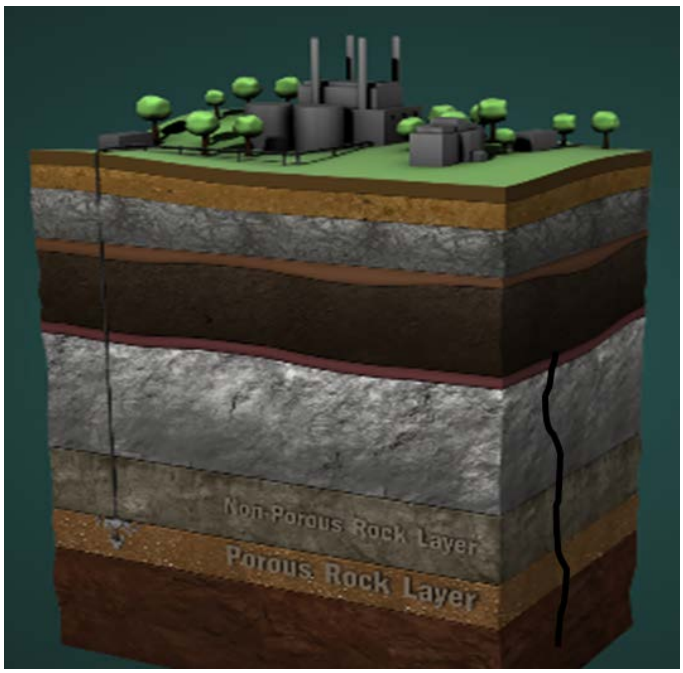
National Risk Assessment Partnership



NRAP Phase I Tool Development and Quality Assurance Process

10 November 2016

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Office of Fossil Energy

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Cover Illustration: Artist rendition of a CO_2 storage reservoir and surrounding geologic system.

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NRAP Phase I Tool Development and Quality Assurance Process

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Acronyms, Abbreviations, and Symbols

Acronym	Descriptive Name
AIM	Aquifer Impact Model
ANLEC R&D	Australia's National Low Emissions Coal Research & Development
BP	British Petroleum
CO_2	Carbon dioxide
CCS	Carbon capture and storage
CCUS	Carbon capture utilization and storage
COTS	Commercial off-the-shelf tools
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DOE	U.S. Department of Energy
DREAM	Designs for Risk Evaluation And Management
EDX	Energy Data eXchange
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
FE	Office of Fossil Energy
FEHM	Finite Element Heat and Mass model
FEP	Features, events, and processes
GCS	Geological carbon sequestration
GMPIS	Ground Motion Prediction applications to potential Induced Seismicity
IAM	Integrated Assessment Model
IEAGHG	International Energy Agency Greenhouse Gas R&D Programme
ITRI	Industrial Technology Research Institute
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
MSLR	Multiple Source Leakage Reduced-order model
NETL	National Energy Technology Laboratory
NRAP	National Risk Assessment Partnership
NRAP-IAM-CS	NRAP Integrated Assessment Model-Carbon Storage
NSealR	NRAP Seal barrier Reduced-order model
NUFT	Nonisothermal Unsaturated-Saturated Flow and Transport code
PADEP	Pennsylvania Department of Environmental Protection

Acronyms, Abbreviations, Symbols (cont.)

Acronym	Descriptive Name
PNNL	Pacific Northwest National Laboratory
QA	Quality assurance
R&D	Research and development
RCSP	Regional Carbon Sequestration Partnership
REV	Reservoir Evaluation & Visualization
ROM	Reduced-order model
RROM-Gen	Reservoir Reduced-Order Model-Generator
SCC	Strategic Center for Coal
SINTEF	The Foundation for Scientific and Industrial Research
STOMP	Subsurface Transport Over Multiple Phases model
STSF	Short-Term Seismic Forecasting
TOUGH2	Transport Of Unsaturated Groundwater and Heat 2 model
UQ	Uncertainty quantification
USGS	U.S. Geological Survey
WLAT	Wellbore Leakage Analysis Tool

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EXECUTIVE SUMMARY

The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) and the National Energy Technology Laboratory (NETL) lead the National Risk Assessment Partnership (NRAP), a multi-national laboratory effort that leverages broad technical capabilities across the DOE into a mission-focused platform to develop critical scientific advances and predictive tools that can be applied to quantify and manage risks associated with long-term storage of CO_2. NRAP brings together researchers from five DOE national laboratories: NETL, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Pacific Northwest National Laboratory.

During Phase I (2011–2016), NRAP researchers developed a suite of simulation tools for use in evaluating the risk performance of and quantifying uncertainties for candidate CO_2 storage sites. These tools went through several years of development and trial by the NRAP team of researchers before having been made available to the carbon capture and storage (CCS) research and development community for testing and use initially in 2014.

The NRAP tools were subjected to extensive review and iterative refinement during the course of their development. This document was created to summarize the development process and the related review/refinement cycle so that information is available to demonstrate to potential tool users the robustness of the NRAP Phase I toolset. In the following sections, the technical scope of the NRAP project and the set of NPAP Phase I tools are introduced, the process by which those tools were developed is summarized, and the steps taken in internal and external review of those tools prior to their formal release are detailed.

The set of NRAP Phase I tools are available through the NRAP website at: https://edx.netl.doe.gov/organization/nrap-phase-i-tools.

1. INTRODUCTION

This Phase I tools development document describes the process by which the National Risk Assessment Partnership (NRAP) carried out software development and modeling activities to design, develop, test and verify modeling results associated with carbon capture and storage (CCS) activities. While a rigorous software development program is not currently required by the U.S. Department of Energy's (DOE) Office of Fossil Energy (FE), this document summarizes development of NRAP tools and detail steps taken to ensure their quality, to build confidence in the user community about the predictive capability of these tools.

1.1 NRAP PROJECT OVERVIEW AND OBJECTIVE

The primary objective of NRAP is to develop a defensible, generalized, and science-based methodology and platform/tools for quantifying risk profiles at carbon dioxide (CO_2) storage sites, and to then apply and extend those tools and applications to understand how assessed risks can be managed, if needed, through mitigation and other engineering interventions, and how uncertainties in assessed risks can be reduced through strategic monitoring, conformance evaluation, and iterative improvement of site characterization and system-wide performance prediction. The methodology must incorporate and define the scientific basis for assessing residual risks associated with long-term stewardship of CO_2 storage sites, and help guide site operational and regulatory decision-making and risk management. Development of an integrated, strategic, risk-based monitoring and mitigation protocol is part of the NRAP objective; this protocol and related monitoring design tools will help to reduce uncertainty in the predicted long-term behavior of the site and thereby increase confidence in storage integrity.

In NRAP Phase I, researchers addressed environmental risk performance by focusing on probabilistic quantification of site-specific risk profiles. In general, risk profiles (risk vs. time) describe the time-dependent components of risk as the state of the engineered natural system evolves in response to perturbation from CO_2 injection and eventually equilibrates with the regional subsurface environment. The site-specific nature of the assessment methodology allow for spatially varying components of risk. The probabilistic approach is designed to capture uncertainties associated with site heterogeneity and complexity, and thereby provide the basis for uncertainty quantification (UQ).

The overall NRAP effort has been divided into three general technical components:

1. Development of a methodology and computational tools for quantifying risk profiles based on integrated assessment models (IAMs) and UQ
2. Targeted scientific investigations at the laboratory and field scale to help quantify and reduce uncertainties in the predicted risk profiles
3. Integration of risk-based monitoring and mitigation strategies to reduce both uncertainty and overall risk

These research products were developed in the context of, and have benefitted from the insights of, the broader CO_2 Storage Program, including the U.S. DOE's Regional Carbon Sequestration Partnerships (RCSPs). Moreover, the NRAP research team was actively engaged with the international CCS research, development and deployment community, including participation in

the International Energy Agency Greenhouse Gas Programme's international research networks related to geologic carbon storage performance and risk assessment.

1.2 EXPECTED PROJECT IMPACTS AND BENEFITS

The expected results for NRAP include:

- A platform (and associated computational tools) and robust methodology for quantifying potential risks and associated uncertainties for long-term CO_2 storage at a site
- A protocol for integrating risk-based strategic monitoring and mitigation to reduce uncertainties and risk at a site
- A science-based ability to identify safe operational envelopes to minimize potential risks

The tools and improved science base generated by NRAP can be used by both operators and regulators to insure a common ground in discussing risks and risk management strategies associated with a storage site, thereby reducing barriers to deployment at storage sites. These products will aid operators in the design and application of monitoring and mitigation strategies. Furthermore, they are intended to provide a technical basis from which stakeholders can evaluate potential associated long-term liability, and for use by regulators to consider those risks and related cost-benefit performance.

1.3 NRAP PHASE I OVERVIEW

NRAP Phase I was a partnership among national laboratories, industry and academic institutions to develop and deploy state-of-the-art computational modeling and simulation tools to accelerate the commercialization of carbon capture technologies from discovery to development, demonstration and ultimately the widespread deployment carbon capture and storage sites. The initiative to develop the NRAP toolset, integrated suite of validated science-based computational models and methodologies, will provide simulation tools that increase confidence in designs, thereby reducing the risk associated with incorporating multiple innovative technologies into new carbon capture solutions.

Led by DOE's Office of Fossil Energy and the National Energy Technology Laboratory (NETL), NRAP leverages broad technical capabilities across the DOE complex by combining the expertise of five national labs: NETL, Los Alamos National Laboratory (LANL), Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL) and Pacific Northwest National Laboratory (PNNL). Directed by multi-lab technical working groups, these research organizations conduct integrated, collaborative research. The NRAP Executive Committee, comprising senior management representatives from each of the participating national labs, provides high-level guidance and sets the program's research priorities and goals. The program also benefits from the perspective of a group of stakeholders consisting of technical experts from industry, academia, regulatory agencies, non-governmental agencies, and insurance companies.

NRAP is improving the science base and building confidence for long-term CO_2 storage decisions by:

- Developing physics-based models
- Demonstrating validity and limitations of the IAMs

- Performing key computational and experimental analyses
- Simulating long-term carbon storage system performance

NRAP has developed and released to the geological carbon sequestration (GCS) research, industrial, and regulatory community a set of ten tools useful to help evaluate several parts of the carbon storage subsurface containment system (e.g., reservoirs, seals, wells, and aquifers), as they relate to two major types of environmental risks: leakage and induced seismicity. The tools are:

- NRAP Integrated Assessment Model-Carbon Storage (NRAP-IAM-CS)
- Wellbore Leakage Analysis Tool (WLAT)
- NRAP Seal barrier Reduced-order model (NSealR)
- Reservoir Evaluation & Visualization (REV)
- Reservoir Reduced-Order Model-Generator (RROM-Gen)
- Aquifer Impact Model (AIM)
- Multiple Source Leakage Reduced-order model (MSLR)
- Short-Term Seismic Forecasting (STSF)
- Ground Motion Prediction applications to potential Induced Seismicity (GMPIS)
- Designs for Risk Evaluation and Management (DREAM)

Table 1 provides a brief summary of those tools and their functionality.

Table 1: Purpose of the NRAP Phase I Tools

Group	Tool	Functionality
INTEGRATED ASSESSMENT MODEL (IAM)	NRAP Integrated Assessment Model-Carbon Storage (NRAP-IAM-CS)	Simulates long-term full system behavior (reservoir to aquifer/atmosphere). This tool generates time-dependent CO_2 and brine leakage and resulting impacts, which can be used to compute probabilistic and dynamic environmental risk profiles. This tool ties together many of the system component models represented in other NRAP fluid migration tools.
RELEASE & TRANSPORT TOOLS	Wellbore Leakage Analysis Tool (WLAT)	Evaluates existing wells for leakage potential. The tool also models migration of brine and/or CO_2 outside of storage reservoir and explores leakage response as a function of well disposition.
	NRAP Seal barrier Reduced-order model (NSealR)	Estimates leakage through a fractured or perforated seal. This tool computes two-phase (brine and supercritical CO_2) flux and includes fluid thermal/pressure dependence.
STORAGE RESERVOIR	Reservoir Evaluation & Visualization (REV)	Visualizes pressure and CO_2 plumes sizes over time. This tool can inform decisions about Area of Review (AoR).
	Reservoir Reduced-Order Model-Generator (RROM-Gen)	Generates reservoir look up table ROMs in a format that can be used directly by the NRAP-IAM-CS.
RECEPTOR RESPONSE TOOLS	Aquifer Impact Model (AIM)	Designed for rapid estimation of aquifer volume impacted by a leak, and to distinguish between impact of CO_2 and brine leaks. They can also and can be used to determine the influence of threshold criteria.
	Multiple Source Leakage Reduced-order model (MSLR)	Calculates the probability that a surface receptor within a given radius of an atmospheric leak of CO_2 will be able to detect that leak. MSLR handles single- or multiple-source CO_2 leakage using a reduced-order model (ROM).
SEISMICITY-RELATED TOOLS	Short-Term Seismic Forecasting (STSF)	Uses site-specific catalogs of measured seismicity to forecast future event frequency over the short term and can complement stoplight approaches for addressing seismic risk.
	Ground Motion Prediction applications to potential Induced Seismicity (GMPIS)	Estimates ground motion at the surface that may be expected from different earthquake scenarios, providing useful information during the project planning and permitting stages.
MONITORING TOOL	Designs for Risk Evaluation And Management (DREAM)	An optimization software that determines site specific monitoring configurations with the highest potential to detect CO_2 leakage and minimizes aquifer degradation in the shortest amount of time.

2. OVERVIEW OF NRAP TOOL DEVELOPMENT PROCESS

The NRAP tool development effort was planned and implemented through a series of research project management documents (field work proposals, program management plans, and research execution plans), and represents the efforts of all contributing national laboratories over the multi-year research project performance period. Those documents are not referenced explicitly in the body of this report, but are referenced as guiding documents that underpin the described research effort.

Work conducted through the first phase of the NRAP project—nominally 2011 through 2016—included research to advance the science and engineering knowledge base to develop a defensible, science-based quantitative methodology and platform for quantifying site-specific risk profiles (potential risk through time) at potential geologic CO_2 storage sites. Steps involved in the tools development effort included:

- Identify features, events, and processes (FEPs) associated with the CO_2 storage system that are important for evaluating environmental risk performance of the system and its (e.g., storage reservoirs, wellbores, groundwater aquifers)
- Develop detailed, physics-based numerical models to capture the critical behavior of various carbon storage system components
- Identify sensitive system parameters and associated parameter uncertainty/variability to use as a basis for assessing risk performance in the context of those uncertainties
- Perform sets of simulations to explore the range of possible performance of system components
- Use those simulation experiments as the basis to build robust reduced-complexity models that are capable of providing rapid (e.g., in a fraction of a second) predictions of system component behavior
- Build component-specific ROMs into stand-alone predictive tools with user interfaces to facilitate stakeholder application for exploring sensitivity and uncertainty in risk-related behavior of each component
- Incorporate ROMs for various system components into an integrated assessment framework so that the coupled environmental performance of the whole CO_2 storage system can be quantitatively predicted
- Exercise the system component tools and integrated assessment models to verify their performance and explore long-term risk behavior of CO_2 storage systems

Early NRAP efforts (2011–2014) focused on conducting simulation and laboratory experiments to constrain uncertainties in the performance of critical system components, developing and testing new quantitative risk assessment methodologies and building numerical simulations and ROMs for system components. This effort included evaluating the performance of various reduced-order modeling approaches, and developing a first-of-kind prototype integrated assessment model for CO_2 storage leakage performance. More recently (2015–2016) NRAP's efforts have focused on distilling those insights, methodologies, and ROMs into a set of user-friendly tools to predict critical behavior of the CO_2 storage system and its components,

internally testing, refining, and verifying performance of those tools, and disseminating those tools to the broader CCS community for testing and feedback.

To support these efforts, NRAP researchers leveraged information available from real and synthetic field characterization efforts to inform model parameter estimation and scenario development. Testing of high-resolution numerical models and ROMs against other comparable simulations was used, as practicable, to verify model and ROM performance. Full validation of those models was inhibited by the lack of availability of real-world datasets; such field datasets are being pursued in the context of NRAP's Phase II efforts. Success of NRAP in its risk assessment tool development efforts can be measured by the utility of those tools to facilitate industrial end users and other stakeholders in their efforts to quantitatively assess CO_2 storage risk performance; it is also a function of their use in effectively accelerating carbon storage site selection and evaluation to advance the goals of the U.S. DOE's CO_2 Storage Program. Figure 1 provides an illustration of the NRAP tool development process, and internal/external review cycle.

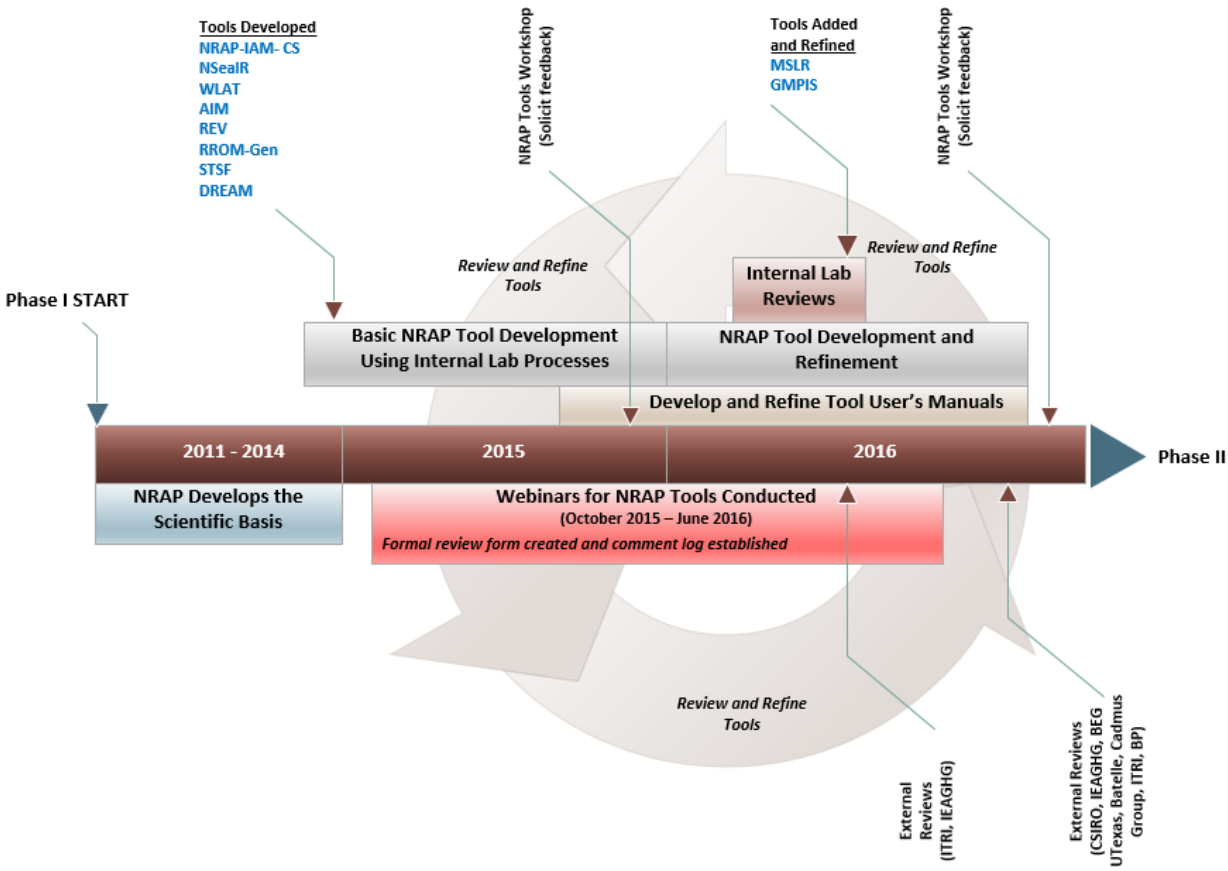


Figure 1: Illustration of NRAP tools development and review timescale.

As the basis to assure the quality of the set of NRAP tools, criteria were established to ensure the development of robust set of NRAP tools to support the assessment of environmental risk performance at CO_2 storage sites. This was performed for a set of risk proxies related to potential atmospheric leakage, groundwater aquifer impact and ground motion that would result from potential induced seismicity. These risk proxies are essentially midpoint indicators of some of the tools developed by NRAP to generate results addressing these risk proxies directly, while

others perform calculations that generate results describing intermediate perturbations in the system. For example, a ROM describing leakage of fluid through a cemented well generates results for the flux of CO_2 and brine at the top of the well (e.g., to a groundwater aquifer). That result itself is not a prediction of the geochemical impact to the groundwater formation (the risk proxy), but is information that is useful input for calculating such impacts.

The process of risk assessment tool development in NRAP's Phase I initially focused on development of ROMs for different system components, and on development of the approach, workflow, and tool for integrated assessment framework for assessing whole system leakage-related risk performance. These products were developed internally through an iterative process represented as three generations of ROM development. The third generation ROMs and IAM were used as the basis developing the NRAP Phase I toolset. Figure 2 illustrates the IAM Development Methodology for a pH Risk Metric.

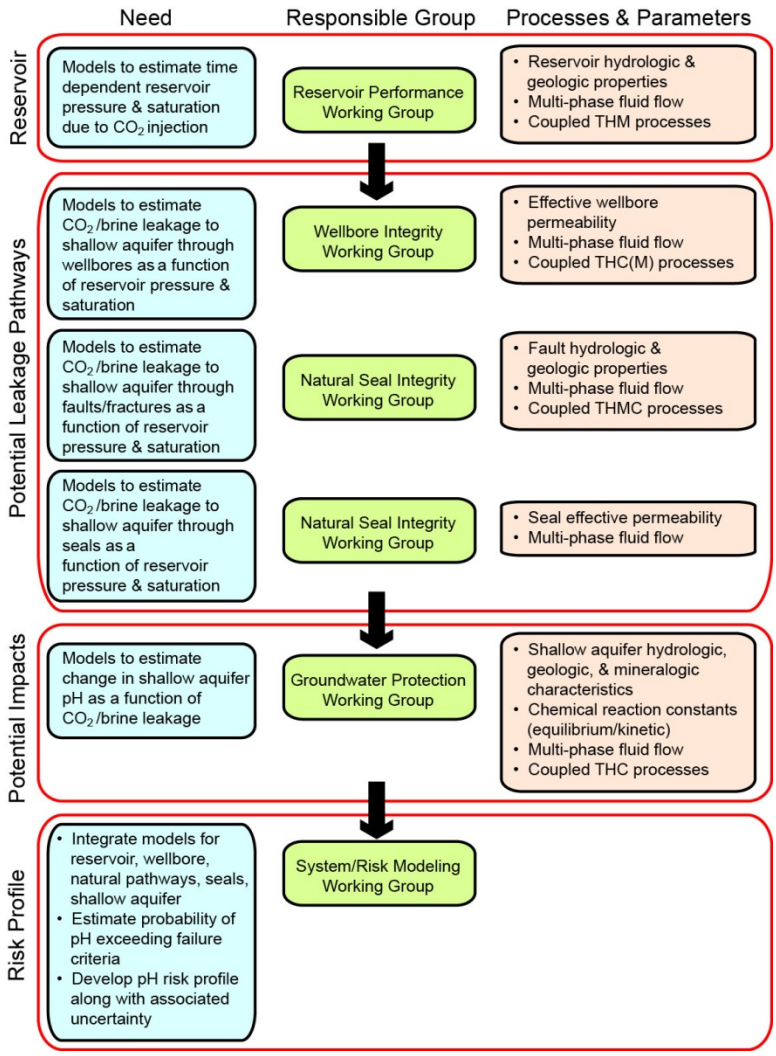


Figure 2: Example of an IAM Development Methodology for a pH Risk Metric.

3. QUALITY ASSURANCE FOR NRAP PHASE I TOOLS

This report is intended to document the steps taken in development, review, and refinement of the set of NRAP Phase I tools to instill confidence that those products meet reasonable expectations for quality. It will be made available with the release of the first version of those tools in November 2016.

Numerical simulation comprises two elements: a computer code that implements the mathematics of our scientific understanding, and a user that implements the computer code as an analytical tool. Successful numerical simulation requires both a proper implementation of the mathematics by the code developer and a proper implementation of the computer code by the code user. Successful numerical simulations provide a quantitative understanding of complex processes. Unsuccessful numerical simulation can lead us to a false understanding of a system. While the tools have been developed with controls to reduce the potential for their unintended application, it is ultimately incumbent upon the tool user to review and scrutinize the results that the tool results provide.

3.1 OVERVIEW OF NRAP PHASE I TOOLS QUALITY ASSURANCE APPROACH

Criteria used in assuring the quality of the set of NRAP tools include:

- Address quantifiable aspects of CO_2 storage important to environmental risk performance
- Develop system component characterizations and integrated system model from a science-based credible and technically defensible basis
- Build tools that are useable by GCS stakeholders, including consideration of the flow and navigability of the tool, and the clarity and completeness of the manual and supporting technical information
- Utility refers to the value of the risk assessment tools to stakeholders in considering risk performance at CO_2 storage sites to support decision making

To assure the quality of the set of Phase I tools, the NRAP research team conducted a series of steps to design, test, and iteratively improve those tools and the underlying system component characterizations/ROMs. Those steps are summarized in Table 2 below.

Table 2: Summary of quality assurance procedures, measures of quality, and related deliverables associated with each stage of NRAP tool development

Development Stage		Milestones	Procedures	Deliverables
1	**Establish Technical Design Basis**	• Preliminary CO_2 storage FEP analysis • Methodology acceptance by NRAP and validation by Carbon Capture Utilization and Storage (CCUS) research peers • Consensus on important system parameters and risk proxies for quantitative assessment	• Methodology conceptual development for whole system and system component characterization • Design and execution of simulation experiments to explore system behavior • Exploration of system integration and key component performance	• Peer reviewed publications and DOE technical reports on focused laboratory and simulation experiments, and methodology design descriptions for risk and uncertainty quantification
2	**ROM and Prototype IAM Development**	• Methodology demonstration • Demonstrate and verify ROM functionality • Demonstrate risk profile development process/uncertainty quantification	• Methodology demonstration • Demonstrate and verify ROM functionality • Develop ROMs through generational testing/refinement • Construct prototype IAM incorporating select system components • Test ROMs and prototype IAM	• Peer-reviewed publications and technical reports on ROM and prototype IAM development/demonstration • Set of system component ROMs verified against numerical simulations • Prototype IAM for CO_2 and preliminary risk profiles for hypothetical scenarios
3	**Tool Development and Beta Testing**	• ROM and IAM refinement based on feedback from the NRAP technical team • ROM and IAM refinement based on feedback from the broader CCUS technical community • Tool demonstration, testing, and performance verification	• Refine ROMs, build user interface to facilitate input/scenario definition, control model execution, and generate output • Internal NRAP beta testing across national laboratories • Tool refinement based on internal comments	• Set of NRAP tools released for beta testing • Draft user manuals and beta example use-cases • Webinar series/workshop • Beta test comment log with tool-developer response
4	**Tool Completion and Release**	• CCUS community acceptance of NRAP tools	• Refine ROMs, build user interface to facilitate input/scenario definition, control model execution, and generate output • Internal NRAP beta testing across national laboratories • Tool refinement based on internal comments	• Set of NRAP tools released for beta testing • Tool user manuals and tool test cases

3.1.1 Establish Technical Design Basis

As described above an approach to quantitatively assess the full subsurface system from the storage reservoir to groundwater aquifers and the atmosphere was developed in NRAP Phase I. This approach relies on the development and appropriate integration of reduced-order models (ROMs) that allow fast computations of entire system performance even for periods of hundreds to thousands of years. Within the NRAP tool and/or the NRAP-IAM-CS, ROMs are exercised in Monte Carlo mode to estimate uncertainties in system components or the entire system, respectively, in a computationally-efficient manner. The NRAP-IAM-CS incorporates ROMs that realistically represent several key processes and properties of the system, and the IAM is used to construct quantitative risk profiles for selected input parameter choices. For a full list of publications related to IAM and tool development, constituent ROM development, and the underlying science base, the interested reader is directed to the NRAP Phase I Accomplishments report (Bacon et al., 2016). Also, many of those publications have been made available through a virtual special issue of the *International Journal of Greenhouse Gas Control* (IJGGC), which represents a compendium of research generated in NRAP's Phase I, and comprises 57 peer-reviewed publications (DOE NRAP, 2016).

3.1.2 ROM and Prototype IAM Development

The work performed in Phase I to develop the tools and underlying ROMs included use of a number of open source, national laboratory, and commercial off-the-shelf (COTS) tools to develop the simulations that underpin many of the constituent ROMs.

Simulation results generated using several different numerical simulation codes, including LBNL's Transport Of Unsaturated Groundwater and Heat 2 model (TOUGH2), LANL's Finite Element Heat and Mass model (FEHM), LLNL's Nonisothermal Unsaturated-Saturated Flow and Transport code (NUFT), and PNNL's Subsurface Transport Over Multiple Phases model (STOMP) were used as the basis from which several of the ROMs were developed. The performance of the numerical simulation tools was not evaluated in the context of the NRAP tool quality assurance (QA) exercise, with the predictive capability of these tools assumed to be adequately vetted through the many years of iterative development, testing and application of those simulation tools (as evidenced by the significant body of peer-reviewed literature citing application of those products). The ROMs developed from sets of realizations for those numerical models was the focus of NRAP internal review.

Similarly, the platform used by NRAP in development of the IAM, the GoldSim® software package (GoldSim Technology Group, 2014), is an established commercially-available research-quality system modeling package tailored for the application in engineered geologic systems, particularly those with large uncertainties and heterogeneities. Goldsim® framework provided a convenient and reliable means to control time-stepping and sampling of uncertain variables in Monte Carlo-type stochastic modeling applications, and incorporates functionality for UQ. The performance of these functions was verified through multiple internal exercises, but did not undergo review for quality assurance. The NRAP-IAM-CS tool itself, including the design basis (extended from CO_2-PENS model structure (Stauffer et al., 2009)), the incorporation of constituent ROMs into the IAM, the appropriate integration of those ROMs in the IAM framework, and the associated calculations and results were all the subject of NRAP QA review.

NRAP's IAM is built on the CO_2-PENS model structure (Stauffer et al., 2009), which was developed with the GoldSim® software package (GoldSim Technology Group, 2014). GoldSim® is a commercially available system-modeling package tailored for the unique needs of engineered geologic systems, particularly those with large uncertainties and heterogeneities. Various approaches can be used to build and implement models for system components that can be integrated using GoldSim®, including mathematical expressions, look-up tables, and dynamic link libraries for external executables including process-level models such as reservoir simulators.

ROMs developed based on sets of numerical simulations were extensively reviewed and iteratively improved through a generational ROM development process; most tools were iteratively improved through three generations of internal development. Additionally, the methodologies used in coupling ROMs together to develop quantitative assessment of leakage risk performance at CO_2 storage sites was similarly developed and iteratively improved. The method by which the appropriateness of these methods and ROMs was verified was through internal vetting and comparison of ROM predictive performance against comparable numerical simulations; it was also through detailed documentation of methods and results and vetting of those through the peer review process. Additionally, findings form laboratory and simulation based experiments conducted in the context of NRAP and intended to address/constrain key uncertainties in the performance of CO_2 storage system/system components were also documented and vetted through the peer-review publication process. The product of these efforts was a robust set of technical reports and publications in peer-reviewed journals. For a summary of the DOE technical reports and journal publications resulting from NRAP Phase I efforts, see the NRAP Phase I Accomplishments Report (Bacon et al., 2016).

3.1.3 Tool Development and Beta Testing

Figure 3 provides a simplified schematic of the process by which Phase I tools were developed.

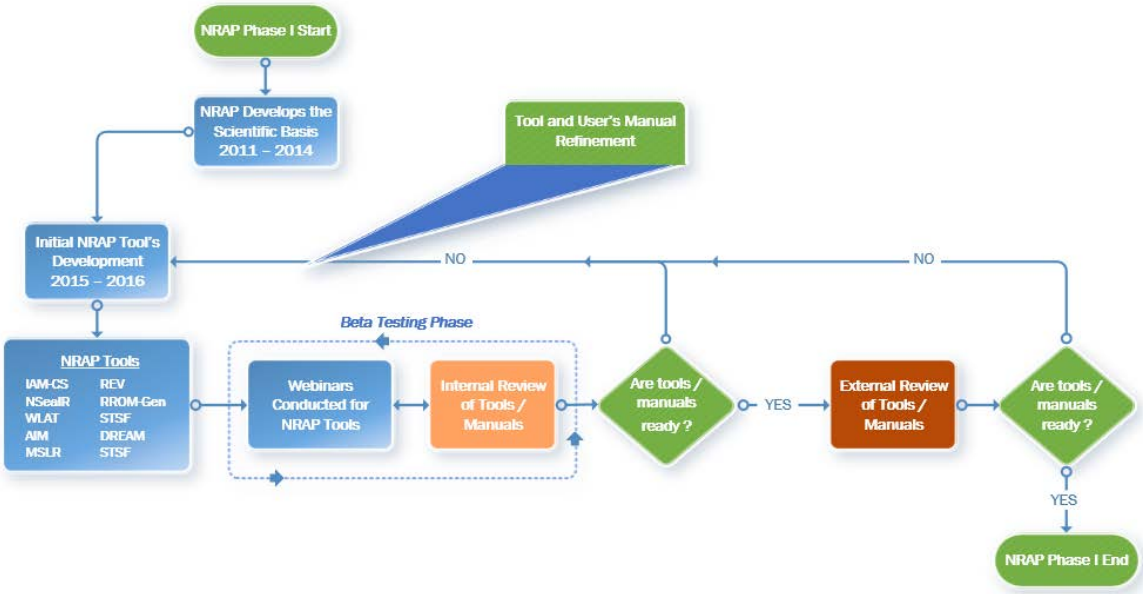


Figure 3: Flowchart showing NRAP tools development and review cycle.

3.1.3.1 Internal Reviews by NRAP Technical Team

The NRAP Phase I toolset beta testing phase included internal reviews by the partner laboratories using expert researchers to stress the tools and provide feedback. Table 3 shows each NRAP tool and participation by partner laboratories in reviewing the toolset. The asterisk indicates that multiple reviewers from a given laboratory provided feedback on a tool. Reviews were collected using the questionnaire in Appendix A; comments from NRAP beta testing are logged in the comments register shown in Appendix B. Comments were addressed by tool developers, with modification to the tools and corresponding user manuals made prior to tool release for external beta testing.

Table 3: Summary of internal reviews by laboratory partners

NRAP Tool	Laboratory				
	NETL	LANL	LBNL	LLNL	PNNL
NRAP-IAM-CS	✓	✓*	✓		✓*
WLAT	✓*	✓	✓	✓	✓
NSealR	✓*				✓
REV	✓*		✓		
RROM-Gen	✓*		✓		
AIM		✓*	✓	✓*	✓*
MSLR	✓	✓	✓*		
STSF	✓	✓*	✓*	✓*	
GMPIS		✓*			
DREAM	✓			✓	✓*

Note: ✓*= multiple reviewers

In addition to the internal NRAP QA process described, the DREAM tool followed a QA protocol required by PNNL; a summary of that procedure is not included in this report, but can be furnished upon request.

The References section of this report includes reference to other published documents that serve as supporting information for the design basis of the models and methodologies, the verification of performance of ROMs, and tool functionality/example scenarios.

3.1.3.2 External Review of NRAP Phase I Tools

After completion of the NRAP internal beta testing and tool revision, the set of NRAP tools were made available to stakeholders in the broader CCUS community through the a password-protected file transfer portal on the U.S. DOE NETLs' Energy Data Exchange (EDX). EDX was used during periods of ROM and tool development for internal revision control, data and code sharing, and tool versioning.

Availability of these tools was announced to a large set of those stakeholders at the *Strategic Center for Coal's (SCC's) 2015 Carbon Storage Research and Development (R&D) Project Review Meeting* (Pittsburgh, Pennsylvania; August 18–20, 2015) at which time eight of the 10 NRAP Phase I tools were available; the remaining two NRAP tools (the MSLR and the GMPIS tools) were made available for public beta testing in November of 2015.

Through the fall of 2015 and spring of 2016, NRAP hosted a set of 10 webinars designed to introduce external tool users/testers to each of the NRAP tools, their functionality, input requirements, user interface, and output. Table 5 provides the schedule for that webinar series and presenters.

Table 4: Summary of Webinar presentations for NRAP tools

Webinar	Presenter(s)	Date
NRAP-IAM-CS	Rajesh Pawar	October 13, 2015
NSealR	Ernest Lindner	October 19, 2015
REV	Seth King	October 26, 2015
WLAT	Nicolas Huerta	November 2, 2015
AIM	Diana Bacon	November 9, 2015
DREAM	Catherine Yonkofski	November 16, 2015
STSF	Josh White, Corinne Bachman	November 30, 2015
NRAP-IAM-CS and RROM-Gen	Rajesh Pawar, Seth King	December 7, 2015
NRAP Tools Revisions Update	Multiple	March 30, 2016
GMPIS and MSLR	Chris Bradley, Yingqi Zhang	June 20, 2016

Presenters walked through an example case for each tool – with test case information included with each tool distribution. This webinar series served as an additional means of communicating to an international group of GCS stakeholders and prospective beta testers about the availability of the tools, and providing information to facilitate their testing of the tools. Figure 4 provides summary counts of webinar invitations, attendance, and unique downloads of the tools.

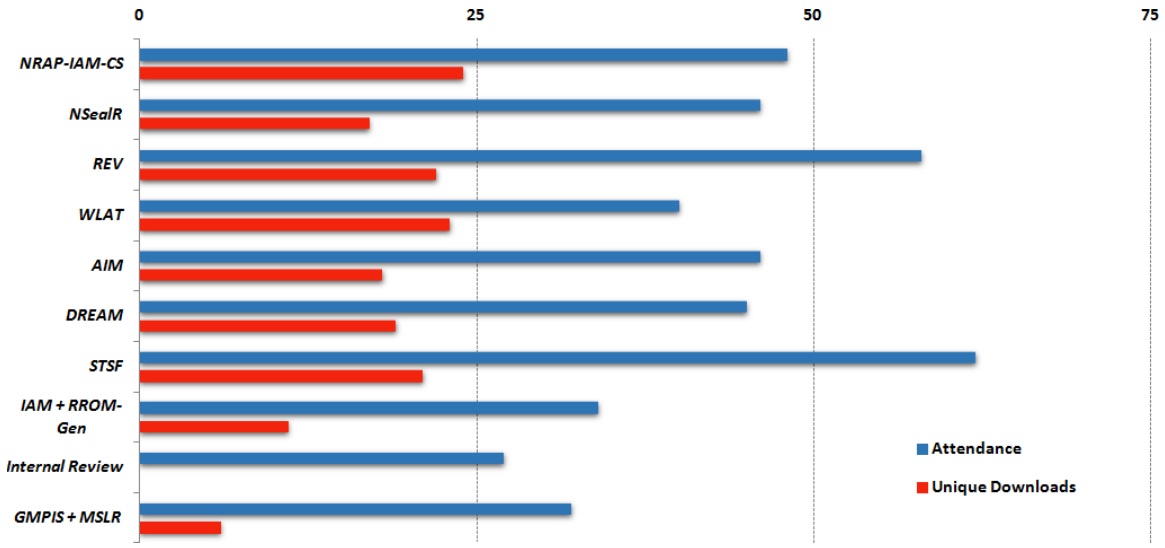


Figure 4: NRAP tools webinar and download statistics.

NRAP has provided outreach to the user community through stakeholder organizations:

- NRAP membership national laboratories (LANL, LBNL, LLNL, NETL, and PNNL)
- Oak Ridge National Laboratory
- Regional Carbon Sequestration Partnerships
- U.S. Environmental Protection Agency (EPA)
- U.S. Geological Survey (USGS)
- Pennsylvania Department of Environmental Protection (PADEP)
- Electric Power Research Institute (EPRI)
- University of North Dakota's Energy & Environmental Research Center
- Multiple Universities
- Industrial Technology Research Institute (ITRI) of Taiwan
- The Foundation for Scientific and Industrial Research (SINTEF)
- International Energy Agency Greenhouse Gas R&D Programme (IEAGHG)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Australian National Low Emissions Coal Research & Development (ANLEC R&D)
- British Petroleum (BP)
- Royal Dutch Shell

As with internal beta testing, external beta testers were asked to provide feedback on their tool testing experience using a questionnaire (Appendix A), which was both provided with the tool download as an MS Word interactive form and accessible by hyperlink to a Google form. Feedback from external beta testers provided in other formats was also accepted. All comments

from external NRAP beta testing were logged in the comments register shown in Appendix B, and addressed by tool developers as detailed therein.

NRAP also solicited feedback on the NRAP tools from participating members of the International Energy Agency's Greenhouse Gas Programme's Combined Meeting of the IEAGHG Modeling and Monitoring Networks, held in July 8, 2016 (Edinburgh, Scotland, UK). In that meeting, representatives of NRAP's Technical Leadership Team presented an overview of the 10 NRAP tools that were previously released for beta testing and accepted feedback from meeting attendees, and submitted input from other IEAGHG Network participants. That feedback was documented in a report by meeting organizers from the IEAGHG, entitled "Beta Testing NRAP Tools: Summary from the Combined Meeting of the IEAGHG Modeling and Monitoring Networks, July 2016" (IEAGHG, 2016). Select feedback from that work is included in the NRAP tool beta testing comments register, attached as Appendix B.

Additionally, the NRAP Technical Leadership Team engaged with Australia's National Low Emissions Coal Research & Development (ANLEC R&D). ANLEC R&D agreed to sponsor a detailed review and testing of the NRAP suite of tools using a test case from Australia. At the time of the publication of this report, that study is still underway. Preliminary input was provided on the ANLEC R&D NRAP beta tool testing experience as part of the aforementioned IEAGHG report, and improvements to the NRAP tools (and in particular the RROM-Gen and REV tools) were made in response to those comments.

3.1.4 Toolset Completion and Release

Following completion of internal and external beta testing of NRAP tools, the tools were released as a "version 1" toolset in November 2016 on the EDX Web site at https://edx.netl.doe.gov/organization/nrap-phase-i-tools. These tools will continue to be improved as more feedback is received, and as the tools are applied to field sites and further developed to incorporate aspects of risk management and strategic monitoring for uncertainty reduction – in the context of NRAP's second phase of research.

4. REFERENCES

Bacon, D.; Cihan, A.; Coen, D.; Daley, T.; Dilmore, R.; Huerta, N.; Pawar, R.; White, J.; Bromhal, G. *National Risk Assessment Partnership* (*NRAP) Phase I Accomplishments 2011–2016;* NRAP-TRS-I-020-2016; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Morgantown, WV, 2016; p 64.

Bacon, D.; Dai, Z.; Zheng, L. Geochemical Impacts of Carbon Dioxide, Brine, Trace Metal and Organic Leakage into an Unconfined, Oxidizing Limestone Aquifer. *Energy Procedia* **2014,** *63*, 4684–4707. GHGT-12. DOI:10.1016/j.egypro.2014.11.502.

Bromhal, G. S.; Birkholzer, J.; Mohaghegh, S. D.; Sahinidas, N.; Wainwright, H.; Zhang, Y.; Amini, S.; Zhang, Y.; Shahkarami, A. Evaluation of Rapid Performance Reservoir Models for Quantitative Risk Assessment. *Energy Procedia* **2014,** *63*, 3425–3431, http://www.sciencedirect.com/science/article/pii/S1876610214021869.

Carroll, S. A.; Bianchi, M.; Mansoor, K.; Zheng, L.; Sun, Y.; Spycher, N.; Birkholzer, J. *Reduced-Order Model for Estimating Impacts from CO_2 Storage Leakage to Alluvium Aquifers: Third-Generation Combined Physical and Chemical Processes*; NRAP-TRS-II-009-2016; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Morgantown, WV, 2016; p 44.

Craig, J.; Rycroft, L.; Dixon, T. *Draft Beta Testing NRAP Tools: Summary from the Combined Meeting of the IEAGHG Modeling and Monitoring Networks*; July 2016; Summary Report: 2016-TR09.

DOE. *National Risk Assessment Partnership Research Execution Plan (REP);* RIC NRAP FY 2017-2021 FWP, Plan Period: Oct 1, 2015–Sept 30, 2017, Delivery Date:, Robert Dilmore, Technical Portfolio Lead; U.S. Department of Energy, National Energy Technology Laboratory, Office of Research and Development, Sept 30, 2016; **2016a**.

DOE. National Risk Assessment Partnership, Initiative. U.S. Department of Energy, National Energy Technology Laboratory, **2016b**. (https://edx.netl.doe.gov/nrap/?page_id=52, accessed Sept 14, 2016).

DOE. NRAP, *Virtual Special Issue: National Risk Assessment Partnership*; Carroll, S., Richard, T., Bromhal, G., Eds.; U.S. Department of Energy, National Energy Technology Laboratory, Aug 17, 2016.

DOE. *Strategic Center for Coal, AR National Risk Assessment Partnership (NRAP), Quarterly Progress Report FY15-Q4*; U.S. Department of Energy, National Energy Technology Laboratory, Robert Dilmore, Technical Portfolio Lead; Oct 30, 2015.

Keating, E.; Harp, D.; Dai, Z.; Pawar, R. Reduced order models for assessing CO_2 impacts in shallow unconfined aquifers. *International Journal of Greenhouse Gas Control* **2016,** *46*, 187–196. http://dx.doi.org/10.1016/j.ijggc.2016.01.008.

Last, G. V.; Murray, C. J.; Botta, Y.; Brown, C. F. Threshold Values for Identification of Contamination Predicted by Reduced Order Models. *Energy Procedia* **2014,** *63*, 3589–3597. http://www.sciencedirect.com/science/article/pii/S1876610214022048.

Mukhopadhyay, S.; Doughty, C.; Bacon, D.; Li, J.; Wei, L.; Yamamoto, H.; Gasda, S.; Hosseini, S. A.; Nicot, J. P.; Birkholzer, J. T. The Sim-SEQ Project: Comparison of Selected Flow Models for the S-3 Site. *Transport in Porous Media* **2015,** *108*, 207–231.

Mukhopadhyay, S.; Hou, Z.; Gosink, L.; Bacon, D.; Doughty, C.; Li, J. J.; Wei, L.; Gasda, S.; Bacci, G.; Govindan, R.; Shi, J.-Q.; Yamamoto, H.; Ramanathan, R.; Nicot, J. P.; Hosseini, S. A.; Birkholzer, J. T.; Bonneville, A. Model Comparison and Uncertainty Quantification for Geologic Carbon Storage: The Sim-SEQ Initiative. *Energy Procedia* **2013,** *37*, 3867–3874,

Oldenburg, C. M.; Nicot, J.; Bryant, S. L. Case Studies of the Application of the Certification Framework to Two Geologic Carbon Sequestration Sites. *Energy Procedia* **2009,** *1*, 63–70. DOI:10.1016/j.egypro.2009.01.011.

Pawar, R.; Harp, D.; Keating, E.; Chu, S.; Stauffer, P.; Guthrie, G. *Verification of the Performance of Integrated Assessment Model's (NRAP-IAM) Component Reduced-Order Models*; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Morgantown, WV, in review.

Stauffer, P. H.; Viswanathan, H. S.; Pawar R. J.; Guthrie, G. D. A System Model for Geologic Sequestration of Carbon Dioxide. *Environmental Science & Technology* **2009,** *43*, 565–570.

Stauffer, P.; Chu, S.; Tauxe, C.; Pawar, R. *NRAP Integrated Assessment Model-Carbon Storage (NRAP-IAM-CS) Tool User's Manual, Version: 2016.11-1.1*; NRAP-TRS-III-010-2016; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Morgantown, WV, 2016; p 64.

Trainor-Guitton, W.; Foxall, W.; Johnson, S. *Parameter Sensitivity Analysis with the Seismicity Simulation Program RSQSim*; NRAP-TRS-III-006-2016; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Morgantown, WV, 2016; p 24.

Wainwright, H. M.; Finsterle, S.; Zhou, Q.; Birkholzer, J. T. Modeling the Performance of Large-Scale CO_2 Storage Systems: A Comparison of Different Sensitivity Analysis Methods. *International Journal of Greenhouse Gas Control* **2013,** *17*, 189–205.

Wainwright, H.; Finsterle, S.; Zhou, Q.; Birkholzer, J. *Modeling the Performance of Large-Scale CO_2 Storage Systems: A Comparison of Different Sensitivity Analysis Methods*; NRAP-TRS-III-002-2012; NRAP Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory, Morgantown, WV, 2012: p24.

Yonkofski, C. M. R.; Gastelum, J. A.; Porter, E. A.; Rodriguez, L. R.; Bacon, D. H.; Brown, C. F. An Optimization Approach to Design Monitoring Schemes for CO_2 Leakage Detection. *International Journal of Greenhouse Gas Control* **2016,** *47*, 233–239. http://www.sciencedirect.com/science/article/pii/S1750583616300408.

Zhang, Y.; Oldenburg, C.; Pan, L. Fast estimation of dense gas dispersion from multiple continuous CO_2 surface leakage sources for risk assessment. *International Journal of Greenhouse Gas Control* **2016,** *49*, 323–329. https://doi.org/10.1016/j.ijggc.2016.03.002.

APPENDIX A: NRAP TOOL SURVEY FORM

You can fill out the survey at **Google Forms**

NRAP TOOL SURVEY FORM

If you are willing to have follow-up conversation about this response by phone or email please contact Deborah Coen (deborah.coen@netl.doe.gov) or Chris Wyatt (christopher.wyatt@netl.doe.gov). Also, return your response to one of these emails if you don't fill out this form online.

NRAP Tool Under Review (select one)

- (●) 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 Reduced-Order Model Generator (RROM-Gen)
- ( ) Multiple Source Leakage ROM (MSLR)
- ( ) Ground Motion Prediction applications to potential Induced Seismicity (GMPIS)

1) Manuals

Please comment on the level of detail provided in the manuals, indicate descriptions or steps that you found confusing, or offer other suggestions that would make it easier for new users to get started using these models. You can make both general and specific comments on this survey. Both types of comments are extremely useful, but specific comments are particularly appreciated. If you prefer to note specific comments on the manuals themselves, please be sure to return copies to us.

Click here to enter text.

2) Software Navigation

Please comment on your experiences using the software tools. Were the interfaces easy to navigate, or did you find yourself lost? Where were the on-line menus or directions non-intuitive or confusing? For specific suggestions, please be sure to reference the relevant software tool(s) or input/output page(s) in your response.

Click here to enter text.

3) Input Data

Was the required input data preprogrammed as defaults or easy to find elsewhere, or are there required inputs that users will find problematic to acquire? Are there common data sources (please specify) that users are likely to want to use as inputs that we should develop import functions or data translators for? For specific suggestions, please be sure to reference the relevant software tool(s) and input (s) in your response.

Click here to enter text.

4) Output Data and Reports

Were the output data generated easy to interpret? Were the units, spatial location, time and overall context of the output data obvious, or did you find yourself unsure what the results meant? Was the formatting of the output results convenient,

or should it be reformatted to interface with other software that you use (please indicate that software if known). For specific suggestions, please be sure to reference the relevant software tool(s) and output page(s) in your response.

Click here to enter text.

5) Missing Tools and Applications

Are there important aspects of storage site development, design, permitting, monitoring, operation, and/or closure that appear to be missing from the current NRAP toolset? What are they? Knowing what you now know about the NRAP toolset, how would you suggest we target such tool development (as a stand-alone ROM, a module within NRAP-IAM-CS, etc.)? Feel free to point us to examples of other relevant and available software tools you are aware of.

Click here to enter text.

6) Overall Relevance

If you were developing, designing, regulating or monitoring a CO_2 storage site, would you use the NRAP toolset? What specific component(s) did you find most useful? What component(s) did you find least useful in the current version, and why?

Click here to enter text.

7a) Limitations

What is most likely to limit your interest or ability to routinely use NRAP tools once they are released? Ease of use? Confidence in its fidelity or resolution? Acceptance of the toolset by regulators for permitting? Software licensing requirements? Incomplete suite of applications? Poor documentation?

Click here to enter text.

7b) Limitations

What might NRAP do to reduce or eliminate the limitations you have experienced?

Click here to enter text.

8a) Your Experience and Expertise

Please provide an indication of your experience with risk assessment: (novice…some experience…expert)

Click here to enter text.

8b) Your Experience and Expertise

Please indicate your expertise relative to technical aspects of CO_2 storage: (geology/hydrology/chemistry/etc.; scientist/engineer/lawyer/etc.)

Click here to enter text.

8c) Please indicate your institutional category (select one)

- ○ Industry
- ○ Academia
- ○ Government
- ○ Consultant

9) Additional Comments

What else should we know that we forgot to ask?

Click here to enter text.

Please add your email so we can respond back to any issues you raised.

Click here to enter text.

APPENDIX B - NRAP TOOLS SURVEY COMMENTS REGISTER

Notes:

Type of Comment		Assessment		Comment from author	
G	General	**RS**	Revision suggested	**R**	Rejected
E	Error	**NR**	No revision necessary	**A**	Accepted

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
WLAT	Yunwei Sun / Government No date stamp	1	G, RS	**User Manuals:** Four models are provided and described in the manual. The order of models in the manual differs from that in WLAT package. Technical details are given in Sections 7 and 8 respectively for brine leakage model and multi-segmented well model. Cemented wellbore model is a ROM developed from high-fidelity numerical models; multi-segmented wellbore model is a ROM developed from an analytical solution; brine leakage model is a ROM developed from an empirical model; and open wellbore model is based on an analytical solution. Information about conditions to use each of the four models is important for users, but is currently lacking in the manual. The quality of ROMs has not been reported in the manual. Comparison between ROM results and physical model results can be added to the manual as an appendix.	A: We plan to make this information available to the users in the manual, or a separate TRS.	**Internal**
		2	G, RS	**Software Navigation:** Basically, the software is easy to use. The order of models differs form that in the manual. To integrate the software with the manual, it is beneficial to make text boxes clickable and link to message windows to specific sections in the manual.	Part 1 – A: Switched order of components to match User's Manual. Part 2 – R: There were no goal to integrate the software with the manual. Once the user is familiar with the tool this feature is not really needed.	
		3	G, RS	**Input Data:** Most input text boxes are clear. However, without clickable message boxes, it is hard for users to understand why and how to enter values. It would be ideal to link a file of time-dependent pressure for the text box of "pressure of bottom" of brine leakage model.	R: One of the brine leakage model assumptions is constant pressure change. Varying in time pressure does not fit this assumption.	
		4	G, RS	**Output Data/Reports:** 1. In addition to "Plot" and "Save", it is better to add a "Print" function to printers and files (tiff or postscript). 2. Multiple flux curves. Since the advantage of WLAT is the ease of use compared to high-fidelity models, users may be interested in visualizing fluxes produced using different sets of parameters. The option of maintaining the last flux figures is useful for comparison purposes, instead of replacing figures in graphics windows for a new dataset.	Part 1 – R: One of the buttons below the graphing area allows user to save the output in any of the available formats, including eps, pdf. We may think about adding a Print button. Part 2 – A: We may consider adding this option	
		5	G, RS	**Missing Tools/Applications:** To apply this tool for a site-specific system, there is a need to develop more generalized ROMs. Among 4 models, the cemented wellbore model considering a thief zone with a fixed thickness (22.4 m) is closest to the geology at Kimberlina site, but fails to capture the geology. Adding one more dimension of thief zone thickness and the option to have more than one thief zone in the uncertain parametric space makes the ROM applicable to many more sites.	R: The multisegmented wellbore model can be used in the described scenario when one of the aquifers is considered to be a thief zone.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		6	G, NR	**Overall Relevance:** Yes, I will use those models to verify and validate new ROMs of wellbore leakage. The usefulness of 4 models for the current NRAP project is ranked (from most to least) as cemented wellbore model, open wellbore model, multi-segmented wellbore model, and brine leakage model. The quality of them is ranked (from most to least) as open wellbore model, multi-segmented wellbore model, cemented wellbore model, and brine leakage model. The detailed evaluation of those models depends on the report of ROM quality, such as R-square index, etc. Among four models implemented in WLAT for estimating CO_2 and brine leakage fluxes, the cemented wellbore model is the most relevant to the geological formation at Kimberlina site, where thief zones plays a big role in CO_2 and brine transport. The reduced-order model (ROM) of cemented wellbore leakage was developed in a five-dimensional parametric space (reservoir depth, thief-zone depth, thief-zone permeability, wellbore permeability, and wellbore diameter) by fixing all layer thicknesses.	A: No correction necessary.	
		7	G, NR	**Limitations:** The restricted assumptions limit the application of those models in realistic systems.	A: No correction necessary.	
		8	G, NR	**How to Eliminate Limitations:** There is always a tradeoff between ROM quality and generality. Usually, a high-quality ROM can be developed in low-dimensional parametric space while the generality requires high dimensions. To my understanding, there is no need to develop ROMs on analytical solutions and simple empirical models since they are computationally less expensive. Therefore, I feel that we may focus on the cemented wellbore model and improve it for more generalized geology. The other 3 models are restricted for strong assumptions.	A: No correction necessary.	
		9	G,NR	**Experience w/Risk Assessment:** Reactive transport modeling and uncertainty quantification.	A: No correction necessary.	
		10	G,NR	**Experience w/CO_2 Storage:** Geology, hydrology, and computer science.	A: No correction necessary.	
		11	G,NR	**Additional Comments:** Connection to downstream models: The leakage through wellbores is considered as the source term in geochemical models, which outputs other risk measures, such as pH, TDS, concentrations that impact water quality. The current version is defined for a single set of five uncertain parameters together with given boundary conditions. To fully take advantage of ROMs, it is beneficial for users to emulate CO_2 and brine fluxes using ROMs at a large number of sample points. Then, statistical results (mean values and standard deviations as functions of time) can be provided. Susan Carroll and Yunwei Sun reviewed this tool. If you have questions, let us know. Thanks.	A: No correction necessary.	
WLAT	Alex Rolland / Academia 01.18.2016	12	G, RS	**User Manuals:** Manual provided, sufficiently detailed and clear. No dedicated 'installation & user guide' section but very simple so not really required. One minor point is that the directory 'WLAT 0.8.1.0 Application' is quite messy (88 files), might be better to include the actual application file in the 'nrap-wlat-0-8-1-0-application' directory next to the user guide just to tidy it up a bit and avoid confusion.	A: We agree with the comment although it may be hard to achieve the desired modification. The Python library that we use to produce an executable for our tool packages all files in this way and it cannot be modified.	**External**
		13	G, NR	**Software Navigation:** Yes all simple and intuitive.	A: No correction necessary.	
		14	G, NR	**Input Data:** Default data preprogrammed and runs fine.	A: No correction necessary.	
		15	G, NR	**Output Data/Reports:** Brine leakage model: Output works fine but no accompanying data table and not clear how to access this data. Multisegment well model: Same as above. Cemented wellbore model: Same as above. Open wellbore model: Same as above – small note; on initial installation this model would not plot and returned 'error in main python script' message (possibly something to do with VDI environment here), reinstalled in offline directory and worked fine.	A: No correction necessary. Each tool within ROM has a Save button which allows user to save the input parameters and output results as two *.txt files in the location specified by the user.	
		16	N/A	**Missing Tools/Applications:**	N/A	
		17	N/A	**Overall Relevance:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		18	N/A	**Limitations:**	N/A	
		19	G, RS	**How to Eliminate Limitations:** Tidier 'WLAT 0.8.1.0 Application' directory and/or place actual application file up a folder level. Include accompanying data tables to the plots and allow these to be saved as a text or excel file for ease of use.	A. This comment relates to the comment 12 above.	
		20	G, NR	**Experience w/Risk Assessment:** Novice	A: No correction necessary.	
		21	G, NR	**Experience w/CO_2 Storage:** Geology	A: No correction necessary.	
		22	N/A	**Additional Comments:**	N/A	
WLAT	Argha Namhata / Government 02.08.2016	23	G, NR	**User Manuals:** The manual is well documented and provide all the necessary information regarding the use of the tool.	A: No correction necessary.	**Internal**
		24	G, NR	**Software Navigation:** The software was easy to use. In fact, it is one of the most user friendly softwares that I have ever used.	A: No correction necessary.	
		25	G, NR	**Input Data:** The format of required input data is well explained in the document and also through the example scenarios.	A: No correction necessary.	
		26	G, RS	**Output Data/Reports:** The software generates plots of output. The results were easy to interpret and save. I would suggest that the software is able to save the data points as output file (.txt or .xls formats).	A: No correction necessary. Each tool within ROM has a Save button which allows user to save output results as a *.txt file in the location specified by the user.	
		27	G, NR	**Missing Tools/Applications:** WLAT does not allow permeability values less than 10^-14 m2 for cemented wellbores. Looks to me 10^-14 m^2 may be too high for cemented wellbores.	A: The boundaries for the cemented wellbore parameters are defined by the library developed by LANL. Tool developers have no controls over the library and parameters that go into it. The WLAT has these bounds hard-wired into the GUI to prevent users from selecting values outside this range. Additionally, we are looking at expanding the underlying models in future releases to account for a wider range of parameters, permeability being one of them.	
		28	G, NR	**Overall Relevance:** Yes I would use this tool. The fact that the tool is very easy to use and captures a lot of geomechanical features with efficient computational time makes it useful. The conceptual model for integrating this tool to thief zones is not very clear to me.	A: No correction necessary.	
		29	G, RS	**Limitations:**. In case of the open wellbore model there are some issues. Given an increase of CO_2 saturation with time in input files, I expected to see a decrease in brine leakage rate with time, but WLAT predicts that the brine leakage rate keeps increasing until reaching a peak value. When trying to use the model for leaky scenarios, the flux outputs follow some strange pattern whose reason I couldn't understand. In case of cemented wellbore model, only results from 0 to 30 years are produced because the code requires the difference between the pressure history values and initial pressure to be in the range of 105,891 to 9,326,181 Pa for cemented wellbore model, but the difference between TOUGH2 pressure and initial pressure is less than 105,891 Pa beyond 30 years. The cemented wellbore model failed to run when I tried to run a leaky zone scenario simulation. Detailed report has been submitted to Bob Dilmore.	A: There is not much that we can do to address these issues. The cemented wellbore may fail to run if the input data such as pressure or saturation do not satisfy the constraints of the ROM. Among those constraints are the change in pressure and the magnitude of the first and the second derivatives of pressure and saturation. So even though the change in pressure satisfies the constraints, the first and/or second derivative may not. As for the open wellbore model, since there is no reservoir coupling, the current state of model is valid only for the short period of time. We have included the following language in the user's manual to alert users to this issue "Disclaimer: The current version of this open wellbore model does not simulate the coupling of the pressure at the bottom of the leaking well with time-dependent reservoir pressure. Therefore, the open wellbore model provides a reasonable estimate of the leakage rate through an open wellbore only for a short initial transient period. The user should use his/her own best judgment when using the results provided by the model	
		30	G, NR	**How to Eliminate Limitations**: Some of the issues that I faced while using the tool is described above. The developers need to check these cases. Other than that the tool is ready to be used by the wider	A: No correction necessary.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
				community.		
		31	G, NR	**Experience w/Risk Assessment:** I have been involved with NRAP projects for 4 years now. I have good working experience with risk assessment.	A: No correction necessary.	
		32	N/A	**Experience w/CO_2 Storage:** Scientist	N/A	
		33	N/A	**Additional Comments:**.	N/A	
WLAT	Seth King / Government 04.22.2015	34	N/A	**User Manuals:**	N/A	**Internal**
		35	N/A	**Software Navigation:**	N/A	
		36	N/A	**Input Data:**	N/A	
		37	N/A	**Output Data/Reports:**	N/A	
		38	N/A	**Missing Tools/Applications:**	N/A	
		39	N/A	**Overall Relevance:**	N/A	
		40	N/A	**Limitations:**.	N/A	
		41	N/A	**How to Eliminate Limitations**:	N/A	
		42	N/A	**Experience w/Risk Assessment:**	N/A	
		43	N/A	**Experience w/CO_2 Storage:**	N/A	
		44	G, RS	Additional Comments: My overall impression is that the tool itself is very well done, but the documentation is lacking for a product that we want to distribute. I will go through some of the larger issues I think need to be addressed first, and then suggest some small changes that aren't as pressing. The model names in the tool (Evolving permeability, MARS based, and Leakage along well) don't match up with the documentation model names (Precipitation induced sealing, MARS approach, and Nordbotten). It isn't difficult to straighten out which model is which, but a new user may be frustrated with this (in the documentation it might be nice to list them in the order they are listed on the main tool form as well). In the MARS model, I believe we grabbed the second generation wellbore rom instead of the third (this may have been my fault, sorry). The issue is this model doesn't seem to have leakage into a thief zone (aquifer 1 or aquifer 2). So a user when a user selects calculation type 3, there is zero leakage into aquifer 1 or 2, which isn't the behavior they would expect. The simple fix for this will be to hide the calculation type 3 option and the aquifer 1 and 2 plots. The better fix is going to be to replace the gen 2 rom with the gen 3 rom (I think there is two more inputs in the gen 3 rom, so some coding will need to be done for this swap). I'm told the gen 3 rom still zeros out one of the thief zones but has leakage into the other; if that is the case, the plot for the aquifer that is zeroed out should be hidden. The Nordbotten model was harder for me to grasp how to use, possibly because of my bias having familiarity with the MARS model, but I think a diagram of the system could really help a user orient themselves. Beyond that, I had a hard time seeing how as a user I would have the needed input to run the model, specifically the saturation for shale layers. I could have pressures and saturations for the reservoir like in the MARS model, and I could do a linear pressure gradient if I didn't have any other knowledge for pressure which you have automated, but the saturation values seems like I would need a full system	Part 1 – The names of the models in the tools were changed to match those in the manual. Part 2 – Different generation ROM (as of discussion here) was implemented in WLAT. Part 3 – The multisegmented (Nordbotten) model has changed since these comments were made, and comments are no longer applicable. Part 4 – The output provided by the brine leakage model has changed since these comments were made. Part 5 – We plan to add examples section to the manual. Part 6 – The discrepancy between that expected from the user and what is actually entered is handled now with the popup messages. Part 7 – Considering that the number of layers, aquifers can be different from case to case we found that it is easier to handle this situation with the input text files rather than inside of the GUI.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
				simulation to know, and if had that, what would the rom be telling me? The documentation also describes the saturation as the average saturation value in the shale layer, is that the correct description? I would have thought it was the saturation value at the base of the shale layer. The evolving permeability model is where I start to get really lost (sorry Nik). I thought I had grasped the idea of the three zones, but the fluid front versus time plot didn't make sense to me. With your default input in this model, the x_f values on this plot seem to range from 10^4 to 10^7 meters, and I can't figure out what that is telling me. Is there a way in the documentation to orient the user to the model and what the output is telling them? After understanding the model, I think a user will want a plot of leakage rate versus time as well to compare to the other models. With each of the models, there is an empty section on the wiki for examples. Maybe just a quick description of the default input and an interpretation of what the output is telling the user would be a good step in getting the user understanding the models. If we could get some diagrams of the system and models to put onto the wiki as well that may help the users understanding better. Minor issues Main window: ● In the reservoir analysis toolkit, I hide the distribution in a sub-folder and provide a shortcut to the executable in the main folder, it prevents the users from having to dig through all the *.pyd and *.dll files that cx_freeze or py2exe creates. ● To view the wiki on edx, I had to log in. This means that all of your users will have to have an edx account. Maybe this is an issue EDX can fix, I'm not sure. MARS: ● The description of well properties/well types seemed a bit sparse. Maybe it could be fleshed out more. ● It might be nice to auto select a plot based on the calculation type, then let the user change it. That is, if the user selected type 1, it would change the plot type to atmosphere, and the user could change it to aquifer 3 if they wanted. Nordbotten: ● In the text file input, the program will fail if the user doesn't but in the appropriate number of data points (3 numbers given in aq_thick.txt when only 2 aquifers specified). This error could be handled better, maybe a popup message or something rather than the basic error code in the console. ● I know Matric is looking at user interface things, should the shale thickness, shale permeability, and aquifer thickness properties be moved inside of the GUI instead of in text files?		
WLAT	*IEAGHG Report (July 2016)*	45	G, NR	The WLAT tool was used to compare the observed sustained casing pressure (SCP) of gas flow rates with existing cemented wells and open wellbores but at gas storage sites. A total of 23 wells were also surveyed for SCP at the Michigan Basin Site at CO_2-EOR sites. Six wells were tested for SCP. No significant CO_2 leakage has been detected, but there is only limited field data to calibrate against the model. Additional data collection and model validation is planned. Field data from other natural gas wells has been used for some analysis. In general, field patterns agree with WLAT published test cases. (comments from Batelle)	A: Need to document as this develops. Think this falls under Task5 of Phase II.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
STSF	Josh White/ Government 01.19.2016	46	G, RS	**User Manuals:** -- The current manual uploaded on EDX site contains bogus information irrelevant to the STSF tool after page 22. It appears the theory section from a leakage ROM has been pasted into this manual, and should be removed. -- Instructions on locating, running, and analyzing the tutorial data set should be provided. It is difficult to track down the location of this example data set (hidden in "bin/DATA"	A: Bogus entries have been removed. The appendix includes the Readme file for the installation now. Location of Data files is described better in the Tool User's Manual.	Internal
		47	G, RS	**Software Navigation:** -- As a "power" user I was able to get the tool running. However, I believe requiring users to open up a terminal to get the thing going is unacceptable. We should just be able to double-click an application icon. Anything more involved than that will severely limit the user base. -- Is it possible to require a java version less recent than 8? It would be nice to not force everyone to upgrade their java prior to using the tool. -- The tool command window will occasionally spit out the message "ATTENTION: No Convergence!!" during the run. As someone familiar with the algorithm, I know that this situation is properly handled and the final results may be trusted. To a new user, though, they would think the code is failing even for the tutorial dataset. This should be fixed to say something more precise or else removed. Also, a more conclusive "Analysis Complete" should be printed at the end.	A: The Tool User's Manual has been updated; program apparently could be started by a button already. Error messages in the program have been updated.	
		48	G, RS	**Input Data:** -- The example data sets should be included in their own, obvious to locate, directory called "Examples" or "Tutorial," rather than hidden in "bin/DATA/"	A: Manual has been updated to stress that all relevant folders are located in the /bin folder.	
		49	G, RS	**Output Data/Reports:** -- The files themselves were straightforward, but we should make sure they are being written to an obvious location (perhaps allowing the user to specify the output file names).	A: Specification of names could be part of Phase II.	
		50	N/A	**Missing Tools/Applications:**	N/A	
		51	N/A	**Overall Relevance:**	N/A	
		52	N/A	**Limitations:**	N/A	
		53	N/A	**How to Eliminate Limitations:**	N/A	
		54	G, NR	**Experience w/Risk Assessment:** NRAP team member.	A: No correction necessary.	
		55	G, NR	**Experience w/CO_2 Storage:** Geomechanics, Induced Seismicity	A: No correction necessary.	
		56	N/A	**Additional Comments:**	N/A	
STSF	Alex Rolland / Academia 01.18.2016	57	G, RS	**User Manuals:** The manual describes the use of the tool well and provides sufficient detail of actually operating the tool. I found the actual setup of the tool (ie. the installation) complicated and took more time than it should have. This process is not covered at all in the manual, although there is a small (README.txt) text file included in the package which helps explain the process. I think the package would benefit if a setup section was included in the manual that is more substantial than the brief text file currently provided.	A: A Readme file has been added to the appendix of the Tool User's Manual that describes the setup process.	External
		58	G, NR	**Software Navigation:** Yes all simple and intuitive.	A: No correction necessary.	
		59	G, NR	**Input Data:** Input preprogrammed as defaults and work so very easy.	A: No correction necessary.	
		60	G, RS	**Output Data/Reports:** Of all the tools this has the most basic output data. Not particularly user friendly with just simple text files or within terminal. Time would be saved for users if the output data could be exported as an excel file. That way quick data presentation methods are available. Additionally there were no visual displays of results on the tool as in many of the other models. (This response applies to the STSF tool).	A: Visual options and reformatting of the output might be part of NRAP Phase II.	
		61	N/A	**Missing Tools/Applications:**	N/A	
		62	N/A	**Overall Relevance:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		63	N/A	**Limitations:**	N/A	
		64	G, RS	**How to Eliminate Limitations:** Improved user friendliness and output options (relevant to STSF tool).	A: Adding options that will improve user friendliness will be part of Phase II.	
		65	G, NR	**Experience w/Risk Assessment:** Novice	A: No correction necessary.	
		66	G, NR	**Experience w/CO_2 Storage:** Geology	A: No correction necessary.	
		67	N/A	**Additional Comments:**	N/A	
STSF	Rich Lee and Chris Bradley / Government 02.04.2016	68	N/A	**User Manuals:**	N/A	**Internal**
		69	N/A	**Software Navigation:**	N/A	
		70	N/A	**Input Data:**.	N/A	
		71	N/A	**Output Data/Reports:**	N/A	
		72	N/A	**Missing Tools/Applications:**	N/A	
		73	N/A	**Overall Relevance:**	N/A	
		74	N/A	**Limitations:**	N/A	
		75	N/A	**How to Eliminate Limitations**:	N/A	
		76	N/A	**Experience w/Risk Assessment:**	N/A	
		77	N/A	**Experience w/CO_2 Storage:**	N/A	
		78	G, RS	**Additional Comments:** 1.General comment. The tool user guide appears to be well written and the input parameters clearly described other than the exceptions cited below. 2.Title. I'm concerned that the tool title "Short-Term Seismic Forecasting" could be misinterpreted as an earthquake prediction tool. The tool does not predict the potential start of induced seismicity but is a model to predict changes in the rate of induced seismicity as a function of changes in flow rates or other injection parameters. Perhaps a slight modification to the title such as "Short Term Seismic Rate Assessment" might be appropriate. 3.Page 2, equation 3. The seismic rate being proportional to the forcing term (e.g., the applied flow rate) seems reasonable. I suggest that references to other successful applications of this approach would add credibility to the approach. 4.Page 2, next to last par. "... any other parameter can be used for Fr as well and it will be fit as shown in Equation 3." This is confusing because I don't see an option for running a fit to Fr or to exercise a "what if" and increase Fr. 5.Page 3, Section 2. Maybe it's stating the obvious, but I suggest stating that the tool cannot predict the onset of induced seismicity. 6.Page 3, Section 2. I suggest adding guidance to assist the user for locations where induced seismicity may have already occurred over a number of years and thus contaminated the "background seismicity" catalog. The user would then need to "sort-out" induced and background seismicity before using the program. 7.Page 4, Section 3. I suggest that a flow chart be included in this section so that the user can understand how the code operates. 8.Page 7, Catalog File. I assume that the natural event catalog has all aftershocks removed. This should be stated.	A: 2. We will consider an update for the name: right now we think that together with the Tool User's Manual, the scope of the tool is clear. 3. References can be found within the referred paper (Bachmann et al., 2011). 4. This refers to the dropdown menu of the tool where the input flow parameter is chosen. Any parameter that is input there will be fit. A "what if" scenario would be if the input parameter/Fr is increased. 5. A line has been added to the manual. 6. As this tool is based on the seismic during the injection, there shouldn't be made a distinction between induced and background seismicity. 7. A simple flow chart was added to the manual. 8 and 9. This is not a natural event catalog. 10. There is no option to provide more than one input parameter in the current setup. Adding the possibility to fit two parameters would mean adapting the underlying model. 11. A detailed analysis of input parameters/output is shown in the referred paper (Bachmann et al, 2011) and would be too extensive here. 12. The influence of X,Y might be a scope for Phase 2	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
				9.Page 7, Catalog File. How is the geographic area of interest incorporated (normalized?) in the input of background seismicity? 10.Page 7, Flow file. What does the code do when two different parameters are provided, for example downhole flux and surface pressure? 11.Page 10, Output Examples. Suggest adding a complete example to this section with listing of input and output files and graphical results similar to the cover page. 12.Would it be useful to comment on how a spatial component might be used (X_deg, Y_deg) in future versions of this?		
STSF	Bill Harbert / Government and Academia 01.13.016	79	N/A	**User Manuals:**	N/A	Internal
		80	N/A	**Software Navigation:**	N/A	
		81	N/A	**Input Data:**	N/A	
		82	N/A	**Output Data/Reports:**	N/A	
		83	N/A	**Missing Tools/Applications:**	N/A	
		84	N/A	**Overall Relevance:**	N/A	
		85	N/A	**Limitations:**.	N/A	
		86	N/A	**How to Eliminate Limitations**:	N/A	
		87	N/A	**Experience w/Risk Assessment:**	N/A	
		88	N/A	**Experience w/CO_2 Storage:**	N/A	
		89	G, RS	**Additional Comments:** Bill Harbert provided a report to NETL summarizing his review of STSF. The report is available for review by others. His key comment follows: My only suggestion is that a step-by-step walk through this process using the specific example files perhaps included in the user documentation. Please note that this detailed parameter description and tips about which parameters to set is already present to some extent, but might be useful to the beginner user in a rigid step-by-step format.	A: The Tool User's Manual has been updated with more steps, unfortunately, it's not yet straightforward about what parameters will work best for each dataset, as there hasn't been enough testing with different datasets so far. The pre-set parameters in the tool are a good starting point.	
STSF	Bill Foxall / Government 02.19.2016	90	G, RS	**User Manuals:** Clear but brief and lacking in some information as detailed below. I suggest explicitly referring the reader to Bachmann et el. (2011) for detailed background.	A: See response to line 78, Question 3.	Internal
		91	G, RS	**Software Navigation:** Straightforward, but having to initiate from a terminal window is really clunky. I would suggest that a clear indication of when a simulation run is completed should appear at the end of the screen output. There appears to be no error handling; for example, on some runs using input parameters different from the defaults the screen output returned "segmentation faults", in which case one would have thought that the run would abort with a clear error message. As another example, omitting to specify input files generates a brief information message but the run continues, presumably using the default input (or perhaps files from the previous run?).	A: Requested from MATRIC See response in line 100 for segmentation faults: Warning messages have been updated.	
		92	G, RS	**Input Data:** Straightforward, but the bin directory is a strange place to put the test input data directory. I suggest cleaning up the header format in the test "fluxrate,dat file", i.e. so the headers are centered above the columns, to make it easier to read. The manual should explain that the parameter estimation time window applied to each forecast starts at the specified "Time Est" and ends at the beginning of the forecast	A: Manual has been updated to indicate all relevant files/codes are in the /bin folder. Relocation and reformatting of output files would require a complete update of the code structure and might be part of Phase II. Updates were made to the Tool User's Manual for clarity.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
				interval. The manual should explain how the fitted parameter estimates are applied. For example, a run using Δt=0.5 and Step Size=1.0 resulted as expected in forecasts for intervals 1-1.5 days, 2-2.5 days, etc., but the corresponding parameter estimation windows were 0.5-1.0, 0.5-2.0, 0.5-3.0, and 0.5-4.0 thereafter. Admittedly the discontinuous intervals in the example above might not make much sense, but are there constraints on specifying the forecast interval parameters? Definition of "Max Mag" in thje manual implies that this should be the expected Mmax that would be used in hazard calculations, suggesting M6 -M7. The forecast output is apparently the total number of events in the magnitude bin between "Mag Complete" and "Max Mag". Therefore, to get an estimate of the actual maximum magnitude in a particular forecast time interval, and finer binning that could be used for frequency-magnitude estimation, several separate runs having progressively smaller Mmax values would be required.		
		93	G, RS	**Output Data/Reports:** Locate the Output directory somewhere other than in the bin directory. Center the column headers in the output parameter files to make the files easier to read. Get rid of repeat headers in the "allparameter_fut.out file". What is the purpose of the "checkmodelling.out" file? Why are the numbers of event in the forecast output files given as floating point values? The fire hose of screen output will be mostly incomprehensible to the average user. Retain only information that is judged essential. It would be useful to clearly demarcate the beginning and end of each forecast time period in the screen output. The "NO CONVERGENCE" message is disconcerting, but the consequences and how they are handled is not explained in the user manual.	A: The Tool User's Manual has been updated. Error messages have been updated. Non-verbose version was discussed but based on other tools; verbose seems to be a better option as it is clearer that the tool is actually working and not frozen.	
		94	N/A	**Missing Tools/Applications:**	N/A	
		95	N/A	**Overall Relevance:**	N/A	
		96	G, RS	**Limitations:** For the tool to be truly useful for forecasting, at least the maximum magnitude or the magnitude range is needed (see response under "Input Data") No occurrence probabilities or uncertainty estimates.	A: Added in the Tool User's Manual for which magnitude range the event numbers are forecast (magnitude of completeness to maximum magnitude).	
		97	G, RS	**How to Eliminate Limitations:** Further tool development utilizing additional aspects of Bachmann et al. (2011) and Bachmann's PhD thesis.	A: Further development (e.g. spatial components, visual output etc) should be part of Phase II.	
		98	G, NR	**Experience w/Risk Assessment:** Member of NRAP Induced Seismicity Working Group. Extensive expertise in seismic hazard analysis and induced seismicity.	A: No correction necessary.	
		99	G, NR	**Experience w/CO_2 Storage:** NRAP member.	A: No correction necessary.	
		100	G, RS	**Additional Comments:** Note that once a segmentation fault had occurred the same happened for succeeding runs, even using the default input parameters. I'm not sure under what circumstances the faults occurred, but the only way I could find to rectify the situation was to reload the application from scratch.	A: Segmentation fault was likely due to the deletion of files in the /OUTPUT folder. Reloading the application from scratch added the files again as they are included with the installation. The Tool User's Manual has been updated to stress that the files should not be deleted.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS	Alex Rolland / Academia 01.18.2016	101	G, RS	**User Manuals:** No manual included in download package which would be useful for those having issues with installation. When application loads up a link to the user guide is provided but clicking this returns 'the specified linked document was not found'. Another minor point is that the 'IAM-NRAP_control_08102015' folder is untidy. Would be good to separate main application from this folder to avoid confusion.	A: The manual is included in the download package. We will update the broken link from the main application and tidy up the main folder to separate the main application.	External
		102	G, NR	**Software Navigation:** Yes all simple and intuitive.	A: No correction necessary.	
		103	G, RS	**Input Data:** Lack access to all required data so could not complete full testing. Lots of preprogrammed data is available which is useful.	A: The user comment "lack access to all required data" is not clear. The model can be edited to input any user-specified data.	
		104	G, RS	**Output Data/Reports:** N/A - Could not run without all data. Attempted run on preset variables but returned 'Intel(r) Visual Fortran run-time error' ("forrtl: severe (29) file not found, unit 1, file C:\Users...\Output_Files\simccus.txt").	A: The error reported by the user should be fixed in the current version of IAM on the EDX Web site.	
		105	G, RS	**Missing Tools/Applications:** The toolset seems to lack risk assessment specifically related to fluid migration pathways (eg. Gas chimneys, glacial features) and trapping mechanisms in the overburden (eg. Hydrate trapping). The overburden makes up a key unit of the storage complex and consequently should be well characterized and evaluated. A tool that incorporated this would also help to focus monitoring programs. It is appreciated that research in this area is limited and at IEAGHG we have very recently commissioned a study to try and review this area of CO_2 storage. This may be of use to you if you wish to incorporate this aspect of the storage complex in your toolset if possible.	A: The focus on current version of IAM is on risk assessment of leakage through wellbores. Issues identified by the user such as gas chimneys, glacial features as well as hydrate trapping are not the focus of IAM or NRAP scope. The current version of IAM includes leakage into shallow, intermediate permeable formations (thief zones) and groundwater aquifers which are part of overburden. Integration of monitoring with IAM will be focus of NRAP Phase-II effort.	
		106	G, RS	**Overall Relevance:** Of all the tools, STSF (although very interesting and useful) seems to be the least complete in terms of user friendliness and output options etc.. would benefit if some work on this tool focused on this area.	A: Phase II will include more work towards user friendliness	
		107	G, RS	**Limitations:** OS compatibility may be an issue, it is frustrating that STSF only runs only on Linux or OSX, would be more efficient and simpler if all tools were compatible in one OS (although I understand this is in development) REV and DREAM inputs are difficult to access and would be good to have sample datasets included in the packages for these tools. This would help beta-testers in testing the models.	A: As the STSF tools are based on C codes, it's not as straightforward to translate the tool to a windows environment. Some efforts have been made and it seems to work there. This could be part of Phase II.	
		108	G, RS	**How to Eliminate Limitations:** Include manual and tidy 'IAM-NRAP_control_08102015' directory and/or move actual application file up one folder level. Additionally, a set of sample datasets included in the download package would help beta testers provide more complete feedback on this tool. (Relevant to IAM-CS tool)	A: We will be including example problems as part of the download package for next release version. The current setup requires the IAM and multiple other files required for execution of IAM to be at the location where they currently reside. Moving IAM and other files will require significant updates to the dlls that are part of IAM which will be a major undertaking that we can look into as part of Phase-II effort. We will tidy up the folder as much as possible such that IAM execution and performance is not affected.	
		109	G, NR	**Experience w/Risk Assessment:** Novice	A: No correction necessary.	
		110	G, NR	**Experience w/CO_2 Storage:** Geology	A: No correction necessary.	
		111	N/A	**Additional Comments:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS	Cheryl Yang / Government 02.09.2016	112	G, RS	**User Manuals:** The tool manual (found in the folder) is well structured (input, model, output/result) and clearly written with key information presented. For this kind of complicated system model, I really appreciated this straightforward style. As already noted in this draft, some sections need more detailed information. (So I am looking forward to the updated version.) Moreover, it is really nice to focus on the complex case with example user input files [*.txt] listed, and I think it would be great to also list their work paths (i.e. the folders they are located) to save users' time to find them out one by one.	A: The user's manual will be updated with additional details as part of the next release version. That version will also include example test cases with input files.	Internal
		113	G, RS	**Software Navigation:** Given the model complexity in mind, the user interface of current version is relatively easy to navigate. The updated control panel really considers what users need to do and want to see. And I am looking forward to the futher development of AoR section.	A: AoR related developments are part of Phase II scope.	
		114	G, NR	**Input Data:** The input data was preprogrammed as defaults.	A: No correction necessary.	
		115	G, RS	**Output Data/Reports:** The output looks very good. In additional to volume, it would be nice to get the output of groundwater ROM in 2D (5%, mean, 95% over z direction).	A: The groundwater ROM is limited in that the outputs are in 2-dimensions but only in x-y direction. Getting output in z direction will require developing new ROMs with that capability and may be looked into in Phase II.	
		116	N/A	**Missing Tools/Applications:** NA	N/A	
		117	G, NR	**Overall Relevance:** NRAP-IAM-CS, which fits my work needs. (I am also interested in AIM and WALT, but haven't tested them personally).	A: No correction necessary.	
		118	G, NR	**Limitations:** Applicability and usefulness.	A: No correction necessary.	
		119	N/A	**How to Eliminate Limitations**: NA	N/A	
		120	G, NR	**Experience w/Risk Assessment:** 2 year experience in human health risk assessment + 5 year experience in CCS related risk identification and assessment	A: No correction necessary.	
		121	G, NR	**Experience w/CO_2 Storage:** Hydrology/Monitoring/Risk Assessment; scientist/engineer	A: No correction necessary.	
		122	G, NR	**Additional Comments:** No. This questionnaire is very good.	A: No correction necessary.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS *Atmospheric ROM implemented in NRAP-IAM-CS*	Shaoping Chu / Government 02.09.2016	123	G, RS	**User Manuals:** Review IAM atmospheric ROM section: see comments marked on the tracking-change version of the IAM user manual section 5.3 (Reviewer provided User Manual w/track changes version.	A: The changes are implemented in the latest version of User's Manual.	**Internal**
		124	G, NR	**Software Navigation:** The interfaces and results panel are easy to navigate. User can follow the user manual to modify input dashboard interface parameters.	A: No correction necessary.	
		125	G, NR	**Input Data:** Required input data is pre-entered on input dashboard (Land Surface) and can be easily modified by user. The receptor location file CheckPoints_CO2concentration.txt is pre-written and can also be easily modified by user.	A: No correction necessary.	
		126	G, RS	**Output Data/Reports:** It is somewhat confusing to interpret the results. Example: on Atmospheric Dispersion Results dashboard, the Location_of_PotentialLeak button show the x and y coordinates of the ROM combined new locations for potential leakage. However, Number_of_PotentialLeak button show a time series for the number of potential leak locations which change with time, so the confusion is: 1) Which locations corresponding to the Number_of_PotentialLeak in time series? Some simulation show the Number_of_PotentialLeak varies with time, while the Location_of_PotentialLeak show only one set of locations. 2) For some simulation case, the Location_of_PotentialLeak button show 5 locations, while the Number_of_PotentialLeak show 8	A: We will update the dashboard and corresponding results/charts in the next release version. Issues were resolved by working with the reviewer together: 1. The leakage locations were updated to be time series as well; and 2. This is due to some locations fall into critical zones more than once. The reason has been added to the Tool User's Manual.	
		127	N/A	**Missing Tools/Applications:** N/A to atmospheric ROM review	N/A	
		128	N/A	**Overall Relevance:** N/A to atmospheric ROM review	N/A	
		129	N/A	**Limitations:**. N/A to atmospheric ROM review	N/A	
		130	N/A	**How to Eliminate Limitations**: N/A to atmospheric ROM review	N/A	
		131	G, NR	**Experience w/Risk Assessment:** Some experience	A: No correction necessary.	
		132	G, NR	**Experience w/CO_2 Storage:** Hydrology; scientist	A: No correction necessary.	
		133	N/A	**Additional Comments:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS	ITRI Comments per Grant Bromhal / Government 12.16.2015	134	N/A	**User Manuals:**	N/A	External
		135	N/A	**Software Navigation:**	N/A	
		136	N/A	**Input Data:**	N/A	
		137	N/A	**Output Data/Reports:**	N/A	
		138	N/A	**Missing Tools/Applications:**	N/A	
		139	N/A	**Overall Relevance:**	N/A	
		140	N/A	**Limitations:**.	N/A	
		141	N/A	**How to Eliminate Limitations**:	N/A	
		142	N/A	**Experience w/Risk Assessment:**	N/A	
		143	N/A	**Experience w/CO_2 Storage:**	N/A	
		144	G, E, RS	**Additional Comments:** Summary of comments from ITRI: 1) Several instances of negative leakage rates into groundwater, sometimes a small spike at very early times (could be numerical error), but there were several instances at late times, when the leak rate went negative. This was particularly true of brine leakage, though I believe it was seen in both brine and CO_2. Nik seemed to think that we had seen and fixed some of these errors in an earlier version of the wellbore/groundwater model. This also could be an issue with the post-processor? 2) There were several cases when using the "thief zone" wellbore model, they had fewer wells "leaking" into the intermediate zone than the groundwater aquifer. For example, in one case, there were 9 wells that leaked brine into intermediate aquifer and 2 in gw aquifer, but 10 wells leaked CO_2 into intermediate aquifer and 20 leaked into gw. 3) The depth of the intermediate aquifer impacts results, but not thickness, but the code allows you to enter values that don't have an impact. Nik says this is consistent with WLAT manual. Probably IAM manual just needs updating? 4) Question: what is the difference between the AoR model and the other model? They seem to produce the same results. 5) What does the "plume size scaler" do in the post-processor? Seems to change size of gw plumes in figure, but not sure why?	A: 1. The issue with negative leakage rates has been fixed in the current version of IAM-CS on EDX 2. We have not been able to replicate this problem and will have to work with ITRI to get the specific problem setup to understand and fix the issue. 3. We will update the IAM manual. 4. The AOR model is a place-holder for future updates related to AOR calculations. 5. The plume size scalar is an utility that allows user to zoom-in on the location of the plumes since most of the plumes are very small and need to be zoomed-in.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS	Yingqi Zhang / Government 02.11.2016	145	G, RS	**User Manuals:** For the Java viewing manual, the requirement of the software should be stated (I started with a lower version of Java and the program cannot be started).	A: We will update the manual to specify the minimum required version of Java.	Internal
		146	G, RS	**Software Navigation:** There are many user's input scenarios/options. It will be helpful to have an overall chart (tree structure) in the manual for the users to keep track of their choices. A few comments: 1. When "Leakage to groundwater through wells" is selected, the "Land Surface" button is still active. It is not clear to me if in this case, "land surface" input is actually used in the model (From the figure on the front page, it seems CO2 can leak into groundwater aquifer and then to atmosphere. But from the simulations I run, I have not seen after CO_2 leaks into groundwater, it continues to atmosphere). How this is handled is not very clear in the User's guide. In addition, it is not clear to me if the left panel of "Land surface" is used (e.g., not sure when geothermal gradient is active) 2. When "Multiple wells with unknown locations" is selected, the lower panel asks to provide "Location of single known well". The title should be changed to "Locations of wells	A: 1. We will update the manual to specify the various scenarios/options in the future release version. 2. The land-surface is needed to calculate depth of the wellbore in the wellbore leakage ROM irrespective of whether it is leak to the atmosphere or to the groundwater. We will update the model to change the title.	
		147	G, RS	**Input Data:** • When the look-up table option is used for reservoir, the injection rate stays the same and the total injection amount is specified by the user. Does it mean only the injection length is changed based on total injection amount? Then how does the look-up table work? Should not the look-up table interpolate the injection rate, not the length? • If the injected CO_2 temperature is not specified, how is the reservoir temperature calculated? • For the simple reservoir model, a maximum injection pressure is specified. It is not clear what will happen to the simulation if the injection pressure exceeds this maximum pressure?	A: 1. The look-up table option is based on the Kimberlina model which was run for a fixed injection rate. We have not implemented a look-up table model based on variable injection rate but will update the next release version with that option. 2. The IAM-CS does not compute change in reservoir temperature. If it is provided as part of the look-up table input data, it is used in the model. 3. The manual will be updated to clarify how the maximum injection pressure input is used in the model.	
		148	G, RS	**Output Data/Reports:** • Wish the user's guide have a little more information on reservoir model. What are limitations of using a look-up table vs. a simple model? • In general, I hope the User's guide can provide more guidance on how to use IAM model for a real site and provide pros and cons of each component ROM. • When results are viewed in JAVA viewer, occasionally I got message like "error to upload pressure", details show "For input string: "0.308848E"". I am not sure how to find out what pressure results are having trouble to display.	A: The next release version will include example use cases. The error is fixed in the latest Java Viewer.	
		149	G, RS	**Missing Tools/Applications:** I think it is important to develop a demonstration example: how to use the tools to design or monitor a site? How to go with site specific features? Or how well the approximations can be without those site-specific features?	A: This will be done as part of Phase II work.	
		150	G, RS	**Overall Relevance:** I will be cautious about using NRAP-IAM-CS. I do not have experience with other toolset. There are two reasons: 1. Problems related to CO_2 storage is very site specific and the tool is very generic, so I am not sure how well the IAM can be applied to a real site; 2. I need to have enough confidence in the IAM solutions. This confidence is based on an example that was not used in the IAM development, but at least modelled both by a set of high fidelity models and IAM. with agreeable results. So far I have not seen such an example and I do not have a sense of how much error can be accumulated to the last component of the IAM	A: A set of examples are being developed to verify applicability of the IAM.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		151	G, RS	**Limitations:** Each component in IAM is represented by a ROM. Many related questions (include how site specific these ROMs are, how well they predict – what is accuracy level? And what is the accumulated error? Under what conditions can these ROMs apply?) need to be answered. For the open well option, the leakage rate from wellbore could be very large. When CO_2 leaks out directly to atmosphere with a large rate (e.g., more than 10 kg/s, in some case, 100kg/s), it is more realistic to stop the IAM simulation when it happens.	A: The next release version will include an option to stop the IAM execution if the leak rate exceeds certain user-specified cutoff.	
		152	G, RS	**How to Eliminate Limitations**: Build an example modeled both by a set of high-fidelity models throughout and IAM, and compare results.	A: See the response to comment on line 150.	
		153	G, NR	**Experience w/Risk Assessment:** I have sufficient experience in risk assessment.	A: No correction necessary.	
		154	G, NR	**Experience w/CO_2 Storage:** I have a PhD in hydrogeology. My expertise include numerical modeling for multiphase flow, uncertainty quantification, risk assessment	A: No correction necessary.	
		155	N/A	**Additional Comments:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS	*IEAGHG Report (July 2016)*	156	G, RS	Include detailed instructions for the NRAP-IAM-CS tool, previously known as CO2-PENS, and include the development of efficient techniques to create project-specific input tables for complex cases . This may support permitting authority evaluations (documented and provided in user manuals). More detail in the manuals to tie in with the webinar videos.	A – The user's manual will be updated accordingly and also an example use case will be incorporated. The tie in with webinar videos requires additional time and will be provided in the later version of the manuals.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	157	G, RS	Expand the reservoir thickness range from 10m-200m in the ROM tool so that it can model the low end of the thickness range (~1m) to simulate CO_2 in thin high permeability layers.	A: This will require development of a new version of reservoir ROM and will be addressed as part of the IAM update during Phase-II.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	158	G, RS	A means for the user to check the results of the intermediate calculation steps should be provided.	A: We will update the manual accordingly.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	159	G, RS	Include the ability to model CO_2 injection for a period of time and then monitor leakage from legacy wells while the injection well is shut in.	A: This can be done by the user, but would require specific res. simulation to predict p/sat response through time at res/seal interface. It's not possible with the current version of the simple res. Response that's built into the IAM.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	160	G, RS	Cadmus suggested that for Class VI operations, it might be helpful to use consistent terminologies with the regulations. It was also suggested that detailed instructions, and the development of efficient techniques to create project-specific input tables for complex cases, may support permitting authority evaluations (documented and provided in user manuals).	A: The RROM-GEN tool allows efficient implementation of project-specific input tables. We will update the terminology consistent with Class-VI operation regulations.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	161	G, NR	Subhash Thakur from BP Carbon Solutions reported that he had tested the NRAP-IAM model. Subhash encountered some bugs when starting to use the tool, but these have been mostly addressed by the developers.	A: No correction necessary. Have worked with Dr. Thakur since comment to address issues that he has identified. REV/RROMGEN revised accordingly.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	162	G, RS	During the beta testing period, there was no dedicated user support or training on offer although the introductory webinars were useful, but not sufficient . Subhash reported that the developers were very helpful, but were also busy with other tasks. Data imported from the Eclipse simulator (and possibly other commonly used reservoir simulators) should be made available. He suggested that this import should be seamless and easy for the user to implement and that it should not be assumed that the Eclipse model has been run or will be run by the same user who is using NRAP-IAM. The file names and file formats on both sides (Eclipse and IAM) should be clearly explained in the user manual. The Eclipse import has been added recently according to Subhash.	A: Formal training workshop has since been offered. We have limited resources to support a help line or more frequent training sessions, but still hope to be responsive to beta testers and users. We are pursuing other options going forward.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
IAM-CS	*IEAGHG Report (July 2016)*	163	G, RS	Another recommendation for tool development and application is the ability to model CO_2 injection for a period of time and then monitor leakage from legacy wells while the injection well is shut in.	A: This will be part of Phase II task 2, but users can already do this with their own simulations and then bring into IAM through RROM-Gen.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	164	G, RS	Include detailed instructions for the NRAP-IAM-CS tool, previously known as CO2-PENS, and include the development of efficient techniques to create project-specific input tables for complex cases . This may support permitting authority evaluations (documented and provided in user manuals). More detail in the manuals to tie in with the webinar videos.	A: RROM-Gen is to create look-up tables for the IAM, it is assumed that the IAM manual is the best place to describe how to import/use look-up tables once they are created.	**External**
IAM-CS	*IEAGHG Report (July 2016)*	165	G, RS	Expand the reservoir thickness range from 10m-200m in the ROM tool so that it can model the low end of the thickness range (~1m) to simulate CO_2 in thin high permeability layers.	A: This is an issue with the internal IAM semi-analytical simple reservoir model, it has no relevance to the REV tool and is not a limitation to the Look up tables created by the RROM-Gen tool.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
REV	Alex Rolland / Academia 01.18.2016	166	G, NR	**User Manuals:** The manual provides sufficient detail and installation is covered.	A: No correction necessary.	External
		167	G, NR	**Software Navigation:** Yes all simple and intuitive.	A: No correction necessary.	
		168	G, RS	**Input Data:** No access to reservoir simulation data so cannot test tool fully. May be useful to provide a simple sample dataset in tool package.	A: Included sample files folder in the REV tool distribution	
		169	G, RS	**Output Data/Reports:** N/A – Couldn't run with no data.	A: Included sample files folder in the REV tool distribution on EDX.	
		170	N/A	**Missing Tools/Applications:**	N/A	
		171	N/A	**Overall Relevance:**	N/A	
		172	G, RS	**Limitations:** Include sample reservoir dataset for those without immediate access to reservoir simulation data. This would be particularly useful for beta testers.	A: Included sample files folder in the REV tool distribution on EDX.	
		173	G, RS	**How to Eliminate Limitations:** Include sample reservoir dataset for those without immediate access to reservoir simulation data. This would be particularly useful for beta testers.	A: Included sample files folder in the REV tool distribution on EDX.	
		174	G, RS	**Experience w/Risk Assessment:** Novice	A: No correction necessary.	
		175	G, RS	**Experience w/CO_2 Storage:** Geologist	A: No correction necessary.	
		176	N/A	**Additional Comments:**	N/A	
REV	Abdullah Cihan / Government 02.16.2016	177	G, RS	**User Manuals:** It is great that the package when opened includes example files. But, I find that the manual doesn't described these files in a sufficient detail. I think the examples in a manual like this are very important for users and reviewers to understand and test what a tool can or cannot do. The manual should include a separate section describing each of the example files and their content in detail. The outcomes from each reservoir type output should be also demonstrated in the manual, with sufficient detail on interpretations of the results in terms of what they may mean when evaluating or assessing AoR. At least one example should be described for each simulator type.	A: Cleaned up Tool User's Manual and clarified several points in the Tool User's Manual.	Internal
		178	G, RS	**Software Navigation:** Installation and use appear very easy, but often times, the software became stuck (stating processing, but not doing anything), when I tried to test other reservoir type inputs.	R: Different input data sets require different processing times.	
		179	G, RS	**Input Data:** As mentioned in section (1), the example input data for testing and using the tool must be described in much greater detail in the manual. Also, the manual states that the pressure plume calculation based on the EPA's guidance document (critical pressure buildup to lift the brine from reservoir into USDW through an open well bore) was included, but I didn't see any data entry or output for this calculation. Was this already completed?	A: This was clarified in the user's manual.	
		180	G, RS	**Output Data/Reports:** Please see my comment in (Input Data section). Also, the units appear to be missing in generated plots.	A: This was clarified in the user's manual.	
		181	G, NR	**Missing Tools/Applications:** In general, I think the existing tools are very useful for initial planning related to storage site development and design. However, they must be carefully tested with perhaps more accurate but computationally demanding tools, and the applicability of the tools must be demonstrated for actual CO_2 storage operations.	A: No correction necessary.	
		182	G, NR	**Overall Relevance:** I would probably use or recommend if the toolset would be tested comprehensively and demonstrated to be accurate enough to use in real applications. However, the results from the REV tool must be more trustable than the individual ROMs since the outcomes are based on numerical reservoir simulators. There appear some interpolation algorithms in the REV tool, but I think such algorithms can be easily proven to work properly. In general, the results from the REV should be subject to the same assumptions related to the models in the simulators where data come from.	A: No correction necessary.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		183	G, RS	**Limitations:** Confidence in its fidelity, specifically ROMs	A: There are no ROMs supplied with this tool	
		184	N/A	**How to Eliminate Limitations:**	N/A	
		185	G, NR	**Experience w/Risk Assessment:** Some experience	A: No correction necessary.	
		186	G, NR	**Experience w/CO_2 Storage:** Hydrogeology; scientist	A: No correction necessary.	
		187	N/A	**Additional Comments:**	N/A	
NSealR	Alex Rolland / Academia 01.18.2016	188	G, NR	**User Manuals:** Manual provided, sufficiently detailed and clear.	A: No correction necessary.	External
		189	G, NR	**Software Navigation:** Yes all simple and intuitive.	A: No correction necessary.	
		190	G, NR	**Input Data:** Default data preprogrammed, very easy.	A: No correction necessary.	
		191	G, NR	**Output Data/Reports:** Output very good, lots of options and result plots with accompanying excel compatible table is very handy. Output to excel is a very user friendly feature. Would be good if all tools had this kind of output interface and options, seems most advanced and user friendly of all the tools	A: No correction necessary.	
		192	N/A	**Missing Tools/Applications:**	N/A	
		193	N/A	**Overall Relevance:**	N/A	
		194	N/A	**Limitations:**	N/A	
		195	G, NR	**How to Eliminate Limitations:** None relevant to NsealR.	A: No correction necessary.	
		196	N/A	**Experience w/Risk Assessment:**	N/A	
		197	G, NR	**Experience w/CO_2 Storage:** Geology	A: No correction necessary.	
		198	N/A	**Additional Comments:**	N/A	
NSealR	Lewei Zhang and Argha Namhata / Government	199	N/A	**User Manuals:**	N/A	Internal
		200	N/A	**Software Navigation:**	N/A	
		201	N/A	**Input Data:**	N/A	
		202	N/A	**Output Data/Reports:**	N/A	
		203	N/A	**Missing Tools/Applications:**	N/A	
		204	N/A	**Overall Relevance:**	N/A	
		205	N/A	**Limitations:**.	N/A	
		206	N/A	**How to Eliminate Limitations**:	N/A	
		207	N/A	**Experience w/Risk Assessment:**	N/A	
		208	N/A	**Experience w/CO_2 Storage:**	N/A	
		209	G, NR	**Additional Comments:** This is a placeholder for the report developed by Lewei and Argha comparing NSealR to TOUGH2. Lilia Reddy also provided a presentation comparing NSealR to other models	A: Comment provided	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
NSealR	Jason Hou / Government 02.12.2016	210	G, RS	**User Manuals:** The manual is well written and easy to follow. More details are needed in the section "Software loading and external file input", which I think is a critical component of this tool that can be integrated into other modules (reservoir, fault, wellbore, etc). More explanations or demos can be added regarding the types of variables/outputs (e.g., saturation, pressure, flux) that can be imported from other modules and the required formats.	R: The details of external file input are provided in the Appendix E of the user manual (not in the abbreviated Tool User's Manual). Output is described in the GoldSim manuals. Both sets of manuals were included with the software. More demos could be added in the next version of the code, but the description of input is provided in user's manual as well.	Internal
		211	G, RS	**Software Navigation:** The user interface is easy to navigate. Some letters/words in the dashboards (e.g., the porosity range and the note in seal permeability dashboard, the relative permeability dashboard, etc.) are smeared or cut off, but it is easy to guess what are missing.	A: The GoldSim interface does not "smear" (?) txt and the cutoff of text suggests that the resolution of the user's screen was too small for good code operation (the seal permeability Dashboard is the largest one). A vertical resolution of 800+ pixels is required for the code.	
		212	G, RS	**Input Data:** It is helpful to provide guidance on what variables/outputs can be loaded and the required format, especially if the user wants to use NSealR as a standalone tool.	R: Again, the user is referred to the user's manual; it is located in the "user guide - manuals" subdirectory, and is titled, "NSEALR - NRAP-TRS-III-001-2015_NSealR-User-Guide-Gen3.pdf."	
		213	G, RS	**Output Data/Reports:** The output data and figures are generally clear and illustrative. Colorbars are needed for 3D CO_2 plume and brine distributions.	R: The colors used in the 3D charts from GoldSim do not represent intervals, but rather the colors are used to make it easier to view. GoldSim does not include color bars for these charts. No change is possible.	
		214	G, RS	**Missing Tools/Applications:** Possible improvements of the NSealR module: • The stochastic seal permeability model is based on traditional Monte Carlo sampling, but not based on widely used geo-statistical approaches (e.g., variogram models). It doesn't make full use of spatially distributed point measurement once available. • It is better to use logarithmic permeability as the variable to be sampled. Also one helpful option is to let the users choose log transformation or not, and/or assign more probability distribution types, especially for the parameters varying by several orders of magnitude, where the uniform or normal distributions are not appropriate. • The model runs fast, as it is 1D model at each grid. However, horizontal permeability Kh is much larger than Kv, and therefore horizontal movement might not be negligible, although not as significant as reservoir plume expansion. • How about vertical variability in hydraulic parameters? Also I don't see options to deal with the vertical resolution, which I think would affect the flux simulations. • Since the tool is not handling multiphase CO_2, it is helpful to guide the users not to generate a model with a seal top shallower than, say, 1000m bgs. • One difficulty is the integration with reservoir and fault/wellbore leakage modules. Let's say the CO_2 injection starts, and the reservoir module is used to simulate the CO_2 plume expansion for 200 years. At what time step should the users extract outputs (e.g., CO_2 pressure, saturation) to feed into NSealR?	A: Suggested additions could be useful but would involve substantial efforts not in current scope. Part 1: The Monte Carlo basis is part of the GoldSim environment and cannot be changed without substantial effort. Part 2: Incorporating different functions is possible. It would add to the interface complexity. Part 3: As noted in the user's manual, flow is assumed to be along vertical fractures through the unit as the matrix is relatively impervious. Also, a 1-D vertical-flow model does not typically incorporate lateral flow (2D). Potentially, a "spreading" function could possibly be developed to simulate horizontal dispersal. Part 4: As noted in the user's manual, the caprock layer is assumed to be thin and that vertical variability can be ignored. The reviewer is correct that vertical variability could affect results. Part 5: The supercritical assumption and depth limit is discussed in Section 2.8 of the user's manual. As CO_2 storage is to be in saline environments, it is expected that storage will be at depths greater than 1,000 m (i.e., below potable water aquifers). As error check on input elevations directly is not practical as the storage horizon can be higher than an elevation of -1,000 m, and depth below grade is not directly input. A correction flag could be developed, Part 6: Input is based on time step values as discussed in the user manual. The time steps for input are defined by internal array variable (which can be changed by the user).	
		215	G, RS	**Overall Relevance:** The simulation monitoring and output visualization are quite useful. I would use the toolset, particularly if it is improved to be a standalone package with the capability of loading/generating initial and boundary conditions data with standard format.	R: Unfortunately, the suggested improvements are not in current scope of work. As mentioned, input of the boundary conditions and reservoir input is possible with the current code, and the input format is defined in the user manual.	
		216	G, RS	**Limitations:** It is a great tool for uncertainty quantification and decision making associated with CO_2 leakage through caprock. It would be a plus to implement the several applications as listed above in item#5.	R: Unfortunately, the suggested improvements are not in current scope of work.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		217	G, RS	**How to Eliminate Limitations:** It is impossible to implement all the major missing applications as explained above as well as those listed in the future work section in the report; but it is realistic to implement the ideas to address spatial heterogeneity (e.g., correlation patterns), grid resolution, anisotropy, and parameter distribution types.	R: Changes are possible, but are not part of the current scope and will take substantial effort (on the order of several weeks). Changes would also require an up-to-date license for GoldSim.	
		218	G, NR	**Experience w/Risk Assessment:** My research focuses on exploratory data analyses, uncertainty quantification, and inversion approaches, solving problems related to carbon sequestration, oil/gas exploration, environmental remediation, climate change, and power system management.	A: No correction necessary.	
		219	G, NR	**Experience w/CO_2 Storage:** Geostatistics; coupled hydrogeological-geochemical-geomechanical modeling	A: No correction necessary.	
		220	N/A	**Additional Comments:** n/a	N/A	
AIM	Alex Rolland / Academia 01.18.2016	221	G, RS	**User Manuals:** No manual included in package only a README text file with very basic installation instructions. Link to manual provided when application actually starts up but this won't be much use to somebody who is struggling with the initial installation. Therefore recommend including a copy of the manual with the download package as is the case with most of the other tools. Another minor point is that the installation instructions in the manual do not match the download and installation process (eg. there is no 'gwrom-1.0.0 folder') so this should be updated to avoid confusion	We want to keep the installation and user guide together in one document, but will put a copy in the download folder to aid in installation. The download page now includes a copy of the user's manual stand alone as well as being included in the tool (application) zip file.	**External**
		222	G, NR	**Software Navigation:** Yes all simple and intuitive.	A: No correction needed.	
		223	G, NR	**Input Data:** Default data preprogrammed with upper and lower bound data which is useful.	A: No correction needed.	
		224	G, RS	**Output Data/Reports:** Output good and easy to interpret. Just a side-note, initially when I installed the tool and tried to run the analysis it returned 'C:\Program' is not recognized as an internal or external command, operable program or batch file'. Not entirely sure why it was returning this message (possibly something to do with the Virtual Desktop Infrastructure we have here). Eventually re-downloaded and re-installed in another directory and it worked. Thought it maybe worth mentioning incase other users have come across this issue. UPDATE: This error occurred again and can't seem to solve it this time.	Referred to MATRIC. The batch file error is solved by not allowing spaces in the directory structure. This information will be added to the next version of the user's manual.	
		225	N/A	**Missing Tools/Applications:**	N/A	
		226	N/A	**Overall Relevance:**	N/A	
		227	N/A	**Limitations:**	N/A	
		228		**How to Eliminate Limitations:** Minor updates to manual and include in download package to help installation. Providing the installation & user guide as a separate document may be helpful to distinguish between the practical side of the using the tool and the theoretical background to the tool. Not sure of reason for the "C:\Program' is not recognized as an internal or external command, operable program or batch file" error but may be worth investigating.(Response relevant to AIM tool)	We want to keep the installation and user guide together in one document, but will put a copy in the download folder to aid in installation. The download page now includes a copy of the user's manual stand alone as well as being included in the tool (application) zip file. Referred to MATRIC. The batch file error is solved by not allowing spaces in the directory structure. This information will be added to the next version of the user's manual.	
		229	G, NR	**Experience w/Risk Assessment:** Novice	A: No correction necessary.	
		230	G, NR	**Experience w/CO_2 Storage:** Geology	A: No correction necessary.	
		231	N/A	**Additional Comments:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
AIM	Mansoor Kayyum / Government 01.14.2016	232	G, RS	**User Manuals:** The manual clearly explains the science, objectives and limitations of the AIM software, and it does a good job instructing the user how to install the software, run the application and how to analyze the output. The installation package was straight forward, but issues with Java compatibility had to be resolved in order for the interface to work.	A: Yes, you have to install the correct version of Java, but this is clear in the instructions.	Internal
		233	G, RS	**Software Navigation:** The interface is easy to navigate, but it would be helpful if the second screen (after chosing the aquifer type) would indicate if AIM is applying the unconfined carbonate aquifer or confined alluvium aquifer – or a status bar such as: Main -> Unconfined Carbonate Aquifer-> Leak Rate Model The 'hover' capability of the Leak Rate Model tab can be removed since no labels contain '*'	A: Referred to MATRIC to fix. The hover capability (tool tip) has been added to the tool application.	
		234	G, NR	**Input Data:** The parameter bounds for the Leak Rate Model were based on running a specific wellbore leakage ROM for the High Plains aquifer. Since the confined aquifer ROMs are very sensitive to CO_2 and brine input fluxes, correctly estimating the upper flux bounds is an important consideration. This may be accomplished when the AIM tool is used in conjunction with the wellbore ROM tool. Conversely, the aquifer parameters can be obtained from literature and web searches. Parameters deemed most sensitive (sand permeability and sand fraction) can easily obtained from well logs permeability tests, and well hydraulic tests – most of which is readily available. The sand fraction can be estimated by calculating the proportion the high and low permeability units from well logs.	A: No correction necessary.	
		235	G, RS	**Output Data/Reports:** The AIM software generated a full suite of outputs for the unconfined aquifer that include in the input flux curves, quartile plots, probability plots and sensitivity analysis. The output is straightforward to interpret, and the software can be run for multiple aquifers to compare and rank their vulnerabilities to leakage impacts. It may be helpful to show the probability density functions (PDF) derived from the cumulative probability curves of the various leakage rates since the means and tails can be more easlily interpreted from the PDFs. The sensitivity analysis is useful indicator, which can allow operators to focus their data collection and interpretation efforts on the most sensitive parameters. The post-processed results for the confined aquifer are incomplete and only contain the flux input curves.	A: The plotting issue was resolved in v1.1.3. PDFs of the leakage scenarios will not be added.	
		236	G, RS	**Missing Tools/Applications:** The post-processed results for the confined aquifer are incomplete and only contain the flux input curves. It would be helpful to have a master document detailing the suite of tools, accompanied by a flowchart to inform users which tools are useful for their efforts.	A: The plotting issue was resolved in v1.1.3. Referred flowchart suggestion to the systems group.	
		237	G, RS	**Overall Relevance:** This suite of tools can be used to initially determine site selection and site comparisons. This can help to narrow down potential storage sites and focus on specific site characterization efforts. The quartile plots and the sensitivity analysis are useful since they show the potential magnitude of impacts and which parameters have the greatest influence on impacts. But these plots appear to be available only for the confined aquifer.	A: The plotting issue was resolved in v1.1.3.	
		238	G, NR	**Limitations:** These tools were based on a small selection of site-specific data and they can be applied to sites with similar characteristics. However, tool limitations should be considered when applying these to other sites with different aquifer characteristics. The tool can be used to infer initial impact and it can be used as a basis to focus data collection and site characterization efforts. The AIM ROMs are based on specific thresholds. The EPA MCL guidelines can be applied broadly, but the impact thresholds are specific for a given USDW (Edwards Aquifer and High Plains Aquifer). Additional ROMs may have to be developed if the site-specific impact thresholds vary significantly from those used with the AIM. Leakage rates should fall within the prescribed ranges used in the software, since CO_2/Brine leakage is a primary driver for the plume volume output. If leakage volumes are too low or beyond the prescribed upper limits of the input flux, new ROMs have to be developed.	A: No correction necessary.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		239	G, NR	**How to Eliminate Limitations:** One useful method is to flag the users if their parameter ranges fall outside the bounds prescribed for the ROMs or if the parameters are narrowly bounded (i.e.: very specific flux rates). Since the ROM is an empirical model individual results cannot capture the behavior of a system and multiple realizations are required to establish a realistic statistical representation of the system. Since the no-impact thresholds in the AIM are location specific, additional ROMs can be implemented at a range of thresholds (ex. pH < {5.75, 6, 6.25, 6.5, 7}) to extend the tools applicability to sites with different impact standards.	A: No correction necessary.	
		240	G, NR	**Experience w/Risk Assessment:** Developer of confined aquifer ROM for NRAP., Experienced hydrology modeler in risk assessment groundwater contamination and remediation, hydrologic impacts from surface water sources and nuclear waste disposal.	A: No correction necessary.	
		241	G, NR	**Experience w/CO_2 Storage:** Experience in site characterization, geologic interpretation, multiphase reactive transport modeling, statistical analysis, uncertainty quantification as a scientist and engineer.	A: No correction necessary.	
		242	N/A	**Additional Comments:**	N/A	

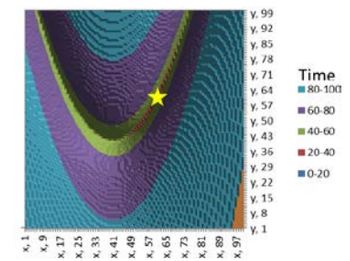
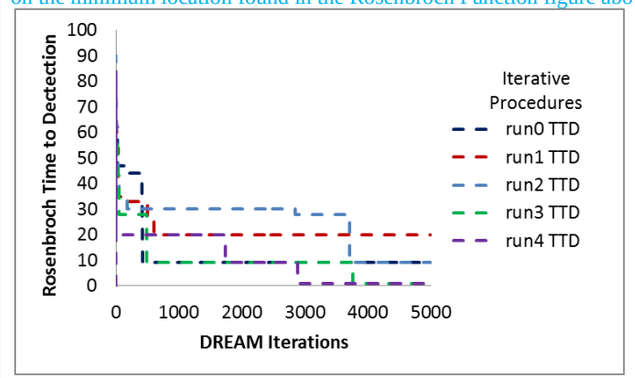
NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
AIM	Susan Carroll / Government 01.22.2016	243	G, RS	**User Manuals:** Need to read manual. The installation package was straight forward, but issues with Java compatibility had to be resolved in order for the interface to work.	A: Yes, you have to install the correct version of Java, but this is clear in the instructions.	Internal
		244	G, NR	**Software Navigation:** Navigation of the tool was very easy, perhaps in part because I was familiar with the content.	A: No correction necessary.	
		245	G, NR	**Input Data:** In testing the ROM, I sought to use the ROM to assess an acceptable leakage volume and the impact of fixing the leaking source. I was easily able to explore each of these phenomena by varying the maximum flux and the mitigation time respectively. One could further explore these outcomes by varying the other parameters in the leakage model. I did not vary any of the aquifer parameters, because past work has indicated that total amount of CO2 or brine leaked correlates to the volume of the aquifer impacted.	A: No correction necessary.	
		246	G, RS	**Output Data/Reports:** A big shortcoming of the aquifer tool is the data output. A flexible format is needed so that the user can easily look at the results with the flexibility of plotting ranges TDS, pH, trace metals, organics, leakage mass, time, confidence levels, pdf and cdf. Currently, the model outputs fixed leakage fluxes, leakage masses, cdf, and quartile distributions vs time for pH and TDS only. There are no graphics for the trace metals or the organics. Furthermore all data output is in "R" and does not allow the user to import the output into spreadsheet for further analysis.	A: The output file is now available for the user to use as they like. A description of the file format has been added to the user's guide.	
		247	G, RS	**Missing Tools/Applications:** The AIM is a stand alone ROM. It usefulness is mostly in assessing groundwater impacts that exceed the MCLs, because the current thresholds are specific to the fields on which the simulations were based. The toolset would be much more useful, if it allowed the threshold to be defined. This could done with synthetic data already compiled by NRAP.	A: This is a feature for v2.	
		248	G, RS	**Overall Relevance:** The AIM is a stand alone ROM. It usefulness is mostly in assessing groundwater impacts that exceed the MCLs, because the current thresholds are specific to the fields on which the simulations were based. In testing the ROM, I sought to use the ROM to assess an acceptable leakage volume and the impact of fixing the leaking source. I was easily able to explore each of these phenomena by varying the maximum flux and the mitigation time respectively. The ROM was useful for assessing a leakage volume for a given flux, such that volume of impacted water decreased with decreasing max flux. The mitigation time made not difference in the impacted volume. That struck me as odd.	A: This is related to the underlying physics based model, and is a function of the background hydraulic gradient.	
		249	G, RS	**Limitations:** Use would be limited by • poor graphics • predefined thresholds • lack of plume dimensions in x, y, and z.	A: Font size for plots has been increased.	
		250	G, RS	**How to Eliminate Limitations**: Improve data output and manipulation of output. Construct Gen 4 ROM that allows for variable threshold and plume dimensions.	A: The output file is now available for the user to use as they like. A description of the file format has been added to the user's guide.	
		251	G, NR	**Experience w/Risk Assessment:** I have been working with NRAP for the past six years.	A: No correction necessary.	
		252	G, NR	**Experience w/CO_2 Storage:** I am a geochemist with more than 25 years of experience working on fate and transport of contaminants.	A: No correction necessary.	
		253	N/A	**Additional Comments:**	N/A	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
AIM	Chris Brown / Government 02.10.2016	254	G,NR	**User Manuals:** The manual was organized in a manner that provides the user with clear direction on how to set the model up, including what the parameters are for, and information on the appropriate ranges for the parameters.	A: No correction necessary.	Internal
		255	G,NR	**Software Navigation:** The software was easy to navigate and the interface, including the buttons that allow you to turn features on and off, was user friendly. The progression through the various pages/steps within the software was logical.	A: No correction necessary.	
		256	G,NR	**Input Data:** Yes, the pre-programmed ranges for the inout parameters was a huge help in setting up the model, and ensuring you were not trying to develop ROMs outside their appropriate range (i.e., beyond the parameter ranges used in the high fidelity models to "train" the ROMs).	A: No correction necessary.	
		257	G,RS	**Output Data/Reports:** The output data was easy to follow. In general, it would be good to have a bit larger font size for the figure labels.	A: Font size for plots has been increased.	
		258	G,RS	**Missing Tools/Applications:** The team should begin looking at leakage detection in the first confining zone above the reservoir. It would be good to develop a simple way to estimate what type of pressure change could be expected in this layer as a function of CO_2 and/or brine leakage from the reservoir.	A: This would involve work on a future tool version.	
		259	G,NR	**Overall Relevance:** Yes, the tools are relevant for performing initial assessments of site suitability. The ability to build off of high fidelity data using the ROMs is a nice feature that will add to their deployment.	A: No correction necessary.	
		260	G,NR	**Limitations:**. Some of the tools are quite site specific. For AIM, the team is still trying to understand the applicability of the High Plains and Edwards ROMs to other sites.	A: No correction necessary.	
		261	G,NR	**How to Eliminate Limitations:** For AIM, a paper has just been completed that describes the different scenarios in which the two ROMs are applicable. Once we get additional feedback from the user community we can determine if additional ROMs need to be developed to better support the user base and broaden the range of applicable sites.	A: This would involve work on a future tool version.	
		262	G,NR	**Experience w/Risk Assessment:** I am part of the NRAP team providing a review of one of the tools.	A: No correction necessary.	
		263	G,NR	**Experience w/CO_2 Storage:** Geochemistry	A: No correction necessary.	
		264	N/A	**Additional Comments:**	N/A	
AIM	Shaoping Chu / Government 02.11.2016	265	G, RS	**User Manuals:** Review Aquifer Impact Model (AIM) Tool User's Manual (17 Aug 2015): see comments marked on the pdf version of the IAM user manual downloaded from EDX (attached).	A: Edits to the Tool User's Manual have been made based on comments.	Internal
		266	G,NR	**Software Navigation:** The interfaces and results are easy to navigate. User can follow the user manual to modify input dashboard interface parameters.	A: No correction necessary.	
		267	G,RS	**Input Data:** Required input data is pre-entered on input dashboard and can be easily modified by user. However one place needs clarify: on the user manual section 5.1.2, it mentioned that for unconfined carbonate aquifer, trace metals and organics in the brine are scaled according to chloride concentration, using factors detailed in Bacon et al. (2014). Does user need to do the scaling if they want to modify the input parameters? If so can user manual provide instruction on how to do scaling instead of pointing user to a reference?	A: The trace metal concentrations were independent variables for the complex geochemistry simulations used to derive the scaling functions.	
		268	G,RS	**Output Data/Reports:** There are some problems regarding results: 1) On some of the pdf files of the results (leakage_scenarios.pdf and leakage_scenarios_mass.pdf), X-axis (time) doesn't show unit. 2) Run user manual specified example for unconfined carbonate aquifer on windows system, results only show two pdf plots instead of 4 as mentioned by user manual (see attached screen capture 1 and 2, missing quartiles.pdf and cdf.pdf). Same happened when run with default parameters for unconfined carbonate aquifer (missing quartiles.pdf and cdf.pdf). Confined Alluvium aquifer simulation with default parameters	A: Issues with the bat scripts and plots have been addressed.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
				is fine with all 4 results pdf files in output, however the run java panel seems complain missing some files (see attached screen capture 3).		
		269	N/A	**Missing Tools/Applications:** N/A to Aquifer Impact Model review	N/A	
		270	G,NR	**Overall Relevance:** I would	A: No correction necessary.	
		271	G,NR	**Limitations:** None	A: No correction necessary.	
		272	N/A	**How to Eliminate Limitations:**. N/A to Aquifer Impact Model review	N/A	
		273	G,NR	**Experience w/Risk Assessment:** Some experience	A: No correction necessary.	
		274	G,NR	**Experience w/CO_2 Storage:** Hydrology; scientist	A: No correction necessary.	
		275	N/A	**Additional Comments:**	N/A	
AIM	*IEAGHG Report (July 2016)*	276	G, RS	The Aquifer Impact Model AIM was found to be easy to run with a user friendly interface, the software navigation was generally considered intuitive. The tool was quick and simple to use, however, the user manual was difficult to navigate and generally needs to be updated .	A: I would appreciate more specifics on why the reviewer found the User's Guide difficult to navigate. I can't find any specifics in the report. Which version of AIM was reviewed? The User's Guide was updated in version 1.1.4.	**External**
AIM	*IEAGHG Report (July 2016)*	277	G, RS	The user manual was difficult to navigate and generally needs updating. (from Seyyed Hosseini from the Bureau of Economic Geology (BEG) – plus next two comments)	A: I would appreciate more specifics on why the reviewer found the User's Guide difficult to navigate. I can't find any specifics in the report on which version of AIM that was reviewed? The User's Guide was updated in version 1.1.4.	**External**
AIM	*IEAGHG Report (July 2016)*	278	G, RS	Some further outputs were suggested such as plume size and density as well as the range of parameters (e.g. 0 wanted for minimum but not allowed).	A: The parameter ranges correspond to the minimum and maximum values used to train the ROMs. The ROMs are not valid outside of the allowed ranges.	**External**
AIM	*IEAGHG Report (July 2016)*	279	G, RS	Some output issues were also noted as quartiles.pdf and cdf.pdf are not yet incorporated.	A: Those issues should have been fixed in version 1.1.4. We tested output from both ROMs on Mac and PC.	**External**
DREAM	Alex Rolland / Academia 01.18.2016	280	G, NR	**User Manuals:** The manual describes the installation and operation of the tool well. One note is the size of the extracted file is quite large and so bulky to move around computer etc.	A: The current size of the extracted DREAM folder is ~20 MB. The tool shouldn't be bulky to move around. The example simulation data is ~30 MB and might seem bulky to the user; unforutnately, there is not much to be done as we are handling ensembles of large numerical simulations. The files for the example are preconverted to HDF5 file format, which should help. This tool works best with at least 4 GB of RAM. If there are continuing issues with the file sizes we are willing to load the tool to a dvd for limited distribution.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		281	G, NR	**Software Navigation:** The manual describes the installation and operation of the tool well. One note is the size of the extracted file is quite large and so bulky to move around computer etc.	A: See above.	
		282	G, NR	**Input Data:** Have no personal access to the correct data so difficult to properly test this tool. Including a sample dataset might be useful, especially for beta testers.	A: From the above comments, it seems like the user had the example simulation data. Examples files are on EDX under DREAM V.1 - PC Beta Test.	
		283	G, NR	**Output Data/Reports:** N/A - Couldn't run without data.	A: See above.	
		284	N/A	**Missing Tools/Applications:**	N/A	
		285	N/A	**Overall Relevance:**	N/A	
		286	N/A	**Limitations:**	N/A	
		287	G, NR	**How to Eliminate Limitations:** Reducing the size of the tool might be beneficial if possible. Also providing a sample dataset would help out beta testers with lack of access to data.	A: See above.	
		288	G, NR	**Experience w/Risk Assessment:** Novice	A: No correction necessary.	
		289	G, NR	**Experience w/CO_2 Storage:** Geology	A: No correction necessary.	
		290	N/A	**Additional Comments:**	N/A	
DREAM	Diana Bacon / Government 2.02.2016	291	G, RS	**User Manuals:** In section 3.1.1, it is not clear how to get from the "Dream Welcome Window" shown in Figure 1 to the "Input Directory Selection" shown in Figure 2. Do I click on "Next" or "Launch Visualization"? The only reference in section 3.1.1 is a forward reference to the "Launch Converter" button. The "Launch Visualization" button is not described in section 3.1.1, nor is the "Next" button. This is all made clear in the example application, but could be clearer up front.	A: We have disabled the unnecessary buttons until the time of appropriate use.	**Internal**
		292	G, RS	**Software Navigation:** It was easy to follow the example application. Ran into one bug. On the final DREAM window, if I did not select an output directory and just used the default, it was not able to write a file.	A: The output direction now automatically chooses to use the DREAM tool source folder.	
		293	G	**Input Data:** Just followed example in manual for beta testing.	A: No correction necessary.	
		294	G, RS	**Output Data/Reports:** In following the example problem, I couldn't find the BetaTest_Results_6_1_1000_bak file I'm supposed to compare to. I am not able to reproduce figure 16, I get an error message that "Series formula is too long" in Excel if I choose more than 5 output columns.	A: The results file was added to EDX. Users may need to add data to the figure in separate selections to work around the limits in Excel.	
		295	N/A	**Missing Tools/Applications:** N/A	N/A	
		296	G, RS	**Overall Relevance:** I think a discussion of whether/how this tool provides a "better" monitoring network than a uniform or random distribution of wells would be a helpful addition to the user's guide.	A: This discussion is had in Yonkofski et al. (2016), which is now referenced in the manual and on the tool Welcome screen.	
		297	N/A	**Limitations:** N/A	N/A	
		298	N/A	**How to Eliminate Limitations**: N/A.	N/A	
		299	G, NR	**Experience w/Risk Assessment:** Expert	A: No correction necessary.	
		300	G, NR	**Experience w/CO_2 Storage:** Geology/hydrology/chemistry scientist	A: No correction necessary.	
		301	G, NR	**Additional Comments:** I'm an internal tester.	A: No correction necessary.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
DREAM	Cheryl Yang / Government 02.05.2016	302	G, RS	**User Manuals:** It is well written in general. Just couldn't find the file "BetaTest_Results.zip" mentioned. (but it is not used anyway if testing the example only).	A: The results were added to EDX.	Internal
		303	G, RS	**Software Navigation:** Suggest to add "Cancel" or "Return" bottom for unfamiliar users. (Talk to PNNL already)	A: 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. There are "Back" buttons on every appropriate page, that can be used while the algorithm is not running.	
		304	G, NR	**Input Data:** Yes, it is preprogrammed as defaults.	A: No correction necessary.	
		305	G, NR	**Output Data/Reports:** The output looks good.	A: No correction necessary.	
		306	N/A	**Missing Tools/Applications:** NA	N/A	
		307	G, NR	**Overall Relevance:** NRAP-IAM-CS, which fits my work needs. (I am also interested in AIM and WALT, but haven't tested them personally).	A: No correction necessary.	
		308	G, NR	**Limitations:** Applicability and usefulness.	A: No correction necessary.	
		309	N/A	**How to Eliminate Limitations**: NA	N/A	
		310	G, NR	**Experience w/Risk Assessment:** 2 year experience in human health risk assessment + 5 year experience in CCS related risk identification and assessment	A: No correction necessary.	
		311	G, NR	**Experience w/CO_2 Storage:** Hydrology/Monitoring/Risk Assessment; scientist/engineer	A: No correction necessary.	
		312	G, NR	**Additional Comments:** No. This questionnaire is very good.	A: No correction necessary.	

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
DREAM	Yunwei Sun / Government 02.17.2016	313	G, RS	**User Manuals:** DREAM is developed for post-processing of simulated results and optimizing monitoring strategies. I consider this tool as the centerpiece from NRAP monitoring team. However, the user's manual is lack of technical details about why and how this tool is developed. Data processing is not the ultimate goal of this work. Optimization of monitoring strategies should be emphasized in the introduction section. Ordinary users may not be familiar with the simulated annealing method used in the tool for searching optimal monitoring strategies, but it is helpful to present the optimization models. For example, what are decision variables (e.g., number of wells, well locations), state variables (e.g., pH and TDS), objective function (e.g., maximized detectability or minimized budget), and constraints (e.g., budget, detection thresholds)? It is always beneficial to add a standard benchmark problem (such as high dimensional Rosenbrock function, in section 4) for testing the simulated annealing method.	A: The DREAM manual is intentionally more application focused than theory focused. Since the manual was first completed, a technical paper was published in the IJGGC special issue (Yonkofski et al., 2016). This paper is cited to explain more technical details of development. Revisions to the introduction have been made to place more emphasis on the optimization procedure. In the current state, DREAM is not readily applicable to a continuous function as it was built to optimize over discrete output data. The reviewer may find the resolution to this comment in our paper cited above (Yonkofski et al., 2016), which demonstrated the simulated annealing algorithm vs. a full enumeration of the solution space as a benchmark. To demonstrate how DREAM could be used on data representing the Rosenbrock function, we discritized the Rosenbrock function in time and space, creating a timeseries of 2D plots, where the time, *t*, is represented by a Rosenbrock function: *t(x,y)= (1-x^2)^2+100(y-x)^2*. For the grid read into DREAM, the 2D plots are sorted by discrete times between 1 and 100. If the Rosenbrock function existed at (x,y) in a time plot, then (x,y)=1; otherwise it was 0. This would be analogous to a leakage location wherever the Rosenbrock function is 1. Dream minimizes based on time to first detection, so the algorithm searches for the minimum time that one of the (x,y) coordinates is 1. The results of 5 iterative procedures testing 5,000 configurations each are shown below and a yellow star is on the minimum location found in the Rosenbroch Function figure above.   All 25,000 iterations took 10 minutes to complete with a standard workstation. This demonstrates the iterative efficiency and accuracy with which DREAM found the solution time.	**Internal**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		314	G, RS	**Software Navigation:** It is easy to follow steps described in the manual. However, it is not straightforward to understand why we do those steps. An overall flowchart may be useful in introduction section. It is beneficial to make text boxes clickable and link to message windows to specific sections in the manual.	A: A flow chart has been added as Figure 1 in the manual and clickable information buttons are now available on windows.	
		315	G,RS	**Input Data:** Detailed information is needed for preparing input data. For example, if we take pH as a risk measure (state variable), we need to know how to write high dimensional data files (x, y, z, and time). The pre-prepared hdf5 data work fine. We expect the detail requirement about data format.	A: The easiest way to do this is to format simulation output into one of the acceptable HDF5 conversion formats: NUFT, STOMP, TECPLOT. This is discussed in Section 3.2. The TECPLOT option is new and 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.	
		316	G, NR	**Output Data/Reports:** The output data from the package depend on the user-defined optimization models. For example, if we optimize monitoring-well locations, we may interactively locate wells on the study domain during the optimization process.	A: No correction necessary.	
		317	G, NR	**Missing Tools/Applications:** To apply DREAM for a site-specific system, such as Kimberlina site, a high-quality database is needed for state variables that are simulated using various numerical codes and used in optimization. Of course, the task is for the entire monitoring group. In the moment, we can use what have (TDS and/or pH as functions of spatial coordinates and time) to demonstrate the tool.	A: No correction necessary.	
		318	G, NR	**Overall Relevance:** Definitely, I will use this tool to optimize monitoring strategies. However, within NRAP monitoring team, we need to specifically define what state variables can be monitored and what decision variables need to be optimized. The current DREAM package provides a framework for implementing user-defined optimization models and getting optimal solutions, but the outcome of using the tool depends how users describe (formulate) their problems.	A: No correction necessary.	
		319	G, RS	**Limitations:** The tool is limited to simulated annealing method. I do not see how the temperature function (annealing parameter) is used for calculating the probability of accepting a trail point from the current point. Can user control the randomness for balancing the local and global optima?	A: The temperature function is discussed in Yonkofski et al. (2016). The user cannot control the randomness for balancing the local and global optima.	
		320	G, NR	**How to Eliminate Limitations:** It is beneficial to add technical details in the manual.	A: No correction necessary.	
		321	G, NR	**Experience w/Risk Assessment:** I am familiar with reactive transport, risk assessment, and system optimization.	A: No correction necessary.	
		322	G, NR	**Experience w/CO_2 Storage:** Geology, hydrology, and computer science.	A: No correction necessary.	
		323	N/A	**Additional Comments:** NA	N/A	
DREAM	*IEAGHG Report (July 2016)*	324	G, NR	A project is currently in development with PNNL and Battelle to use DREAM to evaluate CO_2 storage legacy sites in Ohio and Michigan based on the Midwestern Wellbore Integrity Database which contains records of ~500,000 wells. Data from Systematic Assessment of Wellbore Integrity for Geologic Carbon Storage Projects Using Regulatory and Industry Information (FE0009867) was used as a basis for DREAM and compliments work on determining costs and the level of effort to plug and repair legacy oil and gas wells. The combination of the well integrity database, and the DREAM tool, will bolster the use of both as decision making tools.	A: This will be included in NRAP Phase II work.	**External**
DREAM	*IEAGHG Report (July 2016)*	325	G, NR	A general assessment created from a combination of database interrogation and the DREAM tool has already been compared with a sample of 5-6 areas in Michigan with storage potential. The comparison exercise is being used to estimate remediation measures and associated costs such as well plugging.	A: No correction necessary.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
RROM-Gen	Lewei Zhang and Argha Namhata / Government 11.06.205 - 01.11.2016	326	N/A	**User Manuals:**	N/A	Internal
		327	N/A	**Software Navigation:**	N/A	
		328	N/A	**Input Data:**	N/A	
		329	N/A	**Output Data/Reports:**	N/A	
		330	N/A	**Missing Tools/Applications:**	N/A	
		331	N/A	**Overall Relevance:**	N/A	
		332	N/A	**Limitations:**.	N/A	
		333	N/A	**How to Eliminate Limitations**:	N/A	
		334	N/A	**Experience w/Risk Assessment:**	N/A	
		335	N/A	**Experience w/CO_2 Storage:**	N/A	
		336	G, RS	**Additional Comments:** Simulations were run by Lewei and Argha comparing RROM-Gen to TOUGH2 output. This information was provided to the developer. Partial threaded message: To help you better visualize our TOUGH2 scenario, we have prepared a Word document demonstrating how our TOUGH2 scenario looks like. Our scenario has eight layers (from Layer 1 at bottom to Layer 8 at top). For each layer, there are 54 lines. It is important to note that cell numbers are marked in ELEM. column, not INDEX column. Some ELEM. numbers are missing in the output file because those cells are boundary cells and are set as fixed pressure and fixed CO2 saturation cells.	A: Worked with user to clarify issues and update the Tool User's Manual.	
RROM-Gen	Abdullah Cihan / Government 02.16.2016	337	G, RS	**User Manuals:** Introduction states "The tool defines a new grid based on user input options, then uses piecewise bi-linear interpolation to convert the reservoir data from the original grid to the new grid, and the results are written out in the file format specified by the NRAP-IAM-CS" IAM file format conversion is mentioned here, but it is never shown or described in the rest of the document how this is done and where the generated files are located. Is '100x100' grid size the maximum limit for IAM tool only or both IAM and the visualization part of this tool? This can be made more explicit. The tool creates an areal view of the variables for specific times, but times do not show up in the generated plots. It would be really nice to print plotted times on the graphs. Also, one can often have 3D model results in one output file from the reservoir simulator, and the manual doesn't seem to describe how to specify or discriminate which grid number or location in the third dimension would be used. There appears to be an elevation file that needs to be provided to the tool. But, there is no discussion or description of how this file would be generated out of a reservoir simulator output file. I believe one of the key sections that a manual must include would be examples. There are some pictures copied from the gui, but a separate section as a tutorial for entering and visualizing the data in the manual would be very helpful. The number of the examples in such a section must be as many as the number of different ways one can enter/visualize the data using the tool.	A: Sample input files are available for all data types. The outputs visualized will be similar for all. The sample files will be included with the distribution on EDX.	Internal

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
		338	G, RS	**Software Navigation:** The interface for RROM-gen tool seems very easy to use, but I couldn't locate any tutorial or example input files. Providing some of those example files for users who don't have the reservoir simulators (listed in the manual) would be great for them to test the tool.	A: Sample files now included with distribution on EDX.	
		339	G, RS	**Input Data:** As mentioned above, I couldn't locate the example input data files if provided any. However, since I am using one of the listed reservoir simulators, I was able to upload an input file and test how the plots look like. The example input files should be provided for the users or reviewers to test, and the provided example files must be described in the manual.	A: Sample files now included with distribution on EDX.	
		340	G, RS	**Output Data/Reports:** Please see (Input Data responsee) for my specific comment on the example input files. I was able to upload an input file and test how the plots look like. The generated results (contour plots of pressure changes and saturation) look good, but as I mentioned in (1), the tool creates an areal view of the variables for specific times, but times do not show up in the generated plots. It would be really nice to print plotted times on the graphs. There appears to be an elevation file that needs to be provided to the tool. But, there is no discussion or description of how this file would be generated out of a reservoir simulator output file.	R: Time is now included in the plot file name within the Tool User's Manual.	
		341	G, NR	**Missing Tools/Applications:** I think the existing tools are very useful for initial planning related to storage site development and design. However, they must be carefully tested with perhaps more accurate but computationally demanding tools, and the applicability of the tools must be demonstrated for actual CO_2 storage operations.	A: No correction necessary.	
		342	G, NR	**Overall Relevance:** I would probably use or recommend if the toolset would be tested comprehensively and demonstrated to be accurate enough to use in real applications	A: No correction necessary.	
		343	G, NR	**Limitations:** Confidence in its fidelity	A: No correction necessary.	
		344	N/A	**How to Eliminate Limitations**:	N/A	
		345	G, NR	**Experience w/Risk Assessment:** Some experience	A: No correction necessary.	
		346	G, NR	**Experience w/CO_2 Storage:** Hydrogeology; scientist	A: No correction necessary.	
		347	N/A	**Additional Comments:**	N/A	
RROM-Gen	*IEAGHG Report (July 2016)*	348	G, RS	Include detailed instructions for the NRAP-IAM-CS tool, previously known as CO2-PENS, and include the development of efficient techniques to create project-specific input tables for complex cases.	A: It is assumed that once a look-up table is created with RROM-Gen, the IAM users manual is the best place to describe how to import and use them inside of the IAM. The tools IAM-CS, REV and RROM-Gen will be cross-referenced in the next version of the Tool User's Manuals.	**External**
RROM-Gen	*IEAGHG Report (July 2016)*	349	G, RS	For the RROM-Gen tool include a data assimilation function for vertical direction.	A: Should be addressed in Phase II. If this comment means that the user would like analysis on plume thickness in addition to the plume extent, this is an issue for REV not RROM-Gen. The comment requires more clarification to respond properly.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
RROM-Gen	*IEAGHG Report (July 2016)*	350	G, RS	The team did not make much progress with running a SW Hub example because they ran into problems with translating their simulation outputs using the RROM-Gen tool. This tool creates the input format for all successive modules. CSIRO has provided the NRAP developers with an Eclipse output example and an update of RROM-Gen is expected inwith functionality to import Eclipse simulation results was released from NRAP to beta testers in July 2016.	A: Eclipse data input functionality added to RROM-Gen and bugs fixed with TOUGH2 data input. Worked with user to address issues and will reflect changes in the next version of the REV and RROM-Gen Tool User's Manual.	**External**
RROM-Gen	*IEAGHG Report (July 2016)*	351	G, RS	The input data format could be elaborated with more detail. This beta tester team would like the tool to have a data assimilation function for vertical direction.	A: Additional input data types have been added to the tool. Descriptions of input data types are included in the REV Tool User's Manual.	**External**
MSLR	*IEAGHG Report (July 2016)*	352	G,NR	The MSLR tool could have more ease of use for GUIs.	A: This comment is too general to address with a specific response.	**External**
General	*IEAGHG Report (July 2016)*	353	G, NR	A workshop, to be held in an upcoming project review meeting of the U.S. DOE's NETL will serve as a venue for interested beta-testers.	A: No action required. Workshop held on August 15, 2016.	**External**
General	*IEAGHG Report (July 2016)*	354	G, NR	The ability to rapidly review the results created by the viewer was a positive feature.	A: No correction necessary.	**External**
General	*IEAGHG Report (July 2016)*	355	G, RS	A view was expressed that model outputs can present a general representation of reality but there is a risk of generating specific outputs that could be used by third parties for different purposes but without critical judgement.	A: There is no means by which to prevent the user (and, in particular, the user with insufficient technical knowledge of the range of possible geologic storage system behavior) from generating inappropriate and non-credible results. The tools do include a disclaimer statement that indirectly addresses this concern.	**External**
General	*IEAGHG Report (July 2016)*	356	G, RS	Models should be restricted to a predefined range of parameters to prevent reduce the possibility of their misuse.	A: The set of NRAP tools have been revisited to address this issue. In most cases, this issue has been resolved by constraining the possible user parameter input to ranges for which the tools will generate credible results. In limited cases where such constraints have not been made through engineered control, an appropriate note/disclaimer is included to alert the user to related potential pitfalls.	**External**
General	*IEAGHG Report (July 2016)*	357	G, NR	Hypothetical values produced by different tools are for demonstration purposes only. These values might be useful to insurance companies or for a carbon tax credit point of view.	A: No correction necessary.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
General	*IEAGHG Report (July 2016)*	358	G, RS	The rationale for values used in models needs to be clearly stated in the operator manuals.	A: Model user manuals include brief description of parameters in each model, and often some rationale for the parameter ranges specified; such rationales are often provided in significantly greater detail in the referenced supporting peer-reviewed publications and technical reports.	**External**
General	*IEAGHG Report (July 2016)*	359	G, RS	The feedback from these beta testers recommends more detail in the manuals.	A: Manuals are intended to provide the user with practical information on download/installation and navigation of the tools user interface to exercise the model and generate results. The tool user manuals typically include only a general overview of model design and underpinning research, but references to publications including those details are referenced.	**External**
General	*IEAGHG Report (July 2016)*	360	G, RS	A broader commentary from network meeting delegates with experience of modeling tools included experience from the EU MiReCOL project. The project team is generating multiple outputs and statistically evaluating them. A view was expressed that model outputs can present a general representation of reality but there is a risk of generating specific outputs that could be used by third parties for different purposes but without critical judgement.	A: Again, this is a very good comment (though not specific to the tools themselves).	**External**
General	*IEAGHG Report (July 2016)*	361	G, NR	There is a danger of misusing model outputs and confining interpretations based on limited inputs or one-off scenarios.	A: Already addressed in other comments.	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
General	*IEAGHG Report (July 2016)*	362	G, RS	Another delegate commented that these tools are designed to use arbitrary threshold numbers to aid modelling scenarios. These values may be very low (~1 t/year) which might be useful for comparison with much larger scale emissions. It should also be noted that a small leak over a timescale of 100+ years could be a large amount of CO_2. It is important to ensure that geological storage is secure over the long term.	A: We have done some work in the past to put the scale of predicted emissions in context, but since this is identified as an important piece of information, we should revisit and do a better job of communicating this message.	**External**
General	*IEAGHG Report (July 2016)*	363	G, RS	The use of statistically based tools and the outputs they generate needs to take account of a regulator's attitude to risk. This may depend on the well density which might be quite low especially for deep saline formations. It is possible that a regulator may ask a storage developer to identify where leakage risk (specifically well location and depth) is most likely to occur (ie. the weakest points) and then the probability of failure that such an event will occur and its consequences. In the US the EPA requires an AoR as part of any risk assessment. There will be a degree of variability within an AoR which the REV2 tool is designed to address. The tool is also designed to simulate specific weak points within the AoR. Uncertainty within an AoR, for example a wellbore of unknown status, can be explored by applying a Monte Carlo computational method.	A: From RD - This is a good comment. We should include this in the log and see how best to address. I think that part of that answer will be that through Task 5 in Phase II we will incorporate more practical considerations. We hope that our tools can be responsive to regulator needs, but it is not in our purview to explicitly meet that requirement.	**External**
General	*IEAGHG Report (July 2016)*	364	G, NR	The desire for a tool for broader leakage risk would be useful to address general concerns across a CCS chain. However, the goal of NRAP tool developers is not to develop tools that can be used everywhere but to concentrate on demonstration methodologies that can be applied to site-specific situations.	A: No correction necessary.	**External**
General	*IEAGHG Report (July 2016)*	365	G, NR	NRAP could make model outputs more user friendly.	R: The comment is not sufficiently specific for us to respond in a meaningful way.	**External**
General ?	*IEAGHG Report (July 2016)*	366	G, RS	Leakage thresholds are very low from some models and there are no regulatory thresholds for atmospheric leakage.	A: The AIM tool allows for two threshold values for each volume calculation: on based on the maximum contaminant level for each constituent of concern, and one based on a no-impact threshold (background 95th percentile) described by Last et al. (2016). In the case of atmospheric leakage, the user of the MSLR tools is allowed to define thresholds of interest based on detectability or potential impact concentrations of interest	**External**
General	*IEAGHG Report (July 2016)*	367	G, NR	The feedback received has been largely positive, however, in most cases, there has been only limited use of data to trial these tools which would enable them to be compared with real field data.	A: From RD - This will be a focus going forward (Phase II, Task 5)	**External**

NRAP Tool	Author/ eMail/ Category	Number	Type/ Assess	Comments	Correction or Justification for the Rejection	Internal/ External
General	*IEAGHG Report (July 2016)*	368	G, RS	Some beta testers have reported that the webinar videos were very helpful and the initial tests could not have been run with just the respective manuals. The introductory webinars were also useful to introduce the NRAP toolkit to interested users.	A: Webinar videos for the NRAP tools are available on the NRAP website – located with the directory from which the NRAP Phase I tools can be downloaded.	**External**
General	*IEAGHG Report (July 2016)*	369	G, NR	One beta tester commented that the toolkit will be very useful for the CO_2 storage technical community. Other models do not offer the level of integration of subsurface processes provided in this toolkit.	A: No action required.	**External**

NRAP is an initiative within DOE's Office of Fossil Energy and is led by the National Energy Technology Laboratory (NETL). It is a multi-national-lab effort that leverages broad technical capabilities across the DOE complex to develop an integrated science base that can be applied to risk assessment for long-term storage of carbon dioxide (CO_2). NRAP involves five DOE national laboratories: NETL, Lawrence Berkeley National Laboratory (LBNL), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Pacific Northwest National Laboratory (PNNL).

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