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Protecting People and the Environment

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International Panel Discussion on Radionuclide Sources and Migration in the Subsurface

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Question

- How were conceptual models formulated for the various radionuclide sources?

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Conceptual Site Models (CSMs)- Basis

- CSMs in the hydrologic safety review of new reactors are used to characterize the site in terms of its ability to delay, disperse, dilute, or concentrate accidentally released radioactive liquid effluent during its transport from a tank in the liquid waste management system (LWMS).
- Conceptual models are used in the review process to streamline site characterization.

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CSM - Process

- Conceptual models are usually constructed using the following components:
  - Geologic framework to characterize the subsurface and fluid flow and transport.
  - Hydrologic framework to identify fluid flow processes in the physical framework.
  - Assessment of risk sources such as radionuclide source terms, contaminant chemicals and plausible pathways.
- Radionuclide sources in this case are determined by the reactor design and the source terms of significance are determined based on the level of activity and volume of the tank.

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CSM – Process…

- All plausible conceptual site models need to be considered.
- Plausible models are required:
  - to make the argument defensible
  - to ensure the assumptions are acceptable
  - to ensure the conclusions are credible
- The applicant has to adequately demonstrate the process followed to identify plausible conceptual models.

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CSM – Process…

- The applicant has to adequately demonstrate the process followed to determine the most conservative of all the plausible models considered.
- The applicant has to satisfactorily describe the processes affecting release, migration and fate of radionuclides.

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Question

Do the conceptual models incorporate:

- Uncertainties in sampling and measurement of the radionuclides (e.g. tritium);
- Evolution of the chemical form of the radionuclide in the atmosphere, soil and ground water;

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CSM - Uncertainties

- In the context of new reactors hydrologic safety review analysis there are uncertainties in:
  - Methods
  - Data
  - Processes
- Uncertainties are addressed through a combination of regulatory conservatism and technical uncertainty analysis aimed at
  - ensuring safety and
  - protection of the public and the environment.

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CSM – Uncertainties…

- In the context of hydrologic safety review the requirements are:
  - adequate description of the subsurface, groundwater flow processes, use, and pathways for accidental release of radioactive liquid effluents.
  - Identification of a potable water source
  - Selection of the most conservative but plausible approach

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CSM – Uncertainties…

- Uncertainties in CSM formulation are accounted for by :
  - Consideration of alternate CSMs: sufficient to bound the hydrogeological conditions at the site,
  - Consideration of alternate pathways: bounding set of plausible surface and subsurface pathways from the points of release.

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CSM – Uncertainties…

- Consideration of site characteristics that affect transport:
  - Characteristics of the groundwater environment with respect to existing and known and likely future users.
  - Estimates and bases for flow and transport parameters.
- Consideration of other site related evaluation criteria: potential effects of site-proximity hazards, seismic, and non-seismic events on the radioactive concentration from the postulated tank failure related to accidental release of radioactive liquid effluents.

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CSM – Uncertainties…

- Consideration of the most conservative measured, estimated and derived parameters.
- Consideration of the most severe of historical phenomena and historical records as part of the regulatory requirements 10 CFR Part 50, Appendix A, General Design Criterion 2 (GDC2)

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CSM - Uncertainties and Regulation

- 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2 - Design bases for protection against natural phenomena – sets the designs basis to reflect:
  1. Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated,
  2. appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and
  3. the importance of the safety functions to be performed.

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CSM - Uncertainties and Regulation…

- 10 CFR 100.20 (c) (3) : Factors important to hydrological radionuclide transport (such as soil, sediment, and rock characteristics, adsorption and retention coefficients, ground water velocity, and distances to the nearest surface body of water) must be obtained from on-site measurements. The maximum probable flood along with the potential for seismically induced floods discussed in § 100.23 (d)(3) must be estimated using historical data.

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Question

- What was learned in the testing of conceptual site models?

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CSM Lessons Learned

Based on experience in the review of new reactor application

- Staff performs independent confirmatory analyses.
- Based on Staff's confirmatory analysis the CSMs and pathways identified by applicants were not always consistent with the most conservative and plausible chosen by the Staff.
- Hierarchical approach is important in building CSMs.

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CSM Lessons Learned…

- Longer records of data and proper interpretation and integration of data from different sources is vital for building a good CSM.
  - The different sources include hydrogeologic investigation, core sampling, geophysical methods, pump tests, etc...
- Understanding of data anomalies and what they represent in the overall site hydrology and hydrogeology.
- Proper QA/QC procedures for monitoring data collection, reporting, and analysis.

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CSM Lessons Learned…

- Conversion of CSMs into numerical computer models for simulating flow and transport requires careful consideration to ensure:
  - Proper representation of hydrogeologic and stratigraphic layers.
  - Proper representation of engineered features and parameter values to show the post-construction site configuration.

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Question

- What specific monitoring data (e.g., hydraulic, radiochemical, geochemical, geophysical, meteorological) and analyses were used to test the conceptual models?

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CSM – Monitoring Data

- Monitoring data in the context of the safety review of new reactors are limited to data used to construct numerical computer models or analytical models to simulate flow and transport.
- The data requirement is set in 10 CFR 100.20 (c)(3), 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 2, 10 CFR 52.17(a)(1)(vi), for ESP applications, and 10 CFR 52.79(a)(1)(iii).

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CSM – Monitoring Data

- Monitoring in the operational phase is the responsibility of Staff of NRR .
- The monitoring data are usually tied to hydraulic heads in wells to make sure that the hydraulic gradients are as designed in the analysis included in the safety analysis report.

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CSM – Monitoring Data…

- Radionuclide monitoring is based on a mechanism set *a priori* as determined by the safety and environmental analysis.
- The environmental analysis has a radiological environmental monitoring program (REMP).
- Staff reviews the applicant's proposed REMP.

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CSM – Monitoring Data…

- Review of REMP includes:
  - Verifying the adequacy of ground and surface-water sampling points.
  - Verifying that air monitoring and sample points are adequately located.
  - Obtaining the radiological effluent points.
  - Obtaining the principal radiological exposure pathways.
  - Providing a summary of additions, modifications, or deletions to the proposed radiological

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CSM – Monitoring Data…

- Environmental monitoring program requirements:
  - preoperational monitoring program should be initiated 2 years before plant operation
  - Surface water, groundwater, and drinking water need to be monitored for at least 1 year.
  - a detailed description of the proposed monitoring program needs to be provided

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CSM – Monitoring Data…

The details of the monitoring plan include:

1. number and location of sample collection points and measuring devices and the pathway sampled or measured,
2. sample size, sample collection frequency, and sampling duration,
3. type and frequency of analysis,
4. general types of sample collection and measuring equipment,
5. lower limit of detection for each analysis,
6. the approximate date on which the proposed program will be effective, and
7. the quality-assurance program for radiological environmental monitoring programs

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Radiological Environmental Monitoring Program

Exposure Pathway and Sample	Number of Samples and Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
Waterborne Radiation			
Surface	1 sample upstream 1 sample downstream	Composite sample over 1-month period	Gamma isotopic analysis monthly. Composite for tritium analyses quarterly
Ground	Samples from 1 or 2 sources only if likely to be affected	Quarterly	Gamma isotopic and tritium analysis quarterly
Drinking	1 sample of each of 1 to 3 of the nearest water supplies that could be affected by its discharge	Composite sample over 2-week period if I-131 analysis is performed, monthly composite otherwise	I-131 analysis on each composite when the dose calculated for the consumption of the water is greater than 1 mrem per year. Composite for gross beta and gamma isotopic analyses monthly. Composite for tritium analyses quarterly
	1 sample from a control location		
Sediment from shoreline	1 sample from downstream area with existing or potential recreational value	Semiannually	Gamma isotopic analyses semiannually

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Question

- What role did modeling have in estimating and confirming radionuclide migration behavior, and in assessing vulnerabilities to environmental resources (e.g., potable aquifers)?

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The Role of Modeling

- Modeling is an integral part of the new reactor applications review process.
- Pathways to potable water sources identified in the analysis of accidental release of liquid radioactive effluents were greatly enhanced by CSMs and modeling using post-construction scenarios.
- Numerical models are used to simulate the transport of radionuclides in both surface water and groundwater pathways.

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The Role of Modeling…

- Radionuclide isotopes and their progenies are simulated to determine travel time and concentration and to confirm compliance with the regulatory limits for effluents
- Plausible conservative pathways are used to track the migration of radionuclides to potable water sources.

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Question

- Were concentration or dose criteria used to determine compliance and the need for remediation?

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Concentration or Dose?

- Safety reviews of new reactor applications rely on estimations of both concentration and dose
- Staff in the Hydrologic Engineering Branch (RHEB)use effluent concentration limits (ECLs) provided in the regulation (10 CFR 20 Appendix B Table 2 Column 2).
- Staff in RHEB provide locations, dilutions, and travel times corresponding to the bounding set of plausible surface and subsurface pathways for radionuclides.

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Concentration or Dose?...

- Staff in the Health Physics Branch (CHPB)obtain information from RHEB and calculate doses.
- If ECLs are exceeded applicants can resort to mitigative design features, tech-specs, or more plausible analyses with less conservatism, but still conservative enough.

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