

KRCEE FFY 2013 Annual Activity Report

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PROGRAM BACKGROUND

Project text below summarizes the administrative, technical and public outreach activities conducted during FFY 2013, *October 2012–September 2013*. The activities addressed in the summary report were undertaken by the Center for Applied Energy Research – Kentucky Research Consortium for Energy and Environment (KRCEE) through Department of Energy Award Number DE- FG05-03OR23032. Accompanying this report is a brief electronic PowerPoint presentation provided to the Center for Applied Energy Research Board of Directors at its annual meeting in November 2013. The text in this document supplements the bulleted summary in the PowerPoint.

University of Kentucky faculty, staff, and contractors have been participating in environmental and outreach/education projects related to the Paducah Gaseous Diffusion Plant (PGDP) for twenty plus (20+) years. For the past eleven (11) years, in-depth projects have been undertaken and completed to address a variety of specific subject matter needs related to site cleanup and re-use. The projects address topics that are generally outside of specific requirements posed by regulatory and compliance programs. Project focus areas include: Education & Public Outreach; Environmental and Geographic Data Distribution; Technical Data Assessment Training; Sampling Design & Risk Assessment, Ecological System Characterization & Monitoring, Development of Groundwater Remedial Methods to address PGDP conditions (dissolved phase contamination via microbes, nano iron & oxidative applications), Groundwater System Characterization, Groundwater Modeling, Characterization of Contaminated Groundwater Discharge to Surface Water, Soil Characterization/Remediation methods, Seismic Setting & Hazard Characterization, Seismic Activity Monitoring, and Geophysical Characterization Method Development and Application.

University of Kentucky Colleges and Departments involved with PGDP environmental and outreach projects include: the Kentucky Water Resources Research Institute, Center for Applied Energy Research, Kentucky Geological Survey (Water Resources, Mapping, & Hazards Sections), Superfund Basic Research Program, College of Engineering (Civil and Chemical Engineering Departments), Kentucky Transportation Center, College of Law, College of Communications, Earth and Environmental Sciences (Geology/Geophysics), College of Agriculture (Ag and Biosystems Engineering), and University of Kentucky Research Media. In addition to UK's internal resources, KRCEE has collaborated with in-state academic institutions and researchers as well as with national university programs, Department of Energy and EPA national laboratories and many independent subject matter experts. A complete listing of collaborators is available on the KRCEE web pages at www.ukrcee.org.

ADMINISTRATION ACTIVITIES

KRCEE projects are administered by management, financial, administrative and technical staff at the UK Center for Applied Energy Research. To date, KRCEE has completed more than 50 in-depth projects related to PGDP. In order to provide access to the materials produced by or supporting projects, a significant portion of FFY 2013 administrative time was expended developing the KRCEE web pages at www.ukrcee.org. This report is the first official announcement of web page availability.

The KRCEE web pages provide access to project background material, presentations and project reports produced through grant activities since 2003. In the execution of projects, KRCEE compiled several thousand technical and regulatory documents that are currently maintained by project topic on a file transfer protocol (ftp) site at the University. Those documents are presently available on an "as needed" basis related to project participation but will be made accessible on project-specific web pages.

Meetings were held between University officials and Kentucky's Congressional Delegation offices in late spring 2013. In those meetings the University proposed: 1) continued funding for KRCEE activities; 2)

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University-based collaborative initiatives related to independent review/recommendations regarding the effectiveness and future direction of PDGP Environmental Remediation activities; and 3) the Development of Environmental Education Facilities at the site.

The Environmental Remediation Review proposes an in-depth independent-expert evaluation of PGDP environmental impacts and development of recommendations to technically address short and long-term site restoration needs. The end product of the Environmental Remediation Review would be actionable recommendations to address the nature, size and scale of future remedial activities.

The Environmental Education Facility request addresses the development and implementation of a Field Environmental Laboratory at the PGDP. This project is a reiteration of Congressional Office/University requests to develop a Field Environmental and Computational Lab at PGDP in CY's 2006-8. The PGDP site would be an ideal field laboratory to train future industry and government environmental scientists on source scale thru sub-regional scale management and remediation of environmental impacts. An important aspect of the field laboratory would be the development and pilot-testing of technologies to address source, soil, and groundwater contamination at the site. Development and utilization of computational models as predictive tools for remediation would be "proofed" and refined based on project results during actual site deployment.

Administrative requirements for financial and activity reporting have continually increased over the past eight years and today require nearly four-fold more time and resources than early grant activities. Commensurate funding for administration activities has decreased three-fold since early grant activities. Addressing the funding of administrative and administrative support activities will be necessary for effective administration of future program activities.

PGDP CHALLENGES

Throughout PGDP project activities researchers and participants have identified a number of common themes that relate to PGDP cleanup and re-use. Those themes are the technical and outreach CHALLENGES that face the DOE, the regulatory community, stakeholders, and industry in efforts to restore the environment and re-use the facility for future economic benefit. Those challenges are identified in the bullets below:

- PGDP TCE & Technetium-99 (99Tc) Groundwater Plumes are among the largest documented plumes in U.S. and WORLD. The size poses challenges via extents approaching 3.5 miles downgradient from source areas and the sheer volume of contaminated water within the plumes.

Experience remediating large multi-contaminant plumes is a "not available" resource as there are not similar plumes that have been successfully remediated or documented in academic, government and regulatory accomplishments literature.

- State of Applied Environmental Science
 - Physical Environment. Multiple source areas cumulatively occupy more than one square mile of the PGDP industrial site and pose characterization and remediation challenges from both methods and funding perspectives. Many of the individual PGDP source area management units correlate in size, contamination and potential impact to standalone Superfund Sites elsewhere.

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The PGDP aquifer (Regional Gravel Aquifer-RGA) is very deep relative to most aquifers impacted by surface operations. This makes characterization and engineering control implementation challenging and very expensive at both source and plume scales.

The PGDP occupies a site in the northeastern extreme of the New Madrid Seismic Zone (NMSZ). Subsurface materials have been displaced by geologically historical seismic activities. The axis of the PGDP Northwest Plume exhibits near perfect correlation to underlying bedrock displacement trends. Concurrently the aquifer materials exhibit few structural characteristics of a paleo high-energy stream or river capable of moving and depositing the thick sequences of aquifer gravels and sands.

- Geochemical Environment (Contaminants, Groundwater Chemistry). PGDP surface water exhibits similar geochemical characteristics to local and regional waterways. The surface water also exhibits local areas of contaminated groundwater discharge (seeps and boils) not typical of streams and watersheds in unconsolidated material.

PGDP groundwater is aerobic meaning it contains significant concentrations of dissolved oxygen. This characteristic applies to shallow groundwater in the vadose zone, shallow semi-saturated materials overlying the aquifer and in the RGA. Geochemical processes impacting contaminant fate and transport in the aerobic PGDP groundwater are distinctly different from groundwater-contaminant reactions in the anaerobic environments typical of most contaminated sites studied and described in literature.

The nature of the radioactive soil and groundwater contaminant technetium-99 is not well understood at the PGDP. Because technetium-99 forms a very mobile ion in groundwater, its presence serves as an excellent tracer for the extent of groundwater movement.

The reactivity and stability characteristics of technetium-99 in soil, waste, and partially saturated conditions are more complicated than currently understood and explained in PGDP environmental investigations and industry technical literature. The longevity of ⁹⁹Tc as an active groundwater contaminant source is not known.

The presence and reactivity of minerals in the aquifer media relative to PGDP contaminants is poorly understood. In part this results from an inability to obtain intact and cohesive RGA media samples. The characteristics of iron and sulfate bearing minerals on aquifer media remains unknown although it is necessary to understand and possibly exploit all of the reactive processes impacting Trichloroethene (TCE) and technetium-99 fate in groundwater.

- General Scale of Industrial Operations (1 square mile). The main process buildings at PGDP were the largest structures in the world when constructed in the early 1950's.

The PGDP operated with the support of dedicated power plants to support its square mile of enrichment and industrial activities. PGDP's daily electrical consumption is comparable to daily use in the Nashville or St Louis metropolitan areas.

PGDP operations utilized 11 to 22 million gallons of water per day. The water supply system and several other "city-scale" water systems used for process cooling, waste water, fire response and

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storm water were constructed in the early 1950's. Those systems were not constructed to be "lossless" because of the relatively insignificant cost of the resource at the time and a general lack of understanding of potential environmental impacts.

Conservative estimates of PGDP water losses are slightly more than one (1+) million gallons per day (per square mile of the industrial facility). Industry estimates suggest that losses from heavy industrial operations may reach 30 per cent of supply which would result in anthropogenic losses of 3 – 6 million gallons per day on the industrial site.

Plant system usage and water losses have not been quantitatively characterized relative to impacts on source areas or effects on extensive groundwater plumes.

- Until recently, PGDP was an Operating facility with active surface and subsurface infrastructure. Active surface and subsurface infrastructure precluded investigation, characterization or remediation of many areas within the industrial site.
- Facility SHUTDOWN operations in May 2013
- Public Outreach – Cleanup, Re-use, Economics

The loss of 1,500 high paying skilled labor and professional jobs in a city of 25,000 will impact public and private financial and economic resources in Paducah, McCracken County, and the northeastern Jackson Purchase Region.

Re-use of sites at the scale of PGDP, with anticipated residual contamination and long-term monitoring requirements, is not common. Potential future uses need to consider the unique nature and benefits of the nuclear industry which have influenced the site and the community to date.

- Future direction of environmental restoration

With shutdown of active "for-profit" enrichment activities at the PGDP, DOE's role at the site is shifting to Decontamination and Decommissioning (D&D). Immediate federal resources for the site will shift from operations and environmental considerations to dismantling and disposing of significant quantities of contaminated and hazardous waste from deprecated site infrastructure.

It remains unclear whether significant funds will be made available to aggressively pursue remediation of extensive soil and groundwater contamination underlying the site and its vicinity.

KRCEE PROJECT ACTIVITIES FFY13-14

Technology Development Projects

- GIS and Environmental Database for the PGDP (DWGIS - PEGASIS)

Steve Hampson/KRCEE; Knut Torgerson/SAIC, DOE-PPPO, PORTS-PGDP DWGIS Team

This project remains active via participation in the PORTS-PGDP data warehouse project team and thru the development and deployment of a number of databases for inclusion on PGDP's

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PEGASYS data warehouse system which was originally developed by KRCEE and its contractors. The specific databases that have been completed or are nearing completion are identified in specific project tasks below.

This project is an ongoing administrative activity.

- Risk Assessment Numerical/Spatial Tool

Knut Torgerson/SAIC; Rich Bonczek/DOE-PPPO, Steve Hampson/UK-KRCEE;

This project reformats environmental monitoring data and integrates data access thru the DWGIS system to provide a digital framework for communicating and assessing human health risk across PGDP media.

PROJECT COMPLETION and DEPLOYMENT SPRING 2014

- Biological Removal of Tc-99 and TCE from GW

Dr. Rodney Andrews/CAER, Dr. Czar Crofcheck/UK-AgBSE, Mark Crocker/CAER

This project is assessing ex-situ microbial applications for the removal of TCE from groundwater.

Draft project findings are due late Spring 2014 in a brief summary report.

Seismic, Geophysical & Geotechnical Projects

- PGDP & Vicinity Seismic Monitoring

Dr. Zhenming Wang/UK –KGS, Dr. Ed Woolery/UK Geology (EES)

This project installed, operated, and maintained seismic monitoring stations in the Jackson Purchase Region including those in the vicinity of the PGDP. Data from the monitoring activities was assessed in the submitted project report.

Final Project Report submitted to DOE and posted on KRCEE website August 2013.

PROJECT COMPLETED Spring 2013.

- Seismic Imaging of Near-Surface Geologic Controls on PGDP Contaminant Plume Migration

Dr. Ed Woolery/UK Geology (EES), Ali Al-Mayahi/UK-EES, Steve Hampson/UK-KRCEE

This project collected several kilometers of new surface geophysical data and utilized historical SH and P wave surface geophysical data to discretize the upper boundary of the Regional Gravel Aquifer. Historical geophysical studies had been unable to discretize the top of RGA gravels and sands or any overlying confining material across the extent of the PGDP & vicinity study domain. New field data acquisition methods and grossly improved data filtering/processing options allowed for top of McNairy Formation and RGA surface discretization. The methods applied in this study were also utilized to identify and fast and a slow energy response directions in RGA depositional

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material. The response directions correlate with the general orientations of gravels via depositional energy in the placement environment and correlate with orientations of materials identified in outcrop.

Over the past 3 years this project was invited to several national seismic and geophysical professional meetings. It received national attention because of its importance in the development and refinement of geophysical characterization approaches for the shallow subsurface versus the traditional deep subsurface uses in the exploration industry.

Dr. Al-Mayahi defended his Ph.D. Dissertation May 2013 and has returned to Iraq as a geophysics professor at Basra University

Dr. Al-Mayahi's Dissertation was provided to DOE as one of two significant documents summarizing completion of the 3+ year field acquisition, methods development, and data assessment project.

1 Journal Article is presently in publication review and expected to be finalized by the end of CY13

1 Journal Article is pending for early CY 2014.

● Development of LithoStratigraphic & Materials Databases for PGDP

Steve Hampson/UK-KRCEE, Dr. Junfeng Zhu/KGS, Dr. Alan Fryar/UK-EES

Compilation of paper lithologic logs completed in CY2011.

Digital lithologic logs (digital copies of original paper logs) provided to DOE in August 2013.

Digital lithologic log database completed Spring 2013 (19,000 individual lithologic interval descriptions digitally entered and indexed)

Final draft of digital files for top and bottom of aquifer surfaces utilized in 2012 PGDP GW Model Recalibration

USCS Materials (C-clay, S-sand, G-gravel, and M-silt designations,etc.) partial database utilized in pilot point recalibration of hydraulic conductivity (K) fields in 2012 PGDP GW Model Recalibration. Materials and material suites were correlated to "relative" K characteristics identified in numerous literature studies.

Draft Final USCS Materials, lithologic and hydrostratigraphic databases due to DOE December 2013.

Groundwater Projects

● Groundwater Modeling Update for Land Study Appendix E

Dr. Junfeng Zhu/UK-KGS, Steve Hampson/UK-KRCEE

Completed Numerical Groundwater Model runs Fall 2012

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The project utilized the USGS MODFLOW Flow Model developed for the PGDP. Model runs considered several potential and possibly likely remedial action placements to address plume sources, high concentration on-site groundwater contamination (secondary sources), and off-site dissolved phase plumes. The model run results were evaluated to identify downgradient properties impacted by PGDP-related groundwater contamination over the next 100 years. Evaluation of the model inputs and results indicates that significant uncertainties exist relative to source areas, continuing contaminant contribution and the life cycle of the Northeast Plume at the PGDP. Uncertainties will be addressed in pending GW Model Project Team meetings with DOE, DOE contractors and regulators.

Recommendations to revisit and update the Land Study Report model relative to the present uncertainties associated with NE Plume and its sources will be discussed with DOE.

Final Report delivered to DOE November 2013

● Contaminant (TCE) Fate and Transport – TCE BioGeochemical Evaluation Workplan

Dr. Kevin Henke/CAER, Steve Hampson/UK-KRCEE, Dr. Hope Lee/PNNL, Dr. Brian Looney/SRNL

This project continues to evolve to include intensive groundwater geochemical data and potentiometric data collected at PGDP in CY's 2010 – 2012. The evaluation of historical releases and geochemical soil and groundwater distributions for contaminants and degradation related chemical constituents was completed in draft form and project team proceedings along with draft TCE BioGeochemical Workplan recommendations are posted on the KRCEE website.

Draft TCE BioGeochemical Workplan due to DOE Spring 2014

● Final Characterization of Contaminated Groundwater Discharge to Little Bayou Creek

Dr. Alan Fryar/UK-EES, Ganesh Tripathi/UK-EES

Dr. Ganesh Tripathi successfully defended his Dissertation in May 2013 and has returned to Nepal where he works for the Nepalese Geological Survey

This project built upon historical LBC seep and seep-reach monitoring and several non-DOE funded projects characterizing and monitoring contaminated groundwater plume discharges to Little Bayou Creek. Based upon application of rigorous field measurements/methods the seep reach was quantitatively characterized relative to discharge rates and contaminant levels. Evaluation of contaminant concentration trends for ⁹⁹Tc and TCE indicate that seep and seep-reach contaminant concentrations have decreased an order of magnitude over a ten year period. A follow up evaluation of the discharge trends and possible cause/effect relationships of seep contamination declines will be the subject of a final journal article for this project (below).

1 Dissertation detailing methods and results of the LBC Project submitted to DOE in July 2013.

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1 Journal Article completed and submitted for publication final review and DOE FAR review in November 2013.

1 Journal Article due Summer 2014

Public Outreach and Education Projects

- Display of PGDP & Environs Physical Models (Infrastructure & Aquifer)

Gary Rohrbacher/UK-College of Design (CoD), Ann Filson (CoD), Sydney Kidd (CoD), Carolyn Parish (CoD), Joe O'Toole (CoD), Maggie Kleins/CoD + @ 20 CoD Graduate Students

Completed February 2013

Displayed at WKCTC Emerging Technology Lobby February – June 2013

On display at UK Engineering Building – Paducah from Summer 2013 - Present

- PGDP Physical Model Development and PGDP Future Use Challenge Video

Alicia P. Gregory/UK-Reveal Research, Chad Rumford /UK-Reveal Research

UK's Reveal Research documented the conceptual and physical development of PGDP scale models as tools for informing stakeholders and the public about the site and the challenges facing stakeholders charged with its restoration and re-use.

- PGDP Groundwater Accomplishments Displays

Sydney - Kidd/CoD, Steve Hampson/UK-KRCEE

Completed February 2013

Displays and Display Dates same as above

- Development of KRCEE Web Site, <http://www.ukrcee.org/>

Jeanne Hartinger (CAER), Alice Marksberry (CAER), Steve Hampson/UK-KRCEE

This project compiled and organized historical project reports and supporting information for deployment on the web. Project -specific web architecture was developed and deployed for the multi-platform provision of web page information and user-friendly download of project resources, maps, and videos.

KRCEE NEW PROJECTS (FFY 2013 – 2014)

- Annual Site Environmental Report (ASER)

Marybeth McAlister (CAER), Jeanne Hartinger (CAER), Alice Marksberry (CAER)

Marshall County High School, science teacher Tina Marshall & AP Environmental Science Class

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Summarizes PGDP's annual site monitoring summary publication in lay terms as it is produced by the AP science students. Provides hands-on educational experience about the significance of local DOE facility on local environs.

● PGDP Virtual Museum

Gary Rohrbacher/UK-College of Design (CoD), Ann Filson (CoD), Jon Ripy (KTC), Jeanne Hartinger (CAER), + @ 14 CoD Studio Students

Development of conceptual approach for Physical & Virtual Museums and the development of an interactive web-based virtual museum for the PGDP.

Interactive history of PGDP for Web including development, operations, impacts & responses

● Groundwater Model Upgrade/Recalibration

Dr. Junfeng Zhu/UK-KGS, Dr. Alan Fryar/UK-EES, Steve Hampson/UK-KRCEE

Facilitate GW Model Upgrades per Shutdown