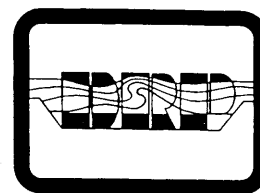




# *Dredging Research Technical Notes*



## **GEOtechnical SITE Investigation Methods (GEOSITE)**

### **Purpose**

This technical note describes a knowledge-based expert system (KBES) computer program, "GEOtechnical SITE Investigation Methods" (GEOSITE), which was developed as part of the U.S. Army Engineer Waterways Experiment Station's (WES) Dredging Research Program. GEOSITE is intended to provide guidance to geotechnical engineers, engineering geologists, and others in the selection of sampling and testing equipment *for use at a single exploration site* during a subsurface investigation for a dredging project.

### **Background**

Geotechnical engineers plan and execute site investigations for a dredging project. Dredging project subsurface investigations differ in many respects from the typical foundation engineering investigation. Turnovers in personnel, or changes in their assignments, mean that geotechnical engineers who are inexperienced in dredging works can become involved in the subsurface investigation. The knowledge of the more experienced geotechnical engineers is often not adequately transferred and is usually lost on retirement or position change. There is a continuing need for guidance and training of those persons lacking experience in the dredging-related investigations. For this reason, it is desirable to retain expertise and make it available for use by the less experienced workers.

Expert systems are computer programs capable of providing the necessary vehicle for recording the accumulated knowledge and experiences of experts, in any specific discipline, in a knowledge base and providing for interaction between the user and the knowledge base. Inexperienced personnel can learn from the guidance program. Also, knowledgeable and experienced personnel can benefit from consultation with their peers for review and as a check of their own work.

## **Additional Information**

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## **Knowledge-Based Expert Systems**

A KBES such as GEOSITE uses expertly derived rules for its solutions. The rules can incorporate and process judgment, experience, empirical rules of thumb, intuition, and other expertise as well as proven functional relationships and experimental evidence. The knowledge base contains a database of facts and a series of IF - THEN rule statements that include all of the questions a typical user may ask. The control system for searching the knowledge base (the inference engine) for GEOSITE is independent of the knowledge base, permitting simple modifications and additions to the answers contained in the knowledge base without modifying the program.

During a guidance session, a KBES searches the knowledge base through the chain of IF - THEN rule statements. The logic of the IF statements can be modified by using such modifiers as AND, OR, or NOT, and the arguments can be either English words or phrases or numbers. For each question, the user selects from a menu of possible answers, sometimes limited to a simple YES or NO. The menu may even include a term such as "Unknown" or "Don't know." The path through the matrix of rules is not predetermined; rather, the path depends on the specific questions and on the generated replies that lead to the next question.

When all of the prerequisite questions have been asked, the answers are used to filter the knowledge base, ruling out all inapplicable IF - AND - OR - NOR statements, searching for the appropriate solution or group of solutions. The net effect is one of having an expert in a field answering the questions, each answer presumably leading the user to the next question until the appropriate solution is reached.

At any time during the guidance sessions, the user may view a text discussion of any of an extensive list of GEOSITE topics and then return to the guidance session. The discussions present the rationale for a suitability rule and other topics that may be helpful in understanding the recommendations.

Two equivalent versions of GEOSITE have been developed, both operating within the Microsoft FoxPro 2.5 Relational Database Management System. The DOS version operates in the conventional MS-DOS character-based

environment. The Windows version runs in the Microsoft Windows or OS/2 graphical environment. The knowledge base, the content of the user interface screens, and the inference engine (control programs) for both versions are identical. Both versions are user friendly and support mouse input. This practically eliminates the need for the user to type words for data input during guidance sessions; only numbers and mouse-pointer selections from input menus are needed. This should greatly facilitate the use of the system by nontypists.

In the present version, the rules developed for GEOSITE (Spigolon and Bakeer 1993) represent the knowledge and expertise of the authors that was developed through professional experiences and research studies and therefore reflect their personal biases. In future upgrade versions of GEOSITE, the present rules are expected to be critically reviewed once again by a group of geotechnical engineering and dredging experts, and expanded or modified as needed. In the ideal knowledge base, there are multiple experts who either reinforce each other or present valid alternate solutions to problems.

## **Geotechnical Properties Affecting Dredgeability**

The objective of a geotechnical site investigation for a dredging project is to obtain the most complete and accurate estimate of the location, description, and dredgeability properties of the materials to be dredged that is possible within the limits of practicality and available time and money. The geotechnical properties needed for a complete and adequate evaluation of the dredgeability properties are (Spigolon 1993):

- In situ shear strength—defined in terms of consistency, compactness (relative density), or cementation.
- Grain size distribution—including maximum size, median size, and amount of fines.
- Angularity of coarse grains.
- Plasticity of fine grains—based on the Atterberg limits.
- Organic content—ash content or other indicator.
- Presence of shells, debris, or other nonsoil materials.

## **Description of the GEOSITE Program**

GEOSITE provides guidance in the selection of methods and equipment, for use at a single exploration site, for four different objectives in a site exploration program (Spigolon and Bakeer, in preparation):

- **Regular (Complete) Investigation.** Selection of sampling and testing methods for in situ strength and material identification properties.

- **Limited to Density Testing Only.** Selection of field sampling and testing methods for in situ density only.
- **Limited to Finding Rock Surface Only.** Selection of methods useful in the search for the surface of a hard layer or rock below soil overburden.
- **Limited to Material Identification Tests Only.** Recommended laboratory and/or field-expedient tests for material identification properties.

In addition to an objective, GEOSITE also must know the type of sediment to be expected. This information must come from a literature review or desk study, that is, the research of all pre-existing (prior) geological and geotechnical information about the site. GEOSITE is limited to one sediment type per guidance session. If more than one sediment type is expected to be present, each deposit must be evaluated separately and the recommendations combined into a coherent plan for that site. The knowledge base for all objectives is restricted to eight sediment types plus shells, debris, and UNKNOWN:

- Fluid mud.
- Highly organic soil.
- Cohesive soil.
- Friable mixed-grain soil.
- Clean granular (cohesionless) soil.
- Boulders and cobbles.
- Shale or cemented soils.
- Rock or coral.
- Unknown (soil or rock).

If UNKNOWN is chosen, GEOSITE displays a message directing the user to obtain more complete information before continuing.

### **Objective—Regular (Complete) Investigation**

If the REGULAR (Complete) INVESTIGATION objective is chosen and a specific sediment type is selected, the program proceeds in sequence through the selections of the following queries:

- Sampling Query—suitable sampling methods for the sediment type.
- Testing Query—strength testing methods suitable for the sediment type and sampling method.
- Access Query—methods for accessing (reaching) the sampling/testing depth.

- Platform Query—work platforms for personnel and equipment.
- Material Tests Query—suitable material identification tests.

The program can be used repeatedly to investigate the suitability of any combination of sediment types, sampling methods, and strength testing methods. Provision has been made for printing a report of the strength testing methods suitable for any combination of sediment type and sampling methods.

**Sampling Query.** For the selected sediment type, the SAMPLING knowledge base is queried for the suitability of each of a fixed list of eight samplers in the *Sampling Query*:

IF            Sediment type is:  
THEN        What is the suitability of each of the following SAMPLING methods?

Undisturbed, thin wall tube sampler  
Undisturbed, core barrel sampler  
Disturbed, split-tube drive sampler  
Disturbed, gravity projectile sampler  
Disturbed, vibrating tube sampler  
Disturbed, bucket auger sampler  
Disturbed, surface grab sampler  
Disturbed, powered scoop sampler

The results are shown on the SUITABILITY OF SEDIMENT SAMPLERS screen, which displays each sampler name and its suitability for the selected sediment type. Perhaps all of the sampling methods are suitable or, perhaps, some are not. The suitability of each is given in a short message; some are marked NOT SUITABLE. Further discussion of the various samplers is given in the DISCUSSION screens. One of the sampling methods is chosen for further guidance in suitable testing methods.

In the unique case of fluid mud, a special screen displays the sampling method and strength testing methods suitable for that consistency and composition of material.

**Testing Query.** For the selected sediment type and the chosen sampling method, the TESTING knowledge base is queried for the suitability of each of a fixed list of 18 strength testing methods in the *Testing Query*:

IF            Sediment type is:  
THEN        Which of the following STRENGTH TEST methods are suitable for the sediment type?

Field, standard penetration test (SPT)  
Field, static cone penetration test (CPT)  
Field, vane shear test of cohesive soil

Field, dynamic penetrometer test, thick wall tube  
 Field, dynamic penetrometer test, solid cone  
 Field, penetration rate of vibrating tube corer  
 Field, deceleration rate of gravity projectile  
 Field, hand-held sounding rod test  
 Laboratory, compression test of undisturbed cohesive sample  
 Laboratory, vane shear test of cohesive sample  
 Laboratory, compression test of thick wall tube cohesive sample  
 Laboratory/field, hand penetrometer/Torvane test of cohesive sample  
 Laboratory, direct shear test of redensified sand sample  
 Field, drilling parameter recorder test  
 Field, diver-operated rebound hammer test of rock  
 Laboratory, unconfined compression test of rock core  
 Laboratory, splitting tensile test of rock core  
 Laboratory/field, point load test of rock core

Each combination of sediment type and sampling method has one or more test methods that are suitable for measuring or estimating in situ strength. GEOSITE selects *all of the suitable in situ strength test methods* from among the 18 methods listed above, 13 pertaining to soils and 5 to rock, and displays them on three METHODS FOR TESTING IN SITU STRENGTH screens—field soils tests, laboratory soils tests, and tests of rock. Those that are not appropriate are marked “NOT SUITABLE.”

No attempt is made on the testing guidance screens to recommend one method over another. However, two judgment factors are given for each test method: a confidence factor and a utility factor. A *confidence factor* is defined as the relative accuracy and precision of a strength testing method compared to the other methods in the group. A *utility factor* is defined as the relative efficiency of a testing device in terms of time and money expended, including difficulty of mobilization of equipment at the site, time for making a test, complexity of test method, and need for securing a sample using a different device.

**Access Query.** For any chosen combination of sediment type, strength testing method, and sampling method, each of six general methods of accessing the sampling/testing depth is evaluated in the ACCESS knowledge base using the *Access Query*:

IF	Sediment type is:
AND	Strength testing method is:
AND	Sampling method is:
THEN	What is the suitability of the following methods of ACCESSING the sampling/testing depth?
	Surface sample or test
	Machine-dug pit or trench

Cased boring, machine operated  
Cased boring, hand operated  
Hollow stem auger, machine operated  
Self-penetrating sampling/testing device

The suitability of each of the six access methods is shown on the METHODS FOR ACCESSING SAMPLING AND TESTING DEPTH screen. One group of test methods listed in Testing Query above includes devices that are self-penetrating, that is, for which no boring or pit is needed. Their suitability is grouped under the general heading "Self-penetrating sampling/testing devices."

**Field Work Platform Query.** Selection of any of the suitable general testing/sampling access methods leads to the suitability of various types of field work platforms. Evaluation of work platform suitability also involves consideration of the water roughness and current velocity. These are selected from among the choices given on the WATER CONDITIONS AT THE SITE screen. Water depth was not considered a significant factor because, at present, dredging site investigations are rarely done in water over 15 m deep.

GEOSITE then determines the suitability of various types of field work platforms from the PLATFORM knowledge base using the *Platform Query*:

IF           Method of accessing sampling or testing depth is:  
AND        Water roughness is: (calm, rough)  
AND        Current speed is: (slow, fast)  
THEN       What is the suitability of the following types of FIELD WORK  
            PLATFORMS?

Bottom supported surface platform  
Bottom supported submersible platform  
Ship, with swell-compensating devices  
Small boat or barge  
Diver, operating from surface vessel

Guidance concerning these platforms is shown on the SUTABILITY OF PLATFORMS FOR SAMPLING AND FIELD TESTING screen.

**Material Identification Tests Query.** Finally, the selected sediment type is used to query the MATTEST (materials testing) knowledge base using the *Matttest Query*:

IF           Sediment type is:  
THEN       What is the suitability of the following MATERIALS TESTS?

Visual-manual cohesive soil tests  
Visual-manual granular soil tests  
Coarse grain sizes (mechanical sieve analysis)

Fine grain sizes (hydrometer, decantation, pipette)  
Atterberg limits  
Ash content test for organics  
Water content  
Specific gravity of grains

The suitability of each of eight common, standardized methods for determining the identification properties of the sediment listed above is shown on the APPROPRIATE MATERIALS IDENTIFICATION TESTS screen.

This completes the guidance for a chosen combination of sediment type, test method, sampling method, and access method for the "Complete Investigation." At any time during the conduct of the guidance session, the user may return to any of the previous screens to modify any of the choices and pursue a different combination of testing method, sampler, and access method.

### **Objective—Limited to Density Testing Only**

If the LIMITED TO DENSITY TESTING ONLY objective is chosen and a specific sediment type is selected, the DENSITY knowledge base is queried for the suitability, for that sediment type, of each of six methods, as shown in the *Density Query*:

IF            Sediment type is:  
THEN        What is the suitability of each of the following FIELD  
              DENSITY TEST methods?

Field, geophysical acoustic impedance  
Laboratory, undisturbed tube sample  
Laboratory, drilled rock core  
Laboratory, resuspended density of sand  
Field, static nuclear gauge probe  
Field, towed nuclear gauge

GEOSITE evaluates the sediment type, and the suitability of each of the six methods is shown on the METHODS FOR MEASURING IN SITU DENSITY screen.

### **Objective—Limited to Finding Rock Surface Only**

If the LIMITED TO FINDING ROCK SURFACE ONLY objective is chosen and a specific sediment type is selected, the ROCKSURF knowledge base is queried for the suitability, for that sediment type, of each of five methods using the *Rock Surface Query*:

IF            Sediment type is:  
THEN        What is the suitability of each of the following methods for locating  
              the ROCK SURFACE?



Geophysical—acoustic impedance, seismic, or equivalent  
Dynamic penetrometer—SPT, thick wall tube, solid cone, or  
similar  
Static penetrometer—CPT or similar  
Hand-held sounding rod, water jet, or similar  
Penetration rate of vibrating tube corer, or similar

GEOSITE evaluates the sediment type, and the suitability of each of the five methods is shown on the METHODS FOR LOCATING ROCK SURFACE screen.

### **Objective—Limited to Material Identification Tests Only**

If the LIMITED TO MATERIAL IDENTIFICATION TESTS ONLY objective is chosen and a specific sediment type is selected, all other queries are bypassed and the MATTEST knowledge base is queried directly for the suitability, for that sediment type, of each of the eight common, standardized methods for determining the identification properties of the sediment shown above for the *Mattest Query*. GEOSITE evaluates the sediment type, and the results are shown on the APPROPRIATE MATERIALS IDENTIFICATION TESTS screen.

### **Commentary**

GEOSITE, as with all KBES-type programs, increases in knowledge and has the capability of growing and improving with time. The present version of GEOSITE represents the knowledge, experience, and biases of the authors. As users develop expertise in the use of GEOSITE, they may find valid reasons for changing parts of the knowledge base or the interactive screens. Comments and suggestions submitted to the Manager of the Dredging Research Program will be considered for use in future versions.

### **References**

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