ArcPad Application Supporting Los Alamos National Laboratory's Storm Water Monitoring Program

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Abstract:

Los Alamos National Laboratory has been using an Oracle database for several years to track inspections of sites where storm water runoff issues are a concern. An ArcPad interface has been developed running on Trimble GeoXTs that allows the inspection and maintenance records to be entered directly in the field. The field units can download/upload data directly with the main Oracle database. This system allows users to enter an inspection for each area of concern, with all of the related Best Management Practices (BMPs). Maintenance that is required or has been completed may also be entered. This allows for inspections to be completed and entered more quickly and accurately than with the previous paper map and inspection sheet. It also ensures follow-up is completed in a timely manner. The GPS aspect of the system ensures that users inspect the correct area and that areas needing maintenance can be easily located.

Project Location:

Los Alamos National Laboratory (LANL) is located in Los Alamos County, an incorporated county, in north-central New Mexico, approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. LANL, which occupies an area of 40 square miles, and the associated residential and commercial areas of Los Alamos County, which occupy an area of 109 square miles, are situated on the Pajarito Plateau. The plateau consists of a series of finger-like mesas separated by deep east-west trending canyons. Ephemeral or intermittent streams lie at the bottoms of the canyons. The mesa tops range in elevation from approximately 7,800 feet above mean sea level at the flank of the Jemez Mountains, located to the west of Los Alamos, to about 6,200 feet at their eastern extent, where they terminate above the Rio Grande.

LANL's central mission is the reduction of global nuclear danger supported by research that also contributes to conventional defense, civilian, and industrial needs. This includes programs in nuclear safeguards and stockpile stewardship; nuclear, medium energy, and space physics; hydrodynamics; conventional explosives; chemistry; metallurgy; radiochemistry; space nuclear systems; controlled thermonuclear fusion; laser research; environmental technology; geothermal, solar, and fossil energy research; biomedicine, health, and biotechnology; and industrial partnerships. LANL is operated by the Los Alamos National Security, LLC for the Department of Energy's NNSA.

Background:

Storm water run-off from industrial activities at LANL is regulated by the National Pollution Discharge Elimination System, Multi Sector General Permit [MSGP] (2000) and Federal Facility Compliance Agreement [FFCA] (2005). Under these regulations, storm water flowing off potentially contaminated areas, called Solid Waste Management Units [SWMU], must be monitored to insure that potential pollutants do not exceed State of New Mexico water quality standards. Monitoring of storm water is accomplished by use of permanent stream sampling locations and portable site specific samplers. MSGP and FFCA monitoring work is conducted by the Water Quality and Hydrology Group [WQH] at LANL.

Under the MSGP and FFCA, collection of a storm water sample from a SWMU triggers a visual field inspection of the Best Management Practices [BMPs] that have been placed on or around a SWMU to reduce the erosive action of storm water. Each field visit requires the inspectors to navigate to the SWMUs location on the LANL reservation and document the condition of the BMPs that have been installed on the site.

Existing System:

LANL's existing system for recording inspection data consists of paper maps of the SWMUs that are generated by ArcGIS, paper data forms and an Oracle database, called the Storm Water Tracking System [SWTS], to store and query field data. Field data collection begins by printing paper field forms and maps for the SWMU that will be visited during the day. Personnel drive or hike to the SWMUs, using the paper maps to navigate, and fill out the paper forms by hand. Back in the office, field data is entered by hand into the SWTS database.

Goals of Handheld System:

The data collection system described above worked well in the past when the work level was manageable. However, the FFCA of 2005 increased the number of samples collected and therefore the number of sites to be inspected each year. The FFCA also raised the bar on compliance and requires quarterly reports of the inspection results from SWMUs where samples were collected. This increase in work load put strains on the paper based field data collection system.

In the past, WQH had used Trimble GeoXT hand held GPS units with ArcPad to collect data on the condition of storage tanks and results of a forest fuels thinning project. The handheld computers functioned well and allowed field personnel conducting these surveys to locate the features of interest using the GPS and then record data on the condition of the tank or thinning unit via data forms in ArcPad.

Based on these successes, WQH decided to retrofit the SWTS system to utilize the process improvement that the GeoXT and ArcPad could add. Field crews would use the GPS to navigate to the SWMU of interest. The display on the GeoXT would show the outline of the SWMU and any BMPs that were in the vicinity of the SWMU. Data entered onto paper field forms in the past would be entered into forms in ArcPad and linked spatially to the SWMU. This new data entry method would have the added benefit of standardizing responses so that post inspection queries could be conducted in SWTS. GPS navigation will ensure that field crews are inspecting the correct location, and GPS entry of maintenance needs will allow for swift and accurate location of problems by maintenance crews. These process improvements would enable the field crews to improve the accuracy of their inspections and allow the field data to be entered into SWTS directly from the handhelds thus reducing the introduction of errors that may have occurred during hand data entry. These improvements would also allow LANL to meet its reporting obligations under the FFCA.

Hardware & Software Used:
Previous experience led WQH to choose the Trimble GeoXT handheld unit with ArcPad GIS software for the project. WQH attempted to use laptop computers for field data collection several years ago, but stopped when the units proved too bulky for field use. The laptops' short battery life was also a significant problem. More recently, it was decided to use handheld computers for field use. As mentioned above, the combination of Trimble GeoXT handheld computers and ArcPad proved very successful.

The Trimble GeoXT is a ruggedized handheld computer running the Windows CE operating system. The GeoXT has all-day battery life, two gigabytes or memory, and a built in GPS receiver. It is less sensitive to minor impacts than similar devices and is somewhat water resistant. The GPS receiver has submeter accuracy. The GPS receiver, ability to withstand normal field conditions, and long battery life were all important to creating the desired functionality and high levels of user acceptance.

The ESRI ArcPad 6.0.2 software package was installed on three of the GeoXT units. It provides similar functionality to ArcGIS on a handheld computer. ArcPad was used as a map viewer and interface for the custom data entry forms and GPS. ArcPad Application Builder 6.0.2 was used to develop custom data entry forms and create additional functionality. All of the data commonly entered in an inspection and during maintenance can be entered via the custom forms. Features such as drop-down boxes and check boxes were used to simplify data entry and improve data consistency. Visual Basic scripts were written to ensure that all required data was entered.

A critical part of the application was the need to get data from the existing Oracle SWTS database and load the finished inspections back into the database. Since the Oracle database was not spatially enabled, downloading data from the Oracle database and uploading data to it required a custom interface. Most of the data tables were downloaded as dbf files for use in ArcPad. Unfortunately, Oracle cannot read dbf files directly. Microsoft Access 2003 was used to create an upload/download interface between the handheld units and the Oracle SWTS application. Oracle Forms were used to add data review functionality to the SWTS application prior to adding collected data to the Oracle database.

Design Process:

It was obvious from the start of the project that only a small subset of the SWTS database should be edited on the handheld devices. The SWTS database includes a large assortment of data related to the SWMUs and inspections, including data on contacts, pollutants, monitoring stations, permits, and SWPP plans. It was far too much data for the inspection and maintenance personnel to deal with. A series of user's group meetings were held to determine desired functionality and data requirements. The outcome of the meetings was an extensive paper on design requirements. Among the elements specified were the tables and fields to generate on the handheld device, allowable values for entry in each field, and which data must be entered for an inspection or maintenance record to be considered complete. The user's group also considered issues of data consistency, such as how to deal with field entry of the memo fields, which office staff often entered several paragraphs in. Four tables were selected for data entry in the handheld application. The tables were: Inspections, Inspection Findings, Site Structural BMPs, and Maintenance Requirements.

One major focus of the initial design effort was simplifying data entry. Pick lists or check boxes were used wherever possible to limit entry to valid data and reduce the number of stylus clicks necessary to enter data. Text boxes for comments were maintained, but limited in size.

The Inspection Findings data was re-designed entirely to minimize typing. The Oracle table for Inspection Findings consisted of an ID, a date noticed, and a large memo field where users commonly type multiple paragraph entries. Multiple findings could be entered for each inspection. The long entries were inconsistent and hard to read, and extensive typing is cumbersome using a stylus on a handheld device. The Oracle table could not be modified without causing other issues, but the data entry form on the handheld device could still be designed differently. The user's group decided to break the findings field down into a series of yes/no questions describing runoff, erosion, vegetation, and various site conditions. The entries in these fields would then be concatenated to form a long text entry in the findings field when data was uploaded. The straightforward nature of the new questions eliminated most typing, and also eliminated the need to allow multiple findings for each inspection.

Since very few of the people at the user's group meetings had any mapping or GIS experience, the GIS component of the system was an afterthought in the initial design. The selected set of tables created a significant issue; none of those tables had existing spatial data. ArcPad is fundamentally a spatial interface; users click on a location to open related data. Without related spatial data, much of the advantage of using ArcPad is lost.

The development team contacted WQH's GIS staff to determine what GIS data was available to meet the need. The SWTS system was originally designed around inspection of areas of concern, called sites. In practice, all of these sites had a Potential Release Site ID, though it was not a key value in the database. This could be mapped to the internal Site ID that is used as a key value for inspections, BMPs and maintenance requirements. A Potential Release Site [PRS] shapefile was obtained from the WQH GIS team. The Potential Release Site shapefile was modified to include the Site ID value used in the inspections table. That allowed access to the records for Inspections, Findings, and BMPs, but would be too indirect a relationship for entry of Maintenance Requirements.

Northing and Easting values were added to the Maintenance Requirements table and used to create a Maintenance Requirements point shapefile on the fly during the download process. No Northing and Easting values for Maintenance Requirements existed, so the centroid of the related Potential Release Site was used to create a point if no Northing and Easting values had been previously entered. The centroid Northing and Easting was calculated for each Potential Release Site and stored in the PRS shapefile. If multiple Maintenance Requirements exist for a site, the system will offset the interpolated points from each other. Interpolated Northing and Easting values are not uploaded into the Oracle database. If a user creates a new maintenance requirement or moves an existing one within ArcPad, those Northing and Easting values are written to fields in the shapefile and uploaded to the SWTS database in Oracle.

Based on this spatial data, the ArcPad application was designed so that Inspections can be performed by clicking on the related Potential Release Site. If multiple Potential Release Sites are present in that location, the user may select which one to inspect from a list. Inspection Findings and Site Structural BMPs are accessed through the Inspection form. If multiple BMPs are available for a site, the user can select which one to view using a pick list. Maintenance Requirements can be created or edited by clicking on the correct map location, and the BMP requiring maintenance can be accessed from the Maintenance Requirement form.

Application Development:

Once the design phase concluded, application development began. Application development proceeded in parallel; one team developed the upload and download interface while another developed the ArcPad application.

Both aspects were far more complex than originally anticipated. Previous ArcPad applications had been developed using shapefiles as the basis for data collection. Upload and download had consisted of merging shapefiles and copying data. But this application required converting Oracle tables into dbf files, editing the dbf files on the handhelds, then converting the data back into Oracle and editing the field data before applying changes to the SWTS database.

ArcPad Application Builder will work with dbf files, but it is really designed for use with shapefiles. Its documentation is extremely sketchy. The development team relied on the user forums to get information about how to perform common tasks. Many common issues are documented only in the user forums. For example, check boxes only work with boolean fields from ArcView 3.x, and radio buttons cannot be set or their settings “read” using code. In many cases, the development team’s learning curve was steep.

Developing a set of custom ArcPad forms for use with shapefiles is quick and easy. It takes a matter of weeks to put a new application together. Working with dbf files is much more difficult. A shapefile is “bound” to the custom form being built. All that has to be done in most cases is add controls such as text boxes and combo boxes to the form, then select the field whose data should be used with each control. ArcPad takes care of opening the correct data and saving it after edits are made. DBF files cannot be bound to a form. The form must be created in an applet, and Visual Basic scripts must be written to load data into the form, validate data, and save data into the dbf file. Using unbound forms is more flexible than using bound forms, but requires far more code. Since much of the code is repetitive, the development time is reduced each time the developer creates a new form. However, creating forms to work with dbf files takes considerably more time than creating forms from shapefiles, even for a skilled developer.

The upload/download interface was also more complex than anticipated. The ArcPad and Access programmers had not worked with Oracle before, while the Oracle staff was only marginally familiar with Access. Due to staffing and coordination issues, Oracle personnel were charged with developing the entire upload/download interface, including the Access component. Had Access programmers been assigned to develop the interface, the process would have gone much more smoothly. Unclear communication between the two development teams also made development of the upload/download interface more difficult.

Finally, GIS data was obtained to create a base map. To reduce visual complexity on the small screen, each GIS layer was given maximum and minimum display thresholds. Orthophotography was available in MrSID and ECW formats. After testing, it was determined that while MrSID performed poorly on the handheld device, the ECW imagery gave reasonable performance. Planimetric data, the Potential Release Sites data, and contours were added to complete the base data. An ArcPad project was developed for use with the custom application.

Although the development process was more complex than originally anticipated, the results were successful. After completing training field crews were looking forward to working with the new system and managerial staff was eager to implement.

The Finished Application:

The finished ArcPad application consisted of a custom toolbar to access the forms, and four custom forms for use with an ArcPad project displaying a map of Los Alamos National Laboratory. Upload and download tools were built in Access 2003, and data review forms were built in Oracle Forms.

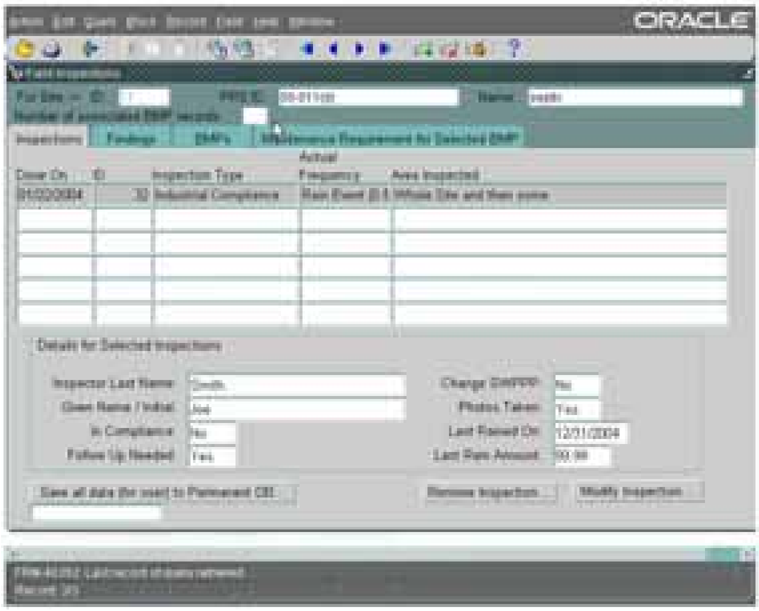
The main portal to enter inspection data was the Site Inspection form. After clicking on a Potential Release site, the user selects which site at that location they wish to inspect.

Then they can proceed to enter an inspection and its associated findings and view, edit, or enter structural BMPs for the site. Data to be entered as part of the inspection includes the inspector, inspection date, purpose of the inspection, whether or not photos were taken as part of the inspection, site compliance, whether changes to the SWPP Plan are required, whether or not follow up is needed, and the details of the last rain event.

From the inspection form, users generally proceed to fill out the site findings. The Site Findings form contains a detailed set of checkboxes on multiple tabs describing the site conditions and erosion on site. If an entry precludes other answers (for instance, if run-off does not exist, it cannot cause visible erosion), the precluded answers are disabled in the form. The entire set of entries is converted into a single paragraph of text during the upload process.

Next, a user will check to make sure the BMP information for the site is up-to-date. As with the inspection form, the user must select which BMP to view or enter information about before viewing the form. BMP data includes the type of structure, a text description, the installation date, current status, and the function/purpose the BMP serves.

Finally, if the user encounters maintenance that needs performed while conducting the inspection, they can click on the map to create a maintenance requirement point and fill out the maintenance requirement form. Once the user selects the site needing maintenance and chooses a BMP to maintain at the site, summary information about the BMP is displayed. It is then possible to view the BMP form if additional information or edits to the BMP are needed. The user can enter information about the work needing performed. If maintenance has been completed since the last inspection, the inspector or maintenance personnel may enter a date completed and details regarding the work done. This allows for efficient tracking of maintenance needs across the entirety of LANL without relying on the vagaries of human memory.



Data upload and download each require a simple file transfer, selection of the data needed, and a single button click. Once data is transferred into temporary tables in Oracle, the user can edit the data prior to approval and transfer of data to the SWTS database. The data review forms are nearly identical to standard forms in SWTS to reduce the user's learning curve.

In summary, the SWTS handheld application is expected to improve speed and accuracy of inspection and maintenance procedures at Los Alamos National Laboratory by a significant amount. The improvement in fulfilling legal reporting requirements will be very important. The combination of Trimble GeoXT devices and ArcPad with custom forms is powerful and is serving the needs of Los Alamos National Laboratory.

Acknowledgments:

The authors would like to thank the following:
- Los Alamos National Laboratory Water Quality and Hydrology Group members
- Staff at Merrick & Company
- Staff at Shaw Engineering

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