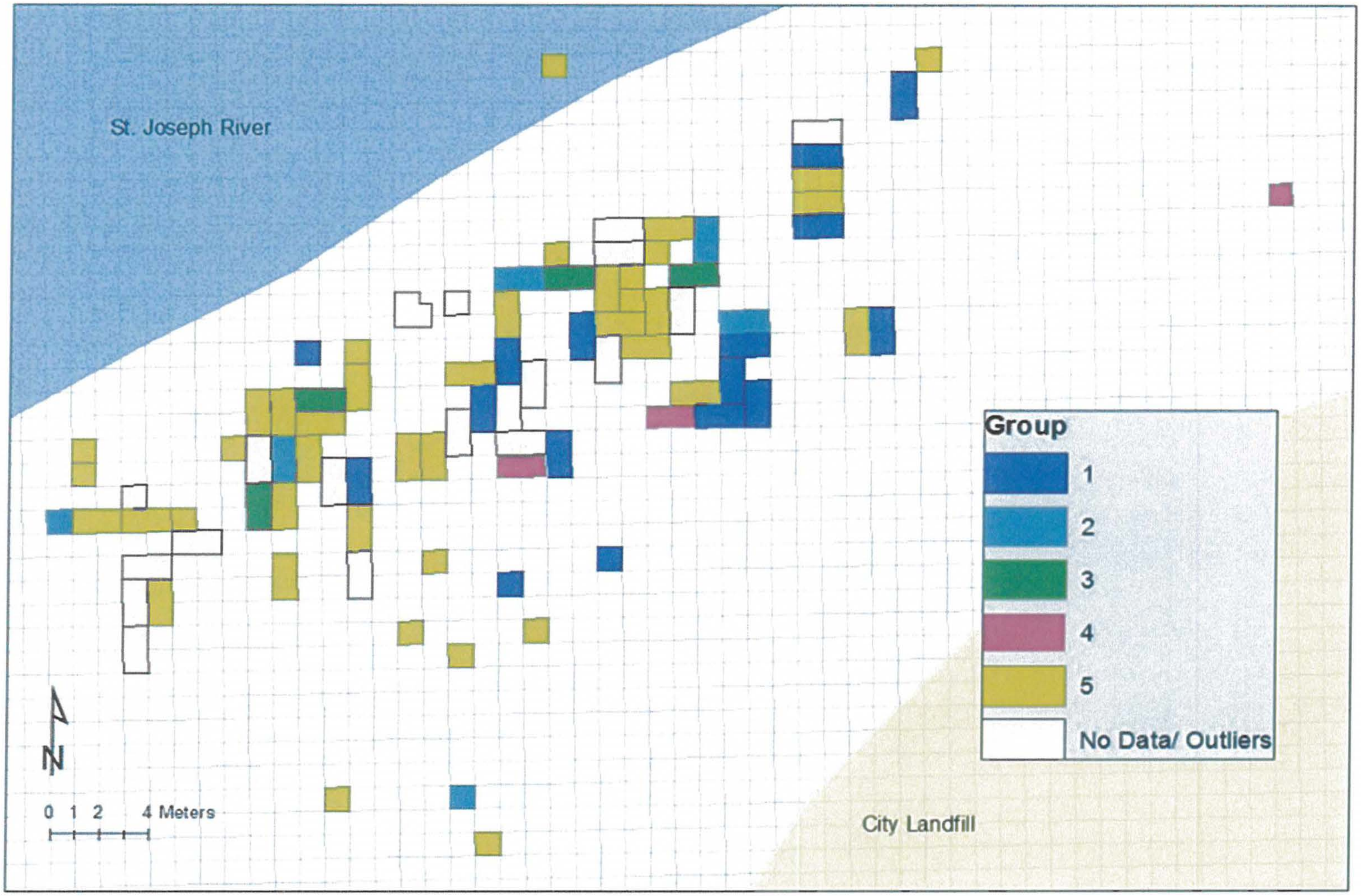


Figure 2 – Map showing units divided into five cluster groups based on cluster analysis of artifact inventories for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

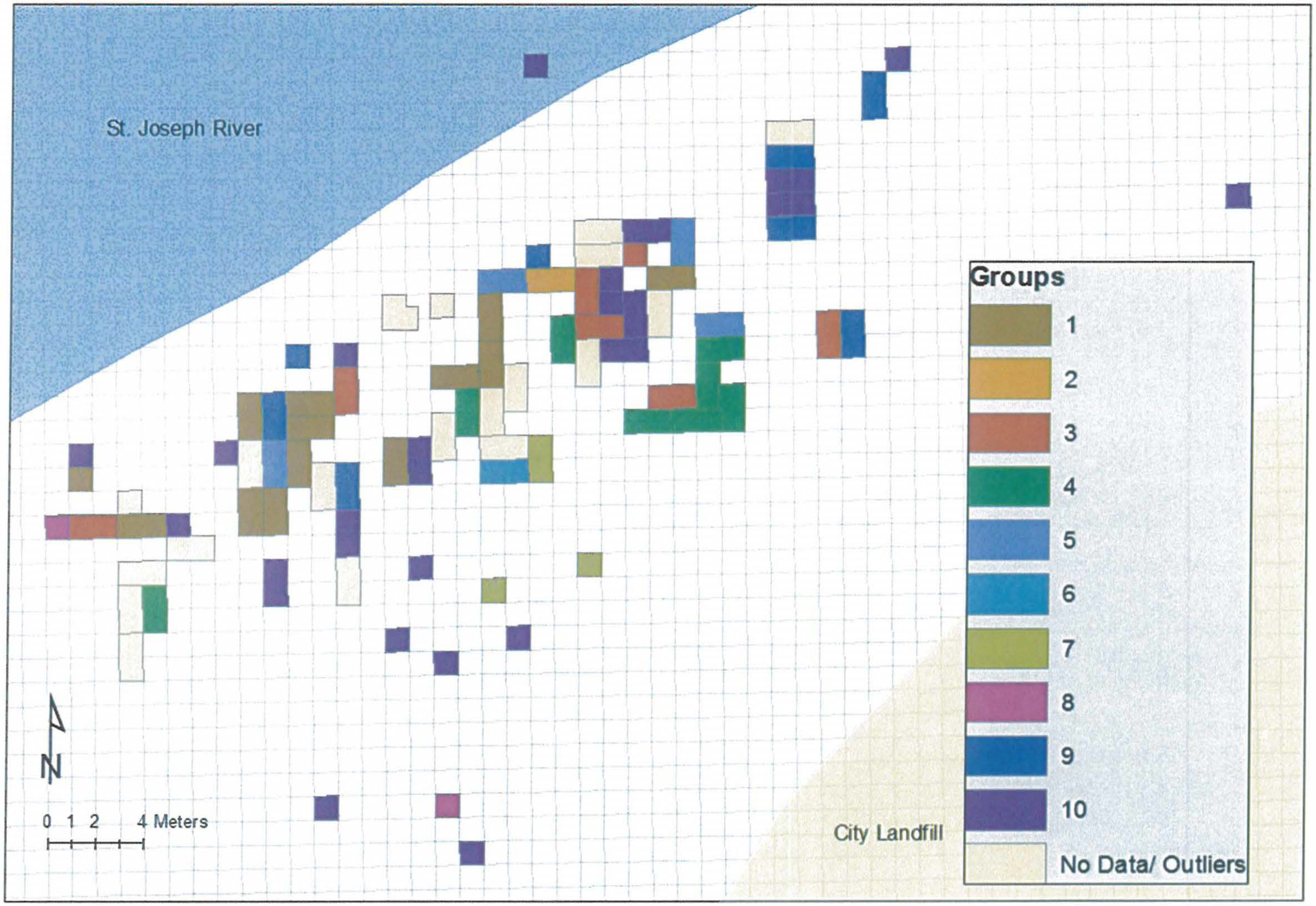


Figure 3 – Map showing units divided into ten cluster groups based on cluster analysis of artifact inventories for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Group 7 is associated with a cluster of units containing a fireplace and trash pit, yet to be defined as an individual structure. The units that make up the other groups have relatively unique artifact compositions.

When the units are divided into 15 groups (Figure 4), a different pattern begins to appear. Units that were considered outliers in the previous clusters remain outliers. Group 5 and 13 covers a broad swath of the site and includes most of the 1 meter^2 units and camper units. Groups 1, 2, 7, 8, and 10 include mostly units excavated since 2010. The remaining groups mostly contain units excavated from 2002 – 2009. This correlation of unit composition to the year of excavation provides an interesting pattern. Although this pattern doesn't correspond to the distribution of artifacts, it may be related to a change in methods of excavation or artifact categorization. Either way, the findings will need further research to explain.

The clustering of artifacts provides an interesting representation of distribution of artifacts at the fort site. It defines the relationship of artifact compositions to specific areas of the site, specific features, and also years of excavation. These results show that across the site there are units with similar artifact compositions and similar features, but also units with a very unique artifact composition that require further investigation. What specifically creates these patterns can be further examined through the mapping of densities of specific artifact categories.

Artifact Density and Frequency

Dimensional Analysis of Variance

The main focus of this research is an analysis of the spatial distribution of artifacts and identification of possible activity areas and areas for future excavation. The results of the one-way ANOVA established the significance of certain grid sizes, or scales of analysis, in relation to the distribution of artifacts at the original excavation grid size. A one-way ANOVA was used

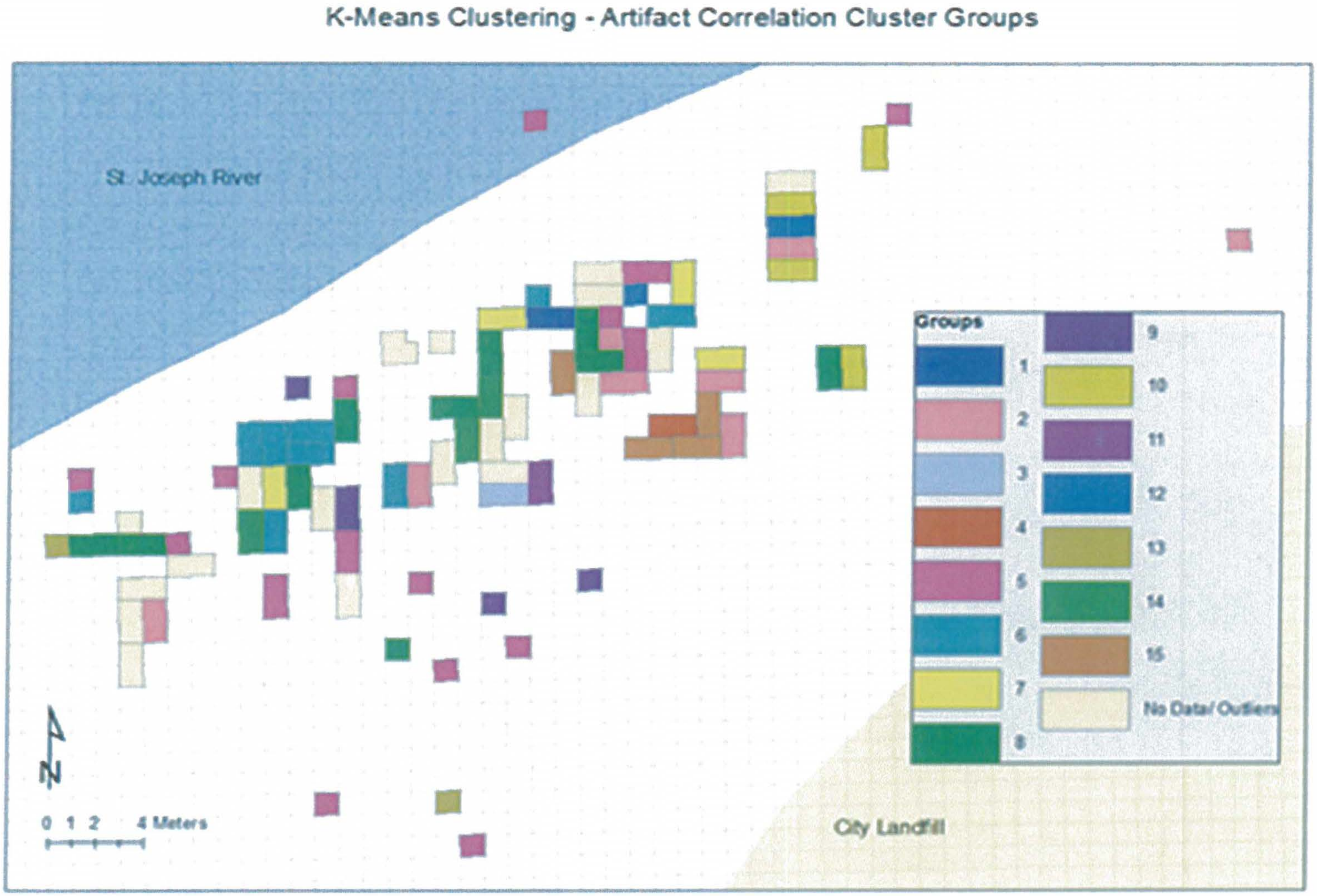


Figure 4 - Map showing units divided into fifteen cluster groups based on cluster analysis of artifact inventories for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

in conjunction with a Tukey post-hoc test to compare the significance of various grid sizes for each artifact category. Significant differences between groups were found among all categories except for unknown materials. The Tukey post-hoc test was used to determine the nature of the differences between the grid sizes.

The analysis revealed that adornment ($F(5,771)=92.39$ $p=.0001$), burnt wood ($F(5,771)=11.09$ $p=.0001$), guns or weaponry ($F(5,771)=13.14$ $p=.0001$), and household materials ($F(5,771)=11.18$ $p=.0001$) had significant differences in the patterning at different grid levels (Table 3). When evaluating the Tukey Pairwise comparisons (Table 4), means that do not share a letter (A, B, C) are significantly different from each other. These artifact categories have more than one grid size in grouping A, in addition to the 1 meter^2 grid. This indicates they are not significantly different from the 1 meter^2 grid and each other, but different from grids in other letter groupings. Grid sizes with means that are not significantly different show similar spatial distributions at different sizes and are mapped to show a more general distribution of artifacts.

For adornment artifacts, the 4 meter^2 and 16 meter^2 grid sizes are not statistically different, and therefore comparable to the 1 meter^2 grid based on the Tukey significance testing. These three grid sizes also correspond to peaks on the interval plot in Figure 5 and were mapped to display the spatial patterning present at each size. In Figure 6, the spatial distribution of artifacts for the 1 meter^2 grid are presented. While the total artifact count for this category is relatively low, there are three areas with a relatively high density of adornment related artifacts. Two units in the southwest corner, one unit towards the center of the site, and a cluster of three units near the east corner of the site have a density of approximately two to five artifacts per square meter. These areas of higher density carry over to the 4 meter^2 grid presented as Figure 7.

Table 3 - ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter² (Sig. p<.05) for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Artifact Category		**Sum of Squares**	***df***	***M* square**	***F***	**Sig.**
Adornment	Between groups	326.2	5	65.2452	92.39	0.0001
	Within groups	544.5	771	0.7062		
	Total	870.7	776			
Household	Between groups	160095	5	32019	11.18	0.0001
	Within groups	2207667	771	2863		
	Total	2367762	776			
Gun or Weaponry	Between groups	940673	5	188135	13.14	0.0001
	Within groups	11041621	771	14321		
	Total	11982294	776			
Burnt Wood	Between groups	134133	5	26827	11.09	0.0001
	Within groups	1865055	771	2419		
	Total	1999188	776			
Unknown	Between groups	82887	5	16577	0.91	0.472
	Within groups	13992449	771	18148		
	Total	14075336	776			
Modern	Between groups	0.2896	5	0.05791	3.51	0.004
	Within groups	12.7002	771	0.01649		
	Total	12.9897	776			

Table 4 - Tukey groupings for comparable artifact categories based on ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter² for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Grid Size	**Adornment**		**Burnt Wood**		**Guns or Weaponry**		**Household**		**Modern**		**Unknown**	
.25x.25	.32	C	6.86	B	17.89	B	7.22	B	0.001	B	5.53	A
1x1	2.18	A	46.3	A	120.8	A	48.7	A	0.07	A	37.3	A
2x2	1.25	B	25.48	A	69.4	A	33.5	A	0.035	AB	20.9	A
4x4	1.72	AB	28.15	AB	69.8	AB	24.43	AB	0.026	AB	14.4	A
8x8	1.05	B	24.35	AB	81.2	AB	28.68	AB	0.037	AB	13.2	A
16x16	1.25	AB	21.94	AB	60.1	AB	23.70	AB	0.025	AB	22.5	A

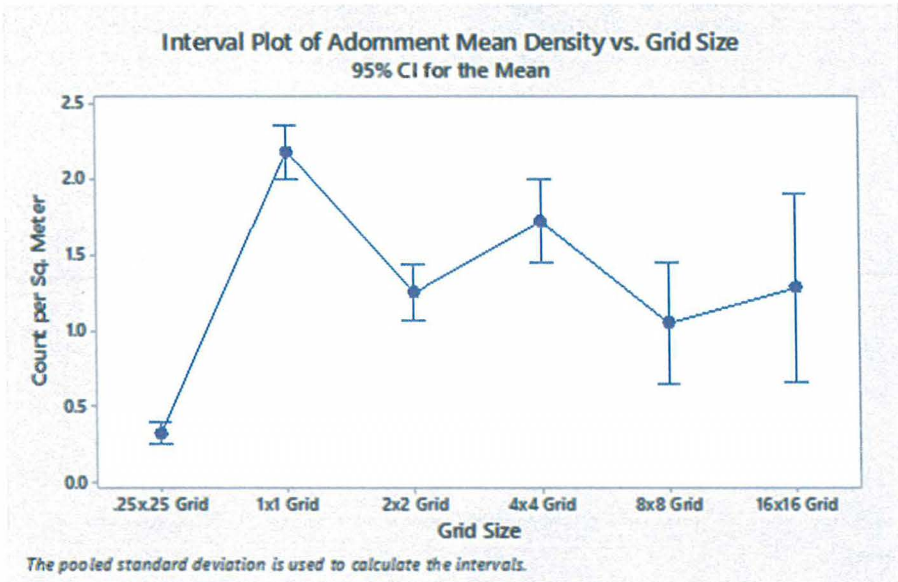


Figure 5 - Interval plot for adornment artifact mean density vs. grid size, based on ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter² for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

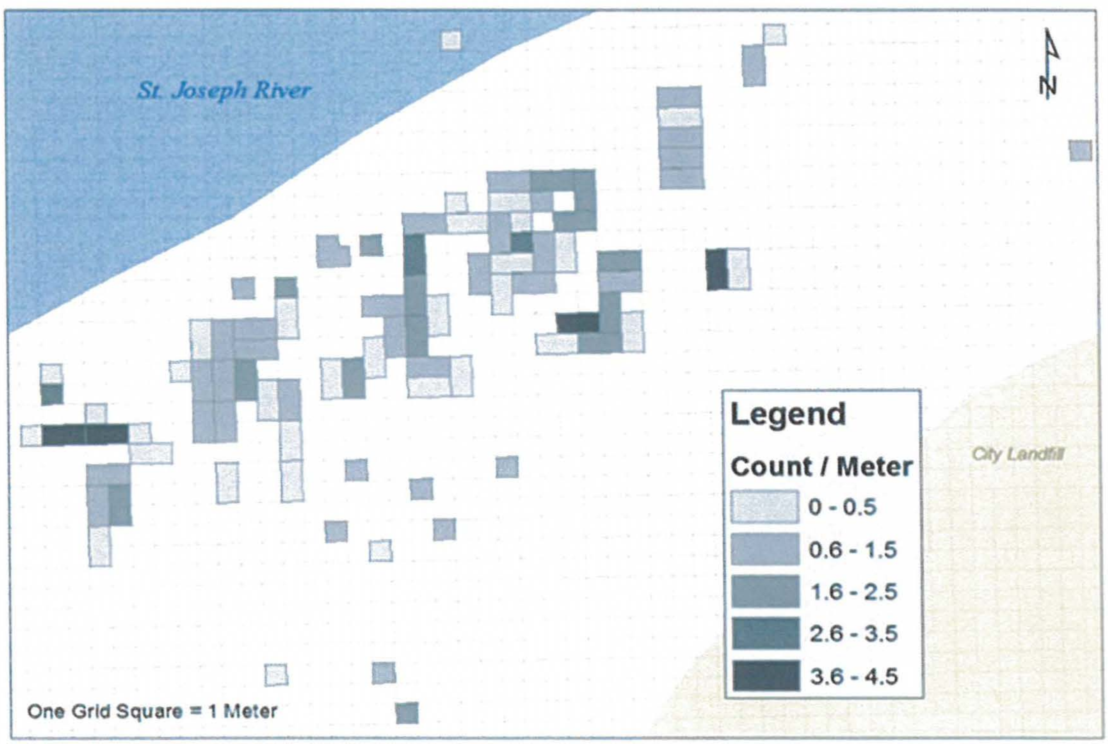


Figure 6 - 1 meter² artifact density map for adornment artifacts based on inventories of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

Figure 1 - Adornment - 4 meter² artifact density map

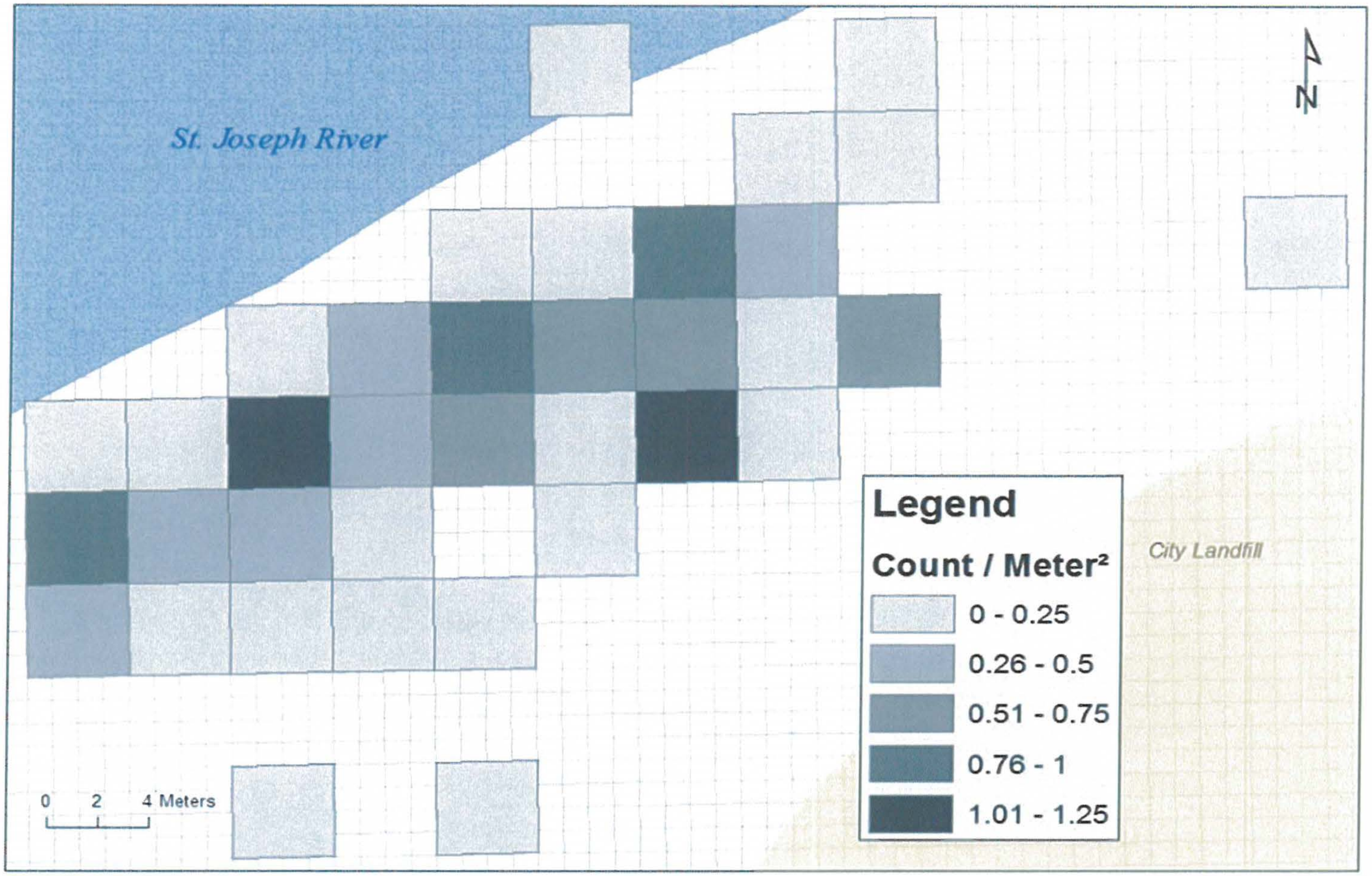


Figure 7 - 4 meter² artifact density map for adornment artifacts based on inventories of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

With this larger grid size, the areas with a high artifact density are similar to the 1 meter^2 grid, with the addition of a region of high density near the central-southwest corner. Although some generalizations are made in regards to unexcavated areas, spatial patterns and areas of high density can still be recognized. While the 16 meter^2 grid (Figure 8) is considered statistically comparable, the actual visualization of artifact density is over generalized. Areas of high density appear to exist in a relatively similar location, a single grid square covers most of the site. Analysis at this grid size may be pertinent for making a broad generalization about distribution at the site, but it cannot account for spatial patterning on a smaller scale.

Tukey results for the burnt wood category (Table 4) show that all grid sizes, except for .25 meters^2 are part of group A and are not statistically different from the 1 meter^2 grid. This means exaggeration at the 2, 4, 8 and 16 meter^2 grids are comparable. Based on the Tukey groupings, the 4, 8, and 16 meter^2 grid sizes are also comparable to each other in grouping B. Since grouping B also contains the .25 meter^2 grid, which is statistically different from the original 1 meter^2 grid, these sizes will not be considered for mapping. When compared to the interval plot (Figure 9), only the means for the 1 and 4 meter^2 grid are identified as peaks, with the interval bars of each larger grid, except the 1 and 2 meter^2 grids, incorporating those of the smaller grids. These broader intervals cause all the grid sizes to be included in the same groupings. Only the grids with mean intervals not overlapping, 1 and 2 meter^2, for this artifact class are comparable. When comparing the two maps visually (Figure 10 and Figure 11), two distinct areas of artifact density appear on the maps for both grid sizes. The first area is in the North central section of the site, and the second in the South central section of the site. Both of these areas of high density exist in or near fireplace features.

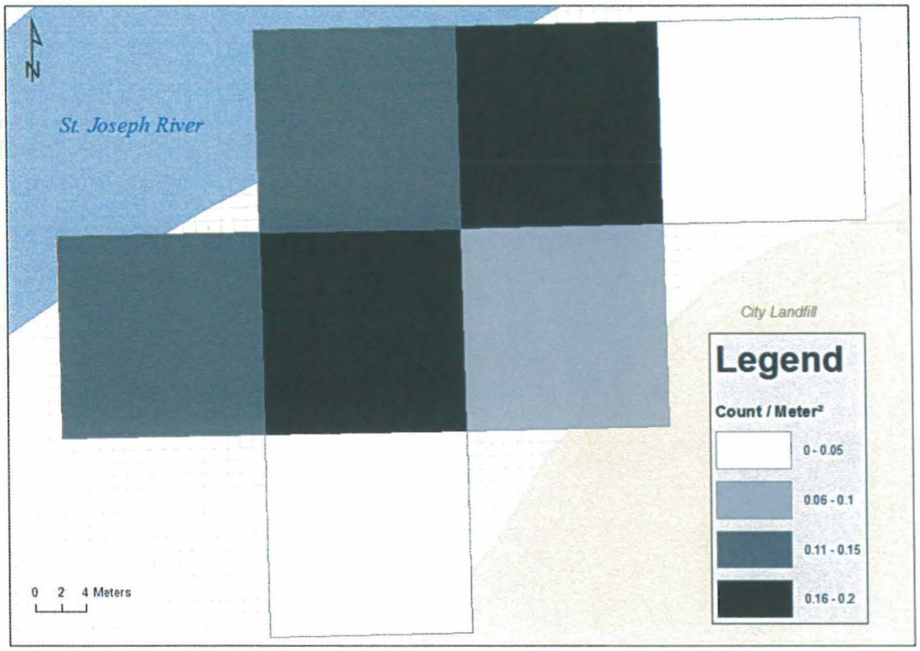


Figure 8 - 16 meter² artifact density map for adornment artifacts based on inventories of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

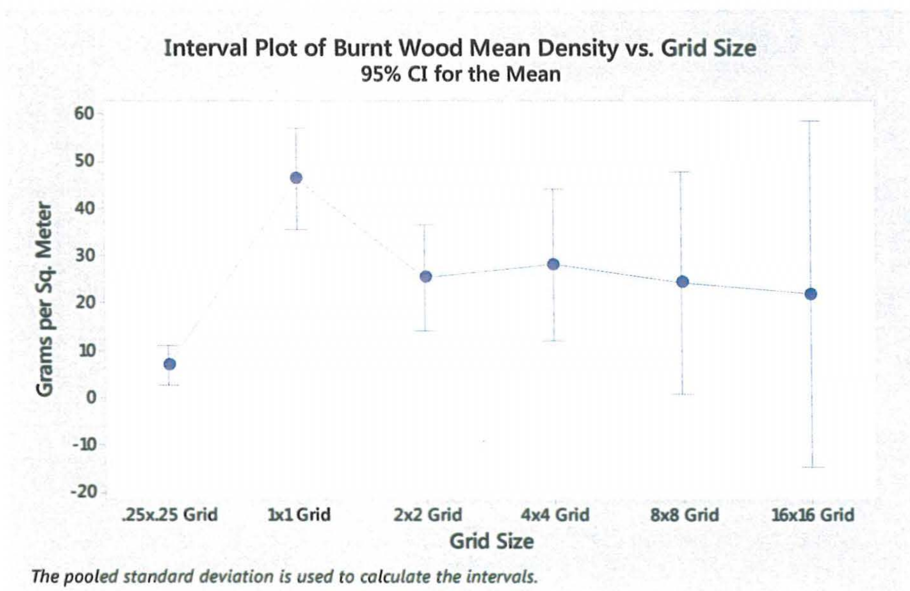


Figure 9 – Interval plot for burnt wood artifact mean density vs. grid size, based on ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter² for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

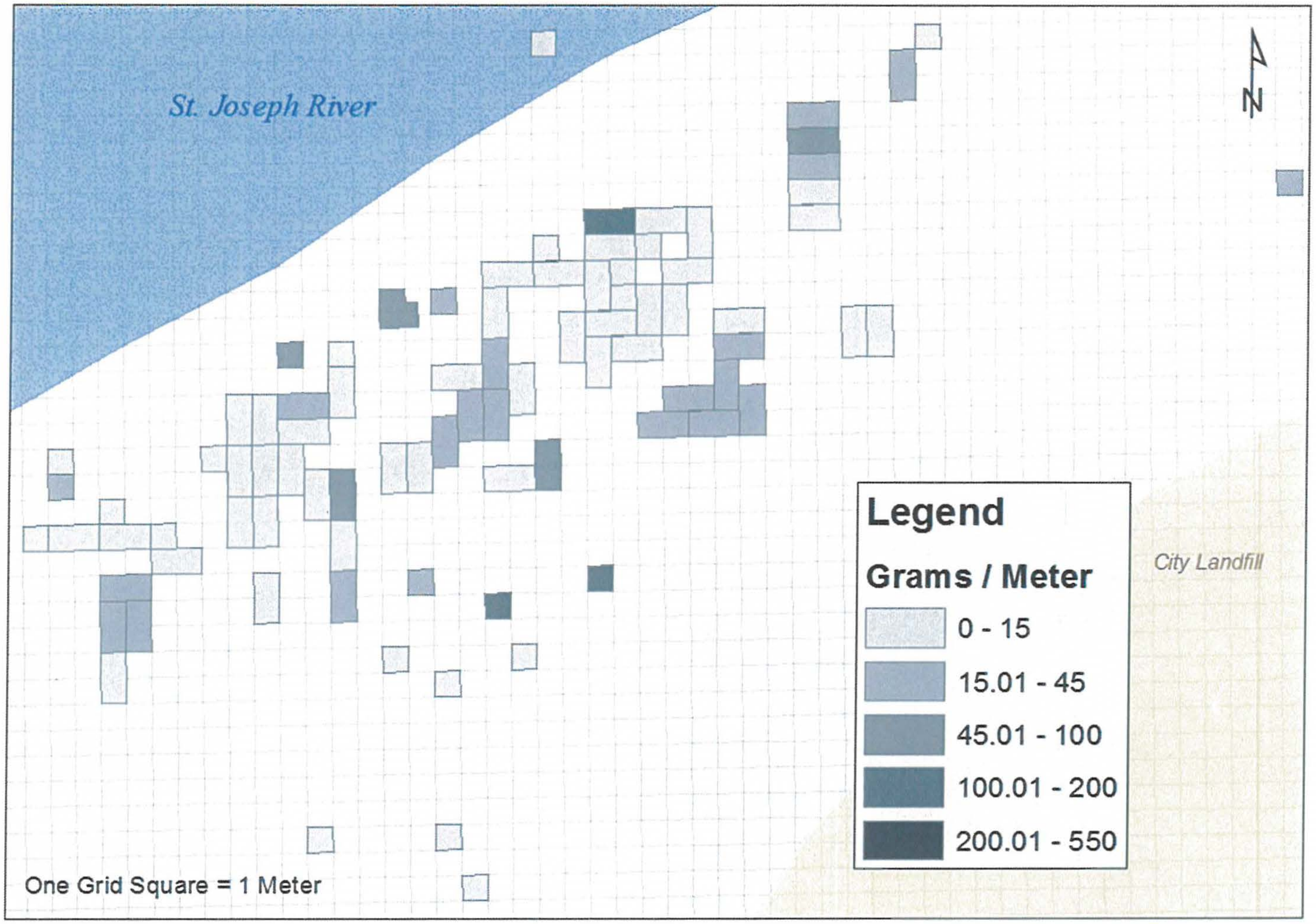


Figure 10 - 1 meter² artifact density map for burnt wood artifacts based on inventories of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

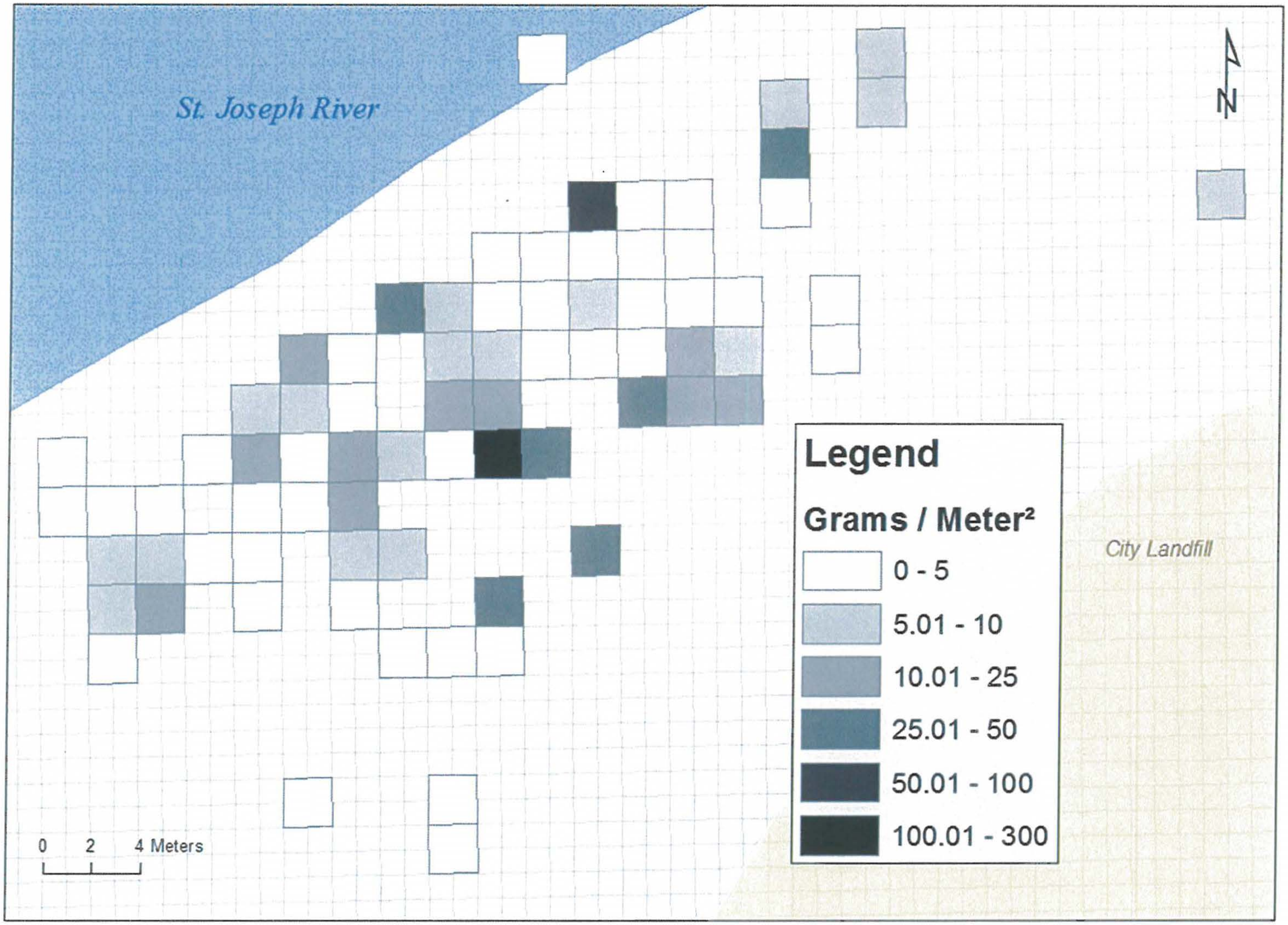
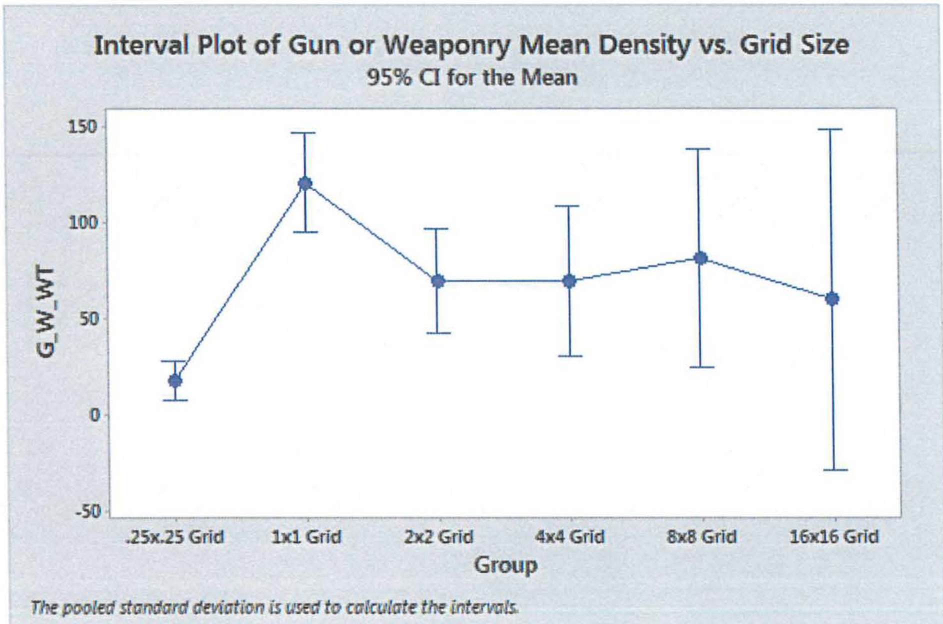


Figure 11 - 2 meter² artifact density map for burnt wood artifacts based on inventories of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

The last artifact groups with significant differences among grid sizes are household and guns and weaponry related artifacts. These two artifact groupings are similar to the burnt wood category, being that all the grid sizes larger than 1 meter^2 are considered statistically insignificant, and comparable to the 1 meter grid. Based on the mean intervals from the interval plots in Figure 12, only the 1 meter and 2 meter grids have ranges that do not fully overlap and should be considered for further analysis. The maps for both artifact groups show similar areas of artifact density between the two sizes, and therefore similar patterning at the larger grid sizes.

Modern and unknown artifacts are also including in this grouping, but results of the one-way ANOVA showed that between groups they were insignificant ($F(5,771)=3.51$ $p=.004$, $F(5,771)=.91$ $p=.4727$). It should be noted that the mean for these two groups is skewed from extremely small sample sizes, compared to the other artifact categories in the group. A majority of the artifacts included in the modern category are present day trash items that were most likely randomly deposited litter or deposited by flood events of the river. Artifacts in the unknown category are undiagnostic and do not contribute information to any of the other artifact categories. These two artifact categories do not represent any significance in the history of the Fort, except for remaining part of the artifact catalog.

While the aforementioned groups have patterning that is visible at different grid sizes, the remaining artifact categories are significant ($p = .0001$) and show significant differences between all grid sizes, with some similarities at the 8 meter^2 and 16 meter^2 grid sizes (Table 5). This is shown in the post-hoc Tukey results in Table 6. These grid sizes are included in group A with the original grid, but are also included in groups B and C with the remaining grid sizes. Although the 16 meter grid appears statistically insignificant and comparable to the original grid size, the visual representation through mapping shows an overgeneralization of the site. At this



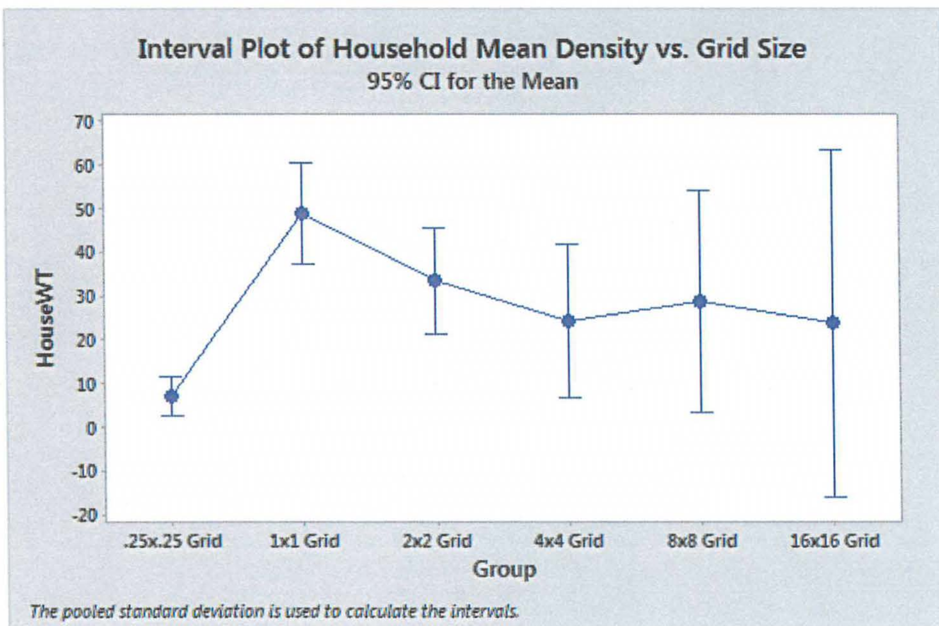


Figure 12 – Interval plot for household artifact mean density vs. grid size (top) and gun and weaponry artifact mean density vs. grid size (bottom), based on ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter² for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Table 5 - ANOVA results of grid size comparisons of artifact categories with over-generalized grid sizes comparable to 1 meter² (Sig. $p<.05$) for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Artifact Category		**Sum of Squares**	***df***	***M* square**	***F***	**Sig.**
Button	Between groups	9.746	5	1.94913	27.04	0.0001
	Within groups	55.577	771	0.07208		
	Total	65.323	776			
Glass	Between groups	179798	5	35959.6	43.75	0.0001
	Within groups	633759	771	822		
	Total	813557	776			
Metal or Coal	Between groups	5762390	5	1152478	70.91	0.0001
	Within groups	12530658	771	16252		
	Total	18293048	776			
Natural	Between groups	791.2	5	158.235	26.19	0.0001
	Within groups	4658.7	771	6.042		
	Total	5449.9	776			
Smoking Pipe	Between groups	4014	5	802.81	31.56	0.0001
	Within groups	19615	771	25.44		
	Total	23629	776			
Structural	Between groups	522909482	5	104581896	67.13	0.0001
	Within groups	1201167078	771	1557934		
	Total	1724076560	776			

Table 6 - Tukey groupings for over-generalized artifact categories based on ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter² for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Group	**Buttons**		**Glass**		**Metal or Coal**		**Natural**		**Smoking Pipe**		**Structural**	
.25x.25	0.057	C	8.121	C	43.91	C	0.53	C	1.15	C	433.7	C
1x1	0.39	A	54.79	A	296.3	A	3.59	A	7.74	A	2930	A
2x2	.25	B	29.61	B	181.4	B	2.02	B	5.05	B	1645	B
4x4	0.20	BC	27.43	B	178.4	B	2.05	B	4.64	B	1497	B
8x8	0.24	ABC	25.05	BC	170.3	B	1.35	BC	4.15	ABC	1275	BC
16x16	0.20	ABC	25.25	ABC	169.3	ABC	1.44	ABC	4.01	ABC	1534	ABC

size, one grid square is approximately the size of the entire site and the lack of detail at this size proves it not useful in studying patterns on an intra-site level. The artifact categories in this grouping with the smallest artifact counts, buttons and smoking pipe related artifacts, showed minimal patterning at the 8 meter² level. Some patterning is visually present, but the grid size is too large to provide a detailed look and define patterns at the Fort site. Maps showing artifact density for these categories can be found in the appendix.

The final grouping of artifacts were considered statistically significant ($p<.0001$), however individually all the grid sizes were also statistically significant and not comparable to the 1 meter grid size (Table 7). In the Tukey post-hoc (Table 8) only the 1 meter grid was included in group A. The other grid sizes were part of group B, C, or B and C. While comparable to each other, the larger grid sizes were not comparable to the 1 meter grid. Based on these results the only comparable patterning for these artifact categories can be seen at the 1 meter grid level. Based on the results of the ANOVA and Tukey post-hoc for all the artifact categories, it is evident that some spatial patterning does exist across the site. When observed unit by unit, there is a specific distribution affected by placement. For many of the artifact categories, by changing the grid size away from the 1 meter² grid, completely new patterns are projected.

The analysis of total weight of artifacts for each stratigraphic layer in terms of this thesis, proved insignificant. Results of the one-way ANOVA showed that each grid size was statistically different from the original 1 meter² unit and also from each other. The Tukey post-hoc placed each layer in a separate grouping. To continue analysis of the stratigraphic layers, only the 1 meter² grids were used as centroids for generating an interpolated density surface.

Table 7 - ANOVA results of grid size comparisons of artifact categories non-comparable to 1 meter^2 (Sig. p<.05) for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Artifact Category		**Sum of Squares**	***df***	***M* square**	***F***	**Sig.**
Beads	Between groups	852733	5	170547	111.52	0.0001
	Within groups	1179032	771	1529		
	Total	2031765	776			
Nails	Between groups	37254	5	7450.79	181.72	0.0001
	Within groups	31611	771	41		
	Total	68865	776			
Ceramics	Between groups	5813	5	1162.69	75.21	0.0001
	Within groups	11920	771	15.46		
	Total	17733	776			
Food	Between groups	266045547	5	53209109	148.49	0.0001
	Within groups	276282933	771	358344		
	Total	542328479	776			
Total Weight	Between groups	2105331623	5	421066325	153.11	0.0001
	Within groups	2120259022	771	2750012		
	Total	4225590644	776			
Total Count	Between groups	386215670	5	77243134	197.19	0.0001
	Within groups	302016553	771	391721		
	Total	688232222	776			

Table 8 - Tukey groupings for non-comparable artifact categories based on ANOVA results of grid size comparisons of artifact categories with grid sizes comparable to 1 meter^2 for the Fort St. Joseph archaeological geodatabase. Prepared by Katelyn Hillmeyer.

Group	**Beads**		**Ceramics**		**Food**		**Nail**		**Total Count**		**Total Weight**	
.25x.25	17.255	C	1.4471	C	307.0	B	13.013	C	325.64	C	764.5	C
1x1	116.4	A	9.76	A	2072	A	87.89	A	2429	A	5725	A
2x2	67.26	B	5.559	B	1194.2	B	52.64	B	1427.8	B	3270	B
4x4	66.22	B	4.941	B	1119.3	B	49.22	B	1351.2	B	3013	B
8x8	60.7	B	4.395	B	954.9	B	45.83	B	1166	B	2633	B
16x16	58.8B	C	4.370	BC	1046	B	50.97	B	1238	B	2962	B

Overall, this method showed that different artifact categories at the FSJ site show patterns at different scales. By disassociating the artifact count or weight with an individual unit and looking at the distribution at a broader scale, patterns and associations with features can be better established. Distribution of these artifacts can also be used to create a more general idea of areas of interest for the entire site, rather than unit by unit. Significant patterns do not occur among all categories of artifacts uniformly. A majority of the categories had consistent patterning only at the 1 $meter^2$ grid size. This may have been caused by the occurrence of excavation units with extremely high or low artifact weights and counts, either at the original grid size or through the combination of units at larger grid sizes.

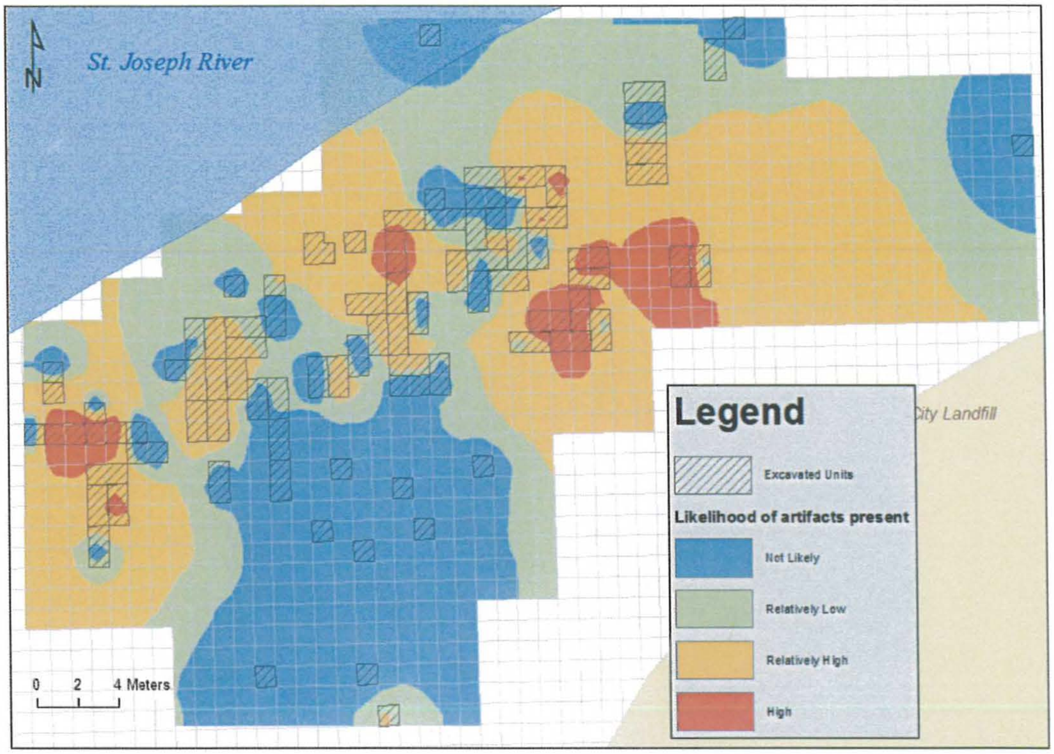
Inverse Distance Weighting and Prediction Surfaces

Once the significant scales of patterning for a particular artifact type was established through the use of the one-way ANOVA, the data at that scale were used as inputs to interpolate distribution of artifacts for unexcavated units. This was done through the use of Inverse Distance Weighting, or IDW, in ArcMap 10.3. Areas out of range of multiple units were masked out based on Tobler's First Law of Geography, which states, "everything is related to everything else, but near things are more related than distant things." (Smith et. al., 2007: pg. 44). Areas towards the edges of the site are predicted based on fewer points, than areas in the center and are therefore less reliable predictions, than areas interpolated based on multiple points. Each IDW surface was classified into 4 classes based on the likelihood of finding artifacts;

1.) Not Likely
2.) Relatively Low Likelihood
3.) Relatively High Likelihood
4.) High Likelihood

The adornment category was found to be best represented by the original 1 meter^2 grid and the 4 meter^2 grid based on ANOVA results. Areas of high artifact density are congruent in both maps (Figure 13), although slightly exaggerated in the 4 meter^2 grid. There is also an additional area of high density towards the western edge of the site. This new region of high density is caused by a cluster of units that are combined as a consequence of the larger grid size. A region of higher density on the eastern edge of the site disappears in the larger grid. This was caused by a cluster of units that were combined with larger unexcavated areas and the artifact count dispersed over more area so the density decreased. A similar, but inverse pattern appears toward the center of the site. Excavated units that contained no adornment artifacts, have been generalized by the surrounding units to show a relatively high chance of finding artifacts.

The other three categories where a larger grid size yielded results comparable to the original grid included household related artifacts, guns and weaponry, and burnt wood. For each of these categories, the 1 meter^2 and 2 meter^2 grids were found to be comparable. A comparison between the two grids for household related artifacts (Figure 14) showed an increase in likelihood near the interior of the site on the 2 meter^2 grid, while the rest of the grid stayed relatively the same. Areas of high likelihood for household related artifacts are surprisingly located around the gun and iron cash, and are less associated with structural features. The burnt wood grids show a similar pattern (Figure 15). Likelihood of artifacts being present increases and becomes somewhat generalized with an increase of grid size. Areas of high likelihood appear around or near fireplace features and are notably high near the center of the site. The guns and weaponry grids (Figure 16) have a decrease in likelihood of finding artifacts throughout the site as the grid size increases. As would be expected, the regions with the highest likelihood correlate with a gun cache feature and an iron cache feature. With all three artifact categories



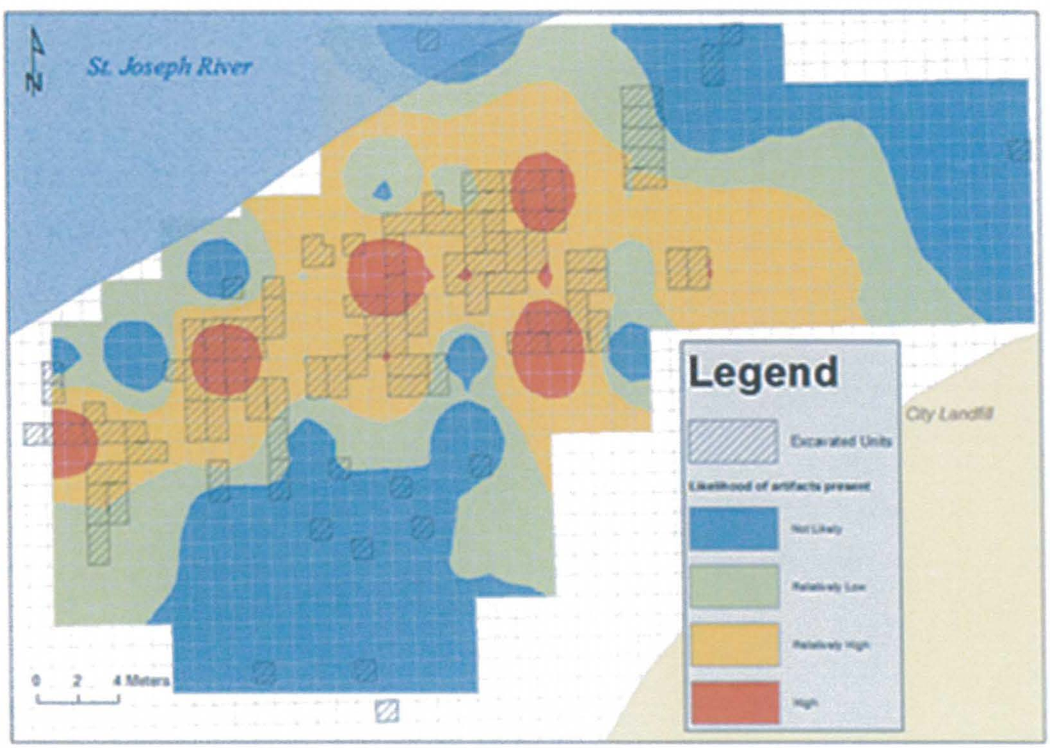
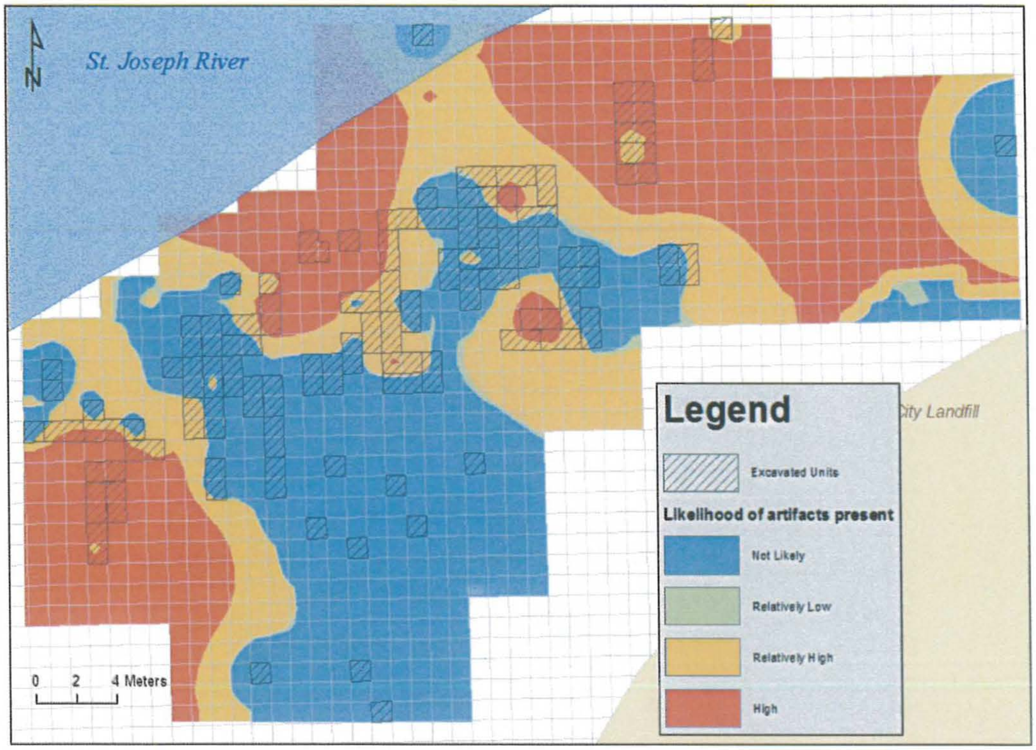


Figure 13 – IDW raster surface for adornment artifacts interpolating from centroids of the 1 meter² grid (top), and 4 meter² grid (bottom) based on the artifact density of each excavation unit of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.



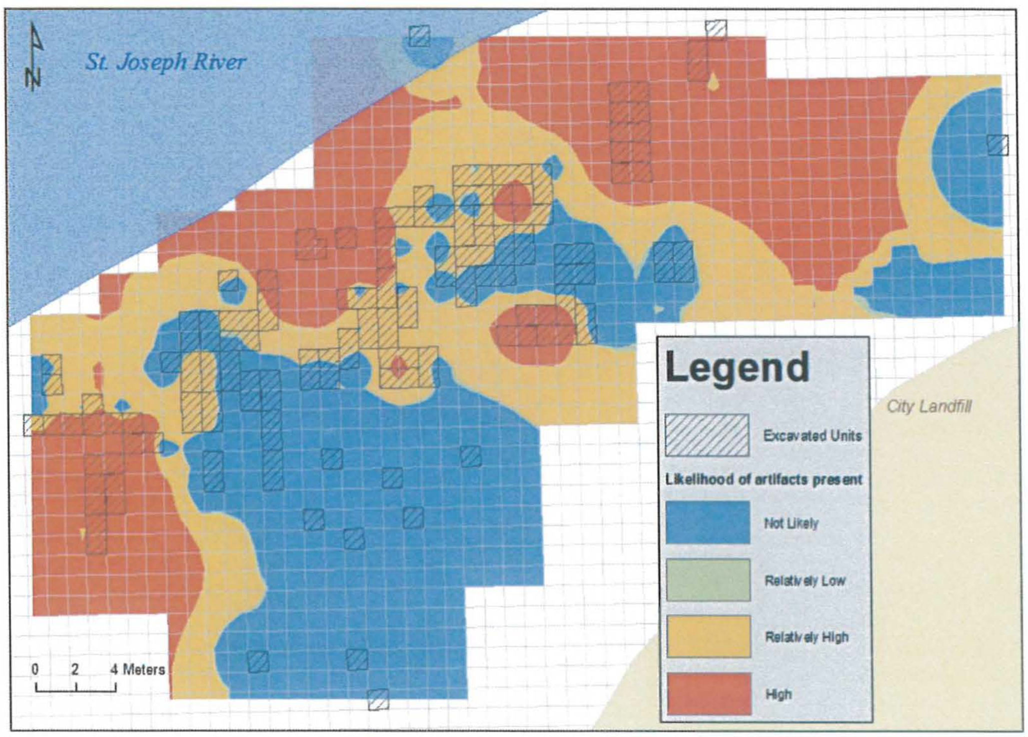
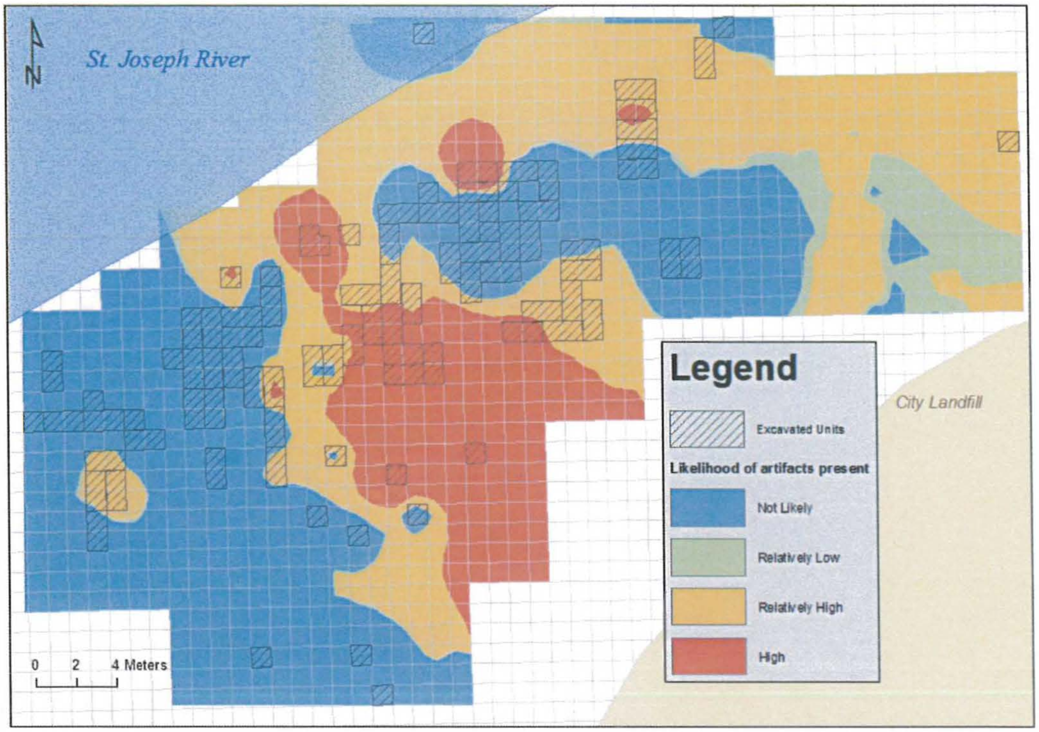


Figure 14 - IDW raster surface for household artifacts interpolating from the centroids of the 1 meter² grid (top), and 2 meter² grid (bottom) based on the artifact density of each excavation unit of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.



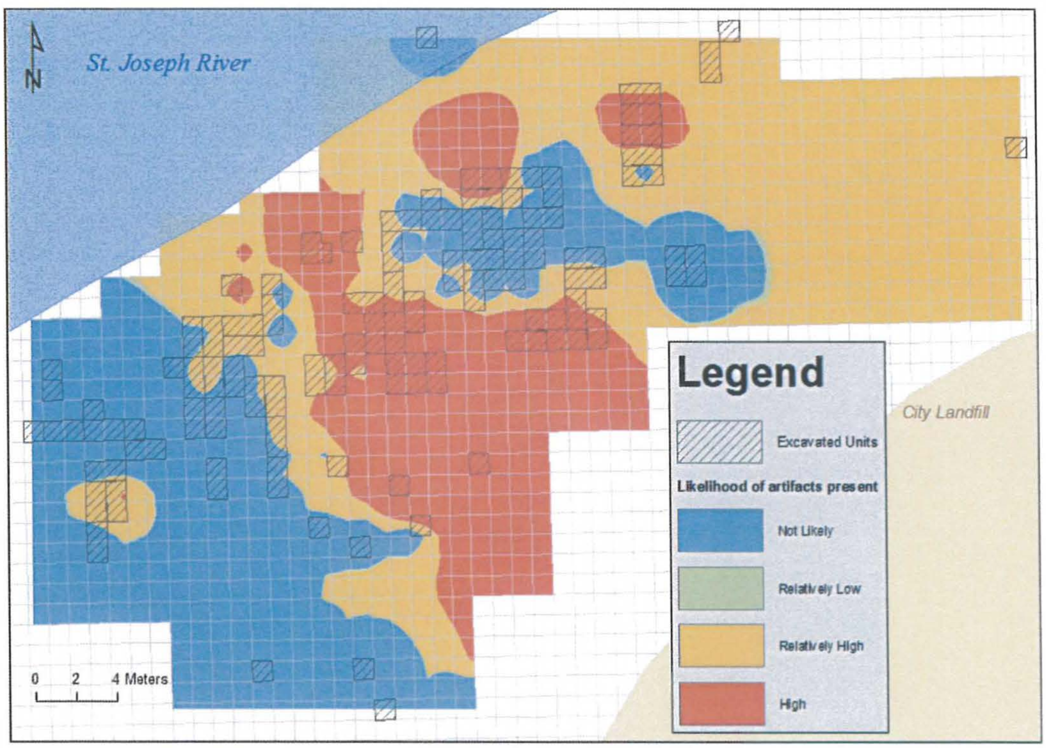
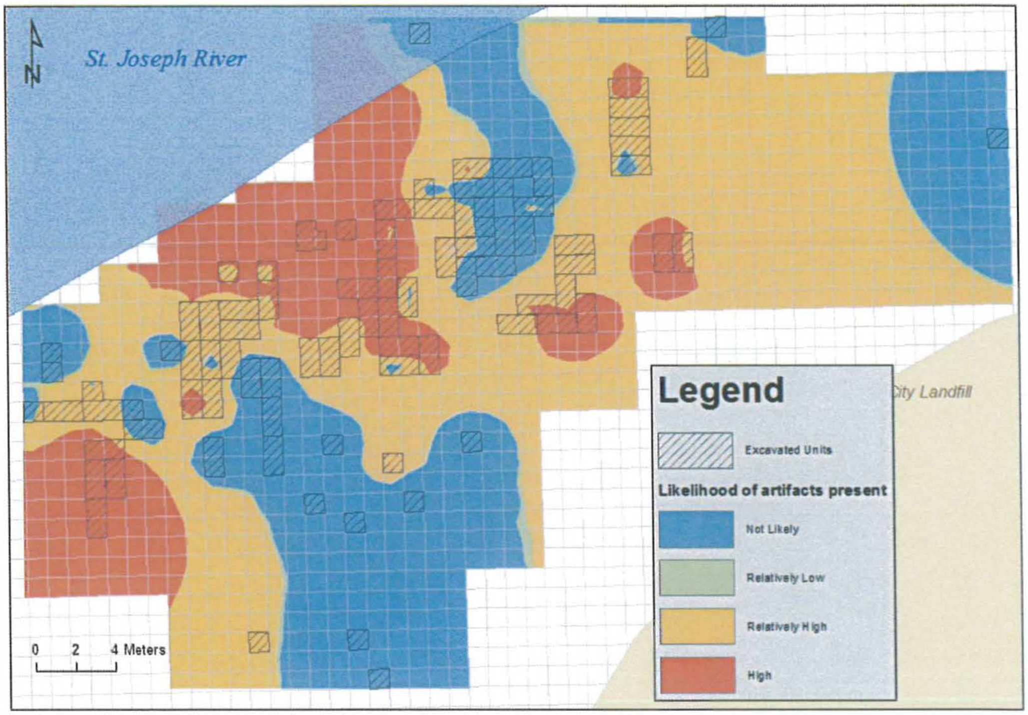


Figure 15 - IDW raster surface for burnt wood artifacts interpolating from the centroids of the 1 meter^2 grid (top), 2 meter^2 grid (bottom) based on the artifact density of each excavation unit of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.



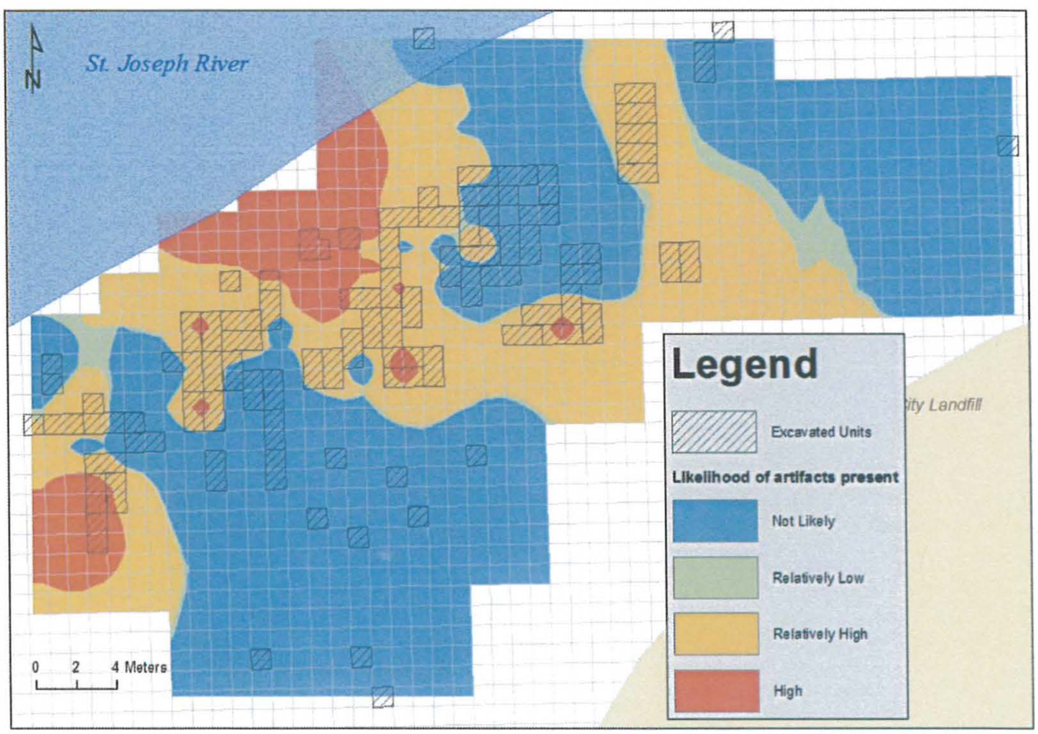


Figure 16 - IDW raster surface for guns and weaponry interpolating from the centroids of the 1 meter² grid (top), 2 meter² grid (bottom) based on the artifact density of each excavation unit of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

there are very limited areas of relatively low likelihood, artifacts are either not likely to be present or there is a relatively high chance of finding artifacts of each category.

Although, many of the other artifact categories are only reliable at the original grid size, the IDW surfaces created for the 1 meter^2 grid show some interesting patterns. While beads are found throughout the site, the highest density and likelihood of beads being present is centered on the iron cache in the southwest corner of the site. Ceramics (Figure 17) have a relatively high chance of being present throughout the site, however the two largest areas are centered on two trash pit features; one in the center of the site and one at the southern edge. Aside from the iron cache on the western edge of the site, a majority of metal artifacts or coal (Figure 17) are most prevalent on the eastern half of the site. While the unknown artifacts (Figure 18) can't provide much information on the site, it is notable that almost all the undiagnostic artifacts come from the same unit, N24 W7, on the western edge of the site. The remaining artifact categories had a relatively even distribution throughout the site with no significant patterning. While the larger grid sizes are not comparable, there is still some patterning present in the IDW surfaces created from the larger grid sizes. These areas do not present a specific location, but rather a larger area of interest.

Based on the results of the ANOVA for the stratigraphic layers, only the 1 m^2 grid was used to create the IDW surfaces for the vertical distribution of artifacts. The only notable patterning when looking at the total density of artifacts for each stratigraphic layer occurred between the plow zone and occupation (Figure 19). When comparing the two surfaces, a region in the central part of the site has a higher density of artifacts in the plow zone layer, as compared to the occupation layer. This may be caused by differences in the historical terrain or a misinterpretation of the stratigraphy in those units.

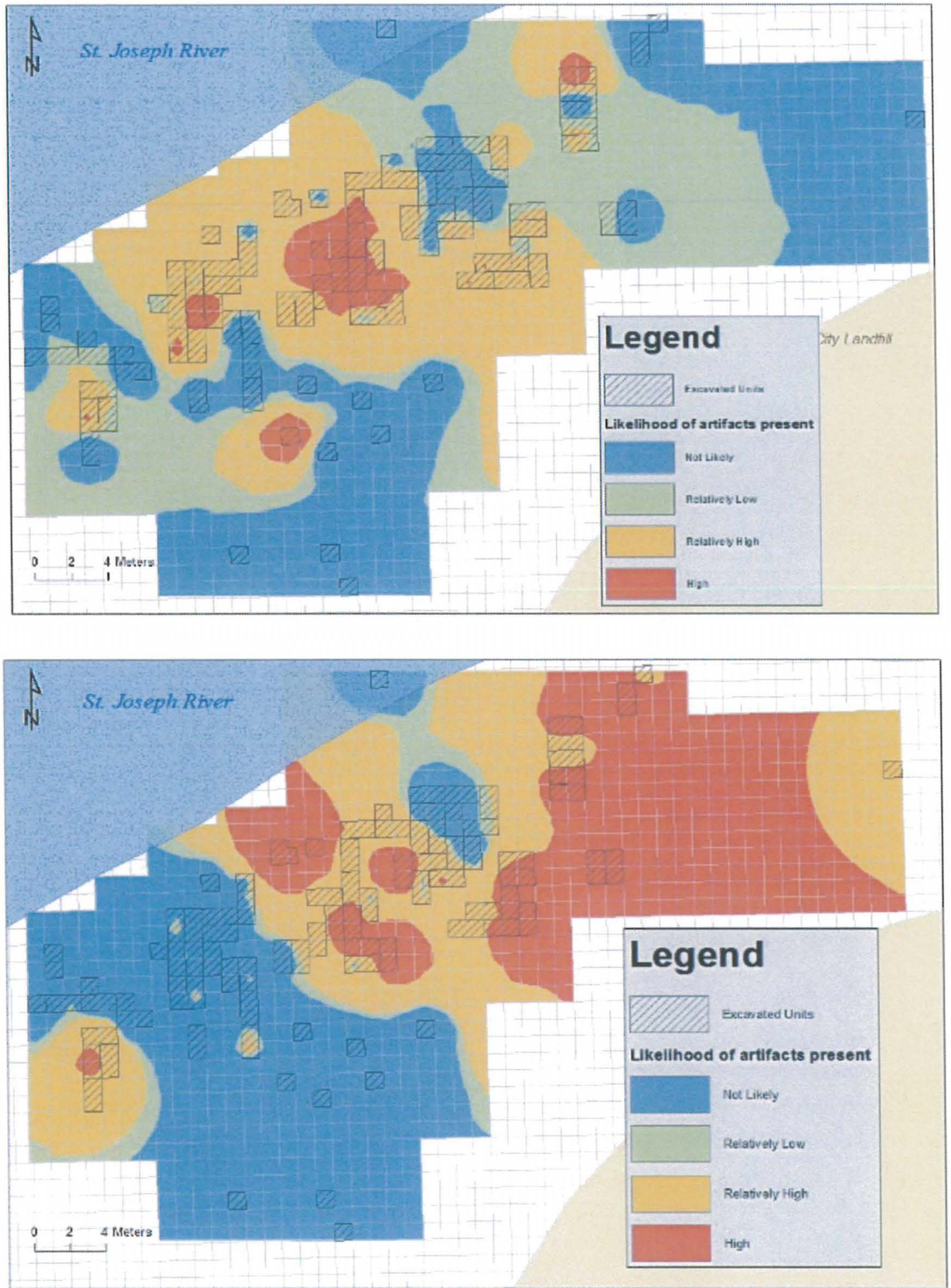


Figure 17 – IDW raster surface interpolating from the centroids of the 1 meter² grid for ceramics (top), metal and coal (bottom) based on the artifact density of each excavation unit of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

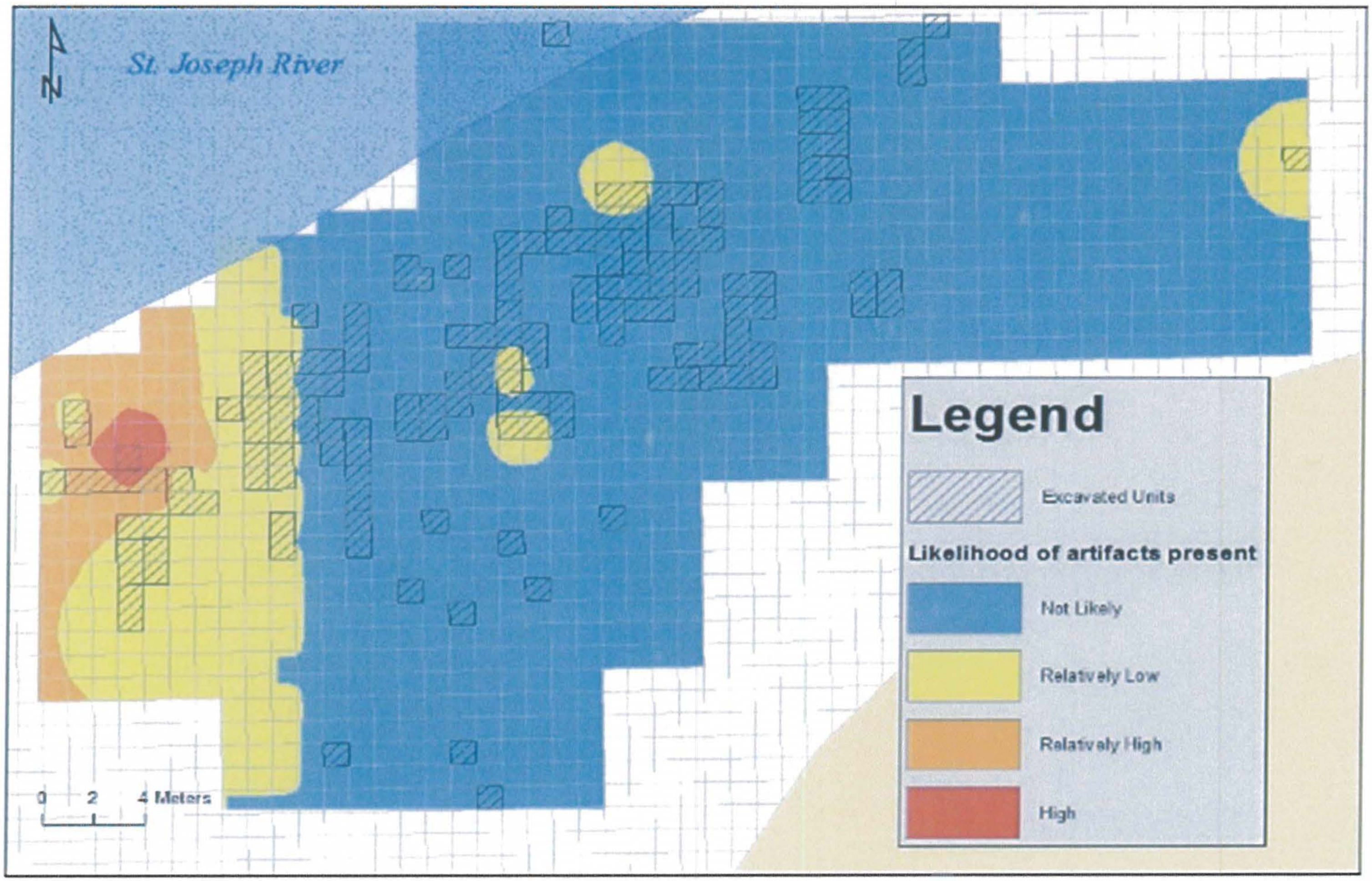
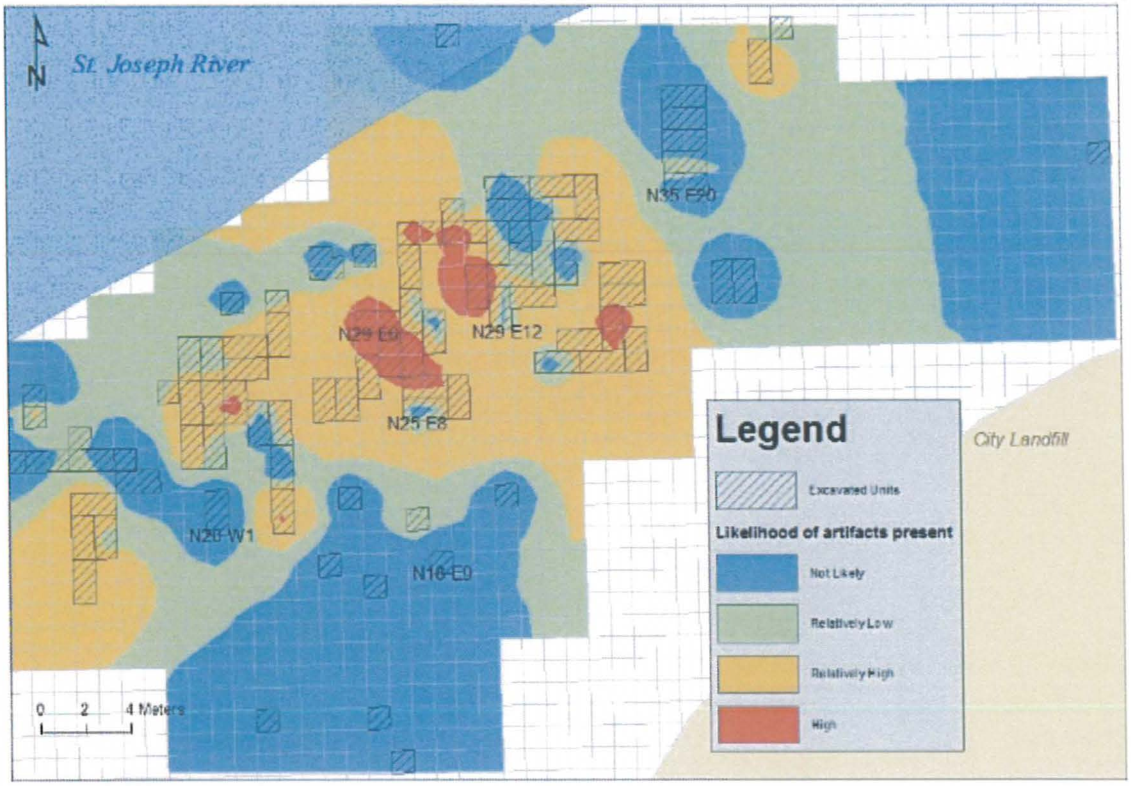


Figure 18 - IDW raster surface interpolating from the centroids of the 1 meter² grid for unknown artifacts based on the artifact density of each excavation unit of the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.



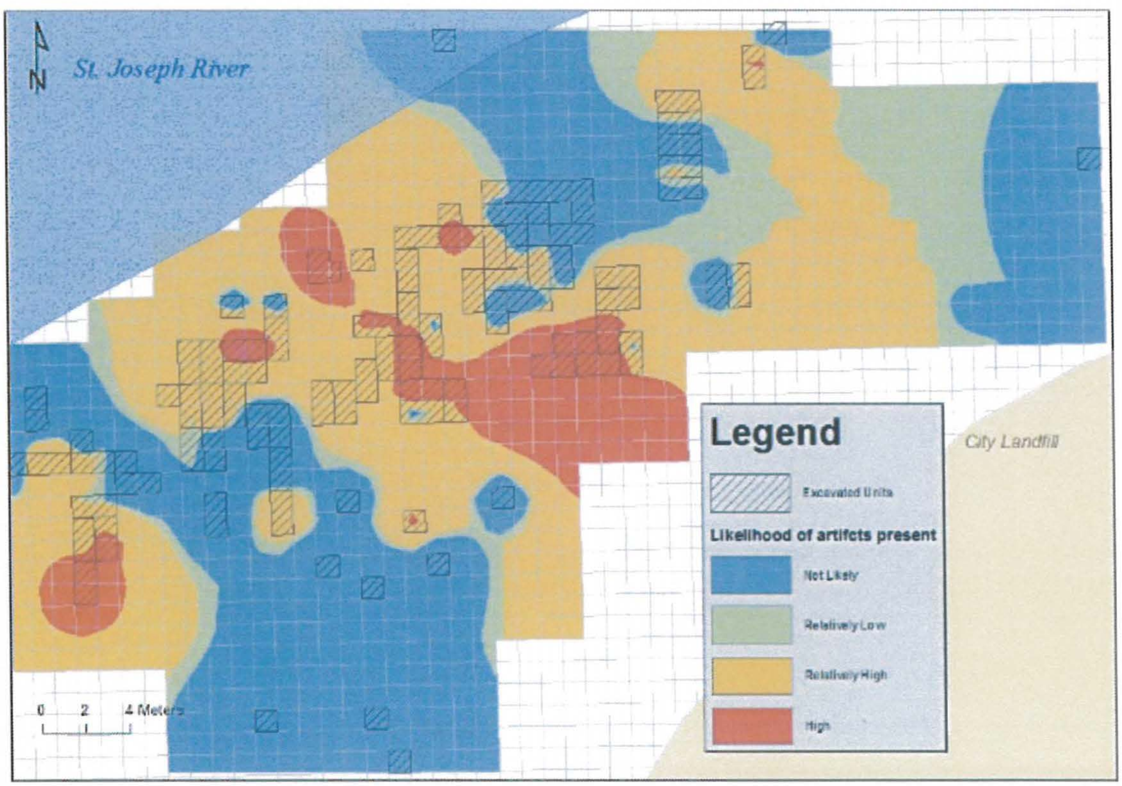


Figure 19 – IDW raster surface interpolating from the centroids of the 1 meter² grid for plow zone (top), occupation (bottom). Prepared by Katelyn Hillmeyer.

Conclusions

Through the use of statistical analysis and visualization methods, a unique perspective of the Fort St. Joseph site has been created. Statistical methods have aided in the creation of maps for each artifact category that can be used to further interpret the site and ultimately predict areas with greater artifact densities. Cluster analysis found similarities among units in terms of the type and density of artifacts and their individual artifact composition. The one-way ANOVA across all categories establishes comparable grid sizes to analyze the site beyond a 1 meter excavation unit. Each of the aforementioned methods abetted the creation of raster surfaces to represent the likelihood of similar artifacts being found in unexcavated units. Through these investigations, a better understanding of the spatial distribution to Fort artifacts and their relative dispersal is established. The example of structural material deposits in relation to features has shown the capabilities of this research and a continued analysis of artifact distribution can contribute to a greater understanding of those who lived and worked at Fort St. Joseph.

CHAPTER V
DISCUSSION AND CONCLUSIONS

Introduction

Spatial analysis in archaeology provides important opportunities to study the distribution and relationship among artifact assemblages and site features. In turn, this information can be used to further push the boundaries of what can be explained in terms of site composition. Historic sites, especially those occupied for multiple decades by different groups of people and adapt to multiple purposes, and inevitably develop a complex artifact assemblage. Therefore, the application of an appropriate, statistically based methodology is necessary. The results of this research prove the efficiency of joining statistical methods and Geographic Information Systems with the more traditional examination and interpretation methods.

Overall Interpretations and Comparison

Looking at the distribution of individual artifact categories across the site creates a unique perspective of the artifact assemblage from Fort St. Joseph. By comparing artifact density predictions based on multiple grid sizes, a more generalized depiction of the assemblage is made. These predictions can generate new ideas of the sites spatial organization and provide new perceptions regarding its occupants.

In general, each grid size displayed relationships among the different artifact categories. The smallest grid size, .25 meters^2, was a division of the 1 meter units into quarters. No real patterns were identifiable at this level of analysis as compared to the 1 m^2 units, but statistical tests found it to be significantly different than the other grid sizes. The 1 m^2 grid, the original excavation grid, included the two by one units with their assemblage evenly divided into one meter units. Any patterning present at this level was accurate to the unit and provided the most reliable patterning. The 2 m^2 grid was only comparable with assemblage categories with relatively high densities of artifacts. The next largest grid size, 4 m^2 was comparable for adornment artifacts only. At these larger grid sizes, the difference in means became more statistically significantly different relative to the original grid. The last two grid sizes, 8 m^2 and 16 m^2, were comparable for some artifact categories, but overall oversimplified the patterns identified in the spatial distributions of the overall site. The next step is to look at how these patterns change or support the current interpretations.

With continued excavations a subsequent increase of knowledge about the Fort site is occurring with new interpretations of the layout of the site constantly being made. In previous research, it was predicted that a row of houses or barracks ran southwest to northeast, through the central region of the site. In addition, there was one main trash pit feature, located near the sites center. Running along the northwest edge was a lane or pathway, as seen in Figure 20 (Benston 2010). Since 2010, additional excavations have uncovered fireplace features and possible foundations as described in field notes and maps (Figure 21). By placing houses with known fireplace features, there is a possibility of two more houses towards the center of the site. However, the lack of further excavations in this area and other supporting evidence prevents the positive identification of more houses.

With this more recent interpretation of the Fort site, additional information can be added from the interpolated surfaces. From overlays of the structure and feature layers with the structural material interpolated surface, an idea of how the structures deteriorated begins to unfold. Based on Table 2, the structural material category consists of "clay, stone, wood, and mortar", the materials most structures at the site would have been constructed with. When this category is mapped and interpolated (Figure 22), the areas of highest density or likelihood fall to

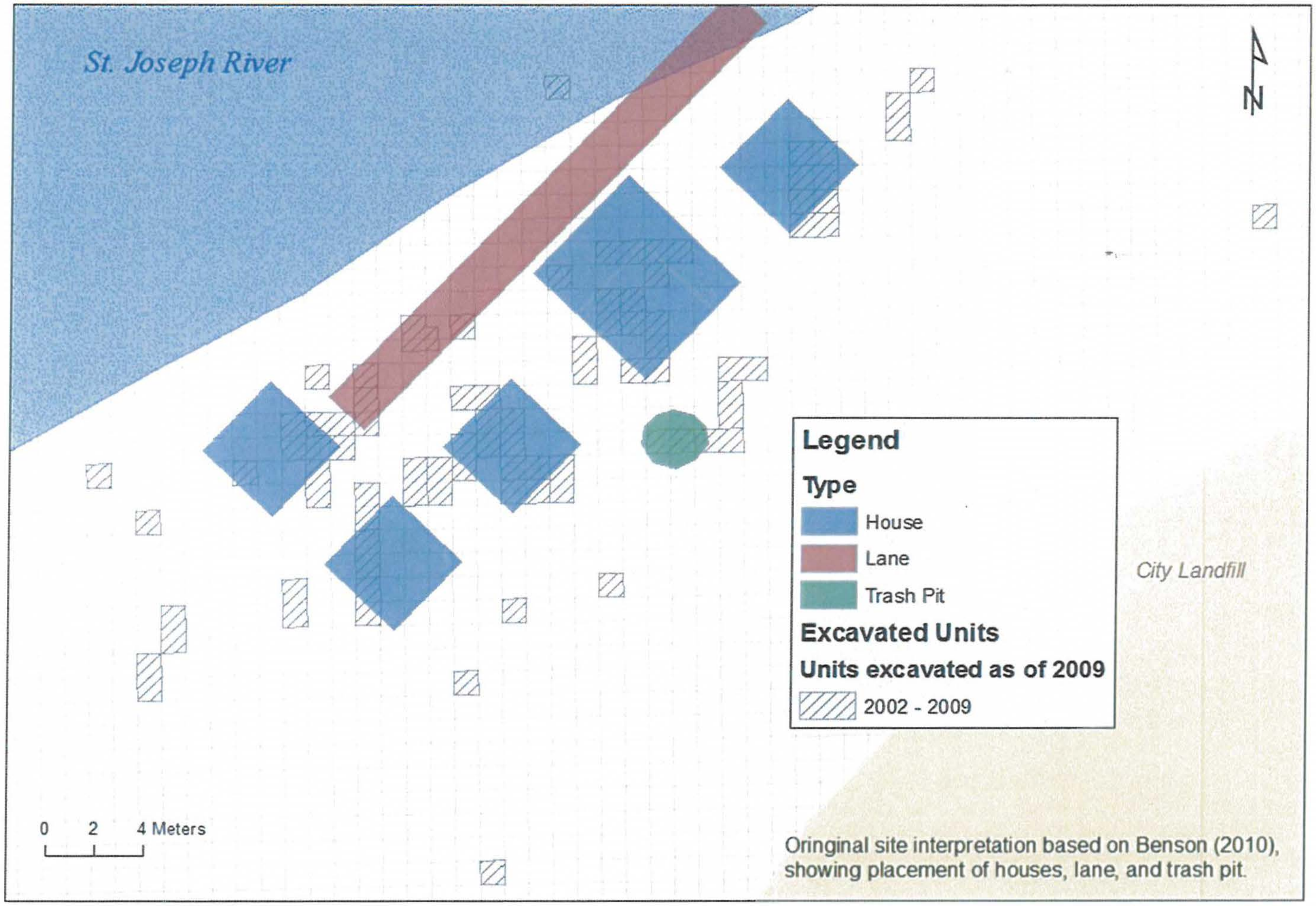


Figure 20 – Former site interpretation showing a row of houses and a trash pit along a lane, based on Benston, (2010) and data from the Fort St. Joseph Archaeological Project. Prepared by Katelyn Hillmeyer.

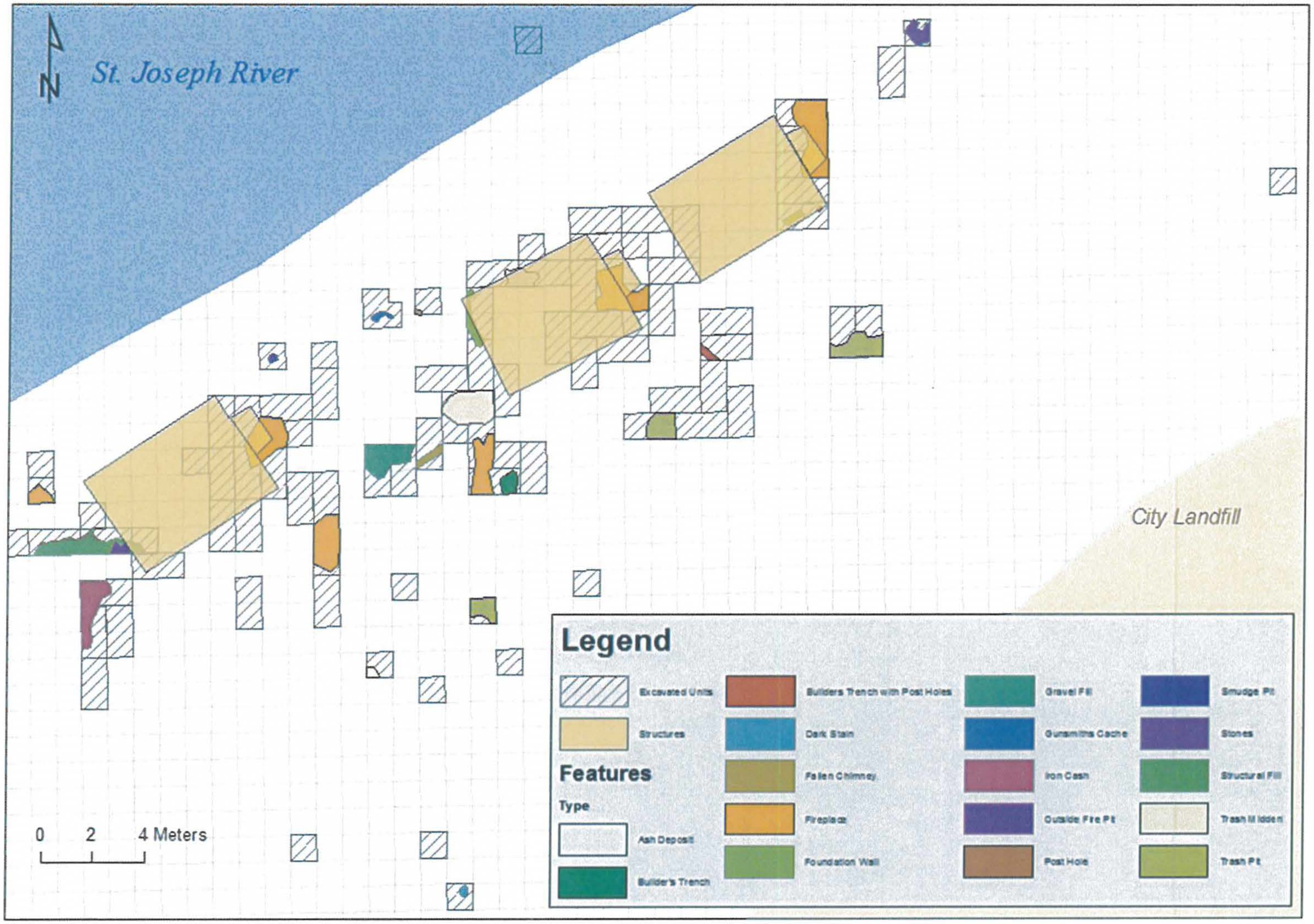


Figure 21 –Current site interpretation showing three identified houses in relation to known features based on information from the Fort St. Joseph Archaeological Project and geodatabase. Prepared by Katelyn Hillmeyer.

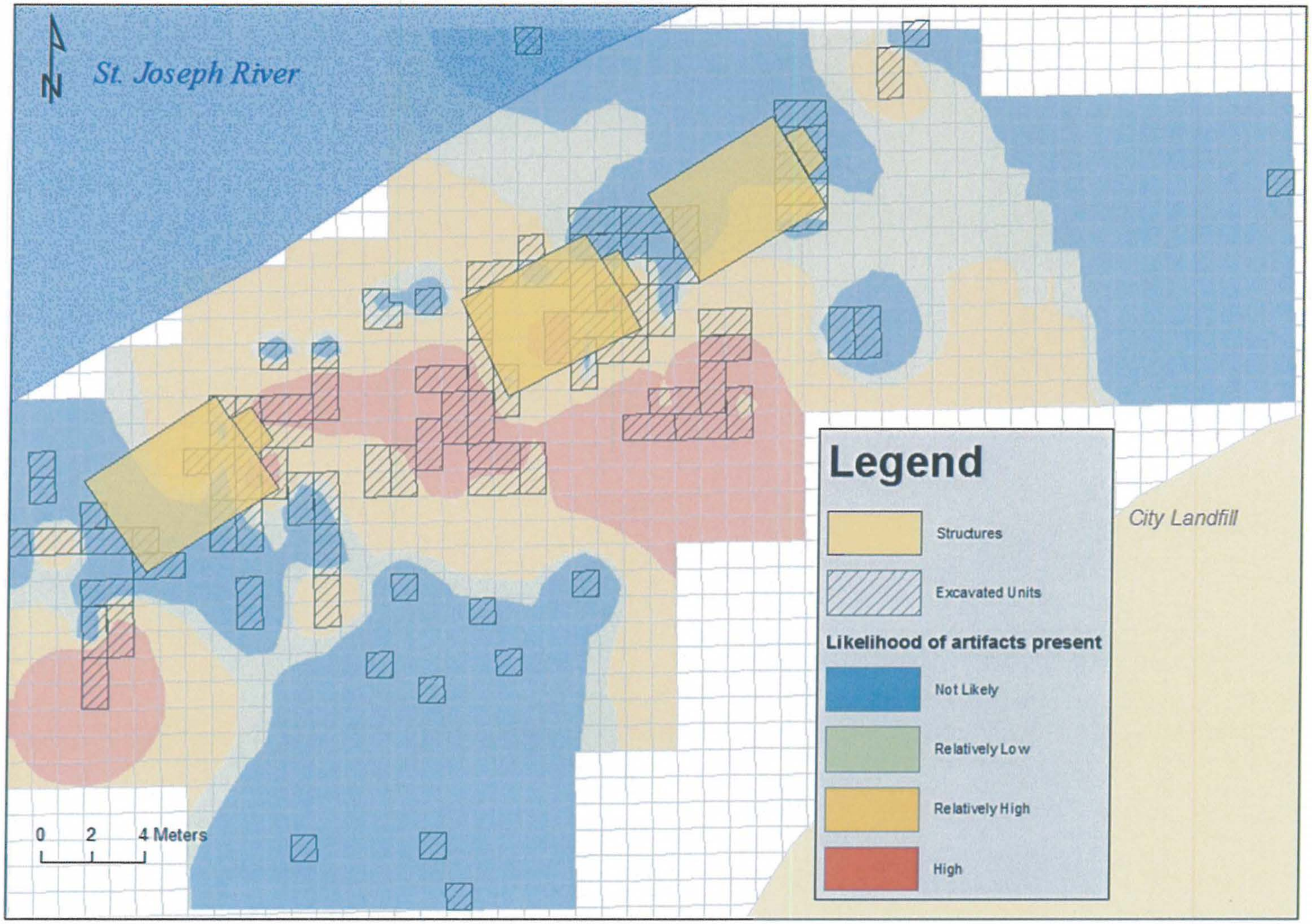


Figure 22 –Overlay of the three interpreted structures and the IDW raster surface for structural material interpolated from the centroids of the 1 meter² grid to show the relationship of related artifacts to structural feature interpretation at Fort St. Joseph. Prepared by Katelyn Hillmeyer.

the southwest and southeast of the house structure at the center of the site. The interpolated surface for the likelihood of finding nails also centers on this same structure, in a similar pattern. By including the features in the same overlay (Figure 23), gravel and structural fill features are also in close proximity. The location of these dense areas and features in relation to the structure could show the gradual deterioration and eventual outward collapse of the structure's walls. The compilation of the previously mapped features and structures with the newly created interpolated surfaces show the interaction between in-situ deposits such as foundations, with the more widely dispersed artifacts found in the assemblage, which in turn reinforces interpretations and fuel new ideas.

Methodological Concerns

There are several methodological concerns to be considered with respect to the dataset and methods used for this research. Questions of concern rise from the collection of site data, continuity of artifact inventories, and method of analysis. In regards to the collection of data, some of the data collected from field notes and related records may contain some errors. Much of this information is collected by students during summer field schools. Many of these students are new to archaeology and still gaining skills in measuring, identifying soils and associated stratigraphic data with artifacts, and recognizing artifacts themselves. Each unit is excavated by different people, with different backgrounds and different approaches to the same methods. These differences can influence how and what data gets recorded, particularly in regards to the interpretation of features.

The inclusion of some particular excluded m^2 units may also impact the predicted artifact density. Certain units have only been excavated to the bottom of the plow zone or the very top of the occupation layer. Although these units may have produced a high density of artifacts,

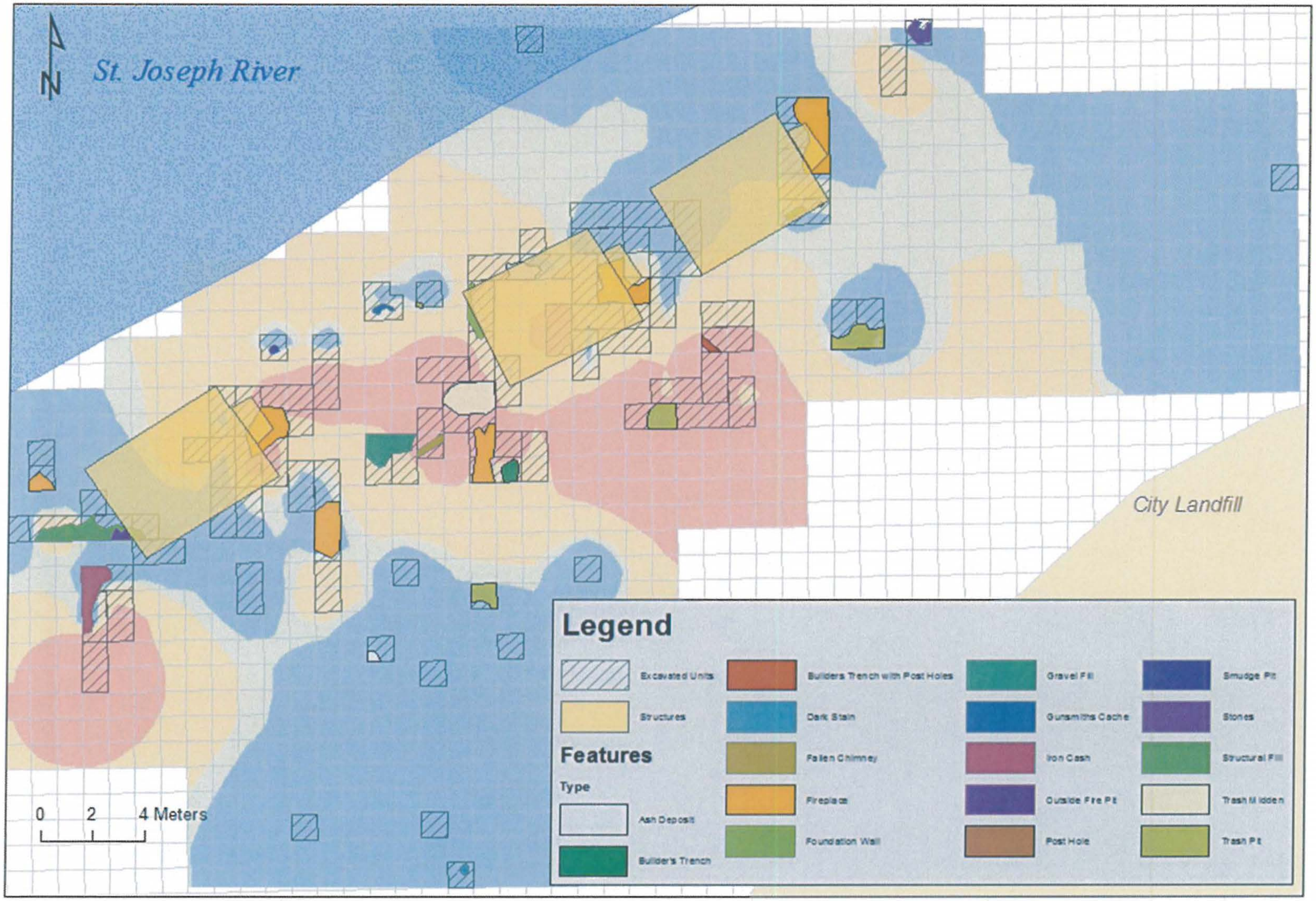


Figure 23 – Overlay of the three interpreted structures and the IDW raster surface for structural material interpolated from the centroids of the 1 meter² grid to show the relationship of related artifacts to structural feature interpretation with the addition of all known site features at Fort St. Joseph. Prepared by Katelyn Hillmeyer.

many of those artifacts were most likely not in-situ, or in their original location of deposition. Artifacts no longer in their original location of deposition may not be the most reliable source of information on specific activity areas, but may still provide information on the overall site. It is also important to note that many of the categories are lost items; stray buttons, beads that fell off clothing, etc. There are patterns in where items may be discovered, but these patterns cannot describe 100% of the cases (loss, abandonment, and discarding) and how artifacts end up where they are found.

Contiguity and continuation of artifact inventories and the database create another area of methodological concern. Adjustments were made to the artifact inventories. Additional fields existed in some of the artifact inventories. While these fields were not necessary for this analysis, a uniform format should be encouraged for subsequent years to provide a reliable, well-structured data source over time. Another issue arose from the use of different wordings and acronyms for the same term. Although database programs have the ability to create and maintain subtypes and domains for a field, Excel does not. Having multiple wordings for the type of artifact or any given stratigraphic layer will pose major drawbacks when querying or summarizing the dataset. An attempt was made to overcome this setback by creating new fields and combining similar groupings. A common terms dictionary should be developed and promoted for all subsequent excavations.

Some methodological concerns also exist with methods of analysis selected for this research specifically. The first comes with the use of Dimensional Analysis of Variance (DAV), or rather the modern approach to DAV using one-way ANOVA. The best application of this method is a continuous excavated surface. The standardization of each unit does not necessarily account for unexcavated areas within the larger grid sizes. The inclusion of these areas lowers the overall density by spreading the count or weight of artifacts out over unknown units. Another methodological concern is related to the vertical analysis. Rather than looking at each category individually, the total count was used. The main reason for this was a lack of all artifacts assigned to all the categories in each unit for each stratigraphic layer and the differences in weight for each category. While two units may have 50 artifacts, 50 beads weigh much less than 50 nails. By considering total count, the discrepancy of weight is discarded and a general idea of individual objects being excavated is analyzed. Different approaches to the same problem of distribution can provide unique answers. When attempting to visualize unexcavated areas, interpolation surfaces are predictions. Only through further analysis and the testing of those predictions can we establish each methods suitability.

Spatial Organization at Fort St. Joseph

The analysis of the several artifact categories of the assemblage at Fort St. Joseph measured at six different grid sizes (presented in Chapters 3 and 4) identified discrete, but statistically comparable patterning, which could be used to enforce current interpretations and establish new ideas. Over the relatively long occupation of the Fort, varied and diverse groups inhabited the site resulting in a large, rich artifact assemblage. Densities of smaller artifact categories relate to trash pits, caches, and random distribution. The larger artifact categories showed relations to structural features, but also established densities in certain portions of the site. Despite disturbance throughout much of the site from seasonal flooding and agricultural use, it is still possible to distinguish areas of interest based on artifact distributions. Due to the complexity of the artifact assemblage, precise activity areas were hard to distinguish, aside from high density areas associated with features.

Two-Dimensional Spatial Analysis

At the outset, one of the primary goals was defined as the implementation and evaluation of an effective method of spatial analysis for the artifact collection from Fort St. Joseph. Minitab 17 was selected for quantitative analysis and combined with ArcMap 10.3 quantitative analysis and visual display. The analysis produced clusters that were generally representative of patterns among the individual units. ANOVA analysis identified some artifact distributions at varied grid sizes that were comparable to the original unit size; however, important limitations associated with the procedure became apparent. First is related to the lack of precise artifact locations, which limits the analysis at smaller grid sizes. When a .25 meter^2 grid was used, artifact weights and counts were evenly divided in four equal sums from the original unit.

Next, is the influence on results of the non-continuous excavation surface at the site. As grid size increases, the unknown measurements for unexcavated units begins to distort estimates of predicted artifacts. The differences in definition of stratigraphic levels proved problematic in creating a definitive interpretation of the site's stratigraphy. The limited stratigraphic separation at the Fort site is influenced the ability to distinguish natural vertical separations in the dataset. The ANOVA method can be used as a general check for the varied grid sizes, but is not an effective method for the analysis of complex stratigraphy.

The results of this analysis support the use of cluster analysis and ANOVA in combination with Geographic Information Systems for the evaluation of archaeological data. ArcMap 10.3 was used in conjunction with quantitative analysis, providing an effective means of viewing cluster locations, artifact densities, and aiding in their interpretation. Quantitative analysis demonstrates strength in quantitative identification in larger datasets by providing a reliable and easily replicable method. When combined with the impressive graphical capabilities of GIS, it is possible to recreate and interpret artifact distributions.

Incorporating GIS and spatial statistics into this site analysis facilitates the evolutions of intra-site artifact distributions through complex data-handling. Although the distribution of artifacts can be analyzed using conventional methods, such as paper layer maps, the digital capabilities of GIS allow for maps to be linked to a spatially-registered relational database that contains relative attribute data. This information can be used to identify and interpret various characteristics of the dataset, improving the ease and effectiveness of analysis and interpretations. While statistical methods can identify and highlight statistically significant concentrations, the added potential of GIS visualizations are vital to understanding the vertical and horizontal distributions of a site.

Contributions to Archaeology

The results of the intra-site spatial analysis at Fort St. Joseph give evidence that spatial patterning exists within the site, and although it does not define specific activity areas, it can assist over time in explaining possible features. This research provides evidence that a distinction in distributions is possible. The presence of identifiable areas of interest in some artifact categories and a relation between high areas of density and specific features demonstrates a level of complexity within the site that is distinguishable from completely disrupted deposit. Further investigation and interpretation are necessary to fully understand the site and contribute to the expansive application of statistical methods in the field of archaeology.

The complexity and diversity associated with historic sites, such as Fort. St. Joseph, result from various depositional and post-depositional processes that suggest that continued investigation and refinement of methods is required. This research demonstrates the combined application of statistical methods and GIS should be considered an innovative step towards aforementioned methodological refinements. The spatial distribution of artifacts at the Fort site illustrates the importance of true spatial investigations, which may reveal phenomena in the dataset that otherwise are unidentifiable. The successful application of GIS emphasizes its potential for use in all archaeological applications. Even though it has generally been used more commonly for inter-site applications, the continued use and application of GIS will allow these technologies to gain status as a powerful analytical tool for archaeological research.

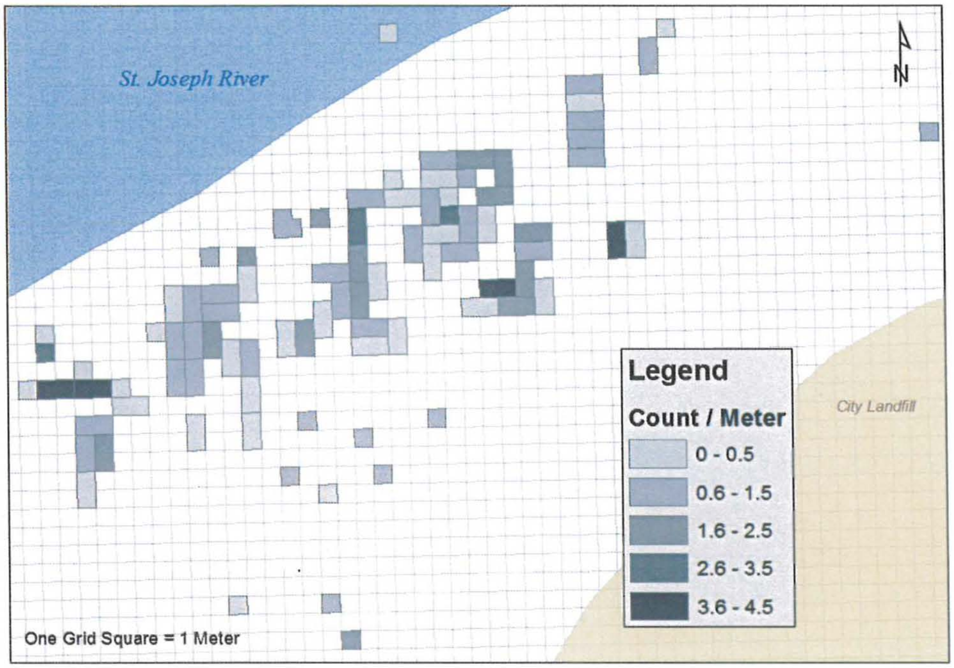
Future Recommendations

Spatial analysis has the potential to reveal information about the use of space in archaeological sites, as shown by this research. Through a mostly successful application of methods, research was limited by constraints of the dataset. The continued collection of data and developments of the database will continue to improve results of any spatial analysis, strengthening and establishing the means to more precisely identify activity areas. To do this spatial analysis should be established as part of the investigation before excavations begin. This will allow for a suitable strategy for mapping features, artifact locations, and the stratigraphic profile. This information can be incorporated into established databases. This would help refine analysis and develop a better understanding of the complete distribution and activities that are occurring within the floodplain.

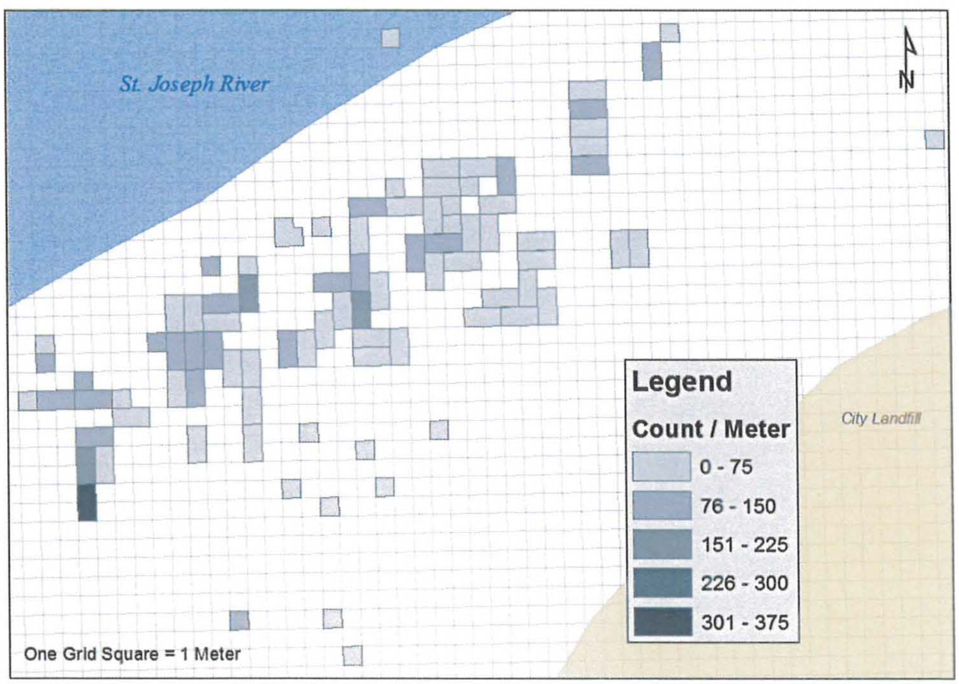
GIS was implemented in the research specifically for query, visualization, and interpolation, while a majority of the statistical analysis was completed by other methods. Current GIS software is still limited in its ability to analyze horizontal and vertical based (3-D) datasets. As GIS software continues to develop, the capabilities to further analyze the site will advance. This will permit future researchers to better use archaeological datasets in a timely fashion and with limited error. Continuing to pursue the digitalization of the FSJ materials including maps, notes, and possibly artifact images in combination with the geodatabase as part of off-season lab work will aid in conserving and protecting Fort St. Joseph for the future. Through the continued excavation of the Fort site and similar historic sites, the FSJ Geodatabase may contribute to a more regional perspective on the spatial organization of the history of the Great Lakes region.

APPENDIX A
Artifact Density Maps by Functional Category

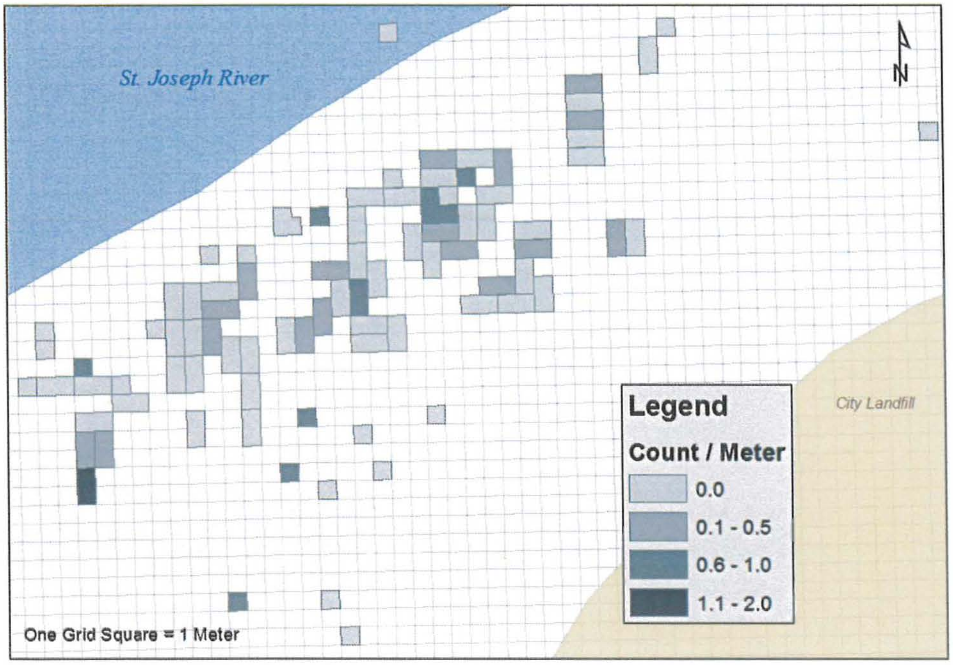
Adornment Count by Area – 1x1



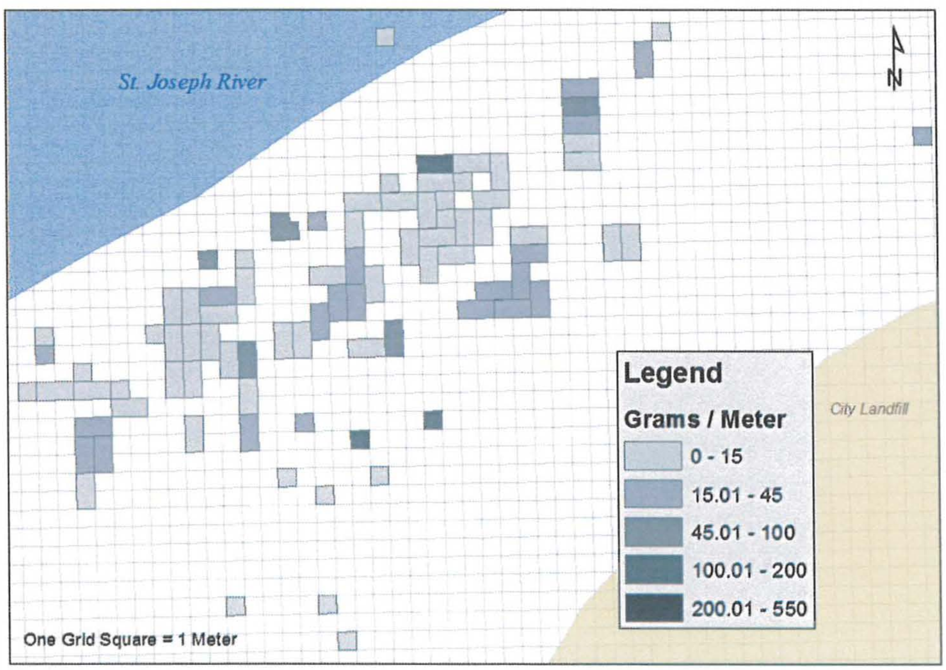
Bead Count by Area – 1x1



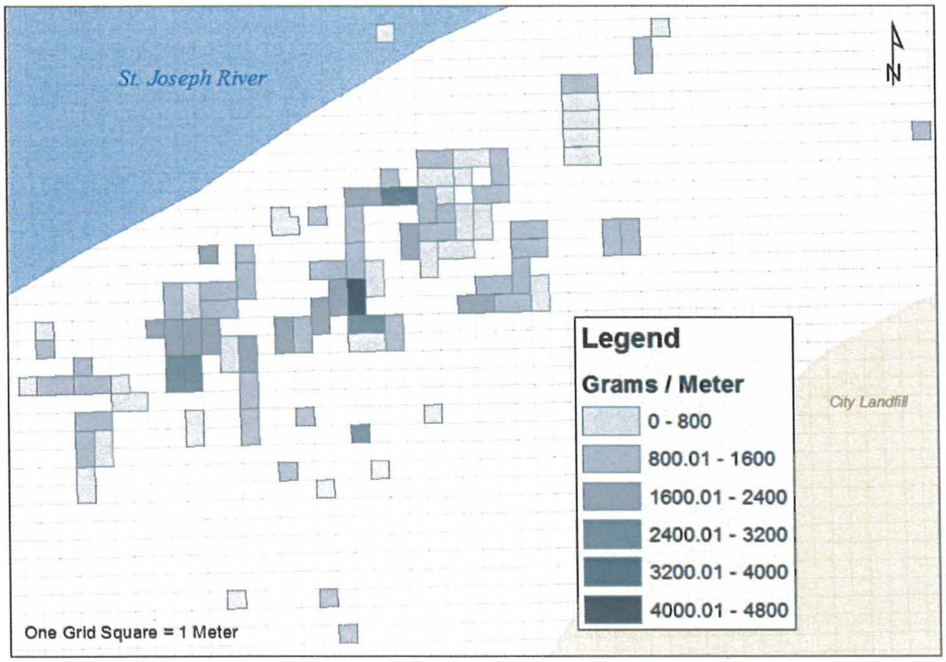
Button Count by Area – 1x1



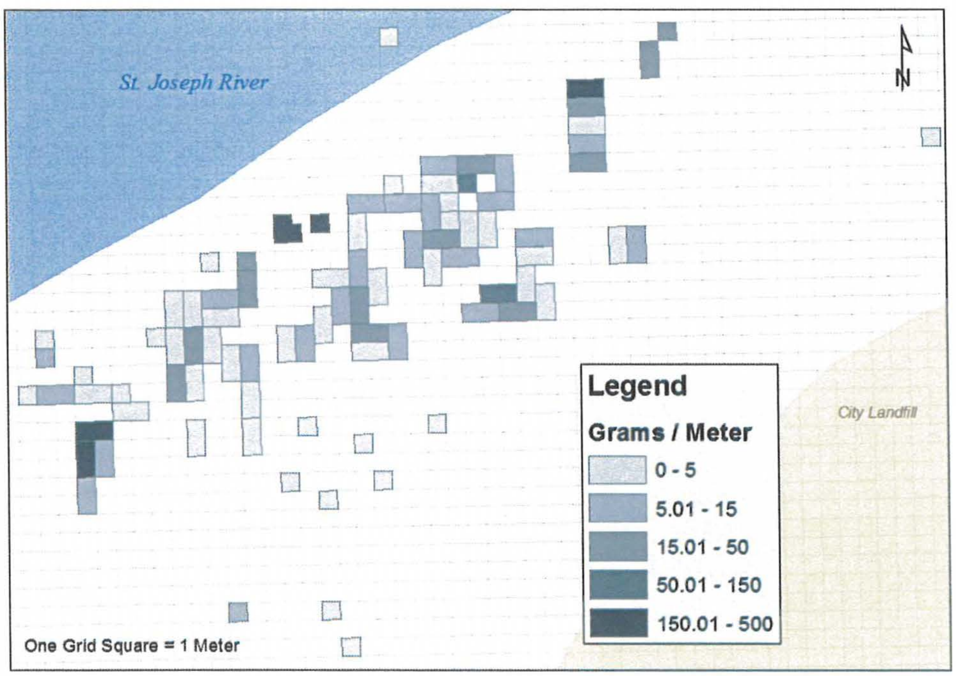
Burnt Wood Weight by Area – 1x1



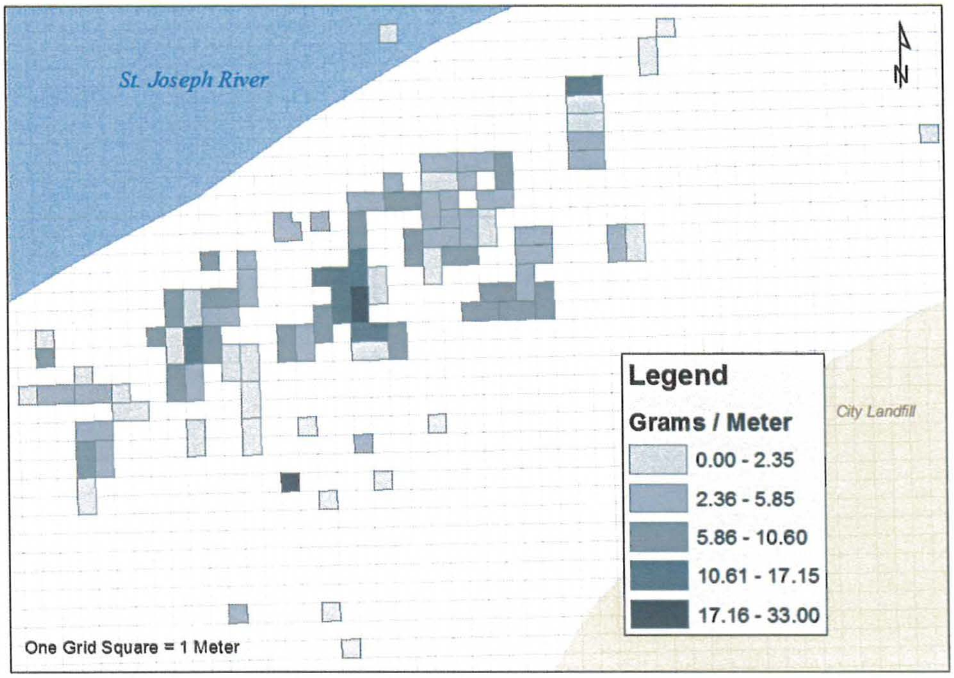
Food Prep Weight by Area - 1x1



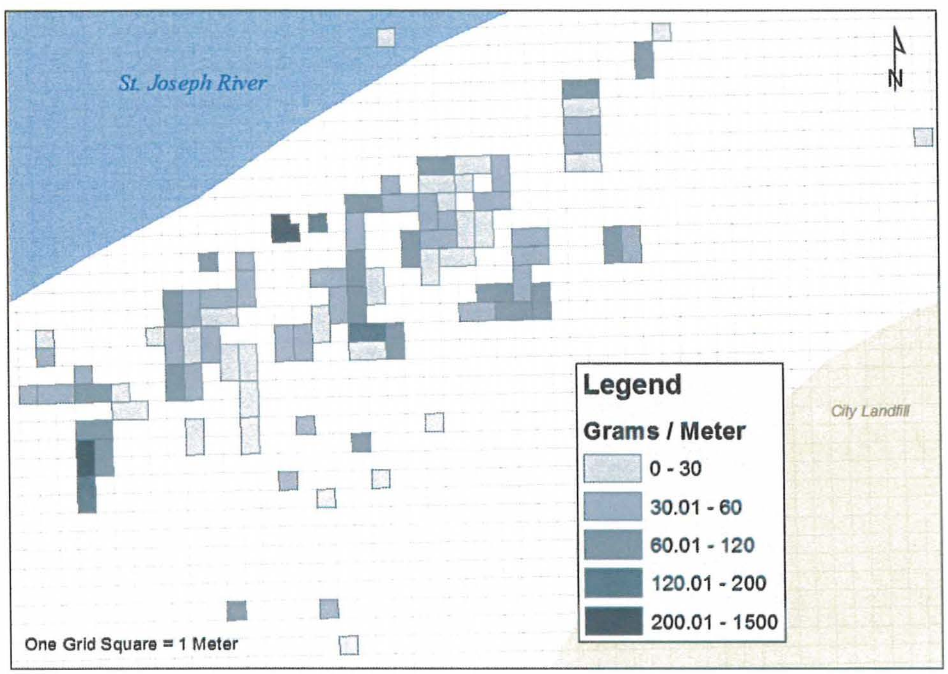
Household Material Weight by Area – 1x1



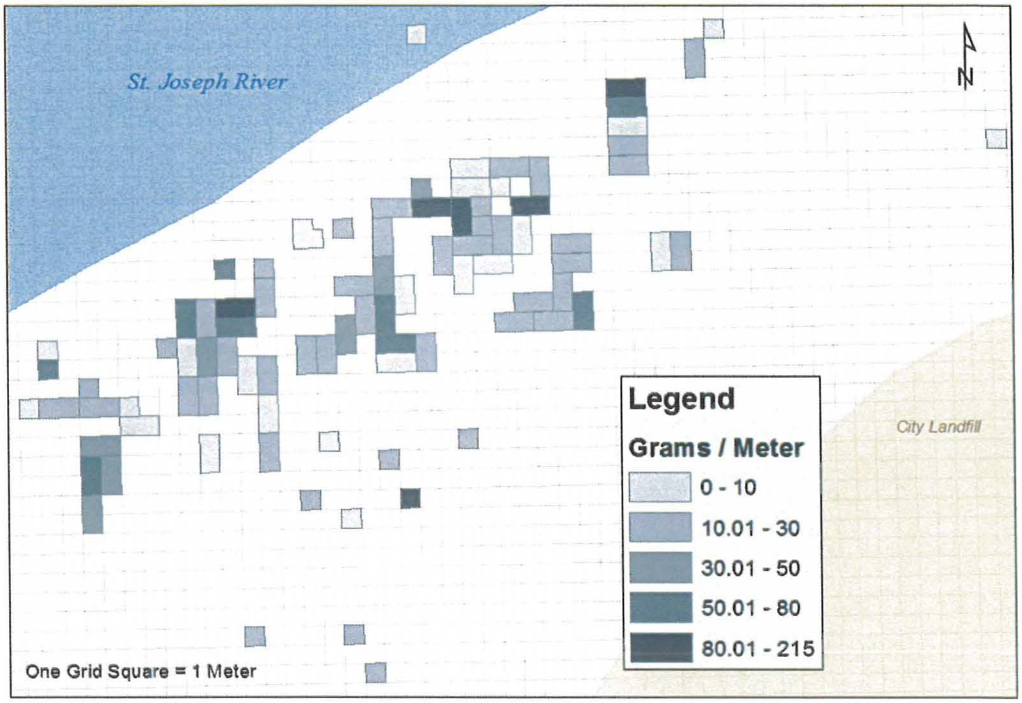
Ceramic Material Weight by Area – 1x1



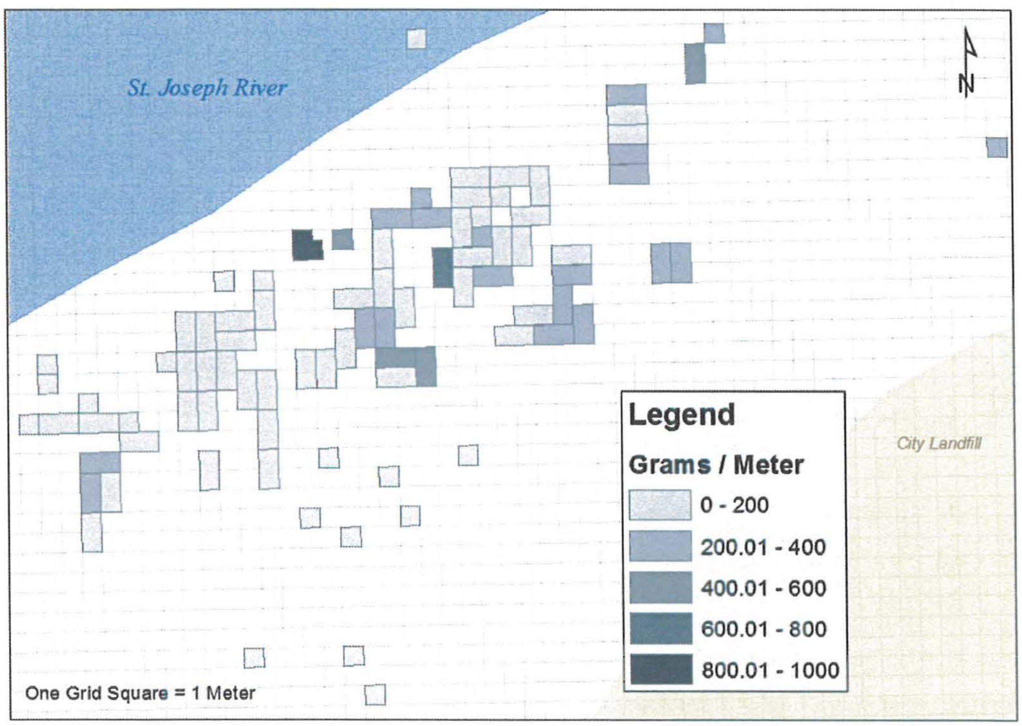
Gun and Weaponry Weight by Area – 1x1



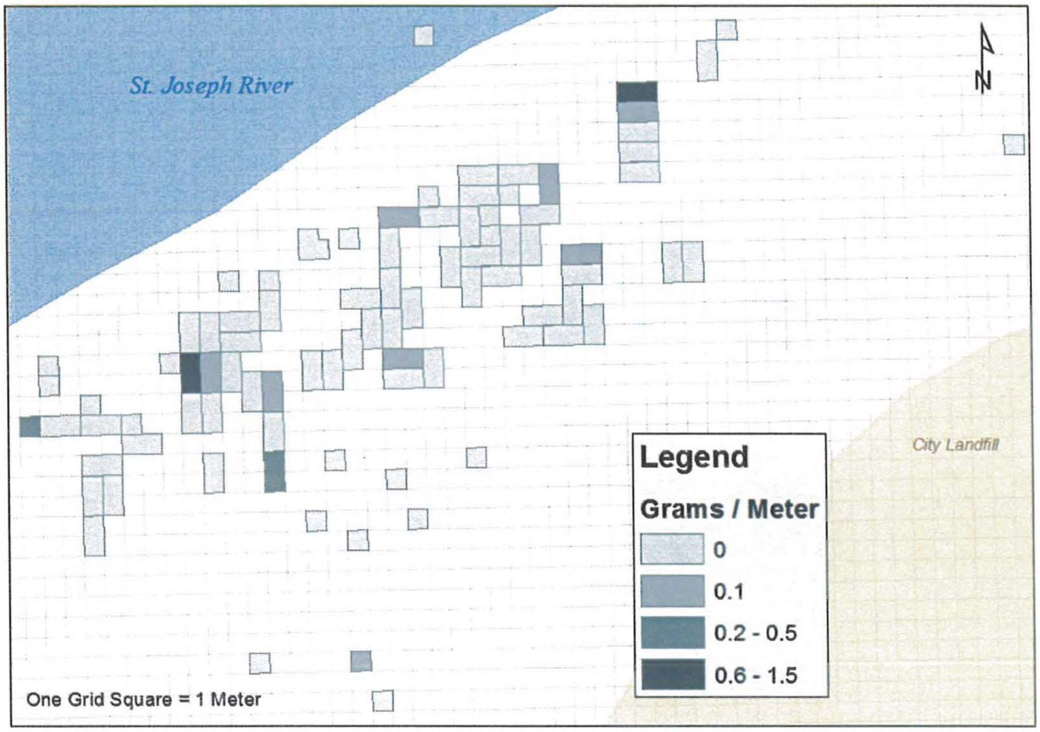
Glass Material Weight by Area – 1x1



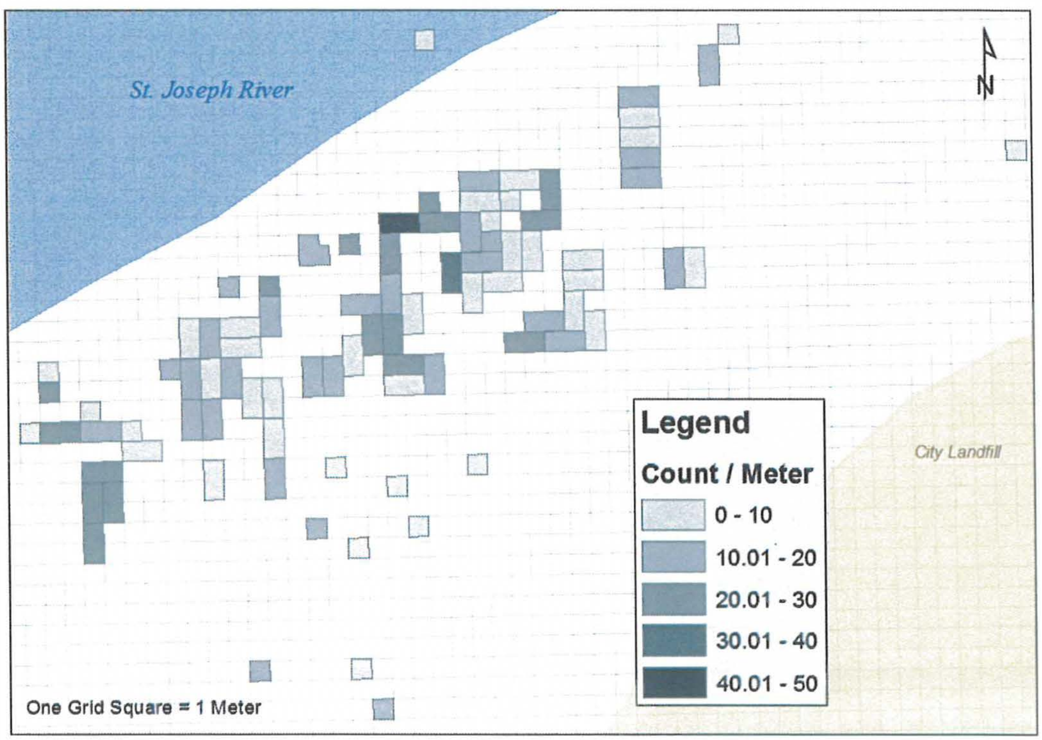
Metal or Coal Material Weight by Area – 1x1



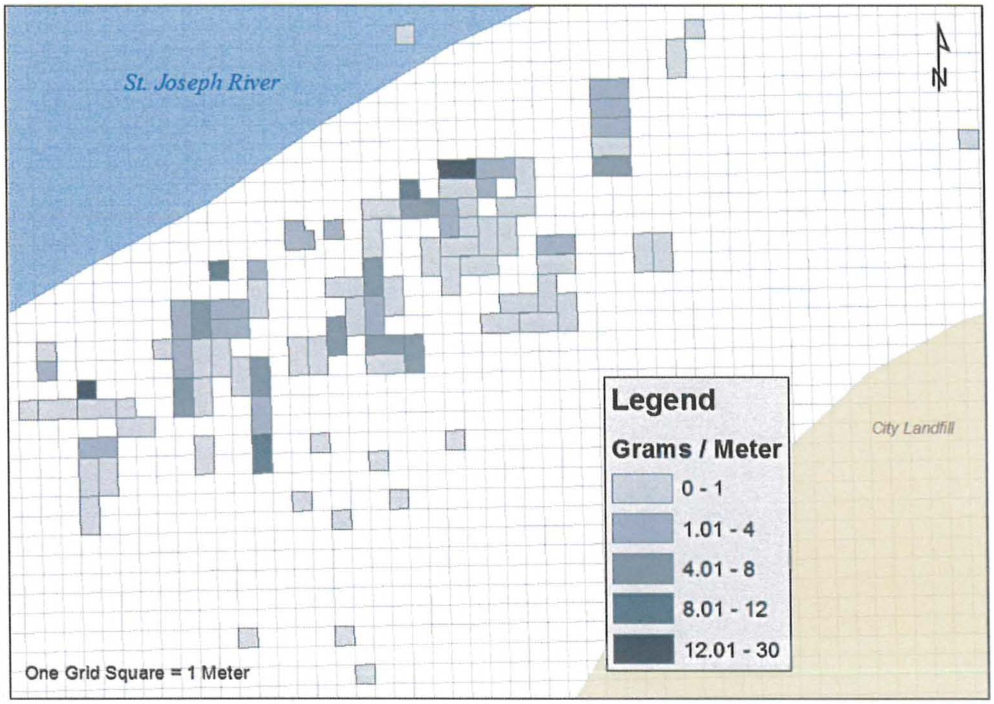
Modern Material Weight by Area – 1x1



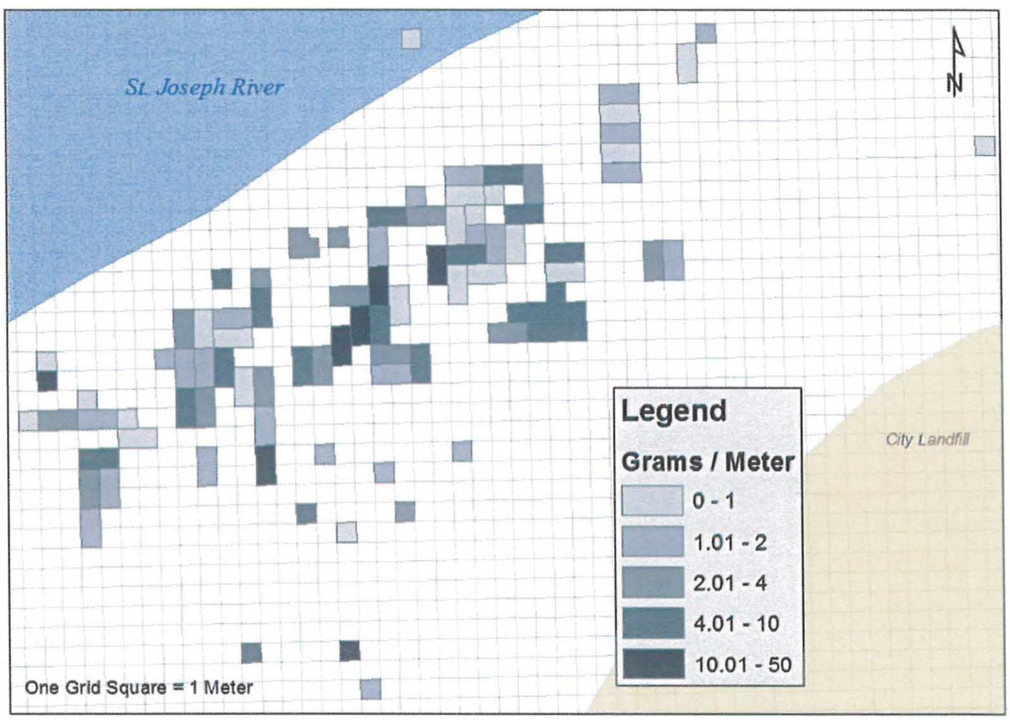
Nail Count by Area – 1x1



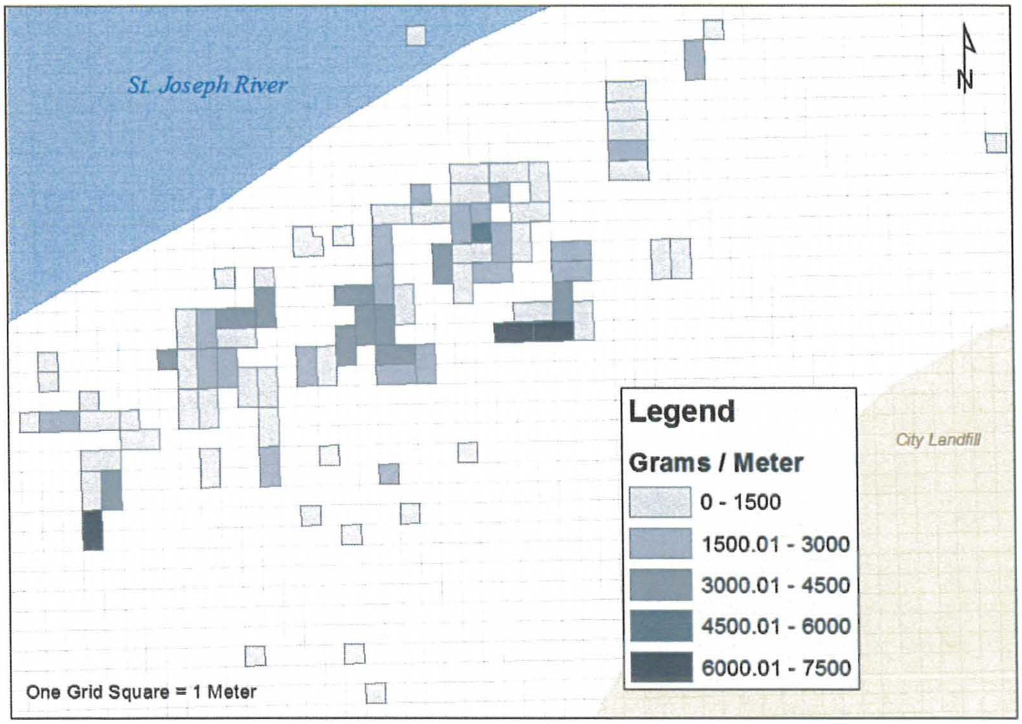
Natural Material Weight by Area – 1x1



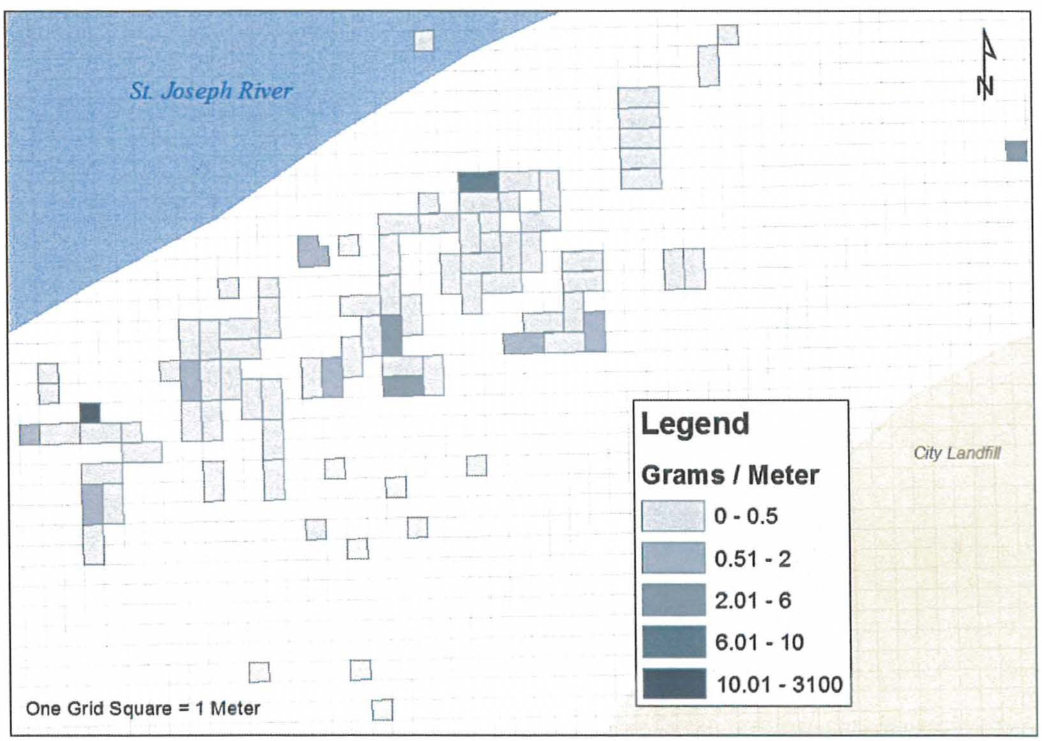
Smoking Pipe Material Weight by Area – 1x1



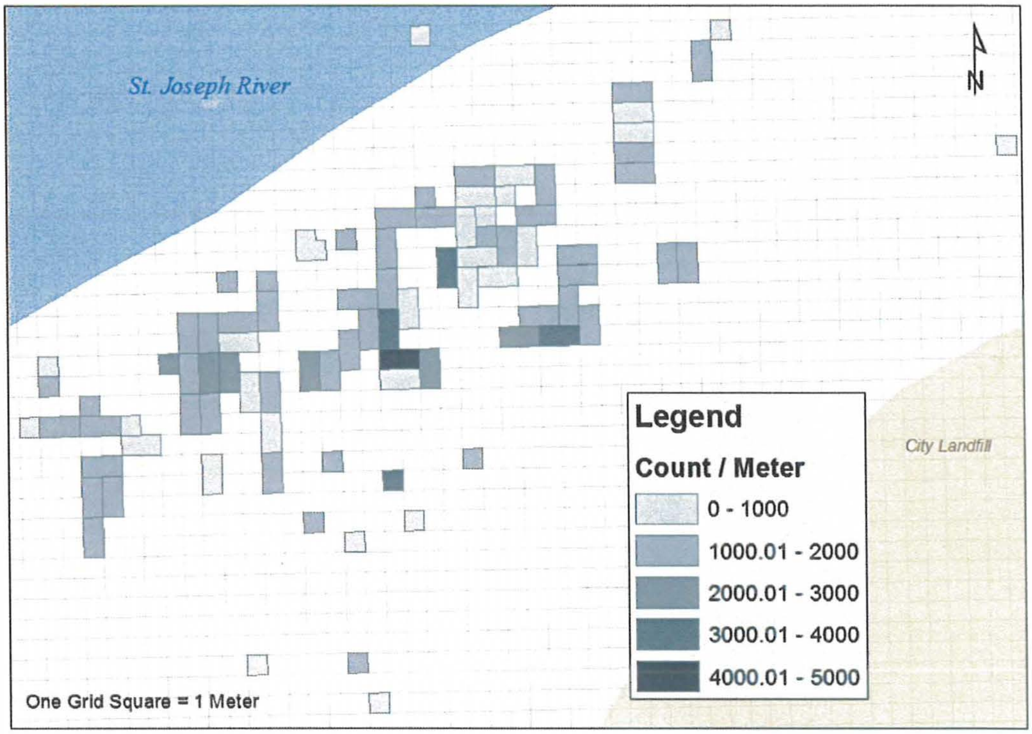
Structural Material Weight by Area – 1x1



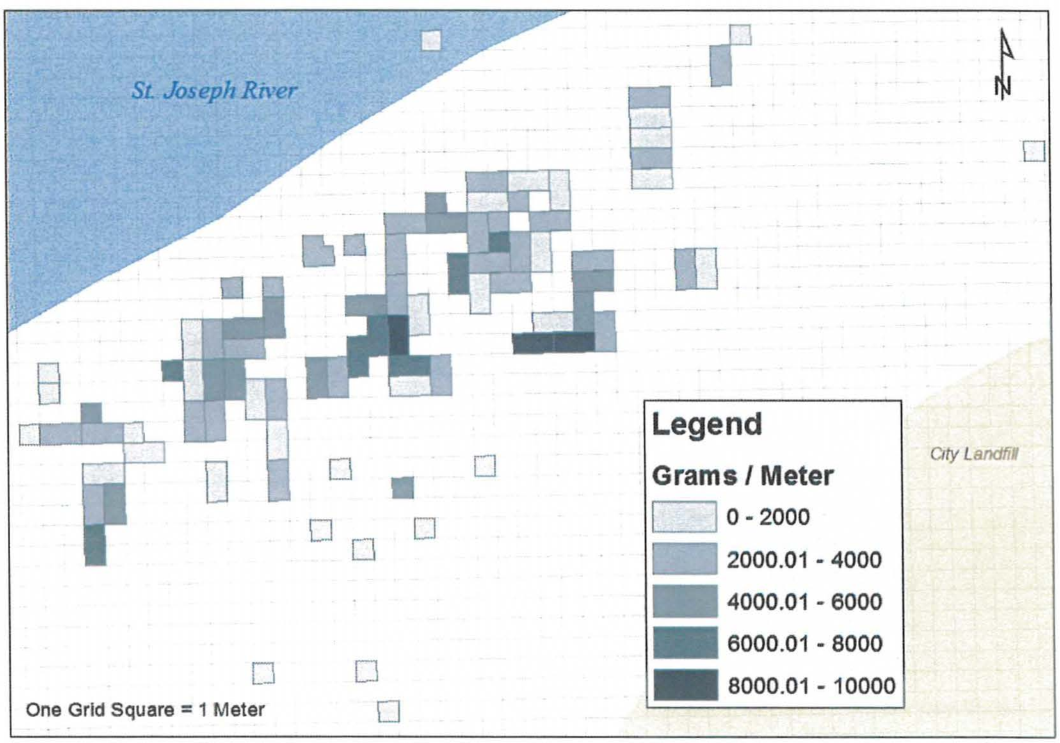
Unknown Material Weight by Area – 1x1



Total Artifact Count by Area – 1x1

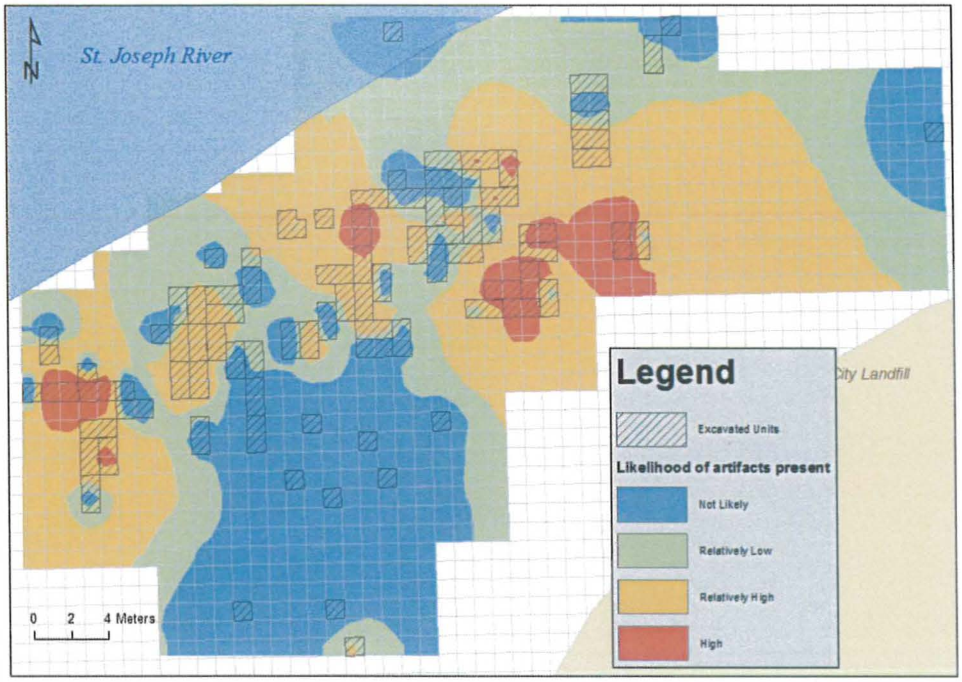


Total Artifact Weight by Area – 1x1

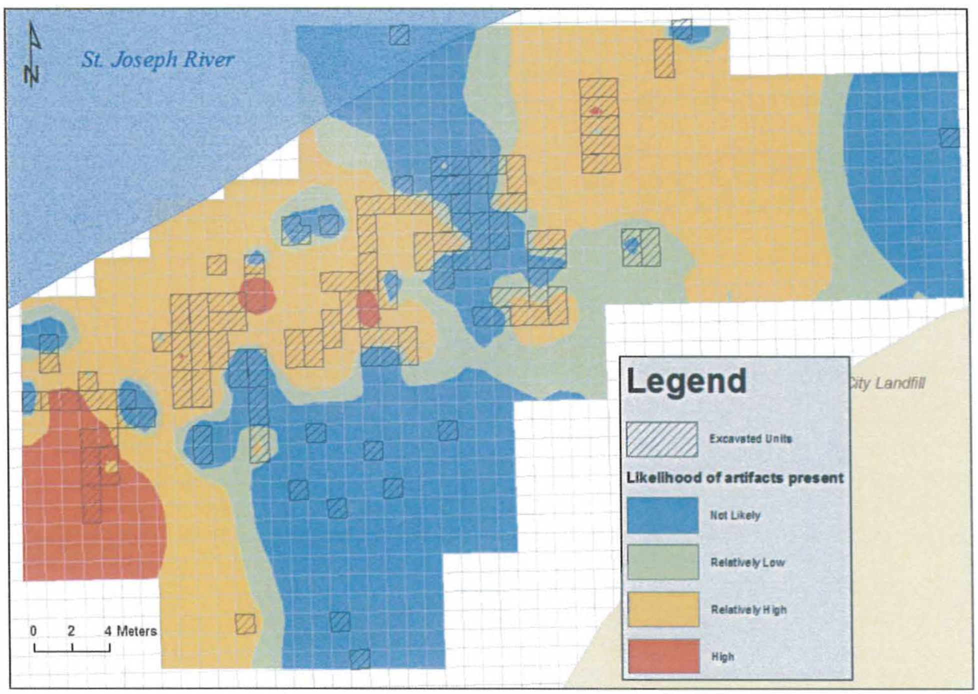


APPENDIX B
Inverse Distance Weighting Maps by Functional Category

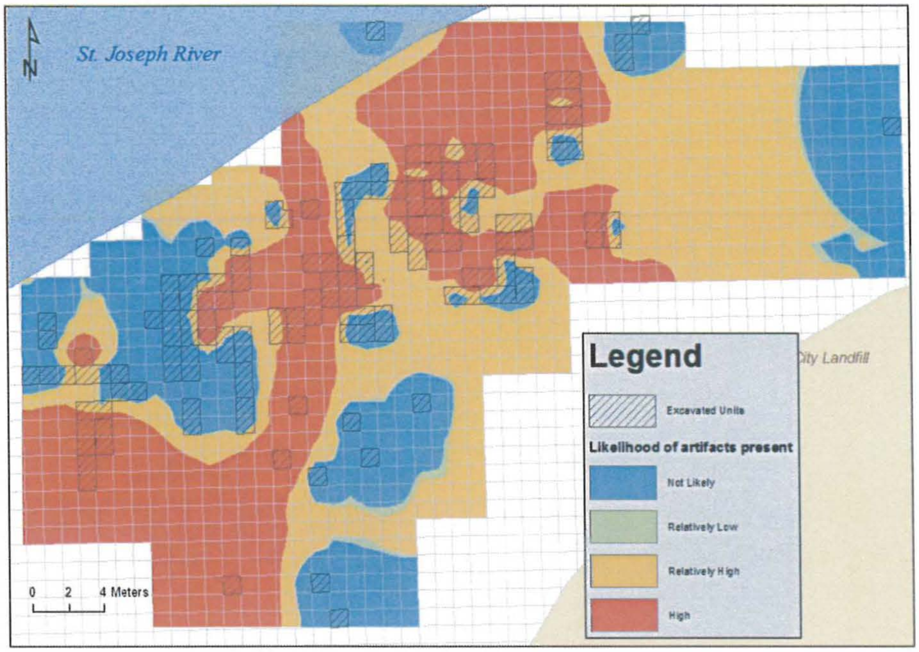
Adornment Count Density – 1x1



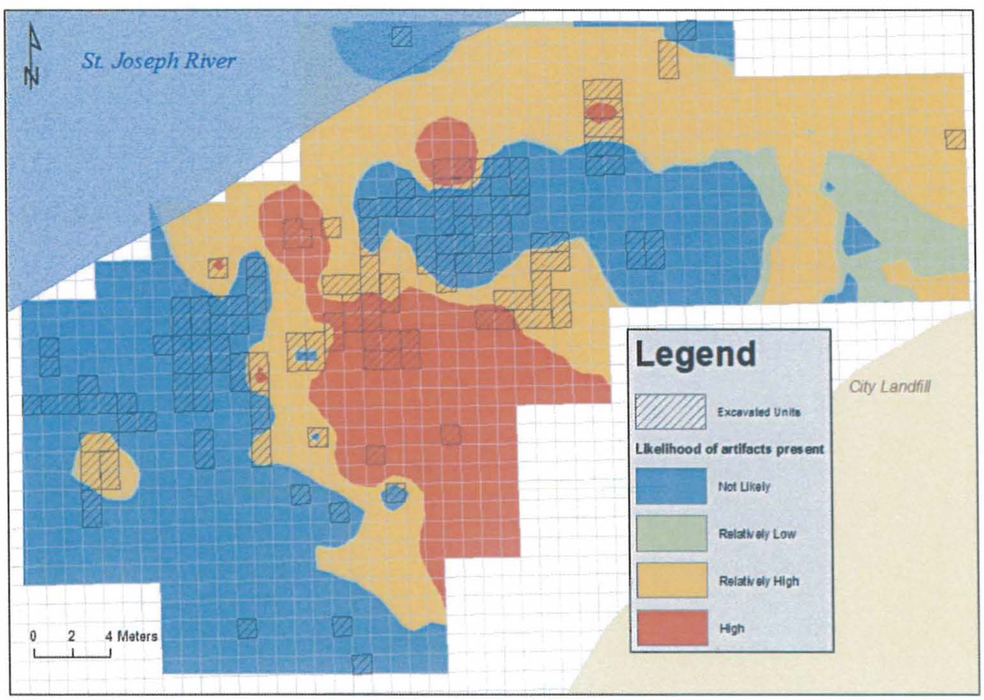
Bead Count Density – 1x1



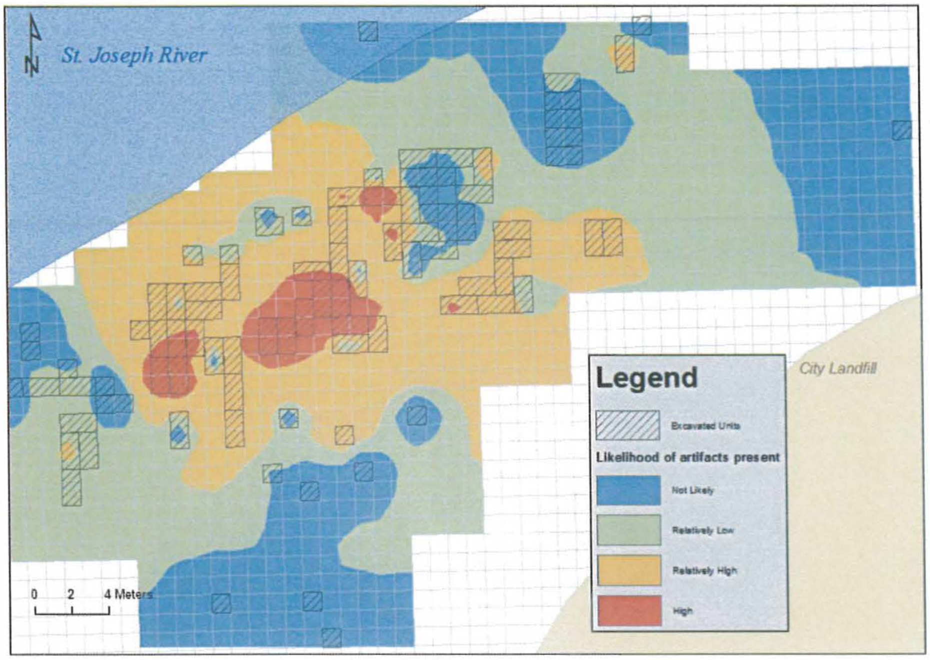
Button Count Density – 1x1



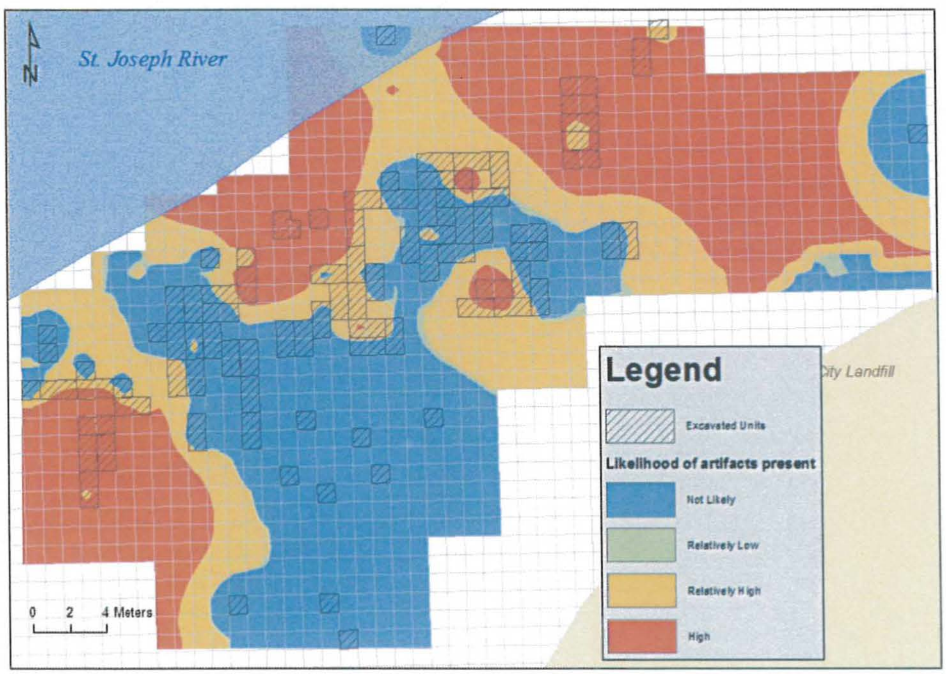
Burnt Wood Weight Density – 1x1



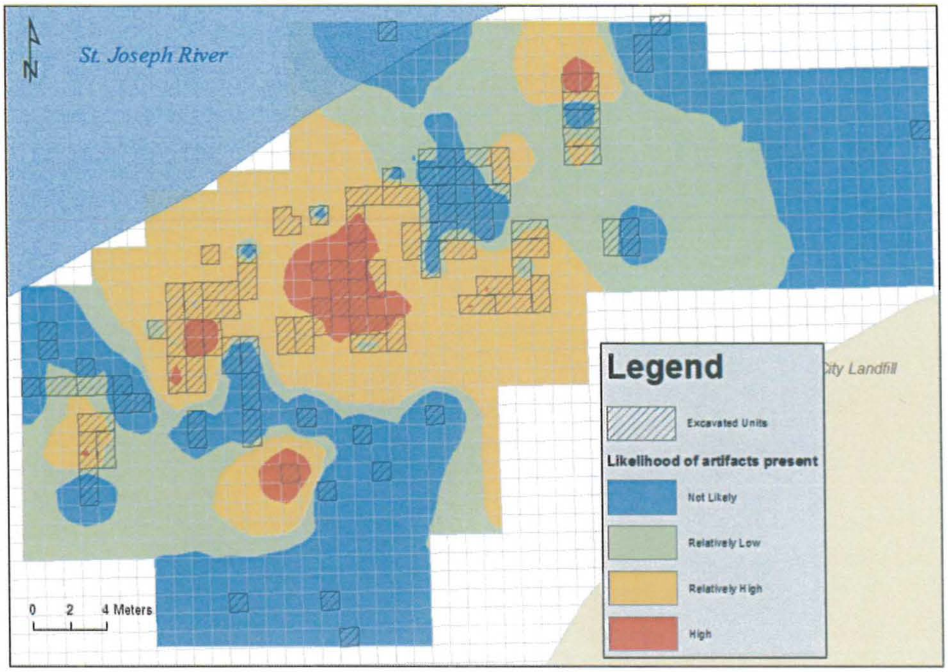
Food Prep Density- 1x1



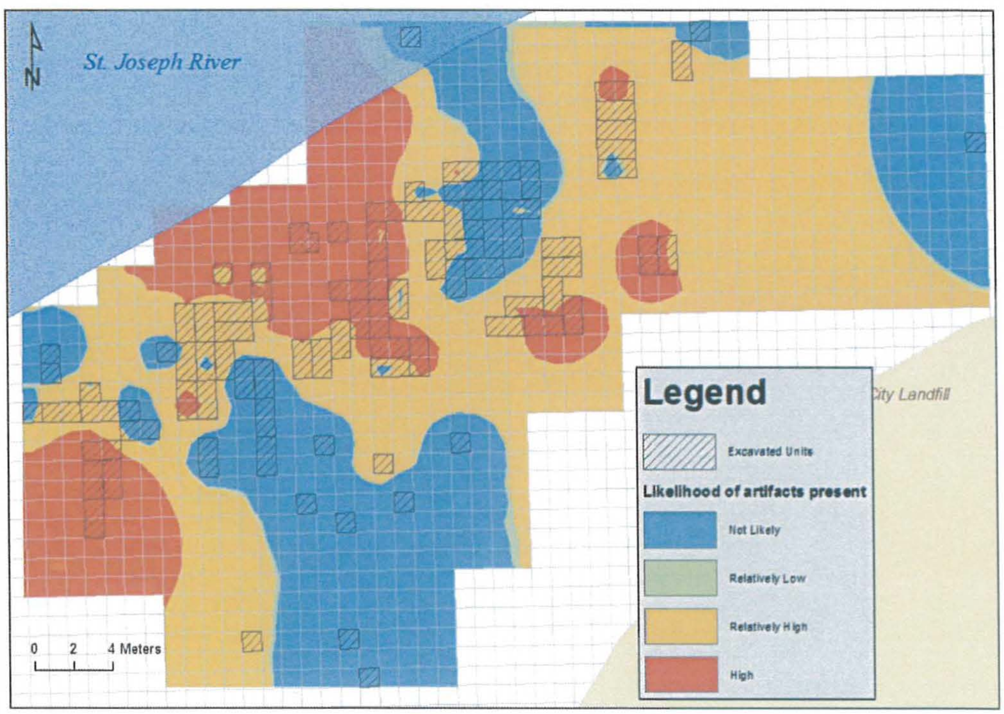
Household Material Weight Density– 1x1



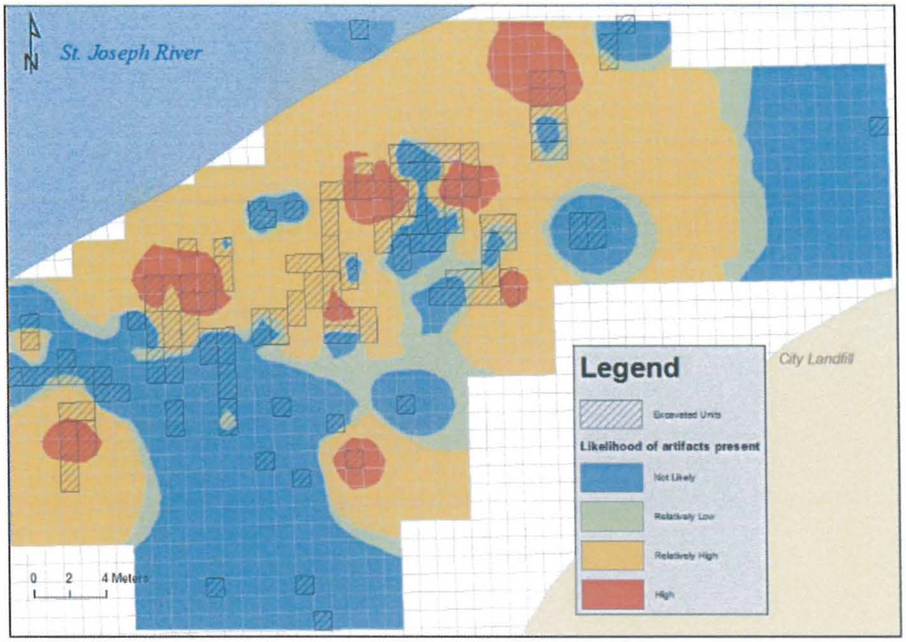
Ceramic Material Weight by Area – 1x1



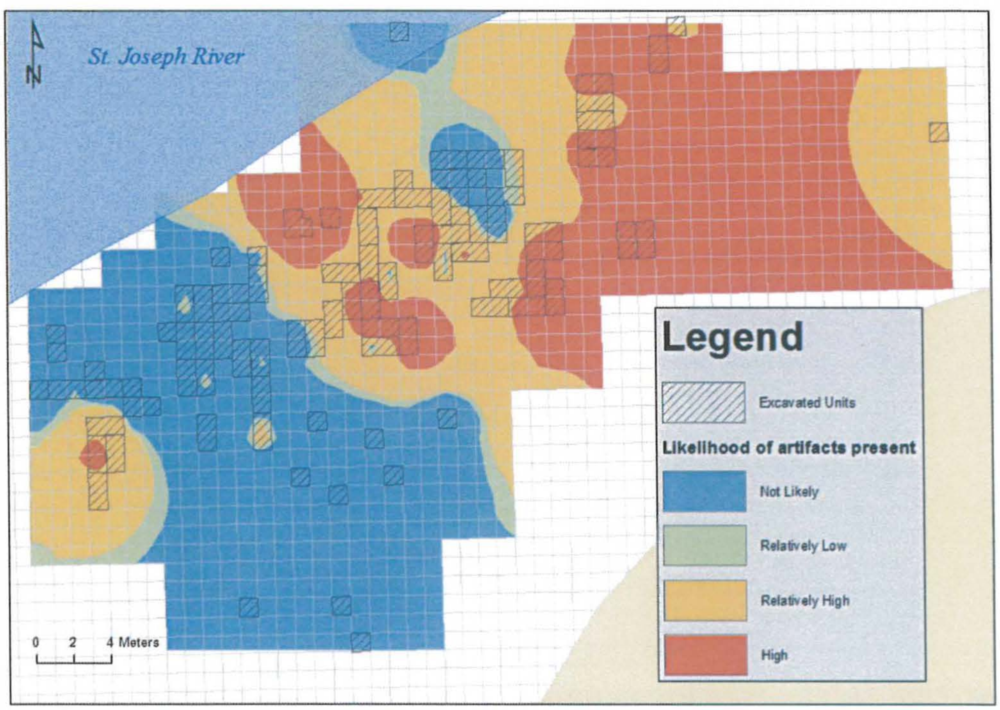
Gun and Weaponry Weight by Area – 1x1



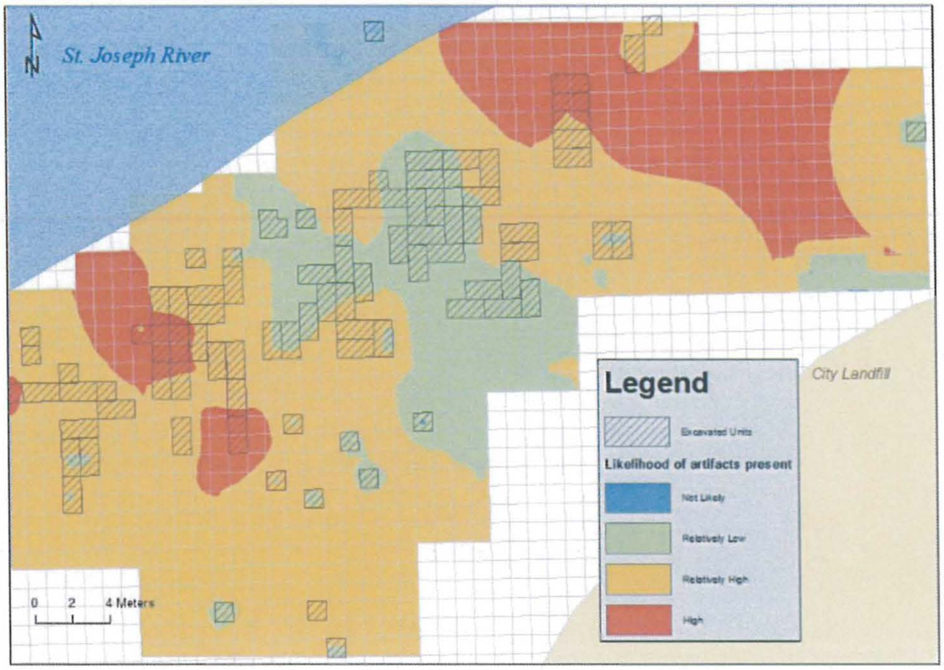
Glass Material Weight by Area – 1x1



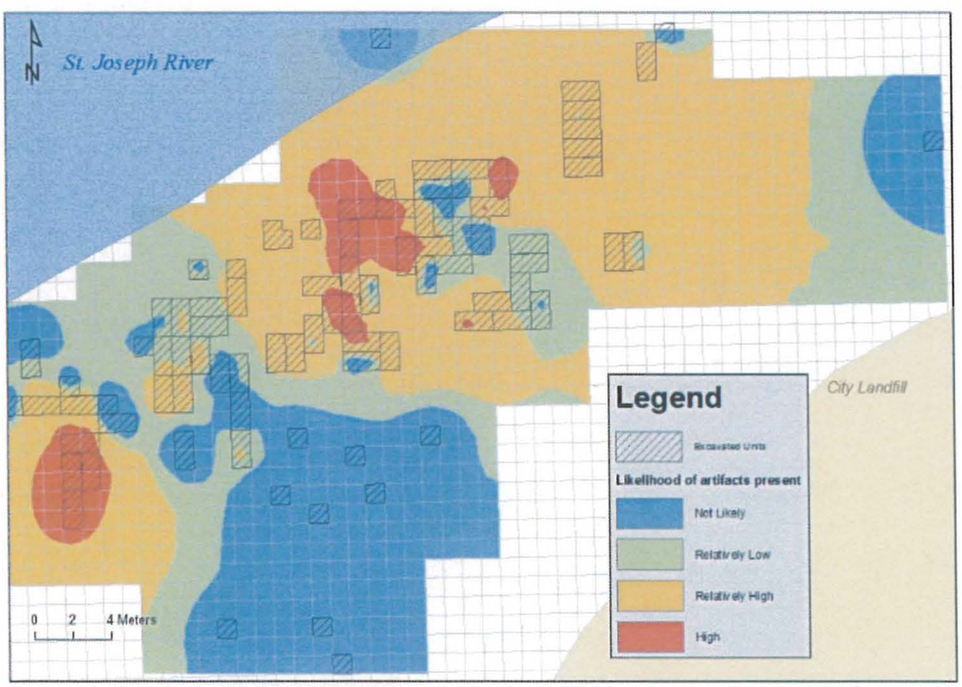
Metal or Coal Material Weight by Area – 1x1



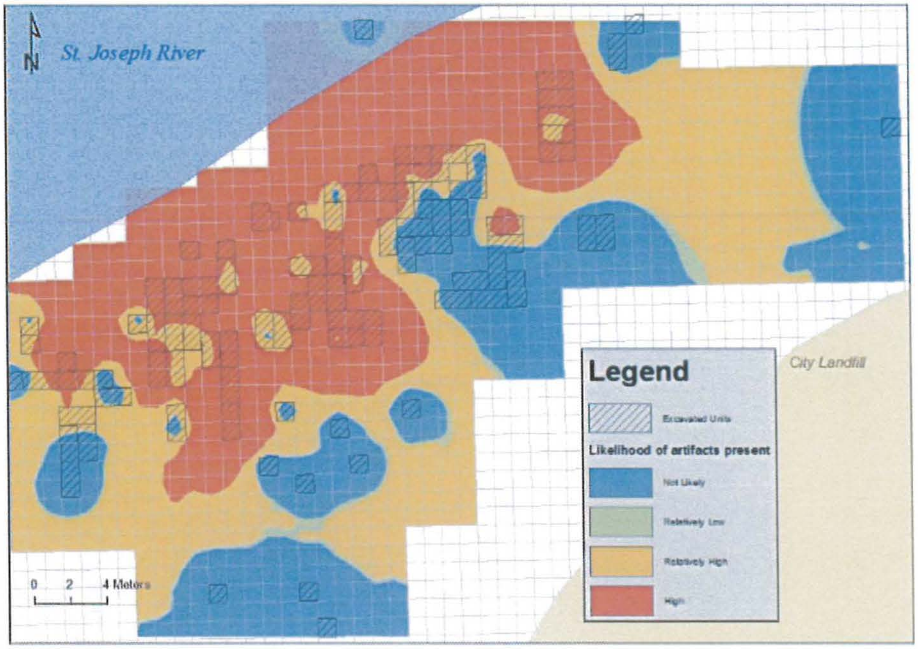
Modern Material Weight by Area – 1x1



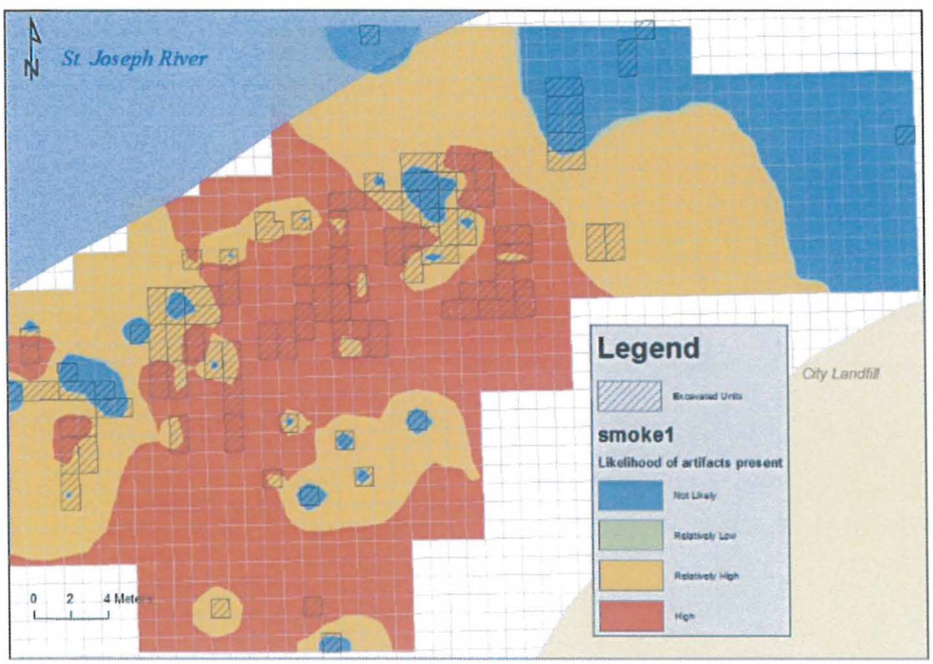
Nail Count by Area – 1x1



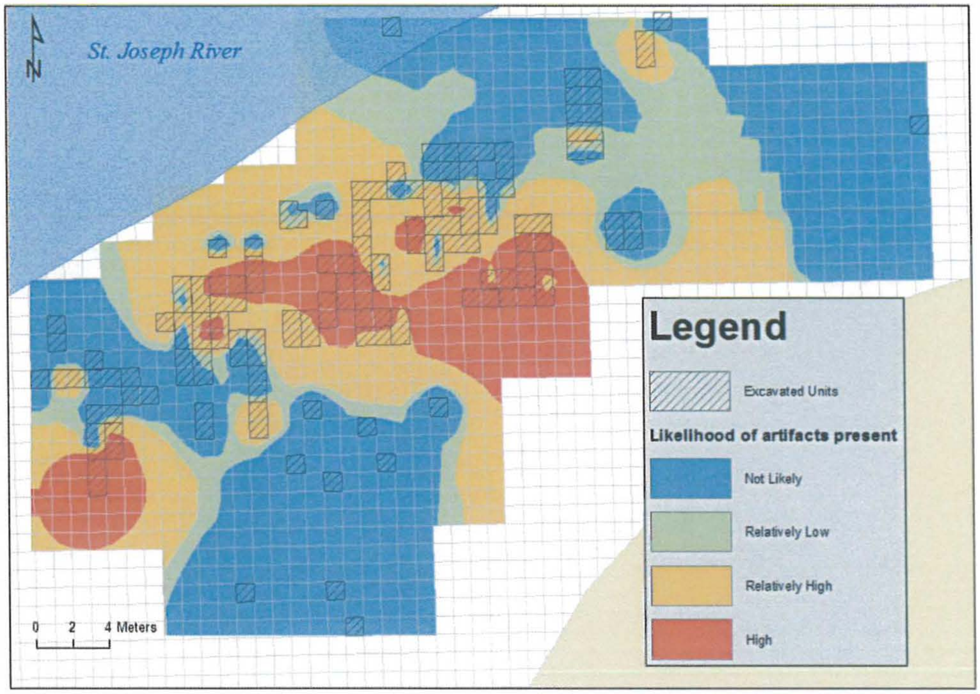
Natural Material Weight by Area – 1x1



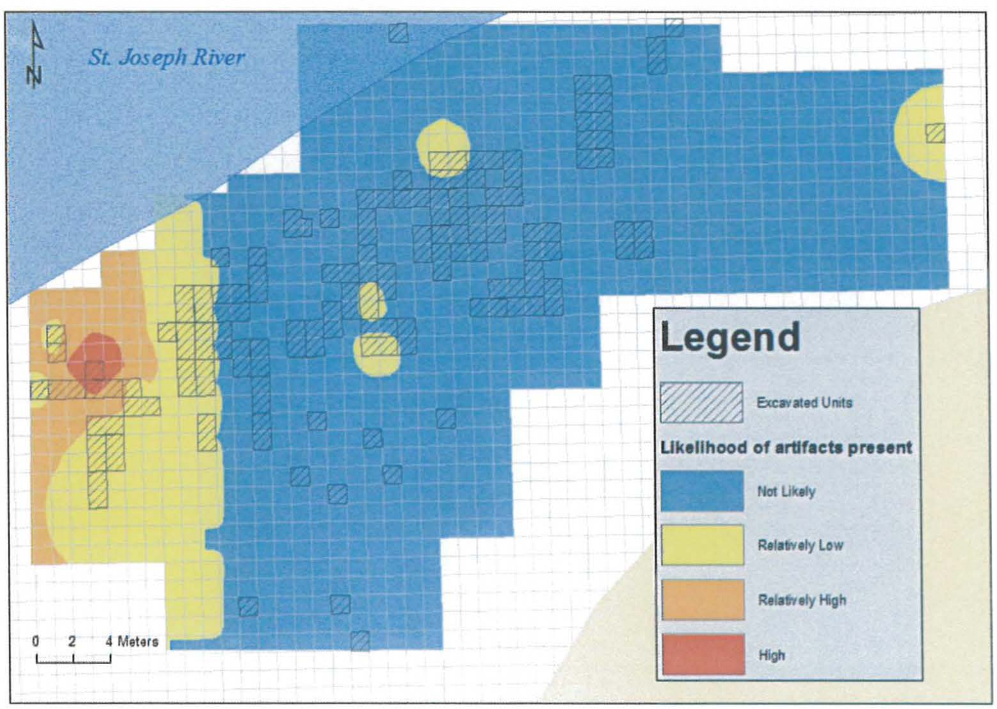
Smoking Pipe Material Weight by Area – 1x1



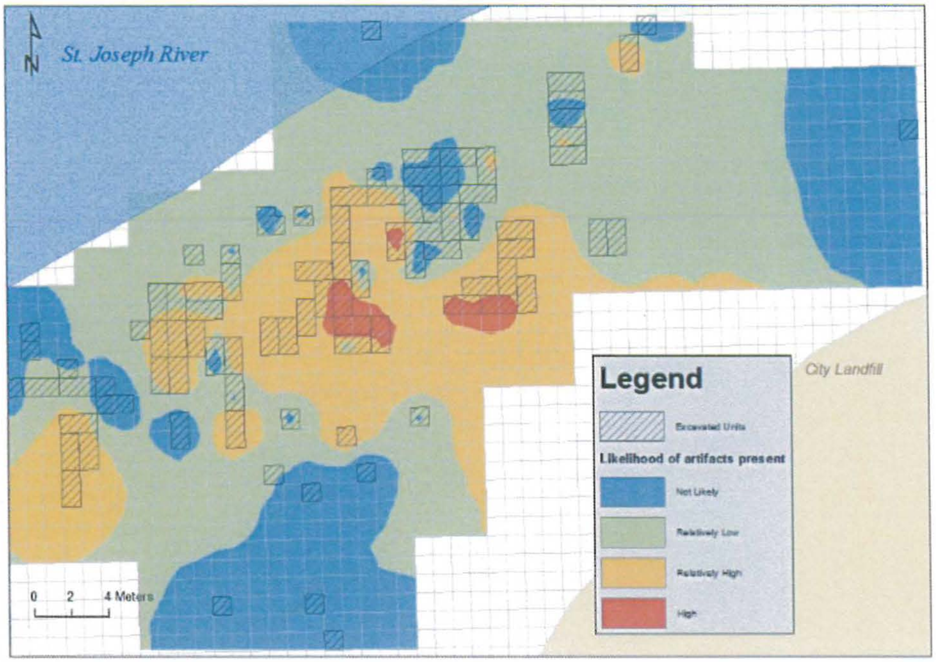
Structural Material Weight by Area – 1x1



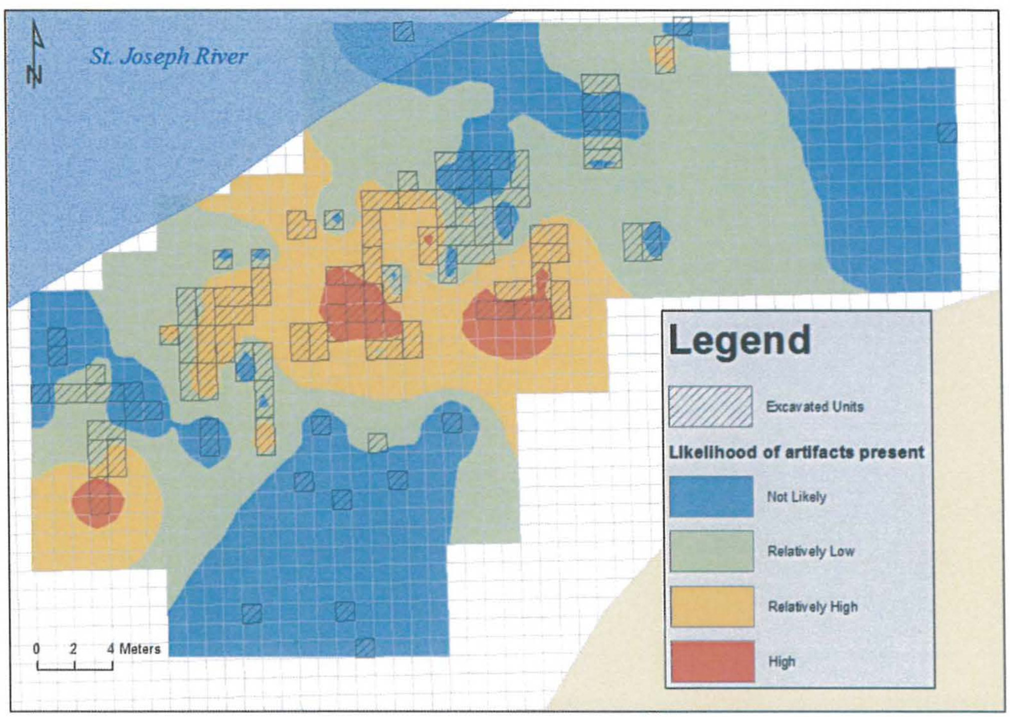
Unknown Material Weight by Area – 1x1



Total Artifact Count by Area – 1x1

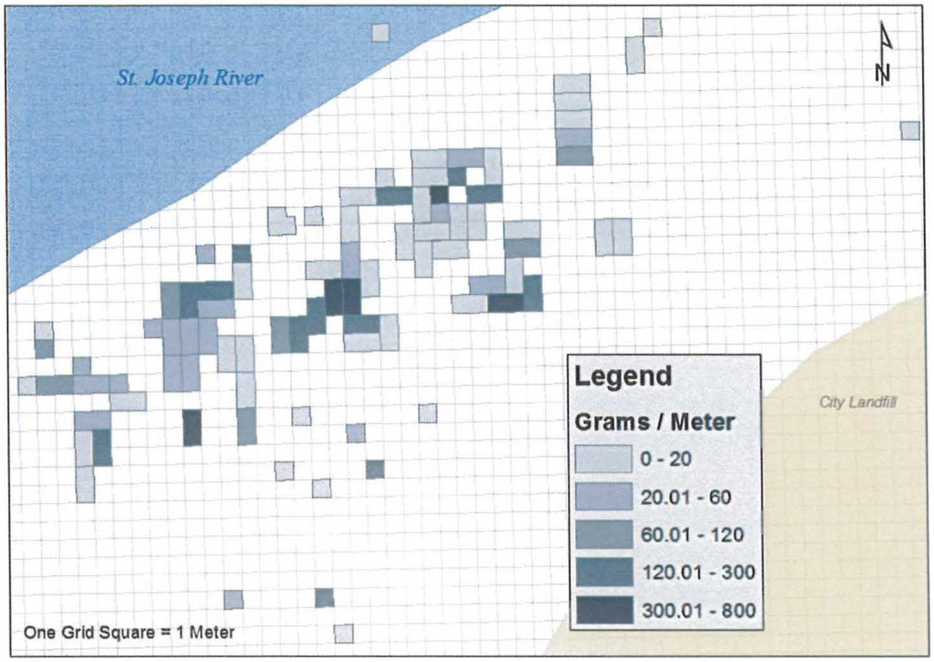


Total Artifact Weight by Area – 1x1

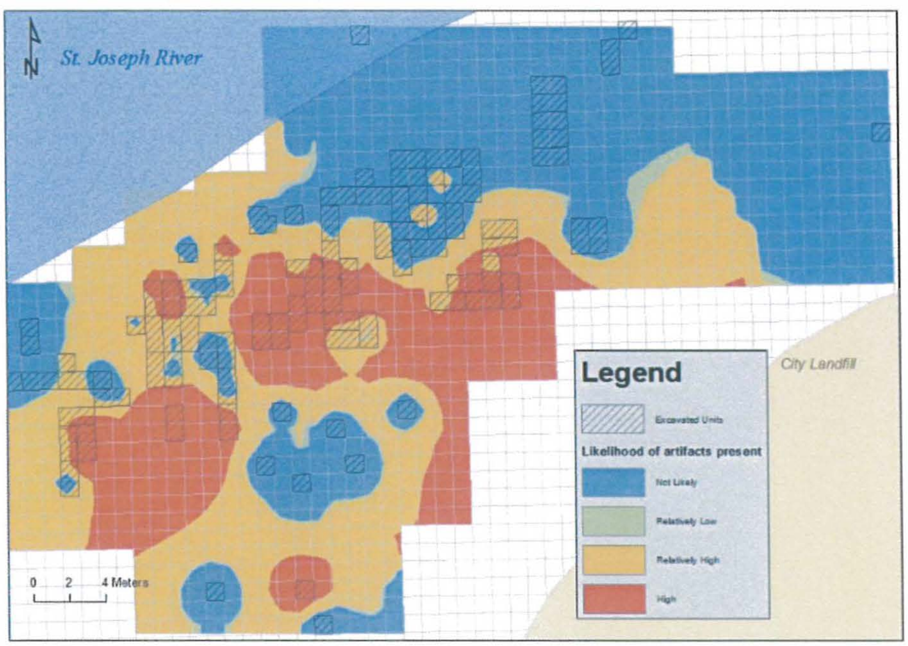


APPENDIX C
Artifact Density and Inverse Distance Weighting Maps by Stratigraphic Layer

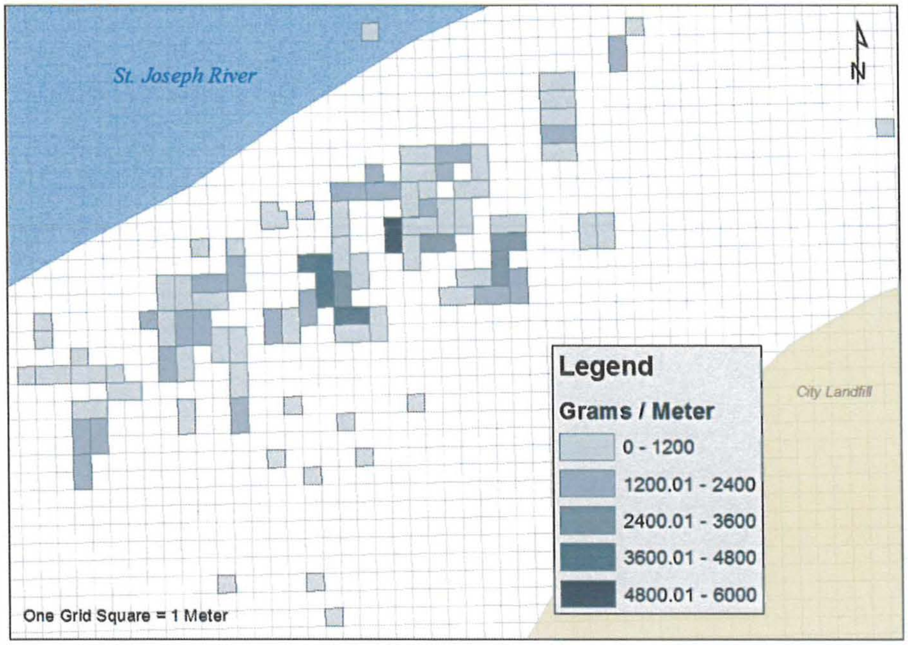
Alluvium Weight by Area– 1x1



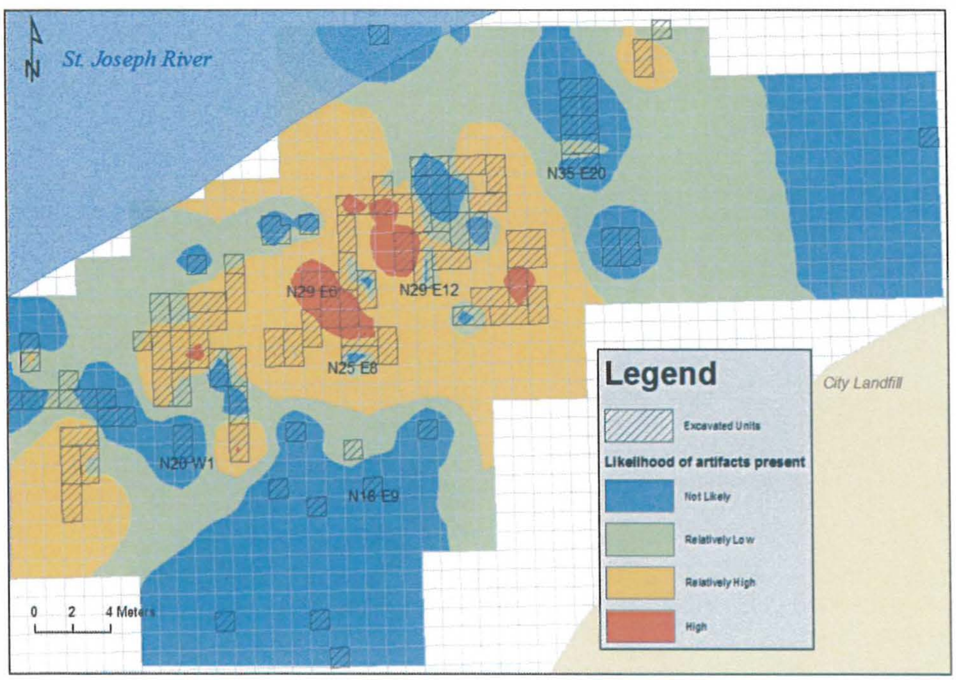
Alluvium Density – 1x1



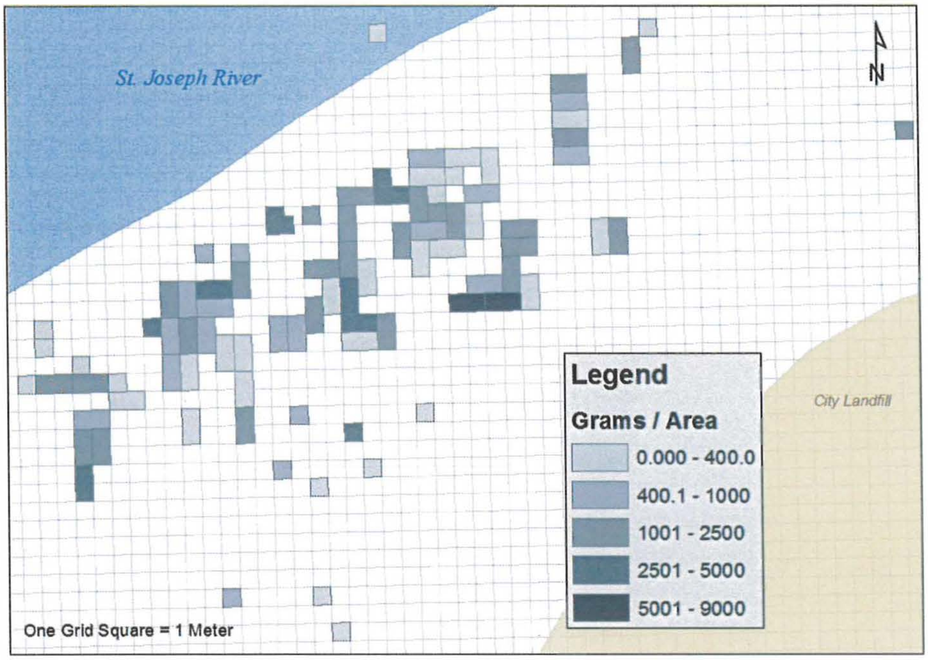
Plow Zone Weight by Area– 1x1



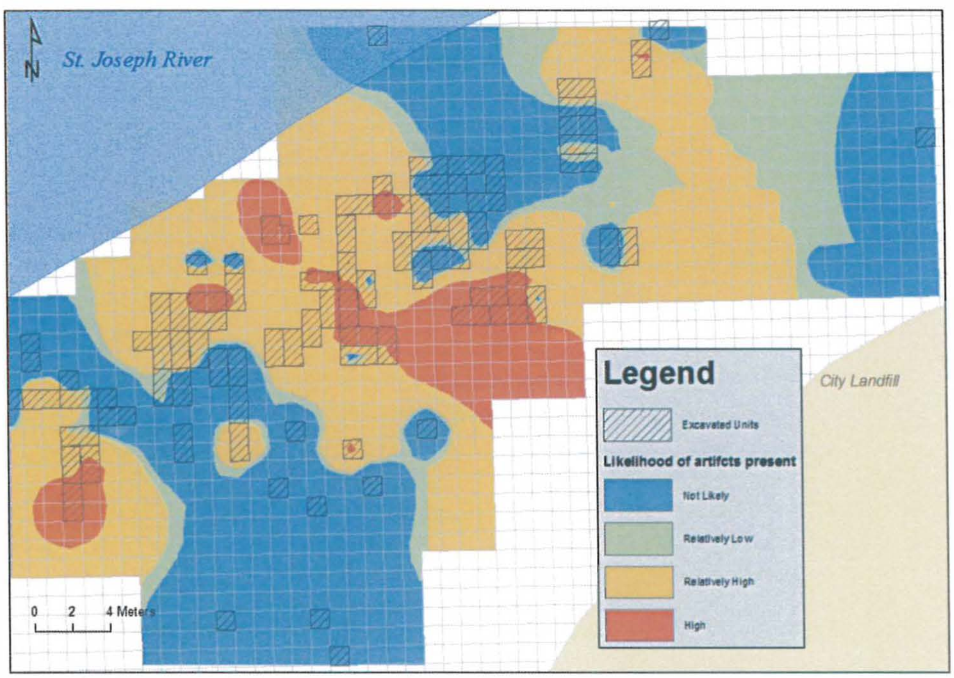
Plow Zone Weight Density – 1x1



Occupation Weight by Area- 1x1



Occupation Weight Density– 1x1



REFERENCES

Allen, K., Green, S., & Zubrow, E. (1990). Interpreting Space. In *Interpreting space: GIS and archaeology* (pp. 383–386). Bristol, PA: Taylor and Francis Inc.

Anderson, K. L. (2003). Refining the definition of cultural levels at Karabi Tamchin : a quantitative approach to vertical intra-site spatial analysis. Retrieved from http://mspace.lib.umanitoba.ca/xmlui/handle/1993/19811

Banning, E. B. (2012). *Archaeological Survey*. New York: Springer Science & Business Media.

Barceló, J. A., & Pallarés, M. (1998). Beyond GIS: The archaeology of social spaces. *Established by: Mauro Cristofani and Riccardo Francovich*. Retrieved from http://www.progettocaere.rm.cnr.it/databasegestione/open_oai_page.asp?id=oai:www.progettocaere.rm.cnr.it/databasegestione/A_C_oai_Archive.xml:22

Beeson, L. H. (1900). Fort St. Joseph - The Mission, Trading Post, and Fort, Located about One Mile South of Niles, Michigan. *Collections of the Michigan Pioneer and Historical Society*, (28), 179– 186.

Benston, S. (2010). Using GIS to Describe and Understand Archaeological Site Distribution: Mapping Fort Saint Joseph. *Master's Theses*. Retrieved from http://scholarworks.wmich.edu/masters_theses/308

Blankholm, H. P. (1991). *Intrasite Spatial Analysis in Theory and Practice*. Aarhus University Press.

Carr, C. (1984). The Nature of Organization of Intrasite Archaeological Records and Spatial Analytic Approaches to Their Investigation. *Advances in Archaeological Method and Theory*, *7*, 103–222.

Carr, C. (1987). Dissecting Intrasite Artifact Palimpsests Using Fourier Methods. In S. Kent (Ed.), *Method and Theory for Activity Area Research: An Ethnoarchaeological Approach* (pp. 236–291). New York: Columbia University Press.

Chapman, H. (2006). *Landscape Archaeology and GIS*. Great Britain: Tempus Publishing Limited.

Clarke, D. L. (1977). *Spatial archaeology*. London: Academic Press.

Cowgill, G. L. (1968). Archaeological Applications of Factor, Cluster, and Proximity Analysis. *American Antiquity*, *33*(3), 367–375. http://doi.org/10.2307/278705

Dacey, M. F. (1973). Statistical Tests of Spatial Association in the Locations of Tool Types. *American Antiquity*, *38*(3), 320–328. http://doi.org/10.2307/279719

Djindjian, F. (2015). A Short History of the Beginnings of Mathematics in Archaeology. In J. A. Barcelo & I. Bogdanovic, *Mathematics and Archaeology* (pp. 65–79). Boca Raton, Florida: CRC Press.

Ebert, D. (2002). Predictive modeling and the ecology of hunter-gatherers of the Boral forest of Manitoba. Retrieved from http://mspace.lib.umanitoba.ca/xmlui/handle/1993/3739

Ebert, D. (2004). Applications of Archaeological GIS. *Canadian Journal of Archaeology / Journal Canadien d'Archéologie*, *28*(2), 319–341.

ESRI. (2015). What is a geodatabase? —ArcGIS Help | ArcGIS for Desktop. Retrieved December 2, 2015, from https://desktop.arcgis.com/en/desktop/latest/manage-data/geodatabases/what-is-a-geodatabase.htm

Fisher, P. F. (1999). Geographic Information Systems: Today and Tomorrow? In M. Gillings, D. Mattingly, & J. van Dalen (Eds.), *Geographic Information Systems and Landscape Archaeology* (pp. 5 – 11). Oxford: Oxbow Books.

Gaffney, V., & van Leusen, P. M. (1995). Postscript - GIS, Environmental Determinism and Archaeology. In G. Lock & G. Stancic (Eds.), *Archaeology and Geographic Information Systems: A European Perspective* (pp. 367 – 382). London: Taylor and Francis Ltd.

Gilbert, C. (1991). Cultural Landscapes and the New Technologies. *The Public Historian*, *13*(3), 109–112. http://doi.org/10.2307/3378556

Graham, I. (1980). Spectral Analysis and Distance Methods in the Study of Archaeological Distributions. *Journal of Archaeological Science*, *7*(2), 105–129. http://doi.org/10.1016/S0305-4403(80)80015-X

Green, S. (1990). Approaching Archaeological Space: An Introduction to the Volume. In *Interpreting space: GIS and archaeology* (pp. 3–8). Bristol, PA: Taylor and Francis Inc.

Hietala, H. J., & Stevens, D. E. (1977). Spatial Analysis: Multiple Procedures in Pattern Recognition Studies. *American Antiquity*, *42*(4), 539–559. http://doi.org/10.2307/278927

Howard, P. (2006). *Archaeological Surveying and Mapping: Recording and Depicting the Landscape* (New Ed edition). New York: Routledge.

Jermann, J. V., & Dunnell, R. C. (1979). Some Limitations of Isopleth Mapping in Archaeology. In *Computer Graphics in Archaeology* (Vol. 15, pp. 31–60). Tempe: Arizona State University.

Johnson, I. (1984). Cell Frequency Recording and Analysis. In H. Hietala (Ed.), *Intrasite Spatial Analysis in Archaeology* (pp. 75–96). London.

Kincaid, C. (1988). Predictive Modeling and its Relationship to Cultural Resource Management Applications. In J. W. Judge & L. Sebastian (Eds.), *Quantifying the Present and Predicting the Past: Theory, Method, and Application of Archaeological Predictive Modelling* (pp. 493 – 548). Denver, Colorado: US Department of the Interior, Bureau of Land Management.

Kintigh, K. W. (1990). Intrasite Spatial Analysis: A Commentary on Major Methods. In A. Voorrips (Ed.), *Mathematics and Information Science in Archaeology: A Flexible Framework* (pp. 165–200). Holos, Bonn.

Kintigh, K. W., & Ammerman, A. J. (1982). Heuristic Approaches to Spatial Analysis in Archaeology. *American Antiquity*, *47*(1), 31–63. http://doi.org/10.2307/280052

Knoerl, J. J. (1991). Mapping History Using Geographic Information Systems. *The Public Historian*, *13*(3), 97–108. http://doi.org/10.2307/3378555

Koetje, T. A. (1992). The Simulation and Recovery of Archaeologically Meaningful Levels. In P. Reilly, *Archaeology and the Information Age: A Global Perspective* (pp. 177–187). London: Routledge.

Kohley, A. (2013). *Change and Continuity: Euro-American and Native American Settlement Patterns in the St. Joseph River Valley*. Western Michigan University, Kalamazoo, Michigan. Retrieved from http://scholarworks.wmich.edu/masters_theses/163/

Kvamme, K. (1995). A View from Across the Water: the North American Experience in Archaeological GIS. In G. R. Lock & G. Stancic (Eds.), *Archaeology and Geographic Information Systems: A European Perspective* (pp. 1–13). Oxford: Taylor and Francis Ltd.

Kvamme, K. L. (1989). Geographic Information Systems in Regional Archaeological Research and Data Management. *Archaeological Method and Theory*, *1*, 139–203.

Kvamme, K. L. (1993). Spatial Statistics and GIS: an Integrated Approach. In J. Andresen, T. Madsen, & I. Scollar (Eds.), *Computing the Past* (pp. 94 – 104). Denmark: Aarhus University Press. Retrieved from http://proceedings.caaconference.org/paper/10_kvamme_caa_1992/

Kvamme, K. L. (1999). Recent Directions and Developments in Geographical Information Systems. *Journal of Archaeological Research*, *7*(2), 153–201. http://doi.org/10.1007/s10814-005-0002-9

Kvamme, K. L., & Kohler, T. A. (1988). Geographic Information Systems: Technical aids for data collection, analysis, and display. In J. W. Judge & L. Sebastian (Eds.), *Quantifying the Present and Predicting the Past: Theory, Method, and Application of Archaeological Predictive Modelling* (pp. 493 – 548). Denver, Colorado: US Department of the Interior, Bureau of Land Management.

Marble, D. F. (1990). The Potential Methodological Impact of Geographic Information Systems on the Social Sciences. In K. Allen, S. Green, & E. Zubrow (Eds.), *Interpreting Space: GIS and Archaeology* (pp. 9–21). London: Taylor and Francis Ltd.

Maschner, H. D. G. (1996). New Methods, Old Problems: Geographic Information Systems in Modern Archaeological Research.

McCoy, M. D., & Ladefoged, T. N. (2009). New Developments in the Use of Spatial Technology in Archaeology. *Journal of Archaeological Research*, *17*(3), 263–295. http://doi.org/10.1007/s10814-009-9030-1

Moyes, H. (2002). The use of GIS in the spatial analysis of an archaeological cave site. *Journal of Cave and Karst Studies*, *64*(1), 9–16.

Nassaney, M. S. (2015). *The Archaeology of the North American Fur Trade*. Gainesville, Florida: University Press of Florida.

Nassaney, M. S., Cremin, W. M., Kurtzweil, R., Brandão, J. A., & Kurtweill, R. (2003). The Search for Fort St. Joseph (1691-1781) in Niles, Michigan. *Midcontinental Journal of Archaeology*, *28*(2), 107–144.

Nassaney, M. S., Cremin, W. M., & Lynch, D. P. (2002). The Identification of Colonial Fort St. Joseph, Michigan. *Journal of Field Archaeology*, *29*(3/4), 309–321. http://doi.org/10.2307/3250895

Rigaud, J.-P., & Simek, J. F. (1991). Interpreting Spatial Patterns at the Grotte XV. In E. M. Kroll & T. D. Price (Eds.), *The Interpretation of Archaeological Spatial Patterning* (pp. 199–220). Springer US. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4899-2602-9_7

Riley, T. (1974). Constraints on Dimensions of Variance. *American Antiquity*, 489–490.

Savage, S. H. (1990). GIS in Archaeological Research. In K. Allen, S. Green, & E. Zubrow (Eds.), *Interpreting Space: GIS and Archaeology* (pp. 22–31). London: Taylor and Francis Ltd.

Schiffer, M. B. (1974). On Whallon's Use of Dimensional Analysis of Variance at Guila Naquitz. *American Antiquity*, *39*(3), 490–492. http://doi.org/10.2307/279443

Silverman, B. W. (1986). *Density Estimation for Statistics and Data Analysis*. Boca Raton: Chapman and Hall.

Smith, M. J. D., Goodchild, M. F., & Longley, P. A. (2007). *Geospatial Analysis* (2 edition). Leicester: Troubadour Publishing Ltd.

Spurling, B., & Hayden, B. (1984). Ethnoarchaeology and Intrasite Spatial Analysis: A Case Study from the Australian Western Desert. In H. Hietala (ed.), *Intrasite Spatial Analysis in Archaeology* (pp. 224–241). Cambridge: Cambridge University Press.

State of Michigan. (2002, 2016). MI Geographic Data Library. Retrieved from http://www.mcgi.state.mi.us/mgdl/

Straus, L. G. (1979). Caves: A paleoanthropological resource. *World Archaeology*, *10*(3), 331–339. http://doi.org/10.1080/00438243.1979.9979741

Wansleeben, M. (1988). Applications of Geographical Information Systems in Archaeological Research. In S. P. Q. Rahtz (Ed.), *Computer Applications and Quantitative Methods in Archaeology* (pp. 435 – 451). Oxford: British Archaeology Reports.

Whallon, R., Jr. (1973). Spatial Analysis of Occupation Floors I: Application of Dimensional Analysis of Variance. *American Antiquity*, *38*(3), 266–278. http://doi.org/10.2307/279714

Whallon, R., Jr. (1974). Spatial Analysis of Occupation Floors II: The Application of Nearest Neighbor Analysis. *American Antiquity*, *39*(1), 16–34. http://doi.org/10.2307/279216

Wheatley, D. (1992). Going over Old Ground: GIS, Archaeological Theory and the Act of Perception - CAA Online Proceedings. Retrieved from http://proceedings.caaconference.org/paper/13_wheatley_caa_1992/

Wheatley, D. (1996). Spatial Technology and Archaeological Theory Revisited - CAA Online Proceedings. Retrieved from http://proceedings.caaconference.org/paper/15_wheatley_caa_1996/

Wheatley, D. (2004). Making space for an archaeology of place. *Internet Archaeology*, *15*. Retrieved from http://dx.doi.org/10.11141/ia.15.10

Wheatley, D., & Gillings, M. (2002). *Spatial Technology and Archaeology: The Archaeological Applications of GIS* (1 edition). New York: CRC Press.

Williamson, R., & Nickens, P. (Eds.). (2000). *Science and Technology in Historic Preservation*. New York City: Kluwer Academic/ Plenum Publishers.

Wobst, H. M. (2006). Artifacts as Social Interference: The Politics of Spatial Scale. In G. Lock & B. L. Molyneaux (Eds.), *Confronting scale in archaeology* (pp. 55–64). Springer US. Retrieved from http://link.springer.com/chapter/10.1007/0-387-32772-3_4

Zubrow, E. (1990). Contemplating space: a commentary on theory. In *Interpreting space: GIS and archaeology* (pp. 67–72). Bristol, PA: Taylor and Francis Inc.