Delineation of Archaeological Site Looting Damage in Central Iraq

ABSTRACT

Looting of archaeological sites has taken place throughout antiquity. This is especially the case on the Central Mesopotamian Plain of Iraq. Such looting has been accelerated since the overthrow of the former Iraqi government and thus the need to document the extent of this damage has become imperative. To aid in this determination imagery from DigitalGlobe's WorldView satellite, with its half meter resolution, was employed to identify over 40,000 individual looting pits at 265 sites. The satellite data were manipulated in ERDAS and the Image Analyst tool in ArcGIS. These data were combined with a GIS database compiled from decades of ground investigations. The observations and delineations obtained have been combined for spatial data analysis involving distribution and density measures using the Spatial Analysis tools in ArcGIS.

Throughout the present-day country of Iraq thousands of archaeological sites can be found; dating back over thousands of years. A major concentration of these sites is on the Mesopotamian Plain south of the capital of Baghdad. The settlement pattern history in Mesopotamia is one of continuous change and seemingly delicate balance (Gauche, 1998). Over the last two centuries a number of these locations have been studied and excavated by teams of archaeologists. Some of the most extensive work was done in the central portion of the Plain. The systematic investigation of agriculture and irrigation systems through archaeological survey began with Jacobsen and Adams' work in the Diyala Basin Archaeological Project in the 1950's (Adams, 1965; Jacobsen, 1957). Adams surveyed one third of the central alluvial plain of southern Mesopotamia. His largest survey area was the central portion of the plain that he investigated from 1968 to 1975. He covered an area of hundreds of kilometers both on foot and in vehicles. In areas where ground survey was difficult or not possible, Adams supplemented his study by using aerial photographs (Adams, 1981). Small subsidiary surveys helped to fill in more specific settlements questions aimed at understanding the development of settlement systems through time in this dynamic environment (Adams, 1972; Gibson, 1972; Wilkinson, 1990).

Unfortunately, along with the scientific study of ancient sites comes their plundering and destruction. This is a problem world-wide and is certainly no different in Iraq. What is different here; however, is the combination of systematic plundering and casual looting on a national scale. Following the ouster of Saddam Hussein's regime during the last Gulf War there is no longer any central control or authority in the rural areas to stop such destruction.

An expedition organized by the National Geographic Society (NGS) in 2003 documented some of this destruction (National Geographic, 2003). Looters will dig holes about three to four meters wide and several meters deep to uncover what artifacts they can find. If they find nothing of value they move a few meters away and dig a new hole (Figure 1). At some major sites such as Umma or Zabalam the area has been turned into a moonscape. With such potential for irreversible destruction and loss of archaeological evidence it is vital to find out how widespread is the occurrence of this plundering. More recent evidence is needed to indicate what has been happening in the intervening years (Hamdani, 2008; Stone, 2008). Because of the political and military situation in the country, ground investigations are no longer safe.

The most viable option would be to employ remote sensing techniques using either aerial photography or precision satellite imagery. With no civilian commercial air photo projects being flown, satellite imagery is the logical choice (Richason and Hritz, 2007). Considering the dimensions of the holes being dug, imagery with a resolution of around 1 meter would be needed. At first Digital Globes Quickbird satellite imagery was going to be used; however, in 2007 a new sensor system became available; Worldview 1. This newer satellite had better positional accuracy and resolution, approximately 50 cm, rather than the 61 cm of Quickbird (Digital Globe, 2010). Moreover, geolocational accuracy is greatly improved with Worldview 1 at 5 meters as compared with

Quickbird's 23 meters. With the selection of the study area, Digital Globe tasked the satellite to obtain the needed coverage.

STUDY AREA

The location of the study area was chosen because of the author's previous experience in working on other research project in the vicinity. The dimensions of the study area were constrained by the amount of funding available for the purchase of satellite imagery. While a much larger area would have been desirable, an area determined by the number of affordable square kilometers was selected. Actually three separate image regions were chosen (Figure 2). The rationale for the selection was to choose some major locations to see to what extent, if any, well known sites had been damaged. The first two sites centered on specific excavations, Nippur and Zibliyat, The third area consisted of a single region located in an irrigation over-flow depression called Lake Dalmaj. . The Lake Dalmaj site was chosen because previously water filled the lake basin, though water levels vary greatly with seasonal flow. Today much of the lake area is dry throughout the year.. Many smaller sites that were inaccessible to looters because of their isolation by water are now vulnerable. It was thought that this area would serve as a good indicator of how widespread the problem of plundering has become. This could show that not only have major locations been attacked, but perhaps minor, undocumented ones as well.

GEODATABASE

Upon the receipt of the Worldview 1 imagery the first task was to create an ArcGIS geodatabase to hold the various feature datasets and remote sensing raster imagery. The first dataset entered was the digitized version of Adams's Site Catalog. This digital catalog was used as a reference guide in order to get a basic idea of where to look for various archaeological sites within the study area. When overlaid on top of the satellite imagery it was apparent that there was not a perfect correspondence between the catalog site locations and the apparent archaeological sites on the imagery. Once again it must be remembered that the site locations gathered on the ground were the result of a wide-area ground reconnaissance survey done prior to the implementation of the Global Positioning System (GPS). The positional shifts between these two sources, while noticeable, were still within an average linear distance of about 300 meters. To compensate for these errors a multiple ring buffer was performed on the catalog site points of 300, 400, and 500 meters and from it a new feature dataset was created. Furthermore, a simple density map from the catalog sites was created in order to ascertain the concentration of sites within the study area (Figure 3). It would be used later to compare site concentrations with the density of looting pits within the site polygons.

In addition to these datasets, others were created for the location of the boundaries of archeological sites, individual looting pits, and the boundaries marking the extent of damage in each individual site. Finally, additional image sets were also added. These included Landsat TM, SPOT, Corona, and Radarsat imagery. While these images did not possess the needed resolution for the identification of single pits, they did provide a good backdrop for site locations and land cover/use information.

INTERPRETATIVE TECHNIQUES

The techniques used in the study were primarily those of simple visual interpretation. The first task was to delineate the known archaeological sites in the study area taken from the Adams dataset. Starting with those in the northern part of Lake (Hawr) Dalmaj. The digital site catalog was overlaid onto the mosaic of Worldview 1 imagery. The site buffer dataset was also overlaid because of the potential for spatial site offsets in location. These buffers provided a search radius for image detection. The delineation of sites for identification relied on looking for areas where there was a lack of either natural or cultural vegetation. Most of the sites stood out in stark contrast to the surrounding land cover reflectance. These tonal variations, in addition to size, shape, and shadow, were all utilized to define the boundaries of the Adams sites. Shadows, in the form of edge definition, were quite useful in these demarcations because wherever there is relief on the plain it is probably and ancient occupation site (Figure 4) . As Dr. McGuire Gibson of the University of Chicago stated; "…there are no natural hills in southern Iraq, and if you see a hill, in most cases it's the mound of a buried ancient settlement." (Wilford, 2003).

Another important set of linear features that were studied for site identification were vehicle tracks (Figure 1). The assumption being made here was that these were the vehicles of the looters going to and from the sites; necessary in hauling the looters and their equipment to the sites and their plunder away. Such tracks, usually occurring in multiple sets, were quite prevalent throughout the study area. By following the course of these tracks they usually lead to mound sites in the lake region. It could certainly be argued that not all of these tracks were made by looter vehicles, but instead by farmers getting to fields or workers maintaining the canal system in the area. While this is certainly the case, many of the track patterns were seen in areas devoid of cultivation or the presence of canals. They lead to mound sites and wove in and around what would later be identified as looting pits.

The digital catalog also held information on the shape, area, and orientation of each site. This information also proved to be of great value in deciding which site referred to which image location. Many of the outlines of the site polygons closely corresponded to the original descriptions in the site catalog; particularly the distances between them. The outline dimensions of the sites did vary from the original ground descriptions. While some of this was the result of individual interpretation, the remote sensing perspective did provide an overview not afforded from ground observation. After the initial site delineations were made they were reviewed once again and adjustments were made as needed. Furthermore, as the original Adams sites were located, additional ones that were not identified and cataloged during the original ground survey were discovered and added to the Site_Polygon dataset.

Once the site boundaries were ascertained and defined, the next step was to go back over each individual site and see if, and to what extent, any looting damage was present. This damage was in the form of holes or pits that looters had dug to discover clay tablets, pottery, inscribed cylinders, and other artifacts. Once again visual interpretive techniques were employed to detect each individual pit and count it. Here the image characteristics of shape, shadow, and tone were to prove especially helpful as pits varied quite a bit in their dimensions and concentration (Figure 5).

Most pits were circular in shape, though rectangular ones occurred as well. Care had to be taken not to confuse loot pits with the forms of ancient circular mounds or building foundations; perhaps from some previous archaeological excavations. Also of importance in pit identification were the interrelated factors of tone and shadow. Similar to interpreting features such as volcanoes or the tops of oil tanks, the shadows cast down into depressions is one of the key elements in pit identification. Closely associated with this would be the tonal variation between the dark shadow at the bottom of a pit and the much lighter excavation debris found around the rim of the pit which tends to form a sort of "bull's-eye" effect. Also contributing to darker tones inside the pits would be the possibility of darker subsurface soil material and moisture at depth (Stone, 2008).

While these techniques proved valuable from time to time there were difficulties in pit identification. One potential problem with simply assuming that groupings of small, dark tones represented pit shadows or moist soil, was the fact that clumps of small desert shrub vegetation tend to yield similar tones. In some instances it was difficult to make the distinction between the two; however, other factors helped differentiate pits from surrounding plant growth. First, the central portions of the occupation sites tended to be devoid of vegetative cover. It was not until the edges of the site were approached that vegetation began to occur (Figure 6). Secondly, some of the individual shrubs tended to be larger than some of the pit circumferences and the vegetation did not have the lighter-toned ring of excavation debris around them. Care also had to be taken to not confuse looting pits with spoil debris from the excavation and maintenance of nearby irrigation canals.

Another problem that presented itself in detecting individual pits was overlap (Figure 5). On some sites the number, size, and spacing of the pits was such that they appeared to be coalescing. The debris from one pit was piled onto that of an adjacent one. The effect was to produce a landscape of rolling, hilly piles of rubble making the discovery of individual pits very difficult. Further complicating defining pits was the problem of erosion and deposition of surface material by eolian effects. During certain times of the year Iraq is subjected to serve, wide-ranging dust storms. For older pits that have been subjected to such conditions over the years the form and tonal reflectances will change. As they fill in with windblown material, the pit depths become shallower thus reducing the shadow effects and subduing tonal differences. While this makes detection more difficult, it also affords the advantage of relative age differentiation (Stone, 2008).

Finally, pit size also affected interpretability as can be seen in Figure 5. The dimensions of individual pits can vary quite a bit, and thus the detection of smaller sized pits becomes a factor of resolution. As previously noted, the Worldview 1 satellite resolution is .5 meters (50 cm). Still, it takes a group of contiguous pixels to form an identifiable image shape. Operating at the edge of resolution (a scale of around 1:900) for pits of these small sizes, individual shape identification was difficult.

Beyond using simple visual techniques, the digital enhancement of the sites was also employed to bring out the detail of the pits. Various techniques such as contouring and embossing were utilized to enhance detail not readily seen on the original image. To carry out these enhancements the sites from the original image mosaic were clipped out in ArcMap and then saved as a GeoTiff file. In this format the image could be exported to a program such as Adobe Photoshop for enhancement; specifically using routines such as Contour and Emboss. In the case of embossing the detail of the loot pits would have a “raised” effect which offered the ability to better isolate individual features (Figure 7). Similarly, the contour effect allowed for the boundary outline of individual depressions to become more evident. The results of both of these techniques were saved and imported back into the geodatabase where they were overlaid on the original imagery. By specifying a certain amount of transparency in the display both the imagery and the embossed enhancement could be seen together. Such a composite brought out detail, especially of smaller or degraded pits, that was not as clearly visible on the original image. Once again, care had to be taken not to confuse vegetation with pit shadows as the techniques for enhancing pits would also enhance dark vegetation in a similar manner. With the completion of the pit count, polygons were digitized around each concentration of holes in order to be able to ascertain the area covered by this damage. An example of these results can be seen in Figures 8 and 9.

RESULTS AND CONCLUSIONS

While some sites presented challenges in interpretation, most were easily enough resolved. With the completion of the identification and delineations of the pits an initial total of 61,235 individual pits on 196 sites were found; an average of 316 pits per site. On some sites the distributional pattern of the pits appeared to be irregular or haphazard, while on the others portions of a grid-like or regular pattern could be discerned. There were also a differences in the concentration of these distributions, which would vary from a site being completely covered with pit damage to others where the damage, though extensive, was concentrated in one or two parts of the site.

With the creation of the geodatabase and manipulation of the feature datasets, a number of new datasets were created to study the degree and extent of looting damage. A density map of the pits was first created to display the distribution and concentration of the destruction (Figure 10). It was then compared to the density map of the Adams site catalog. It might be expected that areas with the greatest amount of damage would be associated with the greatest degree of site concentration in terms of looter access and activity. In addition to the density display, an Intersect overlay was generated from the site polygons and the looting area polygons. This was done to see what the percent of destruction was for each site.

In studying the point density display and comparing it to the site density display some interrelated spatial patterns were discerned. To an extent where there was a high density of sites there was also a correspondingly high density of damage (Figure 10). Other areas of high density damage; however, were also seen in portions of the study area that were some distance away from these site concentrations. These were located out in the lake area and along the orientations of ancient canal lines. It had been thought that some of these sites might have been afforded some protection because of the water coverage in the lake. This does not appear to be the case. As Lake Dalmaj has undergone seasonal and diversional fluctuations in water level, many areas, including the study area, have dried up. Looters now have access to these sites and are taking advantage of the situation.

This is evident in the quantitative measure of the damage. Aside from the sheer number of pits, what was more noteworthy were the percentages of each site that sustained plunder. The two larger sites, Nippur and Zibliyat, were excluded from the calculations. Fortunately, these sites did not appear to have suffered much damage when the imagery was studied, and tended to negatively skew the average calculations. By including them the average area of site damage was about 13%, but in excluding them the average rose to 20.47%. It is believed that this figure is more representative of the average destructive suffered by the smaller sites spread throughout the countryside of the study area. When considered as a frequency the distribution the percent damage can be noted in the histogram in (Figure 11). A breakdown of this general average shows that 37% of the sites showed loot damage covering about a third of the site area. When looking at a range of 40 to 60% damage 16 % of the sites are affected. A further 7% of the sites had damage between 60 to 80%. These figures should be viewed as generalizations. An important variable influencing the accuracy of the percent value is the amount of area delineated for the site polygons. Care was taken in these delineations and was usually considered to be relatively accurate. Still, a conservative approach was used to define an area that was thought to be all inclusive; meaning that some site polygons could be larger than they should be. Taking this into account, the number of sites with a larger percent of damage would probably increase.

The conclusions drawn from this research are twofold. First, in assessing the looting impact on known, cataloged sites in the study area it was evident that considerable destruction has occurred. While the good news was that damage to two large, prominent sites appeared to be negligible, this was not the case for smaller sites in the more remote countryside. Each of the sites observed showed some degree of looting desecration. The intensity of this destruction varied over space as noted on the density displays, but the patterns did coincide with cultural and terrain features in the form of mound sites, ancient canal systems, and former drainage channels. Regardless of what percentage of a site experienced damage, all were compromised and the integrity of the context of their artifacts will be very difficult, if not impossible to determine.

The second set of conclusions concern the integrated use of precision, high resolution satellite imagery and GIS geodatabases in such studies. This particular study could not have been accomplished without the use of the Worldview 1 imagery data. The ability to detect and differentiate the relatively small, compact, and in some cases degraded, loot pits would have been impossible without such imagery. While other sensors are available, the accuracy and resolution provided by Worldview 1is invaluable for studies of this type. In addition to the imagery, just as important was the ability to integrate it into a GIS geodatabase. Being able to create and overlay a digital version of the Adams site catalog provided an initial guide as to where concentrate the search for evidence of looter impact. Furthermore, being able to have high resolution imagery as a backdrop for digitizing in ArcMap was invaluable. Finally, the ability to generate density displays from the digitized points provided a means of interpreting the concentrations and patterns of looter destruction. The quantification of the loot point data by intersecting site and looting polygons enabled the creation of percentage values to better comprehend the impact of the site damage.

The techniques and results discussed above confirm the fears that many professional archeologists and academics have had concerning the loss of invaluable information in this ancient region of Mesopotamia. While ground verification may be out of the question at this time, the use of remote sensing imagery and GIS spatial analysis can fill the void until such time as ground investigations and verification can be done.

FIGURES

Figure 1

The oblique photo above shows a landscape of looter pits and vehicle tracks on the Mesopotamian Plain. (Copyright of Comando Carabinieri T.P.C. Italy)

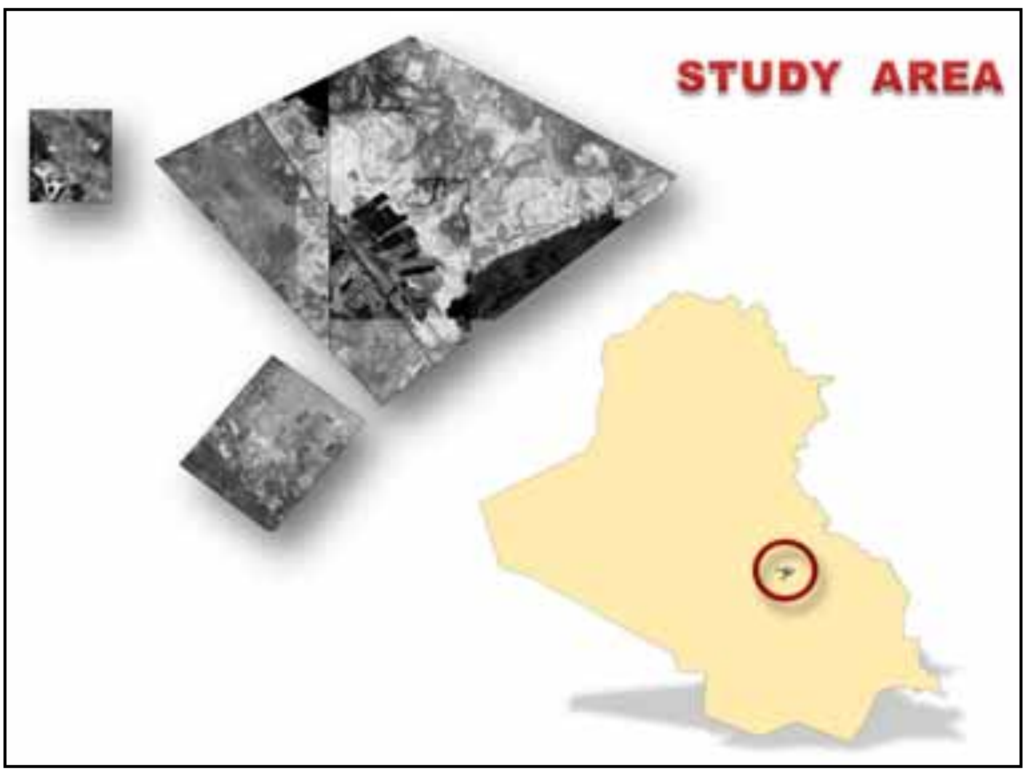

Figure 2

This figure shows the general location of the study area in Iraq, as well as a satellite mosaic of the three study area regions.

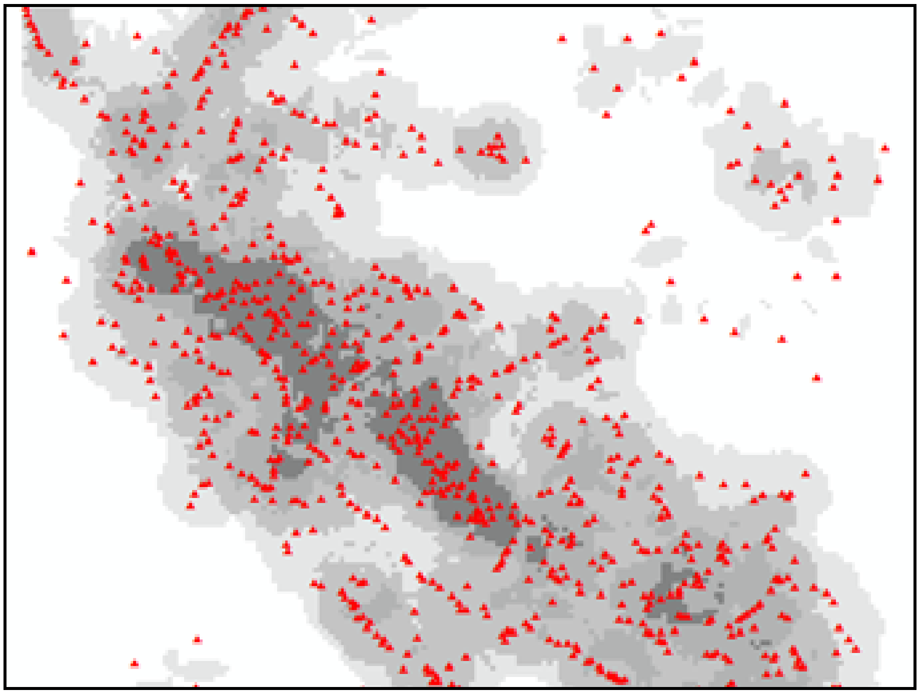

Figure 3

The red triangles on this display represent a portion of the sites from the Adams digital catalog covering the study area. The gray areas represent a portion of a ArcMap density display of these same sites showing their concentration.

Figure 4

The oblique photo above illustrates the raised outline and edge definition of a site.. (Copyright of Comando Carabinieri T.P.C. Italy)

Figure 5

This photo shows the concentration and variable pits sizes in an area of loot destruction. (Copyright of Comando Carabinieri T.P.C. Italy)

Figure 6

This is a Quickbird image showing the distribution of vegetation around a mound site in the southern portion of Lake Dalmaj. Note how it defines the edges of the site as seen at the arrows. (Courtesy of Google Earth)

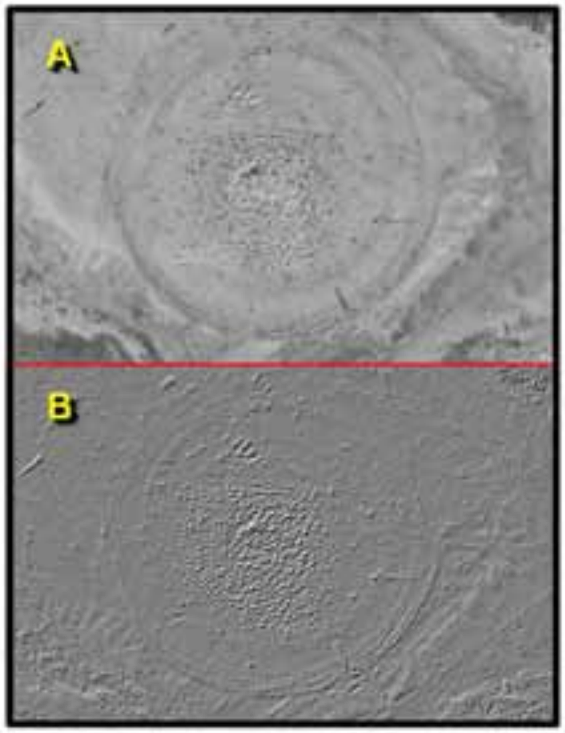

Figure 7

The figure at "A" is Tell Arsan, a site in the Lake Dalmaj area which shows major loot damage. The bottom image at "B" represents the results of embossing enhancement. Note how the pits now stand up in "relief" making them easier to detect.

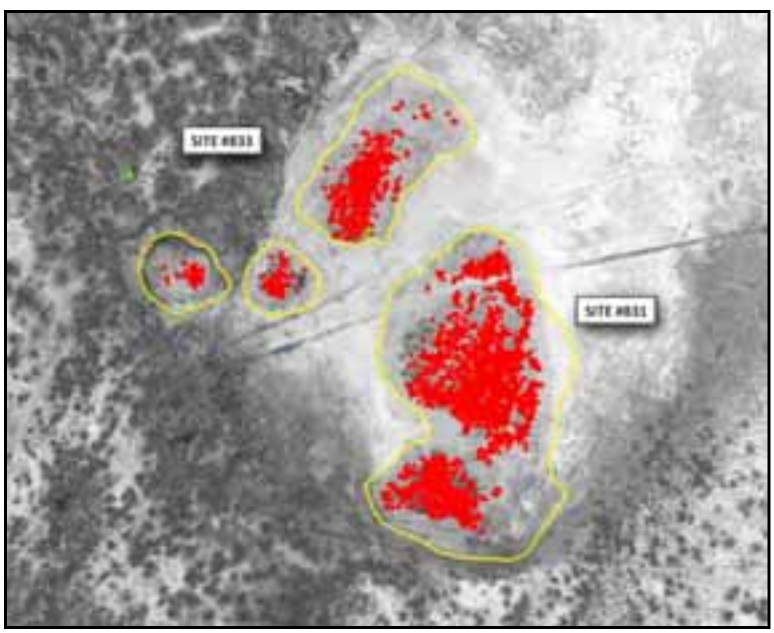

Figure 8

An image from ArcMap that represents the boundaries of two site complexes in Lake Dalmaj. The yellow lines indicate the extent of the site boundaries and the red dots indicate the location of individual loot pits. (Courtesy ESRI)

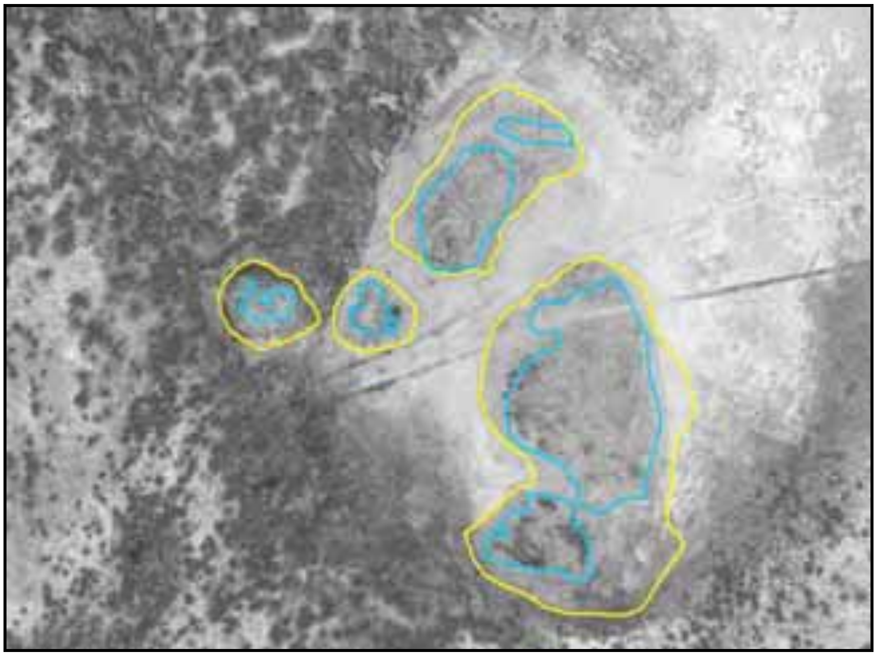

Figure 9

The same two site complexes are seen above.. Again, the yellow lines indicate the extent of the site boundaries, but now the interior blue outlined polygons represent the extent of site damage. (Courtesy ESRI)

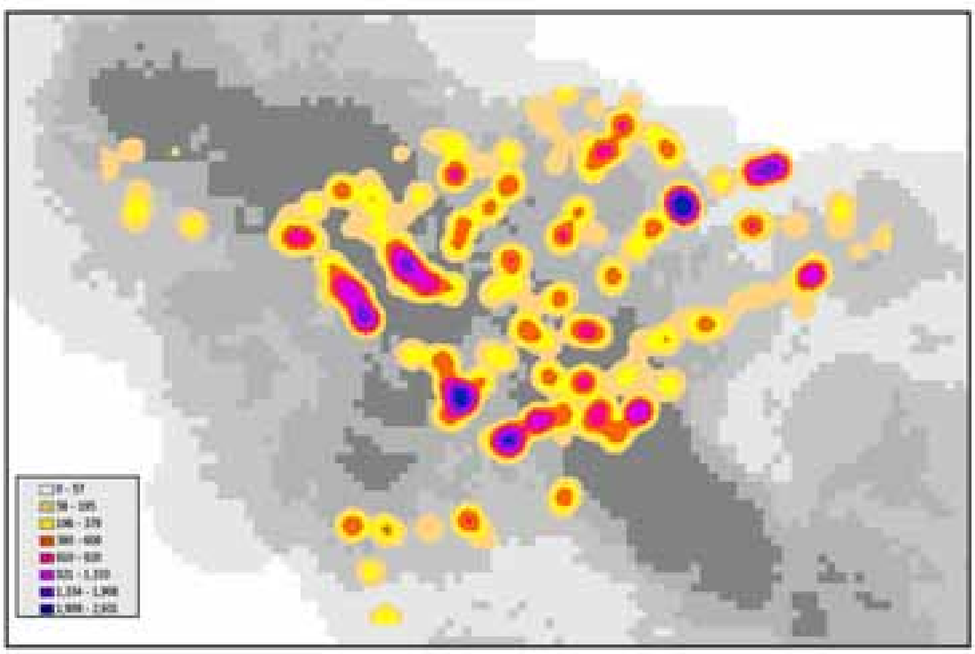

Figure 10

The display above is a portion of the pit density calculation. The dark blue and purple colors indicate the most severe damage detected. This display has been overlaid on the site catalog density display for comparison.

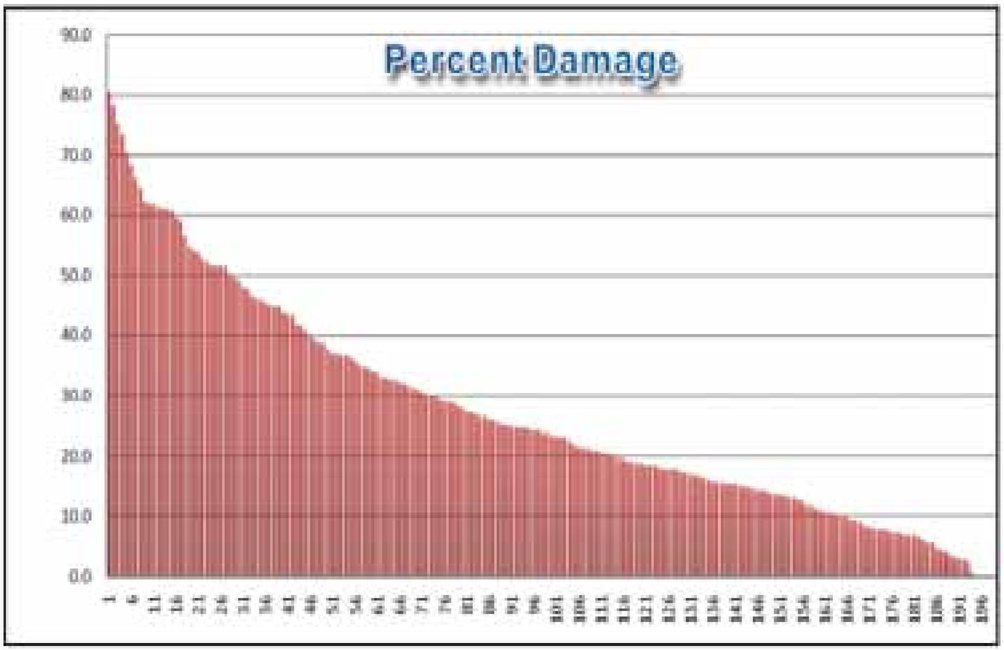

Figure 11

A frequency histogram showing the percentage of loot damage for each of the sites in the study area. This calculation was the result of an intersect overlay operation of loot polygons over the site polygons.

SELECTED REFERENCES

Adams, R. McC., 1972, Settlement and Irrigation patterns in Ancient Akkad. In *The City and Area of Kish*, edited by McG. Gibson, Field Research Projects, Miami.

Adams, R. McC., 1981, *Heartland of Cities*. University of Chicago Press, Chicago.

Algaze, G., 2001, Initial Social Complexity in Southwestern Asia: The Mesopotamian Advantage. *Current Anthropology* 42: 199-233.

Buringh, P., 1960, *Soils and Soil Conditions in Iraq*. Republic of Iraq, Ministry of Agriculture, Baghdad.

DigitalGlobe, 2010, *DigitalGlobe Core Imagery Products Guide*, pp. 1-31.

Ebert, J. and Lyons, T. Eds., 1983, Archaeology, Anthropology, and Cultural Resources Management. In Estes, J. Vol. II Ed., *Manual of Remote Sensing*, pp. 1233-1304. American Society of Photogrammetry. The Sheridan Press, Falls Church, VA.

Ehlers, M., Edwards, G., and Bedard, Y., 1989, Integration of Remote Sensing with Geographical Information Systems: A Necessary Evolution. *Photogrammetric Engineering and Remote Sensing*, 57: 669-675.

Gasche, H and Cole, S., 1998, *Changing Watercourses in Babylonia: Towards a Reconstruction of the Ancient Environment in Lower Mesopotamia*, edited by H. Gasche and Tanret, M., University of Ghent and the Oriental Institute of the University of Chicago, Mesopotamian History and Environment Series II: V., University of Chicago Press, Chicago.

Gibson, McG. 1972, *The City and Area of Kish.* Field Research Projects, Miami.

Hamdani, Abdulamir, 2008, Protecting and Recording Our Archaeological Heritage in South Iraq, *Near Eastern Archaeology*, 71:4, pp. 221-230.

Hritz, C. 2010 *Tracing Settlement Patterns and Channel Systems in Southern Mesopotamia Using Remote Sensing Journal of Field Archaeology* 35:2 In Press summer 2010

Hritz, C. 2007 Remote Sensing of Sites in and Around The Hawr Al-Hammar and Hawr Al-Hawiza. *Akkadica 128* Appendix III.

Jacobson, T., 1957, *Salinity and Irrigation Agriculture in Antiquity. Diyala Basin Archaeological Project.* Report on Essential Results. June 1, 1957-June 1, 1958. Unpublished.

Kennedy, D.,1998, Declassified Satellite Photographs and Archaeology in the Middle East: Case Studies from Turkey. *Antiquity* 72: 553-61.

Lawler, A. 2003. Iraq's Antiquities War. *National Geographic*. October 2003: pp. 58-75.

Postgate, J and Moorey, P., 1976, Excavations at Abu Salabikh. *Iraq 38:* 133-170.

Pournelle, J., 2003, *Marshland of Cities: Deltaic Landscapes and the Evolution of Early Mesopotamian Civilization*. University of San Diego, Anthropology unpublished dissertation.

Richason, B. and Hritz, C., 2007, Remote Sensing and GIS Use in the Archaeological Analysis of the Central Mesopotamian Plain, In Wiseman, J. and El Baz, F., *Remote Sensing in Archaeology*, Chapter 12, pp. 283-328.

Stone, E., 2008 Patterns of Looting in Southern Iraq, *Antiquity*, vol. 82, no 315, pp 125 – 138.

Verhoeven, K., 1998, Geomorphological Research in the Mesopotamian Flood Plain, In *Changing Watercourses in Babylonia: Towards a Reconstruction of the Ancient Environment in Lower Mesopotamia*. edited by H. Gasche and Tanret, M., University of Ghent and the Oriental Institute of the University of Chicago Press, Mesopotamian History and Environment Series II: V.

Wescott, K. 2000, Introduction, In *Practical Applications of GIS for Archaeologists*, edited by Wescott, K. and Brandon, J., Taylor and Francis, London.

Wilford, J. War in Iraq Would Halt All Digs in Region, *New York Times*, February 25, 2003, Section E, p. 1.

Wilkinson, T., 1990, Early channels and Landscape Development Around Abu Salabikh: A Preliminary Report". *Iraq 52:* 75-83.

Wilkinson, T., 2003, *Archaeological Landscapes of the Near East.* University of Arizona Press, Tucson.

Wright, H., 1981, The Southern Margins of Sumer: Archaeological Survey of the Area of Eridu and UR, In *Heartland of Cities*. Adams, R.McC. University of Chicago Press, Chicago.