

## *NRAP Tools for Assessment of Carbon Storage Risk Performance: Supporting Decision Making Amidst Uncertainty*

*Tool Updates based on tester feedback*

March 30, 2016; 4:00 PM EDT  
Webinar Presentation

Technical Contributions from across the NRAP Working Groups



U.S. DEPARTMENT OF  
**ENERGY** | National Energy  
Technology Laboratory

# NRAP Phase I CO<sub>2</sub> Storage Risk Assessment Toolset



Available at: [www.edx.netl.doe.gov/nrap](http://www.edx.netl.doe.gov/nrap)

**Integrated Assessment Model – Carbon Storage (NRAP-IAM-CS)**

**Reservoir Evaluation and Visualization (REV) Tool**

**Wellbore Leakage Analysis Tool (WLAT)**

**Natural Seal ROM (NSealR)**

**Aquifer Impact Model (AIM)**

**Design for Risk Evaluation and Monitoring (DREAM)**

**Short Term Seismic Forecasting (STSF)**

**Reservoir ROM Generator (RROMGEN)**

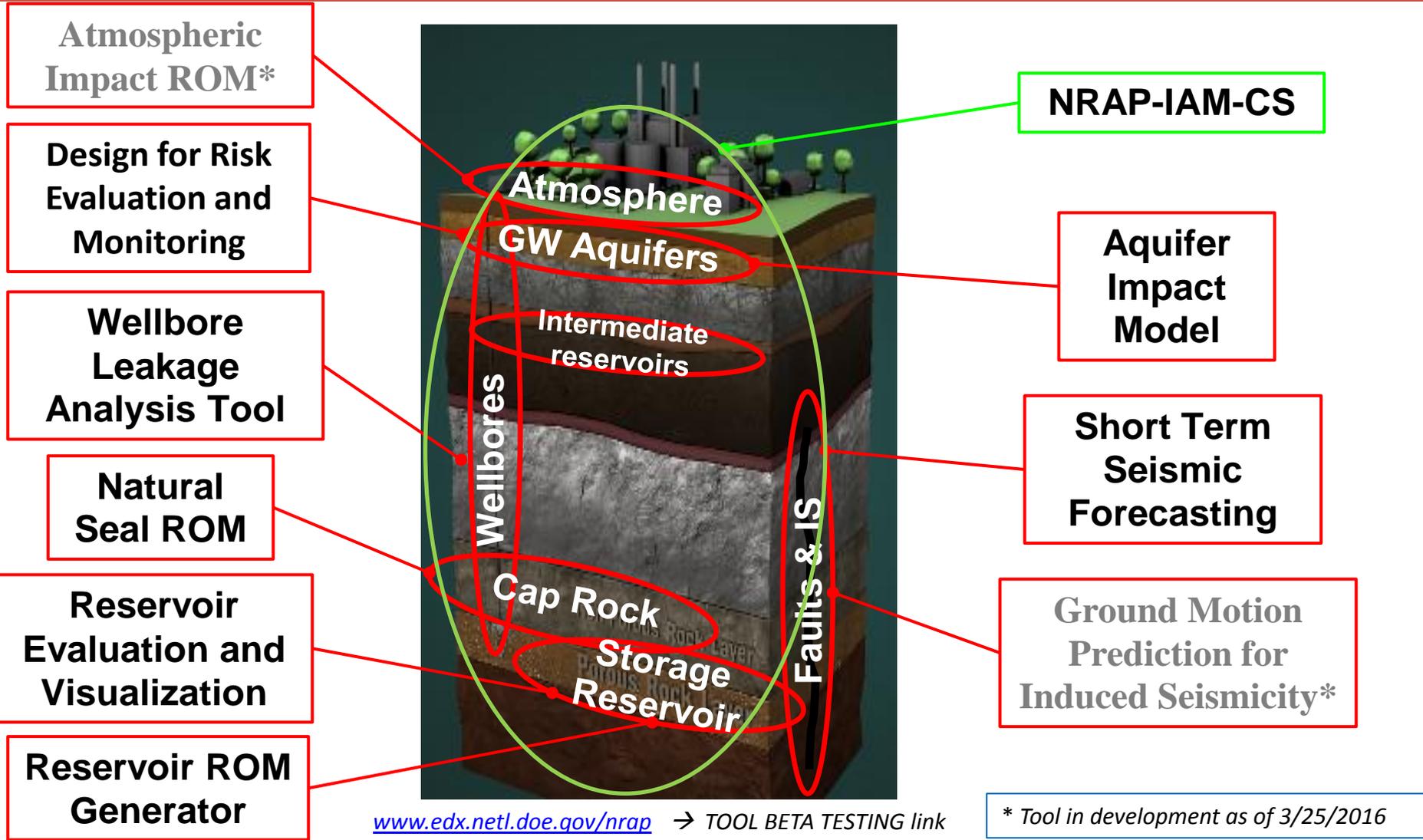
**Atmospheric Impact ROM (AIR)\***

**Ground Motion Prediction for Induced Seismicity (GMPIS)\***

• *Tools in development as of 3/29/2016*



# NRAP Phase I CO<sub>2</sub> Storage Risk Assessment Toolset



# NRAP Tool Webinar Series – Fall, 2015



Scheduled Date/Time	NRAP Tool	Presenter(s)	Recorded Webinar Link	
			SLIDES	VIDEO
October 13, 2015 Time: 1:00 - 3:30 PM EDT	Integrated Assessment ModelCarbon Storage (NRAP-IAM-CS)	Rajesh Pawar		
October 19, 2015 Time: 1:00 - 2:00 PM EDT	Natural Seal ROM (NSealR)	Ernest Lindner		
October 26, 2015 Time: 1:00 - 2:00 PM EDT	Reservoir Evaluation and Visualization (REV) Tool	Seth King		
November 2, 2015 Time: 1:00 - 2:30 PM EST	Wellbore Leakage Analysis Tool (WLAT)	Nicolas Huerta		
November 9, 2015 Time: 1:00 - 2:00 PM EST	Aquifer Impact Model (AIM)	Diana Bacon		
November 16, 2015 Time: 1:00 - 2:00 PM EST	Design for Risk Evaluation and Monitoring (DREAM)	Catherine Ruprecht		
November 30, 2015 Time: 1:00 - 2:00 PM EST	Short Term Seismic Forecasting (STSF)	Josh White, Corinne Bachman		
December 7, 2015 Time: 1:00 - 2:30 PM EST	NRAP-IAM-CS and RROM-Gen Webinar	Rajesh Pawar, Seth King		

Presentation video and slides available for download: [www.edx.netl.doe.gov/nrap](http://www.edx.netl.doe.gov/nrap)



# NRAP Integrated Assessment Model for Carbon Storage (NRAP-IAM-CS) Tool Updates



- Tested reservoir lookup table approach for simulations performed with STOMP: Need defined by EPA.
- Implemented atmospheric dispersion module, developed dashboards and tested performance.
- Fixed error in assignment of wellbore cement permeability for single wells: Error initially reported by ITRI, previously wellbore cement permeability was assigned a fixed value irrespective of user input.
- Fixed the error in calculations resulting in negative brine leak rates: Error reported by ITRI and NETL.
- Updated reservoir reduced order model for simple reservoir to fix issues related to computation of CO<sub>2</sub> saturations, the error was noted for a problem developed by BP.

# NRAP-IAM-CS – Tool Updates (cont.)



- Updated plots for cumulative brine and CO<sub>2</sub> leakage to ensure correct reporting on cumulative leakage. Error first reported by ITRI.
- Fixed JAVA viewer problems associated with viewing single realizations and results of simple reservoir with injector well placed at an off-center location.
- Updated input dashboard for shallow aquifer and intermediate aquifer physical characteristics.

# Well Leakage Analysis Tool (WLAT)

## Tool Updates



- No Substantive Change to Code From Prior Release
- Updated Version Number and Date on Initial Dashboard to Correspond with Tools Manual
- Minor changes to GUI
  - Switched order of components to match User's Manual
- Reviews Did Not Indicate Any Operational Concern
- Reviews Suggested Several New Options or Example Use Cases (Not Implemented):
  - Comparison between ROMs and full-physics models
  - Ability to save/print the plots in different formations
  - Expand leakage models to match more types of geometries (e.g. multiple thief zones with different properties)
  - Clean up folder space to make navigating the input and output easier

# NRAP Seal ROM (NSeaIR) Tool Updates



- No Substantive Change to Code From Prior Release
- Updated Version Numbers and Date on Initial Dashboard to Correspond with Tools Manual
- Review Did Not Indicate Any Operational Concern
- Review Suggested Several New Options (Not Implemented):
  - Seal Permeability to include Geo-Statistical Approaches for Spatial heterogeneity (e.g., Variogram Models)
  - Vertical Variability In Hydraulic Parameters
  - Additional Probability Functions Such as Logarithmic Permeability
  - Time-Variant Permeability
  - Additional Cases Studies

# NSealR User Guide Updates



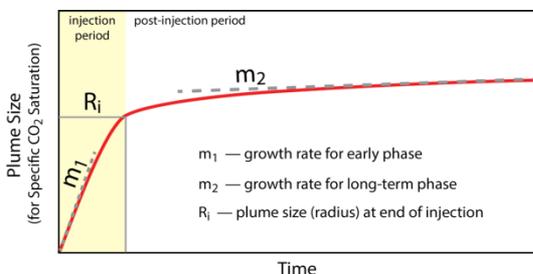
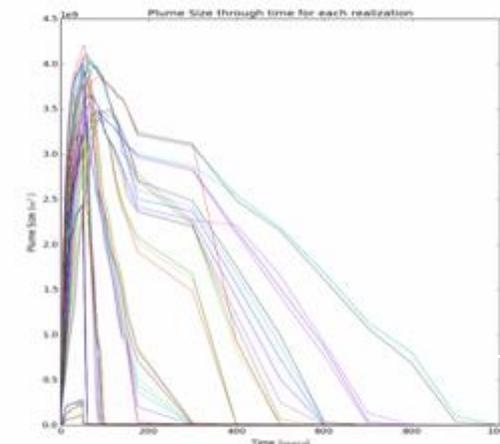
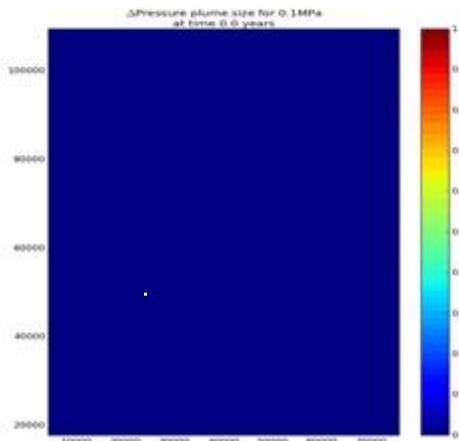
- No Substantive Change to Tools Manual From Prior Release
- Changes to the Tools Manual Text to Clarify the Options for the Upper Boundary in Appendix A
- Updated Technical Leadership Team Membership Listings
- Minor Number of Typographical Errors Corrected

# Reservoir Evaluation and Visualization (REV) tool Updates

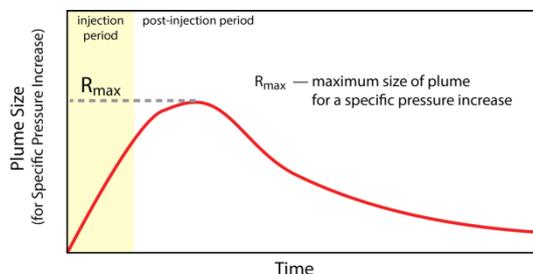


Generates risk metrics from reservoir simulation results

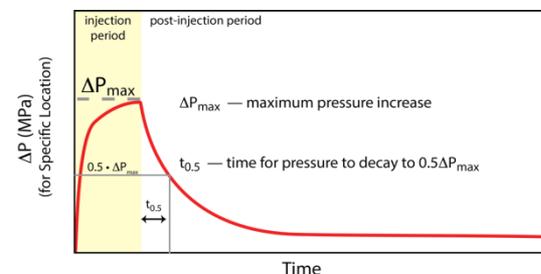
- Fixed XY- inversion issue in Tough 2 style inputs
- Fixed hard coded reservoir size in FEHM style inputs
- Cleaned up user's manual and clarified several points
- Included sample files folder in the REV tool distribution



**Size of CO<sub>2</sub> Plume**



**Size of Pressure Plume**

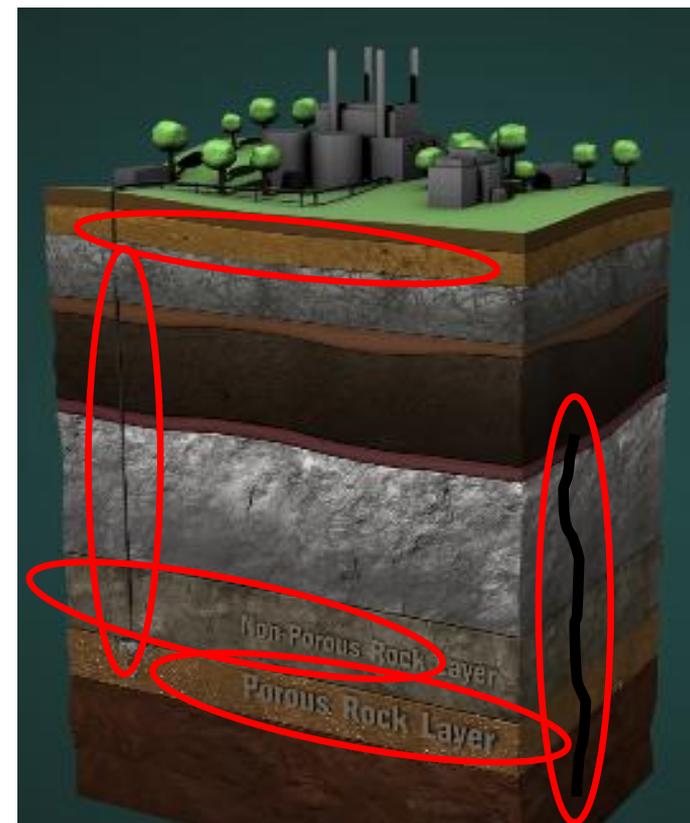
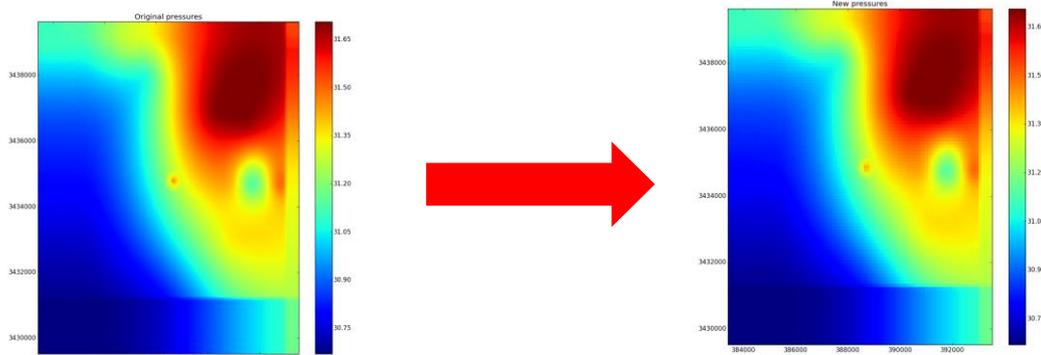


**Pressure at at a Location**

# Reservoir Reduced Order Model Generation (RRROM-Gen) Tool Updates

Generates Reservoir ROM look-up tables for use in the NRAP-IAM-CS

- Fixed XY- inversion issue in Tough 2 style inputs
- Fixed hard coded reservoir size in FEHM style inputs
- Cleaned up user's manual and clarified several points
- Included sample files folder in the REV tool distribution



# Aquifer Impact Model (AIM) Updates



- Expanded functionality to include sensitivity analysis for the confined alluvium ROM
- Improved error trapping and reporting
- Cosmetic improvements to auto-generated plots
  - larger fonts\*
  - more clear axis labels, titles, and legends\*
  - multiple pages of plots, to better visualize large number of water quality metrics
  - log-scale quartile plots added\*
- User interface improvements
  - user can now easily see which ROM has been selected, on all screens\*
  - dx, dy outputs have been removed from confined alluvium option list
  - expanded list of acknowledgements, list of contacts

# AIM User Guide Updates



- User guide placed in main folder of download package to help with installation\*
- Installation instructions were updated\*
- Noted that for Carbonate Aquifer, concentrations of trace metals and organics in the brine are automatically scaled according to chloride concentration\*
- Added description of Monte Carlo and Sensitivity analysis methods and related references
- Example problem was simplified so that just one input parameter needs to be modified by user

# Design for Risk Evaluation and Monitoring (DREAM) Tool Updates

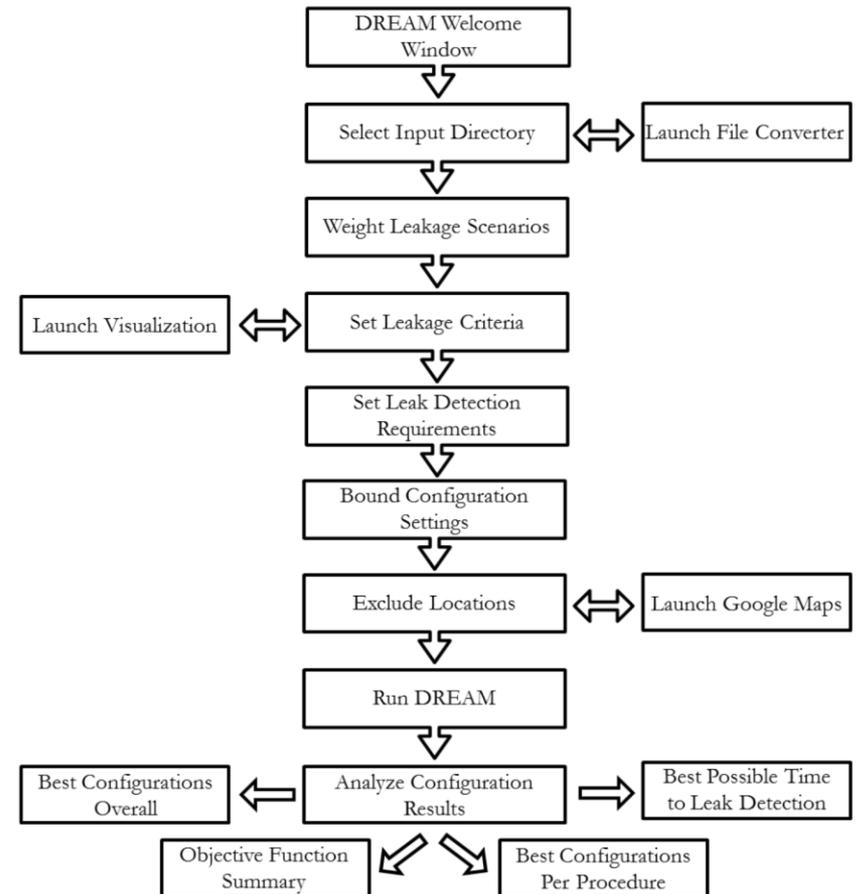


- Yonkofski et al. (2016) is referenced in the manual and on the tool welcome screen for background on the simulated annealing theory.
- Clickable information buttons are now available on windows.
- A “Cancel” button was added to the *Leakage Criteria* page.
  - Because of the way that the memory is distributed while in use, it is currently not recommended to cancel the iterative procedure or go back through the DREAM windows mid-process.
- The TECPLOT input option was added because it is a common post-processing tool for subsurface simulators.
  - We suspect that most flow simulators will be able to use parsers to convert output data to TECPLOT format relatively easily.

# DREAM User Guide Updates



- Reorganized the user manual to present the example problem along with the UI walkthrough.
- A workflow chart has been added as Figure 2.
- The easiest way to prepare DREAM input files is to format simulation output into one of the acceptable HDF5 conversion formats: NUFT, STOMP, TECPLOT. This is more thoroughly discussed in Section 3.2.



# Short Term Seismic Forecasting (STSF) Tool Updates



- Running the application with one click is enabled
  - File named 'application' starts tool with double click
- Error messages during the run were updated
  - No more 'ATTENTION...' error messages which could have been confusing to average users
- "Run finished" message added
- Example files were updated
  - Starting values were updated
- Visual output options and spatial variation within tool will be part of Phase II

# STSF User Manual Updates



- Update to clarify file structure within tool and location of relevant files
- Added example of input files to manual to explain the structures of those files
- Emphasis in manual on files that should not be deleted as that will lead to a segmentation fault during a run
- Higher emphasis in manual on Bachmann et al, 2011 as different options of runs are explained there

Thank you!  
[www.edx.netl.doe.gov/nrap](http://www.edx.netl.doe.gov/nrap)  
[NRAP@netl.doe.gov](mailto:NRAP@netl.doe.gov)



## National Risk Assessment Partnership



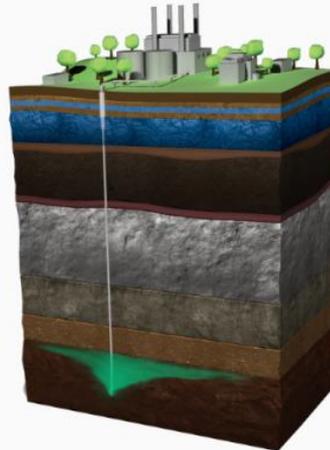
<a href="#">Home</a>	<a href="#">Initiative</a>	<a href="#">Approach</a>	<a href="#">Research Products</a>	<a href="#">Tools</a>	<a href="#">Team</a>	<a href="#">TOOL BETA TESTING</a>	
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### Become an NRAP Tool Beta Tester!

*NRAP leverages DOE's capabilities to help quantify uncertainties and risks necessary to remove barriers to full-scale CO<sub>2</sub> storage deployment.*

NETL's Office of Research and Development (ORD) is leading a multi-laboratory effort that leverages broad technical capabilities across the DOE complex into a mission-focused platform that will develop the integrated science base that can be applied to risk assessment for long-term storage of CO<sub>2</sub>: the National Risk Assessment Partnership (NRAP). NRAP involves five DOE national laboratories: NETL, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Pacific Northwest National Laboratory.

The motivating goal of NRAP is to develop science-based methodologies and tools for calculating risks at any CO<sub>2</sub> storage site while providing necessary scientific and technological advances to support that methodology. Fiscal Year 2016 will span a period of transition for the NRAP research program, with Phase I of this multi-year research effort expected to come to completion by June 2016, and Phase II research beginning concurrently. Phase I is focused on assessment of risk associated with large-scale CO<sub>2</sub> storage, and with quantifying uncertainties associated with those assessments; Phase II will focus on management of risk associated with large-scale CO<sub>2</sub> storage, and with reducing associated uncertainties.



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