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Building an Enterprise Geotechnical Database to Support Geologic Mapping Activities

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INTRODUCTION

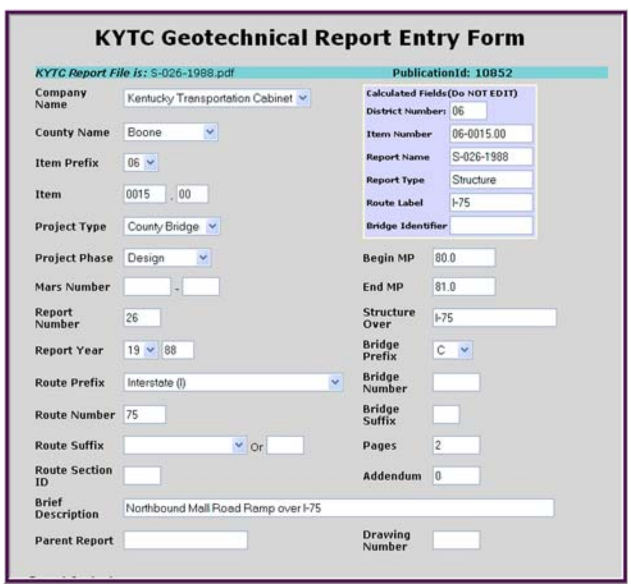
The Geotechnical Branch of the Kentucky Transportation Cabinet (KYTC) employs engineers and geologists to prepare design plans for roadway cuts, fills, and associated structures. Almost all projects involve site investigations that require drilling, sampling, and testing of geologic materials, including rock and soil. These data are reviewed by project staff, and standard engineering practices are used to create design drawings and recommendations for construction work. Drawings are prepared in CAD software and then combined with text documents to produce the final issued reports. Historically, the reports were produced as paper documents, and approximately 6,000 were filed in the Branch library. Supporting data, such as drillhole logs and lab analysis results, were loosely and inconsistently filed by county of location.

Public access to the reports, mainly by engineering consulting firms, was through verbal or written requests; however, there was no catalog of projects from which to identify reports of interest. Branch staff would respond to requests by making copies of reports or by scanning them into electronic files. Supporting data were generally not released because they were not easily accessible. Reductions in staffing levels at KYTC made it increasingly difficult to provide this information, and the system was vulnerable to losing important historical records.

In 2006, KYTC approached the Kentucky Geological Survey (KGS) for assistance with transitioning their records system from paper to electronic. KGS had extensive experience with similar document conversion processes, and had a Web system for disseminating geologic information. KGS geologists would benefit from easier access to the KYTC data for geologic mapping projects, since the KYTC project reports contain information about depth to bedrock, soil properties and classifications, rock descriptions and physical properties, water table data, and fracture measurements. KYTC would benefit from a reduced effort for distributing their data, and could save significant financial resources by reusing drillhole data and analyses from historical projects. A 3-year program was initiated; the objectives were to make all historical reports available to the public through a Web service, create a Web-based management system for tracking the activities and characteristics of future projects, develop a software system for entering borehole and lab analyses into a relational database, and serve these supporting data to the public on the Web.

ARCHIVING LEGACY GEOTECHNICAL REPORTS FOR WEB DISTRIBUTION

The first phase of the project dealt with scanning, cataloging, and distributing the historical reports. KGS developed a database and corresponding data entry form based on interviews with KYTC staff familiar with the content of the reports. The goal was to attribute those characteristics that would be likely search criteria. Figure 1 shows the upper part of the form, which includes information about who conducted the geotechnical study, the location of the study in reference to the transportation network, what type of construction activity it was related to, when it was done, and an assortment of identifiers that relate to the Cabinet's central tracking database of road plans. To minimize typing errors and inconsistent entries, pull-down menus with standard lists were implemented, validation rules were applied where appropriate, and formatting of certain concatenated text values was done programmatically. Administrative functions were designed into the form so that users could update the interface (for example, to add new values to pull-down menus) without the assistance of a programmer. Figure 2 shows the lower part of the form, where contents of the report are described; this information was specified by the KYTC engineers and geologists to facilitate finding reports that deal with specific topics or engineering practices. Check-box controls were used to speed the data-entry process. A free text field was included to add items not covered on the lists, and periodically these nonstandard items were reviewed, and some were eventually included as standard check boxes.


KYTC Geotechnical Report Entry Form

KYTC Report File is: S-026-1988.pdf — PublicationId: 10852

Company Name	Kentucky Transportation Cabinet	Calculated Fields (Do NOT EDIT)	
		District Number:	06
County Name	Boone	Item Number	06-0015.00
Item Prefix	06	Report Name	S-026-1988
Item	0015 . 00	Report Type	Structure
		Route Label	I-75
Project Type	County Bridge	Bridge Identifier	
Project Phase	Design	Begin MP	80.0
Mars Number	-	End MP	81.0
Report Number	26	Structure Over	I-75
Report Year	19 88	Bridge Prefix	C
Route Prefix	Interstate (I)	Bridge Number	
Route Number	75	Bridge Suffix	
Route Suffix	Or	Pages	2
Route Section ID		Addendum	0
Brief Description	Northbound Mall Road Ramp over I-75		
Parent Report		Drawing Number	

Figure 1. Upper part of project data-entry form, showing the variety of descriptive information stored for each report.

Report Contents

Cut Slope Designs		Friction Piles	☐
Rock Fall Fence	☐	End Bearing Piles	☐
Wire Mesh	☐	Black shale remediation	☐
Back Stowing	☐	Mining	☐
Shape Ditches	☐	Geophysics	☐
Soil Modification		Instrumentation	☐
Dynamic Compaction	☐	Seismic design	☐
Wick Drains	☐	Litigations	☐
Surcharging	☐	Lightweight fill applications	☐
Special Structures		Shotcrete	☐
Gabian Baskets	☐	Excess Materials Sites	☐
RSS Slopes	☐	Chemical Stabilization	☐
Tunnels	☐	Sinkholes	☐
Tied Back Walls	☐	**Sheet Types**	
Soil Nail Walls	☐	Project Layout	☐
Cantilever Wall	☐	Location Map	☐
Cantilever H-Pile Wall	☐	Subsurface Data Sheet	☐
Cantilever Railroad Steel Wall	☐	Soil Profile	☐
MSE Wall	☐	Geotechnical Notes	☐
Drilled Shafts	☐	Cut Stability	☐
Settlement Platform	☐	Embankment Stability	☐
Rock Bolts	☐	Loading Diagrams	☐
		Coordinate Data Sheet	☐

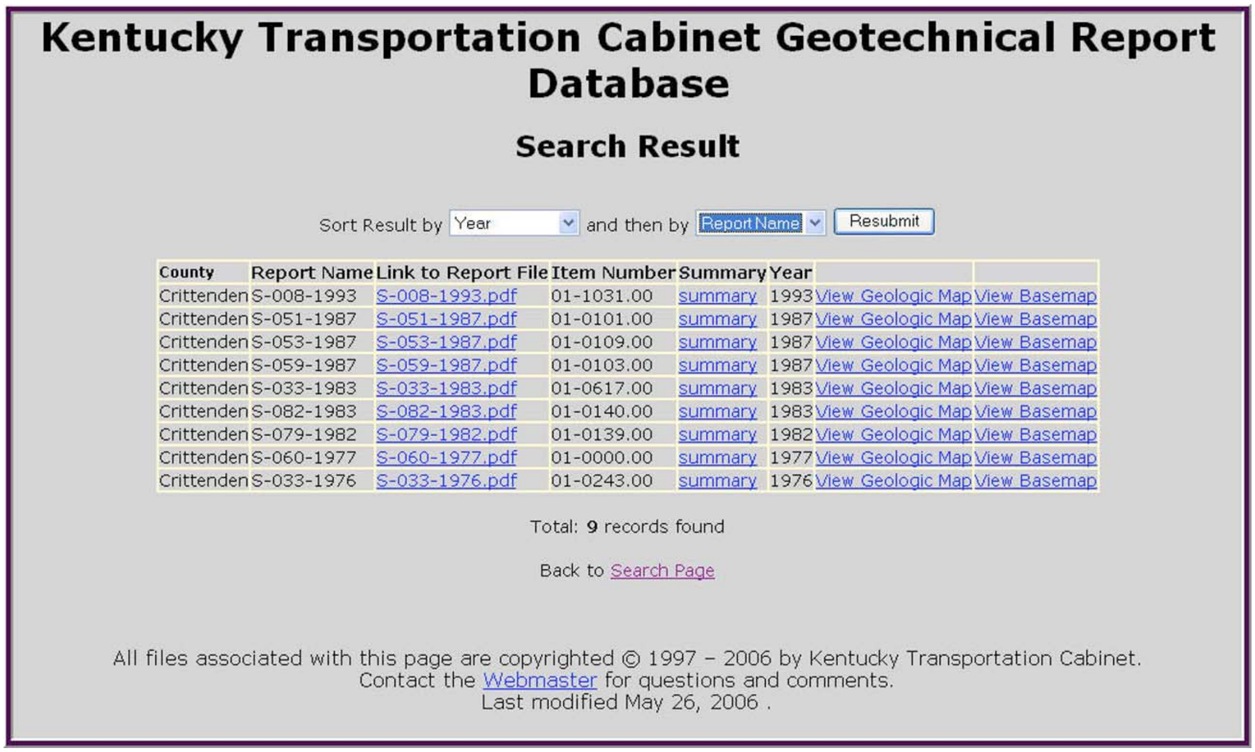
Other Content Items: (Separate by ;)

Figure 2. Lower part of project data-entry form, showing check-box contents that can be associated with a report.

Two other key elements were included at the suggestion of KGS. The first was the ability to assign one or more geologic units to a report. A search form was designed to look up standard stratigraphic names from the KGS geologic mapping database and translate them to alpha-numeric codes. The second allows for locating KYTC projects on a geographic base. Although many projects had geographic descriptions, such as route numbers and milepoint designations, these are not easily translated to geographic coordinates and moreover can change when roads are realigned. KGS developed an Internet map service that included a function to zoom to route milepoints or road intersections so that Branch staff could verify the project location on a topographic or photographic map base. Once the location was determined, a tool was used to define a bounding rectangle for the project, and the coordinates for that rectangle were added to a database table and its primary key was assigned to the report. This facilitated both drawing the project extents on a map as well as searching for reports using geographic criteria. A second way of locating projects was implemented for recent work in which lists of surveyed hole locations were available. These lists could be uploaded to the map service, posted for verification, and then used to define the project extent.

At the end of each data-entry session, the electronic report is selected on the user's computer; the report is uploaded to the KGS Web server for public dissemination and the attribute data are submitted to the database. Public access to these data is provided by an active server pages (ASP) Web service hosted by KGS (http://kgs.uky.edu/kgsweb/KYTC/search.asp). Users can search for reports by any combination of attributes that are included in the database. The result of the search (Figure 3) is a simple list of projects identified by county of origin, date of completion, project number, and KYTC item number that relates to the State's 6-year roadway plan. A number of links (formatted in blue) are also provided. One is to a summary page for the project giving more detailed information about the report and another is to the online version of the report. Two other links lead to Internet maps zoomed to the extent of the project—one a topographic map with other transportation information provided and the second showing the geologic context of the project with access to a variety of KGS geologic site data and descriptions (Figure 4).

The development of this phase of the project and the scanning of documents began in late 2006, and all the historical reports were cataloged and publicly available by fall of 2007.


Kentucky Transportation Cabinet Geotechnical Report Database

Search Result

Sort Result by Year and then by Report Name Resubmit

County	Report Name	Link to Report File	Item Number	Summary	Year		
Crittenden	S-008-1993	S-008-1993.pdf	01-1031.00	summary	1993	View Geologic Map	View Basemap
Crittenden	S-051-1987	S-051-1987.pdf	01-0101.00	summary	1987	View Geologic Map	View Basemap
Crittenden	S-053-1987	S-053-1987.pdf	01-0109.00	summary	1987	View Geologic Map	View Basemap
Crittenden	S-059-1987	S-059-1987.pdf	01-0103.00	summary	1987	View Geologic Map	View Basemap
Crittenden	S-033-1983	S-033-1983.pdf	01-0617.00	summary	1983	View Geologic Map	View Basemap
Crittenden	S-082-1983	S-082-1983.pdf	01-0140.00	summary	1983	View Geologic Map	View Basemap
Crittenden	S-079-1982	S-079-1982.pdf	01-0139.00	summary	1982	View Geologic Map	View Basemap
Crittenden	S-060-1977	S-060-1977.pdf	01-0000.00	summary	1977	View Geologic Map	View Basemap
Crittenden	S-033-1976	S-033-1976.pdf	01-0243.00	summary	1976	View Geologic Map	View Basemap

Total: 9 records found

Back to Search Page

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Contact the Webmaster for questions and comments.
Last modified May 26, 2006 .

Figure 3. Example project search result page with links to the online report and to Internet maps that show the geographic and geologic context of the projects.

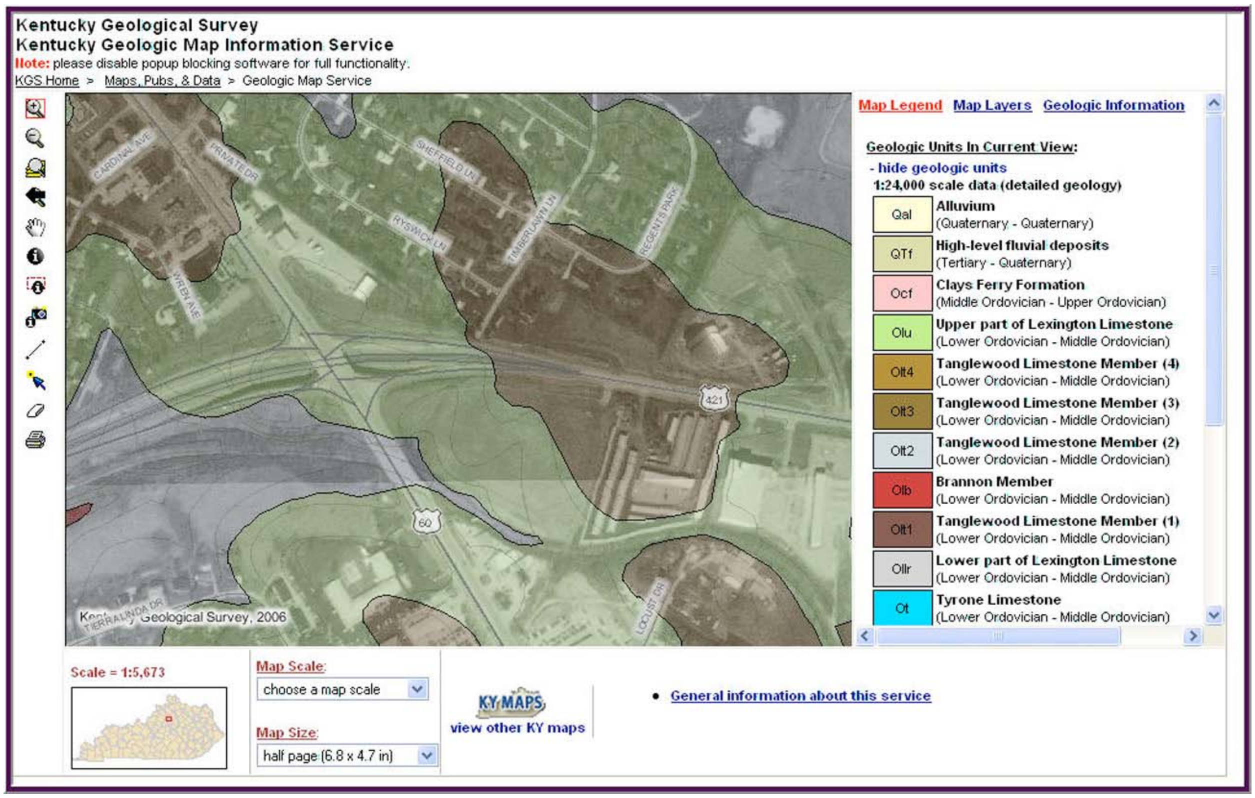


Figure 4. Geologic map zoomed to the extent of a linked project, showing formation contacts along a major route intersection.

MANAGING GEOTECHNICAL PROJECT ACTIVITIES

Once phase I was accomplished, the next phase of the project addressed management of active projects. In many ways this was similar to cataloging historical reports, except for the timing of data entry. Rather than beginning with a finished report, new project data are entered over time as the project work proceeds. Once the project is complete, the final report is issued and uploaded to the system and the project status is changed from active to complete, making the information available to the public. The cataloging program was modified to reflect this workflow, and an additional set of functions was added to track project activities. These included a form to record the dates of completion for project milestones such as completion of drilling or issuance of various documents. This is an extremely useful function for the Branch manager, because from 100 to 200 projects may be active at a given time. Standard reports were designed for various aspects of projects, such as those related to a geologist's or driller's activities, or specific types of projects such as landslide mitigations or structural designs. The manager can now create a report to quickly assess the status of activities to identify impediments to project completion.

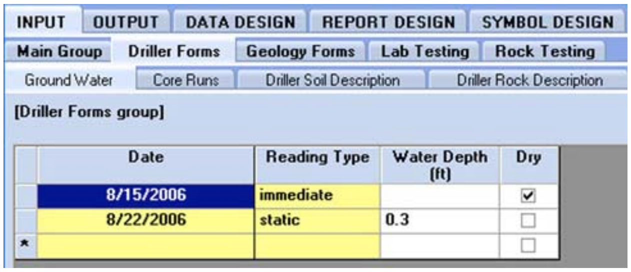
Another function was added that analyzes the catalog to find relationships between projects. For example, planning projects usually precede roadway designs, and a number of bridge and culvert structure designs may relate to a roadway project. This function builds the complete hierarchical relationship tree beginning with any specified project and looking upward and downward in the tree.

BUILDING AN ENTERPRISE DRILLHOLE DATABASE

Almost every KYTC geotechnical study involves drilling holes—rock soundings, soil sample holes, and rock coreholes—to obtain samples for material testing and to visually assess those materials. Structure projects typically require from 2 to 12 holes, whereas roadway projects may have as many as 300 holes. Over 2,300 holes were drilled in 2007, and more than half of those had samples that were laboratory tested. Historically, such drillhole data were used solely for the project on which they were obtained, but given the substantial costs of acquiring the data, KYTC was interested in developing a database that would enable them to reuse data for future projects conducted at nearby locations. A historical database of drilling and testing data would also facilitate characterization of rock and soil intervals over larger areas than are typically studied for site assessments—information that could greatly enhance geologic and soils mapping of Kentucky. Therefore, the third phase of this project was intended to develop an enterprise software system for storing drillhole data and a Web interface for exploring the data to find holes that could be useful for new design projects or for regional analysis.

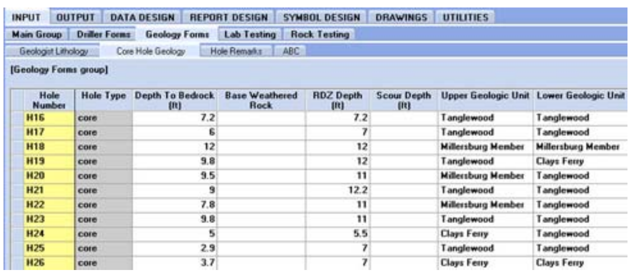
Geotechnical projects are conducted by teams that include engineers, geologists, lab technicians, drillers, and CAD operators. Standards for data collection, analysis, and reporting have been developed over the years at KYTC to maintain consistency in results and report formats. The design requirements for the data entry system included forms that modeled the workflow of team members, and extensive controls to adhere to standard vocabulary, methods, and calculations. Another objective was to minimize data entry by providing functions to import data from external databases, using pull-down menus, and by calculating numerical values programmatically wherever possible. The gINT software suite (www.gintsoftware.com) was selected to develop the data-entry application, because of its capabilities for customization and powerful report development modules. gINT uses Microsoft Access for its data storage format and Visual Basic for Applications for program customization. It includes modules for building data-entry applications, for designing text or graphical output, and for import and export of data. At the time of development for this project, gINT software did not have the capability to build and maintain an enterprise database. It was designed for the consulting industry, which typically performs separate, discrete projects; therefore, each project's data are stored in a separate database. Consequently, PLog Enterprise (http://www.dataforensics.net) was acquired to convert the gINT projects to a SQLServer database for permanent archival and to facilitate the most efficient mechanism of Web distribution.

Project description information is already stored in the project management system described above; therefore, it can be imported directly into gINT to initiate a new database. Similarly, KYTC surveyors are required to prepare a list of hole locations in a standard format so that these data can be imported as well. Once these sets of data are imported, the project manager adds other details about the characteristics of each hole to prepare it for further data entry by team members. Drillers enter information about groundwater levels, core recovery, rock intervals, and soil sample intervals. An example form (Figure 5) shows entry of both immediate and static groundwater readings for a hole. Geologists enter the lithologic data for coreholes and a variety of rock assessments that depend on the type of project. Figure 6 shows depth to rock and RDZ, a parameter related to weathering of rock material, along with geologic unit designations. Finally, lab personnel enter all the results of soil and rock analyses, including moisture, size analysis, California bearing ratio tests, and a variety of strength tests. Figure 7 shows the summary table for soil classifications, in which raw size data are used to derive a variety of soil classifications required for engineering designs.



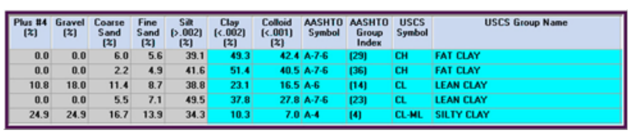
Date	Reading Type	Water Depth (ft)	Dry
8/15/2006	immediate		☑
8/22/2006	static	0.3	☐
			☐

Figure 5. Data-entry form in gINT software, for groundwater readings.



Hole Number	Hole Type	Depth To Bedrock (ft)	Base Weathered Rock	RDZ Depth (ft)	Scour Depth (ft)	Upper Geologic Unit	Lower Geologic Unit
H16	core	7.2		7.2		Tanglewood	Tanglewood
H17	core	6		7		Tanglewood	Tanglewood
H18	core	12		12		Millersburg Member	Millersburg Member
H19	core	9.8		12		Tanglewood	Clays Ferry
H20	core	9.5		11		Millersburg Member	Tanglewood
H21	core	9		12.2		Tanglewood	Tanglewood
H22	core	7.8		11		Millersburg Member	Tanglewood
H23	core	9.8		11		Tanglewood	Tanglewood
H24	core	5		5.5		Clays Ferry	Tanglewood
H25	core	2.9		7		Tanglewood	Tanglewood
H26	core	3.7		7		Clays Ferry	Clays Ferry

Figure 6. Form for entering a geologist's rock evaluations in gINT software.



Plus #4 (%)	Gravel (%)	Coarse Sand (%)	Fine Sand (%)	Silt (>.002) (%)	Clay (<.002) (%)	Colloid (<.001) (%)	AASHTO Symbol	AASHTO Group Index	USCS Symbol	USCS Group Name
0.0	0.0	6.0	5.6	39.1	49.3	42.4	A-7-6	(29)	CH	FAT CLAY
0.0	0.0	2.2	4.9	41.6	51.4	40.5	A-7-6	(36)	CH	FAT CLAY
10.8	18.0	11.4	8.7	38.8	23.1	16.5	A-6	(14)	CL	LEAN CLAY
0.0	0.0	5.5	7.1	49.5	37.8	27.8	A-7-6	(23)	CL	LEAN CLAY
24.9	24.9	16.7	13.9	34.3	10.3	7.0	A-4	(4)	CL-ML	SILTY CLAY

Figure 7. Soil classification form in gINT software, showing soil classifications calculated from raw input data.

Each data-entry form represents a table in the Access database, and may have one or more Visual Basic subroutines assigned that are executed at different times relative to saving the dataset. These procedures are used extensively to validate data entry, to initialize new records in related tables, to perform calculations, and to issue error messages.

Use of the gINT software product allowed KYTC to maintain standardization throughout the database. It also provided a mechanism to enforce standards for projects that are subcontracted to consultants. All consultants are required to use the same software, and KYTC supplies each vendor with a preformatted database that includes the list of holes to be drilled.

The contractors enter the data when holes are completed and return the gINT database to KYTC at the end of the project.

Since the gINT application was completed in early 2007, 200 projects with 3,200 holes have been entered and archived in the KGS SQLServer database using the PLog software. Currently, a system is being implemented that will allow KYTC personnel to remotely upload the completed project files into the KGS database.

The final task of this phase was to develop Web services to search the drillhole database and return a variety of tabular and formatted reports. These services were developed using ASP, and are available to the public (http://kgs.uky.edu/kgsmap/gINT/gINTSearch.asp). Figure 8 is the search form that permits queries ranging from any information for holes drilled by a specific project, to all holes containing a specified soil type. The criteria can be geographic, stratigraphic, the presence of specific soil or rock types, or particular kinds of analyses. The result of a query is a list of all projects that contain at least one hole that met the criteria (Figure 9). The project summary line contains a link to the final report as well as a hole summary report that contains descriptive information and geotechnical values such as depth to rock and allowable bearing capacity. Each project line can be expanded to show a list of holes, and each hole has a page containing links to available reports such as the geologist's log and any soil or rock test results (Figure 10).

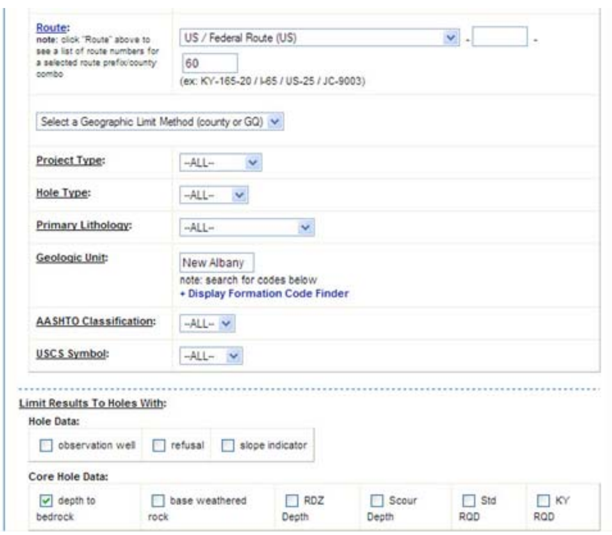
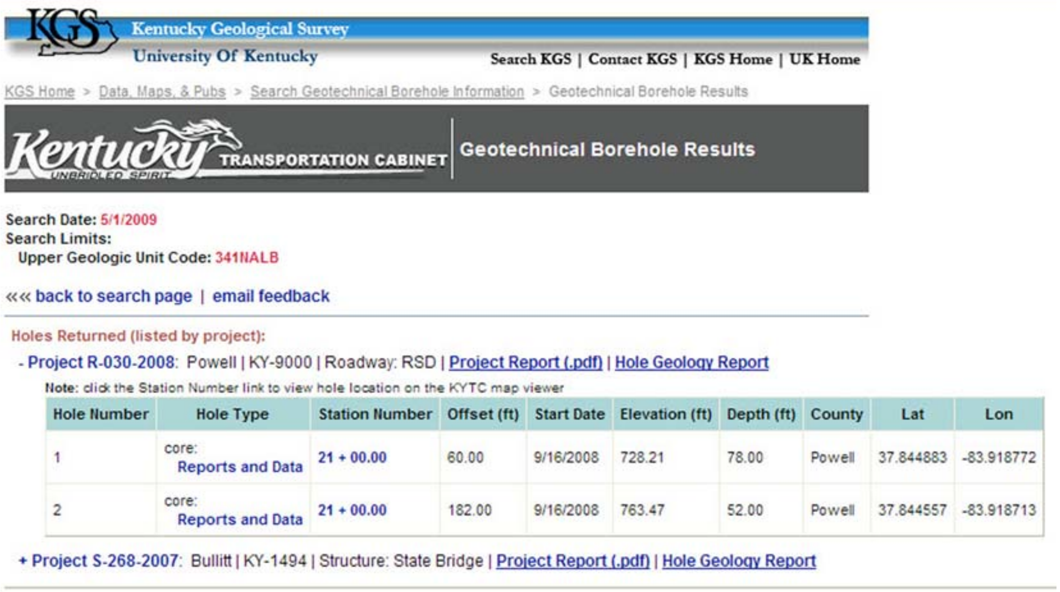


Figure 8. Online search form for finding holes that contain specified kinds of information.



Kentucky Geological Survey
University Of Kentucky
Search KGS | Contact KGS | KGS Home | UK Home
KGS Home > Data, Maps, & Pubs > Search Geotechnical Borehole Information > Geotechnical Borehole Results
Kentucky TRANSPORTATION CABINET | Geotechnical Borehole Results

Search Date: 5/1/2009
Search Limits:
Upper Geologic Unit Code: 341NALB

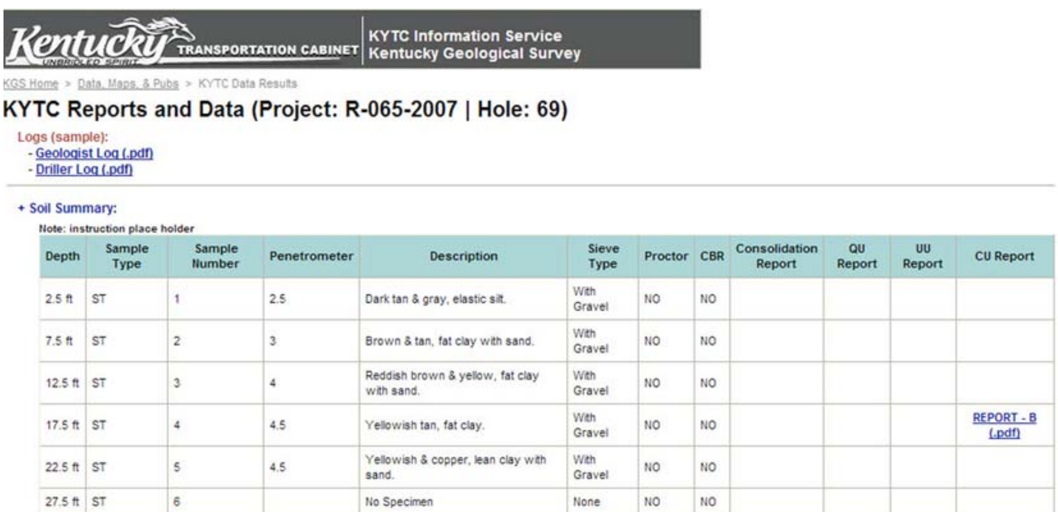
«« back to search page | email feedback

Holes Returned (listed by project):
- Project R-030-2008: Powell | KY-9000 | Roadway: RSD | Project Report (.pdf) | Hole Geology Report
Note: click the Station Number link to view hole location on the KYTC map viewer

Hole Number	Hole Type	Station Number	Offset (ft)	Start Date	Elevation (ft)	Depth (ft)	County	Lat	Lon
1	core: Reports and Data	21 + 00.00	60.00	9/16/2008	728.21	78.00	Powell	37.844883	-83.918772
2	core: Reports and Data	21 + 00.00	182.00	9/16/2008	763.47	52.00	Powell	37.844557	-83.918713

+ Project S-268-2007: Bullitt | KY-1494 | Structure: State Bridge | Project Report (.pdf) | Hole Geology Report

Figure 9. Primary search result report, listing all projects that met the hole search criteria.



Kentucky TRANSPORTATION CABINET | KYTC Information Service
Kentucky Geological Survey
KGS Home > Data, Maps, & Pubs > KYTC Data Results

KYTC Reports and Data (Project: R-065-2007 | Hole: 69)

Logs (sample):
- Geologist Log (.pdf)
- Driller Log (.pdf)

+ Soil Summary:
Note: instruction place holder

Depth	Sample Type	Sample Number	Penetrometer	Description	Sieve Type	Proctor	CBR	Consolidation Report	QU Report	UU Report	CU Report
2.5 ft	ST	1	2.5	Dark tan & gray, elastic silt.	With Gravel	NO	NO				
7.5 ft	ST	2	3	Brown & tan, fat clay with sand.	With Gravel	NO	NO				
12.5 ft	ST	3	4	Reddish brown & yellow, fat clay with sand.	With Gravel	NO	NO				
17.5 ft	ST	4	4.5	Yellowish tan, fat clay.	With Gravel	NO	NO				REPORT - B (.pdf)
22.5 ft	ST	5	4.5	Yellowish & copper, lean clay with sand.	With Gravel	NO	NO				
27.5 ft	ST	6		No Specimen	None	NO	NO				

Figure 10. Summary of soil samples for a single drillhole, with links to online reports containing analytical results.

INTEGRATING GEOTECHNICAL DATA WITH GEOLOGIC MAPS

Future additions to this system will include search functions to return tabulated test results of specified parameters for regional analysis and modeling. For example, all strength tests for clay soil types could be extracted to facilitate comparison to mapped soil or geologic units. Because all the holes are geographically referenced in the database, it will be possible to integrate information from these holes with the statewide geologic map database developed from Kentucky's 7.5-minute geologic map series. This online, interactive geologic map site (http://kgs.uky.edu/kgsmap/KGSGeology) has the ability to display derivative classifications of geologic units. The availability of this extensive geotechnical data will provide opportunities to add new classifications that will facilitate the use of geologic maps by engineers.