NRC Modeling Applications and Needs

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1 INTRODUCTION

The US Nuclear Regulatory Commission (NRC) regulates all civilian uses of nuclear power and nuclear materials in the United States. Its primary mission is to protect the public health and safety and the environment from adverse effects from licensed activities. In carrying out this mission the NRC is faced with assessing the impacts of its actions. To assess these impacts it employs mathematical models, implemented in computer codes, of complex engineered and natural systems. Natural systems are modeled to estimate the migration of radioactive materials that have reached the natural environment through routine operational releases or because of accidental spills or other types of contamination (e.g. the mobilization of materials at an in situ leach uranium mine). Contaminated sites range from small, minimally contaminated areas that are easily remediated to large industrial processing sites with extensive surface and volumetric contamination and contaminated groundwater systems. The licenses for these sites cannot be terminated and the land released for unrestricted use until the potential doses to future users can be projected to meet the standards in the NRC's License Termination Rule (10 CFR 20, Subpart E). For disposal sites such as low-level waste disposal facilities and the proposed high-level waste (HLW) repository site at Yucca Mountain, NV, specific regulations govern their long term performance. The important concepts for this paper are that periods of regulatory interest extend from hundreds to thousands of years and concentrations of concern may be very small. Because we are dealing with radioactive species, phenomena such as radioactive decay and daughter in-growth in decay chains must be considered.

Performance assessment methodologies used in most early licensing and pre-licensing actions employed deterministic hydrologic models and constant distribution coefficients to account for sorption processes. We have known from the beginning that the simplifying assumptions inherent in these models were incorrect for most natural systems but limitations on computational systems made it impractical to do better. Although we accepted this limitation in a practical sense, we also acknowledged the need for modeling capabilities that could deal with more complex natural systems from both geochemical and hydrogeological perspectives. In particular, in order to be assured that public health and the environment received adequate protection, the NRC staff has consistently applied "conservative assumptions" and "bounding analyses" in a deliberate attempt to overestimate potential effects before applying regulatory criteria for guiding its decisions. With the substantial improvements in analytical capability that have evolved in the past thirty years the NRC has shifted its emphasis to more realistic assessments of the evolution of contaminated sites over time because it views unnecessary conservatism as a burden on licensees. The NRC's Office of Nuclear Regulatory Research is actively engaged in developing more realistic models to assess contaminated natural and anthropogenic systems.

2 THE SCOPE OF CURRENT EFFORTS

The current research program on radionuclide transport (NRC, 2002) at the NRC is approaching the problem of establishing more realistic waste-system performance models on several fronts. Natural heterogeneity in hydrologic systems has been addressed through a

systematic effort to develop probabilistic techniques to accommodate parameter uncertainty, conceptual model uncertainty, and scenario uncertainty (Meyer and Orr, 2002; Neuman and Wierenga, 2003). This work has been focused at the University of Arizona and the Pacific Northwest National Laboratory (PNNL). The limitations of off-the-shelf models have led to support of developmental work on models implemented in software that can combine and interface computational modules to represent discrete subsystems. The current focus for this work, in cooperation with the Department of Energy, the Environmental Protection Agency, and the U.S. Army Corps of Engineers is the FRAMES modeling system being developed at PNNL. Simpler models have not been abandoned because most of sites that the NRC regulates have minimal contamination in a relatively confined area and are thus compatible with such modeling systems. However, even these are being improved with probabilistic capabilities and improved databases to support selection of parameter values and to move away from the use of default values. A third area of recent study has been model abstraction techniques to help focus model definition with respect to actual site data.

The last area to mention here is the area of reactive transport. Since the late 1980's the NRC has been supporting work on sorption in one form or another. Early efforts focused on the potential HLW repository at Hanford, Washington, and were focused on the distribution coefficient measurements at elevated temperatures for the rock systems and radionuclides of interest (Apps et al., 1989). This work evolved into the geochemistry program at the Center for Nuclear Waste Regulatory Analyses which has made significant advances in modeling sorption processes for the NRC performance assessment code for the current potential HLW repository at Yucca Mountain (Turner, 1993, Pabalan et al. 1998, Prikryl et al., 2001). Later talks will discuss this work in some detail. The non-HLW research at the NRC has focused on ambient temperature systems which will still be relevant in the far field of the repository but are also more relevant to decommissioning of nuclear facilities and near-surface disposal facilities. The early focus was on the natural analogue studies at the Koongarra Ore Body in northern Australia (Duerden et al., 1992) and involved the U.S. Geological Survey (USGS) as our principal contractor (Davis. 2001). After two multinational international projects studying uranium migration at this hydrologically and geochemically complex site, our principal investigator concluded that semi-empirical surface complexation models could be used to develop more realistic models of uranium migration at a chemically complex site. We then funded a demonstration project with the USGS at the Naturita uranium remediation site in Colorado in the United States. Most of the work at that site has been completed and a final report has been issued (Davis and Curtis, 2004). We are now working to broaden these techniques for use at a wider range of sites and a wider range of radionuclides. Our interest in this topic has led us to be participants in both the first and second phases of the multi-national NEA Sorption Project (NEA, 2000) which is nearing the completion of its second phase. This project has been testing the modeling approaches used to describe sorption by modelers in the participating

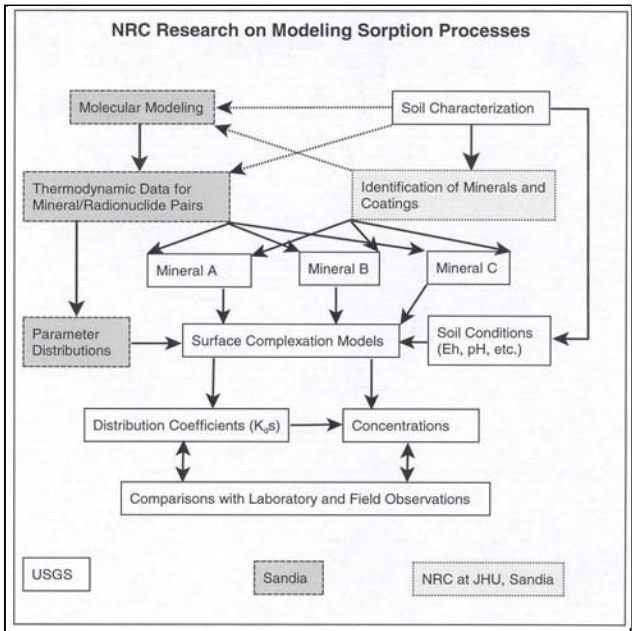

Figure 0: The NRC sorption research program, showing roles of the USGS, Sandia, and the NRC staff

countries. The last and perhaps most intriguing part of our program is that being carried out at Sandia National Laboratories. Part of this program has been supporting characterization of sorbing minerals at the Naturita site in suppport of the USGS team (McLain et al., 2002, and Jové-Colon et al., 2004). Other parts of this research include (1) assessing the effects of adsorption constant uncertainty on contaminant plume migration through one and two dimensional studies, and (2) modeling sorption processes at the molecular level (Cygan, 2002, Teter and Cygan, 2002, Cygan et al., 2004). Figure 1 presents a crude flow chart for how this work might be integrated with field measurements. It has been, and remains, our goal to connect this work and produce a technically credible, scientifically sound basis for the semi-empirical models.

3 SUMMARY AND RELATION TO WORKSHOP

The NRC is not the only federal agency that uses environmental models to inform its decisions. It has been evident for many years that expertise and parallel research programs existed in several federal agencies. Bilateral cooperation on individual projects happened but was usually not sustained. About three and a half years ago a group of federal researchers met to discuss the difficulties of exchanging data and computational modules between programs. That interagency workshop led to the idea that a more permanent structure would be a real benefit to all of the agencies involved. Two and half years ago the Memorandum of Understanding under which this workshop is being held became effective with the signature of the last of six original participating organizations. This is the third working group formed under the MOU to reach the stage of sponsoring an international workshop to discuss opportunities and new approaches for an important area of scientific investigation related to the improvement of multimedia environmental models. As one of the organizers and a member of the MOU's Steering Committee, we look forward to the further deliberations of this workshop and the fruits of continued cooperation among the participating agencies.

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