A Web-Based Core Library for Rhode Island

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Based upon consultation with the Rhode Island Department of Transportation and others, we have developed a web-based database of borehole data that will facilitate the planning of transportation systems in Rhode Island and serve as model for other states and regions. From this Internet web site (http://geoluri.edu/borehole/index.asp), users can access, query, download, or add to the pre-existing database. Retrieval access is available for all users, but data entry privileges are reserved for registered users.

The database consists of dynamically coupled areal GIS coverages and subsurface data to create a spatially referenced digital catalog of borehole data for a pilot area within a transportation corridor near the University of Rhode Island in Kingston, RI. The borehole database is populated with data derived from RIDOT geotechnical reports, with supplemental data from the US Geological Survey ground-water-site inventory system and local storm-water and sewer projects. Unification of these data into a single relational database yields two primary benefits: 1) historical data are readily accessible for review and can therefore be easily incorporated into the planning stages of new projects, and 2) sophisticated analysis of the region becomes possible with access to data from multiple projects with both spatial and temporal coverage. In addition to engineering applications, the spatial data are also 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.

Geologic data include bedrock geology, surface outcrops, unconsolidated materials, soil types, topographic and orthophotographic base maps, and location of ground-water-wells and boreholes. Subsurface geologic and hydrologic data associated with the site-specific wells and boreholes include land-surface elevation, depth to bedrock, and material properties including presence of fill, high and low blow-count zones, and organic sediment. This database marks a significant advancement for the State of Rhode Island, permitting rapid identification of existing boring locations and retrieval of key subsurface data. The database permits the addition of new data as it is acquired.

No restrictions. This document is available to the Public through the URI Transportation Center, 85 Briar Lane, Kingston, RI 02881.
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1 INTRODUCTION

1.1 Background
Knowledge of surface and subsurface geology is fundamental to the planning and development of new or modified transportation systems, as well as other land-use issues. Toward this end, we have compiled a pilot GIS database consisting of critical geologic, cartographic, environmental, and cultural data along a transportation corridor in southern Rhode Island. The database includes spatially defined themes, largely selected from the public domain RI GIS database, which can be overlain on-screen or in printed format to show quickly the geographic distribution of the diverse types of data. A key feature of the database is the inclusion of subsurface information from boreholes in the region. A cooperative program with RIDOT and the Town of South Kingstown provided access to boring logs, which greatly facilitated data compilation. Subsurface geologic and hydrologic data associated with the boreholes are an integral component of the database, and include the following elements: land-surface elevation; depth to water table; depth to bedrock; and interval data on selected material properties, including low and/or high blow count zones, organic soils, and artificial fill. Geologic data also include bedrock geology, surface outcrops, unconsolidated sediment (surficial material), soil type, topographic and orthophotographic base maps, and location of boreholes and ground-water wells.

This project is a continuation of one carried out under the auspices of the URI Transportation Center during 1999-2001 (referred to as TC1). In that recently completed study we presented the data in a user-friendly format on a CD-ROM with an attached simplified viewer (ArcExplorer). The reader is directed to Appendix A for a copy of that CD-ROM. We extended our previous results in two ways in the present study. First, we substantially increased the size of the subsurface database, primarily through the addition of borehole information from the RI Department of Transportation on bridges and from sewer line construction by the Town of South Kingstown. Thus, the number of boreholes has increased from 32 to over 500 and the total number of boreholes and wells has increased from 722 to 1,302. More importantly, we have
developed a protocol for the inclusion of borehole data that permits the conversion of disparate types of logs into an internally consistent data set that are useful in the construction of cross sections. This interactive database, which is available on a website maintained on the Department of Geosciences server, can be queried, viewed, and downloaded into a variety of formats. The database is structured to easily incorporate new data as it is acquired, thus providing condensed, accessible information of the type essential to transportation planning.

1.2 Organization of this Report
This report consists of two parts. The first describes the results, in the same manner that they were presented at professional meetings. The following section provides a list of outcomes and products of this project keyed to the goals and tasks of the original proposal plus additional requirements (e.g., student involvement) of the funding agency. The Appendix includes: 1) the CD-ROM (APPENDIX A) produced in the previous project (TC1). An essential component of this project is that web site, which the reader is encouraged to explore at http://geo.uri.edu/borehole
2 PROJECT RESULTS: A Narrative Description

2.1 Introduction
During the development of the CD-ROM (in TC1), we had several discussions with local and state transportation departments, in which it became clear that they had a pressing need for a digital core library. Drilling and the collection of borehole information is an essential and expensive initial step in most highway projects, such as the construction and maintenance of bridges. In developed regions such as the Northeast, most transportation corridors have an extensive history of drilling because of the widespread construction and maintenance of bridges, roads, rail systems, and sewer systems. Nevertheless, new borings are done repeatedly at places where drilling had previously occurred. Thus, ready access to this database of prior drilling would permit substantial savings. Ideally, such a repository of borehole data would contain a record of all recent drilling that had occurred in the state (i.e., within the last ~ twenty-five years), stored in an internally consistent format that included relevant information about the subsurface geology, hydrology, and rock mechanics. Moreover, this library would be easily accessible (i.e., a web site accessible to the public) and capable of incorporating new subsurface data, as it becomes available. Unfortunately, this is rarely possible for the following reasons: 1) Drilling records are often lost or stored in inaccessible places; 2) Driller’s logs vary widely in terms of their detail and format; 3) Records and accompanying location maps may become separated, or crucial location information may simply be lacking; 4) Borehole records for a site of interest may reside in disparate places, making it difficult to assemble information; and 5) Duplicate records may not be available, making it hard to borrow or copy them.

2.2 Data
Based upon consultation with the Rhode Island Department of Transportation and others, we have developed a web-based database of borehole data that will facilitate the planning of transportation systems in Rhode Island and serve as a model for other states and regions. In order to do this, we conferred with the transportation and drilling
communities as a prerequisite for development of a core logging protocol that was user-friendly (by drillers, engineers, etc.) and captured the essential information. That protocol formed the basis for the development of an ACCESS™ computer form, into which borehole data were entered into the database. We then established a web site from which users can access, query, download, or add to the pre-existing database. At present, this database exists for the same geographic area covered by TC1, and includes 500 boreholes not included in that earlier study. However, it is easily expandable to other parts of the state or to other states. Subsequent sections describe these components of the project in more detail.

2.2.1 Data Sources
Figure 1 shows the geographic distribution of boreholes incorporated into the database. They derive from the following sources: 1) RI Department of Transportation (249 sites); 2) South Kingstown sewer lines (294 sites); 3) USGS water wells (690 sites); and 4) others (69 sites). We think that this data set includes all of the useful boreholes in the study area. Boreholes not included either were incomplete or spatially duplicated other sites.

2.2.2 Data Form
Before we could begin to create a web site and populate it with borehole data from the sites described previously, we had to develop a protocol for recording information acquired from driller’s logs. There is no standard for recording information at the drill site, and every drilling company and geotechnical firm involved in logging drill sites has their own scheme. Figure 2 shows a typical driller’s log. Based upon numerous discussions with the RI Department of Transportation and other organizations, we constructed a form that includes essential information (Fig 3). We then entered, by hand, all of the data for the drill sites in the study area. Drilling sites were located on large-scale maps (i.e., less than 1:5000) based on information in the drillers logs.
Figure 1. Location of wells, borings, and cross-section included in the web-based digital database.
Figure 2. Example of borehole log used to populate the digital database.
<table>
<thead>
<tr>
<th>Engineering Co.</th>
<th>Report #:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contracting/Funding</td>
<td>Contract #:</td>
</tr>
<tr>
<td>Agency:</td>
<td></td>
</tr>
<tr>
<td>Geotechnical Co.:</td>
<td>Geotech File #:</td>
</tr>
<tr>
<td></td>
<td>if applicable</td>
</tr>
<tr>
<td>Drilling Company:</td>
<td>Drilling File #:</td>
</tr>
<tr>
<td></td>
<td>if applicable</td>
</tr>
<tr>
<td>Project Name:</td>
<td>Bridge #:</td>
</tr>
<tr>
<td>name</td>
<td>if applicable</td>
</tr>
<tr>
<td>Hole ID:</td>
<td>Date Drilled:</td>
</tr>
<tr>
<td></td>
<td>DD/MM/YYYY</td>
</tr>
<tr>
<td>Town:</td>
<td>County:</td>
</tr>
<tr>
<td>Location X:</td>
<td>Location Y:</td>
</tr>
<tr>
<td>XY Method:</td>
<td>XY Projection:</td>
</tr>
<tr>
<td>GPS digitized other</td>
<td>state plane NAD 83 preferred</td>
</tr>
<tr>
<td>Land Surface Elevation</td>
<td>Elevation method:</td>
</tr>
<tr>
<td>(ft):</td>
<td>GPS survey estimated altimeter</td>
</tr>
<tr>
<td>Hole Type:</td>
<td>Log Type:</td>
</tr>
<tr>
<td>boring or well</td>
<td>driller geotechnical geologist</td>
</tr>
<tr>
<td>Hole Depth (ft):</td>
<td>Scanned log available:</td>
</tr>
<tr>
<td></td>
<td>yes no</td>
</tr>
<tr>
<td>Depth to Bedrock (ft):</td>
<td>Visual Description on log:</td>
</tr>
<tr>
<td></td>
<td>yes no</td>
</tr>
<tr>
<td>Depth to Water (ft):</td>
<td>Sample type:</td>
</tr>
<tr>
<td></td>
<td>split spoon auger cuttings core</td>
</tr>
<tr>
<td>Water level Date:</td>
<td>Number of sample intervals:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subsurface Units:</th>
<th>Present/Absent</th>
<th>Top ft below land surface</th>
<th>Bottom ft below land surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial Fill:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic Soils</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blow Counts &lt;= 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do not include top of hole</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blow Counts &gt;= 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do not include bottom of hole</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hole ended in: bedrock refusal unconsolidated stratified unknown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other Data Available:

For URI use only:

Internal ID: YYYYMMDD###
Entered By:                      
Date Entered:                   

Figure 3. Database template used to record borehole information.
The maps were registered into the RI State Plane coordinate system (NAD 83), and location coordinates were read digitally from the map using ArcView. Locations are accurate to within five feet.

The hand-generated data sheets were then converted into computer forms in ACCESS™ (Fig. 4), where each form represents the record of one borehole log. The borehole database that resides on the web site is in ACCESS™ format. For selected sites we have also included scanned images of stratigraphic logs, blow counts, etc., as attachments to a given record.

![Figure 4. Access form used to populate the digital database.](image)
2.3  Borehole database and web interface

2.3.1 Overview.

The web interface represents the heart of the project. Users may access the web site at http://geo.uri.edu/borehole. There, one may choose from the following options: 1) Log-in; 2) As a first-time user, request a user ID with password access; 3) Access the database and carry out simple searches; 4) View results on-screen or download as an EXCEL™ file; and 5) submit data to be incorporated into the database, subject to evaluation by the web site administrator.

2.3.2 Background.

The Principal Investigators constructed the database in ACCESS™ and outlined the framework and requirements for the web site. The design and development of the web site was carried out under subcontract to John Peterson, under the auspices of the URI Transportation Center. The beta version of the product was submitted to us in early December 2001. It consisted of 1) a zip disk containing a largely bug-free version of the web site, and 2) a rough draft of documentation to accompany the software. Since then we have made minor modifications to the code and installed it on our server. Access to the web site is achieved at the aforementioned address.

2.3.3 Documentation

The following section represents an edited version of the documentation submitted to us by the subcontractor. Editorial changes are mainly limited to issues of grammar and style.

The database and web interface will allow registered users to search the current borehole database and to submit new records to the borehole database. Administrators, before final acceptance and incorporation into the database, will review a new submittal of a user’s borehole log sheet.
The architecture, or navigational structure, of the web page includes: 1) **ABOUT BOREHOLES AND THIS DATABASE** (system information); 2) **SEARCH NOW** (report search engine); 3) **LOGIN** (registered user and administrator Login); 4) **REGISTER FOR AN ACCOUNT** (new user registration); 5) **CONTACT US** (system contact information); 6) **SUBMIT BOREHOLE REPORT** (Report Submission from valid users); and 7) **ADMINISTRATIVE OPTIONS** (System management for administrators).

### 2.3.3.1 System Models

Active Server Pages implement a common request/response paradigm for the handling of the messaging between the client and the server. A high-level Database-driven online borehole reports system model:

1. Client (general user, the registered user, and administrator) sends a request to the server.
2. The web server sends the request information to the Active Server Pages.
3. The Active Server Pages build a response and passes it to the web server. The dynamically built response and the content of the response depends mainly on the client’s request. The services are provided via a database server (external resources). This Open Database Connectivity (ODBC) server provides robustness and efficiency when dealing with the database connections.
4. The Active Server Pages send the response back to the client (general User, the registered user, and administrator).

### 2.3.3.2 Technology

The system is programmed in Hyper Text Markup Language (HTML), Standard Query Language (SQL), Active Server Pages (ASP), and Javascript. The Adobe Photoshop software deals with graphics design. The Macromedia Dreamweaver UltraDev 4 is used as well. Open-source ODBC and standard non-proprietary SQL is used as the database server.
2.3.3.3 Level of Users

- General Users are able to browse and navigate within the authorized area of the Borehole Database website.
- Registered Users are allowed to submit Borehole report.
- The System Administrator can carry out the aforementioned tasks, as well as review reports submitted by registered users and input reports into the main database so that general users on the site can view these reports.

2.3.3.4 Scenarios

- General Users can navigate the Borehole Database Website.
- General User can utilize the database search engine.
- General Users can download the results of query (Multiple records or single record) as an Excel™ Sheet.
- General Users also can be registered authorized users on the system.
- Both registered users and administrators are required to log into the system.
- Registered users may submit Borehole log reports and digital copies (gif, tif, jpg, pdf, etc.) of the log sheet, if available.
- The Administrators review submitted records, and either add them to the main database or reject/delete them when incomplete.
- The Administrator manages user accounts.
- Registered users and administrators are required to log-off the system at the end of a session.

2.3.3.5 Relationships

- A Network Administrator must configure the web application before the system operates.
- General users must input and select a topic before they search for information via the search engine.
- Registered users must select a unique user name when they register onto the system.
- Users must have registered user status in order to submit a borehole report.
• All required fields of borehole reports must be completed before they are submitted.

• Submitted borehole log records are temporarily saved in a “holding tank” before they are reviewed by a designated administrator. Administrators are either a hydrogeologist or geologist.

• The Administrator must add newly accepted records to the main database before they can be viewed by the public.

2.3.3.6 Nonfunctional Requirements

• The web interface must allow access to the system by multiple users (general users, registered users, and administrators).

• User access through a web interface must provide a single point of distribution.

• The system should be able to notify a designated administrative contact via email.

• IP-based security will be used to prevent unauthorized access to the system.

• User based security should be implemented to control user’s access level.

2.3.3.7 Features

2.3.3.7.1 Navigation

For general and registered users, the navigation structure has eight functional links. Log In allows users to log into the system. About Borehole and this Database contains the introduction and information about the Boreholes and the Database website. Search Now allows users to search information from the database. Submit Borehole Report provides a report submission form and interface for registered users so that they can submit reports. Register for an account provides a registration form for general users to register. Contact Us allows users to submit questions, or to request forgotten passwords to the system administrator. Users can exit the system by simply clicking Log Off at the navigation links. Map allows the user to access a site map, as well as a geologic cross section for the area.
For administrators, the navigational structure has four additional functional links. *View records in holding* allows administrators to view all reports. *Submit Borehole Report* displays the report submission form and enables administrators to submit reports. *Manage User account* permits administrators to manage all user accounts that are registered. The administrator exits the system by simply clicking *Log Off* at the navigation links.
2.3.3.7.2 Search records

Currently the database can be searched on the basis of five criteria: 1) town name, 2) quadrangle name, 3) depth to water table, 4) depth to bedrock, and 5) project name.

2.3.3.7.2.1 Search by town

This search criterion permits users to search the Boreholes database on the basis of town/city name where the boreholes are located. All town names in the database are listed on the pull-down menu, by selecting any of the towns and clicking the *Go* button, the user can search for boreholes located in that town.
2.3.3.7.2.2 Search by Quadrangle
Users using this search criterion can search the Boreholes database based on quadrangle name where the boreholes are located. By selecting any of the quadrangle names and clicking the Go button, the user can search for boreholes located in that quadrangle. (Because all boreholes in our model template are located within the Narragansett Pier Quadrangle, only one quadrangle is listed).

2.3.3.7.2.3 Search by Depth to Water
Using this search criterion, the Boreholes database is searched based on depth to the water table. By selecting any given range of depth, and clicking the Go button, users search for boreholes with the depth to water table that falls within that range.

2.3.3.7.2.4 Search by Depth to Bedrock
Using this search criterion, the Boreholes database is searched based on depth to bedrock. By selecting any given range of depth, and clicking the Go button, users search for boreholes with the depth to bedrock that falls within that range.

2.3.3.7.2.5 Search by Project Name.
This query allows searches for all the boreholes drilled for a specific project. The user provides only a project name.

Users have the option of displaying search results either on-screen or downloading as an Excel Sheet. After the system receives a search request from the user with the Display function, a new screen appears to show search result listing all records with its hole-ID, the date drilled, town or city, and project name. The user then can display a single record by selecting a specific record from the list.

On the other hand, if the user chooses the Excel Sheet function, the user can download all the records found through the search routine into an Excel sheet. The user can choose to either “save the document” or to “open directly” when prompted by the browser.
For registration, users either select “register” from the navigator panel at the left hand side of main page or “REGISTER FOR AN ACCOUNT” link on the main page. Users are required to read and accept the disclaimer before registering for an account. If the user selects the Decline button to disagree to the disclaimer, the system terminates the registration process and sends the user back to the home page. If the user selects the Accept button, the registration form pops up. After completing the form with the requested information, the user may request a user account by clicking the “Request User Account” button. If a user account of the same name already exists on the system, he/she will be asked for a different username. A password confirmation field covers misspelling and uppercase/lowercase problems. A successful registration will prompt the user to login.
Registered users/administrators can login either by entering his/her account and password, or by clicking the **LOG IN** navigation link on the main page.

After a registered user/administrator enters their valid user name and password in the login-form and clicks the **“Login Now!”** button, the system responds with a successful login screen.

For a lost/forgotten password, a user can click the **“Forgot your password”** link to find his/her password. After the user provides the system with the username and email address, the system displays the password hints. If the user still does not remember the password, he/she is asked to contact the system administrator via the **Contact Us** screen.
2.3.3.7.5  5. Report Submission

To submit a Borehole report, an authorized user must first log onto the system. The Report Submission input form appears by selecting **Submit Report**. The user is required to complete all fields in the report submission form. For incomplete forms, a window appears to alert the user to the missing field(s). Drop-down lists are provided for Engineering Companies, Contracting/Funding Agencies, Geotechnical Companies, Drilling Companies, and Project Names. Users can select the existing items from the drop-down menu. If the menu does not include the desired input, the user can enter a new input at the text field under the drop-down list.

When an image of the borehole log sheet is available, the system will provide an upload file form. In this form, the user is required to point to the appropriate image file on the local computer, and then click the **“UPLOAD image!”** button. Note that all
submissions should include a scanned copy of the user’s field report. The acceptable image file formats are JPG, TIF, or PDF. Maximum file size is 1 megabyte. If desired, the user may cancel the uploading process by clicking the “CANCEL Upload!” button. In this case, the Report is submitted without a picture attachment.

2.3.3.7.6 Report Review

Access to the Report Review screen is reserved for users with Administrative privileges. Before accessing the report review screen, administrator must select a record from a list of all submitted reports. On the report review screen, the administrator confirms the details of the report and submits the confirmed report to the main database. Once submitted, the report is available for general users at the site. Additionally, the system provides functions for report modification and deletion.
Report Modification and deletion functions are accessed by links labeled “Modify this submission” and “Delete this record.”

2.3.3.7.7 Management of User Accounts

To manage user accounts, the administrator navigates to the Manage User Accounts screen at the home page. The Manage User Account link displays a users list, including the user’s first name, last name, ID, and access level. The Administrator may modify this user information, and delete the user account by selecting respective “Modify” and “Delete” links. Furthermore, the administrator may view user information by clicking user ID on the list. To change the access level of users, the administrator can select either “user” or “admin” from the drop-down menu on the modifying user screen.
To exit the system, a user must click “Log Off” from the navigation panel at the left-hand side of screen. A new screen then confirms that the user successfully logged-off the system.
2.3.3.7.9 Contact Us

The Contact Us screen provides an electronic contact form for users. The user must enter his/her name, address, e-mail address, telephone number, and message in the form and send it to the system administrator by clicking the E-mail Us button.

2.4 Discussion

2.4.1.1 Summary of results
Through the effort of two projects funded by the URI Transportation Center (Geologic Transportation Maps For The 21st Century and A Web-Based Core library for Rhode Island) and a third project funded by RIDOT (Digital Databases to Create Geologic Maps), we have developed the capacity to organize and store subsurface
data in a unified digital geographic information system database that is accessible via the internet. This database marks a significant advancement for the State of Rhode Island, permitting rapid identification of existing boring locations and retrieval of key subsurface data.

2.4.1.2 Future work.

A limitation of this database is the absence of a complete subsurface record (layer by layer visual description, blow counts, etc.) and associated layer-specific data (laboratory analyses and geologic/geotechnical interpretations) in a unified database that provides real-time digital access to the full subsurface record (for example, display of cross-section results). Commercially available software, such as gINT®, permits storage of borehole data (and associated field and laboratory measurements) in a database, but these data are not part of a spatial relational database or geographic information system.

The need for a more integrated system can be addressed through the development of a multi-dimensional relational database management system (compatible with gINT® format), which will permit storage and retrieval of the complete boring record and associated subsurface data. This type of relational database would use Access for data storage and ArcView/ArcInfo for data access, display and analysis. This would permit querying and display of borehole lithology, retrieval of laboratory data, and access to all borehole related information. Once such a database is established, RI contractors would be able to submit all their geotechnical data in electronic format.
3 PROJECT RESULTS: A Task-Oriented Description

The following description of outcomes and products are keyed to the list of tasks given in the project proposal.

3.1 TASK DESCRIPTIONS

3.1.1 Log template design
The template is available in two formats. The first (Fig. 3) is intended to be used in the field, or in the translation of preexisting logs into the current format. The second format represents the computer "page" into which data is entered (Fig. 4). It is derived from the former "field sheet", and is in Microsoft ACCESS™ format. Both forms were developed after extensive consultation with the RI Department of Transportation and engineering firms engaged in drilling in the region.

3.1.2 Tabular graphic design
The web site utilizes a variety of graphic elements in the design of a borehole database. The reader should examine the web site for examples.

3.1.3 Quaternary (surficial) geology
Quaternary geology is incorporated into the database in several ways: 1) As layers displayed on the CD-ROM (see Appendix); 2) As information included in the database for each site; 3) As scanned logs for selected sites; and 4) As a geologic profile across the area (Fig. 5). As most of the borings occur in materials above the bedrock surface, we give below a detailed discussion of the surficial geology.

Quaternary geology describes all processes, or geologic agents, that have shaped the landscape in the past million years; it also considers all materials deposited or modified as the result of those processes. The most important processes relevant to this study were continental glaciation, ending in Rhode Island about 15,000 years ago, and the subsequent modification to the landscape by flowing water. Most of the geologic material described on the borehole logs is either sediment deposited in a
glacial environment or later redeposition of that sediment in post-glacial streams, lakes, and wetlands. Unstratified glacial material is till, deposited in direct contact with glacier ice. Stratified glacial material is gravel, sand, silt and clay, deposited in rivers and lakes beneath, beside, or in front of the ice.

Geologists use the term **lithofacies** for the objective descriptive terms used to describe the material in the boreholes (sand, gravel, etc.) and the term **depositional environment** to describe the place where processes such as flowing water deposited the lithofacies (e.g., delta plain). Glacial geologists also use the term **morphosequence**¹ to describe a time-equivalent group of glacial landforms composed of stratified material. Time equivalent means that the group of landforms may be related to a particular ice-margin location. This is important because it helps the glacial geologist to interpret the sedimentary materials found in boreholes. Figure 5 illustrates the concepts of lithofacies, depositional environments and morphosequences. The boreholes form a north-to-south cross-section down a portion of the present Chipuxet River valley. Cobble gravel is indicated in red, pebble and granule gravel in brown, coarse to fine sand in yellow, and very fine sand and silt in gray. Depositional environments are glacial lacustrine fan, glacial delta plain slope, and glacial lakefloor. Morphosequences are the Slocum Plains morphosequence indicating deposition into a glacial lake in the Slocum area and the Chipuxet morphosequence illustrating deposition into a glacial lake that occupied the Chipuxet valley. The Wolves Rocks end moraine is not a morphosequence because it represents a modification by glacier motion of previously deposited stratified materials. Figure 5 illustrates the complexity of glacially-derived materials when considered in boreholes and not just on maps. Many maps of glacial materials depict only the sediment exposed at the surface and can be very misleading. These maps are best called glacial surface materials maps; true glacial geologic maps utilize a morphosequence interpretation that gives insight into subsurface materials.

Figure 5. Sample geologic cross-section (location shown on figure 1).
3.1.4 Bedrock geology
Bedrock geology is incorporated into the database in several ways: 1) As layers displayed on the CD-ROM (see Appendix A); 2) As information included in the database for each site; 3) As scanned logs for selected sites.; and 4) As a geologic profile across the area (Fig. 5). For the last three items, information about the bedrock geology consists primarily of “depth to bedrock” data.

3.1.5 Hydrogeology
Hydrologic information includes the following: 1) layers on the CD-ROM showing the location of aquifers, watersheds, wells, etc; 2) Depth to water table for each site.

3.1.6 Collection of core- and well-log data
The database contains 600 records for the study area. Each record contains 50 fields with information on the core- and well-log data. Table 1 shows the description of these fields. Additionally, a complete set of copies of all logs are archived in the Department of Geosciences. They also are available from the State Geologist.

Table 1. Definition of database header fields

<table>
<thead>
<tr>
<th>Field/attribute name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access database</td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td>Numeric identification of borehole</td>
</tr>
<tr>
<td>Enginr_Co</td>
<td>Name of Engineering Co. participating in the drilling project</td>
</tr>
<tr>
<td>Fund_Agency</td>
<td>Name of Funding Agency (e.g. RIDOT, USGS, Town DOT, etc.)</td>
</tr>
<tr>
<td>Geotech_Co</td>
<td>Name of Geotechnical Engineering Company(if any) participating in the drilling project</td>
</tr>
<tr>
<td>Drill_Co</td>
<td>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.</td>
</tr>
<tr>
<td>Project_name</td>
<td>Name of project for which drilling was completed.</td>
</tr>
<tr>
<td>Field</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hole_ID</td>
<td>Identification number/code for boring/well</td>
</tr>
<tr>
<td>Town</td>
<td>Name of Town in which drilling site is located.</td>
</tr>
<tr>
<td>Altitude</td>
<td>Elevation of land surface measured in feet above sea level. Datum is NGVD 1927.</td>
</tr>
<tr>
<td>Report_No</td>
<td>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.</td>
</tr>
<tr>
<td>Contrct_No</td>
<td>Funding Agency’s contract number</td>
</tr>
<tr>
<td>GeofileNo</td>
<td>Geotechnical Company file number for well log/project</td>
</tr>
<tr>
<td>DrillfileNo</td>
<td>Drilling Contractor file number for well log/project</td>
</tr>
<tr>
<td>Bridge_No</td>
<td>RI DOT bridge number if applicable</td>
</tr>
<tr>
<td>Date_Drill</td>
<td>Date hole/well was drilled. (yyyymmdd)</td>
</tr>
<tr>
<td>County</td>
<td>Name of County in which drilling site is located.</td>
</tr>
<tr>
<td>X Coord</td>
<td>state plane X coordinate</td>
</tr>
<tr>
<td>Y Coord</td>
<td>state plane Y coordinate</td>
</tr>
<tr>
<td>XY_Method</td>
<td>source of XY data (GPS, digitized, map)</td>
</tr>
<tr>
<td>XY_Proj</td>
<td>Type of map projection employed</td>
</tr>
<tr>
<td>AltitudeMeth</td>
<td>Method used to determine 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.</td>
</tr>
<tr>
<td>Hole_Type</td>
<td>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.</td>
</tr>
<tr>
<td>Log_Type</td>
<td>Type of well/boring log available: D = driller, G = geologist, GT = geotechnical</td>
</tr>
<tr>
<td><strong>Column</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Hole_Depth</strong></td>
<td>Total depth drilled in feet below land surface</td>
</tr>
</tbody>
</table>
| **Scan_Log**  | Is a scanned log available?  
Yes or No.                                                                                                                                                                                                 |
| **Depth_Bdrk**| Depth to bedrock measured in feet below land surface                                                                                                                                                              |
| **Depth_Water**| 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 minimum depth to water during the period of record. |
| **Water_Date** | Date of water level measurement. (yyyymmdd)                                                                                                                                                                        |
| **VisualDesc** | 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                                                                                                                                 |
| **Artif_Fill** | Artificial Fill: present or absent                                                                                                                                                                                 |
| **Organ_Soil** | Organic Soil: present or absent                                                                                                                                                                                    |
| **BlwCnt<10**  | Low blow count (<10) zone in subsurface: present or absent.  
NOTE: do not include top of hole.                                                                                                                                                                               |
| **BlwCnt>100** | High blow count (> 100) zone in subsurface: present or absent.  
NOTE: do not include bottom of hole.                                                                                                                                                                           |
<p>| <strong>Geol_boh</strong>  | Geologic material encountered at bottom of hole (bedrock, refusal, unconsolidated, stratified, unstratified, unknown)                                                                                               |
| <strong>Top_Fill</strong>  | Depth to top of fill measured in feet below land surface.                                                                                                                                                           |
| <strong>Bot_Fill</strong>  | Depth to bottom of fill measured in feet below land surface                                                                                                                                                        |
| <strong>TopOrgSoil</strong>| Depth to top of organic soil measured in feet below land surface.                                                                                                                                                   |
| <strong>BotOrgSoil</strong>| Depth to bottom of organic soil measured in feet below land surface.                                                                                                                                                 |</p>
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>land surface</td>
<td></td>
</tr>
<tr>
<td>TopLoBCnt</td>
<td>Depth to top of low blow count zone measured in feet below land surface.</td>
</tr>
<tr>
<td>BotLoBCnt</td>
<td>Depth to bottom of low blow count zone measured in feet below land surface.</td>
</tr>
<tr>
<td>TopHiBCnt</td>
<td>Depth to top of high blow count zone measured in feet below land surface.</td>
</tr>
<tr>
<td>BotHiBCnt</td>
<td>Depth to bottom of high blow count zone measured in feet below land surface.</td>
</tr>
<tr>
<td>Other_Data</td>
<td>List of other data available: multiple water levels, hammer blows, geochemical data, etc.</td>
</tr>
<tr>
<td>Intrnal-ID</td>
<td>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</td>
</tr>
<tr>
<td>Entered_By</td>
<td>Last name of person responsible for entering the data into the database.</td>
</tr>
<tr>
<td>Date_Enter</td>
<td>Date data were added to the database. (yyyymmdd)</td>
</tr>
<tr>
<td>Elev_Bdrk</td>
<td>Elevation of bedrock surface in feet above sea level. This is a calculated field (Altitude– Depth_Bdrk).</td>
</tr>
<tr>
<td>Elev_Water</td>
<td>Elevation of water level in well, in feet above sea level. This is a calculated field (Altitude – Depthwater).</td>
</tr>
<tr>
<td>State</td>
<td>State where borehole is located</td>
</tr>
<tr>
<td>Quadrangle</td>
<td>Map quadrangle where borehole located</td>
</tr>
</tbody>
</table>

### 3.1.7 Digitization of log data

Table 1 shows a list of the categories of digital data that were extracted from logs. The reader is directed to the web site for displays of digitized borehole logs.
3.1.8 Location of log data
The locations of all sites were digitized in state plane coordinates (the coordinate system used by RI Department of Transportation) and the coordinates included into the database.

3.1.9 Attribute attachments
Definitions of attributes of the digitized data are given in Table 1.

3.1.10 Generation of well-log location maps
Figure 1 shows the location of all boreholes, including wells.

3.1.11 Construction of geologic cross-sections and isopach maps
Figure 5 shows a representative cross-section of the study area, which illustrates the complexity of the Quaternary geology. The cross-section also exists on the web site. Isopach maps were not constructed, as there is insufficient information to justify them.

3.1.12 Web-page development
The web-page is complete, and is summarized in the previous section and available at the following URL: http://geo.uri.edu/borehole.

3.1.13 Design and construction of on-line data entry
These aspects of the web-site are covered in previous sections.

3.1.14 Meetings with private/public officials
The forms for data entry, both field and database versions, were designed in close consultation with RI Department of Transportation, Haley Aldrich Engineering, and Pare Engineering.

3.1.15 Student involvement
Undergraduate and graduate geoscience students, from URI (Mark King, Shilpa Ranganathan, John Mulligan) and Brown U. (William Aaron Pratt), were extensively involved in the acquisition and entry of borehole data into the database.
Additionally, a URI graduate student in Computer Science (Mr. Lin Tech Lee) played a major role in the development of the web-site.

### 3.1.16 Relationship to other projects

This project builds and expands upon our URITC 1 project. It also interrelates with an ongoing project with RIDOT-funded project, whose goal is to assemble a core-log database for the Providence area.

### 3.1.17 Technology transfer activities

In addition to transportation applications, the spatial data also are of interest to a broader audience, including state agencies dealing with environmental management and planning issues, town planners and engineers, conservation and environmental groups, and concerned citizens. To date we have presented the results in a variety of venues, including the national and regional Geological Society of America meetings, and the Annual Northeast States Geotechnical Engineers Conference. We have also presented the results on campus and at the RI DOT. We have proposed workshops for the transportation community in southern New England, in which the results of this and subsequent projects would be demonstrated. Finally, we have prepared two CD-ROMS, which contain data from companion projects, and have disseminated them among the transportation community.
4 APPENDIX A

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 (CD-ROM)