

FIU PROJECT 3 - 2014 FACT SHEET

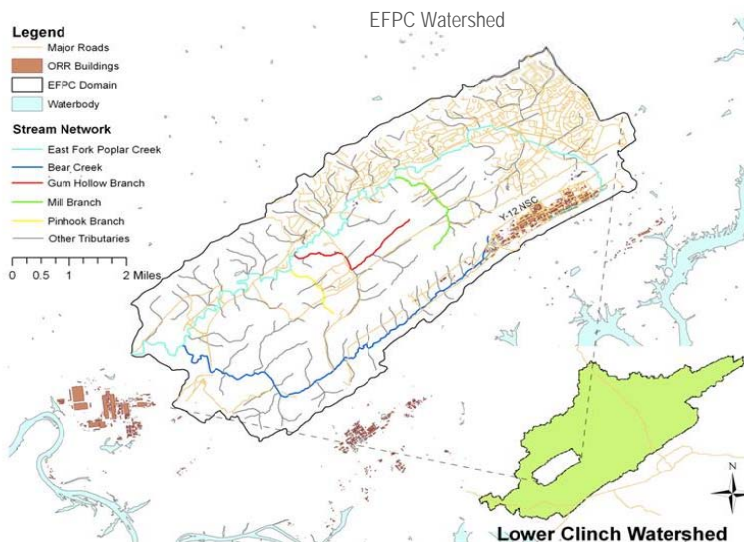
## Remediation and Treatment Technology Development and Support

*FIU's Applied Research Center (ARC) has developed integrated flow and transport models of the East Fork Poplar Creek (EFPC) and White Oak Creek (WOC) watersheds to analyze the mercury (Hg) transport patterns within Oak Ridge Reservation, TN. The models were applied to determine the effect of historical hydrological events on mercury transport within the relevant watersheds and to determine the efficiency of selected remedial alternatives.*

The integrated surface/subsurface numerical model of EFPC includes sedimentation and reactive transport modules, and has been used to perform numerical simulations that are relevant for NPDES and TMDL regulations.

A geodatabase was developed as a strategy for centralization, management, processing, and analysis of spatial and temporal numerical modeling data. The hydrologic geodatabase model used possesses a structure that enables linkage with scalable hydrologic modeling tools and applications, and can be used to automate and simplify the process of calling stored GIS and timeseries data.

FIU-ARC is also supporting U.S. DOE's Offices of Environmental Management (EM) and Health, Safety & Security (HSS) that established a cross-programmatic team in 2012 to benchmark, train, and evaluate the cost-benefit of Green & Sustainable Remediation (GSR) practices applied to cleanup and closure projects at field sites and Headquarters' management of those projects.



### Project Objectives

- Assessment of the effectiveness of ongoing and future remedial actions at ORR via:
  - Development of an integrated surface/subsurface model to study multiphase transport of Hg species in the saturated and unsaturated zones of EFPC watershed, including physical, biological and chemical transformations under site-specific environmental conditions.
  - TMDL analysis on EFPC and development of a TMDL methodology for analysis of flow and load duration exceedance probabilities for key monitoring stations along Bear Creek and EFPC.
- Development of a geodatabase to support hydrological model development and simulation of contaminant fate and transport at the Oak Ridge Reservation.
- Assist the U.S. DOE's goals to lower costs and improve effectiveness of remediation strategies applicable to soil, groundwater, radioactive waste, and facility D&D by:
  - Comparing and contrasting alternatives for remedial, monitoring, waste handling and D&D design using SITEWISE™ software that will generate results for cost benefit and sustainable decision-making for regulatory compliance.
  - Calculating sustainability factors for the investigation, construction, operation, and long term monitoring phases to estimate the overall footprint of remedial alternatives.

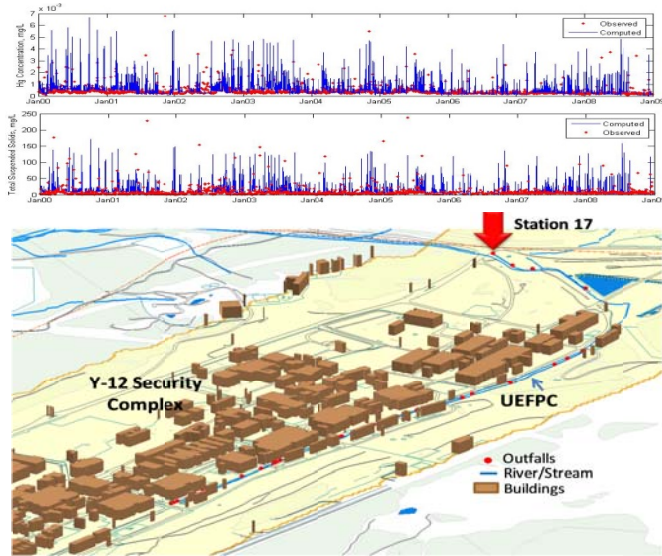
### Project Benefits

- Better understanding of the flow and transport of Hg within the ORR watersheds on a regional scale and the risks associated with D&D operations and potential mobilization of Hg at ORR.
- Provides stakeholders with a tool for "what if" analyses to achieve lower uncertainty and considerably better spatial and temporal forecasting of the Hg contamination at ORR under varying environmental conditions.
- Modeling will support development of TMDLs to estimate source loading and evaluate loading capacities that will meet water quality standards. (*EFPC identified on Final 2008 303(d) List by TDEC as impaired waterbody not supporting designated uses due to contamination by mercury, PCBs, nitrates, and phosphates*).
- TMDLs may be used to develop controls for reducing pollution from both point and nonpoint sources to restore and maintain the quality of water resources.
- Utilizing a building block approach will reduce redundancy in the sustainability evaluation and facilitate identification of specific activities that have the greatest environmental footprint.
- The methodology employed will provide a decision matrix for remedy selection, design, or implementation and allows for a remedy optimization stage as well.

**FIU PROJECT 3 - 2014 FACT SHEET**

**Project Accomplishments**

- Integrated flow and transport models of EFPC and WOC watersheds; numerical simulations and reviews of monitoring data available from OREIS related to Hg contamination and remediation within these watersheds.
- A report of water quality criteria and TMDL target, water quality assessment and deviation from the TMDL target, water quality data analysis, and source identification.



**Total suspended solids and Hg concentration compared with historical data at Station 17**

- Development of a geodatabase to serve as a centralized data management system facilitating storage, editing, and versioning of flow and contaminant transport modeling parameters in EFPC and WOC watersheds.



**Figure 1. Multi-user editing and versioning capability of the ORR geodatabase.**

- A review of available statistical or geostatistical software, including MAROS or GTS.
- Tests with monitoring module in SITEWISE™. Results used to calculate reduction in emissions, energy and water usage, waste generation, and accident risk over the program total life cycle in MS Excel.



**SITWISE site info sheet.**

- A review to determine factors impacting GSR metrics, including:
  - Excessive number of monitoring locations
  - Inefficient chemical injection strategy
  - Excess quantity of chemicals used
  - Inefficient power usage by over-sized equipment
  - Installing less energy efficient equipment
  - Unnecessary continuously running equipment
  - Unnecessary unit operations
- Development of optimization strategies for integrated surface and groundwater models capable of predicting contaminant fate and transport within the site domain to achieve the following:
  - Reduction of the number of monitoring locations
  - Improvement of the chemical injection strategy
  - Reduction of the quantity of chemicals used
- Publication of several scientific articles in peer-reviewed journals and conference proceedings from the experimental and modeling results derived from this project work.

FIU PROJECT 3 – TASK 3.1 – 2014 FACT SHEET

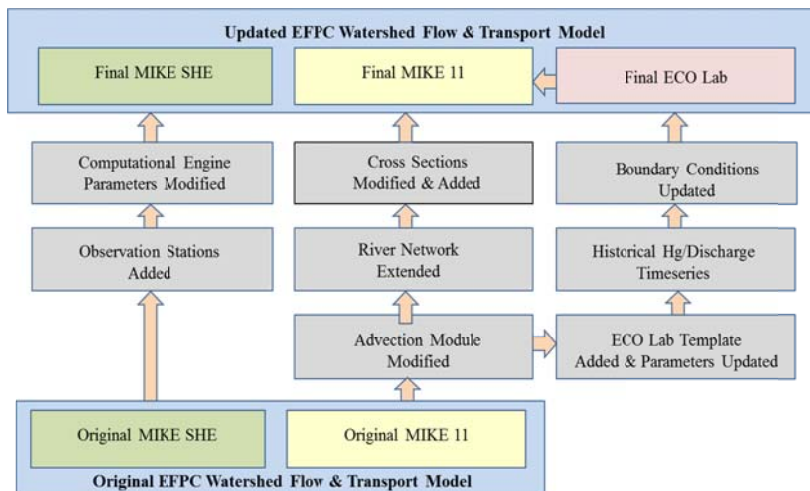
## East Fork Poplar Creek Model Update, Calibration & Uncertainty Analysis

*FIU-ARC is providing technical assistance and performing research on mercury remediation at Oak Ridge Reservation (ORR), TN. The objective of this project is to support the remediation efforts at ORR through hydrological modeling in order to provide a better understanding of the fate and transport of inorganic and organic pollutants of concern with a focus on mercury (Hg).*

FIU-ARC researchers developed a numerical model of EFPC to determine the impact of remediation alternatives on the complete hydrologic cycle, the transport overland and in surface water and rivers, sediment transport and reactions, and mercury exchange with sediments. Historical measurement records including the timeseries for precipitation, evapotranspiration, groundwater levels, and river discharges were obtained from the OREIS and ORNL databases and incorporated into the MIKE model as boundary conditions. The hydrological model was calibrated and validated by comparing the computed discharges and water levels with the historical records at selected monitoring stations (the outfalls listed in the NPDES document for Y-12 NSC). Uncertainty and sensitivity analyses were performed for critical hydrological parameters such as the Manning number, and the vertical and horizontal hydraulic conductivities of each of the five geologic layers.

### Project Objectives

The objective of this project is to provide an analysis of the coupling between hydrology and mercury transport within the context of decreasing risk of D&D activities. Numerical and stochastic analyses of observed and computed timeseries for flow and contaminant concentration for NPDES-regulated outfalls within the EFPC watershed were conducted. The EFPC model was then used to simulate a range of hydrological impacts related to planned remediation alternatives.



### Project Benefits

- Use of conventional hydrologic and remediation analytical tools (accepted by EPA, USACE, and USGS) in combination with latest scientific software (2D and 3D numerical flow and transport models integrated with reaction kinetics and thermodynamic software) provides an integrated solution for understanding mobility and impacts of contaminants at DOE sites.
- Provides state of the practice tools for analysis of sustainable and green remediation alternatives (developed for DOD sites), which are needed to address long term sustainability in terms of reduced environmental and energy footprints of remedial actions.

### Project Accomplishments

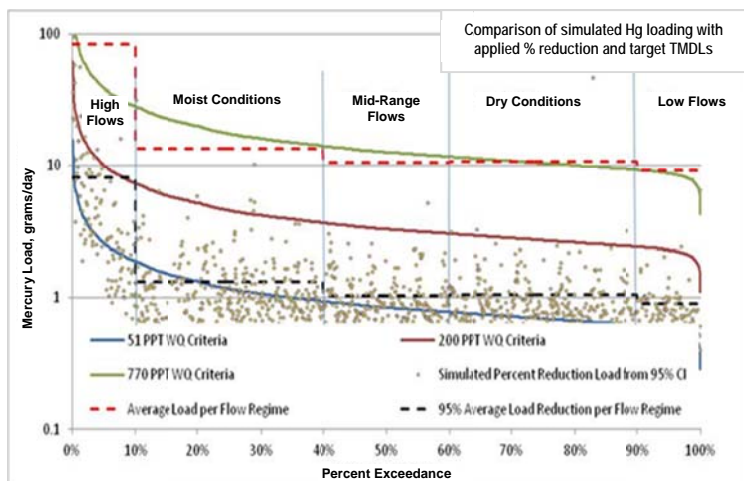
- Developed and calibrated a numerical model for hydrology, sediment and Hg transport in UEFPC (1996 to present).
- Reconfigured model to incorporate a sedimentation module and then extended it to include 52 additional outfalls covering the entire EFPC and Bear Creek.
- Performed numerical simulations using a range of Manning's numbers, threshold run-off water depths, and drainage coefficients to calibrate flow from 2000 – 2008. MATLAB scripts were used for statistical analysis of observed and computed data.
- Provided U.S. DOE with assessment reports on the effectiveness of 8 different remedial scenarios.
- Reviewed and updated the existing Hg thermodynamic database specific to EFPC environmental conditions and integrated it into the flow and transport models already developed for the site.
- Implemented equations in the kinetic solver (ECOLAB) which provides distribution between total-Hg and methyl-Hg species based on observed distribution coefficients (as fraction).
- Conducted preliminary tests to calibrate the model using observed ratios of total-Hg and methyl-Hg concentrations. Initial results showed that the template predicts, as expected, the ratio between total-Hg and methyl-Hg concentrations.



FIU PROJECT 3 – TASK 3.2 – 2014 FACT SHEET

## Simulation of NPDES- and TMDL-Regulated Discharges from Non-Point Sources for the EFPC and Y-12 NSC

FIU-ARC is supporting the remediation efforts at the Oak Ridge Reservation (ORR) by performing research that will provide a better understanding of the fate and transport of inorganic and organic pollutants of concern with a focus on mercury (Hg).



The numerical model of East Fork Poplar Creek (EFPC) developed by FIU-ARC simulates fate and transport of mercury (Hg) and volatile organic compounds (VOCs) within the EFPC watershed.

This task focused on analysis of the relative contribution of point and non-point sources to Hg pollution in the watershed including contributions from:

1. Floodplains of EFPC and Bear Creek.
2. Remobilization of sediments during stormwater events.
3. Groundwater exchange and transport within the creeks.

### Project Accomplishments

- Update of existing EFPC database for all 57 outfalls along EFPC up to 2013 including:
  - Boundary conditions such as rainfall, evapotranspiration, surface & groundwater levels and water flow timeseries of outfalls, rivers and canals.
  - Pollutant sources in soil, water and sediments.
  - Bioassessment data.
- Spatial and temporal analyses to identify spatial variations of Hg in EFPC soil, water, and sediments. Effect of rainfall and runoff on Hg conc. in EFPC was also investigated.
- Comprehensive review of TMDL requirements for EFPC established by EPA and TDEC, revealing a target Hg conc. for EFPC of 51 ppt for recreational use based on TDEC regulations for surface waters, from which a "Loading Capacity" duration curve was developed.
- Development of a report specific to EFPC which includes:
  - Water quality criteria and TMDL target.
  - Water quality assessment and deviation from TMDL target.
  - Water quality data analysis and source identification.
  - Development of flow and load duration curves.
  - Load allocation analysis.
- Development of several target load-duration curves for EFPC. Hg target concs. of 51, 200, and 770 ppt were applied to each ranked flow and used to generate flow duration curves.
- Incorporation of the newly developed ECOLAB template into the existing EFPC hydrological model which includes methylmercury into the set of kinetic and thermodynamic equations. Several initial simulations were completed and the results are being analyzed.

### Project Objectives

- Understand the relationship among impaired domains and evaluate the timing of impairment and potential source loading or other conditions contributing to impairment.
- Analyze relationships among multiple parameters such as:
  - Contaminant concentration and flow.
  - Suspended sediments and contaminant concentration.
  - Hydraulic parameters such as Manning's number and contaminant concentration.
- Identify the nature of the impairments being addressed by the TMDL, perform TMDL analysis on EFPC and develop a TMDL methodology for analysis of flow and load duration exceedance probabilities for key monitoring stations along Bear Creek and the EFPC from numerical simulations and observed data.

### Project Benefits

- Modeling will support development of TMDLs to estimate source loading and evaluate loading capacities that will meet water quality standards. (EFPC identified on Final 2008 303(d) List by TDEC as impaired waterbody not supporting designated uses due to contamination by mercury, PCBs, nitrates, and phosphates).
- TMDLs may be used to develop controls for reducing pollution from both point and nonpoint sources to restore and maintain the quality of water resources.

FIU PROJECT 3 – TASK 3.3 – 2014 FACT SHEET

# Environmental Remediation Optimization: Cost Savings, Footprint Reductions, and Sustainability Benchmarked on DOE Sites

*FIU's Applied Research Center (ARC) is supporting U.S. DOE's Offices of Environmental Management (EM) and Health, Safety & Security (HSS) that established a cross-programmatic team in 2012 to benchmark, train, and evaluate the cost-benefit of Green & Sustainable Remediation (GSR) practices applied to cleanup and closure projects at field sites and Headquarters' management of those projects.*

The SITEWISE™ tool is designed to calculate the environmental footprint from user input and impact factors contained within the tool using a series of Microsoft Excel spreadsheet applications. SITEWISE™ is designed to be used in the planning stages of a project to estimate the environmental impacts of that project using different treatment technologies. The tool can support the identification and selection of the ideal remediation technology for a given project. SITEWISE™ is being used to estimate the environmental impacts associated with a particular selected remediation project. The remediation technologies used for the project will be implemented using the tool. The result will be based on input data supplied by the user and on software-specific calculations to translate the quantities of materials, use of equipment and vehicles, and use of energy into impacts and environmental footprint.

## Project Objectives

- To greatly lower costs and improve effectiveness of remediation strategies applicable to soil, groundwater, radioactive waste, and facility D&D.
- Compare and contrast alternatives for remedial, monitoring, waste handling, and D&D design that will generate results for cost benefit and sustainable decision-making for regulatory compliance.
- Calculate sustainability factors for the investigation, construction, operation, and long term monitoring phases to estimate the overall footprint of remedial alternatives.

## Project Benefits

- The building block approach used will reduce redundancy in the sustainability evaluation and facilitate the identification of specific activities that have the greatest environmental footprint.
- The methodology employed will provide a decision matrix for remedy selection, design, or implementation and allows for a remedy optimization stage as well.

## Project Accomplishments

- A review of available statistical or geostatistical software, including MAROS or GTS, was conducted. The software is used to downsize a compliance monitoring program (i.e., remove wells, analytes, or frequencies).
- Tests were conducted with the monitoring module in SITEWISE™ and the results used to calculate the reduction in emissions, energy and water usage, waste generation, and accident risk over the program total life cycle in MS Excel.
- Initial simulations were conducted and data gaps are being identified and researched.



SITEWISE site info sheet.

- A review was conducted to determine factors which may significantly impact the GSR metrics, including:
  - Excessive number of monitoring locations
  - Inefficient chemical injection strategy
  - Excess quantity of chemicals used
  - Inefficient power usage by over-sized equipment
  - Installing less energy efficient equipment
  - Unnecessary continuously running equipment
  - Unnecessary unit operations
- Optimization strategies were developed for integrated surface and groundwater models capable of predicting contaminant fate and transport within the site domain to achieve the following:
  - Reduction of the number of monitoring locations
  - Improvement of the chemical injection strategy
  - Reduction of the quantity of chemicals used

FIU PROJECT 3 – TASK 3.4 – 2014 FACT SHEET

# Geodatabase Development for Hydrological Modeling Support

FIU-ARC is providing technical assistance and performing research on mercury remediation at Oak Ridge Reservation (ORR), TN. The objective of this project is to support the remediation efforts at ORR through hydrological modeling in order to provide a better understanding of the fate and transport of inorganic and organic pollutants of concern with a focus on mercury (Hg).

During FY11 ARC-FIU researchers developed a geodatabase to support the hydrological work being performed at ORR, which serves as a centralized data management system, making the large amounts of data generated from the simulations of contaminant fate and transport accessible to all users. The geodatabase facilitates storage, concurrent editing and import/export of data specific to the hydrologic models being used. FY12 work extended the geodatabase capabilities and created models using ArcGIS ModelBuilder and Python scripting to automate the processes of querying the existing EFPC geodatabase and generating maps. Easily downloadable free/open source geographic information systems (GIS) software along with required security protocols for viewing and querying the hydrological model data and for generating maps, graphs and reports, were investigated to determine a simple way of sharing project derived data with other project stakeholders such as U.S. Department of Energy (DOE) personnel and ORR site contractors.

## Project Objective

To create a geodatabase that supports hydrological model development and simulation of contaminant fate and transport at Oak Ridge Reservation (ORR), TN. The geodatabase will serve as a centralized data management system facilitating storage, editing, and versioning of model parameters.

## Project Benefits

- Facilitates centralized storage, backup, access and management of model configuration files and computed simulation data (which in many cases exceed 20 GB per simulation).
- Organizes data into a structured, coherent, and logical computer-supported system that can be used to automate and simplify retrieval of stored GIS and timeseries data.
- Possesses versioning tools that enable proper security management and quality assurance while data editing.
- Possesses a database structure that enables linkage with scalable hydrologic modeling tools and applications that model hydrologic systems.
- The ArcGIS geodatabase is an XML-based GIS data exchange system which facilitates the export and import of preconfigured data as XML files which can contain both the data definition and the data itself.

## Project Accomplishments

- Development of an ArcSDE geodatabase which stores data for hydrological modeling of contaminant flow and transport in EFPC and WOC watersheds at Oak Ridge Reservation (ORR), TN.
- Automation of processes for querying the EFPC geodatabase and generating maps and reports via data models created using ArcGIS ModelBuilder and Python scripting.
- Evaluation of free/open source GIS software and required security protocols for viewing, querying and sharing project-derived hydrological modeling data with other project stakeholders, such as U.S. DOE personnel and ORR site contractors.

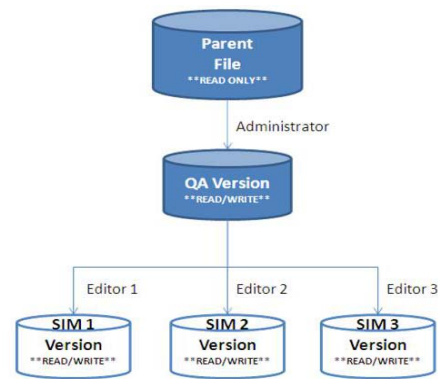


Figure 1. Multi-user editing and versioning capability of the ORR geodatabase.

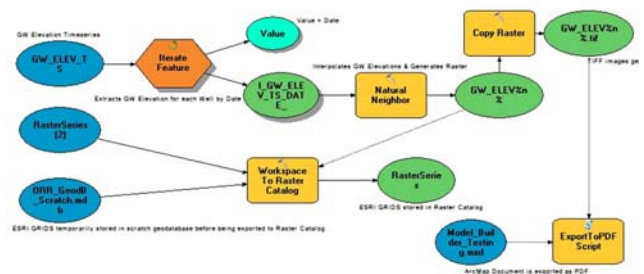


Figure 2. Process workflow diagram created using ArcGIS ModelBuilder and Python scripts.

Software	Version	Operating System	Free/Open Source	Website
ArcReader	10.1	Windows, Mac OS	Free	<a href="http://www.esri.com/software/arcgis/arcreader">http://www.esri.com/software/arcgis/arcreader</a>
ArcGIS Explorer Desktop	2500	Windows, Mac OS	Free	<a href="http://www.esri.com/software/arcgis/explorer">http://www.esri.com/software/arcgis/explorer</a>
Quantum GIS	1.8.0	Windows, Mac OS, Linux	Free/Open Source	<a href="http://www.qgis.org/">http://www.qgis.org/</a>
DIVA GIS	7.5	Windows, Mac OS	Free/Open Source	<a href="http://www.diva-gis.org/">http://www.diva-gis.org/</a>
TatukGIS Viewer	4	Windows, Mac OS	Free	<a href="http://www.tatukgis.com/">http://www.tatukgis.com/</a>
MapWindow	4.x	Windows, Mac OS	Free/Open Source	<a href="http://www.mapwindow.org/">http://www.mapwindow.org/</a>
HydroDesktop	1.5	Windows, Mac OS	Free/Open Source	<a href="http://hydrodesktop.codeplex.com/">http://hydrodesktop.codeplex.com/</a>
GRASS GIS	6	Windows, Mac OS, Linux	Free/Open Source	<a href="http://grass.osgeo.org/">http://grass.osgeo.org/</a>
Google Earth		Windows, Mac OS, Linux	Free	<a href="http://www.google.com/earth/index.html">http://www.google.com/earth/index.html</a>

Figure 3. Table of free/open source GIS software reviewed by ARC-FIU.