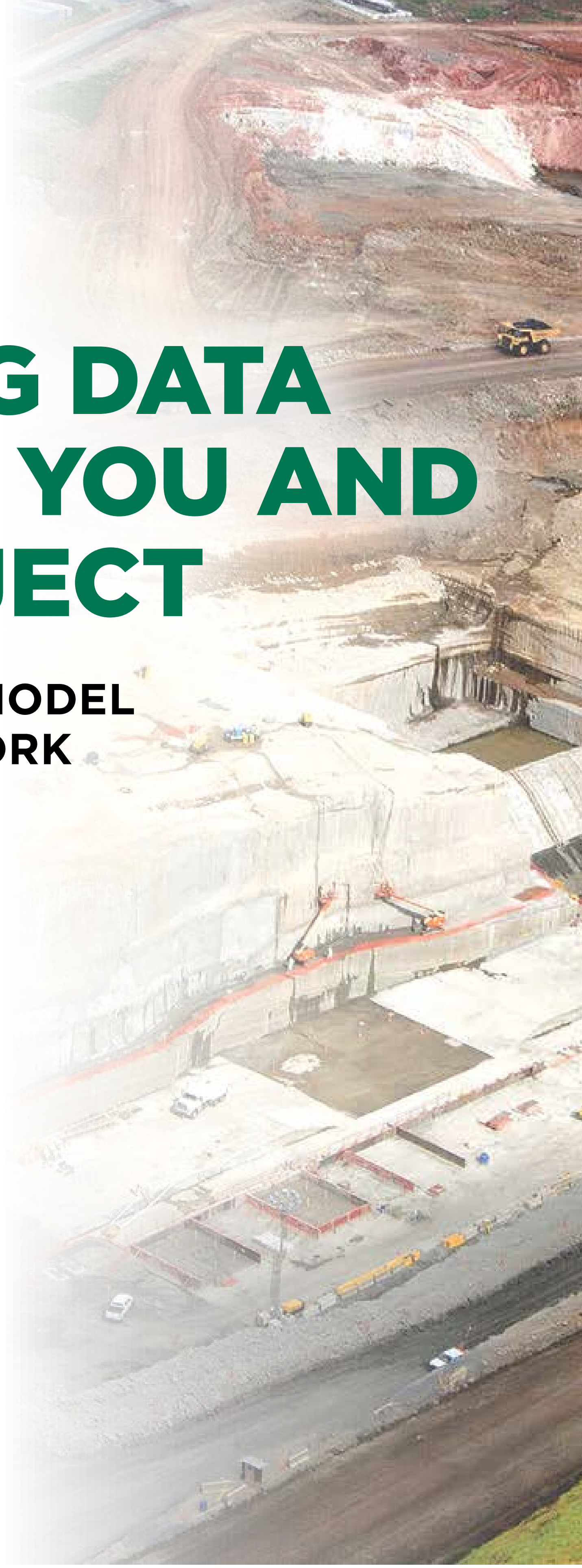


MAKING BIG DATA WORK FOR YOU AND YOUR PROJECT

A 3-D GEOTECHNICAL MODEL IS A SMART WAY TO WORK

By Katie Aguilar, PE, M.ASCE

Modeling the stratigraphy beneath a site and assigning soil and rock properties are important steps in geotechnical engineering. Geotechnical engineers often need to model ground conditions over extensive terrain. Although a vast amount of information is available in the form of electronic quad maps, satellite images, and elevation models, these sources by themselves do not provide the level of detail needed to accurately depict site conditions. Surveyors provide a wealth of additional data useful to the civil aspects of capital projects, such as electronic data in the form of ground elevations, ground features, terrain configuration, and more. These data, when further processed, give engineers a graphical representation of the areal extent, surficial features, and topography at a site.

Another source of information is borings, which are often taken along the project at predetermined intervals. For example, a typical roadway project may require borings spaced between 150 and 500 ft apart along the roadway centerline, or they may be advanced at planned foundation locations. The geotechnical engineer must combine information from the topographic survey and the borings to create a "realistic" subsurface map of the project. More detailed information about the subsoil conditions may be obtained afterward through additional borehole explorations. Furthermore, a

Figure 1. Jan De Nul dredged 20 million cubic meters of rock from the Pacific north access channel and the Atlantic entrance.

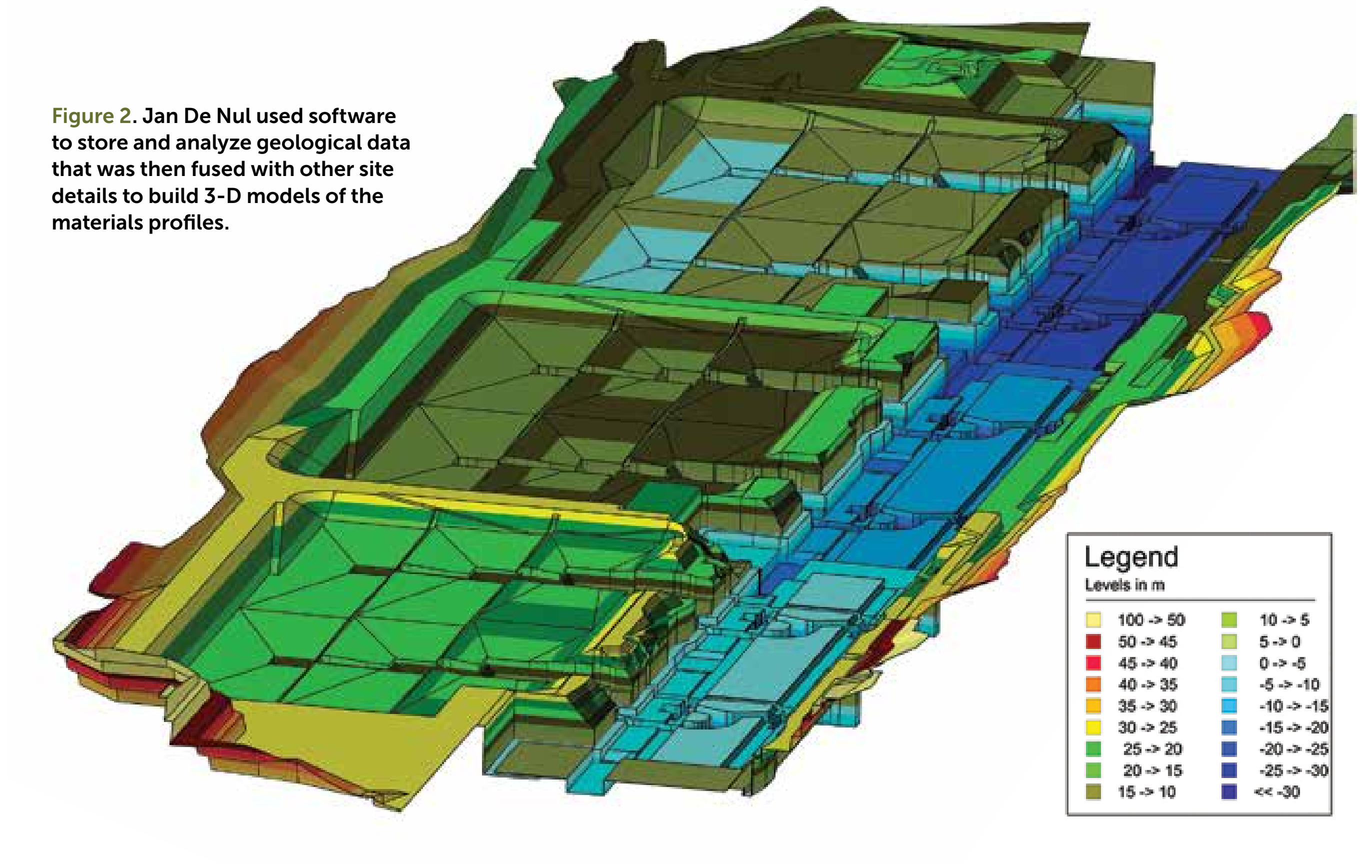


Figure 2. Jan De Nul used software to store and analyze geological data that was then fused with other site details to build 3-D models of the materials profiles.

wealth of historic geotechnical data may be available that can be useful in creating the geotechnical engineer's model. These older boring logs are often in paper form with cumbersome formatting, however.

Determination of soil and rock properties is usually accomplished through in-situ testing and/or soil and rock sampling and lab testing. Typically, this information is transcribed to geotechnical logs that are either output electronically as PDFs, or printed on paper for distribution with a geotechnical report. Soil information may be incorporated into the final plans of the project and depicted along the alignment, profile, building footprint, and sometimes cross sections. A geotechnical boring or sheet accompanies the final deliverable, and this information is then used by different specialties for design, including drainage, structures, hydrology, and more.

It can become quite a challenge to determine the soil and rock layering and the subsurface profile using this information. A geotechnical model covering large areas is typically generated with relatively distinct point data information from the boreholes, and assumptions and extrapolations are made toward developing the model. This requires the engineers to use their best judgment to achieve a realistic representation of subsurface conditions.

A further challenge is that other engineering disciplines (e.g., civil, structural, and drainage) will use the geotechnical engineering data to establish their respective designs. Moreover, they will sometimes have to do so without knowledge of the level of extrapolation, or of assumptions incorporated into the model developed by the geotechnical engineer. All of this information must be analyzed, interpreted, and compiled in a final geotechnical report. The production of plans represents a challenge for the geotechnical professional as disciplines must merge various details during production, including:

- Geometry and location information provided by civil engineering
- Topography and ground modeling by surveying
- Subsurface data by geotechnical engineering

There are many software techniques that can be used to process and analyze these data. Interacting in real time with a geotechnical database provides the geotechnical professional with a means to better represent the ground and subsurface conditions. This interaction helps in the final production of construction plans for the project. The methodology involves a coordinated effort among civil and geotechnical engineers, and surveyors, to standardize the type of information taken in the field. Key factors for success include:

- Setup of a geotechnical database to capture data describing geometry, ground, and subsoil conditions
- Better analysis tools for representing the substrata model, and determining how this information can be represented in the final geotechnical plans using civil and drafting tools

The following projects illustrate how a topographic survey and information from boreholes can be used to create 3-D geotechnical models and produce final plans in a CAD environment.

Jan De Nul and Panama Canal Expansion Dredging Contracts

Jan De Nul is part of the consortium Grupo Unidos por el Canal, SA (GUPC), which was contracted in 2009 to design and construct the $3.2 billion Third Set of Locks – the main project in the canal expansion program. The work involved removing millions of tons of wet and dry materials from the project sites (Figure 1). The largest of the projects awarded to Jan De Nul included the $54 million dredging of 5 million m^3 of rock from the Pacific Entrance North Access Channel, and the $89 million dredging of 15 million m^3 of material from the Atlantic Entrance.

Modeling Multi-layer Materials

Jan De Nul used a geotechnical database and reporting program to gather, manage, present, and report on subsurface data for multi-strata soil layers with efficiency and accuracy. Data for hundreds of boreholes were then exported from the database program for use in a CAD application to create a subsurface model.

At the site of the Pacific works, Jan De Nul imported the geotechnical database borehole data into a CAD application using the provided CAD files, and fully designed the theoretical earthworks model of the locks and water-saving basins (Figure 2). The team built 26 models of soil layers, then checked for mistakes by making profiles of the models. The resulting cross-profile of the locks and water-saving basins combined the topographic model, the theoretical design model, and the ground models for sands, silts, clay, basalt, and sandstone.

Jan De Nul split the material volumes into contractual boundaries, calculating pricing based on how many cubic meters of soft materials had to be dredged by a hopper dredger, for example, and how many cubic meters of hard materials (i.e., sandstone, basalt, and siltstone) had to be dredged by a cutter section dredger, or be blasted and dredged.

Executing Theoretical Models Onsite

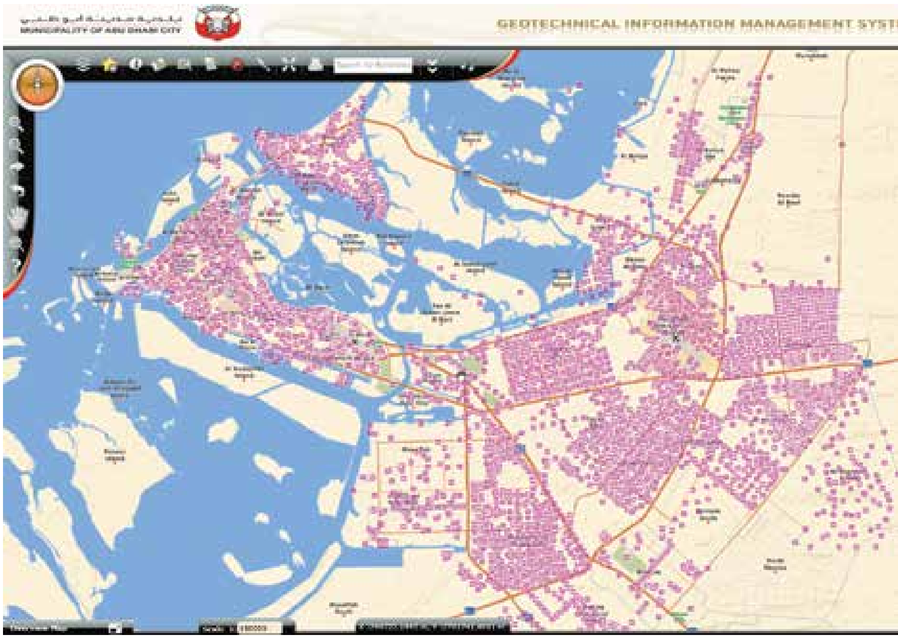
Jan De Nul was able to use accurate calculations for various material types by combining the data into the geotechnical database and with the ability to evaluate the resulting database. This process enabled Jan De Nul to submit winning bids for several projects in the Panama Canal Expansion Program. Work began in September 2008 at the Pacific Entrance. Once the construction phases started in each location, the team supported the projects by producing GIS overlays for logistics planning, such as checking shipping routes and sailing distances for dredging vessels. The team also delivered 2-D models with volume checks and balances. The models were directly imported into the software for GPS guidance of the machines used for leveling, excavating, and dredging works. The theoretical 3-D designs were imported without data loss, enabling the machine operators to use highly accurate, real-world coordinates on these large-scale projects.

Comprehensive Geotechnical Information Data Management System for Abu Dhabi City

The Municipality of Abu Dhabi City routinely commissions and manages projects where large volumes of data from site investigations and design are archived and accessed by internal and external users. Using a geotechnical database software application and Web mapping, the municipality's spatial data division developed a geotechnical information management system (GIMS) (Figure 3). GIMS is a comprehensive geotechnical database and information system that allows quick access to all geotechnical data. Providing instant access to subsurface investigation data supports rapid decision-making and appropriate resource allocation, thereby saving time and money.

The municipality had extensive legacy information from site investigations, such as borehole log reports and cross sections. Much of this information was in paper format. The paper filing systems were cumbersome for users to access, documents were often misplaced or deteriorated, and users were frequently unaware of what information was available. These glitches led to underutilization of the existing geotechnical data. Geotechnical information needed to be digitized and effectively archived so that it could be made available internally and externally for future projects.

Figure 3. The Geotechnical Information Management System (GIMS) provides easy access to data for all boreholes around Abu Dhabi City.



The municipality's then current system also lacked interoperability with other software, such as the existing geographic information system (GIS) and civil design software. The spatial data division determined that the solution was to centralize and validate, where possible, all subsurface information using a geotechnical database management system (GDBMS) and reporting software.

Implementation Challenges

The GIMS implementation project required capturing 20,033 hardcopy logs and reports for input into the GDBMS. The objectives were to validate data and capture errors at the source to reduce the risk of inaccurate subsurface information entering future infrastructure projects such as bridges, drainage systems, road networks, transportation systems, and comprehensive development programs. The reports were scanned, and the actual borehole records to be used were extracted for detail and linked to the GDBMS. The project team created semi-automatic, robust submission standards for controlling geotechnical data uniformity and quality.

Project Outcomes and Benefits

GIMS was integrated with the municipality's GIS Web portal by creating a custom geotechnical Web map application for the GDBMS (Figure 4). The GIS integration allows access to the existing geotechnical data at any time, from anywhere, via the Internet or the municipality's intranet. The robust geotechnical data submission standards ensure the uniformity and quality of data that is submitted. The streamlined data management processes, using a standard geotechnical database, improved the spatial data division's daily productivity twofold. By having a data submittal standard, site investigation data can now be instantaneously available to the GIMS database upon submission by geotechnical consultants.

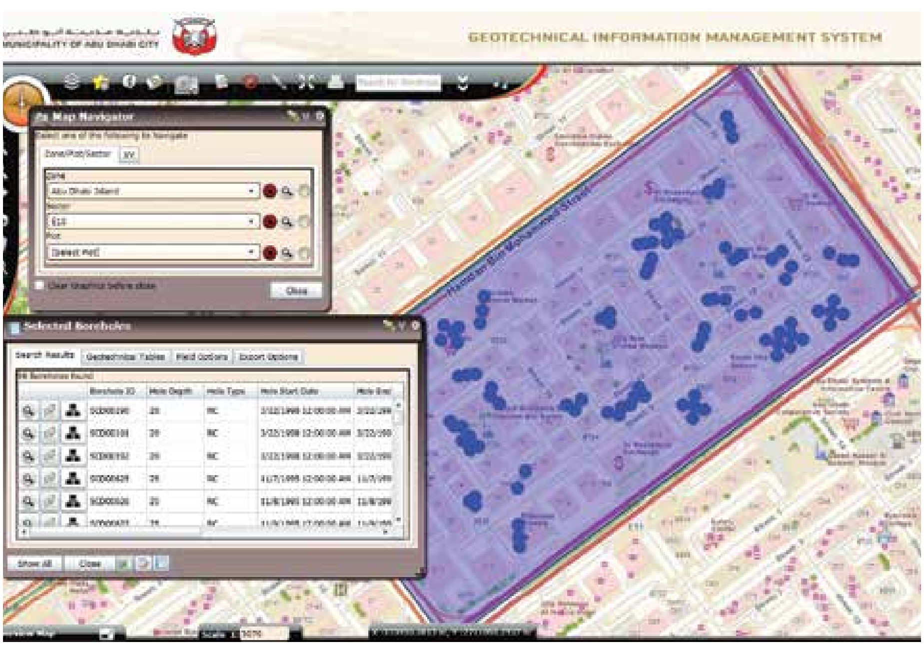
Data Are Assets

Both case studies exemplify the use of a geotechnical database with external applications to perform site analyses faster, and obtain more insight from existing information. Jan De Nul's system was developed to help make accurate estimates based upon existing information, win project bids, and perform the work in a timely and cost-effective manner. The Municipality of Abu Dhabi developed an information system that enables instant access to subsurface investigation data from multiple projects over many years, supporting rapid decision-making and appropriate resource allocation.

Geotechnical investigations are often the first things done on a site prior to construction. Geotechnical engineers look to gather whatever information they can, whether from geologic maps, geomorphic data, or nearby previous site investigations, to help develop an appropriate investigation plan for a specific site. Geotechnical designs are made based on limited (point) information across large areas and typically involve assumptions and interpretations. Models can be developed and tweaked based upon available information – both historic and current.

Once the new information is obtained, it can be used in every facet of design across a site. The use of a geotechnical database combined with external applications such as CAD and GIS can help to create accurate models, resulting in time and money savings. GS

Figure 4. Users can query boreholes based on zones and spatial locations.



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