Report of the

Biological and Environmental Research Advisory Committee (BERAC)

Review of the Environmental Remediation Sciences PART (Performance Assessment and Rating Tool) Measure:

Findings and Recommendations

October 16, 2006

TABLE OF ACRONYMS

BER	Biological and Environmental Research
BERAC	Biological and Environmental Research Advisory Committee
COV	Committee of Visitors
DOE	Department of Energy
EMSP	Environmental Management Science Program
EMSL	Environmental Molecular Sciences Laboratory
ERSD	Environmental Remediation Sciences Division
ERSP	Environmental Remediation Science Program
FRC	Field Research Center
LTM	Long Term Measure
NABIR	Natural and Accelerated Bioremediation Research
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
PART	Program Assessment Rating Tool
SC	Office of Science

WEBSITE ADDRESSES

Office of Science Strategic Plan --
http://science.doe.gov/about/Mission_Strategic.htm

PART website --
http://www.sc.doe.gov/measures/

ERSD Strategic Plan --
http://www.sc.doe.gov/ober/ERSD/Strategic_plan_cover_letter.html

ERSD long term measure website --
http://www.sc.doe.gov/measures/scprograms/ber/measures/longterm/measure3/longterm3_frame.htm

Quarterly Milestone reports --
http://www.lbl.gov/NABIR/generalinfo/milestones.html

ERSD project database --
http://emsp.em.doe.gov/search.jsp

ERSD research solicitation --
http://www.sc.doe.gov/grants/FAPN06-12.html

ERSD field research center solicitation --
http://www.sc.doe.gov/grants/FAPN06-16.html

BER Performance Measure website --
http://www.sc.doe.gov/ober/performance.html#joule

At the July 10, 2006, meeting, the Department of Energy (DOE), Office of Science (SC), Biological and Environmental Research Advisory Committee (BERAC) was asked by the Office of Biological and Environmental Research (BER) to assess progress on the long term research goals of the Office. These goals are defined in the Office of Science Strategic Plan and through the Program Assessment Rating Tool (PART) (Link to PART website). BER supports three subsidiary divisions: Life and Medical Sciences, Climate Change Research and Environmental Remediation Sciences. A subcommittee of BERAC, (list of members provided in **Appendix A**) chaired by Dr. James Tiedje, undertook the task of assessing the progress of the Environmental Remediation Sciences Division (ERSD) toward meeting its Long Term Measure (LTM). This report evaluates the appropriateness of the ERSD LTM, progress to date and expectations for future progress toward successful accomplishment of the 2015 goal. The three tasks that were assigned to this subcommittee are:

Task 1 – Assess BER's progress toward its current long term Environmental Remediation Sciences PART measure.

Task 2 – Assess the appropriateness of BER's current long term Environmental Remediation Sciences PART measure.

Task 3 – Assess how well BER is positioned to make progress toward the long term Environmental Remediation Sciences PART measure.

ERSD supports two major activities: 1) a scientific research program, the Environmental Remediation Science Program (ERSP), that seeks to provide the fundamental scientific knowledge needed to address challenging environmental problems that impede the remediation of DOE's contaminated environmental sites; and, 2) the W.R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility located at Pacific Northwest National Laboratory (PNNL) in Richland, Washington, which provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences. This report focuses on the PART LTM associated with the scientific research program—ERSP.

The ERSP supports fundamental scientific research that underpins the Department's needs in environmental remediation and long term stewardship. DOE is responsible for what has been described as the largest, most complex, and diverse group of environmental remediation challenges in the Nation. While some of these challenges are tractable and require only time and resources to resolve, a large fraction of them cannot be resolved with existing knowledge and technology. It is this need that drives ERSD's scientific research program to develop novel, science-based solutions for DOE's challenging environmental remediation problems.

The ERSD has developed a Strategic Plan (link to ERSD Strategic Plan) that outlines the objectives and strategy for the Division's research program. The long term goal of the ERSD program is fixed in the PART that ERSD will "*provide sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes into decision making for environmental*

remediation and long-term stewardship." Progress toward this LTM is evaluated by annual measures and by quarterly milestones. Those measures and that progress are the subjects of this report. More information on PART and a detailed description of the ERSD LTM and underpinning definitions are found at ERSD long-term measure website and **Appendix B.**

The ERSD Strategic Plan outlines a three-part approach to meeting the LTM:

1. Develop an improved understanding of the processes governing the fate and transport of contaminants to predict and control the long term performance of environmental remediation and facilitate stewardship of DOE sites;

2. Explore new options and concepts for remediation and long term stewardship of subsurface systems; and,

3. Provide the scientific foundation for new measurement and monitoring tools to better understand and manage contaminant transport.

The ERSD Strategic Plan outlines a program of fundamental scientific research that is consistent with the mission of the DOE SC and with the resolution of some of the most challenging problems being faced by other DOE program offices (Office of Environmental Management, Office of Legacy Management, and Office of Civilian Radioactive Waste Management).

Program alignment - ERSD maintains awareness of DOE program needs in the area of environmental remediation through close interaction with the applicable program offices; through visits to DOE sites/facilities and meetings with the problem holders and by encouraging and providing opportunities for funded scientists to have similar interactions. The Division supports fundamental scientific research that has potential application to those program offices, requires that funded investigators clearly state how their research will benefit DOE (Program Managers are required to state the connection between each award and the ERSD LTM) and works to disseminate scientific findings to pertinent DOE Program Offices through formal and informal interactions.

Fundamental science - ERSD recognizes its role within the SC to sponsor "basic research in support of the Energy Department's missions of energy security, national security, environmental restoration, and science" (Ray Orbach, 2006). This commitment is reinforced in the Strategic Plan: "*ERSD supports externally peer-reviewed research in collaborative fundamental science using interdisciplinary approaches to address environmental remediation and stewardship of DOE sites.*" Program staff also cited text from the FY 2006-2012 funding solicitation, which states, "*Multi-investigator projects are expected to integrate multiple disciplines into the project. All projects should clearly delineate a hypothesis-driven approach to research and describe how the results of the research would ultimately improve understanding of subsurface processes at the field scale in the context of the DOE cleanup mission. A specific and well documented DOE relevance justification will be an important component of successful applications.*"

In preparation for this review, ERSD staff developed a graphical representation of their strategic goals and how those relate to elements of the FY 2006-2012 solicitation. That depiction provides a useful summary of this process and is included in **Appendix F**.

With the foregoing background information, this review committee evaluated each of the three tasks with which it was charged.

Task 1 – Assess BER's progress toward its current long term Environmental Remediation Sciences PART measure.

Current Environmental Remediation Sciences PART Measure: *By 2015, provide sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes into decision making for environmental remediation and long-term stewardship.*

ERSD has assessed its progress toward the LTM through the use of annual measures. The long term measure is ambitious and the path to completion will not be linear. ERSD appears to have recognized this challenge in the development of their annual measures (**Appendix C**) and quarterly milestones (**Appendix D**), which are used to track progress toward the LTM. ERSD supports research across spatial scales and seeks to integrate laboratory, and field-scale research encompassing a broad range of disciplines to advance our understanding of contaminant behavior and to provide a scientific basis for remediation and stewardship and achieve the LTM. Annual measures are generally complementary and there is a recognition that scientific advances often identify short-comings or knowledge gaps that must be addressed by subsequent iterations of the research plans. In its Strategic Plan (link to ERSD Strategic Plan), ERSD has developed a table of scientific goals and expected accomplishments (see Table 1, page 7-8) for each of three focus areas. In discussions with ERSD, it is clear that those accomplishments represent planning tools and that progress and needs may change over the anticipated 8-10 years associated with this plan. However, these goals provide a technical basis for program planning and formed the basis for the development of the existing annual measures (see below).

The review committee recognizes the non-linear nature of scientific progress and encourages BER to stress that point in its communications. For example, successful completion of a modeling-oriented annual measure in FY 2006 does not obviate the need to further advance our understanding of environmental processes relevant to DOE sites and to incorporate these advances in future modeling efforts (*e.g.*, FY 2010 annual measure). However, this point may not be clear to an uninformed outsider evaluating these measures and the programmatic progress. In discussions of this point, ERSD staff felt constrained by the annual measures format guidelines that require brief and simple measures. BER is cautioned to balance brevity with accuracy in developing annual measures. One potential approach would be to provide supporting discussion in addition to the annual measures.

The committee finds that BER's progress toward the LTM over the past three years has been excellent.

Supporting documentation:
The committee reviewed the quarterly PART progress reports (in response to quarterly milestones) posted on the ERSD website (Link to Quarterly Milestone reports). The reports document successful completion of the quarterly milestones which support the annual measures. The annual measures were found to provide a reasonable path toward completion of the LTM.

ERSD has developed and maintains a searchable, web-based database of funded projects (Link to ERSD project database). This tool originally was developed for the Environmental Management Science Program (EMSP) and contains project records dating to the beginning of that program (1998). ERSD recently has expanded the database to include all of its funded projects. This website provides a user-friendly tool that enables interested parties to access the technical details of ERSD science and sort the information by date, investigator, topic, keyword, or other parameters. This tool is, and will continue to be valuable to evaluating the technical aspects of ERSD progress. BER should maintain this tool and continue to explore opportunities to enhance it.

Overall progress for the Division was evaluated by a Committee of Visitors (COV) in the fall of 2004 (ERSD will again host a COV in the fall of 2007). The COV recommended that "….ERSD develop and implement a strategic plan for the integration of all efforts supported by the Division." In response to that recommendation, ERSD developed a Strategic Plan and posted/circulated it for comment by the scientific community (link to ERSD Strategic Plan). In developing this report, the committee also reviewed the ERSD Strategic Plan. The Plan provides a clear and well organized approach to achieving the Division's goals (including accomplishment of the LTM). The scientific goals and expected accomplishments listed in the ERSD Strategic Plan are well aligned with both the annual and long term PART measures. The review committee supports the Plan and recommends that it be approved by BERAC as a component of this review.

While evaluation of the PART measure and progress was not an explicit charge to the COV, comments from the report do support progress toward that measure. The review committee identified representative language from the COV reports below and highlights key comments that apply to the Division's goals and progress.

> *The COV reconfirms that the integration of biology into the understanding of fate and transport of metals and radionuclides and remediation is of fundamental, critical importance to the DOE mission. The NABIR program has had some significant successes of which DOE should be justly proud. Many of the funded principal investigators (PIs) are highly respected, well known researchers in their fields, whose research programs have been advanced by NABIR funding, with research results published in peer reviewed international journals. Graduate students and post-doctoral fellows that represent the future workforce in bioremediation have been trained under the auspices of the NABIR program. In addition, it is obvious that NABIR has catalyzed many inter-DOE National Laboratory collaborations, something that was not at all common when the*

NABIR program was being established, resulting in increased efficiency and effectiveness in the use of DOE's human and infrastructure resource.

The COV subcommittee concluded that the research being funded by EMSP is of the highest quality and that it addresses both the fundamental and applied needs of the DOE. The program is quite balanced between National Laboratories and Universities with approximately 50 percent of the lead PIs in each category. Additionally, many of the projects represent formal collaborations between scientists in the National Laboratories and in academia. It is clear that much of the research is at the "cutting-edge," is highly interdisciplinary, and spans a wide range of specialties representative of the breadth of the environmental problems present in the DOE complex.

In general, the solicitation and review processes work well, and the current program managers appear dedicated to the ultimate success of the programs in terms of fundamental research contributing to DOE's long-term mission and goals for environmental remediation and restoration.

Task 2 – Assess the appropriateness of BER's current long term Environmental Remediation Sciences PART measure.

The review committee finds the ERSD PART measure to be reasonable and appropriate with one reservation. As written, success for this measure is dependent on actions/decisions outside of the Office of Science ("*to allow a significant fraction of DOE sites to incorporate*"). The review committee supports the Division's vision of applicability to DOE site needs, but suggests revising the measure such that BER's success is independent of third-party's actions. The review committee recommends the following minor modification to the current ERSD PART:

By 2015, provide sufficient scientific understanding such that DOE sites would be able to incorporate coupled physical, chemical and biological processes into decision making for environmental remediation and long-term stewardship.

The review committee, working with ERSD staff agreed on this revised long term measure and developed a set of supporting definitions (**Appendix E**). The annual measures that accompany the ERSD PART measure were found to be reasonable and appropriate.

Supporting documentation:
Major scientific challenges exist in defining and quantifying the complex, interdependent biological, chemical and physical phenomena that occur over a range of scales in subsurface environments at DOE sites. However, understanding how these processes and their interactions are manifested at different scales in the environment is critical to prediction of long term contaminant behavior and development of new remediation technologies supporting responsible site stewardship [Davis, J.A.; S.B. Yabusaki; C.I. Steefel; J.M. Zachara; G.P. Curtis; G.D. Redden; L.J. Criscenti; B.D. Honeyman 2004. Assessing Conceptual Models for Subsurface Reactive Transport of Inorganic

Contaminants EOS 85, 449-455]. The ERSD PART measure incorporates these challenges and states how their resolution would benefit site remediation and stewardship,

The proposed PART LTM includes definitions (from "Excellent" to "Poor") that are to be used to quantify progress towards the LTM. These definitions will rate progress in development of the scientific understanding and computational models needed to quantitatively describe the fate and transport of critical DOE contaminants over the range of hydrogeologic settings encountered on the DOE site complex. The committee supports this method of assessing progress as a practical way to address the very difficult problem of quantifying the impact of fundamental ERSD science on DOE remediation goals. The impact of fundamental research supported by ERSD is best quantified by a broad review of the ERSD research and Environmental Management site remediation strategies; its impact may be difficult to determine with precision using simple statistical approaches.

Task 3 – Assess how well BER is positioned to make progress toward the long term Environmental Remediation Sciences PART measure.

The committee finds that overall achievement of the BER LTM for environmental remediation science is possible and that a reasonable pathway toward that achievement exists and is being implemented.

Supporting documentation:
The ERSD Strategic Plan and proposed future annual measures identify important and appropriate paths and milestones to achieving the Division's long term measure. ERSD has made a strong commitment to its LTM. Division staff provided examples of their routine use and explanation of the LTM in presentations and reports. The LTM is specified in the FY 2006-2012 solicitation (Link to ERSD research solicitation). For example, the solicitation states:

> *The Environmental Remediation Sciences Division (ERSD) within the Office of Biological and Environmental Research (BER) is tasked with developing the fundamental scientific basis for understanding the fate and transport of contaminants in the subsurface. This task is guided by the ERSD long term performance measure to "provide (by 2015) sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes into decision making for environmental remediation." In order to meet this measure the ERSD will fund multi-disciplinary research in a variety of science areas investigating key processes affecting the mobility of subsurface contaminants found at DOE sites*

Division staff cited the success of the currently-funded Field Research Center (FRC) at Oak Ridge National Laboratory (ORNL). Research projects utilizing the FRC have provided important scientific findings on the transport and fate of contaminants and have resulted in new *in situ* remediation concepts. ERSD also cites the importance of the FRC as a source of contaminated media from an actual DOE site for scientists throughout the

ERSD research program. Work at the FRC and with FRC sediments and groundwater provides an avenue for validation of process-level research at the field scale and serves as a designed link between experiment and application. This capability will be expanded in FY 2007 to include two FRCs (Link to ERSD field research center solicitation).

Division staff discussed proposals submitted in response to the recent call for the development and operation of two field research centers. In response to this solicitation ERSD has received five proposals, which currently are under review. While the proposals were not provided to the review committee, ERSD staff described strong support from and integration of other DOE program offices (*i.e.*, Office of Environmental Management and Office of Legacy Management) in the proposals. The committee believes that strong integration of the DOE offices responsible for remediation and stewardship of DOE sites into the proposals will help ensure the relevancy of fundamental research and progress toward this LTM.

In discussions regarding the difficulty of quantifying scientific progress, and the even greater difficulty of predicting such progress, ERSD staff provided several anecdotes that demonstrate progress to date and support a finding that expectations of future progress are well founded. These anecdotes include:

- The role of basic science in the closure of Rocky Flats. Scientists supported by the Office of Basic Energy Sciences and BER to study plutonium transport processes in the environment were enlisted by DOE and its contractor (Kaiser-Hill) to support the process for cleanup and closure of the Rocky Flats Environmental Technology Site. SC-supported scientists were instrumental in elucidating the dominant fate and transport mechanisms controlling plutonium mobility in the environment at the Rocky Flats Site. The important role that SC-funded science played in the decision making process is highlighted in a September 2006 *Physics Today* article.

- The role of ERSD-supported scientists in resolving issues associated with the migration of high-level waste from tanks at Hanford toward the Columbia River. Cesium-137 is a major component of radioactive waste that is stored in the high-level radioactive waste tanks at the Hanford Site. Several tanks have leaked, releasing the isotope into the subsurface environment. Since cesium salts are in general highly soluble, there was great concern that the radioactive material would migrate into the groundwater and into the nearby Columbia River. Research by scientists at PNNL discovered that the highly alkaline solutions of cesium alter the minerals underneath the tanks. The minerals are converted into forms that bind cesium tightly through an ion exchange process. The radioactive cesium thus is retained in the immediate vicinity of the tanks from which it leaked and expensive remediation processes thus were avoided**.**

- The use of ERSD-supported expertise in flow and transport at ORNL by the Hanford site contractor to help in the design of onsite disposal facilities.

- The use of ERSD-supported fundamental research as a basis for in situ redox manipulation technology for highly mobile redox-sensitive contaminants that is a key part of the Hanford groundwater cleanup technology portfolio.

- The adoption of ERSD-supported research advances in biologically-mediated immobilization of chromium from groundwater at the Hanford site.

- The use of high-level waste expertise developed under ERSP support at the Savannah River Site in resolving issues associated with the transfer of liquid waste.

- The "Grand Challenge" in biogeochemistry at PNNL, which focuses on understanding electron transfer at the interface between microbes and redox-sensitive minerals will enhance our ability to predict and manipulate the mobility of key DOE contaminants and shows promise in its application to carbon sequestration and energy technologies.

- The interest and support provided by the Office of Legacy Management in the ongoing research on subsurface transport and remediation of uranium at the Old Rifle uranium mill tailings site.

- The positive impacts of the ERSD EMSL (not a subject of this review) on several DOE environmental cleanup issues, including most recently, the rehabilitation of a reactive barrier on the Hanford site.

The committee recognizes the difficulty of fully quantifying what can be very practical benefits of scientific progress in environmental remediation research and accepts these anecdotes as evidence of progress and as validation of the optimism expressed by ERSD staff for continued future progress and accomplishments. The staff is urged to continue to document these impacts.

The committee was impressed with the quality of reports posted on the ERSD website supporting accomplishment of the quarterly measures. These reports will be important for future evaluation of progress toward the LTM. The committee recommends that BER continue to post detailed, technical reports of quarterly accomplishments toward the annual measure.

The committee requested information on the ERSD research budget over time. The resulting graphic is provided in **Appendix E**. Based on this information, the committee is concerned that continued budget reductions and consequent narrowing of the program's scope will impede progress toward the long term measure. The Division appears to be aware of this concern and has worked to focus on those scientific topics that appear to be most likely to benefit from fundamental scientific advances over reasonable timeframes. Nevertheless, the committee recommends that BER carefully consider the impacts of budget reductions on ERSD's mission and consider revising this measure if additional research funds cannot be made available to ERSD. Achieving a broad impact on a large number of DOE remediation sites, as described in the LTM, will require both

laboratory and field research across a wide range of geologic, hydrologic and microbiologic conditions. ERSD's expansion of FRCs is an example of ERSD's attempt to broaden its impact on DOE remediation sites. However, broadening ERSD's impact may not succeed under conditions of stagnant or decreasing budgets.

Findings & Recommendations

The review committee finds:

- The ERSD long term measure is appropriate with one reservation. As revised (**Appendix E**) its achievement would markedly assist DOE in meeting its remediation goals;

- BER's progress toward the current LTM over the past three years has been excellent;

- Overall achievement of the revised LTM is possible and a reasonable pathway toward that achievement is being implemented.

The review committee finds that the ERSD Strategic Plan provides a clear and well-organized approach to meeting the Division's goals (including accomplishment of the LTM). The review committee supports the Plan.

BER has developed a satisfactory method for quantifying the impact of the ERSD LTM on DOE site remediation goals. The degree of success will be defined in terms of the types and numbers of critical DOE contaminants addressed and the applicability of new scientific understanding and computational models to quantifying contaminant fate and transport in four hydrogeologic settings representing the DOE site-wide complex. These are also the critical factors that should be considered in measuring interim progress toward the LTM. This committee would like to stress that an attempt to quantify the impact of fundamental ERSD science on the remediation goals of DOE sites using other approaches may prove to be difficult. The impact of fundamental research supported by ERSD is best quantified by documenting ERSD research accomplishments in the context of DOE site conditions and EM remediation strategies; its impact may be difficult to determine with precision using simple numerical and statistical approaches.

It is recommended that BER seek opportunities to provide supporting discussion to its annual measures. As stand-alone spreadsheet cells, the measures are difficult to put into context and may be misinterpreted by interested parties who are not familiar with the program.

It is recommended that BER continue to maintain (and seek opportunities to expand and enhance) the ERSD online project database. The review committee found this to be a valuable tool to search and evaluate project-specific progress within the program.

It is recommended that BER continue to post quality, technical reports of quarterly accomplishments toward its annual measures. These technical documents provide important, substantive support for successes in meeting quarterly and annual goals.

It is recommended that BER continue to ensure that the ERSD focus on fundamental science that is commensurate with the long term scientific needs of the appropriate DOE Program Offices. This can be accomplished by additional efforts to involve those offices in planning activities, research meetings and workshops and to solicit their input, in

developing future solicitations and in making funding award decisions based on scientific merit.

It is recommended that BER carefully consider the impacts of budget reductions on ERSD's mission and consider revising this measure if additional research funds cannot be made available to ERSD. To impact a large number of the diverse DOE remediation sites (as identified in the LTM), ERSD will need to continue to broaden its research (through expansion of field research centers, etc.). This broadening will be difficult if the ERSD budget remains flat or is reduced.

Appendix A
Subcommittee Membership

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Appendix B
Current ERSD Long-term Measure

Environmental Remediation - By 2015, provide sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes into decision making for environmental remediation *and long-term stewardship**.

Definition of "Excellent"
BER-sponsored advances in understanding the biological, chemical and physical components of contaminant fate and transport are incorporated into conceptual models at 20% of the DOE cleanup and long term stewardship sites.

Definition of "Good"
BER-sponsored advances in understanding the biological, chemical and physical components of contaminant fate and transport are incorporated into conceptual models at 10% of the DOE cleanup and long term stewardship sites.

Definition of "Fair"
BER-sponsored advances in understanding the biological, chemical and physical components of contaminant fate and transport are incorporated into conceptual models at less than10% of the DOE cleanup and long term stewardship sites.

Definition of "Poor"
BER-sponsored advances in understanding the biological, chemical and physical components of contaminant fate and transport are incorporated into conceptual models at more than one DOE cleanup and long term stewardship site as a technology demonstration.

How will progress be measured?
Progress toward achieving these measures will be reviewed every 3 years by BERAC and its Environmental Remediation Research Program subcommittee. Progress will be measured based on actual research results including peer reviewed publications, on discussions with "customers" of BER research in EM, and on an evaluation of BER's overall approach of research investments that will or could logically lead to the achievement of both its interim and long term goals. Expert Review will rate progress as "Excellent", "Good", "Fair" or "Poor" and will include an evaluation of progress to develop a scientific understanding of the coupled biological, chemical and physical processes that control contaminant fate and transport as this relates to DOE environmental remediation needs.

*Note that the italicized text "*and long-term stewardship*" was added at the recommendation of BERAC. That additional text is currently under review by OMB and is not yet an official part of the posted measure

Link to ERSD long-term measure

Appendix C
ERSD Annual measures (FY 2003 – FY 2012)

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007Targets	FY 2008Targets
Environmental Remediation					
Determine scalability of laboratory results in field environments: Identified naturally occurring microbial populations responsible for transformation of metals and radionuclides at DOE contaminated sites. [Met Goal]	Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales: Quantify contaminant immobilization and remobilization by different factors: 1. natural microbial mechanisms; 2. chemical reactions with minerals; and 3. colloid formation. [Met Goal]	Determine scalability of laboratory results in field experiments - Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings. [Met Goal]	Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests.	Implement a field-oriented, integrated experimental research program to quantify coupled processes that control reactive transport of at least one key DOE contaminant.	Identify the critical redox reactions and metabolic pathways involved in the transformation/ sequestration of at least one key DOE contaminant in a field environment.

FY 2009 Target	FY 2010Target	FY 2011 Target	FY 2012 Target
Test geophysical techniques that measure parameters controlling contaminant movement under field conditions in at least two distinct subsurface environments.	Evaluate contaminant transport model in the context of field results and initiate revisions to model.	Conduct subsurface field studies to test predictions from previously developed models.	Perform time-lapse geophysical experiments to monitor subsurface dynamics caused by varying hydrogeological, geochemical and microbial conditions. These experiments will be performed at well characterized field sites where previously established flow and transport models can be used to quantitatively model the time-lapse geophysical responses. These experiments will be conducted in at least two distinct DOE subsurface environments.

Appendix D
Quarterly Milestones

Link to BER Performance Measures website

GPRA Goal/Annual Target		1st Quarter	1st Quarter Results	2nd Quarter	2nd Quarter Results	3rd Quarter	3rd Quarter Results	4th Quarter	4th Quarter Results	End-of-year Results
FY 2006 This GOAL is to be given 14.31% of SC ranking (based on percent of SC total budget) Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally alter the future of medical care and human health.	Documentation for all quarterly performance measures can be found at: http://www.lbl.gov/nabir/generalinfo/milestones.html									
(SC GG 5.21.1) FY 2006 ANNUAL MEASURE Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests.	Quarterly - Emails from the designated performers reporting the research results and field site experiment results (per documented control process). EOY - Emails reporting the results and publication/availability of the results (per documented control process).	The HQ Program Manager discusses with appropriate Site Office POC and the Lab Primary Investigator to make sure they understand that this analysis is being tracked in Joule, and expectations for the year. Report results of updated small-scale model using recent advances in understanding of coupled thermodynamic and biologic factors to predict changes in Oak Ridge Field Research Center microbial community composition in response to exogenous alterations in subsurface chemistry.	Model results predict the effect of chemical amendments on the subsurface microbial community at the Oak Ridge Field Research Center. The model explicitly couples the thermodynamics of microbial growth and geochemical reactions to make quantitative predictions of microbial community dynamics.	Run updated large-scale 3-D flow and chemical transport model for the Oak Ridge Field Research Center site based on new information on biogeochemistry, groundwater and subsurface media.	Milestone met. New information on biogeochemistry, groundwater and subsurface media from the Oak Ridge Field Research Center (FRC) was utilized to update and run large-scale 3-D flow and chemical transport models. The FRC is a focal point for ERSD program field research on natural and stimulated biologically-mediated attenuation of metals and radionuclides. Information from these studies on the interactions among biological, chemical and physical processes in a real-world setting with complex hydrogeology and contaminant characteristics promises to significantly improve DOE's ability to effectively manage legacy waste sites.	Compare model results from Q1 to corresponding Oak Ridge Field Research Center field data and report results.	Q3 Milestone met. Model results from Q1 were compared to corresponding Oak Ridge Field Research Center field data. Model predictions of stimulated subsurface microbial processes agreed with field data collected during single well (batch) and multi-well (flush) field tests at the Oak Ridge Field Research Center. Increases in biomass, the consumption of energetically favorable electron acceptors and precipitation of radionuclides (uraninite) were observed to be consistent with modeled predictions.	Compare model results from Q2 to corresponding Oak Ridge Field Research Center field data and report results.		
FY 2005 This GOAL is to be given 17% of SC ranking (based on percent of SC total budget) Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally alter the future of medical care and human health.										
(SC GG 5.21.1) FY 2005 ANNUAL MEASURE Determine scalability of laboratory results in field experiments - Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings.	Quarterly - Emails from the designated performers reporting the research results and field site experiment results. EOY - Emails reporting the results and publication/availability of the results.	The HQ Program Manager discusses with appropriate Site Office POC and the Lab Primary Investigator to make sure they understand that this analysis is being tracked in Joule, and expectations for the year. Conduct monitoring at old Rifle UMTRA experimental site and collect data on the bioreduction of uranium.	Q1 milestone met. Data collection and analyses of the uranium bioreduction field test at the Old Rifle UMTRA site show loss of uranium.	Conduct Hydrogen Releasing Compound (HRC) injection monitoring at Hanford chromium contamination site and collect data on the bioreduction of uranium.	Q2 milestone met. Data collection and analyses (monitoring) indicate that Cr(VI) concentrations are significantly decreased at the test site. Results posted at: http://www.lbl.gov/nabir/generalinfo/ersda_data05.html	Report results of Old Rifle field experiments and compare to previous laboratory studies.	Q3 milestone met. Stimulated U(VI) reduction in field experiments was observed as predicted by laboratory studies and occurred at expectedly slower rates. Reactive transport model simulates observed field data. Results postd at: http://www.lbl.gov/NABIR/generalinfo/ersda_data05.html.	Report results of Hanford field experiments and compare to previous laboratory studies.	Q4 Milestone met. Stimulation from more than a year ago continues to stimulate bioactivity, keeping Cr(IV) at undetectable levels. In comparison to previous laboratory studies, the electron donor (HRC) has persisted longer then expected.	Annual milestone met. Determined the scalability of laboratory results in field experiments through field experiments to evaluate biological reduction of chromium and uranium. Stimulated microbial reduction of uranium and chromium at field scale mirrors processes observed at the lab scale by substantially lowering soluble concentrations of these contaminants. Lab results accurately predicted dominant members of the microbial community involved in metal bioreduction. Rates of reduction require mathematical scaling in order to match geochemical modeling results at the field scale.
FY 2004 This GOAL is to be given ??% of SC ranking (based on percent of SC total budget) Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally alter the future of medical care and human health.										
(SC GG 5.21.1) FY 2004 ANNUAL MEASURE Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales. Quantify contaminant immobilization and remobilization using one or a combination of the following potential pathways: natural microbial mechanisms, chemical reactions with materials, and colloid formation.	Quarterly - Emails from the designated performers reporting the research results and field site experiment results. EOY - Emails reporting the results and publication/availability of the results.	Publish peer-reviewed results of first field experiment to stimulate microbial communities to immobilize uranium contamination plume at Uranium Mill Tailings Remediation Action (UMTRA) site in Rifle, Colorado	Yes. Publication in October 2003 issue of Applied & Environmental Microbiology (pdf)	Initiate push-pull experiments to immobilize uranium with humics at the NABIR Field Research Center	Yes. Preliminary results described at March 2004 NABIR PI meeting (pdf)	Complete laboratory microcosm experiments on mechanisms of microbial reoxidation of uranium	Yes. Results described at March 2004 NABIR PI meeting (pdf)	Conduct field site monitoring to quantify uranium remobilization at the Old Rifle, CO UMTRA site	Yes 4th Quarter target and annual target met. Supporting Documentation: Results on NABIR-UMTRA website: http:www.pnl.gov/nabir-umtra/	n/a for FY 2004

Appendix E
Proposed Annual Measure and Definitions

By 2015, provide sufficient scientific understanding such that a majority of DOE sites would be able to incorporate coupled physical, chemical and biological processes into decision making for environmental remediation and long-term stewardship.

Definitions
The majority of DOE sites can be classified into one of four hydrogeologic settings: wet climate/granular sediments (*e.g.*, Savannah River Site, parts of Oak Ridge, Brookhaven); wet climate/fractured sediments (parts of Oak Ridge); dry climate/granular sediments (parts of Hanford, Rocky Flats, Los Alamos, many Uranium Mill Tailings Remedial Action sites); dry climate/fractured sediments (Idaho National Laboratory, parts of Hanford).

ERSD focuses its research on critical DOE contaminants including cesium, iodine, neptunium, strontium, technetium, uranium, plutonium, chromium, mercury and a class of organic contaminants described as chlorinated solvents.

Excellent:
ERSD science will develop scientific understanding and computational models that together quantitatively describe the fate and transport of at least two of the critical DOE contaminants listed above in at least three of the four hydrogeologic settings listed above.

Good:
ERSD science will develop scientific understanding and computational models that together quantitatively describe the fate and transport of at least two of the critical DOE contaminants listed above in at least two of the four hydrogeologic settings listed above.

Fair:
ERSD science will develop scientific understanding and computational models that together quantitatively describe the fate and transport of at least two of the critical DOE contaminants listed above in at least one of the four hydrogeologic settings listed above.

Poor:
ERSD science will not provide the necessary scientific understanding and computational models needed to quantitatively describe the fate and transport of any DOE contaminants in the hydrogeologic settings listed above.

<u>How will progress be measured?</u> – Expert Review every three years will rate progress as "Excellent", "Good", "Fair" or "Poor". This review will rely on a variety of metrics, as identified below. The metrics that are proposed at this time include:

- Answers to scientific questions relevant to DOE mission areas are developed by funded research.
- Development of fundamental knowledge that results in strategies and methodologies that impact remediation and stewardship of DOE site
- Development of novel remediation or stewardship technologies
- Papers published on research supported by this program.
- Patents filed for research supported by this program.

Appendix F
ERSD Research Strategy Flowchart

ERSD Long Term Measure By 2015, provide sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes into decision making for environmental remediation	**Goal 1:** Develop an improved understanding of the processes governing the fate and transport of contaminants in the subsurface in order to predict and control environmental remediation and long term stewardship of DOE sites.	Fundamental Molecular Scale Research	Surface Chemistry	EMSL, EMSIs Synchrotrons
			Aqueous Complexes	
			Nanoscale Research	
		Subsurface Biogeochemistry	Microbe-Mineral Reactions	Notice 06-12 Projects
			Contaminant-Mineral Rxns	
		Subsurface Microbiology	Microbial Ecology/Metabolism	
			Microbially Catalyzed Rxns	
		Groundwater Flow and Transport	Aquifer Characterization	
			Groundwater Hydrology	
		Vadose Zone Processes	Geochemical Gradient Rxns	
			Unsaturated Zone Chemistry	
		Conceptual/Computer Model Development	Scaling of Processes	SciDAC 06-04
			3D HPC Framework	
	Goal 2: Explore new options and concepts for the remediation of subsurface environments.	Physical/Chemical Remediation Processes	Immobilization	Notice 06-12 Projects
			Removal Techniques	
			Barrier research	
		Biological Processes	Bioremediation	
		Long Stewardship Research	MNA processes/ Modeling	TBA
		Field Scale Research	Fate & Transport/ Remediation Research at Large DOE Test Sites	Notice 06-16
	Goal 3: Develop new measurement and monitoring tools to better understand and manage contaminant transport.	Site Characterization Technologies	Geophysics Techniques Seismic, GPR, EMT etc.	Notice 06-12 & SBIR/STTR Projects
		Biological, Chemical and Physical Sensor Technology	Genomics-based techniques	
			Chemical speciation detection	
			Flow detection	
			Autonomous Sampling and Data Collection/Reporting Systems	

Definitions:

EMSL = Environmental Molecular Sciences Laboratory (ERSD-sponsored national scientific user facility at Pacific Northwest National Laboratory;

EMSI = Environmental Molecular Science Institute – interdisciplinary fundamental research initiatives funded in collaboration with the National Sciences Foundation;

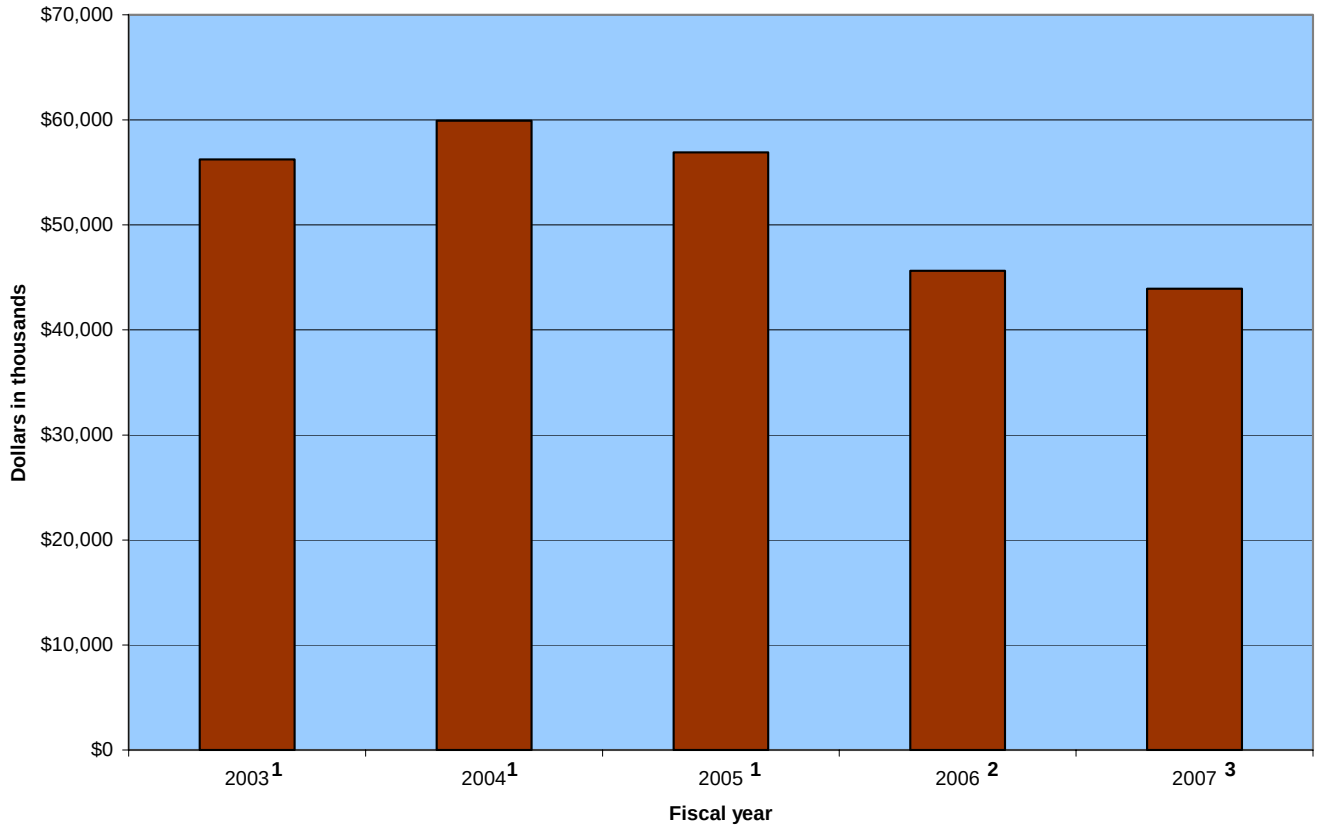
3D HPC = three dimensional high-performance computing; SciDAC 06-04 = Scientific Discovery through Advanced Computing – large collaborative research projects funded in collaboration with the Office of Science, Office of Advanced Scientific Computing Research (ASCR);

Notice 06-12 = research solicitation issued by ERSD in FY 2006, successful projects will be initiated in FY 2007;

MNA = Monitored Natural Attenuation, an alternative environmental remedial technology that takes advantage of natural processes;

Notice 06-16 = solicitation for the development of two ERSD-sponsored field research centers

Appendix G
ERSD research funding history



Footnotes:

1 – Budget values for FY 2003-2005 are actual expenditures

2 – Budget value for FY 2006 is from the September 2006 Financial Plan

3 – Budget value for FY 2007 is the President's Request