Mapping Cultural and Archeological Features for a GIS Database, Big Bend National Park, Texas

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INTRODUCTION

A Geographic Information System (GIS) is essential to managing large amounts of spatially referenced data. Hence, it is no surprise that the National Park Service (NPS), with more than 83 million acres in 49 States, the District of Columbia, and the US territories, employs a Geographic Information System as a land management tool. One of the 378 areas the park service manages is Big Bend National Park, located in southwest Texas. The GIS database of Big Bend is a work in progress, but the NPS is working to store all of its land management data in the GIS. In the future, this GIS will be used to make informed policy decisions and produce more accurate, visitor friendly maps.

The purpose of this Keck project was to facilitate the construction of the park's database by accurately mapping several cultural and archeological features that were designated as high priority by the NPS staff at Big Bend. Feature positions, feature specific information, and an accompanying metadata file were incorporated into the park's GIS database. The mapped features included campsites and other notable features along a 40-km backcountry jeep trail known as Old Ore Road, campsites and trails in the Chisos Mountains, and the ruins of an early 20th century farming village, Terlingua Abaja.

In 1890, Mexican immigrants to the Big Bend area established the small town of Terlingua Abaja. Terlingua, a corruption of the Spanish *tres lenguas* meaning "three tongues", may refer to the three forks of the nearby Terlingua Creek. (Gómez, 1990). When "quicksilver" was found in the area in 1903, the mining town of Terlingua sprang up around the Chisos Mine, a few miles to the north. As a result, Terlingua Abaja became a thriving, predominantly Mexican farming village, supplying produce, fresh water, and firewood to the miners in Terlingua. The population of Terlingua Abaja peaked in the 1920's during the Mexican Revolution, but by the 1930's was in rapid decline. By this time, the mining boom had ended, the US Immigration Service had begun enforcing border regulations, and the cottonwood trees that had lined the creek were gone. Terlingua Abaja was abandoned by the end of World War II, as were the mine and village at Terlingua. Today, Terlingua Abaja consists of a large number of foundations, remnants of adobe walls, gravesites, irrigation canals, and rusted piles of tractor and "Model-T" parts. As part of its goal for documenting archaeological sites, the NPS has done rudimentary reconnaissance mapping of the village, but no detailed or georeferenced mapping had been done prior to our work.

FIELD METHODS

The NPS required sub-meter accuracy mapping for all points, and a preference for sub-50cm accuracy. This necessitated the use of Differential GPS (DGPS) with C/A code phase. Since base station to rover distances of 200-300 km are the maximum for C/A code phase work and since the Texas Department of Transportation (TXDOT) base stations in El Paso and Midland are at the extreme limits of this range, we erected a base station within the park itself. A Trimble Pro-XRS served as the base station. For the work at Terlingua Abaja and the Chisos Mountains, a Trimble GeoExplorer II served as a roving GPS. For the mapping along Old Ore Road, a Magellan ProMark-X was employed.

Along Old Ore Road and in the Chisos Mountains, the park service was interested in the location of the backcountry campsites, the number of tentpads available at each site, the trails leading from the main trail to each site, and the perimeter of each site. C/A code phase DGPS was chosen for its ability to resolve the individual tent pads and trails, and for its ease of use, which ensured that the 40 km of Old Ore Road could be mapped in a timely fashion.

GPS POSTPROCESSING PROCEDURES

DGPS post processing removes correctable clock errors, satellite orbit errors, ionospheric interference, and the intentional noise of Selective Availability from GPS positions. Even though the TXDOT base stations were too far away for carrier phase correction, our base station position was pinpointed to less than a meter using real time, satellite relayed, virtual base station correction data from the OmniSTAR system.

Using the Trimble Pathfinder Office software, both code and carrier phase differential corrections between our base stations and GeoExplorer rovers were carried out automatically. The resulting point, line and area features were exported directly to shape file format compatible with ESRI ArcView software. The output was generated in UTM coordinates using a NAD27 datum for consistency with existing NPS GIS layers. The NPS will later convert all GIS data to the NAD83 datum (about a 40m shift at Big Bend). Using customized data dictionaries in the Trimble rovers, attribute data such as campsite numbers or ruin numbers were entered in the field. The Pathfinder Office software transferred this attribute data into the appropriate database files for direct use in ArcView. With the Magellan unit, attribute tables were constructed in ArcView after the geographic data was transferred.

The Magellan Corporation provided a software utility that enabled data to be downloaded from the ProMark-X unit; however, this program was so old that it did not support any ArcView file formats. In addition, the Pro-Mark-X software utility did not offer any datum or coordinate system transformation, but forced all the data to be exported in Lat/Long WGS84. After exporting the campsite coordinates as a text file, we used Geographic Transformer (Blue Marble Software) to transform the datum to NAD27 and the coordinate system to UTM.

OTHER GIS LAYERS

Digital Elevation Models (DEM) Once the cultural and archaeological features were imported into ArcView they sat amidst a plane of nothingness. In order to see their position in relation to the rest of the park, a DEM layer was incorporated into the database. A DEM is essentially a grid that is superimposed over the topography. The elevation of each cell is determined by averaging the elevations within that cell. One degree, 30 minute, 15 minute, and 7.5 minute DEMs can be obtained for free from the USGS GeoData web site. DEM accuracy is ranked into three levels. Level one DEMs are generated from stereo aerial photographs and may have a vertical Root Mean Squared Error (RMSE) of 15m. Level two DEMs are level one DEMs where obvious errors have been removed, and the elevation data set has been smoothed over in an attempt to introduce better consistency between neighboring cells. Neighboring cells may be very different in their elevation since each cell's elevation is an average of the elevations within it. In addition, level two DEMs include data derived from hyposographic and hydrographic data digitizing resulting in better consistency with contour maps and known drainage systems. Level two DEMs may have a vertical RMSE of one half a contour interval. Level three DEMs are compiled from Digital Line Graphs and employ spot elevations, river channels, and drainages (among other topographic and hydrologic features) to confine elevation values. A level three DEM is the most accurate because it ensures that streams and lakes are the lowest points in the immediate vicinity.

The scale of the features within the Big Bend GIS (telephone poles, benchmarks, etc) demanded the highest resolution DEM, and so 7.5 minute DEMs were employed. The majority of USGS 7.5 minute DEMs are classified as level one DEMs, and all 7.5 minute DEMs have an elevation value for every 30m x 30m raster cell, are projected in UTM coordinates, and conform to either the NAD27 or NAD83 datum. The 7.5 minute DEMs were available on-line only in the USGS's new SDTS format which requires an additional piece of software to translate the files into a standard raster format. Software companies are beginning to support the SDTS format (ESRI has released a beta version of an SDTS plug-in for ArcInfo), but in the mean time conversion utilities are available from the Bureau of Land Management. Using one of these conversion utilities called sdts2dem, all of the 7.5 minute quadrangles for Big Bend were imported ArcView. Once inside ArcView, the DEMs were spliced together and the sample smoothing algorithm found in the ArcView help documentation was applied to "enhance" the data set. At this time the paved and unpaved road themes that the National Park Service had already mapped were added to the GIS database.

Landsat Imagery The National Park Service now had all it needed to monitor the backcountry campsites along Old Ore Road. But what if the Park Service desired to monitor other things in the area such as the geology of this sparsely vegetated area, or the growth and decline of the nearby oases? For these purposes, satellite imagery would have to be used, and the first part of any analysis would be geo-referencing and importing the images into ArcView. To illustrate to the Park Service that remote sensing data could easily be incorporated into the existing database, and to gain a first hand knowledge of the procedures involved in doing so, we endeavored to superimpose the Landsat image of the area surrounding the Old Ore Road campsites. A program called ER Mapper was used to cut, stretch, and geo-reference the Landsat. The image must be stretched because the Landsat satellite often takes pictures from the side, with the result being that two objects which x units apart but close to the satellite appear closer in the photograph than two objects which are x units apart but far from the satellite. ER Mapper allows stretching and geo-referencing to be done at the same time by allowing the user to enter the coordinates of several ground control points (in the desired coordinate system and datum). The location of these ground control points is then set, and an algorithm is used to stretch the map so that each point can be triangulated from its nearest ground control points with the minimal amount of error. With this accomplished, the image was exported as a .bil file, brought into ArcView and combined with the existing layers. A view of the completed GIS is shown in Figure 1.

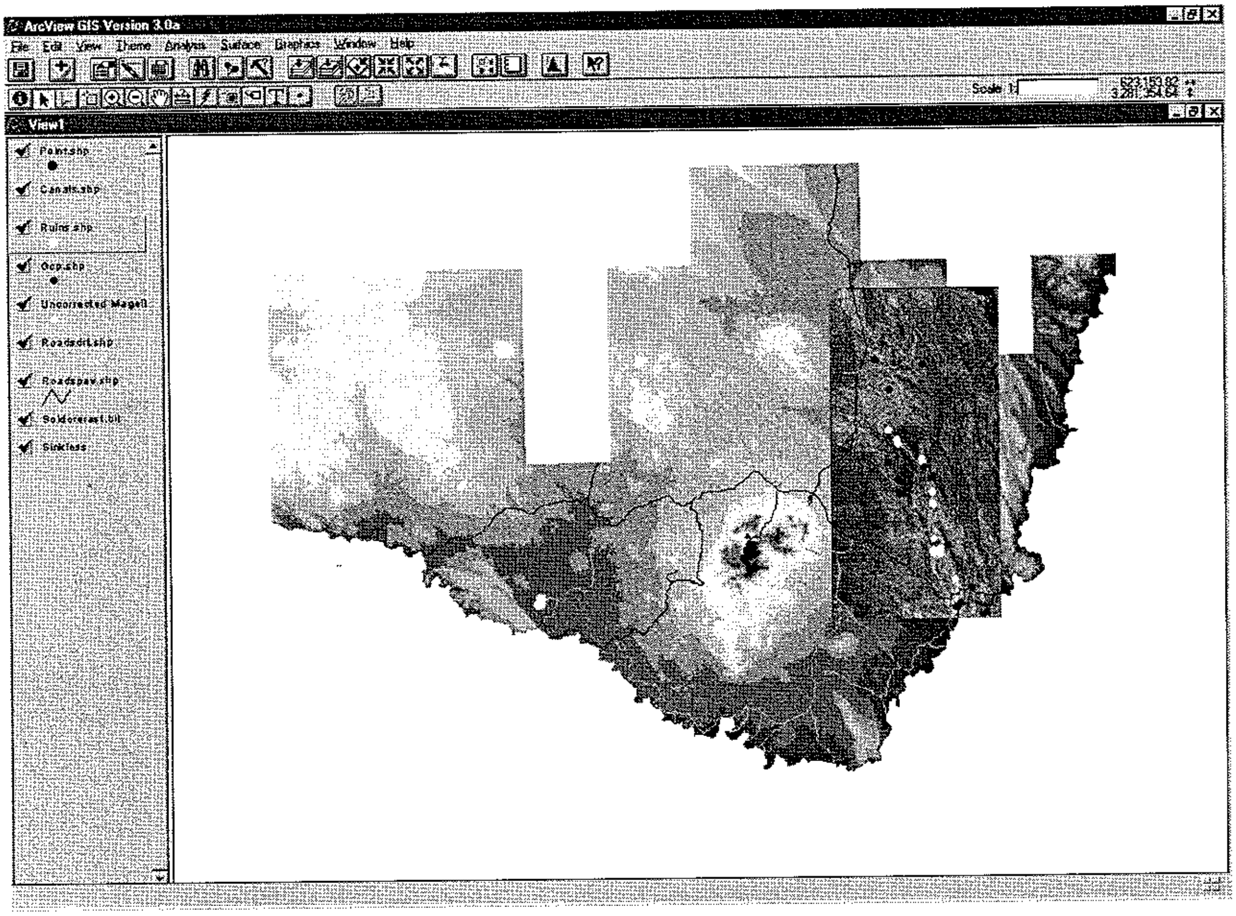

Figure 1. Screenshot of the GIS showing DEM overlain by a Landsat and several feature themes. In additon to the NPS road theme, the Old Ore Road feature theme (overlying the Landsat), the Chisos Mountain feature theme (center) and the Terlingua Abaja feature theme can all be seen.

RESULTS

Old Ore Road In DGPS, both the base station and rover unit must record raw satellite data at the same time so that the error calculated by the base station can be used to correct the error in the rover unit's position. The two units have synchronous clocks because "atomic clock" accuracy time is automatically computed from the GPS satellites. The only remaining procedure is to set the logging interval and start the logging at the same time. Most modern GPS units (rover and base station), including our Trimble instruments, are programmed so that they record on even intervals of system ephemeris time. Thus instruments can be set to log data at 5, 10 or 15 second intervals with assurance that the intervals at the base station and rover will be synchronized to GPS time (1:05 or 1:25 or 1:45 etc). According to the Magellan manual for the ProMark-X, the unit should be set to log data at the same rate as the base station. All TXDOT base stations, and the standard setting for the Trimble units, log data at 5 second intervals. So, following the manual, we set the ProMark-X to record rover files at 5 second intervals. Unfortunately, the manual is wrong! The ProMark-X was designed to be used only with base station recording at 1 second intervals, and thus does not synchronize its 5 second intervals to even 5 second intervals of ephemeris time. Of course this was not known at the time and was only discovered upon post-processing back at the lab. The result is a catastrophe for anyone interested in correcting the data since if the unit doesn't happen to start on a five second multiple of ephemeris time, no differential corrections can be carried out. The end result is that the resolution of GPS is limited to that of basic GPS: 100 meters. However, because data was logged for several minutes at each point, in hopes of doing DGPS, the averaging of the data over that time interval improves the probable accuracy of each point feature significantly.

Lacking the fine resolution of DGPS, the tentpad locations, trails, and perimeter data were lost and only an approximate location of the campsites could be found. Once inside ArcView, an attribute table was constructed as a step towards a meaningful database. The resulting layer for the Old Ore Road contained 12 campsites, 3 ruins, an abandoned mine, a gravesite, and two USGS benchmarks.

Chisos Mountains Successful C/A code phase DGPS of the trails and campsites of the rough and rugged Chisos Mountains allowed these features to be mapped with sub-meter accuracy (Fig. 2). A customized data dictionary was created for the GeoExplorer II to allow field entry of relevant attribute data. Attribute tables were constructed containing names, positions, and relevant information such as the number of tentpads if the feature happened to be a campsite or the elevation if the feature happened to be a benchmark.

A comparison of our ArcView themes with the local USGS 7.5 minute topographic map, and derived trail maps, revealed that these maps contained some errors in switchbacks on some trails. Since topographic maps are made from aerial photographs, which contain obscuring effects such as vegetation and shadows, minor mistakes such as these are understandable. Our data has been made available to the NPS for use in their master GIS of the park.

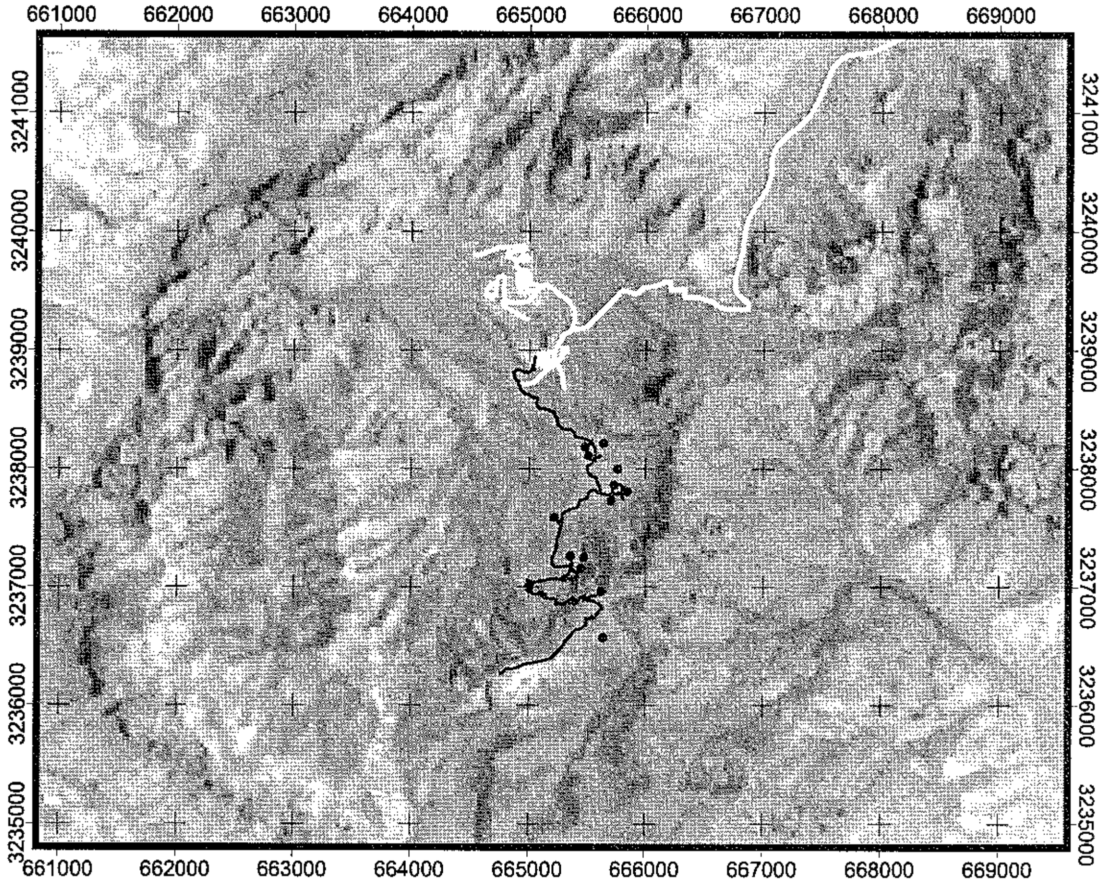

Figure 2. Map of Chisos Mountains campsites and trails surveyed with GPS. Paved roads (in white) from NPS GIS layer. Background is a rectified and georeferenced Landsat TM band 2 image. Map is UTM Zone 13 projection, NAD27 datum. Grid is UTM northing and easting at 1000 m intervals.

Terlingua Abaja Code and carrier phase DGPS were employed for mapping the ruins a Terlingua Abaja. For many ruins, only a central point was mapped. For larger foundations or adobe walls, the geometry of the ruin was mapped. We found that with a local base station, even code phase mapping, with approximately 1 m guaranteed horizontal accuracy, was good enough to map the shape, size and orientation of larger ruins. Over 35 ruins and artifacts were mapped. Customized data dictionaries allowed field entry of specific attribute information. For many ruins, an important attribute was a ruin number from NPS reconnaissance maps. In addition to adobe walls and foundations, Model-Ts were a common feature type.

NPS reconnaissance maps included sketches of an irrigation system on the west banks of Terlingua creek, south of the center of town. We attempted to map, with GPS, several of the remaining feeder canals of this system. These canals are shown in Figure 3. Many of the canals are no longer visible from the ground. Digital orthophoto quarter-quads, georeferenced to our GPS positions for ruins, hold the most promise for mapping what remains of the irrigation network. However, our GPS maps of feeder canals, along with georegistered DEM data suggest, that unlike the NPS sketches, some of the irrigation network was probably fed not by water from Terlingua Creek, but from intermittent streams flowing from hills west of Terlingua Abaja into the Terlingua Creek flood plain.

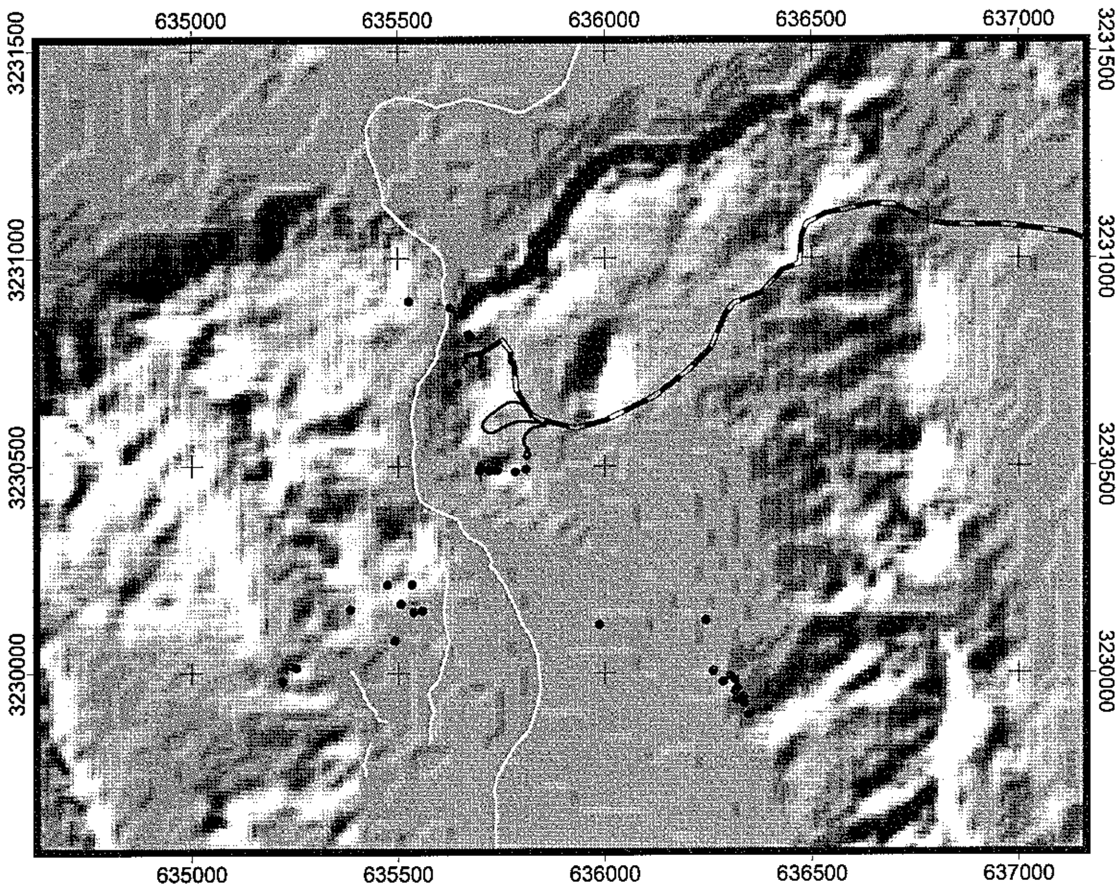

Figure 3. Map of GPS located ruins (black circles) at Terlingua Abaja. Terlingua Creek and GPS located irrigation canals are shown in white. Dirt road and campground loop road are shown in black. Background is a hillshade image from the 7.5 minute USGS DEM of the Castolon Quadrangle. Map is UTM Zone 13 projection, NAD27 datum. Grid is UTM northing and easting at 500 m intervals.

REFERENCES CITED

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IGNEOUS AND METAMORPHIC GEOLOGY OF VINALHAVEN ISLAND, MAINE

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