COMPUTERIZED INTEGRATION AND VISUALIZATION OF DATA FOR SITE CHARACTERIZATION

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ABSTRACT

Expedited site characterization (ESC) emphasizes the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize environmental site investigations. This requires rapid integration and analysis of large volumes of disparate data. Argonne's ESC process is flexible and adaptable to the unique characteristics of each site. Therefore, integration and visualization of ESC data require a wide range of techniques. This paper illustrates three of these methods: (1) spatial data integration in a geographic information system (GIS), (2) two-dimensional visualization through the use of automated cross section generation, and (3) three-dimensional modeling where data are sufficiently dense.

The Applied Geosciences and Environmental Management Section (AGEM) of the Environmental Research Division at Argonne National Laboratory uses software components that include a GIS, spreadsheets, database management systems, computer-aided design (CAD), graphing programs, geotechnical programs, contouring and modeling software, and custom routines to provide dynamic support for ESC. The best features of each program provide computer visualization that supports geoscientists in making correct, timely, and cost-effective decisions.

INTRODUCTION

Expedited site characterization is an interactive, integrated process emphasizing the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize environmental site investigations (Burton and Walker 1997). Argonne's ESC is a flexible process that can be tailored to the unique characteristics of each site, rather than a prescriptive regimen. An important component of ESC is computerized visualization of large volumes of data. Just as not every geoscientific technique works for every site characterization, not every computer program in the ESC suite of visualization applications is suitable for every site. A varying subset of computer programs handles dynamic data requirements to allow rapid integration and visualization of relevant site data.

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TECHNIQUES

This paper illustrates three techniques of data visualization as applied to ESC: (1) spatial data integration in a GIS; (2) two-dimensional visualization via cross section automation; and (3) three-dimensional visualization where data are sufficiently dense.

One of the hallmarks of successful ESC is the efficient use of existing site data. The goal of the first phase of an ESC investigation is to understand the geologic and hydrogeologic controls on a site. This understanding guides formation of scientific hypotheses to be tested, refined and revised throughout the site work. In preparation for the Phase I work, existing regional and local geographic and geoscientific data are extensively researched. Results of any previous investigations are studied. Preparation of the Phase I work plan usually reveals a large amount of data from various sources that requires organization and analysis. As the on-site investigation begins, the site database grows to even more challenging proportions and diversity. The AGEM suite of computer applications helps the scientists assimilate the growing body of information about the site.

Spatial Data Integration in a GIS

A GIS provides order for disparate data by allowing spatial access to relevant information as it is georeferenced to the base map. Two current AGEM ESC projects will illustrate ESC GIS and other visualization techniques. The first is a rural site in Kansas where the Commodity Credit Corporation/U.S. Department of Agriculture (CCC/USDA) formerly operated a grain storage facility. As at many similar sites, the grain storage bins were fumigated in the 1950s and 1960s with carbon tetrachloride, a then commonly used pesticide that is now known to be a carcinogen. AGEM is investigating potential groundwater contamination at this site and many other CCC/USDA sites. The second project for illustrative purposes is a study of geology and hydrogeology at Argonne National Laboratory.

Figure 1 shows the integration of an orthorectified aerial photo from the U.S. Geological Survey, a street map, and the various locations of Kansas Department of Health and Environment monitoring wells, domestic wells, public wells, and the former CCC/USDA site. Site data are georeferenced; the system can allow spatial access to related analytics, lithology, and groundwater hydrology. When the user selects a well, a table of recorded parameters is displayed.

Zooming out presents a more regional view. Figure 2 shows the area centered on the town in Figure 1, but covering nearly 400 square miles as compared to less than one square mile in Figure 1. At the regional scale, the GIS incorporates logs from Kansas Geologic Survey test holes and from public and domestic wells, as gathered from publications and agency offices. Through this graphic interface, a geologist can select a line of section at a regional scale. Figure 2 shows the A-A´ section marked for cross section generation.

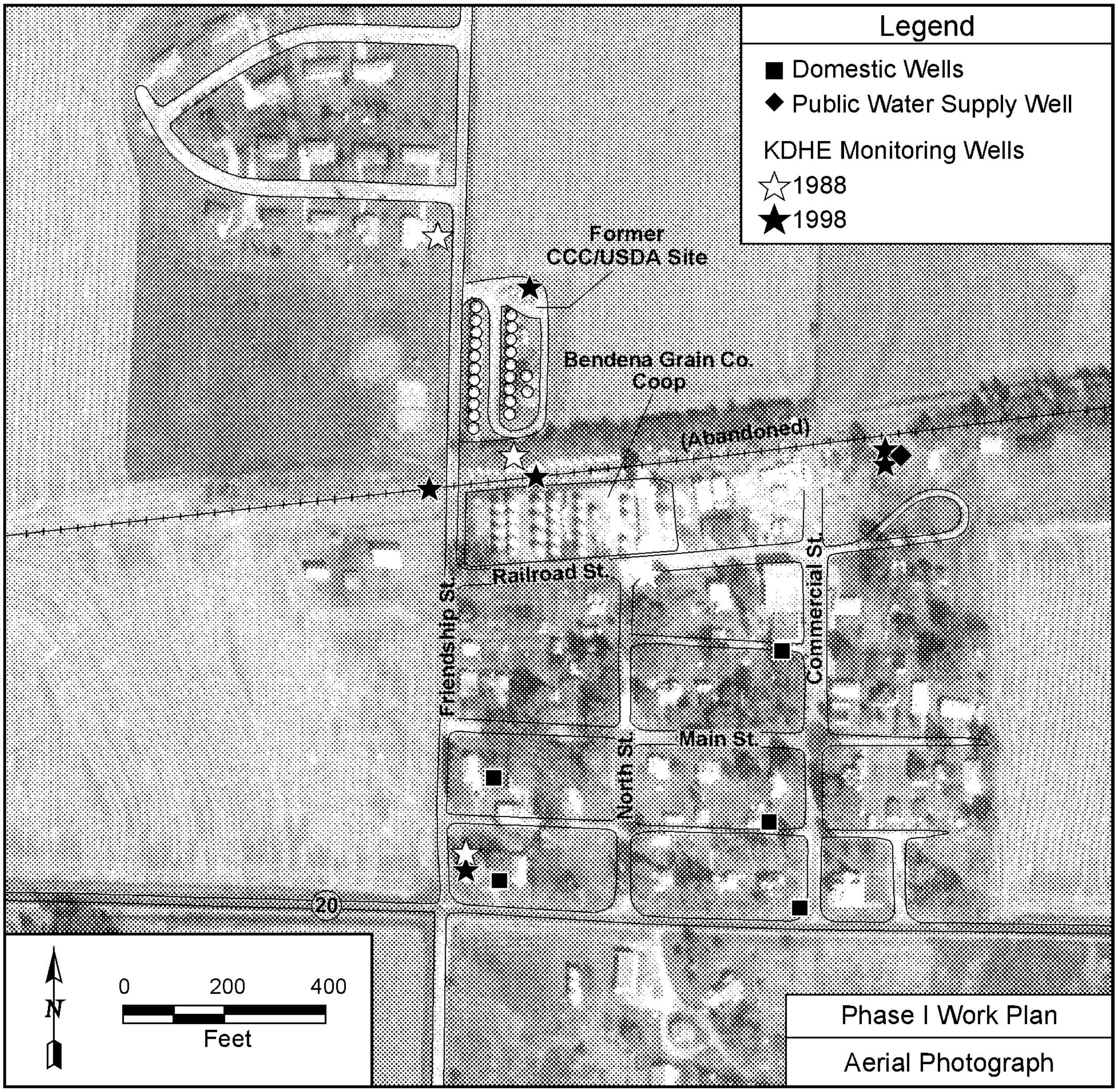

FIGURE 1 Spatial Database for a Rural Kansas Site, Prepared for the Phase I Work Plan

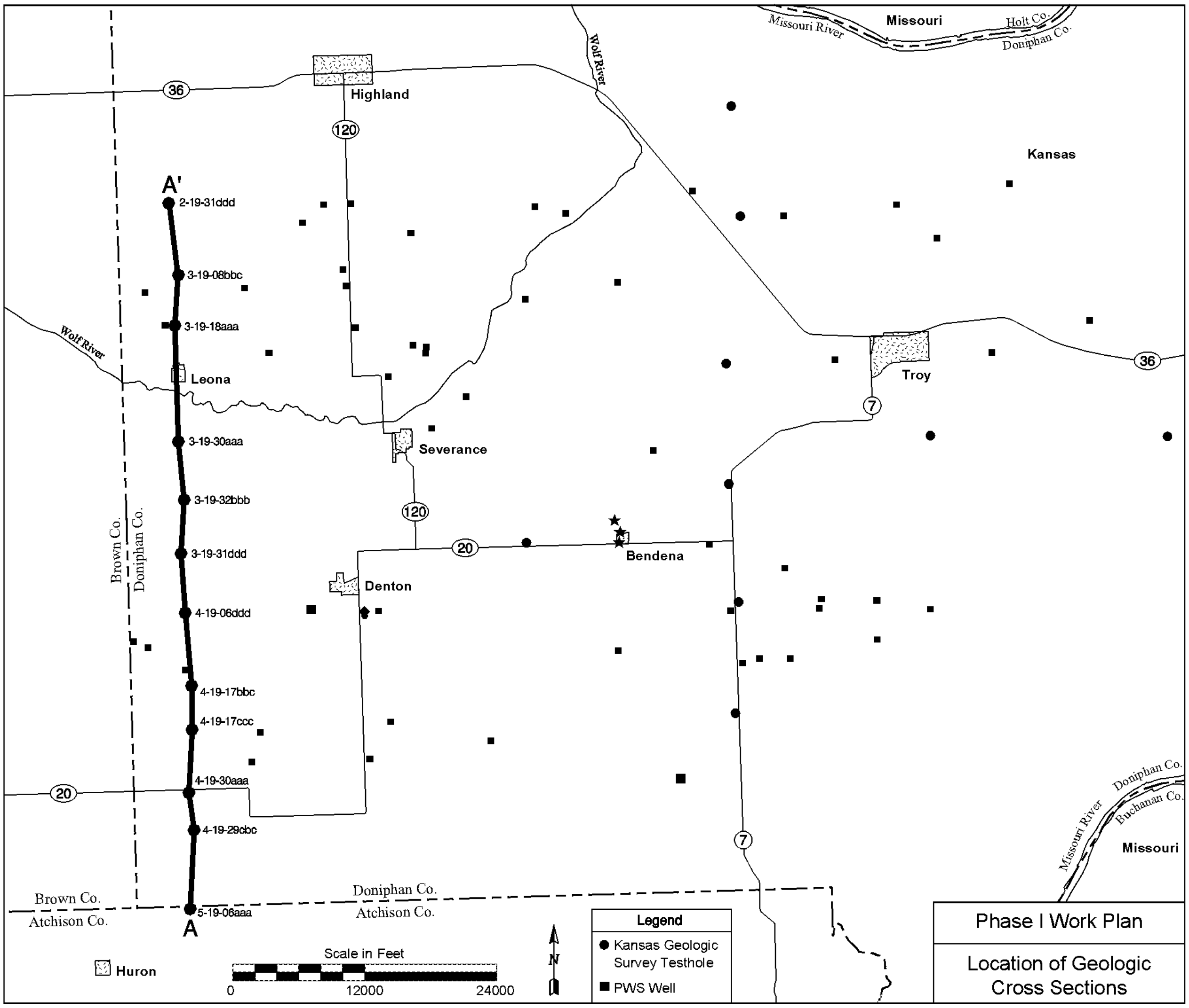

FIGURE 2 Cross Section Location Selected from Regional View

Two-Dimensional Visualization: Regional Scale

Lithologic data from the boring locations shown in the GIS become the basis for a cross section that can be automatically generated from the database. A selection like that shown in Figure 2 is automatically entered into a program that generates cross sections in AutoCAD Data Exchange Format (DXF). Figure 3 shows the output generated by this custom routine. The initial cross section output in the work plan phase prints to a large plotter. The section format is designed to include all the descriptive text detail, rather than symbols or patterns. Other section formats include cone penetrometer data curves, downhole geophysics, analytics, or other parameters, in addition to lithologic descriptions. The purpose of this section is to display as much detail as possible to aid the geologist in creating an interpretation. The example in Figure 3 includes extreme vertical exaggeration over the section length of approximately 15 miles

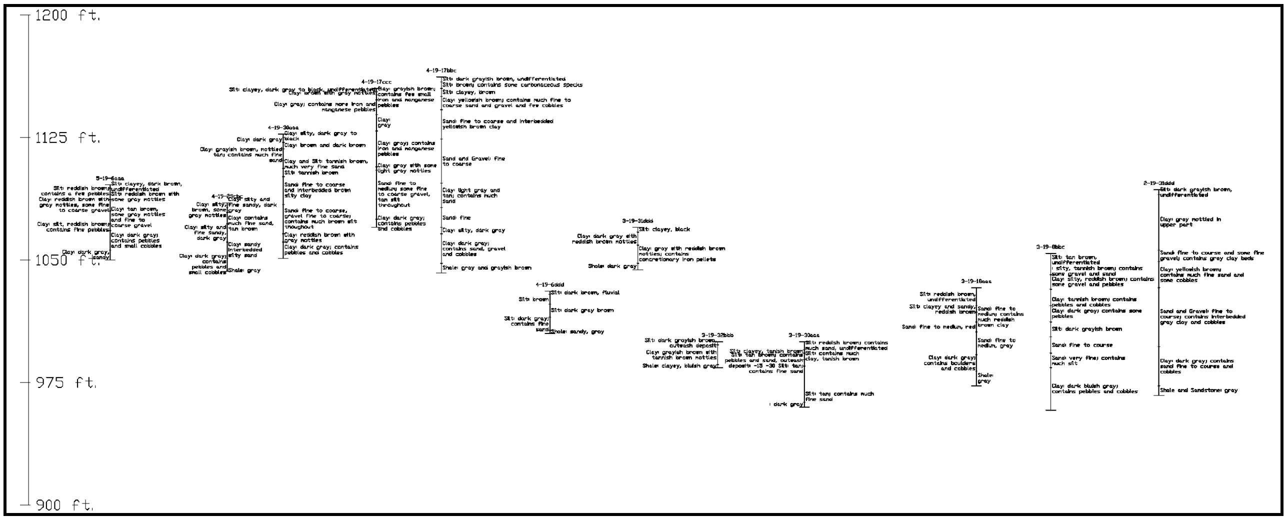

FIGURE 3 Automated Cross Section, Which Must Be Printed on a Large Plotter to See Detailed Lithologic Descriptions

in order to see the unit descriptions. The DXF file generated by the cross section program is read into AutoCAD for printing, display, and (later) addition of the interpretation.

The skeletal cross section shown in Figure 3 is the basis for the interpretation, shown in Figure 4. The latter figure shows the geologists' interpretation of connections in lithologic units. The simplification from the very detailed descriptions shown previously requires the input and skills of the human experts, not automated computer processing. The computer assists by displaying the complexity, but the scientists do the interpretation.

Two-Dimensional Visualization: Local Scale

The second example of visualizing the subsurface comes from Argonne National Laboratory, a site very different from the rural CCC/USDA site. Here, in an area of less than two square miles, data exist from nearly 900 wells and borings. In the process of studying the geologic and hydrogeologic controls on the site, the geologists evaluated data from all of these locations and selected 359 logs for their "pick file" database. These logs became the basis for creating a series of 11 detailed cross sections to study very localized subsurface structures. Figure 5 illustrates the clustering of data in several operational areas, along with the lines of section chosen for study. The GIS interface allows selection of these sections to create a table that is input to cross section generating programs.

For each of the 11 selections, the custom program accessed the lithologic database to create a skeletal cross section similar to that of Figure 3. The program also calculated the topography for each line of section by automatically accessing the topographic database at each intersection of the line of section and a contour line. The program then added the line of topography to the section drawing as another DXF layer. One of the final interpreted sections is shown in Figure 6. This example shows a striking contrast in current surface topography compared to the original boring elevations, reflecting the construction of a berm.

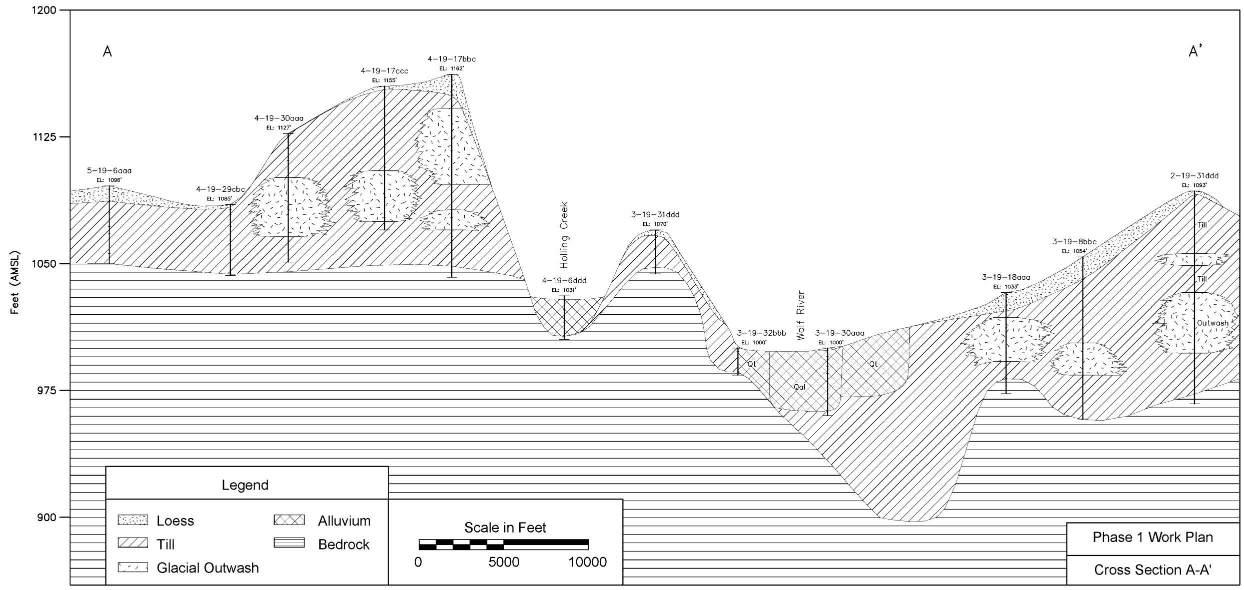

FIGURE 4 Final Cross Section, Showing Geologists' Interpretation

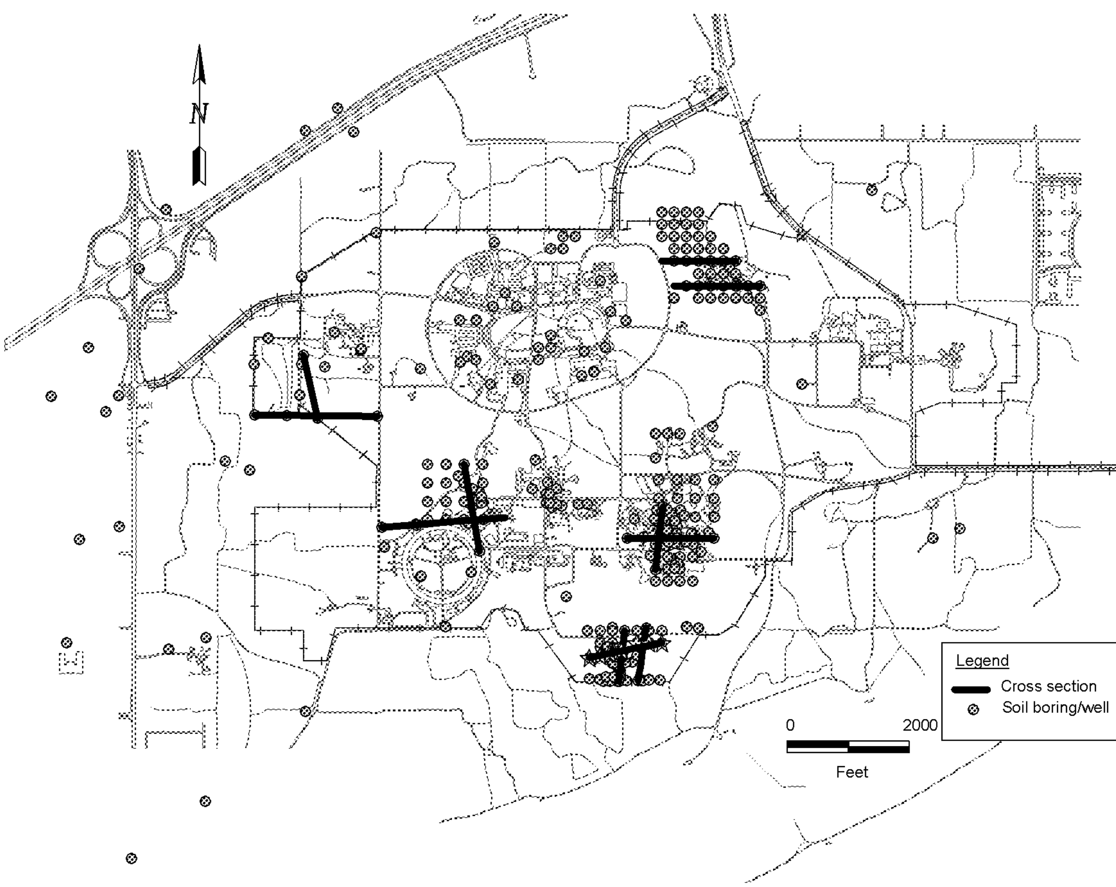

FIGURE 5 Eleven Cross Sections Selected from a Database of 359 Logs of Sufficient Quality for Detailed Local Study

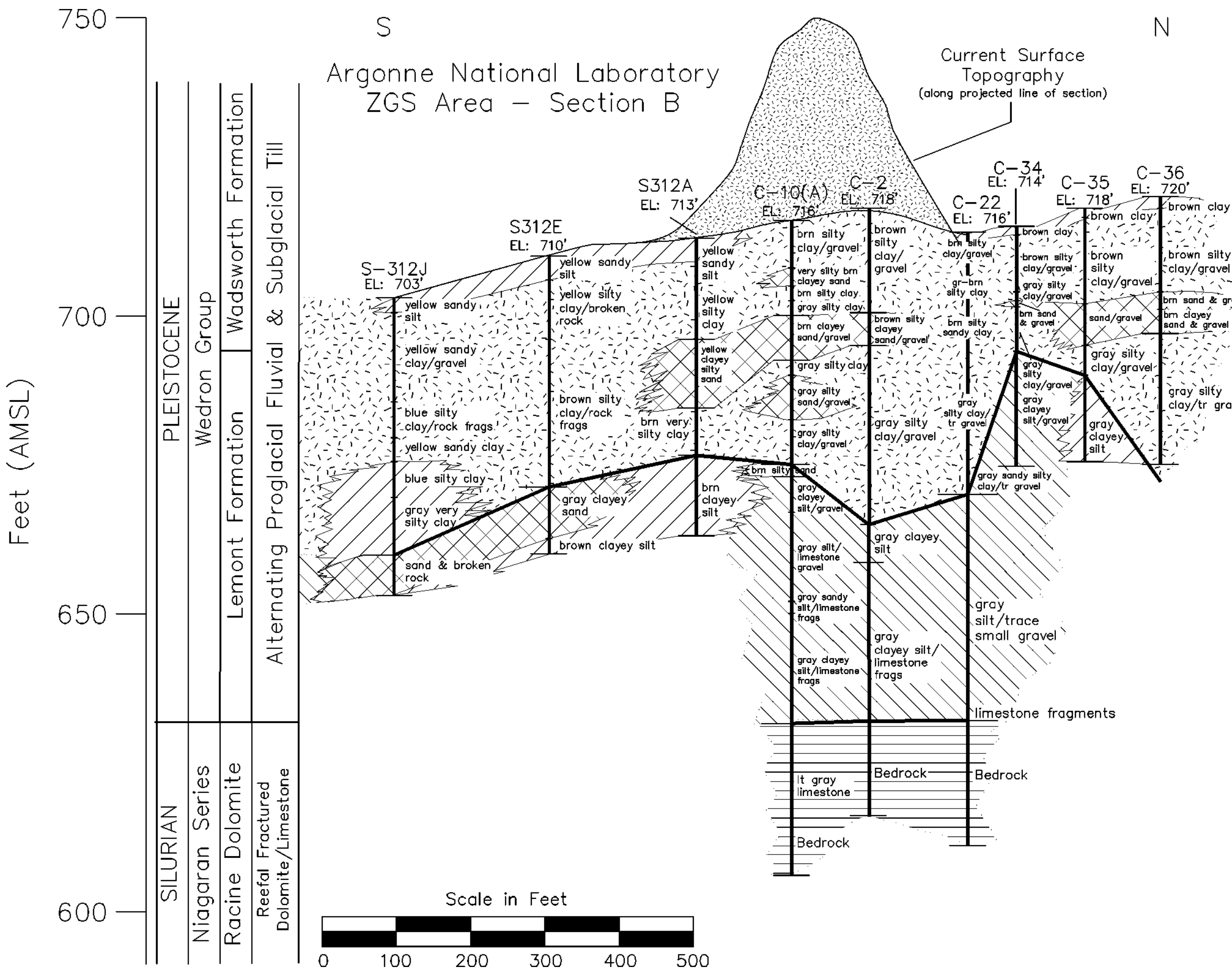

FIGURE 6 Line of Topography on Interpreted Section, Automatically Generated from Topographic Database

Figure 6 includes the final interpretation that was added manually after analysis by geologists. The ease of automatically generating multiple sections from the database of logs allows greater visual access to the data than would be possible otherwise.

Three-Dimensional Visualization Where Data Are Sufficiently Dense

As shown by the number of borings in Figure 5, several operational areas at Argonne have been studied extensively over the years. The 317 Area, an early waste disposal site, offered good lithologic information from 110 logs in an area of less than 30 acres. This density provided the data for a three-dimensional model that shows the potential for groundwater movement. The model is not, however, a true representation of geologic units, but shows the generalized distribution of sand and gravel within the local area. The model was developed by dividing the lithologic descriptions into fine-grained and coarse-grained (sand) areas and calculating the percent sand in each five-foot horizontal slice. This description was extrapolated into horizontal cells 50 feet on a side. The resulting matrix is displayed with a color table representing a continuum of percent sand. The black-and-white depiction in Figure 7 represents the model results. However, the color model shows the percent sand differences more clearly. When it is animated by making increasing percentages of sand transparent, the model reveals the sandiest units. At around 25-30% sand, the areas with most potential to allow water movement become apparent, as shown in Figure 8.

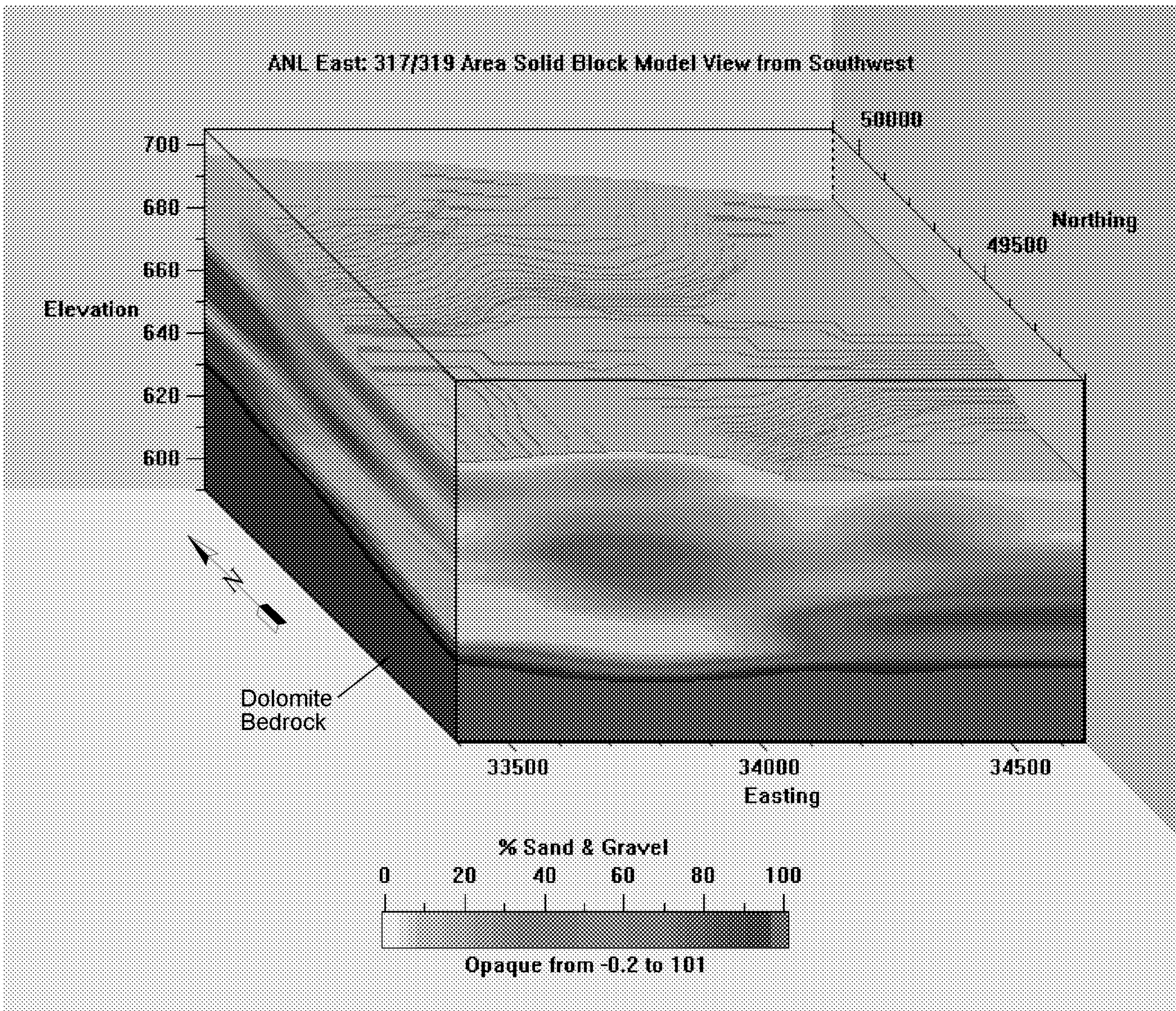

FIGURE 7 Solid Block Model, Showing Generalized Distribution of Sand and Gravel above the Bedrock Surface

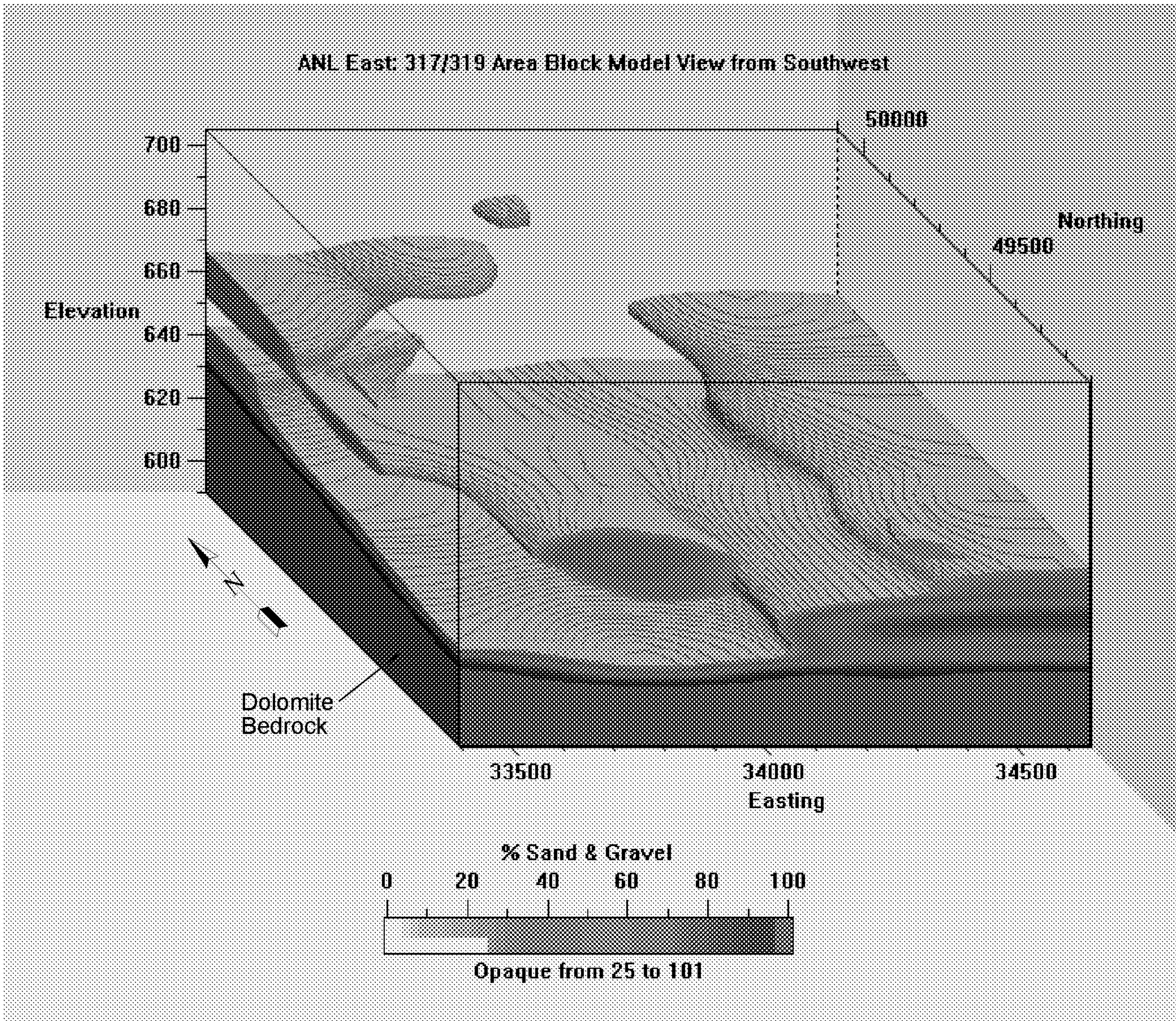

FIGURE 8 Solid Block Model at about 25-30% Sand, with Areas of Most Potential to Allow Water Movement Becoming Apparent

CONCLUSIONS

In the AGEM experience, no single computer system has been able to fulfill all data integration and visualization needs. The ESC is a dynamic process, and our computer systems have developed dynamically as well. We are continually establishing the suite of applications that contribute to the ESC process. The key requirement of data integrity is carefully maintained. Our data are accessed via the network and our servers. Few users have write access to the data in our Oracle, FoxPro, and MapInfo databases.

MapInfo provides users with spatial access to our data. One of the strengths of that software is its ability to access data in many formats. We use it to access files directly from Oracle, FoxPro, Excel, Access, and AutoCAD, as well as bitmapped and ASCII text files.

We use geotechnical applications from RockWare, Spyglass, Visual Logic, Golden Software, and AutoDesk. In addition, we have written our own program to automate cross section generation and allow access to data in any of our formats.

Our computer systems have been described as a “software democracy,” where every scientist has a favorite, and the challenge is to combine the best features from a wealth of tools. This dynamic mix and our custom routines allow us to integrate input from many data sources and output from many programs. The goal in employing all these systems is data visualization that will guide the geoscientists in making correct decisions.

ACKNOWLEDGMENTS

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Burton, J.C., and J.L. Walker, 1997, “Correct Implementation of the Argonne QuickSite^{SM} Process for Preremedial Site Investigations,” 13th Annual Environmental Management and Technology Conference West, Long Beach, California, November 4-6, 1997.