BOSTON UNIVERSITY

GRADUATE SCHOOL OF ARTS AND SCIENCES

Dissertation

HYDROLOGY AND CLASSIC MAYA URBAN PLANNING: A GEOSPATIAL ANALYSIS OF SETTLEMENT AND WATER MANAGEMENT AT XULTUN, GUATEMALA

by

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A.L.B., Harvard University, 2008

Submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
2015

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Acknowledgements

There are many people who contributed to my understanding of archaeology, digital archaeology and Maya civilization, all of which led to the formulation of this dissertation. All of my committee members were supportive of my work, and conclusions, and provided me with insights into how to better structure my arguments. Within the Boston University community, many professors and graduate students contributed to my development as an archaeologist. Interacting with the many scholars who work on the San Bartolo-Xultun project over the last five years has had a great impact on my interpretations. Finally, my family has been an incredible support through graduate school.

My advisor, William Saturno, has provided invaluable support both through encouragement and financial resources. As director of the San Bartolo-Xultun project he allowed me access to the project and the freedom to explore my research interest at Xultun. Financially, Bill provided me with teaching fellow positions for two of the three field seasons in which my research was completed. He also provided assistance in my being awarded a GRAF which provided funding for the third field season. Bill provided me with full access to the remote sensing and geospatial data contained within the projects GIS as well as the technological equipment necessary for mapping at Xultun. Finally, he guided me in the fundamentals of remote sensing which started me along the research path I chose.

into how archaeology is performed differently depending on region and climate. He also provided endless advice and encouragement along the way. Mary Beaudry was a great help during the first few years of graduate school providing invaluable advice and guidance.

Interacting with fellow graduate students both at Boston University and in the field provided me with constant intellectual conversation which aided me in the development of my research ideas. Franco Rossi and Jenny Wildt were steadfast companions both in the classroom and the field. Benjamin Vining provided me with the technical expertise needed to begin the mapping project at Xultun. Alex Smith, of Brown University, helped me increase my understanding of survey methodology and interpretation. Lauren Santini, of Harvard University, provided countless insights into the environment at Xultun and past settlement in the area. Mary Clarke created incredible field drawings, of the excavated stela fragment, which contributed to my dissertation.

There were many others who I worked with in the field, without whom this research could not have been completed. T. U. Walter Omar Schwendener S. who supervised excavations, under my direction, within an elite compound at Xultun provided me with a great deal of data. Conversations with him also provided me with insights into the overall organization of settlement in this part of Xultun. My students Alex Kara, Josue Nieves, and Dan Cline provided invaluable assistance during the excavation process, providing field drawings,

Hydrology and Classic Maya Urban Planning: A Geospatial Analysis of

Settlement and Water Management at Xultun, Guatemala

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ABSTRACT

In this dissertation, I explore the relationship between water management, urbanism, and socio-political organization at the Classic Maya site of Xultun, Guatemala. In an area without permanent surface water, provisioning and maintenance of large stores of water was a necessity for agricultural stability. Combining evidence from archaeological survey, excavation, remote sensing, and geospatial analysis I demonstrate that settlement at Xultun was organized topographically. Elite ritual structures were concentrated on the highest areas, and in proximity to reservoirs. This gave leaders control over the release of water, and by extension control over their subjects.

Xultun was built on a natural hill. Urban space was concentrated into three topographic areas: administrative on the summit, residential on lower terraces, and agricultural on the lowest land. Using geospatial analysis, I modeled the relationship between the site's public and private buildings, its 15 reservoirs, and

its hydrology. Water was collected and stored within each of the three topographic zones for local use; however, administrative neighborhoods were located close to reservoirs in order to maintain tight control. Excavations at the site's summit revealed that the central reservoir was in use since the late Preclassic (400 BC-250 AD). They also revealed a complex drainage system that diverted water into an aqueduct that emptied into a canal feeding this reservoir. Overflow from the reservoir was directed to reservoirs farther downhill. Drainage flowed from the administrative center to the cardinal directions in accordance with Maya cosmological principles. The link between water and authority is further illustrated by the discovery, in an administrative neighborhood, of a stela depicting a royal ancestor in the act of impersonating Chak, the Maya Rain God.

At Xultun, the association of administrative neighborhoods with reservoirs in all three topographic areas reflects centralized control and management of urban water resources. The arrangement of hydrological systems emphasized cosmological principles and reinforced authority through ritual association with the rain deity. Water management was instrumental in the maintenance of power. As a key element of statecraft, its stratified spatial organization supported the hierarchical social order that took root in the Preclassic and came to characterize Maya urbanism.

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Chapter 1: Introduction and Theoretical Approach

Introduction

The goal of this dissertation is to refine current theories of ancient Maya urbanism through geographical analysis of settlement and water management features at Xultun, Guatemala. Settlement pattern studies in Mesoamerica began with Gordon Willey's study of the Belize Valley (Willey et al. 1965). In looking at various sites in the valley, Willey (1956) identified three models for the settlement patterns of Classic Period Maya sites: (1) densely packed residences around the ceremonial center (concentric); (2) residences scattered equally over a 10 mile radius (dispersed); and (3) the community clustered into hamlets around the ceremonial center (clustered). Maya settlement study techniques have developed over the past sixty years most dramatically with the addition of environmental studies, satellite imagery, computers and GIS software. The research presented here demonstrates that water management was a major factor in the settlement patterns displayed at Classic Maya sites. This is accomplished by viewing landscape data at Xultun at two levels. The entire 16 km² site was modeled using a high resolution DTM (Digital Terrain Model) and satellite data. This information is used primarily to identify water storage features across the site. The second level of analysis consists of excavations within an urban zone associated with a large central reservoir. These excavations facilitate better interpretations of the past uses of these spaces. Borrowing from

the field of urban geography, settlement is organized into four zones of use. These zones are labelled administrative, residential, production and open. The spatial distribution of these zones is patterned against water management features. This analysis lead to interpretations as to how the ancient Maya modified their landscape to collect water and organized their spaces around these modifications.

Theoretical Perspective

This research is concerned with the social archaeology of the landscape. I approach the question of spatial organization from the standpoint that there is a materialist-idealist unity in the way ancient landscapes should be interpreted. Whereas materialist views focus exclusively on physical resources and idealists focus on symbolic layouts, a combination of these approaches must be adopted to approach interpretations of how ancient societies viewed their urban centers. In this case, artificial water storage serves as the resource, and the patterning of settlement around this resource can be used to interpret the ideology behind Classic Maya site planning. GIS is an ideal tool for the combination and analysis of these varied data sets.

Basing this methodology heavily in practice theory as outlined by Bourdieu (1979); I follow Llobera (1996), who made a strong argument for combining Bourdieu's theory of practice, Giddens' (1984) structures, and Gibson's (1986)

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affordances into a theoretical methodology for using GIS for archaeological research. To apply this to my research I analyzed the distribution of various types of settlement to water resources at Xultun in an effort to interpret how individuals residing there perceived this part of the urban environment.

At large Maya urban centers, the landscape was modified in order to collect and store water. This process took advantage of the natural landscape but with heavy modification. It is my hypothesis that the urban design of these sites was planned ahead of construction. How people moved through the site and where certain types of behavior took place would have been carefully ordered onto the landscape based on a combination of resource availability and ideology. This would have affected how different classes of ancient Maya society experienced their urban space. Understanding the principles involved in this ordering adds important information to current discourse on issues of Maya social organization. To interpret the ordering of urban spaces I have found it helpful to borrow from the field of urban geography.

Urban Geography

Adoption of techniques used within other fields is commonly practiced in archaeology as the focus of research can cover virtually any aspect of ancient cultures. As early as 1968, K. C. Chang argued that different methodologies should be used in archaeology depending on the goals of the research. In fact, it could be argued that all of the social science disciplines share a common

underlying theoretical background and as such researchers should be defined first as social theorists and second as disciplinary specialists (Peet 1998:6). As ancient urbanism increasingly becomes a topic of interest within Mesoamerican archaeology, it makes sense to understand how geographers examine modern urban spaces. Smith (2010) has recently stated that there needs to be an increased interaction between modern geographers and archaeologists for researchers to understand urbanism holistically. Following Smith's suggestion, I compile data in a way that is easily accessible to geographers, and interpret these data using tools common to the field of urban geography.

Urban geography is a subfield of human geography. Human geographers study a variety of activities that take place over geographical space including economic, social, and political behaviors. Because of this, it is an ideal discipline to combine with archaeological data to answer questions related to ancient social processes and the spaces in which they were performed. Urban geography more specifically focuses either within urban centers, the *intrametropolitan approach*, or between urban centers, the *intermetropolitan approach* depending on the particular research question (Kaplan et al. 2004:3). Modern theoretical approaches to this discipline are varied, although my research focuses on humanistic urban geography and social theory. Humanistic geography attempts to understand the human world through examining people's relationship with nature, their geographical behavior, and their feelings as related to space (Tuan

1976:266). Social theory states that to interpret spatial data, power relationships

and social context must be understood and human agency must be considered

(Kaplan et al. 2004:10). These two approaches are combined into a holistic

understanding of the hydrologically induced ordering of space at Xultun.

Hierarchy, Heterarchy, and Hydrology

Analysis of premodern water management has traditionally focused on

tensions between heterarchy versus hierarchy perspectives (compare

Crumley1995; Scarborough 2003; Scarborough and Valdez 2003; Wittfogel

1957). Scholars tend to either take the stance that water management systems

were controlled centrally and redistributed or that they were controlled at the

household level with group coordination occurring as a form of collective action.

In the Lowland Maya region, it has been established that large ceremonial sites

functioned hierarchically in terms of political rulership with a king (*ajaw)* at the

top. In addition, translations of hieroglyphic inscriptions have pointed to

hierarchical relationships between sites (Martin and Grube 2008). Taking into

account the amount of labor invested in the construction of reservoirs, dams,

canals, and diversion weirs, it is proposed that the collection and storage of water

at large urban centers was organized and controlled by the elite (Scarborough

2003:113). It does not prove, however, that the resource was redistributed by

elites. The heterarchy/hierarchy debate is overly simplistic as it limits the options

to one or the other ignoring the possibility of hybrid forms such as proposed by

Garrison (2007) and discussed by Scarborough and Lucero (2010). Even if the construction of water management systems was organized by elites, it is possible that once built they served as a public amenity. This is found in other ancient cultures such as the public fountains in ancient Greece (Crouch 1993).

Beach and Dunning (1997) excavated a dam and residential reservoir on the outskirts of the site of Tamarindito in the Río de la Pasión region of El Petén, Guatemala. This Late Classic complex was in the midst of an area of intense terracing and functioned to conserve both soil and water for agricultural purposes. The researchers concluded that there was a strong elite interest in the maintenance of rural agricultural practices. The results, however, could also support a heterarchical model of water management because it is an example of small scale rural water management in a farming community and therefore I argue more likely represents the interests of the local residents and not distant elites.

In opposition to Beach and Dunning (1997), Hughbanks (2006), looking at landscape management at Guijarral, Belize, worked from a hypothesis that the water management system's most important managerial positions were held by wealthy occupants at the site center. Borrowing from the work of Lansing (1991) and Lansing and Kremer (1993) in Bali, Hughbanks determined that there was an identifiable relationship between the spatial organization of the community and the management of its water resources. In turn, social status was determined

through an assessment of wealth based on housing type, material remains, and burials. This study supports a hierarchical model of water management in that elite residences were associated with stored water sources but stopped short of looking at overall settlement patterns. Hughbanks (2006) also makes the leap of tying together water management and settlement studies.   These two fields have traditionally been studied separately but recent work at sites like Palenque (French 2009) and Tikal (Scarborough et al. 2012) have demonstrated their interconnectedness.

Relevant Framework and Studies

Survey and mapping within the Maya Lowlands has always been problematic due to the extremely dense vegetation. From early on, researchers have looked for ways to identify sites without having to trek into the forest. The use of emerging technologies to look at the forest canopy from above has become established practice in modern survey methods. One of the earliest attempts at this was an aerial survey conducted over the Lowland Maya region in 1929 (Kidder 1930; Ricketson and Kidder 1930). This proved only mildly successful as several previously unknown ruins were identified poking out of the trees. The density of the forest was still a problem. Later, from the 1980's forward, attempts were made to identify vegetation signatures associated with ancient settlement using 30-meter Landsat TM data, airborne 5-meter Thermal Infrared Multispectral Scanner (TIMS), and airborne color infrared (CIR)

photography (Sever 1998, 1999; Sever and Irwin 2003). Although not successful, due to resolution limitations, these studies were able to identify ancient anthropomorphic modifications on the landscape such as sacbeob (causeways) and reservoirs. In 2003, Dr. Saturno was the first to identify a vegetation signature associated with ancient settlement using high resolution 1-meter IKONOS image data (Saturno et al. 2007). Through the creation of a false color composite, vegetation stress associated with ancient settlement was visible making this technique very exciting for its potential to reduce the time involved in traditional ground survey. Further attempts were made to refine these techniques through the classification of different vegetation types and their likely association with ancient settlement. Garrison developed a new ground survey technique using a random block survey to better represent the distribution of settlement within the various classes of vegetation in the Petén (Garrison 2007). Using remote sensing techniques to specifically focus on water resources, Thomas (2010) used a combination of multispectral 1-meter IKONOS data and 5-meter AirSAR DTM to identify *aguadas* (artificial and natural depressions used to store water) around Tikal, Guatemala.

GIS is a powerful tool providing new ways for researchers to organize and visualize data. In the Maya region, it is particularly useful when combined with remote sensing data for modeling the landscape and as such has been used extensively in modern landscape archaeological research. A recent publication

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by Dorshow (2012) has served as a great inspiration for the hydrological aspects of my research. In this study, Dorshow used ArcHydro to model the watershed of Chaco Canyon during the Bonito phase (ca. AD 850-1150). He was then able to model and compare the agricultural potential of the region using various farming techniques. Although focused on agriculture and not urban settlement, this study utilized a sophisticated hydrological model and weighted map layers to predict past behaviors. Llobera (2001) performing a geospatial analysis of topographic prominence within the Yorkshire Wolds, England demonstrated that archaeological remains over a broad time span (Late Nealithic to Iron Age) consistently clustered by type on either prominences or in ditches. This study demonstrates the strength of GIS for visualizing statistical information that is not usually apparent when looking at conventional archaeological data. It also demonstrates the importance the landscape plays on where people chose to build in antiquity.

As an extension on landscape studies, GIS has also played an important role in settlement studies. Folan et al. (2009) used GIS to test the concentric model of settlement at the site of Coba, Mexico. They found that large elite residential compounds seemed to be concentrated around the site core diminishing with distance. This supported the concentric model for settlement at Coba. On the other hand, Estrada-Belli (2003) working at La Milpa, Belize used GIS to look at the topography as well as settlement and found that large elite

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compounds were built on four roughly evenly spaced hills oriented to the cardinal directions from the ceremonial center. This demonstrated a new form of settlement based on an idealized cosmogram. These results demonstrate that the Maya had varied reasons for choosing sites in which to build their cities.

There has been a recent drive in archaeology, specifically in Mesoamerican archaeology, to better understand the past urban environment. This focus on urbanism has been spearheaded by Michael Smith. He has proposed that archaeology has the potential to benefit modern urban studies. Unfortunately, archaeological data are not organized in a way that is easily accessible for urban geographers, and he hopes to change this trend and will be focusing his research on GIS analysis of inequality of access to basic services at ancient sites (Smith 2012:17). Following Smith, I developed a GIS of Xultun and examined patterns of drainage and water storage within different urban zones. My analysis highlights the type of inequality in which Smith is interested and provides data that are accessible and usable to policy makers interested in tropical sustainability.

Fletcher (2012) compared a number of ancient tropical sites from around the world and identified a new type of urbanism he coined as low-density, agrarian-based urbanism. The Lowland Maya were one of the main inspirations for his work. These types of settlements are dispersed with extensive urban agriculture. Based on Netting's (1993) model of smallholder intensive cultivation,

this low-density urbanism model has been taken a step further and suggested for preindustrial sites outside of the tropics also (Isendahl and Smith 2013:133). In these communities, housing is clustered into neighborhoods each serving as a local administrative unit. These local units tend to have a common economic function and are self-governed which increased sustainability due to the forces of local interaction (Isendahl and Smith 2013:133). Not all open spaces at these sites were agricultural in nature. Obviously in the Maya area many of the larger plazas served as public ritual venues; but in urban centers, public spaces tend to serve many functions. In addition to top-down performances of symbolic public display, often these spaces served as centers of bottom-up, grassroots activities (Stanley et al. 2012:1090).

Water management has been implicated as a major factor in the formation of settlement patterns at ancient sites throughout the world. In the broad sense, this has been examined in interpretations of site location. Often there are permanent supplies of fresh water associated with ancient sites. Early researchers viewed this as necessary to support the agricultural surplus required for urbanism to develop (Childe 1950). This was not true of the many sites in Mesoamerica. My research, however, is focused on how the intra-site management of water influenced settlement on the small scale. I will be investigating how the design of a water management system impacted settlement decisions of the population at Xultun. Fletcher's (2012) work

highlighted the water management induced settlement at Angkor, Cambodia. Here large open spaces were used to store water for the intensive agricultural activity taking place there and creating an orthogonal site plan. At Tenochtitlan, Mexico, the former Aztec capital, the layout was also relatively orthogonal. The city was built on reclaimed land in the middle of Lake Texcoco, and the "roads" separating sections of the city were canals. *Chinampas* are agricultural fields build on reclaimed land, and it has been suggested that it was chinampa agriculture that led to the orthogonal layout of the city (Smith 2008:475). Both of these examples demonstrate how water management features within a site can impact settlement.

Overall, the Lowland topography is much flatter than the mountainous highlands. The risk of seasonal flooding in this low, flat region led to the development of settlement on higher elevations, which are distributed irregularly. Because of these environmental constraints orthogonal planning is not seen in the Maya Lowlands. At Palenque, Mexico, one of the most important Classic Maya capitals, hydrological engineering was used extensively to impact settlement. This site is unique in the Maya region due to the presence of permanent spring fed waterways. Here the Maya increased building space by constructing aqueducts with building platforms over them (French 2002, 2007). In the Lowlands, the Maya constructed their urban centers on upland areas as a series of terraces designed to capture, direct, and store rainwater. Scarborough

(2003) refers to this design as artificial convex microwatersheds. Fletcher's

(2012) work compared Angkor with the Maya Lowlands and also categorized

Maya settlement as low density, agrarian-based urbanism.

Social Area Analysis and the Urban Mosaic

Urban geography specializes in the categorization of urban spaces based

on any number of factors. Most often these factors are based on modern issues

such as changing economic trends or ethnic concentrations. These are usually

difficult to see in the archaeological record and archaeologists seldom have the

volume of data that are available to modern geographers. That being said, the

tools used by urban geographers can be adapted to categorize and analyze

ancient urban centers based on available data. In the following section, I

describe the historical development of models of urban spatial structure and

describe how they can be modified and applied to Classic Maya urbanism.

Urban ecology is the overarching term used to describe the understanding

of how urban space is organized. The clustering of similar groups is based on

the principle of social distance which states that social groups want to have little

to no contact with other groups and as a result they create spatial distance

(Kaplan et al. 2004:180). There have been three major models used to describe

urban spatial structure developed during the twentieth century (Fig. 1.1). These

models focus on more or less the same factors and are based on modern cities. These factors include a central business district, manufacturing, various classes of residential zones, and sometimes ethnic divisions. The first model was a concentric zone model with rings around the central business district representing the various residential classes roughly moving up as one moved away from the center, although this is reversed at ancient Mesoamerican sites (Burgess 1925). The second model was a sector model, still oriented around a central business district but with some concentric rings and branches, especially the upper class who were grouped together (Hoyt 1939). The third model abandoned the central core for a multiple nuclei model in which urbanism is clustered around several centers (Harris and Ullman 1945).

CONCENTRIC ZONE THEORY

SECTOR THEORY

MULTIPLE NUCLEI

THREE GENERALIZATIONS OF THE INTERNAL STRUCTURE OF CITIES

DISTRICT
1. Central Business District
2. Wholesale Light Manufacturing
3. Low-class Residential
4. Medium-class Residential
5. High-class Residential
6. Heavy Manufacturing
7. Outlying Business District
8. Residential Suburb
9. Industrial Suburb
10. Commuters' Zone

CDH-ELU 1945

Figure 1.1 Three models of urban structure within cities (Harris and Ullman 1945:13).

These models served as the inspiration for the development of social area analysis. This analysis was focused on the three primary forces that shape the modern city: (1) socioeconomic status, (2) family structure, and (3) ethnic status (Shevky and Bell 1955). In theory, each of these forces would have a spatial expression that could be mapped empirically, and it was noted that high income houses tended to cluster into sectors as Hoyt's model predicted. These ideas and the advent of large data sets and computers led to the development of quantitative methods known as factorial ecology (Timms 1971). These techniques were used to test the three spatial models but none of them seemed to fit the data.

The next important development was proposed by Murdie (1969) as a solution to the problem with the spatial models. He proposed an urban mosaic attributing specific data sets to specific models and layering them much like modern GIS models. Murdie found that the socioeconomic factor best fit the sector model, family structure best fit the concentric model, and ethnic and racial concentrations best fit the multiple node model. The layering of these data sets creates new visual patterns that better represent the data collected.

The three social factors described above are not entirely compatible with archaeological data. As Smith and Novic (2012:2) recently stated "development of archaeological methods for analysis of neighborhoods is still in its infancy."

Within the Maya Lowlands, socioeconomic data can be inferred at the household

level. As for the second factor, household structure can be reconstructed based

on ethnography and ethnohistoric accounts (Wilk 1988). The third factor is

problematic, although there are some examples of immigrant enclaves found at

Teotihuacan, Tikal and some other sites, they are often difficult to identify

archaeologically. Because of this, it is important to identify other archaeologically

apparent social factors.

Through excavation and comparative analysis with similar structure

groupings at other sites, the processes taking place in these various groups at

Xultun can be hypothesized. It will first be necessary to categorize the various

spaces within the site. Households can be grouped into neighborhoods which

can be grouped into districts, although this is more apparent in Highland Mexico

(Smith and Novic 2012). Some of these neighborhoods and districts had specific

craft specialization functions such as local administration, elite ceramic

production, or textile production (Isendahl and Smith 2013; Becker 2003;

Sanders and Webster 1988). In addition to the built environment, open spaces

also served a variety of purposes within urban environments and will be

categorized accordingly **(**Stanley et al. 2012).

Categories of Spatial Analysis

This research focuses on the distribution of urban space within one site and as such the intrametropolitan approach to urban geography is appropriate. Through the use of selective excavation and comparison with similar structure types at other Classic Maya centers, I categorize the urban settlement at Xultun into multiple zones. The distribution of these zones is modeled against the hydrological system in place to identify settlement patterns associated with the water management system at this Classic Maya site.

The hydrological system is modeled digitally with the use of a high resolution DTM of the site. This allows me to identify streams, reservoirs, and other hydrological features within the site. These water management features are combined into a GIS with various spatial zones identified through the survey and mapping of the site. These zones are administrative, production, residential, and empty space and are described below.

Administrative zones are defined as elite governmental and or ritual structures which served as a control over the processes of daily social interaction. These structures fall into two broad categories for the purposes of my research. The first being politico-ritual structures including temples, plazas, palaces, and other monuments to the state. The second is water management which consists of large structures which are positioned in such a way to control access to stored water.

Production zones are defined as areas used primarily for the production of goods and procurement of natural resources. These areas are categorized into three sub-types. These include quarries for the collection of limestone and chert, plaster production zones, and craft production areas such as neighborhoods that specialized in the production of ceramics.

Residential zones are defined as areas that consist of mostly housing groups. These will most likely overlap with other zones, especially production zones, however patterns may still be evident based on a residential typology. Broadly, residences will be divided into elite and non-elite groupings, although these may be subdivided if there seems to be several categories such as royal, elite, non-elite.

Empty spaces are divided into a number of different zones that represent public spaces, agricultural fields, water storage, etc., depending on the context in which they are associated.

Excavations focused on a "neighborhood" located within the catchment area of a central reservoir at the site. These excavations were performed to better understand what types of activities were taking place within a water collection zone and to determine if the stored water was elite administered. The data collected through excavation is combined with the survey data of the site and through geographical analysis of these different data sets the interpretations

are made about the impact of water management features on settlement choices by the ancient Maya at Xultun.

Figure 1.2 Locations of major archaeological sites mentioned in this dissertation.

Outline of Dissertation Chapters

In Chapter 2, I tie together settlement studies with hydrological studies and urban studies. This is done through a description of trends in Maya settlement studies most notably a focus on ecological conditions. This leads to a discussion of studies of ancient hydrological technologies from around the globe and then focusing on water management within the Maya Lowlands. I then outline the historical development of archaeological research into urbanism focusing particularly on research within Mesoamerica. I explore the discipline of urban geography, its history, and how urban geography has been applied to archaeological research. Finally, moving forward from this foundation, I describe three different ecological regions where settlement is found within the Lowlands. These regions are related to available water in the form of rivers, lakes, and only collected and stored supplies. How settlement patterns differ between these three regions is discussed in an effort to lay the foundations for my more in depth description of how water management affects settlement patterns.

In Chapter 3, I focus on the mapping of Xultun and the use of remote sensing to aid in this effort. I begin with an historical description of the discovery of Xultun and previous mapping attempts. I then discuss the methods used in the development of the current digital map followed by a description of some of the new groups and features added to the map. The information from the map is tabulated into a table that describes the distribution of recorded features. Following the description of the current map, I discuss the use of remote sensing

in the identification of Maya settlement and how these techniques are used at

Xultun to identify both settlement and water storage features.

In Chapter 4, I describe how urban geography is applied to my research,

and I map the four urban zones identified within the map of Xultun using ArcGIS

10.1. I also identify various neighborhoods within the site. This visualization is

used to describe the distribution of urban space at Xultun.

In Chapter 5, I describe the methods used to model hydrological flow over

the site. This is done in two phases: (1) a low resolution model of the entire site,

and (2) a high resolution model of the mapped areas of the site. This information

is combined with the mapped water storage features to describe how water was

redirected and collected across the site with a specific focus on the large central

reservoir. This model is combined with the urban zone map developed in

Chapter 4 to examine the spatial relationships between these four urban zones,

water storage, and water collection.

In Chapter 6, I describe the excavations conducted within the central

reservoir and its catchment area. Within the catchment area two different canals

were discovered as well as an elite residence associated with the reservoir.

In Chapter 7, I describe the conclusions of my research. Through the

combination of multiple lines of evidence, including satellite data, modeled

hydrology, urban zoning, excavations, and iconographic interpretations, it is

determined that the Maya elite maintained hierarchical control of water resources, within urban areas. Although there is some evidence for riparian rights, administrative groups were associated with stored water, even in residential zones. The hydrological model at Xultun matches the convex microwatershed described by Scarborough (2004) for Classic Maya sites. This includes a three tier system of collection and storage with administrative use at the top, residential use in the middle, and agricultural use at the bottom. The three tiers represent the underworld, the human world, and heaven and with the drainage diverted to the cardinal directions, replicates Maya cosmology.

Chapter 2: Settlement, Water Management, and Urbanism

Introduction

In this chapter, I highlight the major historical trends in the development of Mesoamerican settlement studies, and urban studies in general, with a focus on the Lowland Maya. The majority of this chapter takes the form of a literature review of trends in Maya settlement studies, hydrology, and urban studies. I then go on to discuss some of the major ecological zones settled by the Maya, with a focus on local hydrological conditions, and how these influenced settlement patterns. Finally, I discuss settlement archaeology and hydrological analysis methodologies that are used in my research at Xultun. This chapter demonstrates the overall influence that hydrology played on Maya settlement patterns at both the macro and micro scales, laying the foundation for my research into how the Maya elite organized urban space to manage this resource.

Trends in Maya Settlement Studies

New World settlement pattern studies began with the work of Gordon R.

Willey (1953), who developed his methodology in the Virú Valley of coastal Perú.

Willey defined ancient settlement patterns as the way in which man disposed

himself over the landscape. These patterns reflect the culture's natural

environment, level of technology, and institutions of social interaction. The four

main goals of his research were to (1) describe sites geographically and

chronologically, (2) interpret function, (3) reconstruct cultural institutions, and (4)

compare with other regions. Willey used aerial photography in combination with

site maps and extensive ground survey to map the settlement in the valley and

draw conclusions about the development of complex society within this region.

Willey's study had an enormous impact within the field of archaeology, and

settlement studies were adopted by researchers around the globe (Chang 1963;

Adams 1965; Butzer 1976). He classified three main site types (1) living sites,

(2) community ceremonial structures, and (3) fortified areas. Reconstruction of

occupation periods was accomplished through ceramic chronologies. These

data were then combined to reconstruct the cultural development within the

valley. The gradual addition of new data sets has allowed researchers to shift

from large regional to intra-site analysis. Willey's three models, however, have

served as the starting point for most studies into Lowland Maya settlement

including modern debates into issues of political organization such as hierarchy

and heterarchy. Many of these debates focus on urban water management at

large Maya sites.

The use of aerial photography and extensive ground survey has proven most productive in arid regions with little vegetative ground cover. In the Petén region of Guatemala where dense semi-tropical forest dominates, these techniques have been less useful and as a result different settlement analysis methodologies have been developed. These began with mule train explorations within the forest, to identify sites, and most recently researchers have incorporated multispectral satellite imagery, radar DTM's, and in at least one case LIDAR (Bullard 1960; Chase and Chase 1998; Sever and Irwin 2003; Saturno et al. 2007). The use of satellite imagery within the Petén is still experimental and requires ground truthing which is time consuming and laborious. Often the forest is so dense that it is impossible to see more than a few feet in front you, and it can be difficult to locate your position without a GPS. These new techniques do hold the promise of making the locating of sites and features easier, although much of the survey methodology developed here is still slow and time consuming due to visibility and mobility limitations.

All settlement studies in the Maya area can be boiled down to one of two broad research questions: (1) the question of people's relationship with their environment, and (2) people's relationships to each other. Until recently the vast majority of research was focused on the politico-ceremonial structures at the core of these sites. Many early mapping projects only detailed these central cores due to both time constrains and the focus on collection of hieroglyphic

inscriptions. There were, however, some early researchers who saw the importance of analyzing smaller domestic structures and how they associated with the ceremonial cores.

The first archaeologist to focus on domestic structures and their relationship to centers was Edward H. Thompson (1886, 1892) with his early work in the Yucatan. After this, there were no major developments in settlement studies until S.K. Lothrop's (1924) work at Tulum, Mexico where he focused on density and distribution of small mounds. During the 1930's Maya research was dominated by the Carnegie Institution of Washington. It was during this period that several settlement analysis procedures were developed. Ricketson and Ricketson (1937) performed a transect survey around Uaxactun with four one mile long arms stretching to the cardinal directions. These types of transect surveys have served as a standard for estimating regional settlement until today. J. Eric S. Thompson (1931) performed the first systematic settlement survey integrating ceremonial and residential mounds at Mountain Cow Belize. These studies along with Smiths (1936) ceramic chronology and Morley's (1936-1939) regional survey influenced all subsequent settlement research in the Lowland Maya region.

During the 1950's and 1960's further developments were made in the settlement study methodologies. Willey (1956) attempted to summarize overall patterns across time and regions noting that many smaller groupings of house mounds tended to have one larger group suggesting local political and religious

practices. He described three models of Classic Maya settlement (1) dispersed,

(2) concentric, and (3) clustered and that true urbanism didn't develop until the

Postclassic in the Yucatan (Willey 1956). Today it is understood that there are

many different forms of urbanism and most Mayanists consider large Classic

period sites to represent true urbanism.

Other important analytical developments at this time were the

categorization of sites into hierarchical units (Bullard 1960; Sanders 1962-63).

Bullard (1960) performing survey work primarily around lake Yaxhá and Dos

Aguadas identified three categories of archaeological site: (1) house ruins, (2)

minor ceremonial centers, and (3) major ceremonial centers based mainly on the

complexity of architecture. He further categorized regional settlement into

clusters of house groups, zones around minor centers representing dispersed

towns and districts around major centers similar to what we would call a county.

This represents a good early attempt at understanding how the Maya organized

themselves in space. In addition, at this time research into social organization

and population density was begun at Tikal (Haviland 1963, 68-70).

Further developments went hand in hand with the development of

processual archaeology in the late 1960's and 1970's and focused on systematic

sampling of regions moving toward a focus on large scale patterns and intersite

surveys (Puleston 1973; Rice 1976; Tortellot 1970-76). This is best represented

by the Basin of Mexico settlement survey in which surface debris were translated

into settlement pattern maps illustrating processes of sociopolitical evolution as

well as ecological adaptation (Sanders et al. 1979). Sanders et al. (1979)

combined these survey data with colonial tax records, contemporary settlement

patterns and burial data to estimate past population. During this period, Puleston

(1983) developed an improved method of survey for intersite areas in the Petén

at Tikal. Understanding that simple transect surveys can miss key environmental

factors to settlement, he modified this technique by staking out the transects and

using a five man team spaced at 25 meters to map as much area off of the

transects as possible. In this way he was able to determine that the Maya

preferred to build on well drained higher elevations.

Much of the work from the 1980's to today has focused on developing

interpretive theories to describe the settlement patterns observed at various

sites. These have ranged from agricultural necessity and cosmological order to

looking for underlying mathematical principles such as fractals (Adams and

Jones 1981; Brown and Wischeg 2003; Killion 1992; Mathews and Garber 2004).

In essence there has been an effort to find an underlying order for patterns that

do not conform to western ideals. One popular theory during this time, borrowed

from geography, was Christaller's central place theory. This theory focused on

commercial factors as influences in the distribution of sites over the landscape.

Smith (1979) adapted this theory to analyze the placement of Aztec

marketplaces and to create a hierarchy of five ranks of site. Mathews and Garber

(2004) examined Maya cosmology as an underlying principle in the layout of

sites, structures, and agricultural fields as an explanation for the universality of

quadripartite organization. Brown and Wischeg (2003) used mathematical models to identify intrasite fractal patterns at sites in the Yucatan and determined that family groups likely represented a microcosm of the state.

There has also been an increased focus on the excavation of households which has increased the amount and types of data that can be used in settlement studies (Carballo 2011, Robin 2003). The major benefit of this type of research is in the interpretation of various zones of use within a site and information on how domestic spaces were used by both elite and non-elite households Becker (2003) identified a household unit that served as a fine ceramics workshop at Tikal. He was also able to categorize what he termed an *architectural grammar* of specific types of house groups associated with different functions (Becker 2004). Carballo (2009) working at the site of La Laguna in Tlaxcala, Mexico excavated two households, one elite and one not. The major differences between the two groups were the amount of labor involved in construction and the lack of ritual lancets for bloodletting at the non-elite site (Carballo 2009). There must have been a difference in ritual practices between different levels of society. Very recently there has been an increased focus on categorizing and interpreting ancient urban spaces in ways that are accessible to modern geographers allowing for comparative studies across cultures and time. This direction has been pioneered by Michael Smith and his colleagues at Arizona State University.

Although aerial photography continues to be useless in survey within the Petén, recent advances in the use of multispectral satellite imagery have shown promise in the identification of anthropogenic modifications on the landscape. Work pioneered by Tom Sever was able to identify large features such as causeways and signs of ancient agricultural intensification. Recent work by Saturno et al. (2007) identified a reflectance signature on the forest canopy that is associated with ancient settlement. These techniques hold promise for speeding up the process of mapping sites in this region and gaining a better understanding of regional settlement here. The focus on ecological factors invariably leads to the importance of water.

Hydrology

Water management studies have been undertaken by archaeologists in virtually every region of the ancient world to gain a greater understanding of urbanism, agricultural practices, politics, and population dynamics. The adoption of hydrological analysis within these studies, involves the building and testing of hydrological models based on a region's topography, water resources, weather systems, and soils. Many of these studies incorporate GIS analyses to assess the landscape and environmental confines that define the flow of water. Water management studies incorporating GIS analyses have great potential for also

ascertaining how the organization of water systems, and specifically Maya water systems, influenced settlement patterns.

Archaeological studies of hydrology span the globe. In Mesopotamia, for example, studies have focused on the intensification of cultivation during the Iron Age (1200-600 B.C.) using irrigation and other methods (Altaweel 2008; Altaweel and Chikako 2012; Crook 2009; Harrower 2010). These studies employed hydrological modeling of the environment based on modern records of rainfall patterns. GIS techniques were then used to adjust the data through time based on the models. With these methods, agricultural intensification technologies were analyzed and assessed, concluding that the most sustainable systems used a combination of practices from irrigation to rainwater diversion and fertilization with animal waste (Altaweel 2008:822; Crook 2009:2428). Another example resulting from a hydrological study is found at the Wadi Sana, Yemen, Southwest Arabia. Check dams were built in high flow areas, while diversion dams were built in low flow areas demonstrating that the ancient inhabitants intentionally focused on redirecting low energy runoff for agricultural purposes (Harrower 2010:1449, 1451). In Chaco Canyon, New Mexico, hydrological and GIS techniques were used to classify the topography and watershed into regions that would have been suitable for cultivation in the past (Dorshow 2012). As a result, it was shown that the total useful agricultural area, and thus potential yield in the region, was much higher than previous estimates indicating the potential

for a much larger population (Dorshow 2012:17). Research in Hawaii on pre-contact settlement using GIS techniques modeled two forms of agricultural intensification: (1) irrigated wetlands, and (2) rain-fed drylands on the topography (Ladefoged et al. 2009:2377). Though the results were not ideal due to the coarseness of the digital elevation model and more modern landscape modifications, the model predictions corresponded well with previous archaeological surveys (Ladefoged et al. 2009:2378). This makes the Hawaiian model a good predictive indicator for areas of past agricultural activity associated with settlement. Ancient Greece also saw early development of very sophisticated water management technologies, not only for agricultural purposes. Cities dating to before 400 B.C. often used a variety of water sources such as aqueducts, springs, wells, and rainwater cisterns to provide drinking water and to supply public fountains (Crouch 1993).

In Mesoamerica, one of the most monumental early water management structures is the Purrón Dam in highland Mexico. This complex, begun around 700 B.C., was 400 meters across, 100 meters wide, and entirely faced with cut stone blocks. At its largest phase, it would have created a reservoir of up to 2,640,000 cubic meters, which would have been used to irrigate adjoining fields (Woodbury and Neely 1972). It has been argued that control of this water management structure was instrumental in the development of a chiefdom level

civilization in this area—an example of water management by a local faction leading to institutionalized hierarchy (Spencer 1993:51).

Taking advantage of local geography to build specialized water management systems is also seen at Teotihuacan, Mexico. To the south of the city, evidence exists of drainage canals consistent with *chinampa* use, though these may be Postclassic, as well as rerouted waterways that clearly brought water into the city during the Terminal Formative and Early Classic periods (Nichols et al. 2006:62). The natural course of the San Juan river was changed to conform with the city's grid and it has even been argued that rerouted water served a ritual purpose associated with the Feathered Serpent Pyramid (Sugiyama 2005:65). These examples demonstrate how management of water resources can be instrumental in the rise of an elite class through both the development and control of agricultural production and the use of monumentality, ritual, and ideology. Water as the source of life has inherent symbolic power which was exploited in Mesoamerica by the religious elite.

Another example, and probably the most well-known water management system in Mesoamerica, was found at the Postclassic Aztec capital of Tenochtitlan whose remains now lay beneath Mexico City. This city was built through land reclamation in the center of Lake Texcoco. According to Palerm (1973), there were four basic hydraulic organizations used for agriculture in the Basin of Mexico: aqueducts, canals, *chinampas*, and dikes. Some dikes, in

addition to separating bodies of water, connected the city to other communities (Diaz del Castillo 2008:156). The Chapultepec aqueduct fed the city much of its freshwater and had an advanced two-pipe design with a gate to switch flow between pipes while cleaning (Soustelle 1956:46). To prevent flooding, the city used a grid system of canals (Carballal, Staedtler, and Flores Hernández, 2006). Also in place was the *chinampa* system. These "floating gardens" were kept fertile through a combination of mucking and manuring with human waste collected from canoes stationed beneath latrines throughout the city (Armillas 1971).

Water Management in the Maya Lowlands

The importance of water systems for agriculture, urban development, and even political stability is appreciated in cases ranging from Mesopotamia to Greece to North America and Mesoamerica. The Maya were not an isolated culture and indeed would have exchanged ideas and technology with groups from other parts of Mesoamerica. As such similar technologies are seen in the Lowland Maya region including dams, canals, diversion weirs, aqueducts, reservoirs and forms of agricultural land modification (French and Duffy 2009; Gallopin 1990; Scarborough et al. 2012). The environmental constraints within the Maya Lowlands were however, starkly different than other parts of Mesoamerica. The seasonality of rainfall within the semi-tropical environment created problems not only of collection and storage but also for drainage and

flood mitigation. These problems were overcome by the design and implementation of complex hydrological systems based on an in depth understanding of the environment. Maya storage systems also required outflow capacity during heavy rains to prevent flooding of their urban cores. In some instances this was performed by the building of causeways with internal sluice gates (Scarborough et al. 2012). These structures would function as dams, containing water within an adjacent reservoir and releasing this water down slope when supply was too high. "[W]ater systems are a principal facet of a society's overall institutional arrangements which order or structure it" (Scarborough 2003:29). Analysis of water management has traditionally focused on a heterarchy versus hierarchy perspective (compare Crumley1995; Scarborough 2003; Scarborough and Valdez 2003; Wittfogel 1957).

In the Petén, during both the Preclassic and Classic periods, the Maya used the complex system of *bajos* (low lying areas that experience seasonal flooding) as water sources for both the population and irrigation (Beach, et al. 2006), since many Lowland Maya centers were built on the edges of such features. During the early Classic period reservoirs were built to develop a higher level of water control. The reservoirs were constructed through modification of natural depressions and limestone quarries and in association with diversion dams and sluice gates. These gates were used to control the flow of water to and from these reservoirs (Scarborough 2003:111). Classic Period

sites such as Tikal, La Milpa, and Kinal used convex surface micro-watersheds to exert greater control over drainage and runoff (Gallopin 1990:6; Scarborough 2003:111). Estimates of water containment at Tikal, for example, determined that the population could easily be maintained through the dry season (Gallopin 1990:98; Scarborough 2003:51).

It has also been suggested that control and cleanliness of these aquatic resources served as the basis of Lowland Maya kingship (Lucero 1999). Lucero et al. (2011:483) propose that the Maya transformed their reservoirs into wetland biospheres with pond plants and associated algae and bacteria. These natural additions could regulate water toxins and attract natural predators for small flying insects keeping the water clean. In Maya iconography, water lily symbolism is associated with kingship (Lucero 1999). Because water lilies grow only in clean water, a link can be made between the role of water management and the rise of kingship in this region. In other studies performed in parts of Mesoamerica, water management has been closely associated with the evolution of complex societies (Spencer 1993; Spencer and Redmond 2004).

Regarding the Classic Maya, the most impressive water management system is found at Palenque, Mexico. The environment in which this center was built is very different from the Petén, with rugged topography and nine waterways emanating from 56 springs (French and Duffy 2010:1028). Settlement was very dense as there was little area for residential structures. The planners of the city

did engineer a water management system of aqueducts, bridges, dams, drains, walled channels, and pools both to reduce flooding in the rainy season and to maintain water during the dry season (French 2002:1). In addition, they used aqueducts to build artificial plazas over existing waterways to increase building space. There is even an example of a pressure building system that may have been used to feed a fountain, the only known use of this technology in the ancient Americas (French and Duffy 2010). Furthermore, there were no water storage features built at this site due to the abundance of surface water, and paleo-hydrological studies determined that drought could not have led to the collapse of this site (French et al. 2012). Located in a unique environment, the site demonstrates the ingenuity of the Classic Maya and their mastery of engineering and settlement planning.

Urban Studies

The theoretical foundations for studies of ancient urbanism have gone through major transitions throughout the second half of the twentieth century. These changes in theoretical position have led to archaeologists thinking about new approaches and asking new kinds of questions. This in turn has led to the development of new methodologies for answering these questions. Although there is still much to learn about ancient urbanism in Mesoamerica, archaeologists have made significant headway. Urban geography has

developed strong theoretical and methodological approaches to the study of modern urbanism, and it is a great resource for helping archaeologists understand what to look for and how to organize data in meaningful ways. In this chapter I will outline the historical development of archaeological studies of urbanism focusing on major theoretical developments that have altered research paradigms. I will then review some of the major applications of these theoretical developments to Mesoamerica as researchers have attempted to understand how urbanism functions in this region. I will then briefly describe the discipline of urban geography and discuss some major studies in which geographical principles have been adapted to archaeology in Mesoamerica with a focus on the Maya. Finally, I will describe how techniques derived from urban geography will be applied to my research.

Historical Development of Archaeological Research on Urbanism

One of the problems with understanding urbanism is deciding on an appropriate definition for this social structure. For example, the Merriam-Webster dictionary defines urbanism as (1) the characteristic way of life of city dwellers, (2a) the study of the physical needs of urban societies, (2b) city planning, and (3) urbanization. The first definition gives us a place to start based in social science; we are looking at the characteristic way of life for those who live in cities. The sociological definition of the city involves three factors: (1) large population, (2) dense nucleation of the population, and (3) internal heterogeneity (Wirth 1938).

In opposition to this, modern geographers tend to define cities based on specific population numbers. The disconnect between modern urban geography and archaeological investigations into urbanism is based on the amount and types of data available to researchers. While geographers are able to examine living human systems, an archaeologist must find evidence of the past based on what little has been preserved. As a result, archaeologists have spent decades debating the nature of urbanism and devising theories and methodologies originating in philosophy, anthropology, ethnography, economics, and geography to define cities in a way that allows for meaningful interpretations of what is found in the archaeological record (Blanton 1976; Sanders and Webster 1988; Cowgill 2004; Marcus 2008).

The first and most influential theoretical work on the development of urbanism based on archaeological evidence was Childe's (1950) Urban Revolution. Using data from Woolley's excavations at the Mesopotamian site of Ur, Childe adopted a cultural evolutionary theory based in Marxism to describe how the first cities formed from pre-urban societies. He defined three stages of cultural evolution using terminology borrowed from sociology. These stages were: (1) savagery which represented hunter-gatherer society, (2) barbarism which equated to pre-urban domestication of plants and animals, and (3) civilization which is represented by urbanism. A series of technological advancements which increased agricultural surplus allowed for the development

of sedentism and then full-time specialists. Of particular importance, Childe

outlined ten criteria of urbanism that were seen in the first cities. Roughly stated

these were: (1) high and dense population; (2) full-time specialists; (3) surplus

provided to a central authority; (4) monumental architecture; (5) a ruling class; (6)

writing; (7) calendrics and math; (8) high art; (9) long distance trade; and (10)

state ideology.

Childe's ten criteria of urbanism have been criticized as not being useful in

comparative studies of early states (Smith 2009b). Specifically, monumentality

and writing are not found in every example. The Shang (1850-1100B.C.) had no

monumental architecture, only wattle-and-daub construction on large earthen

platforms (Chang 1974:4). From historic sources it is believed that the capital

city changed through time following the king as he moved from place to place,

and thus place was less important than the political lineage (Chang 1974:5).

Chang (1974:12) describes the urban revolution in China in terms of agricultural

advancement, weaponry advancement (chariot), and industrial advancement

(specialization). In Andean South America, no writing system existed among the

Inka. They did, however, have a record keeping technology in the form of

knotted strings known as *quipu*; although complex, these cannot be considered a

form of writing. Smith (2009b) more specifically questions the usefulness of art

as a determinant to urbanism. Although I agree that art existed to various levels

in pre-urban societies and is difficult to quantify, it cannot be dismissed outright.

It might be more productive to consider state ideological art as a form of propaganda to compare how various regimes chose to use this medium. Childe's use of Lewis Henry Morgan's antiquated terms savagery, barbarism, and civilization have also been updated into terms more appropriate for understanding cultural evolution and the development of urbanism. The current stages of development are hunter and gatherer, segmentary, egalitarian village, hereditary inequality societies, and pristine states (Marcus 2008:252-259). Nonetheless, most modern research into issues of urbanism and the ancient state are influenced by Childe's work.

Moving from Childe, researchers seeking explanations for how and why urbanism developed, and where and when it began, devised or borrowed theoretical models from other fields. Economics and geography have both been strong contributors to archaeological theory during the latter half of the twentieth century. One of the more widespread models for describing settlement patterns was developed by German geographer Walter Christaller. Christaller's central place theory states that sites in a network should naturally adopt hexagonal territorial tessellation of space, based on rational assumptions that the population is distributed evenly over the landscape, and will choose to meet at central places to exchange goods in a market system, minimizing costs and maximizing profits (Hodges 1987:119). Although developed as an economic model, it has been adopted by archaeologists to explain settlement patters of various levels of complexity.

The concepts put forth in central place theory were further developed into a typology of five classes of urban society by Richard Fox (1977). Understanding that large heterogeneous societies need to centralize a variety of activities, Fox determined that Childe's ten themes were too general and through an anthropological examination of urban forms decided that cities can evolve along one of five types of administrative organization. He termed these: (1) regal-ritual, (2) administrative, (3) mercantile, (4) colonial, and (5) industrial, although obviously only types one through three are relevant to preindustrial societies. Regal-ritual urbanism is focused strongly on ideology, with the city as an extension of the king's house. These societies tend to have no clear distinction between urban and rural populations. Administrative urbanism is larger and denser than regal-ritual and tends to be strongly political in nature with extensive bureaucratic diversification. Mercantile cities are those that have risen as centers of trade and are centers of wealth production, not just consumption.

Trigger (2003) defines two basic forms of urbanism with relation to political organization: (1) the city state where the majority of the population is centered in one urban capital, and (2) the territorial state where there are several centers of administration at different hierarchical levels such as local, district, provincial, and national. This is an over simplification of the types of urban centers as the lines are drawn arbitrarily, and if the categories were defined slightly differently the category a particular state falls within could easily shift.

The overall development of a centralized authority is the fundamental impetus for the development of urbanism. There are two main results from this: (1) the concentration of elites, specialists, and service oriented positions, and (2) the building of monumental structures as a sign of power and possibly as a unifying symbol for members of the state. The large population growths witnessed archaeologically at many early centers are too rapid to be due to increased birthrate and must have been due to nucleation. This was due to the centralized elite creating an environment which attracted individuals to their sites. This would have been through the commissioning of monumental works, the dissemination of ideology, the accumulation of important resources, or some other similar mechanisms. This would have brought large amounts of labor and specialists into the center. These individuals would then have needed to have been fed, housed, and cared for which would have created a demand for other workers.

Recent developments have focused on agency; the need to understand individuals' practices, perceptions, experiences, attitudes, values, calculations, and emotions to understand ancient cities as well as to what extent early cities were intentionally created. These studies have taken place in virtually every ancient center as researchers adopt new philosophical and methodological paradigms to understand the emergence and development of urbanism (Kenoyer 1989; Bard 1997; Blanton et al. 1999; Kemp 2000; Possehl 2002; Baines 2003;

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Emberling 2003; Cowgill 2004). Examinations of public amenities such as

fountains, reservoirs, paved streets, and public baths have highlighted the debate

between hierarchy and heterarchy as researchers explore whether these

resources were created by rulers or developed on a local grassroots level

(Cowgill 2004:537).

Application of Urban Theory to Mesoamerica

Turning my attention to Mesoamerican archaeology, theoretical work on

the development of urbanism has undergone major transitions over the last half

century. Early studies were basically descriptive and borrowing from Childe tried

to identify specific traits associated with urbanism. Tikal was the first large scale

project in the Central Lowlands and as such has received a majority of attention.

Haviland (1970:193-195) directly compared Tikal to Sumerian cities claiming

similar population estimates and nucleation as well as economic differentiation,

social stratification, urban art, and a calendar system. He also attempted to

explain Tikal's location through cultural ecological arguments stating that there is

a large chert deposit at the site and that the site's position between two rivers

may have placed it on an important trade route.

Although perspectives derived from cultural ecology have dominated the

field, the approach to these interpretations has been varied. One consistent

question posed by researchers is why the Lowland Maya core developed where

it did. The region is considered less than ideal for the development of urbanism

with no permanent waterways and limited local resources. Rathje (1971) took

the novel approach of dividing the region into a network of three areas, the

resource rich highlands, an intermediate zone near the highlands, and the central

Lowlands. He identified three resources needed for Maya civilization that did not

exist in the Lowlands: obsidian, hard stone grinding tools, and salt. He

suggested that complex socio-political organization developed in the Lowlands in

response to the need for procurement and allocation of these imported materials

(Rathje 1971:278). Basically, he adopted a modified form of central place theory

in which Maya elite developed centers as collection and distribution points for

these three resources. In response, the Maya elite in these central places

developed the Maya cult and traded out ideology. This was demonstrated in the

archaeological evidence through diffusion of pottery, ideology and Maya cult

technology from the Lowland core over time (Rathje 1971:283).

Sanders and Webster (1988) adapted Fox's model into what they term a

multi-line evolutionary framework based on a three prong typology with

processual underpinnings, although they basically exclude the mercantile type as

it is difficult to identify in Mesoamerica. Core to separating out Mesoamerican

societies from other ancient societies was the understanding that centralization of

this region was limited due to the lack of wheels, metal tools, draft animals or in

most areas waterways, what they termed a "low-energy" society (Sanders and

Webster 1988:529). Most Mesoamerican cities are characterized by weak

decentralized rule, strong ritual function, poorly developed economic institutions, and relatively small populations as compared to Old World sites and as such fall into Fox's regal-ritual category (Sanders and Webster 1988:534). Fox's administrative type is best exemplified by the Aztec capital of Tenochtitlan due to the fact that historic accounts add data confirming population density and heterogeneity with a large bureaucratic, military, and ritual urban class (Sanders and Webster 1988:536). Other administrative sites were also located in Highland Mexico and identified as Teotihuacan, Monte Alban, Tula, and Cholula (Sanders and Webster 1988:538-539).

Blanton et al. (1996) criticized the limitations of neoevolutionary theories based on their focus on directionality of development through progressive stages. They instead advocated for an agency based focus on strategies used by political actors to both form and maintain polities, what they termed a dual-processual theory. They described two opposing strategies for development of political power, the network strategy and the corporate strategy. Basically, the network strategy is a system built around an exclusionary trade relationship between an individual and extra-group partners which raises the individual's status or rank. The two problems that develop in attempting to maintain this strategy are the inability to control intra-group competitors and to control distant partners. These problems are dealt with through the social development of patrimonial rhetoric and prestige-goods systems (Blanton et al. 1996:4).

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Corporate strategy "involves the establishment and maintenance of a cognitive

code that emphasizes a corporate solidarity of society as an integrated whole"

based on interdependence between groups (Blanton et al. 1996:6-7). This leads

to a greater degree of wealth equality and social themes that promote fertility and

renewal. Examining Mesoamerica as a whole, through time, the researchers

noticed a trend of cycling between dominance with these two strategies with the

corporate style dominating during times of strong centralized power such as

when Teotihuacan dominated the region (Blanton et al. 1996:11). Their theory

predicts that during times when the network strategy is dominant, technological

advancement and dispersal will be rapid due to increased competition (Blanton et

al. 1996:13). They conclude their work by proposing the development of "one

grand theory of sociocultural transformation" that incorporates both network and

corporate strategies into a dual-processual theory (Blanton et al. 1996:13).

Urban Geography

In this section I will introduce the discipline of urban geography and its

relationship to analytical social sciences. Urban geography was developed

during the twentieth century as urbanism increased around the globe. Research

in urban geography is broken into four broad traditions which represent historical

trends. These four traditions in chronological order are known as the physical,

the human-environmental, the regional, and the spatial traditions. These

traditions are described in detail below. Recent trends in urban cultural

geography and urban historic geography are also important to my research and will be discussed.

Geography as a social science is predominantly focused in the field of human geography. Human geographers examine systems developed by humans that are visible in geographic space. These studies include examinations of economic, social and political issues. Urban geography is a subfield of human geography that focuses exclusively on urban areas. Studies in urban geography are broadly divided into two categories: (1) intermetropolitan (between urban centers), and (2) intrametropolitan (within one urban center). One of the strengths of urban geography is its ability to study urban centers by looking at spatial interactions between various locations or social units within an urban area. On a larger comparative scale, the discipline evolved out of observations that settlement locations and internal organization of cities were similar across enough cultures that generalizations could be made. Harris (1945:7-8) notes that cities are organized on the landscape in several different ways depending on how they supply urban services: (1) central place, (2) transport cities, and (3) specialized-function cities. These three organization types conform to the three models (concentric, sector, and multiple nuclei) outlined in the last chapter. Harris also went on to state that most cities combine all three of these organizations.

As stated above, urban geography developed along the path of four historic traditions. All of these four traditions are still practiced today and can be combined to varying degrees dependent on the research questions being asked. The physical tradition focuses on how the physical environment affects urban spaces and people. This tradition is often overlooked by urban geographers today. The second tradition to develop, the human-environmental tradition developed initially within the philosophy of environmental determinism. As this philosophy fell out of favor, geographers in this tradition transitioned to a philosophy of "possibilism" in which human culture, as an adaptation, allows settlement in areas that might be considered less than hospitable under normal circumstances. Research in this tradition focuses on site location of cities and economic potentials of those locations. The third tradition, the regional tradition focuses on collection of as much data as possible within a specific location and is solely descriptive in nature. The lack of analysis has made this tradition unpopular with modern urban geographers, although these studies can be useful for comparative analysis. That leaves us with the spatial tradition to examine.

The spatial tradition evolved from the regional tradition, but it is based in modern social theory and as such focuses on the development of theory, quantitative methods, and mathematical models. This is the dominant tradition today. Critiques and modifications to this tradition were developed almost as soon as the tradition itself. Behavioral urban geography developed out of one of

these critiques. Although it still uses the quantitative methods developed in the

spatial tradition, behavioral urban geography focuses on how individuals make

spatial decisions. Marxist philosophy also entered this tradition with research

focusing on the spatial relations of capitalist production, labor relations, and

inequality to services (Cresswell 2010:172). There was also a trend to humanize

the data in what was termed humanistic urban geography in which the focus is

on people's relations with nature, their geographical behavior and their feelings

and ideas about place and space (Tuan 1976:266).

Two recent trends within urban geography that are important to my

research are known as urban cultural geography and urban historical geography.

Urban cultural geography focuses on the symbolic nature of the urban landscape

and how the meanings imparted into the landscape are used to advance or

retard social and political goals (Leitner 1992:110). Urban historical geography

focuses on past cities, and these studies tend to focus either a specific point in

time or over a span of time. These two trends are most applicable to my

research as I am investigating issues of heterarchy and hierarchy in urban

spaces based on water management and settlement patterns at an ancient Maya

city.

How Urban Geography can be Adapted to Archaeology

In effect, urban geography is the study of socio-spatial interactions within

densely settled heterogenous societies. That makes it an ideal discipline from

which to borrow to answer archaeological questions about ancient urbanism. Some geographic principles have always been incorporated into archaeology, although the two fields were philosophically divergent for most of the second half of the twentieth century until the early nineteen eighties when they developed a common background in anthropology and social theory (Hodder 1987:144). One area where archaeology has borrowed heavily from geography is in landscape studies. Landscape is an abstractions which has allowed archaeologists to bring together loosely related approaches to describe a cultures environmental interactions and has led to the development of distribution and settlement studies with particular focus on settlement ecology which observes patterns of land use over time (Anschuetz 2001:163-177). This has led to big picture studies of urbanism in Mesoamerica and the Maya area in particular. Many early researchers did not believe that the Lowland Maya represented an urban civilization; in fact, for much of the twentieth century it was believed that Maya centers were not cities but ritual centers occupied only by priest-astronomers (Thompson 1954). We now know that all of the hallmarks of complex urban society were present as early as the late Preclassic in the Maya Lowlands. Saturno (2009:111) demonstrated that by 100 B.C. during the late Preclassic, there were full-time specialists in the form of well-trained artists and kings.

Some of the first attempts to look for urbanism in the Maya Lowlands focused on demographics (Thompson 1966, 1971). Settlement surveys were

conducted to count house mounds and make estimates of the regional

population. Ricketson and Ricketson (1937:18) argued for five persons per

house and only 25% of residences occupied at any one time. This and other

early studies were completed without proper excavation for dating of houses and

as such were performed based on the theory at the time that population densities

were very low and the land could only support a dispersed population. Drawing

on an ethnographic study of the Yucatán village Chan Kom by Redfield and Villa

Rohas (1934:91), it was determined that Maya households contained nuclear

families with an average size of 5.6 people. In contrast, ethnohistoric post-

conquest documents state that multiple families occupied residences with 10-25

individuals, although most archaeologists disregard this and use an estimate of

4-5.6 individuals per household (Rice 2006:262). Based on excavations, recent

studies have also elevated the number of occupied residences during peak

periods of occupation to approximately 80% (Lemonnier 2012). Understanding

demographic trends is at the basis of urban studies and important in any further

analysis. Current data on population estimates, especially at larger sites like

Tikal, support an urban interpretation.

Epigraphic studies have been used to map historic interactions between

Lowland Maya sites. The epigraphic record indicates interactions of both conflict

and political alliance suggesting a few larger sites, namely Tikal and Calakmul,

held sway over many smaller ones (Martin and Grube 1995, 2000). These

studies demonstrate a higher level of political and social complexity than was previously thought to exist in the Lowlands. Of interesting note, subject cities to the larger sites were not always spatially closer than enemy states. A geographic analysis of the Maya region mapping these patterns over time could be helpful in determining how the Maya interacted with their environment on a regional scale. For example, there could be natural blocks in the environment which made travel difficult and conquering forces may have had to take specific routes.

Other researchers have examined site formation patterns in the Maya area over time to understand developments in socio-political organization within the Lowlands. Ashmore and Sabloff (2002:202-208) noted that settlement patterns at ancient Maya centers displayed ideational foundations based in both cosmology and politics; the transitions from the Preclassic east to west orientation to the Classic north to south orientation may have represented a change in political order, with increased focus on the king as opposed to the sun. Golden et al. (2008) were able to map the urbanization of the Middle Usumacinta over centuries and identified archaeological traits which demonstrated ethnic differences between populations at Piedras Negras and Yaxchilan. This, in turn, enabled them to locate a border zone between the two sites establishing the limits of each state.

The progression from broad landscape studies into more narrow urban studies is a natural one. As archaeological studies on urbanism increase, methods can be borrowed from modern urban studies to interpret the data. One of the most successful recent archaeological inroads into urban studies has been the examination of ancient neighborhoods. Trigger (2008:16) suggests that there are three areas that need further study in this area: (1) low density city neighborhoods, (2) social variation in neighborhoods, and (3) whether neighborhoods were organized in top-down or bottom-up processes.

Probably the most well know and easily identifiable urban neighborhoods in Mesoamerica are found at Teotihuacan, Mexico. Ethnic neighborhoods have been identified at this site for several different areas including Oaxaca, the Gulf Coast, and Michoacán (Gómez-Chávez 1998; Rattray 1988, 1989, 1993; Spence 1990, 1996). In addition to neighborhoods of specific ethnic groups, Teotihuacan has an identifiable merchants neighborhood as well as craft production areas for obsidian, lapidary work, ceramics, and lime plaster (Manzanilla 2012:58). Through quantitative spatial analysis, it was also found that Teotihuacan could be divided into several districts (Trigger 2008:8-9).

Identifying urban neighborhoods within the Maya Lowlands has been more complicated due to more dispersed settlement patterns. It has been noted, however, that Maya settlement tends to cluster in association with civic architecture and that these groupings can be interpreted as urban neighborhoods

(Trigger 2008:11). These clusters are interpreted as second order administrative

groups and analyzed as such. Hendon (2012:168-173) examined three ridge top

neighborhoods at Cerro Palenque, Honduras near Copán and identified this type

of second-order administrative building at each, although none were found at

greater Copán.

Probably the most advanced examination into spatial patterns at Lowland

Maya urban neighborhoods was performed recently at the site of La Joyanca.

Lemonnier (2012:183) in attempting to quantify clustering of house mounds and

evaluate internal heterogeneity of each cluster for differentiation of commoner

and elite residences created a typology of four types at the site. Type one was

the Guacamaya group which is the most monumental and as such considered

the royal residence at the site, type two was composed of the remaining ten

monumental compounds. Both of these types of clusters consisted of compact

heterogeneous assemblages of several courtyard units. Through excavation it

was determined that the earliest of these monumental compounds was

constructed close to the main plaza moving farther away through time

(Lemonnier 2012:186-188). Types three and four included concentrations of

smaller dwelling units interspersed among the monumental types and each

cluster was closer to one of the monumental groups than to any of the other

smaller clusters (Lemonnier 2012:188). This pattern demonstrated eleven

residential zones or neighborhoods each delimited by seasonal swamps and

containing an empty cultivable area (Lemonnier 2012:191). One interesting

conclusion made by Lemonnier (2012:193) was that aguadas may have affected

the face-to-face interactions of neighborhood residents; the largest reservoir at

the site was spatially associated with only type one and two clusters, while there

were groupings of one to six smaller aguadas that seem to have been shared by

the members of each type three and four cluster. It was also noted that there

was no concentric zonation of the elite residences at this site which was

interpreted as autonomous land tenure units of secondary elites (Lemonnier

2012:189).

The Application of Urban Geography at Xultun

As discussed above, recent investigations into urbanism at ancient

Mesoamerican sites have focused on the identification and spatial analysis of

urban neighborhoods. This type of research is ideal for collecting data that will

make ancient urban centers more accessible to modern geographers for

comparative studies. Work is still needed in this area, however, as neighborhood

and urban studies, especially in Mesoamerica, are in their infancy. Recent work

in the Maya area has focused on the identification of intermediate levels of

administrative organization to demonstrate levels of bureaucracy consistent with

urbanism (Hendon 2012; Lemonnier 2012). Inspiration for these studies has

come from the Aztec *calpolli* which served as social and administrative unit or as

both neighborhoods and districts (Smith and Novic 2012:5-6). I will be following

from the work of Lemonnier (2012) in that I will be working from the Map of Xultun and organizing clusters of structures into neighborhood groups.

These neighborhoods once identified can be analyzed in an effort to categorize them into different urban types. It may even be possible to identify ethnic differences in variations of architectural form, although this would require extensive excavation (Tourtellot 1983:51). Lemonnier noticed that there were associations between reservoirs and certain clusters, although this was not further explored. The examination of links between hydrology and urbanism has been performed at other archaeological sites such as Angkor, Cambodia in which it was noted that regional settlement was tied to water management (Evans et al. 2007:14279). In Mesoamerica studies of the great Aztec capital of Tenochtitlan have also focused on water management technologies used in support of the population (Palerm 1973). Extensive hydrological engineering was also performed in the Maya region, most notably at Palenque (French 2002, 2007, 2009; French and Duffy 2010; French et al. 2012). It is my proposal that the hydraulic engineering of the urban landscape at Xultun and other Classic Maya centers directly impacted settlement patterns and that patterns of access to this stored water will suggest public versus private or exclusive use resources. Using GIS I model the hydrology of Xultun and perform spatial analysis on various urban neighborhoods to better understand the role water management played in the settlement of the Classic Maya urban center of Xultun.

Interpreting urban function from archaeological mounds is problematic at best. Research in the Lowland Maya area has a long history of disagreement as to what constitutes a residence versus a ritual structure, for example. Making these interpretations without extensive excavations is even more difficult. There are several approaches that researchers have used to classify Classic Maya architecture. One of the most common is based on historical description. This will be the basis of my classification.

Maya Ecological Regions, Settlement, and Hydrology

The Lowland Maya were heavily influenced by their local environment which consisted of a limestone shelf and inland upthrust mountains. The limestone bedrock served as the primary building material in both stone blocks and lime mortar. Chert outcroppings served as a major source for tool production. Settlements in this area depended on importation of other necessary materials such as hard stones like basalt, used in the grinding of maize, and obsidian, which served both utilitarian and ritual functions. The soils available for agriculture were rendzina or similar, black calcareous soils. Rendzina soil is poorly developed and formed by the weathering of limestone through carbonization (Ellis and Mellor 1995:106). The climate is generally humid and warm with a rainy season from May to December. The region has variation in both topography and hydrological resources. There are several major river

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sources present in the Lowlands, including the Grijalva, Usumacinta, Motagua, Rio Hondo, and Belize River. All of these rivers have major settlement associated with them. There are also two major lake systems in the region, lakes Yaxha-Sacnab and lake Peten Itza. Interestingly, the area considered the heartland of the Maya Lowlands which contains some of the largest and most important sites is devoid of any of these permanent water sources. These central sites were built on the edges of bajos, some of which may have served as seasonal swamps but they also had to build major reservoir systems to catch and store rain water. (Hammond and Ashmore 1981).

As stated above, the Lowland Maya built major settlements in several ecological zones. These include along rivers, next to lakes, coastal sites, and the northeast Petén which was devoid of permanent surface water. It is important to look at these various hydrological zones to identify settlement patterns associated with each. This will serve as a backdrop to the fundamental hypothesis that Classic Maya settlement was influenced by hydrological factors and that this extends to the design of urban centers within the northeast Petén including Xultun.

Maya settlement built along rivers tends to spread out along the length of the river just above the flood zone (Fig. 2.1). The ceremonial centers of these sites are generally close to the river but built on a high prominence. Some of the major centers built along rivers are Yaxchilan, Piedras Negras, Seibal, Copan,

Cancuen, Aguateca and Palenque. The Belize river valley has also been subject

to extensive settlement studies (Willey 1965; Ford and Fedick 1992). Palenque

is a unique case as it was constructed in an area with steep topography, 9

waterways, and 56 springs which led to the construction of aqueducts, bridges,

and other management features as well as artificial plazas over the waterways to

increase building space (French 2007).

Figure 2.1. Riverine Sites of Yaxchilan (L) and Aguateca (R) (Martin & Grube
2008).

Two major sites built adjacent to lakes are Coba and Yaxhá. Both of

these sites generally conform to the same settlement distribution with large

ceremonial cores built adjacent to the lakes, with increasingly smaller centers

distributed as you move farther out. Folan et al. (2009) working at Coba tested

the settlement distribution and concluded that it conformed to a concentric

pattern with the highest concentration of large structures built close to the site core. This differs from research at Tikal that found settlement to be more dispersed (Arnold and Ford 1980). It is likely that this more concentrated settlement in lakes regions is due to the large aquatic resource present.

As mentioned above, the large sites within the central Petén are characterized by a more dispersed settlement. The ceremonial centers and other settlement types were mainly built on upland areas adjacent to bajos or well-drained bajo islands. Large areas were levelled off for the building of ceremonial centers and a system of reservoirs were constructed to provide water for the populations here. The most prominent sites in this ecological zone are Tikal and Calakmul that served as competing states during the Classic Period (Martin and Grube 2008).

Xultun is situated in the northeast Petén region of Guatemala and as such has no permanent surface water. Classic period sites in this region are categorized by the presence of artificial reservoirs which were built to collect and store water for their populations, what Scarborough (2003) has termed artificial micro watersheds. My research is based on the theory that water management systems at Classic Maya Lowland sites directly influenced settlement patterns. This means that building within catchment areas was carefully planned and controlled. The Maya carefully engineered their landscape to collect water from very specific areas into central storage reservoirs. Water from less desirable

areas was redirected for collection in lower tanks or away from storage tanks all together. I will be exploring the patterns of settlement associated with specific reservoirs to determine what decisions the ancient Maya made in organizing their hydrological space. Administrative structures would have served to control access to this important resource.

At the beginning of my research in 2010, the site map consisted only of the major structures within the ceremonial core. Our project was focused on digitizing the map created by the Peabody museum's Corpus of Maya Hieroglyphic Inscriptions project (Von Euw 1978). To explore my theories I would need a more complete settlement map of Xultun and one that contained some of the reservoirs that I knew had to be there. The results of my settlement survey and mapping are discussed in chapter three.

Conclusion

The major historical trends in the development of Mesoamerican settlement studies, and urban studies were highlighted in this chapter. Through a literature review of trends in Maya settlement studies, hydrology, and urban studies, the foundation of my research was presented. Many examples were presented of water management being used as a foundation or reinforcing element of elite control. Some of the most elaborate hydrological systems were

found at Teotihuacan, Tenochtitlan, and Palenque. Maya sites were often

organized according to cosmological principles of directionality with a

quadripartite organization. It was also demonstrated that hydrological

engineering of the urban landscape impacted settlement patterns. This is

demonstrated at the macro, site wide, level with different patterns seen: (1) along

rivers, (2) next to lakes, and (3) in areas without permanent surface water.

Extrapolating down to the micro level, it makes sense that settlement within a site

will also be organized around water resources. The quadripartite organization

seen across the Maya Lowlands, based in cosmological ideology, will also have

a hydrological component. This will be demonstrated in chapters 6 with the use

of hydrological modeling at Xultun.

Chapter 3: Mapping and Remote Sensing at Xultun

Introduction

This chapter describes the mapping project at Xultun, an undertaking that provides the foundation upon which all spatial analyses are based. The map provides the foundation upon which all of the spatial analyses are performed. Previous attempts at mapping the site were performed; however, none of these were adequate by modern archaeological standards. The history of the discovery and previous mapping projects are described before moving onto the methods used in the current project. The digital map produced for this study uses high tech satellite and laser survey devices to achieve an accuracy of within one centimeter. Due to the heavy vegetation, mapping is still ongoing and progressing slowly, and has therefore been supplemented with satellite remote sensing. The satellite data was successful in identifying both previously unrecorded structures and water storage features beneath the forest canopy. This provided important information about the association of administrative structures with stored water at Xultun, demonstrating continued elite involvement in the management of this resource. It is hoped that the methods used in the

mapping of Xultun will be beneficial for researchers investigating settlement and

hydrological issues within this and other semi-tropical forest environments.

History of the Discovery and Mapping of Xultun

Xultun was first discovered in 1915 by a *chiclero* (men who harvest tree

sap for the production of chewing gum) named Aurelio Aguayo; however, the site

was not examined by the scientific community until 1920 during the Carnegie

Institute's fourth expedition to the region (Morley 1938a:383). During that and

subsequent visits by the Carnegie Institute, Sylvanus Morley attempted to map

the site. Due to its large size, he focused on what was considered most

important, the major ceremonial architecture (Morley 1938a:385). He mapped

the two largest ceremonial groups and labeled the southern one Group A and the

northern one Group B. At that time the focus of research was the recording of

stelae, and in particular, their inscriptions. Mapping was not attempted again

until 1975 when Eric Von Euw working for the Corpus of Maya Hieroglyphic

Inscriptions Project at Harvard University's Peabody Museum visited the site. He

spent a total of ten days mapping the site but decided, like Morley, that the site

was too large to map, although he did add several important structures to the

map including a ballcourt, a causeway, and a large ceremonial structure to the

north (Von Euw 1978:8). Like Morley, the focus of his visit was to record inscriptions, limiting the time that could be devoted to mapping.

The techniques used in mapping Lowland Maya sites have changed over the decades as researchers gained experience and as research questions have changed. The focus of early research in the 1920's was to map the location of ceremonial centers, the positioning of major architecture, and identify carved monuments. Researchers were collecting data on hieroglyphic inscriptions to work on translations which would lead to an historical understanding of the Maya. As a result, site maps were often limited to major ceremonial architecture where stelae were found.

The first incarnation of the map was created during the Carnegie Institution of Washington's 1920 visit to the region. In late April, Sylvanus Morley and Dr. Carl E. Guthe conducted an exploration of the northern Peten to ascertain if any new sites with hieroglyphic monuments were discovered by chicleros, and Xultun was brought to their attention (Morley 1921:321). Morley and Guthe gave the site the name Xultun meaning "end stone" due to the fact that Stela 10 at the site had, at the time, the latest known long-count date. Morley (1921:322) described the site as having two principle plazas, 50 subsidiary courts and 18 sculptured monuments, and it was assumed to be the largest site within the region. The initial published map consisted only of Group A (Fig. 3.1).
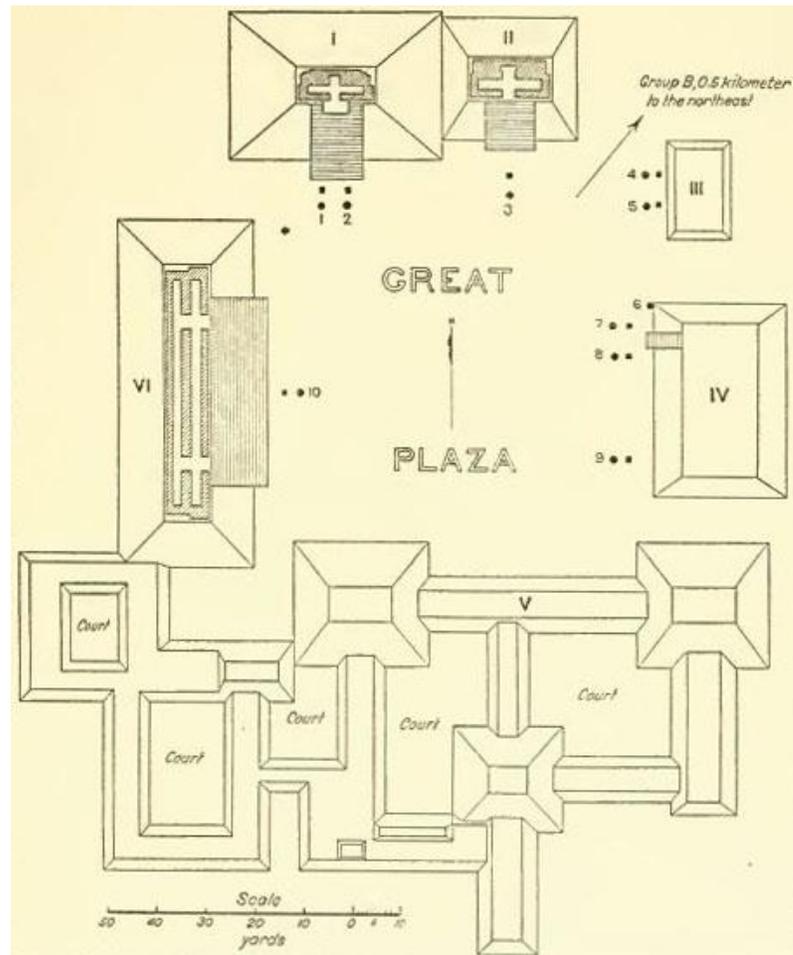
Figure 3.1. Morley's first map of Xultun (Morley 1921).

In 1921, 1923, and 1924 the Carnegie Institution of Washington returned to Xultun with a larger team of researchers including Morley, Guthe, Mr. William Gates, O.G. Ricketson jr., A.K. Rutherford and W.A. Love. During these visits they expanded the site map to include the second large plaza to the northeast of the main one (Fig. 3.2). They also determined the location of Xultun to be lat. 17°

30.5' N, lon. 89˚ 24.5' W at an elevation of 257 meters above sea level (Morley 1922:359; 1924:271; 1938a:383).
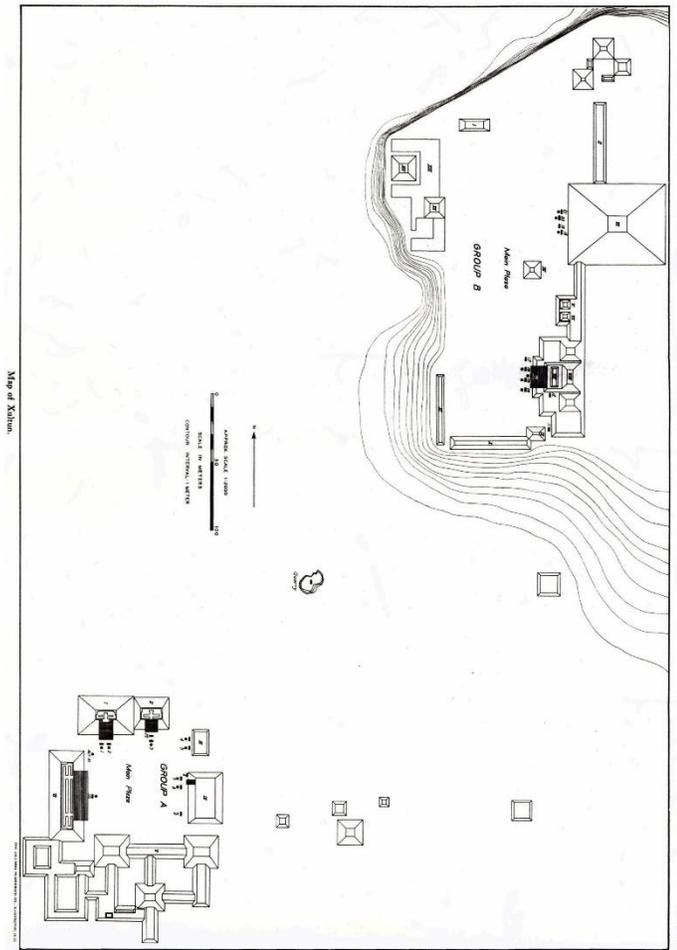
Figure 3.2. Morley's second map of Xultun (Morley 1938).

In the 1940's a convention for representation of Maya ruins was established at the site of Piedras Negras which is still followed today. Although the technique used in Morley's time was similar, different elaborations for recording detail were added. Mounds are represented stylistically depicting

orientation, configuration, and relative height in a prismatic form (Carr and Hazard 1986:3). During the 1970's there was a growing focus on regional settlement patterns, and new techniques were developed to better map hinterland areas and modest mounds. Although Von Euw did not highlight the specific techniques used in his mapping of Xultun, it can safely be assumed that they conformed to the practices used at the time at other large sites such as Tikal. A permanent datum would be set up as a reference point and a survey grid would have been created for drawing the site. The survey would have been completed with a Brunton transit, plane table, and telescopic alidade (Carr and Hazard 1986:2).

As part of the Peabody Museum's Corpus of Maya Hieroglyphic Inscriptions project, Von Euw visited Xultun in 1974 and 1975 and spent a total of ten days mapping the site (Von Euw 1978). Within those ten days he was able to survey a remarkable amount of area remapping all of Morley's map and expanding the map considerably (Fig. 3.3). Group A was expanded to the west, south, east, and the ballcourt to the north was added. Group B was expanded to the west and two groups were added to the north. Another important addition Von Euw made was the sacbe connecting Groups A and B. Von Euw's map served as the most complete representation of Xultun from its publication in 1978 until our current work which began in 2008.
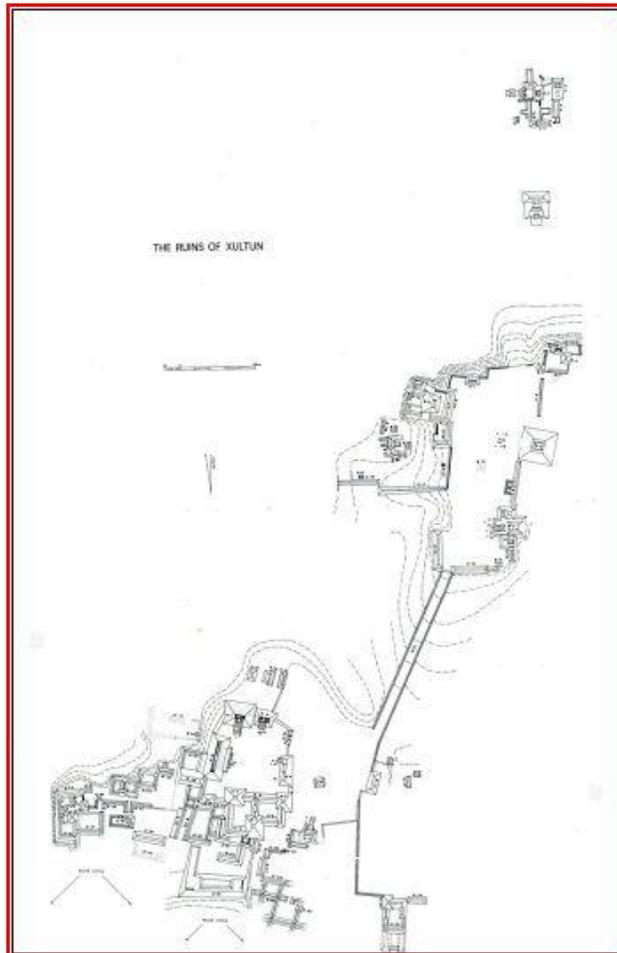
Figure 3.3. Von Euw's map of Xultun (Von Euw 1978).

The Proyecto Arqueologico Regional San Bartolo-Xultun under the

direction of Dr. William Saturno began preliminary investigations at the site of

Xultun in 2008. Adam Kaeding served as the project topographer that year and

began the process of creating a modern digital map. His primary goal was the

remapping of Von Euw's work using a total station to create a more accurate

representation than was possible with traditional survey methods. Kaeding was

able to complete much of this goal missing only some peripheral structures. He

also mapped several groups to the west and south of Group B which had not previously been recorded. It was also during this time that the digital grid was developed and the current structure numbering system put in place. These details will be discussed in more detail below in the methods section.

In 2010 and 2012 I took over the role as project topographer and continued with the digital remapping of previously recorded structures, primarily to the west and south of Group A. The density of structures encountered here was surprising and many previously unrecorded groups were added to the map. Of particular importance was the identification of a large number of structures to the west of the sacbe. These included a large reservoir and a new roadway extending from the north of Group A to the west of Group B. In addition to these areas, one group was added to the map on the far northern extent of the site. To create the current map, the topography of the site was visualized in ArcGIS 10 as one meter contour lines and the map was exported into Adobe Illustrator. In Illustrator the lines were redrawn to better conform to current mapping conventions.

Methods

In positioning Xultun and other sites on the globe, Love (1924:262) along with O.G. Ricketson attempted an accuracy of within half a mile using latitude and longitude measurements. For the time their techniques were very advanced.

They used a theodolite-magnetometer and latitudes were determined using circum-meridian observations of the Sun and local mean times. They used a long wave wireless receiving set for corrections on standard time for their chronometers. Although in the 1920's this was cutting edge, the level of accuracy is unacceptable today.

The rise of satellite technology has led to mapping that is much more accurate. Instead of positioning a site to within a half a mile of its location, specific points can be measured to within one centimeter using high-resolution GPS units (Garrison 2007:134). Today's digital mapping technology makes mapping faster and more accurate than was previously possible. This is especially important within the dense vegetation of the Petén, Guatemala.

It was decided to project the digital map in Universal Transverse Mercator (UTM) coordinates. This coordinate system divides the globe into a grid. Each grid is given a designation, in this case our region is located in Grid 16N. All points within this grid are measured in meters north and east from the south west corner of 16N. The site datum was placed within the plaza of Group A. The coordinates for this datum were recorded with a GPS receiver. To collect points for the creation of the digital map, a Topcom GTS 229 total station was used. This tool uses a laser to measure distances and angles from a known location and is accurate to within one mm. The total station was then used to collect points defining the shape, orientation, and height of structures as well as

topographic changes in the landscape. These points were then entered into

ArcGIS 10.1 for the drawing of structures and development of a digital terrain

model (DTM).

The Guatemalan government (IDAEH) determined that the extent of

Xultun's urban core was 16 km² and as a result a 4x4km square was measured

around the site datum and projected in ArcMap (Kaeding 2008:220). This square

was further divided into 400 equal squares of 400 m² each (Fig. 3.4). Moving

from north to south each horizontal column was given a letter designation from A

to T. Moving from west to east, each vertical column was given a numerical

designation from 1 to 20. The combination of these letters and numbers gives

each grid square a unique designation, for example, the most north-west grid

square is designated A1.

To expand the map, a systematic survey of each grid square within the

ceremonial core was performed moving outward after the known structures were

remapped. This was done through the walking of transects in a north and south

direction. Although similar to Puleston's technique, I did not have as large of a

team and wanted higher coverage than he achieved. I had a team of between

two and three surveyors spread out 20 m from each other which allowed me to

complete a 200 m grid quadrant in four or five passes. This technique was used

to identify surface mounds, looters trenches, chultunes and topographic changes.

During survey of a grid quadrant a sketch was made using pace and compass as

each transect was completed. The small brush was then cleared around the identified groups and the structures were mapped using the total station.

A series of stakes, linked to the original site datum, were shot in with the total station. These stakes were used as stations of known coordinates on which the total station could be set up. They were shot in one by one piggybacking off of the last. To avoid error these stations were shot in a circular pattern of five or six stakes. From the final stake in the loop, the total station was used to shoot in the first stake to make sure the coordinates matched the original recorded values. If this was not performed, any error would multiply with each additional stake distorting the location and orientation of mapped structures.

The coordinate points collected with the total station were then entered into ArcGIS 10.1 to be used as reference points for digitally drawing the map. The points also record elevation and were used to project a digital elevation model of the area (Figure 26). After the structures were drawn with ArcGIS 10.1, they were named. Each structure and plaza was given a specific numerical designation. This provides each structure with a unique name consisting of the quadrant in which it is contained followed by its numerical designation. For example, the structure with the newly discovered mural is designated 10K-2; that is structure 2 in quadrant 10K.

The Map

The site of Xultun follows the pattern seen at Classic Maya sites in the Petén. The large ceremonial core is built on well drained upland areas on the southern edge of scrub bajos and most structures are oriented in a north-south direction (Ashmore 1991). Groups A and B are both built on high points at the northern extent of a ridge that extends from the southwest. The platform on which Group B was constructed is slightly higher in elevation than Group A at 242 masl vs 235 masl. The architecture of the major ceremonial groups has been described previously therefore I will be focusing on descriptions of the newly mapped quadrants (Morley 1921,1938;Von Euw 1978; Garrison 2007).

In total, 22 quadrants have been at least partially surveyed, with a total of 398 structurs, 79 plazas, and 15 chultunes mapped. The highest settlement density is found on the southern periphery of Group A in quadrants 10K and 11K. One interesting feature of the various clusters around Group A is that different areas were levelled off at different elevations. The group extending from the southwest corner is roughly level with the central plaza at 235 masl. The cluster extending from the west of Group A around to the north is lower at 225 masl. The area to the south of Group A slopes down from 235 masl on the west to 227 masl on the east. The group in 9K drops down to 224 masl and 9J and 8J are lower again at 220 masl. These plateaus can be seen on the digital elevation model depicted below (Fig. 3.5).

The area between Groups A and B had previously been left unmapped. There is a wide (28m) roadway that extends from the northeast corner of the ceremonial plaza in Group A to a large plaza west of Group B. This roadway runs almost parallel to the sacbe but differs in that it is not built up but defined by long range structures. At the northern end of this roadway are stelae 26 and 27, which were discovered in 2010. There is another roadway to the west from these stelae defined by east-west running range structures and two long low walls, although the northern wall has not yet been mapped. A third new roadway extends east from the southeast corner of the large plaza to the east of Group A (Fig. 3.6).

A total of four reservoirs have been identified and mapped within the urban core of Xultun (Fig. 3.7). By far the largest of these was constructed between the two central roadways. There are a pair of small reservoirs north of Group A which appear to be interrelated. To the southwest of the map is the fourth reservoir which lies within a drainage slope. All four of these reservoirs appear to be modified quarries.

The data calculated from the map are listed in the table below. A total of 22 quadrants have been surveyed and mapped thus far. Roughly 0.88 km² of the 16 km² total gridded area or roughly 5.5% of the area. One of the most important realizations is the enormous extent of looting that has taken place at the site. Nearly every structure has at least one looters trench dug into it and

many have multiple. This highlights the need for expanded survey and recording

of structures throughout the Petén. It was clear that the dense vegetation was a

major hindrance to the survey. To alleviate this issue I decided to test remote

sensing techniques at Xultun to increase the speed and efficiency of both

mapping and the identification of hydrological features.

Table 3.1. Xultun Map Data

Quadrant	# Groups	# Structures	# Plazas	# Looters Trenches	# Chultunes
10J	6	46	11	35	1
10K	3	69	7	113	2
11J	3	15	3	27	0
11K	11	65	14	85	3
12H	2	9	2	36	0
12I	6	20	6	47	2
13H	0	4	0	8	0
13G	1	6	2	7	0
12F	0	19	3	34	0
9K	3	19	4	29	1
10L	2	11	1	3	1
11I	5	27	5	7	1
12E	1	5	1	6	0
8J	3	11	1	1	0
9J	4	22	5	16	2
10H	1	4	1	9	0
10I	0	2	0	1	1
12K	1	15	5	18	0
11H	3	24	6	39	1
11L	0	2	0	0	0
12J	0	1	0	2	0
13F	0	2	2	0	0
Total	**55**	**398**	**79**	**523**	**12**
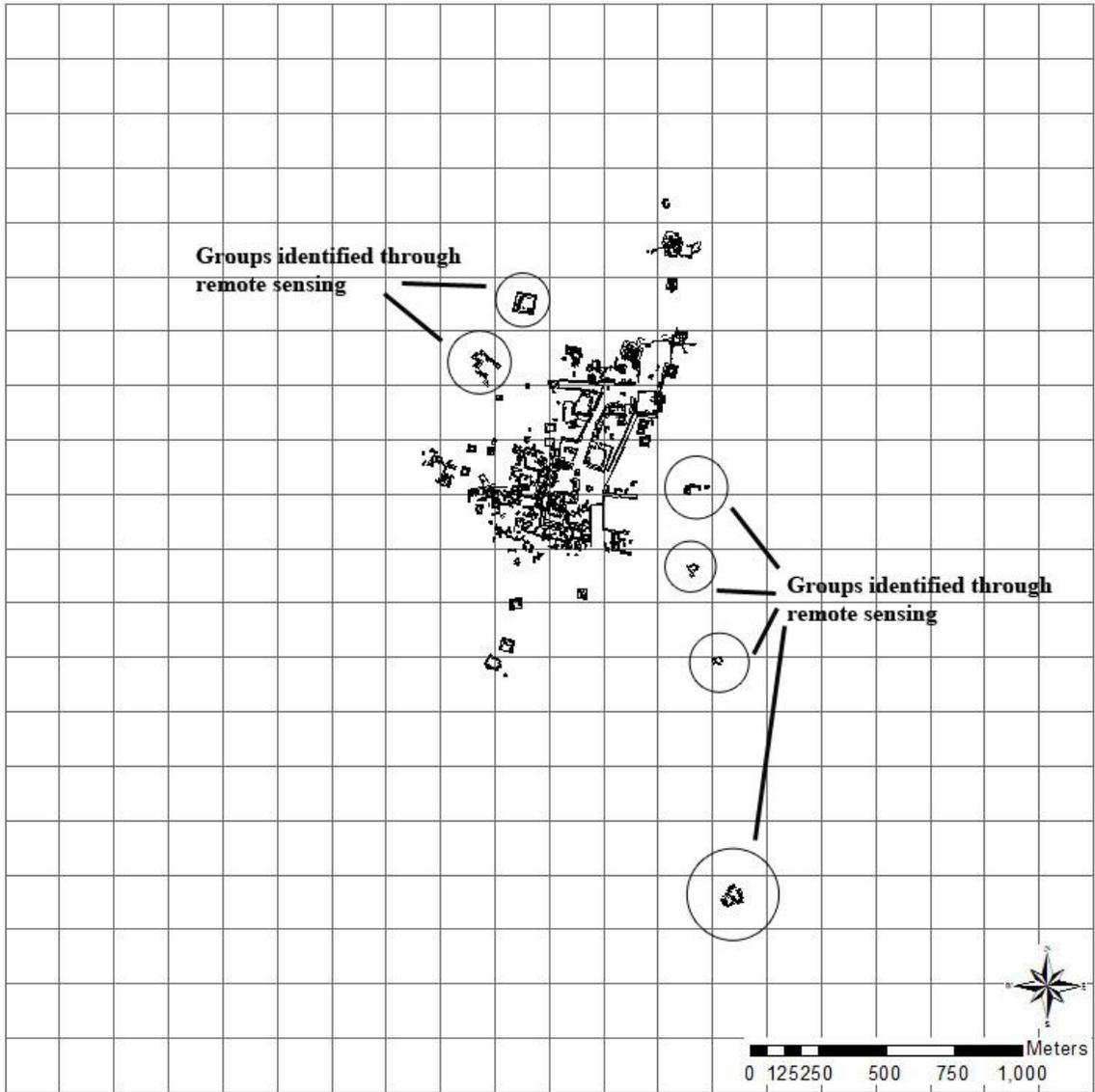
Figure 3.4. Grid defining the 16 km² extent of Xultun with mapped structures.

Legend

<VALUE>

- 198.2934418 - 200
- 200.0000001 - 205
- 205.0000001 - 210
- 210.0000001 - 215
- 215.0000001 - 220
- 220.0000001 - 225
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- 230.0000001 - 235
- 235.0000001 - 240
- 240.0000001 - 245
- 245.0000001 - 250
- 250.0000001 - 255
- 255.0000001 - 260
- 260.0000001 - 265

Meters

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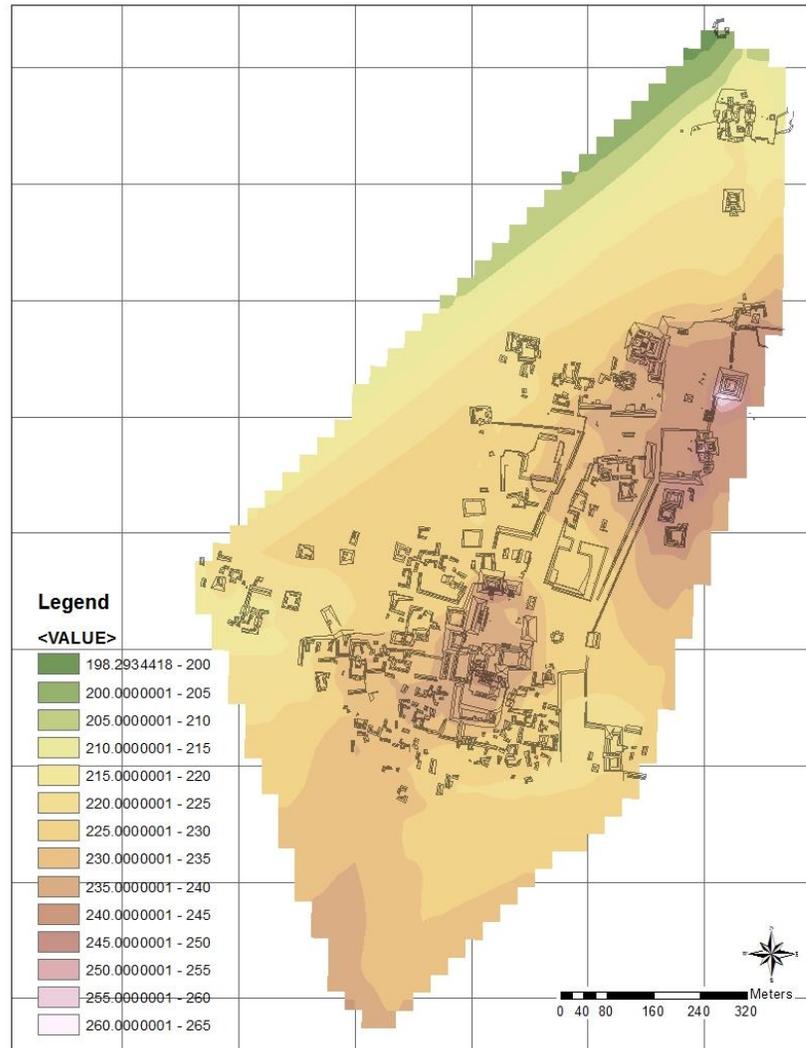
Figure 3.5. DTM of Xultun core with 5 m elevations changes.
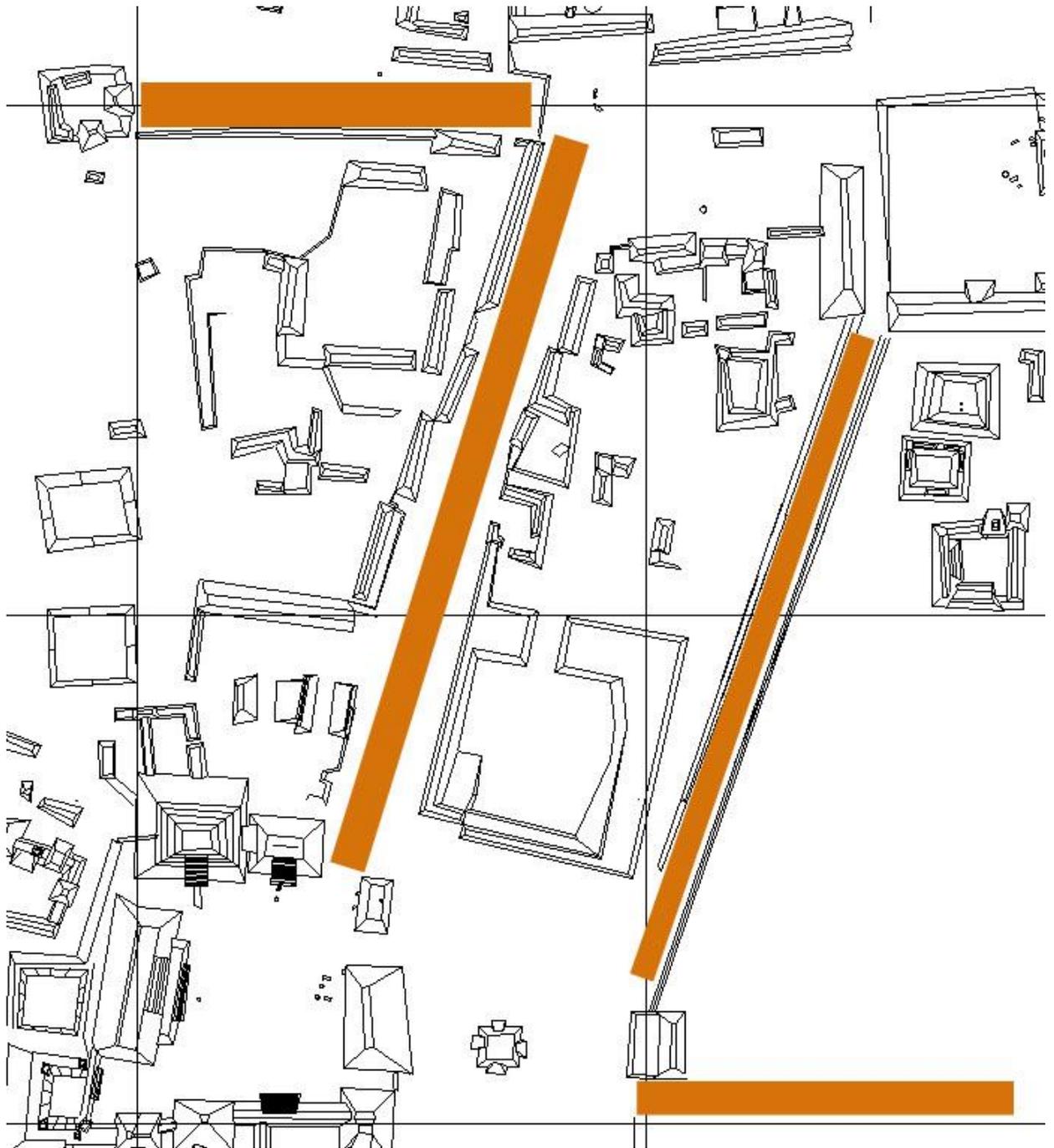
Figure 3.6. Causeways (orange) in central Xultun.

Figure 3.7. Reservoirs (blue) in central Xultun.

Remote Sensing

Since Stephens and Catherwood first investigated Maya ruins in 1841,

one of the largest problem facing archaeologists in the Maya region has been the

difficulty in surveying the region due to the dense vegetation. Traditional

methods of survey are logistically difficult, expensive, and time consuming in this

region. The dense vegetation makes the systematic walking in straight lines

virtually impossible as well as impeding communication and visibility between

individuals performing these surveys. As a result many researchers have resorted to the use of local guides to identify sites. Many sites identified in this manner suffer from significant looting. This makes the use of satellite and airborne sensing platforms indispensable in this region (Saturno, et al 2007, 138). These newer techniques increase the chances of identifying sites that have not been disturbed by looters.

These techniques collect data from various regions of the electromagnetic spectrum, both within and outside of the visible range. Archaeological features below the forest canopy can be made visible with these techniques. In addition, the health of the plants can be determined, and the topography of the canopy and even the ground can be mapped. Many novel approaches have been developed in the attempt to identify past settlement or environmental factors associated with past settlement.

One useful tool in looking at forest canopy is the use of radar which can map the topography of the canopy often hinting at structures beneath. The first use of radar in the Maya Lowlands with an archeological slant was in the Yucatan and led by Adams in 1980. His study uncovered a large network of agricultural and drainage canals. This was initially interpreted as evidence of intensive cultivation dating from the 4th to 10th centuries A.D. Follow-up survey using SAR led to the detection of a vast system of canals, chinampas, and extensive paved surfaces throughout the entire Maya Lowlands (Holcomb and

Shingiray 2007, 18). This clearly indicated that several forms of agricultural intensification were being performed in the Maya Lowlands and was a successful use of radar to answer an archaeological question in a tropical environment.

Shortly after Adams' study and in the mid-80's, Tom Sever of NASA started looking at vegetation signatures in an effort to recognize archaeological sites. He felt that it could be possible to locate structures associated with specific species of trees. He was initially unsuccessful in his attempts using Landsat Thematic Mapper (TM) data, Thermal Infrared Multispectral Scanner (TIMS) data, and airborne Color Infrared (CIR) data. He did, however, identify certain hydrological structures such as causeways, reservoirs, and canals. This was a success but not the goal; Sever wanted to be able to directly identify archaeological sites through vegetation reflectance. The resolution of the images was not sufficient to identify variation in the biodiversity of forest tree species. Recently this problem has been overcome using IKONOS high resolution images (Saturno, et al 2007, 144).

Vegetation based approaches to radar were developed using polarimetric, multi-frequency data sets which can identify human modification of the landscape indirectly. In 1990 AIRSAR, which has a 5 m resolution, was used in Belize, Guatemala, and Mexico. This was done in an experiment code-named Tropical Rainforest Ecology Experiment (TREE) with the aim of identifying various types of vegetation and where these types are most likely to be found. In the process

of developing this experiment a 3-component scattering model was developed for this region to aid in identifying vegetation types (Holcomb and Shingiray 2007, 33). With this, a large area could be examined and ecological variation could be mapped, helping to identify areas that are more likely to contain ancient settlements.

As technology has improved the types of remote sensing being attempted in the Maya region have become more sophisticated. In 2002, remote sensing was used around the site of Holmul, Guatemala. The research included elevation data as well as various terrain information. Attempts were made to classify vegetation types that were associated with sites to create further predictive models. It was determined that several classes of forest could be differentiated, and two in particular had a high incidence of co-locality with archaeological sites. Combining these two different classes of vegetation, a correlation to 64.7% of structures was achieved; one interesting piece of information that was noticed is that the Ramón tree often grows on ancient structures due to their superficial root system that can wrap around areas of ruined structures (Estrada-Belli and Koch 2007:271). This allows for the potential of building models mapping Ramón patterns to predict the presence of structures.

In 2003, images of both Landsat TM data and IKONOS were provided to William Saturno and three-band false color composites were created to assist in

survey of the area around the site of San Bartolo in the Peten region of

Guatemala. Saturno noticed a distinct vegetation signature that correlated with

archaeological sites allowing him to accurately predict location (Saturno, et al

2007:148). Thus, for the first time the direct observation of archaeological

structures was possible in tropical forests through the use of remote sensing and

focused on the reflectance signature of vegetation.

Remote Sensing at Xultun

Based on the work of Saturno et al. (2007) and Thomas (2010), I

determined that high resolution IKONOS data would be a good place to start

when looking for both settlement and water storage in the Petén. This was

supplemented with Quickbird data and Advanced Spaceborne Thermal Emission

and Reflection Radiometer (ASTER) DTM of the region. The goal of using these

data sets was to identify a signature for aguadas and associated settlement

groups at Xultun which could then be ground truthed during the 2014 field

season.

IKONOS was the first U.S. commercial high resolution satellite and was

launched by Space Imaging Corporation on September 24, 1999 to an altitude of

681 kmasl and uses linear array technology (Lillesand et al. 2008:455). IKONOS

data have four spectral bands with a four meter resolution: (1) red, (2) green, (3)

blue, and (4) near infrared. It also comes with a one meter panchromatic band which can be used to pansharpen the spectral bands. These bandwidths can then be combined into a composite image with three color of guns red, green, and blue. Depending on which bandwidth is placed in which gun, the resultant image will be different and highlight different reflectance signatures.

Similar to IKONOS, although higher in resolution, is the Quickbird platform. This satellite was launched by DigitalGlobe, Inc. on October 18, 2001 to an altitude of 450 kmasl and uses the same technology as IKONOS (Lillesand et al. 2008:456). Quickbird is able to achieve a multispectral resolution of 2.4m and a panchromatic resolution of 0.61m because it sits at a lower altitude than IKONOS.

Remote sensing techniques were used to supplement the survey methods described above in 2014. The IKONOS data were collected on December 16, 2002 and the Quickbird on April 19, 2003 (Garrison 2007:118, 186). Based on the settlement signature discovered by Saturno (2007) at the nearby site of San Bartolo, it was hypothesized that stress due to decreased access to soil moisture and nutrients would be higher on vegetation growing on top of ancient structures. In the satellite images this takes the form of a decreased reflectance of near infrared wavelengths of electromagnetic energy. Saturno et al. (2007) discovered that when using the band combination 4, 2, 1, there was a yellowing of canopy over known settlement at San Bartolo. This visual yellowing

corresponds to a comparatively lower reflectance in the near IR bandwith compared to other areas. Healthy vegetation is very good at reflecting near IR radiation and as such this signature correlates with stressed vegetation.

Initially it was thought that this settlement signature did not function over Xultun, possibly due to environmental differences between the two sites. The IKONOS data were collected during the rainy season and thus vegetation stress was at a minimum. The Quickbird data, although collected during the dry season, also seemed problematic. Although there were large areas within the site that seemed to contain the settlement signature, they did not align with the mapped structures (Fig. 3.8). Upon ground truthing of the satellite imagery, it became clear that the settlement signature did indeed work over Xultun and this is discussed in greater detail below.
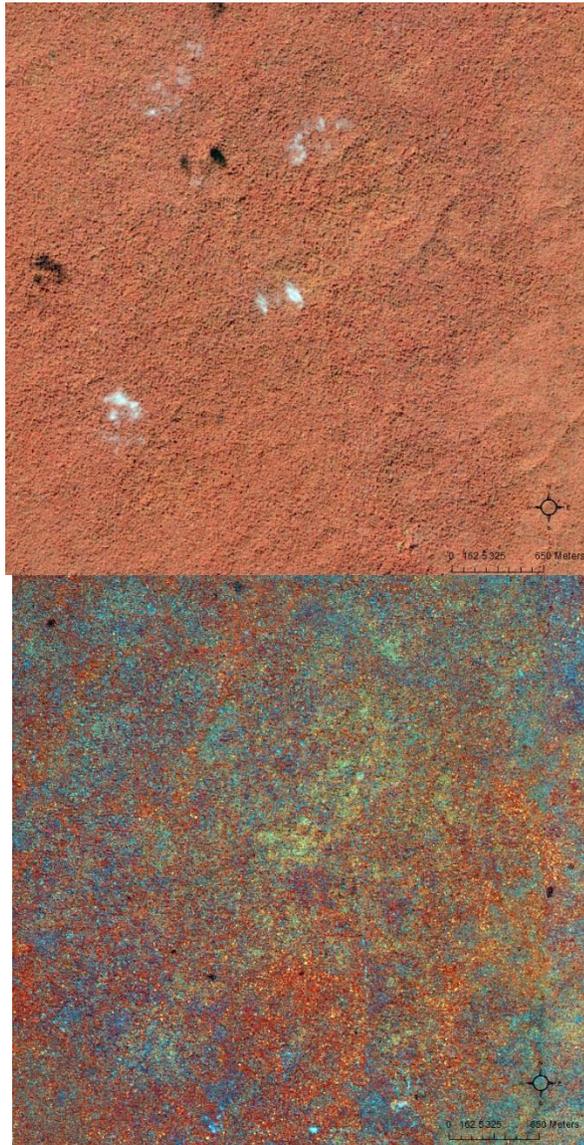
Figure 3.8. IKONOS (L) and Quickbird (R) NIR, G, and B bands over Xultun.

Using the false color settlement composite replacing the red band with the near-IR band on the Quickbird data, I was able to identify a signature for aguadas. Aguadas tend to be roughly circular or oval and usually have an inner and outer ring visible in the satellite images. These rings correspond to

vegetation differences based on maximum and minimum water containment

levels. In addition, they tend to appear blue and purple due to the high

reflectance of both near-IR and blue bandwidths. The high reflectance of the

near-IR demonstrates the lack of stress of the associated vegetation which

supports greater access to water in these locations. With this signature, I was

able to identify 15 aguadas within the 16 km² grid of Xultun. I used ArcGIS 10.1

to create a point shape file to mark the UTM coordinates of each of the aguadas

for later ground-truthing. The aguadas were numbered arbitrarily from one to

sixteen as they were identified within the Quickbird image (Fig. 3.9). Aguada 8

was deleted as upon review of the image it did not match the signature.
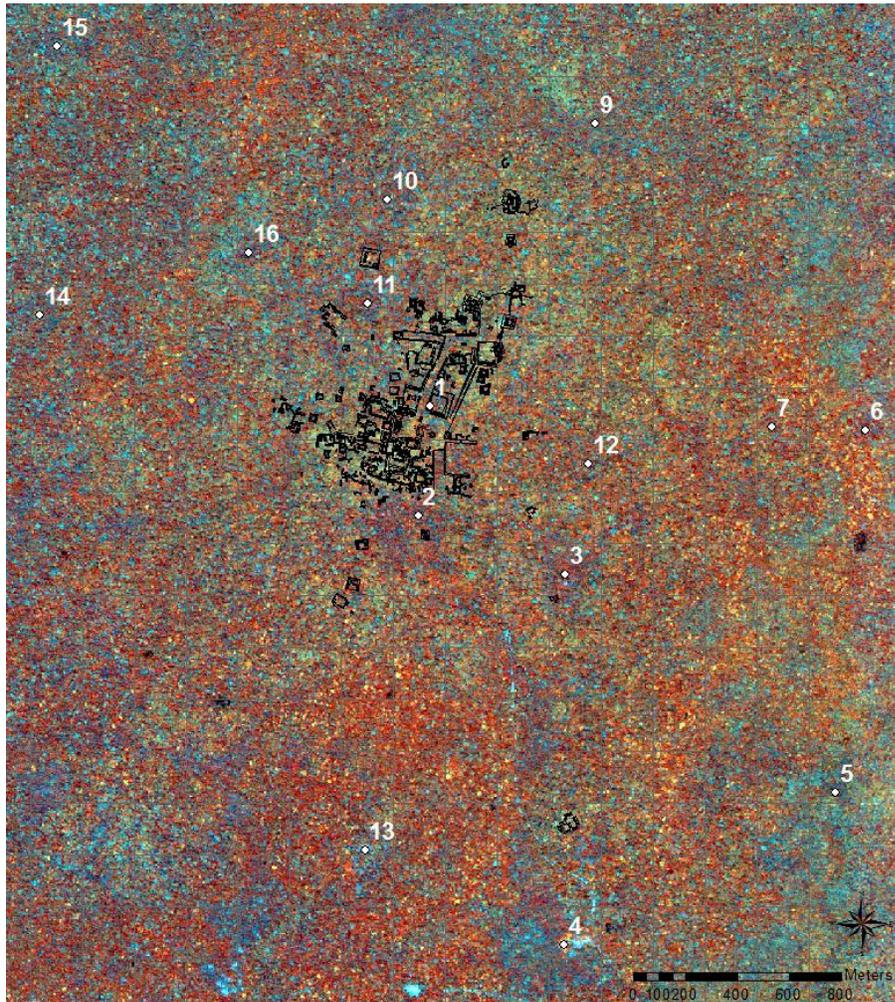
Figure 3.9. Locations of 15 aguadas identified using Quickbird data at Xultun.

IKONOS data were used to supplement these results, and it was noted that the vegetation within the aguadas had a different texture than the surrounding forest. Open aguadas around Tikal are often filled with water lettuce or "lechuga de agua" (*Pistia stratiotes*) which appears lime green in satellite images (Thomas 2010:7). This or other vegetation differences are the likely explanation for the textural differences noticed in the IKONOS images.

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ASTER radar data over Xultun were also acquired (Figure 3.10). These data provided a 30 m resolution DTM of the entire region. The original file was very large covering a much larger region and needed modification to focus on the region of interest. The file was loaded into ArcGIS 10.1 and clipped down to the area around Xultun. The color scale used to denote elevations then needed to be reset to the new extent. This was performed by exporting the raster. The data were compared to the results of the Quickbird aguada search to determine if the aguadas fell in topographical depressions. It was hypothesized that this could provide another avenue of exploration for the identification of aguadas. All but two of the aguadas (numbers 7 and 13) were located on the edge of large depressions.
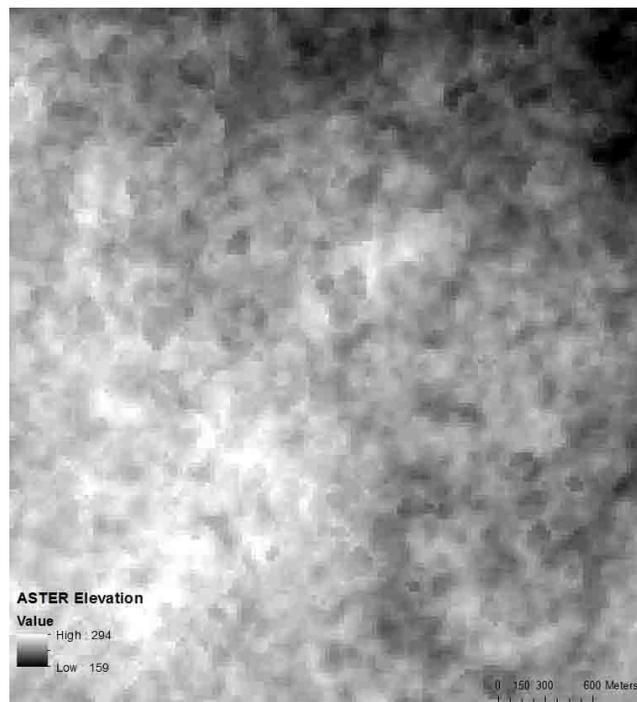
Figure 3.10. 30 m resolution ASTER DTM of Xultun region.

Groundtruthing

GPS

When looking at the Quickbird false color images, it was clear that the settlement signature identified by Saturno did not match with the structure groups on the map. It was, however, noted that the settlement signature existed and in the shape of the site core but more north than the total station mapped coordinates (Fig. 3.11). When comparing the IKONOS, Quickbird, and ASTER images, it was clear that all three of these data sets were georectified as major topographic features were aligned. Because of this, I felt that the original GPS datum was placed or recorded incorrectly. I went out with a handheld Garmin etrex 10 GPS receiver to read the UTM coordinates of three specific locations to compare with the map and satellite images. The accuracy of this device is 3 m with a good reading. I took a reading on the southwest corner of structure 11J-3, the tallest structure at the site, a reading of the northwest corner of structure 11J-6, and a reading on the southwest corner of structure 13H-1, the most massive structure at the site. The readings confirmed my suspicions and aligned well with the Quickbird settlement signature for where those corners should fall.
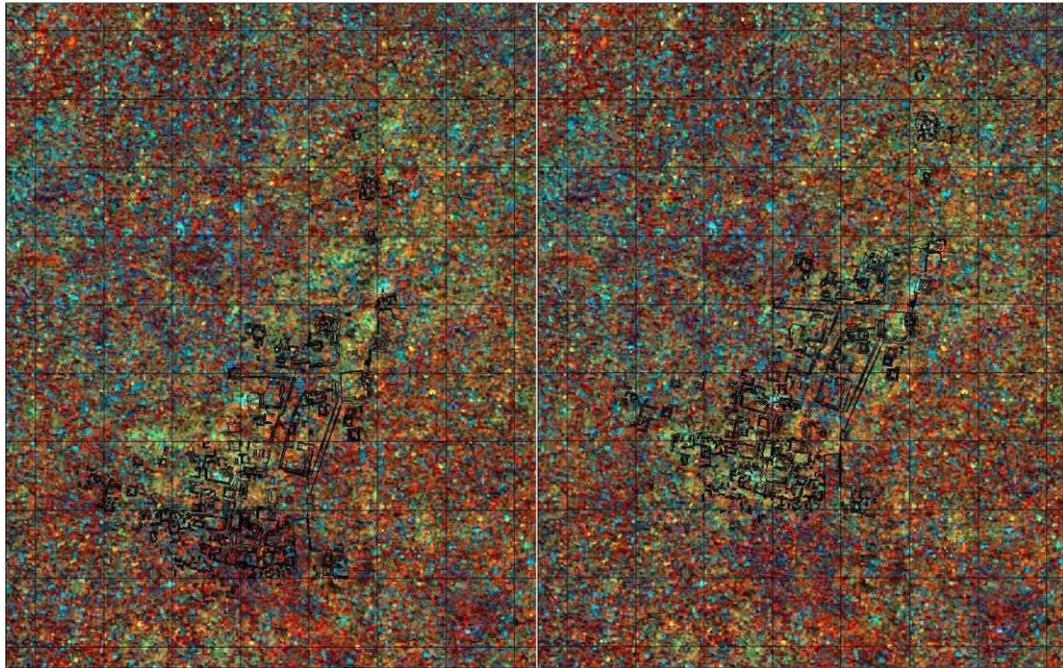
Figure 3.11. Original (l) and corrected (r) position of map on Quickbird settlement
signature.

Aguadas

There were several dark spots visible around the site in the Quickbird

imagery which were at first thought to be aguadas. It was hypothesized that

these dark spots represented areas of strong reflectance, specifically pools of

water. There was an arc of these features on the south end of the site, and I

decided that I should investigate these. I only had time to visit one of these sites

during the 2014 field season, and it did not appear to be an aguada when I

visited it. There did, however, seem to be a ravine at this location that continued

downslope to the east but no area where water could pool.

On March 11 2014, my guide took me to two aguadas near the core of Xultun. The first one (Aguada 3) was small and to the east side of the road running south from the core. It is located at UTM 244012, 1933578. This aguada was visible in the IKONOS image as a roughly round texture difference (Figs. 3.12-3.14). The second aguada was Los Tambos (Aguada 4) which is about a 20 minute walk farther south down the road and on the west side (Figs. 3.15-3.17). It is located at UTM 244038, 1932191. My guide informed me that Los Tambos contains water year round. It is very large and clearly visible in both the IKONOS and Quickbird images.
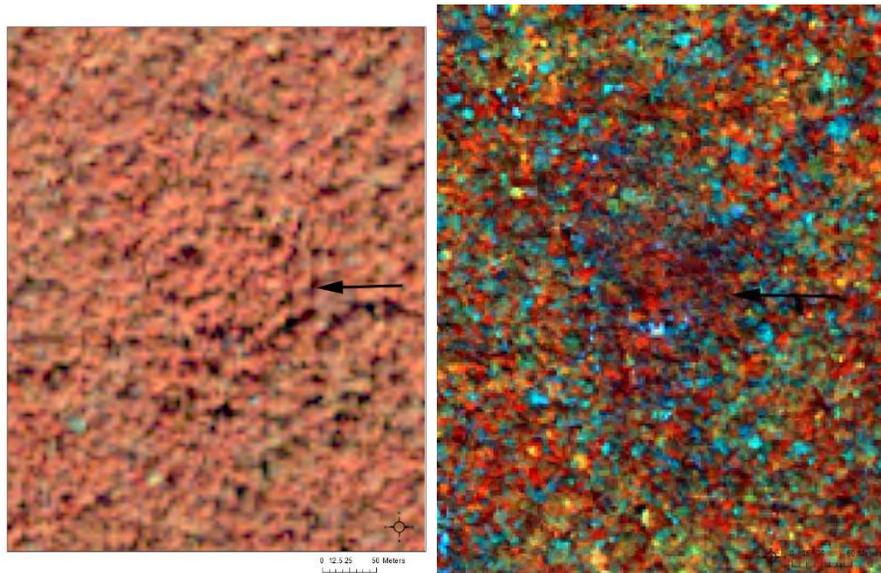
Figure 3.12. False color IKONOS (l) and Quickbird (r) imagery of Aguada 3.

Figure 3.13. Aguada 3 with standing water, facing east.

Figure 3.14. Open canopy at Aguada 3.

Figure 3.15. Aguada 4, Los Tambos, facing west.

Figure 3.16. Detail of water lettuce growing on surface of Los Tambos.

Figure 3.17. Open canopy at Los Tambos, facing west.

The large amount of water lettuce on the surface of Los Tambos is significant due to the presence of this plant in aguadas at other sites like Tikal (Thomas 2009). Other vegetation types, such as the water lily, were important in Maya iconography and was closely tied to kingship. It has even been suggested that the maintenance of clean water was the source of power for Maya kings (Lucero 1999). It is interesting to note that these plants were not seen within the aguadas at Xultun.

On March 31, 2014 to further test the predictive capabilities of Quickbird data for the identification of aguadas, I went on a reconnaissance mission to inspect and document two locations that I felt represented aquadas, based on a

Quickbird survey. The first location was Aguada 11 to the west of the map at UTM coordinates 243224E, 1934677N (Fig. 3.18). Although it was dry during my visit, the environment was significantly different within the aguada. The vegetation was very open, and there was cracked mud in many areas where the soil had been very moist and then dried out, and the ground was very spongy in other areas. There were also many palms and *bial*, a thorny vine, in this area, as well as a carpet of leafy green vegetation under the open canopy. One of my guides, Majunche, confirmed that he was familiar with this location and that it does fill with water, and animals like *jabali*, a type of wild pig, can often be found there. I mapped the extent of the aguada by cutting *brechas*, straight lines, to the cardinal directions and pacing out the distance until a significant topographic rise was encountered.

Figure 3.18. Carpet of leafy green vegetation of floor of dry Aguada 11.

Settlement Signature

The Quickbird data also predicted a large area of settlement to the
southwest of this aguada. We did indeed find a very large group in this location
at UTM coordinates 243148E, 1934670N (Fig. 3.19). The same technique was
used at aguadas 3 and 4, where settlement was also found (Figs. 3.20-3.21).
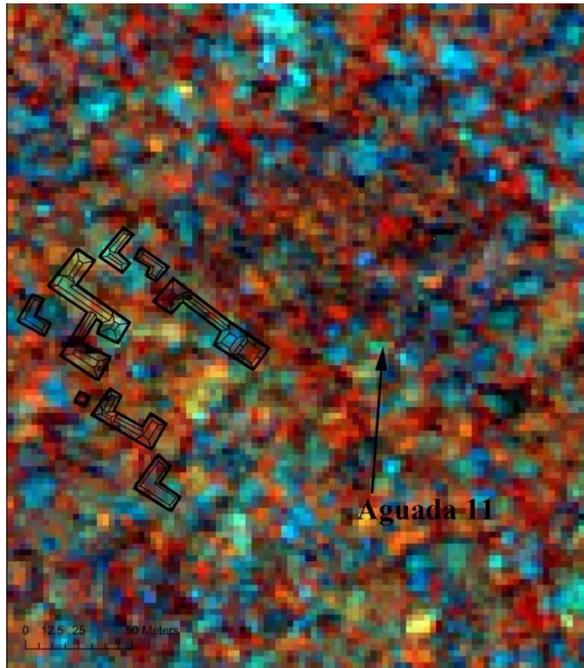
Figure 3.19. Aguada 11 with predicted settlement drawn in.
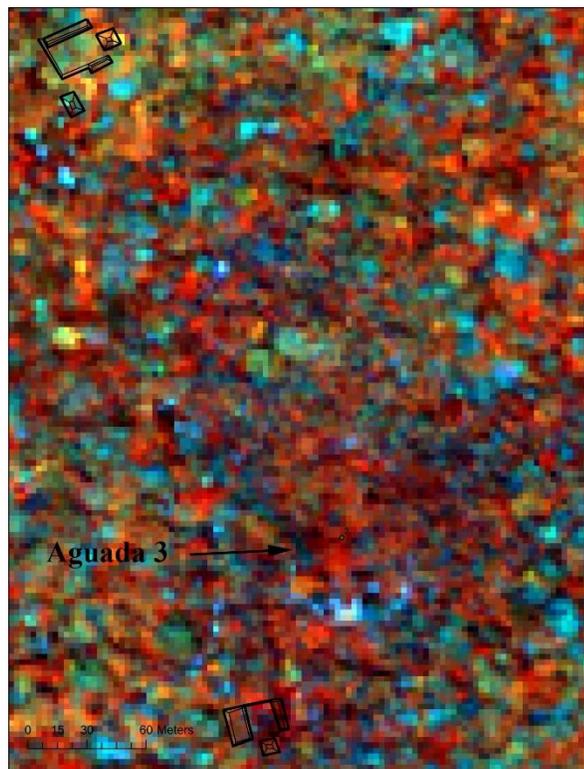
Figure 3.20. Aguada 3 with predicted settlement drawn in.
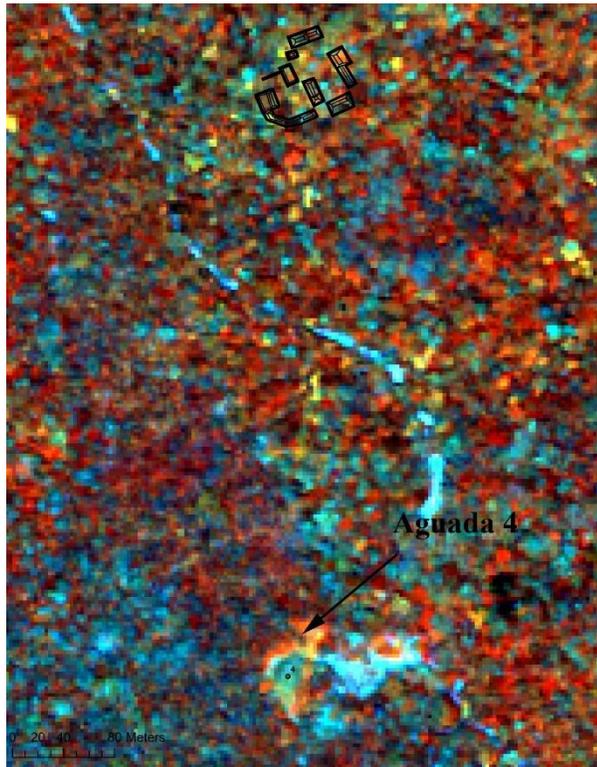
Figure 3.21. Aguada 4 (Los Tambos) with predicted hilltop settlement drawn in.

Conclusion

The digital map developed here provides the foundation upon which the

spatial analyses, presented later, are performed. The digital map being

produced uses high resolution GPS, satellite, and laser survey devices to

achieve a global accuracy of within one centimeter. The Quickbird satellite data

facilitated the identification of both previously unrecorded structures and water

storage features beneath the forest canopy. This demonstrates how remote

sensing techniques can be used to speed up survey within semi-tropical forest

environments. The satellite data was also key in identifying, and fixing, an error

in the permanent datum coordinates used to map Xultun. Large administrative

groups were identified in association with the identified aguadas, demonstrating

continued elite involvement in the management of this resource. The methods

used in the mapping of Xultun will be beneficial for researchers investigating

settlement and hydrological issues within this and other semi-tropical forest

environments.

Chapter 4: The Archaeology of Urbanism and Urban Geography

Introduction

In this chapter, a brief literature review of methods used in categorizing urban space at Mesoamerican archaeological sites is performed to lay the foundation for the direction taken in this study. The urban space at Xultun is then described in both broad and more specific terms. All of the mapped areas are broken down into one of four categories; open space, administrative structures, residential structures, and production zones. These broad categories are described and when possible subdivided into more specific forms. The entire map is then divided into these four urban types for spatial analysis of the site as a whole. Using topographic changes, open spaces, and architectural divisions 23 are identified. Four of these are described in detail. These four conform to a newly identified hydrological management neighborhood group. This information lends further support to the contestation that there was a continued involvement of elite individuals in the management of hydrological resources at Xultun.

Urban Categories at Xultun

The majority of studies into ancient Maya urban form have adopted descriptive terms for general architecture and can be misleading. The use of these terms is based predominantly on historical tradition and less often on

archaeological evidence. For example, the term palace is used by many scholars to describe range structures or structures that are more than twice as long as they are wide. This terminology serves as a categorical term and does not imply that the structure was used as a royal palace. This is confusing and as such more general and formative descriptive terms should be used in the absence of excavation data. Other researchers have attempted to decipher cultural cues from the way people interact with their environment.   These cues would impart meaning onto the built environment allowing archaeologists to understand past value systems, how environmental quality was determined, and what levels of meaning were transcribed onto the environment (Rapoport 1977, 1990). In opposition to the historical approach mentioned above, some researchers have attempted to use excavations as well as architectural elaboration to define the past use of structures. At Copan, statistical analysis of artifact distributions in association with structure types was used to positively identify the Sepulturas group as elite and residential (Hendon 1987). A comprehensive study of anthropological interpretations of the built environment was conducted by Lawrence and Low (1990) and is thus not necessary here.

Probably the most productive urban settlement study in Mesoamerica was performed at Teotihuacan, Mexico. In addition to different neighborhood groups, hundreds of workshops for materials such as obsidian, ceramic, stone, figurine, lapidary, basalt, and slate were identified within the city (Millon 1970:1081). The differences between urban form in Central Mexico and that in the Maya Lowlands

led many early researchers to conclude that there was no urbanism in the

Lowlands. More recently, research has focused on interpretations of meaning in

urban form across the Lowlands. Ashmore and Sabloff (2002) suggest that

similarities in urban layout between some late Classic and other earlier sites may

be evidence of some form of political allegiance between these sites.

Postmodernist interpretations have also taken hold in interpretation of urban form

in concepts such as 'the architecture of expectation' which points out a biased

focus on what the designers and builders intended while neglecting the role of

the viewer in interpreting buildings (Houston 1998:524). Becker has made an

attempt to categorize Maya plaza plans into one of ten groups identified at Tikal.

Of these, Plaza Plan (PP) 2 is the most important in a discussion of urban

studies as it has been adopted and described by others.

In examining the urban forms at Xultun, I have determined that due to the

lack of excavation it is necessary to use descriptive terminology similar to the

historic approach mentioned above. I will describe specific architectural

groupings without interpreting the past use of specific structures.

Although there is a large amount of urban development within the core of

Xultun, the majority of space is open. This does not mean that these open

spaces were not developed and used in ancient times; it simply means that there

is no direct evidence of that past use on the surface of the forest floor today.

According to Smith (2008:216) "emptiness is a particularly potent cultural

category because of the many meanings and activities that may be

simultaneously and sequentially encoded there." In fact, archaeological work at Chan Nóohol, Belize demonstrated that neither domestic nor agricultural spaces were segregated spatially or socially (Robin and Rothschild 2002:166). Since the survey methodology used in mapping the site focuses on raised mounds, many of the spaces between these mounds are not examined in detail. Undoubtedly, many of the smaller open spaces between were used for production of one form or another, but these are not the focus of this study.

These open areas within the urban core can be broken down into four main forms: public space, private space, agricultural space, and water storage. These major forms can be further broken down into use types. Through excavation, public space can be broken down into ritual space, marketplaces, entertainment, and transportation routes. Private spaces can similarly be broken down into residential and ritual areas. With proper sediment analysis, it is even possible to subdivide agricultural spaces into what was being grown.

To understand the urban form at Xultun, it is important to further subdivide these large general groups into smaller functional categories such as administrative, production, and residential. Administrative structures can take on many functions including ritual, resource allocation in the forms of access control and/or distribution as well as other functions. This includes water management features used to divert and collect runoff. Production areas include all goods produced within the site. These can take the form of quarries and workshops for the production of specialty items such as ceramics or lithics. Although not many

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of these workshop groups have been found within the Maya Lowlands, they are known through archaeological excavation (Becker 2003).

Residential groups are probably the most abundant structures at any Lowland site. There is no clear uniformity in arrangement or number of structures within these groups. The most widely studied are those belonging to royal or elite individuals. Although many studies have been done assuming the residential function of these groups, palace or elite residential groups are more clearly identified through excavation of complexes and have been demonstrated specifically at Copan (Webster 1989; Andrews and Fash 1992, Willey et al. 1994; Webster 1998). The major differences between royal, elite, and non-elite residences are architectural elaboration and quality of interred goods. Many of the residential architectural forms seem to be the same across socioeconomic groups as demonstrated by the PP2 groups at Tikal (Becker 2004:131).

An analysis of various architectural forms at Xultun will be completed in order to understand how they are distributed and grouped. This will be used to justify a description of general urban forms within the site. Neighborhood groups will be selected based on topological changes and architectural separation. In cases where groups seem to be associated with an aguada, the aguada is grouped into the neighborhood. When palace/range structures are attached to larger groups, they are considered part of the larger group. Many of these structures seem to serve as visual and physical separations between different neighborhoods or topographic changes. Very few lone range structures appear

north or at the southern edge of Group B, suggesting that these could be a later

addition after the early Classic period. Several large, multi-plaza groups made

up of many structures seem to be in close association with modelled drainage

over the site, and these groups may represent elite water management,

administration, or production of a product which requires water such as plaster or

alcohol.

Urban Space at Xultun

The total area mapped at Xultun was calculated by combining both the

total station mapped areas and the areas that were mapped using remote

sensing techniques (Fig. 4.1). The total area equals 751,699 m² (0.75 km^2). This

is the area within the map that will be used to calculate the urban zones within

the site. Of the total area, open spaces account for 655,650 m² (0.66 km²) with

the building space equaling 96,049 m² (0.96 km²) (Fig. 4.2).
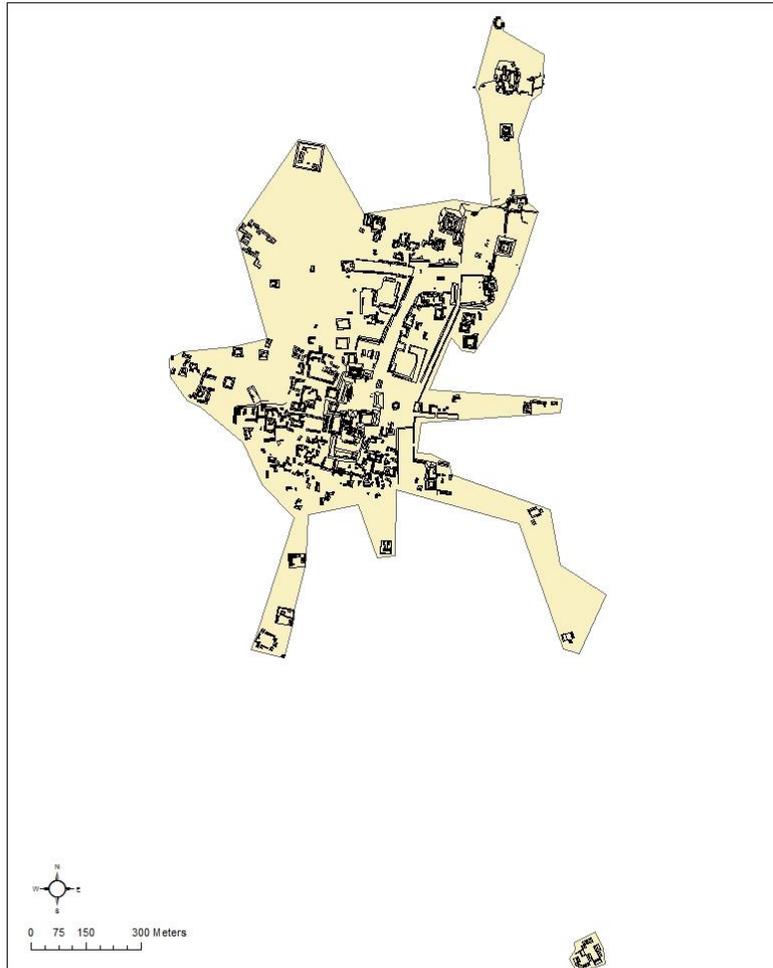
Figure 4.1. Total area divided into zones at Xultun.
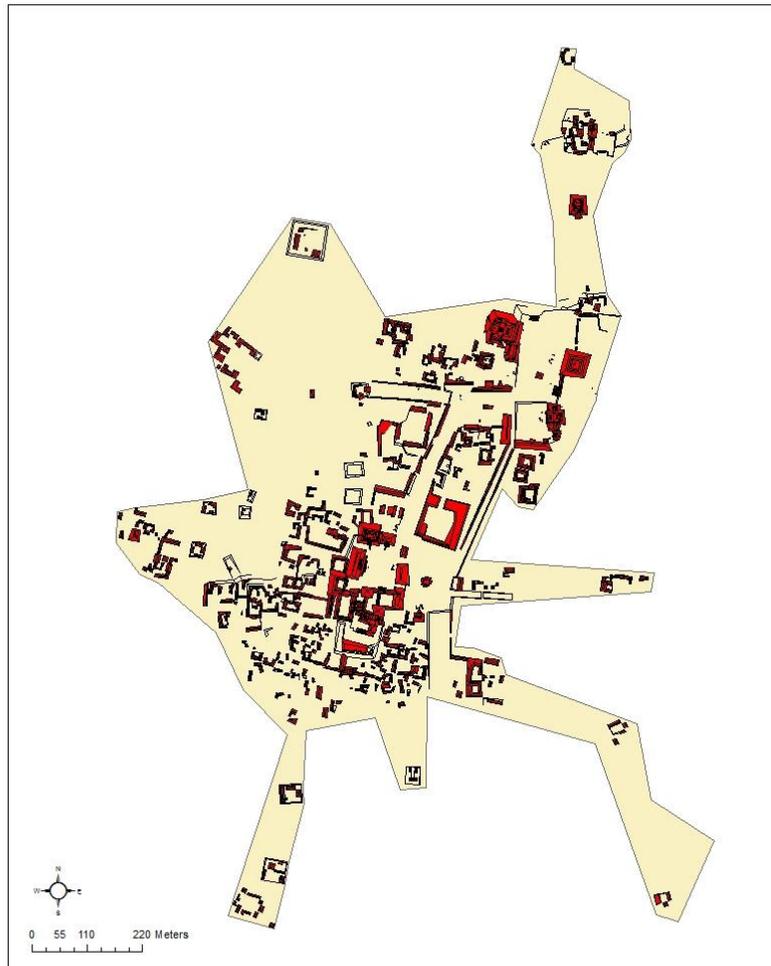
Figure 4.2. Built space (red) and open space at Xultun.

Open Space

To interpret the open space at Xultun, it is first important to discern what

can be said about how the space may have been used; for example, public

space versus private space. Excavations in regions without permanent

architecture have shown that open spaces often have the same level of

complexity found in structures (Robin and Rothschild 2002:163). In urban

settings, the activities within empty spaces would have been more flexible than within structures but with higher public visibility (Smith 2008:216). Large open plazas with ritual groups as well as causeways are likely to represent public space. The monumental architecture surrounding ritual plazas was designed to have an impact on the population, and thus to be seen and experienced. Causeways allow the population to move between different groups at the site and impose an ordered control on both the movement of people and goods. Private spaces would have likely had a local household purpose, with areas of household production, administrative function, or exclusive ritual practices.

Public Spaces

The public space within the center of Xultun is represented below and covers an area of 97,493 m² (Fig. 4.3). The public space can be further divided into two basic categories; public plazas and transportation routes. There are five large public plazas within the core of Xultun, each of which contained stelae. These plazas dominate the space within Groups A and B, and the stelae serve to reinforce the authority of the king. Whatever other activities were taking place within the public plazas, there was definitely administrative influence at play. These were undoubtedly areas where large numbers of the community would congregate.
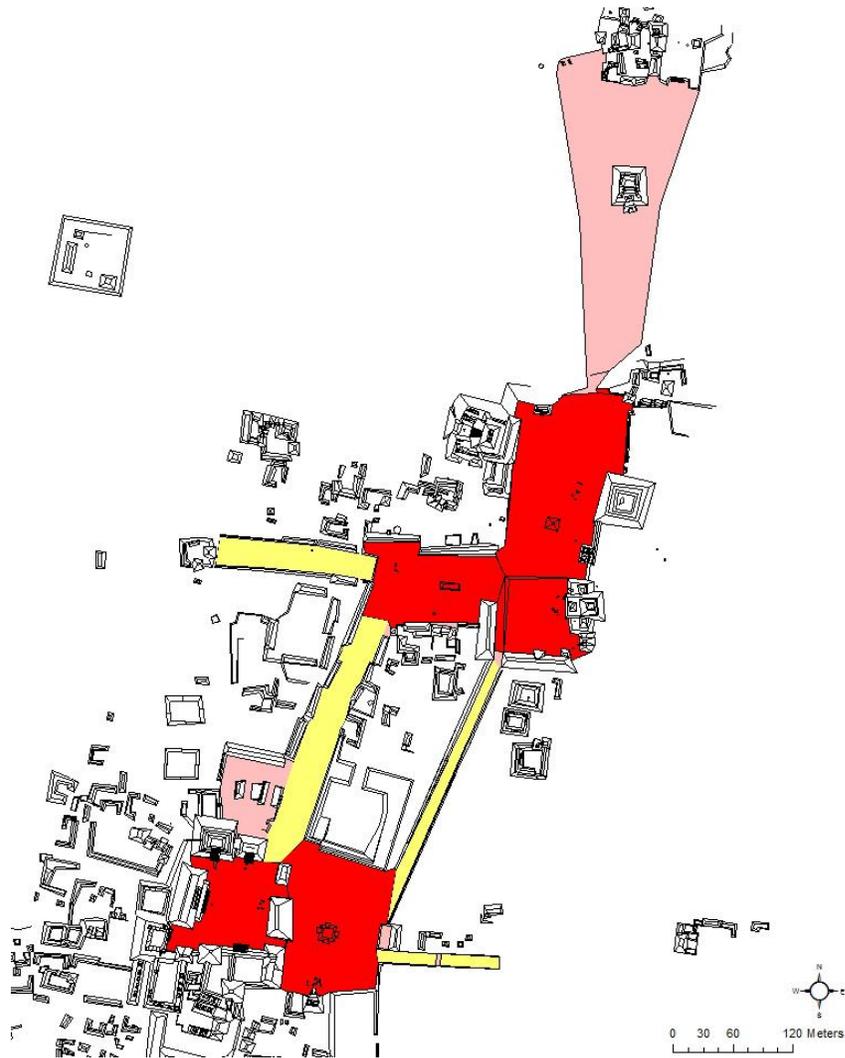
Figure 4.3. Public space: plazas (red), causeways (yellow), and other (pink).

Connecting the southern and northern plazas and providing access into these groups are four causeways. The northernmost causeway leads from the west into the Group B. There are two central causeways running roughly north/south connecting the eastern and western plazas of Groups A and B. The southernmost causeway leads from the east into Group A. These four causeways served as important transportation routes for the population of Xultun,

both into the ritual center and from Group A to Group B. These causeways

totaled 16,860 m² in area.

Private Space

In opposition to the public space, there are many private plaza groups

within the core of Xultun. Of the currently mapped structures, there are a total of

101 separate private patio groups (Fig. 4.4). These total an area of 35,443 m²

and range in size from 9 m² to 2338 m², with the mean falling at 350 m². These

private plazas are found across the site with the majority clustered to the south

and west of Group A. These plazas are found in administrative and residential

zones. These represent limited access spaces where likely only the residents or

those involved in administrative activities would be present.
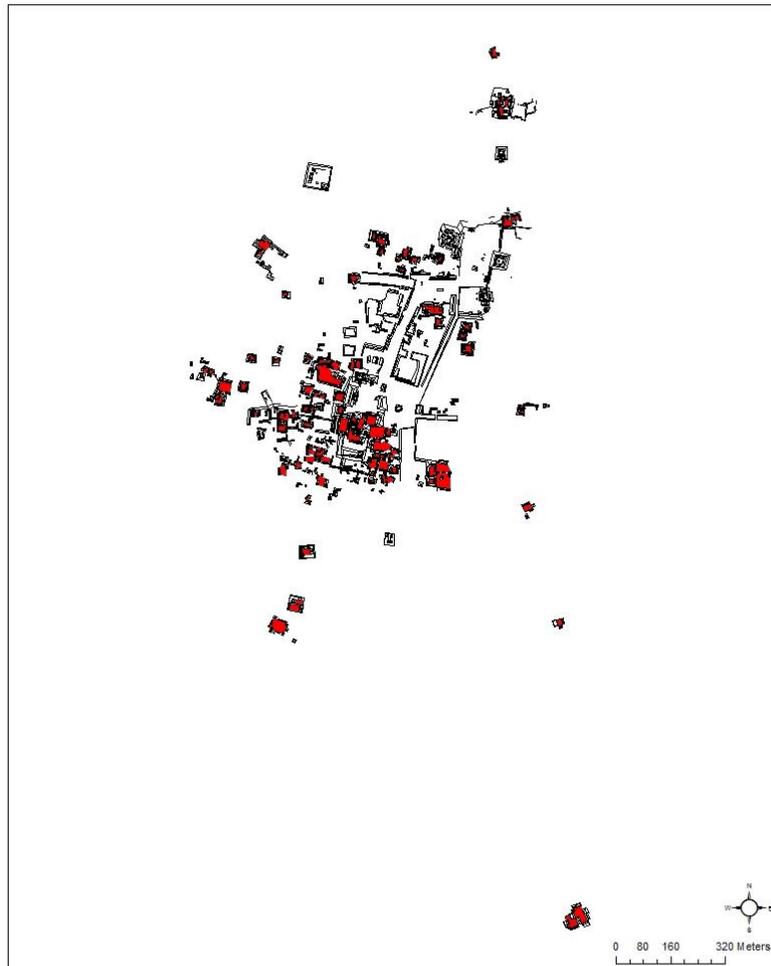
Figure 4.4. Private plazas (red).

Administrative Structures

Administrative structures within Maya centers are divided into two main

categories. These are political/ritual and resource control. Political structures

serve to reinforce and maintain the focus of power on the royal elite. These can

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take the form of monumental constructions which were often the focus of ritual

performance or administrative buildings where various societal needs would be

met. Resource control structures can be used to control access to specific

resources such as water. In the case of water, this can take the form of diversion

and containment structures as well as administrative groups that oversee stores.

Political/Ritual

These structures are categorized by their monumentality, and their

placement around large plazas containing many stelae and altars depicting kings

and often documenting their histories. There are 18 structures that fall into this

category within Xultun (Fig. 4.5). Of these 15 of the structures are within Group

A, including a ritual double ballcourt. Group B has two of these structures and

the final structure is north of Group B. These structures total an area of 13,418

m². Due to the prismatic style in which Maya structures are mapped, most

structures tend to fall into either a square or a rectangular form. The structures

with square bases tend to be of a ritualistic nature such as pyramids with temples

built on top. There are 10 square structures in this category, and if the three

ballcourt structures are added it can be assumed that 13 structures served a

ritual function and five served a more political function.
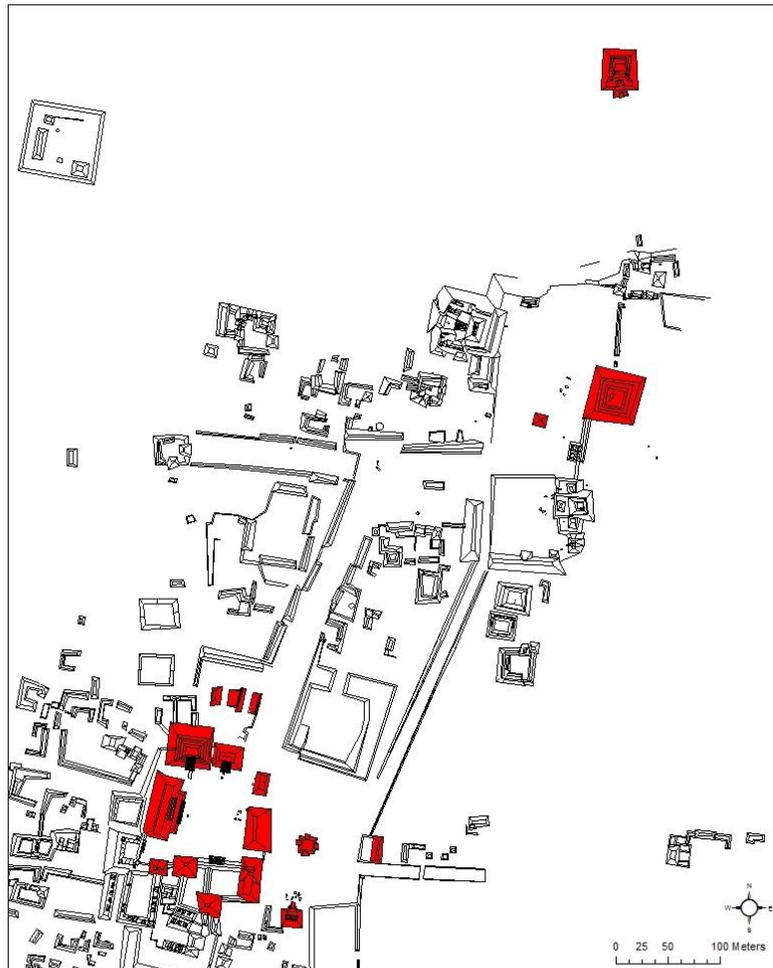
Figure 4.5. Political and ritual structures (red).

Another group of administrative structures that fall into this category are acropolises. These groups tend to contain many structures and plazas built up on a large platform. There are three groups that fit this category at Xultun, two are within Group B and one in Group A (Fig. 4.6). The acropolis in Group A is different than the other two in that there does not seem to be direct access from

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the plaza as it is south of several of the large ritual structures. These three

groups have a total area of 14,936 m².
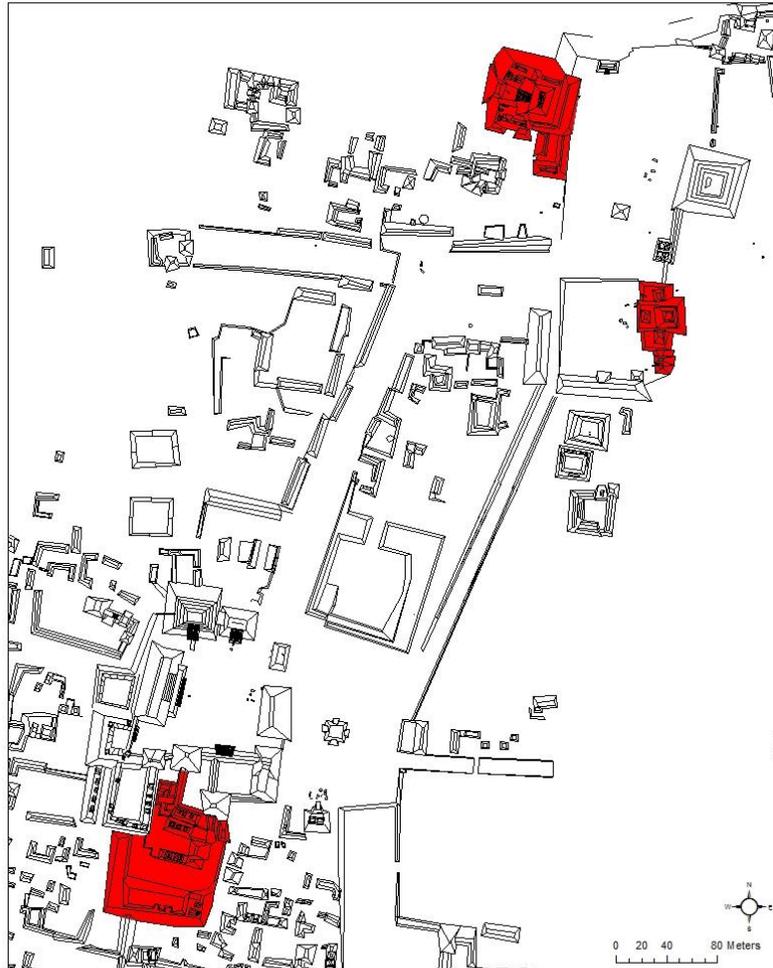
Figure 4.6. Acropolis groups (red).

Resource Control

The final form of administrative structures that will be mentioned here are

those built with the aim of resource control. The focus here will be on water only.

These structures can be designed to alter the hydrological landscape to divert

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and collect water, or they can be designed to oversee access to stored water. In total, 42 structures were identified as designed for hydrological control covering an area of 15,392 m². There were 14 structures designed to divert and store water (Fig. 4.7). These include four pairs of balustrades on three of the causeways, a drainage ditch to the southwest of the central causeway, a large sloped drainage wall to the west, two large containment walls built around the central reservoir and two walls to the south with a drainage opening to the east.
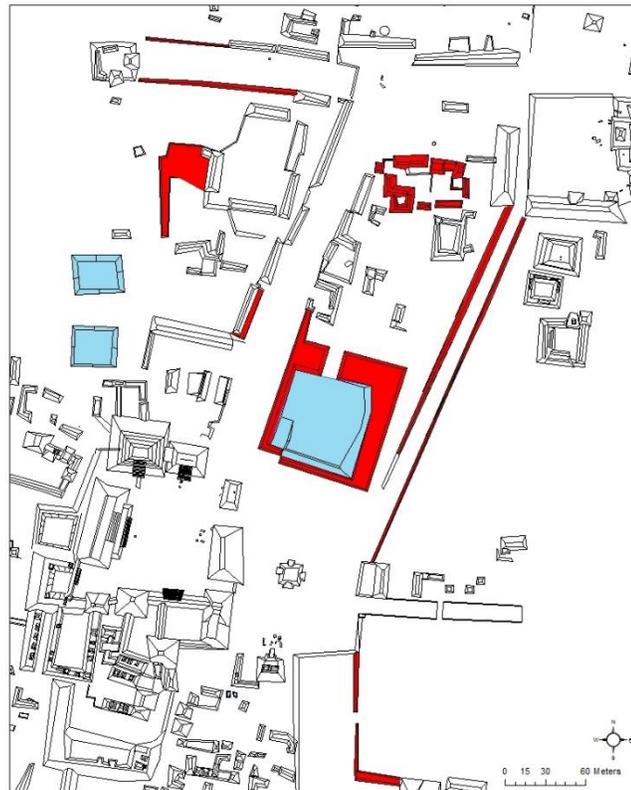
Figure 4.7. Hydrological diversion and storage structures (red), stored water (blue).

The remainder of the structures are organized into 5 administrative groups each associated with an aguada or reservoir (Fig. 4.8). Group 1 is a very large group built to the southwest corner of a large aguada beyond the western extent of the mapped site. This group is completely enclosed on three sides but open to the southeast suggesting that this may have been the direction of approach. Group 2 is a large enclosed complex within the center of the site, and it is associated with the large central reservoir. Group 3 is constructed around the edges of a small reservoir built from a converted quarry on the western edge of the site. Group 4 is a small grouping of three structures associated with an aguada to its north. Group 5 is a large hilltop complex that overlooks the very large aguada Los Tambos which sits approximately 2 km south of the site core.
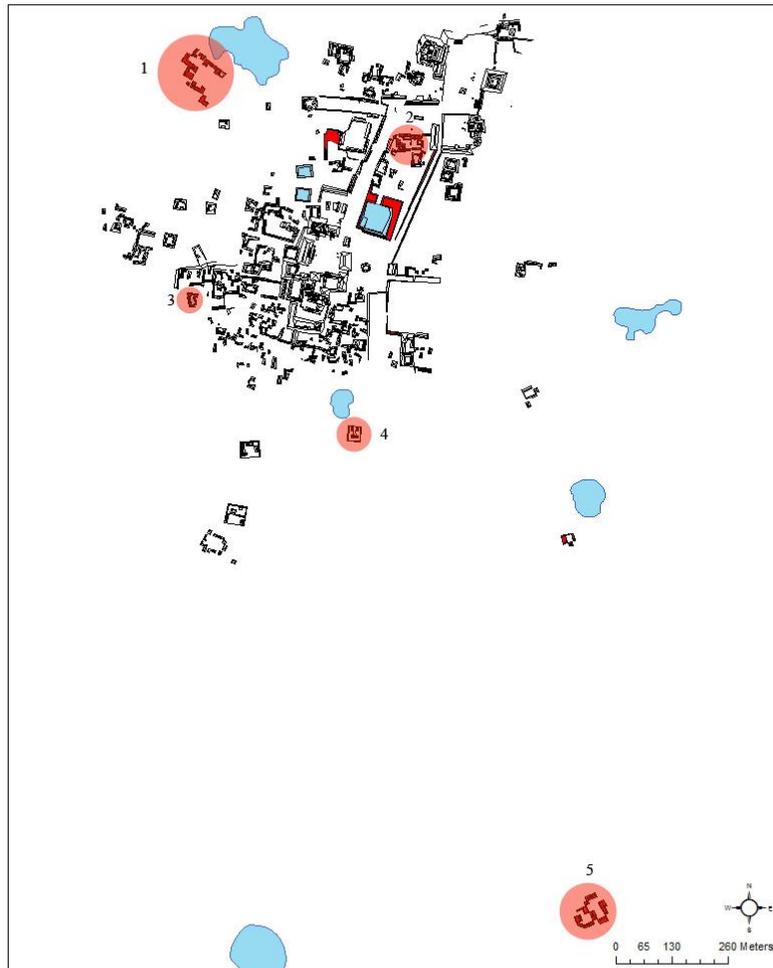
Figure 4.8. Hydrological management groups (circled in red) and aguadas (blue).

Residential

Traditionally, Maya house groups are categorized into general terms such as royal, elite, and non-elite based on comparative size and architectural elaboration. The determination that a particular group represents a residence is

often disputable as this is usually an assumption rather than based on archaeological evidence. Nonetheless, and in part because of the lack of excavation at Xultun, I will be categorizing the majority of remaining structures as residences. There are 316 of these structures covering a total area of 49,388 m².

To break these structures down further, I will use the categories small, medium, and large to avoid associations with class structure. The majority of the mapped area covers only the urban core of Xultun, and thus almost all of the structures would be categorized as elite with stone masonry. To make these divisions, I created a boxplot of the areas and chose to make the high outliers large residences and the low outliers small residences (Fig. 4.9). All of the structures below 55 m² were classified as small and all of those above 240 m² were classified as large. This means there are 100 small structures, 171 medium structures, and 45 large structures (Fig. 4.9). It must be noted that the sample size is biased, being focused in the core, and that there are likely many more of the small structures towards the periphery of the site.

Box Plot of Residence Areas
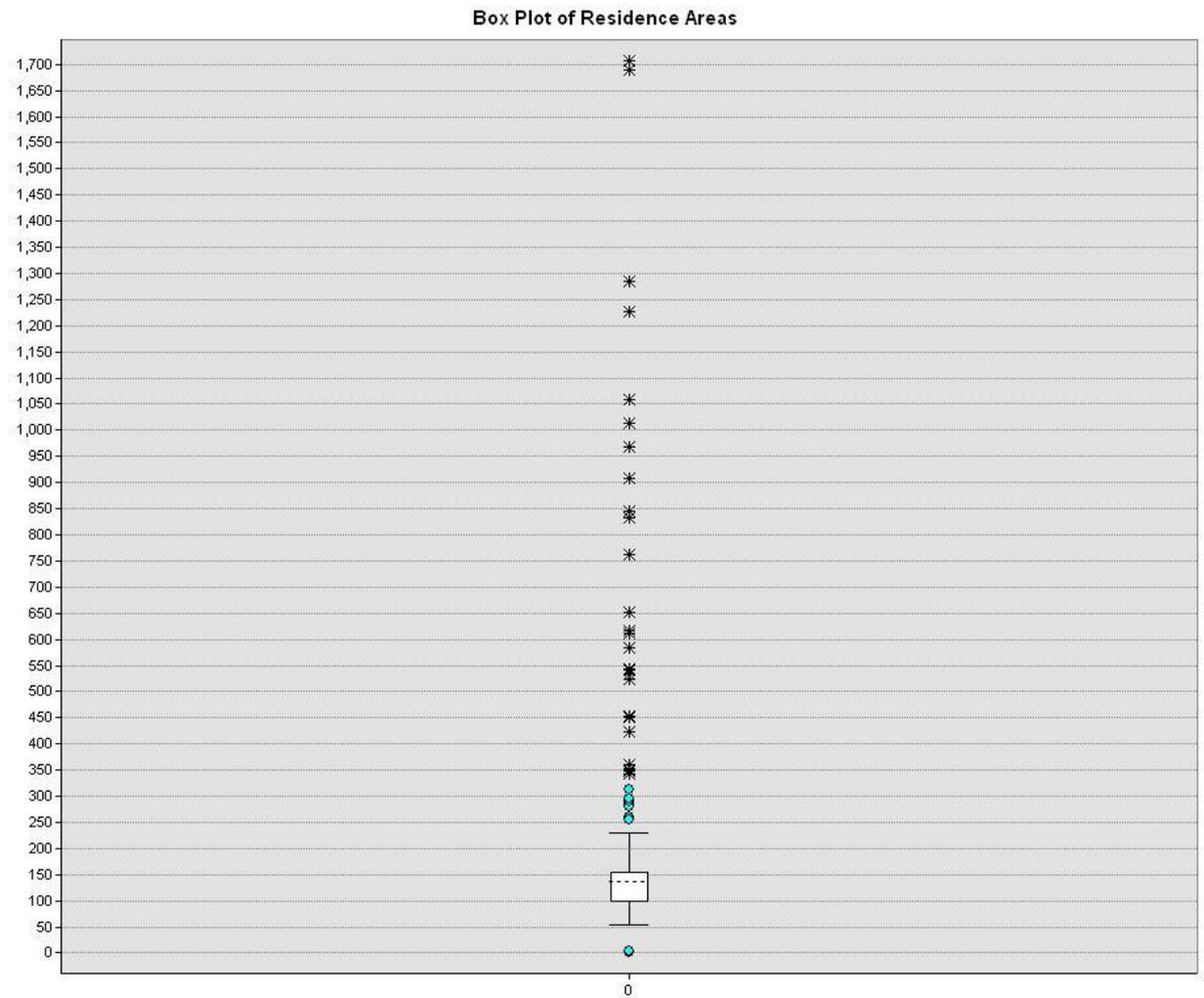
Figure 4.9 Boxplot used to divide residential groups into s/m/l categories.

Probably the most exclusive residential groups are the fully enclosed quadrangle groups. There are a total of 10 of these groups mapped at Xultun (Fig. 4.10). All of them are south of Group B, and all of them fall into the large structure category. Four of these are grouped around the northern end of the eastern causeway, three to the east, and one to the west. Five of them are

grouped off the southwest corner of Group A, and the final one is off the

southeast corner of Group A.
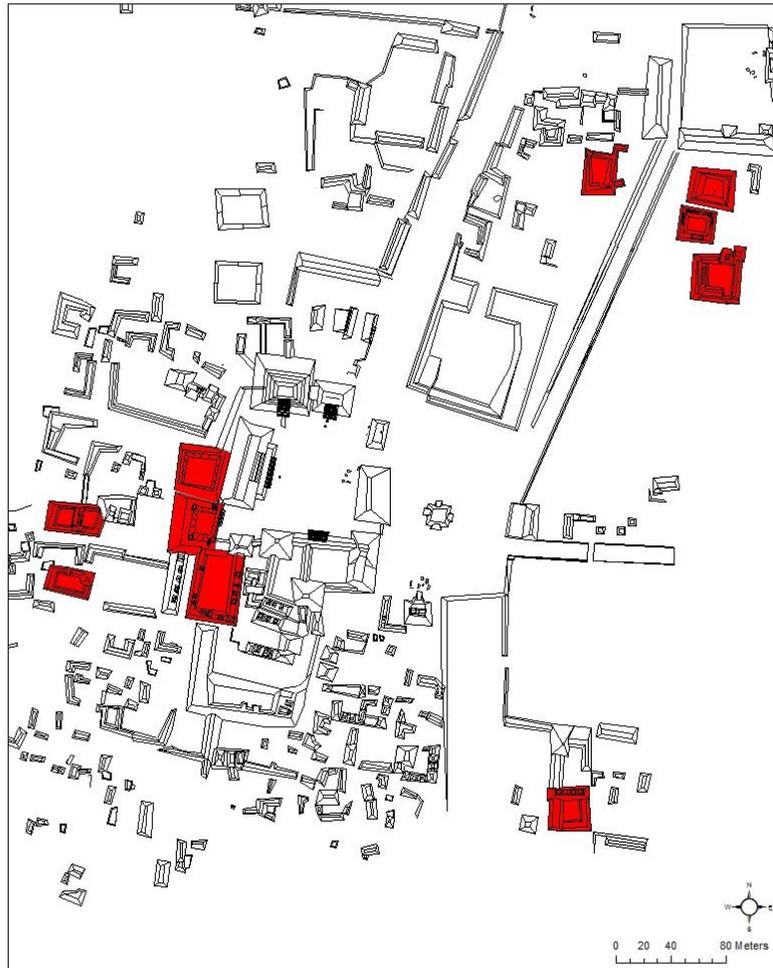
Figure 4.10. Residential quadrangle groups (red).

Production

Although there were undoubtedly many production areas around the site,

these cannot be identified through surface survey. Excavation of specific groups

is required to better interpret the past use of space. This includes craft

production, plaster production, stone carving, etc. The only evidence of

production areas left on the surface are exposed cut bedrock areas

demonstrating that these were areas of past quarrying. There are many areas

across the site of Xultun with exposed cut bedrock (Fig. 4.11). It appears that

many of the quarrying zones were adjacent to the architectural groups for which

they were being used. There are 22 of these quarry zones currently identified

within the site totaling an area of 10,345 m².
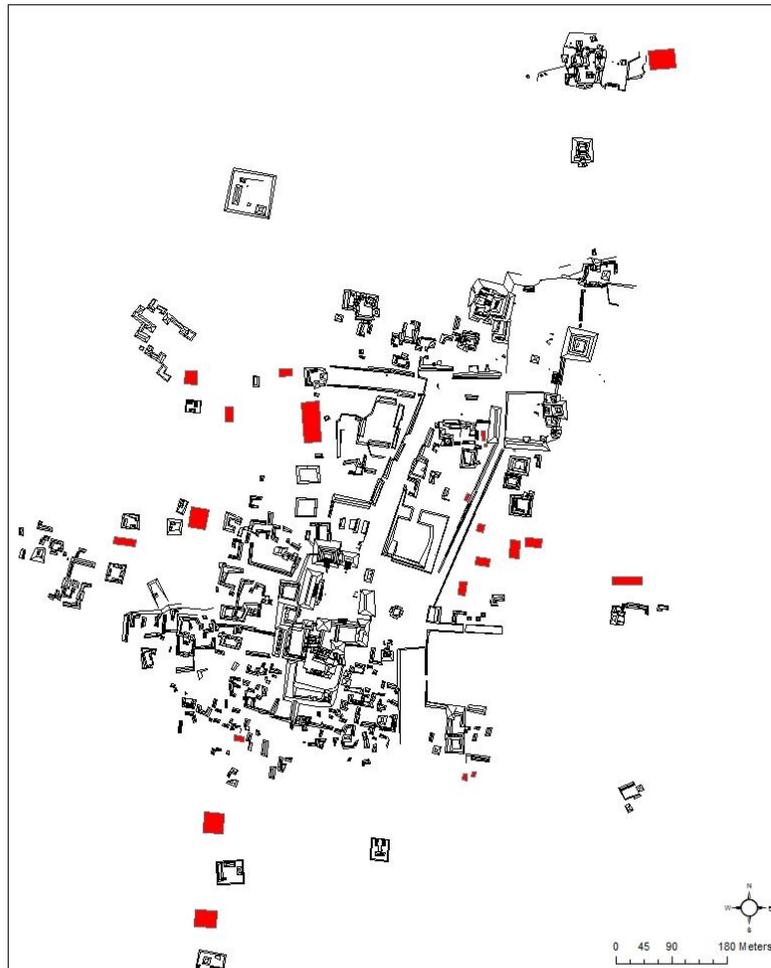
Figure 4.11. Quarrying sites around Xultun (red).

Other Urban Forms

Geographic Separation

There are urban structures that do not cleanly fit into the categories

described above. One of the most clearly identifiable are range structures that

seem to have been used to separate different urban zones within the site (Fig.

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4.12). These very long structures served as physical barriers between different areas within the site, both defining space and blocking the viewshed of individuals standing on either side. These structures define the southern edge of the neighborhood west of Group B. They also define the western edge of the western causeway and the southern entrance to Group B. There are four individual structures spread across the south of Group A.
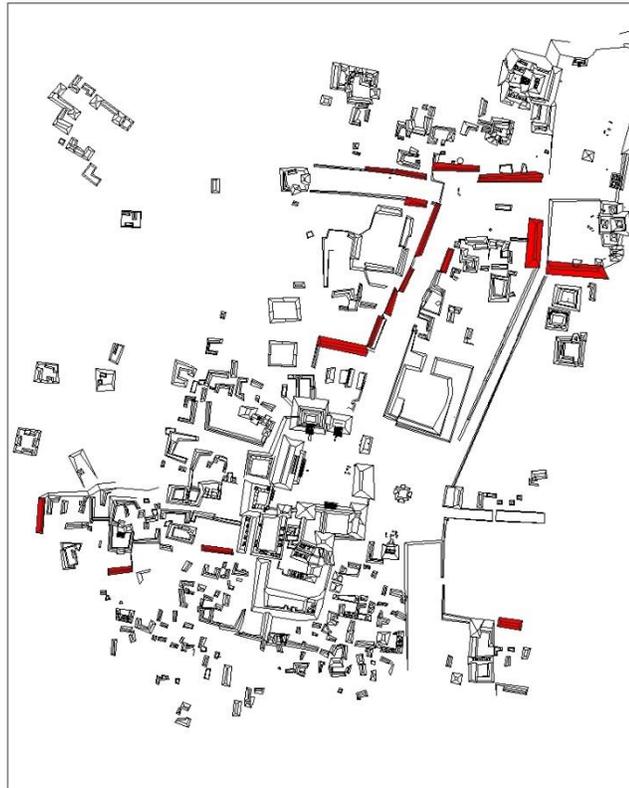
Figure 4.12. Range structures (red) forming boundaries between different urban areas.

The Urban Landscape of Xultun

It was decided that the easiest way to compare the four urban zones at Xultun was to generalize the areas. The different groups described in Chapter 4 were reduced down to the four basic categories of administrative, residential, production, and open Space (Fig. 4.13). Through a visual inspection of the urban patterning, it appears that the site conforms to a concentric model with administrative functions in the center surrounded by a ring of residential structures, then open space and production zones.
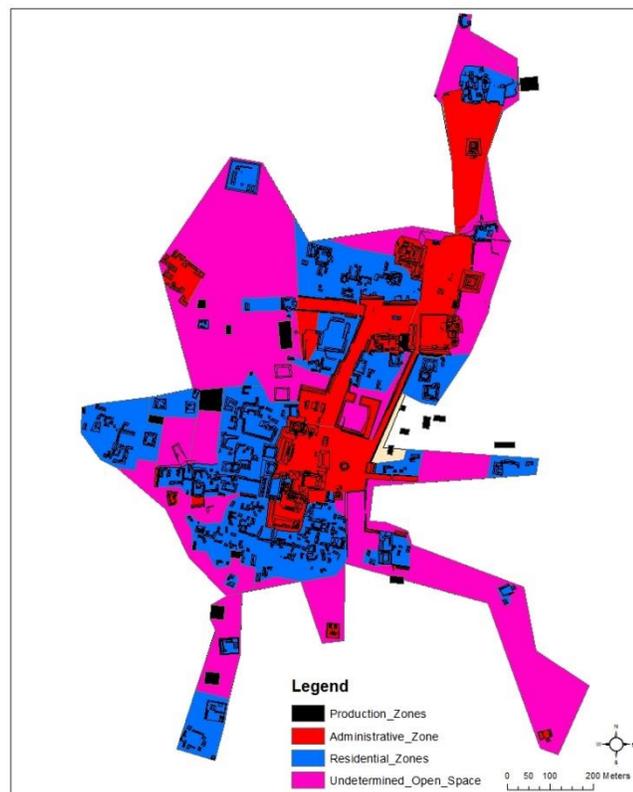
Figure 4.13. Four Urban Zones Categories at Xultun

Table 4.1. Percentage of Total Area by Zone

Zone	Area in m²	Percentage of Total Area
Administrative	164,834	22.08%
Residential	247,343	33.13%
Open Space	320,553	42.93%
Production	13,885	1.86%

Neighborhoods

Smith and Novic (2012:4) define the neighborhood as a residential zone

that has face-to-face interaction and a distinctive form or character. Identifying

where neighborhoods begin and end can be difficult. These groupings are often

separated by open spaces or topographic changes. At Rio Bec there were clear

topographic boundaries and drainages between groups while at La Joyanca

nearest neighbor spatial statistics was used to define neighborhood groups

(Arnauld et al. 2012; Lemonnier 2012). At Xultun, topographic changes, open

spaces, and architecture used to separate geographic areas were used to define

neighborhoods. A total of 23 neighborhood groups were isolated on the map of

Xultun (Fig. 4.14). Four of these groups deserve special mention here in relation

to water management functions groups 1, 6, 17, and 20. These groups seem to

have a combination of residential, ritual and possibly administrative groups

clustered together close to either aguadas or drainage paths. Each of these four

neighborhoods has a large rectangular possibly administrative group arranged

around a central plaza, an elite residential group, and groups that seem to have performed a ritual function.
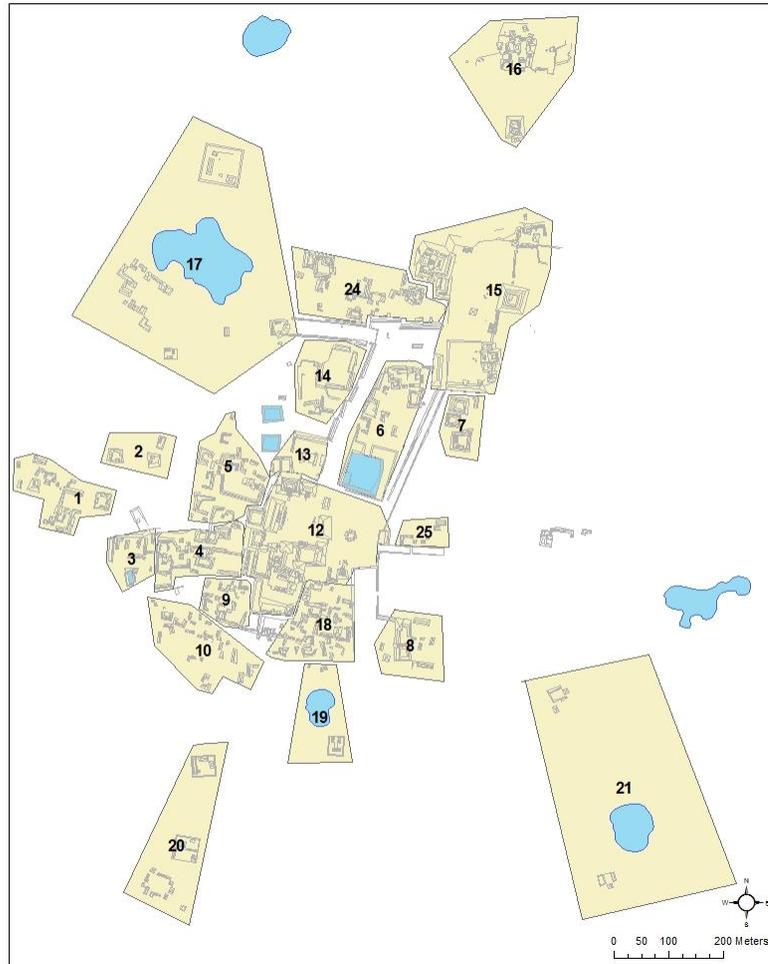
Figure 4.14. Neighborhood groups at Xultun.

Group 1 is to the far southwest of the currently mapped site. It is located in an area of decreased elevation from the groups to the north and east. The western boundary is defined by a large ditch which drains to the north. There are three groups which make up this neighborhood (Fig. 4.15). The eastern-most

group conforms to a small PP2 plan with four low, inward facing structures oriented to the cardinal directions. The structure on the east is somewhat squarer than the others. This is likely a residential group with the eastern structure serving as a family shrine. The central group is the largest and is made up of several very large structures and likely administrative in function. There is a very large plaza on the northern section of this group that is open on the eastern side which may have allowed the residents in the PP2 group to the east preferential access. The third group is separated from the second by two small reservoirs. This group is dominated by a very large platform on the south which had two small structures built on it. Two small range structures to the west seem to have defined the end of the group.
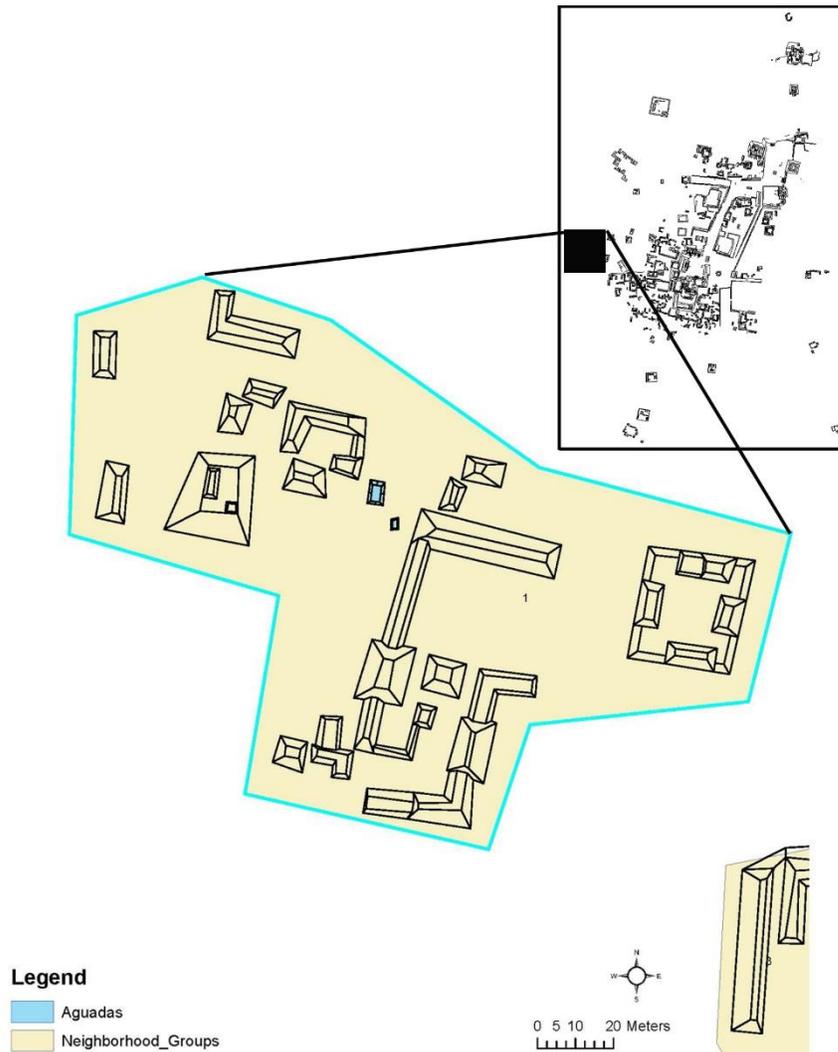
Figure 4.15. Neighborhood group 1.

Group 6 is situated in the center of the site between the two large

causeways connecting Groups A and B (Fig. 4.16). This neighborhood contains

the large central reservoir within its southern extent. The northern boundary is

made up of a large rectangular grouping of nine structures with three tiers within

the patio group descending to the west. To the north of this group is a large

public plaza where the causeway to the west opens. The western boundary is

defined by the large range structures which boarder the causeway's eastern side,

and the eastern boundary is defined by the western balustrade of the eastern

causeway. Within the northeast corner of this neighborhood, south of the

administrative group, is a large quadrangle group which likely served the

residential function within this neighborhood. Along the western edge of this

neighborhood, there is an open canal that fed directly into the central reservoir.

To the north of the neighborhood is a long sub-plaza canal that emptied into the

open canal which will be discussed later. There are two platform groups to the

west of the canal and three groups of structures to the east of the canal.
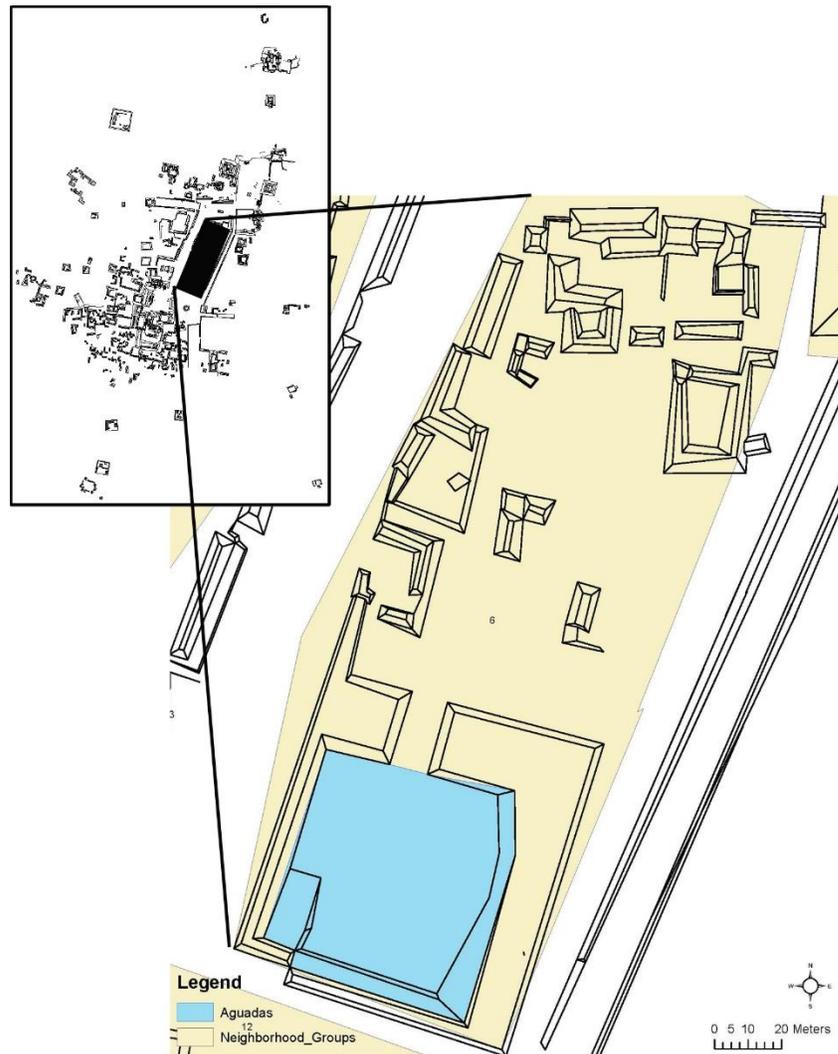
Figure 4.16. Neighborhood group 6.

Group 17 is situated to the west of Group B at the end of the short causeway that projects west from the center of the site. This group is clustered around Aguada 11 and is made up of five separate groups (Fig. 4.17). To the far east at the end of the causeway is a large PP2 group with large square structures on both the east and south sides and relatively low long structures on the north and west sides. Roughly 75 meters west from this group is a solitary

range structure oriented north to south. To the southeast of this structure is another smaller raised rectangular group, this one with a structure to the east, north, and south. North of this and adjacent to the southwest corner of the aguada is the large administrative center. This group is made up of 17 structures, and one small reservoir around a large open area that is open to east. To the north of the Aguada 11 is a very large platform with a range structure oriented to the north/south along the western edge, a large square structure in the southeast corner, a small square structure in the northwest corner with a low wall extending east from this structure, a possible destroyed altar between the two largest structures and a chultun close to the small structure.
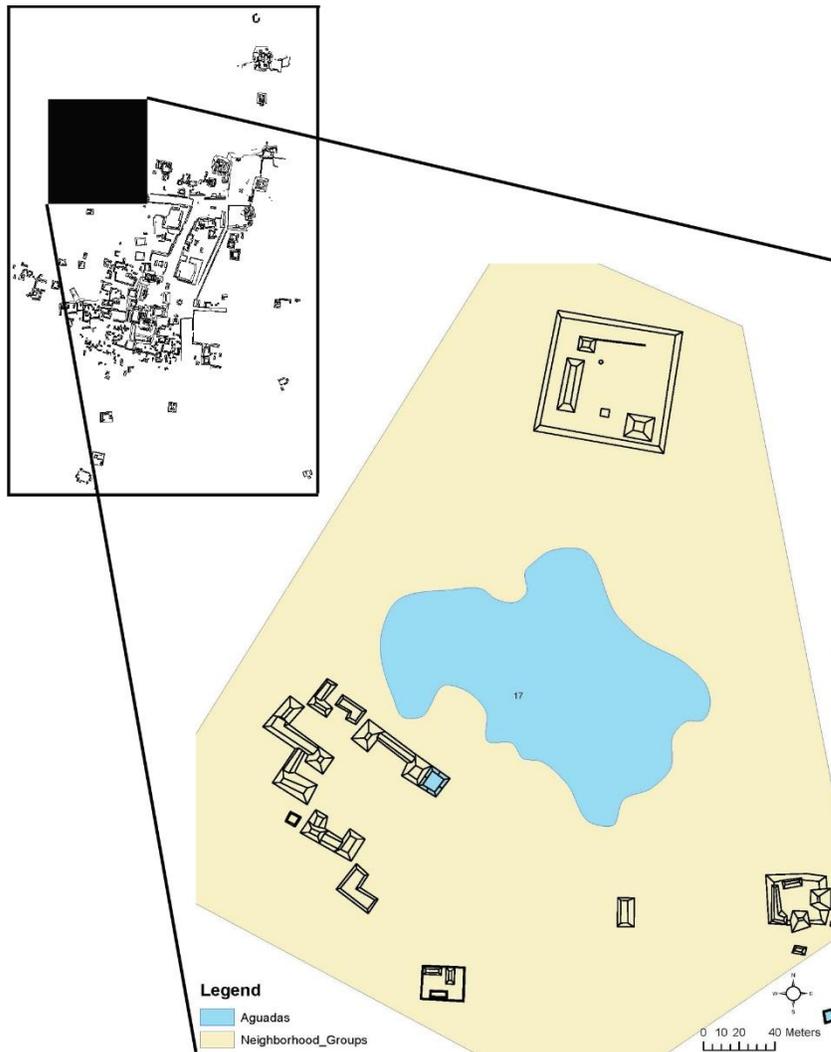
Figure 4.17. Neighborhood group 17.

Group 20 is to the extreme south of the map and located on a topographic rise that increases to the south. This neighborhood is composed of three groups oriented roughly north south from each other (Fig. 4.18). The northern-most group conforms to the PP2 style grouping with structures on the west, north and east and open to the south. The second group is a raised rectangular platform with a large square structure in the northwest corner and two low range

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structures running south and east from this structure. There is a low platform in
the northeast and the southeast has a smaller square structure and low platform.
The administrative group is the furthest south and composed of nine structures
around a large open area. A lone square structure is situated east of this group.
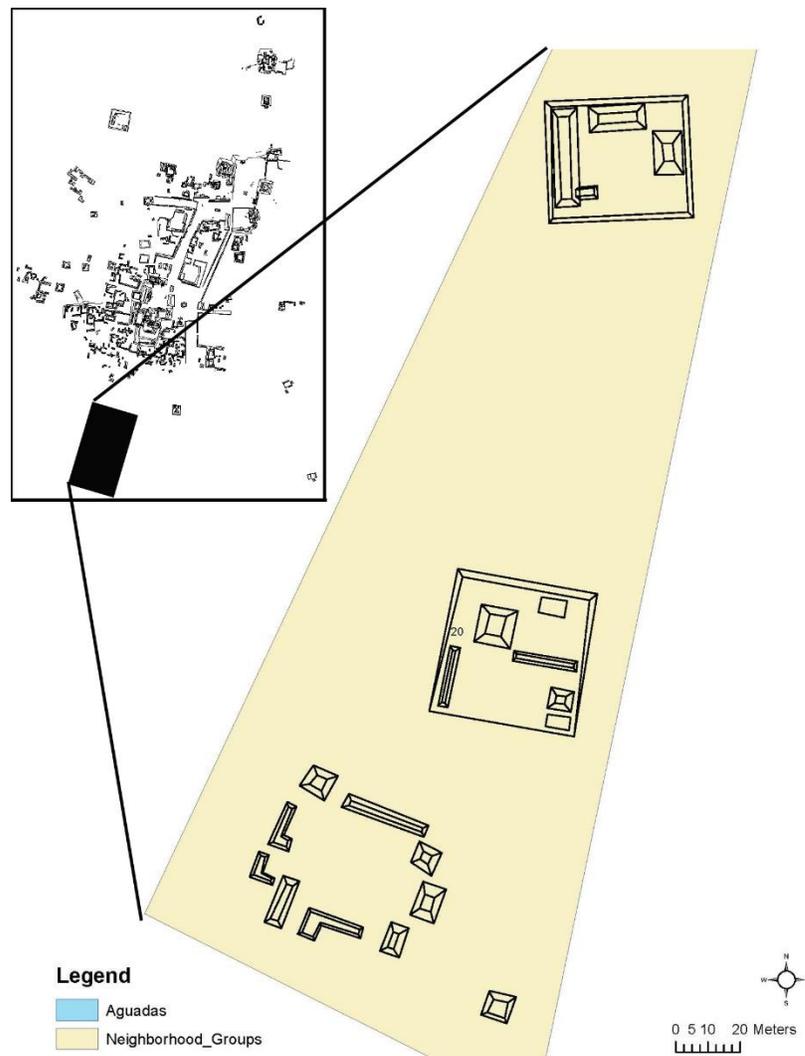
Figure 4.18. Neighborhood group 20.

Conclusion

The urban space at Xultun is described as fitting into one of four categories: (1) open space, (2) administrative structures, (3) residential structures, and (4) production zones. Because of problems with historic architectural terminology used to describe Maya sites, they are avoided when possible. Unfortunately, the focus of household archaeology on issues of social diversity, and not necessarily urban form, often leaves no other choice (Robin 2003). Overall only about 12.50% of the area surveyed has structures, however when the area is zoned the unknown open space is reduced to 42.93%. In addition, using topographic changes, open spaces, and architectural divisions 23 neighborhoods have been identified. Four of these are described in detail because they conform to a newly identified hydrological management neighborhood group. These groups contain an elite residence, a large administrative group, and ritual structures. These data support the hypothesis that there was a continued involvement of elite individuals in the management of hydrological resources at Xultun.

Chapter 5: Hydrological Modeling and Spatial Analysis

Introduction

In this chapter I highlight the methods and results of geospatial analyses using ArcGIS 10.1 within the 16 km² limit of the site of Xultun. Three different analyses were performed within this area. The first is a hydrological analysis of the entire Xultun landscape using the 30 m ASTER DTM to model the watersheds, flow direction, and flow accumulation. The proposed aguadas, identified using remote sensing techniques, are added to these data in order to visualize how these water storage features relate to drainage within the site. The second analysis is the same type of hydrological examination but at a higher resolution within the mapped portion of the site core. A digital surface was created of this area using the total station points collected during mapping. This surface is used to create a higher resolution 4 m DTM. Hydrological analysis is then performed on this surface to visualize how water flows over the mapped area. This provided insights into how water was redirected and collected within the urban core of Xultun. The results of this analysis were edited based on architecture mapped during the ground survey and it was combined with the landscape hydrology to create an overall flow model of the 16 km² of the site. The final level of analysis is a spatial analysis of the urban zones identified at Xultun in relation to drainage and water storage features. This lead to interpretations as to how the ancient Maya organized their urban space toward

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the collection and storage of water and what kinds of urban forms, if any, are more closely associated with water management.

General Landscape Hydrology of Xultun

The majority of the 16 km² extent of Xultun is not mapped. This poses a problem for modeling the hydrology of the greater landscape at the site. It was necessary to find an alternate data set with which to model the topography of the landscape. In this case, 30 m ASTER data was acquired from NASA and added to the project's GIS. The ASTER data covered an enormous area around the site (Fig. 5.1). Elevation is visualized on a scale from high (white) to low (black). This image is so large that the geology of the region is visible with various limestone upthrust ridges running southwest to northeast across the image. Major drainages are also visible in this image.
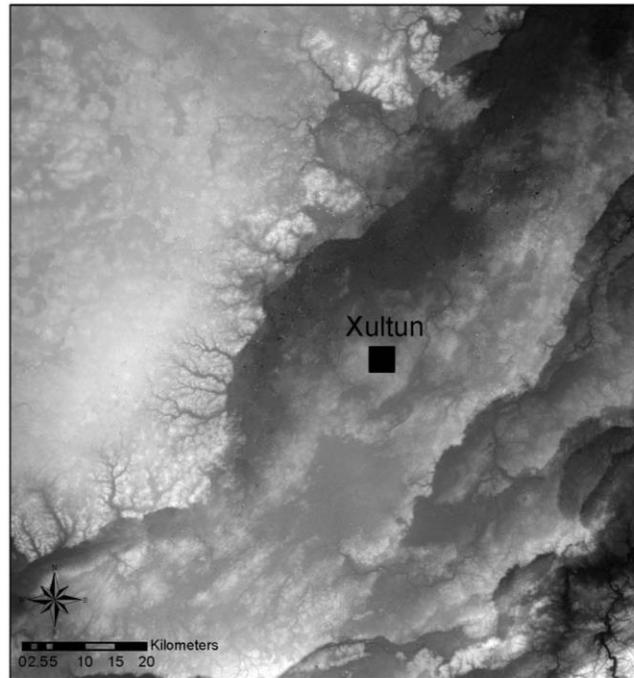
Figure 5.1. ASTER image of greater Xultun region with location of site.

    To decrease the file size and make the ASTER data more functional for my research, I limited the extent of the data to just around the Xultun grid. This decreased data was then used to execute hydrological modeling of the extent of the site. Figure 5.2 is a Triangular Integrated Network or TIN. This is a type of digital terrain model projected from a DTM. In this figure, the differences in elevation are highlighted both by the shape of the TIN and by the selected coloration of 32 ranges of elevation. Generally, the reds are higher in elevation than the greens with white at the highest elevations and light blue at the lowest. From this image it can be seen that the core of Xultun was constructed on a low ridge within this area. There are higher hills to the southwest and west, a large bajo to the north, and drainage into this bajo to the east.
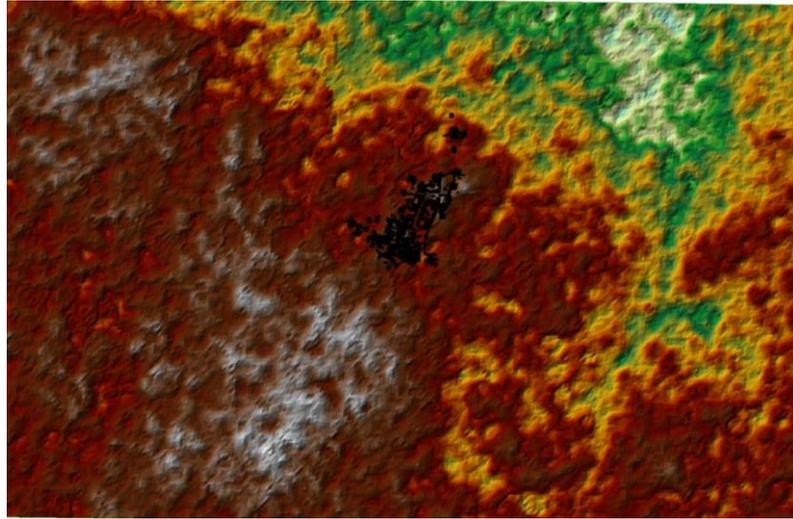
Figure 5.2. DTM generated from ASTER around Xultun core.

Using the hydrology toolbox within ArcGIS 10.1, I was able to model the

hydrological flow within and around the 16 km² extent of Xultun. The process

involved the inputting of raster data into various processes to generate visual

data that represent hydrological flow over the site. A total of eight basins were

identified for water draining out of the site. Figure 5.3 overlays the drainage

channels onto these basins. It is clear from these data that the vast majority of

water flowing over the site eventually drains into the northern bajo. All of the

drainage from the eastern half of the site flows into the major drainage to the east

which in turn flows north. The respective areas represented by the eight

catchments as well as their direction of drainage can be seen in Table 5.1 below.

The drainage map is generated by assigning each of the 30 m² pixels a slope

direction. This determines the direction flow moves over the pixel and into which

adjacent pixel water will drain. The results of this calculation were visualized on

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a color scale of increasingly darker blues, where the darker the blue the more upstream pixels were accumulating. This is how ArcGIS 10.1 models hydrological flow over an area.
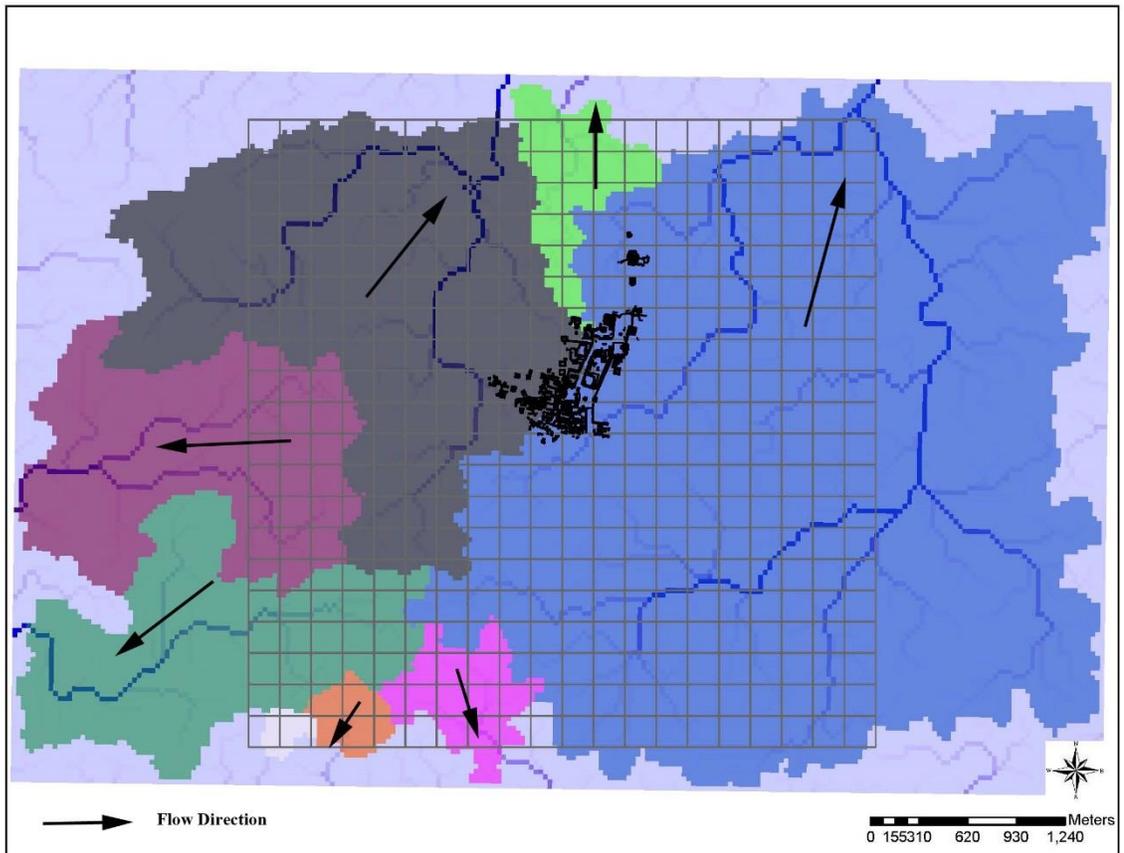
Figure 5.3. Map of Xultun with modeled drainage and eight catchment areas.

Table 5.1. Xultun Catchment Areas

Catchment	Total Pixels Exiting Grid	Area Represented by Pixels	Direction of Drainage
Blue	9589	8.70 km²	East/North
Green	537	0.49 km²	North
Dark Grey	5522	5.01 km²	North
Magenta	1005	0.91 km²	West
Dark Green	896	0.81 km²	West
Grey	73	0.07 km²	South
Orange	220	0.20 km²	South
Pink	546	0.50 km²	South

To limit these data to the prescribed extent of Xultun, I created a vector file of the drainage patterns over the site and where they exit on the grid. It is interesting to note that the site core was constructed at the meeting place of three of the drainage catchments within the area, including the two largest, and all three of the drainages flowing to the north (Fig. 5.4). The final element for visualization of the hydrology over the entirety of the site was the addition of aguadas and reservoirs (Fig. 7). These features were identified using Quickbird satellite data as described in Chapter 4.

There are three major drainages out of the 16 km² grid around the ceremonial core of Xultun. The largest of these flows to the north 1.6km east of the northwest corner. The second largest volume drains from the northeast corner of the grid and the third largest from the eastern side, 1.5 km north of the southeast corner. There are a total of 27 water storage features that have been identified within the site, 11 of which were identified within the site during the

survey. The remainder identified through remote sensing as described in

Chapter 4. The reservoirs within the site core will be discussed below. All of the

reservoirs outside of the site core are closely associated with the modelled

drainage leaving the grid to the east or north (Fig. 5.5). Going beyond simply

visualizing changes in elevation over the landscape at Xultun, when looking at

water management it is important to examine areas that would have been at

threat of flooding. By changing the colors of the elevation categories on the

DTM, it was possible to visualize what areas would be most likely to flood during

the rainy season. I chose an elevation of 230 masl and below to visualize this

flood plain (Fig. 5.6). It is clear that the northern bajo, as well as the drainage

along the eastern extent of the site, are the areas most likely to suffer from

seasonal flooding. These areas would likely prove to be the most productive

areas for large scale agriculture within the site. Six of the aguadas identified

through remote sensing are located within this flood plain. These aguadas are

the ones most likely to be associated strictly with agricultural practice. The total

flood plain area within the grid of Xultun equals 5.45km².
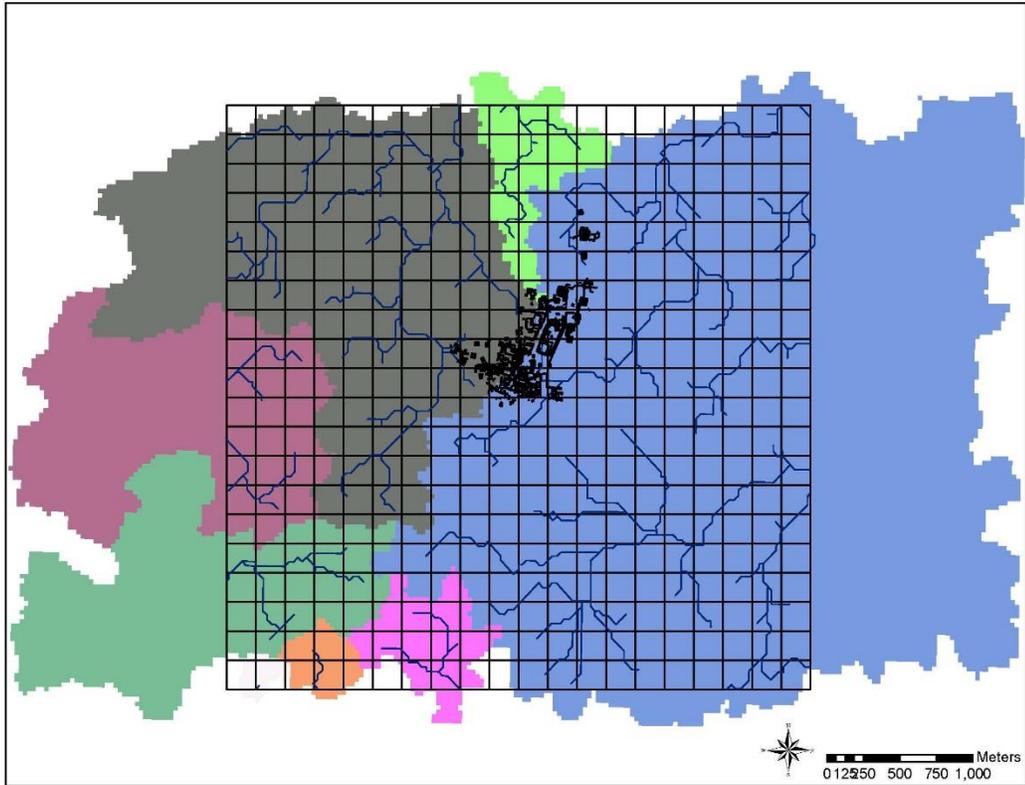
Figure 5.4. Map of Xultun and catchments with drainage limited to site grid.
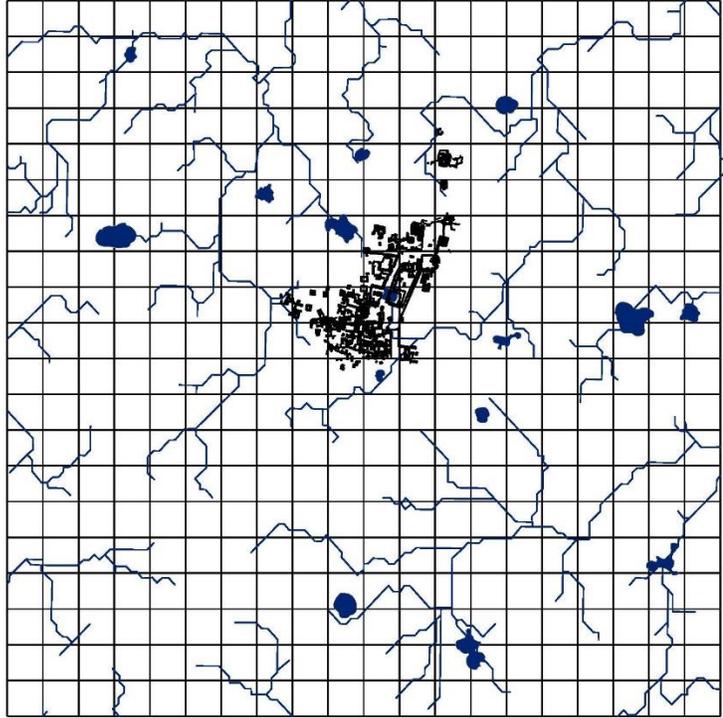
Figure 5.5. Map of Xultun extent with drainage and water storage features.
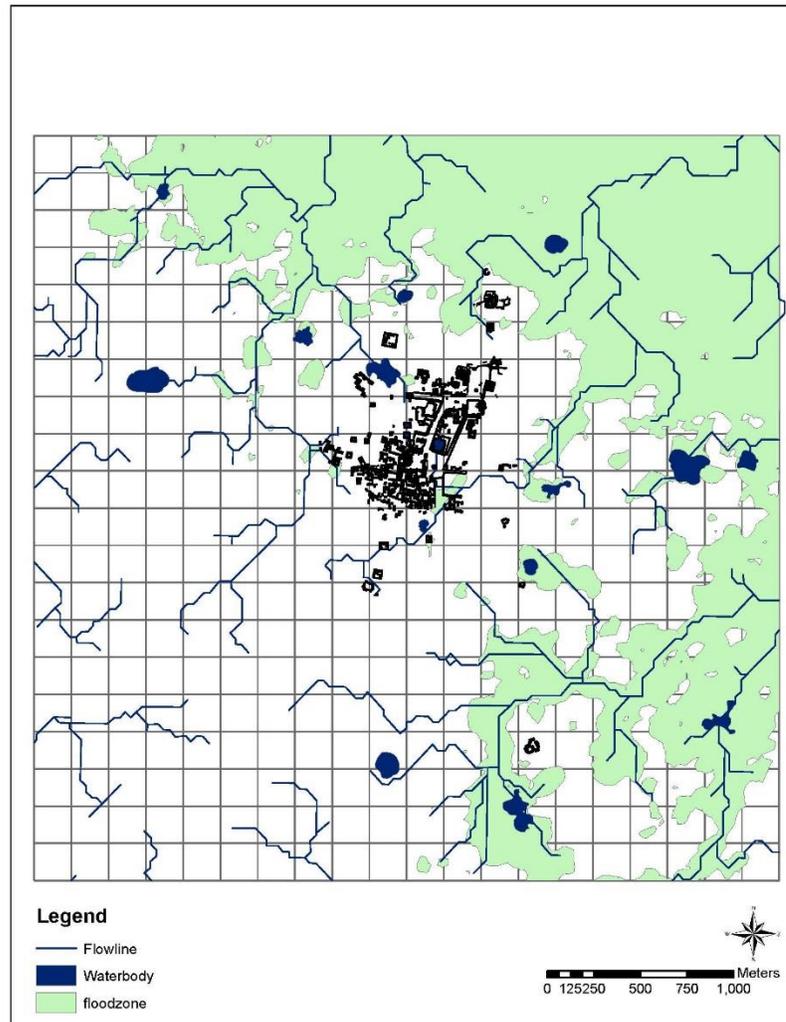
Figure 5.6. Xultun flood zone below 230 masl.

Hydrology within the Site Core

The process of modeling the hydrology within the mapped site core was different from above in that a DTM needed to first be projected from a point file (Fig. 5.7). During the mapping of the site, total stations were used to collect three dimensional survey points. These points were chosen at specific places on

and around structures and at specific topographic changes on the landscape.

The next step in expanding this point map will be to run radial transects out from

the center. The data collected using the total stations recorded points in UTM

coordinates x, y, and z. The x was recorded in easting, the y in northing, and the

z in meters above sea level. Using ArcGIS 10.1, I was able to create a DTM

surface from these points by accessing the point to raster command and

selecting the z coordinate or elevation as the raster value.

Figure 5.7. Map of total station point file of Xultun.

The resulting image (Fig. 5.8) is a digital terrain model of the mapped area projected as a triangulated irregular network (TIN). With added shadow effects, the TIN is a dramatic reproduction of the surface terrain at Xultun. When generating a TIN, the software fills in the empty spaces between points often filling in large areas where there is no actual data with inaccurate averages. To overcome this problem the original image was cropped to only display areas with known data points. To further enhance the visual effect of elevation changes, the raster was divided into 32 color coded categories.
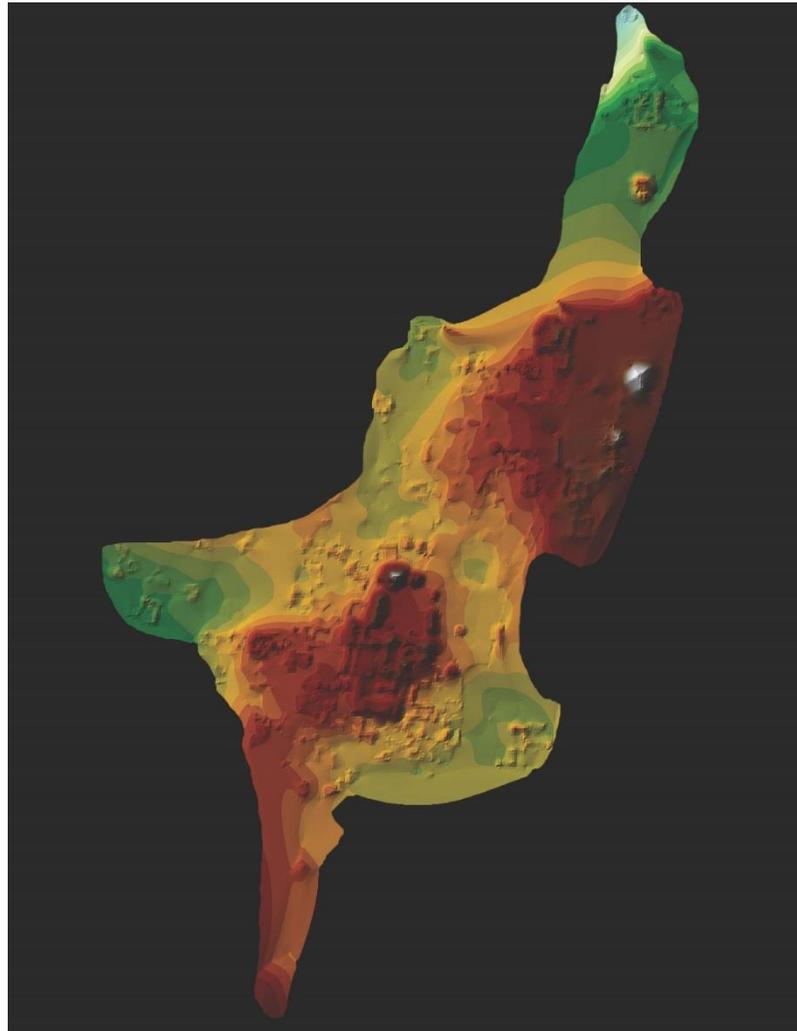
Figure 5.8. DTM of Xultun core.

The hydrological tool set in ArcGIS 10.1 was used to visualize drainage within the site core. To understand where the major drainage basins were within the site core the basins tool was run on the generated raster DTM. As can be seen in figure 5.9, there are four drainages within the site core. The smaller group of drainages at the far north can be discounted as errors due to lack of data.
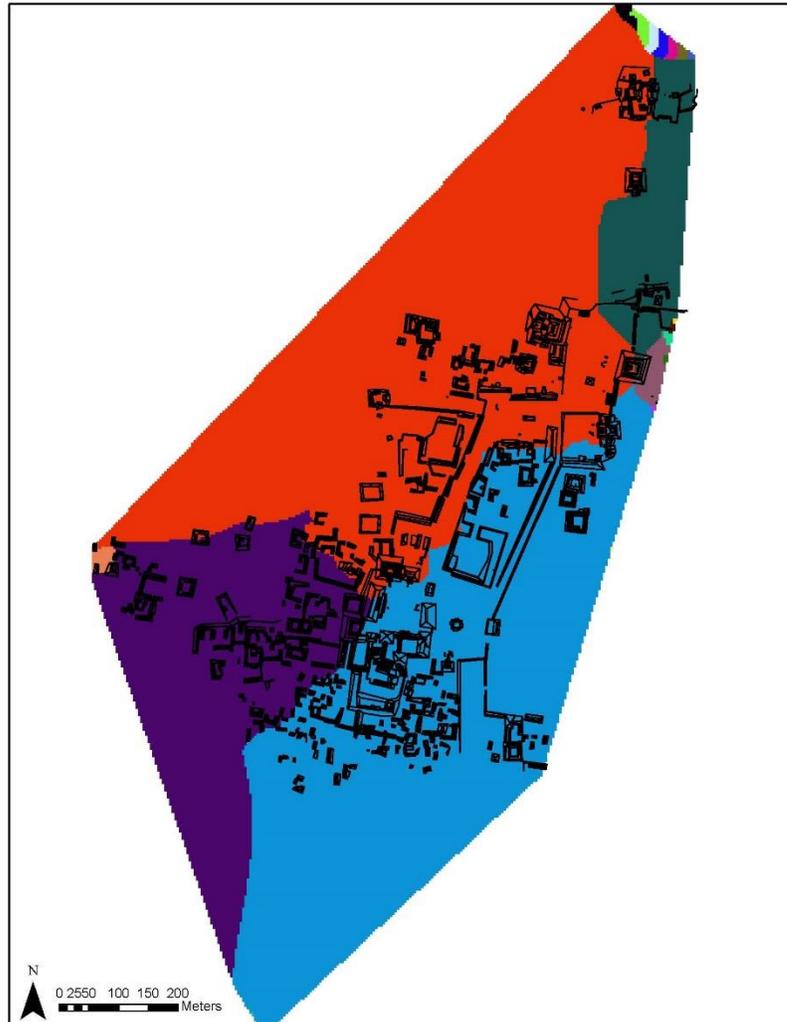
Figure 5.9. Major drainages out of Xultun core.

The flow accumulation tool was then used to create a visual

representation of the drainage streams. This tool models the slope of each pixel

in order to determine in which direction water that falls here will flow. It creates a

raster visualization of the accumulated number of pixels upstream from each. As

can be seen (Fig. 5.10) the resultant image demonstrates how water is

concentrated into drainage streams within the site core. The higher the number

of units upstream from any given pixel the darker blue it will appear. As can been seen, there are some errors that need to be corrected. As mentioned above, the software fills in the data between points over areas where there are no data. In this case, the northwest and southeast areas of the map have long straight drainage lines that are unlikely to be accurate.

Figure 5.10. Flow accumulation raster of core.

To rectify this situation, a vector file of the drainage was created by drawing a linear feature over the modelled drainage (Fig. 5.11). The drainage map of the greater site and the aguadas were then added to this vector drainage file. This generated a clear image of how water drains over the site, and where water stored in specific reservoirs originally fell as rain. Other small edits were made to correct for constructed drainage features that were identified during the ground survey of the site. Specifically, the drainage from the public plaza north of the central reservoir was redirected into this reservoir with the use of a sub-plaza canal which contained seven surface openings across the plaza (Fig. 5.12). This feature will be described in detail in chapter six. Using the flow accumulation raster, it is also possible to use the query tool to get the exact number of pixels draining out of the core at various locations: eastern drainage at the southeast corner is 19,495 pixels, western drainage is 9,787 pixels, northwest drainage is 7,491 pixels, and the central reservoir is 3,275 pixels.
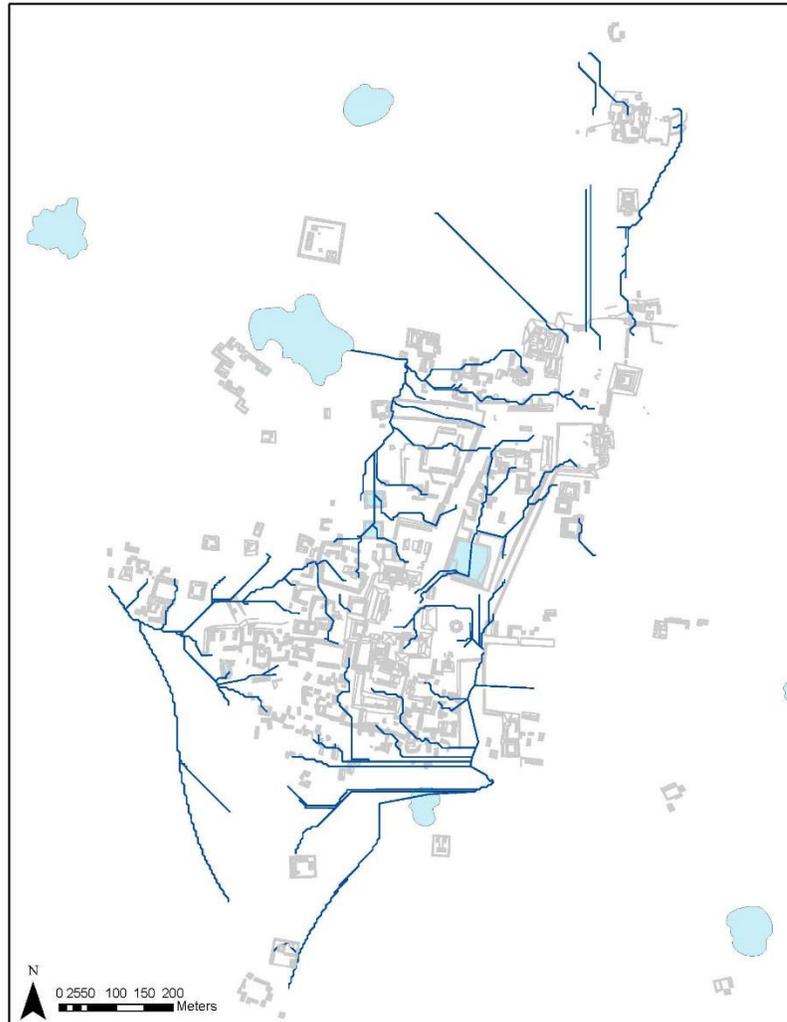
Figure 5.11. Flow accumulation vector over structures and reservoirs.
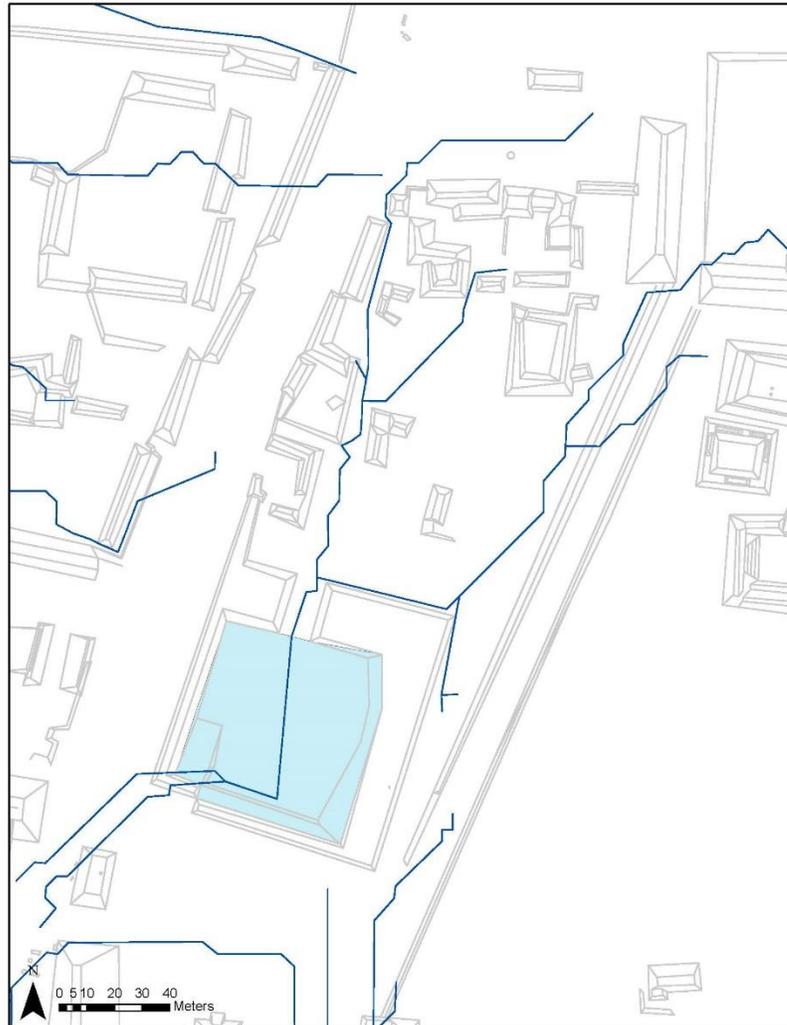
Figure 5.12. Water collection into central reservoir.

Spatial Analysis of Hydrology and Urban Form

The next step in my analysis was to combine the urban categories

selected for in Chapter 4 with the modelled hydrological flow. Combining these

different data sets in ArcGIS 10.1 allowed for spatial analysis of these different

features to look for correlations between specific urban forms, drainage, and

storage of water. This information will add to the growing bodies of work on

Classic Maya settlement patterns, ancient hydrological engineering, and ancient

urban planning.

Some of the groups that were added to the map were identified during a

ground survey using remote sensing and are outside of the total station mapped

core. I felt that it was important to combine the high-resolution modelled

drainage of the site core with the low-resolution drainage of the entire site so that

these groups could be added to the drainage analysis (Fig. 5.13). In doing this,

areas from the low-resolution model that did not match with the high-resolution

model were deleted. This gave a good approximation of drainage over the site

as a whole but with an emphasis on the mapped core.
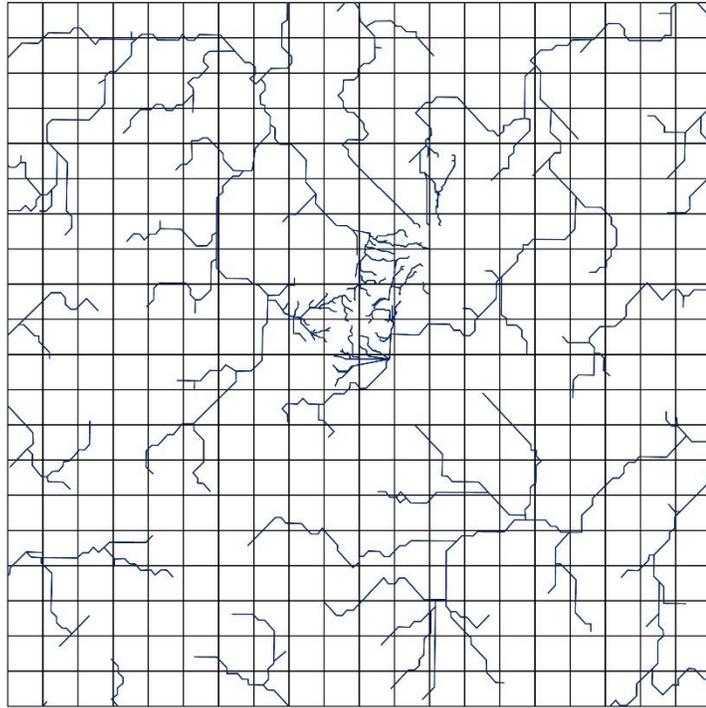
Figure 5.13. Combined hydrological flow model.

The drainage data were then combined with the mapped urban zones

from Chapter 4 (Fig. 5.14). The geoprocessing merge tool was used to combine

the urban zones into one layer. This was used to describe the patterns both

visually and numerically. First I edited the attributes tables of the four urban zone

layers adding a category tab to which I gave a numerical value. These were (1)

administrative, (2) residential, (3) production, and (4) open space. This category

tab allowed me to differentiate between the four zones when they were combined

into one layer. I then used the merge tool to create a new single layer that

combined the four urban zones. To visualize the different urban zones the

symbology was set to the category tab coloring each urban category differently. I

was also able to calculate the totals for the area mapped in this way. Table 5.2

below lists the percentage of the total area of each zone mapped within the

urban core.

Figure 5.14. Urban zones with modeled drainage.

Table 5.2. Percentage of Total Area per Zone in the Urban Core

Urban Zone	Area in Square Meters	Percentage of Total Area
Administrative	164,834	22.1%
Residential	247,343	33.1%
Production	13,885	1.9%
Open	320,553	42.9%

Drainage and Urbanism

Site Wide Drainage Patterns

      I then turned to the Overlay Analysis tool in ArcGIS 10.1. With this I was able to overlay the drainage streams with the new single layer urban zones feature. I used the feature overlay tool to generate a new line feature class with attributes of the urban zones (Fig. 5.15). This allowed for easy calculation of the total length of drainage within each of the urban zones. Table 5.3 below lists the percentage of total stream length over each urban zone.
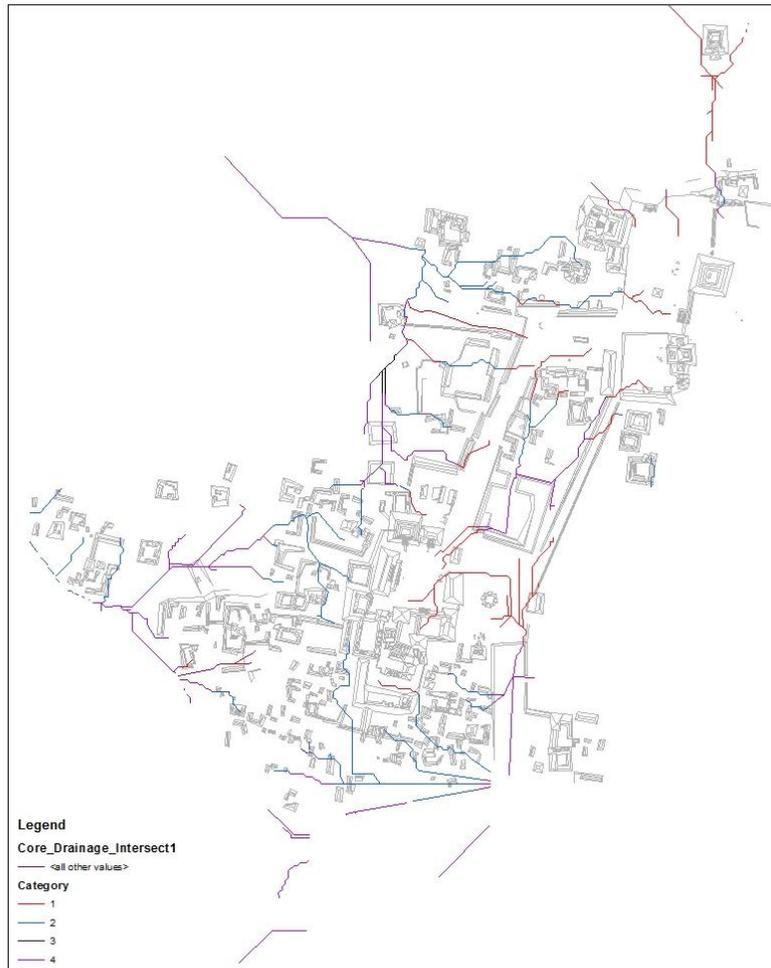
Figure 5.15. Drainage/urban zone overlay.

Table 5.3. Percentage of Total Stream Length by Urban Zone

Urban Zone	Length in Meters	Percentage of Total Length
Administrative	2274	23.7%
Residential	3695	38.5%
Production	139	1.4%
Open	3498	36.4%

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Logic would dictate that if drainage patterns within the urban core of

Xultun were random, the stream lengths associated with specific urban zones

should be equal in proportion to those urban zones. Residential zones make up

33% of the total area within the study but 38% of the drainage length was within

residential zones. The open areas zone also demonstrated a significant

difference between total area and total drainage length. These results

demonstrate that drainage was higher than expected within residential zones and

lower than expected within open area zones. Drainage within administrative and

productions zones closely matched the values of their mapped surface areas. In

many ways this makes sense. During the rainy season inundations would create

problems with flooding in many zones. Thus having more drainage modifications

in and around residential zones would have kept water from accumulating within

and would have improved the quality of life for those residing there.

Drainage into Reservoirs

I next looked at the drainages feeding the reservoirs around the urban

core. Three different reservoirs were examined: (1) the central reservoir, (2) the

double pool reservoir north of Group A, and (3) the large reservoir west of Group

B. The drainage/urban zone overlay was used to calculate the total

proportionality of land cover draining into each reservoir.

The central reservoir was used to collect runoff from five different locations

(Fig. 5.16). Four of these locations are to the north and one to the south. The

northern drainage sites are: (1) the closed in neighborhood with the southern

portion of the inlet canal, (2) the northern part of the inlet canal and the sub-plaza

canal, (3) the large plaza to the south of Group B, and (4) the eastern sacbe.

The southern drainage comes from the ritual plaza in Group A. The total length

of drainage over each urban zone was calculated to compare the proportionality

of drainage types into this reservoir with those at the site as a whole. The data

from these calculations are listed below in table 5.4.
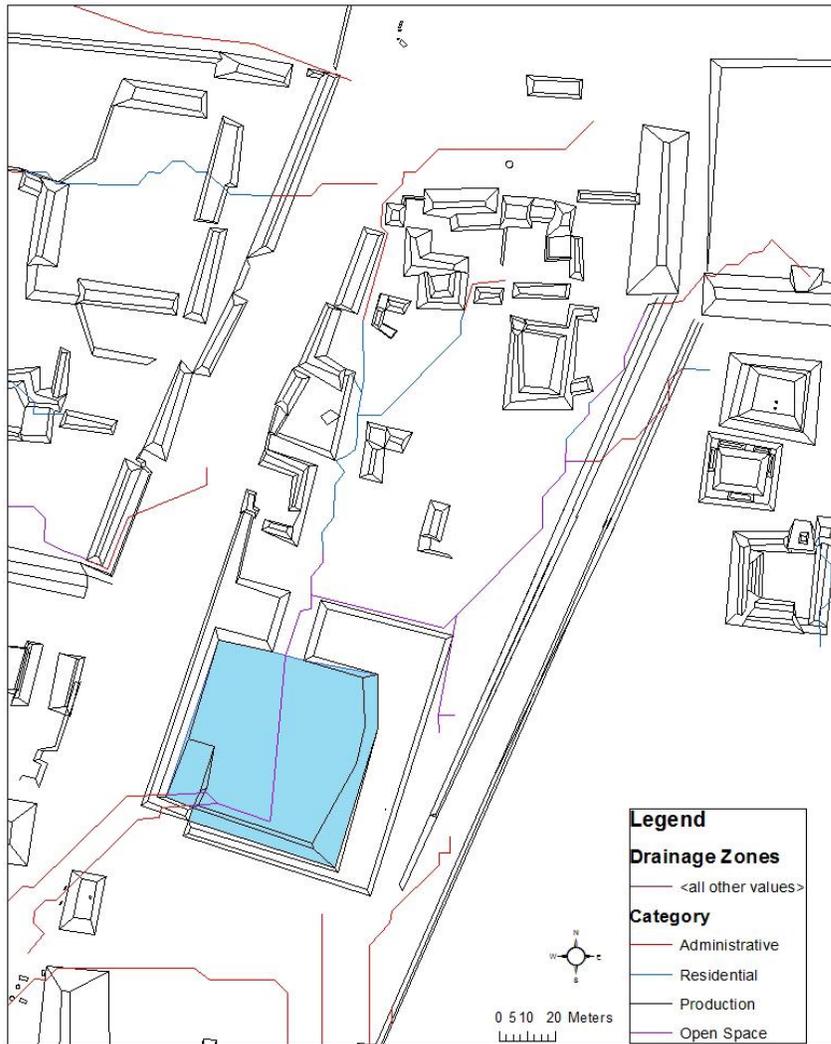
Figure 5.16. Drainage into central reservoir.

Table 5.4. Central Reservoir Drainage Type Proportions

Urban Zone	Length of Drainage in Meters	Percentage of Total Drainage
Administrative	439.9	46.4%
Residential	177.7	18.7%
Open	331.1	34.9%

It can be seen that the results differ drastically from the site as a whole. Drainage from administrative zones is much higher in relation to this reservoir than the site as a whole and drainage from residential zones is much lower than the site as a whole. Although drainage from residential zones represent the highest proportion of drainage within the site (38.5%), only 18.7% of the drainage collected in this reservoir was from residential zones. The opposite is true for drainage through administrative areas, where the site percentage is 23.7% and the reservoir is 46.4%.

What do these patterns mean? When the large central reservoir was designed and constructed, the Maya were very careful about where water was collected. Open administrative and ritual plazas were preferred and residential groups were seen as less desirable for the collection of water. This could have been due to the accumulation of waste associated with residential areas. It also suggests that this reservoir was closely associated with the city's leadership, who would have had control over these administrative zones. This association with administrative drainages as well as the central location of this reservoir demonstrate that it was constructed as a symbolic statement of power by the Maya elite reinforcing socioeconomic inequalities (Scarborough 2003:84).

The twin pool reservoir collected drainage from three different areas (Fig. 5.17). The overflow from this reservoir drains to the north. Two of these are to the west and one is to the south. The western drainage comes from the western

causeway and the ball court. The southern drainage comes from the northern

section of the residential group west of Group A. Similarly, here the total

drainages were calculated by urban zone and can be seen in table 5.5 below.

These numbers are much closer to those observable across the site as a whole.

It was calculated that there was no significant difference between the

administrative zone percentages. The proportional distribution of drainage types

that feed this reservoir matches what is seen across the site. No information can

be extracted about this reservoir from these data. However, the placement and

design of this feature strongly supports the proposition that it served some ritual

functions.
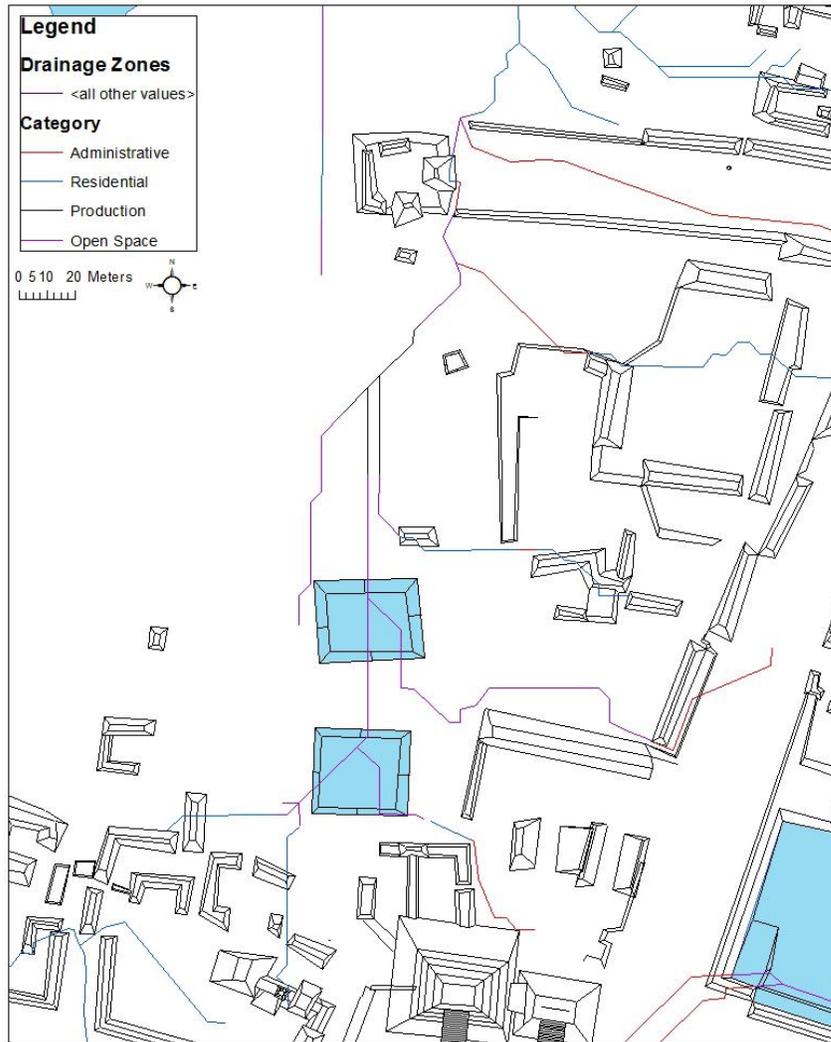
Figure 5.17. Drainage types into twin pool reservoir.

Table 5.5. Twin Pool Reservoir Drainage Type Proportions

Urban Zone	Length of Drainage in Meters	Percentage of Total Drainage
Administrative	110.6	27.7%
Residential	125.4	31.4%
Open	163.9	41.0%

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The large northeastern reservoir collects drainage from five different areas (Fig. 5.18). These areas are: (1) the twin pool reservoir overflow, (2) the northern section of the large western causeway and the large plaza group west of there, (3) the east to west running causeway in this section of the site, (4) the area south of the reservoir, and (5) the large residential group west of B and part of the main plaza at B.
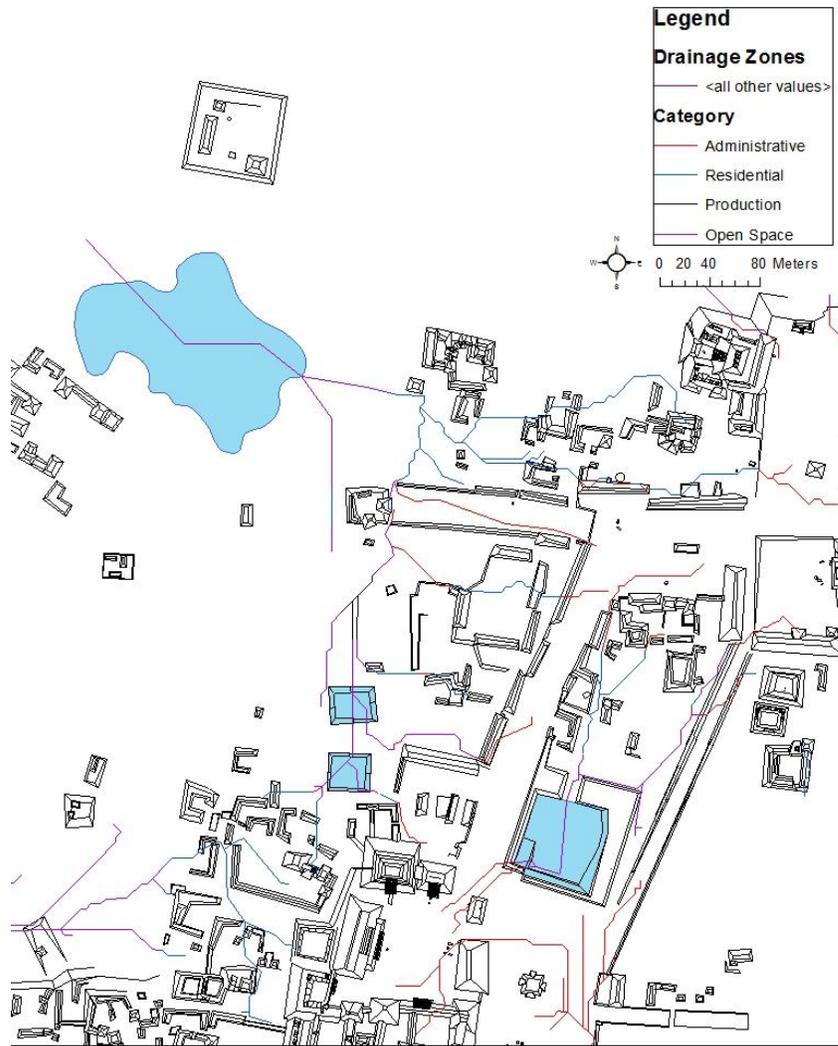
Figure 5.18. Drainage types into northwest reservoir.

Table 5.6. Northwest Reservoir Drainage Type Proportions.

Urban Zone	Length of Drainage in Meters	Percentage of Total Drainage
Administrative	535.2	19.9%
Residential	1168.9	43.5%
Production	96	3.6%
Open	885.3	33.0%

The results of a comparative analysis on proportionality of drainage types between this reservoir and the site as a whole demonstrated a significant difference. Drainage over administrative areas was less than expected while drainage over residential areas was higher than expected. Drainage over production areas was higher than expected while drainage over open areas was significantly less than expected. In the case of this reservoir drainage collected from both residential and production zones was higher than expected. The association between residential groups and this reservoir supports an interpretation of this reservoir having served as a residential reservoir for this community. There is still a large administrative group adjacent to the reservoir, which may have served to control access to the stored water. This would imply an elite interest in managing water even at the residential level.

Conclusion

This chapter described the methodology employed in the modeling of hydrology at Xultun. Drainage patterns across the urban core were modeled by combining the flow model with urban zone data. These data were then combined with three central reservoirs for analysis, the results of which are summarized below.

The hydrological drainage model over the entirety of the site calculated

three major drainages. All three of these flowed into the northern bajo.

Furthermore, all of the reservoir locations predicted with remote sensing are

closely associated with these three drainages. The site core was constructed on

a ridge where the three northern drainages meet. Flood zones were also

modelled to predict areas of probable high agricultural productivity within the site.

These areas were concentrated around the northern and eastern perimeter of the

site along the major drainages. Six of the remotely sensed reservoirs were

located within these flood zones. This demonstrates that these reservoirs likely

served an exclusively agricultural function.

Within the mapped site core, there are four major drainage basins. Each

of these drains roughly toward the cardinal directions. This suggests that there

may have been a cosmological significance in the ordering of space as

connected with drainage at Xultun. Through an overlay of the urban zone data

and the drainage data, it was found that drainage appeared more than expected

in residential zones and less than expected in open zones. These results

support adaptations to the rainy season where excessive rainfall would have

been diverted away from living areas. In looking at drainage and water storage,

it was determined that the large central reservoir served as a symbol of power for

the elite of Xultun while the large northwestern reservoir served as a residential

water source. The data were inconclusive for the twin pool reservoir, although its placement and form suggest a ritual purpose.

There is also evidence here for the allocation of water based on where it was drained. The central reservoir seems to have collected more water from administrative zones than would be expected and the residential reservoir collected more water from residential zones than expected. This could demonstrate that the Maya may have used a concept similar to riparian rights where individuals had rights to the water that fell on their land (Scarborough 2003:96). This research would have to be expanded to explore this possibility but it is an exciting prospect.

The analysis performed here provides evidence in support of Scarborough's (2003) Convex Microwatershed model with three tiers of reservoirs. The topmost serving elite and ritual functions (tier 1), the middle serving residential communities (tier 2), and the lowest serving agricultural purposes (tier 3). Geospatial analysis of hydrology and urban zonation at Xultun provided evidence for one tier 1 reservoir, one tier 2 reservoir, and 6 tier three reservoirs.

Chapter 6: Excavations within and around Neighborhood 6 at Xultun

Introduction

Excavations were undertaken at Xultun's neighborhood 6 to further explore water management within the city, and to provide important complimentary evidence to the mapping, remote-sensing, and modeling work. This neighborhood was named *Grupo Tortuga* in honor of a tortoise that was found here during the initial survey. The group conforms to the special management type identified in Chapter 4. As a unit, the neighborhood contains a large reservoir, an elite or royal residential quadrangle enclosure, and an administrative group. There are also several smaller groups which may have served a ritual function.

Excavations were focused on both the water management system and on the residential quadrangle. The water management system was composed of three distinct structures. These were the reservoir, the open canal feeding the reservoir, and a sub-plaza canal which fed into the open canal. One important discovery within the residential group was an elite residence in the eastern structure which contained two niche offerings, a burial, and a large stela fragment. Based on style, size, and theme, this stela fragment it thought to be

the top of Stela 18, one of the badly eroded stela from Group B dating to the Early Classic.

Excavations

Reservoir

Structure 11J-19 is a large reservoir to the northwest of the main ceremonial group (Fig. 6.1). It lies between the two causeways that connect groups A and B.   In addition to a means of transportation, these causeways functioned as dams directing and separating runoff variously into and away from this reservoir. This depression was first described by Morley (1938) as a quarry between Groups A and B; however, it was not properly surveyed and mapped until 2012. Although this structure may have begun as a quarry during the Preclassic, the bedrock floor was modified for water management and plastered over. Later, it was again modified with the construction of walls (11J-18 and 11J-20) surrounding the depression and increasing the total volume.
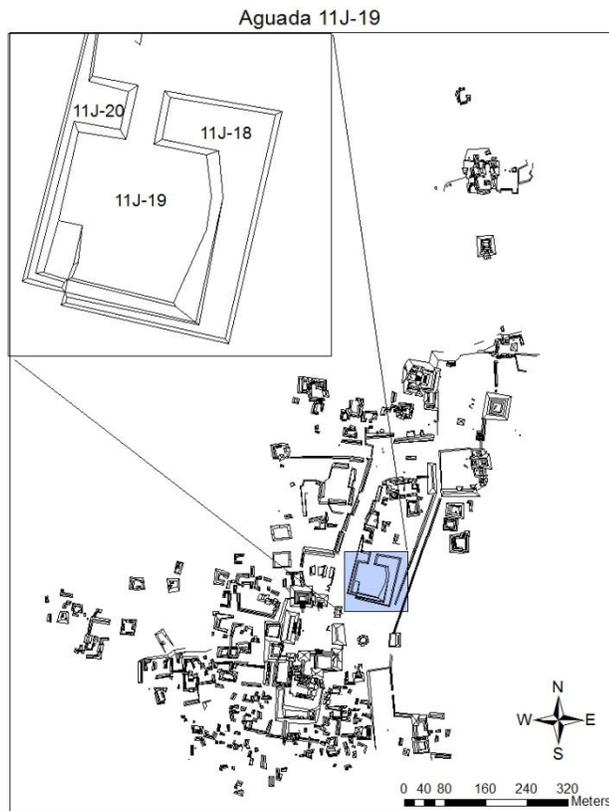
Figure 6.1. Aguada 11J-19.

Reservoir 11J-19 is roughly rectangular in shape, 59 m across (east to west) and 60 m long (north to south) with a drainage channel ingress in the northern wall allowing for the collection of runoff from the north. The floor of the reservoir is sloped, descending to the south. The depth of the structure increases as one moves southeast from an elevation of 227.67 masl at the northern opening to 225.36 masl in the southeast region where excavation 11J-19-D-1 was placed. There is a modified bedrock ramp in the southwest corner of the reservoir. Following estimates performed at Tikal on reservoir capacity, two extra meters of depth can be used in the calculation of volume. One extra meter

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for the original height of the walls and one for the original depth of the floor. Interpreting the space as a triangular prism, the volume can be calculated as 8850 m³ (Carr and Hazard 1986; Gallopin 1990). Excavation of this reservoir uncovered subsurface structures that demonstrate a use history extending to the Late Preclassic.

During the 2012 season, two sites were chosen for excavation, one in the southern central part of the reservoir and the other along its western periphery, close to the wall 11J-20 (Fig. 6.2). These excavations were conducted to determine: (1) if the depression functioned as a reservoir, (2) its use history, and (3) the dates of construction. The first excavation 11J-19-D-1 was laid out as a 1.50 m x 1.50 m square and dug in natural levels. Two tunnels were dug into the profile walls of the excavation beginning with level 10: sub-operation A1 in the northern half of the west wall, and sub-operation A2 in the southern half of the east wall (Fig. 6.3). The second excavation, 11J-19-C-1, was laid out as a 1.00 m x 1.00 m square and also dug in natural levels. A sample of ceramic artifacts was collected based on size. Only sherds large enough to label were collected for processing at the lab. Due to the density of the sediment screening was very difficult and the majority of artifacts recovered even from levels that were fully screened were identified during excavation, not during screening.
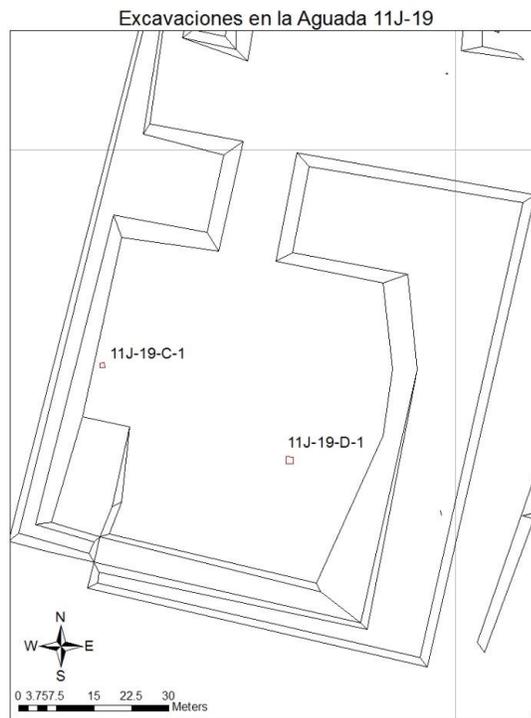
Figure 6.2. The locations of excavations in aguada 11J-19.
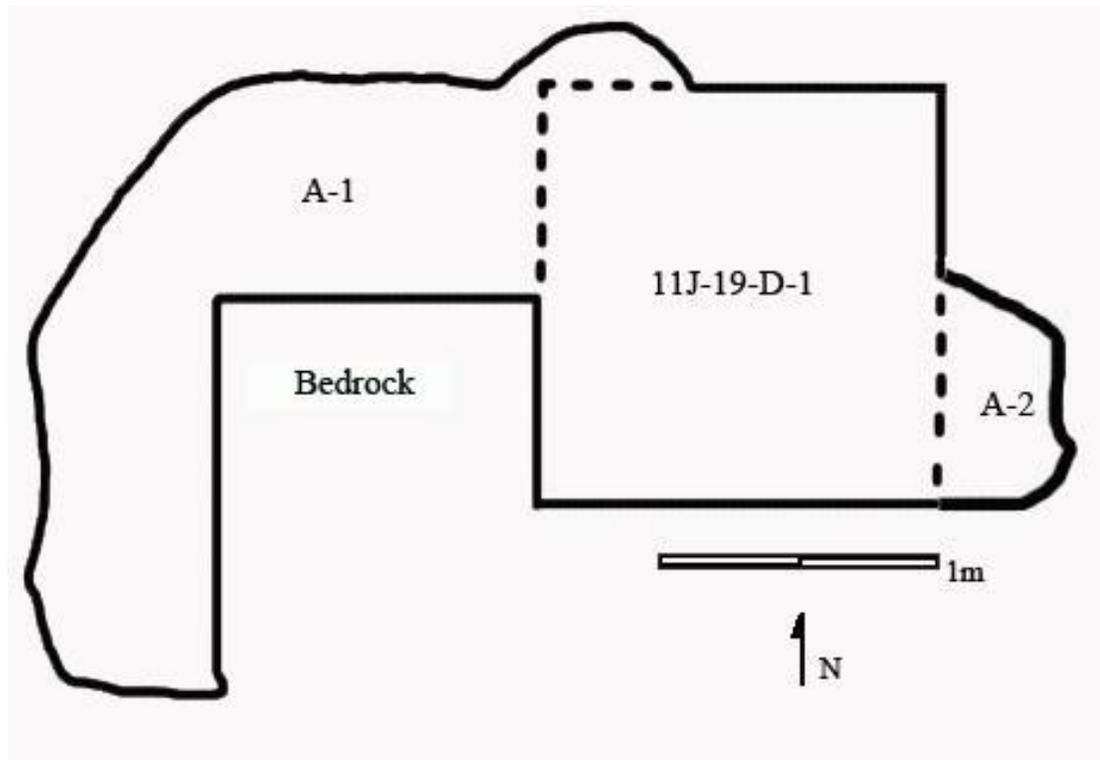
Figure 6.3. Plan view of 11J-19-D-1.

A few centimeters below the surface of unit 11J-19-D-1 a linear rock formation was encountered (Fig. 6.4). The sediment here was extremely deep due to the unit's location within the depression. Runoff from seasonal inundations had caused sediment to accumulate here in large amounts over the centuries. Because the rock formation's location close to the surface, it likely represents recent collapse from the southern wall. The sediment within this unit was consistent throughout being thick, wet, and dark grey to black. A very low concentration of artifacts, mostly ceramics, was excavated from this unit. All artifacts are listed below in Tables 6.1 and 6.2.

Figure 6.4. Limestone rocks within level 1 of 11J-19-D-1.

At a depth of 2 m below the surface, the remains of a plaster floor were encountered (Fig. 6.5). This floor was heavily deteriorated and only discernable as a thin layer of small limestone pieces spread across the unit. This feature consisted of numerous limestone inclusions averaging 0.07m in diameter and concentrations of calcite crystals.

Fig. 6.5. Badly decomposed stucco floor at level 5 of 11J-19-D-1.

Bedrock was encountered in the southwest corner of the unit at a depth of 2.57m along with a layer of rocky collapse occupying the eastern half. As the remainder of the bedrock was uncovered, it became clear that it had been carved into an uneven surface of rectangles resembling a checker board. The northwest corner was the deepest. The rectangular voids were most likely the result of past quarrying of blocks from this location (Fig. 6.6).

Figure 6.6. Detail of cut bedrock from level 9 of 11J-19-D-1.

Because of the dense nature of the soil and the unusual shape of the
bedrock, it was decided to tunnel to the west along the deepest part of the unit to
better understand the modifications to the bedrock. The floor depth of this tunnel
began at 3.25 m below the surface and the tunnel ceiling was 100 cm above the
unit floor. A large cut stone was discovered following the end of excavation (Fig.
6.7). A similar size stone was removed from above the bedrock to the east and it
was determined that these stones represent collapse from a structure to the east,
built directly on the bedrock. The surface of the bedrock also had a layer of
plaster over it, smoothing it out and creating a curved surface at the intersection
of the cut rectangular segments.

Figure 6.7. A large cut rock within the excavated tunnel A1 of 11J-19-D-1.

After continuing the tunnel to the west and then to the south following the cut bedrock wall it became clear that this wall curved back again to the east completing a rectangular shape (Figure 6.3). The bedrock floor of the tunnel continued to step down first to the west and then to the south. It stepped down again, farther south beyond the tunnel but excavations were suspended due to safety concerns. Along the southern segment of the tunnel between depths of 2.81m and 2.91m, a layer of large fill layer of ceramics was found imbedded within the western profile of the tunnel wall.

A second tunnel was excavated at the southern portion of the eastern wall. This was given the designation sub-operation A-2. Another large cut stone

rock was found in the northern area of the tunnel floor and a rise in bedrock was discovered in the southeast corner of the tunnel wall. This added to the evidence of collapse from an eastern structure filling the area.

The second unit within the reservoir was excavated along the western edge of the reservoir's depression adjacent to the wall structure 11J-20. This unit was a small 1m x 1m test pit. It was excavated to see if the bedrock was also deep in this portion of the reservoir and to better identify the architecture of 11J-20. This unit was relatively shallow and unproductive consisting mostly of collapse from the wall to the west. The bedrock sloped gently to the west and showed no signs of quarrying. The form of the bedrock here suggests that there was a natural depression before quarrying.

During the 2014 field season operation 11J-20-B-1 was placed across the opening in the north of the reservoir and overlapping part of structure 11J-20 (Fig. 6. 8). The unit was a 3m x 1m excavation running east to west. This location was chosen to determine if the perceived channel running into the reservoir was constructed or a natural formation and to determine the phases of construction of structure 11J-20.
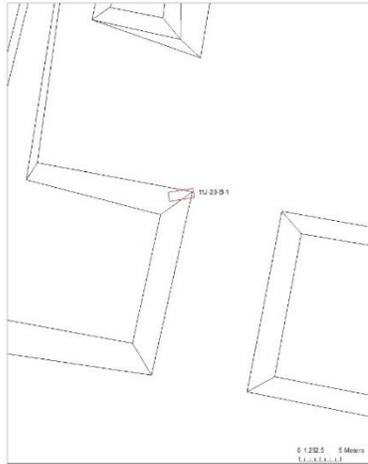
Figure 6.8. Location of excavation 11J-20-B-1 at reservoir inlet.

Not surprisingly, as soon as the excavation began it was clear that the surface layer of humus was much deeper in the proposed channel to the east of the unit. This gave immediate support to the theory that the channel was an intended part of the construction. If it were the result of natural processes such as surface water runoff one would expect the surface soil to be shallower not deeper.

Below the surface a rocky fill was excavated on the western half of the unit. This represented the final phase of construction for the western wall of the reservoir. The structure was a densely packed fill with medium sized cobbles. There were no visible facing stones within the unit. Below the rocky fill was another fill layer, this one composed of brown soil mixed with small limestone fragments. This third layer extended further to the east than the layer above and seems to have been the base of the final construction layer.

Levels 4 and 5 were both sediment layers that were roughly flat and

extended across the entire unit. These represent a leveling episode which

served as the base for the raised fill structures built upon it, defining the channel.

Below this leveling event the unit consisted of a rocky fill; however, on the

eastern-most 50cm of the unit was a thin cap of red clay. Both of these features

were directly on top of bedrock. This rocky fill formed a level surface to the west

with a step down to the clay layer (Fig. 6.9).
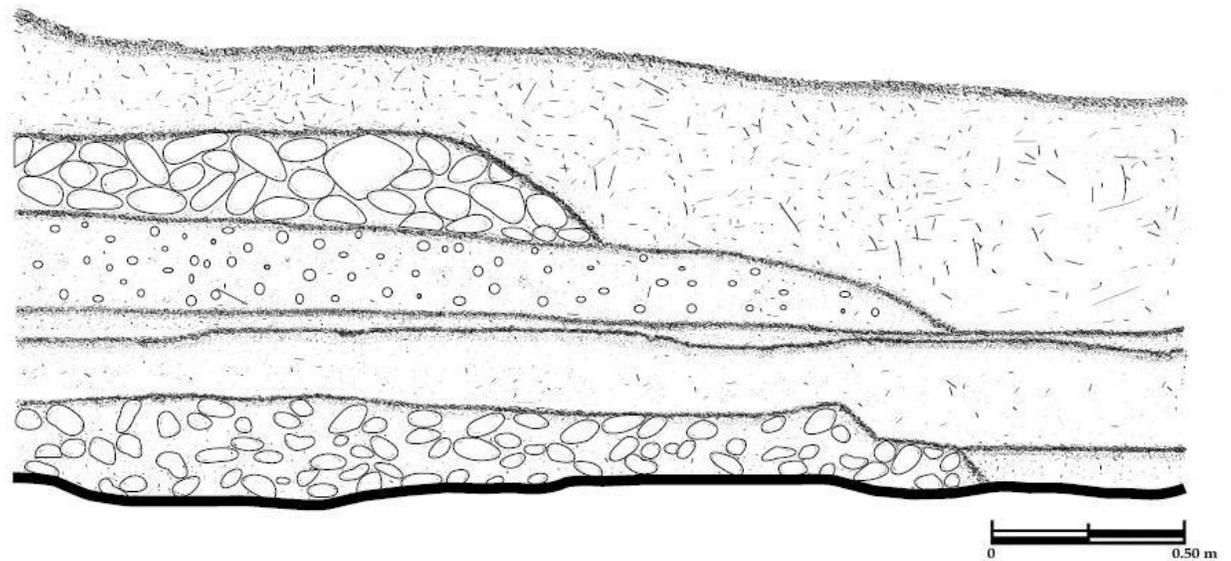
Figure 6.9. North profile of 11J-B-1.

Conclusions of Reservoir Excavations

By the end of excavations, there was sufficient evidence that 11J-19 was

indeed a reservoir. Beyond the humus layer, thick dark gray clay dominated the

stratigraphy of all of unit 11J-19-D-1's levels. Much of this is sedimentation from

seasonal inundation, although some of this clay may have been brought here in an effort to seal and level the reservoir. The scarcity of archaeological material recovered further supports the reservoir theory. This interpretation is based on the idea that the Maya would have kept refuse out of water stores. The much higher concentration of artifacts on the western periphery of the reservoir is consistent with architectural collapse from the western wall. Evidence of three successive lime-plaster floors dating to the Classic Period was discovered (Fig. 6.10). Below this, the deeper levels and tunnels were dated to the Preclassic and exhibited signs of early modification suggesting it was used to store water from the late Preclassic through the late Classic periods.
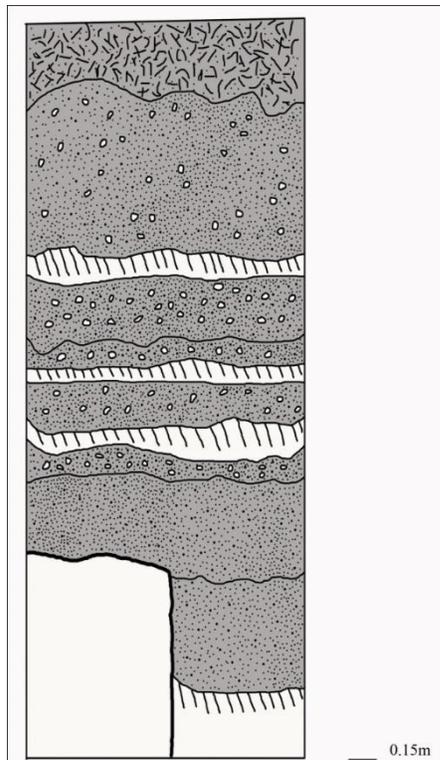
Figure 6.10. Western profile of 11J-19-D-1 with detail of floors.

The ceramic assemblage collected from Levels 1 through 6 of operation 11J-19-D-1 represent Late Classic materials while Levels 7 and below contain only Preclassic ceramics. Interestingly, Late Classic and Preclassic ceramics were not found together within the transitional area between Levels 6 and 7. This indicates that during the Late Classic the reservoir was modified and the floor associated with Level 5 was constructed. Dredging of the reservoir by Xultun's Late Classic inhabitants removed layers of accumulation from the Early Classic to a depth of 2.22 m below the current surface. The floor of the reservoir was then leveled off and plastered over at a depth of 2.07 m below the current surface. The combined fill and floor laid down were roughly 0.15 m thick. This construction indicates an expansion of the reservoir during the Late Classic. This floor depth can be used to recalculate the estimated capacity to 10,620 m³. Two successive floors were constructed over this one at depths of 1.70 m and 1.20 m below the current surface. This suggests regular maintenance of the reservoir throughout the Late Classic.

At the end of Level 7, 8, and 9 excavations, bedrock began to emerge within the southwestern and the northeastern corners of the unit floor. Noticing the bedrock had a unique checkerboard shape, tunnel A-1 was excavated in the unit's northwestern corner to better define the shape of the unit's southwestern bedrock. By the end of A-1's excavation, the bedrock was discovered to be artificially cut into rectangular-shapes with a series of plastered steps moving

down to the west and then south toward the lowest part of the 11J-19.

Interpreting the bedrock's shape and that it was sealed with plaster, it was

concluded that the 11J-19-D-1 bedrock represents cut stairs for access to water

in the lowest part of the reservoir during the Preclassic (Fig. 6.11).
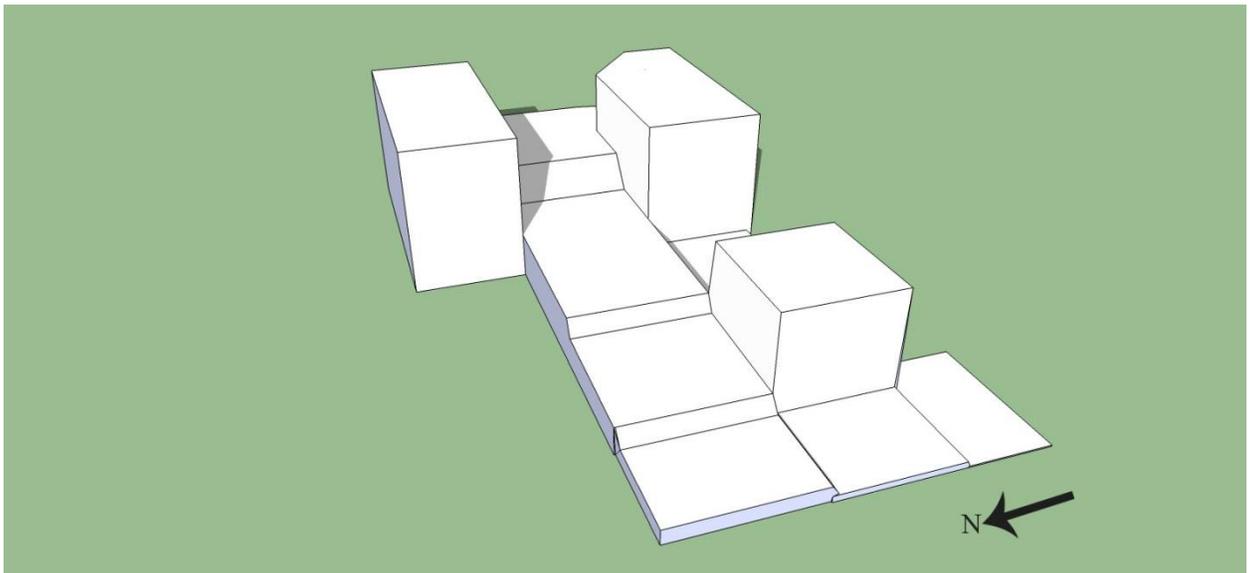
Figure 6.11. Reconstruction of cut bedrock within 11J-19-D-1.

With this hypothesis under consideration, excavations of tunnel A-2 began

within the unit's southeastern corner to discover the overall shape of the cut

bedrock within the unit floor. After excavating a single level, Level 14, the corner

of a new bedrock platform 1.85 m below the surface was discovered. In addition,

another large cut stone rock was discovered within indicating that some kind of

structure had collapsed into the reservoir. Unfortunately, excavations ended

abruptly following a rainstorm which destroyed the unit's profiles and buried both

tunnels under large sediment deposits (Fig. 6.12). The flooding that occurred

during the rainstorm further supported this structure's function as a reservoir.

The pit which was over 3.00 m deep was overflowing with water and remained full for several days.

Figure 6.12. Flooding of unit 11J-19-D-1.

Operation 11J-19-C-1 consisted mostly of architectural collapse from the wall to the west. The bedrock within this pit, however, sloped toward the center of the reservoir. This sloping appears to be natural and points to 11J-19 having been a natural depression before modification by Xultun's inhabitants. The uppermost sediment levels (1-5) conform to this shape. Level 6 is interesting as the pattern of soil settlement is relatively flat in the profile (Fig. 6.13). This could

represent an intentional leveling or simply the sedimentation of clay particles out

of water that pooled here.
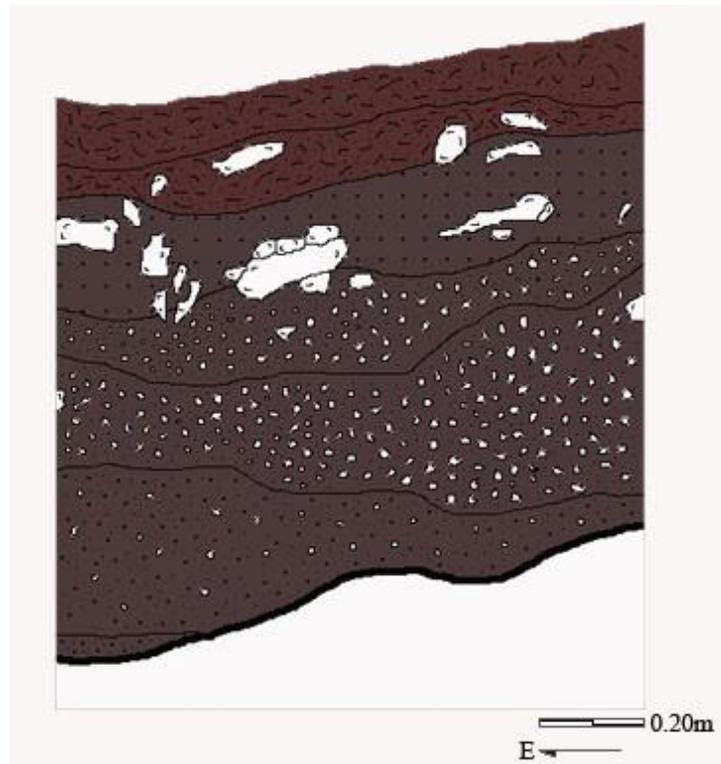
Figure 6.13. Southern profile of 11J-19-C-1.

The ingress channel to the north underwent two phases of construction.

The earliest phase was built during the Late Preclassic and involved the laying

down of a rocky fill with two steps to define the channel. Red clay was used to

seal the bedrock within the channel. Eventually this structure was covered over

during a leveling event and larger side structures of fill were built creating a much

wider and deeper channel. This mirrors the modifications seen within the

reservoir during the Late Classic dredging and expansion.

In conclusion, during the Preclassic the occupants of Xultun took advantage of a natural depression within an elevated zone surrounded by bajos to the north and east. This area was quarried for architectural material before being modified. The bedrock was shaped to allow easy access to water which collected in this depression. A low wall of fill was built to define the inflow channel to the north which was then sealed with red clay. During the Late Classic, Xultun's occupants undertook a major construction project on the reservoir. It was dredged, leveled off and a plaster floor was laid down. At the same time, the walls around the reservoir were expanded, widening and deepening the inflow channel. Throughout the Late Classic, maintenance was performed on the reservoir. Instead of further dredging, successive floors were constructed to reseal the reservoir.

Table 6.1. 11J-19-D-1 Concentration of Ceramics by Level

Excavation Level	Number of Ceramic Sherds	Approximate Volume of Soil Excavated	Percentage of Soil Screened	Estimated Number of Artifacts per m³
1	10	0.90 m³	0%	11.11 t/m³
2	57	1.67 m³	50%	34.13 t/m³
3	30	0.89 m³	25%	33.71 t/m³
4	49	0.87 m³	25%	56.32 t/m³
5	15	0.19 m³	100%	78.95 t/m³
6	6	0.46 m³	90%	13.04 t/m³
7	28	1.05 m³	100%	26.67 t/m³
8	8	0.80 m³	100%	10.00 t/m³

Table 6.2. Table of Materials Excavated

Unit	Ceramic	Chert	Bones	Carbon	Other	Notes
11J-19-D-1-1	10					Linear Structure of Limestone
11J-19-D-1-2	57	1	2			
11J-19-D-1-3	30	1				
11J-19-D-1-4	49					
11J-19-D-1-5	15			2		Floor
11J-19-D-1-6	6			2		
11J-19-D-1-7	28	1				A Group of Rocks
11J-19-D-1-8	8	1		2		The Removal of the Group of Rocks
11J-19-D-1-9						
11J-19-D-1-10	2			1	1 Large Cut Stone	
11J-19-D-1-11						The Removal of the Cut Stone
11J-19-D-1-12	4					
11J-19-D-1-13	34			1		Line of Ceramics in Western Wall
11J-19-D-1-14	1				1 Large Cut Stone	
11J-19-C-1-1	1	1				
11J-19-C-1-2	4					
11J-19-C-1-3	26	8			1 Mano	
11J-19-C-1-4	38					
11J-19-C-1-5	100	3				
11J-19-C-1-6	38					
11J-19-C-1-7						On Bedrock
11J-20-B-1-1	148	2			1 Obsidian	
11J-20-B-1-2	163		1			
11J-20-B-1-3	147					
11J-20-B-1-4	97					
11J-20-B-1-5	133					
11J-20-B-1-6	2					
11J-20-B-1-7	65					

Drainage Canal

To further explore the hydrological system related to this reservoir, an excavation unit was placed in a drainage canal to the north. This unit was placed roughly adjacent to and east of structure 11I-8 and 45 m west of the quadrangular residential group (Fig. 6.14). The 2 m x 1 m unit was dug to examine the architecture of the canal and to see if refuse material from the residential and administrative groups was accumulating within. This interpretation would be made based on the amount of ceramic material or other artifacts contained within.
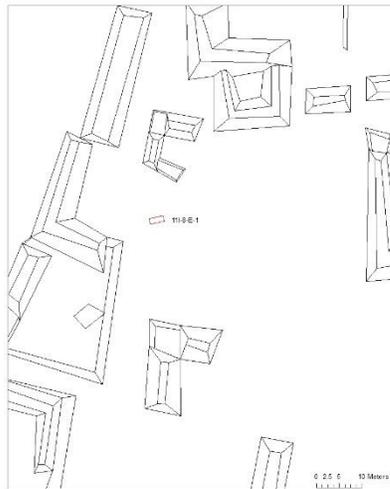
Figure 6.14. Location of excavation 11I-8-E-1 in open canal.

Bedrock was encountered very close to the surface in the eastern third of the unit, at a depth of 23 cm. The soil composition did not change between the levels in this unit. It was all the same black or dark brown. In continuing excavation, it became clear that the bedrock on the east was cut on its western

facing side forming the eastern wall of the canal. Below this there was a lower

inner canal wall composed of a row of large stones running roughly north to

south (Fig. 6.15).

Figure 6.15. Level 2 detail of carved bedrock and stone wall.

The unit only captured the eastern wall of the canal, so it was decided to

dig a 1 m x 1 m extension to the west in search of the western wall of this

structure. This unit was designated 11I-8-E-2. The dark humus layer continued

below the surface in this unit also. At the completion of the second level, the

western wall appeared. It mirrored the eastern half of the structure with an outer

high wall and a lower wall made of a row of stones (Fig. 6.16). On the western

side, the larger wall was not cut bedrock but a pile of very large stones. The final

level combined both units and reached bedrock at a depth of 71 cm on the west

and 49 cm on the east (Fig. 6.17).

Figure 6.16. Level 2 detail of large two stone walls on west side of canal.
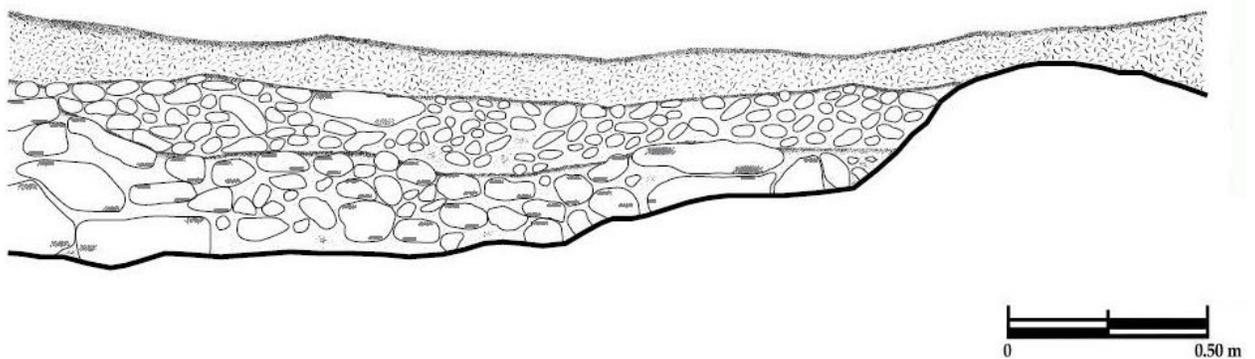
Figure 6.17. North profile 11I-8-E-1 and 2.

The open canal that fed into the reservoir was built by carving down the bedrock on the eastern side and piling up stones on the western side to a width of about 1.5 m and a depth of about 0.5 m. Inside these walls, lower walls made of a single row of stones were built. Gravity would have caused larger pieces of refuse to collect along the edges of the canal, and this feature would have kept these out of the flow of water.

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Sub-Plaza Canal

        During the 2012 field season while I was mapping the area north of Grupo Tortuga, I noticed a series of depressions running roughly north. I did not have time to carefully examine these features, but I did notice that they seemed to line up with the northern end of the open canal. In 2014, I investigated these features and further identified two openings in a sub-plaza canal. I hypothesized that the depressions running north from these may have been canal collapse continuing across the plaza. This project became the main focus of my work during the 2014 season as the canal proved to be larger and more interesting than I could have imagined. In total 10 units were excavated in trying to define this feature (Fig. 6.18). The section of the canal that was identified on the surface was given the designation 11I-32. Excavations on this structure were difficult due to the large number of roots and the narrow space between the canal walls.
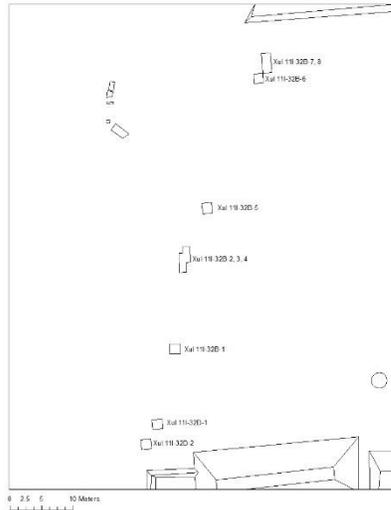
Figure 6.18. Map of 11I-32 excavations.

The first unit was placed directly over the northern opening of 11I-32. A

1.5 m x 1.5 m unit was excavated to define the architecture of the canal, collect

ceramics for dating of construction and termination of the canal, and further

excavations were planned to identify the extent of the canal. Figure 6.19 is a

photograph of what the opening looked like before excavation. There was a thin

roofing stone exposed above the opening and a large cut block on the surface in

front of it and a second large block on the surface south of the opening. These

blocks were placed here in modern times.

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Figure 6.19. Unit 11I-32-B-1 facing south before excavation.

Below the humus layer was a rocky fill which when removed exposed the opening cover stone, and part of the walls. The fill throughout the canal was uniform and different from that above, demonstrating that it's use was terminated in a single event. It consisted of a brown soil with few rocks. The canal floor ranged in depth from 125 cm in the north to 136 cm in the south demonstrating that it was sloped in the direction of the open canal that fed into the reservoir. The majority of the canal here was carved out of bedrock. Once the fill was removed from the canal, it was possible to view the interior of the canal to the south (Fig. 6.20). Although there were no roofing stones over the section that was excavated, they are clearly visible within the canal to the south. The fill also continued along the length of the canal as far as could be seen.

Figure 6.20. View south into canal opening detail of architecture.

Excavations continued outside of the canal walls to define the architecture and to collect ceramics that could be used to date the construction of the canal. Bedrock was encountered at 80 cm below the surface. The architecture can be seen in the southern profile drawing of the unit (Figure 6.21). The canal was carved from bedrock, and large cut blocks of limestone were placed at the lip of the canal on both sides. Above this, smaller stones were piled up to create a level elevated surface for the placement of the very large roofing stones.
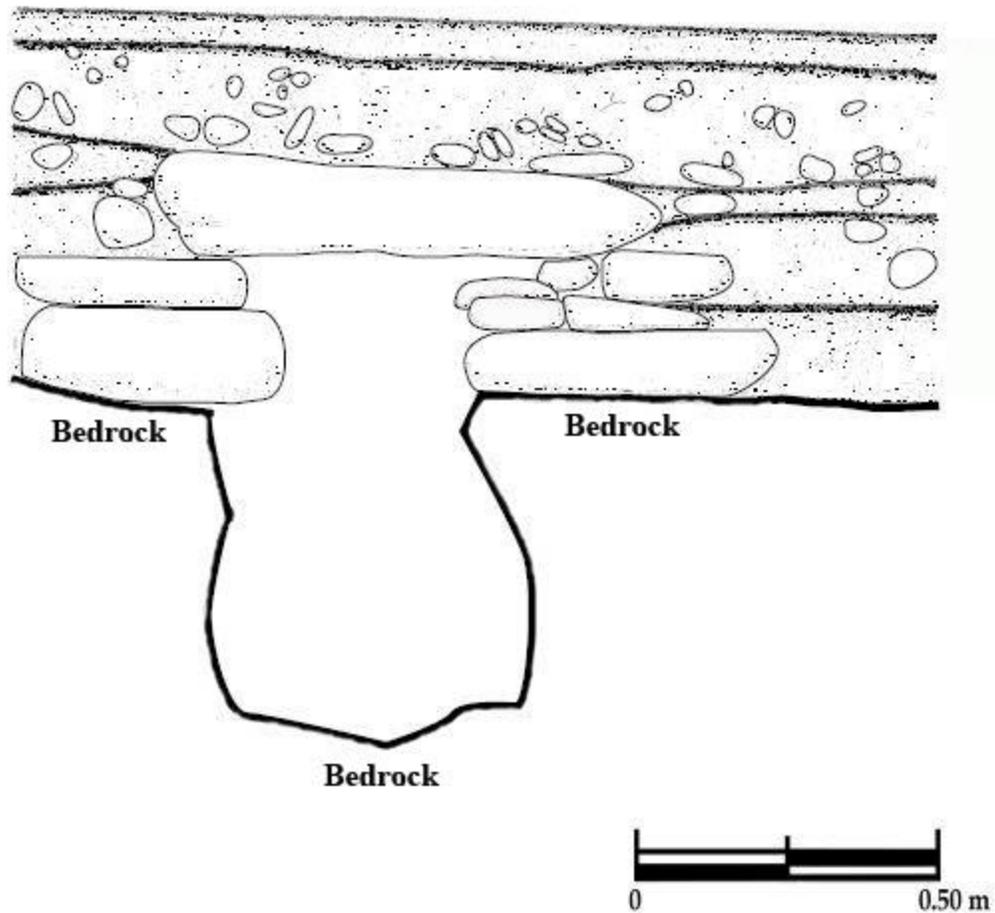
Figure 6.21. South profile of 11I-32B-1.

Fifteen meters north of unit 11I-32-B-1 was a large curved depression in the surface. This feature curved to the northeast and roughly aligned with smaller depressions to the north. I hypothesized that these depressions represented caved in sections of the canal. I placed unit 11I-32-B-2, a 1.5 m x 1.5 m unit, in the center of this curved feature. This area also had three large cut blocks on the surface which had been placed there recently. This excavation had many more roots than the previous but the surface stratigraphy was the same, humus above a rocky fill layer. The fill within the canal was also the same

as the previous excavation. Where this section of the canal differed was in the

construction of its walls. Here they were fully constructed of cut stone blocks laid

on the bedrock floor and not carved from the bedrock (Fig. 6.22). It was also

noticed that the canal here curved to the northwest, in opposition to the overall

form of the depression. To understand this anomaly, I excavated two extensions,

one to the north and one to the south.

Figure 6.22. Unit 11I-32-B-2, level 3 east wall detail.

The excavation to the north, 11I-32-B-3, was a 1 m x 1 m unit extended

along the eastern wall of the previous unit. The same surface pattern of a rocky

fill below the humus and above the canal fill was encountered. The walls here

were straighter, and there was a large roofing stone visible within the north profile

of the unit (Fig. 6.23). The eastern wall of the canal curved back towards the

northeast here demonstrating that the canal had an undulating form. Unit 11I-32-

B-4 was a 1.5 m x 1 m southern extension along the western wall of unit 11I-32-

B-2. The fill within the canal of the southern section of this unit was full of

collapse from the western wall. The excavation of the second extension

confirmed the undulating form of the canal which can be seen in the plan view

(Fig. 6.24).

Figure 6.23: Level 3 north profile detail of broken roofing stone in wall.
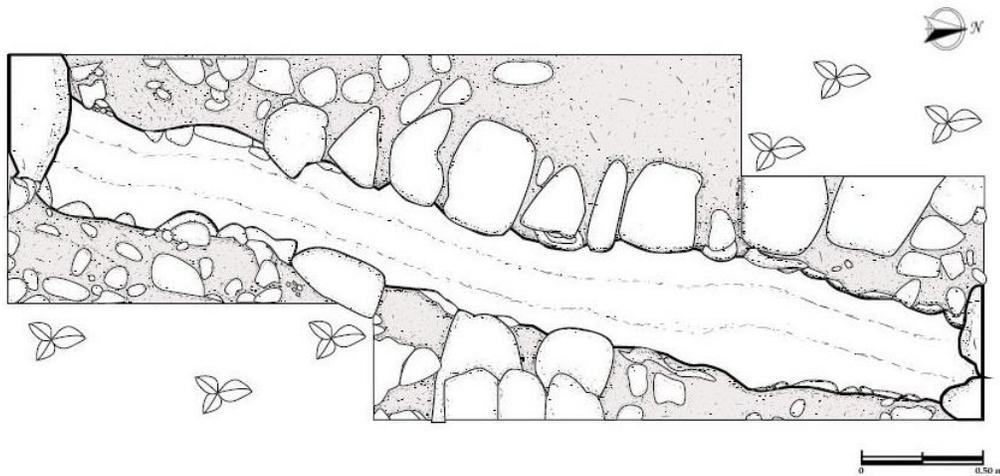
Figure 6.24. Plan view of 11I-32B-2, 3, and 4 depicting deliberate undulation.

Because the two areas excavated so far lacked roofing stones, and the

stones were not on the surface, these depressions were interpreted as collection

points for drainage from this plaza. To further explore this idea I placed the next

excavation over the closest of the four remaining depressions to the north. Unit

11I-32-B-5 was a 1.5 m x 1.5 m excavation. This depression also had several

large cut blocks on the surface. It is likely that someone recently placed these

stones to mark the depressions. In this unit there was a small opening in the

canal where the roofing stone had been removed. I was able to excavate outside

of the eastern wall down to bedrock. Under this fill was part of the superstructure

of the canal (Fig. 6.25). The canal had originally been closed here but at some

point in antiquity this section was modified. The wall was dug out and an

opening was made in the top of the canal. It was then refilled up to this opening.

Figure 6.25. Detail of past modification of canal.

Unit 11I-32-B-6 was a 1.5 m x 1.5 m excavation placed to the far north of

the plaza over the northernmost depression. This unit was placed in the hopes

of defining the northern limit of the sup-plaza canal. It was very close to the large

range structure which defined the northern extent of the plaza. After removal of

the humus and rocky fill layer, it appeared that there were two low walls east of the canal opening and perpendicular to the canal (Fig. 6.26). These walls would have directed runoff from the east into the surface opening in the canal here. It was also clear that the canal continued to the northeast toward the range structure.

Figure 6.26. Level 4 detail of surface diversion walls for channeling water into canal.

Unit 11I-32-B-7 was a 1.5 m x 1.5 m excavation placed directly northeast of unit 11I-32-B-6. This unit was placed in hopes of defining the northern extent of the canal. This unit exposed the exterior of the canal, with roofing stones where it entered a larger substructure (Fig. 6.27). The substructure extended to the east in the northern profile of the unit. There was also a larger rectangular cut roofing stone where the canal met the substructure. The quality of this cut block is indicative of its past exposure. The bedrock to the east of the canal here had been quarried out.

Figure 6.27. Level 6 detail of canal entering substructure.

The final unit placed in the northern section of the canal, 11I-32-B-8, was a 1.5 m x 1.5 m northern extension of 11I-32-B-7. This unit was excavated to better understand how the canal interacted with the substructure encountered, and in the continuing effort to define the northern extent of the canal. The surface here was steeply sloped to the northeast approaching the large range structure. There was a subsurface wall excavated along the eastern section of the unit below the humus. This wall ran south from the range structure and was only one stone deep with fill beneath. The size of the rocks within the fill increased in size with depth. The canal was identified continuing through the substructure when three large roofing stones were encountered north of the rectangular cut block (Fig. 6.28). Two of these stones were removed, and it was noted that there was a significant gap between the canal fill and the roofing stones here (Fig. 6.29).

Figure 6.28. Level 5 before removal of roofing stones.

Figure 6.29. Level 5 after removal of roofing stones.

The fill within the canal had the same consistency as in other areas. It

was removed in an attempt to explore further north, below the range structure.

There was enough space between the fill and the roofing stones for an individual

to climb into the canal here (Fig. 6.30). The visible extent of the canal was

measured to be an additional 12m in length. This placed the canal on the
northern side of the range structure. The plaza to the north was examined in the
hopes of finding more depressions or openings but none were located. There
were also no openings in the canal roof within the range structure.

Figure 6.30. View north into open canal.

The final two units were to the south of the original unit and placed to
confirm that the sub-plaza canal continued into the open canal to the south. Both
of these units were 1.5 m x 1.5 m and they did confirm that the structure
continued to the open canal.

In conclusion, the sub-plaza canal was much larger and more complicated
than originally anticipated. To maintain the slope of the canal, some sections
were built up of cut limestone blocks and others were carved into the bedrock.
The canal also had an undulating form which would have protected the structure
from erosive forces by slowing the flow of water. The canal is older than the
large range structure to the north of the plaza as it passes completely under this

structure. There were two original openings in the canal toward the southern

end, presumably to allow runoff from this area to enter. During a later stage, five

openings were made in the canal--one large opening in the center of the plaza

and four small ones to the north. The surface was modified with small diversion

walls to direct water into these openings. These were likely added after the

erection of the two stelae to the west. Their placement is ideal to protect the

stelae from runoff from the east.

Residential Quadrangle

During the 2014 field season, excavations were completed on Grupo

Tortuga's residential quadrangle. This group is situated 200 m northeast of the

reservoir. The central plaza was designated 12I-30, the eastern structure 12I-5.

These excavations were carried out, under my direction, by the Guatemalan

archaeologist T. U. Walter Omar Schwendener S. This residence seemed to

have exclusive access to the reservoir and the canal that flowed into it. To better

understand the architecture of this group and what function it served within the

neighborhood I searched for evidence that it was an elite residence for an

individual who was in charge of managing access to the water stored in the

reservoir. This group had been heavily looted with 14 trenches (Fig. 6.31). The

excavations were focused within the plaza and eastern structure.
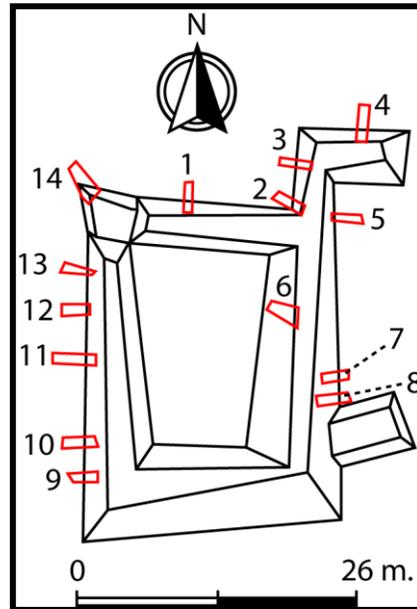
Figure 6.31: Plan of residential quadrangle with 14 looter's trenches.

The first excavation, 12I-30-F1, was focused in the center of the plaza to determine the stages of construction, identify the ceramic groups, and to confirm the existence and depth of bedrock. Below the humus layer the fill was composed of rocky collapse. The bedrock was cut into a series of steps descending toward the northern structure (Fig. 6.32). This represents quarrying that took place before the northern structure was built. There was a retention wall constructed level with the highest elevation of bedrock. There was also evidence of three termination rituals in the form of strong concentrations of ceramics. Each of these were 10cm apart. A northern 1.5 m extension was excavated which determined that there were only two steps cut into the bedrock.
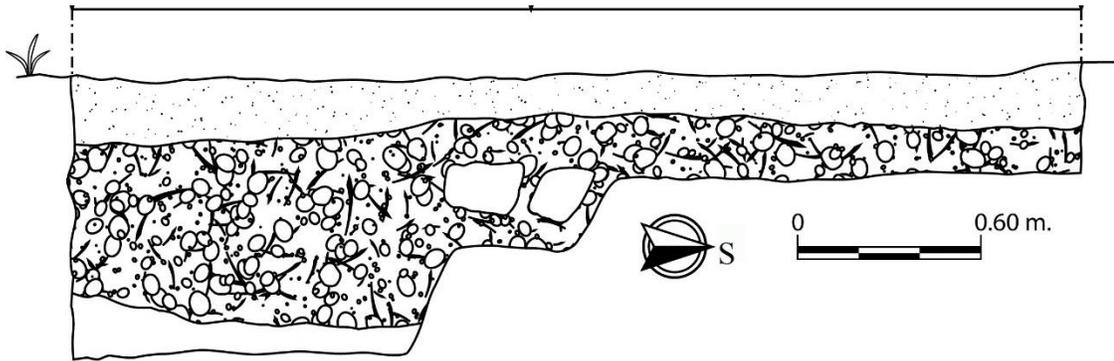
Figure 6.32. Eastern profile of 12I-30F-1, levels 1 and 2. (drawing by Omar Schwendener).

Architectural excavations began with the eastern structure. Initially three units were placed on this structure. First, a 1 m x 3 m unit was placed intersecting the center of the structure along the western façade. Second, a 1 m x 3 m unit was placed to the west of the first unit. The third unit was a 2 m x 1 m unit running north to south in the center of the structure. These units were placed to understand the architecture and artifact assemblage of this structure.

The structure is aligned 4 degrees east of north which is consistent across the entire group. The western, interior facing, side of the structure contained the entry point. Four stairs were identified, the lowest associated with the bedrock and the highest associated with the lowest floor (Fig. 6.33). The door jamb was partially preserved and was 1.40 m wide and the floor within the interior of the structure was elevated. A large bench ran along the interior of the eastern wall and measured 0.54 m high and extended 0.56 m deep. The entrance to the

structure was through the west wall where the stairs came up. Both sides of the

door jamb were extant and the entrance was 1.40 m wide.
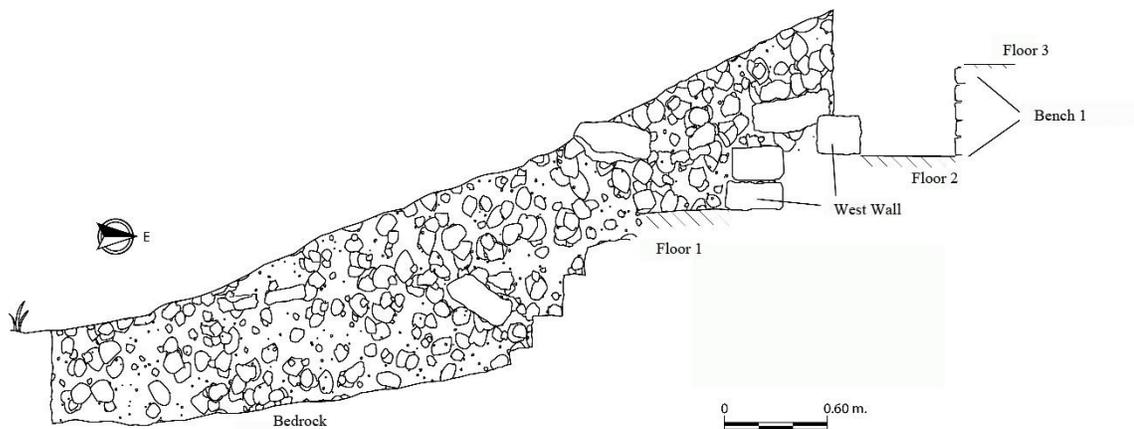
Figure 6.33. North profile of 12I-5C-1 levels 1 and 2 (drawing by Omar
Schwendener).

While examining and cleaning out looters trench number 6 on the western

side of structure 5, niche 1 was discovered (Fig. 6.34). This offering chamber ran

north to south below the western side of the room with the bench. Although

looted, it was noticed upon further examination that the southern extent of the

niche was capped with a large carved stela fragment which was laying at an

incline over the opening (Fig. 6.35). The bench and floor of the room were

excavated to reach the stela and examine the carvings.
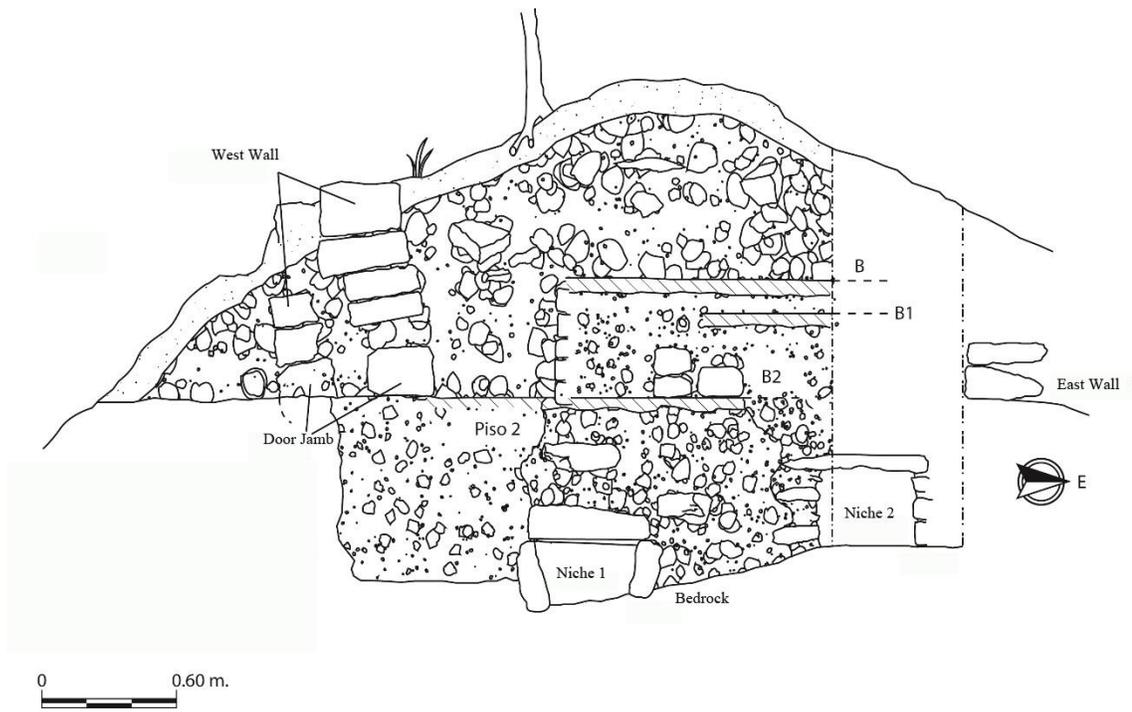
Figure 6.34. North profile of 12I-5F-3, levels 1, 2, and 3 (drawing by Omar Schwendener).

Figure 6.35. Carved stela fragment lying inclined on the southern end of niche 1 (photograph by Patricia Castillo).

An excavation was placed within the door jamb of the structure to allow more room around the stelae (Fig. 6.36). Several other important finds were made while excavating the stelae fragment. These included an intact burial of an

elderly individual positioned in a fetal pose below the southern section of the

room (Fig. 6.37) and niche 2 which contained offering 13 (Fig. 6.38).
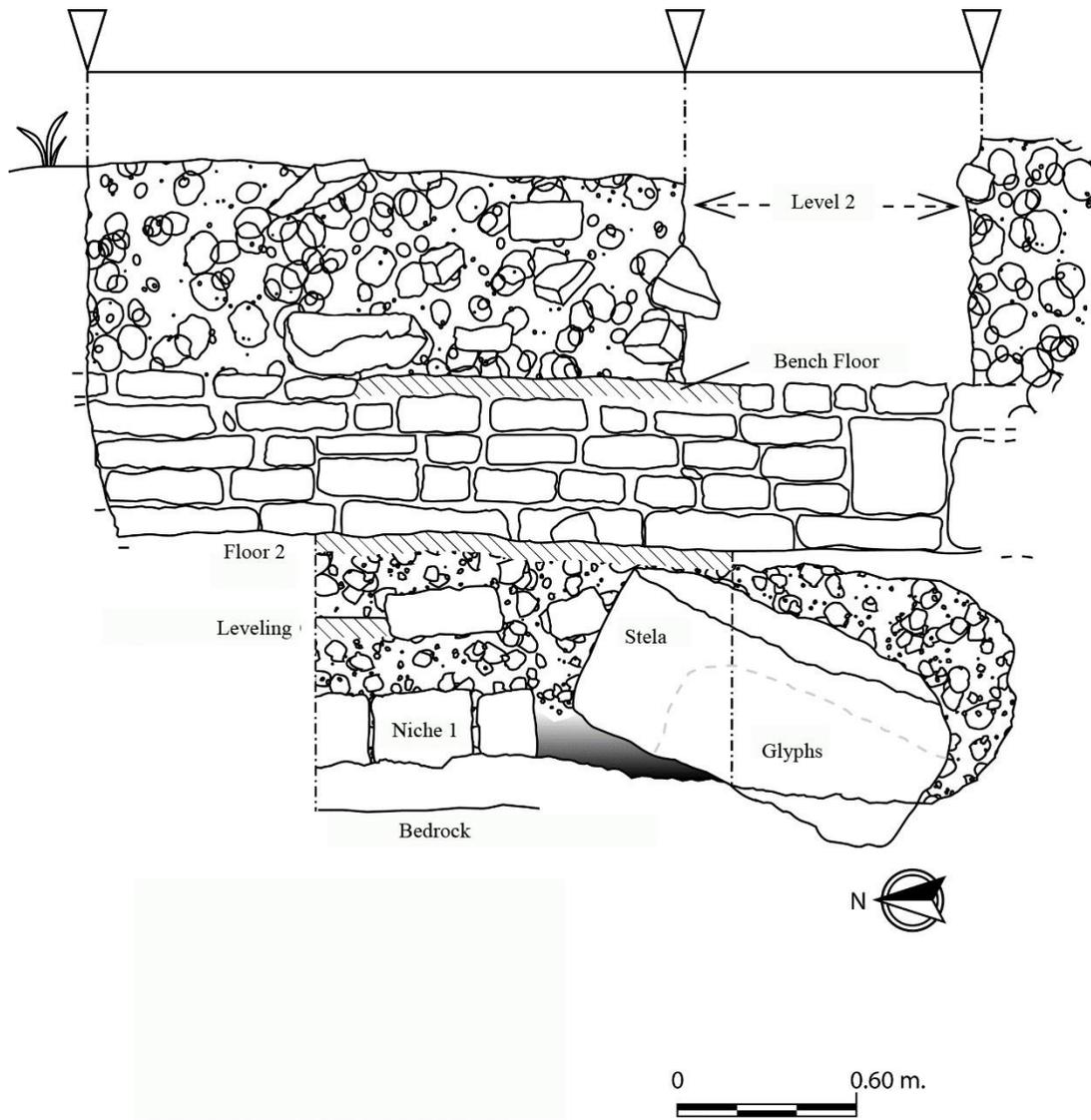
Figure 6.36. Detail of location of stela below bench and floor in structure 5
(drawing by Omar Schwendener).
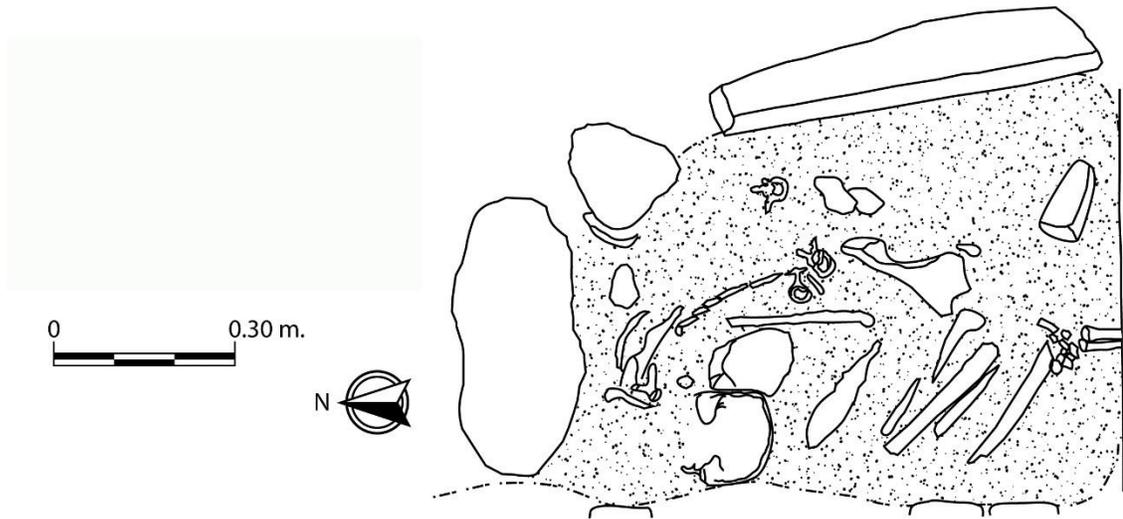
Figure 6.37. Plan view of burial 16.
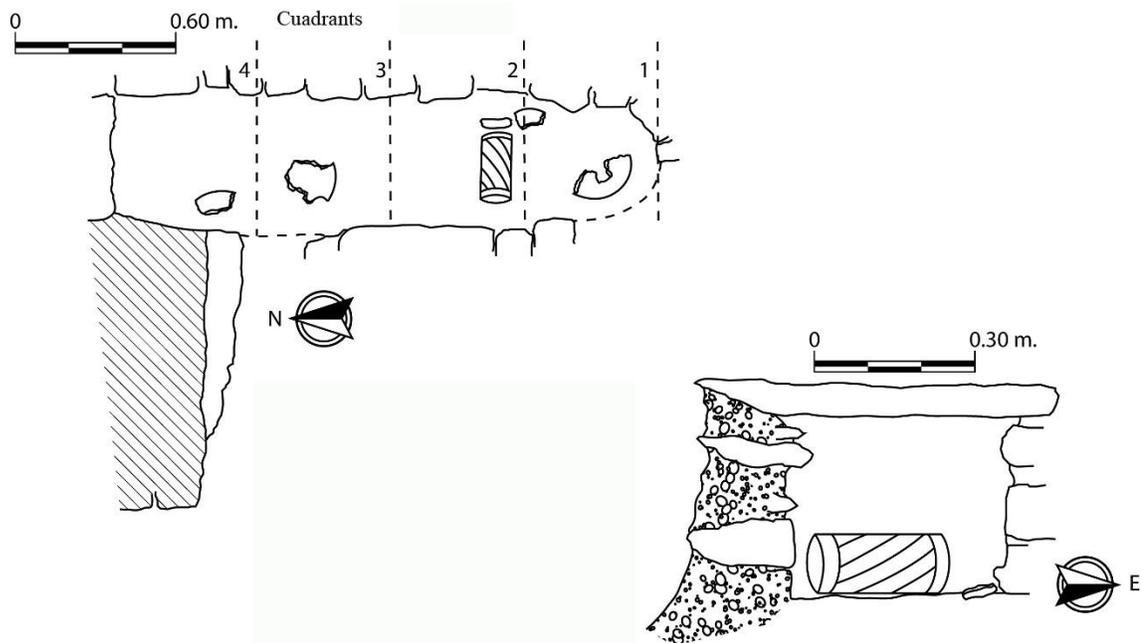
Figure 6.38. Plan view (above) and north profile (below) of offering 13 within niche 2 (drawing by Omar Schwendener).

Structure 5 was built on a high platform with an entrance facing inward toward the patio group. There was a very large bench across the room which

was recessed to the back wall. The room functioned as a private living space for an individual or small group. The placement of offerings within the structure to the cardinal directions also demonstrates that the person held an important position within society and may have been a member of the royal family. This is further highlighted by the placement of a carved stela fragment below the room as part of one of the offerings. This archaeological evidence acquired from structure 5 supports an interpretation as an elite residential group. Beyond the geographic association with the reservoir, the iconography on the stela fragment also points to a hydrological connection.

Stela Fragment

The stela fragment placed within structure 5 is thought to be the top of stela 18, an Early Classic carved stela found in Group B (Fig. 6.39). The fragment contains iconography associated with the Maya gods Chac and K'awiil. Chac, the rain god, is typically depicted with a pendulous nose, wears a spondylus shell earflare and often wields a hafted stone axe and hammer stone (Ishihara 2009:10; Fig. 6.40). K'awiil, the god of royal dynasties, is depicted with a serpent foot, a long upturned snout, a fire element at the forehead, and is often carried by Chac, as the lightning axe (Ishihara 2009:24; Fig. 6.41).
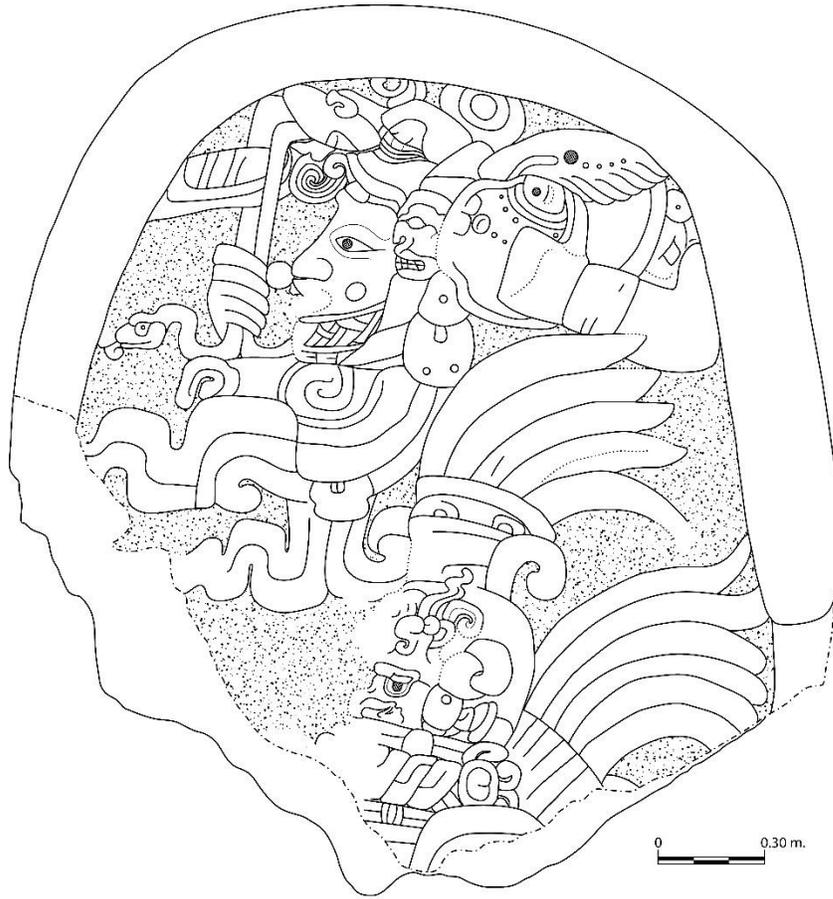
Figure 6.39. Detail of stela fragment from structue 5 (drawing by Mary Clarke and digitization by Omar Schwendener).

Figure 6.40. Early Classic Chac, detail of modeled and incised vessel (Ishihara 2009:10).
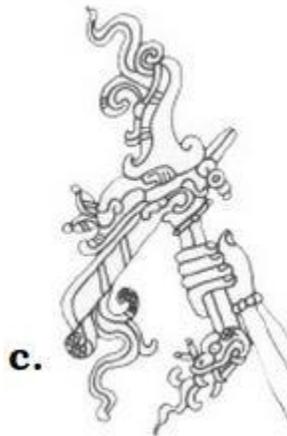
Figure 6.41. K'awiil scepter held by Chac, detail of Early Classic incised and modeled vessel (Ishihara 2009:24).

The stela fragment depicts the feathery top of the king's headdress with a disembodied ancestor in the space above. This figure forms the headdress of Chac. Surrounding the ancestral figure are two arms. The right hand carries the serpent footed lightning axe and the left the hammerstone. The ancestral figure

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wears a god impersonator helmet representing Chac. The ancestor has a decorative nose element and a prominent spot on his cheek.

As is common in Maya iconography, the various elements often conflate to represent more than one idea. Here the hammer stone carried in the left arm symbolizes other elements. There are two decorative elements suspended from the hammer stone. This combined with its placement, near the ear position of the god impersonator helmet, suggest that it also represents the spondylus shell earspool worn by Chac. There are strong similarities between this iconography and the earspool depicted in figure 6.40.

The iconography also seems to contain hieroglyphic elements which likely named the ancestor figure. Chac made up part of the ancestral rulers name. In Late Classic and Post Classic periods, Chac is often identified as Chac Xib Chac. This has been translated to red man Chac or Chac of the east. The Xib glyph is a face in profile with a prominent spot on the cheek, although this spot is also diagnostic of the personified day sign Ahau (Taube 1992:17) (Fig. 6.42). If one combines the Chac headdress, the ancestors face, and the floating monstrous Chac it can be read as Chac Xib Chac referencing the eastern Chac (Fig. 6.43).

Figure 6.42. Xib glyph from K1609 (Barrios et al. 2004:7).
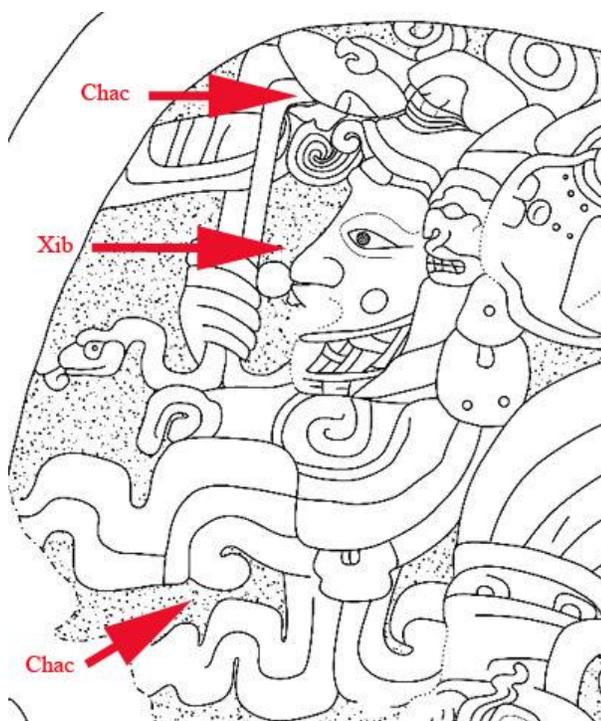
Figure 6.43. Interpretation of glyphic iconography for Chac Xib Chac.

It was also noted that the hammer stone element and surrounding iconography has a strong similarity to the Xultun emblem glyph (Fig. 6.44). This emblem glyph is made up of three elements: (1) a glyph that resembles an eccentric flint or possibly a mandible, (2) the Witz glyph, and (3) Ahau (Garrison and Stuart 2004). All three of these elements appear grouped together in the stela with the hammer stone serving as the Witz glyph. The ancestor could have been named Red Chac and been a former king of Xultun. If these interpretations are correct, the hammer stone iconography has three distinct meanings on the stela (1) the hammer stone of Chac, (2) The spondylus shell ear flare, and (3) the witz glyph element in the Xultun emblem glyph.
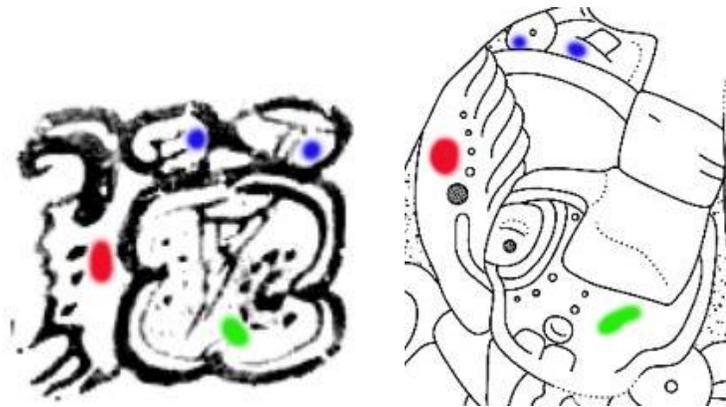
Figure 6.44. Xultun emblem glyph from K3743 and emblem glyph from stela with color coded glyphs.

Conclusion

Excavations were focused on the central reservoir and associated neighborhood group to provide complementary evidence of elite involvement in

the management of water resources at Xultun. These excavations provided

important information concerning when the reservoir was constructed, how it was

modified over time, and its overall use history. Excavations within the catchment

area north of the reservoir identified two interconnected canals that fed the

reservoir. One open canal which ran through the west end of the neighborhood

and one sub-plaza canal farther north that emptied into the open canal.

Excavations on the eastern structure of the enclosed quadrangle group within the

neighborhood identified an elite residence containing several offerings that were

placed during construction. These included two niche offerings, one to the east

and one to the west, and a burial to the south. The western niche offering was

capped with a carved stela fragment directly below the room's bench.

This stela fragment was placed with a burial offering during the

construction of an elite residence in Grupo Tortuga. The resident of this structure

was most likely a member of the royal lineage at Xultun. The strong

iconographic associations with Chac, the rain god, in addition to the location of

this group within an isolated neighborhood which included the central reservoir,

supports my interpretation that the resident of the quadrangle group performed

an administrative role in the management of water associated with the reservoir.

They presented themselves as divine intermediaries to Chac, which

substantiated their role in water management. The large administrative group

which forms the northern limit of the neighborhood is positioned adjacent to

where the sub-plaza canal emptied into the open canal. This would provide an

ideal place to monitor water flow and quality as well as to control the collection of

water from this point or from the reservoir.

Chapter 7: Conclusions

Introduction

The integrated methodology developed in this study will make it easier for multidisciplinary researchers to approach urban studies at premodern sites. Historically, studies of urban form within the Maya Lowlands have been difficult because the organizational principles involved do not conform to modern conventions. Combining data from mapping, remote sensing, topographic analysis, urban-zone analysis and hydrological modeling I interpreted he ordering of the urban environment at Xultun. From the Preclassic, Maya elite developed and maintained a complex water management system. Xultun's inhabitants divided the urban landscape into 3 tiers with administrative groups at the top, residential in the middle, and agricultural areas concentrated in the north and east. The control of access to hydrological resources led to the development and maintenance of social inequality. In addition to ecological factors influencing the layout of drainage and settlement, the Maya elite used ideology to reinforce their authority in the management of water. Xultun's leaders used cosmological concepts of directionality and iconography related to the Maya Rain God as tools in this manner. The combination of multiple lines of evidence in interpreting the past use of space has supported the hypothesis that access to water within Lowland Maya cities was managed hierarchically.

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Methodological Results

The use of high resolution survey methods in the mapping of Xultun is a departure from previous mapping efforts. High powered GPS and laser survey equipment were used to locate the position of buildings; to theoretically within one centimeter of their actual location in space. Problems were identified with the placement and orientation of the digital map through the use of secondary remotely sensed data,. Because the digital map of structures was correct in size and shape, it was easy to move the layers to the correct UTM coordinates. This error demonstrates the necessity of having checks on every aspect of digital mapping. The original survey team introduced the error during the placement of the site datums. The taking and confirmation of multiple GPS readings with more than one device when setting the site datum will prevent these errors. Supplementing GPS readings with remote sensing data is ideal when available.

I partially borrowed the methodology employed in the use of remote sensing from past work by Saturno et al. (2007). Quickbird imagery proved more useful over Xultun than IKONOS. This technique was used to identify areas of past water storage and settlement. Using the inverse of the settlement signature to identify water stores was a novel approach to the use of this tool. The ground survey demonstrated that at least four of these positive results were accurate. Remote sensing, although expanding rapidly as a survey tool in Mesoamerica, is

still underutilized. The ability to identify both settlement and water storage in this way creates the opportunity to build regional maps of water storage and settlement to further examine spatial patterns.

The identification of neighborhood groups within Xultun and the categorization of different structure groupings into urban zones serves to increase the comparative dataset of premodern urban layouts (Stanley et al. 2015). This provides a baseline from which comparisons can be made. Understanding the patterning of urban zones will also drive new inquiries into the socio-political structure of the ancient Maya. The justifications used in classifying Xultun's urban space serve as a starting point from which other researchers can improve. The best methodology would incorporate excavation data into interpretations of urban zones. Without excavations, we only have the option of using descriptive terminology based on surface information and topographic changes.

I used the hydrology tools within ArcGIS 10.1 were to model drainage over the site, combining two different spatial resolutions to give an overall description of Xultun's drainage. High resolution analysis was performed on the site core, while lower resolution analysis of larger trends was performed over the 16km² site. To create a hydrological map of the whole site I added the reservoirs and flood zones. Using these data, six reservoirs associated with agricultural practices were identified within the flood zones. The central, high resolution,

drainage exhibited a quadripartite form, which suggests a cosmological ordering to the way the Maya diverted and collected water (Scarborough 1998). This information was combined with the map of major drainages out of the site. The ability to visually combine multiple sources of data is the real strength of GIS technology.

The combination of the mapped urban zones with the mapped hydrology allowed for a comparative analysis of the organization of drainage over the site and for the drainage associated with three different reservoirs. These data demonstrated that residential zones are especially well drained and that one of the reservoirs served an administrative function while another served a residential function. The data suggests that water collected from within specific zones was stored for use in that zone.

Overall, it was necessary to draw the map, categorize the map into different urban forms and model the hydrology; to perform the spatial analysis. To make archaeological data more accessible to geographers, those conducting digital survey should approach the project with these issues in mind. Survey methodology should incorporate the collection of urban information. The addition of urban zones and hydrology to the data during the initial mapping would have made the performance of this research less time consuming.

Summary of Findings

Hydrological engineering of the landscape was a major influence on settlement patterns at Lowland Maya sites. The organization of sites can be categorized on the macro scale based on the availability and type of hydrological resources. The differences between riverine, lakeside, and central Petén sites demonstrates this. Settlement at riverine sites spreads out along the edge of the river, above the flood zone, while lakeside sites exhibit concentric patterning, and central Petén sites exhibit dispersed patterning. There are a number of socio-economic variables that can explain these settlement differences. In areas with available natural water sources, the elites maintained locations of preferential access. In lakeside sites, the development of large administrative and ritual centers were close to the lake with diminishing settlement as one moves further from the center. Elites within the central Petén organized the building of artificial water storage features leading to a more dispersed settlement pattern. Like at other sites, elites here maintained preferential access to water. All of these examples demonstrate systems that propagate inequality through disproportionate access to water between elites and nonelites.

This hydrologically induced settlement organizational also exists at the micro, intrasite scale. Many researchers have demonstrated a connection between hydrological management and the rise of hierarchical society in Mesoamerica (Lucero 1999, Spencer 1993, Spencer and Redmond 2004). As

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stated above elites maintained settlement close to hydrological resources in order to control access and distribution. If fact, that is exactly what we see within the site core at Xultun. Elite hydrological management neighborhoods are adjacent to reservoirs and important drainage channels.

I divided the site core into four main urban zones; (1) administrative, (2) residential, (3) open space, and (4) production. Administrative zoning was concentrated in the center, at the highest elevations, with residential surrounding, followed by open spaces, and then more residential. Production or quarry zones were located within open spaces close to residential zones. Based on topography, open spaces, and geographical separation I divided the urban core into 23 neighborhoods. Four of these conformed to a newly identified hydrological management group.

The ancient inhabitants constructed their ceremonial core on a ridge where the three largest drainages originated. All of the remotely sensed reservoirs were also associated with these drainages. Flood zones were concentrated to the north and east along these drainages, and six of the reservoirs were within these areas. Due to seasonal inundations, these areas had the highest agricultural potential and as such, these six reservoirs provided for irrigation. This provides information about site planning principles used by the Maya. The placement of administrative groups at the source of major drainage,

and building or reservoirs and management groups along the drainages allowed the Maya elites to control almost all of the water that fell on the site.

I performed spatial analysis on correlations between drainage and the urban zones and noted that there was higher than expected drainage from residential zones and lower than expected drainage from open spaces. This finding implies that the Maya built residential areas on raised, well-drained platforms. This adaptation would have improved the quality of life for residents during the rainy season by reducing the risk of residential flooding. The open spaces, being relatively flat, would have collected more water and may have served as urban agricultural plots.

A separate spatial analysis was performed on drainage into three central reservoirs. The drainage into the reservoirs displayed a different pattern than that over the site as a whole. The central reservoir contained runoff collected from mostly administrative zones. The twin-pool reservoir's drainage had no statistically significant difference to the overall site. The northwest reservoir contained runoff collected from residential zones, quarries and overflow from the twin pool reservoir. This suggests that the quality of water may have been lower than the central group.

This pattern, along with the agricultural reservoirs identified in flood zones, matches Scarborough's (2003) model of a convex microwatershed. This model

divides the urban landscape into three hydrological tiers with administrative use at the top, residential use in the middle, and agricultural use at the bottom.

Within the site core of Xultun there were four main drainage basins. Each of these drained to one of the cardinal directions. This quadripartite division follows the Maya cosmological view of the universe. Each of these four drainages would have held directional significance to the urban planners and designers of the site. The Maya worldview divided the universe into five directions, the four cardinal directions with a fifth direction of sacred center (Valdés 2005:58). Maya rulers in designing urban centers that would reinforce associations with religion, kingship, and the gods exploited this ideology. The use of ritual caches and the organization of Maya centers both demonstrate the modeling of cosmological ideals in architecture (Ashmore 1991; Estrada-Belli 2006). In this instance, it is hydrological drainage and not surface architecture that is conforming to this cosmological ideal. Drainage flowing out from the sacred center of the site to the four cardinal directions, dividing the city, hydrologically, into the four corners of the universe.

The association of water with the four cardinal directions is reminiscent of the rain god Chac. Chac was a quadripartite god with a representative form in each of the cardinal directions and possibly a fifth in the center. The eastern Chac is called red man Chac because red is the color associated with the east in Maya cosmology. The stela fragment representing Chac and an ancestor figure

may spell out the name Red Man Chac iconographically. This is significant because the group where this fragment was excavated falls within the eastern drainage and near its source. The placement of the offering under the residential structure during construction imbued the structure and its inhabitant with the authority and power over management of the eastern drainage.

This three tier design further reinforces the symbolic representation of Maya cosmology and religion onto the landscape. The highest tier and administrative zone is associated with heaven. The middle tier and residential zone is associated with the world of humans. The lowest tier and agricultural zone is associated with the underworld. This would have a profound impact on how the Maya viewed their environment and their place within it. The association of administrative zones and heaven would have reinforced the ideological connection between the Maya elite and the gods. The association of the Maize God with the underworld is attested to in both iconography and within the 16th c. Popol Vuh. It is common to see images of the Maize God emerging from the underworld.

The fact that drainage from specific and different urban zones was concentrated in these two reservoirs says something about how the ancient Maya viewed their land and resources acquired from it. There is evidence for a concept of riparian rights here. Water collected primarily from administrative zones served an administrative purpose and water collected primarily from

residential zones served residential needs. It seems that residents had a form of ownership over runoff collected from within their zone.

The quadrangle enclosure that housed the individual or group responsible for managing the central reservoir was part of a larger neighborhood group. This grouping of elite residence, ritual structures, and administrative compounds seems to be closely associated with water management at Xultun. These groups are located adjacent to reservoirs or important drainages. Another of these neighborhoods was adjacent to the residential reservoir to the northwest of the site.

When including the archaeological evidence excavated in Grupo Tortuga and the close association of similarly organized neighborhood groups with hydrological drainage and storage features, there is strong evidence that these groups represent administrative water management centers. This points to a continued elite involvement in the collection, storage, and distribution of water resources. Very probably, these groups served to control access to this resource and to control its release downstream. This supports a hierarchical model for water management at Xultun. Although there is some evidence for riparian rights to water, the reservoir associated with residential usage also maintained a large administrative group suggesting elite oversight.

Excavations within the central reservoir, its drainage system, and an associated residential group demonstrated that by the Late Preclassic the

ancient inhabitants had shaped, sealed, and enclosed the area to function as a reservoir. The monumentality of this initial construction points to elite management in site planning. Several structures collected drainage from administrative areas to the north. These included diversion weirs, an aqueduct, an open canal, and a large dam in the form of the eastern causeway. The system developed over time and was modified and expanded when necessary demonstrating the continued involvement of elites in the management of this resource.

Water management was instrumental in the maintenance of power for the Classic Maya rulers. The maintenance of additional storage tanks provided Maya elite with a means in which to control the agricultural productivity of their populations. This control would have led to an increasing agricultural surplus, providing for nonagricultural specialists, and the development of urbanism. During times of decreased rainfall, having backup stores provided an economic insurance policy for the population. The provisioning of water downhill from the administrative center may have justified the extraction of tribute, in the form of food and other products, from the population further reinforcing social inequality. As a key element of statecraft, the stratified spatial organization supported the hierarchical social order that took root in the Preclassic and came to characterize Maya urbanism. The introduction of cosmological principles and associations

with the Rain God served to reinforce the social inequalities propagated through disproportionate access to water at Xultun.

Future Directions

The next step in understanding water management at Xultun and the role of elite management is to concentrate excavations on the administrative groups within the water management neighborhoods. Excavations within these groups would better define how they were associated with the water management and what types of activities were taking place there. The patterning of settlement into these water management neighborhoods should also be looked for at other large Maya Lowland sites. This would help to determine if these groups are a local phenomenon at Xultun or if they represent an administrative practice across the Lowlands.

The use of remote sensing was an important element in the identification of both water storage features and administrative settlement associated with these features. In this instance, the Quickbird data was highly effective at recognizing these features while the IKONOS was not. This was primarily due to the time of year the images were captured but may also have been impacted by differences in the two platforms. This demonstrates that it is not enough to acquire satellite imagery of an area. The time of year the image is collected and

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the platform used will have an enormous impact on the results. Obviously, regional differences in water availability will also impact the results of analysis on vegetation stress. The continued experimentation with new remote sensing technologies will enhance our ability to identify ancient features below the canopy.

The development of a preliminary urban zone map at Xultun was an attempt at organizing the space in such a way that opens up analysis of ancient sites to urban geographers. This will allow new approaches to interpreting how the ancient Maya and other ancient cultures organized their spaces, and how these different zones interacted both with resources and with each other. This approach has the potential to unlock important socio-political information from the archaeological record that was previously unavailable. This was a first attempt at organizing the space at Xultun into urban zones. This technique needs to be refined in order to develop a typology of urban zones that can be applied to other large Maya sites.

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Woolley, L.
    1954 Excavations at Ur: A Record of Twelve Years' Work. New York, NY: Barnes and Noble.

Wright, Lori E. and Francisco Chew
    1999 Porotic Hyperostosis and Paleoepidemiology: A Forensic Perspective on Anemia among the Ancient Maya. American Anthropologist 100(4):924 939.

Wu, Changhua with Crescencia Maurer, Yi Wang, Shouzheng Xue and Devra Lee Davis
    1999 Water Pollution and Human Health in China. Environmental Health Perspectives 107(4):251-256.

Zipf, G. K.
    1949 Human Behavior and the Principle of Least Effort; an Introduction to Human Ecology. Cambridge: Addison-Wesley Press.

Curriculum Vitae

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ACADEMIC POSITIONS

Teaching Assistant, Menorca, Spain   Jun. – Jul.
2013, 2014
Boston University, Department of Archaeology
Supervisors: Dr. Ricardo Elia and Dr Amalia Pérez-Juez
-Instructor: Archaeological Field Methods/Archaeological Heritage Management

School Programs Volunteer, Charlotte, North Carolina   Feb. –
Mar. 2013
The Mint Museum, Randolph Road
Supervisor: Joel Smeltzer
-Analyze de-accessioned Maya Pots
-Update Classroom Component of Ancient American Collection

Teaching Assistant, Antigua/Petén, Guatemala   Spring Semesters
2010, 2012
Boston University, Department of Archaeology
Supervisor: Dr. William Saturno
-Instructor: Archaeological Field Methods: Field Preparation
-Grader/Reader: Maya Archaeology

Teaching Assistant, Boston, Massachusetts   Fall
Semester 2009
Boston University, Department of Archaeology
Supervisor: Dr. William Saturno
-Grader/Reader: Ancient Maya Civilization

Library Assistant, Cambridge, Massachusetts   Jan. 2007 –
Dec. 2008
Harvard University Graduate School of Design
Supervisor: Desiree Goodwin
-Circulation Desk

Research Assistant, Cambridge, Massachusetts   Spring
Semester 2007
Harvard University, Department of Anthropology
Supervisor: Dr. Ian Gilby
-Examination of Field Notes/Data Entry
-Analysis of Data/Identification of Patterns

ARCHAEOLOGICAL FIELDWORK

Part-Time Archaeology Technician
Oct.-2014
Archaeological Consultants, Inc.
-Archaeological Field Technician/Survey Phase 1

Part-Time Archaeology Technician   Mar.-2013 –
Sept.-2014
Barr & Associates
-Archaeological Field Technician/Survey Phases 1-3

Isla del Rey/Torre d'en Galmés Project, Menorca, Spain   Summer
2013, 2014
Boston University, Department of Archaeology
-Archaeological Survey/Field Archaeologist

Xultun/San Bartolo Project, Peten, Guatemala   Spring 2010,
2012, 2014
Boston University, Department of Archaeology
-Cartographer/Field Archaeologist

Salvage Archaeology, Back Bay, Boston, MA
Fall 2010
Boston University, Department of Archaeology
-Excavator

Harvard Yard Archaeology Project, Cambridge, MA   Academic Year
2007/2008
Harvard University, Department of Anthropology
-Lead Excavator/Lab Assistant

Harvard University Field School, San Jose de Moro, Peru
Summer 2007

Harvard University, Department of Anthropology
-Excavator/Lab Assistant

<u>EDUCATION</u>

Boston University Graduate School of Arts and Science, Boston, Massachusetts
Ph.D Candidate, Archaeology
-Archaeology of Mesoamerica   -Settlement Archaeology
-Archaeology of the Ancient Maya   -Remote Sensing and GIS

Harvard University Extension School, Cambridge, Massachusetts
05/2008, *Bachelor's Degree, Special Concentration: Anthropology and Archaeology*
Harvard College, Cambridge, Massachusetts
09/2007 – 05/2008, *Special Student*

<u>PUBLICATIONS</u>

Ruane, Jonathan. 2012. <u>Excavaciones en la Aguada 11J-19, Xultun</u>. In Proyecto Arqueológico Regional San Bartolo y Xultun Informe Annual No. 11. Edited by Patricia Castillo and William Saturno. El Instituto de Antropología e Historia de Guatemala, Guatemala

Ruane, Jonathan. 2012. <u>Mapeo en el Sitio Arqueológico Xultun</u>. In Proyecto Arqueológico Regional San Bartolo y Xultun Informe Annual No. 11. Edited by Patricia Castillo and William Saturno. El Instituto de Antropología e Historia de Guatemala, Guatemala

Ruane, Jonathan. 2010. <u>Mapeo en el Sitio Arqueológico Xultun</u>. In Proyecto Arqueológico Regional San Bartolo Informe Annual No. 9. Edited by Luis Alberto Romero and William Saturno. El Instituto de Antropología e Historia de Guatemala, Guatemala

Gilby, I.C., Emery Thompson, M., Ruane, J., Wrangham, R.W. 2010. No evidence of short-term exchange of meat for sex among chimpanzees. <u>Journal of Human Evolution</u> 59: 44-53

CONFERENCE PRESENTATIONS

"Remote sensing of a Classic Maya hydrological management system at Xultun, Guatemala using high resolution Quickbird satellite imagery.", Paper presented at the South-Central Conference on Mesoamerica. New Orleans, Louisiana, October 25th, 2014.

"Survey on Isla del Rey: A Diachronic Analysis of Menorca's Hospital Island", Poster presented at Archaeology of Iberia: State of the Field, Brown University, February 28th, 2014. (co-author with Alexander Smith and Meredith Langlitz)

"Survey on Hospital Island: Results from the 2013 Field Season on Isla del Rey, Menorca", Paper presented at the Society for American Archaeology 79th Annual Meeting. Austin, Texas, April 27th, 2014. (co-author with Alexander Smith, Meredith Langlitz, Dr. Amalia Perez-Juez, Dr. Paul Goldberg, and Dr. Ricardo Elia)

"An Urban Reservoir at Xultun, Guatemala", Paper presented at the Society for American Archaeology 78th Annual Meeting. Honolulu, Hawaii, April 2013.

"Del Preclásico tardío al Clásico temprano: cambios, continuidades, y nuevos hallazgos en la región San Bartolo-Xultun", Presented as part of *Sociétés mayas millénaires: crises du passé et resilience* Musée du quai Branly. Paris, France, July 2nd, 2011. (co author with Dr. William Saturno, Boris Beltrán, Patricia Rivera, Luis Romero, and Franco Rossi)

QUALIFICATIONS/SKILLS

Fluent in English and Spanish; working knowledge of German.
Computer Programs: Microsoft Office, Adobe Illustrator, Photoshop, ArcGIS, ENVI.
Knowledge of total stations, data collectors and surveying equipment.
Ceramic thin section petrography.

PROFESSIONAL ORGANIZATIONS

Society for American Archaeology
Archaeological Institute of America