QUARTERLY PROGRESS REPORT

July 1 to September 30, 2015

Florida International University's Continued Research Support for the Department of Energy's Office of Environmental Management

Principal Investigator:

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Prepared for:

U.S. Department of Energy
Office of Environmental Management
Under Cooperative Agreement No. DE-EM0000598

Applied Research Center
FLORIDA INTERNATIONAL UNIVERSITY

Introduction

The Applied Research Center (ARC) at Florida International University (FIU) executed work on five major projects that represent FIU-ARC's continued support to the Department of Energy's Office of Environmental Management (DOE-EM). The projects are important to EM's mission of accelerated risk reduction and cleanup of the environmental legacy of the nation's nuclear weapons program. The information in this document provides a summary of the FIU-ARC's activities under the DOE Cooperative Agreement (Contract # DE-EM0000598) for the period of July 1 to September 30, 2015.

The period of performance for FIU Year 5 under the Cooperative Agreement was May 18, 2014, 2013 to August 28, 2015 and the period of performance for FIU Year 6 will be August 29, 2015 to August 28, 2016. Therefore, the activities and accomplishments described in this summary report are divided between the FIU Year 5 and FIU Year 6 periods of performance: July 1 to August 28 and August 29 to September 30, respectively.

The projects have been reorganized for FIU Year 6. Projects 2 and 3 from FIU Year 5 have been combined into a single project (Project 2) focused on soil and groundwater remediation research. Projects 4 (D&D) and 5 (Workforce Development) from FIU Year 5 were subsequently renumbered as Projects 3 (D&D) and 4 (Workforce Development).

Highlights during this reporting period include:

Program-wide:

- FIU hosted a visit from Mr. Rod Rimando (DOE EM-23) on July 17, 2015. FIU presented the accomplishments of the current research tasks under the DOE Cooperative Agreement and discussed future scope of work.
- FIU completed development and uploaded a total of five (5) Year End Reports (YER) covering the technical period of performance for FIU Year 5 (May 2014 – August 2015) on August 28, 2015 (available on FIU's DOE Research website: http://doeresearch.fiu.edu).
- FIU developed detailed Project Technical Plans (PTPs) to guide the completion of the work scope during FIU Year 6.

Project 1- Chemical Process Alternatives for Radioactive Waste:

- The milestones and deliverables associated with Tasks 2.2, 17.2, 18.2, and 19.1 were incorporated into the Year End Report.

Project 2- Environmental Remediation Science & Technology (includes combined projects 2 and 3 from FIU Year 5):

- The following deliverables were submitted to DOE: technical report titled, "Modeling of the migration and distribution of NOM injected into subsurface systems," submitted 7/6/15; technical report titled, "Surface Water Modeling of Tims Branch," submitted 7/17/15; and technical report titled, "Sustainability Plan for the A/M Area Groundwater Remediation System," submitted 7/31/15.

Project 3 – Waste and D&D Engineering & Technology Development: (previously known from FIU Year 5 as Project 4)

- Milestone 2014-P4-M2.2, the draft test plan for baseline incombustible fixatives for subtask 2.1.3, was completed in July 2015.

Project 4- DOE-FIU Science & Technology Workforce Development Initiative: (previously known from FIU Year 5 as Project 5)

- The Technical Fact Sheet for this project was updated during this performance period.

The program-wide milestones and deliverables that apply to all projects (Projects 1 through 5) for FIU Year 5 are shown on the following table.

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Program-wide (All Projects)	Deliverable	Draft Project Technical Plan	06/18/14	Complete	
	Deliverable	Monthly Progress Reports	Monthly	Complete	
	Deliverable	Quarterly Progress Reports	Quarterly	Complete	
	Deliverable	Draft Year End Report	Reforecast to 08/28/15	Complete	OSTI
	Deliverable	Presentation overview to DOE HQ/Site POCs of the project progress and accomplishments (Mid-Year Review)	11/21/14*	Complete	
	Deliverable	Presentation overview to DOE HQ/Site POCs of the project progress and accomplishments (Year End Review)	06/30/15*	Complete	

**Completion of this deliverable depends on availability of DOE-HQ official(s).*

The program-wide milestones and deliverables that apply to all projects (Projects 1 through 4) for FIU Year 6 are shown on the following table:

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Program-wide (All Projects)	Deliverable	Draft Project Technical Plan	10/05/15	Complete	
	Deliverable	Monthly Progress Reports	Monthly	On Target	
	Deliverable	Quarterly Progress Reports	Quarterly	On Target	
	Deliverable	Draft Year End Report	10/14/16	On Target	OSTI
	Deliverable	Presentation overview to DOE HQ/Site POCs of the project progress and accomplishments (Mid-Year Review)	02/29/16*	On Target	
	Deliverable	Presentation overview to DOE HQ/Site POCs of the project progress and accomplishments (Year End Review)	08/31/16*	On Target	

**Completion of this deliverable depends on availability of DOE-HQ official(s).*

Project 1
Chemical Process Alternatives for Radioactive Waste

Project Manager: Dr. Dwayne McDaniel

Project Description

Florida International University has been conducting research on several promising alternative processes and technologies that can be applied to address several technology gaps in the current high-level waste processing retrieval and conditioning strategy. The implementation of advanced technologies to address challenges faced with baseline methods is of great interest to the Hanford Site and can be applied to other sites with similar challenges, such as the Savannah River Site. Specifically, FIU has been involved in: analysis and development of alternative pipeline unplugging technologies to address potential plugging events; modeling and analysis of multiphase flows pertaining to waste feed mixing processes, evaluation of alternative HLW instrumentation for in-tank applications and the development of technologies to assist in the inspection of tank bottoms at Hanford. The use of field or *in situ* technologies, as well as advanced computational methods, can improve several facets of the retrieval and transport processes of HLW. FIU has worked with site personnel to identify technology and process improvement needs that can benefit from FIU's core expertise in HLW.

The following tasks were included in FIU Year 5:

- Task 2: Pipeline Unplugging and Plug Prevention
    - Subtask 2.1.1 – Support for Potential Deployment of the Asynchronous Pulsing System and the Peristaltic Crawler
    - Subtask 2.2.1 – 2D Multi-Physics Model Development
- Task 17: Advanced Topics for Mixing Processes
    - Subtask 17.1.1 – Computational Fluid Dynamics Modeling of Jet Penetration in non-Newtonian Fluids
- Task 18: Technology Development and Instrumentation Evaluation
    - Subtask 18.1.1 – Evaluation of SLIM for Rapid Measurement of HLW Solids on Hanford Mixing Tank Bottoms
    - Subtask 18.1.2 – Testing of SLIM for Deployment in HLW Mixing Tanks at Hanford
    - Subtask 18.2.1 – Development of First Prototype for DST Bottom and Refractory Pad Inspection
    - Subtask 18.2.2 – Investigation of Using Peristaltic Crawler in Air Supply Lines Leading to the Tank Central Plenum
- Task 19: Pipeline Integrity and Analysis
    - Subtask 19.1.1 – Data Analysis of Waste Transfer Components
    - Subtask 19.2.1 – Development of a Test Plan for the Evaluation of Nonmetallic Components
    - Subtask 19.2.2 – Preliminary Experimental Testing of Nonmetallic Components

The following tasks are included in FIU Year 6:

- Task 17: Advanced Topics for Mixing Processes
  - Subtask 17.1 – Computational Fluid Dynamics Modeling of HLW Processes in Waste Tanks
- Task 18: Technology Development and Instrumentation Evaluation
  - Subtask 18.1 – Evaluation of FIU's Solid-Liquid Interface Monitor for Estimating the Onset of Deep Sludge Gas Release Events
  - Subtask 18.2 – Development of Inspection Tools for DST Primary Tanks
  - Subtask 18.3 – Investigation Using an Infrared Temperature Sensor to Determine the Inside Wall Temperature of DSTs
- Task 19: Pipeline Integrity and Analysis
  - Subtask 19.1 – Pipeline Corrosion and Erosion Evaluation
  - Subtask 19.2 – Evaluation of Nonmetalic Components in the Waste Transfer System

Task 2: Pipeline Unplugging and Plug Prevention

<u>Task 2 Overview</u>

Over the past few years, FIU has found that commercial technologies do not meet the needs of DOE sites in terms of their ability to unplug blocked HLW pipelines. FIU has since undertaken the task of developing alternative methods/technologies with the guidance from engineers at the national laboratories and site personnel. The new approaches that are being investigated include an asynchronous pulsing system (APS) and a peristaltic crawler system (PCS). Both technologies utilize lessons learned from previous experimental testing and offer advantages that other commercially available technologies lack. The objective of this task is to complete the experimental testing of the two novel pipeline unplugging technologies and position the technologies for future deployment at DOE sites. Another objective of this task is to develop computational models describing the build-up and plugging process of retrieval lines. In particular, the task will address plug formation in a pipeline, with a focus on the multi-physical (chemical, rheological, mechanical) processes that can influence the formation.

<u>Task 2 Quarterly Progress – July 1 – August 28, 2015</u>

Subtask 2.2: Computational Simulation and Evolution of HLW Pipeline Plugs

July was focused on investigating the 3D turbulent flow based settling of solids in the PNNL test loop. 3D pipe geometry replicating the PNNL test loop was created and modeled for the dynamic settling characteristics of solids.

The nominal diameter of the pipe is 3 inches and the loop consists of eleven 90° elbows with long and short radii. There are twelve straight sections in the loop along with seven vertical elbows and four horizontal elbows. The lengths of the straight sections are proportional to the PNNL standard test loop to predict the settling behavior of solids.

The software used to simulate the flow characteristics in the pipe model is COMSOL multi-physics software. A finite element (FE) mesh of the loop was generated using 3D tetrahedral elements. The mesh consists of 348420 domain elements, 33046 boundary elements and 2146 edge elements for the analysis.

The multiphase fluid flow module in COMSOL was used for modelling. Solid liquid mixture models under turbulent flow conditions were considered. Rans k-ε model was chosen for turbulence and the Schiller-Naumann model was chosen for slip. A step function was used to introduce solid waste particles into the pipe loop at the inlet. Initial and inlet flow conditions were specified along with the outlet pressure condition. Densities of the solid and fluid particles were taken as 3147 kg/m^3 and 1000 kg/m^3, respectively. The flow velocities were varied from 0.5 m/s to 2.5 m/s. Solid particles with diameter of 45 µm were considered. Their volume fraction was varied from 2.9% to 10%.

Sample results obtained from the simulations are as shown in Figure 1-1. The figure shows the distribution of the dispersed volume fraction in the pipe loop for the case with flow velocity of 2.5 m/s and an initial solids volume fraction of 10%. It is evident that the volume fraction is higher (indicated by red) at the bends (elbow sections) than it is in the straight sections. The values of the volume fraction range from about 5% to 30%. Hence, the elbows are regions of potential plug formations. Also, it is to be noted that the intrados of the elbows show larger deposition when compared to the extrados. This can be seen in the detailed view of the PNNL model loop (Figure 1-1). This is due to the local changes in flow velocities at the bends. In longer straight sections, the flow was stabilized and the particles well suspended leading to a lower value of the volume fraction at the top and some deposition at the bottom of the cross section. The dispersion is similar in all the cases. As expected, in cases with higher initial volume fraction, the settlement of solids at the bottom of the straight sections was observed to be higher.

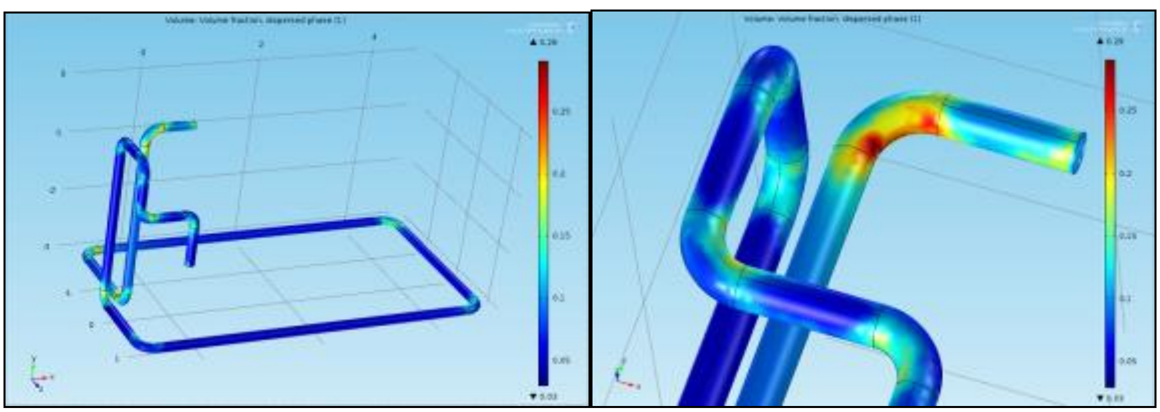


Figure 1-1. Settling of solids in the PNNL test loop (left) detailed view (right).

<u>Task 2 Quarterly Progress – August 28 – September 30, 2015</u>

Task 2 did not continue into FIU Year 6.

Task 17: Advanced Topics for HLW Mixing and Processing

Task 17 Overview

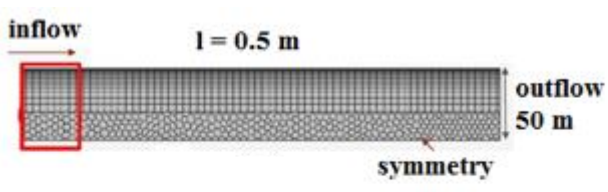
The objective of this task is to investigate advanced topics in HLW processing that could significantly improve nuclear waste handling activities in the coming years. These topics have been identified by the Hanford Site technology development group, or by national labs and academia, as future methods to simulate and/or process waste streams. The task will focus on long-term, high-yield/high-risk technologies and computer codes that show promise in improving the HLW processing mission at the Hanford Site.

More specifically, this task will use the knowledge acquired at FIU on multiphase flow modeling to build a CFD computer program in order to obtain simulations at the engineering-scale with appropriate physics captured for the analysis and optimization of PJM mixing performance. Focus will be given to turbulent fluid flow in nuclear waste tanks that exhibit non-Newtonian fluid characteristics. The results will provide the sites with mathematical modeling, validation, and testing of computer programs to support critical issues related to HLW retrieval and processing.

Task 17 Quarterly Progress – July 1 – August 28, 2015

Subtask 17.2: Computational Fluid Dynamics Modeling of HLW Processes in Waste Tanks

During the month of July, the performance of the proposed alpha method for modifying the viscosity of Bingham-plastic materials was tested. The effectiveness of the method was evaluated in a STARCCM+ RANS simulation (i.e., k-ε model) initialized with the Herschel-Bulkley model ($\tau = \tau_Y + K\,\gamma^n$). Figure 1-2 shows the computational domain used by Peltier et al. (2015) from the ©Bechtel Company on the left and the computational domain created at FIU-ARC with 25600 cells for testing of the proposed modification method.



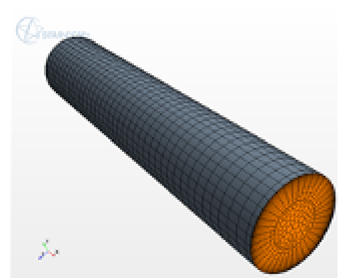


Figure 1-2. Computational domain used for simulation of non-Newtonian fluid, using H-B model with modification method of Gavrilov & Rudyak (2014), 25600 cells.

Eq. (1) shows the definition of the nonlinearity coefficient, alpha. Derivations of the governing equations led to simplified definitions of alpha, as shown by Eq.(2) and Eq.(3). Value of alpha was computed based on the maximum strain rate modulus in each iteration and was used to modify the Herschel-Bulkley viscosity in the next iteration. Two strategies were introduced to the STARCCM+ through Java scripting in order to identify the effective region of the viscosity: one based on a threshold for the dynamic viscosity, Eq.(4), and the other based on the threshold for the dissipation rate, Eq.(5). The first strategy was aimed to directly study the viscosity effect on the numerical results. While, the second strategy, was aimed to more realistically separate the viscosity-effective scales (less than Taylor length scales) from the rest of the scale and implement the viscosity modification on them.

$$\alpha = \frac{\int_0^{\dot{s}_{max}} \tau\dot{s}\, d\dot{s}_{H\text{-}B}}{0.5\times(\dot{s}_{max})_{H\text{-}B}\times(\tau)_{|\dot{s}_{max H\text{-}B}}} \qquad \text{Eq.(1)}$$

$$\alpha = \frac{\int_0^{\Upsilon_{max}}(\tau_0 + K\,\Upsilon^n)d\Upsilon_{(H\text{-}B)}}{0.5\times(\Upsilon_{max})_{H\text{-}B}\times[\tau_0 + K\,(\Upsilon_{max})_{H\text{-}B})^n]} \qquad \text{Eq.(2)}$$

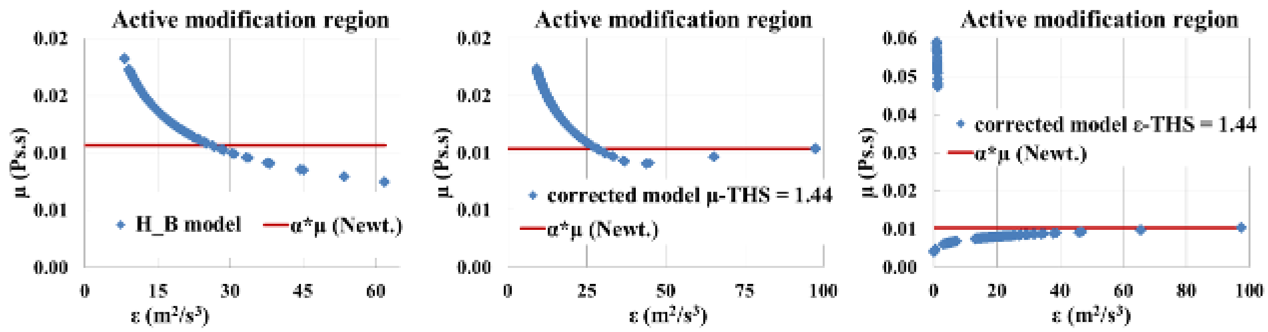
$$\alpha = 2\times\frac{\tau_0 + \frac{K\,(\Upsilon_{max})^n}{n+1}}{\tau_0 + K\,(\Upsilon_{max})^n} \qquad \text{Eq.(3)}$$

$$\text{Strategy \#1}: \begin{cases} \mu = \mu_{H-B} & \mu_{H-B} \geq \mu_{psudo\_Newt.} \\ \mu = \alpha\times\mu_{psudo\_Newt.} & \mu_{H-B} < \mu_{psudo\_Newt.} \end{cases} \qquad \text{Eq.(4)}$$

$$\text{Strategy \#2}: \begin{cases} \mu = \mu_{H-B} & \varepsilon_{H-B} < \varepsilon - THS \\ \mu = \alpha\times\mu_{psudo\_Newt.} & \varepsilon_{H-B} \geq \varepsilon - THS \end{cases} \qquad \text{Eq.(5)}$$

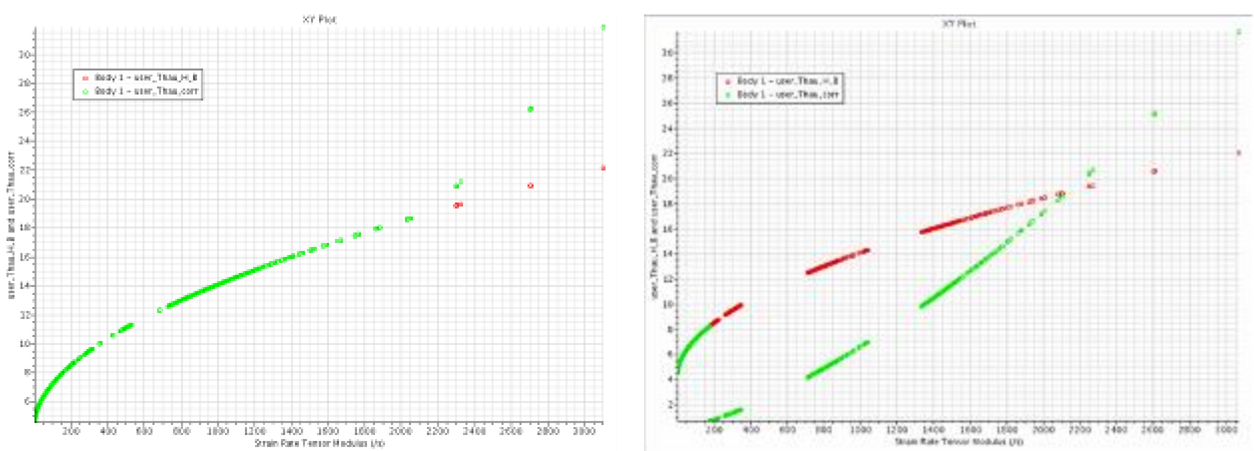
The hypothesis were initially tested in a three dimensional domain without periodicity. Simulation results of the first and second strategies showed differences in the effective areas of manipulation, seen in Figure 1-3. The results in Figure 1-3b show a reduced number of computational cells needing manipulation [shown by the blue symbols in the same effective area ($\varepsilon > 30\ m^2/s^3$)], after implementing the indirect method. In the case of the direct strategy, a small value of the threshold was used to involve more computational cells in the viscosity manipulation. Figure 1-3c shows the tremendous change in the effective area after implementing the second strategy by setting the ε-THS = 1.44. As a result of these manipulations, it was expected to observe significant changes in the stress versus strain profile during the simulation. Figure 1-4 shows the manipulation of the stress-strain profile as a result of both strategies. These results have been obtained after 50 time steps (5000 iterations of the start of manipulations). In Figure 1-4a and b, the red line is the H-B curve and the green color indicates the modified stress-strain profile. As shown, the deviation from the H-B curve is considerably more in the second strategy. In fact, the stress-strain profile has been adapting to the dynamically changing

$\alpha^*\mu_{psudo\_Newt.}$. This shows changes in the behavior of the material from a pure shear thinning after the yield stress, to a shear-thickening after the ε-THS.



(a) (b) (c)

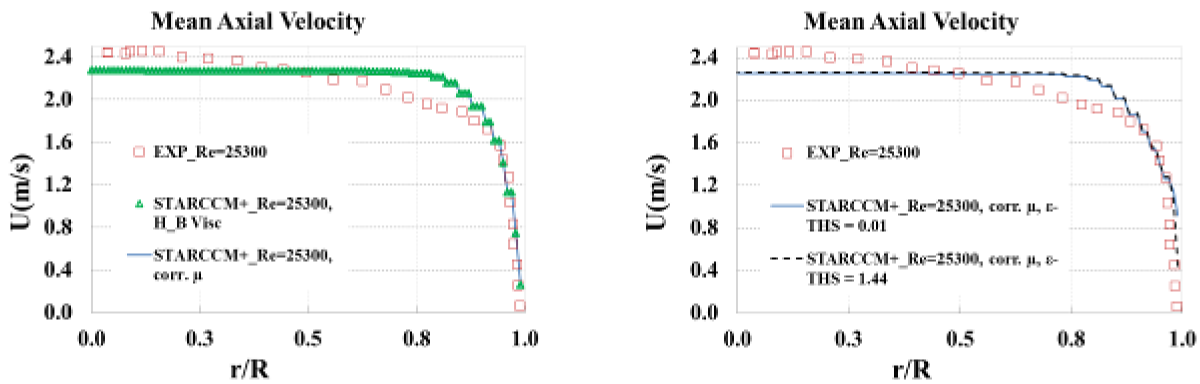
Figure 1-3. Simulation results of the first and second strategies, (a) original effective area obtained from non-modified RANS simulation, (b) effective area of strategy #1 (c) effective area of strategy #2.



(a) (b)

Figure 1-4. Manipulation to the stress-strain profile: (a) strategy #1, (b) strategy#2, results @T=10.05sec. Red shows the H-B profile and green shows the modified viscosity profile.

The results of the RANS simulations after implementation of the proposed methods were compared against the experimental data values. For this purpose, profile of the velocity across the pipe was considered. Figure 1-5a and b show that both strategies could not improve the velocity profile of the H-B model. Results show higher velocity on the cell adjacent to the wall for both methods, which is indicative of stronger shear rate close to the solid boundary. This effect was stronger for the indirect method (shear-correction method or strategy #2), as is shown in Figure 1-5b. Further decrease of the ε_THS to 0.01 (solid blue line in Figure 1-5b) pronounced this effect and a noticeable deviation of the velocity profile in the 0.9< r/R < 1 region occurred. This effect is absent in the region of the pipe flow designated by 0< r/R < 0.9, where the RANS was unable to capture fine scales (dissipative scales) due to the averaging procedure.



(a) (b)

Figure 1-5. Change to the velocity profile after using two strategies in RANS simulation: (a) strategy #1, μ-THS = 1.44, (b) strategy #2, ε_THS = 1.44 and ε_THS =0.01.

Further, the performance of a viscosity modification method devised by Gavrilov & Rudyak (2014) was tested in 2D and 3D computational fluid dynamics (CFD) simulations using the Star-CCM+ software. These researchers hypostatized that Reynolds Averaged Navier-Stokes (RANS) modeling results in averaging of the turbulent scales. Therefore, fluctuation of field variables such as velocity, pressure, and shear rate, as shown by Eq.(4), are missing. This has a direct effect on the strain rate modulus, as shown in Eq.(5).

The Herschel-Bulkley (H-B) viscosity model, as given in Eq.(1), is used widely for the simulation of non-Newtonian fluids; however, the accuracy of the model needs improvement under turbulent conditions.

Direct and indirect approaches exist for the modification of the viscosity in the H-B model. The direct approach comprises of increasing or decreasing the viscosity for dissipative scales of turbulence and the indirect approach can involve modification to the shear rate ($\dot{\Upsilon}$) through modification to the dissipation rate of turbulent kinetic energy (ε). Reynolds Averaged Navier-Stokes (RANS) modeling of the fluid flow results in averaging of the turbulent scales; therefore, fluctuation of field variables such as velocity and pressure are missing. Thus, the tensor of strain/shear rate lacks the fluctuating components of the velocity field.

This fact has a direct effect on the strain rate modulus, as shown in Eq.(2), since it is defined based on the instantaneous tensor of the strain rate.

Theory : $$||\dot{\gamma}||^2 = 2(\hat{s}_{ij}\hat{s}_{ij}) = 2S_{ij}S_{ij} + 2(s'_{ij}s'_{ij})$$ Eq.(6)

RANS : $$||\dot{\gamma}||^2 = 2\,S_{ij}S_{ij}$$ Eq.(7)

In the approach of Gavrilov & Rudyak (2014), the fluctuation component of the shear rate is recovered using an expression for the dissipation rate of turbulent kinetic energy, as shown by **Eq.(8)**.

$$||\dot{\gamma}||^2 = 2S_{ij}S_{ij} + \varepsilon/\nu \qquad \text{Eq.(8)}$$

The k-ε turbulence model solves a transport equation for the turbulent dissipation rate (ε) separately. In the case of the k-ω turbulence model, the solver solves for the specific dissipation rate (ω) and ε can be obtained indirectly using Eq.(6). Thus, the modification of the viscosity is achieved for the k-ω model through Eq.(7).

$$\omega = \frac{\varepsilon}{KC_\mu}, \ C_\mu = 0.09 \qquad \text{Eq.(9)}$$

$$||\dot{\gamma}||^2 = 2S_{ij}S_{ij} + C_\mu K\,\omega/\nu \qquad \text{Eq.(10)}$$

Modification to the viscosity in RANS (method of Gavrilov & Rudyak, 2014)

The computational domain shown in Figure 1-2 was used for investigating the modification method introduced by Gavrilov & Rudyak (2014). To ensure the grid independency of the method, a similar domain with 48000 volume cells was created and used in the simulations.

For brevity, the term "SR-correction method" is used for the modification method of Gavrilov & Rudyak (2014). Figure 1-6 shows that the this method had no effect on the simulation results using the k-ε model. FIU also compared the k-ε and k-ω turbulence models using the unmodified H-B model and found that they perform almost the same way (Figure 1-7). Finally, a similar analysis was performed using the k-ω turbulence model and the results are illustrated in Figure 1-8. The results in Figure 1-8 show a slightly higher modification effect on the results for the k-ω model. Here, the data points are closer to the experimental data in the curve and flat sections of the profile in comparison to those obtained in Figure 1-6.

Further, to investigate the significance of the modification approaches, a set of simulations were run using different turbulent boundary conditions at the inlet of the pipe by varying the turbulent intensity between 1% and 20% and the viscosity ratio from 1 to 1000 at the inlet. The effect was found to be insignificant (right plot in Figure 1-8). Therefore, it was concluded that the effectiveness of the modification approaches are not related to the conditions set at the boundaries of the computational domain.

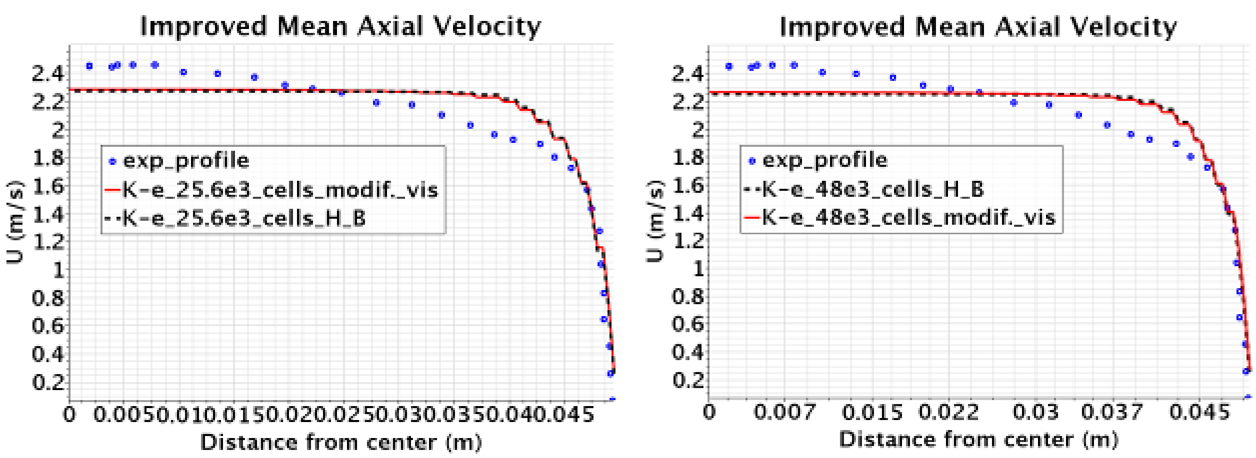


Figure 1-6. Velocity profiles using the modified viscosity and H-B models with k-ε turbulence model for a 3D case. 25600 cells used on the left and 48000 cells on the right.

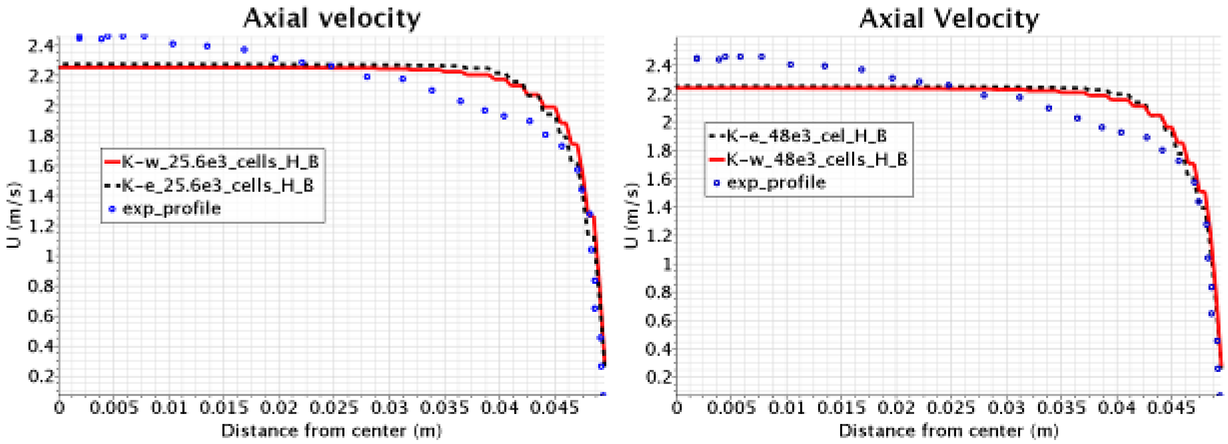


Figure 1-7. k-ε versus k-ω results with the H-B model. 25600 cells on the left and 48000 cells on the right.

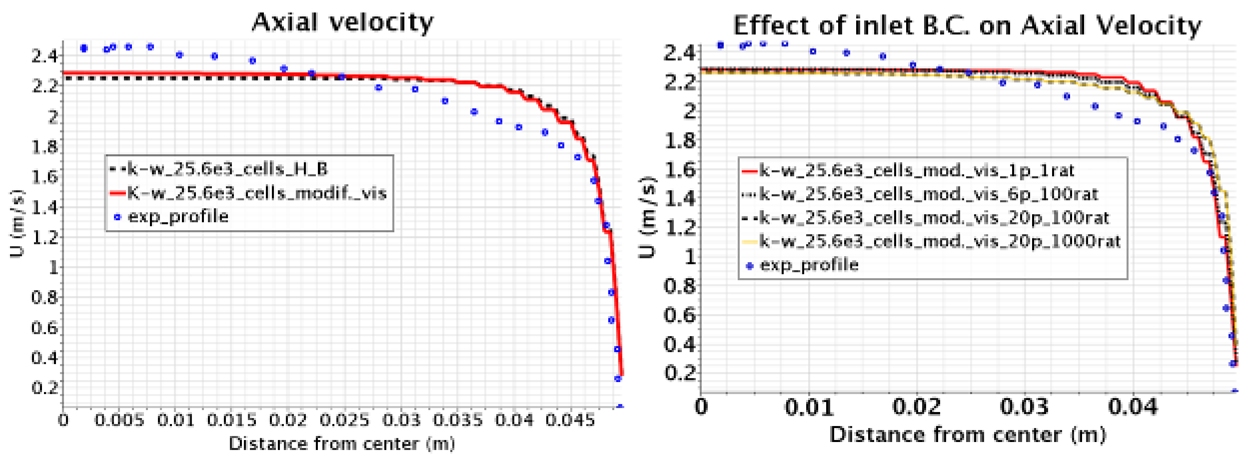


Figure 1-8. Velocity profile obtained with the method of Gavrilov & Rudyak (2014) using k-ω turbulence model for a 3D case with 25600 volume cells (on the left). Effect of the turbulent intensity on velocity profile (on the right).

2D simulations RANS (K-ω) without periodicity condition

In following the approach used by Peltier et al. (2015), a 2D axisymmetric domain was also tested, as displayed in Figure 1-9, that consists of 2177 cells and was close to Peltier et al.'s (2015) domain with 2000 cells. The K-ω turbulence model was used in conjunction with both the proposed direct viscosity modification method [i.e., Eq.(11)] and the indirect method of Gavrilov & Rudyak (2014) given by Eq.(7).

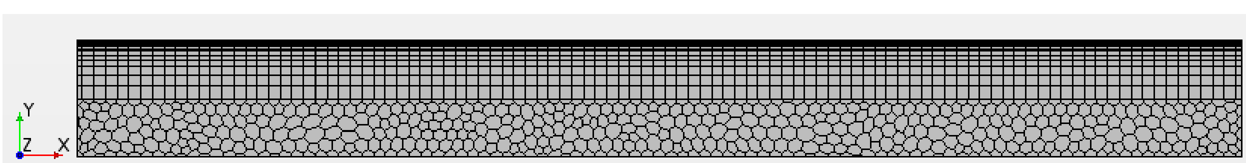


Figure 1-9. 2D computational domain with 2177 cells.

Results of the simulations are illustrated in Figure 1-6 and show significant improvement obtained by the proposed direct method. This result indicated no significance improvement obtained by the SR-correction method of Gavrilov & Rudyak (2014). However, strong fluctuations of the velocity profile around the experimental data was observed, which was due to a strong variation of viscosity in the domain. These fluctuations dampened after a sufficiently long time and results converged to the profile of SR-correction method (the black solid line). It was found in a practice that fluctuations could be reduced slightly by updating the nonlinearity coefficient (α) in every iteration and under-relaxing the viscosity change by introducing a small multiplier coefficient. However, the most effect was observed by increasing the limiting factors, i.e., threshold of the dissipation rate (ε-THs).

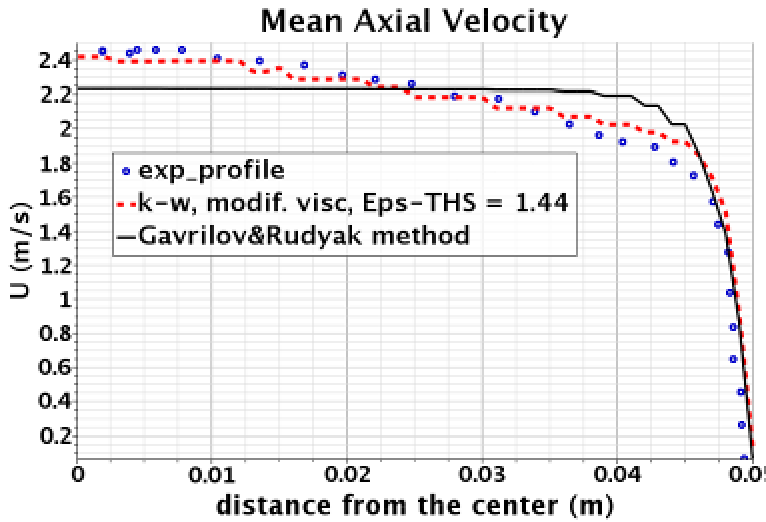


Figure 1-10. Comparison of the velocity profiles obtained from the direct viscosity modification method and the Gavrilov & Rudyak, (2014).

RANS simulations in the presence of viscosity modification methods were run successfully. The method of shear rate correction was tested for the 3D domain with both the k-ε and k-ω turbulence models. No improvements in the results were observed in 3D. The boundary condition settings were also tested for the indirect viscosity modification method and the effect was insignificant. In addition, results of the k-ε and k-ω were very similar for both the original and modified viscosity models.

In a 2D axisymmetric simulation case, the k-ω model was used for both the direct and indirect viscosity modification methods. Significant improvement in the velocity profile was obtained from the direct method using a small threshold for the dissipation rate. It was found that the 2D case is more sensitive to the changes in comparison to the 3D case and further investigation is required to discover the complications associated with the 3D case.

References

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Task 17 Quarterly Progress – August 28 – September 30, 2015

Subtask 17.1: Computational Fluid Dynamics Modeling of HLW Processes in Waste Tanks

In this reporting period, QDNS simulation of a Newtonian (Westerweel, 1996) and non-Newtonian fluid (Escudier et al., 2005) with significantly finer computational grids consisting of almost 6.1m cells were conducted. We have used the H-B model for the non-Newtonian case and compared the results with other turbulent models and experimental data. Definitions of local and overall non-linearity parameters were established and the concept of viscosity correction based on non-linearity and shear rate (SR) correction (Gavrilov & Rudyak, 2014) was investigated in the simulation of a 2-d axisymmetric pipe flow. In addition, we conducted similar investigations for a 2-d axisymmetric periodic pipe flow.

A mathematical description of non-linearity for a stress-strain profile (Figure 1-11) of non-Newtonian slurry can be represented in two forms: overall non-linearity, Eq.(11) and local non-linearity, Eq.(12). In the local definition of α, we treated each point on the rheogram profile as a maximum point and obtained the ratio of total area ($\acute{s}1+\acute{s}2$) over the triangular area ($\acute{s}2$). The definition of pseudo-Newtonian viscosity in local and overall modes are given by Eq.(13) and Eq.(14). In addition, Eq.(15) and Eq.(16) show the definition of the method of Gavrilov & Rudyak, 2014.

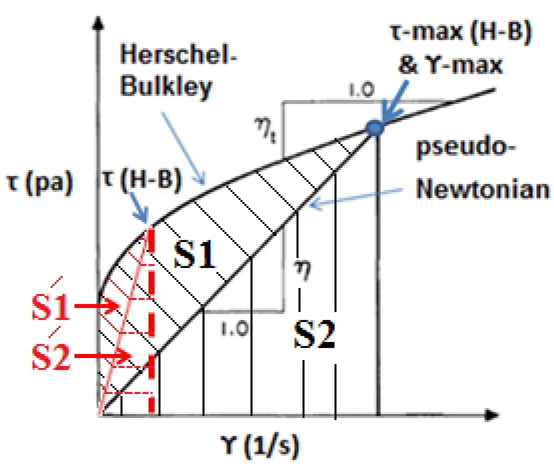

Figure 1-11. Concept of non-linearity of non-Newtonian material, on left: the rheogram based on H-B model ($\tau = \tau_Y + K\,\Upsilon^n$), on right: variation of alpha with maximum of strain rate.

$$\alpha\_overall = 2\times\frac{\tau_0+\frac{K\,(\Upsilon_{max})^n}{n+1}}{\tau_0+K\,(\Upsilon_{max})^n} \quad \text{Eq.(11)}$$

$$\alpha\_local = 2\times\frac{\tau_0+\frac{K\,(\Upsilon)^n}{n+1}}{\tau_0+K\,(\Upsilon)^n} \quad \text{Eq.(12)}$$

$$\mu_{psudo\_Newt.overall} = \frac{\tau_{H\text{-}B\text{-}max}}{\Upsilon_{max}} \quad \text{Eq.(13)}$$

$$\mu_{psudo\_Newt.local} = \frac{\tau_{H\text{-}B}}{\Upsilon} \quad \text{Eq.(14)}$$

$$||\dot{\gamma}||^2 = 2S_{ij}S_{ij} + \varepsilon/\nu \quad \text{Eq.(15)}$$

$$||\dot{\gamma}||^2 = 2S_{ij}S_{ij} + C_\mu K\,\omega/\nu \quad \text{Eq.(16)}$$

Simulation Results

The Quasi-DNS simulation of Newtonian pipe flow using 6.08m cells was performed in STARCCM+. Figure 1-12 shows the comparison of normalized velocity and rms of turbulent fluctuations in the boundary layer. Profiles in both the left and right diagrams show that simulations follow the trend of DNS and experimental data. However, discrepancies can be related to lack of knowledge about inlet B.C. of turbulence which is not mentioned in the referenced publications.

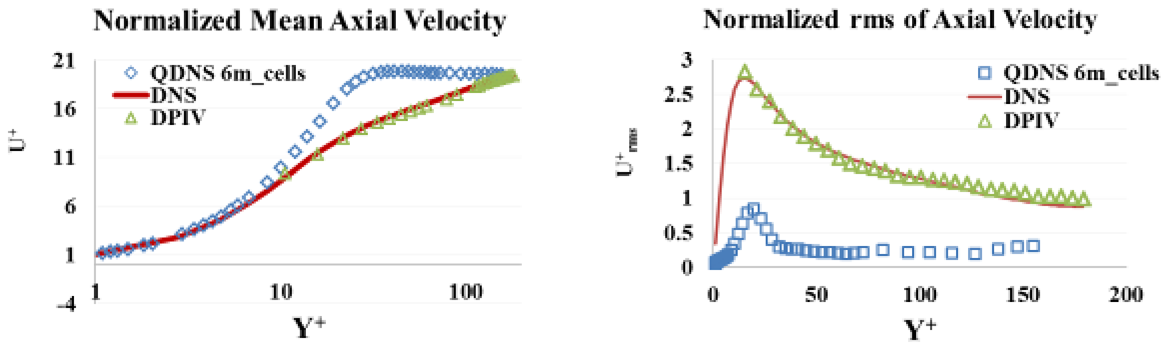

Figure 1-12. QDNS simulation of Newtonian fluid flow in pipe using 6.08m cells.

The Quasi-DNS simulation of non-Newtonian pipe flow in three dimensions and using the Herschel-Bulkley ($\tau = \tau_y + k\dot{\gamma}^{(n)}$) turbulent model was also performed with STARCCM+. Figure 1-13 shows the comparison of axial mean velocity with the experimental data and results of the RANS k-ε with H-B model. The solution reached steady conditions once the volume averaged properties (e.g., viscosity) reached steady values (Figure 1-13b). These results indicated no significance difference between the QDNS and RANS simulations in the wall region ($y < 0.04$m). However, the QDNS predicted higher velocity value adjacent to the solid boundary ($y=0.05$m) which was caused by higher shear rate predicted at the wall. In addition, QDNS predicted a thinner boundary layer (distance between the wall and the location where velocity reached 0.99U) that made the velocity profile more uniform and with lower velocity values in the in the flow core ($y > 0.04$m) in comparison to the RANS model. Prediction of larger shear rate in the QDNS modeling was known accountable for lower viscosity values and consequently thinner boundary layer in the vicinity of the solid boundary.

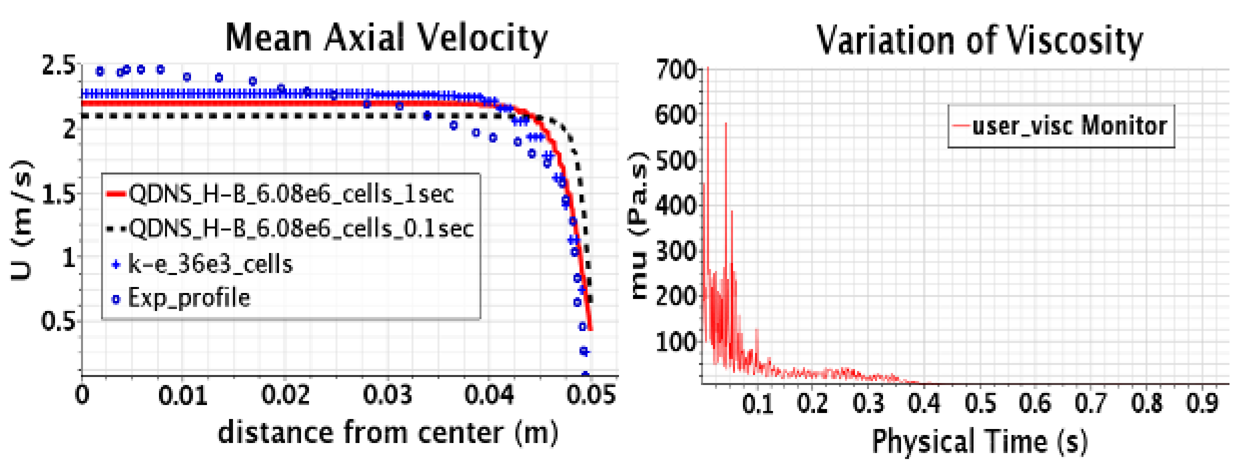

Figure 1-13. QDNS simulation of non-Newtonian fluid flow in pipe using 6.08m cells.

We also continued to investigate the flow in a 2D domain without periodicity for Re = 25300. The concept of direct viscosity correction using local and global non-linear correction terms as well as an indirect viscosity correction method (i.e, shear rate correction) was examined. The output displayed in Figure 1-14 show that results of different methods for the RANS k-ε are not significantly different, although there was still not a significant improvement.

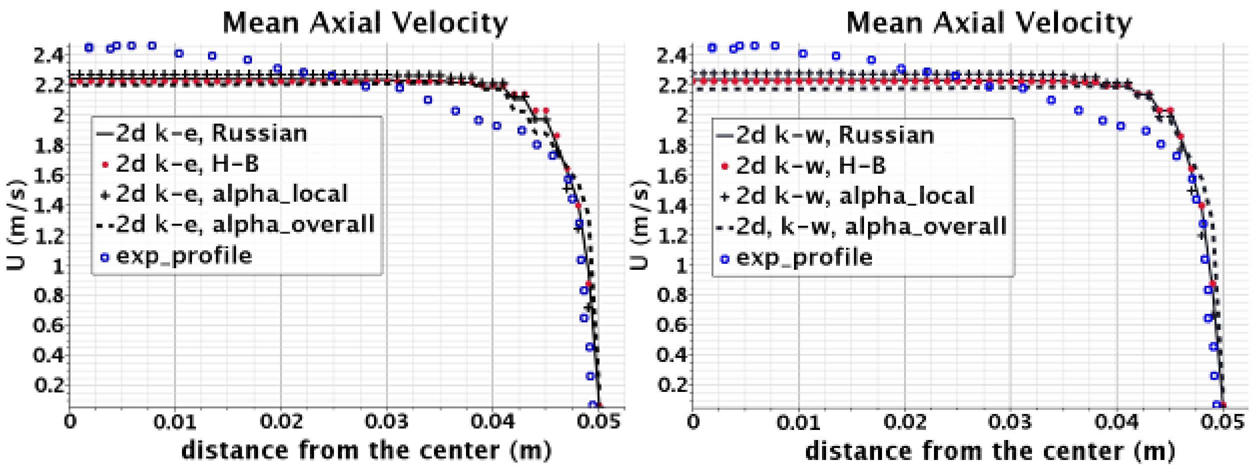

Figure 1-14. RANS simulation of non-Newtonian non-periodic pipe flow using different models of viscosity for the case Re = 25300, k-ε (on left) and k-ω (on right).

RANS simulations of periodic flow using H-B, local correction, global correction, and shear correction method (Gavrilov & Rudyak, 2014) were performed. The k-ε turbulent model was used for two cases, i.e, Re=3,400 and 25,300. We also examined the performance of two additional models: local-inverse and global-inverse alpha methods. In these models, as Eq.(17) and Eq.(18) show, the original H-B viscosity is reduced by the non-linearity coefficient (α) for either of the models (i.e, local or overall). This adjustment was necessary in our investigation since both over predication and under predication of viscosity might occur by using the original H-B model. Additionally, using the regular alpha methods, i.e., Eq.(11) through Eq.(14) might exacerbate the problem where viscosity was already over predicted.

$$\mu = \begin{cases} \mu_{H-B} & \varepsilon_{H-B} < \varepsilon - THS \\ \dfrac{\mu_{psudo-Newt_{local}}}{\alpha_{local}} & \varepsilon_{H-B} \geq \varepsilon - THS \end{cases} \qquad \text{Eq.(17)}$$

$$\mu = \begin{cases} \mu_{H-B} & \varepsilon_{H-B} < \varepsilon - THS \\ \dfrac{\mu_{psudo-Newt_{overall}}}{\alpha_{overall}} & \varepsilon_{H-B} \geq \varepsilon - THS \end{cases} \qquad \text{Eq.(18)}$$

Results of these simulations are provided in Figure 1-15 and Figure 1-16, respectively. The immediate observation here is that significant improvements were obtained by imposing the periodicity condition to the computational domain. The results in Figure 1-15 suggest that overall-inverse alpha model, Eq.(18), worked best for the turbulent case (Re=25300). However,

Figure 1-16 shows that overall alpha method, Eq.(11), worked best for the case of Re=3400. It must be noted that in overall concept, both regular and inverse methods reduced the viscosity in simulations. However, the inverse alpha method reduced the viscosity more than the regular method, since non-linearity coefficient was always more than one. This may indicate that by using the H-B viscosity model, more over prediction occurred for the Re=25300 in comparison to the Re=3400 case.

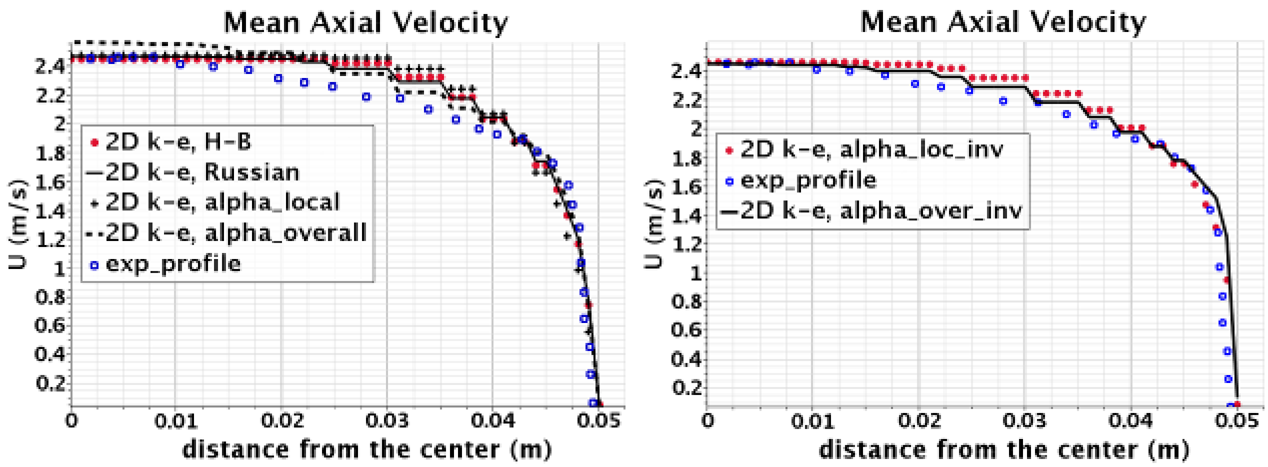

Figure 1-15. RANS simulation of non-Newtonian periodic pipe flow using different models of viscosity for the case Re = 25300, k-ε (on left) and k-ω (on right).

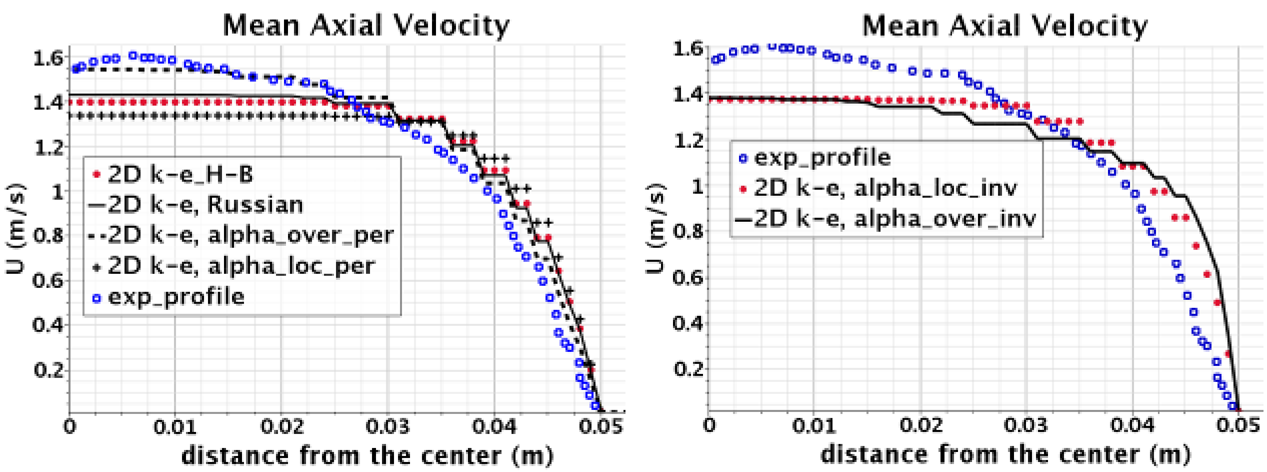

Figure 1-16. RANS simulation of non-Newtonian periodic pipe flow using different models of viscosity for the case Re = 3400, k-ε (on left) and k-ω (on right).

References

Escudier M.P., Presti F., Pipe flow of a thixotropic liquid, J. Non-Newtonian Fluid Mech., volume 62, PP. 291-306, (1996)

Gavrilov A. and Rudyak V.Y., A Model of Averaged Molecular Viscosity for Turbulent Flow of Non-Newtonian Fluids, Journal of Siberian Federal University. Mathematics & Physics 2014, 7(1), 46–57

An additional study under this subtask includes the evaluation of two correlations from a jet impingement experiment developed by Poreh et al. (1967) for use in pulse jet mixing (PJM) vessels. Criticism arises in the application of such correlations due to geometric differences between the experiment from which the two correlations were derived and the PJMs. The correlations dictate whether criticality within a vessel will be reached; therefore, it is imperative to properly validate their accuracy.

The CFD replication of Poreh's experiment at b/d = 12 obtained over the summer showed good agreement in maximum velocity along the radial direction but lacked a degree of accuracy when it came to the velocity gradients near the wall, as shown below.

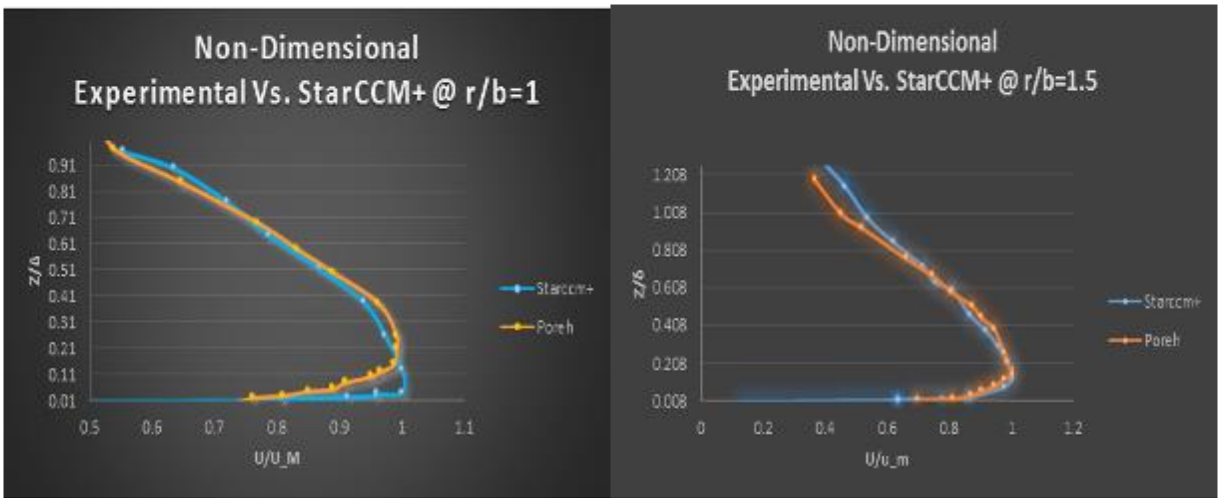

Figure 1-1. Impingement plots of experimental and simulation data for b/d = 12 (r/b=1 and 1.5).

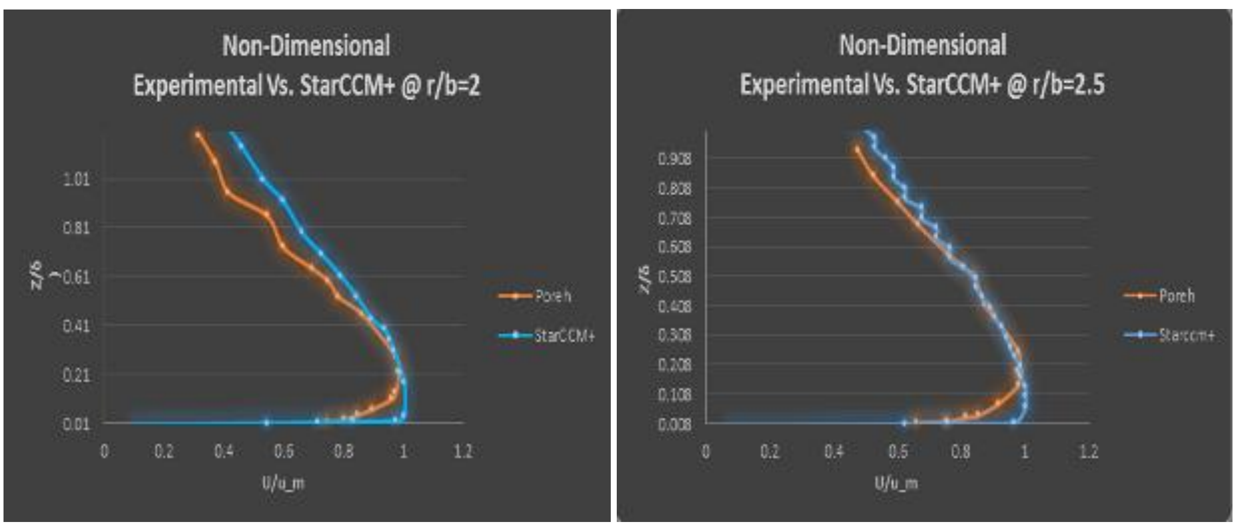

Figure 1-2. Impingement plots of experimental and simulation data for b/d = 12 (r/b=2 and 2.5).

One of the main discrepancies in the replication of the experiment is that of the transition from maximum velocity to zero velocity at the wall. It was observed that the StarCCM+ maximum velocity is maintained longer and suddenly decreases rapidly very close to the wall. Poreh's experimental results show a slower and much earlier transition from maximum velocity to zero velocity at the wall.

Additional simulations were conducted with b/d = 1.5. There is decent agreement in the results comparing Poreh's correlations as shown below.

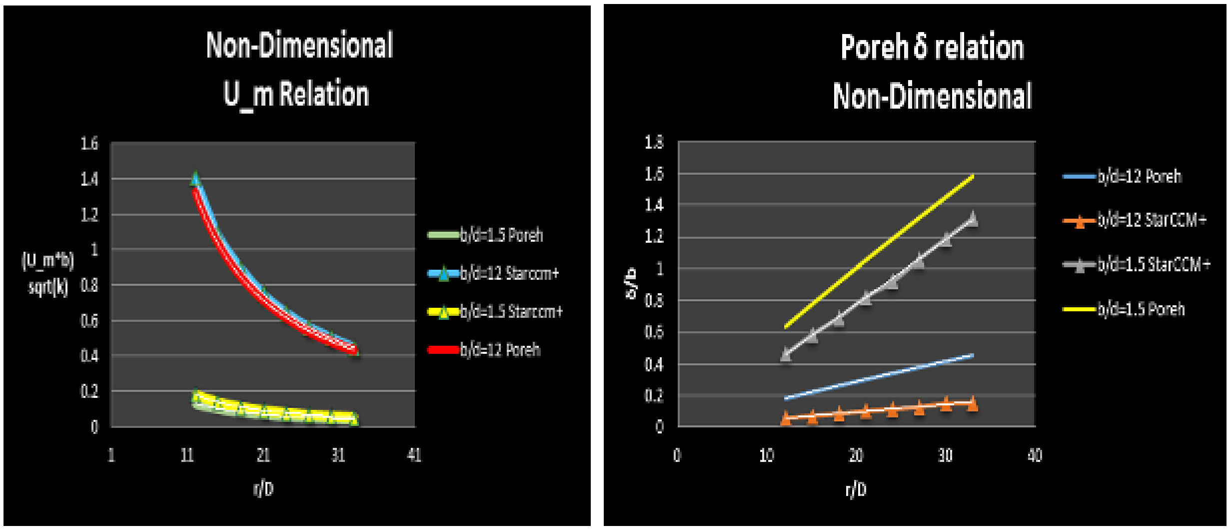

Figure 1-3. Simulation result for b/d = 1.5.

Before we proceed to conducting simulations with further geometrical similarities, both the CFD analysts at NETL and our team find it necessary to investigate this discrepancy further. In order to extend our results to represent real systems, it is imperative that the simulation from which everything is based is as accurate as possible.

The simulation replicating Poreh's experiment is currently undergoing revision to ensure that it was set up correctly. These efforts have been delayed due to a system maintenance procedure that has left the NETL research analysts without access to StarCCM+ for two weeks as of October 5, 2015. Once the simulation is completely assessed, the results will be re-evaluated, if necessary, and the project will continue forward with simulations incorporating the angled impingement plate.

Task 18: Technology Development and Instrumentation Evaluation

<u>Task 18 Overview</u>

The objective of this task is to assist site engineers in developing tools and evaluating existing technologies that can solve challenges associated with the high level waste tanks and transfer systems. Specifically, FIU is assisting in the evaluation of using a sonar (SLIM) developed at FIU for detecting residual waste in HLW tanks during pulse jet mixing (PJM). This effort would provide engineers with valuable information regarding the effectiveness of the mixing processes in the HLW tanks. Additionally, the Hanford Site has identified a need for developing inspection tools that provide feedback on the integrity of the primary tank bottom in DSTs. Recently, waste was found to be leaking from the bottom of the primary tank in AY-102. FIU will assist in the development of a technology to provide visual feedback of the tank bottom after traversing through the refractory pad underneath the primary tank.

Task 18 Quarterly Progress – July 1 – August 28, 2015

Subtask 18.1: Evaluation of SLIM for Rapid Measurement of HLW Solids on Tank Bottoms

During July, FIU completed and sent to PNNL a response to a call for technology (July 10, 2015). Eric Berglin and Carl Lanigan (PNNL) are leading this technology testing program on behalf of the Waste Treatment & Immobilization Plant (WTP). The call for technology contained three measurement challenges (bottom mobilization, bulk or slurry mobilization, and relative concentration of gas bubbles) related to vessel mixing. The measurement challenges are associated with full-scale non-hazardous material testing of the mixing system design. WTP measurement needs pose challenges (e.g., vessel configurations: enclosed metal tank with internal structure; fluid conditions: opaque and periodic/cyclic flows) and will likely require customized techniques to obtain the desired data.

Also during July, the repaired 3-D profiling sonar was extensively tested. Initial testing repeated earlier tests (before the sonar malfunctioned) using the same objects, conditions, and system settings. The spatial resolution of the system seems to be slighted degraded and FIU is sharing results with the manufacturer to identify possible reasons and improvements. One test involved imaging a section of U-channel and a 6-mm thick, L-shaped piece of metal. In Figure 1-20, one can see the sonar, U-channel and L-shaped piece of metal. In the sonar images in Figure 1-21, Figure 1-22, and Figure 1-23, the L-shaped piece of metal was moved to different locations and can be identified in the sonar images. This smaller test tank has been set up to quantify the image resolution of the sonar without any mixing post repairs. Upon completion of this analysis, the sonar will be moved to the 1-meter diameter tank adjacent to this smaller tank and the imaging while mixing test plan will be executed.

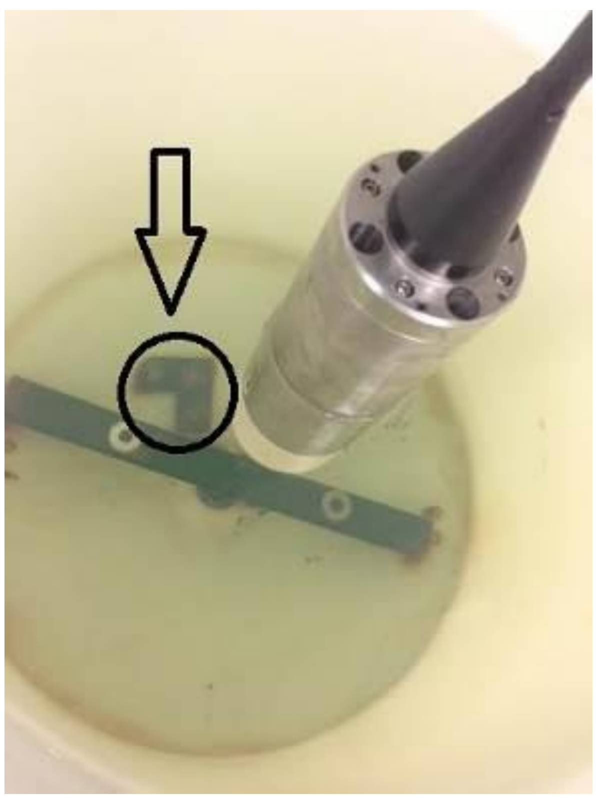

Figure 1-20. Setup to test the ability of the 3-D sonar to image a 6-mm thick metal piece.

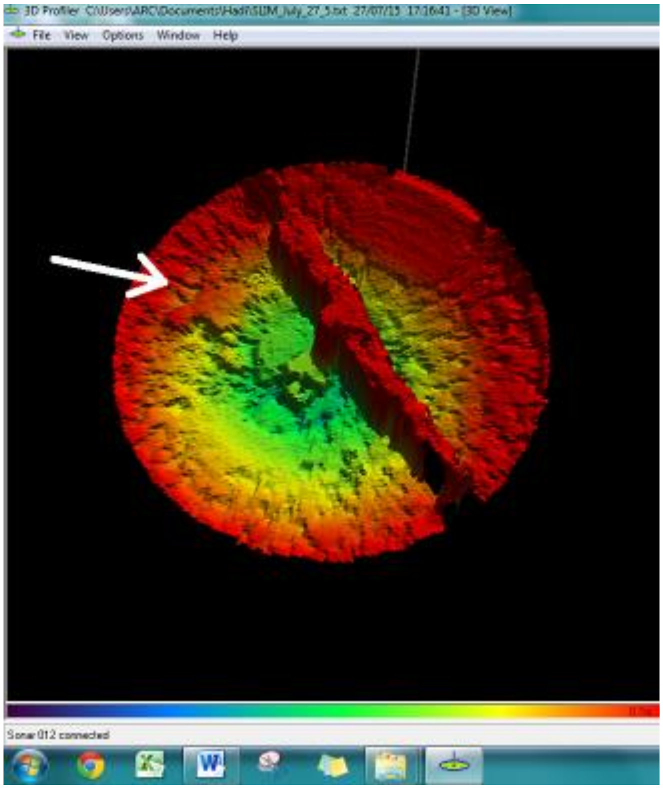

Figure 1-21. Image of the U-channel and the 6 mm thick, L-shaped piece of metal in position 1.

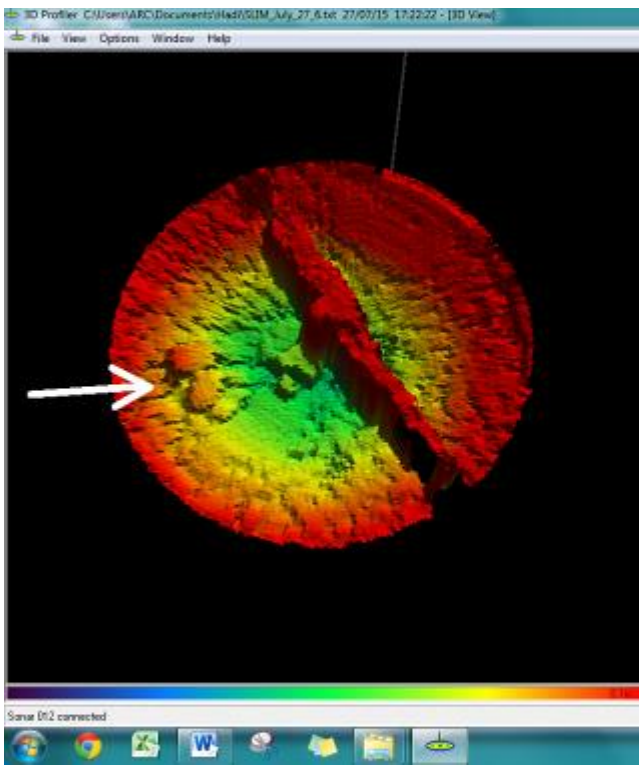

Figure 1-22. Image of the U-channel and the 6-mm thick L-shaped piece of metal in position 2.

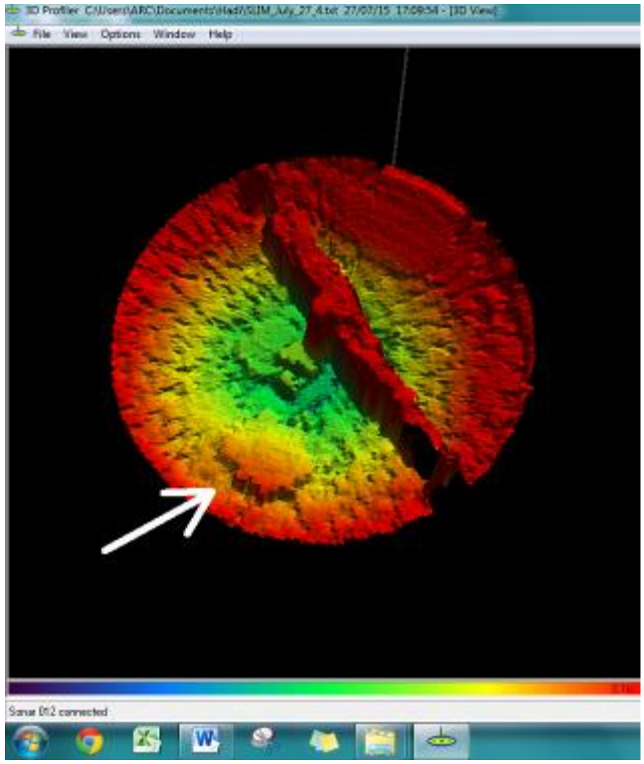

Figure 1-23. Image of the U-channel and the 6-mm thick L-shaped piece of metal in position 3.

During August, FIU continued to evaluate the 3D sonar resolution in mapping the solids layer without any active mixing. Upon completion of this analysis, the sonar will be moved to the 1-meter diameter tank and the test plan for imaging while mixing will be executed. FIU discussed the scope for this subtask with WRPS and it was agreed to shift the scope for the next performance year (Sept. 2015 – August 2016) to two new objectives: (1) imaging a solids layer that is growing due to gas generation and retention in the solids layer; and (2) determination of settling rates of various surrogate HLW particulates.

FIU continued to evaluate the resolution of the repaired 3D sonar by imaging a stack of 3-mm thick plates. The three sonar images below use the commercial sonar imaging software and have imaging times of 90 – 100 seconds. As FIU post-processes the data next month, FIU will extract the number of 2D scans for any given short imaging time (e.g., 20 second scans) and then filter and improve the image resolution and quality in our visualization software. For tanks with the sonar installed, the short scan imaging of the HLW layer on the floor would be continuous, allowing for comparison of multiple scans to see solids being swept across the floor, areas of solids accumulation and any growth in the thickness of the solids layer. Figure 1-24 shows the 3D sonar set to view a stack of small metal plates on top of a larger metal plate. The sonar has been set for a field of view of 30.

Figure 1-24. Test setup in small tank with 3D sonar and small stacked metal plates.

Figure 1-25 is a sonar image of the tank bottom (dark green); the large metal plate (lighter green) and the stack of 6 small metal plates (yellow green) with a total thickness of 18 mm.

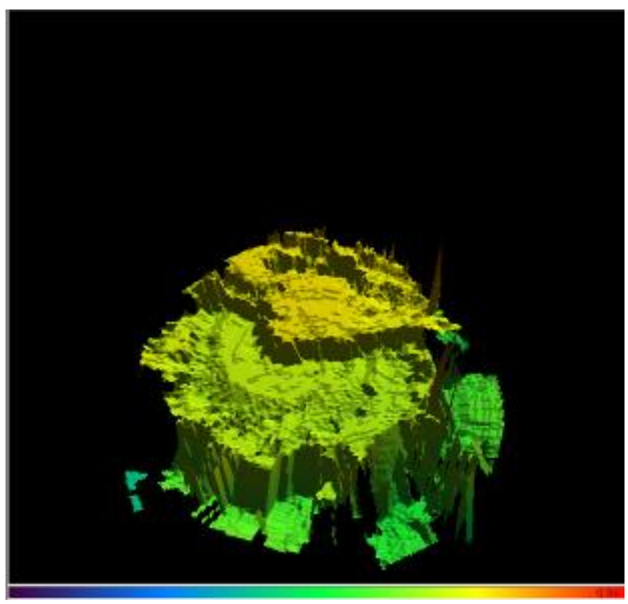

Figure 1-25. Sonar image of 6 stacked metal plates, each 3 mm thick.

The sonar image in Figure 1-26 clearly shows the 2 stacked plates (6 mm total thickness).

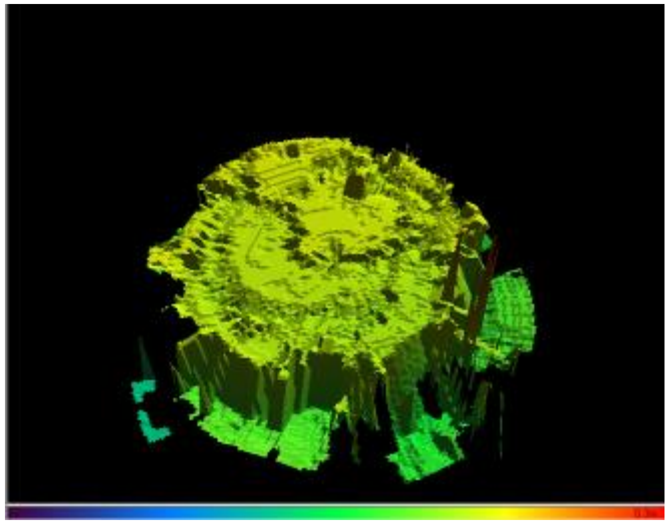

Figure 1-26. Sonar image of 2 stacked metal plates, each 3 mm thick.

Finally, the last sonar image (Figure 1-27) shows the traces of the 3-mm thick single plate. Since the planned operation of the sonar is to monitor the floor continuously, FIU has the ability to combine various scans into a video clip to illustrate how the solids layer might grow, ebb or disappear entirely (to the sonar's image resolution).

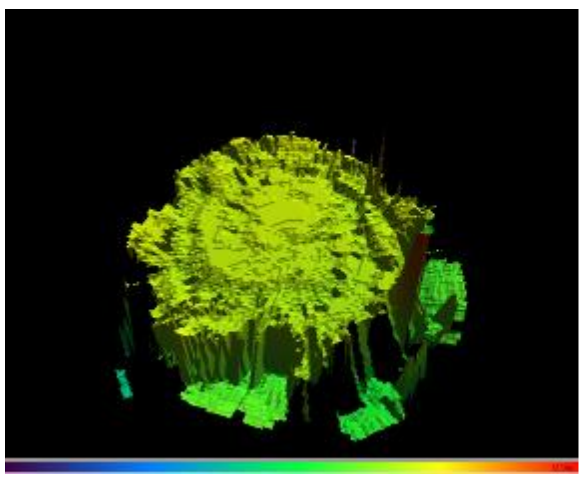

Figure 1- 27. Sonar image of 1 metal plate, 3 mm thick.

Subtask 18.2: Development of Inspection Tools for DST Primary Tanks

<u>Miniature motorized inspection tool</u>

This task involves developing a miniature, motorized inspection tool with the capability of providing live video feedback. Its intended path of inspection is that of the cooling channels of tank AY-102, located at the Hanford Site. The engineers on-site have communicated several capabilities that the tool must possess in order to complete its task, and will provide regular feedback throughout the different design iterations.

During the month of July, a modified version of the inspection tool was 3D printed (Figure 1-28). Modifications to the design addressed obstacle avoidance and reliability issues. A new circuit was implemented to incorporate backward and turn motions and the custom designed wheels with O-rings reduced the total width while providing the required traction force.

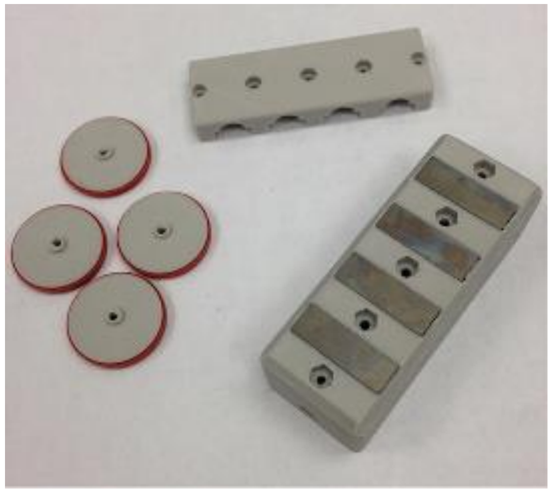

Figure 1-28. 3D printed components with magnets installed on base.

The primary design modification was the implementation of a multi-clamp and bolt system to secure the DC motors (Figure 1-29). The addition of the mechanism prevents the motors from slipping or spinning relative to the housing.

Figure 1-29. The assembled inspection tool using the 3D printed clamp and fasteners.

Nuts were placed in hexagonal spaces in the bottom of the body to hold the clamp in position. Bolts entered from the holes in the clamp and reached to the pair nuts at the bottom. To create space for the nuts in the bottom, four smaller Neodymium magnets were used instead of one large one. The maximum pull force of the magnets is 3 lbs.

The new control circuit (Figure 1-30) consists of two Pololu DRV8835 dual motor driver carriers and a Parallax 2-axis joystick. The DRV8835 dual motor driver can deliver 1.2 A per channel continuously (1.5 A peak) to a pair of DC motors, and it supports an operating voltage range up to 11 V from the power source. Two independent 10 K potentiometers of the 2-axis joystick will increase the obstacle avoidance capability of the unit. This includes improving the response of the unit to the refractory wall contact, tank undulations (weld seams) and making 90 degree turns.

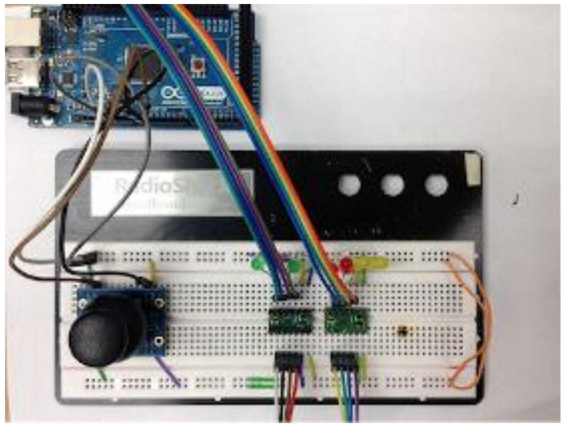

Figure 1-30. The new control circuit consists of a joystick and two H-bridges for DC motor control.

The new design was initially tested to ensure all the systems were operating and functional (Figure 1-31). The altered design of the wheels reduced the width of the inspection tool from 35.5 mm to 30.75 mm and the plastic material has a significantly lower coefficient of friction with the walls of our test bed. It was observed during testing, however, that the wheels wobbled slightly, but could still execute maneuvers. Currently, we are investigating design modifications to eliminate the wobble.

Figure 1-31. Inspection tool maneuvering up a vertical beam.

Through the month of August, FIU's efforts focused on improving the performance of the inspection tool. The device needs to be able to maintain a straight path over the course of the refractory channels, since there is very little clearance between the tool and the refractory wall. By modifying the control code, small adjustments can be executed using the dual-axis joystick. Additional tests showed that the unit did not have enough power to execute a sharp 90° turn. The previous unit's gear/motor system stalled due to insufficient torque and could not overcome the friction encountered during the turn. Another issue with the previous motors is that they contain plastic gearboxes and are susceptible to gear failure, especially at elevated temperatures. A design modification has been introduced which replaces the motors with micro-metal gear DC motors shown in Figure 1-32. These motors provide approximately 8.75 times higher power output at 6 V than the previous motors.

Figure 1-32. Miniature high-power brushed DC motor with long-life carbon brushes and a 297.92:1 metal gearbox (courtesy of Pololu).

The key specifications of the previous motor and proposed motor are shown for 6V operational conditions in Table 1-1.

Table 1-1. Comparison of Motors

Motor type	Operative voltage	Gearbox ratio	No load speed (RPM)	Free-run Current	Stall torque	Stall current
Micro Metal Gear motor HPCB	3 – 9 V	298:1	100	120 mA	70 oz-in (2.9 kg-cm)	1600 mA
Sub-Micro Plastic Planetary Gear motor	3 – 6 V	136:1	500	45 mA	8 oz-in (0.6 kg-cm)	400 mA

A modified design of the tool was developed in order to accommodate the larger motor and can be seen in Figure 1-33. Some of the modifications include the adjustment of the radius of curvature in the motor seats and cap to 5.67 mm, the creation of a 10×12 mm square space for the new motors in the bracket cap and the use of 19-mm inner diameter rubber square-profile O-rings with 2 mm width. These motors were not previously considered due to the longer shafts and the use of wider off-the-shelf wheels; however, with the improved wheel design, modifications can easily be made to the motor shafts for accommodation. The 3D printed components and the assembly are shown in Figure 1-34.

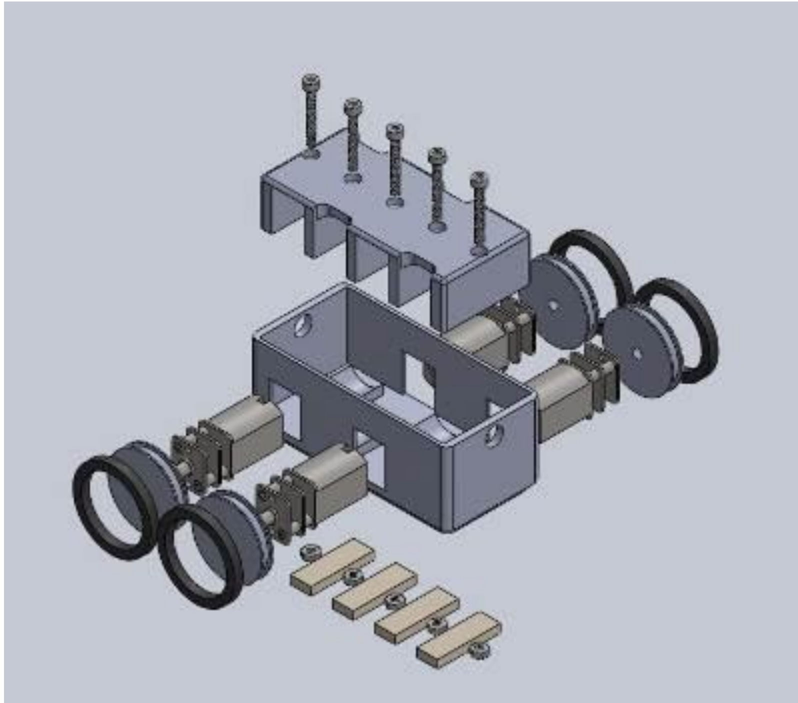

Figure 1-33. Components of the modified inspection tool using the new motors with metal 298:1 gearbox.

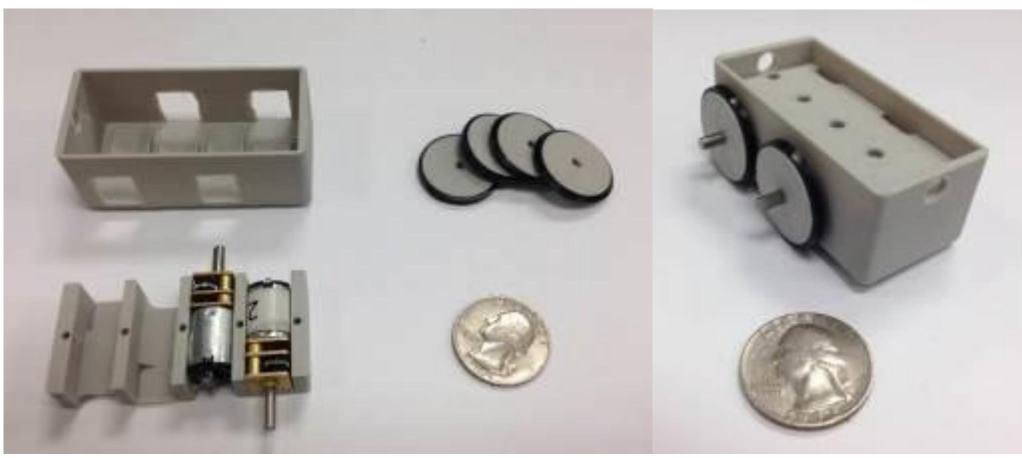

Figure 1-34. 3D printed components for inspection tool with micro metal gear DC motors and the assembly.

<u>Peristaltic crawler inspection tool</u>

An additional effort under this task is associated with developing an inspection tool that can navigate and provide visual feedback through the 4” air supply pipe that leads to the tank central plenum of AY-102.

During this performance period, the tether design was finalized. In the proposed robotic inspection of the ventilation header in the AY-102 tank at Hanford, the main determinant of success in designing the new peristaltic crawler is the ability of the device to be able to pull and overcome the tether dragging forces. As illustrated in Figure 1-35, the task will require maneuvering through approximately 100 feet of piping, which vary between 3 and 4 inches in diameter. Sixty feet of the piping is vertical and the crawler will be gravity fed. The remaining 40 feet contains horizontal runs, including 5 elbows.

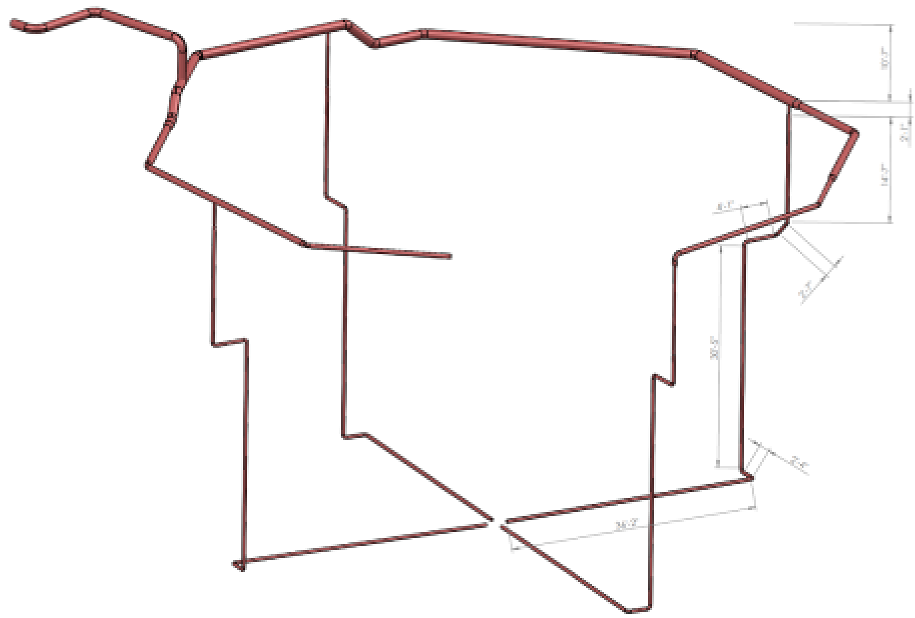

Figure 1-35. The proposed robotic inspection of the ventilation header in the AY-102 tank at Hanford.

For this application, a tether of 100 feet is being manufactured. The tether consists of:

- 8 pneumatic lines,
- 1 digital video feedback cable, and
- 1 retrieval steel cable.

During dragging, the retrieval cable will be responsible for carrying out the pulling load, relieving any tension in the other lines of the tether. The bundle will also be enclosed by an abrasion-resistant sleeve, which will protect the cables from wear and tear.

Additionally, existing leaking problems were solved by installing metal clamps on all pneumatic barbed connectors. The new pneumatic clamps are shown in Figure 1-36. Methods to strengthen 3D printed parts were also investigated, and ways to manufacture custom rubber parts were evaluated during the same period.

Figure 1-36. Metal clamps installed in the crawler pneumatic barbed connectors.

Alternate rubber tip designs for the gripper claws were investigated. Preliminary experimental tests were performed not only to determine the maximum gripping force, but also to estimate the tether dragging force. Varied pipe sizes, lengths and fitting configurations were tested.

Additionally, several kinds of suspension mechanisms were also investigated with the objective of keeping the crawler at center while crawling through different pipe sizes and fittings. This will minimize the crawler bouncing and dragging and will also reduce the bulldozer effect, which is the accumulation of debris in the front camera. An overall picture of the subsystems involved in the crawler operation is shown in Figure 1-37. The schematic of the portable control box is enlarged in Figure 1-38. A portable control box will be suitable for the field deployment of the crawler. We envision the crawler being controlled remotely using any handheld device connected to its secure wireless private network, running a customizable application which will make the inspection tool highly customizable, not having any dedicated control interface.

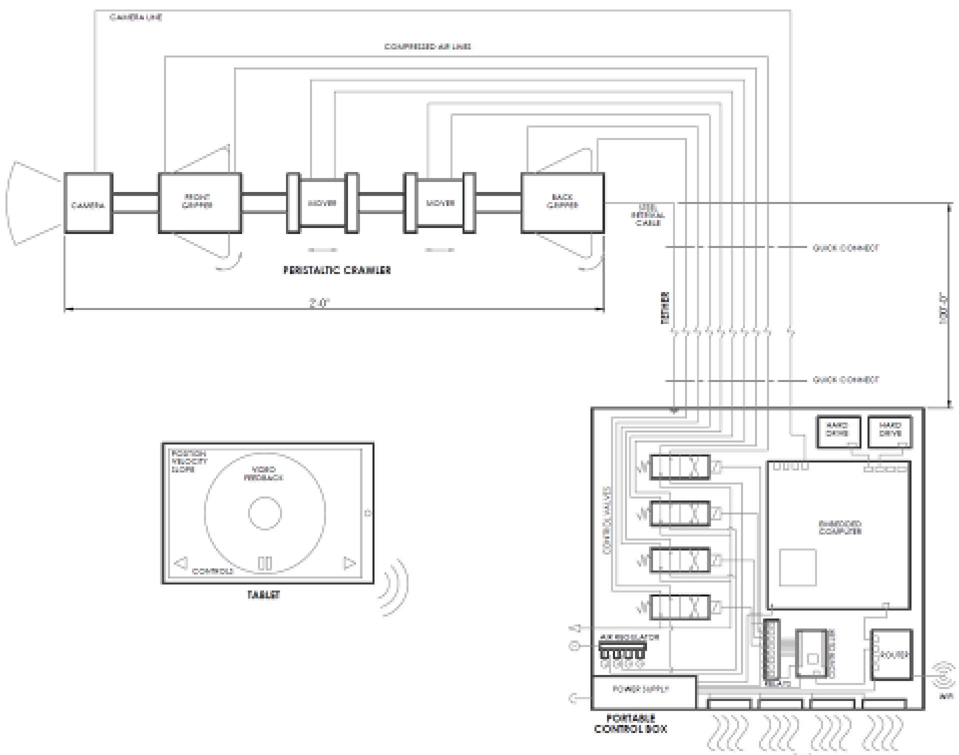

Figure 1-37. Crawler subsystems being controlled by a programmable interface.

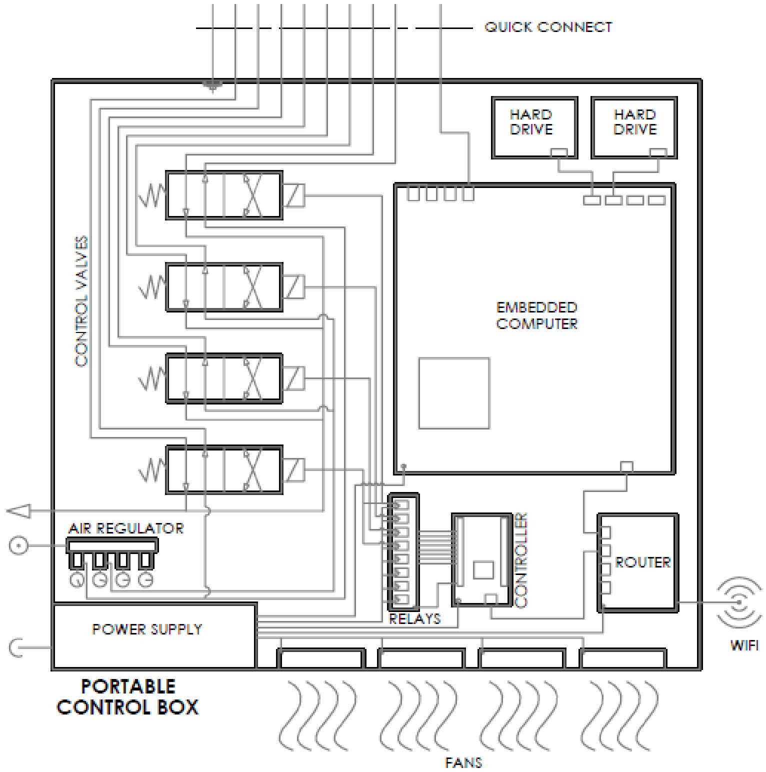

Figure 1-38. Crawler portable control box.

Task 18 Quarterly Progress – August 28 – September 30, 2015

Subtask 18.1: Evaluation of FIU's SLIM for Estimating the Onset of Deep Sludge Gas Release Events

Engineers at WRPS and FIU discussed extending the sonar research and testing for high-level radioactive waste (HLW). The new effort with the 3D imaging sonar for FIU Year 6 has two objectives:

(1) image a solids layer growing due to gas generation and retention in the solids layer; and

(2) determine the settling rates of various surrogate HLW particulates.

In tanks, sonars could provide continuous monitoring and show when a solids layer is present on the floor and if it is growing over time due to settling or the buildup of gas in the solids layer.

Last month, FIU imaged solids with 2-mm to 6-mm thickness to show the viability of the concept that the sonar could image a few millimeters thickness of settled solids. In September, FIU initiated a literature review of this new application for the imaging sonar in HLW. The first report reviewed was entitled, "Gas Release Due to Rayleigh-Taylor Instability within Sediment Layers in Hanford Double-Shell Tanks: Results of Scaled-Vessel Experiments, Modeling, and Extrapolation to Full Scale." FIU also identified some possible software which would support part of the near continuous monitoring of a tank floor (imagery collection, porting, filtering, other post-processing, and visualization).

Data from these thin solids layer experiments will be extracted from the sonar output files, filtered, post-processed, and visualized.

Subtask 18.2: Development of Inspection Tools for DST Primary Tanks

Miniature motorized inspection tool

During the month of September, a new prototype was manufactured based on modifications discussed in the previous monthly report. The primary components comprised in the unit include:

- Arduino Uno board with ATMega328 microcontroller
- Joystick shield kit for the Arduino Uno
- Eggsnow USB Borescope Endoscope 5.5mm inspection camera
- 298:1 Micro Metal Gear motor
- 3D printed 20mm x 2 mm wheels
- 3D-printed body
- Neodymium magnet - 1” x 3/8” x 1/16” – 4.53 lb. pull force (4)

Figure 1-39 shows the components for the inspection tool and the assembly prior to testing. Note that these components are not radiation hardened or designed to withstand elevated temperatures. Future efforts will focus on making the necessary modifications to accommodate these design parameters.

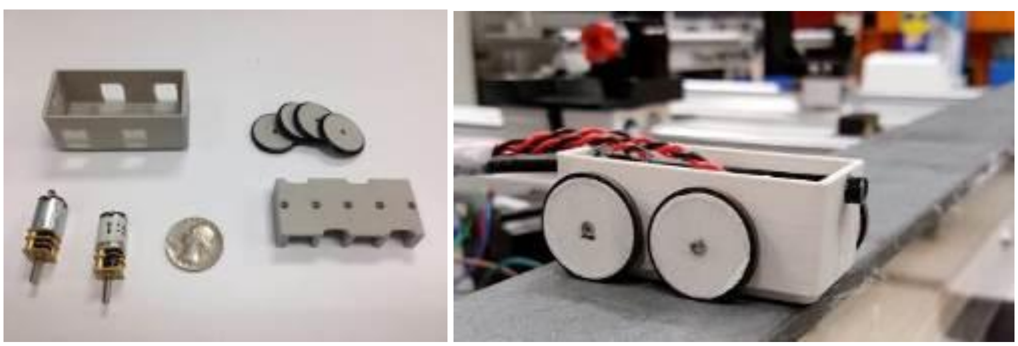

Figure 1-39. Components for the inspection unit (left) and assembled inspection unit (right).

Although the design allows for four magnets, availability from the vendor limited our use to two (Figure 1-40). After assembly, tests were conducted to determine the maximum pull force with the newly installed motors. Fifteen trials were conducted using two power sources: 1) internal source from the micro controller, and 2) external power supply system.

Table 1-2. Maximum Pull Force (Gram-Force)

Power Source	Test Trials														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Internal (5V)	835	850	820	831	836	760	770	829	794	788	805	800	892	860	864
External (6-11V)	932	981	919	905	920	949	941	925	945	955	904	928	929	1040	1051

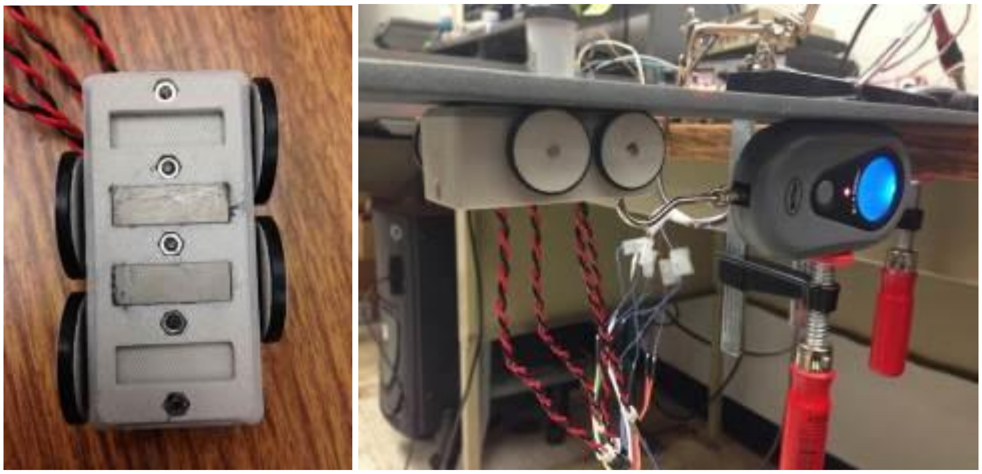

Figure 1-40. Installed magnets (left) and lab scale pull force set up (right).

Measurements indicate the new motors have significantly increased the overall maximum pull force (4x), as compared to the previously used plastic planetary gear motors. The maximum pull force should also be improved with the inclusion of the two missing magnets. Overall improvements obtained during the last design modifications can be summarized as follows:

- Increased torque from larger motors (10x) and larger custom made wheels
- Increased wheel diameter by 6 mm to improve obstacle avoidance ability
- Installed bracket mounts to allow for changing out motors

The inspection tool was tested inside a mock-up of the refractory channel as shown in Figure 1-41. No difficulties were observed in terms of navigation or obstacle avoidance. Videos from both the inspection tool and a camera placed outside the test bed have been created.

Figure 1-41. Inspection lab-scale testing in mock-up refractory channels.

Peristaltic crawler inspection tool

During the month of August, more experimental tests were conducted on the crawler's gripper. Figure 1-42 shows preliminary pulling tests being executed using a hand scale. The measured maximum gripping force is around 18 pounds for a pipe with a diameter of 3 inches.

Figure 1-42. Crawler grippers preliminary pulling tests.

The previous estimation for the maximum theoretical gripping force, presented in Figure 1-43, is around 33 pounds in a 3-in. diameter pipe. The estimation uses a static coefficient of friction of 0.95 for rubber against steel contact, which typically varies from 0.6 to 0.95. A higher coefficient of friction would provide a stronger grip; therefore, several kinds of commercially available rubber materials were tested. A softer rubber would provide a higher friction; however, it would have a lower abrasive resistance.

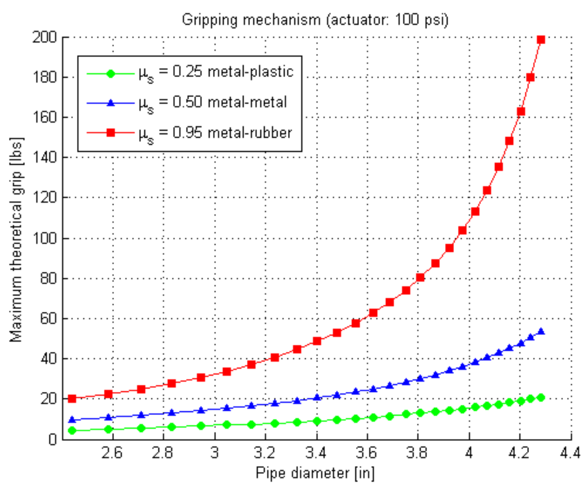

Figure 1-43. Maximum theoretical gripping force.

A stronger grip may also be attained by increasing the number of claws in the grippers. More claws would increase the surface of contact, consequently increasing the friction. The current grippers, illustrated in Figure 1-44, have three claws per mechanism. The design of a new mechanism with five claws was investigated.

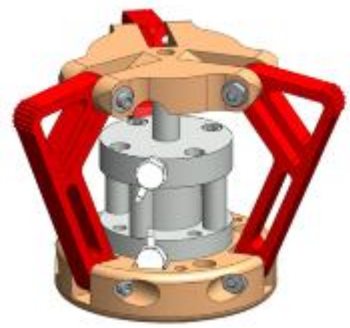

Figure 1-44. Current grippers.

Another set of tests are also being designed with the objective of estimating the life expectancy of the grippers under operation. The tests will pull the grippers cyclically under axial loading, which would be the expected maximum gripping force. The proposed inspection though the air supply lines will require approximately 100 feet of pipe crawling. The current crawler moves 2 inches per peristaltic movement, which would require at least 800 cycles to complete the proposed inspection back and forth. The designed grippers are expected to last for a considerably larger number of cycles than those required for the inspection.

During the same period, the tether was redesigned to carry a 100 lbs load cell, shown in Figure 1-45. The addition of the small load cell, with approximate diameter of 0.5 inch, provides force feedback to the current dragging force of the tether. The force feedback will enhance the system's robustness.

Figure 1-45. Tether load cell.

In addition, several kinds of suspension mechanisms are still being investigated. Figure 1-46 illustrates such a mechanism, which keeps the crawler centered while crawling through pipes and fittings. The suspension would also minimize the crawler bouncing and dragging, and the bulldozer effect (the collection of debris) in the front camera.

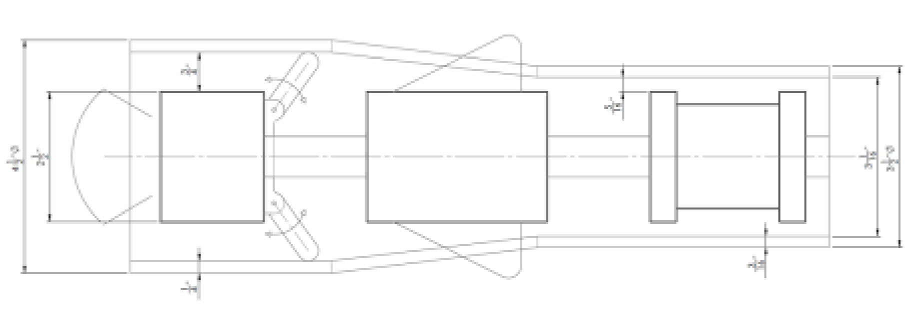

Figure 1-46. Crawler suspension mechanism illustration.

The main activity during this period was to improve the grip strength of the crawler. A stronger grip might be obtained by improving the contact area between the locking mechanisms and the pipe. An improved/increased contact area can be achieved by the following modification:

- redesigning the rubber tip of the mechanism claws, and
- increasing the number of the claws per gripper.

It was aforementioned that the maximum gripping force is the primary determinant of success in designing the new peristaltic crawler. Figure 1-47 below shows a newly redesigned claw. The new claw uses a hinged flat pad to increase the contact area of the tip. It also uses extension springs to retrieve the pad when the mechanism closes, keeping a tight diameter during crawling.

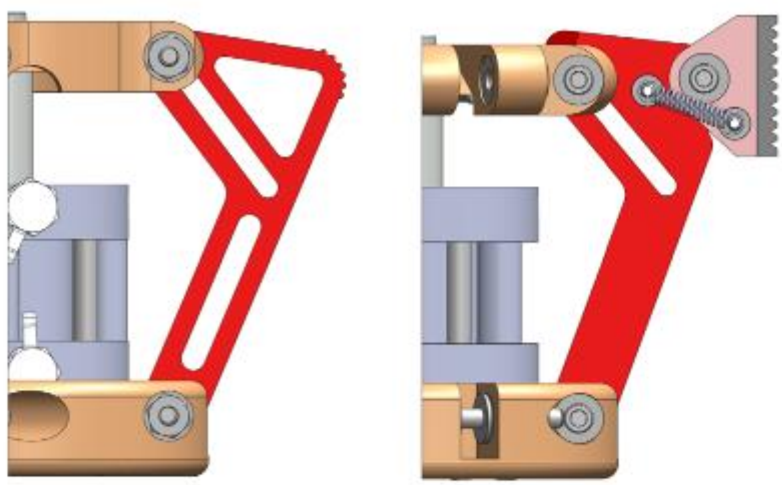

Figure 1-47. The original mechanism claw (left) and the redesigned (right).

A redesigned version of the gripping mechanism with five claws is shown in below Figure 1-48. The mechanism uses the same geometry of the original locking mechanism.

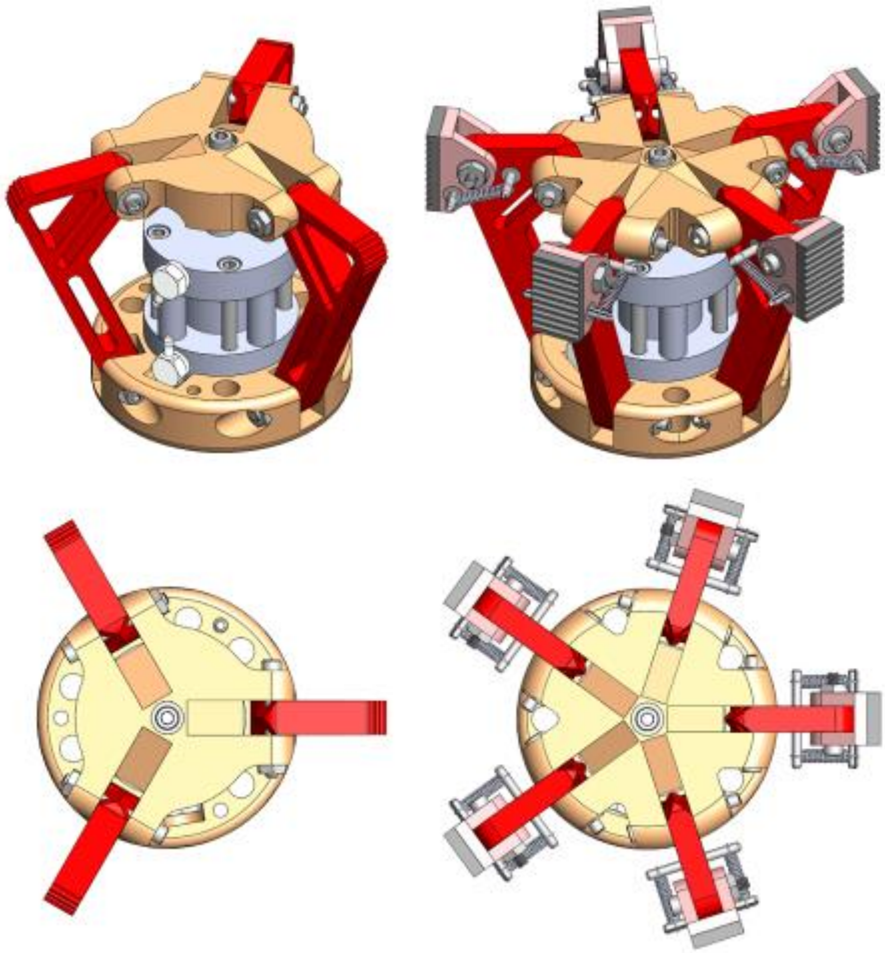

Figure 1-48. The original gripper (left) and the redesigned (right).

The tensile load cell was added to the system which will be used to provide real-time feedback of the current levels of dragging forces during tests and inspection. Figure 1-49 shows the load cell, to be attached to the crawler’s tether, and the USB strain gauge Wheatstone bridge used as interface to the system computer. The necessary modules and programming interfaces were successfully installed the computer operational systems, and the load cell was also calibrated.

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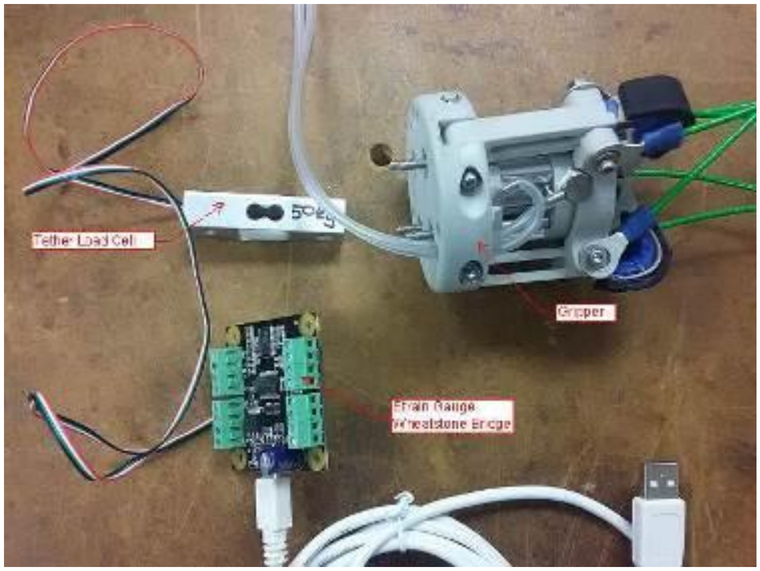


Figure 1-49. Tether load cell and strain gauge Wheatstone bridge.

The new redesigned gripper was manufactured, and is currently being assemble. Later, detailed tests will be conducted to evaluate/determine the correlation with the original mechanism, the current locking modifications, the maximum gripping force, and the mechanical durability.

In addition, during this period, a proposed bench scale test bed, displayed in Figure 1-50, was designed. Currently, the bench scale test is being assembled.

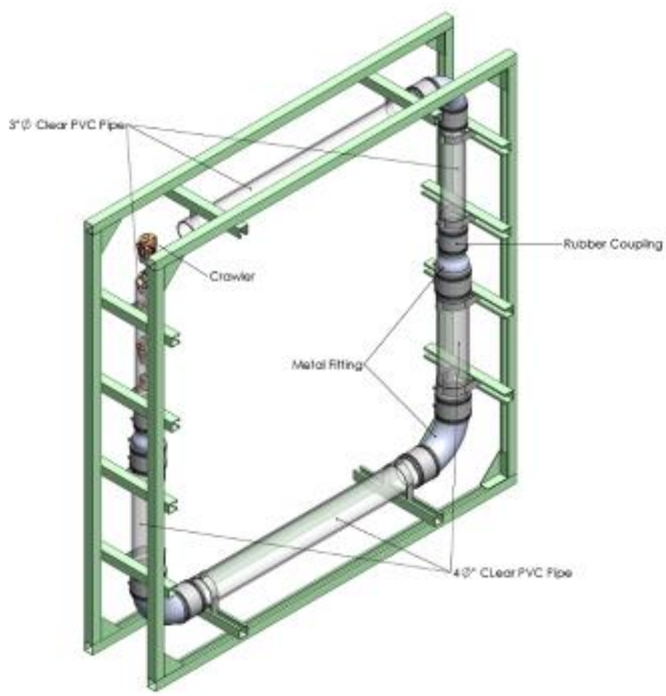


Figure 1-50. Proposed small factor test bed.

Subtask 18.3: Investigation Using an Infrared Temperature Sensor to Determine the Inside Wall Temperature of DSTs

This is a new task to determine the temperature measurements of the inside wall of DSTs at Hanford. The basis for this study is to ensure that the temperature inside the DSTs is as per the standards stated in OSD-T-151-00007. Benefits include avoiding corrosion, improving existing models and accurately estimating the elevation of solid waste levels at the wall.

After discussions with site engineers, the primary subtasks involved in this task are:

1. Utilizing an infrared sensor (IR) to measure the outside of the inner wall temperature (may investigate alternative sensors).
2. Determining estimates of the inside of the inner tank temperature via heat transfer analysis.
3. Setting up a mockup testbed to validate the use of the IR sensor and determining the accuracy of the estimates.

According to the information provided by site engineers, an IR sensor (Raytek MI3) has already been acquired at the site and is currently being investigated for testing. The sensor is attached to the inspection camera as shown in Figure 1-51.

Figure 1-51. IR sensor attached to the inspection camera.

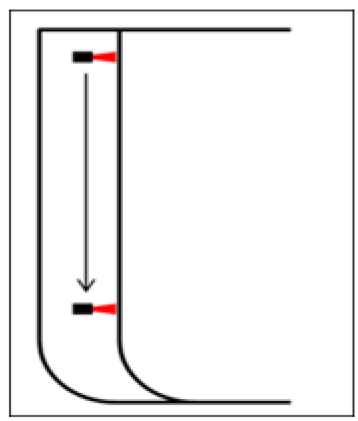


Figure 1-52. Schematic of the DST annulus.

The IR sensor is expected to “piggy back” the existing inspection equipment and trace down the annulus of the DST, taking spot measurements at different locations down the tank. The basic layout of the DST annulus is as shown in Figure 1-52.

Currently, FIU is in the process of acquiring additional information to assist in the development of the test matrix.

References

[1] http://www.raytek.com

Task 19: Pipeline Integrity and Analysis

Task 19 Overview

The objective of this task is to support the DOE and site contractors at Hanford in their effort to evaluate the integrity of waste transfer system components. This includes primary piping, encasements, and jumpers. It has been recommended that at least 5% of the buried carbon steel DSTs waste transfer line encasements be inspected. Data has been collected for a number of these system components, but the data still needs to be analyzed to determine effective erosion/corrosion rates so that a reliable life expectancy of these components can be obtained. An additional objective of this task is to provide the Hanford Site with data obtained from experimental testing of the hose-in-hose transfer lines, Teflon® gaskets, EPDM O-rings, and other nonmetallic components used in their tank farm waste transfer system under simultaneous stressor exposures.

Task 19 Quarterly Progress – July 1 – August 28, 2015

Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

During July, standard vacuum tests were conducted to investigate the effect of load/pressure on the sensor when using the dry couplant (aqualene) and new samples of aqualene were acquired for further testing.

Vacuum tests were conducted using standard procedures. A vacuum bag and a sealant were used and a thin aqualene sample (0.02”) was vacuum sealed on a straight carbon steel pipe section with nominal diameter 3” and average thickness 0.19”. The experimental test set up is shown in Figure 1-53. The UT sensor was placed above the aqualene sample and readings were taken. It was observed that the thickness readings did not have much influence with vacuum sealing.

Figure 1-53. Standard vacuum bag sealing.

Some experiments showed that the thickness readings for each test piece were affected by the amount of pressure applied on the sensor when using the dry couplant (aqualene). To further investigate this effect, dead weights (in the form of readily available PVC and metallic components) were placed on the sensor and readings were observed. A sample test case is shown in Figure 1-54 (left). The sensor has a 0.02” aqualene sheet below it. The actual thickness of the aluminum sheet to be measured is 0.25”. Different sets of weights were placed until a signal was received. It was observed that once a fixed amount of weight (0.8454 lbs) was placed on the sensor, a signal was obtained. Also, no further change in readings was observed with increasing weights. Hence, it was concluded that for a certain threshold weight, significant pressure was exerted on the aqualene to obtain a reading for thickness.

Figure 1-54. Experimental setup with loads on the sensor [aluminum (left) and stainless steel (right) test plates].

Additionally, it was observed that the amount of load/pressure required to obtain a reading (using aqualene) also depends on the type of material. For this, a new sample made of carbon steel with a thickness of 0.25″ was chosen. Similar to the previous case, dead weights were applied until a reading was observed. In this case, the threshold load for reading was 6.17 lbs.

A third test was based on the thickness of the material of the sample. A stainless steel sample with a thickness of 0.02″ was taken as the test sample. Measurements were made by applying the weights to find the pressure required on the sensor. The test arrangement is shown in Figure 1-54 (right). In this case, the threshold load for reading was 2.01 lbs. Also, based on the loads (weight), the pressure exerted on the sensor was calculated using the cross section area (of contact) of the sensor.

A comparison of the readings for the sample cases is shown in Table 1-3. The thickness readings obtained in all the cases along with the corresponding percentage error is given in the table. It is evident from the readings that the variations are based on the type and thickness of the material. Hence, it is concluded that the readings with the aqualene dry couplant are highly unstable and need further investigation.

Table 1-3. Thickness Measurements

Sample	Actual	Glycerin	Aqualene	Aqualene with weights	Weight (lbs)	Pressure (Psi)	% error Glycerine	% error Aqualene	% error Weight
Aluminum	0.25”	0.22”	0.29”	0.29”	0.84	6.93	12	16	16
Carbon Steel	0.25”	0.24”	0.31”	0.31”	6.17	50.75	4	24	24
Stainless Steel	0.02”	0.03”	0.16”	0.16”	2.01	16.53	50	700	700

Currently, we are in the process of acquiring various samples of rubber, silicone and other potential materials for testing with different test pieces using the UT sensor. Also, we are looking into possibility of in-house manufacturing of certain hydrophilic polymers to test.

Alternative sensor solutions are also being investigated for obtaining the thickness measurements. Upon examination of the pros and cons of the traditional UT sensor (Olympus-D790 SM) using various combinations of the dry and wet couplants, it was concluded that available dry couplants will not provide accurate thickness measurements for the pipe systems being integrated in this task. Thus, other options will need to be considered.

One alternative was to re-evaluate the pipe wrap system. Micro-sensors used in the pipe-wrap system appear to be feasible options but information regarding the systems is not available; so, similar sensors were considered. One option is called capacitive micro-machined ultrasonic transducers (CMUT's) which are generally used in micro-electronics. CMUT's consist of arrays of small piezoelectric sensors built-in a substrate, usually silicon. A cavity is formed inside the silicon substrate and a thin layer on top of the cavity acts like a membrane. On the membrane, a metal layer acts as the top electrode and the silicon substrate acts as the bottom electrode. An insulating layer is included to prevent the two electrodes from shorting in case of contact. These details are shown in Figure 1-55. If an AC signal is applied across the biased electrodes, the vibrating membrane will produce ultrasonic waves in the medium of interest. In this way, it works as a transmitter. On the other hand, if ultrasonic waves are applied on the membrane of biased CMUT, it will generate alternating signal as the capacitance of the CMUT is varied. In this way, it works as a receiver of ultrasonic waves.

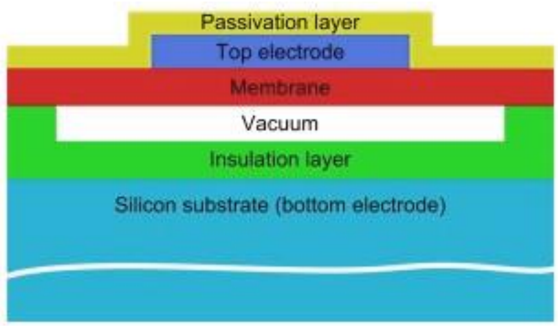


Figure 1-55. Basic CMUT structure [1].

Several piezo-electric micro transducer elements are available on the market. Some are shown in Figure 1-56 and Figure 1-57. Figure 1-56 represents the piezo-electric vibrator (left) and the analog thickness sensor (right). Figure 1-57 shows the aluminum/plastic thickness measurement sensor (left) and the customized piezoelectric ceramic tubes for wall thickness measurements (right).

Figure 1-56. Piezo-electric micro-transducer elements [2].

Figure 1-57. Piezo-electric micro-transducer elements [2].

Although the CMUT's are a viable option, their major drawback is the customized fabrication and data acquisition. The feasibility of this system is currently being investigated.

Additionally, an advanced and readily available sensor system called SMART layer technology [3] is being evaluated as a second alternative. The smart layer system consists of a built-in distributed sensor network of micro piezo-electric sensors. It has the unique capability to provide a wider structural coverage for thickness measurement with its network of sensors/actuators embedded in the layer. This eliminates the need for installing each sensor individually. The smart layer is shown in Figure 1-58.

Figure 1-58. SMART layer technology [3].

The advantages include real-time thickness sensing, permanent mounting capabilities, durability, high temperature and radioactive tolerance. Currently, FIU is awaiting quotes on the smart layer technology.

References:

[1] http://www-kyg.stanford.edu/khuriyakub/opencms/en/research/cmuts/general/index.html.

[2] http://www.alibaba.com

[3] http://www.acellent.com

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

The purpose of this task is to support the integrity assessment of hose-in-hose transfer lines (HIHTL) and Teflon gaskets and to improve the existing technical basis for their evaluation. For this period of performance, efforts were made to ensure the 26-in coupons that are made from a HIHTL were moving forward. A purchase order for the HIHTL was finally issued to Riverbend and we coordinated the shipping of the hose section that will be used to fabricate the test specimens from WRPS to Riverbend. In addition, work has continued on completing the test loops. Parts and piping have been procured, but the specimens from Riverbend will be needed before the loops can be completed. The lead time on receiving the coupons is two months. Figure 1-59 shows the tanks with the heaters installed as well as the pumps for the three test loops. Each loop will contain a 25% NAOH solution and temperatures will be set at 70, 130 and 180° F.

Previously, we noted that modifications of the coupon specimens were required for budgetary reasons. This entailed a simplification of the fittings. Due to these changes, the incorporation of fittings that contain the EPDM O-rings and gaskets needs to be explored. The O-rings and gaskets would be used to provide in-system configuration analysis of these EPDM components. Currently, we are in discussions with engineers at WRPS to determine the optimal configuration for these components. Once the configuration is confirmed, we will complete the loop design and begin obtaining the necessary components.

Figure 1-59. Test loop tanks and pumps.

FIU has ordered the coupons for the hose-in-hose transfer-lines from Riverbend Inc. FIU is still awaiting the delivery of this order. During this period, FIU has also been concentrating on acquiring the components needed for the experimental testing. The initial testing will include performing blowout tests on the hose-in-hose transfer line coupons. The components needed to conduct these tests have been identified and include a hydrostatic test pump similar to Figure 1-60 and various pipe fittings that are rated for 6000 psi.

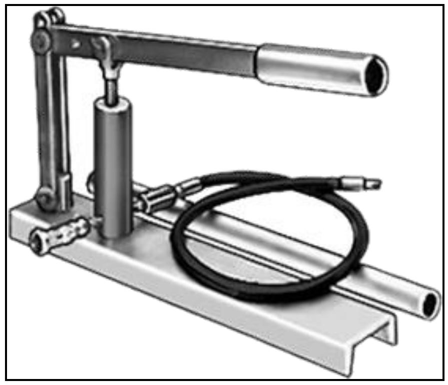


Figure 1-60. Hydrostatic test pump.

Other planned experiments include EPDM coupon, EPDM O-ring and EPDM gasket testing. A vendor has been identified for the EPDM sheets that will be cut into dumbbell shaped coupons that meet ASTM D412 standards similar to Figure 1-61.

Figure 1-61. Dumbbell shaped coupon (www.ptli.com).

FIU is working with site engineers at Hanford to determine the appropriate material hardness of the EPDM sheets as well as the specifications of the EPDM O-rings and gaskets.

Task 19 Quarterly Progress – August 28 – September 30, 2015

Subtask 19.1: Pipeline Corrosion and Erosion Evaluation

During this performance period, efforts were focused on completing the PTP and deciding on the complete scope of work for the next fiscal year. Based on the scope of work, discussions with WRPS site engineers have been initiated. During the discussions, a sample of the pipe wrap system has been requested to investigate the option of using it as a viable UT sensor system since the previous experiments with the commercially available dry couplant (elastomer – acqualene) did not provide accurate readings of pipe thickness. Presently, we are waiting to hear from WRPS.

Additionally, as briefed in previous month, a new flexible sensor system called SMART layer (Acellent technologies [1]) has been investigated. The smart layer system is an integrated system which can be permanently mounted to the pipe and the readings/data can be recorded on a computer. A layout of the configuration for individual sensors is given in Figure 1-62.

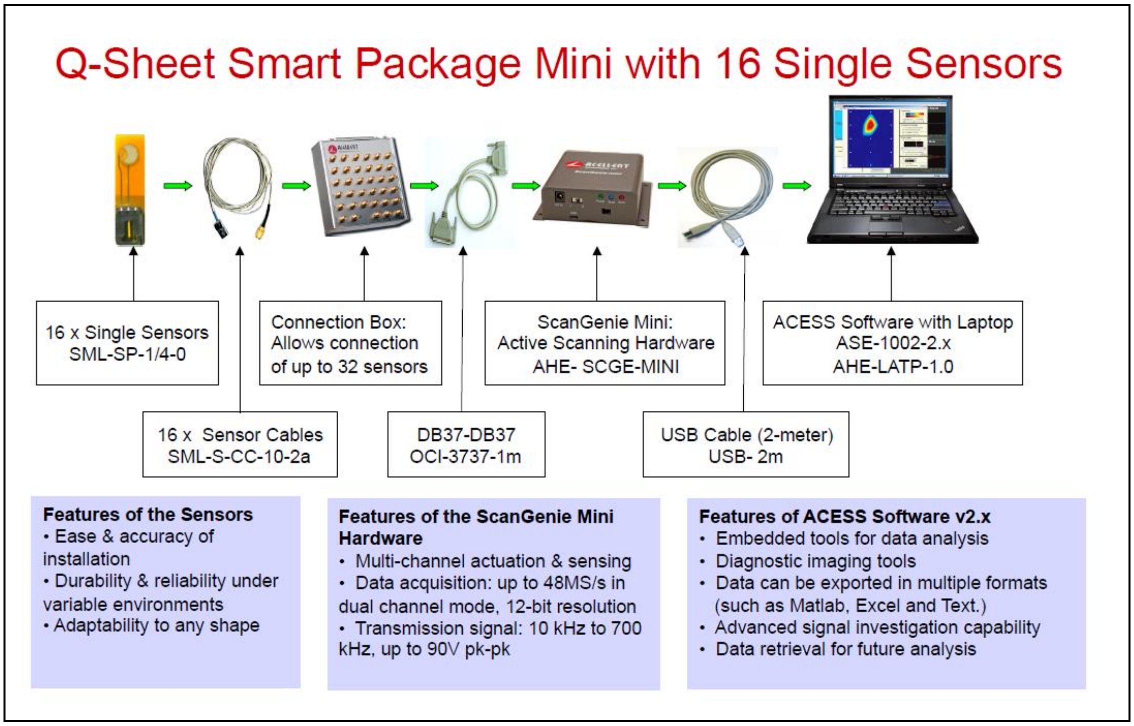


Figure 1-62. **Integrated UT sensor system from Acellent Technologies [1].**

The individual sensors can be integrated and embedded in a single layer called a smart layer strip and can be used in the pipeline (straight or elbow sections) as shown in Figure 1-63.

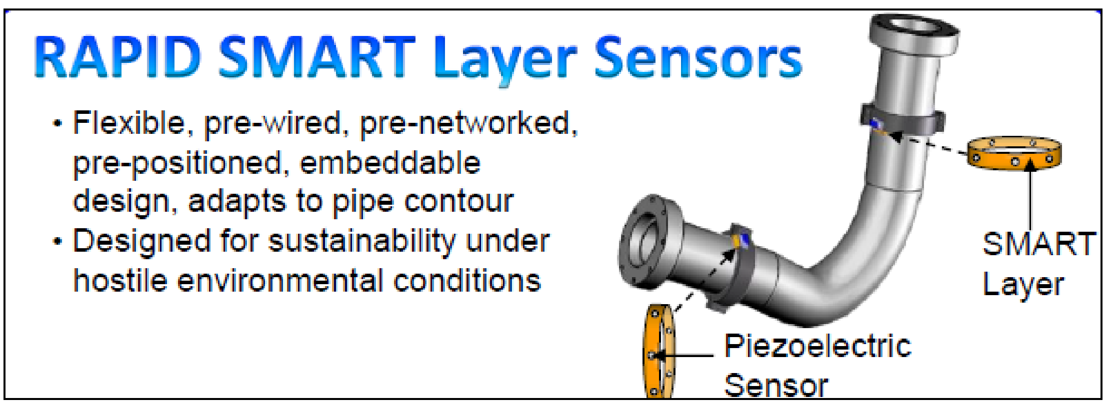


Figure 1-63. **Smart Layer attached to an elbow [1].**

Although the smart layer technology "as-is" is a viable solution for the present task, there are certain limitations that need to be considered with the Smart Layer, such as:

1. Presently used piezo-sensors (in the smart layer) are capable of providing the irregularities in the pipe line. For example, the location and radius of the hole (pitting corrosion). They are not capable of providing the actual thickness directly. Hence, we are working with the company to customize for our thickness needs.
2. A quotation has been received for the entire system and it is expensive.
3. The fixing of the smart layer to the pipes is done using an aerospace grade epoxy. Although the shelf-life of the system is quoted to be about 15 years [1].

Another UT system was also investigated for monitoring the corrosion of pipelines. This system is developed by a UK based manufacturer – Permasense [2] and is as shown in Figure 1-64.

Figure 1-64. **UT sensors [2].**

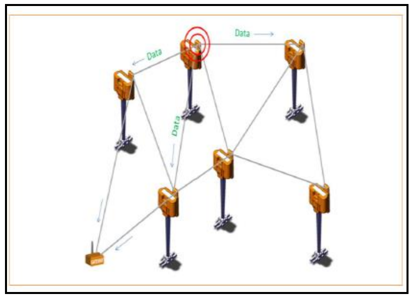


Figure 1-65. **Wireless network [2].**

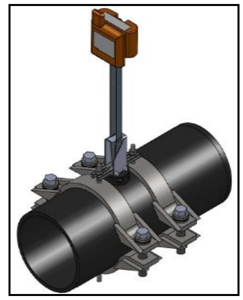


Figure 1-66. **Mounting system [2].**

The Permasense UT system is an integrated wireless system (Figure 1-65) and uses a novel guided wave technology for the acoustic wave propagation. The most advantageous feature with this UT sensor system is that it meets the goal of providing the actual thickness measurement in pipes, is capable for 2-inch pipes and elbows, and is customized for mounting with a mechanical clamping system (Figure 1-66). The limitations of the system include high cost and only 2 sensors can be installed in the 2-inch diameter pipe on the circumference to avoid cross-talks between the sensors in that limited space.

Currently, FIU is investigating the development of an inexpensive in-house circuit with the basic elements. This would improve our options with the use of custom built sensors attached to data acquisition systems. A typical sketch of the potential system is given in Figure 1-67.

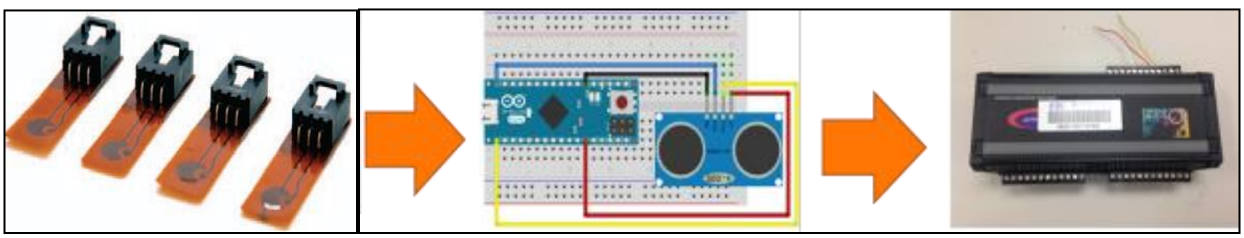


Figure 1-67. **The flexible sensors, circuit board and AC to DC data acquisition unit.**

References:

[1] http://www.acellent.com

[2] http://www.permasense.com

Subtask 19.2: Evaluation of Nonmetallic Components in the Waste Transfer System

For this performance period, efforts focused on identifying the components needed to conduct the blowout tests on the hose-in-hose transfer line coupons, EPDM O-ring and gasket testing.

Representatives from River Bend Transfer Systems contacted us on 9/30/15 to let us know that an issue came up with the hose-in-hose transfer lines (HIHTL) coupon assemblies that we ordered. Of the 24 full assemblies that we ordered, only 15 of them would be ready by the original shipment date of 10/2/15 due to an issue that came up with their fitting supplier. We decided to proceed with shipping the available 15 assemblies as soon as possible to begin running our blowout tests and complete the design of our experimental setup. The other 9

HIHTL assemblies will be shipped as soon as they are complete; we are still waiting on a response for when the final 9 assemblies will arrive.

After speaking with River Bend, we were able to acquire the physical specifications for the EPDM O-rings used in the Hanford HIHTL's. The O-ring specifications are:

- Parker E0540-80 Series 2-135 with a durometer of 80 and an internal diameter of 1-15/16"

We are currently in the process of procuring all necessary O-ring specimens necessary for our testing parameters. In addition, we are researching the availability of stainless or carbon steel O-ring couplings that will be used to simulate the HIHTL couplings in an in-configuration assembly with the EPDM O-rings.

Milestones and Deliverables

The milestones and deliverables for Project 1 for FIU Year 5 are shown on the following table. Due to changes in personnel and reduced funding levels for FIU Year 5, a number of deliverables were reforecast. After discussions with our DOE-EM representative, the deliverables associated with Tasks 2.2, 17.2, 18.2 and 19.1 were incorporated into the Year End Report, submitted on August 28, 2015. For Task 18.1, the sonar malfunctioned during testing and due to lengthy delays in getting the system repaired, these deliverables have been incorporated into the Project Technical Plan for FIU Year 6.

FIU Year 5 Milestones and Deliverables for Project 1

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Task 2: Pipeline Unplugging	2014-P1-M2.2.1	Complete 2D multi-physics simulations evaluating the influence of piping components on the plug formation process	03/02/15	Complete Included in Year-End Report	
	Deliverable	Draft summary report for subtask 2.2.1	04/01/15	Complete Included in Year-End Report	OSTI
Task 17: Advanced Topics for Mixing Processes	2014-P1-M17.2.1	Complete computational fluid dynamics modeling of jet penetration in non-Newtonian fluids	05/11/15	Complete Included in Year-End Report	
	Deliverable	Draft topical report for subtask 17.2.1	05/15/15	Complete Included in Year-End Report	OSTI
Task 18: Technology Development and Instrumentation Evaluation	2014-P1-M18.2.1	Complete development of first prototype of the inspection tool	12/19/14	Complete	
	Deliverable	Draft summary report for first prototype (subtask 18.2.1)	01/30/15	Complete Included in Year-End Report	OSTI
	2014-P1-M18.1.1	Complete pilot-scale testing of SLIM to assess imaging speed and ability to estimate volume of solids on tank bottom during mixing	02/20/15	Reforecast into next year's PTP	

		operations			
	Deliverable	Draft summary report of pilot scale testing of SLIM (subtask 18.1.1)	03/13/15	Reforecast into next year's PTP	OSTI
	2014-P1-M18.2.2	Complete analysis design and modifications to the peristaltic crawler	03/20/15	Complete Included in Year-End Report	
	Deliverable	Final Deployment Test Plan and Functional Requirements for SLIM (subtask 18.1.2)	05/15/15	Reforecast into next year's PTP	
Task 19: Pipeline Integrity and Analysis	2014-P1-M19.2.1	Complete test plan for the evaluation of nonmetallic components	11/14/14	Complete	
	Deliverable	Draft experimental test plan for subtask 19.2.1	11/14/14	Complete	OSTI
	2014-P1-M19.1.1	Complete data analysis of the C-Farm POR 104 Valve Box	05/01/15	Complete	
	Deliverable	Draft summary report for subtask 19.1.1	05/01/15	Complete Included in Year-End Report	OSTI

The milestones and deliverables for Project 1 for FIU Year 6 are shown on the following table. A draft Project Technical Plan was developed which includes the scope of work intended for FIU Year 6. No other milestones or deliverables were due for this project during September.

FIU Year 6 Milestones and Deliverables for Project 1

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Task 17: Advanced Topics for Mixing Processes	2015-P1-M17.1.2	Complete validation of impingement correlations	05/6/2016	On Target	
	Deliverable	Draft Summary Report for Subtask 17.1.1	08/28/2016	On Target	OSTI
	Deliverable	Draft Summary Report for Subtask 17.1.2	05/6/2016	On Target	OSTI
Task 18: Technology Development and Instrumentation Evaluation	2015-P1-M18.1.1	Complete test plan for evaluating SLIM's ability to detect a precursor of DSGREs	12/18/2015	On Target	
	Deliverable	Draft Test Plan for Subtask 18.1.1	12/18/2015	On Target	OSTI
	2015-P1-M18.3.1	Complete test plan for temperature measurements using IR sensors	12/18/2015	On Target	
	2015-P1-M18.2.1	Finalize the design and construction of the refractory pad inspection tool	02/26/2016	On Target	
	2015-P1-M18.2.2	Complete engineering scale mock-up testing	08/28/2016	On Target	
	Deliverable	Draft Summary Report for Subtask 18.2.1 and 18.2.2	08/28/2016	On Target	OSTI
	2015-P1-M18.2.3	Finalize the design and construction of the air supply line inspection tool	02/26/2016	On Target	

	Deliverable	Draft Summary Report for Subtask 18.2.3	02/26/2016	On Target	OSTI
	Deliverable	Draft Summary Report for Subtask 18.3.1	07/29/2016	On Target	OSTI
Task 19: Pipeline Integrity and Analysis	2015-P1-M19.2.1	Complete test loop set up	11/20/2015	On Target	
	2015-P1-M19.1.1	Evaluate and down select alternative UT systems for bench scale testing	03/11/2016	On Target	
	Deliverable	Draft Summary document for Subtask 19.1.1	03/11/2016	On Target	OSTI
	2015-P1-M19.2.2	Complete baseline experimental testing	03/25/2016	On Target	
	Deliverable	Draft Summary Report for Subtask 19.2.2	04/8/2016	On Target	OSTI

Work Plan for Next Quarter

- Task 17:
  - FIU will continue to test the proposed direct viscosity modification in two dimensional RANS simulations for additional Reynolds numbers. This analysis will help to develop a hybrid model composed of direct and inverse alpha methods. In addition, FIU will test the proposed direct viscosity modification in RANS and QDNS simulations of three dimensional periodic domains.
  - FIU plans to continue investigating the jet thickness discrepancies found between the simulation replication of Poreh's experimental data and the actual experimental data. Investigations will be conducted by incorporating adjustments to our simulation that were used in the paper "The Full Scale and CFD Simulation of Impinging Jet Ventilation" (J. Varodoumpun et al.) which more accurately matched the radial jet thickness of Poreh's experimental data.
- Task 18:
  - The focus of the application of the SLIM sonar has changed at the end of the last quarter to two new objectives: (1) imaging a solids layer that is growing due to gas generation and retention in the solids layer; and (2) determination of settling rates of various surrogate HLW particulates. FIU will work with WRPS to develop a Test Plan for the sonar to image Deep Sludge Gas Release Events (DSGREs). FIU continues to: search the literature, develop the automated processing of sonar imagery, further investigate how to combine multiple images together into a movie in near real time, and finally, image thin layers of settled solids in a tank to test the image resolution and reproducibility of the results. The movie format would greatly enhance the ability for operators to see solids swept off the floor by a mixer; the possible rapid resettling of solids that were not mixed; the slower settling of solids after mixing is stopped; and the growth or diminishment of the solids layer due to gas retention in the settled solids layer. Data from these thin solids layer experiments will be extracted from the sonar output files, filtered, post-processed, and visualized.
  - For the refractory pad inspection tool, the efforts will focus on finalizing the design and preparing the tool on engineering scale testing. Currently, the primary components inside the unit are in a mature state and require minimal or no

modifications for the navigation on the first 17 feet of refractory air channels. However, the tether, including the camera and power lines, is comprised of several individual wires and needs to be unified in a single lightweight and flexible assembly. Experiments will be conducted to ensure the successful navigation through 17 ft of channels and to minimize contact of the unit with channel walls. We will also investigate improving the image quality and response delay of the camera will be enhanced.

- For the crawler, the design is in its final stages, and exhaustive tests must to be conducted to access the overall performance and durability of the crawler, components and subsystems. In addition, the design of extra instrumentation modules will be investigated. Additional instrumentation would improve drastically the effectiveness and versatility of the inspection tool. The design of a smaller version of the crawler will also be considered. If viable, the smaller crawler will use electric actuators, will have a radiation hardened design, and will be able to crawl thru pipes with 2" diameter.
- The IR task is new this year and the scope includes the investigation of using an IR sensor to measure the outside of the inner wall temperature of the DSTs at Hanford. A bench scale test plan will be developed to use the IR sensor, for temperature measurements, in a metal (stainless steel/ carbon steel) tank or plate with varying thickness and pre-set temperatures. Also, the type of IR sensor will be investigated.

Task 19:

- FIU will continue to investigate the potential ultrasonic sensor systems for pipes. The possibility of making an integrated sensor system in-house will also be investigated if required. The integrated system would include the UT sensors and the corresponding data acquisition system for thickness measurements. Additionally, the type and size of suitable sensors for mounting into 2" and 3" pipelines will be explored for design alternatives.
- For the non-metallic materials task, the testing start date had to be pushed back due to delays in receiving the HIHTL coupons. FIU anticipates receiving the HIHTL coupons with the fittings installed from Riverbend during the next quarter and testing will commence at that time. Due to modifications of the fittings, FIU will work with WRPS engineers to determine how best to integrate the EPDM O-rings and gaskets. With this finalized, the test loop will be completed. Burst pressure test procedures will be determined and initial baseline burst tests will be conducted. Aging of the specimens will also commence.

FIU Year 5 Project 2
Rapid Deployment of Engineered Solutions to Environmental Problems

Project Manager: Dr. Leonel E. Lagos

Project Description

This section presents the information for the FIU Year 5 Project 2 for July and August 2015. The next section will present the information for the FIU Year 5 Project 3 for July and August 2015 and the subsequent section will present the new combined Project 2 information for FIU Year 6 (September 2015).

In FIU Year 5, Project 2 included three tasks. Each task was comprised of subtasks that were conducted in close collaboration with Hanford and SRS site scientists. FIU ARC continued to provide research support on uranium contamination and remediation at the Hanford Site with subtasks under Task 1 and Task 3 as well as conducted remediation research and technical support for SRS under Task 2. The following tasks were included in FIU Year 5:

- Task 1: Sequestering Uranium at the Hanford 200 Area Vadose Zone by *in situ* Subsurface pH Manipulation using NH_3 Gas
  - Subtask 1.1 – Sequestering Uranium at the Hanford 200 Area Vadose Zone by in situ Subsurface pH Manipulation using NH3 Gas
  - Subtask 1.2 – Investigation on Microbial-meta-autunite Interactions – Effect of Bicarbonate and Calcium Ions
- Task 2: Remediation Research and Technical Support for the Savannah River Site
  - Subtask 2.1 – FIU Support for Groundwater Remediation at SRS F/H Area
  - Subtask 2.2 – Monitoring of U(VI) Bioreduction after ARCADIS Demonstration at F-Area
  - Subtask 2.3 - Sorption Properties of the Humate Injected into the Subsurface System
- Task 3: Evaluation of Ammonia Fate and Biological Contributions during and after Ammonia Injection for Uranium Treatment
  - Subtask 3.1 – Investigation on NH_3 Partitioning in Bicarbonate-Bearing Media
  - Subtask 3.2 – Bacteria Community Transformations before and after NH_3 Additions

Project 2 Subtask 1.1: Sequestering Uranium at the Hanford 200 Area by *In Situ* Subsurface pH Manipulation using Ammonia (NH_3) Gas Injection

<u>Subtask 1.1 Overview</u>

The objective of Subtask 1.1 is to evaluate the stability of U-bearing precipitates created after NH3 (5% NH_3 in 95% nitrogen) pH manipulation in the synthetic solutions mimicking conditions found in the vadose zone at the Hanford Site 200 Area. The study will examine the deliquescence behavior of formed uranium-bearing solid phases via isopiestic measurements and investigate the effect of environmental factors relevant to the Hanford vadose zone on the solubility of solid phases. Solubility experiments will be conducted at different temperatures up to 50^{o}C using multicomponent samples prepared with various bicarbonate and calcium ion concentrations. In addition, studies will continue to analyze mineralogical and morphological characteristics of precipitates by means of XRD and SEM-EDS. An additional set of samples will be prepared with the intention of minimizing nitratine (NaNO3) formation in order to lessen the obtrusive peaks that shadowed the peaks of the less plentiful components found in the sample XRD patterns.

Subtask 1.1 Quarterly Progress

During month of July, FIU continued monitoring the sealing of the newly fabricated isopiestic system by collecting readings from three $CaCl_2$ standard samples. The standard deviations between collected values of three $CaCl_2$ standard samples for the osmotic coefficients and water activities were in the range 0.023-0.035 and 0.007-0.011, respectively.

The drafted proposal for access to the Environmental Molecular Sciences Laboratory (EMSL) was reviewed by PNNL contacts with prior familiarity with the project and the theory behind it. Their feedback was reviewed by FIU and incorporated into a finalized version of the document for submission to EMSL. Sample preparation is ongoing using the methods modified to produce a sample more representative of the conditions and remediation method being studied. The analytical design of the experiment methods were reviewed and applied prior to sample prep in order to ensure the statistical significance of the data produced. The preliminary analysis of these samples will be used to determine the number to be shipped to EMSL for analysis once the proposal is accepted. DOE Fellow Claudia Cardona is interning with PNNL and working under the mentorship of Dr. Jim Szecsody. During the month of July Claudia conducted a series of sequential liquid extractions to measure Tc in the aqueous and surface phase. Sequential liquid extractions are used to operationally define the potential for leaching of Tc. The experiment consisted of mixing of measured amount of sediment with six difference solutions. Each extraction is shaken for a desired period of time, centrifuged, and filtered. After six extractions, the liquid was analyzed for Tc. These liquid extractions define the Tc release from Tc-contaminated sediments.

Other activities included evaluation of the Geochemist Workbench's uranium thermodynamic databases. The four set thermodynamic databases to perform Geochemist Equilibrium Modeling were evaluated for the uranium species. It was found that the thermo and thermo V8.R6+ databases include most of the aqueous/solid uranium species. However, they don't include all the basic species required to simulate the synthetic pore water. The Minteq dataset contains most of the basic species. Therefore, this database was enhanced with the Na-boltwoodite and Uranophone species thermodynamic data since these uranyl silicate species were found in the vadose zone of Hanford Site. Also, the Pitzer database was evaluated to look for the binary and/or tertiary uranium species. It was observed that it doesn't include uranium species. Therefore, it has to be enhanced with the interested uranium species or a different geochemist model needs to be utilized to calculate the theoretical osmotic coefficients and water activities of the U-containing precipitates prepared for the isopiestic studies.

During month of August, FIU completed preparations of U-bearing samples to evaluate for solubility. Eight samples of 10 mL composed of Si-Al-Ca-HCO_3 and U(VI) have been prepared in tarred crucibles and kept at 35^{o}C for drying. The concentration of U(VI) was kept constant at 2 ppm in all samples. This concentration is similar to what was used in the earlier study conducted to investigate the effect of Si and Al concentration ratios on the removal of U(VI) in alkaline conditions by NH_3. The concentration of sodium silicate (100 mM) and aluminum (5 mM) was unchanged for all samples. Four samples were prepared with 3 mM bicarbonate and amended with 0 mM, 5 mM, 10 mM and 15 mM of calcium chloride. Another four samples were prepared with 50 mM of bicarbonate and amended with the same concentrations of calcium chloride as the 3 mM bicarbonate samples. All dried U-bearing multicomponent samples along with three $CaCl_2$ standards were placed in the isopiestic chamber. The chamber was sealed and degassed and left at 25^{o}C in the environmental chamber. The isopiestic chamber was opened two times to weigh the samples when the system reached equilibrium to calculate values for osmotic coefficients and water activities. The relative percent error was found in the range of the previously recorded values.

The drafted proposal for access to the Environmental Molecular Sciences Laboratory (EMSL) was finalized and submitted to EMSL. Sample preparation is ongoing using the methods modified to produce a sample more representative of the conditions and remediation method being studied. The analytical design of the experiment methods were reviewed and applied prior to sample prep in order to ensure the statistical significance of the data produced. The preliminary analysis of these samples will be used to determine the number to be shipped to EMSL for analysis once the proposal is accepted. DOE Fellow Robert Lapierre prepared and submitted a professional abstract titled, "Characterization of U(VI)-Bearing Precipitates Produced by Ammonia Gas Injection Technology," for the Waste Management 2016 Symposia.

DOE Fellow Claudia Cardona returned from her summer internship at PNNL, where she worked under the mentorship of Dr. Jim Szecsody, and began development of her internship report.

Subtask 1.2 Overview

The goal of experimental activities under subtask 1.2 is to investigate the bacteria interactions with uranium by focusing on facultative anaerobic bacteria and study their effect on the dissolution of the uranyl phosphate solid phases created as a result of sodium tripolyphosphate injections into the subsurface at the 300 Area. The Columbia River at the site exhibits water table fluctuations, which can vary up to 3 m seasonally. This rising water table over the extent of its annual vertical excursion creates an oxic-anoxic interface that in turn, due to activates of facultative anaerobic bacteria, can affect the stability of uranium-bearing soil minerals. Previous assessments noted the decline in cultivable aerobic bacteria in subsurface sediments and suggested the presence of facultative anaerobic bacteria in sediment samples collected from the impacted area (Lin et al, 2012). Therefore, understanding the role of anaerobic bacteria as one of the factors affecting the outcome of environmental remediation is very important.

Subtask 1.2 Quarterly Progress

FIU initiated sampling of 99 sacrificial vials; 63 have been sampled and processed (Figure 2-1).

Figure 2-1. Sacrificial vials, 63 of 99 have been samples and processed.

Initially, 1 mL was isolated from each sacrificial sample with the aid of a syringe and filtered through a 0.45 μm PTFE filter. The filtrate was acidified with 1 drop of 1M HNO_3 and kept at 4^o C for further chemical analysis (uranium by means of kinetic phosphorescence analysis and Ca and P by means of ICP-OES). Then, aliquots from the supernatant were isolated and used for the calculation of bacterial numbers using disposable hemacytometers in the optical microscope, as well as for plating agar plates and estimating bacterial colonies after 2 days of incubation at 30^o C (Figure 2-2). Consequently, pH and conductivity of the samples were recorded prior to vacuum filtration (8 μm filter) in order to separate autunite particles that remain on the filter and bacteria, which pass to the filtrate. Filters containing autunite particles are stored at room temperature for further SEM analysis (Figure 2-3).

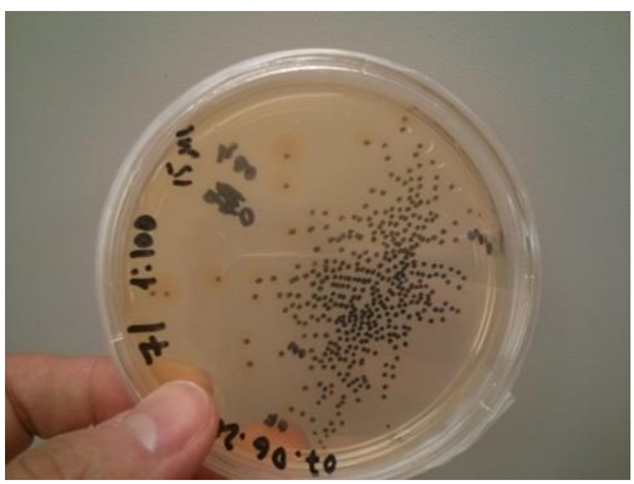


Figure 2-2. Agar plate with *Shewanella oneidensis* MR1 colonies after 48h incubation at 30^o C.

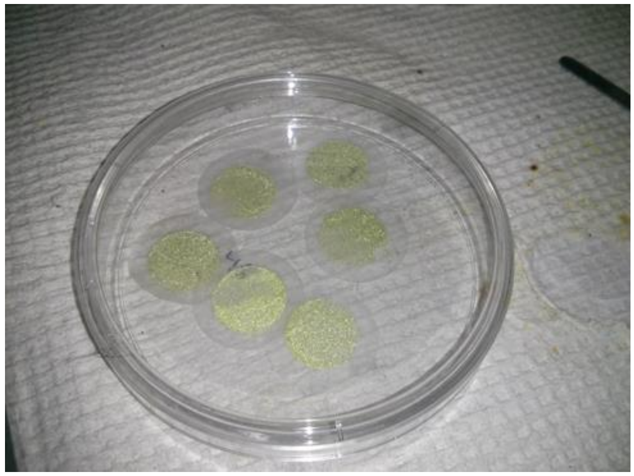


Figure 2-3. 0.45µm filters with autunite particles.

Filtrates were centrifuged (4000 rpm, 5 min, 18^{o} C) and the supernatant was discarded. The pellet was resuspended in a specific volume of autoclaved deionized water and divided into three parts: the first part is destined for protein analysis, the second part is destined for Live and Dead Assay and the third part is diluted with 50% glycerol and stored at -80^{o} C.

During month of August, FIU completed sampling of 99 sacrificial vials and initiated wet and dry procedures for sample analysis of U(VI) via the KPA instrument and Ca and P analysis via ICP-OES. In addition, samples for the last three sampling events were prepared for SEM/EDS analysis; the autunite samples mixed with bacterial cells from the sacrificial vials were fixed in 5 ml of 2% glutaraldehyde in 0.1M HEPES buffer at pH 7.2 for 2 hrs at 4^{o}C. Then, the sample supernatant solutions were removed after centrifugation and the remaining material washed with 50 mM HEPES buffer for 10 min. The rinsed cells were then dehydrated in ethanol/water solutions of 35% (v/v), 70% (v/v), and 90% (v/v) each for 10 min, followed by two times in 100% (v/v) for 10 min. The dehydrated samples were immersed for 10 min each in 50% and 100% pure hexamethyldisilazane (HMDS) followed by 10 min of air-drying to allow the liquid to evaporate from the samples. The dehydrated specimens were then kept in the desiccators until the time of SEM/EDS assay.

The Year End Report for subtask 1.2 (Investigation on Microbial Meta-Autunite Interactions - Effect of Bicarbonate) was completed. The report presents results and conclusions on the dissolution experiments of autunite by Shewanella oneidensis in the presence of different bicarbonate concentrations under oxygen restricted conditions. The data suggested that before bacterial inoculation, there was a significant amount of uranium released in the aqueous phase from autunite and, more specifically, the higher the concentration of bicarbonate in the aqueous phase, the higher the amount of U(VI) leached in the aqueous phase. After bacterial inoculation with Shewanella oneidensis MR1, the results varied significantly across the samples containing different bicarbonate concentrations. In the case of 0 mM bicarbonate, a sharp decrease in uranium concentration was observed in the first three days after bacterial inoculation, but after the fourth day, U(VI) concentrations began to slowly rebound. This is probably due to the lack of organic substrate that was consumed faster in the presence of the remaining oxygen, dissolved and present in the headspace of the oxygen restricted bioreactors. For the samples amended with 3 mM bicarbonate, the decrease in U(VI) concentration was significant, but not as sharp as in the case of 3 mM; whereas, in the case of the samples containing 5 and 10 mM bicarbonate, no change in the U(VI) concentration was observed. Phosphorous levels remained the same before and after inoculation for all bicarbonate concentrations tested; however, calcium levels showed a small yet significant decrease after bacterial inoculation. The slight decrease in Ca levels may be attributed to the formation of secondary minerals in the aqueous phase such as calcite and calcium phosphate.

Based on the results of these experiments, FIU submitted an abstract by Sandra Herrera-Landaez (DOE Fellow), Vasileios A. Anagnostopoulos, Yelena P. Katsenovich, Brady Lee, and Michelle Lee titled, "The effect of bicarbonate on autunite dissolution in the presence of *Shewanella oneidensis* under oxygen restricted conditions," to the WM16 Symposia.

Task 2: Remediation Research and Technical Support for the Savannah River Site

Task 2 Overview

The objectives of the experimental work for subtask 2.1 include: (i) to evaluate whether a base solution of dissolved silica prepared below the equilibrium solubility of amorphous silica, which is usually assumed to be about 100-150 ppm at circumneutral pH conditions, have enough alkalinity to restore the pH of the treatment zone; (ii) to investigate the hypothesis that some uranium in the current treatment zone is bound to silica; and (iii) to study if any synergy between humic acid (HA) and silica will influence the behavior of uranium.

The objective of subtask 2.2 is to replicate the treatment performed by ARCADIS at SRS and investigate the mineralogical changes that occur in the soil due to the addition of molasses. Specifically, the study aims to determine whether forms of reduced iron such as siderite and pyrite would arise in the reducing zone and if any mineralogical changes can occur in sediments during the re-oxidation period. These experiments will also explain the types of reactions that might occur in the anaerobic aquifer. An understanding of the technology will be useful to determining if it is a viable option for remediation. The study will evaluate the addition of sulfate in the solution mixture for the formation of iron-bound pyrite phases. The objectives for this study include analysis of groundwater from the contaminated area if samples became available and evaluate the diffusion trap sediment samples via XRD and SEM-EDS methods to greater supplement the on-going microcosm studies on processes occurring in a bioreduction zone.

Subtask 2.3 relates to the subtask 2.1 and focuses on the humic acid sorption experiments helping to evaluate the distribution of humate injected into the subsurface during deployment for in situ treatment of radionuclides.

Task 2 Quarterly Progress

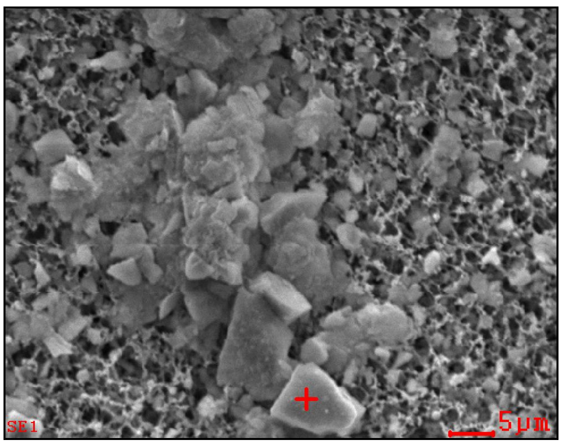
Subtask 2.1: FIU's support for groundwater remediation at SRS F/H Area

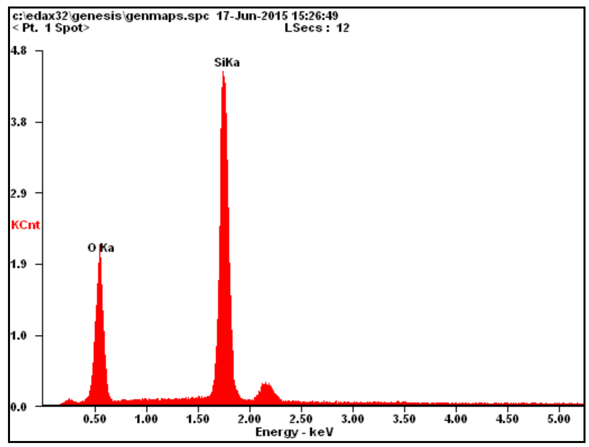
FIU continued experiments to study the effect of sodium silicate additions on the immobilization of U(VI). Batch experiments were performed in polypropylene vials, which contained 400 mg of SRS soil (fraction $0.18<d<2$ mm) and 20 ml of synthetic groundwater, imitating the water composition of SRS (initial pH 3.5), with 0.5 ppm of U(VI). The samples were spiked with 70 ppm of sodium silicate and two samples served as controls (no sodium silicate was introduced) and were equilibrated on a platform shaker (110 rpm) for a period of 3 days at room temperature. Uranium in the supernatant was determined in three different ways through consecutive filtrations: first, an aliquot was isolated from the supernatant without any filtration, then the aqueous phase was passed through a 0.45 μm Teflon filter and an aliquot was isolated again from the filtrate for uranium analysis, and finally, the filtrate was passed through a 0.2 μm Teflon filter and the residual uranium concentration was determined in the filtrate. The measurements suggested that pH stabilizes at ~6.5, percent uranium removal for the not-filtered samples was 50% (data correlate with speciation prediction), and percent uranium removal after 0.45 µm filtration was 70%.

The supernatant solutions containing some uranium were filtered using a 0.45 µm filter. The filtrate was collected and filtered again via 0.2µm filter. After drying (30^{o} C, 5 days), the samples were prepared for both filters (0.45 µm and 0.2 µm) and evaluated via SEM-EDS to examine the surface morphology and elemental composition.

SEM/EDS results for 0.45µm filter

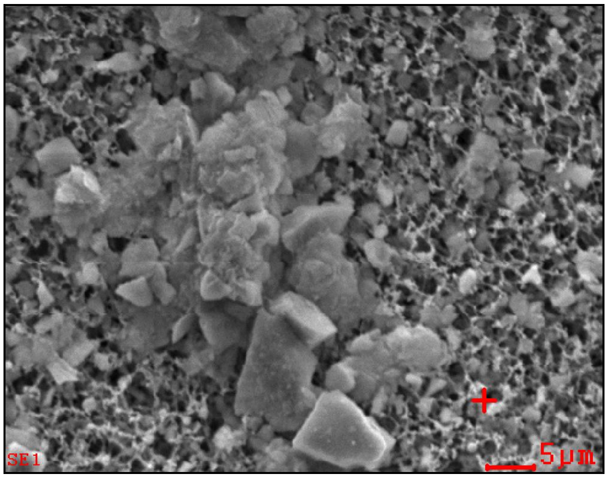
As it can be seen, there are some amorphous particles "sitting" on top or incorporated in a "spongy" layer of smaller particles. The EDS analysis revealed that amorphous particles consist primarily of Si and O (Figure 2-4), while the "spongy" layer consists of Si with significant presence of Al (Figure 2-5). An overall elemental composition of the sample revealed the presence of Fe, presumably associated with one or the other form (Figure 2-6).

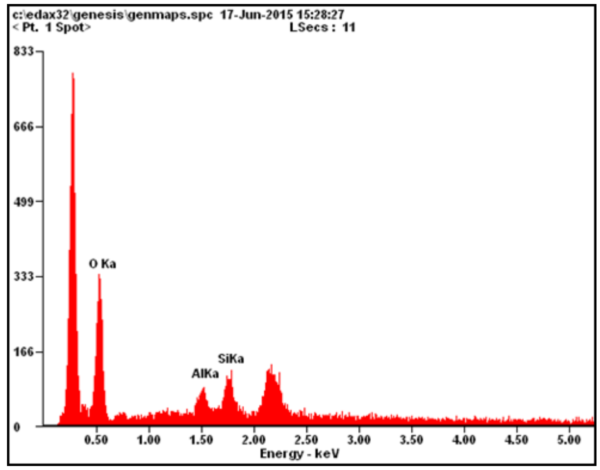




Element	Wt%	At%
OK	43.66	57.63
SiK	56.34	42.37
Matrix	Correction	ZAF

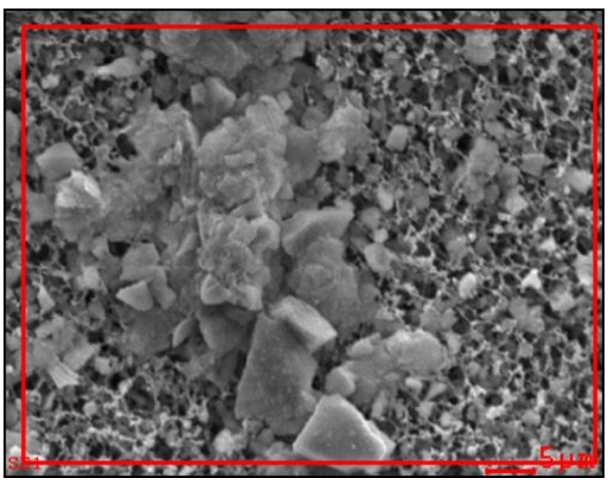
Figure 2-4. SEM image and EDS analysis of 0.45 µm filter.

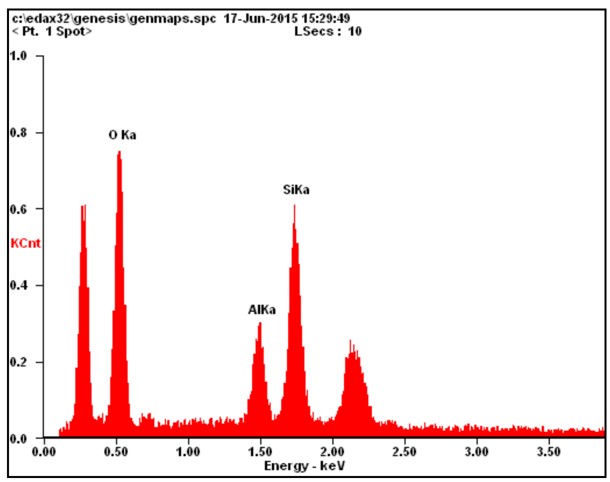




Element	Wt%	At%
OK	69.84	80.02
AlK	10.91	07.41
SiK	19.25	12.56
Matrix	Correction	ZAF

Figure 2-5. SEM image and EDS analysis of 0.45 µm filter.





Element	Wt%	At%
OK	45.50	61.99
AlK	12.05	09.74
SiK	30.34	23.55
FeK	12.11	04.72
Matrix	Correction	ZAF

Figure 2-6. SEM image and EDS analysis of particles accumulated on 0.45 µm filter.

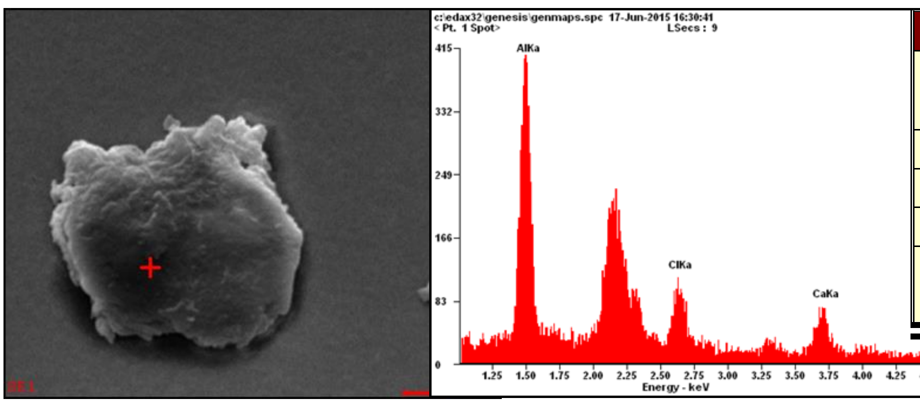
Uranium was not detected via EDS due to the small, 500ppb concentration used to amend all samples. It is estimated that a ~20% of U(VI) is retained by the filter, which roughly translates to 100 ppb, which is lower than the detection limit of EDS. Therefore, in the next round of experiments uranium concentration in the samples will be increased to 100ppm-120ppm; so, U can be detected by EDS. An increase in uranium concentrations will also help to identify on how uranium is associated with these amorphous formations observed on filters via SEM.

Another interesting point is the presence of Fe and Al, something which can be clearly traced back to the soil composition, since there is no iron or aluminum present in the synthetic groundwater. It is clear that Fe and Al are involved in the formation of amorphous silicate particles.

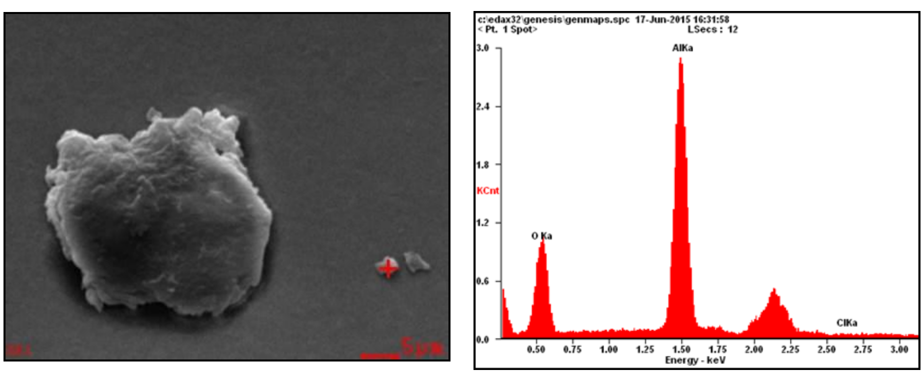
Finally, the formation of amorphous particles comprised of Si (and most possibly U), Fe and Al might justify the reduced mobility of sodium silicate through saturated sediments. It is possible that particles size might also contribute to their reduced mobility in the subsurface.

SEM/EDS results for 0.2 µm filter

It is clear that there is no a "spongy" layer in this case (Figure 2-7). There are a few particulate matter size crystals, which comprise mostly of Al and O (with perhaps some Ca and Cl impurities).



Element	Wt%	At%
OK	21.55	34.67
AlK	43.06	41.08
ClK	18.08	13.12
CaK	17.31	11.12
Matrix	Correction	ZAF



Element	Wt%	At%
OK	36.78	50.31
AlK	57.20	46.40
ClK	00.11	00.07
CaK	05.91	03.23
Matrix	Correction	ZAF

Figure 2-7. SEM image and EDS analysis of sample prepared from 0.2µm filter.

There is a notable absence of Si or any other silica-related formation on this filter. It seems that the addition of sodium silicate does not generate small size particles that are mobile in the subsurface environment.

During August, the Year End Report on subtask 2.1 (sodium silicate treatment for U(VI) bearing groundwater at F/H area at Savannah River Site) was completed. The experimental findings indicate that 70 mg L^{-1} of sodium silicate ($Na_2SiO_3 \cdot 9H_2O$) is sufficient to restore alkalinity in the treatment zone (raising the pH from 3.5 to 6.7). The pH values were monitored for a period of 40 days and the pH remained stable during this period, indicating that the restoration of alkalinity in the treatment zone is sustainable, at least for the period studied. Uranium removal as a result of the pH rise and sodium silicate addition was found to be 60%. A possible mechanism explaining the uranium removal could be synergistic actions including the formation of less soluble uranyl hydroxides and the formation of colloidal species due to silica polymerization in an acidic environment. The results also revealed an association of uranium with sodium silicate in colloidal form in the aqueous phase (particles of average diameter larger than 0.45μm). Furthermore, a significant amount of iron was detected in the aqueous phase, an element that can be traced back to the soil's composition. The change in pH is considered to be the determining factor for iron mobilization from soil to the aqueous phase. SEM analysis of the 0.45 μm filters revealed the existence of a spongy layer and several amorphous particles resting on top. The EDS elemental analysis revealed that these formations are comprised mostly of Si, O, Al and Fe. Cations such as Fe and Al are known to destabilize the negatively charged silica colloidal particles in the aqueous phase and, therefore, the presence of Al^{3+} and Fe^{3+} near the siliceous surface is expected. Finally, there was no uranium detected in the filters, possibly due to the very low uranium initial concentrations used in the experiment. FIU initiated working on the Project Technical Plan to outline future experiments that will involve the artificial increase of initial uranium concentrations in order for uranium to be within the detection limits of the EDS spectroscopy method.

FIU Year 4 Carryover Work Scope

During July, FIU continued with HA, Si and uranium synergy experiments and prepared humic acid-free batch samples using soil obtained from FAW-1. The pH of the samples was adjusted to between 3-8 and the samples were placed on the shaker for equilibration. After the samples reach equilibrium, they will be centrifuged and filtered. Analysis will be done for the filtered and unfiltered samples via KPA and ICP to measure the concentrations of uranium, iron and silica.

FIU completed the Year End Report for the study to investigate synergistic interactions between four key components: U(VI), humic acid (HA), colloidal silica and SRS sediment. The interactions were studied under varying pH conditions ranging from 3 to 8. Multi-component batch systems containing 50 ppm HA, 0.5 ppm uranium and 3.5 mM colloidal silica were evaluated to analyze the removal behavior of U(VI). The Year End Report detailed the results for batches 2, 3, 5, and 6.

Table 2-1. Batch Constituents Used in the Experiments

pH Adjusted Set	Constituents					
	SiO_2 (3.5mM)	Humic Acid (HA) (50ppm)	Sediments	Uranium U(VI) (0.5ppm)	Water H_2O	Total Volume
	ml	ml	mg	ml	ml	ml
Batch No. 2	2.1	10		0.01	7.89	20
Batch No. 3	0	10		0.01	9.99	20
Batch No. 5	2.1	10	400	0.01	7.89	20
Batch No. 6	0	10	400	0.01	9.99	20

Two sets of samples were prepared for each batch. Samples for Set #1 were centrifuged and filtered in order to remove any remaining colloids in suspension, while samples from Set #2 were prepared without filtering. The filtered samples showed the highest uranium removal at acidic pH conditions, which may be attributed to the uranyl cation being the dominant species which allowed for interaction with the negatively charged humic acid. With increasing pH, the mono and poly nuclear hydrolyzed uranyl cations became dominant based on speciation modeling, limiting the interaction between the uranyl ions and humic acid. U(VI) removal steadily decreased with the increase in pH until the pH reached neutral/alkaline pH, where the uranium removal was ~40%. The sediment bearing batches yielded a higher uranium removal (~80%) at low pH (pH 3) compared to non-sediment batches (~55%). The presence of sediment under acidic pH conditions creates more sorption sites for the uranium, allowing for increased removal. The average colloidal silica removal for all batches was about 80%. Unfiltered samples yielded similar results, a lower removal of U(VI) compared to the filtered samples; colloidal silica showed a downward trend in removal as pH increased.

According to the experimental results, at chosen concentration of HA, colloidal silica does not seem to have a significant effect on the removal of U(VI) in unfiltered samples. Humic acid, silica colloids and SRS sediment synergistically effect the removal of U(VI) in the multi-component batch system. The experimental results were also summarized in the abstract by Ravi Gudavalli, Christian Pino (DOE Fellow), Yelena Katsenovich, and Miles Denham (SRNL) titled, "Multicomponent batch experiments investigating uranium synergy with humic acid, silica colloids and SRS sediments at variable pH," and submitted to the WM16 Symposia.

Subtask 2.2: Monitoring of U(VI) bioreduction after ARCADIS demonstration at F-Area

FIU worked on the samples for sulfate analysis during July.

DOE Fellow Aref Shehadeh is currently interning at the Savannah River Site (SRS) located in Aiken, South Carolina. Aref is working under the mentorship of Dr. Miles Denham SRNL. Aref is involved in the experiments mimicking remediation of iodine-129 (I-129) in the SRS F-Area caused by a large radionuclide plume stemming from an old seepage basin. Dr. Denham has proposed the use of silver chloride (AgCl) to react with the I-129 in the sediments to create a binding effect and prevent further spreading of the plume. Aref is researching the mechanisms of the I-129 binding to the silver chloride particles, their particle size and structure, created in a laboratory setting, and is helping determine the optimal concentration of AgCl to be used in future *in situ* remediation efforts.

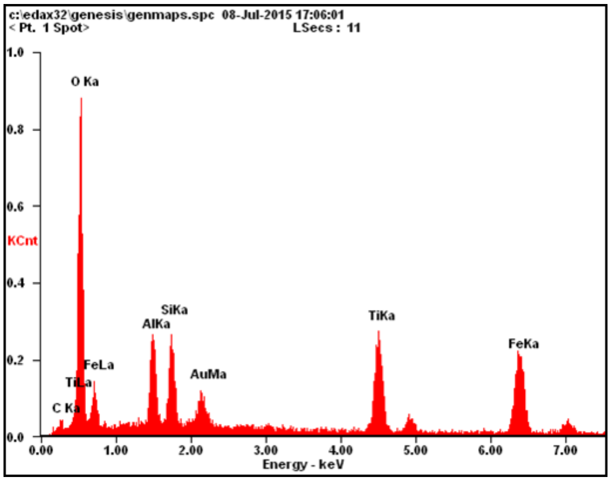
FIU worked on the sulfate analysis via ion chromatography (IC). The first run gave inconclusive results due to the variability in retention times for the sulfate species in the samples. Standards were prepared at concentrations of 1 ppm, 5 ppm, 15 ppm and 25 ppm. The 1 ppm and 5 ppm standards were not detectable by the IC; the 15 ppm and 25 ppm standards yielded a retention time of 15.10 min. The experimental samples yielded a retention time of 14.89 min; so, it cannot be conclusively said that the experimental samples contain sulfate. Further analysis must be completed with newly prepared standards; the addition of molasses to the standard would allow it to more accurately mimic the experimental sample matrix, which might affect the retention time. In addition, FIU is evaluating other techniques for sulfate analyses as the limit of detection for this instrument was 15 ppm.

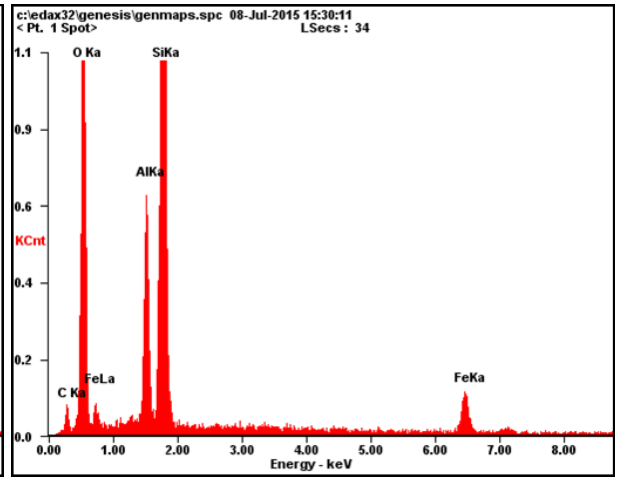
Since there was no indication of bioreduction in the microcosm samples, the planned future work for the project task, which included a re-oxygenation phase, will not be conducted. With the experience gained from this study, speciation modeling may be conducted at a later date to evaluate if there is any possibility of the formation of ferrous iron solid phases.

DOE Fellow Aref Shehadeh returned to ARC from his summer internship at the Savannah River Site (SRS) located in Aiken, South Carolina. Aref is working on the internship report for the experimental work he conducted under the mentorship of Dr. Miles Denham (SRNL). Aref was involved in the experiments mimicking remediation of iodine-129 (I-129) in the SRS F-Area caused by a large radionuclide plume stemming from an old seepage basin. Dr. Denham has proposed the use of silver chloride (AgCl) to react with the I-129 in the sediment to create a binding effect and prevent further spreading of the plume. Aref was researching the mechanisms of the I-129 binding to the silver chloride particles, their particle size and structure, created in a laboratory setting, and was helping determine the optimal concentration of AgCl to be used in future *in situ* remediation efforts.

Subtask 2.3: Sorption properties of humate injected into the subsurface system

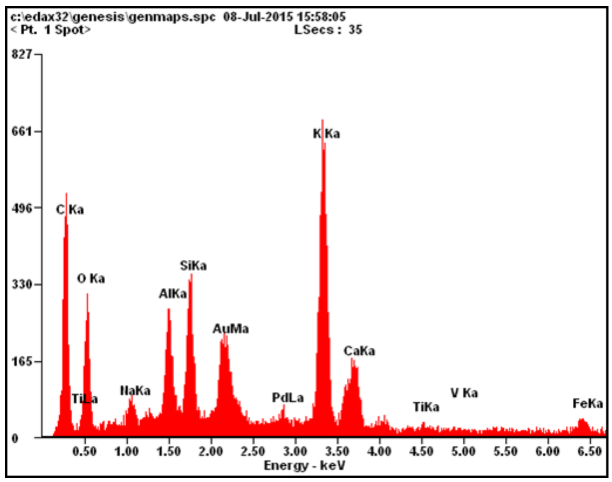
During the month of July, scanning electron microscope equipped with energy-dispersive X-ray spectroscopy (SEM/EDS) was used for the chemical characterization of Savannah River Site (SRS) sediments from the F-area and HumaK. Both materials were placed on top of metal stubs that had a double stick tape where they were coated with an electrical conductive material (gold/palladium) using a sputter coater. After the coating, SRS sediment and HumaK were placed under the microscope in order to be observed and to get elemental analysis by EDS. The results from the EDS analysis are shown in Figures 2-8 through 2-10.





2-8. SRS sediment coarse fraction.

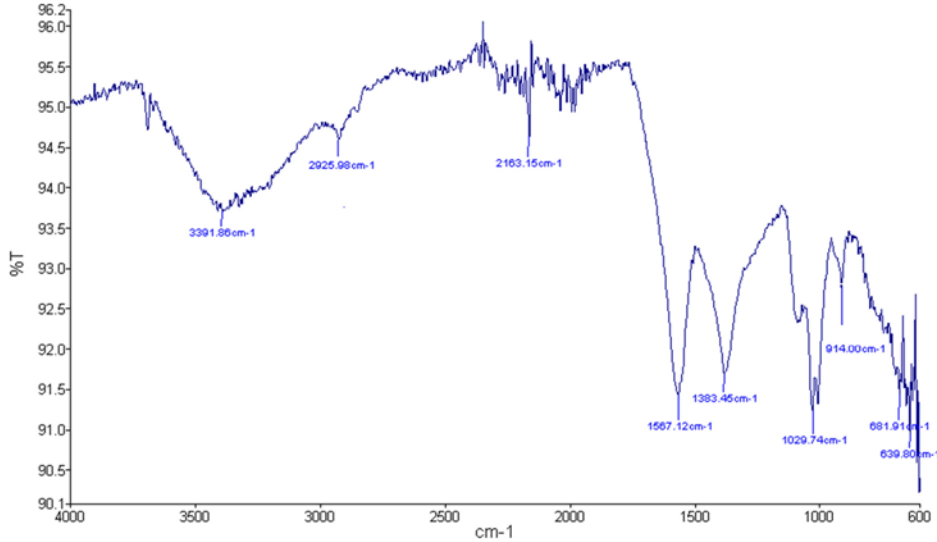
2-9. SRS sediment fine fraction (less than 63 µm).



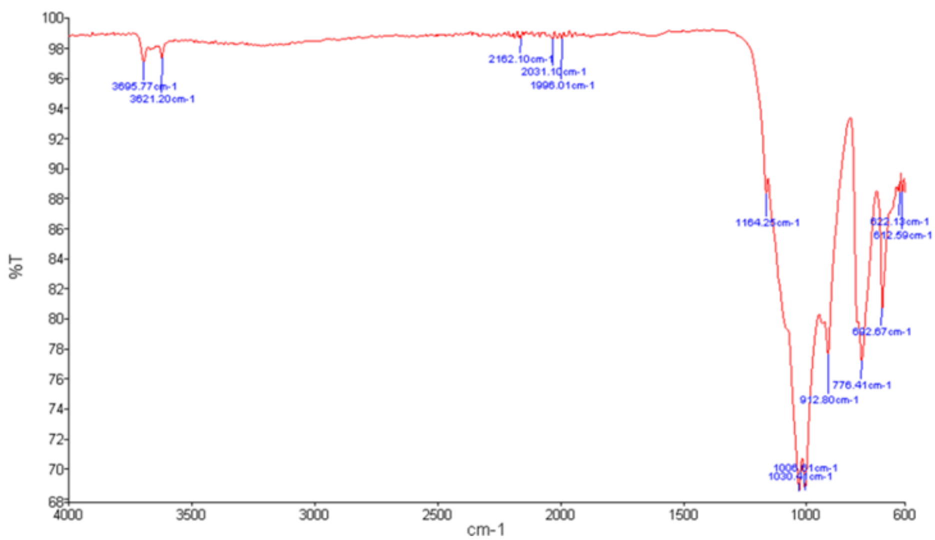
2-10. Composition of HumaK.

The elemental analysis of the coarse and fine fraction shows that SRS sediments have Si, Al, Fe, and Ti. The Si, Al, and Fe comes from the quartz, kaolinite, and goethite minerals present in the sediment. These minerals are characteristic of the F-area based on the literature review. Titanium was also found; probably Ti is in the form of titanium oxide (TiO2). Ti is commonly found in sediments. The elemental analysis of Huma-K shows that it contains K, C, O, Si, Ca, and Al. The K comes from Huma-K treatment procedures that were done to extract the humic substances from the coal leonardite by using KOH. C and O come from the humic substances which are rich in aromatic rings, carboxyl groups, phenols, and aliphatic chains. Since HumaK is an unrefined commercial product, it will contain impurities (elements that were present in leonardite, and were dissolved in the alkaline extraction mainly Si, Al, and Ca).

During the month of August, the characterization of SRS sediments and HumaK by fourier transform infrared spectroscopy (FTIR) was completed. This technique was used for the identification of minerals present in the SRS sediments as well as the identification of the main functional groups present in the HumaK. SRS sediments were sieved to a particle size less than 63 µm in order to analyze the fine fractions, which contain a higher percentage of clay. HumaK had to be mixed with KBr (10 mg of sample with 150 mg KBr) to reduce the blackness of the sample and get a better spectrum. The results are shown below.



2-11. FTIR spectrum of HumaK.



2-12. FTIR spectrum of SRS sediment fine fraction.

A literature research was done in order to identify the peaks in the spectrum of SRS sediments and HumaK. The FTIR spectrum of HumaK shows a broad peak at 3391 cm-1. This peak is attributed to the O-H and N-H stretching of different sources such as alcohols, phenols, amines, or amides that usually appear in the 3400-3000 cm-1 region. The peak at 2925 cm-1 is attributed to the aliphatic C-H stretching of methyl and methylene groups that appear around 2926 and 2855 cm-1. The peaks at 1567 and 1383 cm-1 belong to the carboxylic acid groups in their salt form (COO-). The last peaks of the spectrum at 1029 and 914 cm-1 are attributed to the C-O and C-C stretching vibration of sugars which appear at 1105, 1032, 1010 and 913 cm-1. SRS sediments have a shoulder of absorption band at 1164 cm-1 which it is attributed to the Si-O stretching.

The FTIR spectrum of SRS sediments shows a distinctive pattern in the 3000 region, which is characteristic of kaolinite. The 3695 and 3621 cm-1 peaks belong to the stretching vibration of the OH groups at the surface. The peaks seen at 1030 and 1006 cm-1 for SRS sediments are close to the values for the in-plane Si-O stretching of the kaolinite (1024 and 997 cm-1). Another characteristic peak found in SRS sediment at 912 cm-1 corresponds to the OH bending vibration of the inner surface OH groups in kaolinite which appears at 913 cm-1. All the peaks that have been discussed for the SRS sediment have a close value to the peaks in kaolinite, but there are two peaks at 776 cm-1 and 692 cm-1 in the SRS sediment spectrum that could belong to quartz. The peak at 776 cm-1 may belong to both quartz and kaolinite, and it is attributed to the Si-O symmetrical stretching vibration. The peak at 692 cm-1 is very close to the value reported for quartz at 695 cm-1, and this peak belongs to the Si-O symmetrical bending vibration.

A detailed explanation of the experimental procedure and discussion of the results can be found in the Year End Report, which compiles the results for all of the experiments performed during FIU Year 5 for the characterization of SRS sediments and HumaK as well as the sorption of HumaK onto SRS sediments using different parameters such as time, initial concentration, and pH. The next step will be the start of the kinetic desorption experiment of HumaK at pH 4.

Task 3: Evaluation of Ammonia Fate and Biological Contributions during and after Ammonia Injection for Uranium Treatment

Task 3 Overview

Task 3 relates to the Hanford Site and aims to evaluate the potential biological and physical mechanisms associated with the fate of ammonia after injection into the unsaturated subsurface. These tests will identify and quantify factors controlling the relative rate of these processes. Expected processes include biological transformation, partitioning and geochemical reactions. Tests will examine the mechanisms of potential importance using controlled laboratory systems to complement efforts underway at PNNL.

Task 3 Quarterly Progress

During the month of July, 5% NH_3 (95% N_2) was injected by steps into 100 mM, 60 mM and 30 mM HCO_3^- solutions. In addition, total NH_3/NH_4^+ in the aqueous phase was analyzed in pre-acidified samples pulled at variable timepoints during injection into the 3, 60 and 100 mM HCO_3^- solutions via the ammonia gas-sensing electrode (Orion 9512BNWP). The Nesslerization method was chosen as a complementary method for determination of total NH_3/NH_4^+ in the aqueous phase and materials have been ordered to perform the analysis. This method was chosen because it has an applicable range of detection (detection limit of 2 µg NH_3-N/L with an upper range of 5 mg NH_3-N/L), rapid protocol and avoids alkalinity interferences through the addition of EDTA or Rochelle salt instead of a lengthy distillation step.

Figures 2-13, 2-14, and 2-15 compare the results for injection of aliquots of 5% NH_3 (95% N_2) into 3, 30, 60 and 100 mM HCO_3^- solutions at ~21° C. As shown by the data below, the injection of 5% NH_3 (95% N_2) gas increases both the pH and conductivity of the system as the aqueous NH_3/NH_4^+ concentrations increase. Aqueous NH_3 measurements are still in progress for 30 mM HCO_3^- suspensions and will be included in the Year End Report. However, following injection of at least 10 mL NH_3 (200 mL of total gas), the rate of increase in pH begins to decrease. To reach a pH of greater than 10.0, at least 20 mL of NH_3 gas must be injected for 100 mL of 3 mM HCO_3^- solutions at ~21°C. The rate at which the NH_3 gas is absorbed into solution appears to increase at greater than 10.0 mL of NH_3 gas injected. In addition, speciation modeling (using Visual Minteq), statistical analysis and a literature review are in progress and will be discussed in the upcoming Year End Report.

Additional changes to the experimental setup are still in progress. A peristaltic pump (Masterflex digital L/S with size 14 tubing pump head) will be considered for further injection experiments, replacing the syringe pump used previously for injection. This will allow for the calibration of a specific flow rate being injected as well as continuous injection of 5% NH_3 (95% N_2). In addition, these future experiments will focus on stripping of NH_3/NH_4^+ from the aqueous phase in columns instead of step injection. These changes will allow for comparison with previously published data and greater ease in development of simple models. Batch experiments are also in the planning phase for the next fiscal year in order to measure the equilibrium partitioning of NH_3 and the kinetics of uranium sorption/desorption in the presence of NH_3. Future gas stripping and batch experiments will be conducted at a constant ionic strength (0.15 M, adjusted by addition of NaCl) to allow for direct comparison of HCO_3^- concentrations' effect on partitioning and simpler speciation modeling. Batch equilibrium experiments will be completed for determination of Henry's constants and kinetic rates of partitioning (for both NH_3 and uranium for experiments with soils) with variable HCO_3^- from 0 – 100 mM, constant ionic strength of 0.15 M (as adjusted by addition of NaCl), constant temperature ~21° C, pH 12, variable gas to liquid ratios and variable NH_3 concentrations. A pH of 12 was chosen for initial batch experiments for investigation of NH_3 partitioning to reduce parameters; 99.8% of total NH_3/NH_4^+ in the aqueous phase is present as NH_3. Further, the addition of piperidine, bicarbonate, phosphate and ammonium hydroxide buffers were considered based on theoretical calculations presented in Figure 2-16. However, the natural buffering capacity of H_2O at pH 12 was deemed sufficient based on target NH_3 concentrations.

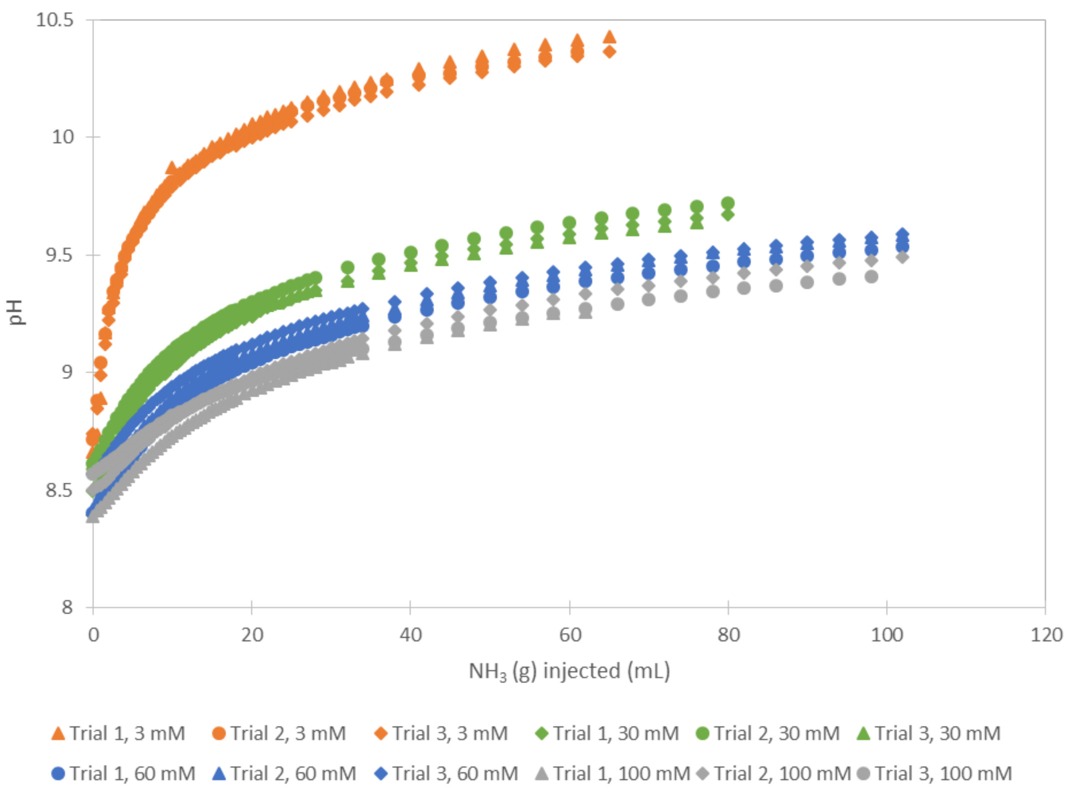


Figure 2-13. NH_3 (g) injected versus pH for step injections of NH_3 (g) for triplicate experiments with 3 mM (orange), 30 mM (green), 60 mM (blue) and 100 mM (gray) HCO_3^- suspensions.

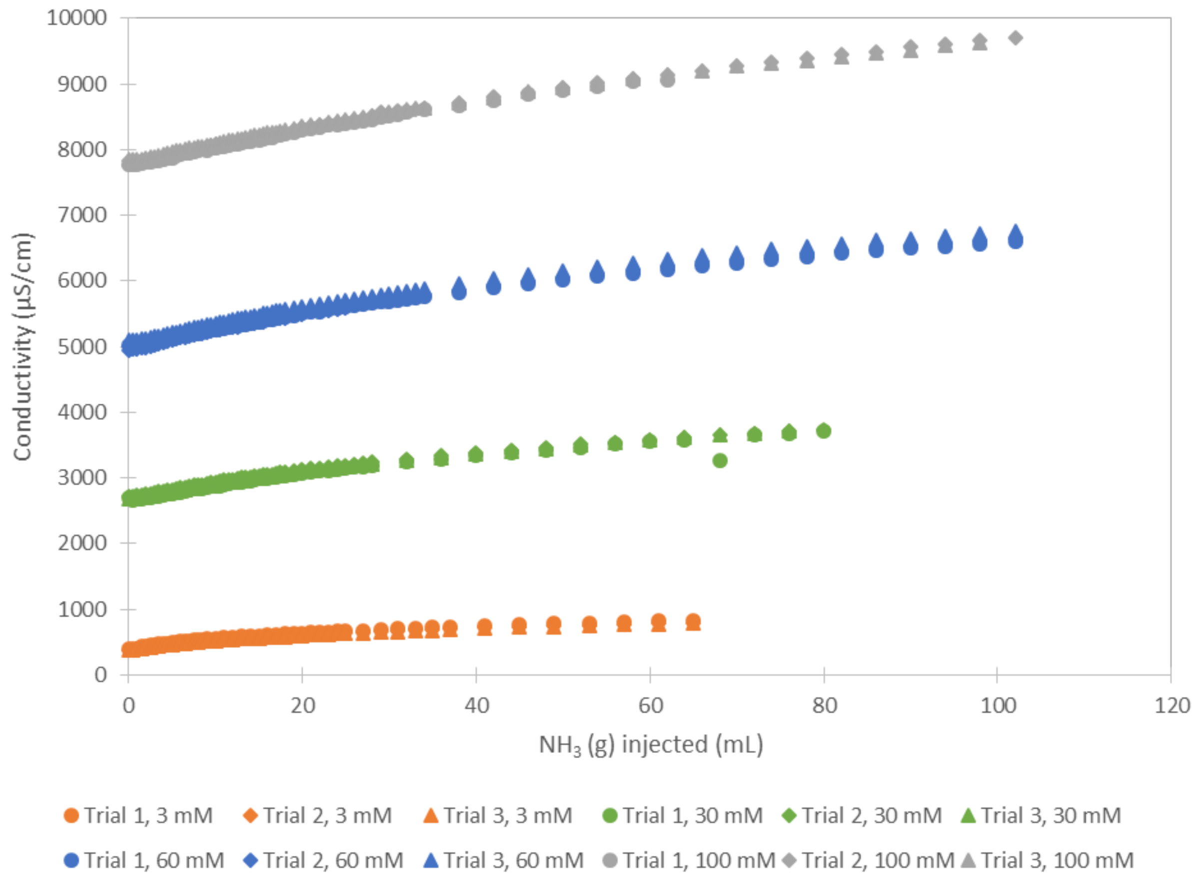


Figure 2-14. NH_3 (g) injected versus conductivity (µS/cm) for step injections of NH_3 (g) for triplicate experiments with 3 mM (orange), 30 mM (green), 60 mM (blue) and 100 mM (gray) HCO_3^- suspensions.

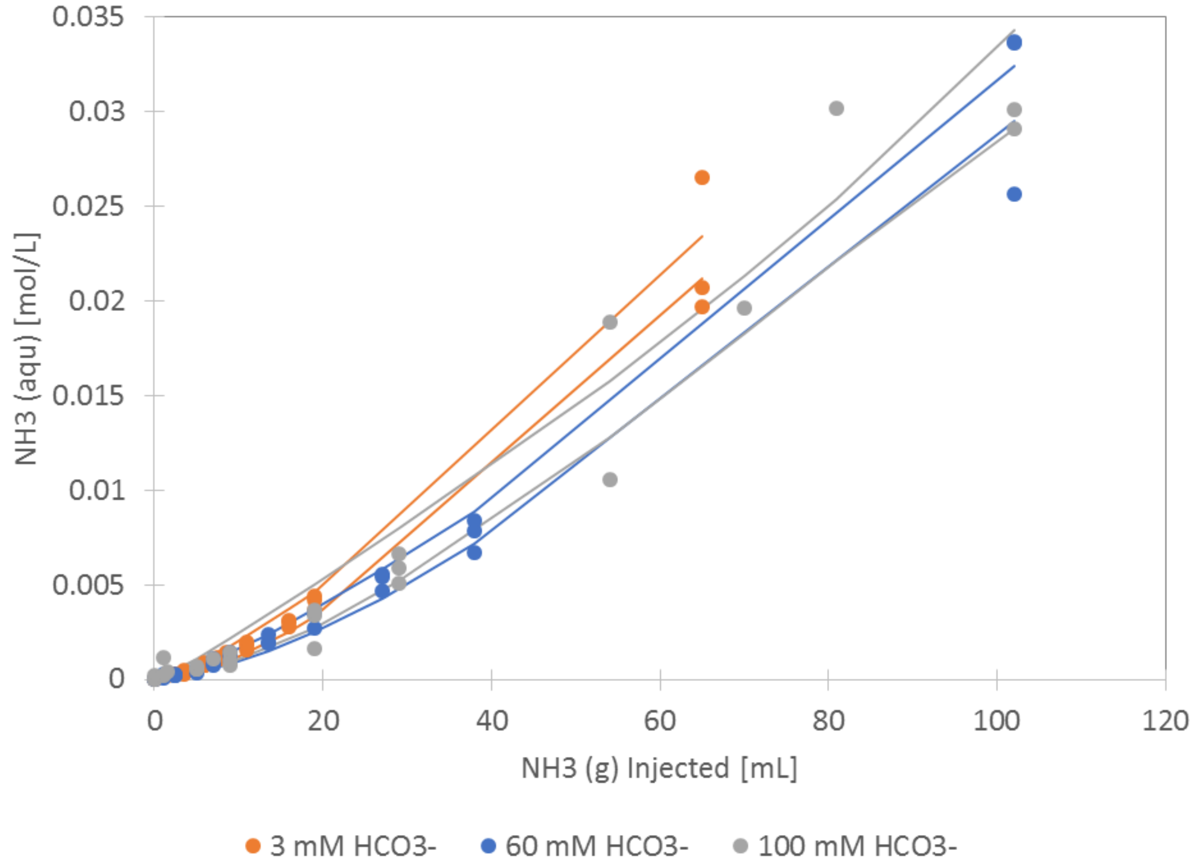


Figure 2-15. NH_3 (g) injected versus aqueous NH_3 (mol/L) for step injections of NH_3 (g) for triplicate experiments with 3 mM (orange), 30 mM (green), 60 mM (blue) and 100 mM (gray) HCO_3^- suspensions, Note: lines represent a 95% confidence interval estimated based on a power law fit to the data in Sigmaplot software.

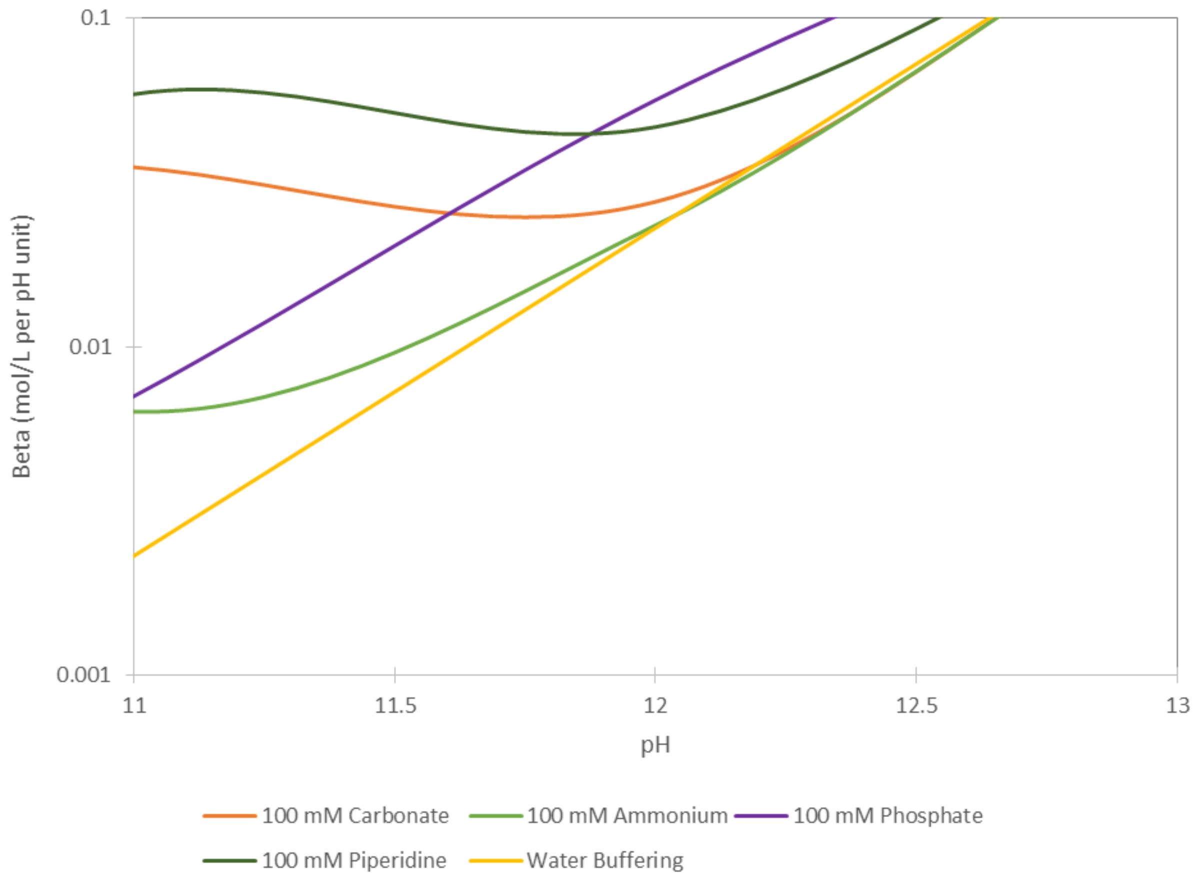


Figure 2-16. Buffering capacity in terms of mol/L of strong acid or base per pH unit versus pH for 100 mM concentrations of common buffers.

During the month of August, data regarding the injection of 5% NH_3 (95% N_2) into 100 mM, 60 mM, 30 mM and 3 mM HCO_3^- solutions was finalized and reported in the Year End Report. The Year End report also included a literature review of ammonia partitioning in previous systems, experimental design options for the measurement of Henry's constants, and methods for analysis in both the gaseous and liquid phases. Data was presented with statistical analysis and speciation modeling which led to the following conclusions:

1) The current experimental design is not adequate for the prediction of Henry's constants for NH_3(g). Possible alternatives are outlined in the Literature Review included as Appendix A to the Year End Report.
2) Because the goal of this remediation process is to raise the pH, the buffering capacity of the porewaters will have a significant effect on the amount of NH_3(g) required to be injected as well as the overall success of this technique. The data presented in the Year End Report depicts a significant increase in buffering capacity in the presence of variable concentrations of bicarbonate.
3) The equilibrium partitioning (Henry's constant) may or may not be different with the variable bicarbonate solutions, but the rate of incorporation of NH_3(g) into these open beaker systems is not statistically different with respect to bicarbonate concentration.

Based on the results presented in the Year End Report and discussion with PNNL collaborators, a different direction will be pursued for future experiments during the next performance year.

Milestones and Deliverables

The milestones and deliverables for Project 2 for FIU Year 5 are shown on the following table. No milestones or deliverables were due for this project during July or August.

FIU Year 5 Milestones and Deliverables for Project 2

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Task 1: Sequestering uranium at Hanford	2014-P2-M5	Obtain anaerobic facultative microorganisms, Shewanella sp., from PNNL and complete preparations to set up autunite leaching experiments.	10/03/14	Complete	
	2014-P2-M3	Completion of sample preparation using a reduced amount of silica (50 mM)	11/07/14	Complete	
	2014-P2-M4	Complete preparation of a draft manuscript on the removal of uranium via ammonia gas injection method	12/15/14	Complete	
	2014-P2-M1	Completion of solubility measurements of U(VI)-free samples (FIU Year 5 scope) **and** Completion of solubility measurements using standards such as calcium chloride and lithium chloride to get better deliquescence predictions at low water activities values (carryover scope).	01/30/15	Complete	
	Deliverable	Prepare a progress report on the solubility measurements via isopiestic method (subtask 1.1)	02/16/15	Complete	OSTI

Task 2: Groundwater remediation at SRS	2014-P2-M6	Complete preparations for the microcosm experiments prepared with SRS sediments using sulfate additions.	09/12/14 Re-forecasted to 10/13/14	Complete	
	Deliverable	Progress report on microcosm studies prepared with SRS sediments augmented with molasses and sulfate (subtask 2.2)	01/30/15	Complete	OSTI
	Deliverable	Progress report on batch experiments prepared with SRS sediments, colloidal Si and higher HA concentration up to 50ppm (carryover scope under subtask 2.1).	03/30/15	Complete	OSTI
	Deliverable	Prepare a progress report on sorption properties of the humate injected into the subsurface system (subtask 2.3)	04/03/15	Complete	OSTI
Task 3: Evaluation of ammonia for uranium treatment	2014-P2-M2	Completion of literature review on physical mechanisms associated with the fate of ammonia after injections into subsurface	10/31/14	Complete	

Work Plan for Next Quarter

The work plan for the next quarter is presented the section titled, "FIU Year 6 Project 2 – Environmental Remediation Science and Technology."

FIU Year 5 Project 3
Environmental Remediation Technologies (EM-12)

Project Description

This section presents the information for the FIU Year 5 Project 3 for July and August 2015. The previous section presents the information for the FIU Year 5 Project 3 for July and August 2015 and the next section will present the new combined Project 2 information for FIU Year 6 (September 2015).

For FIU Year 5, FIU utilized and built upon the capabilities developed under Project 3 in the area of soil and groundwater remediation and treatment technology. FIU coordinated closely with the Savannah River Site during FIU Year 5 in the execution of the work scope. Tasks were synergistic with the work SRNL is performing and included (1) Modeling of the migration and distribution of natural organic matter injected into subsurface systems; (2) Fate and transport modeling of Hg, Sn and sediments in surface water of Tims Branch; and (3) Analysis of baseline, optimization studies and development of a system improvement plan for the A/M Area groundwater remediation system.

Task 1: Modeling of the migration and distribution of natural organic matter injected into subsurface systems

<u>Task 1 Overview</u>

Task 1 aims to assemble, integrate and develop a practical and implementable approach to quantify and model potential natural organic matter (NOM, such as humic and fulvic acids, humate, etc.) deployment scenarios for the range of conditions at DOE sites. Initial laboratory experiments and an initial set of simplified models have been developed at SRNL. Under this task, additional batch and column studies and testing will be conducted at FIU to provide the transport parameters for an extension of the current model scenarios.

<u>Task 1 Quarterly Progress</u>

Subtask 1.2: Column testing of the migration and distribution of humate injected into subsurface systems

- Experimental tests were run on Column 3 that was filled with oven-dried SRS soil.
- The fraction collector purchased from Eldex was received and a few preliminary tests were conducted after its assembly. This device will be used to simplify sample collection during the column experiments.
- It was discovered that one of the columns previously studied appeared to leak sludge from the bottom of the column. This column will be dismantled and the sediment will be dried and analyzed using SEM-EDS to examine the sorption of HA on the sediments.
- The technical report deliverable entitled, "Migration and Distribution of Natural Organic Matter Injected into Subsurface Systems," which was submitted to DOE on July 6, 2015, was reviewed by Drs. Brian Looney and Miles Denham. This report included the results of the preliminary set-up of column experiments to estimate the sorption and desorption

properties of humic acid onto SRS sediment. Based on the feedback received from the SRNL task leads, a path forward has been determined for the next fiscal year to include uranium in the column experiments and to slightly modify the experimental procedure with respect to flow direction in the columns (i.e., bottom up instead of top down).

- A suggestion was also made by Dr. Looney to conduct column experiments with other commercial humic substances besides Huma-K for comparison. A commercial sample will be shipped by Dr. Looney to FIU and experiments using this material will be incorporated into the work plan for the next year.
- An abstract entitled, "Migration and Distribution of Natural Organic Matter Injected into Subsurface Systems," by Ravi Gudavalli, Kiara Pazan (DOE Fellow), Miles Denham, and Brian Looney was submitted to the WM2016 Conference which will be held March 6 - 10, 2016 at the Phoenix Convention Center in Phoenix, AZ.

Subtask 1.3: Development a subsurface flow, fate and transport model of humic acid

This task includes modeling of the migration and distribution of humate injected into subsurface systems during deployment for in situ treatment of radionuclides, metals and organics. Relevant data derived from the column studies will be used for development of a flow and transport model. This task will be initiated this year with collection of GIS data and other relevant model parameters, incorporation of this data into the existing SRS geodatabase developed for Tims Branch, and geoprocessing of the data for hydrological model input. GIS data for the F/H Area has been requested. Further model development has been written into the FIU Year 6 scope of the new 5-year DOE-FIU Cooperative Agreement.

In a recent communication with Dr. Miles Denham, he mentioned that a groundwater flow model has already been developed by Lawrence Berkeley National Lab under the ASCEM program. FIU is awaiting feedback from Miles after he communicates with LBNL to determine if it is feasible to transfer the existing model to FIU for incorporation of the humate deployment into the model, rather than developing a new model.

Task 2: Surface Water Modeling of Tims Branch

<u>Task 2 Overview</u>

This task will perform modeling of surface water, and solute/sediment transport specifically for mercury and tin in Tims Branch at the Savannah River Site (SRS). This site has been impacted by 60 years of anthropogenic events associated with discharges from process and laboratory facilities. Tims Branch provides a unique opportunity to study complex systems science in a full-scale ecosystem that has experienced controlled step changes in boundary conditions. The task effort includes developing and testing a full ecosystem model for a relatively well defined system in which all of the local mercury inputs were effectively eliminated via two remediation actions (2000 and 2007). Further, discharge of inorganic tin (as small micro-particles and nanoparticles) was initiated in 2007 as a step function with high quality records on the quantity and timing of the release. The principal objectives are to apply geographical information systems and stream/ecosystem modeling tools to the Tims Branch system to examine the response of the system to historical discharges and environmental management remediation actions.

Task 2 Quarterly Progress

Subtask 2.1: Development of a detailed GIS-based representation of the Tims Branch ecosystem

- Primary focus this quarter was to provide input for the final technical report deliverable with regards to the GIS work accomplished for this task during FIU Year 5 (FY14), which includes SRS geodatabase development, documentation of the geodatabase schema using ArcGIS Diagrammer, pre-processing of hydrological model data, development of process flow models using ArcGIS ModelBuilder, preparation of maps of Tims Branch watershed to depict topography, hydrology, surface geology, soils, vegetation, Manning's roughness coefficient, paved runoff coefficient, etc.
- Pre- and post-processing of GIS data in ongoing to support the hydrological model development and to prepare maps for the final technical report and Year End Report.
- The model domain has been revised to incorporate the upper portion of the Tims Branch watershed that lies outside of the SRS boundary. Primary focus has therefore been on downloading and geoprocessing some of the GIS data required (e.g. vegetation, land cover, imperviousness, topography, etc.) to accommodate this change.
- An abstract entitled, "Using GIS for Processing, Analysis and Visualization of Hydrological Model Data," by Angelique Lawrence, Mehrnoosh Mahmoudi, Shimelis Setegn, Natalia Duque (DOE Fellow), and Brian Looney, was submitted to the WM2016 Conference which will be held March 6-10, 2016 at the Phoenix Convention Center in Phoenix, AZ.
- An abstract entitled, "GIS as an Integration Tool for Hydrologic Modeling: Spatial Data Management, Analysis and Visualization," by Angelique Lawrence, Mehrnoosh Mahmoudi, Shimelis Setegn, and Natalia Duque, was also submitted to the 2015 American Geophysical Union (AGU) Fall Meeting to be held in San Francisco, CA on December 14-18, 2015.

Subtask 2.2: Modeling of surface water and sediment transport in the Tims Branch system.

- The technical report deliverable entitled, "Environmental Remediation Technologies: Surface Water Modeling of Tims Branch" was submitted to DOE on July 17, 2015. This report provides details of the research being conducted by FIU to develop an integrated surface water and groundwater model to predict the fate and transport of tin in Tims Branch. Understanding the fate of tin and its compounds is of primary importance due to their potential impact on the environment and the toxicity to humans and animals. This report presents the progress FIU has made in the hydrological modeling of Tim Branch using the MIKE SHE model. These preliminary results provide a general understanding of the watershed as a function of precipitation and other catchment characteristics. Future work will incorporate the different hydrological processes in the watershed. The final integrated model will include a fate and transport model (ECOLAB) which will predict the tin spatiotemporal distribution in Tims Branch under various climate scenarios.
- The report has been reviewed by Brian Looney and a phone conversation was held with him and the FIU modeling team (Noosha, Angelique & Shimelis) to discuss some of the details with respect to anticipated results, data gaps and a projected path forward

involving model refinement, model calibration and coupling of the existing model with MIKE 11 (stream model) and ECOLAB (transport model).

- After Brian Looney's discussion with FIU, he was able to source additional stream flow data and provided this to FIU to assist with filling in some of the data gaps identified.
- The path forward established for the work that will be accomplished in the new fiscal year (FIU Year 6) will primarily focus on completion of the set-up of the MIKE SHE model. Milestones will be based on the implementation of each module (i.e., ET, saturated/unsaturated zones, overland flow) with the expected outputs and associated timelines. Preliminary set up of the stream network using MIKE 11 will also begin in parallel with the MIKE SHE set-up, but will not be completed until FIU Year 7 and beyond.
- An email was sent to John Seaman at SREL to initiate communication regarding the idea of using student support for sampling/data collection in Tims Branch and Steed Pond during a summer 2016 internship at SRS.
- An abstract entitled, "Development of an Integrated Hydrological Model for Simulation of Surface Runoff and Stream Flow in the Tims Branch Watershed, South Carolina," by Mehrnoosh Mahmoudi, Angelique Lawrence, Shimelis Setegn, Natalia Duque, and Brian B. Looney was submitted to the WM2016 Conference which will be held March 6 - 10, 2016 at the Phoenix Convention Center in Phoenix, AZ.
- An abstract entitled, "Integrated Modeling System for Analysis of Watershed Water Balance: A Case Study in the Tims Branch Watershed, Aiken, South Carolina," by Mehrnoosh Mahmoudi, Shimelis, Angelique Lawrence, and Natalia Duque was also submitted to the 2015 American Geophysical Union (AGU) Fall Meeting to be held in San Francisco, CA on 14-18 December, 2015.

Task 3: Sustainability Plan for the A/M Area Groundwater Remediation System

Task 3 Overview

This research is conducted in support of EM-13 (Office of D&D and Facilities Engineering) under the direction of Mr. Albes Gaona. FIU will develop a set of proposed actions for the existing infrastructure of the groundwater remediation system that will reduce the environmental burden of the A/M Area groundwater remediation system. Reducing the duration of operation for the treatment system as well as replacing old, inefficient components are preliminary recommendations of these studies. The A/M Area groundwater remediation system has operated continuously for 27 years and is expected to operate continuously for the foreseeable future. Improvements in system performance, increased contaminant recovery, or decreased energy consumption, will have positive enduring benefits due to the long time frame over which the benefits will accrue. This work will directly support the EM-12/EM-13 Sustainable Remediation (SR) program and will be executed in coordination with the SR program lead. The effort is also referred to as "Green and Sustainable Remediation (GSR)" or "Green Remediation" in the literature and in various implemented programs.

Task 3 Quarterly Progress

Subtask 3.1: Analyze Baseline.

- A draft technical report for the Green and Sustainable Remediation task entitled "Green and Sustainable Remediation Options for the M Area Groundwater Remediation System at DOE Savannah River Site", was completed and submitted on 7/27/15 for internal FIU review. The report was also submitted to Albes Gaona, DOE EM and SRNL scientists on 7/29/15 for comments prior to final submittal to DOE EM by the 7/31/15 milestone due date. The report compiles research completed to date and presents it in relation to its significance for the upcoming GSR analyses of the groundwater remediation system. Future work describes the development of a GSR analysis for the current stripper alone by December 2015 and a second GSR analysis that incorporates monitored natural attenuation (MNA) to reduce the size and load of the current remediation system (i.e., reduction or elimination of the recovery wells, volume of water pumped, size of the air stripper system).
- Modifications were made to the draft technical report based on feedback received from SRNL and DOE-HQ (EM-13). The report was then resubmitted to DOE and SRNL.
- The annual report for the GSR task was completed by its due date of 8/28/15. This report includes all data, work, published papers, etc. developed on this task over the May 2014 – Aug. 2015 timeframe, as well as summary information on all earlier work done on this task (2013-2014).
- An abstract on the research and engineering analysis results of this GSR task has been prepared for the 2016 Waste Management Conference and was submitted in August.
- DOE Fellow, Yoel Rotterman, visited SRS and was directed by Ralph Nichols to get some of the data/documents required for the GSR analysis, however, it was determined that a major portion of the data required for analysis of the operations & performance was collected by another agency (ACP), who will have to be contacted for further information. Other issues to be addressed include the planned development of a GSR analysis for the current stripper alone by December 2015 and a second GSR analysis that incorporates monitored natural attenuation (MNA) to reduce the size and load of the current remediation system (i.e., reduction or elimination of the recovery wells, volume of water pumped, size of the air stripper system).
- Consideration is also being given to visiting the site to get measurements from the air stripper such as the flow rate of the pumps, dimensions of the tower, the characteristics of the packing material, voltage of the pumps and/or air stripper, etc. There has also been some discussion regarding the inclusion of a modeling component, however nothing definitive has been decided.
- An abstract entitled, "Green and Sustainable Remediation Analysis of a Packed Tower Air Stripper Used to Remediate Groundwater Contaminated with CVOCs" by David Roelant, Yoel Rotterman (DOE Fellow), and Ralph Nichols was submitted to the WM2016 Conference which will be held March 6 - 10, 2016 at the Phoenix Convention Center in Phoenix, AZ.
- DOE Fellow Yoel Rotterman, under the mentorship of Albes Gaona and Beth Moore during his summer 2015 internship at DOE HQ in Washington, D.C., also submitted an

abstract to the WM2016 Conference professional track entitled, "DOE Climate Change Vulnerability and Adaptation Planning," based on his internship which focused on conducting a climate change vulnerability assessment involving 3 case studies.

Milestones and Deliverables

The milestones and deliverables for Project 3 for FIU Year 5 are shown on the following table. The following deliverables were submitted: Technical Report for Task 1 "Modeling of the migration and distribution of NOM injected into subsurface systems," submitted 7/6/15; Technical Report for Task 2 "Surface Water Modeling of Tims Branch," submitted 7/17/15; Technical Report for Task 3 "Sustainability Plan for the A/M Area Groundwater Remediation System," submitted 7/31/15.

FIU Year 5 Milestones and Deliverables for Project 3

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Task 1: Modeling of the migration and distribution of NOM injected into subsurface systems	2014-P3-M1	Completion of work plan for experimental column studies (Subtask 1.1)	9/30/14	Complete	
	Deliverable	Work plan for experimental column studies (Subtask 1.1)	9/30/14	Complete	
	Deliverable	Technical Report for Task 1	6/03/15 Reforecast to 7/6/15	Complete	
Task 2: Surface Water Modeling of Tims Branch	2014-P3-M2	Completion of literature review (Subtask 2.2)	12/30/14 Reforecast to 3/31/15	Complete	
	Deliverable	Literature review summary (Subtask 2.2)	12/30/14 Reforecast to 03/31/15	Complete	
	2014-P3-M3	Development of preliminary site conceptual model of Tims Branch (Subtask 2.2)	12/30/14 Reforecast to 03/31/15	Complete	
	Deliverable	Technical Report for Task 2	6/10/15 Reforecast to 7/17/15	Complete	
Task 3: Sustainability Plan for the A/M Area Groundwater Remediation System	2014-P3-M4	Completion of Baseline Analysis (Subtask 3.1)	2/27/15	Complete	
	Deliverable	Baseline analysis summary (Subtask 3.1)	2/27/15	Complete	
	Deliverable	Technical Report for Task 3	6/17/15 Reforecast to 7/31/15	Complete	
Project-wide	Deliverable	Draft Project Technical Plan	6/18/14	Complete	

	Deliverable	Two (2) abstract submissions to WM15	8/15/14	Complete	
	2014-P3-M5	SRS site visit and meeting	8/5/14	Complete	
	2014-P3-M6	Meeting and presentation of project progress at SRS	3/18/15 Reforecast to 4/13/15	Complete	

Work Plan for Next Quarter

The work plan for the next quarter is presented under the section entitled, "FIU Year 6 Project 2 – Environmental Remediation Science and Technology."

FIU Year 6 Project 2
Environmental Remediation Science and Technology

Project Description

This section presents the new combined Project 2 information for FIU Year 6 (September 2015).

This project will be conducted in close collaboration between FIU, Hanford Site, SRS, and LANL scientists in order to plan and execute research that supports the resolution of critical science and engineering needs, leading to a better understanding of the long-term behavior of contaminants in the subsurface. Research involves novel analytical methods and microscopy techniques for characterization of various mineral and microbial samples. Tasks include studies which predict the behavior and fate of radionuclides that can potentially contaminate the groundwater system in the Hanford Site 200 Area; laboratory batch and column experiments, which provide relevant data for modeling of the migration and distribution of natural organic matter injected into subsurface systems in the SRS F/H Area; laboratory experiments investigating the behavior of the actinide elements in high ionic strength systems relevant to the Waste Isolation Pilot Plant; surface water modeling of Tims Branch at SRS supported by the application of GIS technology for storage and geoprocessing of spatial and temporal data; and support for the DOE EM student challenge.

The following tasks are included in FIU Year 6:

- Task 1: Remediation Research and Technical Support for the Hanford Site
    - Subtask 1.1 - Sequestering uranium at the Hanford 200 Area vadose zone by in situ subsurface pH manipulation using NH_3 gas
    - Subtask 1.2 - Investigation of microbial-meta-autunite interactions - effect of bicarbonate and calcium ions
    - Subtask 1.3 - Evaluation of ammonia fate and biological contributions during and after ammonia injection for uranium treatment
- Task 2: Remediation Research and Technical Support for the Savannah River Site
    - Subtask 2.1 – FIU's support for groundwater remediation at SRS F/H Area
    - Subtask 2.2 – Monitoring of U(VI) bioreduction after ARCADIS demonstration at the SRS F-Area
    - Subtask 2.3 – Humic acid batch sorption experiments into the SRS soil
    - Subtask 2.4 – The synergetic effect of HA and Si on the removal of U(VI)
    - Subtask 2.5 – Investigation of the migration and distribution of natural organic matter injected into subsurface systems
- Task 3: Surface Water Modeling of Tims Branch
    - Subtask 3.1 – Modeling of surface water and sediment transport in the Tims Branch ecosystem
    - Subtask 3.2 – Application of GIS technologies for hydrological modeling support
    - Subtask 3.3 – Biota, biofilm, water and sediment sampling in Tims Branch
- Task 4: Sustainability Plan for the A/M Area Groundwater Remediation System
    - Subtask 4.1 – Sustainable Remediation Analysis of the M1 Air Stripper

- Subtask 4.2 – Sustainable Remediation Support to DOE EM Student Challenge
- Task 5: Remediation Research and Technical Support for WIPP

Task 1: Remediation Research and Technical Support for the Hanford Site

Task 1 Overview

The radioactive contamination at the Hanford Site created plumes that threaten groundwater quality due to potential downward migration through the unsaturated vadose zone. FIU is supporting basic research into the sequestration of radionuclides such as uranium in the vadose zone, which is more cost effective than groundwater remediation. One technology under consideration to control U(VI) mobility in the Hanford vadose zone is a manipulation of sediment pH via ammonia gas injection to create alkaline conditions in the uranium-contaminated sediment. Another technology need for the ammonia remediation method is to investigate the potential biological and physical mechanisms associated with the fate of ammonia after injection into the unsaturated subsurface. Tripolyphosphate injections are another method being considered to decrease the concentration of soluble uranium in contaminated plumes at the Hanford Site.

Task 1 Quarterly Progress – August 28-September 30, 2015

Subtask 1.1. Sequestering Uranium at the Hanford 200 Area Vadose Zone by In Situ Subsurface pH Manipulation Using NH_3 Gas

During month of September, FIU continued solubility studies of U-bearing samples via the isopiestic method. Eight multicomponent samples of 10 mL, composed of Si-Al-Ca-HCO_3 and 2 ppm of U(VI), have been prepared in tarred crucibles and after drying at 35°C were placed in the isopiestic chamber. In addition, two 10 mL samples of 100 mM of sodium silicate were prepared and placed in the isopiestic chamber after drying. Two standards (sodium chloride and calcium chloride) are being using to evaluate the water activity and osmotic coefficient of the samples. For the last three measurements to weigh the samples when the system reached equilibrium, all calculations were based on the parameters of $CaCl_2$. The molality of sodium chloride is still too high to obtain its osmotic coefficient values. The chamber was sealed, degassed and left at 25°C in the environmental chamber. During this reporting period, the isopiestic chamber was opened three times to weigh the samples when the system reached equilibrium and to calculate the values for osmotic coefficients and water activities. The percent of water lost during the weighing process was in the range of 3.5-5%. Since the molality of the sodium chloride standard was too high to obtain osmotic coefficient values and calculate water activities, the difference between water activity values for both standards was not calculated. However, after a slow increase in moisture content in the chamber, we anticipate that the molality of sodium chloride for the next measurements will be in the range of the literature data to obtain osmotic coefficient values.

Having completed the submission of the Environmental Molecular Sciences Laboratory (EMSL) proposal, sample preparation for the proposed experiments was started. This began with the modification of the calculations for sample solution preparation to meet the parameters of the experiment. Those changes include a wider range of test concentrations being used for optimization purposes during preliminary analysis. Samples are also being prepared in duplicate in order to evaluate the effect of a DI-water rinse step being considered for the procedure. Once sample preparation is complete, initial analysis will continue with preliminary SEM-EDS analysis of the dried precipitates. In addition, the abstract #16600 titled, "Characterization of U(VI)-Bearing Precipitates Produced by Ammonia Gas Injection Technology," submitted by DOE Fellow Robert Lapierre to the Waste Management 2016 Symposia was accepted for the Oral Session 081 - Complex Site Characterization and Remediation Technologies. FIU will start working on the development of the draft proceeding paper, which is due on November 6, 2015.

DOE Fellow Claudia Cardona, after returning from her summer internship at PNNL, began development of her internship technical report.

In FIU Year 6, the research will continue the isopiestic measurements initiated in FIU Year 5 using U-bearing precipitates. The isopiestic method is considered as one of the most accurate methods for the solubility determinations. In addition, U(VI) release will be evaluated via flow-through experiments. Experiments will also continue for the characterization of uranium-bearing solid phases.

Subtask 1.2. Investigation on Microbial-Meta-Autunite Interactions - Effect of Bicarbonate and Calcium Ions

During month of September, FIU initiated analysis of the collected samples to determine the uranium concentration by means of KPA. Prior to analysis, the samples were ashed to remove the organic content by flowing dry ash and wet procedures. For wet ashing, an aliquot of 200 µL was taken from the sample and transferred to a clear 20-mL glass scintillation vial and 0.5 mL of concentrated nitric acid (67%) and 0.5 mL of peroxide were introduced to the sample. An additional 0.1 mL of nitric acid and 0.1 mL of peroxide was periodically added to the scintillation vials placed on the hot plate until a white residue was obtained. Consequently, after wet ashing was completed, the samples were placed in the furnace at 450^{o} C for 15 min (dry ashing). Then, following cooling, the white residue was diluted using 2 M nitric acid and further dilutions took place wherever appropriate, with 1% nitric acid. In the samples amended with 0 mM bicarbonate, the final dilution factor in the samples collected before inoculation was 1:50; after inoculation, the final dilution factor was 1:20. In the samples containing 3 mM of bicarbonate, the dilution factor was 1:50 before and after inoculation. Finally, for samples amended with 10 mM bicarbonate, the dilution factor was 1:200, both before and after inoculation.

The bicarbonate-free samples have been analyzed with KPA. Figure 2-1 presents the uranium concentration in the aqueous phase as a function of time, for biotic (bacteria inoculated) samples, as well as abiotic samples (samples containing only autunite in bicarbonate-free media solution).

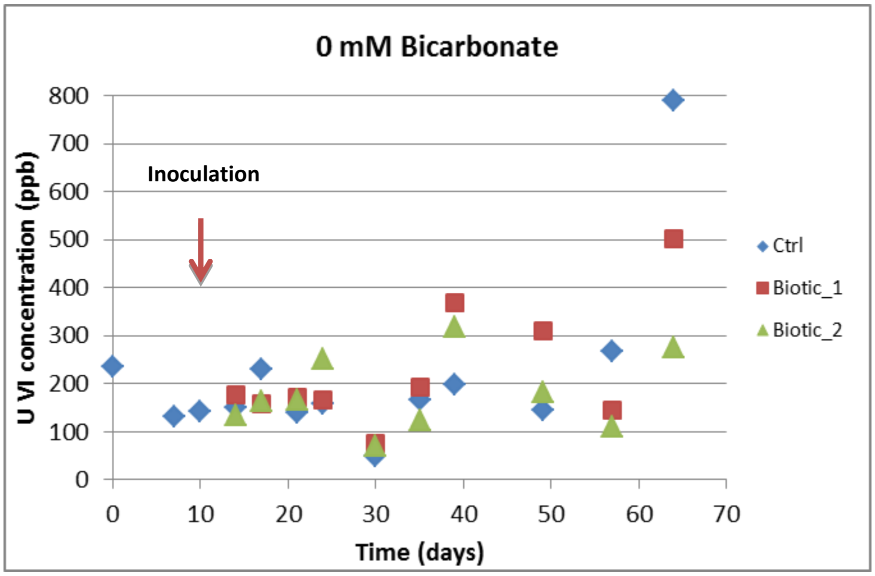


Figure 2-1. U(VI) concentration as a function of time for control (abiotic) samples taken before bacteria inoculation and biotic samples after bacteria inoculation for 0 mM of bicarbonate.

Figure 2.2 below represents the average concentration of the biotic duplicates and conserves the control.

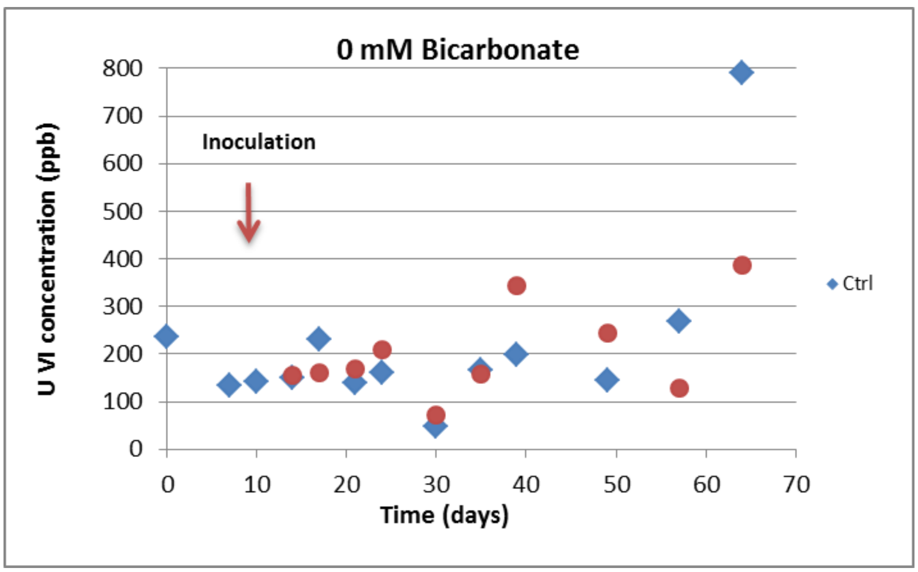


Figure 2-2. U(VI) concentration as a function of time for control (abiotic) samples and biotic samples. In biotic samples the average value of the duplicate samples is presented.

Currently, samples for the rest of the conditions are being analyzed (3 and 10 mM bicarbonate amended samples) by means of KPA. Furthermore, a repetition of some samples is also under consideration.

Other activities during this reporting period included development of the Project Technical Plan. In FIU Year 6, the research will continue to study the effect of a designed bacterial consortium and/or a microbial culture enriched from core samples collected from the 200 Area on the autunite minerals bio-dissolution process and reduction of released U(VI) in the presence of bicarbonate ions. The role of subsurface facultative microorganisms or the microbial consortium to impact the stability of the autunite mineral created in sediments as a result of tripolyphosphate injections to sequester uranium (VI) in the subsurface has not been considered in the past.

Based on the results of these experiments, FIU submitted an abstract by Sandra Herrera-Landaez (DOE Fellow), Vasileios A. Anagnostopoulos, Yelena P. Katsenovich, Brady Lee, and Michelle Lee titled, "The effect of bicarbonate on autunite dissolution in the presence of *Shewanella oneidensis* under oxygen restricted conditions," to the WM16 Symposia to be held on March 6 – 10, 2016 in Phoenix, Arizona. This abstract was accepted for the oral session 010 - Groundwater Remediation Projects. The project team will start working on the draft paper, which is due November 6, 2015.

<u>Subtask 1.3. Evaluation of Ammonia Fate and Biological Contributions During and After Ammonia Injection for Uranium Treatment</u>

At the Hanford Site, the mobility of uranium in groundwater is high due to the natural presence of carbonates. Subtask 1.3.1 is investigating mechanisms that may lead to stabilization of uranium within the subsurface by ammonia gas injection. This study investigates how pH, ionic strength and ammonia affect uranium adsorption/desorption and mineral dissolution processes. During the month of September, batch equilibrium experiments were instigated and the Project Technical Plan was developed for the new fiscal year.

The objective of the FIU Year 6 scope is to understand ammonia and uranium partitioning in synthetic porewaters and pure minerals relevant to the Hanford Site. Initial experiments discussed below will investigate whether the uranium sorption/complexation/precipitation and mineral dissolution/precipitation processes are solely a function of pH changes or if the presence of ammonia has an additional impact. This is to be accomplished through batch sorption experiments with pH adjustments from pH 7.5 to 11.5 through either the addition of NaOH or NH_4OH.

Experiments were begun during the month of September. Twelve samples were prepared with Ottawa sand (six with ~25 g/L 'Trial #1' and six with ~100 g/L 'Trial #2'). Ottawa sand was chosen as it is primarily quartz (SiO_2). This emulates the Harford Site as it is the major mineral present in the subsurface (30-80% of the bulk fraction).

Initial samples were prepared at an ionic strength of 0.008 M NaCl (similar to Hanford groundwater). The pH was adjusted to ~7.5 with 0.1 M NaOH and spiked with 20 µL of 1000 ppm uranium trioxide in 3% HNO_3 for a final U concentration of ~500 ppb. For Trial #1 samples with a 25 g/L sand concentration, the pH was adjusted to ~11.5 by either 2.5 M NaOH or 2.5 M NH_4OH following equilibration at pH ~7.5. The first set of samples with a 25 g/L sand concentration are currently awaiting NH_3 and U analysis and the second set of samples are not yet completed. Si analysis has been completed on the first set of samples and the data is discussed in the 'Lessons Learned' section below.

In addition, standards were prepared for NH_3 (by electrode) and Si (by ICP-OES). Silicon standards were prepared ranging from 10 ppb to 10,000 ppb in 1% HNO_3. NH_3 standards were prepared by serial dilution from 0.1 to 100 ppm in DDI H_2O. U standards were prepared previously from the 1000 ppm stock used for preparation of batch samples.

Lessons Learned:

1. When ICP-OES was run, Si was not detected in the more dilute standards (10 ppb and 25 ppb) due to the high natural background of Si. New standards will be prepared in Plasma

Grade H_2O for comparison and all inlet tubings will be replaced. The limit of detection (LOD) for the calibration was 235 ppb with an R^2 of 0.9997. Standards will be prepared from 200 ppb to 10,000 ppb unless replacing the inlet tubes can decrease background.

2. For silica to be detected in the aqueous phase and in range of the calibration curve, a higher solids concentration was implemented following Trial #1. Significant dissolution of the quartz is expected at high pH. However, only two of the Trial #1 post pH adjustment samples were above detection limits. Therefore, the Ottawa sand concentration was increased from ~1.00g [25 g/L] (Trial #1) to ~4.00g [100 g/L] (Trial #2).
3. pH values fluctuate easily, especially in the initial low ionic strength conditions. Repetitive pH electrode readings and frequent mixing are recommended.

Task 2: Remediation Research and Technical Support for Savannah River Site

Task 2 Overview

The acidic nature of the historic waste solutions received by the F/H Area seepage basins caused the mobilization of metals and radionuclides, resulting in contaminated groundwater plumes. FIU is performing basic research for the identification of alternative alkaline solutions that can amend the pH and not exhibit significant limitations, including a base solution of dissolved silica and the application of humic substances. Another line of research is focusing on the evaluation of microcosms mimicking the enhanced anaerobic reductive precipitation (EARP) remediation method previously tested at SRS F/H Area.

Task 2 Quarterly Progress – August 28-September 30, 2015

Subtask 2.1. FIU's Support for Groundwater Remediation at SRS F/H –Area

A two-step filtration process has been employed in all previous experiments in order to identify whether uranium in the aqueous phase is associated with colloidal particles of different size. SEM-EDS analysis was used to explore the morphology and elemental composition of colloidal particles retained by the filter. In the PTP prepared for FIU Year 6, all procedures and concentrations will remain consistent with the previous experiment with the exception of the uranium (VI) concentration. In the previous experiment, a concentration of 0.5 ppm of uranium was used; however, this initial concentration was not sufficient in order to detect uranium on the filters via EDS analysis. Therefore, the concentration of uranium was artificially increased to 100 ppm. Batch experiments were carried out for a period of three days, followed by filtration and drying of the filters in an incubator at 30^oC for 96 hours. The filters will be analyzed by means of SEM/EDS in the Florida Center for Analytical Microscopy at FIU Modesto Maidique Campus.

The development of the summer internship report was completed by DOE Fellow Christine Wipfli. The report summarizes her tasks and projects during her summer internship at DOE EM headquarters in Germantown, MD. The report includes four case studies that were drafted over the summer with collaboration from EM headquarters mentors and the Interstate Technology and Regulatory Council (ITRC) subgroup. ITRC is an organization of individuals from the public and private sector that create documentation for informational or training purposes supporting the use of innovative technologies that help create a cleaner, more sustainable environment. The case studies explore the remediation strategies utilized at complex sites that proved over time to be effective. In sharing these case studies, the hope is that individuals across the industry will be informed about innovative remediation techniques that proved successful, as well as provide examples to other complex sites with similar conditions where these strategies may also prove successful. The report is in the review stage and awaiting final approval from the DOE sites represented in the case studies.

Finally, during the month of September, a poster presentation was prepared for the DOE Fellows Poster competition that is going to be held at the FIU Applied Research Center on October 21. The poster summarizes the major experimental findings of subtask 2.1 and also highlights some of the main future goals of the experiments.

Subtask 2.2. Monitoring of U(VI) Bioreduction after ARCADIS Demonstration at F-Area

The objectives of this subtask for FIU Year 6 are to conduct thermodynamic speciation modeling for the conditions pertaining to the low alkaline SRS acidic soil augmented with molasses and sulfate to predict the possibility of siderite and pyrite mineral formation. The results of the modeling can also indicate the applicability of this technology for the low alkaline conditions. FIU is in the process of analyzing sulfate via ion chromatography (IC). However, the results are not available yet.

DOE Fellow Aref Shehadeh completed his internship report entitled, “Optimizing Remediation of I-129 using AgCl Colloidal-Sized Particles in SRS F-Area Sediments,” for the experimental work he conducted under the summer internship mentor Dr. Miles Denham (SRNL). Silver chloride (AgCl) is currently being used at the SRS F-Area for the *in situ* remediation of the radioactive iodine-129 (I-129) plume, which has progressed from a series of unlined seepage basins.

Subtask 2.3: Sorption Properties of Humate Injected into the Subsurface System

For FIU Year 6, the batch experiments to investigate the HumaK desorption behavior will be extended in order to evaluate if the sorption of HumaK onto SRS sediments is a fully reversible process. This will be addressed by evaluating the kinetics of desorption experiments and investigate the effect of different pH values in the presence of salts such as $NaNO_3$. During the month of September, FIU initiated kinetics desorption experiments. The experiments started by weighing 1 g of SRS sediments in different centrifuge tubes. A known concentration of HumaK (500 ppm) was pipetted into the tubes, and the pH was adjusted to 4. The final volume in each tube was adjusted to 20 ml. The samples were left on the shaker for five days to be able to reach equilibrium for the adsorption process; this amount of time was previously determined in the adsorption kinetic experiment. After the fifth day, the samples were withdrawn, and the supernatant of the samples was removed and replaced by DI water with the pH adjusted to the same level (pH = 4). The pH of the samples was measured and adjusted daily to pH 4. At predetermined time intervals, samples were withdrawn and centrifuged. The concentration of the supernatant was measured by UV-vis spectrophotometer. This experiment will be completed next month. Also, DOE Fellow Hansell Gonzalez reviewed and collected all of the information necessary to prepare a poster for the DOE Fellows Poster Exhibition which will take place on October 21, 2105. The development of a poster that contains the results on the characterization of SRS sediments and Huma-K by using scanning electron microscopy, fourier transform infrared spectroscopy, and potentiometric titrations was completed during this month.

Subtask 2.4. The Synergistic Effect of HA and Si on the Removal of U(VI)

During the reporting period, unfiltered samples from batches 1, 4, and 7 containing uranium, colloidal silica and/or sediment with no humic acid were analyzed using the KPA instrument.

The data obtained will be compared to previously analyzed samples containing humic acid. Table 2-1 shows the batches and their corresponding constituents.

Table 2-1. Batch Constituents

pH # Adjusted Set	*Constituents*				
	SiO_2	Humic Acid (HA)	Sediments	Uranium U(VI)	Total Volume
	mL	mL	mg	mL	mL
Batch No. 1	2.1	0		0.01	20
Batch No. 2	2.1	10		0.01	20
Batch No. 3	0	10		0.01	20
Batch No. 4	2.1	0	400	0.01	20
Batch No. 5	2.1	10	400	0.01	20
Batch No. 6	0	10	400	0.01	20
Batch No. 7	0	0	400	0.01	20

Batches 1, 4, and 7 at pH 3 provided inconclusive data and the samples will be re-prepared and re-analyzed. Batch 1 showed a decreasing trend starting at 60.90% removal at pH 4 to 20.97% removal at pH 8. Batch 4 also gave a decreasing trend to a lesser degree, beginning at 74.40% removal at pH 4 and 57.72% removal at pH 8. Unlike batches 1 and 4, batch 7 had a maximum removal at pH 5 (93.98%) then decreased to 65.93% at pH 8; further clarity of the trends will be seen once the pH 3 samples are included in the results.

Preliminary analysis indicates that batch 7 yielded the highest removal among the samples, with U(VI) being able to bind to the sediment with no competition from other constituents; unlike batch 4, which contains U(VI), sediment and silica and yielded less removal. It might be that some of the U(VI) is adsorbed to the colloidal Si and cannot be measured without sample filtration. Batch 1, which only contained silica, showed significantly less removal than both batches 4 and 7. In this case, any removal would be due to silica aggregation or coagulation and positive uranyl ions present in the solution at pH 4 can interact with the negatively charged silica surface.

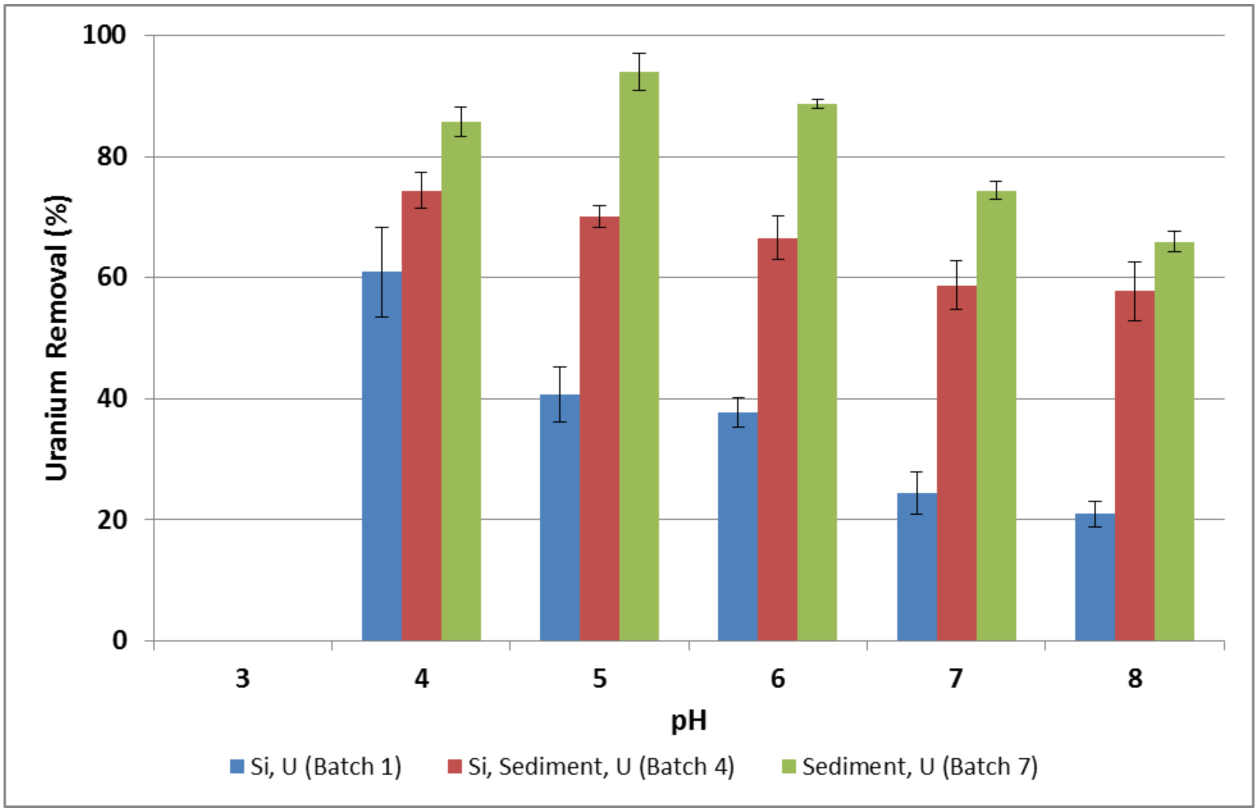


Figure 2-3. Uranium removal for unfiltered samples for batches 1, 4, and 7.

Subtask 2.5. Investigation of the Migration and Distribution of Natural Organic Matter Injected into Subsurface Systems

The work completed for this task will assemble, integrate, and develop a practical and implementable approach to quantify and simulate potential natural organic matter (NOM, such as humic and fulvic acids, humate, etc.) deployment scenarios over the range of conditions at DOE sites. Initial laboratory experiments and an initial set of simplified models have been developed at SRNL. Under this task, additional batch and column studies and testing will be conducted at FIU to provide the transport parameters for an extension of the current model scenarios.

- This month was focused on detailing the scope of work for this task in the Project Technical Plan. Based on discussion with Miles Denham and Brian Looney, experimental analyses on the sediment from Column 1 (pH 3.5) & Column 2 (pH 5) will be conducted.
- The plan for October will be to dismantle and drain the columns to extract the sediment samples to be analyzed using SEM and possibly a TOC analyzer.

Task 3: Surface Water Modeling of Tims Branch

Task 3 Overview

This task will perform modeling of surface water, and solute/sediment transport specifically for mercury and tin in Tims Branch at the Savannah River Site (SRS). This site has been impacted by 60 years of anthropogenic events associated with discharges from process and laboratory facilities. Tims Branch provides a unique opportunity to study complex systems science in a full-scale ecosystem that has experienced controlled step changes in boundary conditions. The task effort includes developing and testing a full ecosystem model for a relatively well defined system in which all of the local mercury inputs were effectively eliminated via two remediation actions (2000 and 2007). Further, discharge of inorganic tin (as small micro-particles and nanoparticles) was initiated in 2007 as a step function with high quality records on the quantity and timing of the release. The principal objectives are to apply geographical information systems and stream/ecosystem modeling tools to the Tims Branch system to examine the response of the system to historical discharges and environmental management remediation actions.

<u>Task 3 Quarterly Progress – August 28-September 30, 2015</u>

Subtask 3.1. Modeling of Surface Water and Sediment Transport in the Tims Branch Ecosystem

- A literature review is being conducted on similar type watershed models developed using MIKE SHE/MIKE 11.
- A review is also being conducted on previous hydrology modeling efforts at SRS.
- Updated GIS data is being incorporated into the model after preprocessing the downloaded data.
- DOE Fellows are being trained by their FIU-ARC mentors on GIS and hydrological modeling software applications (ArcGIS & MIKE SHE/11) to support the project's research activities. They are also applying their knowledge to develop posters and presentations for relevant conferences such as the Waste Management Symposium (March 6-10, 2016) and the FIU McNair Scholars Research Conference (Oct 14-16, 2015).

Subtask 3.2. Application of GIS Technologies for Hydrological Modeling Support

- Land cover data was downloaded from the National Land Cover Database (NLCD) as well as the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database in order to provide updated vegetation/land cover and soil shapefiles for the revised model domain.
- The downloaded GIS data was clipped to the revised model domain and projected to the correct Universal Transverse Mercator (UTM) coordinate system. The relevant attributes and metadata with parameters required for model development were then appended to the new shapefiles. This process was necessary to prepare the raw data for incorporation into the MIKE SHE model being developed.

Subtask 3.3. Biota, Biofilm, Water and Sediment Sampling in Tims Branch

- The proposed work outlined in the Project Technical Plan for this task was approved by Brian Looney (SRNL) and John Seaman (SREL). A new ISCO system is being purchased by SREL for the sediment sampling effort they have planned between September-October in Tims Branch/Steed Pond. This unit will be equipped with a velocity meter and geochemical probes. A request was made by FIU for some additional water and sediment samples to be collected for Sn analysis and to acquire additional data parameters that could be used for the Tims Branch modeling effort.

Task 4: Sustainability Plan for the A/M Area Groundwater Remediation System

<u>Task 4 Overview</u>

The research and analysis performed under this task is being performed to support DOE EM-13 (Office of D&D and Facilities Engineering) under the direction of Mr. Albes Gaona, program lead for DOE's Sustainable Remediation Program.

Subtask 4.1. Sustainable Remediation Analysis of the M1 Air Stripper

- During FIU Year 6, FIU will work with SRNL and DOE EM-13 to complete an engineering analysis of the M1 air stripper's components and operation, and make recommendations for more sustainable alternatives. FIU is proposing to develop a set of actions for the existing infrastructure of the groundwater remediation system that will reduce the environmental burden of the A/M Area groundwater remediation system while potentially reducing the duration of operation for the treatment system.

Subtask 4.2. Sustainable Remediation Support to DOE EM Student Challenge

- Also during FIU Year 6, FIU will use the lessons learned and sustainability expertise gained during FIU Year 5 under this project to provide guidance and support to the new Task 11 (DOE EM Student Challenge) under Project 4 (FIU-DOE Science and Technology Workforce Development Program). The DOE EM Student Challenge is the natural extension to the previous sustainable remediation analysis of SRS's A/M Area Groundwater Remediation System. Sustainability principles will be an integral part of the Challenge teams' technical solutions to the problem set being studied.

Task 5: Remediation Research and Technical Support for WIPP

<u>Task 5 Overview</u>

This new task is in collaboration with research scientist Donald Reed in support of Los Alamos National Laboratory's field office in Carlsbad, New Mexico. This research center has been tasked with conducting experiments in the laboratory to better understand the science behind deep geologic repositories for the disposal of nuclear waste. The majority of their work is conducted in high ionic strength systems relevant to the Waste Isolation Pilot Plant (WIPP) located nearby. WIPP is currently the only licensed repository for the disposal of defense waste in the world. However, the facility is not currently operating, following an airborne release from a waste drum which failed to contain waste following an exothermic reaction of the waste. This was due to incompatibility of mixed waste received from LANL (organic adsorbent mixed with nitrate salt waste). Although off-site releases of $^{239/240}Pu$ and ^{241}Am were detected slightly above background, they were still below levels deemed unsafe to the public. FIU-ARC is now initiating a new task to support basic research efforts requested to update risk assessments for the WIPP site.

The objective of this task is to support LANL researchers in the basic science research required to address concerns in risk assessment models for the re-opening of the WIPP site for acceptance of defense waste.

Task 5 Quarterly Progress – August 28-September 30, 2015

- FIU is working closely with Donald Reed at Los Alamos National Lab (LANL) to refine the scope of work for this task in order to provide environmental remediation research via laboratory experiments. Potential areas of research under discussion include: (1) solubility of the actinides at high temperature (30, 60, and 90°C) in the presence of ligands, and (2) K_d coefficients for actinides under WIPP relevant conditions using batch and/or column experiments and (3) investigate microbial interactions with actinides in high ionic strength systems.

Milestones and Deliverables

The milestones and deliverables for Project 2 for FIU Year 6 are shown on the following table. A draft Project Technical Plan was developed which includes the scope of work intended for FIU Year 6 on all five tasks. No other milestones or deliverables were due for this project during September.

FIU Year 6 Milestones and Deliverables for Project 2

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Project	2015-P2-M1	Submit draft papers to Waste Management 2016 Symposium	11/6/2015	On Target	
Task 1: Hanford Site	Deliverable	Progress report on the experimental results on autunite mineral biodissolution (Subtask 1.2)	2/15/2016	On Target	OSTI
	Deliverable	Progress report on batch experiments for ammonia injection task (Subtask 1.3.1)	6/22/2016	On Target	OSTI
	Deliverable	Literature Review of Geophysical Resistivity Measurements and Microbial Communities (Subtask 1.3.3)	3/18/2016	On Target	
Task 2: SRS	Deliverable	Progress report on batch experiments on sodium silicate application in multi-contaminant systems (Subtask 2.1)	4/11/2016	On Target	OSTI
	Deliverable	Progress report on the synergy between colloidal Si and HA on the removal of U(VI) (Subtask 2.4)	4/21/2016	On Target	OSTI
	Deliverable	Progress report on column experiments to investigate uranium mobility in the presence of HA (Subtask 2.5)	5/20/2016	On Target	OSTI
Task 3: Tims Branch	2015-P2-M2	Complete refinement of MIKE SHE model configuration parameters for the simulation of overland flow using revised model	12/30/2015	On Target	

		domain (Subtask 3.1)			
	2015-P2-M3	Complete input of MIKE SHE model configuration parameters for simulation of evapotranspiration (Subtask 3.1)	2/29/2016	On Target	
	2015-P2-M4	Complete input of MIKE SHE model configuration parameters for simulation of unsaturated flow (Subtask 3.1)	3/31/2016	On Target	
	Deliverable	Progress Report for Subtask 3.1: Modeling of surface water and sediment transport in the Tims Branch ecosystem	4/29/2016	On Target	OSTI
	Deliverable	Progress Report for Subtask 3.2: Application of GIS technologies for hydrological modeling support	4/29/2016	On Target	OSTI
	2015-P2-M5	Complete input of MIKE SHE model configuration parameters for simulation of flow in the saturated zone (Subtask 3.1)	6/30/2016	On Target	
Task 4: Sustainability Plan	Deliverable	Draft sustainable remediation report for the M1 air stripper	12/18/2015	On Target	OSTI

Work Plan for Next Quarter

Task 1: Remediation Research and Technical Support for the Hanford Site

Subtask 1.1 – Sequestering Uranium at the Hanford 200 Area Vadose Zone by in situ Subsurface pH Manipulation using NH_3 Gas

- Continue with isopiestic measurements.
- Prepare new samples for 100mM sodium silicate and re-prepare NaCl standard in another cup due to cup's rusting.
- Set up flow –through experiment to investigate for solid phase's dissolution.
- Complete preparation of new samples followed by initial solid and liquid phase analysis by SEM/EDS and KPA, respectively. The results of this initial analysis will determine the methods used for continued characterization attempts, which may include XRD, EMPA, and/or TEM analysis
- Complete proceedings paper for WM-2016

Subtask 1.2. Investigation on Microbial-Meta-Autunite Interactions - Effect of Bicarbonate and Calcium Ions

- Determination of Ca and P concentrations in the samples by means of ICP-OES
- Perform protein analysis (bicinchoninc acid assay) by means of UV-vis spectroscopy
- Analyze autunite samples exposed to bacterial presence by means of SEM/EDS.

- Complete proceedings paper for the WM-2016

Subtask 1.3. Evaluation of Ammonia Fate and Biological Contributions During and After Ammonia Injection for Uranium Treatment

- The batch sorption experiments will continue to be optimized to understand sorption of U and NH_3 under conditions relevant to the Hanford Site based on the lessons learned.
- Speciation modeling will be completed for comparison with the experimental results.
- Statistical analysis will be used to compare the samples that had pH adjusted by NaOH versus by NH_4OH (t-test).

Task 2: Remediation Research and Technical Support for Savannah River Site

Subtask 2.1. FIU's Support for Groundwater Remediation at SRS F/H –Area

- Perform kinetic experiments on the retention of U(VI) by SRS F/H area soil after sodium silicate amendment (restoration of circumenutral conditions)
- Perform batch comparison experiments in sodium silicate amended samples containing SRS F/H area soil, as well as pure minerals (quartz and kaolinite)
- Assess the longevity of the remediation methods (sodium silicate amendment) in batch experiments

Subtask 2.2 – Monitoring of U(VI) Bioreduction after ARCADIS Demonstration at F-Area

- Conduct Minteq speciation modeling to confirm the results from the batch experiment and to determine in which conditions the iron precipitates would likely form.
- Finalize sulfate analysis via ion chromatography on the supernatant solutions collected from the microcosm tubes, which were augmented with the 500 ppm sulfate.

Subtask 2.3.Sorption Properties of the Humate Injected into the Subsurface System

- Perform desorption experiment of HumaK sorbed onto SRS sediments at different pH values (4-8).
- Study the effects of salts ($NaNO_3$) on desorption of HumaK.

Subtask 2.4 – The synergetic effect of HA and Si on the removal of U(VI)

- Analyze samples for batches 1, 4 and 7 via ICP-OES to determine the concentrations of silica and iron; process the data and report the findings.
- Initiate experiments with 30 ppm of HA.
- Initiate sediment samples analysis via SEM/EDS
- Complete draft technical paper for Waste Management Symposia-2016.

Subtask 2.5 – Investigation of the migration and distribution of natural organic matter injected into subsurface systems

- Drain columns 1 and 7 and collect sediment for analysis via SEM and TOC analyzer.
- Update the experimental procedure based on the discussion with Dr.Miles Denham and Dr.Brian Looney and initiate new experiments to study the migration and distribution of HA and its effect on uranium mobility.

- Complete draft technical paper for waste management symposia.

Task 3: Surface Water Modeling of Tims Branch

Subtask 3.1. Modeling of Surface Water and Sediment Transport in the Tims Branch Ecosystem

- Submit draft paper to Waste Management 2016 Symposium by 11/6/15.
- Complete refinement of MIKE SHE model configuration parameters for the simulation of overland flow using revised model domain (Subtask 3.1)

Subtask 3.2. Application of GIS Technologies for Hydrological Modeling Support

- Submit draft paper to Waste Management 2016 Symposium by 11/6/15.
- Complete the download and pre-processing of model-specific geospatial and timeseries configuration parameters to fill in data gaps needed for the revised Tims Branch watershed model domain using GIS tools.
- Update GIS maps of Tims Branch hydrology, geology, land use, vegetation cover, topography, etc. for revised model domain.

Subtask 3.3. Biota, Biofilm, Water and Sediment Sampling in Tims Branch

- Coordinate with John Seaman (SREL) to collect data from the sampling effort they planned to conduct between September-October in Tims Branch/Steed Pond. A request was made by FIU for some additional water and sediment samples to be collected for Sn analysis and to acquire additional data parameters that could be used for the Tims Branch modeling effort.

Task 4: Sustainability Plan for the A/M Area Groundwater Remediation System

- Perform analysis of available data of air mass flow rates and contaminant removal efficiency. Determine the overall system efficiency and provide recommendations for the optimal air flow rates which will provide the lowest overall cost of operation.
- Perform analysis of the contaminant concentration from all recovery wells feeding the M1 air stripper and the current packing material and recommend component and process changes to improve the efficiency, lower the electrical energy usage and lessen the environmental footprint of the stripper operation.
- Develop an engineering analysis with input from SRNL and the SRS remediation contractor for improvement to the M1 air stripper.
- Perform analysis of a renewable energy system to power the M1 air stripper to include solar and/or wind. This would include costs for components properly sized and for installation.
- Draft sustainable remediation report for the M1 air stripper.
- Submit draft paper to Waste Management 2016 Symposium by 11/6/15.

Task 5: Remediation Research and Technical Support for WIPP

- Work in collaboration with LANL to identify research topic of interest to advance the science in high ionic-strength systems relevant to WIPP conditions.

Project 3
Waste and D&D Engineering & Technology Development

Project Manager: Dr. Leonel E. Lagos

Project Description

This project was known as Project 4 for FIU Year 5 and has been re-numbered to Project 3 for FIU Year 6.

This project focuses on delivering solutions under the decontamination and decommissioning (D&D) and waste areas in support of DOE HQ (EM-13). This work is also relevant to D&D activities being carried out at other DOE sites such as Oak Ridge, Savannah River, Hanford, Idaho and Portsmouth. The following tasks were included in FIU Year 5:

- Task 1: Waste Information Management System (WIMS)
- Task 2: D&D Support to DOE EM for Technology Innovation, Development, Evaluation and Deployment
- Task 3: D&D Knowledge Management Information Tool (KM-IT)

The following tasks are included in FIU Year 6:

- Task 1: Waste Information Management System (WIMS)
- Task 2: D&D Support to DOE EM for Technology Innovation, Development, Evaluation and Deployment
- Task 3: D&D Knowledge Management Information Tool (KM-IT)

Task 1: Waste Information Management System (WIMS)

Task 1 Overview

This task provides direct support to DOE EM for the management, development, and maintenance of a Waste Information Management System (WIMS). WIMS was developed to receive and organize the DOE waste forecast data from across the DOE complex and to automatically generate waste forecast data tables, disposition maps, GIS maps, transportation details, and other custom reports. WIMS is successfully deployed and can be accessed from the web address http://www.emwims.org. The waste forecast information is updated at least annually. WIMS has been designed to be extremely flexible for future additions and is being enhanced on a regular basis.

Task 1 Quarterly Progress

During this performance period, FIU performed database management, application maintenance, and performance tuning to the online WIMS in order to ensure a consistent high level of database and website performance.

An abstract on the Waste Information Management System was accepted for a poster session during the Waste Management Symposia to be held on March 6-10, 2016 in Phoenix, AZ.

Abstract: 16463 – Waste Information Management System with 2015-16 Waste Streams
Session: 050A - Posters: Waste Characterization
Date: Tuesday, March 08, 2016
Time: 8:30 AM - 12:00 PM

Task 2: D&D Support to DOE EM for Technology Innovation, Development, Evaluation and Deployment

<u>Task 2 Overview</u>

This task provides direct support to DOE EM for D&D technology innovation, development, evaluation and deployment. For FIU Year 6, FIU will assist DOE EM-13 in meeting the D&D needs and technical challenges around the DOE complex. FIU will expand the research in technology demonstration and evaluation by developing a phased approach for the demonstration, evaluation, and deployment of D&D technologies. One area of focus will be working with the Savannah River Site to identify and demonstrate innovative technologies in support of the SRS 235-F project. FIU will further support the EM-1 International Program and the EM-13 D&D program by participating in D&D workshops, conferences, and serving as subject matter experts.

<u>Task 2 Quarterly Progress – July 1 – August 28, 2015</u>

Waste Isolation Pilot Plant visit

During the month of July, the Applied Research Center's Director of Research (Dr. Leonel Lagos) visited the United States Department of Energy's Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico (Figure 3-1). WIPP is the world's third deep geological repository licensed to permanently dispose of transuranic radioactive waste for 10,000 years; this waste is left from the research and production of nuclear weapons in the United States. During this site visit, Dr. Lagos accompanied Associate Principal Deputy Assistant Secretary for Environmental Management (Dr. Monica Regalbuto) from the DOE Office of Environmental Management (DOE EM). The trip also included meetings and technical discussions with representatives from DOE's Carlsbad Office, Sandia National Lab and Los Alamos National Lab.

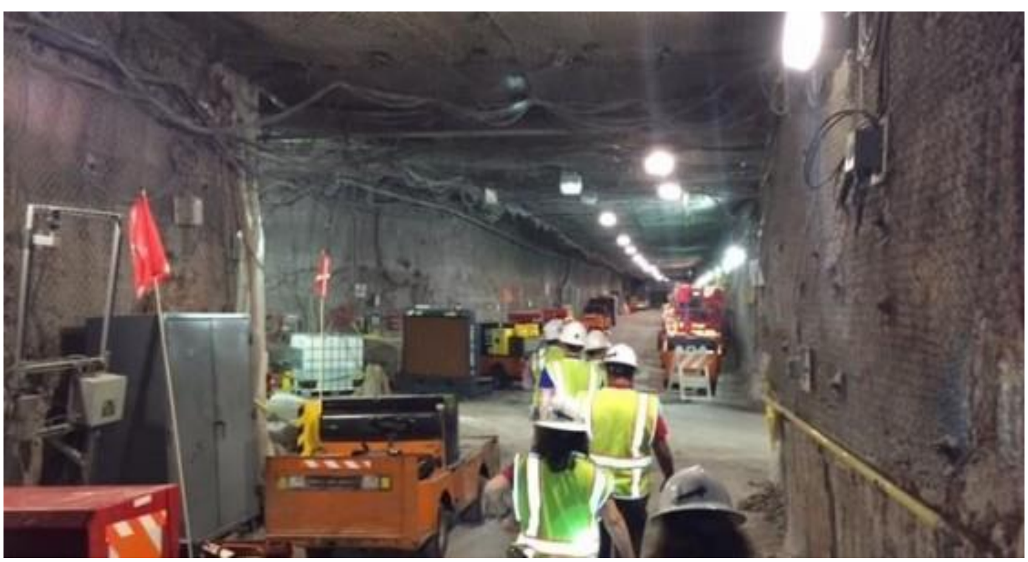


Figure 3-1. WIPP visit.

DOE Fellows supporting this task include Jesse Viera (undergraduate, mechanical engineering), Janesler Gonzalez (undergraduate, mechanical engineering), Meilyn Planas (undergraduate, electrical engineering), and new DOE Fellow Orlando Gomez (graduate, physics). DOE Fellows Jesse, Janesler, and Meilyn completed their 10-week summer internships held from June-August: DOE Fellows Jesse and Janesler at Idahno National Laboratory and DOE Fellow Meilyn at the Hanford Site. They also began preparation of the summer internship technical reports.

Subtask 2.1.1: Development of a Decision Model for Contamination Control Products

In support of the development of a decision model for contamination control products, FIU is interacting with SRS to identify the product search parameters based on project-specific needs and site applications. The contamination control product list is continuously being updated by contacting new potential vendors and requesting the required information about their decontamination products.

The design and development the web-based fixative model application is in progress and will be completed in FIU Year 6. The database will be implemented in SQL server. Once the web-based application is complete, it will be made available through the D&D Knowledge Management Information Tool portal for beta testing and input from field site users.

Subtask 2.1.2: Fogging research and evaluation

FIU began developing a technical abstract to submit to appropriate publications and professional journals to publish findings on FX2 test and evaluation. In addition, DOE Fellows provided support in the research on strippable coating development for fogging applications (Jesse Viera) and mercury abatement through the use of an advanced fogging technology (Janesler Gonzalez) during their summer internships at INL.

All equipment received from INL to support the execution of the FX2 Advanced Fogging Research Test Plan has been successfully shipped back to and received by INL. The final report and DOE Tech Fact Sheet as well as photographs and videos collected during the FX2 advanced fogging agent testing were compiled for posting to the D&D KM-IT..

Subtask 2.1.3: Incombustible fixatives

FIU are collaborating with Mike Serrato and Aaron Washington at SRNL on this task to enhance the stabilization of radioactive contamination even if the facility is subjected to a fire. During July, FIU revised the draft test plan for the Phase I testing based on comments received from SRNL and subsequently finalized the test plan which was approved and signed by FIU and SRNL on July 9, 2015. In addition, ARC met with the FIU Radiation Safety Officer (RSO) and conducted a site survey of the FIU Radiation Lab in order to outline the major components associated with the approved test plan. The results of these series of meetings will serve as the foundation and basis for the Radioactive Materials Handling Request Form that will be sent to the FIU Radiation Control Committee. FIU also moved forward with the requisition of the required fixatives, decon gels, and intumescent coatings needed to support the test plan. Research on the most appropriate muffle furnace and coating thickness gauges to support the experiments was also conducted. Finally, a new DOE Fellow (Orlando Gomez) was assigned to support the execution of this task.

During August, FIU developed an abstract on "Enhancing Fire Resiliency of Fixatives by Layering / Combining an Intumescent Coating" and submitted it for consideration to Waste Management Symposia 2016. FIU also assisted in the review of a parallel test plan from SRNL on enhancing radiation resiliency on the same designated fixatives, decon gels, and intumescent coatings from the FIU Test Plan completed last month. FIU purchased the selected fixatives, decon gels, and intumescent coatings outlined in the FIU Incombustible Fixatives Test Plan. In addition, FIU met with the FIU Radiation Safety Officer (RSO) and members of FIU Radiation Control Committee (RCC) to further lay the groundwork for the radiation component of the test plan. FIU also obtained quotes from approved ASTM testing laboratories for outsourcing of ASTM E84 and ASTM D1360 tests to support test objectives in the approved Incombustible Fixatives Test Plan. Finally, FIU obtained formal quotes for equipment, including a muffle furnace, IR surface thermometer, and dry film / paint thickness gauge, required to successfully execute the test plan.

Subtask 2.2 Support to DOE EM-13 and Interface with EFCOG

FIU was providing support to the EFCOG DD/FE Working Group in the development of lessons learned and best practices for deactivation and decommissioning (D&D) throughout the DOE complex. The objective of these efforts is to capture previous work performed by the D&D community and facilitate the transfer of knowledge and lessons learned. DOE requested that EFCOG restructure the organization and the DD/FE WG was sunsetted as part of this restructuring. FIU staff and DOE Fellows supporting this work will continue to work closely with DOE and members of the D&D community of practice in the collection of information and the development of relevant lessons learned and best practices. Once approved, these documents will be made available via D&D KM-IT. FIU has completed the revisions to two best practices based on comments received from DOE and finalized the documents. These best practices included the following: 1) User of a Remote Tapping Tool at Idaho National Laboratory to Minimize Worker Exposure and Avoid Future Contamination Accidents, and 2) Use of Earthen Benches and Other Technologies to Support Remediation and Removal of Contaminated River Structures (Hanford).

Task 2 Quarterly Progress – August 28 – September 30, 2015

Task 2.1.1: Incombustible Fixatives

An abstract for the incombustible fixatives research was accepted for an oral presentation during the Waste Management Symposia to be held on March 6-10, 2016 in Phoenix, AZ.

> **Abstract**: 16393 - Incombustible Fixatives for D&D Activities
> **Session**: 025 - Application of Innovative D&D Technologies Part 1
> **Date**: Monday, March 07, 2016
> **Time**: 1:30 PM - 5:00 PM

FIU completed the following in preparation for executing the incombustible fixatives test plan:

- Completed initial draft of the FIU Radioactive Material Handling form for review and approval by the FIU Radiation Safety Officer and committee.
- Ordered and received the dry film/paint thickness gauge equipment necessary to ensure that the application of the fixatives is conducted in strict accordance with the

manufacturers' specifications. Conducted orientation training on the equipment with the DOE Fellows supporting this research.

- Coordinated with SRNL to identify the substrate types and coupon sizes to be prepared by FIU in support of a related but parallel research effort being conducted at SRNL.
- Began purchasing process for additional equipment needed to conduct the test plan, including a muffle furnace and infra-red surface thermometer.
- Began planning for a dry run/rehearsal to demonstrate the proof-of-concept of the test plan objectives. This will be conducted using the fixatives and intumescent coatings applied to a substrate but without the radioactive component.

Task 2.1.2: Development of a Decision Model for Contamination Control Products

During September, FIU began to review and update the contamination control product list. This list will be used to develop the web and mobile decision model on the D&D KM-IT framework, described under Task 3. Once the web-based application is complete, it will be made available through the D&D Knowledge Management Information Tool portal for beta testing and input from field site users.

Task 2.1.3: Robotic Technologies for SRS 235-F

This is a new task for FIU Year 6. The SRS 235-F facility has a need to identify a remote system that can make one-time entry to highly contaminated areas. The one-time-entry requirement indicates that the technology will not be retrieved at the end of the work but would remain inside the facility due to the high levels of contamination. FIU will perform research to identify robotic technology systems applicable to the challenges and needs of the SRS 235-F Facility. Research will include working with SRNL to define the requirements for the robotic technology and utilizing the Robotic Database in D&D KM-IT to search and identify potential technologies that meet the defined requirements. A summary report will be developed to document the results.

Task 2.1.4: Fogging Research and Evaluation

The FX2 advanced fogging agent technology demonstration report and fact sheet as well as photographs and videos taken during the testing and evaluation have been published on the D&D Knowledge Management Information Tool (www.dndkm.org).

DOE Fellows Jesse Viera and Janesler Gonzalez participated in a 10-week summer internship at Idaho National Laboratory, under the mentor and guidance of Mr. Steve Reece (Mechanical Engineer) and Mr. Rick Demmer (Chemist). During this internship, the Fellows assisted with a number of different research efforts, including the design, assembly, and testing of a mock-up ruthenium scrubber system in INL's Energy Innovation Laboratory to support development of a scrubber system needed at Rokkasho Nuclear Fuels Reprocessing Facility in Japan as well as an evaluation of the capacity of commercial strippable coatings to be atomized in support of research for an innovative method for mercury decontamination.

Taking place in the Water Chemistry Laboratory at the Materials and Fuels Complex of INL, the scope of work included the evaluation of four commercial strippable decontamination gels and coatings before and after dilution as well as after being combined with a small ratio of specific additives. Because of their adsorption properties and known uptake capacity, activated carbon and elemental sulfur were used as chemical additives to enhance the capability of the coating to abate mercury.

Details of the summer internships as well as research results are detailed in the summer internship technical reports that Jesse and Janesler developed during September. These reports will be posted to the DOE Fellows website (fellows.fiu.edu) in October after review and site approval.

Task 2.2: Technology Demonstration and Evaluation

The primary objective of this new task is to standardize and implement proven processes to refine and better synchronize DOE-EM technology needs, requirements, testing, evaluation, and acquisition by implementing a three-phased technology test and evaluation model. The development of uniformly accepted testing protocols and performance metrics is an essential component for testing and evaluating D&D technologies. Toward these goals, FIU will engage the international testing community and the DOE complex's stakeholders in developing: 1) Uniform testing protocols and performance metrics for the various categories of D&D technologies (e.g.; fixatives, decon gels, robotics, etc.), and 2) Standardized methods to conduct cost savings / cost avoidance assessments for D&D technologies. The objectives for FIU Year 6 include:

1. Obtain official membership on ASTM International's E10 Committee on Nuclear Technologies and Applications.
2. Introduce a requirement for standardized testing protocols and performance metrics for D&D technologies as an agenda item for the E10 Committee meeting in January 2016.
3. In collaboration with E10 Committee membership, develop a detailed plan for implementing the initiative, and gain concurrence from the ASTM International Executive Steering Committee in June 2016.

A member of the FIU ARC staff has completed the first objective, obtaining official membership on ASTM International's E10 Committee on Nuclear Technologies and Applications. In addition, FIU has begun coordination with the committee staff manager (Joe Koury) and E10.03 subcommittee chair (Ed Walker) on the submission of a publication manuscript as well as agenda topics for the January conference. FIU has completed an initial draft of an article titled, "The Expanding Nuclear Niche and Growing Requirement for Standardized Testing Protocols and Performance Metrics for D&D Technologies" for possible publication in the *Journal of Testing and Evaluation*.

Subtask 2.3: Support to DOE EM-13 and the D&D Community

During September, FIU received approval from DOE to publish two best practices developed in collaboration with the EFCOG group: 1) Use of a Remote Tapping Tool at Idaho National Laboratory to Minimize Worker Exposure and Avoid Future Contamination Accidents, and 2) Use of Earthen Benches and Other Technologies to Support Remediation and Removal of Contaminated River Structures. These best practices have been published on D&D KM-IT (www.dndkm.org) as well as on the EFCOG website (www.efcog.org).

<u>Use of a Remote Tapping Tool at Idaho National Laboratory to Minimize Worker Exposure and Avoid Future Contamination Accidents</u>: D&D of facilities at DOE sites often require the draining of piping systems in high radiation areas. In these situations, long-reach or remote

tapping tools can be an effective means of keeping radiation exposures or doses as low as reasonably achievable (ALARA). This best practice describes the development and use of a long-reach remote tapping tool at Idaho National Laboratory to address the need for safely tapping piping systems in high radiation areas by increasing the distance from radiation areas and reducing the dose rate to the deactivation and decommissioning worker, improving worker safety and potentially reducing personal protection equipment requirements.

Use of Earthen Benches and Other Technologies to Support Remediation and Removal of Contaminated River Structures: Washington Closure Hanford (WCH), as part of the River Corridor Cleanup (RCC) Project, was contracted to demolish three structures (including two pump houses and an outfall structure) that were located directly in the Columbia River. This best practice describes the use of earthen benches and other technologies used to support the remediation and removal of the contaminated river structures.

Figure 3-2. Earthen benches used to isolate structures from the Columbia River.

Task 3: D&D Knowledge Management Information Tool (KM-IT)

Task 3 Overview

The D&D Knowledge Management Information Tool (KM-IT) is a web-based system developed to maintain and preserve the D&D knowledge base. The system was developed by Florida International University's Applied Research Center (FIU-ARC) with the support of the D&D community, including DOE-EM (EM-13 & EM-72), the former ALARA centers at Hanford and Savannah River, and with the active collaboration and support of the DOE's Energy Facility Contractors Group (EFCOG). The D&D KM-IT is a D&D community driven system tailored to serve the technical issues faced by the D&D workforce across the DOE Complex. D&D KM-IT can be accessed from web address http://www.dndkm.org.

Task 3 Quarterly Progress – July 1 – August 28, 2015

DOE Fellows and other FIU students are supporting D&D KM-IT by reviewing the information in the vendor and technology modules, updating contact information, and researching additional relevant D&D technologies offered by existing vendors. During August, the data mining efforts focused on adding technology and vendor entries for the robotic technologies and development teams associated with the DARPA Robotics Challenge (DRC). The DRC is a competition of robot systems and software teams vying to develop robots capable of assisting humans in responding to natural and man-made disasters. It was designed to be extremely difficult. Participating teams, representing some of the most advanced robotics research and development organizations in the world, are collaborating and innovating on a very short timeline to develop the hardware, software, sensors, and human-machine control interfaces that will enable their robots to complete a series of challenge tasks selected by DARPA for their relevance to disaster response. As of September 2, the system included a total of 1259 technologies (+ 31 from June) and 924 vendors (+19 from June).

FIU completed and submitted the Google Web Analytic report for D&D KM-IT for calendar year 2014 (January to December 2014) to DOE on July 16, 2015. This report included information from Google Analytic and Google Web Master tools and provided graphics and a narrative to explain the results. Figure 3-3 provides a sample graphic showing a comparison of pages per session, average duration, bounce rate, and the percent of new sessions for calendar years 2012, 2013, and 2014.

FIU completed the development of the next newsletter for D&D KM-IT, highlighting the 1200 D&D technologies included, and sent to DOE for review. Once approved, FIU distributed the newsletter to the D&D KM-IT registered users on June 30, 2015. Figure 3-4 shows a screen snapshot of the newsletter.

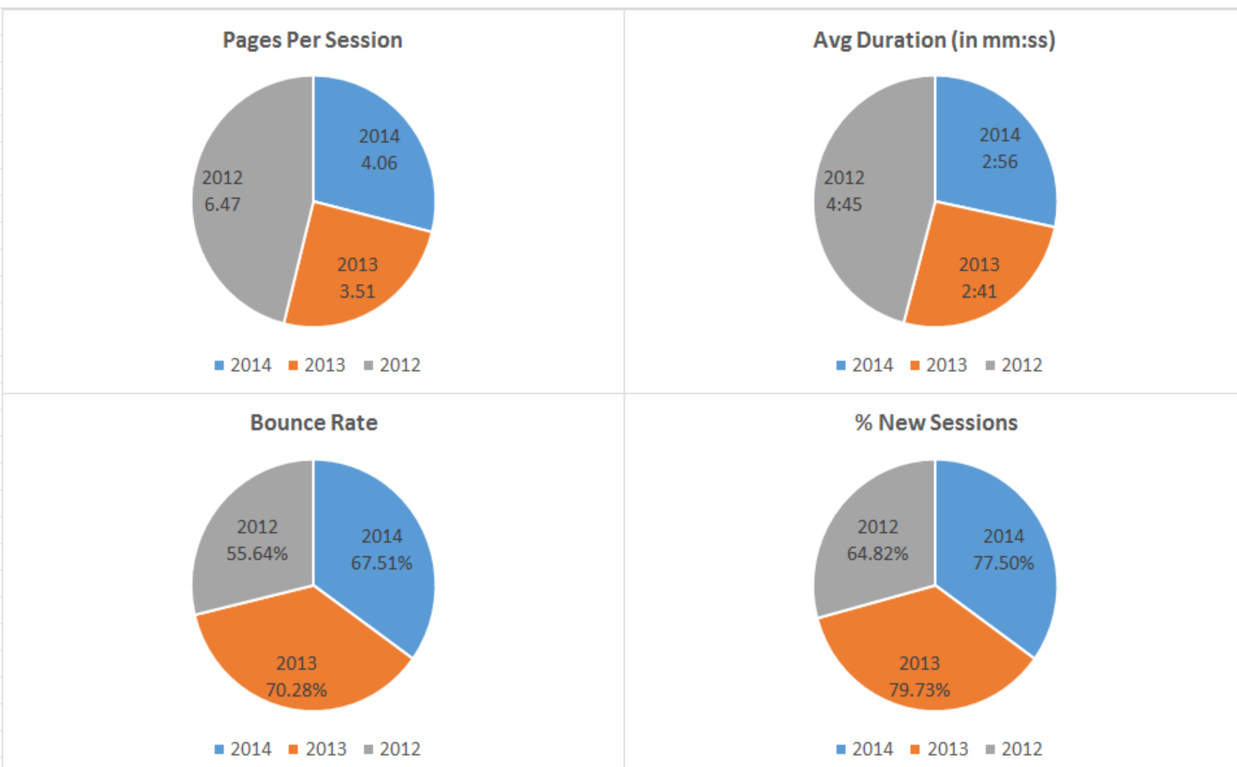
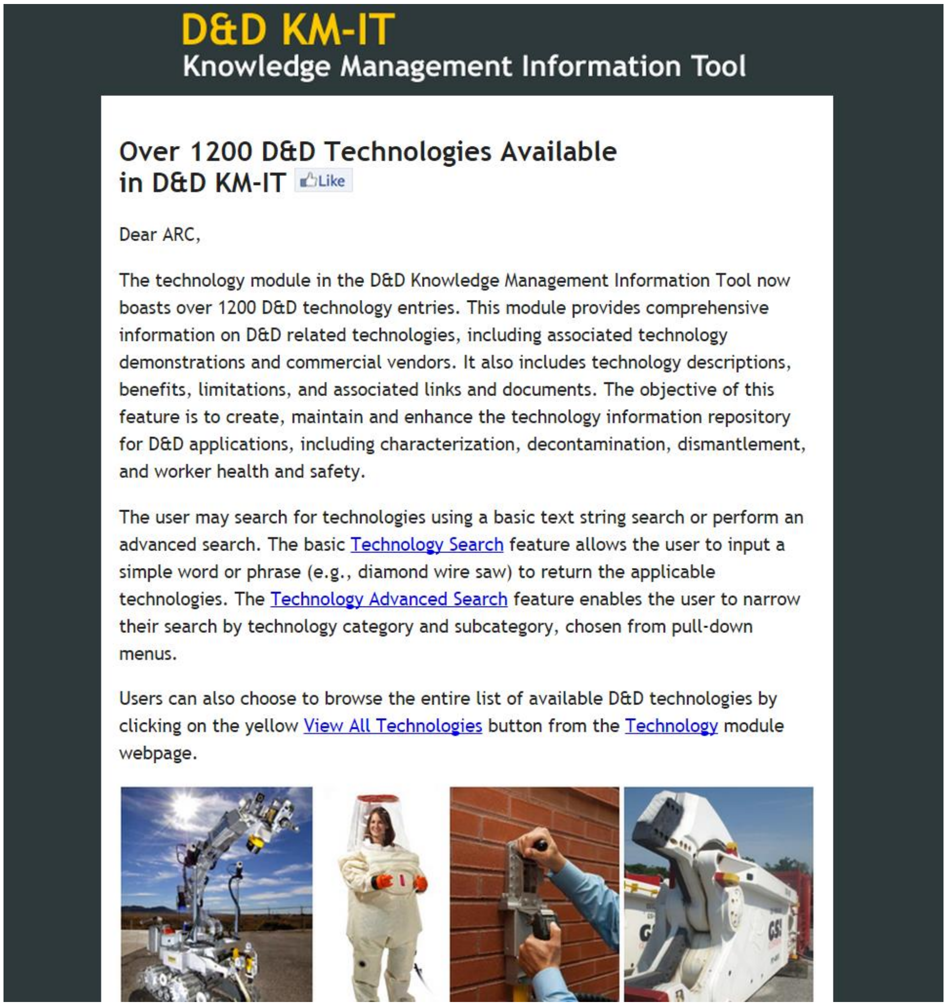


Figure 3-3. 2014 vs 2013 & 2012. Pages Per Session, Average Duration, Bounce Rate and Percentage of New Sessions.



D&D KM-IT
Knowledge Management Information Tool

Over 1200 D&D Technologies Available
in D&D KM-IT Like

Dear ARC,

The technology module in the D&D Knowledge Management Information Tool now boasts over 1200 D&D technology entries. This module provides comprehensive information on D&D related technologies, including associated technology demonstrations and commercial vendors. It also includes technology descriptions, benefits, limitations, and associated links and documents. The objective of this feature is to create, maintain and enhance the technology information repository for D&D applications, including characterization, decontamination, dismantlement, and worker health and safety.

The user may search for technologies using a basic text string search or perform an advanced search. The basic Technology Search feature allows the user to input a simple word or phrase (e.g., diamond wire saw) to return the applicable technologies. The Technology Advanced Search feature enables the user to narrow their search by technology category and subcategory, chosen from pull-down menus.

Users can also choose to browse the entire list of available D&D technologies by clicking on the yellow View All Technologies button from the Technology module webpage.

Figure 3-4. Technology Database newsletter for D&D KM-IT.

FIU attended the American Nuclear Society (ANS) Utility Working Conference and Vendor Technology Expo in Amelia Island, Florida, from August 10 to August 13, 2015. Held annually since 1994, ANS Utility Working Conference provides a venue for sharing expertise, experience and learning on the most immediate needs and challenging issues currently facing the nuclear industry as well as the significant achievements and successes. Annual participation in this conference includes approximately 750 attendees and 92 exhibitors. During the conference, FIU hosted a booth (#510) in the exhibiter hall to provide conference attendees with additional information on the applied research being conducted at ARC for the Department of Energy Office of Environmental Management. At the booth, FIU also provided live demonstrations of D&D KM-IT. Approximately 83 conference attendees took advantage of the opportunity to register with the D&D KM-IT and 6 of those newly registered users also signed up as subject matter specialists (SMS) with the system. The SMS, through a directory of deactivation and decommissioning experts, share knowledge and experience in their areas of expertise, providing solutions to the challenges being faced by other members in the D&D community.

Figure 3-5. FIU ARC hosting information booth at the 2015 ANS Utility Working Conference.

<u>Task 3 Quarterly Progress – August 28 – September 30, 2015</u>

An abstract for the D&D Knowledge Management Information Tool was accepted for a poster session during the Waste Management Symposia to be held on March 6-10, 2016 in Phoenix, AZ.

> **Abstract**: 16465 - Robotics Technologies on Knowledge Management Information Tool (KM-IT) Platform
> **Session**: 087C - Posters: Robotic Technologies
> **Date**: Wednesday, March 09, 2016
> **Time**: 8:30 AM - 12:00 PM

FIU completed the development of an annual Google Web Analytic report for D&D KM-IT for calendar year 2014 (January to December) and submitted it to DOE on September 22, 2015. During this period, D&D KM-IT was visited from every state in the union with the top three being Florida, District of Columbia and Tennessee. D&D KM-IT was also visited from 116 countries with the top five being the United States, United Kingdom, Canada, India and South Korea, with a combined 6,003 visits.

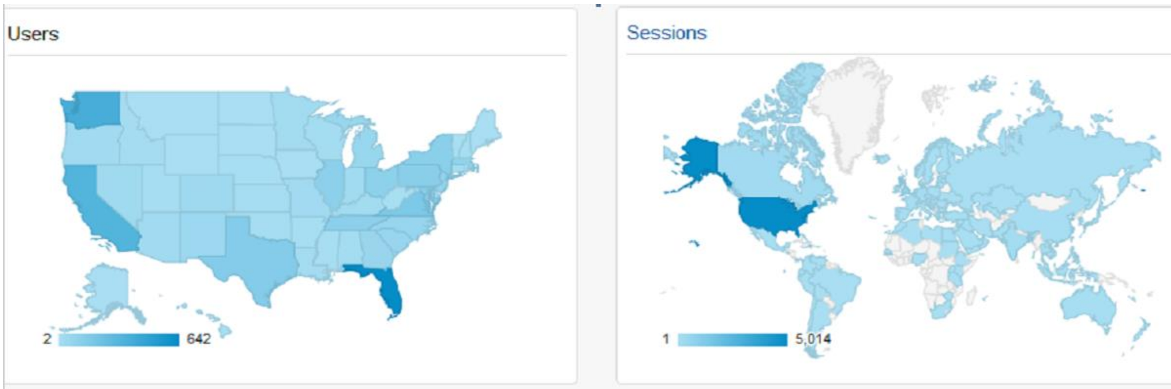


Figure 3-6. Location of visitors to D&D KM-IT.

An infographic has been provided for visual representation of key information in this report. It is intended to present information quickly and clearly.

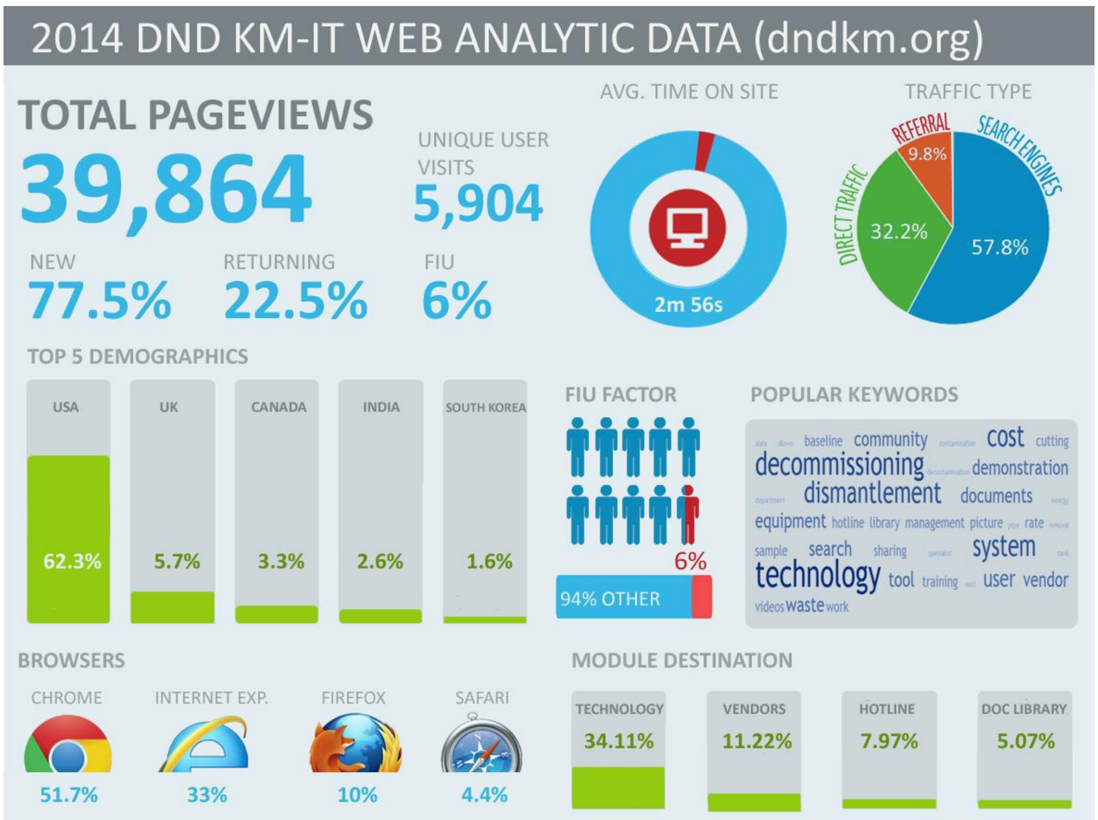


Figure 3-7. Web analytics infographic for calendar year 2014.

FIU also completed the development of a Google Web Analytic report for D&D KM-IT for the second quarter of 2015 (April to June) and submitted it to DOE on September 30, 2015. This report included information from Google Analytics and Google Web Master tools and a narrative to explain the results. A few of the highlights from this report include:

- Overall, this report reflects typical results when compared to the second quarter of the previous year. There were 3,979 total visits in the second quarter of 2014 as compared to a very similar 3,944 visits in the second quarter of 2015.

- The document positions in the search engine results page are in the double digits, which means that users have fewer chances of clicking on the document. Over the last couple of quarters this trend has been identified and the FIU team has reviewed the site to identify possible technical reason for this. So far, there is nothing directly related to the positioning of the documents in the results page other than Google's proprietary algorithm.
- The Training module made it to the top 3 most visited modules, after Technology and Vendors.
- There was a noticeable increase in visits from "other" countries outside the United States. These visits are an encouraging sign of increasing global participation.

The FIU team is working on developing the desktop and mobile decision support model for fixatives. The latest Bootstrap framework is being used to develop the front-end tier of the application for the home screen and summary search. FIU has developed the DSS model and is implementing the application on a Microsoft.Net platform. The fixatives database is developed by defining criteria, sub-criteria, and product information with three levels for the selection and search processes using a SQL server database. The data tables and relationships are being established for all the entities (criteria, sub-criteria, and products) and sample data is being imported for development using the SQL server data integration services. Each entity has multiple attributes; for example, Product has Product ID, Product Name, Manufacturer, etc. as its attributes. The relationship between the entities has been built.

The database was developed in SQL Server Management Studio. The tables are constructed by taking each entity into consideration; each entity is a table with its attributes as columns and the values of the attributes as rows. The relationship between these tables is specified in the database and required settings were defined. The data was then loaded to the tables in the database. Stored procedures were written based on the type of desired results from the decision support model (stored procedures are a set of SQL statements that need to be written once and stored in the database for easy access and data integrity). The stored procedures were then tested.

The design of the web/mobile design with the Bootstrap framework is being developed to fit to the D&D KM-IT theme. The code in the framework is being developed to have the drop-down menus reflect the user's selections. Once this is completed, the backend work, such as linking the database to the design of the website, will be performed.

FIU also completed a quarterly update document for the *D&D KM-IT Strategic Approach for the Long-Term Sustainability of Knowledge* document and submitted it to DOE on September 16, 2015. The strategic plan for D&D KM-IT is a living document. The projected schedule and status evolve over time as the recommended strategic approaches are implemented. The quarterly document provides an update to the table of recommended actions contained in the original document.

FIU developed a set of graphics (one example shown in the following figure) to illustrate the growth of the D&D KM-IT user and subject matter specialist registrations in response to marketing efforts, specifically conference participation where D&D KM-IT is demonstrated to conference attendees.

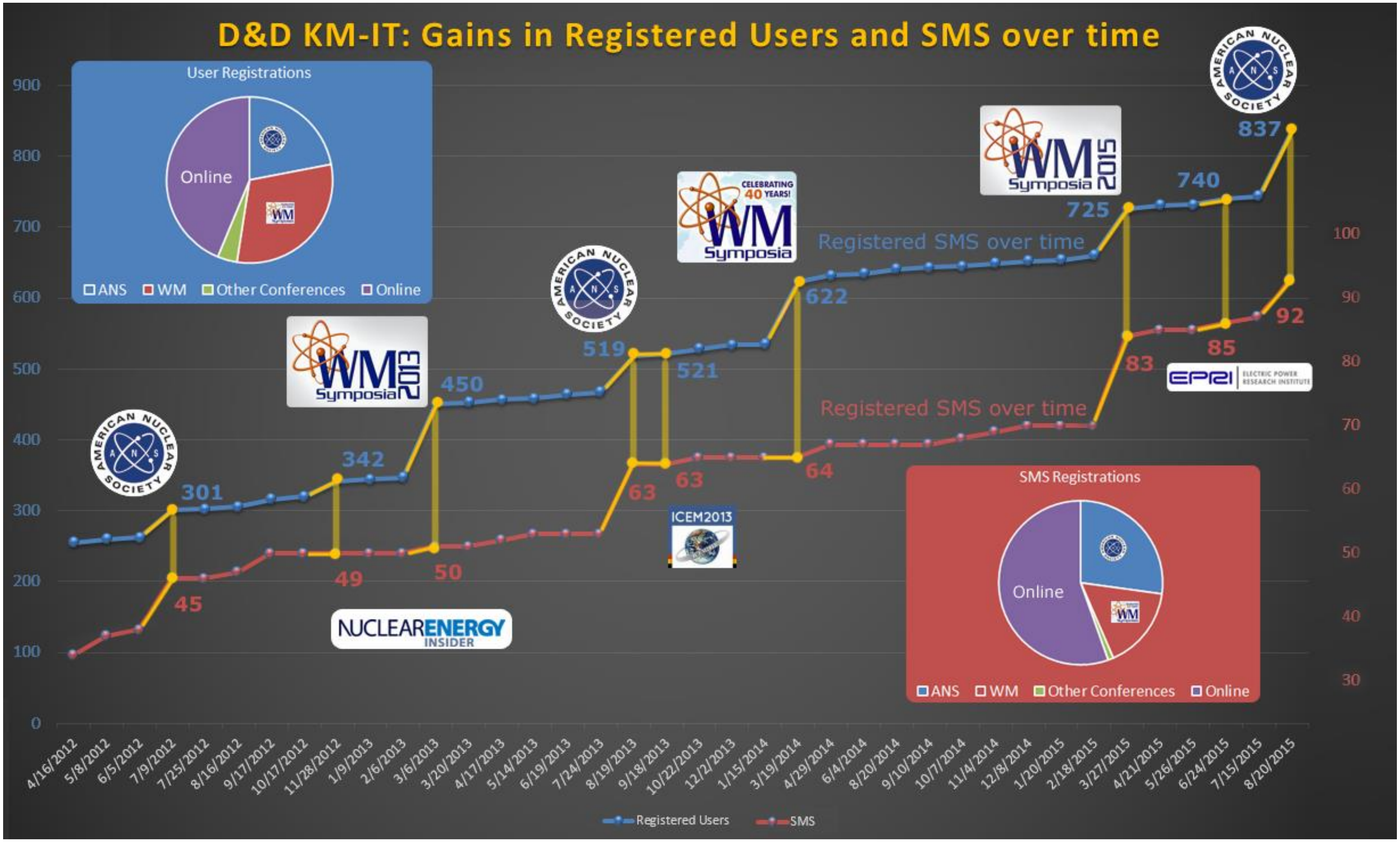


Figure 3-8. Graphic showing the gains in registered uses and SMS over time in connection with conference participation.

FIU completed development of the next newsletter for D&D KM-IT, highlighting cameras and inspection technologies included in the knowledge base, and sent to DOE for review on September 16. Once approved, FIU will distribute the newsletter to the D&D KM-IT registered users. The draft newsletter is shown in the following figure.

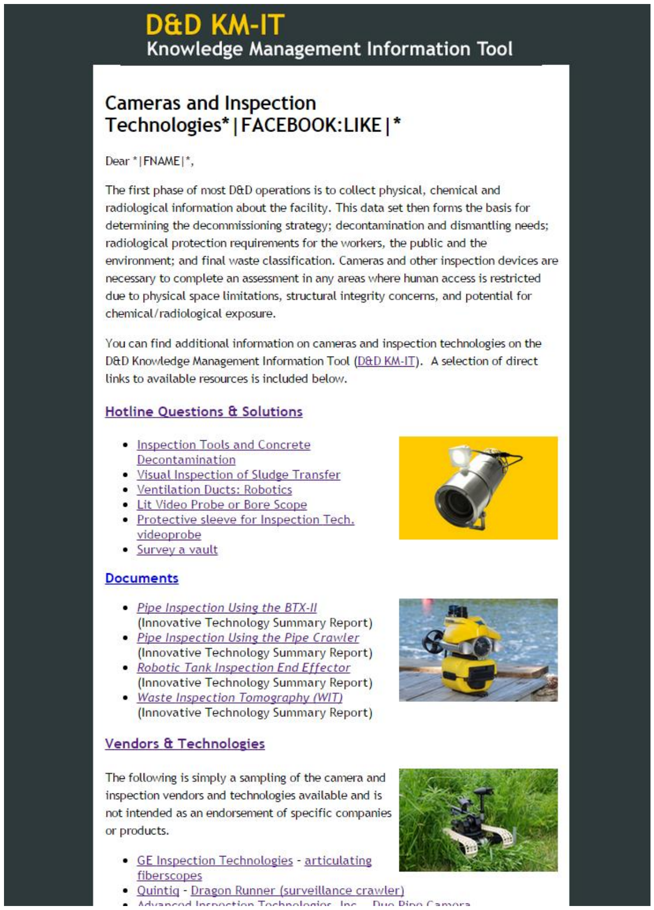


Figure 3-9. Draft newsletter on cameras and inspection technologies.

Milestones and Deliverables

The milestones and deliverables for Project 4 for FIU Year 5 are shown on the following table. Milestone 2014-P4-M2.2, the draft test plan for baseline incombustible fixatives for subtask 2.1.3, was completed in July.

FIU Year 5 Milestones and Deliverables for Project 4

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Task 1: Waste Information Management System (WIMS)	2014-P4-M1.1	Import 2015 data set for waste forecast and transportation data	Within 60 days after receipt of data from DOE	Complete	
	2014-P4-M1.2	Submit draft paper on WIMS to Waste Management Symposium 2015	11/07/14	Complete	
Task 2: D&D Support to	2014-P4-M2.1	Preliminary decision model for contamination control products (subtask 2.1.1)	03/06/15	Complete	

DOE EM for Technology Innovation, Development, Evaluation, and Deployment	2014-P4-M2.2	Draft test plan for baseline incombustible fixatives (subtask 2.1.3)	Reforecast to 07/02/15	Complete	OSTI
	Deliverable	Lessons Learned and Best Practices	30 days after final approval from DOE & EFCOG	Complete	
	Deliverable	Draft technical reports for demonstrated technologies	30-days after evaluation/demo	Complete	OSTI
	Deliverable	Draft Tech Fact Sheet for technology evaluations/ demonstrations	30-days after evaluation/demo	Complete	
Task 3: D&D Knowledge Management Information Tool (KM-IT)	Deliverable	First D&D KM-IT Workshop to DOE EM staff at HQ	08/29/14**	Reforecast to FIU Year 6	
	2014-P4-M3.2	Deployment of popular display on homepage of KM-IT to DOE for review/testing	09/05/14	Complete	
	Deliverable	Metrics Definition Report on Outreach and Training Activities	09/30/14	Complete	
	Deliverable	Second D&D KM-IT Workshop to DOE EM staff at HQ	09/30/14**	Reforecast to FIU Year 6	
	2014-P4-M3.1	Submit draft paper on D&D KM-IT to Waste Management Symposium 2015	11/07/14	Complete	
	2014-P4-M3.3	Deployment of lessons learned lite mobile application to DOE for review/testing	11/07/14	Complete	
	Deliverable	Preliminary Metrics Progress Report on Outreach and Training Activities	01/16/15	Complete	
	2014-P4-M3.4	Deployment of best practices mobile application to DOE for review/testing	01/16/15	Complete	
	2014-P4-M3.5	Four Wikipedia edits/articles	03/20/15 Reforecast to 05/15/15	Complete	
	Deliverable	First D&D KM-IT Workshop to D&D community	03/31/15	Complete	
	Deliverable	Second D&D KM-IT Workshop to D&D community	Reforecast to 6/30/15	Complete	
	Deliverable	Metrics report on outreach and training activities	05/09/15	Complete	
	Deliverable	Draft Security Audit Report	30-days after completion of audit	On Target	
	Deliverable	D&D KM-IT Performance Analysis Report	Quarterly	Complete	
	Deliverable	Draft Tech Fact Sheet for new modules or capabilities of D&D KM-IT	30-days after deployment of new module or capability	Complete	

***Completion of this deliverable depends on scheduling and availability of DOE EM staff*

The milestones and deliverables for Project 3 for FIU Year 6 are shown on the following table. A draft Project Technical Plan was developed which includes the scope of work intended for FIU Year 6. No other milestones or deliverables were due for this project during September.

FIU Year 6 Milestones and Deliverables for Project 3

Task	Milestone/ Deliverable	Description	Due Date	Status	OSTI
Task 1: WIMS	2015-P3-M1.1	Import 2016 data set for waste forecast and transportation data	Within 60 days after receipt of data	On Target	
	2015-P3-M1.2	WM 2016 Paper for WIMS	11/6/2015	On Target	
Task 2: D&D	2015-P3-M2.1	Completion of Phase 1 testing of incombustible fixatives	12/31/2015	On Target	
	2015-P3-M2.2	Participate in ASTM E10 Committee Meeting to introduce a requirement for standardized D&D testing protocols & performance metrics	01/31/2016	On Target	
	Deliverable	Summary Report on Robotic Technologies for SRS 235-F Facility	05/29/2016	On Target	OSTI
	Deliverable	Draft Test Plan for Phase II incombustible fixatives testing and evaluation	06/30/2016	On Target	OSTI
	2015-P3-M2.3	Participate in ASTM International's Executive Steering Committee Meeting to solicit final approval for development of standardized testing protocols and performance metrics for D&D technologies.	06/30/2016	On Target	
	Deliverable	Decision brief to DOE-EM 13 on recommended technologies to test for FY'17 using FIU's 3-Phased Technology Test and Evaluation Model.	07/29/2016	On Target	
	Deliverable	Draft technical reports for demonstrated technologies	30-days after demo	On Target	OSTI
	Deliverable	Draft Tech Fact Sheet for technology evaluations/ demonstrations	30-days after demo	On Target	
Task 3: D&D KM-IT	2015-P3-M3.1	Waste Management Symposium Paper for D&D KM-IT	11/06/2015	On Target	
	Deliverable	First D&D KM-IT Workshop to DOE EM staff at HQ	11/30/2015**	On Target	
	2015-P3-M3.2	Deployment of pilot web-based D&D Decision Model application	01/16/2016	On Target	
	2015-P3-M3.3	Deployment of pilot mobile application for D&D Decision Model	02/20/2016	On Target	
	Deliverable	Preliminary Metrics Progress Report on Outreach and Training Activities	02/29/2016	On Target	
	Deliverable	First D&D KM-IT Workshop to D&D community	03/31/2016	On Target	
	2015-P3-M3.4	Four Wikipedia integration edits/articles	03/31/2016	On Target	
	2015-P3-M3.5	Completion of HLW feasibility study on KM-IT platform	05/15/2016	On Target	
	Deliverable	Second D&D KM-IT Workshop to DOE EM staff at HQ	05/31/2016**	On Target	
	Deliverable	First infographic to DOE for review	07/25/2016	On Target	
	Deliverable	Second infographic to DOE for review	08/08/2016	On Target	
	2015-P3-M3.6	Completion of Global KM-IT Integration	08/14/2016	On Target	
	Deliverable	Metrics Progress Report on Outreach and	08/15/2016	On Target	

		Training Activities			
	Deliverable	Second D&D KM-IT Workshop to D&D community	08/25/2016	On Target	
	Deliverable	Draft Security Audit Report	30-days after audit	On Target	
	Deliverable	D&D KM-IT Web Analysis Report	Quarterly	On Target	
	Deliverable	Draft Tech Fact Sheet for new modules or capabilities of D&D KM-IT	30-days after deployment of new module	On Target	

***Completion of this deliverable depends on scheduling and availability of DOE EM staff*

Work Plan for Next Quarter

- Task 1: Perform database management, application maintenance, and performance tuning to WIMS.
- Task 1: Submit technical paper on WIMS to WM16.
- Task 2: Complete preparations and execute the phase I test plan for evaluating a set of incombustible fixatives, selected by FIU and SRS.
- Task 2: Submit technical paper on incombustible fixatives to WM16.
- Task 3: Develop website analytics report for the third quarter (July to Sept) of 2015 and submit to DOE for review.
- Task 3: Complete first D&D KM-IT Workshop to DOE EM staff at HQ, based on scheduling and availability of DOE EM staff.
- Task 3: Perform outreach and training, community support, data mining and content management, and administration and support for the D&D KM-IT system, database, and network.
- Task 3: Submit technical paper on D&D KM-IT to WM16.

Project 4
DOE-FIU Science & Technology Workforce Development Initiative

Project Manager: Dr. Leonel E. Lagos

Project Description

This project was known as Project 5 for FIU Year 5 and has been re-numbered to Project 4 for FIU Year 6.

The DOE-FIU Science and Technology Workforce Development Initiative has been designed to build upon the existing DOE/FIU relationship by creating a “pipeline” of minority engineers specifically trained and mentored to enter the Department of Energy workforce in technical areas of need. This innovative program was designed to help address DOE’s future workforce needs by partnering with academic, government and DOE contractor organizations to mentor future minority scientists and engineers in the research, development, and deployment of new technologies, addressing DOE’s environmental cleanup challenges.

Project Overview

The main objective of the program is to provide interested students with a unique opportunity to integrate course work, Department of Energy (DOE) field work, and applied research work at ARC into a well-structured academic program. Students completing this research program would complete the M.S. or Ph.D. degree and immediately be available for transitioning into the DOE EM’s workforce via federal programs such as the Pathways Program or by getting directly hired by DOE contractors, other federal agencies, and/or STEM private industry.

Project Quarterly Progress

Fellows continue their support to the DOE-FIU Cooperative Agreement by actively engaging in EM applied research and supporting ARC staff in the development and completion of the various tasks. The program director continues to work with DOE sites and HQ to fully engage DOE Fellows with research outside ARC where Fellows provide direct support to mentors at DOE sites, DOE-HQ, and DOE contractors. All Fellows also participated in a weekly meeting conducted by the program director, a conference line has been established to enable DOE Fellows conducting internship to join to weekly meeting and update program director on their internship. During each of these meetings, one DOE Fellow presents the work they performed during their summer internship and/or EM research work they are performing at ARC.

Nineteen (19) FIU students were selected from the Spring/Summer recruitment for formal interviews for the DOE Fellows program, which were conducted from June 23 through July 6, 2015. The selection committee provided input and recommendations to make the final selections and complete the recruitment process. Six (6) FIU students were accepted into the program. These new Fellows started the DOE Fellowship at ARC on July 20, 2015. A list of the new selected Fellows, their classification, areas of study, ARC mentor, and assigned project is provided below:

Table 4-1. New DOE Fellows from Spring/Summer Recruitment

Name	Classification	Major	ARC Mentor	Project Support
Alejandro Hernandez	Undergrad - B.S.	Chemistry	Dr. Vasileios Anagnostopoulos	FIU's Support for Groundwater Remediation at SRS F/H - Area
Awmna Kalsoom	Undergrad - B.S.	Chemistry	Ms. Angelique Lawrence	Surface Water Modeling of Tims Branch
Christopher Strand	Undergrad - B.S.	Civil & Env. Eng.	Dr. Mehrnoosh Mahmoudi	Surface Water Modeling of Tims Branch
Erim Gokce	Undergrad - B.S.	Mechanical Eng.	Mr. Anthony Abrahao	Development of Inspection Tools for DST Primary Tanks
Orlando Gomez	Graduate - Ph.D.	Physics	Mr. Joseph Sinicrope	Incombustible fixatives
Silvina Di Pierto	Graduate - Ph.D.	Chemistry	Dr. Hilary Emerson	Evaluation of ammonia for uranium treatment

The DOE Fellows Fall recruitment efforts were also completed. Recruitment campaigns were conducted from September 1 to September 25, 2015. Two information sessions, one at FIU's main Modesto Maidique Campus and one at FIU's Engineering Center, were held on September 17 to provide students with insights into the DOE Fellows program and answer any questions they might have (Figures 4-1 and 4-2). A signup sheet was used to collect contact information from interested students. A total of 26 applications have been received and are currently under review. Interviews and selection will be completed during the month of October.

Figure 4-1. DOE Fellow Kiara Pazan discussing her summer internship experience at an info session.

Figure 4-2. DOE Fellows Andre De La Rosa, Christine Wipfli and Maximiliano Edrei sharing their summer internship experiences at an info session.

The DOE Fellows completed their summer 2015 internships with DOE sites, DOE national laboratories, DOE contractors, and DOE-HQ. A total of 15 DOE Fellows interned this summer as detailed in the following table. During August, these DOE Fellows returned to ARC and developed the summer internship technical reports based on the work they performed during their internships. Table 4-2 presents the internship locations and summer mentors for each of the DOE Fellows and Table 4-3 presents their summer internship technical report titles. The reports are undergoing final review and approval at the internship sites and will be posted to the DOE Fellows website (fellows.fiu.edu) in October. Photographs from a few of the summer internships are shown in Figures 4-3 through 4-9. Five DOE Fellows participated in "Summer Intern Presentations for EM-10 HQ" and presented their summer internship accomplishments. DOE Fellows Aref Shehdah, Kiara Paza, Natalia Duque and Jorge Deshon from Savannah River National Laboratory (SRNL) and Christine Wipfli from DOE - HQ EM-12 participated in these presentations.

Table 4-2. Summer 2015 Internships for DOE Fellows

Student	DOE Site	Summer Mentor(s)
Andrew De La Rosa	Oak Ridge National Lab – Cyber & Information Security Research	Joseph Trien
Anthony Fernandez	Washington River Protection Solutions (WRPS), Richland, WA	Ruben Mendoza and Gregory Gauck
Aref Shehadeh	SRNL, Savannah River, SC	Miles Denham
Christine Wipfli	DOE-HQ EM-12, Cloverleaf, Germantown, Maryland	Skip Chamberlain/Kurt Gerdes
Janesler Gonzalez	Idaho National Lab	Rick Demmer/Steve Reese
Natalia Duque	SRNL, Savannah River, SC	Ralph Nichols/Carol Eddy-Dilek/Brian Looney
Jesse Viera	Idaho National Lab	Rick Demmer/Steve Reese
John Conley	WRPS, Richland, WA	Terry Sams and Dave Shuford
Jorge Deshon	SRNL, Savannah River, SC	John Bobbitt and Steven Tibrea
Kiara Pazan	SRNL, Savannah River, SC	Miles Denham and Margaret Millings

Maximiliano Edrei	National Energy Technology Lab, Morgantown, WV	Chris Guenther
Meilyn Planas	WRPS, Richland, WA	Terry Sams
Ryan Sheffield	DOE-HQ EM-20, Cloverleaf, Germantown, Maryland	James Poppiti
Yoel Rotterman	DOE-HQ EM-13, Forrestal, Washington D.C.	Albes Ganoa/John De Gregory
Claudia Cardona	PNNL, Richland, WA	Jim Sczcsody

Table 4-3. Summer Internship Report Titles

DOE Fellow	***Report Titles***
Andrew De La Rosa	*Using a 64-bit Disassembler to Employ Heuristic Analysis of Executable Programs using Hyperion*
Anthony Fernandez	*Overview of DOE Hanford Site Single-Shell Waste Storage Tank Internship*
Aref Shehadeh	*Optimizing Remediation of I-129 using AgCl Colloidal-Sized Particles in SRS F-Area Sediments*
Christine Wipfli	*Development of Case Study Examples for ITRC Remediation of Complex Sites Subgroup*
Janesler Gonzalez	*Mercury Abatement via Strippable Coating Technologies*
Natalia Duque	*Analysis of Solar Generated Power in the Southeastern United States*
Jesse Viera	*Mock- Up Scrubber System*
John Conley	*Stainless Steel Corrosion: Feed Properties Affecting Material Selection for LAWPS Piping at Hanford Site*
Jorge Deshon	*3D Visualization*
Kiara Pazan	*Processing of Diffusion Samplers to Test Remediation of Uranium by Humate*
Maximiliano Edrei	*Radial Jet Impingement Correlation Investigation*
Meilyn Planas	*Heat Transfer Calculations for the Use of an Infrared Temperature Sensor*
Ryan Sheffield	*Waste Isolation Pilot Plant Radioactive Release*
Yoel Rotterman	*Climate Change Vulnerability Assessment and Adaptation Plan for DOE Sites*
Claudia Cardona	*Geochemistry Related to NH_3 Gas Used for Uranium Remediation in the Vadose Zone*

Figure 4-3. DOE Fellows on summer internships: Jorge Deshon (left) working with Visionary Render™ software and Natalia Duque (right) at her work station.

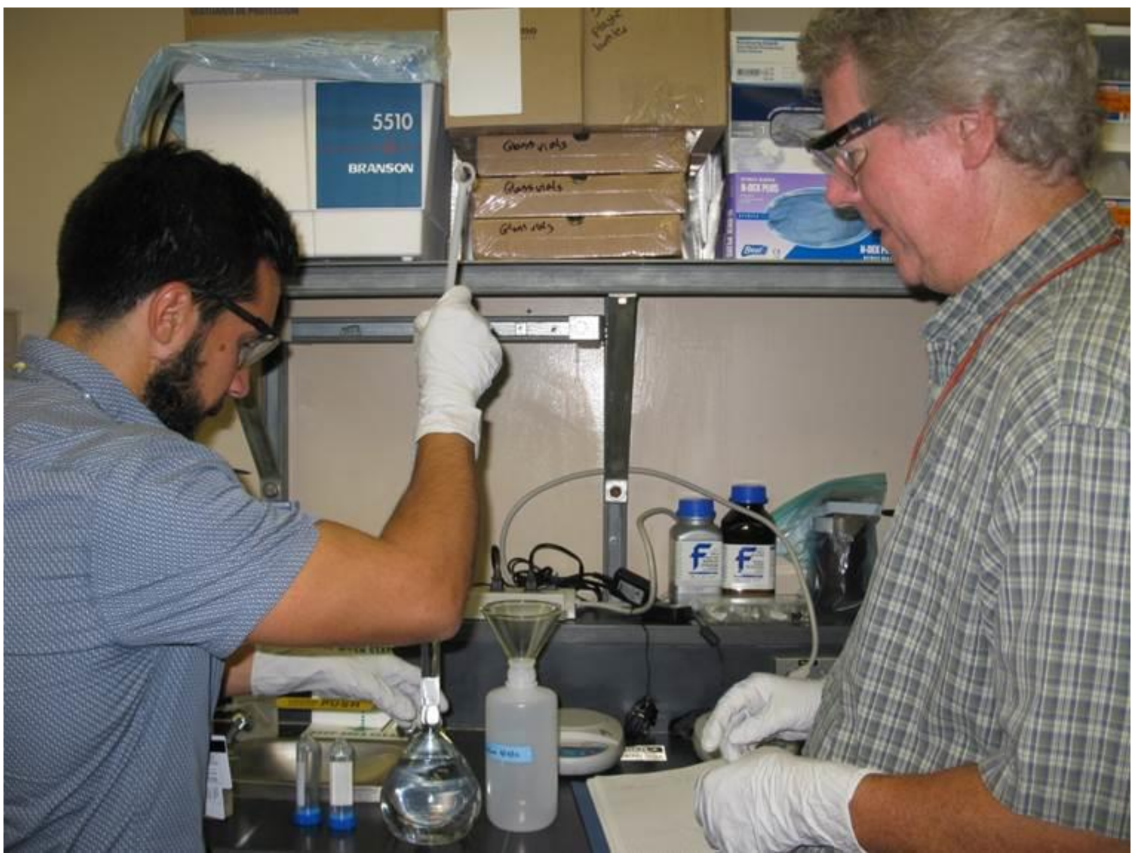


Figure 4-4. DOE Fellow Aref Shehadeh with Dr. Miles Denham (SRNL), conducting an experiment.

Figure 4-5. DOE Fellows Ryan Sheffield, Christine Wipfli and Yoel Rotterman with FIU's president Dr. Mark Rosenberg at DOE-HQ.

Figure 4-6. DOE Fellows Anthony Fernandez, Meilyn Planas and Christine Wipfli with Dr. Hope Lee (PNNL).

Figure 4-7. DOE Fellow Jesse Viera at Idaho National Laboratory.

Figure 4-8. DOE Fellow Maximiliano Edrei at NETL.

Figure 4-9. DOE Fellow Maximiliano Ederi with Chris Guenther (NETL).

DOE Fellow Yoel Rotterman visited the Savannah River Site to meet with SRNL engineers/scientists on the research work he is performing in support of Project 3, Task 3, on the green and sustainable remediation (GSR) research. Yoel toured the site and gathered relevant information to support a GSR analysis of the M-1 Air Stripper. The information collected would serve as a baseline to analyze the performance of the current air stripping system, which would allow the development of optimization recommendations, as well as an evaluation of natural attenuation as a sustainable solution for some regions in the vadose zone.

During their visit to FIU in July, Ms. La Doris Harris (Director of Office of Economic Impact & Diversity) and Ms. Annie Whatley (Deputy Director, Office of Minority Education and Community Development) from DOE interacted with the DOE Fellows and discussed their research experience at FIU- ARC and their summer internships. FIU discussed the success of the DOE Fellows program and the program's importance in helping DOE cultivate a young diverse workforce. Director Harris talked to ARC staff about the importance of instilling principles and values in young people to ensure the future success of our nation. In addition, FIU's College of Engineering & Computing, STEM Transformation Institute, and Division of Research were all part of these meetings.

Mr. Jim Voss, managing director of Waste Management Symposia visited FIU on August 24, 2015 (Figure 4-10). During his visit, Mr. Voss gave a lecture as a part of DOE Fellows lecture series titled “Consent based siting of radioactive waste management facilities” (Figure 4-11). Mr. Voss also donated $10,000 to the DOE Fellows program to sponsor DOE Fellows attending the Waste Management 2016 Symposia.

Figure 4-10. Mr. Jim Voss (front, center) with DOE Fellows and ARC staff.

Figure 4-11. Mr. Jim Voss at DOE Fellows lecture series.

One (1) DOE Fellow prepared a research abstract to submit to the FIU McNair Scholars Research Conference to be held at the main FIU campus on October 14-16, 2015. This Fellow also began developing a research poster to present at the conference.

In addition, 18 DOE Fellows began preparing research posters for the DOE Fellows Poster Exhibition/Competition to be held on October 21, 2015. The winners of this competition will be announced during the 2014 DOE Fellows Induction Ceremony on November 5, 2015.

DOE Fellows attended the Applied Research Center Distinguished Lecture series featuring Dr. Costas Tsouris. The title of his talk was uranium from seawater. Dr. Tsouris toured the ARC facilities and interacted with DOE Fellows.

Five (5) DOE Fellows participated in hands-on radiation safety training provided by FIU's radiation safety officer as a part of the health and safety training. All five (5) of the Fellows and passed the training.

DOE Fellows along with FIU ARC staff had the opportunity to participate in a bicycle tour of the Everglades National Park's Shark Valley (Figures 4-12 and 4-13). Social events such as these serve as team building exercises among the DOE Fellows as well as with the ARC staff.

Figure 4-12. DOE Fellows on bicycle tour at the Everglades National Park.

Figure 4-13. DOE Fellows ready for bicycle tour at the Everglades National Park.

The DOE Fellows who participated in a summer internship are also preparing and presenting an oral presentation at the weekly DOE Fellows meetings. The schedule for these presentations is provided below.

Table 4-4. Presentations on Summer 2015 Internships

DOE Fellow	***Internship Location***	***Summer Mentor(s)***	***Date***
John Conley	*WRPS, Richland, WA*	*Terry Sams/ Dave Shuford*	*Sept 11, 2015*
Andrew De La Rosa	*Oak Ridge National Lab – Cyber & Information Security Research*	*Joseph Trien*	*Sept 18, 2015*
Kiara Pazan & Aref Shehadeh	*SRNL, Savannah River, SC*	*Miles Denham/ Margaret Millings*	*Oct 09, 2015*
Christine Wipfli	*DOE-HQ EM-12, Cloverleaf, Germantown, Maryland*	*Skip Chamberlain/ Kurt Gerdes*	*Oct 16, 2015*
Natalia Duque	*SRNL, Savannah River, SC*	*Ralph Nichols/ Carol Eddy-Dilek/ Brian Looney*	*Oct 16, 2015*
Maximiliano Edrei	*National Energy Technology Lab, Morgantown, WV*	*Chris Guenther*	*Oct 23, 2015*
Yoel Rotterman	*DOE-HQ EM-13, Forrestal, Washington D.C.*	*Albes Ganoa/ John De Gregory*	*Nov 06, 2015*

Ryan Sheffield	*DOE-HQ EM-20, Cloverleaf, Germantown, Maryland*	*James Poppiti*	*Nov 13, 2015*
Jorge Deshon	*SRNL, Savannah River, SC*	*John Bobbitt/ Steven Tibrea*	*Nov 20, 2015*
Janesler Gonzalez & Jesse Viera	*Idaho National Lab*	*Rick Demmer/ Steve Reese*	*Dec 04, 2015*
Anthony Fernandez	*Washington River Protection Solutions (WRPS), Richland, WA*	*Ruben Mendoza/ Gregory Gauck*	*Dec 11, 2015*
Meilyn Planas	*WRPS, Richland, WA*	*Terry Sams*	*Dec 11, 2015*
Claudia Cardona	*PNNL, Richland, WA*	*Jim Sczcsody*	*Dec 18, 2015*

An abstract the development of a workforce for the nuclear industry was accepted for a poster session during the Waste Management Symposia to be held on March 6-10, 2016 in Phoenix, AZ.

Abstract: 16513 - Development of a Workforce for the Nuclear Industry
Session: 028 - Workplace Management and Performance Solutions
Date: Monday, March 07, 2016
Time: 1:30 PM - 5:00 PM

In addition, professional abstracts were developed and submitted by DOE Fellows along with their summer internship mentors and ARC mentors to the Waste Management 2016 Symposia, which were accepted for poster or oral presentations. The list of abstracts submitted that include DOE Fellows as authors:

- Improving the Accuracy of Computational Fluid Dynamics Simulations of Nuclear Waste Mixing using Direct Numerical Simulations : Reza Abassi, **Max Edrei (DOE Fellow)**, Seckin Gokultun, Dwayne McDaniel
- Development of Inspection Tools for the AY-102 Double-shell Tank at the Hanford DOE Site: Anthony Abrahao, **Ryan Sheffield (DOE Fellow)**, Hadi Fekrmandi, Dwayne McDaniel
- Migration and Distribution of Natural Organic Matter Injected into Subsurface Systems: Ravi Gudavalli, **Kiara Pazan (DOE Fellow)**, Miles Denham, Brian Looney
- Green & Sustainable Remediation Analysis of a Packed Tower Air Stripper Used to Remediate Groundwater Contaminated with CVOCs: David Roelant, **Yoel Rotterman (DOE Fellow)**, Ralph Nichols

- Using GIS for Processing, Analysis and Visualization of Hydrological Model Data: Angelique Lawrence, Mehrnoosh Mahmoudi, Shimelis Setegn, **Natalia Duque (DOE Fellow)**, Brian Looney
- Development of an Integrated Hydrological Model for Simulation of Surface Runoff and Stream Flow in Tims Branch Watershed: Mehrnoosh Mahmoudi, Angelique Lawrence, Shimelis Setegn, **Natalia Duque (DOE Fellow)**, Brian B. Looney
- DOE Climate Change Vulnerability and Adaptation Planning: **Yoel Rotterman (DOE Fellow)**, Albes Gaona, Beth Moore
- Multicomponent Batch Experiments Investigating Uranium Synergy with Humic Acid, Silica Colloids and SRS Sediments at variable pH: Ravi Gudavalli, **Christian Pino (DOE Fellow)**, Yelena Katsenovich, Miles Denham
- Characterization of U(VI)-Bearing Precipitates Produced by Ammonia Gas Injection Technology: **Robert Lapierre (DOE Fellow)**, Yelena Katsenovich, Leonel Lagos
- Incombustible Fixatives for D&D Activities: Joseph Sinicrope, Peggy Shoffner, Leonel Lagos, **Janesler Gonzalez (DOE Fellow), Jesse Viera (DOE Fellow), Meilyn Planas (DOE Fellow), Orlando Gomez (DOE Fellow)**, Aaron Washington (SRNL)

FIU updated an infographic highlighting the DOE Fellows Program (see following figure) and posted the new infographic on the DOE Fellows website (fellows.fiu.edu).

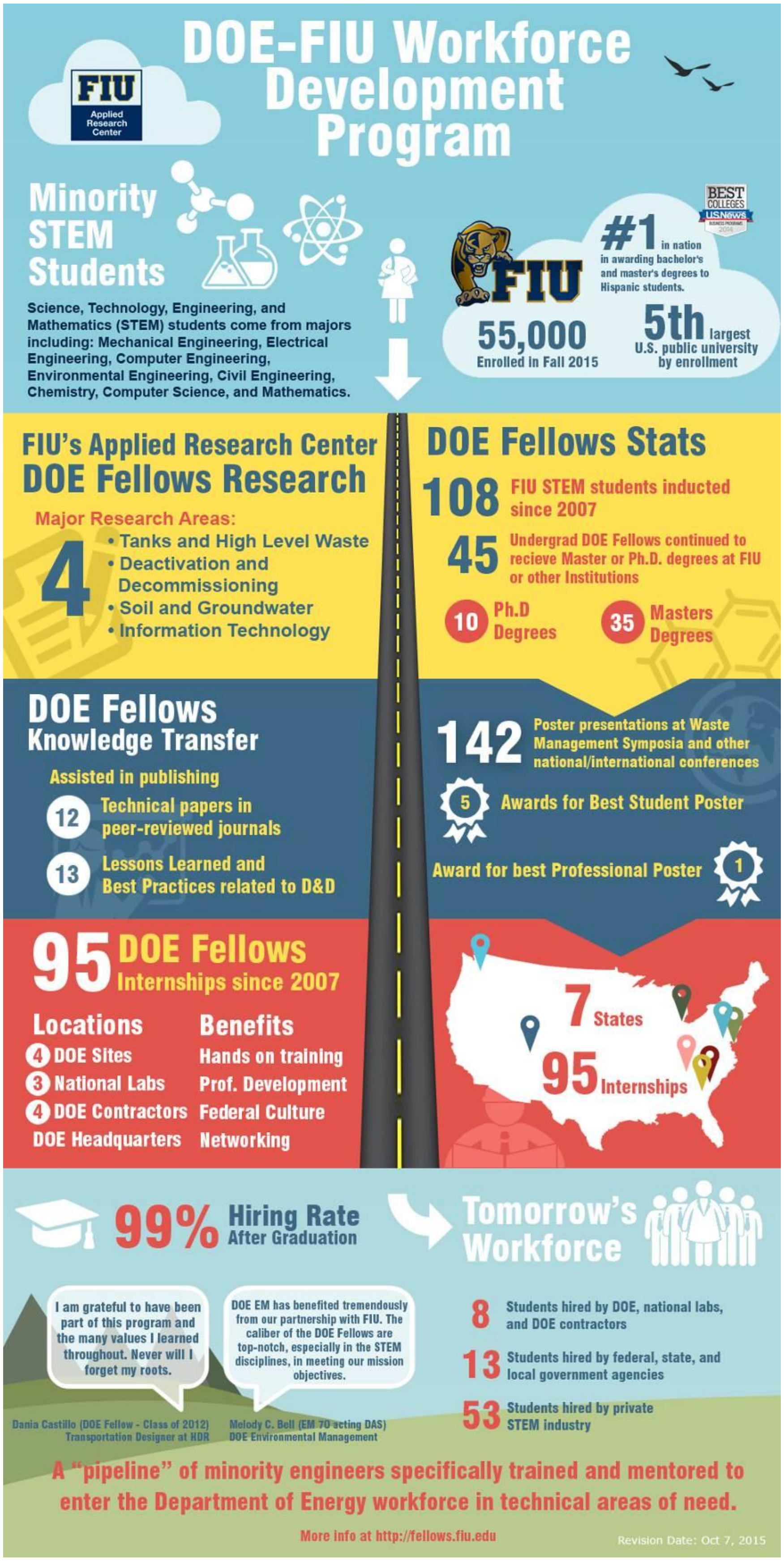


Figure 4-14. DOE Fellows Program Infographic.

During FIU Year 6, FIU will increase efforts to engage EM-70 (Human Resources) to enhance the recognition across the DOE EM complex of the DOE Fellows as they finish the Workforce Development Program, graduate from FIU, and enter the workforce. Employment opportunities at DOE HQ, DOE sites, DOE national laboratories, and DOE contractors will be actively sought. In addition, FIU will engage with the human resource contacts at both DOE and the contractors to highlight the special knowledge and skills these trained DOE Fellows bring with them. ARC mentors will work with individual DOE Fellows as they enter their last terms at FIU to assess their career goals, identify target employers, develop job profiles (e.g., USA Jobs) and resumes, complete employment applications, and practice for interviews.

During September, FIU began to aggressively identify federal entry-level career opportunities within DOE on USA Jobs and forward those vacancy announcements to the DOE Fellows. ARC mentors also began to identify those DOE Fellows who are preparing to transition from academia to the workforce and conducted mentoring sessions with those Fellows on resume preparation, the USA Jobs application process, etc. DOE Fellow Meilyn Planas (with a planned December 2015 graduation date) submitted applications to DOE job announcements [DOE-BPA-15-11159-DE (Electronics Engineer) and DOE-BPA-15-11158-DE (Electrical Engineer)] with the assistance and supervision of her ARC mentor, who subsequently followed up with correspondence to the Agency contact.

The Fellows continued their research in the four DOE EM applied research projects under the cooperative agreement and research topics identified as part of their summer internships at DOE sites, national labs, and/or DOE HQ. Each DOE Fellow is assigned to DOE EM research projects as well as ARC mentors. A list of the current Fellows, their classification, areas of study, ARC mentor, and assigned project task is provided below:

Table 4-5. Projects Support by DOE Fellows

Name	Classification	Major	ARC Mentor	Project Support
Alejandro Hernandez	Undergrad - B.S.	Chemistry	Dr. Vasileios Anagnostopoulos	Groundwater Remediation at SRS F/H -Area
Andrew De La Rosa	Graduate – M.S.	Computer Eng.	Mr. Clint Miller	Information Technology for Environmental Management
Anthony Fernandez	Undergrad - B.S	Mechanical Eng.	Mr. Amer Awwad	Evaluation of Nonmetallic Components in the Waste Transfer System
Aref Shehadeh	Undergrad - B.S.	Envr. Eng.	Dr. Yelena Katsenovich	Monitoring of U(VI) Bioreduction after ARCADIS Demonstration at F-Area
Awmna Kalsoom	Undergrad - B.S.	Chemistry	Ms. Angelique Lawrence	Surface Water Modeling of Tims Branch
Brian Castillo	Undergrad - B.S.	Biomedical Eng.	Ms. Aparna Aravelli	Development of a Micromachined Ultrasonic Transducer System for Analysis of High Level Waste Pipes at Hanford
Christin Pino	Undergrad - B.S.	Chemistry	Dr. Ravi Gudavalli	Synergistic Effects of Silica and Humic Acid on U(VI) Removal

Christine Wipfli	Undergrad - B.S.	Envr. Eng.	Dr. Vasileios Anagnostopoulos	Groundwater Remediation at SRS F/H Area
Christopher Strand	Undergrad - B.S.	Civil & Env. Eng.	Dr. Shimelis Setegn & Ms. Angelique Lawrence	Surface Water Modeling of Tims Branch
Claudia Cardona	Graduate - Ph.D.	Envr. Eng.	Dr. Yelena Katsenovich	Sequestering Uranium at the Hanford 200 Area Vadose Zone
Erim Gokce	Undergrad - B.S.	Mechanical Eng.	Mr. Anthony Abrahao	Development of Inspection Tools for DST Primary Tanks
Hansell Gonzalez	Graduate - Ph.D.	Chemistry	Dr. Yelena Katsenovich	Sorption Properties of Humate Injected into the Subsurface System
Janesler Gonzalez	Undergrad - B.S.	Mechanical Eng.	Mr. Joseph Sinicrope	Incombustible Fixatives
Jesse Viera	Undergrad - B.S.	Mechanical Eng.	Mr. Joseph Sinicrope	Incombustible Fixatives
John Conley	Undergrad - B.S.	Mechanical Eng	Mr. Amer Awwad	Evaluation of Nonmetallic Components in the Waste Transfer System
Jorge Deshon	Undergrad - B.S.	Computer Eng.	Dr. Himanshu Upadhyay	Information Technology for Environmental Management
Kiara Pazan	Undergrad - B.S.	Envr. Eng.	Dr. Ravi Gudavalli	Modeling of the Migration and Distribution of Natural Organic Matter injected into Subsurface Systems
Maximiliano Edrei	Graduate – M.S.	Mechanical Eng.	Dr. Dwayne McDaniel	Computational Fluid Dynamics Modeling of HLW Processes in Waste Tanks
Meilyn Planas	Undergrad - B.S.	Electrical Eng.	Mr. Joseph Sinicrope	Incombustible Fixatives
Natalia Duque	Graduate – M.S.	Envr. Eng.	Ms. Angelique Lawrence	Surface Water Modeling of Tims Branch
Orlando Gomez	Graduate - Ph.D.	Physics	Mr. Joseph Sinicrope	Incombustible Fixatives
Robert Lapierre	Graduate – M.S.	Chemistry	Dr. Yelena Katsenovich	Sequestering Uranium at the Hanford 200 Area Vadose Zone
Ryan Sheffield	Undergrad - B.S.	Mechanical Eng.	Mr. Anthony Abrahao	Development of Inspection Tools for DST Primary Tanks
Silvina Di Pierto	Graduate - Ph.D.	Chemistry	Dr. Hilary Emerson	Evaluation of Ammonia for Uranium Treatment
Yoel Rotterman	Undergrad - B.S.	Mechanical Eng.	Dr. David Roelant	Sustainable Remediation

Milestones and Deliverables

The milestones and deliverables for Project 4 for FIU Year 5 are shown on the following table. The Technical Fact Sheet for this project was updated during this performance period.

FIU Year 5 Milestones and Deliverables for Project 4

Milestone/ Deliverable	Description	Due Date	Status	OSTI
2014-P5-M1	Draft Summer Internships Reports	10/04/14	Complete	
Deliverable	Deliver Summer 2014 interns reports to DOE	10/17/14	Complete	
Deliverable	List of identified/recruited DOE Fellow (Class of 2014)	10/31/14	Complete	
2014-P5-M2	Selection of new DOE Fellows – Fall 2014	10/31/14	Complete	
2014-P5-M3	Conduct Induction Ceremony – Class of 2014	11/13/14	Complete	
2014-P5-M4	Submit student poster abstracts to Waste Management Symposium 2015	01/15/15	Complete	
Deliverable	Update Technical Fact Sheet	30 days after end of project	Complete	

The milestones and deliverables for Project 4 for FIU Year 6 are shown on the following table. A draft Project Technical Plan was developed which includes the scope of work intended for FIU Year 6. No other milestones or deliverables were due for this project during September.

FIU Year 6 Milestones and Deliverables for Project 4

Milestone/ Deliverable	Description	Due Date	Status	OSTI
2015-P5-M1	Draft Summer Internships Reports	10/16/15	On Target	
Deliverable	Deliver Summer 2015 interns reports to DOE	10/30/15	On Target	OSTI
Deliverable	List of identified/recruited DOE Fellow (Class of 2015)	10/30/15	On Target	
2015-P5-M2	Selection of new DOE Fellows – Fall 2015	10/30/15	On Target	
2015-P5-M3	Conduct Induction Ceremony – Class of 2015	11/05/15	On Target	
2015-P5-M4	Submit student poster abstracts to Waste Management Symposium 2016	01/16/16	On Target	
Deliverable	Update Technical Fact Sheet	30 days after end of project	On Target	

Work Plan for Next Quarter

- Continue research by DOE Fellows in the DOE-EM applied research projects under the cooperative agreement and research topics identified as part of their summer 2015 internships.
- Complete and submit the DOE Fellow summer internship technical reports to DOE.
- Complete preparation/coordination and host the DOE Fellows Poster Exhibition & Competition on October 21, 2014.
- Complete selection of new DOE Fellows for the summer/fall recruitment period and submit list of selected DOE Fellows to DOE by October 30, 2015.
- Complete preparation/coordination and host the DOE Fellows Induction Ceremony – Class of 2015 on November 5, 2015.
- Submit technical paper on workforce development to WM16.