[Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	6 (Select the number from "Areas of Technologies Requested")
Title	Integrated model of groundwater flow and radionuclide migration at Fukushima Daiichi Nuclear Power Station
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1. Overview of Technologies (features, specification, functions, owners, etc.)

In order to predict the transport and fate of radionuclides at the Fukushima Daiichi Nuclear Power Station, a numerical model must be able to simulate the coupled groundwater-overland flow system, the planned cryogenic barrier to groundwater flow, and multi-component reactive transport of radionuclides. Los Alamos National Laboratory (LANL) has a unique combination of computational capabilities for developing a technically defensible model combining all of these processes. This model also can be run at very high spatial resolution using multicore and distributed computing, thereby taking advantage of the large amounts of data collected at the site to make predictions. With this model we will be able to answers critical questions such as:

1. How can the cryogenic barrier be optimized to control subsurface-overland flow interaction to prevent migration of Cs, Sr, and other radionuclides to the sea?
2. Do large storm events have the potential to cause groundwater to overtop the cryogenic barrier, thus reducing its performance?
3. To what degree does subsurface infrastructure control flow in and around the contaminated buildings?
4. Will the cryogenic barrier lead to salt water intrusion at the site thereby mobilizing contaminants such as Cs and Sr that are mobile under high salinity conditions?
5. Does overland flow induced by storm events have the potential to mobilize Cs and Sr sorbed onto soil mobile particles (colloids)?
6. Does the current groundwater monitoring program adequately constrain uncertainty in groundwater flow and radionuclide migration predictions?

LANL's integrated modeling capabilities were developed over a period of many years in investigations of flow and radionuclide migration at contaminated sites in the U.S. DOE complex and in other applications. It is proposed to use these modeling capabilities to construct a high-resolution integrated model of groundwater flow and radionuclide transport near the Fukushima Daiichi Nuclear Power Station. The overall objective of the proposed work is to provide a comprehensive flow/transport modeling system that improves understanding of the existing groundwater system and enables rapid evaluation of proposed countermeasures.

The key LANL technology that will be applied in the proposed integrated model is the highly parallel code Amanzi-ATS. Amanzi is a next-generation groundwater flow and reactive transport computer code developed in the DOE Advanced Scientific Computing for Environmental Management (ASCEM) program. ASCEM is an emerging state-of-the-art scientific approach and software infrastructure for understanding and predicting contaminant fate and transport in natural and engineered subsurface systems in the context of performance and risk assessments supporting site cleanup and closure decisions. Amanzi is the multi-process HPC simulator being developed within the ASCEM framework. The modular and open-source HPC tool provides a flexible and extensible simulation capability that enables a wide range of process complexity in flow and reactive transport models. Amanzi capabilities include transient saturated/unsaturated flow, a flexible high-level model representation and input specification, a wide variety of geochemical processes (including surface complexation, aqueous speciation, and several sorption models), support for fully unstructured computational meshes to allow for accurate representation of subsurface structures, parallel input/output for visualization and restarts, and a hierarchical verification and validation testing framework. Amanzi-ATS is a multiphysics extension of Amanzi developed in a LANL laboratory-directed research and development project. The software enables coupling among traditional groundwater flow models and other surface and subsurface process models, and is thus uniquely suited for a model for Fukushima Daiichi Nuclear Power Station because it is an integrated model that includes representations of groundwater flow and transport, unsaturated zone flow and transport, overland flow, freezing processes in saturated and unsaturated soils, and radionuclide transport. Figure 1 shows results from an example Amanzi-ATS simulation that couples surface and subsurface flow. Amanzi-ATS was designed for, and developed and tested on, a range of computer architectures, from laptops to supercomputers, to ensure that available computational resources are effectively utilized.

The proposed work will use the existing geologic framework model of the area. Parameters from the existing groundwater model will be used. Amanzi-ATS has unique capability to represent freezing processes in unsaturated and saturated soils and rocks and can thus accurately model the formation and performance of the cryogenic barrier. Amanzi-ATS also has capability to model overland flow coupled with subsurface flow and surface energy balance, which is a critical integrated capability to optimize the design and assess performance of the cryogenic barrier. Manmade subsurface structures and pumping wells will be accurately represented in the new model using Amanzi-ATS's unstructured grid capability. Three-dimensional radionuclide transport simulations with matrix diffusion and sorption processes will be coupled to the groundwater flow model to complete the integrated capability and allow projections of possible radionuclide releases to the sea to be evaluated. Amanzi-ATS was designed to be driven by sensitivity analysis, uncertainty quantification, and parameter estimation software; this capability will be used as needed.

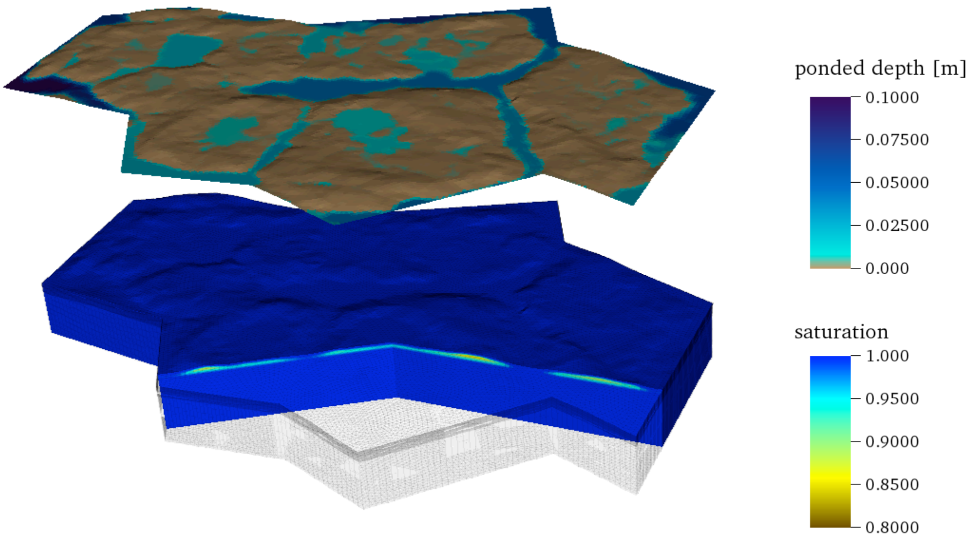

Figure 1. Example Amanzi-ATS simulation of coupled surface and subsurface flows on a fully unstructured grid. The advanced multiphysics capability of Amanzi-ATS will make it possible to model surface and subsurface flows and radionuclide transport in the vicinity of the Fukushima Daiichi Nuclear Power Station with high spatial and temporal resolution, taking into account the effects of the planned cryogenic barrier and manmade subsurface and surface structures on flow.

References

Moulton, J.D., J. C. Meza, M. W. Buksas, M. Day, et al. 2012. High-level design of Amanzi, the multiprocess high performance computing simulator. Technical Report ASCEM-HPC-2011-03-1 (LANL: LAUR 12-22193), Office of Environmental Management, United States Department of Energy, Washington, DC.

Coon, E., M. Berndt, J. D. Moulton, and S. Painter. The Arctic Terrestrial Simulator: Developing a flexible multiphysics simulator based on Amanzi. Presented at *2012 SIAM Annual Meeting* .(Minneapolis, 9-13 July 2012).

Painter, S. L. Three-phase simulations of moisture dynamics in freezing porous media: Model formulation and validation. Computational Geosciences, 2011

2. Notes (Please provide following information if possible.)

- Technology readiness level (including cases of application, not limited to nuclear industry, time line for application)

The flow and reactive transport capabilities of Amanzi have been used in several complex demonstration exercises using data and flow configurations from contaminated sites of interest. Amanzi-ATS is being used in applications involving coupled subsurface and surface flow and freezing/thawing in the Arctic tundra. All capabilities required for the proposed work have been tested.

Amanzi-ATS is not currently in a formal quality assurance program. It does, however, employ a hierarchical verification- and validation-testing framework, and it could be brought to an appropriate quality assurance status with modest additional effort.

- Challenges

No major impediments to deploying the technology have been identified

- Others (referential information on patent if any)

【Areas of Technologies Requested】

(1) Accumulation of contaminated water (Storage Tanks, etc.)
(2) Treatment of contaminated water (Tritium, etc.)
(3) Removal of radioactive materials from the seawater in the harbor
(4) Management of contaminated water inside the buildings
(5) Management measures to block groundwater from flowing into the site
(6) Understanding the groundwater flow