STUDY REPORT

GEOTECHNICAL DECISION-MAKING

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1 SCOPE AND OBJECTIVES OF INQUIRY AND REPORT

1.1 BACKGROUND AND SCOPE

The High-Level Waste (HLW) repository licensing program of the Nuclear Regulatory Commission (NRC) has been established utilizing the NRC's other existing licensing programs as models. While there is significant similarity in process with NRC's other radiological safety programs, the unprecedented long times associated with geologic containment add uncertainty to the regulatory process for the repository, which is not present or is a lesser factor in NRC's other programs. The primary statutory basis, the Nuclear Waste Policy Act of 1982, as amended (42 U.S.C. §10101 et seq.), calls for licensing only one repository for permanent deep geologic disposal of HLW and spent nuclear fuel. Although the need for a second repository continues to be considered, under existing law this licensing program will be executed only once, and it must provide confidence that public health and safety are being protected.

Most other federal and state regulatory activities governing technical endeavors have been refined and modified over time through usage, litigation, and advances in technology. In most cases, changes resulting from early regulatory experiences have added to an agency's ability to evaluate proposals efficiently and have increased the assurance of proper regulatory decision-making. Decision-making under uncertainties has been dealt with in other contexts also. For example, business decision-making in uncertain environments has commonly been based on increasingly sophisticated methods for calculating the probability of success in order to avoid excessive financial losses.

In contrast, the NRC HLW regulatory decision-making program will have little opportunity for evolution and process refinement to heighten the likelihood of success. As part of the preparation of a License Application Review Plan (LARP), which will provide guidance for staff review and analysis of the Department of Energy (DOE) application for a permit to construct, the NRC staff tasked the Center for Nuclear Waste Regulatory Analyses (CNWRA) to study the decision-making processes of other geotechnical programs to gain insight from actual experience in order to increase confidence in, and potentially improve, the NRC HLW regulatory program. Identification and study of analogous regulatory and decision-making activities may serve not only as a model for the HLW program, but may also identify valuable and proven techniques not previously considered by the NRC for adaptation and utilization.

This study examines two programs which have a record of decision-making in an environment of multiple geotechnical and engineering uncertainties. These programs are: (i) the methods and techniques developed by the petroleum industry to increase the probability of successful exploration and development; and (ii) the regulatory program of the Environmental Protection Agency (EPA) for deep well injection of hazardous wastes. The study is exploratory in nature, and thus is not intended to be an exhaustive analysis. Rather, it was initiated to determine the potential value of future, more extensive evaluations. It is important to note that the regulatory and technical relationships of the HLW program to either of these areas are not a factor in this review — the review looks at process only, not the technical bases for the programs. This is particularly true of the EPA injection program, which a federal court has ruled does have a relationship to the HLW program.

1.2 OBJECTIVES

This study has two primary objectives: (i) identification of existing decision-making methods and processes from outside the NRC experience which may have application to the NRC HLW licensing program; and (ii) identification of any potentially valuable study areas worthy of further analysis. It is not intended to explore specific decision-making criteria or technical methods.

2 PETROLEUM INDUSTRY DECISION-MAKING

In the petroleum industry, uncertainty exists in virtually every type of data and in each phase of the process used to make decisions. The NRC HLW program will use geological and geophysical data in determination of appropriate repository design, site suitability, and modeling the waste-isolation performance of a proposed repository site. Considerable emphasis is placed on prediction of future occurrences and potential consequences of discrete natural events, such as volcanic eruptions, earthquakes, fault slips, and ground ruptures. Models are also used to determine the extent and magnitude of more continuous processes such as waste package degradation, evolution of geochemical conditions, unsaturated-zone transport, and groundwater flow. The period of interest for these predictions is up to 10,000 years — a time frame outside of engineering experience but much shorter than is commonly considered for geological processes. Thus, substantial uncertainty exists with respect to analysis and simulation methods appropriate for this time frame. Similarly, the natural resource industries must consider uncertainty associated with use of geological and geophysical data when predicting the types, distribution, and size of natural resource accumulations.

2.1 DESCRIPTION OF PROCESS

Exploration for and development of petroleum resources provide a history of decision-making in an environment of multiple economic and technical uncertainties. Approaches for petroleum exploration and development have been developed that minimize the risk of failure and take full advantage of various kinds of data which the decision-maker may have available. "The industry has actively sought improved methods for rating prospects, especially methods that would minimize the element of human judgment with its attendant inconsistencies" (Harbaugh et al., 1977, Chapter 1). These methods must factor in "structural information from several horizons . . . simultaneously" (Harbaugh et al., 1977, Chapter 1).

In summary, the petroleum/hydrocarbon resource industry's decision process to identify suitable projects for exploration and development consists fundamentally of a subjective blending of data. Probability distributions, including those obtained through expert judgement, associated with site geological structure, presence of hydrocarbons, economic information, and the risk attitude of the organization are combined in a decision analysis paradigm. This decision analysis process uses the combined distributions to produce an overall probability of success and an expected economic return, which serve as quantitative, subjective bases for decisions on individual project approval or as differentiaters for ranking several competing resource projects.

One of the appropriate statistical methods for such studies is multivariate analysis, since the basic data involve many geologic, political, technical, and economic variables, and the interactions between the variables should be considered as well as changes in the variables themselves (Harbaugh et al., 1977, Chapter 6). The challenges with this approach lie in first distinguishing the critical variables that drive the decision process from the set of all included variables and then acquiring data for each of the critical variables.

Another popular approach to the exploration decision process stems from the area of decision analysis (Harbaugh, 1989). The Wildcatter oil exploration problem has been modeled as a classic multi-staged decision analysis problem for a number of years (Raiffa, 1970, pp 34-36). This approach presents the decision-makers with a series of actions with attendant consequences driven by probabilities for these consequences. Examples of this approach are available in the literature (Sage, 1977, pp 315-328, and Raiffa, 1970, pp 34-38 and 240-244).

A strength of this decision analysis approach is the graphical presentation of the problem with accompanying economic display of the value of additional information required to reduce the uncertainty associated with each step [i.e., cost/benefit of obtaining seismic soundings or of drilling test well(s)]. Because all petroleum exploration efforts are eventually reduced to an economic measure, this approach allows options to be costed and compared.

A weakness of this approach is that a source for much of the probabilistic data is human judgment. While experience and associated technical data are available, the human element with its subjective aspect is an integral part of the methodology (Keeney and Raiffa, 1976, Chapter 1). Another aspect of this approach is the requirement for data fusion, that is, the often referred to hard technical data must be mixed or blended with so called softer human-elicited judgment. If done astutely, especially utilizing historical experience, this data blending can lead to better probabilistic estimates (Sage, 1977, Chapter 7).

The risks associated with exploration and development (prospecting) may not all be presented to the decision-maker at one time. It is important to recognize the variety and timing of the various decision points in analyzing the continued viability of a project. For example, in a related area of energy development, comparative evaluation of the development of synthetic fuels against exploration for new sources of crude oil, the analyst must go through a similar series of steps.

> "[T]here are several crucial intermediate decision exit points between the initial exploration go-ahead and the actual production of oil. First, there are geological explorations to determine formations likely to contain commercially significant accumulations of oil and gas. Second, based on these geological data, there are decisions to be made about whether and where to drill. Third, based on the findings of the exploration wells, there are decisions to be made about whether the discoveries (if any) are sufficiently large to justify drilling of production wells. At each decision-making juncture there are risks associated with proceeding to the next juncture, but it is important that there be a series of exit points should the project begin to look unfavorable" (Dickson, 1975, p 655).

An example of a decision analysis approach to evaluating exploration alternatives using probabilistic data is basin evaluation. In basin evaluation, the objective is prediction of the recoverable oil in a sedimentary basin or major petroleum province. It is valuable in comparing one province against another, but it does not deal specifically with locating undiscovered resources within the basin or province, nor with determining exactly where to drill. More comprehensive exploration programs, designed for the province of interest, are required to delineate specific prospects and drilling sites.

In addition to identification of prospects, estimation of reserve size is equally important in predicting ultimate profitability of the exploration venture. Baker describes the steps in assessing an individual prospect or play as: (i) model the play as if it exists with an estimate of the probability that the model is correct; (ii) set out the play as a geologically coherent group of prospects; (iii) after establishing a practical minimum field size, field size distributions are created from known similar field reserves or other samples; (iv) field size distribution is plotted and the possible range of numbers of potential fields is estimated; (v) a play chance is assigned of at least one field of at least minimum size; and (vi) a simulation is computed. "The risk-related probabilities can be guided by experience but will always have an unavoidably subjective cast. As a result, it is still possible to get the wrong answer with the right method, just as the right answer occasionally falls out of the wrong method" (Baker et al., 1986, p 30).

All of the decision analysis techniques have in common the blending of data which have various degrees of confidence. Probability distributions associated with any factor (such as predicted oil reserve size, the chance of a key geologic fault sealing, or the predicted price of crude oil) tend to be normal or log normal in shape, distributed around the most likely value with the spread of the distribution being an indication of confidence in the most likely value. These distributions are supplied by experts who use a combination of historic, empirical, or modeled data as a basis for the distributions. The distributions are treated as independent and combined mathematically to produce a resulting overall distribution of exploration success or return on investment. In the simplest case, the expected value of the distributions or the most likely value of the factors are multiplied together to obtain an estimate of probability of success or investment return (Rose, 1992, pp 72-74). Software has been developed to aid in quantifying the distributions associated with variables in the resource exploration arena so that alternatives can be evaluated (Cheong et al., 1992).

Uncertainty in the oil and gas industry is not confined to geotechnical factors, and, in some aspects, other factors can become dominant. In some cases, economic and political considerations can substantially influence the relative significance of geological uncertainties in exploration and development decisions. The industry manages overall uncertainty in several different ways: (i) hedging with transactions in crude oil futures; (ii) integrating upstream and downstream processes; (iii) using partnerships to spread and dilute the risk; (iv) including in each venture multiple chances for success, thereby mitigating individual failed prospects; and (v) accepting uncertainty and risk as appropriate to the prospective financial gain.

There are numerous measures of success in the exploration and development of oil and gas resources. It is not enough for explorationists to predict the probable presence of trapped liquid or gaseous hydrocarbons. The decision-makers must have some measurable degree of assurance of achieving: (i) geological success — a well will encounter mobile and measurable reservoired hydrocarbon; (ii) completion success — a well can be completed for production; (iii) incremental success — a well will return the cost of completing and operating it; and (iv) commercial success — a discovery well will find a field capable of paying all costs of exploration and development for the field (Rose, 1992). The greater the probability of more of these successes, the less the risk to the company decision-maker and ultimately to the continued existence of the company. Petroleum company decision-makers are now routinely and explicitly using stochastic representation of data in the probabilistic analysis of that data for supporting their decisions (Rose, 1992).

2.2 SIMILARITIES TO THE NRC HLW REGULATORY ROLE

The most significant similarity between the petroleum industry's decision-making methods and those which the NRC will utilize is the extensive use of geologic and hydrologic data, including variables and multiple assumptions, together with engineering design factors in the modeling of prospective exploration and development regions. In addition to these factors, the petroleum industry must include further considerations, such as, difficulty of drilling in a specific area, the political acceptability of the venture, and overriding economic benefits and costs. While these additional factors also impact the HLW program at various levels, the basic NRC decision-making process must be centered on health and safety issues, with their associated political and environmental concerns, and does not explicitly include considerations of economic aspects.

The concept of a performance objective for an HLW repository is similar to minimum field size (reserves) limits established for exploration plays and prospects. A certain minimum level of reserves may in essence be the performance objective of a particular play. The probability of success (P_s) then would be the probability that a specific prospect will produce at least the level of reserves required to satisfy a minimum return on investment threshold. Estimates of P_s often include probabilistic estimates of geologic and reservoir parameters. However, it is important to remember that a resource exploration program is driven by the price of the commodity. The relative importance of geologic and reservoir variables are thus also dependent on economic variables.

Parameter estimation, as addressed previously, is an important source of uncertainty in both exploration and repository performance assessment. The earth's crust is discontinuous, heterogeneous, and anisotropic at virtually all scales pertinent to resource exploration and HLW site characterization. Prediction of spatial variability for key petrophysical (e.g., porosity, oil saturation) and hydrogeological properties (e.g., conductivity, water saturation) is critical for both performance and reserves assessment. Both of these endeavors thus suffer from sparse data. An important question for the HLW program may therefore be: How do resource explorationists use information about spatial variability of key rock properties determined from sparse data? A review of the surveys in this area would be a valuable exercise.

In the NRC HLW program, there will be an analogous integration of scientific data with so-called soft data, obtained by means other than field tests. Both programs must supplement the hard data with information, such as expert opinion, to produce data blending, in order to create the projection models needed to justify action. Because knowledge and data are incomplete and must be used in decision-making, assumptions must incorporate uncertainty in both HLW performance assessment and in petroleum prospect assessment. Moreover, the petroleum industry has been using and testing resource assessment techniques for several decades.

2.3 DISSIMILARITIES IN DECISION-MAKING APPROACHES

The differences between the petroleum industry's and the HLW program's decision-making approaches may be much more striking than the similarities. A major dissimilarity is the industry's ability to include results from multiple prospects into a larger comparative analytical approach. "The exploration business has arranged itself so that it does not need conventional estimating accuracy. Successful companies either got lucky or exposed themselves to sufficient opportunities that only being right on average was necessary" (Capen, 1992). While some of the techniques developed for this industry can and are being used by geoscientists to predict future geologic occurrences and processes at the Yucca Mountain site and to evaluate such predictions, the overall industry methodology involves too much high-risk speculation for direct application to the NRC regulatory task. The petroleum industry mitigates this risk by spreading it over several exploration opportunities. This approach does not appear to be a reasonable option for the NRC where health and safety aspects of a single HLW repository must be considered.

A second dissimilarity is the significant role which financial factors play in consideration of decision-making in the petroleum industry. The analysis must include consideration not only of projections of ultimate development costs, but also of current and projected market conditions in order to determine if development is warranted. This difference enables a single set of data analyses and modeled projections for a petroleum prospect to produce divergent results using the same raw data at separate times or under different market conditions. The NRC regulatory decision-making will be based on objective scientific analysis and is not expected to be subject to such fluctuating economic situations.

A third substantial difference is that exploration decision-making is strongly oriented to selecting among viable alternatives. The particular suite of alternatives substantially influences the relative importance of various sources of uncertainty. Industry generally uses a comparative analytical approach in evaluation and prioritization of plays and prospects. Thus, quantified uncertainties play an important role in deciding which of an inventory of potential prospects will be explored or drilled first. This is an established approach for reducing risk. In contrast, the current HLW program entails comprehensive characterization of a single proposed repository site. The degree of certainty which the decision-maker must have in evaluating one exploratory prospect or region against another may not be as high as that required to evaluate a single, pre-selected location against a specific performance objective.

Another dissimilarity centers on resource explorationists actually seeking to describe occurrences of natural resources that are the net result of geological processes that have operated over long time frames (i.e., over 10^6 to 10^8 years). Performance assessment models for an HLW repository are intended to predict future conditions. Although these are fundamentally different endeavors, they have a common foundation. Each is an attempt to discern unknown past or future conditions based on observations and measurements of contemporary conditions. The present is both the key to the past as well as the key to the future. The important difference is that resource accumulations have already formed and evidence of their genesis is preserved in the rock record. Prediction of future conditions over geologically short time frames may be based necessarily on past and present conditions; however, there is no direct evidence that predicted conditions will occur. Thus, in contrast to exploration, performance assessment is primarily inference based on established trends.

2.4 CONCLUSIONS

Based on the evaluation and comparison of the decision-making processes of the petroleum industry and the NRC HLW licensing program, and the need for relatively high levels of confidence in all of the NRC evaluative decision-making, there does not appear to be a readily adaptable, generally analogous process. However, certain approaches are promising. One area is possible use of the petroleum industry technique of combining field tests and expert opinion, referred to as data blending. This may prove valuable in evaluating data on the leading edge of understanding. In addition, industry techniques for using sparse data for geologic characterization and updating probabilistic information and parametric estimates as more data become available may also have value. However, there are many dissimilarities, and the petroleum industry process includes a dominance of economic motivation and factors; therefore, the benefit of pursuing greater understanding of petroleum industry processes is considered to be limited. It is recommended that only limited additional study be directed to further studying the petroleum industry as described in Chapter 4, Recommendations for Future Work and Use of Conclusions.

3 UIC PROGRAM OF EPA

The Underground Injection Control (UIC) regulatory program of the EPA provides a process whereby proposals for injection of hazardous wastes deep below the surface are evaluated and permitted under standards developed by EPA. The types of uncertainties associated with review and approval of these proposals are similar to those associated with the NRC HLW repository licensing program.

3.1 DESCRIPTION OF PROGRAM

Hazardous waste injection began in the 1950s in an effort to find a safer way of disposing of such wastes. As early as April 1974, EPA began issuing policy statements on protection of groundwater from contamination by injected hazardous wastes. "Under this policy, EPA opposed the emplacement of pollutants by subsurface injection without strict control and without a clear demonstration that waste injection will not interfere with the present or potential use of the ground-water resources, or otherwise damage the environment" (Hernandez, 1977, p 93). The predecessor to the current federal UIC program was established in regulations in 1980 under the Safe Drinking Water Act (SDWA) of 1974 (42 U.S.C. §300f et seq.) as a way of unifying existing federal and state programs. Part C of the SDWA provided for a joint program of state and federal protection of underground sources of drinking water and the establishment of federal standards for individual states to enforce in the regulation of their UIC programs. There are five classes of wells administered under the UIC program. Class One wells include both hazardous (Class I-H) and non-hazardous (Class I) injection. Under the EPA UIC program, some wells allow injection of hazardous waste beneath the lowest underground source of drinking water. In the early 1980s, approximately 11.5 billion gallons of liquid hazardous waste (about half of all disposed) was injected into deep wells (EPA, 1991, Chapter 1).

The UIC program under the SDWA was directed at protection of underground sources of drinking water. The regulatory framework was modified significantly with the passage of the Resource Conservation and Recovery Act (RCRA) and, in particular, the Hazardous and Solid Waste Amendments (HSWA) of 1984 and 1988 (42 U.S.C. §6901 et seq.). The program now is operated under the joint statutory authority of the SDWA and the RCRA, and as such, focuses on both the protection of water sources and the control of injected wastes. It is a portion of the larger hazardous waste disposal program, and most standards are repeated in both the general regulations of 40 CFR Part 268 and the injection regulations of 40 CFR Part 148. The aspect of the injection program which this study focuses on is use of Class One wells for the injection of hazardous material (Class I-H) generally banned from land disposal, including injection, under RCRA. Such injection into an approved well is allowed only under a special EPA permit, the so-called "no migration" permit, to gain assurance that hazardous wastes will not migrate from the injection site. While this represents only one aspect of the EPA total UIC program, it involves many analytical procedures and regulatory determinations similar to those required by the NRC HLW program. This review focuses on the process utilized by the program and not directly on the technical aspects.

The HSWA modified RCRA by prohibiting land disposal, defined to include injection, of specified untreated hazardous wastes [42 U.S.C. §§6924(d)-(m)]. Section 3004(f) [42 U.S.C. §6924(f)] requires a review and determination of protection of human health and the environment for existing deep injection wells. EPA may grant an exemption for continued injection of banned substances if it is demonstrated in an applicant's petition, to a reasonable degree of certainty, that such disposal will not allow migration of hazardous constituents from the injection zone for as long as the waste remains hazardous. These statutory provisions were implemented by rules proposed in 1987 (EPA, 1987) and promulgated in 1988 (EPA, 1988a), which were the result of a regulatory negotiation process. Although the negotiations group (representatives from industry, environmental and public interest groups, and state UIC agencies) reached substantial agreement with EPA on a number of issues and procedures, they were not able to reach a consensus and draft a resultant negotiated proposed rule (EPA, 1987, p 32448). The rule that EPA did issue as a result, albeit without all participants' agreement, required operators of existing Class I-H injection wells and proposed wells to provide proof of environmental protection by submitting a "no migration" petition. This petition was to demonstrate that waste would not migrate from the injection zone for as long as the waste remained hazardous, or 10,000 years, whichever occurred first (40 CFR §148.20). The final rulemaking which established this rule (EPA, 1988a) took into account the significant public comments received by the agency and provided alternatives for applicants, including provision for both site-specific and generic petitions. While the rule permits the generic alternative, it states that successful petitions of this nature will be difficult to develop. As stated in response to public comments, the difficulty would occur because of the likely "petitioners' inability to submit information on geologies and waste streams that would be general enough to describe more than one facility, yet specific enough to insure 'no migration' at every site" (EPA, 1988a, p 28121).

There was considerable comment on the 10,000-year time period; both that it was too long and too short. The time period was retained as proposed with the following justification:

> "The Agency has reviewed these comments and after careful consideration believes the 10,000 year demonstration strikes an appropriate balance between the need to demonstrate 'no migration' with a reasonable degree of certainty and the limits of the technological means of making that demonstration. . . . Concerning those commenters who questioned the accuracy of modeling over a 10,000 year time frame, the EPA would like to note that many of these same commenters had correctly pointed out elsewhere in their comments that modeling need not locate the exact point where the waste would be at that time; determining where it would not be is sufficient. This level of precision is achievable" (EPA, 1988a, p 28126).

The rulemaking also addressed the use of models and concluded that the use of conservative modeling techniques to evaluate projections was supported by legal authority and had a sound technical basis.

The rule was challenged in Federal court by industry groups and environmentalists in Natural Resources Defense Council (NRDC) et al. versus EPA, 1990. The Circuit Court of Appeals upheld EPA's regulatory scheme and stated in conclusion:

> "In sum, the EPA's regulatory scheme contained two important components: (1) the substantive standards that a hazardous waste injection well must meet, and (2) the permit procedures by which an injector must demonstrate that a well meets that standard" (NRDC v EPA, 1990, p 1152).

The court specifically addressed the question of whether "the EPA abuse[d] its discretion in requiring injectors to show that there will be "no migration" of hazardous constituents from the injection zone for 10,000 years" as had been argued by the Chemical Manufacturers Association (CMA), another party in the suit. The court found that the EPA's rationale for choosing the 10,000-year standard, as stated in the final rulemaking, was "reasonable and consistent with the statutory purpose of preventing migration of hazardous constituents for as long as the wastes remain hazardous" (NRDC v EPA, 1990, p 1158). The court rejected CMA's petition to review. The court did rule in favor of the plaintiffs, stating EPA had extended the regulations too far in applying them to geological repositories and salt domes; however, this portion of the decision does not affect the applicability of the UIC regulatory program as a judicially upheld analogous exercise in geotechnical decision-making.

The UIC permitting process is uniform throughout the EPA regions. After receipt of a permit petition, the EPA regional office conducts a completeness review. The petitioner is requested to provide additional information, if necessary. Once the petition is determined to be complete, the EPA conducts another review for adequacy and sufficiency utilizing technical support from associated states. If necessary, permit modification may take place while this review is in progress. As a result of the review, EPA makes a draft decision as to whether it should approve the petition and prepares an approval or denial notice. A period of public comment then takes place, including a public hearing which is conducted thirty days after EPA publishes the draft decision. The public comment period closes fifteen days after the hearing. EPA then responds to significant public comments, makes a final decision to accept or deny the petition, and publishes that decision in the Federal Register.

The "no migration" permit aspect of the overall UIC program has been implemented by a combination of federal and state enforcement. Approximately 70 percent of all wells are located in Texas and Louisiana and are administered by EPA Region VI in Dallas. Nationwide there are presently 175 wells at 80 facilities in 15 states. Under the current UIC program, the volume of liquid hazardous waste being injected has decreased and there have been no documented cases of contamination of underground sources of drinking water (EPA, 1991, Chapter 1). To maintain a consistent review and approval process among the EPA regions and various state agencies which administer the program, UIC Guidance Documents (GDs) have been issued by the Director of the EPA Office of Drinking Water. These documents serve to supplement the basic regulations and address specific items to be considered during the permit review process and may be considered analogous to NRC staff positions, staff technical positions, and regulatory guides. They provide examples and are written for and by individuals in the program, thus avoiding conflicting guidance. GDs 71, 73, and 74 were reviewed in preparing this report and each addresses a separate aspect of the program. Only information from GD 74 was considered relevant for inclusion in this report.

An example of the type of regulatory guidance provided by these documents is GD 74, issued February 13, 1991. While it relates to modification of a granted "no migration" exemption, and 10 CFR Part 60 has specific provision for amendments, it is illustrative of the type of subordinate regulatory instruction which EPA has provided and which may be appropriate to consider for the HLW program. The document specifically provides:

" • The circumstances when an operator should notify EPA of changes which relate to an exemption,
- When it is appropriate to seek formal petition modification or reissuance of the exemption,
- When a modification is appropriate, or whether an exemption must be reissued after a review of additional data relating to the proposed change, and
- Under which circumstances and to what extent will public participation be required for comment on any change."

GD 74 lists conditions such as changes in rate or volume of injected waste or density of fluid which give rise to a need to modify an exemption. Also, a distinction between data which can be utilized from prior submissions and data which must be generated and submitted for the modification is outlined. GD 74 states that the basic showing required of a proponent of modification is "that any additional waste will behave hydraulically and chemically as previously included wastes, and will not interfere with the containment capability of the injection zone." If modeled parameters will be exceeded by proposed changes, the process changes to a reissuance and not merely a modification of the prior authority. This and other guidance documents enable the EPA regional officials responsible for implementing the program to utilize non-specific regulatory language consistently and with greater understanding of how successful petitions are to be developed, supported, reviewed, approved, and ultimately reviewed by the courts.

In an effort to improve the processing of applications for exemption permits, the region with the greatest amount of activity, Region VI in Dallas, developed outlines for both the basic application and supporting modeling demonstrations. These simple outlines contain the basic elements which EPA expects to be included in each petition for "no migration" exception presented in an acceptable format. While neither outline is complex in nature nor contains exhaustive detail, they are good examples of how a regulatory requirement can be supplemented by supporting instructions. These instructions minimize the likelihood that a specific discrete requirement is not complied with in a manner which allows supportable action by the agency and at the same time does not become overly prescriptive nor deprive an applicant of appropriate discretion.

Another EPA undertaking originally designed to ensure high quality data submissions was a draft technical assistance document entitled, Guidelines for the Petitioner and Reviewer on Computer Simulation of Hazardous Waste Injection (EPA, 1988b). Although EPA decided not to finalize this document, the draft provides a valuable example of regulatory guidance below the level of formally promulgated regulations which attempts to enhance the regulatory process without either interfering with the applicants' discretionary ability to design a proposal or forcing a regulatory agency into a required approval. Most of the draft guidelines were incorporated into regional guidelines for petitioners and thus have been informally included into the petition approval process. As stated in the draft, the document was designed to be a manual of "what a proper data set is comprised of, and how to judge proper simulation performance." The sections of the document were "presented in the same order as an engineer or geologist might perform the steps of such a study" (EPA, 1988b). Sections dealt with the selection of problem type and appropriate simulator, as well as verification and validation of simulators. The purpose of this document then, is similar to that of NRC guidance issued in the form of regulatory guides. The draft could be reviewed by technical staffs of the NRC and the CNWRA to determine if it represents the type of guidance which would enhance the quality of the HLW application without pre-approving any course of data analysis or presentation.

There have been three recent challenges to EPA granting of "no migration" permits in the federal courts in Texas, although none has yet to be published in official reporting services. In these three cases (Texans United, 1992; Brazoria County, 1992; and Brent Kay, 1992), the various judges found that, where site specific relevant data have been presented to the EPA in the permit application, the approval of the permit is supportable and is an appropriate exercise of regulatory decision-making. In Texans United and Brazoria County, the two courts rejected challenges to EPA granting of permits and each court granted summary judgment to EPA, holding that the grants of "no migration" permits were proper. In the Brent Kay case, the court agreed to allow EPA to remand the administrative record, upon which it had based its initial decision to issue the permit (covering two wells), for further consideration. The court agreed with the complaining party that EPA had insufficient well-specific documentation on one of the two wells proposed for hazardous waste injection. However, the decision is valuable because the judge outlines in detail the Congressional intent and how it was implemented in the EPA UIC program. The decision also describes the regulator's obligation under both the regulations and the NRDC decision. With regard to the evaluative procedures of the EPA, the Brent Kay opinion states that "a permit would be granted for a deep injection well covered by §§6924(f)-(g) only if the applicant demonstrated in a permit petition, to a reasonable degree of certainty, that 'there will be "no migration" of hazardous constituents from the disposal unit or injection zone for as long as the waste remain hazardous.'" In this case, information central to the EPA ability to evaluate the capability of the wells was not available at the time the grant was made; thus, the court was obliged to vacate the grant. The analogous relationship of the UIC regulatory program to the HLW program is not adversely affected by the conclusion in this case. The court has merely reinforced the concept that reasonable, judicially supported regulations must be strictly adhered to by the regulatory agency charged with enforcement.

In August of 1992, the EPA proposed a modification to its overall "no migration" regulations (EPA, 1992a) found at 40 CFR Parts 268 and 271. This proposal would provide new procedures and substantive criteria and requirements, and also would make available a draft guidance manual for petitioners (EPA, 1992b). The proposal would not supersede the specific UIC standards established by the 1988 rulemaking (EPA, 1988a), but it would add to the EPA overall interpretation of "no migration" and provide additional, consistent guidance.

3.2 SIMILARITIES TO THE NRC HLW REGULATORY ROLE

The obvious similarities between the EPA program of reviewing, approving, and monitoring deep injection of hazardous wastes and the NRC repository program are both numerous and striking. Although the current UIC program was created under a complex legislative scheme serving both the SDWA and RCRA, it nonetheless is both constrained and supported by a very detailed statutory framework. The statutes which provide the bases for the EPA and NRC regulatory programs contain specific technical guidance which have been supplemented not only through regulations of the various agencies, but also by additional supporting regulatory documents such as the EPA GDs and the NRC regulatory guides. In both programs, the prospective applicant is provided standards and guidance containing methodology designed to facilitate documenting the level of assurance required by the regulator in order to support a final decision.

The reliance on modeling and computer simulations of future events is common to both the EPA UIC program and the NRC HLW program. The extent to which an applicant can provide the regulator validated projections is crucial to the regulator's ability to support a finding that the wastes will not pose a threat to either human health or the environment. In both programs, the modeling is based on a 10,000-year time frame for isolation of the waste. This time frame has specifically been upheld in the challenge to the EPA program. While neither regulatory program claims that 10,000 years is the limit of regulatory concern, both assert it is within the range of current modeling capability and has a relationship to the toxic characteristics of the wastes involved.

Another similarity is the site-specific nature of the two programs. Both call for an applicant to address geotechnical uncertainties at a specific known location. Thus, regulators in both programs must evaluate the projections at a geographic and geologic point and within a described region. While the UIC program provides for generic applications, the Brent Kay opinion points out some of the difficulties in supporting an application without detailed site specific justification (Brent Kay, 1992). A particular geologic formation or strata must be described in both programs, and the interaction of the wastes with the target strata and surrounding formations must be modeled as part of the documentation in support of the applications.

A less striking similarity is the integration of engineering factors with geologic and hydrologic considerations. In the case of the UIC program, well integrity is an important factor in demonstrating that the wastes can be emplaced safely, preventing an unintended pathway to a point of discharge. In the HLW program, the interaction carries forward through the containment phase, thus becoming a positive factor in demonstrating isolation of the waste from the accessible environment. The relationship between engineering and geotechnical factors is also discussed in the following section. While not a primary factor in the decision-making process for approving proposals in both programs, extensive monitoring is required to demonstrate compliance with the granted authority of EPA and NRC. It is not clear how long active monitoring will continue in the HLW program; however, the UIC program implies perpetual monitoring since the waste is not contained within an engineered structure.

3.3 DISSIMILARITIES IN PROGRAMS AND APPROACHES

As stated above, the relationship between geologic factors and engineering considerations has only limited similarity. The absence of an engineering containment requirement in the UIC program focuses the decision-making process on the interaction between the waste and the natural environment. The waste is injected into a specified formation from which the applicant relies on natural barriers to prevent or retard migration. The required "no migration" demonstration relates to isolation from a point of discharge and not a specific location within the target formation (EPA, 1988a, p 28126). In the NRC HLW program, the decision-maker must evaluate the performance of multiple engineering and natural barriers individually and in combination.

A related dissimilarity is the ability of the UIC applicant to demonstrate compliance with one of two alternative modeling bases for a finding of "no migration" from a proposed well. The applicant must demonstrate either that the wastes will not migrate out of the injection zone or come into contact with an underground source of drinking water (USDW) within 10,000 years, or, that the wastes will no longer be deemed hazardous [EPA, 1988a, 40 CFR §148.20(a)]. The standards for these determinations are contained in EPA regulations. In contrast, the NRC HLW program does not provide an alternative to meeting the overall system performance objective of 10 CFR §60.112 (NRC, 1992).

Another dissimilarity between the two programs exists with respect to the role of the states. In the UIC program, the states work collaboratively with the EPA in the issuance of permits. In effect, they participate as regulators. In the NRC HLW program, the states are invited to be active participants in the regulatory proceedings, and are provided funds for review, but they have no regulatory functions. In Texas, where a significant percentage of the activity under the UIC program occurs, two separate state agencies have defined roles. The Texas Railroad Commission, the state's primary oil and gas regulatory body, has responsibility for review and approval of well configuration, and specifically, the proposed well casing. The Texas Water Commission has responsibility to transfer the projected waste plume to their water resource maps to aid in determining contact with a USDW. The ultimate decision is an EPA grant of a "no migration" permit accompanied by a state grant of an injection well permit. The EPA action is controlling; however, the involvement of two state agencies provides a close working relationship and minimizes the affect of any conflicting federal/state objectives.

There is also dissimilarity between the supporting documentation required by the UIC and HLW programs. The average UIC "no migration" permit application can be reviewed and decided within three months, including state agency involvement. In terms of decision-making, review of the computer models represents the most substantial analytical challenge, and even here the analysis is significantly less complex than those expected to support performance assessments for the proposed HLW License Application.

The NRC HLW repository licensing process is more complex. There is a statutory program of prelicensing activity which includes development and review of a site characterization plan and periodic progress and technical reports. This activity includes provisions for technical interchanges among the NRC, the applicants, and other affected parties. Additionally, 10 CFR Part 60 contains a broad range of technical requirements for repository siting and design as well as specifications for administrative requirements related to repository operation. The resulting license application will require a detailed technical review by staff with a broad range of technical expertise. After the license application review is complete, an adjudicatory hearing will take place to reach a licensing decision. This review and hearing process is required to be completed within three years.

3.4 CONCLUSIONS

Based upon the evaluation and comparison of the decision-making processes of the EPA "no migration" permitting within the UIC program and the NRC HLW repository licensing program, there appears to be a valuable regulatory analog worthy of further analysis. In particular, field officials actively reviewing proposals and supporting modeling documentation should be interviewed by NRC and CNWRA staffs engaged in preparation of the review plans for performance assessment. There are differences between the two programs, particularly with regard to the breath and depth of analysis required to support an application. However, similarities in the basic regulatory structure provide enough commonality that processes which have been successfully used and judicially reviewed can potentially provide guidance for the conduct of reviews and decision-making. Further review may enhance the NRC ability to provide additional direction to the applicant.

Although this study did not examine the specifics of the "no migration" permitting of the Waste Isolation Pilot Plant (WIPP) site, there may be useful information to be obtained from such an examination. The record of the associated regulatory activity and manner in which technical information was utilized could provide examples applicable to the NRC HLW repository licensing program.

4 RECOMMENDATIONS FOR FUTURE WORK AND USE OF CONCLUSIONS

It is recommended that additional analysis of the petroleum industry decision-making processes be undertaken in the area of techniques for data blending, that is, combining hard data such as field test results with expert opinion. These techniques may prove valuable in evaluating data on the leading edge of understanding. In addition, applying accepted techniques for (i) updating probabilistic information as more data become available, and (ii) using sparse data for geologic characterization may also prove beneficial. It should be noted these activities are already underway. These efforts could be supplemented by a presentation on data preparation and blending given by petroleum industry experts to NRC and CNWRA staff members who design procedures for using and analyzing technical data.

It is suggested that a detailed review of industry methodology, showing proven approaches to process validation, albeit outside of a regulatory environment, should be conducted. The petroleum industry is a leader in developing validation techniques for geologic transport, especially the multi-phase fluid flow situation and the resulting associated simulation of that environment. The results of petroleum industry efforts are available to the scientific community, have been documented, and are providing benefits to associated scientific endeavors.

It is also proposed that additional analysis of the procedures, practices, and supporting administrative tools developed by EPA for the UIC deep injection "no migration" permit program be undertaken by technical staff capable of integrating findings into HLW assessment of projected repository performance. Such analysis should include interactions with EPA regional officials currently reviewing and approving "no migration" permit applications and their supporting modeling demonstrations. These activities could be coordinated by CNWRA performance assessment and waste systems engineering and integration staffs, and results considered in the preparation of additional guidance for the applicant.

A study of the WIPP "no migration" permitting process could be useful as a future activity. Such a study might provide regulatory and technical insights which could be utilized in the NRC HLW repository licensing program. The evaluation of such technical issues as acceptability of use of expert judgment and requirements for model validation and verification within the context of a regulatory process might assist the NRC in preparations for HLW repository license application review.

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