ASSESSING RECLAMATION FEATURES AND ESTIMATING RECLAMATION COSTS ON ABANDONED, INACTIVE, AND PERMITTED MINES USING REAL-TIME GPS AND TABLET COMPUTERS[1]

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Abstract. Real time mobile mapping is now a reality for natural resource professionals such as Abandoned Mine Land (AML) Reclamation Specialists, Mine Inspectors, and Permit Reviewers. During the early 1990's, lightweight global positioning system (GPS) receivers first opened the door for field professionals to accurately locate geographic features and environmental problems without traditional surveying crews and equipment. Further developments in GPS technology during the late 1990's enabled improvements in accuracy of GPS data with the introduction of real-time GPS correction equipment such as portable beacon receivers and Wide Area Augmentation System (WAAS) enabled GPS units. However, standard GPS receivers and even the higher-end GPS mapping equipment lacked the power and capabilities to seamlessly move from the office to the field and back without multiple data conversion and correction exercises. Recent innovations in Tablet computers, card type GPS receivers, integrated GPS technologies along with Geographic Information System (GIS) and Computer Aided Drafting and Design (CAD) software make it possible to use existing aerial photography, satellite imagery, and electronic permitting data to easily and accurately locate natural resource problem features, produce ready-to-use GIS data and maps, conduct in field CAD design, and seamlessly extract the data back in the office. The Office of Surface Mining (OSM) continues efforts in applying mobile computing devices and software to permitting and AML field work. This technology allows Inspectors to take maps and permit data to the field for inspection and verification of mining and permitting activities. The application of AML design and re-design in the field is also being applied along with traditional methods to eventually integrate mobile computing as a tool in AML and Regulatory work. This technology will result in a more efficient means of implementing the Surface Mining Control and Reclamation Act (SMCRA).

Additional Key Words: mobile computing, GIS, GPS, CAD, electronic permitting, and digital mapping.

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Introduction

The Office of Surface Mining (OSM), Mid Continent Regional Coordinating Center Mobile Computing Team (MCRCC) in cooperation with the Technical Innovation and Professional Services (TIPS) National Team, researched and tested various mobile computing technologies over the past several years (for more information on TIPS see www.TIPS.osmre.gov). During a period from October 2001 to September 2003, OSM successfully tested field-oriented software running on mobile computing devices for both regulatory and Abandoned Mine Land Applications (AML). Mobile Computing is the next step beyond basic Global Positioning System (GPS) data collection. It uses full function computing hardware to implement CAD and GIS solutions in the field. With the advent of electronic permitting and GIS, permit data is now readily available in digital format that environmental professionals can take with them to the field with real time spatial location as suggested by Joseph (2000). Mobile computing allows AML Reclamation Specialists, Mine Inspectors, and Permit Reviewers to leverage the vast spatial data sets created for coal mining areas in the United States, along with GPS to use the power of place. To know where you are at all times on a familiar back drop such as satellite and aerial photo images intermixed with permit vector data provides environmental professionals the capability to monitor and assess field conditions in real time.

The MCRCC has utilized tablet and handheld computers, compact flash card type GPS receivers and various software to map landscape features on numerous projects. Data collection efforts have included GPS point, line and polygon locations and feature attribute information. Site assessment efforts are substantially improved by the ability of field investigators to actively view their locations on digital aerial and satellite imagery displayed live on the GPS enabled mobile computers. GPS receivers with integrated Wide Area Augmentation System (WAAS) services provide accuracy levels estimated as less than 3 meters (http://gps.faa.gov/Library/indexWAAS-f.htm). These mobile computing technologies have now been tested in data collection efforts by OSM in the States of Alabama, Missouri, Indiana, Oklahoma, Illinois, Pennsylvania, Montana, and Colorado. We will briefly discuss these overall technologies and then provide a detailed discussion on one of the test sites in Missouri.

Overall Technologies Tested

Mobile Computing Devices

The MCRCC researched several GPS and lightweight computing platforms. We tested two Fujitsu products and one Panasonic product. The Fujitsu products where the Stylistic 4121™ and the Stylistic 3500R ™ mobile computers. The Stylistic 3500R™ is a semi-ruggedized tablet form computer with a 500 MHz Celeron processor, 256 MB RAM and a 15 GB hard drive running a Windows 2000 operating system (Fig. 1). It has a 10.4 inch LCD reflective touchcreen that can be viewed outdoors. The Stylistic 4121™ is a non-ruggedized tablet computer with a 900 MHz Pentium III processor, 768 MB RAM, a 48 MB graphics card and a 60 GB hard drive running the Windows XP Tablet operating system. It has a 10.4 inch digitizer screen that can be viewed indoors and outdoors (http://www.computers.us.fujitsu.com/www/products_pentablets.shtml). The Panasonic we tested is the Toughbook CF18™ w/wo integrated WASS enabled GPS (Fig. 2). This tablet notebook is fully ruggedized with a Mobile Processor running at 900 MHz, 768 MB of RAM, 40 GB hard drive, 64 MB graphics card and the Windows XP Tablet operating system. (http://www.panasonic.com/computer/toughbook/learn_more_tb18.asp) We also tested a Compaq iPAQ 3850 ™ handheld computer (PDA) with 64 megabyte RAM, and the Pocket PC 2002 operating system (Fig. 3). We used a Compaq dual PC card expansion jacket with built in battery to add capacity for a 256 megabyte CF memory card. A similar Windows Pocket PC based product tested was the Trimble GEO XT™.

Figure 1. Touchscreen Computer
Fujitsu Stylistic 3500R™

Figure 2. Tablet Computer
Panasonic Toughbook CF18™

Figure 3. PDA

Global Positioning System Devices

The MCRCC researched several real-time corrected GPS technologies. The four technologies that were reviewed all offer real-time data correction. The first technology is the Trimble Pro XR™ and Pro XRS™ that have an integrated beacon for real time differential correction from the Coast Guard radio beacons and other similar supported radio beacons. The Trimble Pro XR/XRS are backpack units with an antenna mount (for more information see http://www.trimble.com/mappinggis.html). They use TSIP and NMEA protocols to communicate to data collectors or mobile computing devices. The second technology is WAAS enabled compact flash GPS units that receive correction data live from WAAS. We have used the Teletype WorldNavigator ™ compact flash card GPS receiver (Fig. 4) with a Teletype remote antenna and the HAiCOM HI-303CF (Fig. 5) compact flash card. The third technology we have investigated is the use of the Trimble GeoExplorer® 3 with Beacon-on-a-Belt (BoB™) which receives correction data from radio beacons (for more information see http://www.trimble.com/bob.html). The fourth final technology that we have investigated is Leica Real Time Kinematic (RTK) GPS system that allows for setting up a base station on a known point and sending correction data to the field computer using a radio beacon (for more information see http://www.leica-geosystems.com/gps/product/sr530.htm). All four technologies have provided adequate real-time correction for our project purposes.

Fig. 4 Teletype WorldNavigator

Figure 5. HAiCOM HI-303CF

Mobile Computing Software

The MCRCC has researched three software packages; *TerraSync*™ by Trimble Navigation Limited (for more information see http://www.trimble.com/terrasync.html), *ArcPad* ™ by Environmental Systems Research Institute (for more information see http://www.esri.com/software/arcpad/), and *Tsunami* by Carlson Software (for more information see http://www.carlsonsw.com/tsunami.htm). All three programs have provided adequate functionality for our project needs but the TerraSync software would only communicate with the Trimble Pro XR/XRS through the TSIP protocol. We were unable to make the TerraSync software recognize neither the Trimble Geo Explorer 3™ nor the Compact Flash GPS receivers that utilized the NMEA protocol. We also utilized standard Microsoft Office software products as would be found on any desktop computer.

Missouri Test Site

Overview

Data collection was performed in February 2003 when morning temperatures were often recorded below 20 degrees F, yet, no hardware or software problems were encountered. Five different people alternated work in three person teams over a three week period to complete the data collection effort. Only one of the people had any previous experience with tablet computers or ArcPad™ software. The initial data product, ArcView Shapefiles, were easily imported into Autodesk Map™ software for use by engineering staff for estimating reclamation needs and associated costs. The use of GPS enabled tablet computers substantially improved the speed, accuracy and completeness of the mapping project compared to conventional methods.

Project Assignment

The Missouri Department of Natural Resources asked the MCRCC to estimate reclamation liabilities on lands mined for coal under State mining permits and left partially unreclaimed due to bankruptcy of the mining company. Missouri intends to use the information resulting from the assessment to estimate liabilities to its reclamation bond pool and to develop bond forfeiture reclamation designs. MCRCC began the assessment during November 2002 using a Trimble

GeoExplorer® 3 GPS receiver and paper copies of USGS digital orthophoto-quads overlaid with mine permit boundaries. Initial field work revealed that the investigators had great difficulties locating mine permit boundaries and mine features as well as their actual locations on the ground, making it hard to ensure that all problem features were accounted for and mapped. Following the initial field work, the MCRCC Mobile Computing Team was asked to assemble a GPS driven mobile computing system to make the mapping project more efficient and effective. The system had to be capable of displaying the investigator's present location on digital aerial photographs and permit maps and had to enable easy entry of mine site attribute data for site assessment and eventual cost estimating.

Choice of Software and Hardware

We tried ArcPad™ on the Fujitsu Stylistic 3500R™ computer with the Teletype GPS compact flash receivers and had no trouble receiving and processing GPS data. ArcPad™ also worked with the Trimble Pro XR™ and GeoExplorer® 3 GPS receivers. We chose to use the ArcPad™ software largely because it worked with our available GPS receivers and met the performance requirements of our project. ArcPad™ software is capable of creating Shapefiles from scratch or by importing fields from an existing Shapefile. It does not have the capability to create custom menus or data dictionaries. This functionality is provided by a separate software package called "ArcPad Studio 6.0". We used ArcPad Studio to create a custom menu and data entry forms for the ArcView Shapefiles we created.

For GPS capability, we used the Teletype WorldNavigator ™ compact flash card GPS receiver and a Teletype remote antenna. The WorldNavigator GPS receiver is WAAS enabled, which eliminates the need for post processing of data and improves navigation accuracy in the field. When assembled, the computer, padded carrying case and strap, stylus, GPS receiver, and antenna weighed less than 4.3 pounds. This was not at all burdensome when carried on a shoulder strap or one handed for data entry.

Equipment Setup

The Fujitsu Stylistic 3500R™ tablet computer comes with a hot swappable battery and one PCMCIA card slot. It was purchased with a docking station that allows connection of a standard keyboard, monitor, mouse and remote CDROM drive. We used the docking station and CDROM to install ArcPad™ and ArcView 3.3 software. Following software installation, we removed the tablet computer from the docking station and inserted the Teletype GPS card into the PCMCIA slot using a universal compact flash to PCMCIA adapter that fits completely within the card slot. When complete, only the GPS antenna, which measures 1.5 inches square, protrudes from the computer. An aluminum guard was fashioned out 3/32 x 2 inch stock to protect the GPS primary antenna and the plug for the auxiliary antenna from damage in the heavy brush we expected to encounter during the field work. All this we inserted into the padded carry case with neck strap.

Software setup and initial programming

ArcPad™ uses ArcView shapefiles that can be created using ArcGIS Desktop, ArcView 3.x or ArcPad™. Files can be created in the field with ArcPad™ by creating each field within the .dbf or by importing fields from existing shapefiles. We used ArcView Studio in the office to create custom data entry forms with drop down list boxes, required fields and acceptable data ranges. These forms were intended to limit data entry errors in the field. ArcPad Studio provides a wealth of customization functions, some of which are as simple as drag and drop programming. Other functions require a limited amount of "Visual Basic for Applications" (VBA) Programming.

File Setup

To prepare for field work, all files needed for the project were arranged under a simple directory tree on the c: directory of the desktop computer and the project file was tested to ensure that the project would open in the field. Once the directory and project were built, the entire directory and files were copied to each of the field computers. Projects could have been built in the field but we simplified the process to ensure consistency between users and make data download simple. A shortcut was added to the Tablet desktop so that the project could be opened easily from the desktop.

ArcPad™ is capable of using .jpg and .sid compressed images. It does not read .tif image files. On the tablet computers, we were able to use 5 to 8 megabyte digital ortho-quarterquadrangle (DOQQ) aerial photos in .sid format with no delay in the draw or redraw rate. We did not test the maximum file size but we expect it to be the same as on any other 500 megahertz computer. We found that LizardTech Mr. Sid ™ compression software was essential if one wants to use only handheld PDA type computers to do mobile mapping. It is also useful for utilizing standard USGS digital raster graphic (DRG) topographic maps on either the tablet or handheld computer because USGS DRG's are generally found in .tif format and must be converted to .sid or .jpg to be used in ArcPad™. In ArcPad™ we found the redraw rate and clarity to be better with .sid files than with .jpg files. This should be tested further to determine with more certainty if the differences are worth the added expense of the Mr. Sid software. ArcPad™ captures both spatial and attribute information in ArcView shapefile format. Shapefiles may be read directly by ArcPad™, ArcView 3.x and ArcGIS 8.x software and may be imported into Autodesk Map™ using various import tools.

Field Data Collection

Collection of spatial data was easy and quick. Tools on the ArcPad™ toolbar allowed us to draw features using the GPS receiver by selecting the feature type then selecting either the "single vertex" or the "streaming vertex" tool (Fig. 6). In some cases such as near the top of highwalls, we found it safer to find the feature on the digital aerial photograph display and manually place one or more vertices along a feature to keep the data collecter out of harms way. This was easily done with ArcPad™. When the spatial component was defined, we closed each feature which brought up the attribute entry form that we created prior to field work. These forms made data entry easy because they contained drop down lists, required fields and instructions that helped all users answer the questions the same way. All five participants in the data collection effort agreed that the ability to see their GPS location live on the aerial photograph improved their efficiency and effectiveness in the field and made them feel safer in finding their way around unfamiliar territory.

Figure 6. Tracing a gully with a Mobile Computing device

Entry of most attribute data was easy and efficient using ArcPad™. We encountered one problem entering long text strings for the “Comments” field. We found that the 50 character field we created in the shapefile was not adequate in many cases. We found that creation of long comments was made easier by running a word-processor file in the background and tabbing back and forth between ArcPad™ and the word-processor. We did not experiment with programming the ArcPad™ Data Entry Form to enter the comments into a separate word-processor file rather than the shapefile, but that might be possible in the future.

Durability

This data collection effort was performed during times of varying temperatures which ranged from below 20 degrees F to over 50 degrees F. We worked in snowing conditions and in times of high humidity. We did not work during any rain or lightning storms. During the three weeks of this exercise and over subsequent data collection at 3 other sites, we experienced no hardware or software related problems. We believe that the Fujitsu tablet computers that we used would not be appropriate for rainy conditions or where the chance of splashing water is high. Screen visibility was a concern during the computer selection process. We found during the field effort that the Fujitsu computer with the “Full Sun” reflective screen provided more than adequate outdoor visibility during daylight. However, this screen was extremely hard to see when working back in the motel room in the evening. In the office, the Fujitsu was hooked to an auxiliary monitor to improve visibility.

Data Integration

When the field collection crew returned to the office, their data for that week was downloaded to a file server and a read only backup copy was created. The shapefiles were imported into Autodesk Map™ for use by the engineering staff to calculate cost estimates. All attribute data that had been collected in the field were converted to object data during the import process. The engineering staff was then able to utilize this object data in Autodesk Map™ to create report queries. These queries generated comma separated text files that contained information about each physical feature. This data was then imported into a Microsoft Excel spreadsheet. The spreadsheet was set up with each feature type on a separate sheet, and appropriate equations were created on each sheet to determine earthwork volumes, seeding areas, regrade areas, etc. A cover page was placed in the spreadsheet to enter individual unit costs and to report the reclamation cost by feature type and permit number a well as a total cost for all reclamation. As additional data was received, the report queries in Autodesk Map™ were run again, and the spreadsheet would automatically update when it was opened. This allowed the engineering staff to quickly utilize the data that was collected and come up with a current reclamation cost.

Summary

Using Real-Time GPS in combination with Tablet Computers proved very successful for mapping features and collecting attribute data for inadequately reclaimed mine sites. Field investigators found the equipment and software easy to use. Users found the ability to follow their location live on an aerial photograph and to navigate to permit boundaries, pond discharge locations, highwalls and other mine features extremely helpful. Several users commented that they felt safer in the field knowing where they were in relation to roads, streams and residences. Data collected using the mobile computing system were easily used in both ArcView GIS, Autodesk Map™ and Microsoft Excel software packages for site inventory, conceptual design and cost estimation work. The ArcPad™ software performed very well on the Fujitsu Stylistic 3500R™ tablet computer married to the Teletype World Navagitor GPS card. Outdoor viewing of aerial photographs and vector data on the tablet computer was easy. Screen visibility indoors was very limited but was enhanced with the use of an auxiliary monitor in the office or hotel room.

Literature Cited

Joseph, W. L. 2000. Enhanced Computer Software Applications for Mining and Reclamation p. 310-315. *In*: New Area of Land Reclamation. (Tampa, FL, Jun. 11-15, 2000). Proc. 17th Annual Meeting of the American Society for Surface Mining and Reclamation.

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