# Mobile computing and geodatabase application for coal mine inspection [1]

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**Abstract.** Coal mine inspection duties require the repetitive assessment of mining features in order to verify compliance with regulatory requirements. Examples of inspection features requiring routine assessment include: topsoil stockpiles, monitoring locations, sediment ponds, culverts, alternative sediment control measures (ASCM), areas of topsoil application and erosion features such as gullies, or significant rilling and channel head cuts. The advancements of Geographic Information Systems (GIS), Global Positioning Systems (GPS) and their integration with mobile computing technology, e.g., handheld pocket PCs, laptops and tablet PCs has significantly expanded the usability of these technologies. The location of inspection features can be collected and relevant information can be supported in the form of associated attribute tables within the GIS. These locations can then be revisited by navigation and the attribute table information updated at each inspection. With the increasing size of surface coal mines, its rapid and dynamic mine progression as well as the constantly changing number and status of inspection features, a method to collect, organize and track information about inspection features is necessary.

A GIS database and supporting mobile GIS application for mine inspection duties was developed for the North Antelope Rochelle Mine (NARM), Powder River Basin, Wyoming. The inspection GIS utilized an ESRI Personal Geodatabase integrated with ESRI ArcPad mobile computing software operating on a Trimble GeoExplorer Series handheld GPS to collect and update information about inspection features. Examples of supporting information for the geodatabase include: date of inspection, absence or presence of feature, feature type, condition, compliance status and scheduled date for compliance correction. Benefits of this project include enhanced inspection effectiveness and efficiency through improved organization, tracking and retrieval of inspection information that is spatially identified.

Additional Key Words: Geographic Information Systems, mobile computing, mining, inspection, regulatory requirements

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## Introduction

Coal mine inspections, as mandated by the Surface Mining and Reclamation Act (SMCRA), the Wyoming Environmental Quality Act (WEQA) and Wyoming Department of Environmental Quality (WDEQ) Coal Rules and Regulations, require the repetitive assessment of mining activities in order to verify compliance with regulatory requirements and permit commitments. Examples of inspection features requiring assessment include: topsoil stockpiles, sediment ponds, culverts, alternative sediment control measures (ASCM), areas of topsoil application, monitoring locations and erosion features such as gullies, significant rilling and channel head cuts. Inspecting surface coal mines in Wyoming presents a challenge for the regulatory agency, the Land Quality Division (LQD) of the WDEQ. Disturbed areas are large and include many features that require inspection. Wyoming coal mines are also highly dynamic and the extent of the permit boundary and disturbed area are constantly changing over time. Coal market fluctuations also require frequent changes in mine plans and other activities.

Coal inspections are documented in inspection reports including narrative summaries, photographs and sometimes supporting maps. Inspection details are typically transcribed from inspection notebooks. While this method has worked in the past, the increasing scope of inspections and the use of multiple rotating inspectors required a tool to comprehensively inventory and track compliance details. Currently, compliance information may only be recalled via a time consuming review of monthly inspection reports.

Initially, a series of spreadsheet (Excel) were developed for the North Antelope Rochelle Mine (NARM). Various tables were used to track details about inspected features and were included in the submitted inspection report. Tables from the previous inspection report were used to focus inspection tasks, then revised and updated in the field during inspections. A laptop computer and tablet PC were used as much as possible during field inspections. This use shortened the time for writing the inspection report from one-two days to six-eight hours and facilitated a consistent transition between inspections. Collecting and updating inspection data using spreadsheet tables effectively and successfully served to inventory and organize the information.

However, since features were not spatially identified, tracking spatial changes within the disturbance area proved difficult. Spatial analysis, review of inspected features, and compliance

assessment became increasingly more difficult to accomplish due to increasing disturbance areas and coal production. Therefore, the idea of developing a spatial database for inspection purposes was explored. The advancements of Geographic Information Systems (GIS), Global Positioning Systems (GPS) and their integration using mobile GIS technology have extended these technologies to a wider group of users including inspectors of the mining operations (coal as well as non coal mines). The created inspection GIS is used to organize collected information that is spatially identified over the period of the inspections.

## Location

The NARM is a surface coal mine located in the Powder River Basin of Wyoming. The NARM permit contains 45,975 acres of which 27,443 acres are approved to be affected. This includes 6,200 acres of active coal pit area, 3,833 acres of mined and permanently reclaimed area, 1,145 acres of stockpiles, and 1,707 acres of long term mine facilities and environmental monitoring areas. Coal production during the 2007 annual report period reached approximately 89 million tons (NARM Annual Report, 2007).

Since 1999 the permit area has increased approximately 75% from 26,295 acres to 45,975 acres, while the disturbed area increased approximately 70% from 8,496 acres to 14,342 acres. As of December 2007, the inspected features recorded within the permit area included: 88 topsoil stockpiles, 78 pond structures, 109 culverts, 23 ASCM's, 192 groundwater monitoring wells, and 6 surface water monitoring stations.

## Methods

The inspection GIS utilized an ESRI Personal Geodatabase at the ArcInfo 9.2 level, including ArcMap, ArcCatalog and ArcTools. Mobile GIS functions were achieved with ESRI ArcPad 7.1 mobile GIS software operating on a Trimble GeoExplorer Series GeoXM handheld GPS unit running Microsoft Pocket PC operating system. A Fujitsu Tablet PC with integrated GPS card was also used. Data sources included mine map layers submitted from the mine operator, inspection reports, and field collected GPS data. A GPS accuracy of one to three meters was considered acceptable for collecting new spatial data in the field. Software and hardware was chosen based upon GIS and GPS industry standards, software integrated

functionality and significant software, hardware and training support via the Office of Surface Mining Reclamation and Enforcement's (OSMRE) Technical Innovation and Professional Services (TIPS) program.

## Results and discussion

A conceptual model of the inspection spatial database was developed. This step included establishing the types of products that would be supported using the developed spatial database including identifying necessary thematic layers, spatial representations, and data types. The developed GIS also needed to include a mobile GIS application to collect and update inspection features. The inspection data collected in the field is used to populate and update the GIS with inspection tracking and compliance information. The created spatial database is used to query specific inspection information, create maps for inspection summary, and generate reports detailing inspection feature inventory and compliance status.

### Thematic Layers

Spatial databases use thematic layers to organize information. A thematic layer is a collection of common geographic elements or features. All thematic layers require a form of spatial representation. Vector based spatial representation includes entities such as points, lines and polygons. All features contained within the thematic layers are spatially defined (Table 1).

Table 1. Examples of inspection feature classes and feature datasets.

| Thematic Layer or Feature Class | Feature Dataset | Spatial Representation |
|---|---|---|
| Topsoil Stockpile (TSP) | | Polygon |
| Impoundment | | Polygon |
| Culvert | | Point |
| ASCM | | Point |
| Monitoring Location | | Point |
| Topsoil Application | Topsoil Dataset | Polygon |
| Topsoil Depth Verification | | Point |
| Erosion Feature | Erosion Dataset | Polygon |

| | | |
|---|---|---|
| Erosion Point | | Point |

The thematic layers identified are based upon specific regulatory requirements as detailed in the WDEQ Rules and Regulations, permit commitments, and individual needs of the inspector. The thematic layers are comprised of fundamental features that are inspected. A thematic layer within the ESRI Personal Geodatabase environment is called a feature class. Feature classes that are related by the type of data they support can be organized using a feature dataset. As an example, the Topsoil Application and the Topsoil Depth Verification feature classes are grouped into a feature dataset. Similarly, the Erosion Feature and Erosion Point are grouped into a feature dataset.

Attribute Tables

Information contained within a spatial database is structured using tables comprised of rows and columns. Each row represents a record contained within the thematic layer and columns (attribute fields) contain all required types of information associated with the record including where it is located. When a record is spatially defined it is called a feature. All inspection features are contained within their corresponding feature class and their associated data are supported in the attribute fields.

Feature classes were defined in Table 1 and the associated data requirements for each feature class were then developed. Data requirements are determined by the scope and function of the spatial database. The primary goal of the project is to create an inspection tool to (1) inventory the types of existing inspection features (achieved through the creation and population of feature classes) and (2) track associated compliance information associated with each inspection feature. Thus, the data requirements are driven by the needs of the latter.

Attribute fields associated with the Topsoil Stockpile feature classes are presented in Table 2.

Table 2. Examples of Topsoil Stockpile (TSP) attribute fields.

| TSP Feature Class Attribute Fields | Tracking and Compliance Descriptions |
|---|---|
| TSP ID | Unique identifier used to reference the feature |
| TSP Status | Describes construction activity (completed or active) |
| Construction Date | Records date of the last disturbance due to construction |
| Inspection Date | Records date of most recent inspection |
| Inspector Name | Records name of inspector |
| Sign Present | Describes whether sign is present |
| Berm/Ditch Present | Describes if runoff from disturbed area is being controlled and topsoil resources preserved |
| Grading Status | Used to assess slope compliance |
| Seeding Date | Used to assess 1 year seeding commitment |
| Vegetation Status | Describes if runoff from disturbed area is being controlled and topsoil resources preserved |
| Erosion Type | Describes if topsoil resources are preserved |
| Compliance Date | Scheduled date of correction |

According to WDEQ Coal Rules and Regulations the performance standard for the inspection of topsoil stockpile includes the verification of whether the material stored in the pile is protected from wind and water erosion. WDEQ Coal Rules and Regulation state "When topsoil is not promptly redistributed, the topsoil or approved surface material shall be stockpiled on stable areas within the permit area in such a manner so as to minimize wind and water erosion and unnecessary compaction." Therefore, attribute fields such as Berm/Ditch Present, Erosion Type, and Vegetation Status were developed to truck runoff control performance.

Additionally, WDEQ Coal Rules and Regulation state "Topsoil stockpiles shall be marked with a legible sign containing letters not less than six inches high on all approach roads to such

stockpiles. Said signs shall contain the word "Topsoil" and shall be placed not more than 150 feet from any and all stockpiles of topsoil. Such signs must be in place at the time stockpiling is begun." The attribute field "Sign Present" was included in the TSP feature class to track this compliance requirement.

Additionally, the permit commits the operator to seed all topsoil stockpiles within one year after being completed and topsoil stockpile slopes should not exceed 3:1 (approx. 33%). Thus, Seeding Date and Grading Status were included as attribute fields in the TSP feature class.

The WDEQ Coal Rules and Regulations state that "Topsoil, subsoil, and/or an approved topsoil substitute shall be redistributed in a manner that: (A) Achieves an approximate uniform, stable thickness consistent with the approved permit and the approved postmining land uses, contours and surface water drainage system; (B) Prevents compaction which would inhibit water infiltration and plant growth; (C) Protects the topsoil from wind and water erosion before and after it is seeded until vegetation has become adequately established." Therefore the Topsoil Application and Topsoil Depth Verification feature classes were created including the topsoil depth compliance, topsoil depth compliance date, erosion compliance, and erosion compliance date attribute fields. Additionally, the Erosion Feature and Erosion Point feature classes were used to support this performance standard. Their attribute fields included erosion type, erosion compliance, erosion compliance date, cover status and width and length for the erosion point.

The attribute fields for feature classes: Impoundment, Culvert, Alternative Sediment Control Measures (ASCM), and Monitoring Location were developed using the same methodology. According to WDEQ Coal Rules and Regulations the performance standard for the inspection of ASCM's, culverts, surface and groundwater monitoring stations includes the verification of their functionality and stability.

## Data Types and Domains

All inspection features require a combination of narrative, temporal and numeric data types to support tracking and compliance assessment goals. Within a database, attribute fields require specific data type definitions. The assignment of appropriate data types enhances the functionality of a database, including query and reporting requests. For example, if temporal data is not defined as a date data type, then a time based query may not be supported. If numeric calculations need to be supported the attribute field must be defined as a numeric data type.

Domains were utilized to provide data consistency and facilitate data entry. Domains include the list (text) or range (numeric) of acceptable values for attribute fields (Table 3).

Table 3 Examples of data types and domains associated with the Impoundment feature classes.

| Impoundment Attribute Field | Data Type | Domain |
|---|---|---|
| Impoundment Type | Text | Flood Control |
| | | Facility |
| | | Sediment Control |
| | | Sediment Trap |
| | | Diversion |
| Impoundment Status | Text | Permanent |
| | | Temporary |
| Construction date | Date | Calendar |
| Removal date | Date | Calendar |
| NPDES Status | Text | Yes, No |
| Discharge | Text | Yes, No |
| Erosion Compliance | Text | Acceptable |
| | | Not Acceptable |
| Erosion Compliance Date | Date | Calendar |
| Capacity Compliance | Text | Acceptable |
| | | Not Acceptable |
| Capacity Compliance Date | Date | Calendar |
| Water Present | Text | Yes, No |
| Inspection Date | Date | Calendar |
| Inspector Name | Text | Waitkus |
| | | Calle |

According to WDEQ Coal Rules and Regulations the performance standard for the inspection of sedimentation ponds includes the verification of the impoundment capacity and stability. WDEQ Coal Rules and Regulation state “Sedimentation ponds shall be designated and maintained to contain adequate sediment storage as determined by acceptable empirical

methods." Additionally, WDEQ Coal Rules and Regulation state "Faces of embankments and surrounding areas shall be vegetated, except that faces where water is impounded may be riprapped or otherwise stabilized in accordance with accepted design practices…"

Domains were created on a basis of the specific information provided by the operator or were chosen by the inspector. For example, the domain of the impoundment status describing the function of the pond was provided by the operator. The domain of the compliance status in regards to impoundment erosion was chosen by the inspector and it was decided to be acceptable when erosional features do not affect the integrity of the pond. The domain for attribute fields for the other following feature classes: culverts, ASCM's, Monitoring Locations, Topsoil Application, Topsoil Depth Verification, Erosion Feature, and Erosion Type were developed using similar methodology.

Geodatabase Creation

A Personal Geodatabase was created using ArcCatalog. All new feature classes and supporting attribute fields were defined. Domains were defined within the Personal Geodatabase prior to the creation of the feature classes and assigned during attribute field creation as necessary. Populating the Personal Geodatabase was achieved via manual entry in multiple ArcMap editing sessions as well as utilizing data loading tools in ArcCatalog. Data loading tools were used to transfer spatial data and identification information from AutoCAD (*.dwg) format layers submitted by NARM.

Mobile GIS functionality was achieved using ArcPad 7.1. Created feature classes are bundled into an ArcPad project in ArcMap using the ArcPad tools and exported to the Trimble GeoXM GPS unit via a desktop synchronization. In the field existing feature and attribute fields can be updated or new features can be collected utilizing GPS.

All Personal Geodatabase attribute fields and domains are supported in the ArcPad project. During a field editing session the user is prompted for all required attributes and limited to acceptable data values, in an easy to use data collection form that includes drop down data entry capabilities defined by created domains. In this way, complete and consistent data capture is preserved.

All edits and new features are ‘checked’ in using ArcMap and ArcPad tools through a desktop synchronization. Through this process, the geodatabase is updated to include the collected features and edits.

## Conclusions

A GIS database and supporting mobile GIS application for mine inspection duties was developed for the NARM in Wyoming. The inspection GIS utilized an ESRI Personal Geodatabase integrated with ESRI ArcPad mobile GIS software operating on a Trimble GeoExplorer Series handheld GPS to collect and update information about inspection features. Feature classes were defined and the associated data requirements for each feature class were then developed by means of attribute tables.

Benefits of this project include enhancing inspection effectiveness and efficiency, improving tracking and organization that supports multiple rotating inspectors, development of an inspection tool that will support the LQD’s evolution towards GIS enhanced business. However, initial development of the geodatabase application can be time consuming. Due to the increasing size of permits and disturbance areas, an inspection GIS is one effective method to keep track of various features for compliance purposes.

Benefits include improving the quality and efficiency of the coal mine inspection due to:

- Field Mapping - Create, edit, and use GIS maps in the field.
- Feature Inventories - Create and maintain an inventory of inspection locations and attribute information.
- Feature Maintenance - Update asset location and condition, and schedule maintenance.
- Inspections - Maintain digital records and locations of mine features for compliance assessment.
- Inspection Reporting - Document the location and circumstances of incidents and events for further action or reporting.

As the geodatabase is populated query tools will allow the extraction of specific information. For example, the history of the sediment capacity of the specific sediment ponds could allow permitting and creating an additional sediment trap due to the frequency of exceeding storage

capacity. Tracking the development of erosional features will aid in choosing the correct maintenance action. The ability to query specific features according to its compliance status within the developed inspection GIS will assist in identifying and correcting problems before it becomes an enforcement action. The inspection GIS is not a static process, but can be further developed to include other inspection features as needed or the geodatabase can be used as a template for non coal mines.

## References

Wyoming Department of Environmental Quality, Coal Rules and Regulations, 2004.