Implementing GPS and GIS Tools in an Abandoned Mine Land Program[1]

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Abstract. Abandoned Mine Land (AML) programs always employ geospatial information in project design and management. New technologies, the GPS (Global Positioning System) and GIS (Geographic Information System), have been adopted in varying degrees over the last ten years. The Texas AML Program began using a GPS in 1998, to record field observations, collect data, and, more recently, survey for regrading/construction. Management and analysis of spatial information increased drastically when we began using ArcView in 2000, followed by ArcGIS, in late 2002 (both are GIS software packages from ESRI). We now use the GPS and GIS at every stage of AML projects. This paper will focus on their use in site assessments. Our GPS data collector provides a seamless link between the field and the GIS in the office. Expanding the memory of the data collector allowed us to collect and concurrently manage data from multiple AML projects. The GPS mapping capabilities are used to collect radiation observations, infrastructure locations, bathymetric data, soil and spoil characteristics, vegetation data, sample and photo locations, and determine the extent of underground mine subsidence. Conversely, any features that are resident in the GIS can be loaded into the GPS and located in the field. We supplement the GPS mapping information in the GIS with data and images that are available from the Internet and other sources. Historic aerial photographs and maps are scanned and brought into the GIS via georeferencing. The tools included with ArcGIS make it possible to analyze data using spatial analysis, 3D analysis, and geostatistics. Implementing the GPS equipment has been a relatively straightforward process; however, developing each project GIS involved a longer learning curve, especially for those of us who do not have a background in cartography. Fortunately, difficulties associated with different coordinate systems, database design, and software upgrades have been temporary obstacles. The availability of a generic project geodatabase would be very useful to AML programs that are getting started with a GIS. Investing time and effort into these geospatial tools (GPS and GIS) has been of great benefit to our program.

Additional Keywords: site assessment, georeferencing, data collection, geodatabase, Texas

–[1]Paper was presented at the 2004 Advanced Integration of Geospatial Technologies in Mining and Reclamation, December 7 – 9, 2004, Atlanta, GA.

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Introduction

Abandoned Mine Land (AML) programs always employ geospatial information in project design and management. It is essential to record the locations of any features requiring mitigation, as well as have a system with which to keep track of those locations. Any calculations involving distances, areas, volumes, or slopes depend on locational data. Traditionally, surveying equipment and CAD (Computer-Assisted Design) software have been involved, employing either a state plane or an in-house-designed local coordinate system. This paper will focus on the use of geospatial tools to conduct site assessments. It is written presupposing the reader has some knowledge of the geospatial tools that are discussed, therefore, some of the technical nomenclature may not be fully defined.

Until 4 years ago, we used traditional surveying equipment, a Wild Heerbrugg total station, and employed at least two people to accomplish all of the surveying. This manpower requirement sometimes complicated data collection associated with site assessments. As is the case with many kinds of environmental work, sample collection can take a significant amount of time. It was impractical at times to have a surveyor wait around to record the sample location or to temporarily identify the spot with a pin flag or a stake and survey later. Additionally, this traditional surveying method required one person to remain at the total station and another person (sometimes the person collecting samples) to carry the prism, in addition to any other needed sampling equipment.

An alternative method of recording survey and sample locations was used when the surveyors were not available or the work was too time-consuming. This “low-tech” method involved an aerial photograph or topographic map. Recognizable landmarks were used as starting points and subsequent directions and distances were measured with a compass and estimated by pacing, respectively. All of the directions and distances were recorded in a field notebook and then the relative positions were estimated and entered into a CAD drawing. The accuracy of this method was variable and difficult to measure. Additionally, it was cumbersome to link field observations and analytical data to the locations in the CAD-based map.

Tools to Record and Manage Geospatial Information

Global Positioning System (GPS)

A newer technology to provide position coordinates, such as GPS, has been adopted in varying degrees over the past ten years. We had considered buying a GPS almost nine years ago, but found that the cost and accuracy of the units made it impractical. We were able to borrow a hand-held GPS unit in 1998 (a Trimble GeoExplorer II that the Office of Surface Mining had provided the Texas Title V regulatory coal program). We noticed significant improvements in our data-collecting capabilities for site assessments, especially since we no longer needed additional people to survey. The GeoExplorer II was quicker and more accurate than compass bearings and paced distances. It took approximately 60 seconds to collect enough GPS positions to estimate our location. The GPS unit also served as a data collector, a big gain. The GeoExplorer II's drawbacks were a text display and post-processing for differential corrections (to obtain <5-m horizontal accuracy).

We were able to buy a Trimble ProXRS backpack GPS unit in 1999 (Figure 1). The advantages of the ProXRS (versus the GeoExplorer II) were: approximately 5 seconds to collect positions for each point location (90% reduction in time), more memory, graphical location display, background map display, GIS interface, and horizontal accuracy of less than 1 meter instead of 5 meters (differential correction in the field, using a commercial satellite service). We were able to justify purchasing the ProXRS GPS with the timesavings and accuracy it provided. It has become one of the best and most versatile tools we have for assessing and managing environmental information for reclamation. This GPS unit has paid for itself (~$11,000) many times over because of the time it has saved us.

Geographic Information System (GIS)

The management and analysis of spatial information improved drastically when we began using the ArcView GIS in 2000. Arcview 3.1 and 3.2a, developed by ESRI, allowed us to compile GPS information and overlay it on maps or aerial photographs. The GIS finally allowed us to easily link a database to geospatial features. This software was also provided by the Office

Figure 1. Bill Reimer, Texas AML, demonstrates use of ProXRS and scintillometer to conduct radiation surveys.

of Surface Mining's TIPS program (TIPS – Technical Innovation and Professional Services). We started to migrate to ESRI's ArcGIS 8.1 in late 2002. The majority of the work is done in ArcMap. The GPS and GIS seamlessly work together. The GPS software packages (Pathfinder Office and Asset Surveyor) allow GIS features to be loaded into the GPS data collector and located in the field. We can supplement the GPS mapping information with data and images that are available from the Internet and other sources. Digital aerial photographs and maps are brought into the GIS, using georeferencing if the data are not associated with a coordinate system. The raster and vector data can be further analyzed with extensions that are included in the GIS software (i.e., 3D Analyst, Geostatistical Analyst, or Spatial Analyst). We now use a GPS and GIS at every stage of AML projects.

Site Assessments for AML Work

What Is Involved?

Site assessments are performed to obtain a thorough evaluation of the conditions that exist at an AML location. The assessments provide information that is used to design reclamation projects and are necessary to meet AML grant application requirements, such as the nature of different earth materials, the extent of potential environmental hazards, and the condition of soil, plant, and water resources.

Site assessment work can be contracted and conducted by individual consultants or environmental firms. The expertise and additional manpower that contracting can provide might offset the higher costs involved. The need for contracts and contract management may be a disadvantage. On the other hand, there are advantages to conducting the assessments "in-house." The cost is probably lower, there may be greater flexibility in scheduling, and institutional memory can be of great benefit (discounting staff turnover). Unfortunately, in-house work ties up AML personnel, involves a learning curve for new technology (a significant time investment), and possibly requires that analytical work be outsourced. The choice of which route to take, contracted or in-house assessments, will depend on the nature of the problem, funding levels, and time constraints. The use of GPS and GIS does greatly facilitate conducting site assessments and could be considered indispensable.

Benefits from Using GPS

Even though our staff numbers have declined over the past 15 years (from approximately twenty down to eight people), one of the reasons we have been able to maintain our level of work is availability of GPS technology. We purchased and began using a Leica Geosystems SR530 RTK DGPS (real-time kinetic, differential GPS) system in 2000 and can complete all of our survey work with one person. Additionally, the portability of the Trimble ProXRS allows one person to carry sufficient field equipment to be able to work alone and collect much of the data needed for site assessments.

The quality of our site assessment data has improved since we began using the backpack GPS unit because of the horizontal accuracy and increased number of data points we can collect. More data points are necessary at sites that exhibit significant variability (in slopes, vegetative cover, and spoil materials). We are able to quickly collect enough positions so we can get more data with only a slight increase in the time spent.

How We Use GPS and GIS to Conduct AML Site Assessments

The level of information that is needed will be dictated by the kind of project involved. For most of our AML projects, we can divide the process into four steps that will involve a GPS and/or GIS: background information; reconnaissance; data collection; and data analysis.

Background Information

Any maps, aerial photographs, or historical documents that cover a project area will be invaluable. A GIS is the perfect tool for compiling this background information. It is helpful, but not necessary, that the maps or aerial photographs are already in digital form – and more so if they are already in a known coordinate system (and the aerial photographs are orthorectified). Hardcopy maps and aerial photographs can be converted to a digital form by scanning (Figure 2).

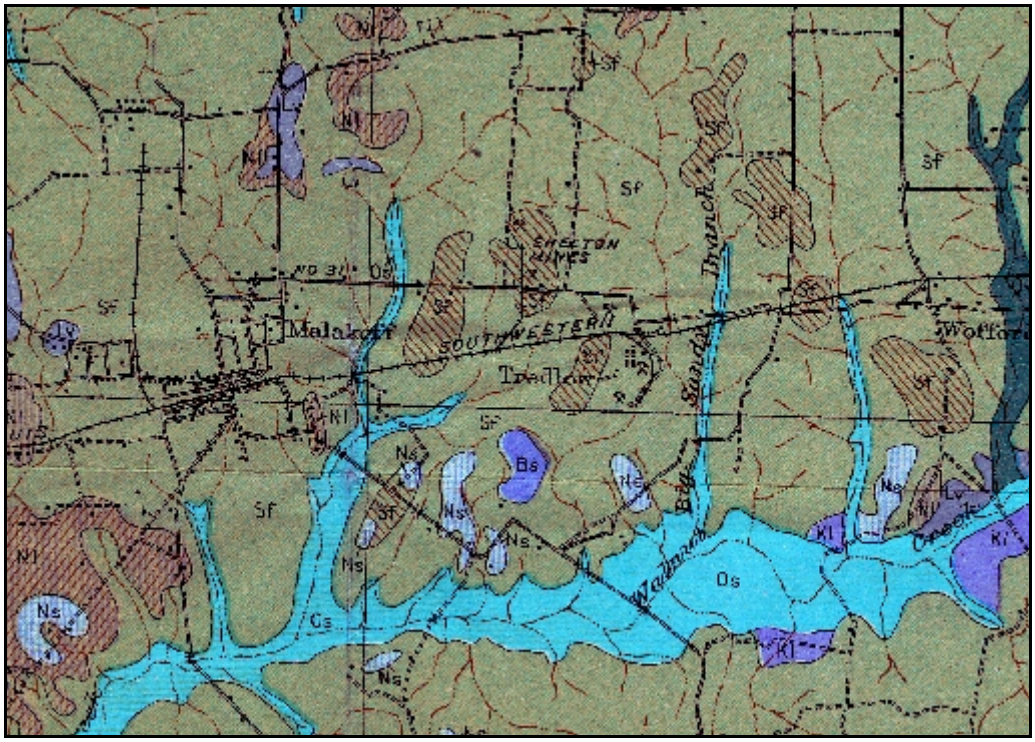

Figure 2. Portion of scanned soil map from Henderson County, showing mine locations (Texas Agricultural Experiment Station, 1929).

A flattop scanner can accommodate smaller-sized media (letter- or legal-size paper, depending on the scanner). Larger media (up to 91 cm) can be easily scanned with a pass-through scanner. Other geospatial data are becoming more available as existing information is digitized. Examples of data that are available from state and federal agencies are digital elevation models, hypsography, hydrology, transportation infrastructure, soils, geology, and precipitation; as well as other documents, such as mining reports, historic maps, and archived aerial photos. It is

difficult to georeference maps from older publications, since they may not be drawn to scale or landmarks, such as roads, may have been moved. Historic maps may be useful in identifying areas that should be examined closely or labeled as having mine subsidence potential (Figure 3).

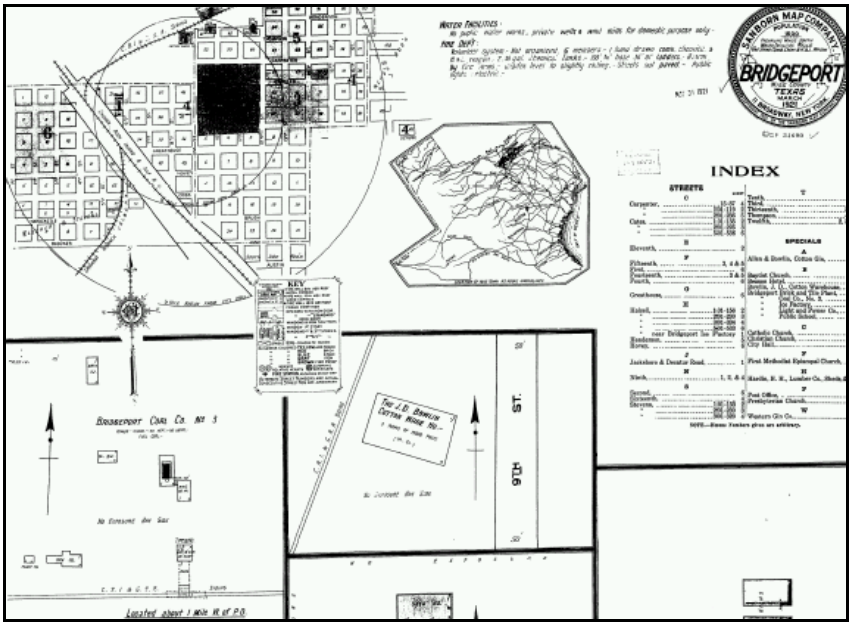

Figure 3. Portion of City of Bridgeport map, showing location of Bridgeport Coal Co. No. 3 mine facilities (Sanborn Map Company, 1921).

ArcMap is able to reproject data in the current coordinate system, as long as there is a projection (PRJ) file associated with the data. Even if there is not a PRJ file present, it will project the data according to the coordinates that are associated with the file. We have found that it is best to define the projection/coordinate system with the ArcToolbox module before adding files to a map. You can find the coordinate system associated with that file by checking the metadata with ArcCatalog.

Reconnaissance

We conduct on-the-ground reconnaissance to familiarize ourselves with sites. We walk over as much of a project area as possible, so equipment portability is important. A hand-held GPS unit is more practical for this preliminary work. We borrow the Title V program's Trimble

GeoExplorer3 if it is available. Field observations are recorded in the GPS, in field books, and on maps or aerial photographs, as appropriate. All of this information is then compiled in the GIS as part of planning comprehensive sampling and data collection later on. The flexibility of the GPS as a data collection device is well suited to on-the-ground reconnaissance.

Data Collection with GPS

Pathfinder Office, version 2.90 (Trimble Navigation Limited, 1997), is the GPS management software that resides on our office PC and field laptop. It includes a utility that arranges the way in which data will be collected, the Data Dictionary Editor.

Data Dictionaries. The data dictionary should be designed to mirror the structure of the GIS, so the GPS can be used to populate the attribute tables. This is why it is important to document the variability of a site during reconnaissance, so the range of features (points, lines, and areas), that may need to be collected in the field, can be included in the data dictionary. A GPS feature is synonymous with a shapefile ("data layer") in the GIS; conversely, a feature's attributes are the shapefile's fields. We ensure that the data type (i.e., text, numeric, date, etc.) for each attribute is appropriate. An example of a data dictionary we use for uranium mine assessments is shown in Table 1. We designed another data dictionary for projects that have subsidence from underground coal mines because we needed to collect other types of information at those projects. We have found that a balance must be struck between designing a comprehensive data dictionary that covers as many scenarios as possible and a more general data dictionary that has enough flexibility to allow adequate data collection in unforeseen situations. Data dictionaries that contain menu attributes may lead to larger files, which can be a problem for some GPS units. We have run out of memory several times with both the GeoExplorerIII and the ProXRS when we had day-long work involved. A simple data dictionary, with few, if any attributes that contain menus, helps reduce the file sizes. You can also add memory to the ProXRS' data collector. This will be discussed in the section that addresses GPS configuration.

Background Maps. Asset Surveyor (v. 5.27) is the software that runs on the TSC1 data collector. It gives the TSC1 the capability to display a background map while collecting data. The map can

Table 1. Data dictionary structure used to collect data at uranium mine sites; default Trimble GPS features are not included in this list.(i.e., generic points, .lines, and areas).

Features	Classification	Number of Attributes	Input Type(s)
Core Location	Point	11 †	Text, numeric, menu, and date
Collects data in undisturbed areas: core ID, radiation, vegetation, soils, and sample log.			
Micro-R	Point	1	Numeric
Records 1-m height scintillometer readings (gamma radiation).			
Rad Piles	Area	1	Numeric
Measures basal area of mine waste piles.			
Rad Sediment	Point	1	Numeric
Records average height of mine waste piles or depth of any widespread radioactive material.			
Topsoil Survey	Point	5	Numeric, menu, and text
Collects soil information in disturbed areas, such as spoil piles topdressed with soil.			
Sediment Depth	Point	6	Numeric, menu, and text
Collects data on spoil materials, their vegetative cover, and nature of underlying material.			
Soil Depth	Point	1	Numeric
Records soil depths (for soil surveys in disturbed areas; where only depth data is needed).			
Auger Core	Point	1	Numeric
Records maximum depth reached (with bucket auger or powered continuous flight auger).			
Traverse Point	Point	1	Text
Records location of survey points (used when developing local coordinate system).			
Photo Point	Point	1	Text
Records location of photographs (includes a comment field).			
Transect	Line	1	Text
Documents path taken while collecting nested points (usually vegetation data).			
Pond Area	Area	1	Text
Measures area of any man-made water feature (includes a comment field).			

† Specific attributes are: Core No. (text); Micro-R (numeric); Ground Cover (menu); Vegetative Type (menu); Dominant Brush Species (menu); Topsoil Depth (numeric); Depth to C Horizon (numeric); Acid Present (yes/no); Samples Taken (yes/no); Sample ID (text); and Date.

be any file resident in the data collector. For example, you can set up vegetation measurement transects with the GIS and import that respective shapefile into Pathfinder Office. You then convert the imported file into a format that can be uploaded to the data collector. That uploaded file can be used as the background map you can follow in the field while collecting the vegetation data. Another helpful function is data filtering, where you can sort data while the file (the GPS "rover" file) is open and actively collecting information. The filter can sort numeric attributes with several operators (i.e., =, <, >) and display only the data that meet the chosen criteri(on/a). This capability allows us to isolate areas of concern that we may need to revisit while we are in the field.

GPS Configuration. The TSC1 datalogger that we use with our ProXRS GPS comes with 2 MB of memory. Fortunately, there is a PC card slot available for memory expansion. The datalogger accepts Type I or Type II ATA format PC Cards (Trimble Navigation Limited, 1999). We currently have an 8 MB CompactFlash card installed - which requires an additional CompactFlash card adapter. The extra memory is necessary when we have fieldwork that spans several days and many features are collected (several files have exceeded 500K). The expanded memory also allows us to work on multiple projects, ranging from site assessments to overseeing radioactive material removal, without having to link the datalogger/data collector to a computer to download/upload files.

The TSC1 also accepts external input from peripheral measurement instruments, such as a laser rangefinder or a depth finder. We perform bathymetric surveys by paddling a canoe around a pit impoundment with a depth finder connected to the ProXRS GPS. The depth data are continuously fed to the GPS as it collects line features.

Field Work. Much of the field data we have collected are associated with radiation surveys (Figure 4). We use the GPS for essentially every phase of our AML projects. See Table 2 for a summary of the kind of data we have collected with the GPS. Over 19,000 features have been collected in the six years we have had GPS equipment. We keep information on each GPS file in an MS-Access database since we often refer back to the GPS data (Figure 5). A considerable use of the GPS is for several kinds of soil surveys. The soil surveys range from evaluating

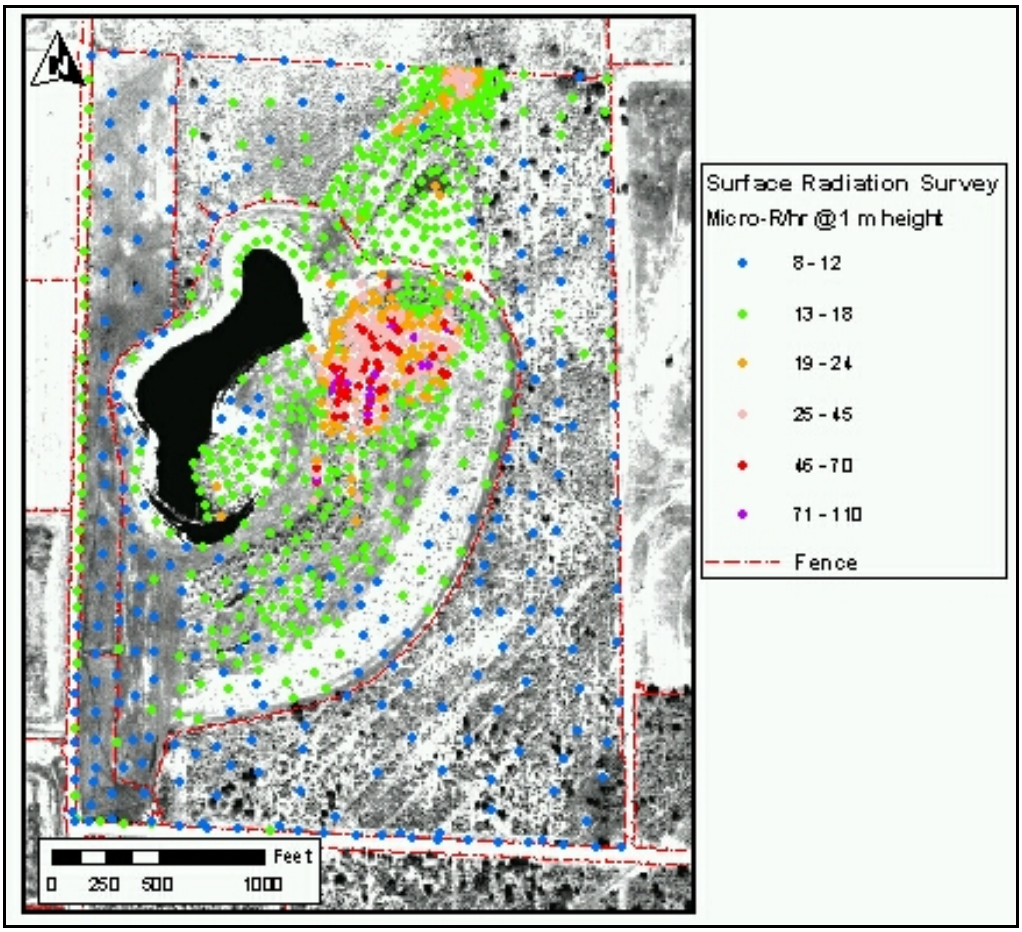

Figure 4. Radiation survey data from Brown mine (1077 measurements; taking 11.5 hours but conducted on 5 separate days; started on 1/27/04 and ended on 3/10/04).

undisturbed, native soils adjacent to AML projects to soils that have been topdressed on regraded spoil. Denuded areas and any other finite area of interest are delineated, using an area feature. Fences, roads, boundaries, and erosion features are commonly traced with line features; however, as much of that as possible is done with the GIS by digitizing features seen on aerial photographs. There are also several GIS and image software utilities that can be used to delineate different features.

Many times the data collection process is iterative, in that we must evaluate data we have already collected before we can continue collecting additional information. That is the case when we suspect there may be buried radioactive materials at a site. We will first core a site in a

Table 2. Types of data collected with GPS (summary of database, 374 files).

Types of Data	Proportion of all GPS Files Collected
Core locations (also auger, hand probe, etc.)	27%
Radiation surveys (at 1-m height)	25%
Sampling locations	10%
Sub-surface radiation surveys	9%
General infrastructure (roads, fences, pipelines, buildings, etc.)	9%
Construction/reclamation monitoring and management	8%
Soil depths	7%
Coordinate system development / other surveying issues	6%
Erosion features	3%
Vegetation delineation	2%
Subsidence evaluations	1%
Bathymetric surveys	< 1%

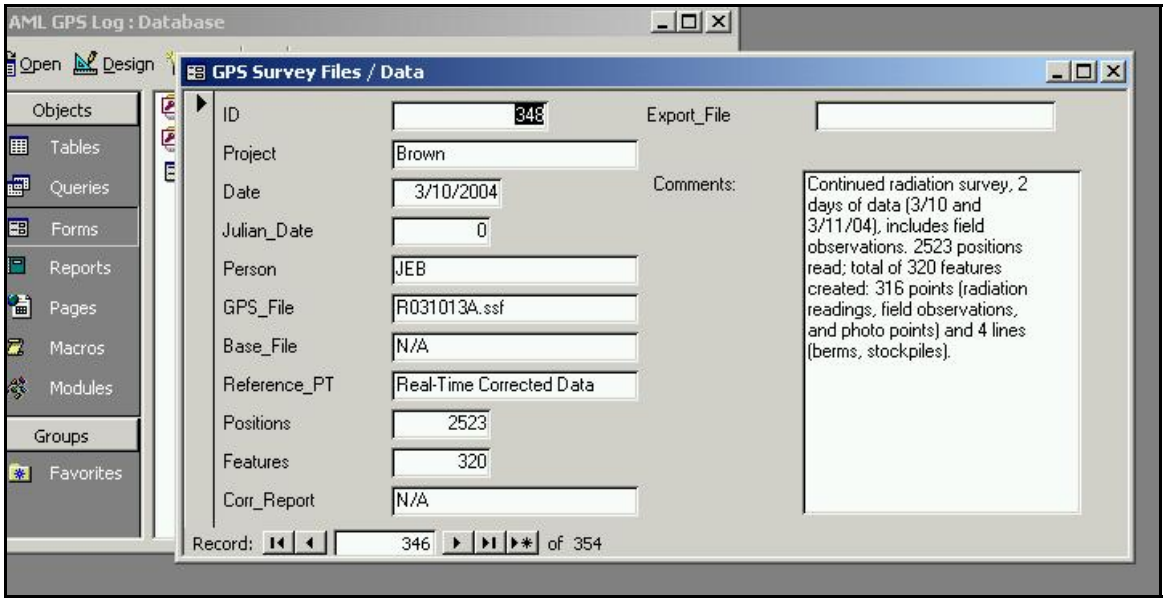

Figure 5. Data entry screen for GPS file log.

widespread manner; collect subsurface radiation readings from each core; then evaluate the data in the office. We identify any locations where additional data would help reduce uncertainty. Those GIS points are transferred to the GPS, which, in turn, is used to locate the next set of cores.

Data Analysis

We use ArcGIS's ArcMap 8.3 (ESRI, 2002) and its extensions 95% of the time. ArcCatalog is used mainly to create and manage shapefiles and ArcToolbox is used to manipulate coordinate systems and convert file types. Imagine 8.5 or 8.6, an image processing and GIS program from ERDAS (Leica, 2002), is routinely used to mosaic orthophotographs, georeference scanned maps and images, and obtain subsets from large images. We have found that it is easier to georeference a raster file using Imagine's polynomial rectification utility (Figure 6) than using ArcMap's georeference tool. We evaluate the data we collect with the GPS and compare it to any other external data (maps, photographs, and vector data) we have compiled with the GIS.

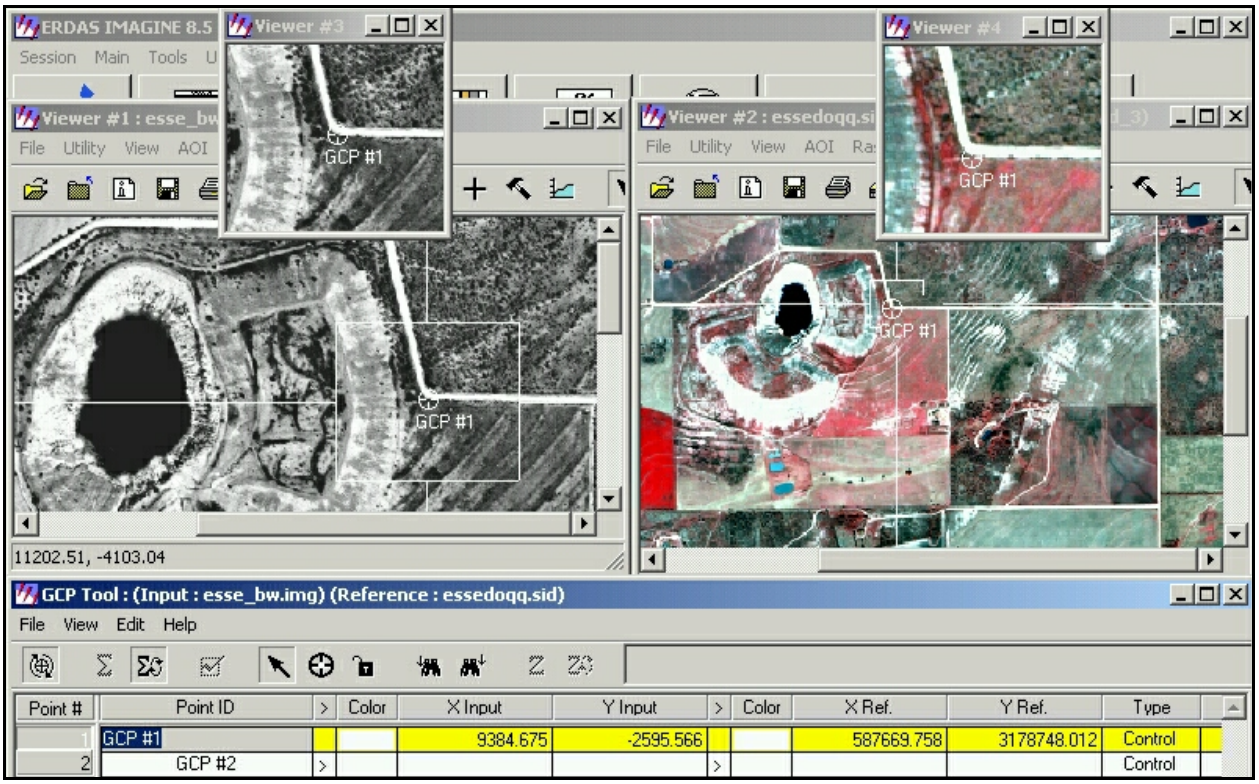

Figure 6. Screen shot of Imagine 8.5 polynomial rectification utility, showing user-friendly controls.

We can also geospatially correlate analytical data from samples to quantitative and qualitative measurements taken in the field. External databases can be linked to GIS shapefiles, as long as there is a unique field in common. Aerial and satellite imagery can be analyzed (using ArcGIS extensions or ERDAS Imagine) and the results (i.e., ground cover, acidic spots, soil depth, etc.) ground-truthed using the GPS to locate measurement points. For the sake of brevity, I will only discuss two kinds of data that we routinely analyze: radiation and soil data.

Radiation Data. We first examine radiation data in ArcMap by simply changing the symbology (appearance) of the data. A quantities symbology, where quantities are drawn with different colors, is chosen, using a natural breaks classification. This procedure is usually sufficient to demarcate areas with elevated radiation levels. A buffer can be drawn around all of the data that exceed a threshold level (i.e., 25 micro-R/hr). We can then plan additional, more intensive data collection within those areas. The GeoSpatial Analyst 8.3 extension is also used to evaluate radiation data. The raw data are rasterized to allow evaluation with Inverse Distance Weighted Interpolation. This process creates areas of specific radiation ranges, which in turn can be contoured (Figure 7). We can pick the radiation level of interest and contour it. The chosen contours will represent areas where more intensive subsurface radiation profiles need to be conducted. The contours also point out where additional exploratory fieldwork may need to be conducted, such as along fences and adjacent properties where offsite excursion of radioactive sediments appears to have occurred.

Soil Data.

Most of the AML sites were mined at least twenty-seven years ago. Since then, there may have been additional disturbance or varying levels of volunteer revegetation. The soil resources within and adjacent to the project may have been mapped before mining occurred. On the other hand, they may have been mapped after mining. In either case, the scale of the mapping would not be adequate to provide the detailed soil information that is needed to properly make reclamation plans. The NRCS maps soils at a 1:24,000 scale. This scale is appropriate for land use planning that does not require detailed information for small areas, with the minimum soil map unit delineation ranging between 1.6 and 16 hectares (Soil Survey Division Staff, 1993).

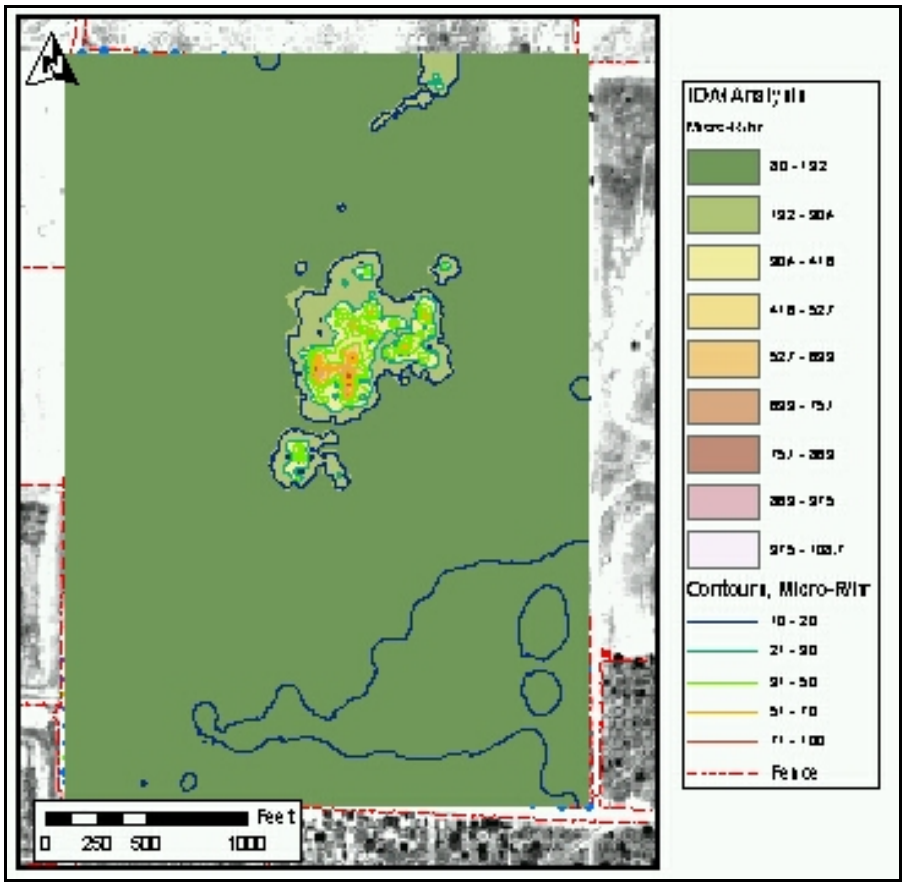

Figure 7. Radiation data from Brown mine analyzed with inverse distance weight interpolation (IDWI) and contoured. Please compare to raw data shown in Figure 4.

For reclamation work, where detailed information is needed for small areas, it is advisable/necessary to evaluate soils at a relatively larger scale (i.e., 1:3,600). We evaluate soils with a much higher density of soil cores (equivalent to a 1st order survey) than used during Natural Resources Conservation Service's (NRCS) soil surveys, trying to get representative locations across the entire project area landscape. We recorded the soil core locations with the GPS and export them to the GIS (Figure 8). We have found that the Geostatistical Analyst extension works well with data from natural systems, as is the case with apparently undisturbed soils adjacent to a mined area. We overlayed the NRCS's mapping unit delineations on the kriging results to compare the data. As you can see (Figure 9), there are differences in data from

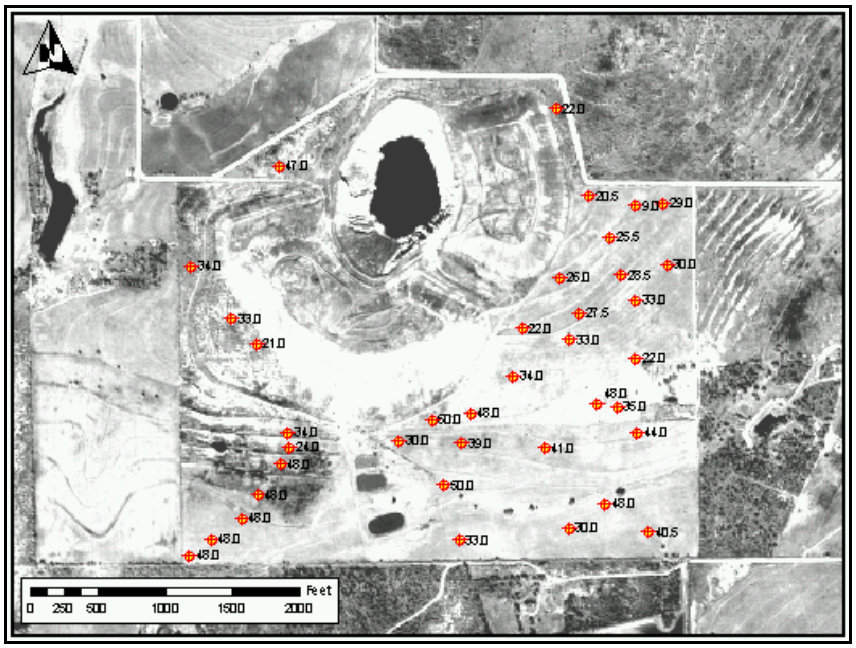

Figure 8. Location of soil cores and depth (in inches) to underlying horizons, where carbonate accumulation has occurred; Esse mine.

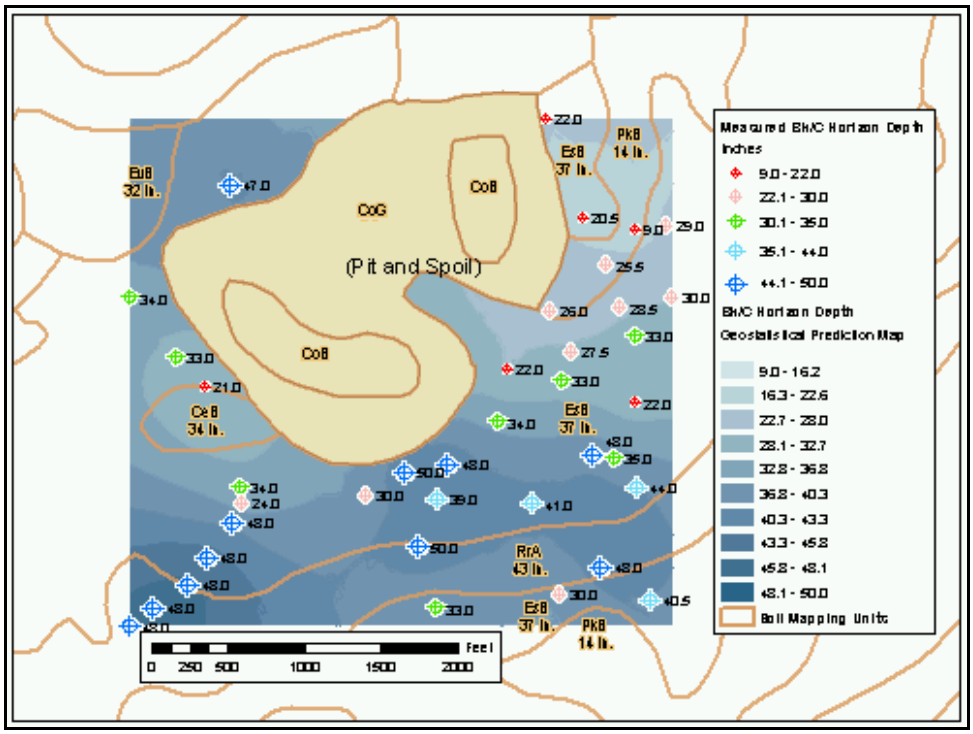

Figure 9. Comparing NRCS soil map unit delineations to model derived from more intensively collected data.

different scales, even though both sets follow a similar pattern. We used the depth to Bk, Bkm, 2Cr, or Bcssyz horizons as the variable, since this zone of carbonate accumulation was easy to observe and measure in the field. There were 8 soil mapping units found within the property that contains this AML project (Table 3). Two mapping units represent land that had been mined (map units CoB and CoG - representated by the tan color). The typical depth at which a Bk, Bkm, Bcssyz, or 2Cr horizon was observed by the NRCS, is listed below each soil map unit symbol. The denser data that we collected and modeled provide more detail – as would be expected. The results of this geostatistical analysis provided us with enough information to designate soil borrow areas and be reasonably comfortable that we would not intercept any shallow soils. It also helped us determine a maximum soil salvage depth for each area, so enough soil would remain to sustain adequate vegetative cover. It is important to analyze field soil data if you find it necessary to borrow soils at an AML site, because actual soil horizon depths may be significantly shallower or deeper than indicated by the NRCS's published soil survey information.

Table 3. Information compiled from official series descriptions (NRCS, 2004); detailed information regarding map symbols used in Figure 9.

Map Symbol, Soil Name, and Slope	Depth Range (inches / centimeters), Material Underlying Subsoil	Horizon †
CeB –Choke silty clay loam, 1-3%	24 – 48 / 61 – 123	Bk
CnA – Condido clay, 0-2%	18 – 24 / 46 – 61	Bkm
CoB – Conquista clay, 1-3%	Not Applicable	Not Applicable
CoG – Conquista clay, 20-40%	Not Applicable	Not Applicable
EsB – Eloso clay, 1-3%	20 – 40 / 51 – 102	2Cr
EvB – Esseville clay, 1-3%	18 – 36 / 46 – 91	BCssyz
PkB – Pavelek clay loam, 0-3%	7 – 20 / 18 – 51	Bkm
RrA – Rosenbrock clay, 0-1%	40 – 60 / 102 – 152	2Cr / Bk

† Bk – subsurface horizon, pedogenic carbonate accumulation; Bkm – subsurface horizon, pedogenic carbonate accumulation, strong cementation; 2Cr – lithological discontinuity, weathered or soft bedrock; and BCssyz – subsurface horizon, slickensides present, pedogenic accumulation of gypsum and salt more soluble than gypsum.

Observations on the Implementation of Geospatial Tools

The easiest steps in implementing geospatial tools for our AML program were acquiring and learning to use the GPS equipment. Becoming proficient with the GIS has been a much bigger challenge. I have compiled some observations on the different experiences we have had with both.

GPS Equipment

Hardware. The Trimble hardware has proved to be exceedingly durable. The antenna has endured falls onto pavement, hitting branches, and other miscellaneous, unintended abuse. The TSC1 data collector is weatherproof, fortunately, and is still working without any problems after 5 years of fieldwork in the South Texas brush. The screen has one small scratch – the only evidence of the hard use it has undergone. The biggest problems with the GPS unit occurred when the battery harnesses and the TSC1 data cable started failing. We replaced those cables and have not had any problems since then.

Software. We found it was critical to conduct timely upgrades to the TSC1 software, so it would be compatible with the version of PathFinder Office software; otherwise, there were file transfer problems. There were occasional bugs in the TSC1 software, but Trimble resolved those relatively quickly. The same was true for the PathFinder Office program. The coordinate system utility was very simple to use and enabled us to quickly develop the local coordinate systems for each AML project.

GIS Software

The first program we used for GIS, ArcView, was relatively easy to begin using. It was adequate for most of the tasks we needed to run, although we did not have access to the geostatistical extension. The migration to ArcGIS was more difficult than the learning process associated with ArcView. Now that we are more familiar with ArcGIS, we have found that it was worth the agony of upgrading to it. We still miss the layout capabilities of ArcView, even though you can mimic them in ArcGIS. One of the biggest improvements in constructing and managing maps is the “data frame” in ArcMap. It allows you to efficiently compile data from

several sources in one map. A significant drawback is the memory requirement (both hard drive and RAM) to run ArcGIS. If it were not for extensions, I am not sure the migration to ArcGIS from ArcView 3.2 would be justifiable – especially if you had to run the program on PCs with less than 512 MB RAM.

Coordinate systems continue to be a stumbling block, since data from various sources are routinely brought into our maps. It is very helpful when there is a complete metadata file that accompanies the data. Another problem is that most of us do not have experience in cartography.

The biggest obstacle we have encountered in implementing GIS technology is a lack of time. The learning curve(s) associated with deploying GPS equipment is minimal, barely measurable, when compared to learning how to use GIS software. The ArcMap files for subsequent AML sites are usually structured differently, since we learn something new each time. Standardization of GIS projects remains an unfulfilled goal. The migration from shapefiles to geodatabases still has not occurred.

Now that ArcGIS has been around for a while and the concept of geodatabases appears to be here to stay, it would be very helpful for us to have access to a generic data model (with an associated geodatabase that we can populate with our own data) that could be customized by each AML program. Even though there are data models available on the ESRI web page, a lack of time to develop our own data model is still a problem.

The GPS equipment is essential for our work. Despite not having a complete, flawless, GIS for our AML projects, we have found the GIS software to be of great benefit. It provides us with the best way to compile data from many sources and tools to analyze them and offers good mapping capabilities.

Acknowledgments

I would like to thank all of the TIPS instructors that have helped us learn how to use the GPS equipment and get started in the right direction with the GIS software. Thanks are also due to the Office of Surface Mining for providing the geospatial software titles that are essential for our work.

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