NRAP Task 5: Developing Workflows and Computational Tools to Estimate the Project Costs of Managing Subsurface Risks

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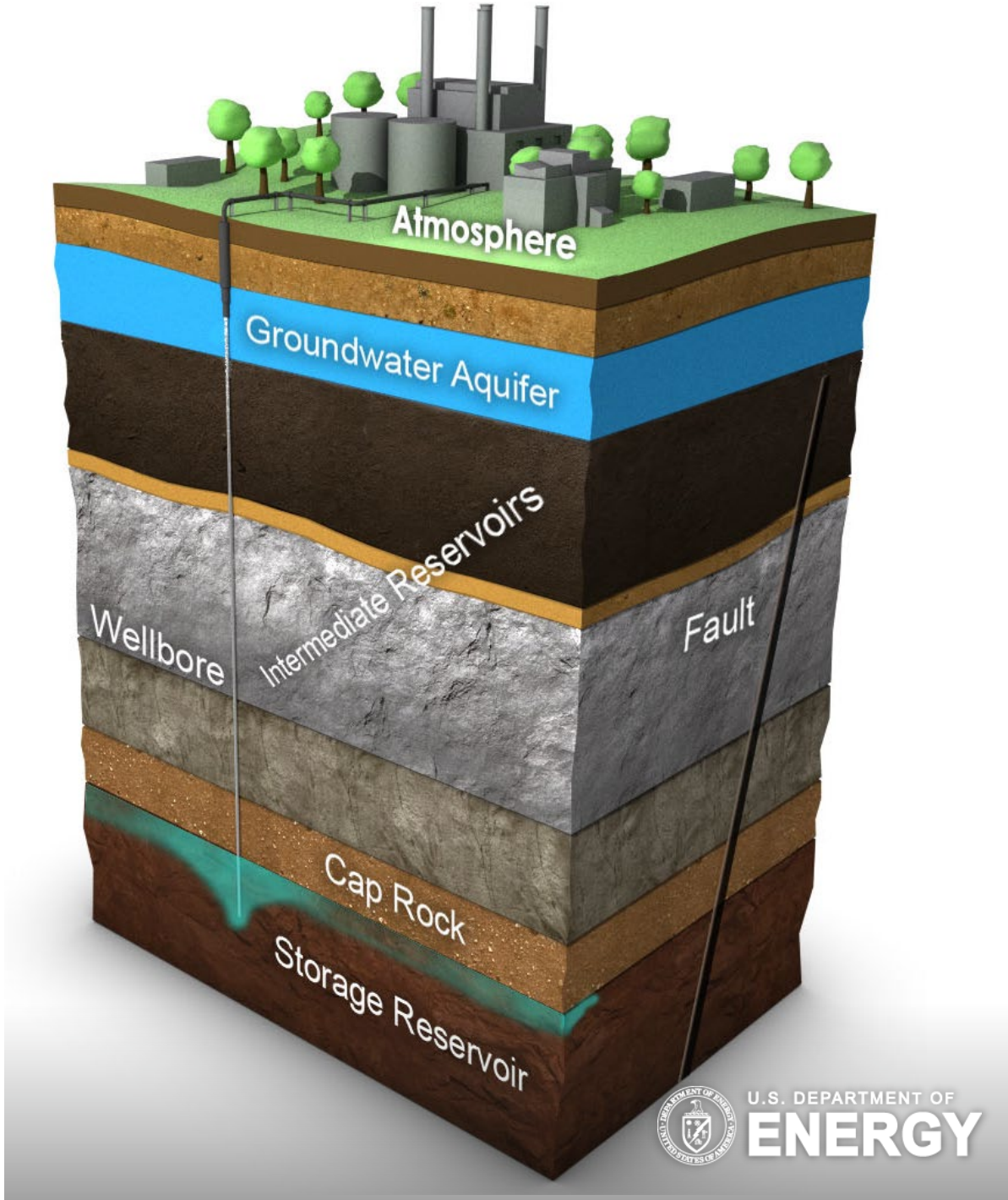
NRAP
National Risk Assessment Partnership



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Overview of NRAP Task 5

- **Objectives**
  - Develop workflows and tools associated with responding to adverse events at a CO_2 saline storage project focusing on
    - Fluid leakage from the storage formation into an underground source of drinking water (USDW)
    - Induced seismic incidents that exceed some threshold criteria
  - Develop plausible remedial responses to such adverse events
  - Develop tools to estimate the performance and costs (i.e., liability) of implementing these remedial responses
    - Costs for implementing aspects of remedial responses can be used to estimate the cost of implementing an Emergency and Remedial Response (ERR) Plan
    - These costs can also be used to estimate the cost of financial instruments to comply with the financial responsibility requirements of the Class VI regulations regarding ERR Plans (e.g., insurance)
  - Perform case studies demonstrating the applicability of these workflows and tools and how they utilize other NRAP tools
- **Justification**
  - The tools described above will be open source which will fill a gap since there are no comparable open-source tools
  - These tools will work with other NRAP tools providing features (performance of remedial responses and costs) that other NRAP tools do not provide
- **Project history and funding**
  - Task 5 work began with NRAP Phase 3
  - Performance dates are April 1, 2022 to December 2026
  - Funding is approved on an annual basis

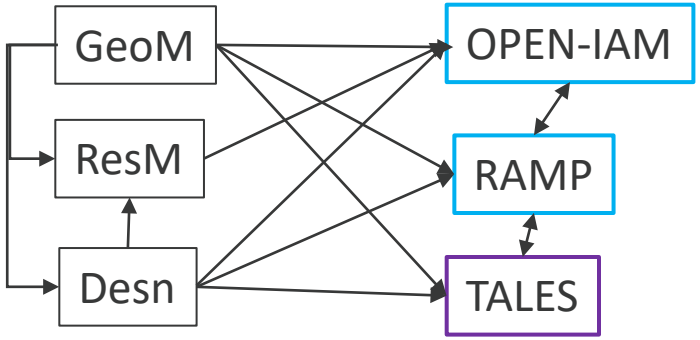
Task 5 Analysis Framework

- **Liability is the cost of responding to potential adverse events.**
- **Of the set of potential adverse events, this task focuses on:**
  - *Potential leakage of CO_2 and/or brine* from storage formation into or toward USDW or into the atmosphere
  - *Potential induced seismic incidents*
- **Remedial responses to adverse events and costs**
  - ***Operational response*:** Altering "baseline or normal" operations (e.g., halting CO_2 injection)
    - Operational response costs may be small; revenues from CO_2 injection can be drastically reduced
  - ***Extrinsic response***: Actions taken outside "normal" operations (e.g., intensive localized monitoring to detect leak, re-plugging a leaking legacy well)
    - Extrinsic response costs are not part of normal operations
  - ***Penalty response*:** Regulatory or contractual costs associated with not injecting CO_2.
    - Penalty response costs are new costs and may be significant
- **Operational and extrinsic responses are basis for Emergency and Remedial Response (ERR) Plans**
  - The cost of implementing the ERR Plan are the costs of implementing extrinsic responses and the costs of implementing some aspects of operational responses
  - The cost of implementing the ERR Plan is needed to determine costs for financial instruments for addressing financial responsibility (e.g., cost of insurance)

Tools to Implement Analysis Framework

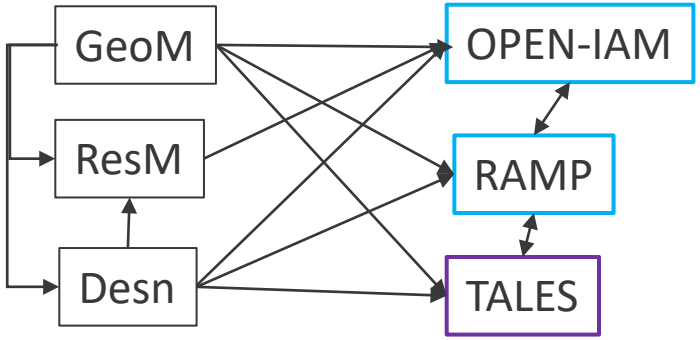
- **Task 5 tools:**
  - NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) model
  - CLEAR tool
  - Remed-Res tool
- **Other NRAP/SMART tools**
  - NRAP OPEN-IAM: predicts leakage of fluid out of the storage formation toward or into a USDW
  - NRAP ORION: predicts induced seismic incidents
  - NRAP RAMP: implements and evaluates monitoring programs for detecting leaks
  - SMART USM
  - SMART Risk Module
- **Other relevant information**
  - Geologic model (GeoM)
  - Reservoir simulation results and geo-mechanical model results (ResM)
  - Design and operation of storage project (Desn)

Evaluation of Fluid Leakage Risks



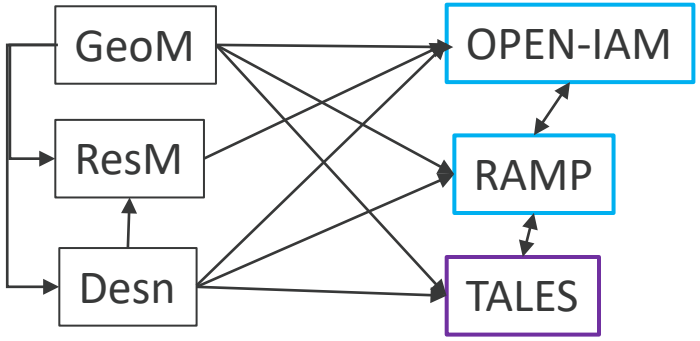
- **Initial setup**
  - Geologic model, reservoir and geo-mechanical modeling results, and project design and operations information are provided to OPEN-IAM, RAMP and TALES
  - OPEN-IAM uses this data to generate different fluid leakage scenarios
  - RAMP evaluates potential monitoring programs by interacting with OPEN-IAM, obtains costs for each program from TALES (not yet done) and provides TALES with one or more preferred monitoring programs that can detect some level of leakage

Evaluation of Fluid Leakage Risks



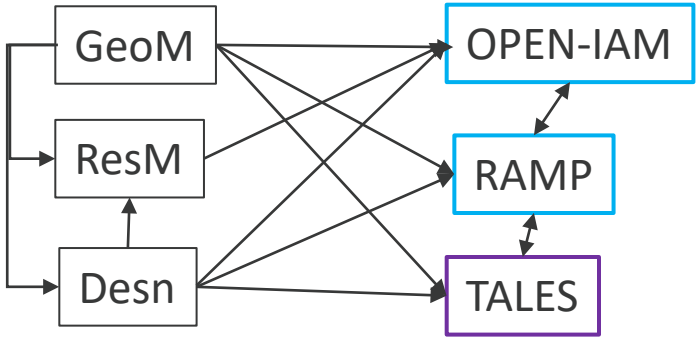
- **Baseline or reference scenario**
  - Leakage scenarios developed by OPEN-IAM are probabilistic and most are unlikely to occur
  - In the baseline or reference scenario, no leakage is assumed to occur during the storage project
  - TALES is used to calculate the revenues, costs and financial performance for the storage project assuming there is no leakage
  - These are baseline or reference results for the storage project
    - Key financial metrics for this scenario, such the NPV for the project or break-even CO_2 cost, are used to compare to the same financial metrics for leakage scenarios

Evaluation of Fluid Leakage Risks



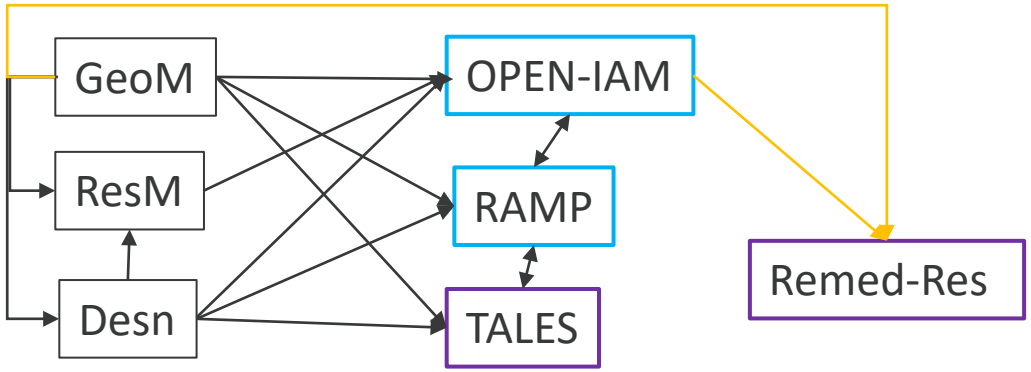
- **Leakage scenarios**
  - There can literally be an infinite number of leakage scenarios
  - A finite number of "realistic" scenarios are developed based on results from OPEN-IAM and RAMP
  - TALES along with the Remed-Res and CLEAR tools are used to evaluate these leakage scenarios

Evaluation of Fluid Leakage Risks



- **Example leakage scenario 1**
  - A leak occurs along an improperly plugged legacy well
  - After additional investigation, a leak is confirmed and injection is stopped
  - An intensive monitoring program is implemented to find the source of the leak which is an improperly plugged legacy well
  - The legacy well is plugged
  - Follow up monitoring confirms that the leak has stopped and CO_2 injection resumes
  - TALES is used to calculate the revenues, costs, financial performance and key financial metrics for this scenario
    - A critical result of this analysis is the cost of extrinsic responses and possibly operational responses that can be used to estimate the costs of implementing the ERR Plan
    - Key financial metrics for this scenario, such as the breakeven CO_2 cost, are compared to the same financial metrics for the baseline scenario to assess the influence of leakage on the financial viability of the project

Evaluation of Fluid Leakage Risks



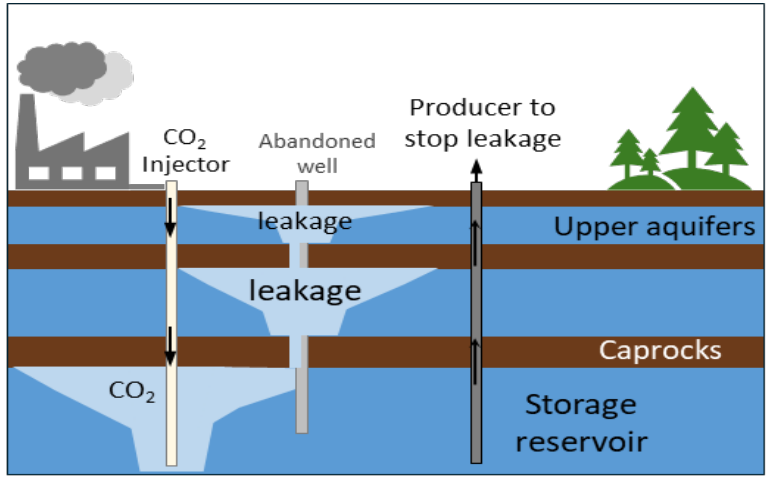
- **Example leakage scenario 2**
  - This is the same as leakage scenario 1 except the legacy well can either not be found or cannot be successfully plugged
  - To stop the leak, a producing well is drilled into the storage formation as close to the leak as possible and brine is produced and disposed
  - The Remed-Res tool is used to assess the mass rate of brine production needed to stop the leak
    - The mass rate of brine production is provided to TALES
  - Follow up monitoring confirms that the leak has stopped and CO_2 injection resumes
  - TALES is used to calculate the revenues, costs, financial performance and key financial metrics for this scenario
    - A critical result of this analysis is the cost of extrinsic responses and possibly operational responses that can be used to estimate the costs of implementing the ERR Plan
    - Key financial metrics for this scenario, such as the breakeven CO_2 cost, are compared to the same financial metrics for the baseline scenario to assess the influence of leakage on the financial viability of the project

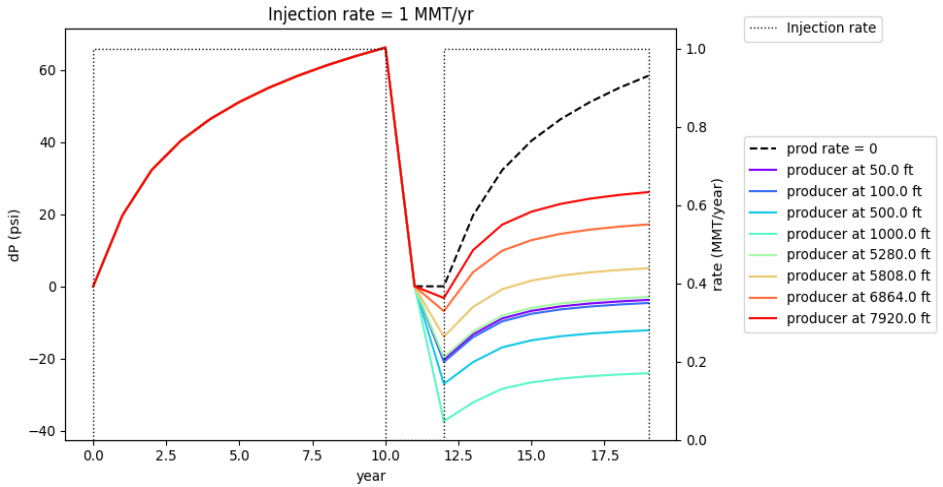
Remed-Res Tool

Remediation of CO_2 leakage from storage formation

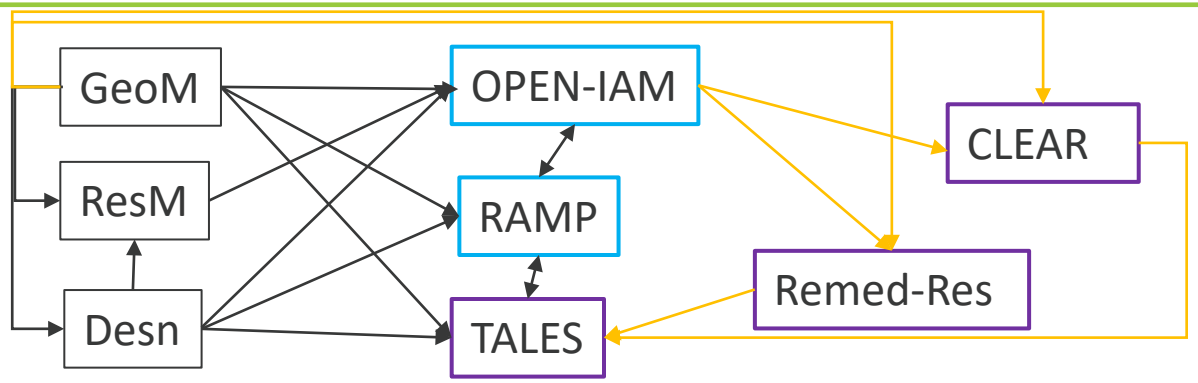
- **Remed-Res simulates production of brine from well and the resulting pressure response over distance and time**
  - Utilizes the Theis equation
  - Predicts the pressure response over distance and time from production well
  - Overall pressure field is superposition of Remed-Res pressure field and pressure field generated injection wells (from reservoir simulation model)
  - Future enhancements may include numerical modeling
- **Example results:**
  - Production well produces brine at a rate of 1 Mtonnes/yr of brine
  - Graph shows pressure response at the location of the leak as a function of the distance between the production well and the leak
  - The closer the production well is to the location of the leak the greater the reduction in the pressure at the leak
  - When pressure at the leak is below a critical pressure, the leak stops

Remediation Scenario





Evaluation of Fluid Leakage Risks



- **Supplement to two previous leakage scenarios**
  - Whenever there is a leak into a USDW (the leakage formation), the material (brine, CO_2) leaked into the leakage formation must be evaluated
  - A USDW is any aquifer with salinity less than 10,000 ppm. The vast majority of drinking water aquifers have salinity below 1000 ppm and at some level nearer 1000 ppm than 10,000 ppm the aquifer cannot be used
  - Thus, leakage into many USDWs will not require active remediation since the water is not usable
  - If the USDW is suitable for use, remediation can be implemented
  - The CLEAR tool can be used to evaluate leakage into a USDW
    - Monitored natural attenuation
    - Pump and treat

CLEAR Tool

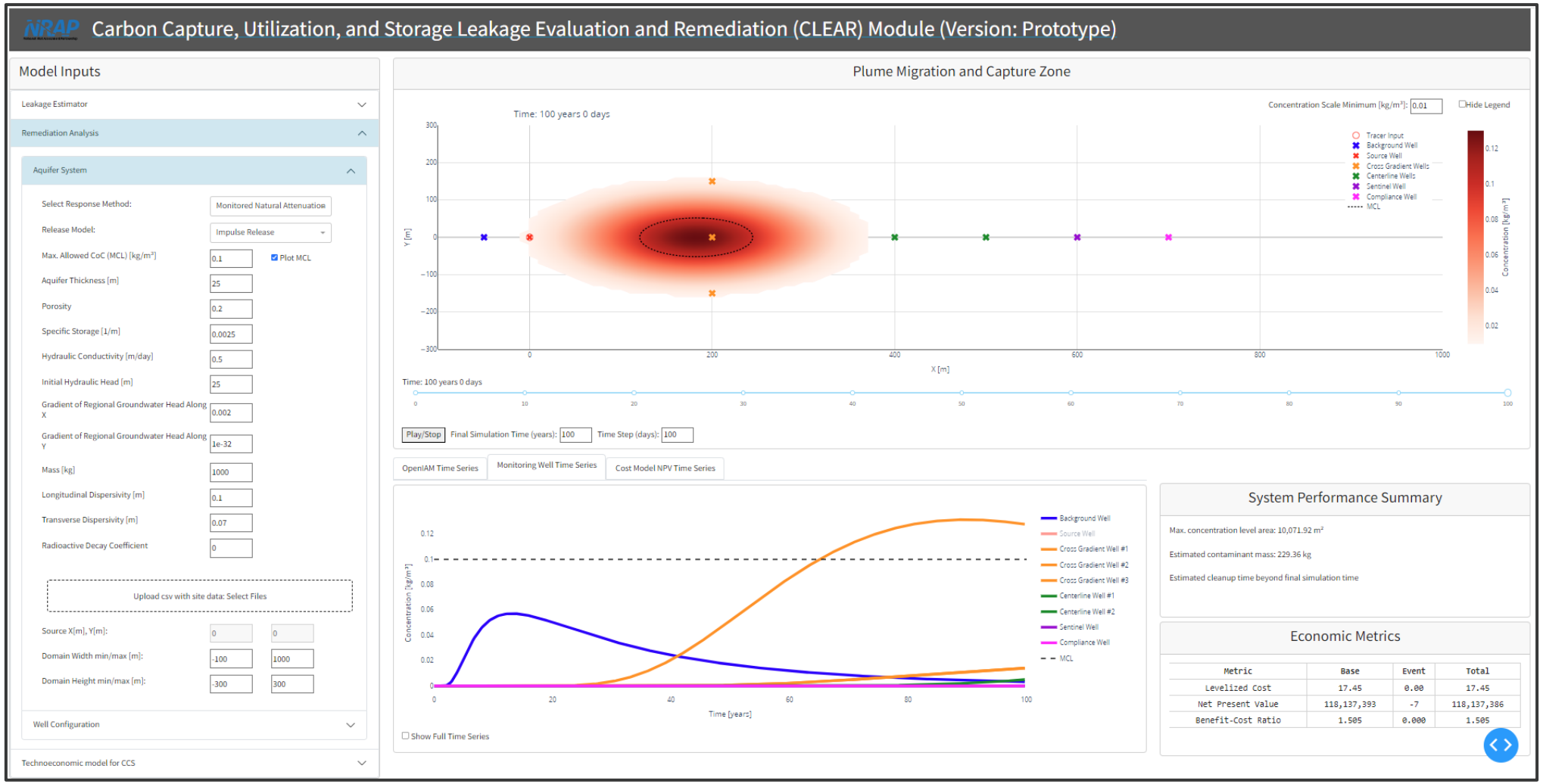
CCUS Leakage Evaluation and Remediation (CLEAR) Tool

- **Features:**
  - Uses estimates of mass of leaked material into USDW from OPEN-IAM to generate contaminant plume over time
  - Can place monitoring wells for characterizing leakage, tracking plume and providing basis for monitored natural attenuation
  - Can also place production wells completed in the leakage formation and predict contaminant plume dynamics to demonstrate proposed remediation should work
  - Provides information on monitoring wells, production wells and the mass rate of brine/water produced from the production well to TALES:
    - TALES calculates the cost of this remedial response and its impact on the financial performance of the storage project

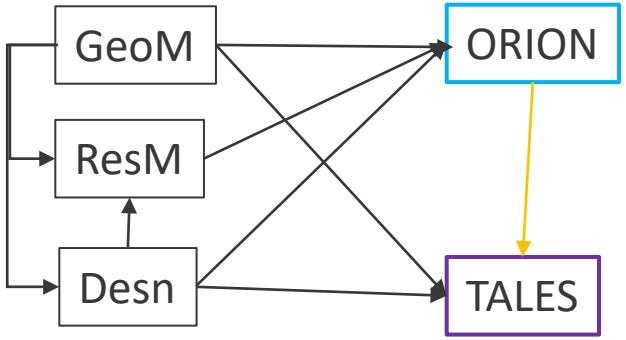
- **CLEAR can work as part of the collection of NRAP tools or as a self-contained application**
  - Can generate input needed for OPEN-IAM and run OPEN-IAM to generate mass rates of leakage for the CLEAR suite of tools
  - Can work with TALES or other engineering economic models to estimate costs of remedial responses to a leak into a USDW

CLEAR

CCUS Leakage Evaluation and Remediation (CLEAR) Tool (prototype version)

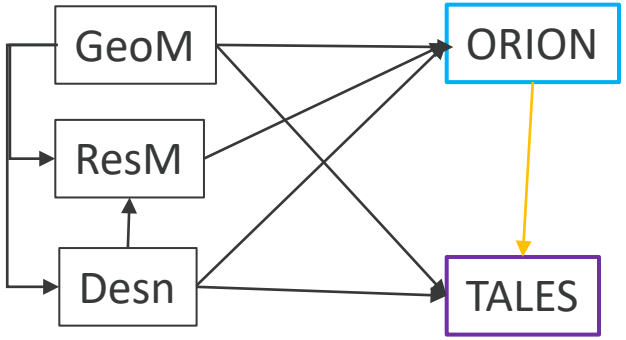


Evaluation of Induced Seismicity Risks



- **Initial setup**
  - Geologic model, reservoir and geo-mechanical modeling results, and project design and operations information are provided to ORION and TALES
  - ORION uses this data to estimate the probability of induced seismicity incidents of varying strength
- **Baseline or reference scenario**
  - Induced seismic incidents predicted by ORION are probabilistic and incidents exceeding a threshold may not occur
  - In the baseline or reference scenario, it is assumed that there are no induced seismic incidents exceeding threshold criteria during the storage project
  - TALES is used to calculate the revenues, costs and financial performance for the storage project assuming no incidents
  - These are baseline or reference results for the storage project
    - Key financial metrics for this scenario, such the NPV for the project or break-even CO_2 cost, are used to compare to the same financial metrics for scenarios where the induced seismic incidents exceed threshold criteria

Evaluation of Induced Seismicity Risks



- **Induce seismic incident exceedances scenario**
  - In this scenario, it is assumed that there are induced seismic incidents exceeding threshold criteria
  - The rate of CO_2 injection in one or more injection wells is reduced
  - ORION is used to evaluate the effectiveness of different fluid reduction rates on the subsequent probability of incidents that exceed threshold criteria (not yet implemented in ORION)
  - These reduced CO_2 injection rates are provided to TALES
  - TALES is used to calculate the revenues, costs, financial performance and key financial metrics for these reduced injection rates
    - Key financial metrics for this scenario, such as the breakeven CO_2 cost, are compared to the same financial metrics for the baseline scenario to assess the influence of leakage on the financial viability of the project
    - Note: Each reduction of the injection rate is its own scenario or sub-scenario

Status

Master Page Subtitle 1

- **NRAP/SMART TALES Model**
  - Soon: Alpha version 0.5 is being released in week or so
    - Contact David Morgan (david.morgan@netl.doe.gov) or Chung Yan Shih (chungyan.shih@netl.doe.gov) of NETL for access
  - Nov 30: Beta version with improved connections with NRAP tools, prototype stochastic analysis, improved GUI
  - March 31, 2025: Version 1 with refined stochastic analysis, refined GUI, initial linkage to RAMP, better connections with NRAP tools
- **CLEAR Tool and Remed-Res Tool**
  - September 30: Alpha version of tools
  - December 31: Beta version of tools
  - March 31, 2025: Version 1 of tools
- **Case studies**
  - June 30: Design basis document for leakage case study
  - Fall: Design basis document for induced seismicity case study
  - April 30, 2025: Reports on case study results
- **Tools for estimating costs of financial instruments to address costs of implementing ERR Plans**
  - March 31, 2025: Alpha version of a tool for estimating the costs of an insurance policy to implement an ERR plan to address leakage and induced seismicity risks

Posters and Demonstrations Presented Tuesday

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- **NETL**
  - A talk providing a detailed overview of the NRAP TALES Model was presented on Tuesday entitled "Overview of the NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) Model"
  - Demonstration: NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) Model
- **NETL and LANL**
  - Poster: NRAP Task 5: Preliminary Evaluation of the Cost of Responding to a Hypothetical Leakage Scenario Using the NRAP/SMART TALES Model and other NRAP Tools
- **PNNL**
  - Demonstration: Carbon Capture, Utilization, and Storage Leakage Evaluation and Remediation (CLEAR) Tool

Contributors

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- **LANL**
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Thank you!

Comments and Questions:

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