USING DIGITAL DATABASES TO CREATE GEOLOGIC MAPS FOR THE 21ST CENTURY

A GIS Model for Geologic, Environmental, Cultural and Transportation Data from Southern Rhode Island

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May 2002

URI-TC PROJECT NO. 536102

PREPARED FOR

UNIVERSITY OF RHODE ISLAND TRANSPORTATION CENTER

1. Report No	2. Government Accession No.	3. Recipient's Catalog No.
URITC 99-03	N/A	N/A

4. Title and Subtitle	5. Report Date
A GIS MODEL FOR GEOLOGIC, ENVIRONMENTAL, CULTURAL, AND TRANSPORTATION DATA FROM SOUTHERN RHODE ISLAND "A GIS Model for Geologic, Environmental, Cultural and Transportation Data From Southern Rhode Island"	May 15, 2002
	6. Performing Organization Code N/A
7. Authors(s) O. D. Hermes, A. I. Veeger, D. P. Murray, N. A. Hamidzada	8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Geosciences University of Rhode Island Kingston, RI 02881	10. Work Unit No. (TRAIS) N/A 11. Contract or Grant No. 536102 13. Type of Report and Period Covered FINAL
12. Sponsoring Agency Name and Address URI Transportation Center University of Rhode Island Kingston, RI 02881	14. Sponsoring Agency Code A study conducted in cooperation with the USDOT

15. Supplementary Notes

N/A

16. Abstract

Knowledge of surface and subsurface geology is fundamental to the planning and development of new or modified transportation systems. Toward this end, we have compiled a model GIS database consisting of important geologic, cartographic, environmental, and cultural data. These data are presented as spatially defined themes that can be overlaid on-screen or in printed format to quickly show the geographic distribution of the diverse types of data. Such capability permits the quick determination of the spatial relationship of transportation corridors to geologic setting, environmentally sensitive areas, areas of cultural importance, and other relevant features, which in turn expedites site evaluation and planning.

Geologic data include Well-Boring Data, Depth to Bedrock, Bedrock Geology, Glacial Deposits, Outcrops, Soils, Groundwater Reservoirs, and Groundwater Recharge Areas. Subsurface geologic and hydrologic data associated with the site-specific well-boring data are an integral component of the database including land-surface elevation, depth to water table, depth to bedrock, and material properties, all of which are invaluable for transportation planning. Users of this database can quickly assess the distribution and quality of existing subsurface data, readily identifying locations where supplementary data are needed. Thus, the need for expensive new borings that duplicate previous effort can be minimized.

Our project serves as a model for 21st Century compilation of geologic and geotechnical information for transportation corridors on a local to statewide basis. The database is structured to easily incorporate new data as it is acquired, thus providing condensed, easily accessed information essential to transportation planning. In addition to transportation applications, the spatial data also is of interest to a broader audience, including state agencies dealing with environmental management and planning issues, town planners, conservation and environmental groups, and concerned citizens.

17. Key Words	18. Distribution Statement
Well-boring, GIS, Geotechnical, Subsurface, CD, Database, Bedrock, Soils, Goundwater, Planning	No restrictions. This document is available to the public through the University of Rhode Island Transportation Center, 85 Briar Lane, Kingston, RI 02881

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	26	N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized (art. 5/94)

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INTRODUCTION

Knowledge of the surface and subsurface geology is fundamental to the planning and development of new or modified transportation systems. Typically, geologic information is displayed on maps that portray the fine-scale architecture of the landscape. A major goal of this project was to compile a multi-layered digital database consisting of important geologic, cartographic, and cultural data for the development of a geographic information system (GIS). For this pilot study, we chose an area in southern Rhode Island in the vicinity of Routes 108 & 138 near the University of Rhode Island. The database was developed in ArcInfo and ArcView. ArcExplorer is, a simplified viewer, is included on the CD to permit users who do not have access to Arc/Info or ArcView to use and view the data.

The major product resulting from this project is a CD-ROM that contains all databases, maps, themes (overlays), and instructions for its use. The CD is a complete package of materials that serves as a model to permit interactive evaluation and synthesis of widely diverse data sets useful in transportation studies and more generally in land-use planning. The CD provides, in one central database, diverse information central to the decision-making process. Although this report gives an overview of the completed project, readers should use the CD to fully understand the scope and significance of our research. Even though the results of the proposed work are site-specific, the CD is designed to serve as a template for establishing similar GIS databases for other areas in Rhode Island and elsewhere in southeastern New England.

DESCRIPTION OF THE CD

Hardware and Software Requirements: For operation of ArcExplorer, ArcView and Adobe Reader, the following hardware and software requirements are suggested in their respective user manuals.

1- ArcExplorer 4.0

- Pentium, Pentium II or Pentium III processor-based personal computer
- Operating system: Windows 98 and NT 4.0 for Intel with Service Pack 4, 5 and 6a
- Disk Space: 8MB

- JRE: 1.2.2-004 with Java Plug-in. ArcExplorer 4 requires JRE 1.2.2-004. Pentium IV processor-based systems require JRE1.3 instead of JRE1.2.2-004. Install JRE1.3 first and then install ArcExplorer. When ArcExplorer installation wizard prompts you for JRE, point to the JRE1.3 directory (generally..\program files\javasoft\JRE\1.3.x).

2- ArcView

- Pentium or higher personal computer
- Operating system: Windows 95, 98 and NT 4.0
- Disk Space: 200 MB is required when all ArcView GIS components are loaded
- 24 MB RAM (32 MB recommended).
- Video graphics adapter (VGA) or better resolution monitor.

3- Adobe Acrobat Reader 4.0

- i486 or Pentium processor-based personal computer
- Microsoft Windows 95, Windows 98, or Windows NT 4.0 with Service Pack 3 or later
- 8 MB of RAM on Windows 95 and Windows 98 (16 MB recommended)
- 16 MB of RAM on Windows NT (24 MB recommended)
- 10 MB of available hard disk space
- Additional 50 MB of hard disk space for Asian Fonts (optional)

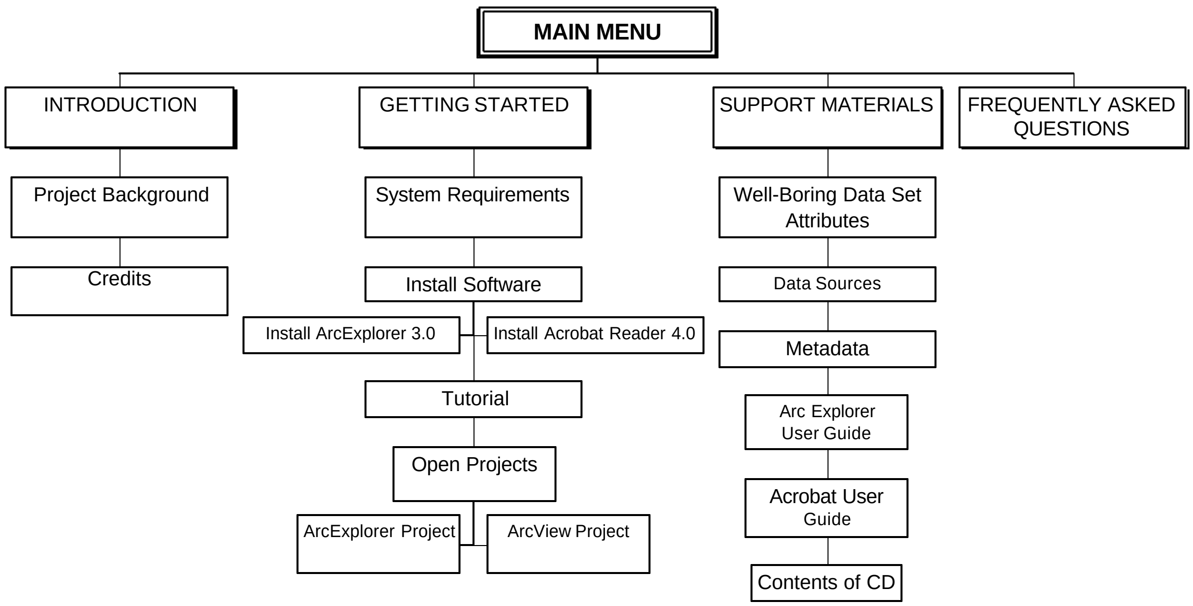
ArcView, ArcExplorer and Adobe Acrobat performance is greatly enhanced with a faster processor, and with a better graphic card and faster CD. Therefore, in order to get acceptable performance, we recommend the following system requirements:

- Pentium II or higher processor-based personal computer
- Operating system: Windows 98, NT 4.0 and 2000
- 64 MB or more RAM
- Graphic card with SVGA or better resolution
- 20x or faster CD

4- CD Organization

The organizational chart below illustrates the nested structure to navigate the CD. The heart of the database is embedded in the "Open Project" button. Upon opening the project, a GIS map view of the study area is presented along with the availability of 34 themes or layers that may be individually or collectively engaged.

CD ORGANIZATIONAL CHART



5- List of Themes/Layers

The data contained on the CD are presented as thirty-four spatially defined layers that can be overlaid on-screen to show the geographic distribution of the diverse types of data. Such capability permits the quick determination of the spatial relationship of transportation corridors to geologic setting, environmentally sensitive areas, areas of cultural importance, and other relevant features, which in turn expedites site evaluation and planning. Specific themes included in the database are as follows.

Geologic Layers	**Cultural Layers**	**Environmental Layers**	**Transportation Layers**
Well-Boring Data	Study Area	Public Water Supply	Roads
Depth to Bedrock	Streams	Wetlands	Railroad Tracks
Bedrock Geology	Ponds	Land-Use	Bike Paths
Glacial Deposits	Town Boundaries	Greenway Corridors	Bridges
Geologic Contacts	Town Names	Community and Non-community Well Head Protection areas	
Bedrock Outcrops	7.5’ Quadrangle Boundaries	Hazardous Waste Site	
Soils	Topographic Quadrangles	Leaking Underground Storage Tanks	
Groundwater Reservoirs	Digital Orthophotographic Quadrangles	Rhode Island Point Discharge Elimination System	
Groundwater Recharge Areas	Historic Sites	Flood Zones	
	Historic Districts		
	Geodetic Markers		
	Bench Marks		

Themes that contain geologic data include Well-Boring Data, Depth to Bedrock, Bedrock Geology, Glacial Deposits, Outcrops, Soils, Groundwater Reservoirs, and Groundwater Recharge Areas. Subsurface geologic and hydrologic data associated with the site-specific Well-Boring Data are an integral component of the database. They include land-surface elevation, depth to water table, depth to bedrock, and material properties, all of which are invaluable for transportation planning. Users of this database can quickly assess the distribution and quality of existing subsurface data, and readily identify locations where supplementary data are needed. Thus, the need for expensive new borings that duplicate previous effort can be minimized.

This database is of interest to planners and engineers of transportation systems, and to a broader audience, including state agencies dealing with environmental management and planning issues, town planners, conservation and environmental groups, concerned citizens, and students.

DATA SOURCES

The digital spatial data (the themes or layers) incorporated in the CD were compiled from maps, reports, and pre-existing digital databases. The main focus of this study is on data sets that deal with subsurface geology. These data sets were compiled from RI Water Resources Bulletin maps, U.S. Geological Survey Water Resources Investigations Reports, the U.S. Geological Survey Ground-Water Site Inventory (GWSI) database and boring logs made available to us by Guild Drilling Company.

Data points from the RI Water Resources Bulletin maps were digitized from paper maps, using a Calcomp 9500 digitizer. Latitude and longitude coordinates for the USGS GWSI data points were transferred directly to the data set. Data point locations from Guild Drilling Company reports were plotted and digitized using available site architectural maps, sketches, and written descriptions of locations.

Pre-existing digital data sets of relevance to the project were utilized. These include data sets from the Rhode Island Geographic Information System (RIGIS), and the Department of Geosciences and Rhode Island Geological Survey at the University of Rhode Island. Data sets from RIGIS include roads, railroad tracks, bike paths, streams, ponds, town boundaries, bridges, hazardous waste sites, bench marks, geodetic markers, community wells, non-community wells, community wellhead protection area, non-community wellhead protection area, historic sites, 7.5’ quadrangle boundary neat lines, flood zone, groundwater reservoirs, groundwater recharge areas, soil, wetland, land-use, 7.5’ topographic quadrangle images and digital orthographic quadrangle aerial photographs. Most of these data sets were used directly without changes. In some cases, however, several data sets were merged, and in a few cases new data fields were appended to the original data set for the purposes of this study. See the metadata section for details of these changes.

The Department of Geosciences and the Rhode Island Geological Survey at the University of Rhode Island provided data sets for the bedrock geology and glacial deposits. A new generalized rock-grouping field was added in the bedrock data set. The digital data set for the glacial geology (surficial material map) originated from the RIGIS database, but was extensively revised and reinterpreted by Jon C. Boothroyd, State Geologist. See the metadata section for details of these data sets.

DISCUSSION OF RESULTS

The intent of this CD is to present a model that demonstrates how fundamental geological information necessary for transportation design and development can be integrated into a coherent spatial database. We have complimented the geologic data with the addition of environmental, conservation, infrastructure, and cultural themes that can be used as background layers to quickly and easily evaluate spatial relationships among a wide array of variables. The user can easily add additional themes for other kinds of applications. For example, one could add other conventional transportation themes such as bus routes, areas of major congestion, problematic accident sites, areas designated for future construction or rehabilitation, etc.

Real time interactive capability permits the user to quickly evaluate interrelationships among all variables in the database, thus enhancing data synthesis and the decision making process. The procedure quickly allows the user to evaluate the completeness of the database, and to identify critical areas where additional data is required. For example, by observing the distribution of well and boring hole sites in our CD, the user is able to observe areas of abundant subsurface information and focus on regions where more drilling may be desirable. As future data becomes available, it can be quickly added to the existing database to provide a continually evolving and complete record of the accessible subsurface information. This bookkeeping capability is extremely important because it permits a large volume of critical spatial information to be stored and efficiently accessed with a centralized computerized system. It avoids the common problem of the repeated need to manually search through hard-copy files and archived materials.

The adoption of our model also can lead to considerable cost savings. Using a GIS based data system will permit quick and ready access to historical data as well as new data as it is added to the database. Hence, the user can readily identify the status and locations of available data, thus avoiding the duplication of effort in future projects. Acquisition of new subsurface information from drilling is an expensive endeavor that can be minimized by having a current, updated book keeping system that provides ready access to the available information.

FUTURE WORK

The model presented here demonstrates the benefits of using an integrated spatial database for record keeping and problem solving in the fields of transportation and environmental studies. Additional development and refinement can enhance the usefulness and capability of the system. At present, attributes attached to the subsurface database are rather limited, but these can be expanded to provide additional useful information. One important enhancement is our plan to attach scanned core logs to each drilling location. This will permit the user to further evaluate details of each drilled hole, thus helping to evaluate the quality of data contained and the potential need for additional complimentary drilling.

We plan to refine the subsurface data template to incorporate important new attributes that are of special interests to transportation engineers. Details of soil properties and specific materials encountered in the hole are examples. We also see the need to incorporate the capability of constructing 2-D cross-sections and 3-D isopach maps. Cross-sections in the form of fence diagrams will permit the user to evaluate the continuity of recognizable subsurface horizons, their changing thickness, and depths of occurrence. Isopach maps will permit depths to key surfaces, such as the bedrock or the water table surfaces, to be contoured so as to show how the depths of these surfaces vary within a given area.

To provide user-wide access to our databases, we plan to develop a web-site. In addition to hosting all data, the web-site will contain instructions on how to access and use the data, complete with some application examples. Eventually, we intend to develop an on-line data entry system that will permit data from new drilling sites to be entered on line as it is collected. By developing a widely acceptable data template, we will work toward encouraging RI-DOT to require future drillers to use this template and complete on-line data entry as part of their contract. This approach will insure that all new data will become part of a centralized computerized database, thus minimizing poor access to the data through the manual filing of the records.

CREDITS

Substantial funding for this project came from the University of Rhode Island Transportation Center (Grant URITC99-6) and the University of Rhode Island Department of Geosciences. In addition, Haley & Aldrich, Inc. and Pare Engineering Corp. generously gave "in-kind" support. Joseph Klinger (Pare Engineering) and Nicholas Strater (Haley & Aldrich) provided valuable input on the project design and work-plan, and evaluated early beta-copies of the CD. Guild Drilling Company also gave us access to boring log data for which we are appreciative. We liberally used available data from RIGIS and extend our appreciation to them. We also wish to acknowledge Colin Franco and Michael Sherrill from RIDOT who recognized early on the potential of an integrated spatial database that utilized subsurface geological information for transportation planning and construction. They both provided valuable feedback on our approach and have encouraged us to continue and expand the applicability of our work. Several students contributed to compilation of data, including Charles Banks and Eric Cyr.

APPENDIX 1: STUDENT PARTICIPATION

The following students worked on, and contributed to this project:

Graduate Students:

1) Mr. Charles Banks, Geosciences
2) Mr. Eric Cyr, Geosciences

Undergraduate Students:

1) Sarah Aldridge
2) Nick Begyn

APPENDIX 2: PRESENTATIONS

The following talks or presentations were given on aspects of this project.

1) O. Don Hermes and Anne Veeger, December, 1999,Geologic Transportation Maps for the 21th Century: Presentation to URITC Seminar, Alton Jones Campus.
2) O. Don Hermes, Anne Veeger, Daniel Murray, October 13, 2000, Geologic Transportation Maps for the 21st Century: 13th Rhode Island Transportation Forum.
3) Hamidzada, N.A., Hermes, O.D., Murray, D.M., and Veeger, A.I., March 2001, Interactive geologic transportation maps: A model for their creation implementation and maintenance: Workshop at NE-Geological Society of America Meeting, Burlington, VT.
4) O. Don Hermes, Anne Veeger, Daniel Murray, Nasir Hamidzada, April 2001, Using digital databases to create geologic maps for the 21st Century: Presentation to URITC Seminar/Workshop.

The following abstracts have been published.

1) Hamidzada, N.A., Hermes, O.D., Murray, D.M., and Veeger, A.I., 2001, Interactive geologic transportation maps: A model for their creation implementation and maintenance: Geological Society of America Abstracts with Program, v. 33, p. A-74.
2) O. Don Hermes, Anne Veeger, Daniel Murray, October 13, 2000, Geologic Transportation Maps for the 21st Century: 13th Rhode Island Transportation Forum. Hosted by University of Rhode Island Transportation Center and Construction Industries of Rhode Island.

APPENDIX 3: DEFINITION OF FIELDS USED IN THE "WELL-BORING DATA" LAYER/THEME

Field/attribute name	**Description**
Shape:	ArcView data type (point, polygon, line)
Hole_ID:	ID number as reported in original data source
Log_Type:	Type of well/boring log available: D = driller, G = geologist, GT = geotechnical
Log_Descr:	Is a visual description included on the log? Yes or No.
Samp_Type:	Type of samples used for visual description: continuous core, split spoon, auger, cuttings
NumSamples:	Number of sample intervals described over the drilled length of the well or boring
Other_Data:	List of other data available: multiple water levels, hammer blows, geochemical data, etc.
Scan_Log:	Is a scanned log available? Yes or No. Note: No scanned logs are available at present. This data field is included for future updates of the database.
Hole_Depth:	Total depth drilled in feet below land surface
Altitude:	Elevation of land surface measured in feet above sea level. Datum is NGVD 1927.
Alt_Meth:	Method used to determined altitude: estimated (from topographic map); provides +/- 5 ft accuracy altimeter; provides +/- 1 ft accuracy, GPS; variable accuracy, generally within +/- 5 ft surveyed; provides a minimum of 0.1 ft accuracy.
Depth_Bdrk:	Depth to bedrock measured in feet below land surface
Elev_Bdrk:	Elevation of bedrock surface in feet above sea level. This is a calculated field (Altitude– Depth_Bdrk).
DepthWater:	Depth to water under non-pumping conditions measured in feet below land surface. For sites with multiple water levels, a single measurement is provided that reflects the minimu depth to water during the period of record.
Elev_Water:	Elevation of water level in well, in feet above sea level. This is a calculated field (Altitude – Depthwater).
Water_Date:	Date of water level measurement. (yyyymmdd)
Geol_BOH:	Geologic material encountered at bottom of hole (bedrock, refusal, stratified, unstratified)
DataSource:	Company or organization that released the data. USGS = US Geological Survey
Report_No:	Numeric code for report that contains the data record. For USGS data this should be the Data Report number. This field may be blank for engineering data or projects for which no report was generated.

Project:	Numeric code, if any, for project that produced drilling record.
Driller	Name of Drilling Company contracted to drill hole/well. May be the same as DataSource if original driller's data sheet is used for data entry.
Hole_Type	Well or boring. A well is generally a permanent structure designed for water withdrawal or monitoring. A boring is generally an uncased hole that is destroyed upon completion of the drilling investigation.
Date_Drill	Date hole/well was drilled. (yyyymmdd)
Entry_By	Last name of person responsible for entering the data into the database.
Entry_Date	Date data were added to the database. (yyyymmdd)
Town	Name of RI Town in which drilling site is located.
County	Name of County in which drilling site is located.
State	Name of State in which drilling site is located.
Quadrangle	Name of USGS 7.5' quadrangle in which the drilling site is located.
Y_coord	state plane Y coordinate
X_coord	state plane X coordinate
XY_Meth	source of XY data (GPS, digitized, map)
Intrnal-ID	11-digit internal ID using the format 20010122001 (yyyymmdd###). The last 3-digits correspond to the nth record entered on that day. For example, the 5th site entered on February 8, 2001 would be numbered: 20010208005

APPENDIX 4: **TUTORIAL**

<u>Overview of ArcExplorer 4.0</u>

Spatial data sets on this CD can only be displayed and manipulated using GIS software. If you have GIS software such as ARC/INFO, ArcView, MapInfo, GeoMedia, AutoCad Map (some may need to translate data format before being able to use it), etc. installed on your computer you will not need to install ArcExplorer. If you do not already have GIS software, ArcExplorer, by Environmental Systems Research Institute, Inc. (ESRI), is provided. ArcExplorer is a freeware program compatible with Microsoft Windows 95/98/NT. To install ArcExplorer click on "Install Software" from the "Getting Started" menu and select "Install ArcExplorer 4.0 Java Edition."

Features

ArcExplorer 4.0 is a complete, easy-to-use GIS data viewer that displays and queries locally stored GIS data as well as map services from ArcIMS 3. ArcExplorer 4.0 is Java based, which allows the user to enjoy cross-platform support. And, as always, ArcExplorer is absolutely free! It is provided for your convenience on this CD or you can download ArcExplorer 4.0 from ESRI's Web site. Note: ArcExplorer performs a limited set of data manipulations, and lacks the advanced data synthesis capabilities of more powerful GIS software such as ArcView.

With ArcExplorer 4.0 you can:

- Compile and display maps with multiple players. These multi-layered maps are called a "PROJECT"
- Pan and zoom through map layers
- Perform simple queries on a data layer
- Create a buffer around selected features
- Measure distances on a map
- Assign unique symbols or graduated symbols to map layer
- Label map features, with many options for effects (such as highway shields)
- Locate an address
- Incorporate georeferenced images (BMP, TIFF, PNG, JPG, and GIF)
- Print maps created on the screen
- Incorporate overview maps
- Create legends and scale bars for displayed map

Note: ArcExplorer is designed primarily as a data viewer and does not permit editing of the data files. Complete copies of the ArcView shape files associated with this database are included on the CD for users with access to more powerful GIS software.

To help you get the most out of ArcExplorer 4.0, please read the ArcExplorer 4.0 - Java Edition User Manual (in PDF format). This helpful manual offers useful tips as well as complete instructions for installing ArcExplorer, creating maps, and saving projects.

Tutorial for exploring the database

NOTE: The tutorial may be viewed as a PDF file (Acrobat Reader required) or as a Word file (version 97 or newer). A minimum screen resolution of 1024 x 768 is required for graphics resolution when viewing the PDF file.

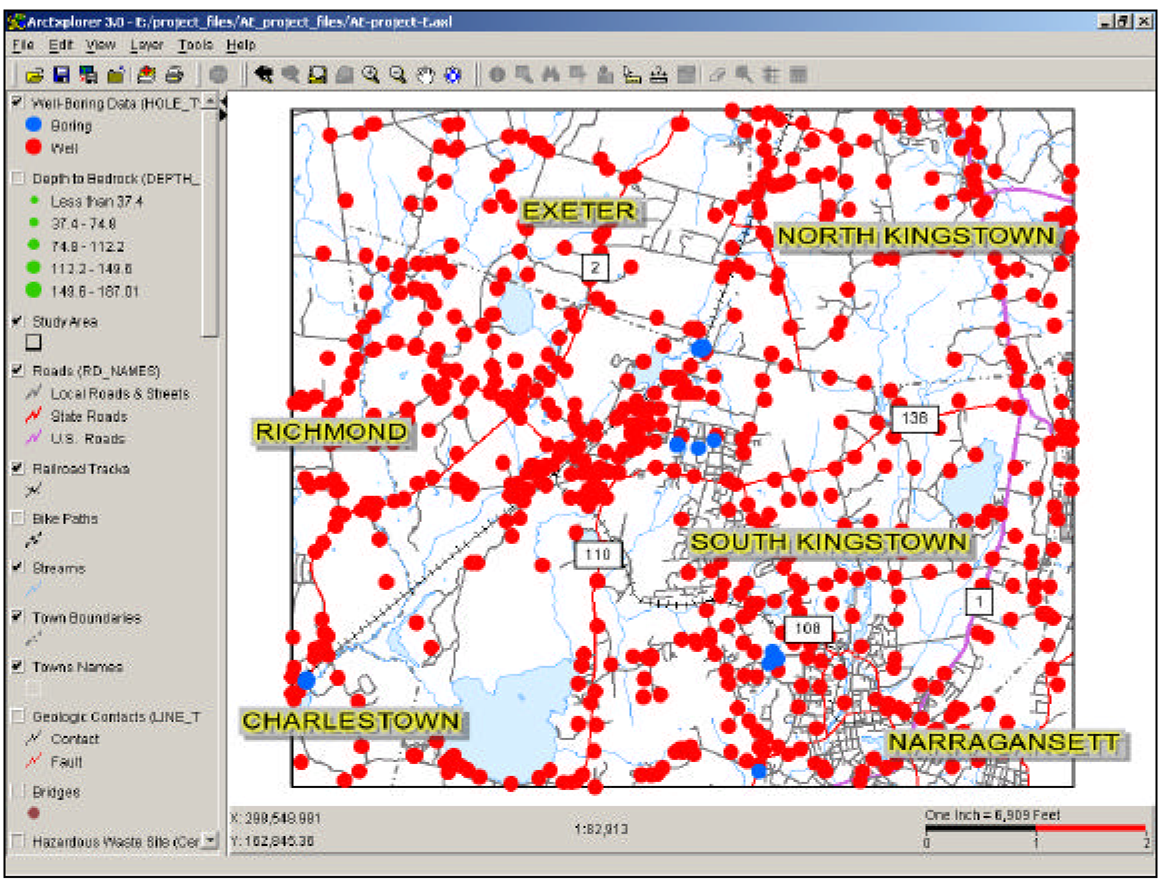
1. Opening the Database

To start ArcExplorer

1. click the *START* button,
2. click *Programs* on the Start menu
3. click *Esri* on the programs menu
4. click *ArcExplorer 4.0* on the Esri menu.

To open the digital borehole database

1. click *FILE*
2. click *Open Project* in the File menu.
3. Use the file menu to navigate to the CD-ROM drive.
4. Select the AEPR-Files directory
5. Select the Borehole database project file (URITC) with the drive letter that corresponds to your CD drive.
6. You should then see the following screen appear.



2. ToolBar and Legend

The function of each button on the menu toolbar is displayed when the mouse cursor hovers over the button. Some buttons will only be active (e.g. the identify and query buttons) if a layer has been selected (see "*Making a layer active*", below).

The *layers*, or data coverages, available in the database are shown to the left of the map in the legend. Layers can be turned on or off by clicking the box to the left of the layer name. For example, click on the Well-Boring Data layer to see the distribution of well and bore holes. Click it off to remove the layer. Some layers may be hidden by overlying layers. For example, the Bedrock Geology layer will mask the underlying Glacial Deposits layer if both layers are turned on.

3. Project Base Map

By default, the map layers are displayed on a base map that includes roads, town boundaries and surface water. Alternatively, topographic quadrangle maps or digital orthophotos can be used as the base by toggling the appropriate box in the of the layer list.
Note: use of topographic quadrangles or digital orthophotos for the base map may slow program response time because of their large file size.

4. Available functions and techniques for exploring spatial databases

Refer to the ArcExplorer user guide for a complete description of the program functions. The following section highlights the functions most commonly used.

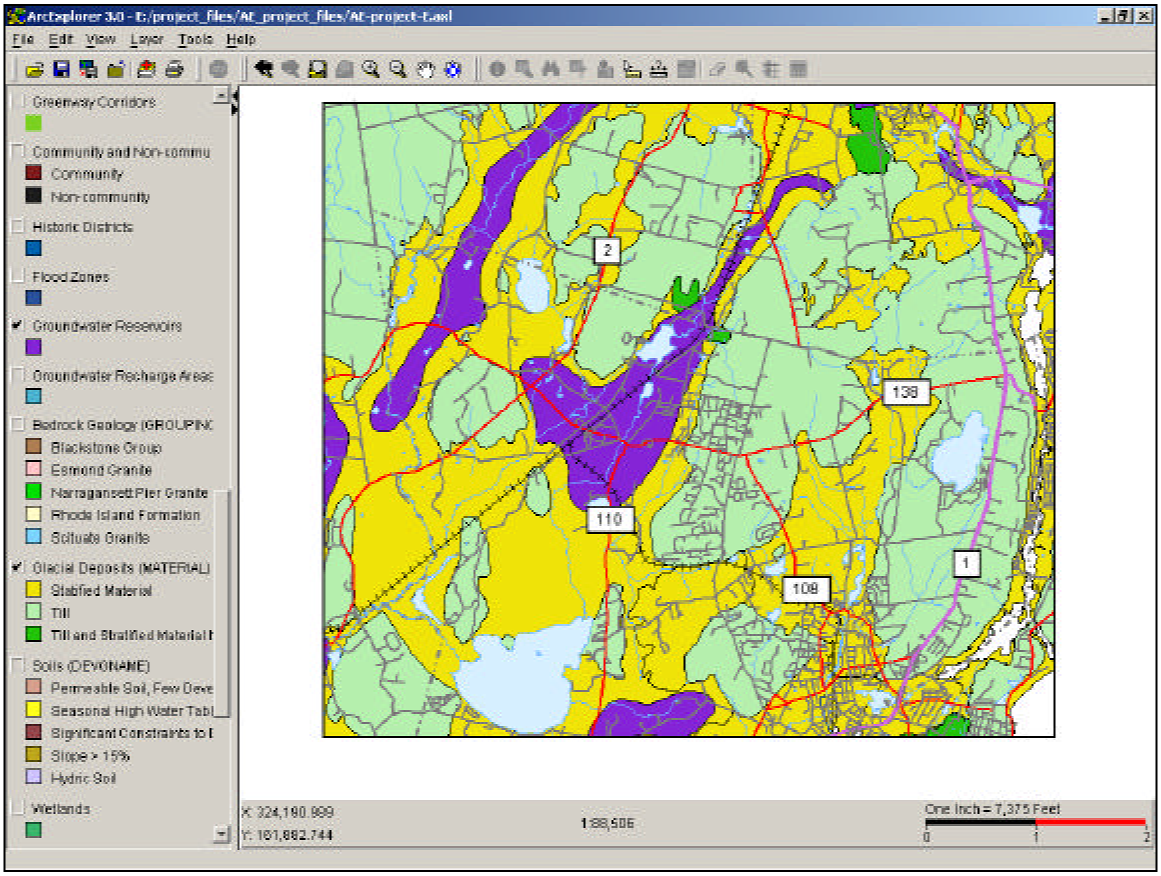
Making a layer active

Make a layer active by clicking on its ***name*** in the legend. Data point identification and manipulation operations work only on active layers. An active layer appears raised in the legend section.

Viewing multiple layers

Multiple layers can be viewed at the same time, however overlapping layers, especially polygon layers, may hide information in the layers underneath. Layers are displayed in reverse order of their appearance in the legend. It is not possible therefore, to view the **Bedrock Geology** layer and the **Glacial Deposits** layer simultaneously because the Glacial Deposits layer will completely obscure the underlying bedrock geology layer.

Example: View relationship between groundwater reservoirs and glacial deposits.



1. First turn off the ***Well-Boring Database*** and the ***Town Names*** layers by clicking the box to the left of the layer name in the legend.
2. Click on the ***Groundwater Reservoir*** layer in the legend to make it visible.
3. Click on the ***Glacial Deposits*** layer to make it visible.

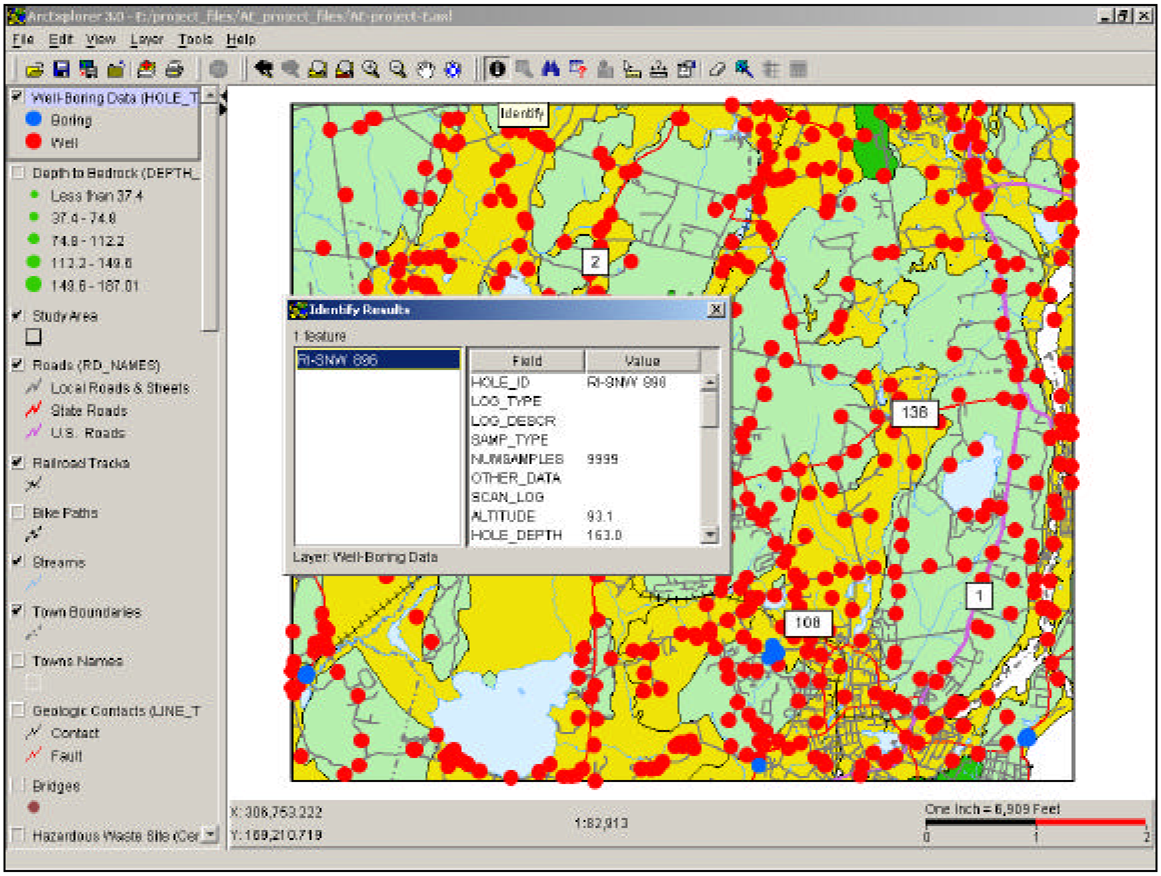
   The groundwater reservoir areas are shown superimposed on the Glacial Deposits layer and correspond to the stratified glacial deposits that are the main groundwater reservoirs in RI.

4. To see which wells and borings penetrate the groundwater reservoir, turn the ***Well-Boring Database*** layer back on.

Identifying Features

To get information about features shown on the map, use the identify tool:

1. Click a layer name (e.g. **Well-Boring Database**) in the legend to make it active.
2. Click the identify button on the menu bar.



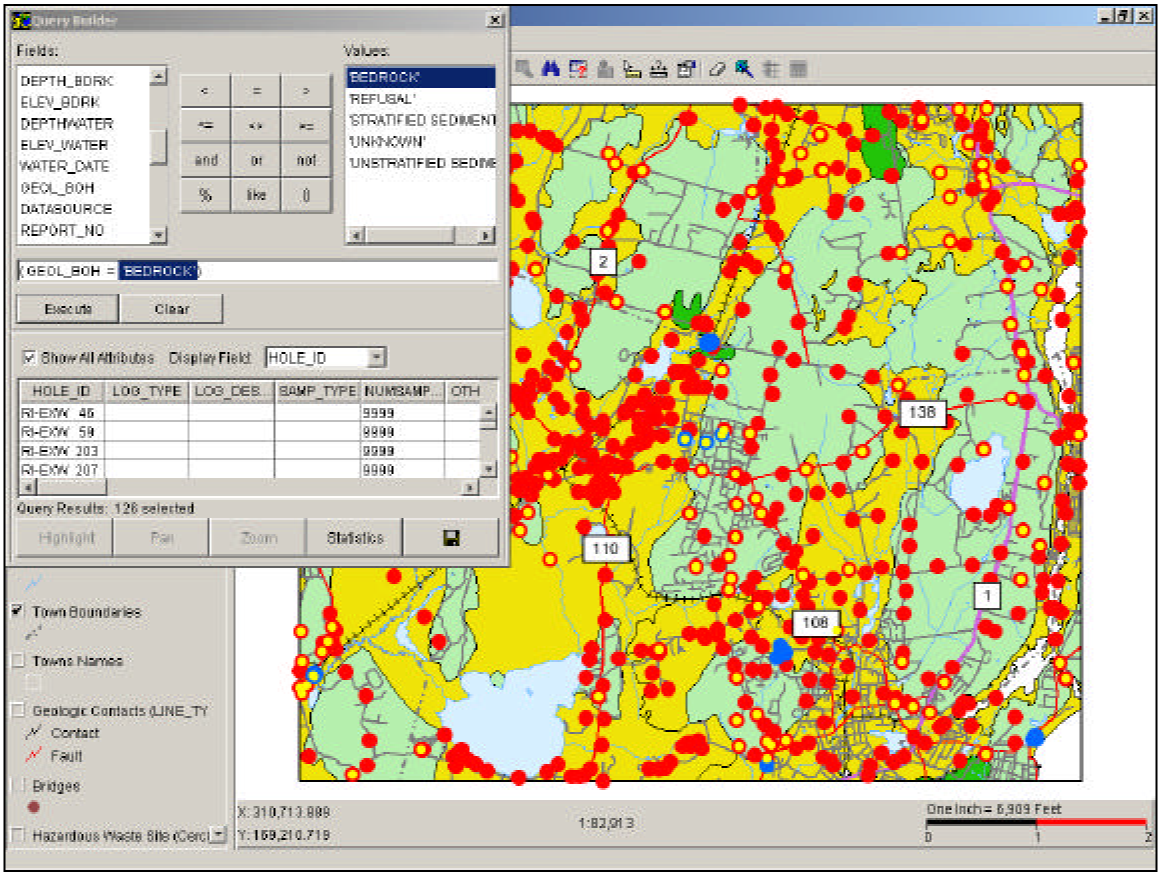
3. Click a feature (**well data point in this example**) on the map that belongs to the active layer.
4. The results (e.g. **depth, type, geology, etc.**) are displayed in the *Identify Results* dialog box.
5. Click on a second well to look at the results for that well.
6. Close the dialog box when done viewing the results.

Identifying Features That Match Certain Search Criteria

To select features that match a set of criteria, use the ***Query Builder*** tool. The following examples show how this tool can be used to select features that match multiple attributes, operators or calculations. Note: since a record with null value is recognized as zero by AE, values of 9999 are assigned to all numeric fields for which no data are available. This only applies to the well-boring data set used in AE project. In well-boring data set used in ArcView project numerical fields with no data are assigned null value.

Example 1. Identify all wells that penetrate bedrock. This is a simple query with a single selection criteria.

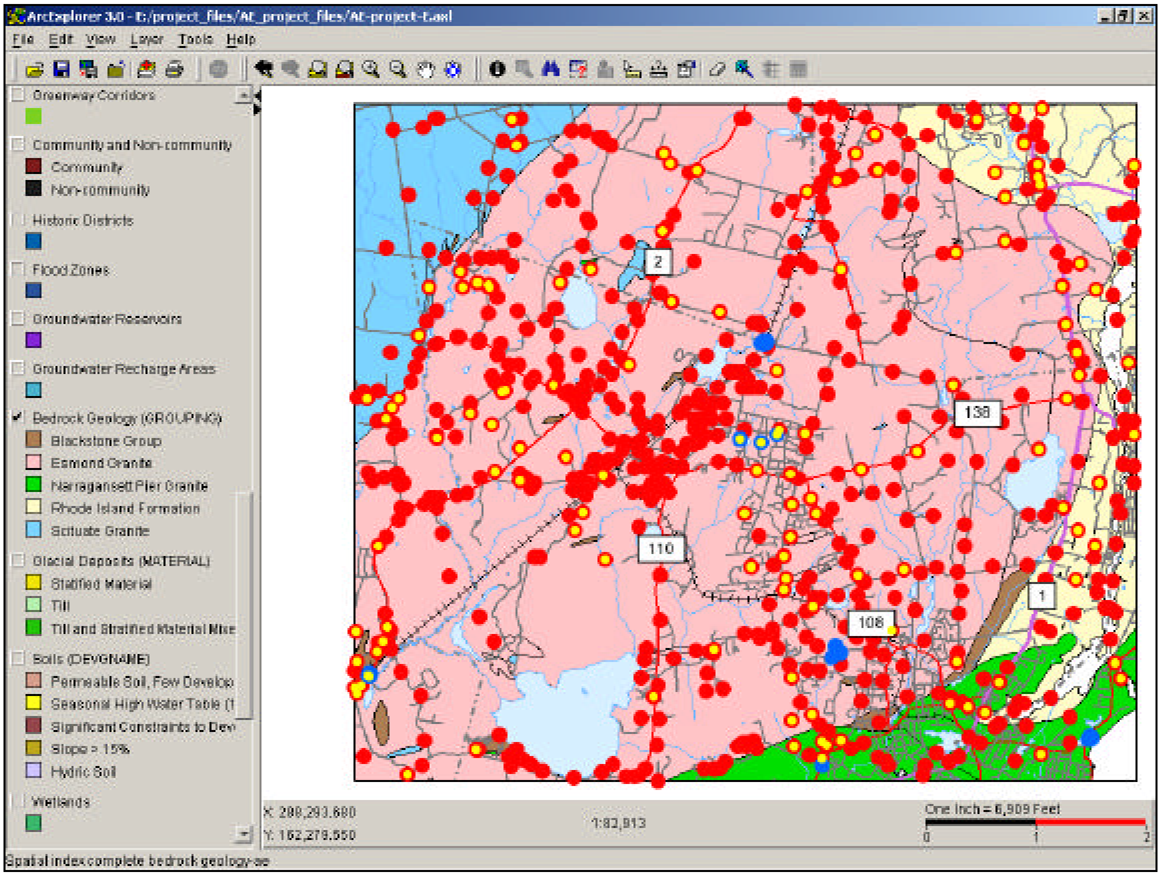
1. Click on the ***Well-Boring Database*** layer in the legend to make it active.
2. Click on the ***Query Builder*** button.



3. Click on the **GEOL_BOH** (Geology, bottom of hole) field to query.
4. Click on the "**=**" operator.
5. Click on the **"Bedrock"** value for the selection criteria.

The query string should look like this:
(GEOL_BOH = 'Bedrock')

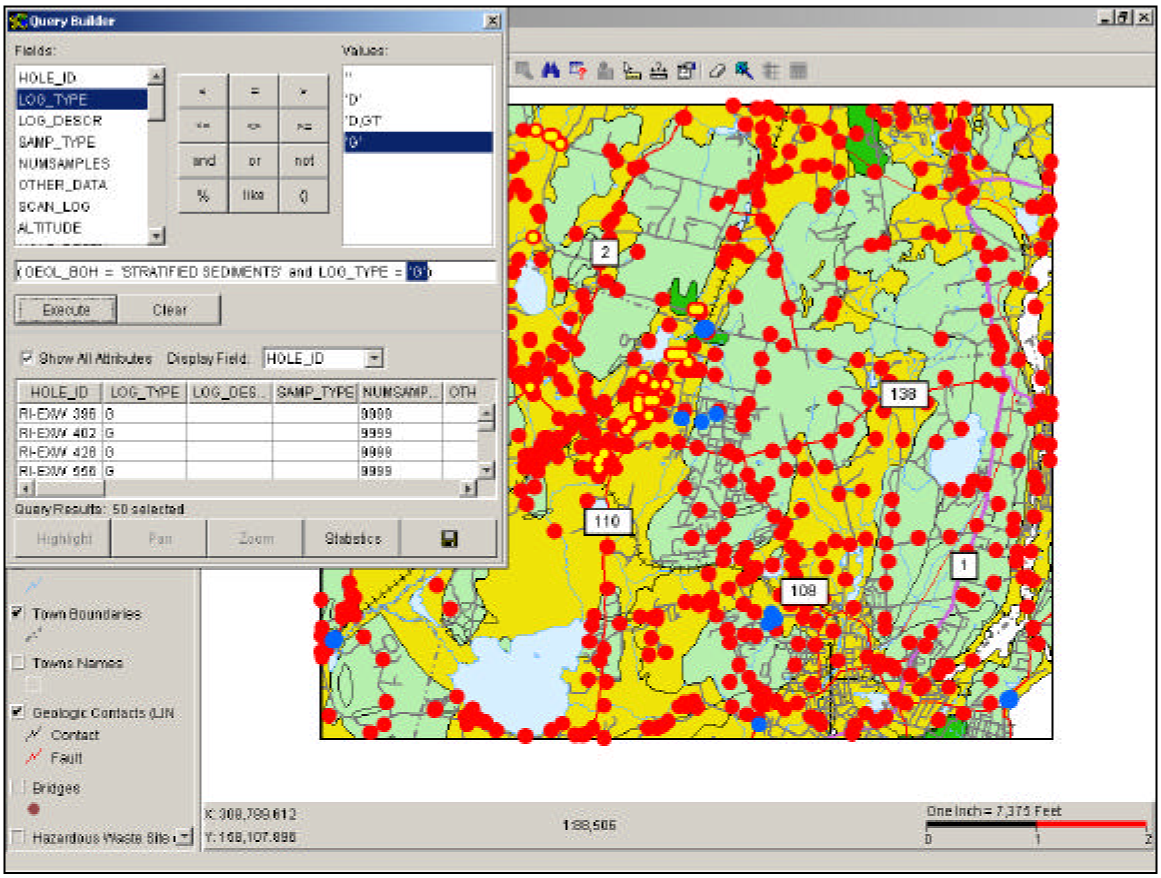
6. Click the execute button to perform the query. The wells and borings that meet the search criteria will be highlighted in yellow and the query results will be displayed in the ***Query Builder*** dialog box..
7. To highlight individual results from the query select a record by clicking on the record in the query results window and then click on ***highlight button***. To select more than one record hold the Ctrl key and click on the individual records you want to highlight. To select a continuous series of records, click on the top record, then hold the Shift key down and click on the record at the bottom of the series. Records highlighted in blue in the Query Results window have been selected and will be highlighted in yellow once the ***highlight*** button is clicked.
8. To see the type of bedrock unit that the well/boring may have penetrated, close the query (do not clear the query) window and display the ***Bedrock Geology*** layer (turn the ***Glacial Deposits*** and ***Groundwater Reservoir*** layers off first).


ArcExplorer 3.0 - E:/project_files/AE_project_files/AE-project-t.axl
File Edit View Layer Tools Help
Greenway Corridors
Community and Non-community
Community
Non-community
Historic Districts
Flood Zones
Groundwater Reservoirs
Groundwater Recharge Areas
Bedrock Geology (GROUPING)
Blackstone Group
Esmond Granite
Narragansett Pier Granite
Rhode Island Formation
Scituate Granite
Glacial Deposits (MATERIAL)
Stratified Material
Till
Till and Stratified Material Mixe
Soils (DEVGNAME)
Permeable Soil, Few Develop
Seasonal High Water Table (1
Significant Constraints to Dev
Slope > 15%
Hydric Soil
Wetlands
2
138
110
1
108
X: 280,293.680
Y: 162,278.550
1:82,913
One Inch = 6,909 Feet
0
1
2
Spatial index complete bedrock geology-ae

Example 2. Identify all wells in stratified material for which a detailed geologists's log is available. This is a compound query that requires two selection criteria.

1. Click on the ***Well-Boring Database*** layer in the legend to make it active.
2. Click on the ***Query Builder*** button.
3. Click on the **GEOL_BOH** (Geology, bottom of hole) field to query.
4. Click on the "=" operator.
5. Click on the **'Stratified Sediment'** value for the selection criteria.
6. Click on the "**AND**" operator.
7. Click on the **LOG_TYPE** field.
8. Click on the "=" operator.
9. Click on the '**G**' value (Note: G = geologist, D = driller, GT = Geotechnical).

The query string should look like this:
(GEOL_BOH = 'Stratified Sediment' AND LOG_TYPE = 'G')

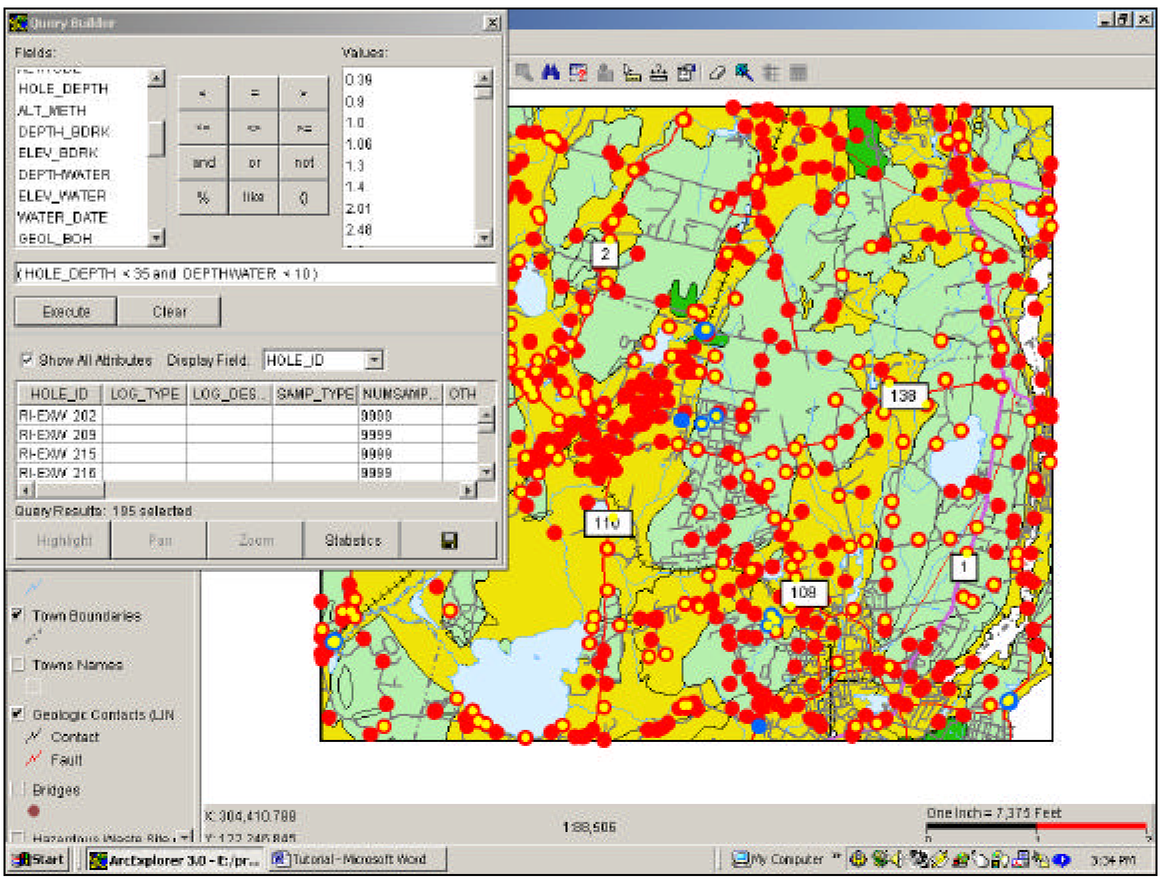


10. Click the execute button to perform the query. The wells and borings that meet the criteria will be highlighted in yellow and the query results will be displayed in the ***Query Builder*** dialog box.

Example 3. Identify all wells less than 35 feet deep that have water levels less than 10 feet below land surface. This is a compound query with user defined numerical values.

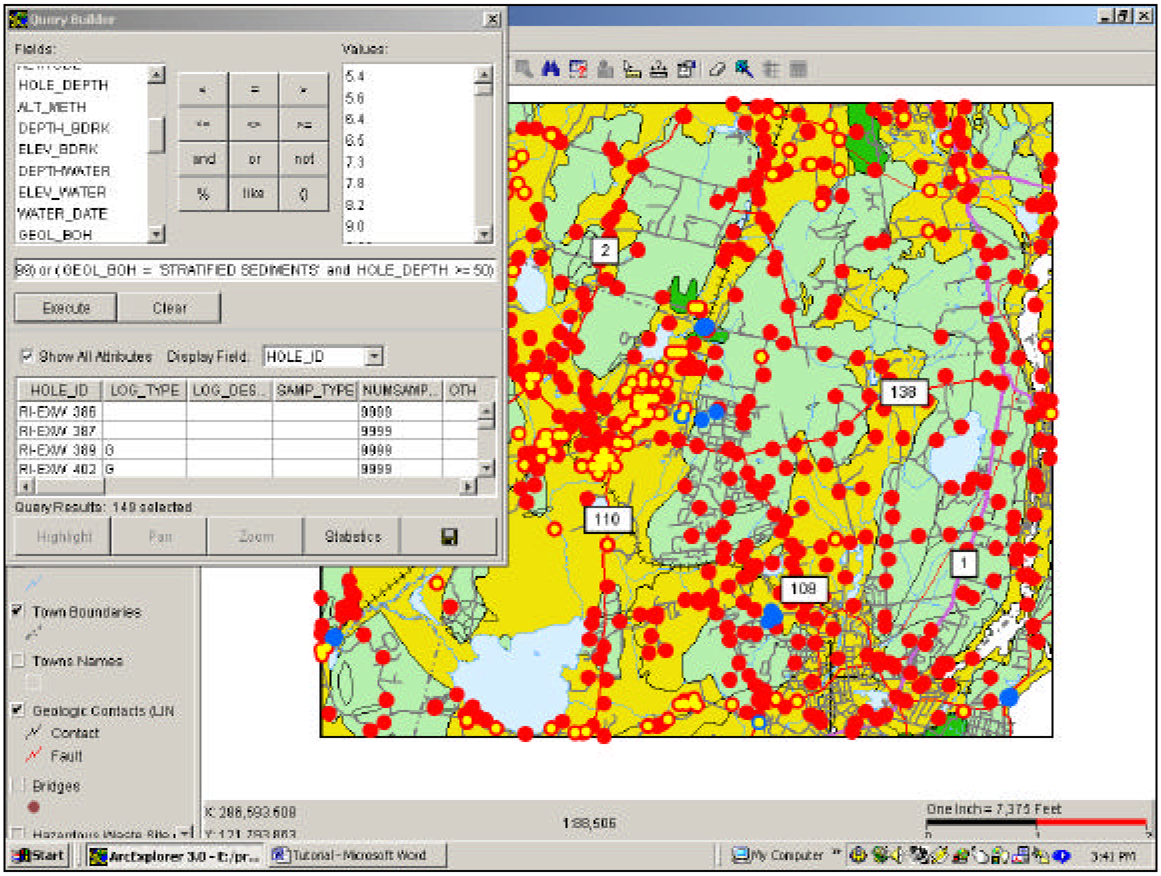
1. Click on the ***Well-Boring Database*** layer in the legend to make it active.
2. Click on the ***Query Builder*** button.
3. Click on the **HOLE_DEPTH** field to query.
4. Click on the "<" operator.
5. Click on the **"35"** value or enter 35 directly by typing it in the query window.
6. Click on the "**AND**" operator.
7. Click on the **DEPTHWATER** field to select second query.
8. Click on the "<" operator.
9. Click on the "**10**" value (or enter 10 directly).

The query string should look like this:
(HOLE_DEPTH < 35 AND DEPTHWATER < 10)



10. Click the execute button to perform the query. The wells and borings that meet the criteria will be highlighted in yellow and the query results will be displayed in the ***Query Builder*** dialog box.

Example 4. Identify all wells that penetrate at least 50 feet of unconsolidated sediment. This is a compound query with multiple operators.



1. Click the ***Well-Boring Database*** layer in the legend to make it active.
2. Click on the ***Query Builder*** button.
3. Click on the **DEPTH_BDRK** field to query.
4. Click on the ">=" operator.
5. Click on the **"50"** value or enter 50 directly by typing it in the query window.
6. Click on the "**AND**" operator and then the **DEPTH_BDRK** field.
7. Click on the "<>" operator.
8. Click on the "**9999**" value (or enter it directly). This will exclude wells and borings for which no depth to bedrock information is available (these are coded as 9999.
9. Use the cursor to move outside the ")" and click the "**OR**" operator.
10. Begin a new query string with a "(" then click the **GEOL_BOH** field..
11. Click the "=" operator.
12. Click the **"Stratified Sediment"** value for the selection criteria.
13. Click the "**AND**" operator then the **HOLE_DEPTH** field.
14. Click the ">=" operator and click or enter **50**.

The query string should look like this:

(DEPTH_BDRK >= 50 AND DEPTH_BDRK <> 9999) OR (GEOL_BOH = 'STRATIFED SEDIMENT' AND HOLE_DEPTH >= 50)

15. Close the query string with "**)**".
16. Click the execute button to perform the query.