GIS/GPS USE FOR RECLAMATION BOND RELEASE PURPOSES AT A SURFACE COAL MINE IN WYOMING[1]

Marcelo Calle and Anna Krzyszowska-Waitkus [2]

Abstract. The Wyoming Department of Environmental Quality, Land Quality Division (LQD), Powder River Coal Company (PRCC) and the Office of Surface Mining (OSM), Denver embarked on a project to develop a bond release tracking system using both Geographical Information System (GIS) and Global Positioning System (GPS) technologies. This pilot project tested the use of electronic permit data, GIS software and GPS mobile computing hardware and software for tracking the reclamation and bond release status of lands within the North Antelope Rochelle Mine permit area.

The GIS application involved creating an ESRI ArcGIS personal geodatabase that contains 15 feature classes with associated attribute fields. The Personal Geodatabase was designed to support the tracking of areas which have achieved backfill verification and incremental bond release, as well as areas that have satisfied performance standards in support of achieving incremental bond release. The incremental bond release process involves the approval of specific requirements for Phase 1 (topsoil applied), Phase 2 partial release (vegetation established) and Phase 3 (reclamation complete).

The GPS application of the project involved using a Trimble GeoExplorer series GeoXT during monthly inspections to monitor selected compliance features necessary to support backfill verification and the incremental bond release process. A project specific data dictionary was developed to include the relevant feature types necessary to monitor and verify incremental bond release requirements. Examples include verification of the extent (acreage) and slopes of backfill areas, surveying the centerline of restored creek channels, verification of topsoil application and depth, delineation of restored wildlife habitat features, and mapping of erosion features.

Additional Key Words: data dictionary, Geodatabase, field inspection, reclamation

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[2]Marcelo Calle and Anna Krzyszowska-Waitkus are Senior Environmental Analysts at the Department of Environmental Quality, Land Quality Division, Cheyenne, WY 82002.
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Introduction

A project to develop a bond release tracking system using both Geographical Information System (GIS) and Global Positioning System (GPS) technologies is discussed for a surface coal mine located in Wyoming. The Wyoming Department of Environmental Quality (WDEQ), Land Quality Division (LQD), Powder River Coal Company (PRCC) and the Office of Surface Mining (OSM), Denver started developing a pilot project and designing a database in 2003. The pilot project tested the use of electronic permit data, GIS software and GPS mobile computing hardware and software for tracking the reclamation and bond release status of lands within two surface coal mines permit areas. This article discuses methods and results achieved for the North Antelope Rochelle Mine (NARM). The pilot project was an innovative approach in preparation for bond release allowing complex data to be processed for this purpose.

As described by the WDEQ, LQD Coal Rules and Regulations, the Wyoming Coal Program requires two types of bonds: an Area Bond and an Incremental Bond (WDEQ, LQD Coal Rules and Regulations, 2005). The Area Bond is the cost required to achieve rough backfilling (the area is backfilled, graded, and ready for topsoiling). The Incremental Bond Release involves the approval of the performance standards concerning the fulfillment of Phase 1 (topsoil applied), Phase 2 (vegetation established) and Phase 3 (full release) requirements. Additionally, the LQD in cooperation with the regulated community has established five categories for assigning bond release criteria for reclaimed mined land (WDEQ, LQD, 1998; Krzyszowska-Waitkus, et al., 2000). The LQD bond release categories are based on the regulatory time frame when the area was affected or used and which law/rule was in effect at that time. All land disturbances within the NARM belongs to Category 5, where land was affected after May 3, 1978. These lands are held to the Surface Mining Control and Reclamation Act and the LQD performance standards.

The project involved creating an ESRI ArcGIS personal geodatabase that contains feature classes with associated attribute fields. The personal geodatabase was designed to support the tracking of areas which have achieved backfill verification and incremental bond release, as well as areas that have satisfied performance standards in support of incremental bond release. Mobile computing technology was applied during monthly inspections to monitor selected compliance features necessary to support backfill verification and the incremental bond release process. The objective of using the GPS in conjunction with GIS was to improve the LQD inspector's ability to assess reclamation adequacy and track features required for bond release.

Study Area

The NARM permit covers 27,187 acres, including a disturbed area of 11,956 acres (NARM Annual Report, 2005). This includes 4374 acres of active coal pit area, 2910 acres of mined and permanently reclaimed area, and 3689.6 acres of temporary cessation of operation, stockpiles, and long term mine facilities. Coal production during the 2004-2005 annual report period was 82,622,918 tons.

Methods

During the initial stages of this project, project team training was provided by the OSM's Technical Innovation and Professional Services (TIPS) group. The training included classes on the fundamentals of using the ArcGIS software, operation of the handheld Trimble GeoExplorer series GeoXT GPS unit and GPS Pathfinder Office, fundamentals of the Spatial Analyst extension within the ArcGIS software, and remote sensing and photogrammetry for permitting and inspection. From this stage, OSM, PRCC, and LQD worked on developing a database design. The focus was to construct the database for use after the pilot project was completed, allowing the LQD to use and maintain the database in the future. Data was collected and processed for approximately one year during pilot project.

Database development

An ESRI personal geodatabase was utilized to organize geographic data into a hierarchy of data objects. These data objects were stored as ESRI feature classes and feature datasets. A feature class is a collection of geographic features with the same type of geometry and same attributes and a feature dataset is a collection of feature classes that share the same spatial reference. For example, the Area Bond feature dataset will contain feature classes that support Area Bond backfill verification such as the Backfill Verification Application, Existing Topography, Permit Topography and Backfill Verification Approved.

GPS/GIS processing

The GPS mobile computing technology was used in the field to evaluate and verify Area Bond and Phase 1, 2, and 3 bond release requirements. Utilizing a data dictionary, the LQD inspectors collected point, line and polygon data using GPS units during inspections. The data dictionary applied was created specifically for collecting spatial data in support of the bond release process and was loaded to the project GPS units. The data dictionary served to enhance data collection by dictating the required feature types and facilitated data entry by offering drop down attribute choices for most fields. Ultimately, it was the most effective way to support a seamless transfer of collected data into the personal geodatabase. This transfer was possible because the data dictionary attributes and fields mirror the attributes and fields within the personal geodatabase for all feature classes.

After inspectors collected GPS data in the field, upon their return to the office they transferred the data using Trimble GPS Pathfinder software and Microsoft ActiveSync. Files were spatially corrected to improve the accuracy of the data and then the files were exported as ESRI shapefiles. Prior to any further processing, electronic copies of the data were made and placed within the Raw Data folder (Figure 1). Following this step the shapefiles were checked for the quality control. The appropriate coordinate system and projection (Wyoming State Plane NAD 1927) was assigned to the shapefile and the associated attribute table was checked for missing or anomalous data. The shapefile attribute table was also checked against the corresponding personal geodatabase feature class to insure a complete merge. If all elements were correct, then the shapefile was merged into the personal geodatabase using the geoprocessing tools within ArcGIS.

A similar technique was applied for shapefiles submitted by the operator. Submitted shapefiles and associated attribute tables were carefully checked to insure a complete merge. Once again, if the shapefile attribute fields did not match the corresponding feature class attribute fields exactly, then an incomplete merge could occur. In this case the shapefile was edited and any missing data provided. The submission of AutoCAD files (*.dwg) was also supported during the pilot project. Data in this form was either exported using the ArcGIS toolbox or within the AutoCAD software platform. Some type of processing was usually required. For example, submitted polylines were cleaned to enable correct closure when converting to a polygon.

Results

GIS geodatabase architecture

The architecture for the GIS geodatabase, including all necessary feature classes was created using the WDEQ, LQD Guideline No. 20, Bond Release Procedures for Coal Mining Operations (2003). This document assisted the project team in defining the appropriate data types (point, line or polygon), feature classes (e.g. permit topography, backfill verification application, post-mine streams, topsoil verification points, wildlife feature, erosion feature) and associated attributes fields (e.g. reclamation status, date of data collection) that would be required to achieve the goals of the project. The GIS geodatabase was designed to track approved bond release areas and support spatial data that could be used to verify certain performance standards and/or specific permit commitments in support of bond release approval.

Discussion concerning the minimum required feature classes and attributes is still ongoing. Originally, 43 ArcGIS feature classes and 19 GPS data types were created. Currently, the LQD has decided to streamline the geodatabase to 4 feature classes necessary for the tracking of approved bond release areas and 11 feature classes used for the verification of bond release performance standards. Specifically, the approved bond release tracking geodatabase contains the following polygon feature classes: Area Bond Backfill Verification, Phase 1 Partial Incremental, Phase 2 Partial Incremental, and Phase 3 Partial Incremental. The attribute fields include polygon ID, acreage, LQD approval date, comments and a hotlink to a scanned copy of the LQD approval letter. Before approval of any bond release, the various performance standards and/or specific permit commitments must be verified through LQD inspection or supported by the operator. The following feature classes were created to support the tracking of verified areas for bond release processing: approved postmining land use, restoration of wildlife habitat, revegetation (cover and production), shrubs (goal or standards), trees, groundwater support land use, surface water supports land use, approved post mining roads and corridors, removal of temporary structures, rough backfilling an sampling, and sediment control release. All of these layers are also polygon feature classes with the attribute fields of polygon ID, acreage, LQD verification date, comments and hotlink.

GIS geodatabase location (settings?)

The pilot project geodatabase is housed within the DEQ intranet server and organized within a created folder file system. Fig. 1 presents a schematic of the pilot project data organization model. The file folder structure allows for production, working and editing areas as well as raw data and archival support. Contained within the WYGIS folder are subfolders for NARM. Data is further organized based on type. The working Geodatabase for NARM is also contained at this level and Fig. 2 presents a schematic for mine data.

GIS geodatabase maintenance

Within the pilot project geodatabase feature classes existed that were essentially static and ones that were dynamic or changing. Static layers included feature classes such as Cadastral data and Bond Release Category delineations. All other feature classes were dynamic and were changing over time with the progression of the mine. A successful bond release tracking GIS application required maintenance and frequent updates to the personal geodatabase to ensure that the data was current and reflected the actual condition. All changes or edits applied to the database were logged and then documented in the Metadata. The dynamic feature classes were populated with data collected by the inspectors using GPS or with data provided by the mine.

This required frequent and constant collection, processing and maintenance of data. Since NARM is contemporaneously actively mining and reclaiming, the permit area is a patchwork of units in varying states of production and reclamation. Frequent database maintenance was required to accurately reflect the most current reclamation status of the mine. This required a close working relationship between the permit coordinator and the operator.

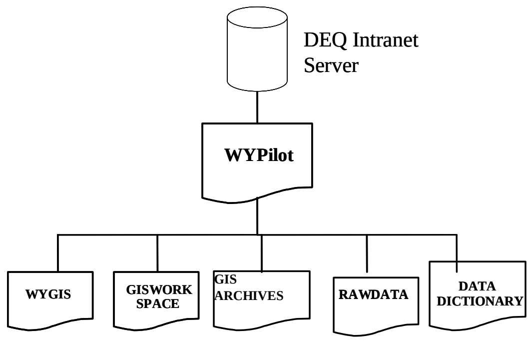

Fig.1 GIS Data Organization on WY DEQ Server

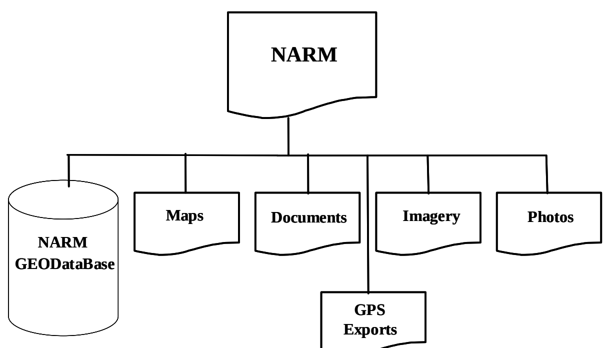

Fig. 2 Production Area for NARM

<u>GPS application</u>

Currently, the pilot project personal geodatabase for NARM has been primarily populated with data that applies to Area Bond Backfill Verification and Phase I Partial Incremental Bond Release. Some of the requirements for Area Bond Backfill Verification and Phases 1 Partial Incremental bond release were verified in the field using GPS.

A compliance assessment and a verification of bond release requirements were achieved during year 2003 field inspections. To complete a compliance assessment a map created using ArcGIS was produced and attached to the field inspection report. To complete a verification of bond release requirement, the data were processed and incorporated into the established GIS geodatabase for NARM. The verification of Phase I Partial Incremental Bond Release included fulfilling the following performance standards: extent (acreage) of rough backfill areas and associated slopes, topsoil depth application, wildlife feature habitats, restoration of creek channels, and erosional stability.

The LQD inspector used GPS and GIS to verify rough backfill commitments after field inspections. Through the 2002-2003 annual report period, the operator asked for the approval of 491 acres of rough backfill. However, during the period between the application and the approval, the operator had to build a facility pond and a road cut in this area. The re-disturbed area was surveyed using GPS. Within the GIS, geoprocessing tools were then used to subtract the re-disturbed area from the total area submitted for the Area Bond Backfill Verification approval. The area of the disturbance was then calculated within the associated attribute table. The use of GPS and GIS helped the inspector to document the correct acreage of the rough backfill that satisfied Area Bond Backfill Verification.

One of the requirements of the Phase 1 Bond Release is to verify topsoil depth applied to the graded areas. The depth of topsoiled areas was verified in the field using a hand auger during the summer of 2003 and 2004. The topsoiled areas verified in 2003 covered 355.9 acres and 228.1 acres in 2004. The points used to verify topsoil depth were chosen randomly at an intensity of one hole per 20 acres. All collected data were processed and entered into the NARM Personal Geodatabase within the Topsoil Verification Points feature class. This information was later used to process a Phase I Partial Incremental Bond Release package submitted requesting the release of 1880.3 acres.

The restoration of a wildlife habitat feature is one of the requirements of the Phase 3 Bond Release. According to the permit commitment, NARM will restore one wildlife feature per 40 acres. The presence of wildlife features (rock piles, nest, dead trees, shrub piles) were verified during field inspections in 2003 and 2004. The densities of wildlife habitat features are much higher than the permit commitment. All collected data were processed and entered into the NARM personal geodatabase within the Wildlife Feature Point feature class.

According to the permit commitment, NARM will restore higher order streams. The center line of the restored Reach 1 and Reach 2 of Porcupine Creek was surveyed in the field using the GPS. Using ArcGIS the inspector verified that the surveyed location reflects the approved post mine topography commitment.

Phase 3 or Full Bond Release requires a demonstration of surficial stability. Erosional features such as rills and gullies can develop on areas at different stages of the reclamation (e.g. area temporarily seeded with barley or recently vegetated areas). In preparation for the future evaluation of a Phase 3 Bond Release request, observed erosional features were surveyed using GPS. The lengths of the erosional features were measured and points were collected where the depth and width of the features were measured. The measured dimensions of the erosional feature were contained within the appropriate fields of the associated attribute table. All collected data were processed and entered into the NARM personal geodatabase within the Erosion feature class. The collected position of each point (northing and easting) will allow the inspector to return to the same point in the future to identify any changes to the erosional feature.

The above described NARM permit commitments, verified during field inspections, including restored wildlife features, higher order streams, and surficial stability were inserted into the geodatabase. This information was and will be used during the revision of submitted bond release packages. Due to the large permit area and the patches size of the requested bond release area, the GIS geodatabase is the only sufficient method to keep track of various categories land. Total of approximately 3100 acres were verified for rough backfill area, total of approximately 3000 acres were verified for topsoil depth application and 1880.3 acres were approved for Phase I bond release. All of this information was managed using the created geodatabase and GPS mobile computing techniques.

GIS analysis

After the geodatabase was populated with the feature classes necessary to support the primary goal of the project (bond release tracking) the potential for using the created geodatabase to perform geospatial analysis was explored.

What tools does the GIS offer that can be used to enhance the speed and quality of the bond release process? Contained within ArcGIS there is a user friendly extension called Spatial Analyst which provides an assortment of geospatial analysis tools. The Spatial Analyst extension works within what is called a raster data model. Space is most commonly represented through the use of points, lines and polygons. This form of spatial representation is called a vector data model, based upon a Cartesian coordinates system. A raster data model depicts these vector features through the use of a cell grid. For example, a line becomes a series of contiguous cells. The advantage to a raster based data model is that any type of data can be assigned to each cell. This raster data can then be visually represented as well as manipulated and related through mathematical or logical expressions and re-represented. New data can also be estimated through the use of interpolation and extrapolation procedures in the Spatial Analyst extension.

Using the tools offered by the GIS and the created geodatabase the following applications were developed: a method to compare and evaluate the "As Built" Topography to the Approved Post Mine Topography (PMT) and a method to evaluate reclamation slope commitments. To quantitatively evaluate how close the reclaimed topography approximates the approved post mine topography, the existing or "as built" topography raster layer can be subtracted from the permit topography raster layer. The result is a new raster layer which spatially presents this difference. The difference layer can be reclassified and color coded to depict acceptable regulatory tolerance limits such as greater than 20 feet and less than 20 feet in vertical difference. The actual volume differences between the permit topography and the "as built" topography can also be calculated using the Cut/Fill application in the Spatial Analyst extension. Using the Spatial Analyst, slope calculations can also be quickly performed once a raster grid has been created for the area of interest.

Conclusions

The GIS platform in conjunction with GPS mobile computing technology offers the utility of powerful database management, the ability to present information contained within the database in a variety of spatial and graphical forms, as well as, support technical and scientific applications that can assist in bond release decisions. The raster based exercises presented within this project demonstrate powerful procedures to quickly and qualitatively evaluate post mine topography requirements. The use of GPS enhances the inspectors/coordinators ability to identify, inventory and track necessary components required for bond release verification. It also serves to provide a data legacy that can support decisions if there is disagreement regarding a condition during the bond release process.

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