Natural Analogues and Validation of Performance Assessment Models

Presentation for the NWTRB

Reno, NV

April 16-17, 1991

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PERFORMANCE ASSESSMENT

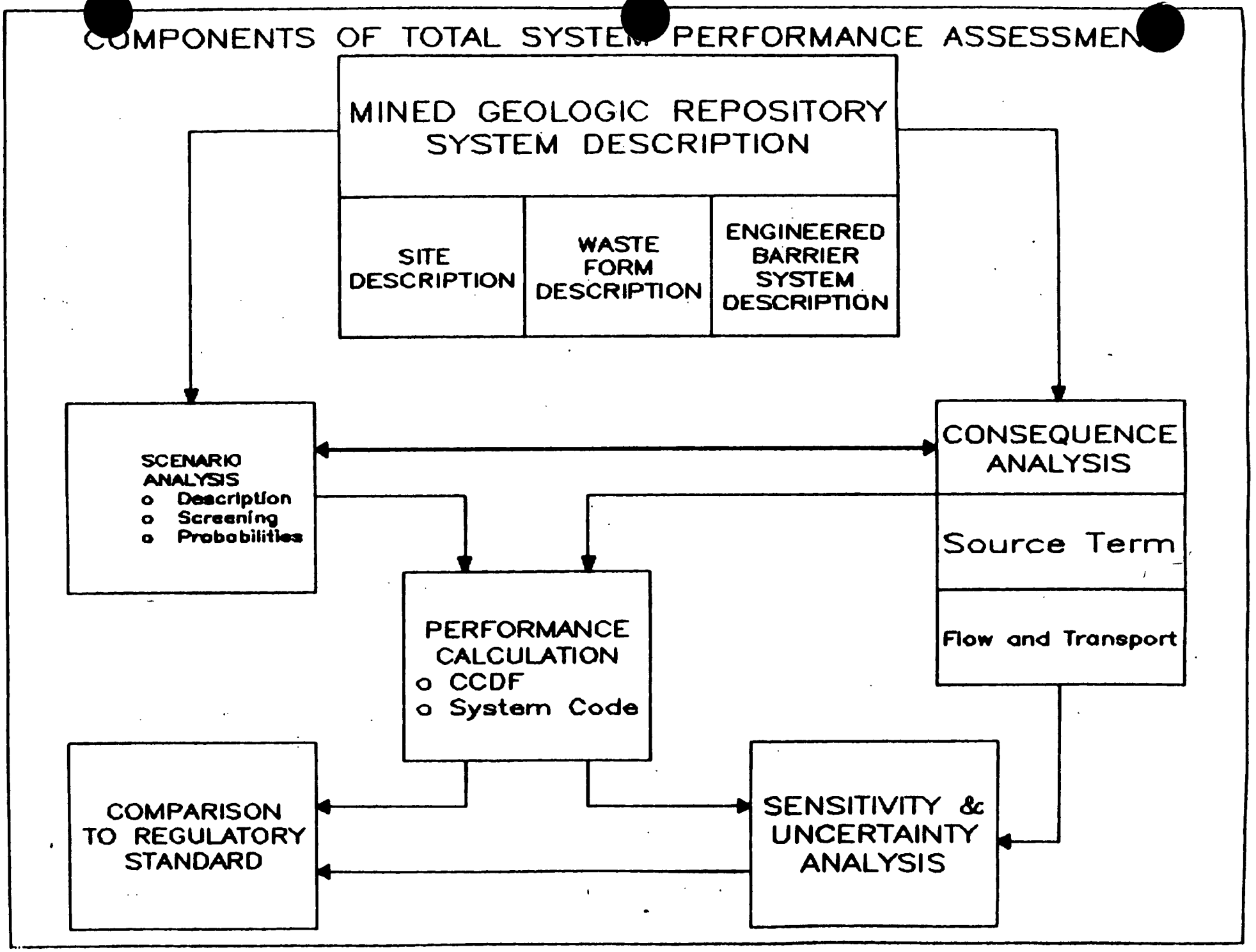
Performance assessment is a type of systematic safety analysis used to:

1. predict the potential health, safety, and environmental effects of creating and using a nuclear waste repository;

2. characterize these effects in terms of their magnitudes and likelihoods;

3. compare the characterization of these effects to acceptability standards; and

4. present the results of these analyses in a format useful to regulators, scientists, decision-makers, and the public.


COMPONENTS OF TOTAL SYSTEM PERFORMANCE ASSESSMENT
MINED GEOLOGIC REPOSITORY SYSTEM DESCRIPTION
SITE DESCRIPTION
WASTE FORM DESCRIPTION
ENGINEERED BARRIER SYSTEM DESCRIPTION
SCENARIO ANALYSIS
o Description
o Screening
o Probabilities
CONSEQUENCE ANALYSIS
Source Term
Flow and Transport
PERFORMANCE CALCULATION
o CCDF
o System Code
COMPARISON TO REGULATORY STANDARD
SENSITIVITY & UNCERTAINTY ANALYSIS

NATURAL ANALOGUE

Broadly speaking, a natural analogue is any occurrence or instance of the behavior of naturally occuring or man-made materials, geometries, configurations, processes, and/or phenomena in a geologic environment that can provide some insight and information about the behavior (especially the long-term behavior) of a nuclear waste repository, its components, or its subsystems.

Why Consider Natural Analogues for Validation of Performance Assessment Models

- Predictive models will be the principal means to demonstrate safety of a nuclear waste repository

- Cannot use the usual method of validating predictive models, viz. comparing model predictions to experiments

- Proof testing is not possible
  - time scales are too long
  - space scales are too long
  - future environments are not certain
  - geologic system is heterogeneous and cannot be precisely defined

But...

Simple demonstrations of repository safety by comparison to natural analogues may not work

- there is no exact analogue to any proposed repository; the differences can be used to undermine the applicability of the analogue

- the analogues exemplifying safety have survived; the analogues exemplifying instability have been transformed and are not present

Types of Natural Analogue Studies

1. Component Studies
    a. Waste Form
    b. Engineered Barriers
    c. Geologic Site
2. System Studies
    a. Scenarios
    b. Sensitivity and Uncertainty Analyses
    c. Overall System Performance

Hierarchy of Natural Analogue Studies

Based on Degree of Validation Provided

1. Process and/or Phenomena Identification
2. Parametric Quantification
3. Component Submodel Validation
4. System Model Validation

CLASSIFICATION	AUTHOR/DATE	SUBJECT	VALIDATION CATEGORY (1)	(2)	(3)	(4)
COMPONENT STUDIES						
Waste Form						
	Kaplan, 1980	Ancient Glass Artifacts	X			
	Haaker/Ewing, 1981	Waste Form/Host Rock Interactions	X			
	Malow/Ewing, 1981	Thermal and Chemical Stability of Waste Glass vs. Natural Glass	X	X		
	Ericson, 1981	Hydration of Obsidian Glass	X	X		
Eng. Fac.						
	Johnson/Francis, 1980	Archeological Objects, Metal Meteorites, and Native Metals (Canister)	X	X		
	Apps/Cook, 1981	Fe-Ni Alloy Formation in Ultra-Basic Rock (Backfill)	X			
	Register, et al, 1980	Clay Minerals In Evaporite Sequences	X			
	Brookins, 1981	Clay Minerals In Uranium Deposits (Backfill)	X			
	Langston/Roy, 1984	Ancient Cements (Seals)	X			
Site						
	Laul, et al, 1984	Migration of Elements From Igneous Intrusions	X			
	Levy, 1984	Alteration of a Vitrophyre At Yucca Mountain	X			
	IAEA, 1975/1978	Oklo	X			
	Brookins, 1981	Oklo-Migration of Alkali and And Alkaline Earth Elements	X			
	Curtis/Gancarz, 1983	Oklo-Mineralogical Changes	X			
	Hubbard, et al, 1984	Migration of Naturally Occurring Radionuclides in Brine Acquifers	X	X		
	Shea, 1984	Uranium Migration from Veins and Veinlets	X	X		
	McKinley, et al, 1984	Migration of Seawater Intrusion Deposits into Lacustrine Sediments	X	X		
	Airey, et al, 1982-84	Migration of Ore Bodies in the Alligator Rivers Region	X	X		

CLASSIFICATION	AUTHOR/DATE	SUBJECT	VALIDATION CATEGORY (1)	(2)	(3)	(4)
COMPONENT STUDIES						
System Studies						
	Brookins, 1981	Migration from an Igneous Dike into Evaporite Rock	X			
	Wollenberg, et al, 1983	Migration from Intrusive Rocks into Various Country Rocks	X	/		
	Brookins, et al, 1983	Migration from Monzonite Intrusion into Tuff	X	/		
	Gancarz, 1980	Tc, Pb and Ru Migration at Oklo	X	/		
	Andrews/Pearson, 1984	Migration of Natural Radionuclides in an Acquifer	X	X		
	Eisenbud, et al, 1982	Radionuclide Migration at Morro De Ferro	X	X		
	Miekeley, et al, 1982	Radionuclide Migration at Morro De Ferro	X	X		
	Gilbert, 1984	Biosphere Transport of Radionuclides			X	

KEY

(1) Process and/or Phenomena Identification
(2) Parametric Quantification
(3) Component Submodel Validation
(4) System Model Validation

Technical Difficulties

in Applying Natural Analogue Studies

to the Validation of Performance Assessment Models

1. Natural analogues cannot be controlled as can laboratory experiments.

2. It is difficult to determine what conditions prevailed.

3. Characteristics of the geologic system can be specified only with large uncertainties, because the system is natural, heterogeneous, complex, and not transparent.

4. Most geologic systems are extremely complex with numerous processes occuring simultaneously; validation of a single aspect of modeling is generally precluded.

5. Quantitative, predictive models for geologic systems is not as advanced as some other sciences and engineering.

6. Natural analogues are often data poor, since the same data are used to fix parameters and to validate the model; redundant data are required for robust validation.

RECOMMENDATIONS

* 1. Natural analogues that are simpler systems may provide more useful quantitative data for comparison to predictive models than more complex systems more closely resembling a repository component or configuration.

2. Broadening the range of analogues studied to include species other than those found in nuclear waste (and their surrogates) may provide important information on the validity of fundamental flow and radionuclide transport processes.

** 3. More emphasis needs to be applied to determining the environmental conditions operative during the formation of the analogue; behavior of species unrelated to the waste analogue may provide valuable clues to these conditions.

4. Some consideration might be given to collecting data to validate (or not) scenario formulation and probability determinations inherent in many performance assessments.

** 5. Natural analogue studies that yield more quantitative data better coordinated with modeling efforts would serve the purpose of validation better.

* This issue has been addressed, since the paper was written.

** This issue has been vigorously addressed, since the paper was written.

3. Criteria for selection and successful use of natural analogs

Chapman et al. (1984) presented the following criteria for selecting analogs:

1) The process involved should be clear-cut. Other processes which may have been involved in the geochemical system should be identifiable and amenable to quantitative assessment as well, so that their effects can be 'subtracted.'

2) The chemical analogy should be good. It is not always possible to study the behavior of a mineral system, chemical element or isotope identical to that whose behavior requires assessing. The limitations of this should be fully understood.

3) The magnitude of the various physico-chemical parameters involved (P, T, pH, Eh, concentrations, etc.) should be determinable, preferably by independent means and should not differ greatly from those envisaged in the disposal system.

4) The boundaries of the system should be identifiable (whether it is open or closed, and consequently how much material has been involved in the process being studied).

5) The time scale of the process must be measurable, since this factor is of the greatest significance (the *raison d'etre*) for a natural analog.

Airey and Ivanovich (1985) added a requirement for transport analogs:

6) A contaminant transport analog requires a spatial discontinuity across which to observe transport.

In addition to the above criteria, the following should be considered:

7) It is important that the source term (e.g. the original distribution of the elements of interest) be well constrained.

8) It is important that the environmental analog be close. The argument that an analog has suffered more extreme conditions than the system of comparison and therefore provides a conservative example is inappropriate. <u>More extreme</u> conditions are <u>different</u> conditions than those present in the system of comparison; such different conditions may include different processes or different combinations of processes than at the site of interest.

Introduction

Since 1981 conceptual and mathematical models for radionuclide and groundwater transport in the geosphere have been evaluated in the international cooperation projects INTRACOIN, HYDROCOIN and now also INTRAVAL, managed by the Swedish Nuclear Power Inspectorate (SKI).

The INTRAVAL project was started in October 1987. The purpose of the study is to increase the understanding of how various geophysical, geohydrological and geochemical phenomena of importance for the radionuclide transport from a repository to the biosphere can be described by models developed for this purpose. This is being done with a systematic use of information from laboratory and field experiments as well as from natural analogue studies.

Twelve Test Cases based on thirteen experiments have so far been included in the study. A Pilot Group has been appointed for each of the Test Cases. The responsibility of a Pilot Group is to compile data and propose formulations of the Test Case. Several of the Test Cases are based on international experimental programmes such as the Stripa Project, the Alligator Rivers Project and the Poços de Caldas Project.

It is a pronounced policy of the INTRAVAL study to support interaction between modellers and experimentalists in order to gain reassurance that the experimental data are properly understood and that the experiences of the modellers regarding the type of data needed from the experimentalists are accounted for. To support this interaction and for the development of a strategy for the systematic application of the experiences and knowledge gained from the Test Cases a committee, the Validation Oversight and Integration Committee (VOIC), has been set up.

Working documents for the Test Cases have been developed by the Pilot Groups and the Project Teams have started their modelling attempts. Two Co-ordinating Group meetings, one general workshop and specific workshops for some Test Cases have been arranged.