DREDGABL AND GEOSITE: KNOWLEDGE-BASED EXPERT SYSTEM GEOTECHNICAL DECISION SUPPORT TOOLS FOR DREDGING

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ABSTRACT

This paper discusses two Knowledge-Based Expert System (KBES) / Decision Support System (DSS) tools entitled "Geotechnical Factors in DREDGeABiLity" (DREDGABL), and "GEOtechnical SITE Investigation Methods" (GEOSITE). Both tools were originally developed in 1990's by the U.S. Army Corps of Engineers (USACE) Dredging Research Program (DRP) for Microsoft Windows® 3.2 and MS-DOS® based platforms. They were subsequently used on fairly limited basis by the USACE and some dredging consultants. The original version of DREDGABL has been recently upgraded by the USACE Dredging Operations and Research (DOER) Program to operate under present Windows platforms (XP, etc.). GEOSITE is currently being upgraded for release in 2010. This paper focuses on the design and use of DREDGABL, but also presents a general overview of GEOSITE. DREDGABL offers the dredging community with a geotechnical engineering "*electronic consultant*" capable of providing guidance relative to the suitability of various types of dredging platforms to specific sediment types whose properties are described in the contract documents from a geotechnical viewpoint (their *dredgeability*). This is defined as the ease with which an underwater soil or rock can be excavated, removed, transported, and disposed off with respect to known or assumed equipment, methods, and in-situ material characteristics. It is also capable of preserving any local knowledge gained from previous dredging projects. GEOSITE provides guidance to geotechnical engineers, engineering geologists, and others relative to the selection of testing and sampling equipment for use in developing a subsurface investigation for dredging projects. Sediment descriptions utilized by both programs are those given in the Unified Soil Classification System (USCS) and American Society for Testing and Materials (ASTM D-2488). However, the KBES package does not provide guidance relative to environmental aspects of dredging and disposal, cost estimates, production rate, recovery volumes, etc

Keywords: KBES, DSS, dredging, geotechnical investigation, dredgeability.

INTRODUCTION

Geotechnical engineers typically plan and conduct subsurface investigations for dredging projects. They describe the physical properties of the sediments that are likely to be present within the dredging prism and provide pertinent geotechnical information to all interested parties. Dredging personnel (dredgers), whether the government's or owner's estimators, planners or the contractor's staff, use the furnished geotechnical information in their estimating and planning. The geotechnical engineers, when designing and executing the site investigation may not be fully aware of the type of information that the dredgers need relative to the sediments to be dredged. Work turnovers in personnel, or changes in their assignments, means that dredging-inexperienced geotechnical engineers may design and execute subsurface investigations and testing of the sediments for dredging projects.

The dredging-related knowledge of the more experienced geotechnical engineers is often inadequately transferred or lost due to retirements or position changes. Dredgers often do not fully understand geotechnical data, and its limitations, in the manner that it has been presented and the expertise of those who do may also be lost through turnovers or retirements. Geotechnical engineering descriptions do not necessarily infer "*dredgeability*" directly any more than they indicate foundation or earthwork behavior properties. All require analysis and interpretation. This leads to possible misinterpretation of sediment-related risks, leading to higher bids, and is occasionally the source for costly claims. Therefore, there is a continuing need for guidance and training for those who are lacking knowledge and experience in dredgeability. For this reason, it is desirable to preserve the expertise of capable personnel involved in

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dredging-related fields and make their knowledge readily available for use by less experienced personnel. Also, knowledgeable and experienced personnel can benefit from consulting with their peers for review and cross-checking.
Decreasing fiscal and manpower resources, current and projected increasing workload, and mounting environmental constraints are presenting the U.S.Army Corps of Engineers (USACE) with challenges to achieve its navigation mission. As per General Don T. Riley (2009) "Our workload is three times the level of 10 years ago, but our workforce is 20 to 30 percent smaller." The Dredging Operations and Environmental Research (DOER) Program supports the USACE Operation and Maintenance Navigation Program with research designed to balance operational and environmental initiatives and to meet complex economic, engineering, and environmental challenges of dredging and disposal in support of the navigation mission. Research results provide dredging project managers with technology for cost-effective operation, evaluation of risks associated with management alternatives, and environmental compliance. In support of DOER objectives, framed by the conditions in which the USACE navigation program is currently operating, two knowledge-based expert systems, DREDGABL and GEOSITE are being upgraded for use by the dredging community. This paper discusses the design and operation of DREDGABL, and presents an overview of GEOSITE.

THEORETICAL BACKGROUND

Knowledge-Based Expert Systems (KBES) and Decision Support Systems (DSS) are branches of Artificial Intelligence (AI) computer technology. AI computer software mimics the logic used by human brains both subjectively and objectively. A KBES provides the necessary vehicle to: (1) preserve the accumulated knowledge and experience of experts in a given field in a knowledge base, and (2) provide a friendly interface between the user and the knowledge base. A DDS provides guidance and support information for decision makers. Both KBES and DSS software use expert-derived rules (if-then type) in their reasoning. 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. There are two primary tasks used by the developers in *building of the knowledge* included in a KBES. The first is that of persons with expertise in coding user-friendly knowledge-based expert systems, called *knowledge engineering expert.* The second is that of the *domain* experts, the contributors to the knowledge base itself. In this case, it refers to geotechnical engineers and dredgers knowledgeable and experienced in dredging operations, simply referred to as the *geotechnical engineering and dredging experts*. In the ideal knowledge base, there are multiple experts who reinforce each other opinions, present valid alternate solutions or, occasionally, conflict.

The KBES/DSS package (DREDGABL and GEOSITE) discussed herein was developed in the 1990's (Spigolon and Bakeer, 1993 and 1994) under the technical oversight of Dr. Jack Fowler of the USACE Waterways Experiment Station (WES) as part of a work unit of the Dredging Research Program (DRP). These programs have been used on fairly limited basis by the USACE and by some dredging consultants. The objective of that specific DRP work unit was to develop standard dredging-related geotechnical descriptors to indicate, or infer, dredgeability of sediments. Earlier studies of the work unit included a literature review to establish the needed type and form of geotechnical descriptors which indicate, or infer, dredgeability of sediments (Dunlap 1989; Spigolon and Fowler 1988 and 1989; Spigolon 1989); and to define a geotechnical site investigation strategies for dredging projects that would provide the necessary geotechnical descriptors (Spigolon and Fowler 1990; Spigolon 1990). Therefore, the KBES/DSS package discussed in this paper was developed to encapsulate the earlier work by the DRP unit into an "*electronic consultant*" that could simulate guidance of experts in their respective fields given to;

- Geotechnical Engineers: for use in planning and execution of subsurface investigations for dredging project (GEOSITE), and
- Dredging Estimators and Planners: for use in interpreting geotechnical site investigation data in terms of classification and dredgeability (DREDGABL).

GEOSITE and DREDGABL were developed utilizing the combined expertise of a research team that included a college professor, a consultant engineer, and a government research engineer. Additional information was also obtained from published research and technical reports. The rules used in GEOSITE were primarily compiled from references such as geotechnical textbooks and unified standards such as the USACE technical manuals and engineer manuals, ASTM and the USCS. However, some reasoning was included in the inference engine of GEOSITE. The original rules coded in the prototype version of DREDGABL represented the extensive personal experiences of the research team including the earlier literature review conducted under this DRP unit. Consequently, the coded KBES rules may reflect some personal bias. Therefore, the rules used in a prototype version of the software were critically reviewed by other geotechnical engineering and dredging experts and expanded or modified, as needed. Additional knowledge was compiled through personal interviews with national experts from the government and dredging industry as well as through workshops organized by WES in different cities that included hands-on experience with using GEOSITE and DREDGABL. The KBES package is intended to serve the planner or estimator as a personal geotechnical engineering and dredging electronic consultant. Because of the knowledge base concept, there is practically no terminal point for the programs. Like a human brain, the knowledge base can increase with time as more experts add their knowledge to the system. A database is available in DREDGABL to compile local information collected by the users for use in future projects.

The original version of DREDGABL was developed using Microsoft FoxPro for Windows® 3.2 and MS-DOS® platforms. It was subsequently upgraded to operate on recent Windows platforms (XP, etc.) by the Dredging Operations and Research (DOER) Program, and GEOSITE is currently being upgraded for release in 2010. The dredging KBES programs can serve a continuing need in one or more of these three situations:

- As a guide, or computerized mentor, for those persons lacking knowledge and experience in dredgeability analysis of geotechnical data, or geotechnical site investigations for dredging projects.
- As an educational aid in the training of new dredging project planners, estimators, administrators, and operators, or for geotechnical engineers and engineering geologists becoming involved in dredging subsurface investigations.
- For peer review, where knowledgeable and experienced personnel can consult with other experts for review, and as a check on their own work.

The KBES DREDGABL serves as a geotechnical engineering consultant to provide guidance regarding the suitability of various types of dredging equipment for specific sediment types whose properties are described in the contract documents. Only for the purpose of these programs, the term "sediment" is used to describe all bottom materials to be dredged, including unconsolidated sediments (soil) and hard materials (cemented soils, rock, coral, etc.). This suitability (in the respective geotechnical conditions) is presented within the context of the sediment dredgeability, defined as the ease with which an underwater soil or rock can be excavated, removed, transported, and deposited with respect to known or assumed dredging equipment, methods, and in-situ material characteristics (Spigolon and Bakeer, 1993).

DREDGABL

Geotechnical engineers typically describe the physical properties of the sediments that are present within the dredging prism using the USCS/ASTM. Dredging-related personnel use the furnished geotechnical information to estimate and plan dredging projects. There is, then, a continuing need for the guidance and training of those persons lacking knowledge and experience in the dredgeability analysis of geotechnical data. For this reason, it is desirable to retain the expertise of the capable persons involved in dredging-related fields and make it available for use by the less experienced workers. Also, knowledgeable and experienced personnel can derive considerable benefit from consultation with their peers for review and as a check on their own work. One very effective manner for retaining knowledge and making it available to prospective users is via KBESs. The objective of DREDGABL is to provide guidance for dredging estimators and planners, from geotechnical and dredging experts, for interpretation of geotechnical site investigation data in terms of dredgeability. This program utilizes the geotechnical information provided by the user to evaluate the dredgeability of the samples described or recorded in a project database.

Several independent, site-specific factors affect dredgeability. DREDGABL considers only the direct effect of soil type and character on dredgeability, separate from all non-sediment factors that affect dredging productivity, such as equipment characteristics, water depth, weather, tides, marine traffic, personnel problems, equipment maintenance, and so forth. However, it does not provide guidance relative to environmental aspects of dredging and disposal, cost estimates, production rate, recovery volumes, etc.

The process of dredging underwater sediment typically occurs in four stages as coded in DREDGABL. *Dislodgement* is loosening or excavation of material from its location at or below the sediment surface. *Removal* is the movement of the excavated material from the bottom up to the pump or transport system. *Transport* is movement of the removed material from the dredge to the placement or disposal site. *Disposal* is the discharge of the material within a land area or into a water placement or disposal area. The term *Dredgeability* is defined as the ease with which an underwater soil, sediment, or rock can be excavated, removed, transported, and deposited with respect to known or assumed equipment, methods, and in-situ material characteristics.

The dredgeability properties associated with each stage as coded in DREDGABL are:

- The *dislodgement* (excavation) suitability of the various dredge types is based on the *suctionability, erodibility, cuttability, scoopability,* and *flowability* (underwater slope instability) properties of the dredged sediment.
- The removal and transport suitability of the various dredge types is based on the *pumpability*, abrasiveness, stickiness (affects clay balling), turbidity, sedimentation rate, and bulking properties of the sediment.
- The disposal area properties of the sediment are based on its *dumpability* (stickiness), turbidity, sedimentation rate, amount of bulking, and *compactability*.

Meanwhile, the geotechnical properties needed for an adequate evaluation of the dredgeability properties listed above are (Spigolon 1993):

- *In-Situ* shear strength defined in terms of relative consistency, compactness, or rock compressive strength.
- 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 non-soil materials.

The foregoing dredgeability properties geotechnical properties listed above form the main logic used in the development of the KBES package. DREDGABL starts with the assumption that the available sediment geotechnical descriptor data are contained in the project plans and specifications in ASTM D-2488 format which is based on the USCS (USAEWES 1960). The flow of the program through the group of display screens is shown on Figure 1. Briefly, the overall strategy of DREDGABL is:

- The first question requests the general type of sediment in the layer or deposit being evaluated. The general sediment type is defined as the predominant material found in the sediment to be dredged, or as the material corresponding to the median grain size, d_{50} as per USCS/ASTM.
- If the sediment type is gravel or sand, DREDGABL requests the USCS/ASTM classification, sediment name, compactness, gradation fineness, and grain angularity.
- If the sediment type is inorganic fines or organic fines, DREDGABL requests the USCS/ASTM classification, sediment name, consistency, and plasticity index. If the consistency is UNKNOWN, and the water content is known or the wetness known, then it may be possible to estimate the consistency from the Liquidity Index.
- If the sediment type is in the other sediments category, then only the sediment name is required to identify the material. Properties of these materials may vary significantly and there are no specific designations for them either in USCS/ASTM.
- After all required antecedents are defined (including the possible choice of "Unknown" in any category), DREDGABL evaluates this information and searches the knowledge base for conclusions about the dredgeability properties of the uniquely described sediment.
- The user may then display DREDGABL's conclusions about the suitability of various generic types of hopper, mechanical, and pipeline dredges for use with the described sediment, or may display the disposal area properties. The user may also choose to print out the complete set of conclusions for the specific sediment.
- Provision has been made in DREDGABL for recording of information and knowledge about, and experiences with, local sediments that have been developed by the user's organization. This is locally-derived information that amplifies or supersedes the information contained in the general knowledge base. The LOCAL INFO database may be viewed and the contents of any memorandum may be printed.

The present version of DREDGABL considers only one sediment type at a time in its evaluation of the suitability of various dredging platforms for that type sediment. Therefore, the user must run DREDGABL again for each sediment or deposit within the dredging prism having a unique set of properties. Subsequently, the most suitable dredging plant, or alternates, could be identified based on the set of individual searches.

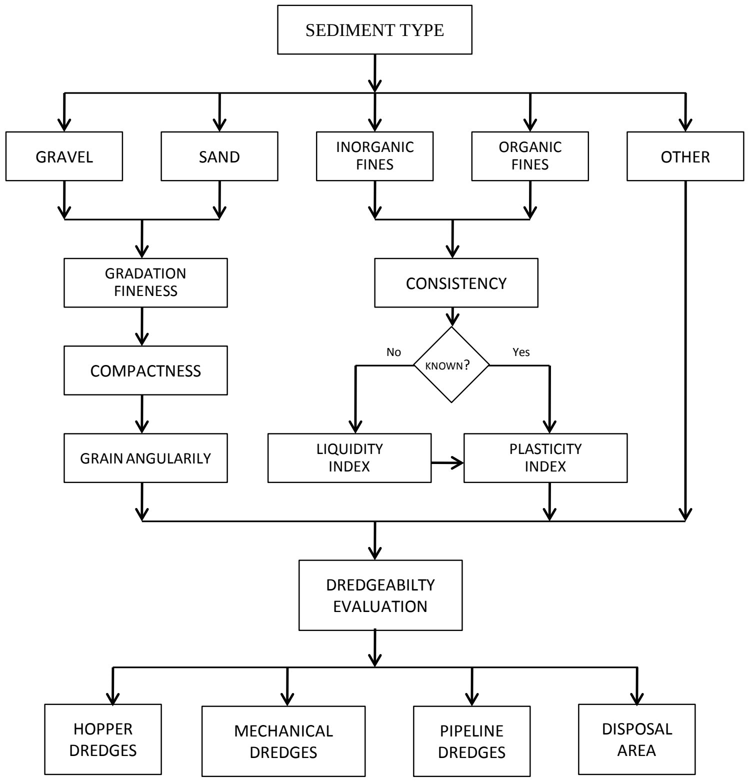

Figure 1. Flow diagram of DREDGABL screen displays (Spigolon and Bakeer, 1994).

Navigating DREDGABL

The following semi-tutorial presentation presents examples of the various input and conclusion screens contained in DREDGABL. It essentially follows each of the several paths shown in Figure 1. The user interacts with DREDGABL through a series of display screens. Figures 2 through 13 show executed screens captured during typical DREDGABL runs. The following four groups of screens are used:

- Introductory displays (Title, Navigating Information, Purpose, Scope, and Disclaimer).
- Input displays (Evaluation and Local Info).
- Conclusion displays.
- Text and graphical explanation (Discussion) displays.

As shown on the flow diagram on Figure 1, the display screens from "Sediment Type" downward to "Dredgeability Evaluation" are DATA INPUT displays. Each input display contains a question asking for the value of one of the geotechnical parameters needed to reach the conclusions about the dredgeability of that sediment. Selections made in each of the input displays are maintained in Context Memory until all of the needed antecedents for a specific sediment type are defined. On the first data input screen, shown in Figure 2, the question posed by DREDGABL is: "Which of the following GENERAL SEDIMENT types best describes the layer or deposit being evaluated?" The screen presents the following choices, one of which must be selected to continue:

- Gravel USCS/ASTM Classification gravel-series soils.
- Sand USCS/ASTM Classification sand-series soils.
- Inorganic Fines Fine-grained soils: silt and clay.
- Organic Fines Fine-grained soils: organic silt, organic day, peat.
- Other Sediments Rock, coral, shale, cemented soils, boulders, cobbles, fluid mud, shells, debris.

The geotechnical antecedent properties used by the DREDGABL program are shown in Table l.

Table 1. Geotechnical antecedent properties used in DREDGABL.

Sediment Type	Geotechnical Properties Used
Gravel Sand	1. USCS/ASTM Classification 2. Sediment Name 3. Gradation Fineness 4. Relative Compactness 5. Grain Angularity
Inorganic Fines Organic Fines	1. USCS/ASTM Classification 2. Sediment Name 3. Relative Consistency 4. Plasticity Index 5. Liquidity Index (an estimator of consistency, used ONLY when the relative consistency is unknown)
Other Sediments	Generic Name of Sediment

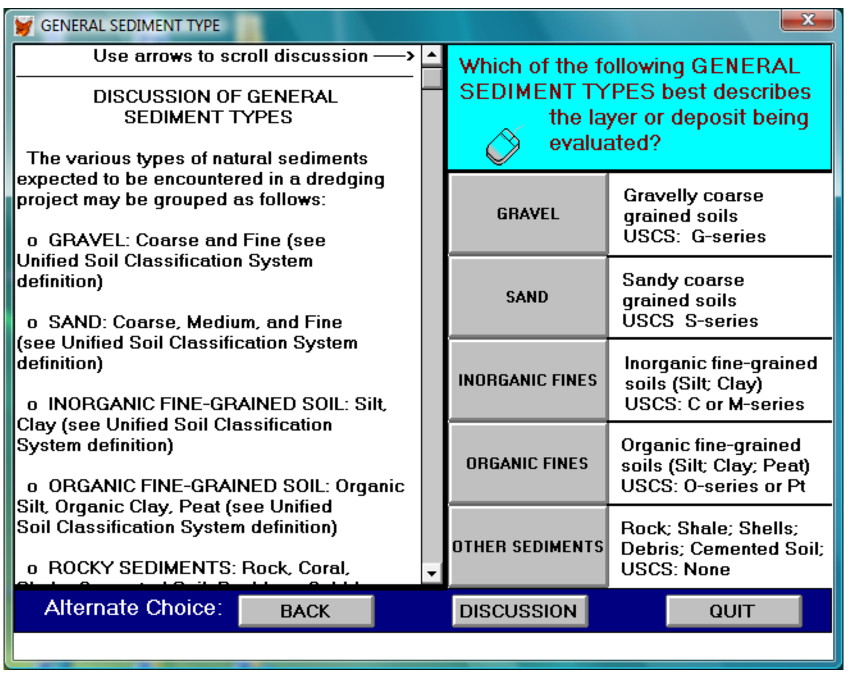

Figure 2. Sediment type selection screen.

If the sediment type is gravel or sand, the next input display asks for the USCS/ASTM Classification. Options are presented for all of the USCS/ASTM classes of each coarse-grained sediment type, as shown in Figure 2. Assuming the sediment type is SAND, then a selection must be made in Figure 3, from the sand classification options offered by the USCS/ASTM. A similar screen is used for gravel. If the sediment type is gravel or sand, the next input display asks for the gradation fineness. For gravel, this includes: Coarse, Fine, and Unknown. For sand, the options are: Coarse, Medium, Fine or Unknown. The gradation fineness display for sand is shown in Figure 4. In all displays, a discussion of the question is displayed on the left hand side of the screen. In this case, on-screen discussion text offers guidance on gradation fineness of gravel and sand. Detailed information of the information and logic contained in the knowledge base could be viewed by clicking on the DISCUSSION button which displays the software library indexed by topic.

The screen shown in Figure 5 requests the relative compactness (density) of coarse-grained sediment. One of the choices is "Unknown." Standard Penetration Test (SPT) blow count values are shown for reference. However, more refined methods of interpreting SPT data is given in the DISCUSSION of the Standard Penetration Test. Figure 6 shows the input display for selection of the grain angularity. Available options include Angular, Subangular, Subrounded, Rounded, and Unknown, as per ASTM. This terminates the antecedent-data collection for gravel or sand. The program now proceeds to the dredgeability evaluation menu screens.

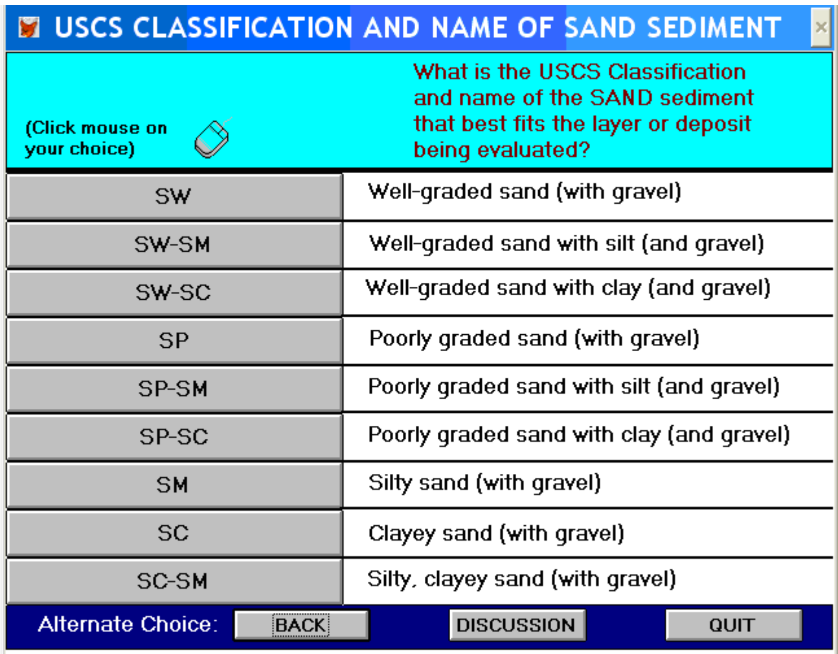

Figure 3. USCS/ASTM classifications of SAND sediments screen.

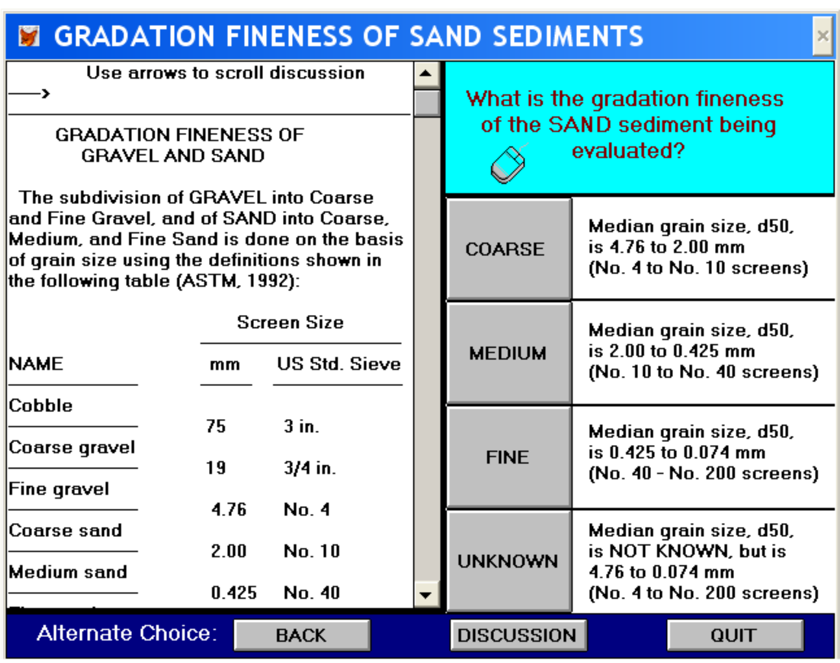

Figure 4. Gradation fineness of sand sediment screen.

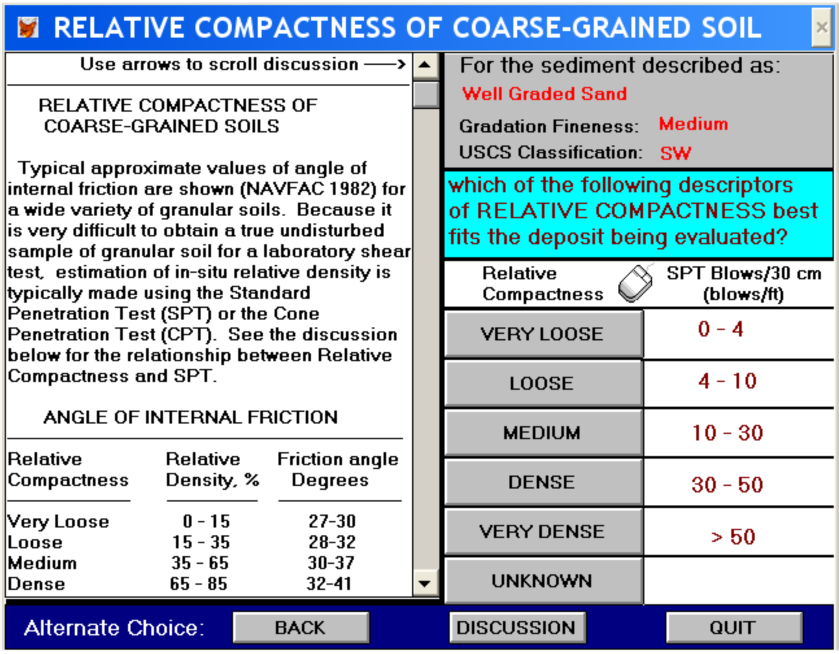

Figure 5. Relative compactness of coarse-grained soils screen.

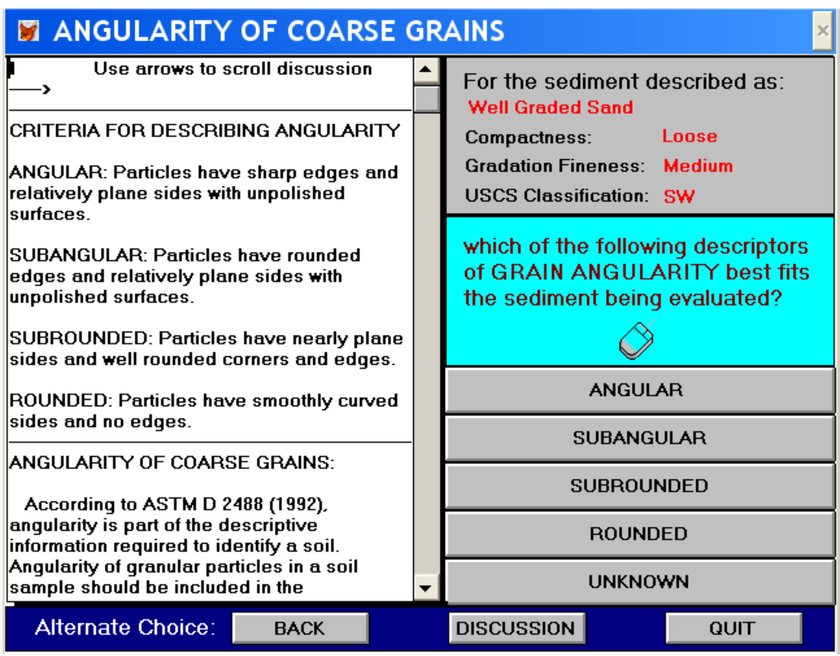

Figure 6. Angularity of coarse grains screen.

If the sediment type selected in Figure 2 is inorganic or organic fine-grained soil, i.e., silt or clay, the next input display asks for the USCS/ASTM classification. Options are presented for all of the USCS/ASTM classes of each fine-grained sediment type. Assuming the sediment type is an INORGANIC CLAY, then selection must be made from the options displayed in Figure 7, which constitute all of the inorganic fines options offered by the USCS/ASTM. A similar screen is used for organic fines.

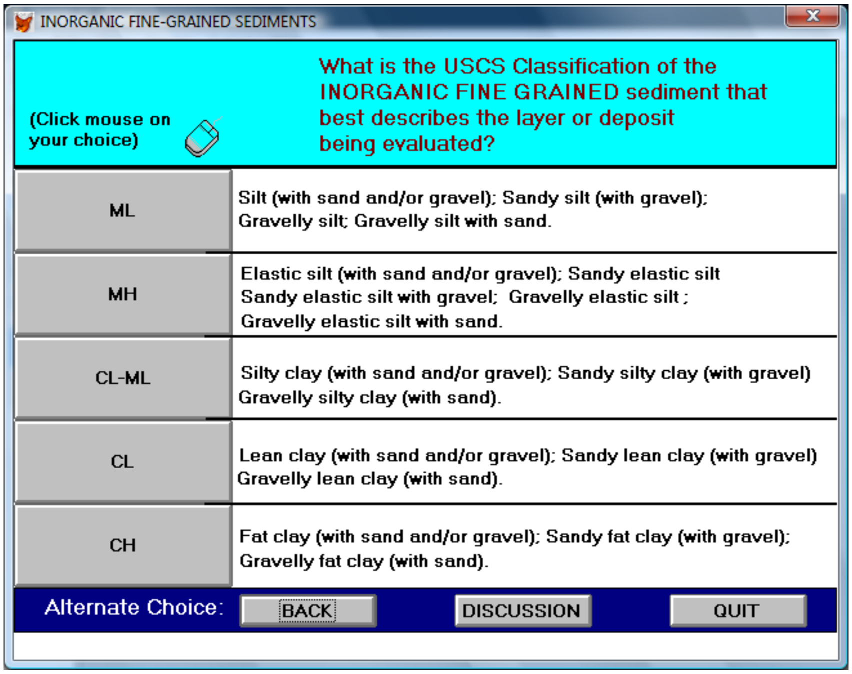

Figure 7. USCS/ASTM classifications and names of inorganic fine-grained material screen.

Figure 8 shows the Relative Consistency input display. A choice is made among the options of relative consistency (Unconfined Compressive Strength): Very Soft, Soft, Medium, Stiff, Very Stiff, Hard, and Unknown. Corresponding values of Unconfined Compressive Strength are also displayed for the user's guidance.

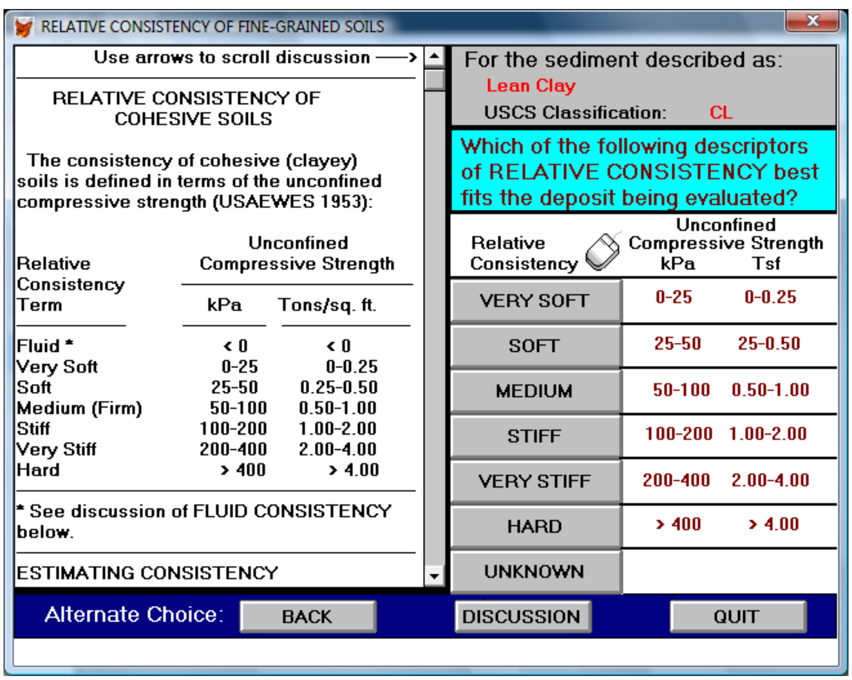

Figure 8. Relative consistency of fine-grained sediment screen.

DREDGABL uses four Plasticity Index categories in its rules: (1) 4 to 7, (2) less than 22, (3) 22 to 38, and (4) above 38. For the Plasticity Index input display, DREDGABL makes a decision about which of three Plasticity Index display screens to show, based on USCS/ASTM classification. The screen for CL or OL (clay) is shown as Figure

9. No input display is used if the USCS/ASTM classification is CL-ML because the Plasticity Index must, by definition, be 4 to 7, or if the USCS/ASTM is ML or OL (silt) because the Plasticity Index must be less than 22.

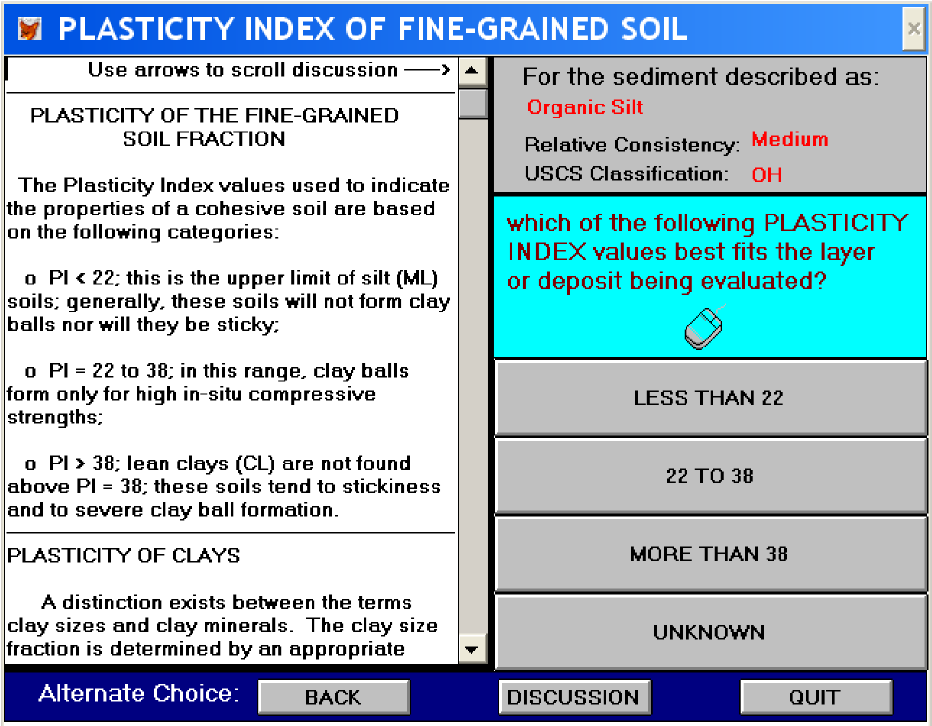

Figure 9. Plasticity Index of fine-grained sediments screen.

The Liquidity Index is calculated from the water content, and indicates liquidity relative to the Liquid Limit and Plastic Limit of a remolded soil. It can be an indicator of relative consistency by itself or a useful cross-check on the measured relative consistency. If the consistency is known and has been indicated, the Liquidity Index display is bypassed to prevent a potential conflict of information. Therefore, Figure 10 is only displayed if the consistency selected in Figure 8 is "UNKNOWN."

This terminates the antecedent-data collection for fine-grained sediments. The program now proceeds to the dredgeability evaluation menu screen. If the chosen sediment type in Figure 2 is "Other Sediments," the next input display, Figure 11, requests a choice among the following sediment types: rock, coral, shale, cemented soils, boulders, cobbles, fluid mud, shells, or debris. At the present version of DREDGABL, no other geotechnical properties are used in the dredgeability rules; therefore none are requested of the user and antecedent-data collection is terminated.

As shown on Figure 1, the four display screens following "Dredgeability Evaluation" are "Conclusion" displays. After the input displays have been used to define all of the necessary antecedent (IF statements) data in Table 1, the inference process starts, i.e., a query is made of the appropriate knowledge base, and an associated set of conclusions (THEN conclusions) is derived. The conclusion set is stored in the Conclusions Memory. The conclusion sets chosen from the "Dredgeability Evaluation" display may be repeatedly viewed in random. The user may also choose to print the complete summary set of conclusions in a report. The context variables and the conclusion set are maintained in memory until the context is changed and a new inference process is triggered or until the program execution is terminated.

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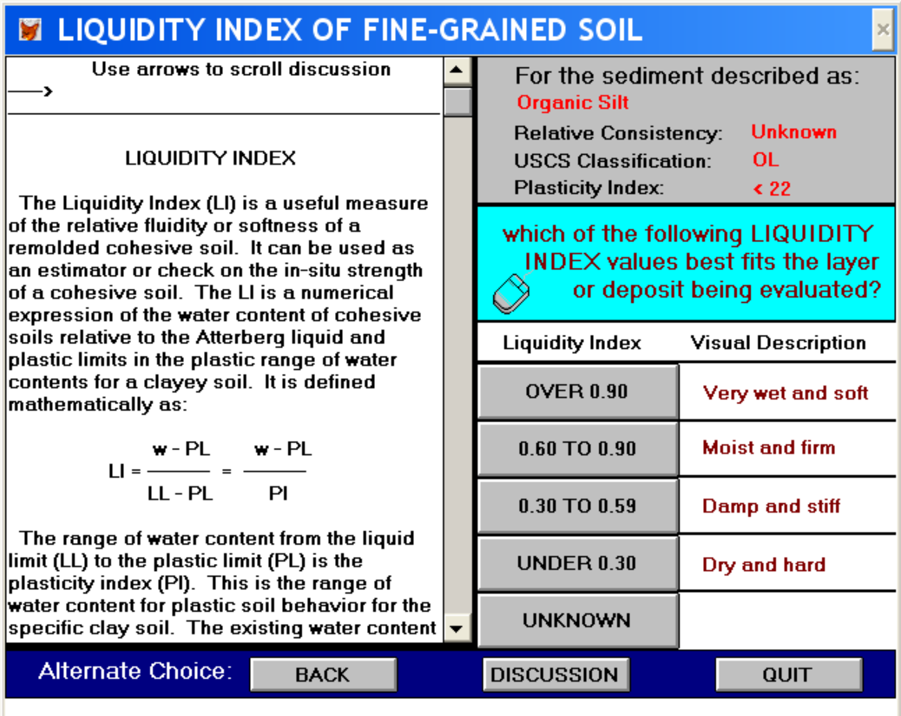

Figure 10. Liquidity Index of fine-grained sediment screen.

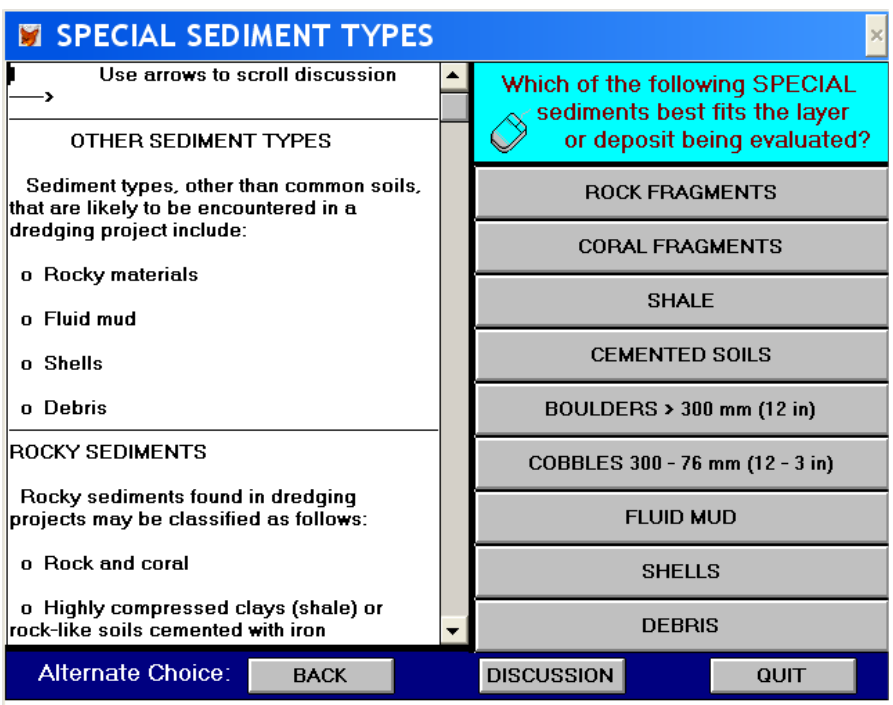

Figure 11. Selection screen for other sediments.

After the appropriate entry of the required geotechnical data in the input displays, DREDGABL proceeds to the evaluation (inference) process and the storage of a unique set of conclusions in the Conclusions memory. The rules for evaluation operate internally in DREDGABL to consider all of that sediment's known geotechnical properties that affect each of the specific dredgeability mechanisms. An evaluation menu is displayed (Figure 12) that contains the available choices.

Figure 12. Menu for selections of conclusions display.

Figure 13 is the conclusions display for pipeline dredge suitability for Medium Stiff Lean Clay (CL) sediments. It is typical of those for hoppers, mechanical, and pipeline dredges. A similar display presents conclusions about the disposal area properties of the described sediment. Disposal area properties are, of course, reasonably independent of the dredge type used for excavation and transport.

If the Print a Summary Report button is activated in the Conclusions display menu, Figure 12, another display screen is activated, requesting information from the user: Date, Project, and User Name. The Summary Print display shows the status of the antecedents in the Context Memory. Then, a one-page summary showing all sediment-specific antecedents in Context Memory and all of the conclusions contained in Conclusions Memory is printed. The report contains all of the information that is displayed in, the four dredge-suitability screens.

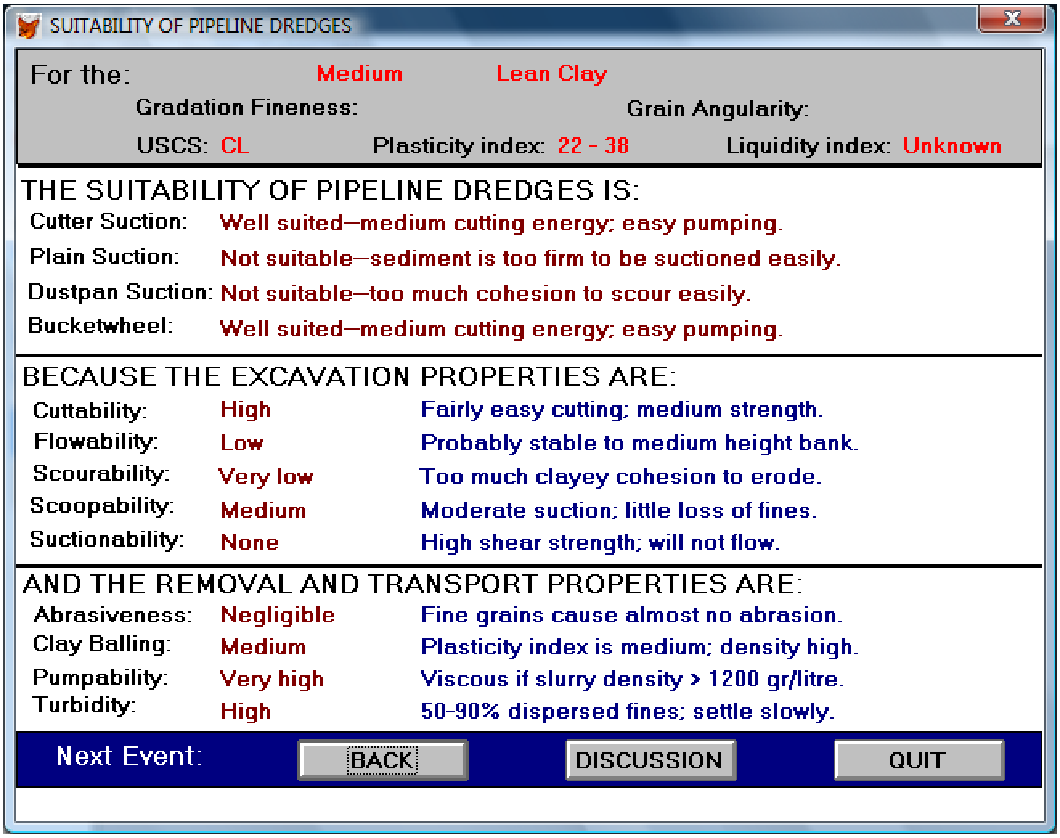

Figure 13. Conclusions display for pipeline dredge suitability.

OVERVIEW OF GEOSITE

The objective of GEOSITE KBES/DSS is to provide guidance, from geotechnical engineering experts, for the selection of equipment and methods for a subsurface investigation at an individual exploration site for a dredging project. It is assumed that the number and locations of the exploration sites have previously been established and that there is a general knowledge of the types of sediments expected to be present at the site. An interactive consultation with GEOSITE is used to select:

- Sediment sampling methods.
- In-situ strength testing methods, considering all appropriate sampling/testing method combinations.
- Methods for accessing the sampling/testing depth.
- Suitable platforms for field work.
- Material identification tests.

The reasoning behind the software recommendations is given in "Discussion" texts. GEOSITE is primarily intended for use by persons familiar with basic geotechnical site investigation and testing methods, such as a civil engineer or geologist. GEOSITE may also be used by dredging contractors, either for internal use or for use by a private geotechnical firm in their employ.

The first step in any geotechnical site investigation is the assembly and evaluation of all prior information about the proposed dredging site. This information is used to develop a tentative geotechnical subsurface profile. Sources of prior information include a review of existing geological and geotechnical data from the vicinity of the project site and may include a geophysical survey of the site. The number and locations of exploration sites is selected, based on a number of factors, including site variability. Therefore, at any exploration point where a pit or boring will be made, a general idea of the stratigraphy profile already exists in the mind of the evaluator, even if it is general.

The consultation process of GEOSITE starts with the assumption that the stratification is generally known. It is reasonable to require this assumption; this demands that every effort be made to assemble and evaluate the pre-existing information and to use geophysical surveys wherever they are feasible. The choice of specific primary sediment types from the expected profile causes GEOSITE to limit its consultation advice only to those topics that apply to those sediment types and to exclude all others. If, in the field, the profile expectation is found to be non representative, then a return to the program for re-evaluation with the updated information will be necessary. Four separate exploration objectives are provided in GEOSITE:

- REGULAR (Complete) INVESTIGATION - The selection of sampling and testing methods for in situ strength and material identification properties.
- LIMITED TO DENSITY TESTING ONLY - The selection of field sampling and testing methods for in-situ density evaluation only.
- LIMITED TO FINDING ROCK SURFACE ONLY - The 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. This option is also included as part of the REGULAR INVESTIGATION program.

Regular Investigation

The Regular, or Complete Investigation objective starts with selection of anticipated sediment type. This causes GEOSITE to display a screen of all generic sediment samplers and a description of their suitability for that sediment type. One of the samplers is selected and the next screen displays a choice of field or laboratory (or none) strength testing methods. This choice leads to a screen containing strength test methods and their suitability for the combination of sediment type and sampling method. The screen also displays, for each test method, a *Confidence Factor* and a *Utility Factor*. If desired, the contents of this screen may be printed in report form for filing. If desired, the user may then return to previous screens for advice on a different combination. Or, once a sampler and test method are chosen, further guidance is given for methods to access sampling-testing depth, for field work platforms, and for material identification tests.

Density Testing Only

The Density Testing Only objective starts with a selection of one of the sediment types expected in the sediment profile. GEOSITE then provides guidance on the suitability of various methods for determining the in-situ density. Most of the methods are different from methods used for sampling and/or strength testing.

Rock Surface Only

The Rock Surface Only objective starts with selection of the sediment type that forms the overburden for the rock or hard surface to be located. Guidance is then given about the suitability of various methods for locating the surface of rock or a hard layer.

Material Identification Tests Only

This option is available for the user that simply wants guidance on material identification tests that are appropriate for identifying, describing, and possibly classifying a disturbed sample. It is also included as part of the sequence of guidance screens in the "Regular Investigation" objective.

SUMMARY AND CONCLUSION

Two KBES/DSS tools, DREDGABL, and GEOSITE, were presented in this paper. DREDGABL is intended to serve the dredging community as an electronic geotechnical engineering consultant that provides guidance in the suitability of various types of dredging equipment for specific sediment types whose properties are described in the dredging contract documents. This suitability (in the respective geotechnical conditions) is presented within the context of the dredges' dredgeability, defined as the ease with which an underwater soil or rock can be excavated, removed, transported, and deposited with respect to known or assumed equipment, methods, and in situ material characteristics. 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.

A KBES is, in effect, a technical report that has been placed into a computerized question-and-answer format. All of the information could, alternatively, have been contained in a written and published report. However, a computer-based KBES has certain advantages over the printed document:

- The sequence of questions is expert-guided for each specific task. The user provides answers to the questions from an exhaustive, but limited, set of correctly phrased answers, using standard terminology. When all appropriate questions have been asked and answered, the knowledge base is searched for all valid conclusions that can be derived from the problem context. The conclusions are presented on screen and, in some instances, can be printed.
- It is simpler, easier, and faster to use than a published report. Pages appear on screen quickly rather than requiring hunting for the contents or index, then searching for the exact page, or pages.
- The knowledge recorded in the knowledge base can be edited and modified to accommodate new research findings or local experiences, permitting relatively easy improvements to be incorporated into the original version.
- The text information contained in the readily accessible "Discussion" topics can also be easily added to or changed. This does not imply that the user will be able to modify the control program or the knowledge base directly. Only the official, development version under the control of the developers or the program administrators will be capable of being modified.

The original version of DREDGABL, released for Microsoft Windows® 3.2 and MS-DOS® platforms, has been recently upgraded to operate on a Windows XP platform by the Dredging Operations and Research (DOER) program and is currently available on compact disks. GEOSITE is currently being upgraded to also operate on a Windows XP platform.

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