WILLIAMS & ASSOCIATES, INC.

P.O. Box 48, Viola, Idaho 83872 (208) 883-0153 (208) 875-0147

Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

January 7, 1987
Contract No. NRC-02-85-008
Fin No. D-1020
Communication No. 163

Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Jeff:

We are forwarding the following proposal for your consideration. We believe that the use of an 'expert system' provides a means for defining conceptual hydrogeological models; the 'expert system' approach provides a consistent rationale for the formulation of conceptual hydrogeologic models. This approach, if used by the Department of Energy, would produce a logical set of questions and answers that the NRC can review. The current approach used by the DOE, and everyone else, is based solely on expert opinion which can be difficult to review.

We have argued consistently that the DOE should consider alternative conceptual hydrogeologic models that fit the current data bases.

A properly designed 'shell' should define alternate conceptual hydrogeologic models using the same data bases where the data are not definitive. The use of a 'shell' will assist in the assessment of uncertainty and the effects of uncertainty on the definitions of the models.

We believe the NRC should investigate the use of 'expert systems' in defining conceptual hydrogeologic models. Please call if you have any questions regarding this proposal.

Sincerely,

Gerry Winter/sl

Gerry V. Winter

GVW:sl

cc: D.L. Chery, Jr.
Mark Logsdon

CONCEPTUAL HYDROGEOLOGIC MODEL DEFINITION USING EXPERT SYSTEM

A conceptual hydrogeologic model synthesizes both quantitative and qualitative data into a description of groundwater flow systems in the area of interest. The description (model) usually incorporates areas of recharge to the groundwater flow system, areas of discharge from the groundwater flow systems, and the intervening groundwater flow paths.

Conceptual hydrogeologic models are important to the high-level radioactive waste disposal program because they form the foundation for understanding groundwater flow systems, designing hydrogeologic tests, interpreting test data, and predicting groundwater travel time. Conceptual models are used to define the direction of groundwater movement and to ascertain the probable discharge areas for the groundwater flow systems. Conceptual models are required for specifying hydrogeologic tests for the quantification of hydrogeologic coefficients within the area of interest; conceptual models also are required for the interpretation of the hydrogeologic data. The use of conceptual models culminates in the prediction of groundwater travel time. A conceptual model is required to formulate any analytical or numerical model used to predict groundwater travel time. A stochastic approach, if used, for predicting groundwater travel time should be consistent with viable conceptual models. It does not appear that current procedures require that the stochastic procedures used to predict groundwater travel time produce flow paths that are consistent with viable conceptual models.

Several problems occur during attempts to define conceptual hydrogeologic models. One of the problems inherent in defining conceptual models stems from the use of a significant amount of qualitative data. Additional problems arise because variations may occur in the interpretation of quantitative data. These variations occur because the evaluators have different conceptual models in mind during their reviews and analyses of test data. Multiple interpretations also are possible because of the uncertainty inherent in the evaluation of the hydrogeologic data. To date the Department of Energy has presented only single conceptual hydrogeologic models for the proposed repository locations. It should be noted that Rockwell Hanford Operations broke with this precedent by presenting alternate conceptual models, on a local scale, in the Environmental Assessment (U.S. Dept. of Energy, Aug. 1986, p. 3-122 - 3-125).

The hydrogeologic community uses various procedures when defining conceptual hydrogeologic models. Defining conceptual models is a non quantitative procedure; the definition of a conceptual model(s) is based largely on experience and professional judgment. For instance, some investigators prefer to begin their formulation of a conceptual model by looking at relevant information near the site of interest. These investigators then expand their area of interest so that it encompasses as large an area as they deem necessary to define the groundwater flow systems of interest.

Conversely, other investigators may prefer to look initially at a broader area when defining conceptual hydrogeologic models. These investigators then reduce their area of investigation to focus upon those pieces of information that help define the conceptual model only in the specific area of interest. The definition of conceptual models requires numerous pieces of information, some of which remain qualitative throughout the exercise.

The basis for deriving a conceptual model is seldom outlined in a logical fashion in any of the documents produced by the Department of Energy. This lack of organization makes it difficult for reviewers of the data and information disseminated by the Department of Energy to determine what conceptual models are valid for the given data base and which of the conceptual models are most representative of the hydrogeologic systems at the sites. The ability to track the development of the conceptual models would be beneficial to both the Department of Energy and the Nuclear Regulatory Commission. We believe that the use of "expert systems" provides a means by which the development of the conceptual models may be documented.

An "expert system" is a computer program that aids the user in decision-making by processing user responses (to situations or questions) through a set of logical, consistent rules that are based on the knowledge and experience of one or more experts (i.e., professionals who are trained and experienced in the field of interest). Rather than just analyzing and presenting data/information as do common decision support tools, an expert system can make interpretations and provide recommendations for conclusions/solutions.

Expert-system development programs are called shell programs because they do not contain any knowledge-based rules themselves, but instead are designed to enable professionals to develop their own rules that can be processed and used by the shell in specific decision-making problems. The rules, which often are of the type "IF...THEN...ELSE...," are input to the shell in a manner so that they mimic the logical steps in a rational decision-making scheme. Until recently, most expert system shells were tied exclusively to 1) computer languages such as LISP or PROLOG, and 2) mainframe computer implementations. In today's software market, several microcomputer-based expert system shells are available that provide substantial flexibility and power; thus, the development and application of expert systems is expected to flourish in a number of technical fields.

The following characteristics of expert systems indicate that they may be of considerable use in the development and preliminary assessment of conceptual hydrogeologic models:

1. An expert system is a reliable, systematic, and consistent tool for condensing and interpreting input information.

2. Non-numerical information (in contrast to numerical data) in the form of qualitative observations or perceptions can be used effectively and efficiently in expert systems.

3. If properly designed, an expert system provides a thoroughly documented trail of the decision-making process. When running the expert system program, the user may interrupt at any point and "question the computer" on why it reached a certain conclusion. The computer program then explains (in English text) how it reached the conclusion, why certain information is required, and how the information will be used. Thus, the entire problem can be documented from start to finish.

4. The sensitivity of a final decision (or outcome or solution) can be studied by repeatedly running the expert system, modifying the input information with each pass. Such sensitivity studies would be extremely useful when input data and information are scarce or uncertain.

5. An expert system cannot forget to consider a pertinent issue, nor will it overlook a critical detail or get bored (such as may be the case with human beings). However, it is important to remember that expert systems do not think, and they only can aid the user to the extent or degree to which they have been "taught" (i.e., programmed with rules).

In addition to these fundamental characteristics, some microcomputer based expert systems have optional capabilities that would make them even more appropriate for conceptual hydrogeologic models. Because of the uncertainty in many hydrogeologic variables (i..e., physical or chemical attributes), the capability of including probability or confidence factors in the rules and in the input is essential. Thus, such an enhanced expert system would be able to handle situations where the data/information may imply a particular model, but other models also are possible; or where the data are sparse (information is incomplete) and only a best estimate of the model is possible. In fact, the possible models even could be ranked according to their likelihood of occurrence (often based on probability values). Other important options include backward chaining (an efficient means to derive and check information during program execution) and the ability to link with external programs or data bases. This latter option is a must for most scientific or engineering expert systems, particularly if sensitivity studies are to be conducted.

We consider microcomputer-based expert systems to be a valuable resource for hydrogeologic studies. Therefore, we propose to conduct a feasibility study of the applicability of expert systems to developing conceptual hydrogeologic models. The study will consist of:

1) an evaluation of currently available commercial expert system shells for IBM-compatible microcomputers and their applicability to building conceptual models;

2) the development of a simple demonstration expert system that would illustrate the flexibility and potential benefits of this technology to the NRC's high-level radioactive waste management program; we intend to focus on a system that would be appropriate to current NRC needs.

Rec'd 1/22/88

WM-11
WM Record File
D1020
W&A

WM Project 11
Docket No.
PDR ✓
XLPDR N

Distribution:
Table

(Return to WM, 623-SS)