# Desktop GIS for Geotechnical Engineering

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**Abstract:**
A desktop Geographic Information Systems (GIS) for Geotechnical Information Management system has recently been developed to assist geo-technical managers, planners through flexible application with all common desktop GIS functionalities and customized tools like *Borehole Viewer* and *Stripchart* to relate alignments and cross-sections to a specific location and/or region on the map, and create thematic maps to perform spatial and non-spatial queries, and print required reports and maps.

The software configuration used includes Visual Basic 6.0, Crystal reports VC++ for custom DLL's, and ESRI MapObjects to fill the gap of domain specific GIS solution to address the need of Geotechnical communities.

**Introduction:**
Geographic Information Systems (GIS) have become a prevalent method of analysis in civil engineering. Flexible GIS models that manipulates, compile and process spatial data above or below the earth's surface have provided a powerful tool in civil engineering applications. Realizing this, RMSI decided to address this niche area by providing a geotechnical Geographic Information Systems solution cum services which are desktop geological applications, Bore hole study, ground engineering, geotechnical engineering, environmental engineering, rural, urban and regional planning. For projects where spatial representation and analysis are not separable from the science and substance, RMSI provide the experience, intellect and guidance needed to produce top-quality GIS applications.

RMSI works at all project levels, from project management, production to technical services. Depending on a client's needs, we perform routine task, or take charge of an entire project, from team building to creation of maps and models. RMSI's GIS technical services cover the full range, from map production, spatial analysis, remote sensing, application development to on-site GIS project executions. Largely to demonstrate the above capabilities at one go for ESRI 2003, we will be presenting desktop geotechnical GIS with live demo of the application itself.

**GIS Based Preliminary Geotechnical Site Investigations:**
The purpose of a preliminary geotechnical site investigation is to create a model of the geotechnical conditions and considerations facing a project. The model is then used to analyze the project and to make project decisions. The intent of this effort is to place the project in the context of its surroundings and to identify potential barriers to project completion early in the design process. A successful preliminary investigation may result in significant cost savings in design, construction, and longevity of the project.

To realize the above, this paper focuses on how a Geotechnical GIS can be used in preliminary and subsequently for the complete project execution and monitoring.

**Desktop Geotechnical GIS:**

The conventional approach to these site investigations can be an arduous task. Existing data sources are found in a variety of hard copy and paper formats such as maps, reports, books, aerial photos, etc. Integrating these data together with photos, notes, borings, and other site specific data can require a significant portion of the effort expended during the preliminary investigation. Less time may be spent on data analysis and acquisition than on data integration. Also, reproducing the work may take as much time as the initial production. Using a GIS to aid preliminary geotechnical site investigations can greatly improve the efficiency and effectiveness of these investigations.

GIS has been defined as "a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analyzing, and presenting information that are geographically referenced (1)." Most data utilized in geotechnical site investigations have spatial attributes, that is, they can be located at a point in space. The power of GIS is that it can link maps and photos directly to data describing their features and allows data to be searched and analyzed spatially. Layers of data, known as "coverages," can be readily combined to provide a wealth of information about a site and can be added or removed from a base map by turning layers on or off. This Geotech GIS is an integrated multi-lingual desktop GIS application designed to perform geological data analysis and extract geological information from spatial and non-spatial data. Such generic solutions intend to cater geo-technical professionals and consultants involved in water resource management and infrastructure related projects.

Geotech GIS is a flexible application with all common desktop GIS application features like zoom-in, zoom-out, pan, feature identify, search, print, and thematic maps. There are also customized tools that have been added to it like *Borehole Viewer* and *Stripchart* to extend the functionality. The system is open enough to support different types of data and can be customized to fit specific user needs. The software configuration used for this includes Visual Basic 6.0, Crystal reports for report creation and generation, VC++ for custom DLL's, and ESRI MapObjects for the display and analysis of maps. The above developed custom desktop GIS serves the purpose of executing geotechnical analysis and evaluation and are being discussed in four ways:

- Data Integration
- Data visualization and analysis
- Planning and summarizing the site activities
- Data presentation

**Data Integration:**

To develop and refine the working site model, data from various sources need to be integrated. These data may consist of readily available existing information, such as soil surveys and topographic maps, and project specific information, such as proposed centerlines, project extents, survey points, aerial photos, and site investigation results. GIS provides tools for integrating these data. Figure 1 shows how the user can shade the map based on desired attributes. The application also generates the corresponding legend enabling users to read the thematic of various datasets used for analysis. When integrating data from various sources, two important considerations are data limitations and project coordinate systems. Each data set has inherent limitations. The source of the data must be considered, positional accuracy may vary from tenths to hundreds of meters, and the applicability of the data to their intended use also needs to be considered. The site model is only as accurate as its components. In some cases, the data accuracy may be inadequate for detailed design, however it may be more than adequate for preliminary investigations.

For disparate data sets to be integrated, each must have the same base coordinate system. Readily available data sets may utilize coordinate systems by using the map Projection functionalities provided in the solutions. Figure 2 shows how user can click on the map and retrieve information from the database for all map layers. Documents can be associated with features. The attributes can also be edited.

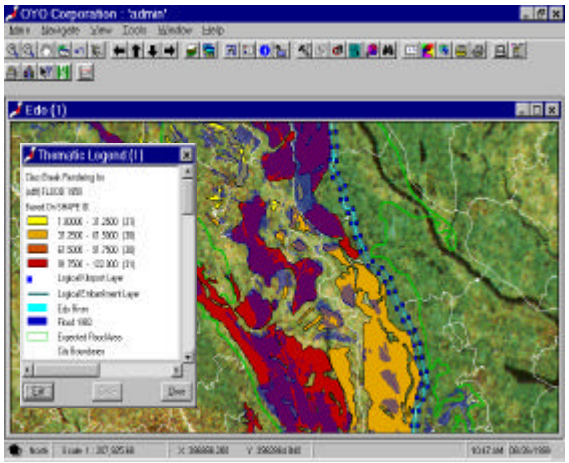


Figure 1

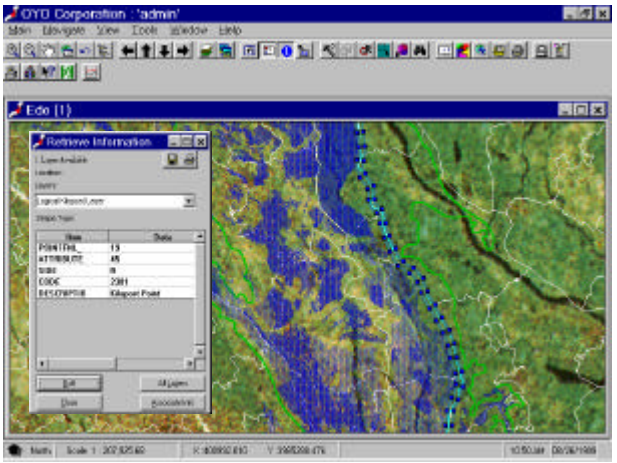


Figure 2

**Data Visualization And Analysis:**

One of the primary purposes of a preliminary geotechnical site investigation is to identify potential barriers to successful project completion early in the design process. Using GIS to visualize and analyze site data can expedite this process, as illustrated in figure 3 through 5. Figure 3 shows how the user can view both the alignment and the corresponding cross-section. The cross-section window also shows the boreholes at specific locations along the alignment. Similarly figure 4 and 5 demonstrates how this tool facilitates the user to view a feature based on its attributes this enabling navigation across the map. The user can select the layer to be used for navigation. Figure 5 shows the user can run a database query and view the results. The results can also be shown on the map using the highlight option.

As described above, the technical engineers using this application can relate alignments and cross-sections to find the geological composition of a specific point along the alignment, associate documents related to a specific location on the map, and create thematic maps based on attributes of a map. Engineers can also zoom to specific parts of an alignment and see the associated cross-section area, perform spatial and non-spatial queries, and print required reports and maps. Also, there are administrative and client components to the system. This gives managers the control needed when dealing with large projects and data sets. The administrator can create, delete, and update users and user rights, create projects, and also audit any data changes made by users.

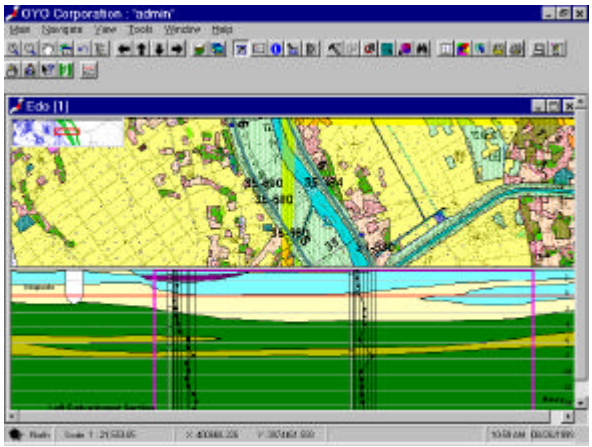


Figure 3

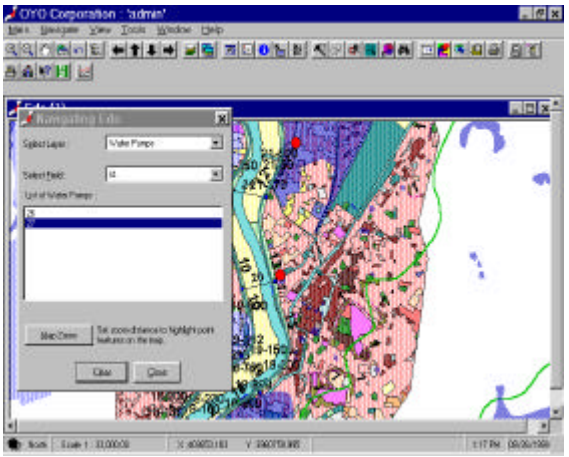


Figure 4

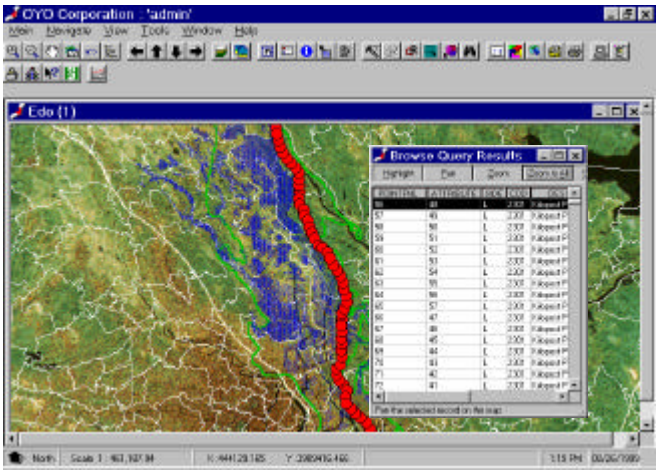


Figure 5

**Planning And Summarizing Site Activities:**

After identifying potential problem areas in the office, the next step in the geotechnical site investigation is to verify field assumptions and perform site reconnaissance to collect more information. Hence it can be used for both planning site activities and to integrate data collected during these activities into the site model, thus further refining it. Figure 6 shows while planning how the user can select boreholes on the map and use the borehole viewer to view the soil composition at that location.

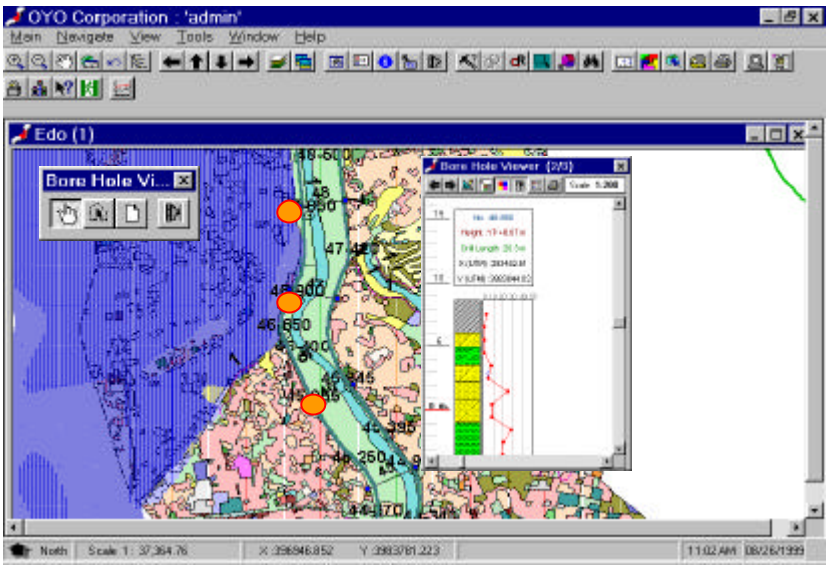


Figure 6

**Data Presentation:**

Another benefit of using GIS is data presentation. Layouts can be created for use in reports, papers, posters, and presentations in varying page sizes and formats. Labels, symbols, scale bars, north arrows, and text can be added to maps to provide clarity and improve information transfer. The figures used in this paper were created in the GIS program and exported in a graphic format. Figure 7 shows the user can use the print layout to customize the output based on the requirements. The print layout incorporates features like adding various map views, text, images and shapes to the layout. The color, size and position properties can be set based on requirements.

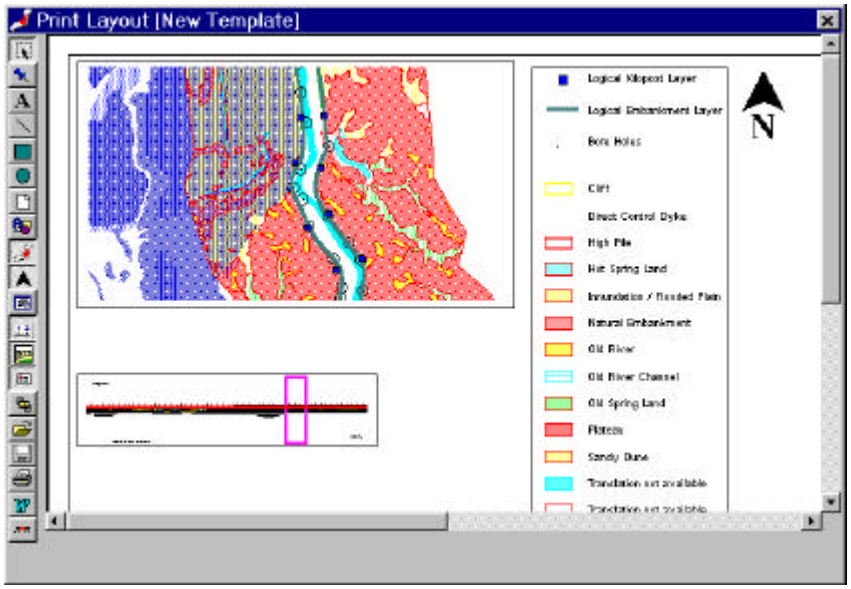


Figure 7

## Conclusion:

Desktop Geotechnical GIS is a versatile tool that can be used to aid various preliminary geotechnical site evaluations, execution and monitoring. So far the system has been used to identify various locations of potential stability problems and possible geologic hazards bore hole logs etc. It is being used to guide field activities and to merge field data with existing information. This provided an accurate, flexible site model that allowed improved site analysis. For an example, the roadway alignment was shifted away from potential barriers to successful project completion early in the design process, before substantial design effort had been invested.

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