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An exploratory GIS approach to Andalusian Archaeological Heritage Records

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13.1 Introduction

The creation of systematic and comprehensive inventories of archaeological sites intended as a means for heritage management and protection started in Spain only very recently. During the last two decades, the transformation of the old centralist state has produced a completely new administrative system, where every autonomous region has assumed full responsibility in the design and implementation of policies addressed towards the protection of archaeological sites. At present, this new administrative structure has come to produce a rather diverse panorama of legislative models and archaeological management strategies across the country, as well as some legal contradictions which have not yet been resolved (Querol *et al.* 1995). However, it seems unquestionable that as far as the archaeological heritage is concerned, one of the most positive effects of the current structure of autonomous administrations has been the impulse to create and permanently update systematic catalogues of archaeological sites, sometimes from scratch. Some recent publications have dealt with general issues and problems arising in the process of the construction and management of these regional archaeological site records (Antona 1993; Burillo 1992; Burillo & Ibañez 1991; Espiago *et al.* 1993; Hernandez & Castells 1993), a field of archaeological work where, unlike other northern European countries (Cleere 1984, 1989), Spain had little or no previous tradition.

In the case of Andalucía, the process of legal decentralization culminated in 1991, when the Law of Andalusian Historical Heritage was passed by the regional parliament, thus completing the national Law of Spanish Historical Heritage promulgated in 1985. One of the basic provisions of this law was the creation of an efficient record of historical and archaeological sites as a tool for heritage protection (Title I, Article 6).

In fact, the creation and maintenance of a general record of archaeological sites in Andalucía had already begun in 1984, soon after the regional government became responsible for the administration of cultural and historical resources. Regardless of some relevant modifications of the data structure and cartographic scale on which the archaeological information has been recorded (described below), one recurrent feature of the approach followed between 1984 and 1994 has been its non-computing nature. In other words, the bulk of data that has been progressively produced over the last decade (a period of intense fieldwork activity, seen both in archaeological surveys and excavations) has been stored, handled and retrieved according to a traditional card index basis. This approach has been in sharp contrast to the data management policy pursued by the environmental protection agency (*Agencia de Medio Ambiente*), largely based on Geographic Information Systems (GIS) and Data Base Management Systems (DBMS — see for example Barragan & Moreira 1990; Moreira & Fernandez 1995; Rosa & Moreira 1987).

The need for a move towards information systems, by which the increasing amount of archaeological data (and historical data in a wider sense) can be managed by the Andalusian administration has lately come to be a subject for public discussion (Gimenez de Azcarate 1996; Ladron de Guevara 1994, 1996; Molina *et al.* 1996). Yet, despite the shift of interest towards information systems, there seems to exist, with some remarkable exceptions, a general lack of practical experience of the theoretical and practical problems involved in the process of transforming traditional data structures and formats into digital ones.

This regional debate concerning new strategies, using computers, for the storage and processing of massive amounts of archaeological data is the departure point of a research project run by the Department of Prehistory and Archaeology of the University of Sevilla, whose main purpose is, more specifically, the exploratory application of GIS for the management of the Andalusian inventory of archaeological sites. Given its essentially integrative nature, comprising tools for the storage, manipulation, analysis, display and exchange of spatially referenced data, GIS have been adopted as a fundamental methodological *workbench*, not only for the archaeological analysis of past societies, but also in the more practical sphere of archaeological heritage management (Allen *et al.*

1990; Kvamme 1989; Lock & Stančič 1995). From the point of view of this research project, the choice of a GIS environment such as ARC-INFO (ESRI, 1992) as the appropiate computing environment in order to test future methodological approaches to the administration of the Andalusian archaeological archives can be explained by three main reasons:

- A high degree of performance in data input, processing, retrieval and exchange.
- A high degree of integration between CAD and Graphic facilities and Data Base Management facilites.
- A high degree of compatibility with the information systems currently implemented in the main agencies and institutions of the region dealing with the management of spatially referenced information.

This work, still in a preliminary stage of development, has focused on two different but complementary regions involving different archaeological problems.

The first is a vast rural area (henceforth referred to as the *Sierra de Huelva*) suitable for two different methodological experiments. It is considered an adequate case study to test the problems of a large scale conversion of archaeological site information, involving different data sources, as well as several different archaeological site types, into a GIS format. Also, it is an appropriate area to test the degree of fit between the administrative site record and the actual archaeological record, in an area where intensive archaeological surveys have recently been carried out. Secondly, the specifically rural socio-economic configuration of the Sierra de Huelva area, and subsequently the predominant patterns of land use (which are in this order: forestry, *dehesa* [oak wood] exploitation, non-intensive agriculture, and mining) suggests a potential set of risk activities affecting the archaeological record. Within the GIS environment, this allows us to address specific cartographic themes, items and areas, as well as defining some priorities in the geographic information to be collected and analysed.

The second area is focused on a more restricted urban area where, unlike the previous case, there is high degree of building activity and, subsequently, of archaeological excavations. The historic centre of Sevilla has undergone, over the last few decades, intense building activity seriously affecting the archaeological record of the protohistoric, Roman, Medieval (Islamic and Christian) and modern (post-medieval) city. In this case, the GIS approach looks at the main variables concerning the archaeological information of every urban lot: preservation of the lot's stratigraphy (expected or observed), information produced by archaeological excavation (if any) and legal status of the lot.

These two empirical cases involve rather different problems of data processing, and can be regarded as highly representative of the two most common spheres of work in the contemporary administration of archaeological information: rural and urban. Thus, they involve two completely different cartographic scales of analysis (1:400,000 in the first case and 1:500 in the second), which, from the point of view of spatial archaeology, refers to the well-defined methodological implications and differences between macro (inter-site) and semi-micro (intra-site) levels of analysis (Clarke 1977). Also, they involve two different units in the data structure, given that, in the first case the variables are attached to individual archaeological sites, while in the second case they refer to contemporary urban lots.

The problem described here is basically a practical one, that of problem-detection and problem-solving explicitly addressed towards the implementation of more efficient and powerful data management tools in administrative regional contexts.

13.2 The Sierra de Huelva — A Rural Case Study

13.2.1 Geographic and Archaeological Data Sources

Part of the geographic information used in this case study has been provided by the administration of industry (*Consejería de Industria y Energía*) as a set of ARC-INFO coverages that include geology, mines and minerals, infrastructure and administrative boundaries (*provincias and municipios*) (Fig. 13.1). Other geographic information has been supplied by the environmental protection agency of Andalucia (*Agencia de Medio Ambiente*) as a series of Arc-Info coverages. This information includes geomorphology, lithology, edaphology, land use and agricultural potential.

The sources for the archaeological information used in this study include published sources, the archives supplied by the Andalusian cultural authorities (*Consejería de Cultura and Instituto Andaluz de Patrimonio Histórico*), as well as unpublished information produced by a systematic research project carried out in the Sierra de Huelva (Hurtado 1993).

13.2.2 Archaeological Data Input

As has been mentioned above, the Andalusian experience of archaeological records began in the mid-1980s. Archaeological sites were initially recorded as points on 1:50,000 maps issued by the Spanish army cartographic service (*Servicio Geográfico del Ejército*), unless more detailed maps were available. Some basic variables concerning chronology, function, conservation and legal status were attached to every site. The 1:50,000 scale often proved unsatisfactory as a potential deviation of a 100m in the site location was practically unavoidable due to the scale limitations.

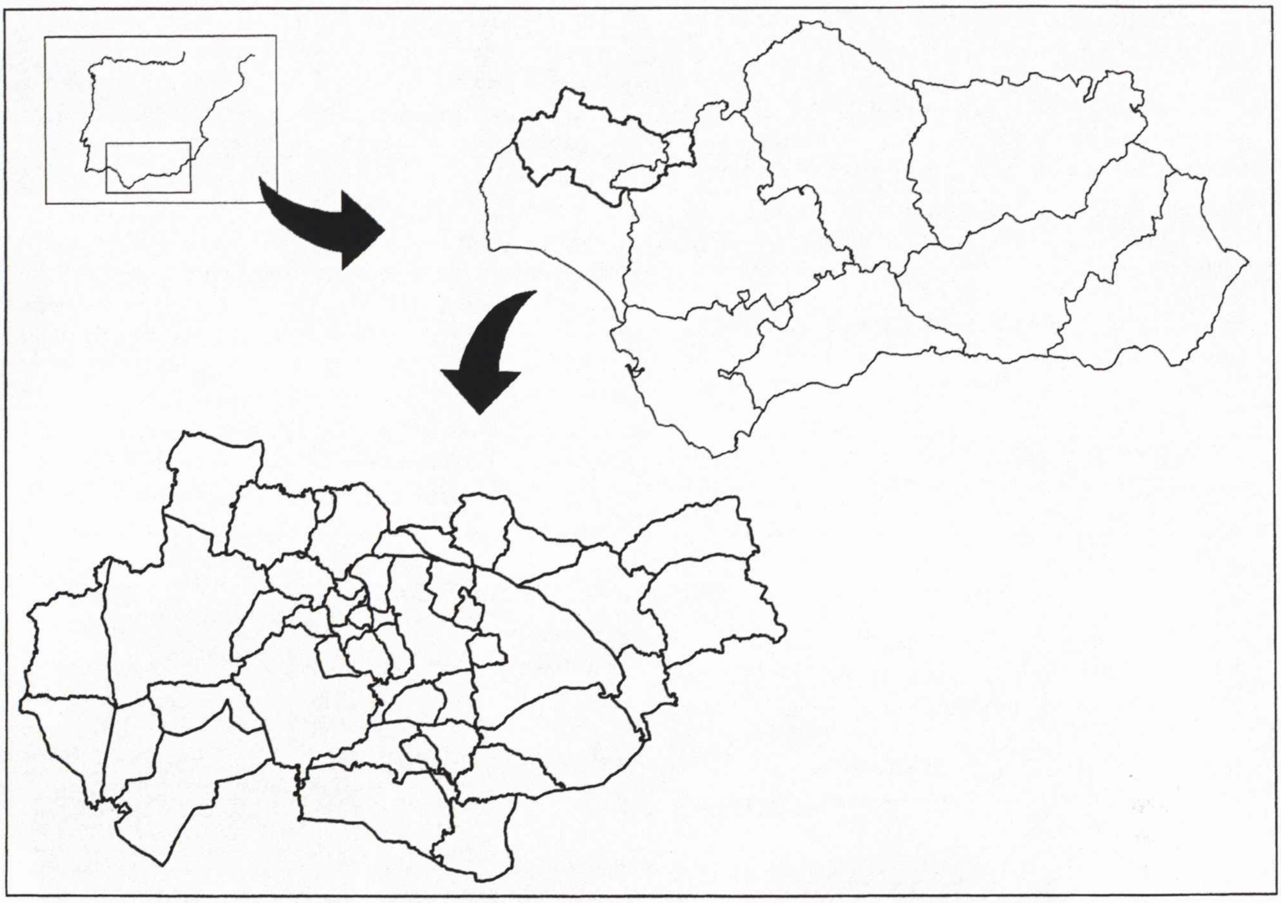


Figure 13.1: The Sierra de Huelva.

However, greater precision was not initially possible as the creation of 1:10,000 maps only started in the late 1980s.

In 1992 a program was started to provide more precise site location data: instead of points on a 1:50,000 map sites would be treated as polygons on a 1:10,000 map. The list of variables attached to every site was then modified and enlarged.[1] The application of this second recording system is progressing rather slowly as it involves re-visiting every site in order to define the nodes of the polygon enclosing the site. It seems likely that the inventory of Andalusian archaeological sites (almost 9000 sites) will remain to a large extent as points, at least for the next few years.

As far as GIS is concerned, both recording systems involve rather different strategies. Whereas the minority of sites identified on the 1:10,000 maps are located to within 1m and their UTM coordinates need no manipulation before input to a GIS, the vast majority of archaeological sites identified on a 1:50,000 map need a preliminary transformation of the coordinates. This leads to the first cartographic problem to be solved prior to data input.

Basically, this transformation involves changing from the military grid system (CUTM) to the UTM system. The CUTM system is a conventional point designation format that does not modify the projection used. Thus, the coordinates of a site are designated by a string of characters and numbers that, once broken down, provide an indication of the zone, the 100km^2 square where the site is located, and the coordinates of the SW corner of the square with as much precision as required (as has previously been mentioned, the precision in this case study is only 100m).

The Bronze age site of Cerro de la Alcornocosa (Fig. 13.3) is a typical example of the coordinate transformation needed prior to input to the GIS. The location of this site is CUTM 29SPC906277, which would be broken down as follows:

- The first two digits (29) identify the geographic UTM zone.
- The next character (S) designates the military zone corresponding to the CUTM grid.
- The next pair of characters (PC) designates one of the 100km^2 squares in which the S zone is divided.
- The following six digits refer to the x and y coordinates within the square PC with a 100m level of precision.

The procedure to transform this data into UTM coordinates is as follows:

- First, the geographic and military zones must be identified. This can be done in a quite straightforward fashion looking at the following tables:

  The relevant coordinates fall between 320° and 400° of latitude north, so that $3{,}500{,}000 < Y < 4{,}500{,}000$.

- Secondly, the 100km^2 square needs to be identified, which in turn would require the use of Figure 13.2a. The procedure here is as follows:
  - For the X axis, we identify the zone number, which in this case is 29, and then look for the multiple of 3 closest to it (27); as:

    $$27 + 2 = \text{multiple of } 3 + 2 = 29$$

    we choose the row marked as a multiple of 3 + 2. Then, given that $6 < P < 7$ we chose as a 100km the smaller of both numbers (6). Therefore, the X coordinate with a 100m level of precision would be $X = 6906$, which expressed in meters is $X = 690600$m.
  - Similarly, for the Y axis, the zone 29 can be considered a multiple of 2 + 1; 4 is equal to a multiple of 2 (the PC square has $Y > 4{,}000{,}000$). Since $2 < C < 3$, then the hundreds of kilometers is equal to 2 and therefore the Y coordinate is 42277 (with an error margin of a hundred meters) or 4227700m.

Finally, the initial CUTM coordinate 29SPC906277 has been transformed into a pair of UTM coordinates composed of six and seven digit integers (in this case 690600, 4227700), now suitable for input as an ARC-INFO coverage.

The second cartographic problem involving the preliminary transformation of the coordinates of the sites derived from the need to convert geographic coordinates expressed in degrees, minutes and seconds, into UTM coordinates expressed in metres. This was necessary in order to make the spatial reference system of the case study fully compatible with the system used by the administration. In fact, this second cartographic problem can be divided into two related ones.

First, in some cases where the information source was not the administration's files but a published source it was found that some local archaeological reports had provided coordinates using a geographic format referred to as the Struve Ellipsoid, instead of the more up-to-date Hayford Ellipsoid. The conversion of these old coordinates into the Hayford Ellipsoid was necessary before the points could be transformed into UTM coordinates.

In the case study this problem was only found with three sites (see Figure 13.3, *La Corteganesa, Llanos de la Belleza and Monteperro I*) out of a total number of 547 archaeological locations, and therefore accounts for a very small proportion of the preliminary work. However, a brief description of the coordinate conversion procedure might be of interest.

The calculus for the change of ellipsoid from Struve to Hayford for these sites has been carried out manually and using two methods. The first method is based on the isorresidual contours provided by the Spanish Army Cartographic Service, where the corrections in seconds that must be performed for both latitude and longitude can be observed. The second is based on the transformation formulae provided by F. Martín Asín (1990). The reference system of departure in this case is:

- Origin: crossing point between the meridian of Madrid and the 40° parallel latitude north.
- Latitude: transformed to the meridian of Madrid.
- Longitude: tangent to 40° parallel in the origin.

In turn, the reference system to be arrived at is:

- Origin: crossing point between the central meridian of each zone and the equator
- Latitude: transformed for the respective meridian
- Longitude: transformed for the equator

The relevant formula being:

$$c_l'' = 2.9368989 + 0.0021600 \times M^\circ + 0.0727200 \times L^\circ - 0.0000179 \times h + dl$$

$$c_f'' = 6.2280987 - 0.0327600 \times M^\circ - 0.0392400 \times L^\circ + 0.0000284 \times h$$

where c_l'' and c_f'' are the corrections in seconds, M° and L° are the old longitude and latitude (Struve) h is the height of the point under consideration and *dl* is the longitude difference between Madrid and Greenwich, that in this case is $3^\circ.6879167 = 3^\circ 41' 16.5''$. The result of this process is shown in table 13.3. The corrections performed in latitude have been of 4.62″ and in longitude 10.8″ or, in other words, some 100m in longitude and 270m in latitude.

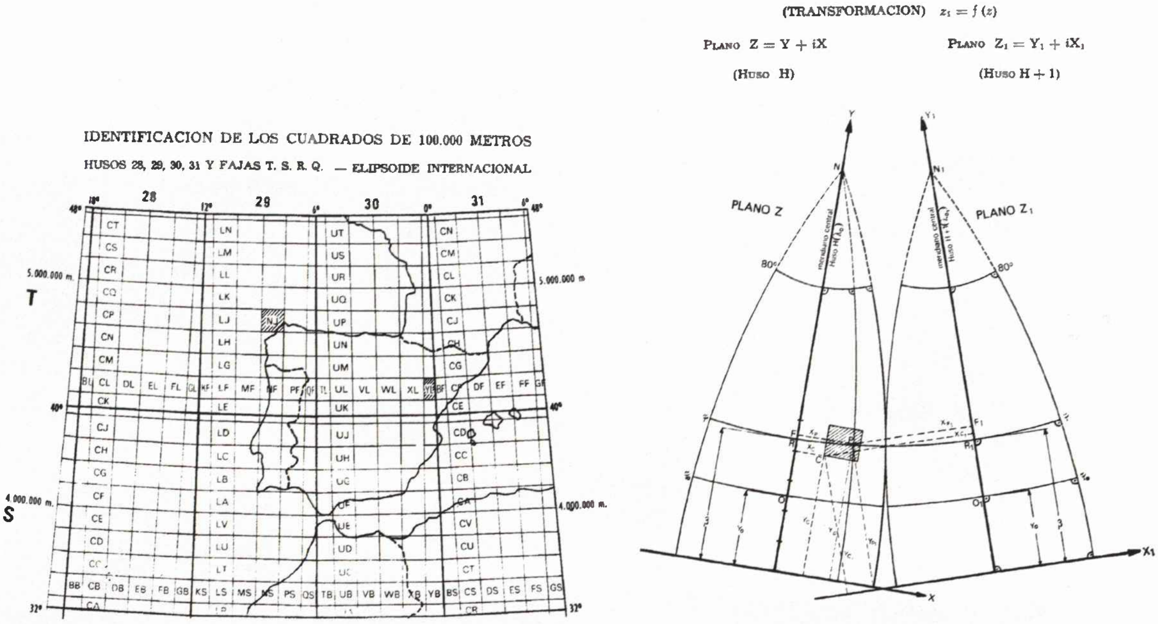
Once this was achieved, the other part of the problem was relatively simple, as it merely involved the transformation of points located in the ellipsoid with geodesic coordinates φ (latitude) and λ (longitude) into UTM coordinates (x, y). This can be mathematically expressed by the formula:

Zone	Hundreds km from X 1	2	3	4	5	6	7	8	9
$\dot{3}+1$		A	B	C	D	E	F	G	H
$\dot{3}+2$		J	K	L	M	N	P	Q	R
$\dot{3}$		S	T	U	V	W	X	Y	Z

Table 13.1: First character of the zone.

Zone (Parity)	1000km from Y (Parity)	Hundreds km from Y 0	1	2	3	4	5	6	7	8	9	0
$\dot{2}+1$		A	B	C	D	E	F	G	H	J	K	
	$\dot{2}$											
$\dot{2}$		F	G	H	J	K	L	M	N	P	Q	
$\dot{2}+1$		L	M	N	P	Q	R	S	T	U	V	
	$\dot{2}+1$											
$\dot{2}$		R	S	T	U	V	A	B	C	D	E	

Table 13.2: Second character of the zone.



(a) UTM zones covering the area of study.

(b) Change of UTM zone.

Figure 13.2: UTM zones.

Figure 13.3: Sites mentioned in the text.

	Struve		Hayford	
La Corteganesa	3°17′10″	37°58′58″	6°58′20.79″	37°59′02.62″
Monteperro	3°25′20″	37°58′10″	7°06′30.80″	37°58′14.62″
Llanos de la Belleza	3°19′50″	37°57′20″	7°00′00.00″	37°57′24.62″

Table 13.3: Conversion from the Struve to Hayford ellipsoid.

$$
\begin{gathered}
y = \beta + \frac{(\Delta\lambda)^2}{2} N \cos^2 \varphi tg\varphi + \frac{(\Delta\lambda)^4}{24} N \cos^4 \\
\varphi tg\varphi (5 - tg^2\varphi + \vartheta\eta^2 + 4\eta^4) + \\
\frac{(\Delta\lambda)^6}{720} N \cos^6 \varphi tg\varphi + \\
(61 - 58tg^2\varphi + tg^4\varphi + 270\eta^2 - 330tg^2\varphi\eta^2)
\end{gathered}
$$

$$
\begin{gathered}
x = \Delta\lambda N \cos\varphi + \frac{(\Delta\lambda)^3}{6} N \cos^3 \varphi (1 - tg^2\varphi + \eta^2) + \\
\frac{(\Delta\lambda)^5}{120} N \cos^5 \\
\varphi (5 - 18tg^2\varphi + tg^4\varphi + 14\eta^2 - 58tg^2\varphi\eta^2)
\end{gathered}
$$

Where

$$\beta = a(1 - c^2) \int_{\varphi_2}^{\varphi_1} (1 - e^2 sen^2\varphi)^{-\frac{3}{2}} d\varphi$$

$$N = \frac{a}{(1 - e^2 sen^2\varphi)^{\frac{1}{2}}}$$

$$\eta e' \cos\varphi$$

and φ and λ are the latitude and longitude of the point.

As can be seen, the transformation of the coordinates depends on the parameters of the ellipsoid taken as the reference by the projection. These parameters are, first, the longest axis of the ellipsoid (a), second the first and second eccentricity of the meridian ellipsoid (e, e'), and third the latitude of the point (φ).

The partial underestimation of the importance of these procedures for coordinate conversion could explain some recent confusion concerning the location of old sites. These sites were originally located on maps that used the Struve ellipsoid, so that in order to locate them on modern maps using the Hayford ellipsoid it is necessary to transform the geodesic coordinates from one ellipsoid to the other. However, tables are available to perform this conversion (Rossignoli 1976), and in fact it can be also automatically be performed by a GIS like ARC-INFO.

Finally, the third cartographic problem that was detected before the archaeological coverages could be generated was again related to the coordinate system. Since the region of Andalucia is divided into two different UTM zones (29 and 30), and, as it is well known, every geographic zone is a different plane with its own reference system (Fig. 13.2b), the coordinates corresponding to one of the zones had to be transformed into the other's system in order to include all the area covered by this research as a single cartographic unit.

Although in this case the conversion was carried out automatically by ARC-INFO and there was no need for manual calculus, an example is given of the transformation performed, again using Cerro de la Alcornocosa.

- Original coordinates:

  $X = 690.600$

  $Y = 4.227.700$

  Zone = 29

- Transformed coordinates:

  $X = 164.987$

  $Y = 4.232.378$

  Zone = 30

- Formulae (Reduction Polynomials):

  $Y = Y_{1c} + nC - eD$

  $X = x + 500.000 = x_{1c} + nD + eC + 500.000$

  $n = (Y - Y_c)1/10^5; e = (x - x_c)1/10^5$

where $Y_c y X_c$ are the coordinates of the multiples of the closest 100km to the given coordinates.

$$
\begin{aligned}
A &= b + nc - ec' \\
B &= b' + nc' + ec \\
C &= a + nA - eB \\
D &= a' + nB + eA
\end{aligned}
$$

where $y_{1c}, x_{1c}, a, a', b, b'c, c'$ are the tabulated coefficients (Rossignoli 1976, p. 178).

Once the preliminary cartographic problems were detected and fixed, the information contained in a series of DBF tables was exported to ARC-INFO version 7.03 as two ASCII files, the first one storing each site's unique ID number and pair of UTM coordinates (imported from the Arc module) and the other containing the unique ID number plus the associated variables (imported from the Info module). Thus, two coverages with archaeological sites were generated, one with 547 sites recorded as points and another with 111 sites recorded as polygons. The point coverage was further sub-divided into coverages based on chronology (Neolithic, Copper Age, Bronze Age, Iron Age and Roman), so that their distribution patterns can be examined individually in the future.

13.2.3 Data visualization.

The GIS mapping of the inventory of archaeological sites of the Sierra de Huelva begins with the observation of the degree of correlation existing between the intensity of surface exploration and the number of locations actually recorded. A basic classification in four categories has been made of every municipality (*municipio*) according to the intensity of the archaeological surveys carried out within its administrative limits:

1. Unsurveyed: all the archaeological sites recorded were randomly detected.
2. Unsystematically surveyed: some kind of survey was carried out in the past, but it either did not produce a systematic list of archaeological locations (they were for example oriented to specific site types in chronological or functional terms) or it was carried out under non-explicit methodological assumptions.
3. Systematically surveyed:
    (a) The methodology and scope of the survey was explicitly declared and the inventory of sites included all chronological and functional site types.
    (b) The same as 3a but in this case the survey was carried out within the context of a systematic research project involving direct intra-site fieldwork (excavations, sondages, *etc.*)

As can be observed in Figures 13.4–13.5 (and as expected) there is a high degree of correlation between the intensity of survey and the number of sites recorded. This map can be assessed in two different ways. On the one hand, the three areas where the scarcity of archaeological sites is clearly associated with low levels of surface exploration, suggest that more attention should be paid to them in the future: in this case, the lack of information becomes in itself a parameter of risk for the archaeological record (Fig. 13.4). On the other hand, those areas with the highest concentration of sites become the only adequate areas for spatial analysis: any attempt to include within the same spatial analysis areas with low and high survey backgrounds would inevitably embody a strong bias (Fig. 13.5).

Another variable of interest, from the perspective of the administrative documentation of the schedule of archaeological sites, is the type of land categories developed by each local (municipal) council. The spatial distribution of this variable (Fig. 13.6) in the Sierra de Huelva suggests a wide predominance of municipalities without specific land-use ordinances (*Sin Planeamiento*), while no one has yet developed the highest level of administrative land planning (*Plan General*). The non-inclusion or incomplete inclusion of the record of archaeological sites in the local land-planning documentation has also been noted as a potential deterioration factor (lack of control at the lowest administrative level) of the archaeological record, as local councils are legally compelled to participate in the control and protection of archaeological sites and monuments (Tejedor *et al.* 1994). Figure 13.7 shows those municipalities where a number of sites have been converted into polygons.

One more map of the area has been produced showing the degree of inbalance between the number of sites recorded as polygons (*i.e.,* recorded with a cartographic precision of 1m) and the number of sites recorded as points (*i.e.,* recorded with a margin of error of 100m). As can be seen in Figure 13.8 only in 10 out of 44 municipalities have more than 50% of sites been recorded as polygons on 1:10,000 maps. Another map (Fig. 13.9) displays the percentage of new sites identified after a systematic survey had been carried out within the limits of some of the local administrative units. This map can be used as an indicator of the expected frequency of sites in those municipalities where the survey background is low.

As far as preservation of the archaeological record is concerned, current land use is undoubtedly an essential variable. As can be observed in Figures 13.10–13.11, one the main types of land use currently observed within the southern part of the area under study is industrial re-afforestation. The systematic plantation during the 1960s of an alien species such as eucalyptus within this area was accompanied by massive terracing of hills which had a devastating effect on the archaeological record. In fact it is hard to find any significant concentration of archaeological sites in any of the polygons representing this type of land cover (Fig. 13.11), even in those areas that have been subject to systematic surface survey.

Finally, more predictive maps have also been produced with ARC-INFO. Figure 13.12 shows a buffering area of 500m in radius around all the main roads within the study area. As is well known, a typical case for rescue excavation is massive earth removal due to large-scale road or railway works. In this case, and with the available archaeological information, a map has been produced displaying the list of sites threatened by any road widening within the study area. Similarly, the existence of important mineral resources (Fig. 13.13) in the Sierra de Huelva has become a major threat to the archaeological record, due to the great impact that these economic activities have. Since studies are frequently published reporting the impact of new mining initiatives on the archaeological heritage, the use of this kind of buffering map can be of great help, saving time and reducing costs in the preliminary stage of documentation.

In general, GIS mapping of the archaeological information produces a quick and intuitive assessment of those gaps where the lack of information points out

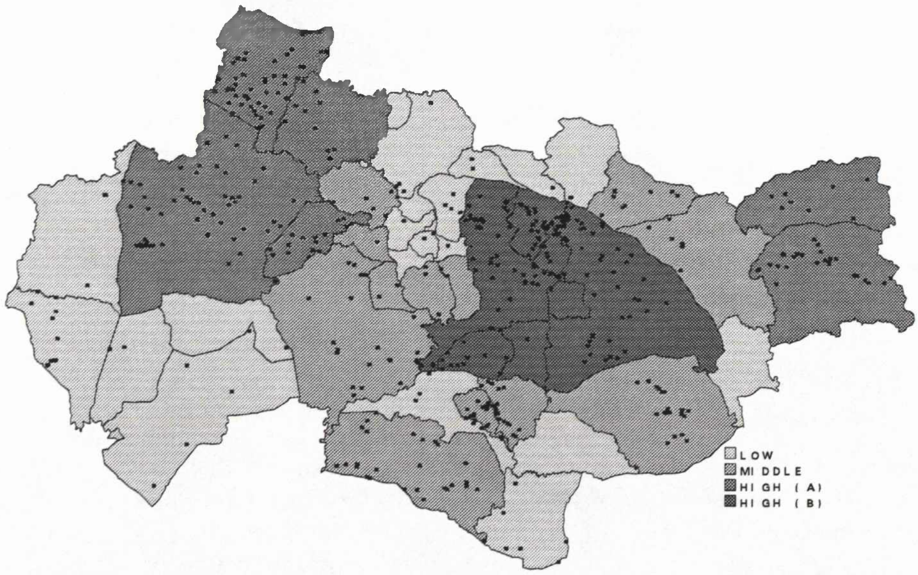


Figure 13.4: Intensity of survey: Administrative units.

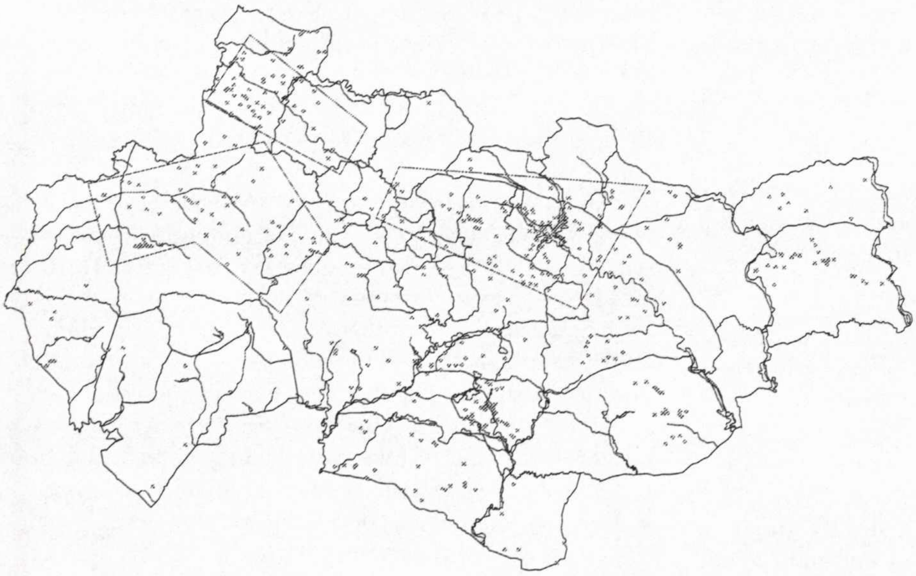


Figure 13.5: Intensity of survey: Adequate areas for spatial analysis.

the need for future investigation. From the perspective of the management of inventories of archaeological sites, this approach is of great help in order to visually detect gaps in the information and in order to generate fast spatially-referenced queries of the databases. From the point of view of the management of large rural territories, the conclusion drawn from this initial experience is that traditional non-computing archaeological planning and data processing can become more efficient and affordable with the support of a GIS.

13.3 The Historic Centre of Sevilla

13.3.1 Data sources

The second case under examination in this paper has its own methodological peculiarities. First inhabited during the Iron Age (7th century BC according to the archaeological evidence) the modern city of Sevilla has one of the largest historic centers of Western Europe (250ha) offering today a wide diversity of historical places and monuments.

Aware of the need for a more centralised and proactive protection of the archaeological record of the city, the regional administration of culture decided in 1994 to establish a permanent research group whose main purpose would be the control and coordination of the frequent archaeological excavations carried out within the limits of the historic city. As was soon realised, one of the main methodological tasks of this research group would be the production of an efficient cartographic base, supported with a computer system, suitable for fast updating and easy retrieval of the large amount of archaeological information constantly produced in a rapidly changing physical environment.

This archaeological computer mapping of the historic center of Sevilla has two main purposes:

Cognitive: It must provide a cartographic basis for the interpretation of the city as a single archae-

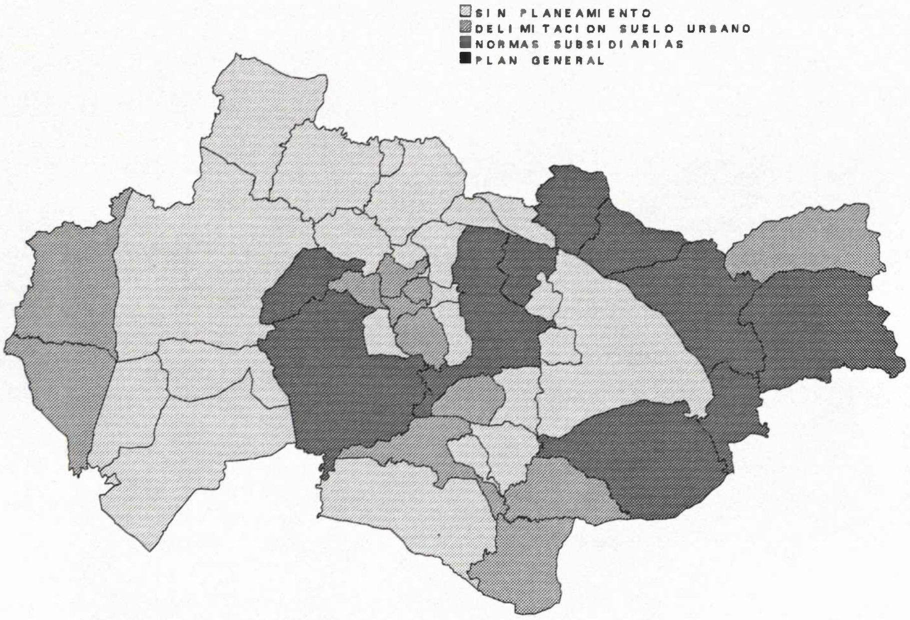


Figure 13.6: Municipal land-planning.

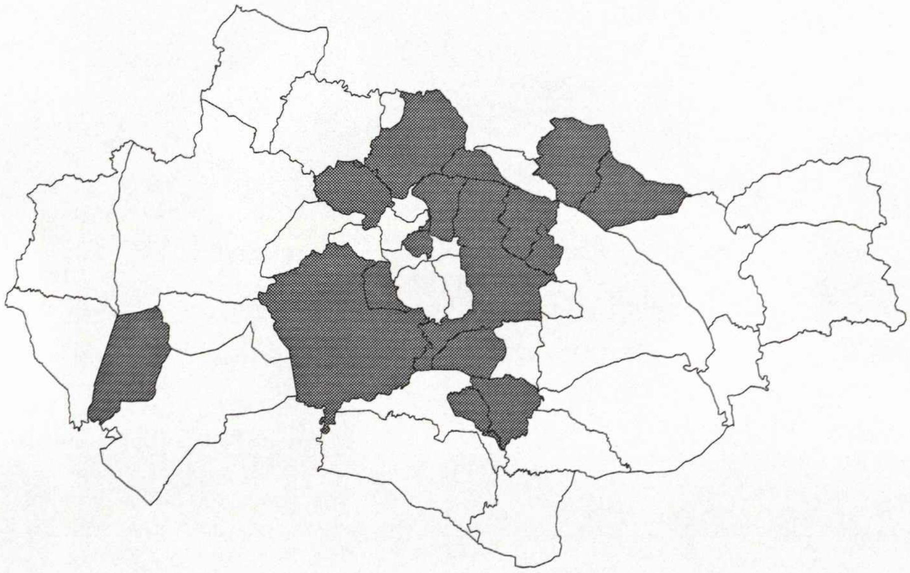


Figure 13.7: Municipalities covered by redefinition of archaeological sites as polygons.

ological site, facilitating the design and testing of hypotheses relative to the urban development of the settlement during different historic periods. At the same time, it is expected to provide a database containing variables such as depth of archaeological sediments, freatic level, deterioration of the archaeological stratigraphy, record of archaeological excavations carried out, type of construction above and under the ground, *etc.*

Evaluation: Also, it is expected to provide a dynamic and interactive basis for the evaluation and assessment of these different parameters in order to generate a more adequate strategy for the archaeology. This basically involves the elaboration of a series of archaeological maps (*Carta de Riesgo*) appropriate for constant updating: maps showing loss of the archaeological record, maps of conservation areas, maps of accessibility of archaeological stratigraphy, *etc.*

Again, a GIS like ARC-INFO provides an adequate set of tools to achieve the above, as urban archaeological information can be, first visually stored, queried and retrieved, second, easily updated, and third quantitatively analysed, as the program provides a module (Grid) for the quantitative assessment of raster information.

13.3.2 Geographic and Archaeological data input

In this case no pre-existing digital maps at an adequate scale were available to map the archaeological information; it was necessary to create these ourselves. This process involved the following steps:

1. A series of raster images of the 43 sheets of the cadastre map covering the historic centre of Sevilla were produced by means of a scanner.

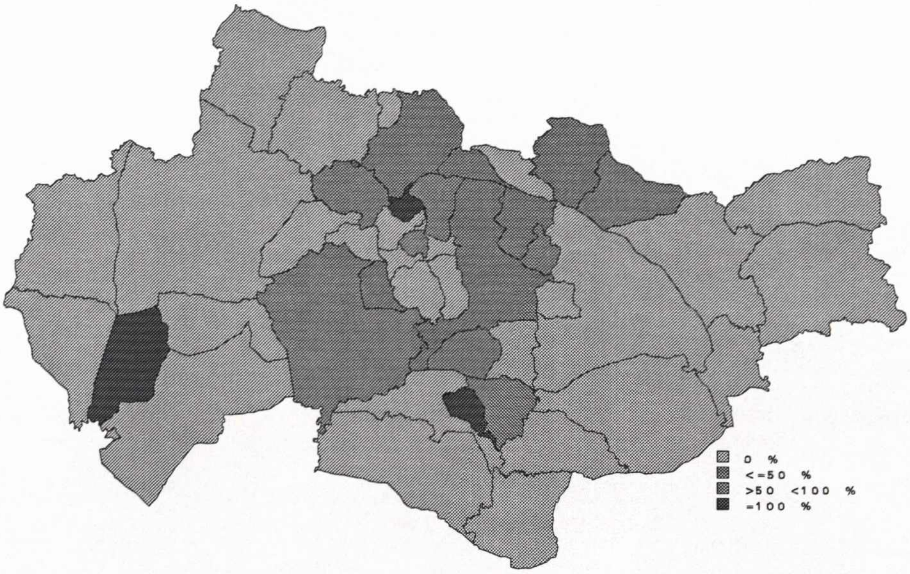


Figure 13.8: Proportion of sites described as polygons.

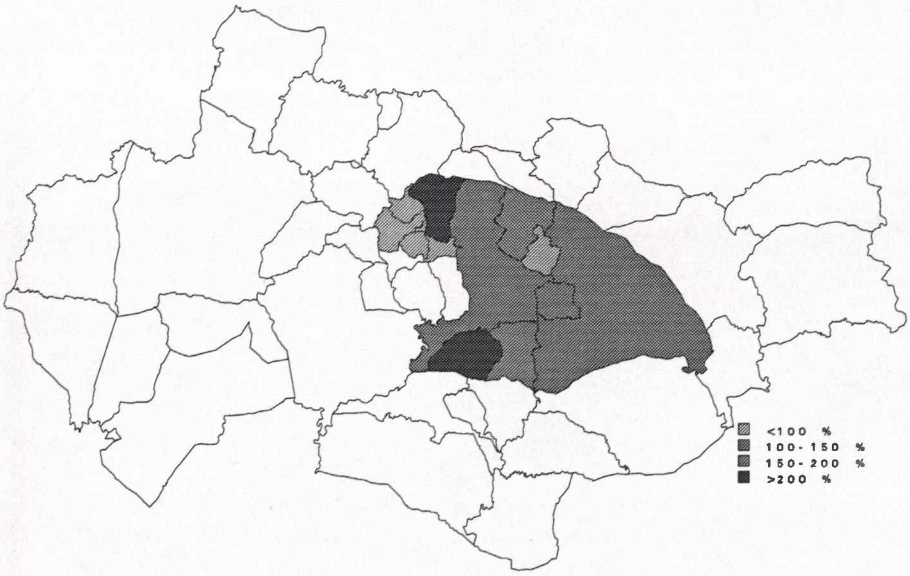


Figure 13.9: Proportion of new sites recorded after systematic survey.

2. These raster images were transformed into vector images with CadCore version 4 and then imported as ASCII files into ARC-INFO.
3. The ARC-INFO coverages were generated and projected to UTM zone 30 (the dividing line between zones 29 and 30 crosses the city).
4. A long period of error detection and correction followed: each vector image was edited either with the ARC-EDIT module of ARC-INFO or with AutoCAD (version 12) and all the arcs and nodes not properly defined were modified.
5. The ARC-INFO tics defining the extent of every digital map were provided with real UTM coordinates.

The final result is a vector map at a 1:500 scale integrating the 43 individual sheets initially scanned (Fig. 13.14) where the basic analytical unit is the lot. After a few months of documentation and fieldwork, several types of information concerning this spatial unit have been recorded and are currently being input into a computer database in order to be loaded into ARC-INFO.

One main variable taken into account in this study is the basic chronology of the buildings currently standing on every lot (Fig. 13.15). Two states have been defined for this variable, namely earlier or later than 1950, as it is precisely at this time that the construction of cellars and underground car parks, leading to the total destruction of the archaeological stratigraphy, started to become popular in the city. This variable provides a preliminary basis for the assessment of the potential accessibility of the archaeological record in the historic centre, as lots with underground constructions can be noted as lost for archaeological study.

Once the losses of information have been detected, the lots have been further classified in order to define their archaeological interest. These categories (Fig. 13.16) range from empty lots where archaeologi-

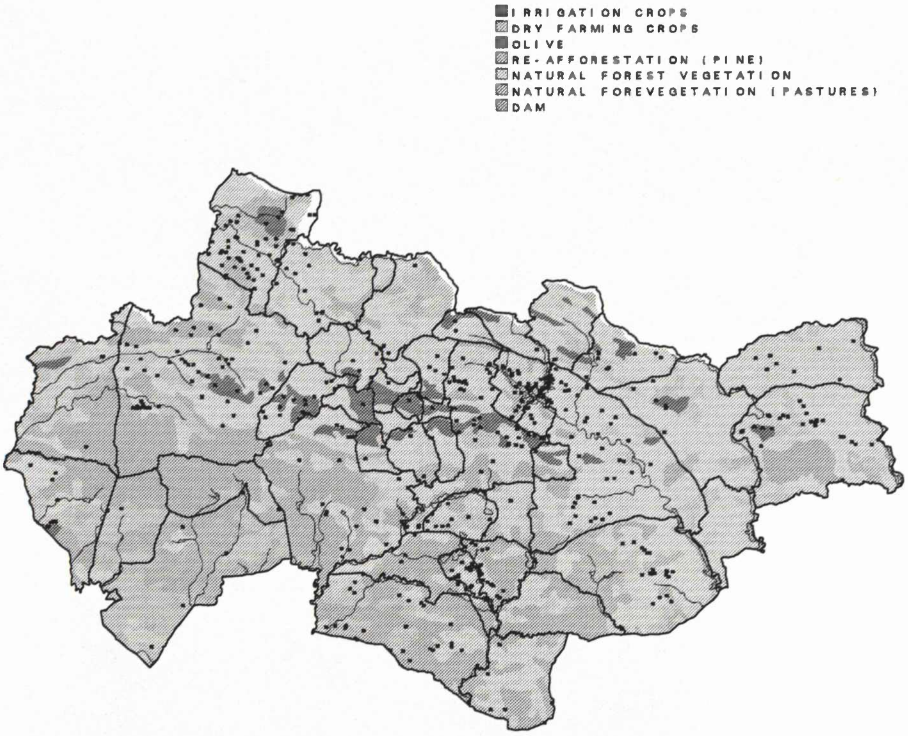


Figure 13.10: Land use *v.* distribution of archaeological sites.

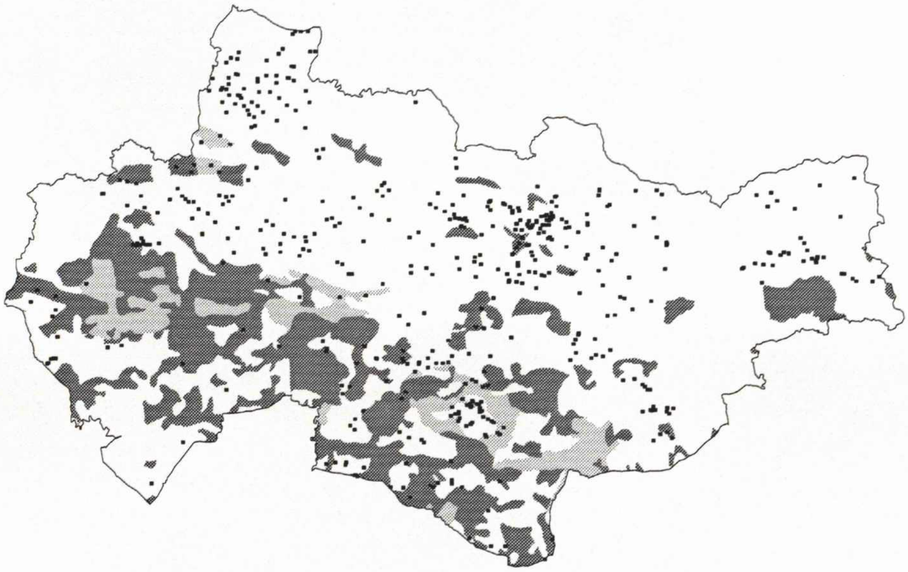


Figure 13.11: The impact of re-afforestation on the archaeological record.

cal excavations are possible, to ruinous buildings likely to produce an empty site in the short term, to historic buildings that have been restored and are inhabited, and finally to historic buildings explicitly protected and declared of cultural interest.

Furthermore, a classification has been made of the type of archaeological excavation that could be carried out in the available lots according to their size (Fig. 13.17). Excavations in narrow lots in Sevilla are frequently limited due to the existence of close standing buildings whose old foundations cannot be disturbed. Therefore, the occasional availability of spaces suitable for open area excavation is of great importance for a better understanding of the past of the city. In this case, lots with less than 200m^2 have been classified as only adequate for sondages, while lots larger than this can be excavated according to an open area system.

13.4 Assessing but not Concluding

The work described above has been drawn from a research project currently in progress whose main purpose is to examine the adequacy of GIS in the field of archaeological heritage management. No previous work has been done in this field in Andalucía, and therefore the investment of time and effort in this project has been mainly addressed to the detection

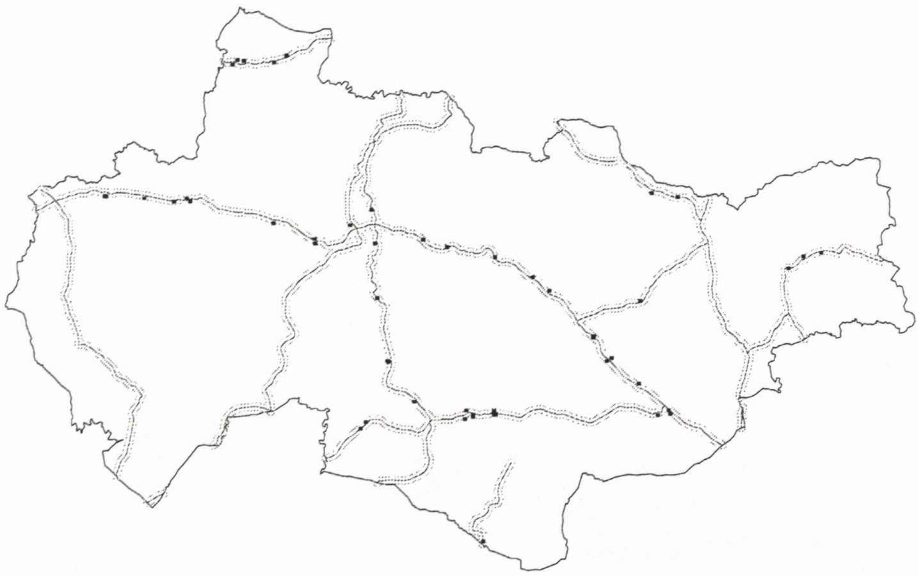


Figure 13.12: Potential risk evaluation: communications network.

Figure 13.13: Potential risk evaluation: mining

and fixing of problems concerning the structure of the archaeological data. The stages of data input, manipulation, and visualization have already been covered with the help of two complementary case studies, but no full exploitation of the analytical capabilities of GIS has yet been achieved. The second phase of this project is intended as an exploration of the quantitative raster processing of the vector coverages that have been generated during the first phase of the project.

At present, it seems that in Andalucía there is a greater disposition among both professional and academic archaeologists to fill the gap created during the last decade between the methodologies followed in the management of environmental information and those applied in the field of historic and archaeological heritage. The experience described in this paper is intended as a contribution towards the consolidation of that disposition, and of course as an experience to be shared with the international community of archaeologists using GIS.

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Notes

1. In 1995 this information had started to be loaded into a computer database, and the structure and

Figure 13.14: The historic centre of Sevilla.

number of variables recorded for every site had undergone some minor modifications.

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Figure 13.15: Assessment of the archaeological record in Sevilla: basic dating of constructions.

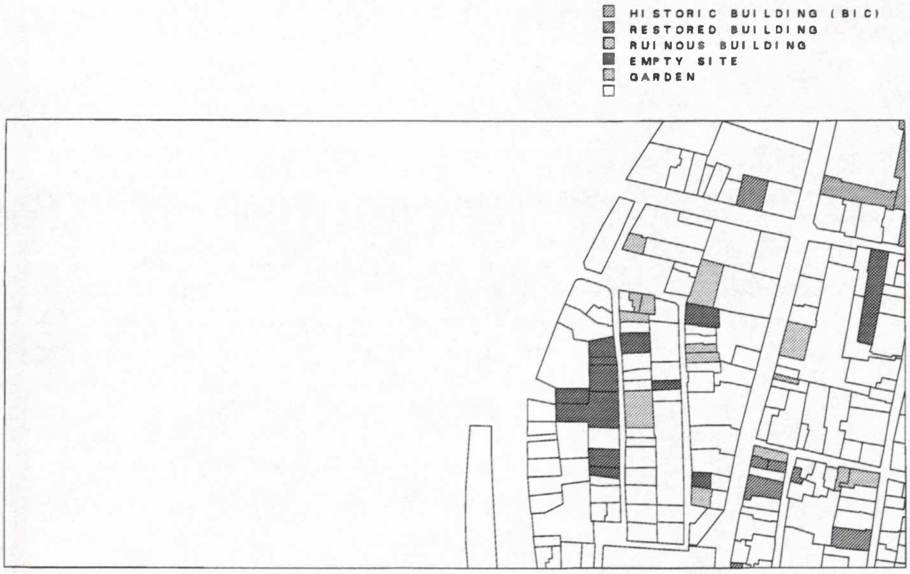

Figure 13.16: Assessment of the archaeological record in Sevilla: ground plots currently suitable for archaeological research.

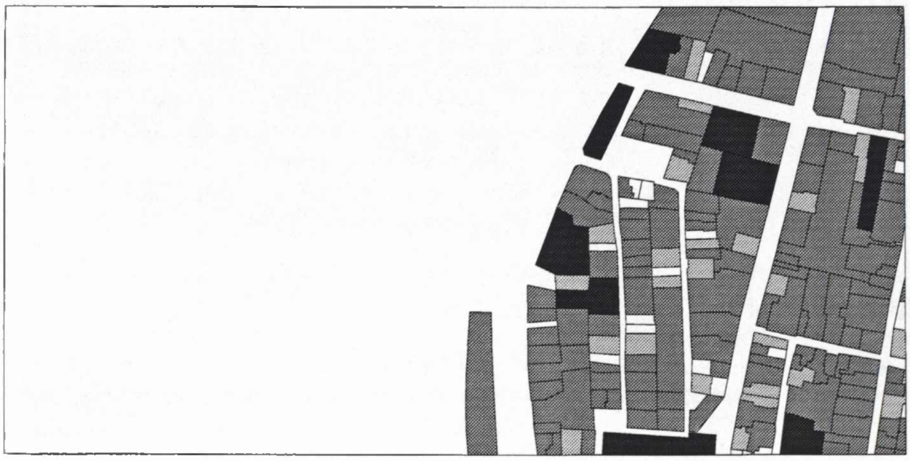

Figure 13.17: Available surface for archaeological excavation.

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