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HANFORD IFRC QUARTERLY REPORT ~ July 2011

John M. Zachara and the IFRC Research Team
Pacific Northwest National Laboratory

I. Management Statement

In this July 2011 Quarterly Report for the Hanford IFRC project, we summarize activities performed during the third quarter of FY 2011. A written report was not submitted for the second quarter of FY 2011 because of the annual SBR investigators meeting where the Hanford IFRC presented thirteen posters, and one plenary talk on recent progress and scientific accomplishments. The primary emphasis of third-quarter research has been characterizing the mitigated well field that accesses the upper high K zone of the U(VI) plume, and performing a U(VI) injection desorption experiment.

At the time of this reporting 73.4% of the FY has elapsed and 83.3% of our total FY 2011 IFRC budget has been spent, including 3rd party commitments (e.g., allocations to University participants and Central Hanford Plateau Remediation Co. (CHPRC) for well drilling and completion. The IFRC project carried over $350K of FY 2010 funds that were used for the installation of four new wells for hydrologic modeling control points, and for well-field remediation. The Hanford IFRC is ahead on spending because of costs incurred during well-field mitigation, effectiveness documentation, and hydrologic characterization of the upper high K zone of the U plume.

Significant attention was given to the Hanford IFRC data management system during the third quarter. This attention has been motivated, in part, by ongoing discussions with SBR management on i.) expectations for the IFRC data management systems, ii.) their future directions given the end of the current IFRC funding cycle and the planned IFRC recompete, and iii.) potential collaborations with data base development by the EM-supported ASCEM project. Data management actions during the third quarter have included the uploading of many new data sets/packages to make the archive current, and the initiation of a review of the content and transparency of all posted data packages to potential external users. Under planning for September 2011 is a “viewing” of the three IFRC data management systems by SBR management, IFRC leads, and several external advisors. The “viewing” will be a first major step in the development of a consistent strategy and approach for data management by all three SBR, IFRC projects.

The IFRC and SFA management teams have also been discussing future research plans for the IFRC site, including scientific approaches to extend IFRC research to the system or plume scale. Initial ideas on this subject will be presented to SBR management in August 2011.

II. Highlights

- Four new far-field groundwater monitoring wells were installed around the perimeter of the IFRC site in March 2011 to provide improved hydraulic head measurements for modeling water flow and solute transport within the IFRC site. The wells are instrumented with pressure transducers for continuous monitoring of water table elevation. Among other things, these wells have helped to further define the paleo-channel feature that runs through the IFRC well-field, as well as the amount of relief (up to 27 ft) on the Ringold aquitard in the vicinity of the site. Regional data from the 11 new 300 Area RI/FS wells has also been integrated into the IFRC/300A hydro-geologic model.

- A U(VI) desorption experiment was performed in the upper high K zone during late March to May, 2011. The experiment was planned through extensive STOMP pre-modeling and involved the injection of 220,000 gallon of low U concentration groundwater (with Cl^- and deuterium tracer) over a two week period (3/25/2011 to 4/9/2011). The experimental objective was to create an extended zone of low U concentration groundwater through the center of the IFRC that would induce desorption of adsorbed U from the aquifer sediments. There was continuous pressure and down-hole specific conductance monitoring at select well locations followed by a month of daily aqueous sampling from all well locations yielding over 1000 samples for analysis. The analysis of all samples has been recently completed, and subjected to QA/QC assessment. The data set showed no evidence of artifacts from well-bore flows, indicating that well field mitigation was successful. Modeling of the data set has now begun by teams using both PFLOTRAN and e-STOMP to evaluate different objectives.

- Significant progress has been made on an integrated experimental and modeling effort with multiple Hanford IFRC and PNNL SFA investigators (PNNL, OSU, USGS, and ORNL) to develop and parameterize a kinetic reactive transport model for IFRC smear zone sediments based on laboratory multi-scale experimentation and field scale characterization. The experimentation is focused on an IFRC composite smear-zone sediment that was created from subsamples collected from 15 different IFRC wells. Experimentation includes pore-scale, batch, and flow-cell reactor experiments with < 2mm sediment fractions to quantify grain scale rates; and saturated and unsaturated column experiments of different sizes and with sediments up to 8 mm to quantify macro- and meso-scale rates. All experiments are being modeled with the same multi-rate surface complexation model. During the last quarter of FY2011, the team will work to integrate these multi-scale results into a field-scale reactive transport model of the upper aquifer (including the smear zone) with our geostatistical model of U distribution for simulation of passive field experimental results of U(VI) mobilization during the spring water table excursion into lower vadose zone.

- The data assimilation task continues to integrate new site characterization measurements as they become available to improve the IFRC site hydrophysical and hydrochemical models. All IFRC wells were surveyed by electromagnetic borehole flowmeter (EBF) at approximate 6” depth intervals before well field mitigation, and then again after the wells had stabilized after mitigation. These results were assimilated into the site-wide hydraulic conductivity model using MAD. The figure below compares hydraulic conductivity distributions developed using the previous (2009) and the current (2011) EBF profiles. Profound differences have been observed in terms of the continuity of the low-conductivity layer at mid-section, and a reduction in the conductivity of the high conductivity layers above and below. The improved results were a consequence of understanding the well-bore flow problem. These new results are being used in a second wave of simulations of the March 2009 injection experiment, with results expected in August 2011.

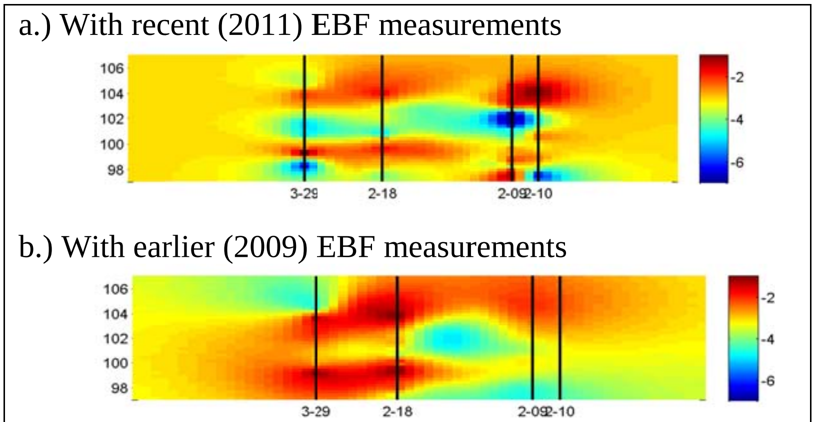

Figure 1. The conditional mean of the log conductivity: a comparison between the previous and current EBF profiles. The cross section goes through the center of the IFRC site from the SE (3-29, left) to the NW (2-10, right).

- Electrical geophysical (ERT) characterization of the IFRC wellfield was completeded in 2009, with the ultimate goal of informing site flow and transport models concerning hydrogeologic structure. The ERT results provide the field scale statistical distribution of electrical conductivity at sub-meter resolution in 3D, and have revealed that the site can be characterized by several continous zones of electrical conductivity, or electrofacies. Core-scale electrical and hydraulic conductivity measurements being collected by Rutgers University are being used to develop site-specific petrophysical relationships that will enable interpretation of these electrofacies in terms of corresponding hydrogeologic properties. The success or failure of this approach depends critically upon the assumption that hydrogeologic facies have unique signatures in terms of electrical conductivity. Core-scale measurements of electrical and hydraulic conductivity collected to date demonstrate that this assumption is valid. For example, Figure 2 shows the complex resistivity (CR) spectra and correspoding hydraulic conductivity of cores belonging to four distinct electrofacies. Each facies possesses a unique hydraulic conductivity. The sample from well 2-9 is Ringold formation material and displays nearly identicle hydraulic conductivity and CR response as the sample from the shallower sample in well 2-12, which is likely a rip-up clast originating from the Ringold.

Because core samples materials are likely biased toward fine grained materials, core scale hydraulic conductivity measurements are assumed to be biased and interpreted as a relative measure of permeability. Instead of absolute estimates of hydraulic conductivity, the interpratation of ERT data using core measurements as described above will provide modelors with information concerning hydro-structural boundaries, thereby reducing the number of hydraulic conductivity parameters necessary during model calibration.

- The winter of 2010-2011 brought much snow and rain to the mountains producing anomalously high river stages from late winter to the current date. Daily water quality monitoring of the IFRC well field was initiated in April and continued to July 1. The objectives of the monitoring was twofold: 1.) to confirm for the third consecutive year that the high spring water table solubilizes U from the lower zone and sustains U concentrations in the plume and 2.) to identify the peak U concentration in groundwater that could be sampled in large volume to support a fall, 2011 high U injection experiment. These objectives were accomplished in full, with 40,000 gallon of groundwater containing 1200 ug/L of U(VI) sampled and placed into storage.

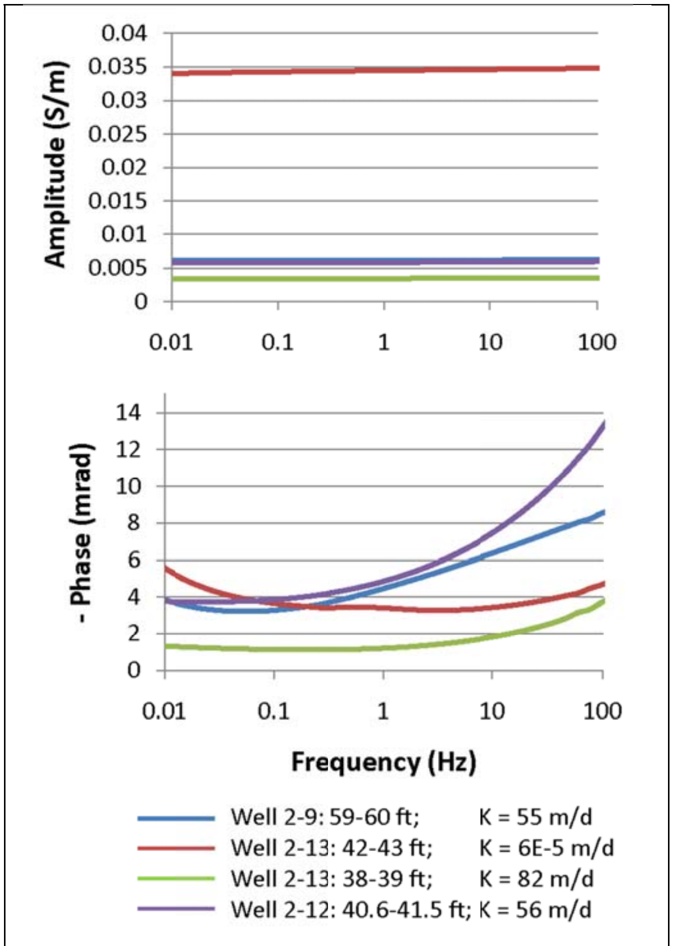

Figure 2. Complex resistivity responses and hydraulic conductivity responses from four cores belonging to distinct electrofacies identified from ERT characterization. The well 2-12 sample is Ringold formation rip up clast, and display nearly identical CR response and hydraulic conductivity as the well 2-9 sample collected from the Ringold formation.

A three-line surface ERT array was installed between the IFRC site and the Columbia River at the end of April to monitor river water – groundwater exchange through the paleo-channel east of the IFRC site. It was expected that the large salinity contrast between the groundwater and river water would be discernable to ERT. This activity was funded jointly by the Hanford IFRC and the PNNL SFA. A set of groundwater monitoring wells that were distributed within the ERT array were continuously monitored for specific conductivity (which varies with river water mixing ratio) to provide ground truth for the surface electrical measurements. So far only data for the Apr. 25 to May 25 time period has been processed, but the results look promising as differences in ERT response are evident throughout the monitored depth column that display correlation with increases and decreases in river stage and water table.

- A manuscript has been drafted by a joint Rifle IFRC-Hanford IFRC team that is titled; "Persistence of uranium groundwater plumes: Contrasting mechanisms at two contaminated DOE sites." The paper is in its final stages of internal review and will be submitted to the Journal of Contaminant Hydrology. It compares and contrasts the hydrology, microbiology, and geochemistry of U(VI) plumes at the Hanford 300 A and the Rifle site (unstimulated) with an emphasis on the groundwater river mixing zone. We find that the much greater hydraulic conductivity of the 300 A and the higher detrital organic matter content of the Rifle site create some important differences in U(VI) behavior and biogeochemical interactions.

III. Issues

There are no issues to report. Previously identified problems associated with well bore flows and the functioning of the geophysics team have been remedied.

IV. Fourth Quarter 2011 Research

Research activities in the fourth quarter will be somewhat abbreviated because of our spend status (e.g., 83.3 %), and need to carry over some dollars to remain operational if a continuing resolution occurs. Important activities that will be pursued are as follows:

1. Complete EBF and pump testing of the upper aquifer zone and submit results to the assimilation task to parameterize a robust spatial hydraulic conductivity model for the mitigated well field.
2. Integrate multi-investigator results on the kinetic geochemical reactivity of the smear zone composite and geostatistical characterization of the spatial distribution of U in the well field to define a reactive source transport model for the upper aquifer and smear zone.
3. Complete core-scale measurements of complex resistivity and hydraulic conductivity (Rutgers) and begin development of petrophysical transfer models.
4. Prepare for and participate in the IFRC data base "viewing" in collaboration with the Oak Ridge and Rifle IFRC's.
5. Prepare for October high U injection experiment through pre-modeling to optimize injection rate, duration, and dilution of high U (1200 ug/L) groundwater; and development and review of the field test plan that defines sampling frequency, monitoring variables, etc.

V. Recent Submissions and Publications

Chen, X., H. Murakami, M. S. Hahn, G.E. Hammond, M.L. Rockhold, J.M. Zachara, and Y. N. Rubin. 2011. Three-dimensional bayesian geostatistical aquifer characterization at the Hanford 300 Area using tracer test data. *Water Resources Research*, under revision.

de Barros FPJ, S. Ezzedine, Y. Rubin. 2011. Impact of hydrogeological data on measures of uncertainty, site characterization and environmental performance metrics. *Advances in Water Resources*, doi:10.1016

de Barros FPJ, Y. Rubin. 2011. Modeling of block-scale macrodispersion as a random function. *Journal of Fluid Mechanics*, doi:10.1017

Greskowiak, J., M. B. Hay, H. Prommer, C. Liu, V. E. Post, R. Ma, J. A. Davis, C. Zheng, and J. M. Zachara. 2011. Simulating adsorption of U(VI) under transient groundwater flow and hydrochemistry – physical versus non-equilibrium models. *Water Resources Research*, accepted.

Hay, M. B., D. L. Stoliker, J. A. Davis, and J. M. Zachara. 2011. Characterization of the intragranular water regime within subsurface sediments: Pore volume, surface area, and mass transfer limitations. *Water Resour. Res.* (Under revision).

Johnson, T.C. 2011. A hybrid stochastic-deterministic approach for sampling highly parameterized inverse solutions constrained by noisy data and uncertain statistics. *Geophysical Journal International*, submitted.

Liu, C., J. M. Zachara, and A. Reed. 2011. Scale dependent rates of uranyl desorption from contaminated sediments: Role of pore-scale reactive mass transfer. *Environmental Science and Technology*, accepted.

Ma, R., C. Zheng, M. Tonkin, and J. M. Zachara. 2011. Importance of intra-borehole flow in solute transport modeling under highly dynamic flow conditions. *Journal of Contaminant Hydrology*. doi:10.1016/j.jconhyd.2010.12.001.

Ma, R., C. Liu, J. Greskowiak, H. Prommer, C. Zheng, and J. Zachara. Model-based quantification of the influence of calcite on uranium mobility in the groundwater-river mixing zone at the US Hanford Site. *Environmental Science and Technology*, submitted.

Shang J., C. Liu, and J. M. Zachara. 2011. Grain-size dependent kinetics of uranium(VI) adsorption and desorption and rate additivity. *Environ. Sci. and Technol.* (Accepted).

Stoliker, D. L., D. B. Kent, and J. M. Zachara. 2011. Application of surface complexation modeling to evaluate difference in equilibrium uranium(VI) adsorption properties of aquifer sediments. *Environmental Science and Technology*, under revision.

Yin, J., R. Haggerty, D.L. Stoliker, D.B. Kent, J.D. Istok, J. Greskowiak, and J.M. Zachara. 2011. Transient groundwater chemistry near a river: Effects on U(VI) transport in laboratory column experiments. Water Resources Research 47: DOI:10.1029/2010WR009369.