FOCUSED ENVIRONMENTAL REMEDIATION USING ADVANCED WEB AND GIS TECHNOLOGIES*

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ABSTRACT

Sites contaminated by the United States' early atomic energy program were cleaned up under guidelines in effect at the time. Today's current, more stringent regulations require site characterization and risk evaluation that can be very costly and time consuming. The Environmental Assessment Division, Argonne National Laboratory, is using new technologies that support more rapid environmental characterization to allow quick and informed decision making in remediation projects. New hardware, software, and wireless technologies allow large amounts of field sample data to be digitally returned to the office, processed using ArcGIS, and posted to ArcIMS sites within minutes of data collection and analysis. XML- and ColdFusion-based Web sites keep stakeholders in the loop. These advanced data collection, dissemination, and communication technologies combined with applied science can save federal and state agencies millions of dollars in cleanup costs. However, data-management and decision-making practices must also be adapted to realize the benefits of the new technologies.

1 Introduction

Before the era of "environmental awareness," few people were concerned about the harmful public health and environmental impacts of dumping, spilling, or burying chemical and radiological waste. On the thousands of properties across the country where such practices occurred, the result was contaminated abandoned buildings and contaminated soils/sediments/surface water/ground water and landfills. Citizen concern over the extent of this problem led Congress to establish the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund, in 1980. The law authorizes response or cleanup actions that permanently and significantly reduce the dangers associated with releases of hazardous substances.

The Superfund cleanup process begins at a site when the U.S. Environmental Protection Agency (EPA) has been notified of possible releases of hazardous substances. Through a series of steps in the Superfund cleanup process, the site is evaluated and the appropriate response actions (i.e., cleanup) are implemented. The site cleanup process can take many years to complete and generally includes the collection of large amounts of environmental data to be used in making cleanup decisions about a site. Characterization and remediation activities at these sites are very expensive. In recent years, remediation has taken a financial toll on shrinking federal dollars as more and more of these sites have reached the remediation stage of the process. It is an ongoing challenge to clean up these contaminated sites in a cost-effective manner.

Environmental data management, analysis, and communication are essential components of environmental characterization and decision making. Recent technological advances in environmental data acquisition, the Global Positioning System (GPS), geographic information systems (GIS), computer modeling, and data visualization have led to expanded use of technical environmental data collected as part of the Superfund process. The Internet and associated World Wide Web technologies have become an integrating force for environmental data management, analysis, and communication, and the increasing use of GIS is changing the way environmental data are being collected and analyzed. This paper discusses the application of these combined technologies to maximize cost-effectiveness and the quality of decisions made in the Superfund cleanup process.

2 Environmental Spatial Data Collection Technology

2.1 Rapid Processing of Field Survey Data

The use of GIS/GPS-enabled handheld devices and wireless communication technology for field data collection facilitates faster and more efficient collection and processing of data. Using these systems in combination provides the following advantages over historical paper-based field data collection:

1) Availability of accurate spatial data at the time of data collection,
2) Avoidance of data conversion from paper to an electronic format,
3) The ability to conduct preliminary quality assurance/quality control (QA/QC) while in the field, and
4) Faster transmittal of collected data to analysts and decision makers.

Given the high cost and technical challenges inherent in field data collection, these advantages can mean more cost-effective data collection and analysis by reducing time in the field, reducing errors in collected data, and enabling faster and more informed decision making.

2.2 Integration of Accurate Spatial Data during Data Collection

GIS- and GPS-enabled personal digital assistants (PDAs) or tablet PCs provide field personnel with real-time access to detailed spatial data while they are collecting additional data in the field. The devices can be used to navigate to predetermined data collection sites or sample locations, to record relatively precise locations for data collection points quickly and accurately, and to tie collected data to those locations immediately. As a result, location errors can be detected immediately. GIS-enabled devices can also combine different types of data onto one GIS map that may assist in choosing sampling locations or interpreting collected data. For example, a GIS map or aerial photo of an archaeological site showing building footprints might help field personnel to select a soil sample location or interpret sample results.

2.3 Collecting Data in Electronic Format

Paper-based field data collection usually requires that the data be converted into an electronic digital format before it can be analyzed. The process of converting data into an electronic format can be expensive, time consuming, and prone to error. In addition, the conversion process delays the distribution and usability of the data for analysis. The use of handheld devices such as PDAs for field data collection usually involves little or no conversion for further processing; this can save an enormous amount of tedious effort and expense, while avoiding transcription errors.

3 Advantages – Real-Time QA/QC and Virtual Communication

3.1 Conducting Preliminary QA/QC in the Field

Because the use of handheld devices allows collection of data in electronic format, field data can be analyzed much faster, either directly in the field or, through the use of wireless communication to transmit data from the field to office locations, by the scientific team. Preliminary QA/QC can be conducted, and errors or gaps that require additional data collection may be spotted more quickly. With appropriate software and hardware, the QA/QC activities can be conducted within a few minutes or hours of collection, allowing immediate recollection or refinement of data collection. This capability can save enormous amounts of time and money if it avoids a return trip to the field to recollect data. Similarly, results of data collection can be checked while still in the field, and, if necessary, data collection activities can be modified immediately to reflect these preliminary results. For example, reviewing data on a GIS-enabled tablet PC immediately after collecting it may indicate areas of high or low interest where the sampling density might need to be increased or decreased, or it might indicate that the sampling area should be expanded. Thus, the ability to adapt the sampling plan on the spot may save an expensive return trip to collect more data, or may avoid costly data collection in areas of low interest.

3.2 Web Maps to Transmit Collected Data to Analysts and Decision Makers

Use of wireless communication technologies in combination with GIS-enabled handheld devices and a Web-enabled GIS (ArcIMS) facilitates the immediate transmittal of data to analysts and decision makers at office locations with access to the Internet. Map and other information can also be “pushed” to field crews to respond to their immediate needs for instructions or data to support their activities.

With GIS techniques that are now fairly routine, even simple ASCII data received from remote survey equipment can be converted to point features and become the foundation for advanced data visualization. If necessary, GPS coordinates are projected to the coordinate system being used for the project, and then symbolized based on recommendations from the scientific team. Depending on the resolution and extent of the survey, this processing may be all that is needed, and can take only minutes to complete after the data has been received from the field crew. Due to advances in Web GIS technologies, the same data can be analyzed in an interactive Web map in only a few more minutes.

Surveys performed over large areas with high resolution can generate hundreds of thousands of data points, and in these cases the limitations of hardware and software start to become a concern. To promote better performance over the Internet, large datasets obtained during characterization surveys can be converted to ESRI Grid format and symbolized as a raster image instead of as individual points. This allows for good performance while symbolizing hundreds of thousands of data points.

Importantly, the symbology and sampling methods used to process the data points should be agreed upon by the scientific team. The choice of what data layers to show along with the survey data is also important in focusing cleanup efforts. Aerial photos taken in series over a given time span have proven valuable in understanding where and how individual areas have become contaminated. At sites with previously identified areas of contamination, aerial photos can serve to focus on “hot spots” that showed up in previously unidentified areas. Other GIS layers involving natural resources, topography, and infrastructure can also help to focus analysis by the scientific team.

The capability to send data and communications back and forth between the field and the office in near real time turns field projects into “virtual collaborations” between field staff and analysts and decision makers back in the office. The virtual collaboration involves rapid communication, consultation, and decision making in a fluid and flexible working environment. With the right technology, the right people, and a project plan specifically geared to take advantage of this fast-paced, flexible approach, the end result can be better decisions made in less time.

3.3 Team Awareness via Secure Web Sites

As noted above, the most effective use of GIS/GPS-enabled handheld devices and wireless communication technologies involves "virtual" collaboration and teamwork involving field and office staff. It also requires a "virtual workspace" where data, documents, photos, and other critical information can be viewed and used by both parties. At Argonne National Laboratory, we use secure project management Web sites with varying levels of access and security to facilitate the sharing of data between field and office staff, and in some cases with other stakeholders such as citizens groups and/or regulatory agencies. GIS data are presented either as static map images or as "live" maps using ArcIMS. Data can be posted directly to the site by field crews or after processing by the scientific team. Besides GIS data, these sites typically contain a document repository, a calendar, news items, staff contact information, Web page links, and an image gallery for sharing photos, drawings, and other graphics.

4 The Required Technology Is Becoming Cheaper and More Available

Like most computer technology, handheld data-collection and communication devices are evolving rapidly and prices are decreasing. Currently, high-end Pocket PC devices are widely available for $500-600, although the ruggedized units that are nearly required for extended field use can cost more than $1500 per unit. Likewise, ruggedized tablet PCs cost significantly more than regular laptops. Wireless modems require service plans that may run to several hundred dollars per annum.

When calculating the cost of these systems, the potential savings in effort cost they may afford should also be considered. If the use of these systems on a project saved just one long-distance trip to the field for a large crew, or meant that one deadline is made that would otherwise have been missed, the cost savings might well dwarf the expenditure for the handheld/wireless equipment and software. Regardless, there is little doubt that handheld and wireless technology prices will continue to decrease as device capabilities improve.

5 Data-Management and Decision-Making Practices Need to Keep Pace with the New Technologies

While wireless GIS/GPS-enabled handheld data collection devices are instruments for field use, full realization of their benefits involves scientific analysts and decision makers. It also involves the adaptation of field data-collection, data-management, and decision-making processes to accommodate the requirements of the technologies and to take full advantage of their unique capabilities.

In the field, data collection with “new-fangled” electronic devices may mean changing the mix of data collectors to include someone more knowledgeable or comfortable with the devices and/or with GIS. The order of data collection tasks may change because the devices may make particular tasks more or less efficient, and, of course, batteries may run out, requiring breaks for recharging or swapping.

In the office, data may have to be analyzed quickly and managed carefully in order to turn it around for immediate use by field crews. There may not be time for detailed QA/QC practices that would normally be applied. Likewise, decision making itself needs to be adapted; decision makers must be more available to make decisions, and may have to make decisions faster. If there are multiple decision makers at remote locations, they may need to consult with one another via phone and reach a decision on the spot. As one field staffer put it, “It’s great that we can get the data to the bosses in an hour, but if it still takes them three weeks to make a decision, what good is it?”

6 Conclusions

Advanced Web and GIS technologies, especially when used in combination with handheld data collection devices and wireless communication technologies, bring unique capabilities to environmental characterization and decision making that can result in reduced data-acquisition, management, and analysis costs while resulting in faster and better informed environmental decision making. GIS-enabled handheld devices bring “spatial intelligence” to field activities, and wireless communication enables a two-way flow of data and communications between the field and the office. Web-enabled GIS on secure project Web sites provides a virtual working environment for near real-time exchange, query, and analysis of spatial and other data, aided by advanced visualization that facilitates pattern and trend recognition.

The advanced technologies mentioned in this paper are becoming more robust, more capable, and more affordable. The key to applying them effectively lies mostly in their acceptance by field personnel, the scientific team, and environmental decision makers.