Publication

REGULATORY PERSPECTIVES OF CONCEPT ASSESSMENT

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PERSPECTIVES RÉGLEMENTAIRES DE L'ÉVALUATION DU CONCEPT

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Résumé

La Commission de contrôle de l'énergie atomique est la principale agence chargée d'examiner sur le plan réglementaire l'évaluation du concept canadien pour l'évacuation des déchets de combustibles nucléaires qu'effectuent l'Énergie atomique du Canada, Limitée et Ontario Hydro. Le présent document décrit la perspective réglementaire sur la manière dont l'évaluation du concept peut démontrer la possibilité d'établir un système d'évacuation conforme aux exigences réglementaires.

Les aspects à long terme de l'évaluation du concept favorisent l'utilisation de diverses techniques de prédiction à différentes échelles temporelles. Chaque technique permettra différemment d'établir la confiance dans les prédictions. Le rendement prévu d'une installation durant l'exploitation doit faire l'objet d'une très grande confiance, puisqu'il peut être fondé sur les calculs ordinaires d'ingénierie et que les prédictions peuvent être confirmées ultérieurement grâce au contrôle durant l'exploitation. Les prédictions de la période transitoire qui suit la fermeture de l'installation devraient permettre d'obtenir un degré moyen de confiance, puisqu'elles peuvent être fondées sur des extrapolations de prédictions du rendement opérationnel, grâce à des modèles qui peuvent être étalonnés au moyen des données de contrôle et des données d'entrée moyennes tirées d'études analogiques naturelles. Les prédictions fondées sur les processus fondamentaux donneront un degré moyen de confiance lorsqu'elles seront faites sur les périodes intermédiaires après la fermeture. Les prédictions à long terme qui font appel à des données d'entrée typiques ou génériques, ou encore aux calculs de Monte Carlo des modèles simplifiés, donneront le moins de confiance, mais ils peuvent toujours contribuer à établir la confiance que le concept d'évacuation sera conforme aux exigences réglementaires.

Regulatory Perspectives of Concept Assessment

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Abstract

The Atomic Energy Control Board is the lead agency for the regulatory review of the Assessment of the Canadian Concept for Nuclear Fuel Waste Disposal being done by Atomic Energy of Canada Limited and Ontario Hydro. This paper describes the regulatory perspective of how the Concept Assessment could demonstrate the feasibility of a disposal system conforming to regulatory requirements.

The long-term aspects of Concept Assessment encourage the use of various predictive techniques for different time scales. Each technique will have a different potential for establishing confidence in the predictions. The predicted performance of a facility during operation should have a very high confidence, as it can be based on standard engineering calculations and the predictions can be validated later by monitoring during operation. The predictions of the transient period following closure of the facility should achieve a medium level of confidence, since they can be based on extrapolations of predictions of operational performance, using models that can be calibrated with monitoring data and with averaged input data derived from natural analog studies. Predictions based on fundamental processes will have a medium level of confidence when made to intermediate times after closure. Long-term predictions using generic or typical input data or Monte Carlo calculations of simplified models will have the least confidence and yet they can still contribute to the confidence that the disposal concept will conform to regulatory requirements.

Regulatory Initiatives

The announcement of the inception of the Nuclear Fuel Waste Management Program by the federal government of Canada and the provincial government of Ontario in June of 1978 (1) assigned the responsibility of performing research into storage and transportation of irradiated fuel to Ontario Hydro, a provincial power utility, and the responsibility of performing research into the immobilization and disposal of the nuclear fuel wastes to Atomic Energy of Canada Limited (AECL), a federal crown corporation. AECL's overall task " to verify that permanent disposal in a deep underground repository in intrusive igneous rock is a safe, secure and desirable method of disposing of radioactive waste " (1) is known as Concept Assessment.

In August of 1981 a second Canada-Ontario joint statement (2) identified the Atomic Energy Control Board (AECB), which regulates the nuclear industry in Canada, as the " lead agency for the regulatory and environmental review of the disposal concept. "

In keeping with its designated role, the AECB has been developing : regulatory requirements; criteria by which to judge the acceptability of the concept and the Concept Assessment documentation; and, guidelines addressing how these requirements and criteria could be met. Policy statements published by the AECB as Regulatory Documents have undergone extensive review by the nuclear industry and by the public before being finalized.

The AECB Regulatory Document R-104, 'Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Wastes - Long-Term Aspects' (3), presents objectives, requirements and guidelines dealing with the long-term aspects of all radioactive waste disposal, including nuclear fuel wastes. This document sets the individual radiological risk limit at 10^{-6} fatal cancers and serious genetic defects in a year and recommends a risk conversion factor of 0.02 per sievert. This conversion factor reflects the probability of a health effect from a given exposure, but does not include the probability of that exposure occurring. The document also identifies 10,000 years as the period for which compliance must be demonstrated. Guidelines to meet the general requirement of compliance to the radiological risk limit without reliance on institutional controls are presented in Regulatory Document R-104, and are discussed in greater detail in Information Report Info-0217, 'Regulatory Criteria for the Disposal of Radioactive Wastes' (4).

Requirements more specific to deep geological disposal of nuclear fuel wastes are published in Regulatory Document R-71, 'Deep Geological Disposal of Nuclear Fuel Waste : Background Information and Regulatory Requirements Regarding the Concept Assessment Phase' (5). This policy statement presents requirements for the disposal concept, requirements for assessing the disposal concept and requirements for documenting the assessment. It also contains discussions on the nature of Concept Assessment. In these discussions the life of a geologic repository is described in terms of pre-closure and post-closure phases. Closure is defined as the sealing and decommissioning of the disposal facility. Pre-closure, then, comprises site selection, facility installation, facility operation and decommissioning. After closure, the facility goes through a period of transient conditions until quasi-steady-state conditions develop. For the purposes of this discussion, the post-closure phase is arbitrarily divided into three time scales : short-, intermediate- and long-term post-closure periods, corresponding to different rates of change of the transient conditions, and roughly equivalent to decades, centuries and millennia, respectively.

The geologic characteristics required for an acceptable disposal site are presented and discussed in Consultative Document C-72, 'Geological Considerations in Siting a Repository for Underground Disposal of High-Level Radioactive Waste' (6). Preliminary recommendations to the AECB concerning the hydrogeologic factors of regulatory importance have been made by consulting experts in Information Report Info-0223, 'Hydrogeologic Factors to be Addressed in Disposal Guidelines' (7).

Regulatory View of Concept Assessment

Concept Assessment is a complex undertaking. To be tractable, it requires a structured approach, beginning with a definition of the problem. The problem definition should specify explicitly what questions need to be answered and what form the answers should take. These specifications then determine what tools and methods are appropriate to use. The problem definition can then be the basis for clear, explicit statements of what is to be accomplished and how. This approach is typical of large-scale, complicated engineering problems.

The discussion in Regulatory Document R-71 states " the concept will be refined until it can be shown with an acceptable level of confidence that the performance requirements established by the regulatory agencies will likely be met. At the completion of Concept Assessment, there must be little doubt that the concept which is finally accepted can be undertaken successfully in Canada." When predicting the performance of a disposal system, Concept Assessment must examine all pertinent conditions and processes which may affect the disposal system, and the predictions made must have a demonstrably acceptable level of confidence.

Thus, one general problem definition for Concept Assessment is that AECL must demonstrate with an acceptable level of confidence that its disposal concept is both theoretically possible and achievable (Figure 1). For the purposes of this discussion, theoretically possible is defined as the existence of a set of conditions or circumstances under which the disposal concept will meet regulatory requirements. By achievable, it is meant that those conditions or circumstances can be duplicated by a disposal facility, i.e. that the concept is technically feasible.

The confidence referred to in R-71 is subjective in nature. Hence, it cannot be quantified *a priori*, and an "acceptable" level of confidence cannot be prescribed in advance. Although criteria by which to judge the confidence in Concept Assessment have not been derived, it is recognized

PROBLEM DEFINITION

DEMONSTRATE CONDITIONS (OR CIRCUMSTANCES) UNDER WHICH THE CONCEPT MEETS REGULATORY REQUIREMENTS (THEORETICALLY POSSIBLE)

DEMONSTRATE THAT THOSE CONDITIONS CAN BE DUPLICATED IN A DISPOSAL FACILITY (ACHIEVABLE)

ASSESS THE CONFIDENCE THAT CAN BE PLACED IN BOTH DEMONSTRATIONS

FIGURE 1 : Example of a problem definition for Concept Assessment

that evaluating the confidence in Concept Assessment will become an important regulatory issue, and will not be a trivial task. The degree of confidence that can be achieved is dependent in part on the tools and techniques used and the confidence that can be placed in each.

Methods for solving a problem can be classified into three categories : quantitative, semi-quantitative and qualitative (Figure 2). Quantitative methods, such as those commonly used for engineering problems, calculate specific values for unknown variables, and result in statements such as "The groundwater velocity will be 0.5 metres per year". Uncertainty in these calculated values can arise from inaccuracies in the method of calculation (often an equation or a computer model) and inaccuracies in the input data. Quantitative methods allow the uncertainty in the calculations to be evaluated explicitly by comparisons between predictions and observations or between results based on different input data or different calculational methods. The confidence that can be placed in conclusions based on these methods of analysis is in general inversely related to the uncertainty in the calculated values.

METHODS OF SOLUTION

QUANTITATIVE : Engineering Calculations
(CALCULATES A VALUE)

SEMI-QUANTITATIVE : Limiting/Bounding Calculations
(IT IS NOT POSSIBLE TO EXCEED THIS VALUE)

: Probabilistic Calculations
(THIS VALUE IS NOT LIKELY TO BE EXCEEDED)

QUALITATIVE : Natural Analogues
(IT HAPPENS THIS WAY IN NATURE)

FIGURE 2 : Methods of problem solution for Concept Assessment

Although the same calculations can be used in both quantitative and semi-quantitative methods of solving problems, the interpretation of calculated results is different. Semi-quantitative methods calculate limiting values, either maxima, minima or asymptotes. These methods allow qualitative statements to be made about the range of unknown quantities of interest, such as "It is not possible to exceed this value" and "It is not likely this value will be exceeded".

There are two basic approaches to semi-quantitative methods. The first uses the set of input data that will calculate a limiting value, such as "The equilibrium aqueous concentration of calcium is 70 milligrams per litre". The conclusion that can be drawn from this result is "The long-term calcium concentration will approach 70 milligrams per litre". The second approach calculates several specific values of the unknown from several sets of input values, to evaluate a bounding value. This approach is useful when the input data are very uncertain, and the conclusion that can be drawn is based on the maximun (or minimum) value predicted. Such a conclusion might be "The maximum temperature predicted is 87 degrees, so the highest temperature should not exceed 100 degrees". Conclusions should be drawn from the results of semi-quantitative analyses only when the calculational methods are used within their limits of applicability. The confidence that can be placed such conclusions will be determined by the uncertainty in the calculated values.

Qualitative methods are essentially logical arguments, with little or no reference to quantitative values. Such arguments are usually based on observation, experience or expert opinion. When reasoned estimates are used (e.g. expert opinion) the confidence in the argument depends on the quality of the reasoning used. Natural analogues can be used in qualitative arguments, leading to the conclusion "It happens this way in nature". The confidence placed in such arguments by the technical community depends on how closely the natural analogue matches the conditions of the problem of interest. This comparison can be facilitated, and the determination of the confidence simplified, by defining appropriate problem specifications.

Demonstration of Theoretical Possibility

There are many methods available to demonstrate that a disposal concept is theoretically possible (Figure 3). Logical arguments based on natural analogues can be used to qualitatively demonstrate isolation capabilities of the geosphere. To make full use of arguments based on natural analogues, the conditions at the analogues must be compared critically to the expected conditions at a disposal facility, and the significance of any discrepancies between the two should be assessed. The greater the similarity between a natural analogue and a disposal system, the greater the confidence that can be placed in the argument. The extent and detail of the comparison between the conditions at a natural analogue and those expected in a disposal facility depends on the level of detail needed for the logical argument, which should be defined as part of the problem specification.

One example of a natural analogue is the Cigar Lake uranium ore deposit in Saskatchewan, Canada. At Cigar Lake a high-grade uranium ore is confined by a clay halo, even though the host sandstone is highly fractured and hydraulically very conductive (8). This ore body demonstrates geochemical containment in the presence of an open flow-field, and is a strong natural analogue argument in support of the theoretical possibility of the concept. AECL's current disposal concept places used fuel, which is about 99% uranium, in an emplacement canister which is embedded in a clay buffer. Although the conditions at the Cigar Lake ore body are not identical to those expected in this disposal concept, and the discrepancies should be evaluated, the similarity between the uranium ore body in a clay halo and the uranium fuel in a clay buffer should inspire confidence in the conclusions drawn from this natural analogue

Another natural analogue is the natural reactors at Oklo, in Gabon. There, fission products have not migrated any significant distance from the location of the reactors, although this system is chemically open (9). This analogue also demonstrates the capacity of the geosphere to isolate

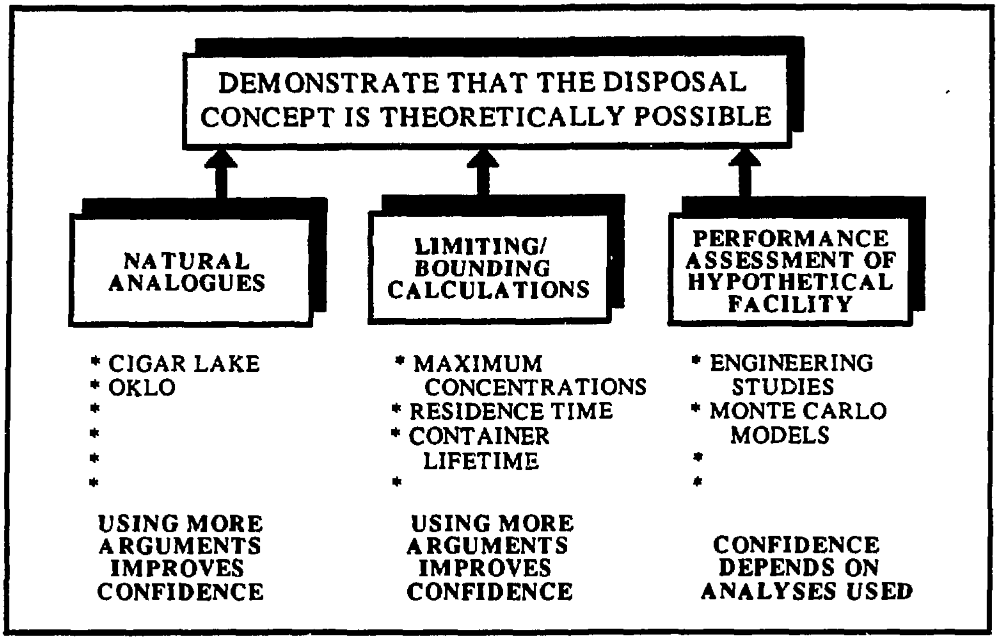

FIGURE 3 : Methods to demonstrate the conditions or circumstances under which the disposal concept will meet regulatory requirements and to improve confidence in the demonstration

radioactive waste. Although the differences between the conditions at Oklo and those expected in AECL's disposal concept need to be critically evaluated, the fact that fission products are retained in the open chemical system improves the confidence that there are conditions under which a disposal system would perform to meet regulatory requirements.

The theoretical possibility of a disposal system performing adequately can also be shown by limiting or bounding calculations. These can be empirical or mechanistic (process-controlled) models. One such model would be to use solubility constraints to estimate the maximum possible contaminant concentration under steady-state conditions. Other examples might include the calculation of limiting values of residence time in the geosphere using various structural models, or the calculation of limiting values of container lifetime based on various corrosion models and various groundwater chemistry models. The confidence that can be placed in such calculations can be very high if they are based on models which are amenable to validation.

The theoretical possibility of a disposal concept can also be demonstrated using a performance assessment of a hypothetical disposal facility, as AECL is doing. This approach should be able to define a set of conditions within which a disposal facility will meet regulatory requirements. Initially, a performance assessment of a disposal facility on a generic site in the Canadian Shield area of Northern Ontario was undertaken. It is now recognized that using generic site data may not provide a usable result, so the current Concept Assessment incorporates a performance assessment at several sites claimed to be typical of the range of conditions in the Canadian Shield. This introduces the problem of demonstrating that the sites used are indeed typical of Shield conditions and that they adequately represent the range of those conditions.

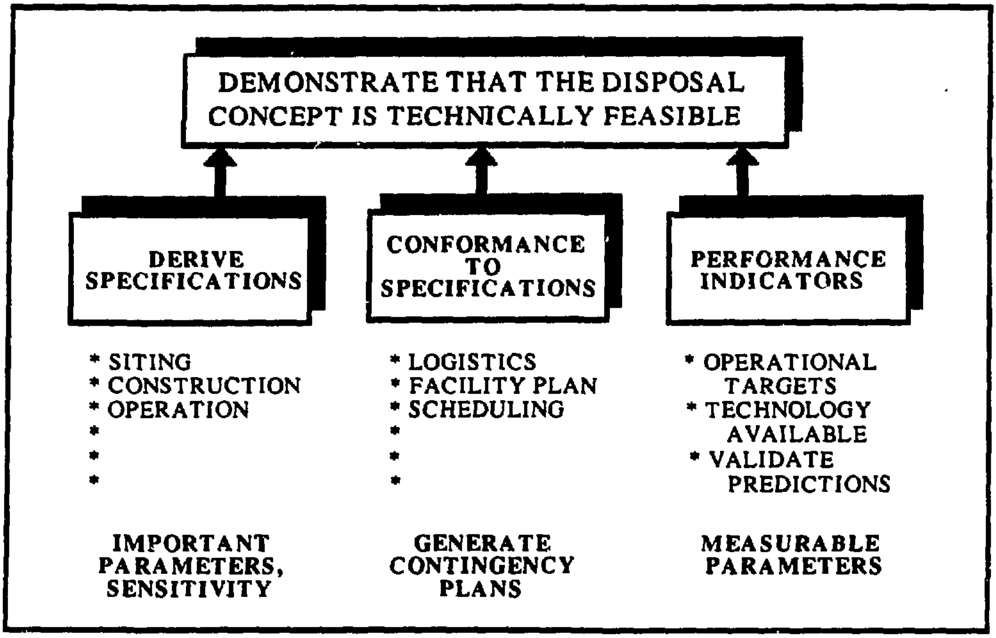

FIGURE 4 : Methods to demonstrate that conditions or circumstances under which the disposal concept will meet regulatory requirements can be duplicated by a disposal system

The ability of a performance assessment to demonstrate the plausibility of a disposal concept will be determined by both the predicted performance and the confidence that can be placed in those predictions. The confidence that can be achieved depends in part on the method used to predict the performance. Although qualitative and semi-quantitative predictions can be made with good subjective confidence, the confidence that can be placed in specific quantitative predictions can vary greatly. For example, it may be possible to predict *maximum* contaminant release rates with confidence, but the confidence in a prediction of the release rate at a specific place or time will be much lower. This is a reflection of the uncertainty in predicting future values of the conditions that control contaminant releases. Since different approaches for making predictions may be more appropriate for different time scales, it is to be expected that the confidence in specific predictions for different times will vary. Generally, conditions, processes and observations used to make specific predictions have less confidence the further into the future they are extrapolated.

Demonstration of Achievability

Concept Assessment must demonstrate not only the set of conditions under which a disposal system will meet regulatory requirements, but also that those conditions can be duplicated in a disposal facility. That is, the concept must be shown to be technically feasible (Figure 4). This means that the performance assessment and any other analyses of a disposal concept must result in the derivation of a set of specifications for the siting, construction and operation of a disposal facility. It must also demonstrate that it is possible to site, construct and operate a disposal facility to those specifications.

For siting, the analyses used in Concept Assessment should demonstrate the capability to distinguish between an acceptable and an unacceptable site. This implies that the analyses should identify the important parameters by which to judge a site and derive a pass/fail criterion for each of them individually or as interrelated subsets. The important parameters would be used to guide site characterization studies and their pass/fail criteria would be the specifications used in site selection.

For facility construction and operation Concept Assessment should identify the parameters which are important to the predictions as performance indicators and should also specify operational targets and normal operating ranges for each of them. Associated with this is the need to demonstrate that the technology is available to monitor these parameters. If it is not technically possible to measure an important parameter, then it is not useful as a performance indicator.

Sensitivity analyses will be vital in identifying the important parameters for siting, identifying performance indicators for construction and operation and for deriving pass/fail criteria and operational targets.

The demonstration of technical feasibility should also include plans and schedules to show the logistics of siting, constructing, operating and decommissioning a disposal facility. These are necessary to show that it would be possible to operate a real facility and to generate contingency plans in anticipation of abnormal or accident conditions.

Development of Confidence in Predictions

One of the regulatory requirements is that models be validated where possible. Validation is accomplished by comparing observed behavior to model predictions based on real input conditions. Validation should provide a measure of the uncertainty in the model predictions based on discrepancies between the predicted and observed data. Thus, for a given range of input values, a validated model will have a quantified uncertainty. This should provide greater confidence in model predictions based on valid input data than if the uncertainty were not measured.

A 'partial validation' is when the range of real input data used to validate the model is smaller than the range of input data for the problem of interest. A partial validation will also improve confidence in model predictions, but not to the extent that a full validation would.

Where validation is not possible, confidence in the model predictions should be enhanced to the extent practicable, for example by demonstrating that the model has realistic sensitivity to input data variations. This improvement in the level of confidence applies only over the range of the input parameter values for which realistic sensitivity is demonstrated where model sensitivity is the local partial derivative of the prediction with respect to the input parameters.

Confidence in model predictions shouldbe increased qualitatively by means of peer review of the model and input data, and, in the specific case of computer models, by use of good software engineering techniques and code-to-code comparisons. However, peer review, good software engineering and code-to-code comparisons do not address necessarily the accuracy of model predictions, only that the model and input data are consistent with our understanding of the real world and processes in it.

Since Concept Assessment is essentially a feasibility study, it relies heavily on predictive modelling. The confidence that can be placed in a disposal concept will be related inversely to the uncertainty in the model predictions. As mentioned earlier, different modelling approaches should be usedfor making predictions at different time scales. The confidence that can be placed in a specific prediction of performance generally decreases with an increase in the time scale of the prediction, due to uncertainty in the occurrance and magnitude of future conditions upon which the

PHASE	PRE-CLOSURE	POST-CLOSURE		
PERIOD	OPERATION	SHORT-TERM	INTERMEDIATE-TERM	LONG-TERM
TIME SCALE		DECADES	CENTURIES	MILLENNIA
METHODS OF ASSESSMENT	Engineering Calculations based on design data Finite Element Finite Difference Systems Analysis	Extrapolation of Engineering Calculations Mechanistic and Process-based Calculations	Extrapolation of Engineering Calculations using data from analogues Mechanistic Calculations Detailed Probabilistic Calculations Qualitative arguments based on analogues	Extrapolation of Engineering and Mechanistic Calculations Probabilistic Calculations based on derived and empirical relationships Qualitative arguments based on natural analogues
METHODS OF DEVELOPING CONFIDENCE	Analogous to other facilities Potential to calibrate models using data from operation Potential to validate predictions with operational data	Predictions can be based on models that have the potential to be calibrated during operation using real data Predictions can be based on models that have the potential to be validated for operational conditions Should be concordance of predicted values from different methods and for common times		
RELATIVE CONFIDENCE LEVEL	HIGH	MEDIUM	MEDIUM - LOW	LOW

TABLE 1: Analyses that could be used to build confidence in Performance Assessment

model predictions are based. Table 1 presents some examples of analyses that can be used in a performance assessment of a disposal facility and how confidence in the assessment can be developed.

The pre-closure phase of a disposal concept includes siting, facility construction, waste packaging and emplacement and facility decommissioning. The predictions made for the pre-closure phase should be able to achieve a low uncertainty, resulting in a high degree of confidence. Most of them will be based on common engineering calculations, employing such methods as conservative estimates, numerical methods of analysis such as finite difference or finite element computer programs, limiting conditions, reliability analysis and sound engineering judgement. These calculations should be similar to those performed for other engineering projects such as mines, dams or generating stations.

When a disposal facility's life is over, it will not be allowed to close until there is substantial evidence that the facility is performing adequately as predicted, and will continue to do so. Thus, one aspect of an acceptable concept is that some of the predictions that will be made in support of licensing can be validated using monitoring data from construction and operation of the facility. This will provide confidence in predictions of continued acceptable performance that is a pre-condition for closure.

Predictions for decades after closure, when the transient conditions will likely be changing most rapidly, should be based on calculations similar to those used for the pre-closure phase. In fact, short-term post-closure predictions will probably be extrapolations of some pre- closure calculations. During operation of the facility these post-closure predictions would be refined, using models validated or at least calibrated with monitoring data. Concept Assessment, then, should be able to justify a moderate degree of confidence in the predictions for the short-term post-closure period. There is also the potential to greatly enhance the confidence in short-term post-closure predictions using models validated by monitoring once the facility is in operation.

Predictions for the intermediate post-closure period will have a somewhat lower level of confidence, since they are being made for centuries into the future and there is less certainty about the conditions that will exist then. These predictions should be made with the same methods of extrapolation as for the short-term, as well as using data averaged over centuries (for example, climatic data). Detailed models based on fundamental processes should be used, as should qualitative arguments based on natural analogues, to improve the confidence in the predictions for the intermediate term.

Specific predictions of behavior in the long-term post-closure period, based on conditions that may exist millennia after closure, are expected to have the greatest uncertainty. The long time scale makes extrapolation of detailed calculations not only highly uncertain but prohibitively expensive. Calculations at these longer time scales are more amenable to the use of assessment models using simplified relationships and limiting assumptions. These assessment models include Monte Carlo type computer models, where distributed input data reflect the uncertainty in future conditions. The algorithms used in Monte Carlo calculations are usually simplifications of more detailed models, so the algorithms themselves include the uncertainties of both the underlying detailed models and of the simplifications. The confidence, then, that can be placed in a single or deterministic prediction using a simplified algorithm and uncertain input data is not very high.

This lack of confidence in a single prediction is balanced by making a large number of predictions using the full range of the distributed input data. The set of predictions is interpretted in a semi-quantitative manner to arrive at a bounding value for the predictions. The confidence, then, that can be placed in a set of Monte Carlo calculations is derived from the use of a large number of different input conditions to explore the domain of possible output conditions, but this confidence is constrained by the appropriateness of the input data and the applicability of the algorithms used. The confidence in these predictions cannot be improved beyond a certain point simply by increasing the number of Monte Carlo calculations.

There is another general approach to demonstrating the feasibility of the concept which will improve the confidence in the predictions. When there are several different methods being used at several different time scales there should be a concordance among predictions for common times (Figure 5). Early predictions for the long-term post-closure period should show reasonable agreement with predictions made for intermediate- and short-term time scales, even though different models may be used. Similarly, early predictions for the intermediate time scale should show reasonable agreement with short-term predictions. This would link the more uncertain long-term predictions to the less uncertain short-term predictions, thus enhancing confidence in the overall predicted performance of the disposal facility.

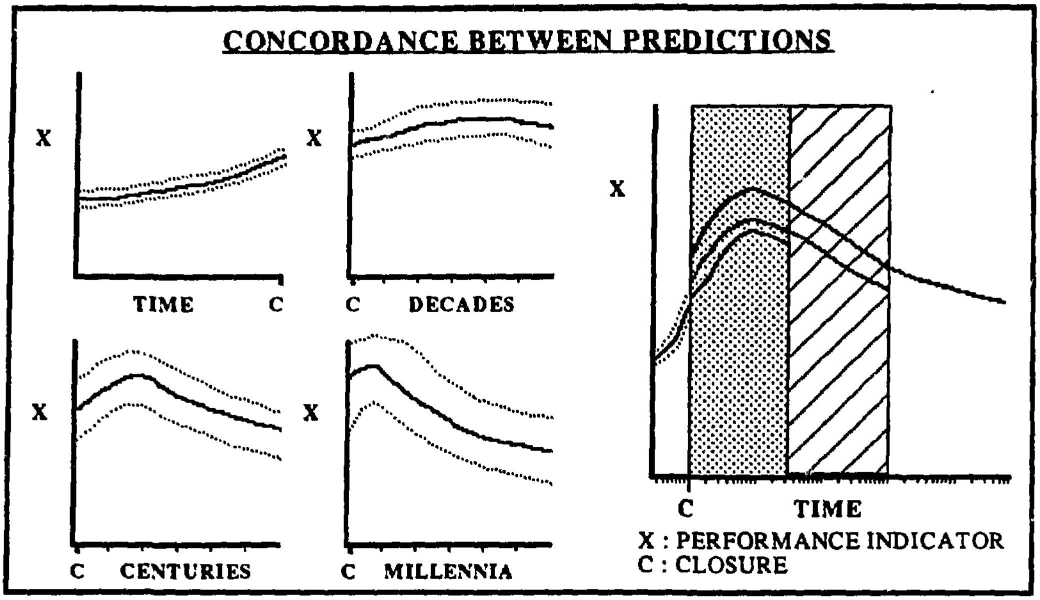

FIGURE 5 : Concordance at common times between predictions made for different time scales

Summary

The Atomic Energy Control Board (AECB) is the lead agency for the regulatory review and evaluation of the Canadian Nuclear Fuel Waste Management Program being developed by Atomic Energy of Canada Limited (AECL) and Ontario Hydro. AECL is responsible for performing and documenting the Concept Assessment, a program to demonstrate that deep geological disposal in crystalline rock is " a safe, secure and desirable method of disposing of radioactive wastes ". The AECB has developed regulatory requirements, guidelines and criteria by which to evaluate Concept Assessment.

Concept Assessment is viewed by the AECB as essentially a feasibility study to show that the disposal concept is theoretically and technically possible. There must be an acceptable level of confidence in the conclusions that AECL will draw concerning the feasibility of the concept. The level of confidence is considered to be directly related to the number and quality of arguments presented in support of conclusions concerning the concept, and inversely related to the uncertainty in calculations performed in support of those conclusions.

Concept Assessment is defined as a demonstration that a set of conditions exists within which a disposal system would meet regulatory requirements, and a demonstration that that set of conditions can be duplicated by the proposed disposal system. The specification of the confidence in the demonstrations requires quantification of calculational uncertainties, the use of several different types of supporting arguments, including semi-quantitative and qualitative approaches, the use of models which are validated or have the potential to be validated, and the concordance of predictions from various sources.

There are several arguments identified which may be useful for Concept Assessment, ranging from logical arguments based on natural analogues to a performance assessment of a hypothetical disposal facility on a typical site. Methods of accomplishing a performance assessment are

presented in terms of how they should contribute to the confidence in the results. The level of confidence will vary with different types of analyses and, for some analyses, will deteriorate the farther into the future a prediction is made. No single analysis or technique is seen to provide the necessary confidence in the demonstration of the feasibility of the disposal concept. Rather, an integrated approach using a variety of methods to generate a suite of different supporting arguments for different time scales is seen as being appropriate for Concept Assessment.

Literature Cited

1. ENERGY, MINES AND RESOURCES CANADA, News Release, "Canada/Ontario Radioactive Waste Management Program," Ottawa, 1978, June.

2. ENERGY, MINES AND RESOURCES CANADA, News Release, "Canada-Ontario Joint Statement On The Nuclear Fuel Waste Management Program," Ottawa,1981, August.

3. ATOMIC ENERGY CONTROL BOARD, Regulatory Document R-104, Regulatory Policy Statement, "Regulatory Objectives, Requirements and Guidelines for the Disposal of Radioactive Wastes - Long-Term Aspects," Ottawa, 1987, June.

4. WAGSTAFF, K. P., "Regulatory Criteria for the Disposal of Radioactive Wastes," Proceedings of the Second International Conference on Radioactive Waste Management, 1986 September 7-11, Winnipeg, Manitoba, Canadian Nuclear Society, Toronto, 1986; also as ATOMIC ENERGY CONTROL BOARD, Information Document INFO-0217, Ottawa, 1986, September.

5. ATOMIC ENERGY CONTROL BOARD, Regulatory Document R-71, Regulatory Policy Statement, "Deep Geological Disposal of Nuclear Fuel Waste:Background Information and Regulatory Requirements Regarding the Concept Assessment Phase," Ottawa, 1985, January.

6. ATOMIC ENERGY CONTROL BOARD, Consultative Document C-72, Porposed Regulatory Guide, "Geological Considerations in Siting a Repository for Underground Disposal of High-Level Radioactive Waste," Ottawa, 1987, January.

7. LAFLEUR , D. W. and K. G. Raven, "Hydrogeologic Factors to be Addressed in Disposal Guidelines," ATOMIC ENERGY CONTROL BOARD Information Document Info-0223, Ottawa, 1986, December.

8. CRAMER, J. J., "A Natural Analogue for a Fuel Waste Disposal Vault," Proceedings of the Second International Conference on Radioactive Waste Management, 1986 September 7-11, Winnipeg, Manitoba, Canadian Nuclear Society, Toronto, 1986.

9. JAKUBICK, A. T. and W. Church, "Oklo Natural Reactors: Geological and Geochemical Conditions - A Review," ATOMIC ENERGY CONTROL BOARD Information Document Info-0179, Ottawa, 1986, February.