Enhanced Analytical Simulation Tool for CO_2 Storage Capacity Estimation and Uncertainty Quantification

Project Number (DE-FE0009301)

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National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
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Presentation Outline

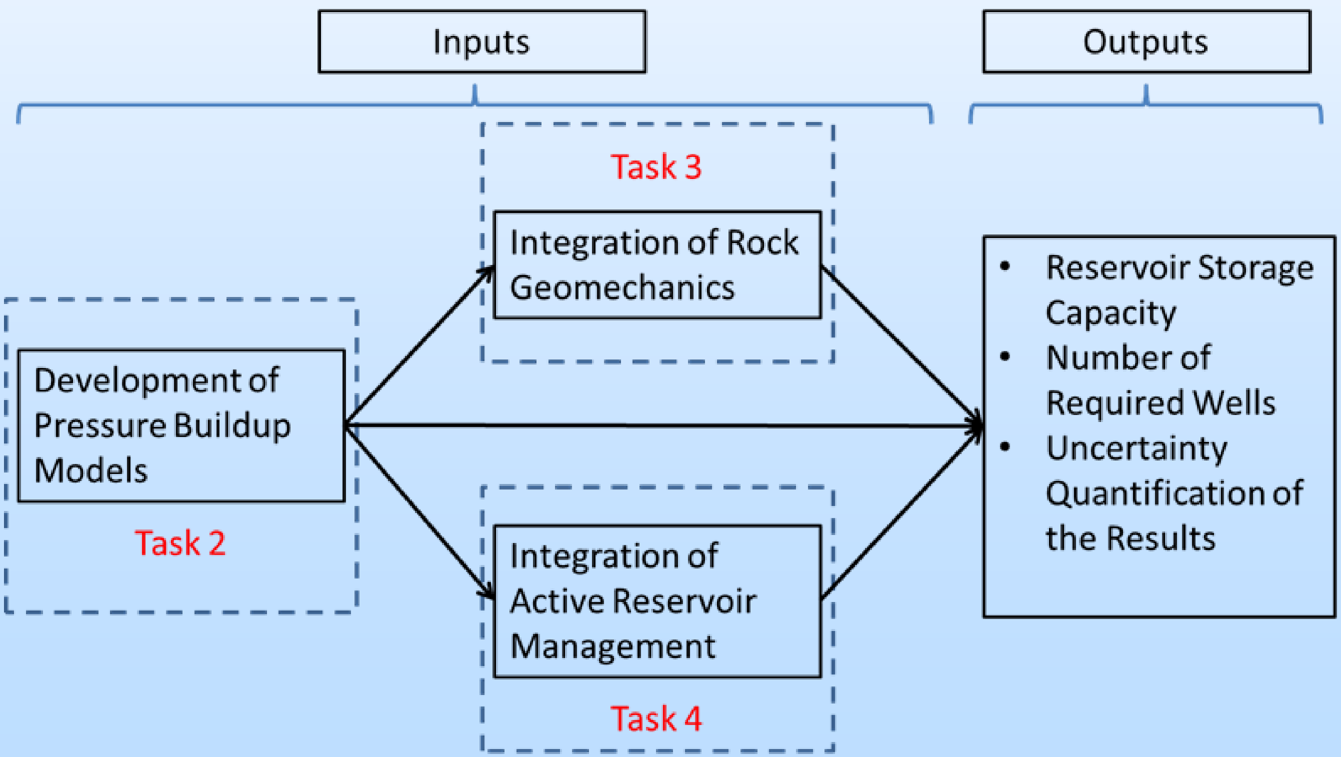
- Project Overview
  - Goals and Objectives
- Technical Status
- Accomplishments to Date
- Synergy Opportunities
- Project Summary
- Future Plans

Project Overview
Goals and Objectives

- Goals
  - Support industry to predict CO_2 storage capacity in geologic formations to within ±30 percent.
  - Develop an Enhanced Analytical Simulation Tool (EASiTool) for simplified reservoir models to predict storage capacity of brine formations (open or closed boundary).
- Objectives
  - Provide fast, reliable and science-based estimate of storage capacity.
  - Integrate analytical/semi-analytical geomechanical models
  - Integrate brine extraction models.
  - Provide sensitivity analysis.

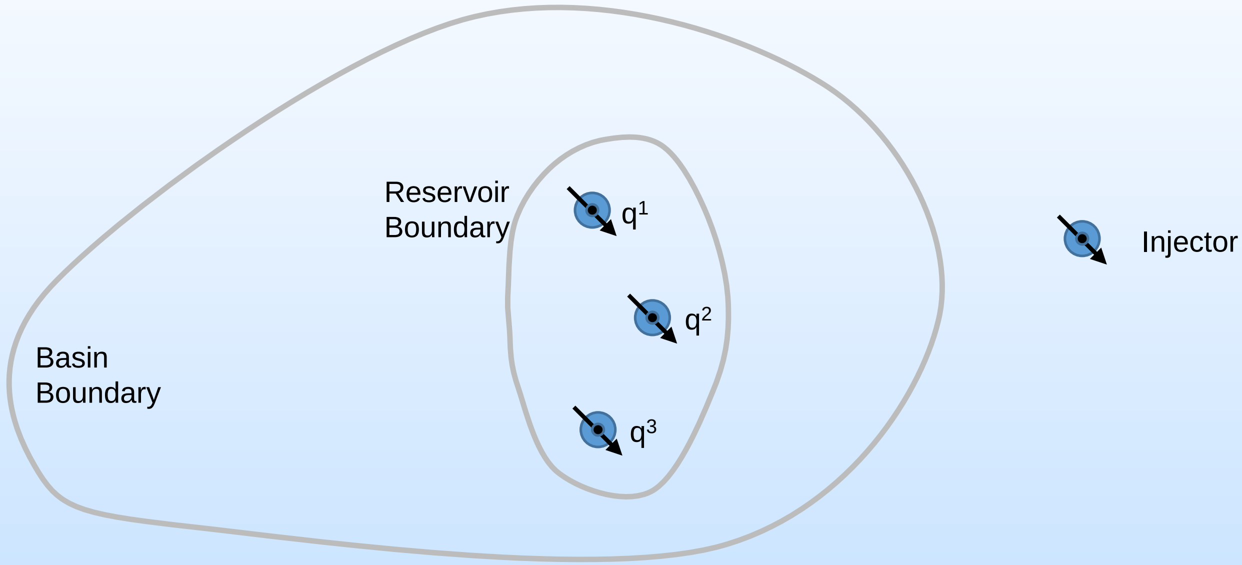
Technical Status

- Task 2, 3 and 4 completed.
- General geometry/pattern completed.
- More verification and application.



Accomplishments to Date

– Finding the optimized rate to maximize storage capacity



$$\begin{bmatrix} \frac{1}{2}\left(\ln(t_D)+0.80908\right)+S_a & -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D1-2}^2}{4\eta_{D3}t_D}\right) & -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D1-3}^2}{4\eta_{D3}t_D}\right) \\ -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D2-1}^2}{4\eta_{D3}t_D}\right) & \frac{1}{2}\left(\ln(t_D)+0.80908\right)+S_a & -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D2-3}^2}{4\eta_{D3}t_D}\right) \\ -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D3-1}^2}{4\eta_{D3}t_D}\right) & -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D3-2}^2}{4\eta_{D3}t_D}\right) & \frac{1}{2}\left(\ln(t_D)+0.80908\right)+S_a \end{bmatrix} \begin{Bmatrix} q^1 \\ q^2 \\ q^3 \end{Bmatrix} = \begin{Bmatrix} \frac{2\pi hk\overline{k_{rg}}}{\mu_g}\Delta P_{\max} \\ \frac{2\pi hk\overline{k_{rg}}}{\mu_g}\Delta P_{\max} \\ \frac{2\pi hk\overline{k_{rg}}}{\mu_g}\Delta P_{\max} \end{Bmatrix}$$

$P_{frac} - P_i$

Accomplishments to Date

- Calculations for maximum injection pressure added to EASiTool.
- Integrates thermal and pore pressure stresses.
  - Normal fault system

$$P_{\max} = \frac{1}{\left[2\alpha - \beta_v - \beta_h - (\beta_v - \beta_h)\cos 2\theta + (\beta_v - \beta_h)\sin 2\theta / \mu\right]} \cdot$$
$$\left[\left\{(1+K) + (1-K)\cos 2\theta - (1-K)\sin 2\theta / \mu\right\}\sigma_{v0} - \left\{(\beta_v + \beta_h) + (\beta_v - \beta_h)\cos 2\theta - (\beta_v - \beta_h)\sin 2\theta / \mu\right\}P_{pi} - \frac{2\alpha_T E \Delta T}{1-2\nu}\right]$$

  - Reverse fault system

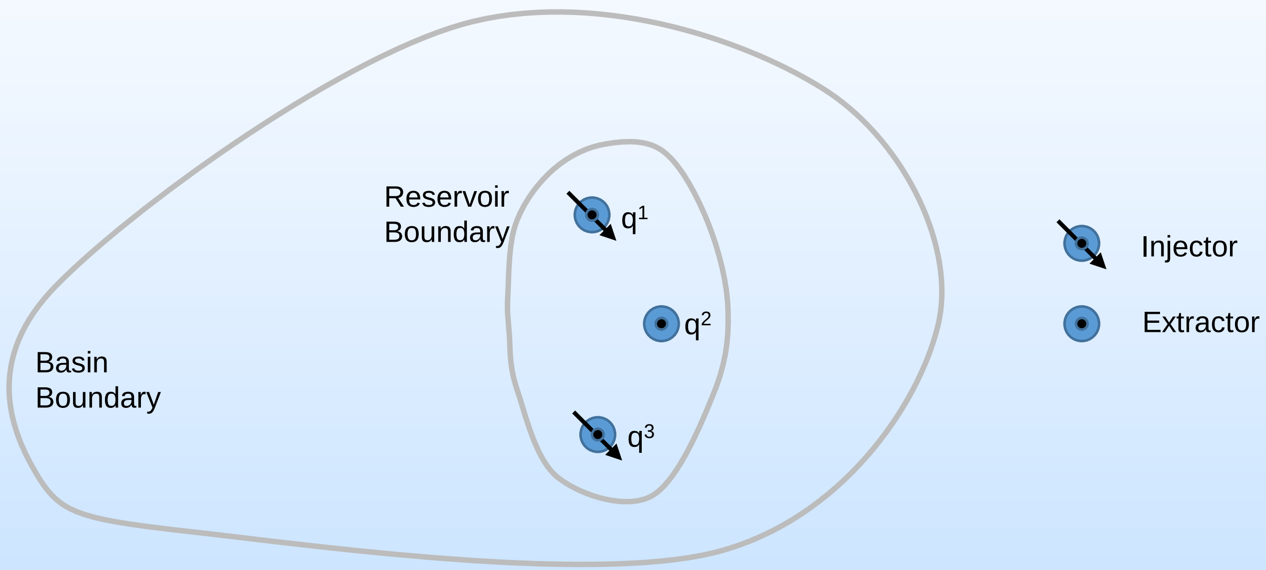
$$P_{\max} = \frac{1}{\left[2\alpha - \beta_h - \beta_v - (\beta_h - \beta_v)\cos 2\theta + (\beta_h - \beta_v)\sin 2\theta / \mu\right]} \cdot$$
$$\left[\left\{(K+1) + (K-1)\cos 2\theta - (K-1)\sin 2\theta / \mu\right\}\sigma_{v0} - \left\{(\beta_h + \beta_v) + (\beta_h - \beta_v)\cos 2\theta - (\beta_h - \beta_v)\sin 2\theta / \mu\right\}P_{pi} - \frac{2\alpha_T E \Delta T}{1-2\nu}\right]$$

  - Strike-slip fault system

$$P_{\max} = \frac{1}{\alpha - \beta_h}\left[\left(\frac{1+K_H}{2} + \frac{1-K_H}{2}\cos 2\theta - \frac{1-K_H}{2}\sin 2\theta / \mu\right)\sigma_{H0} - \beta_h \cdot P_{pi} - \frac{\alpha_T E \Delta T}{1-2\nu}\right]$$

Accomplishments to Date

– Finding the optimized rate to maximize storage capacity

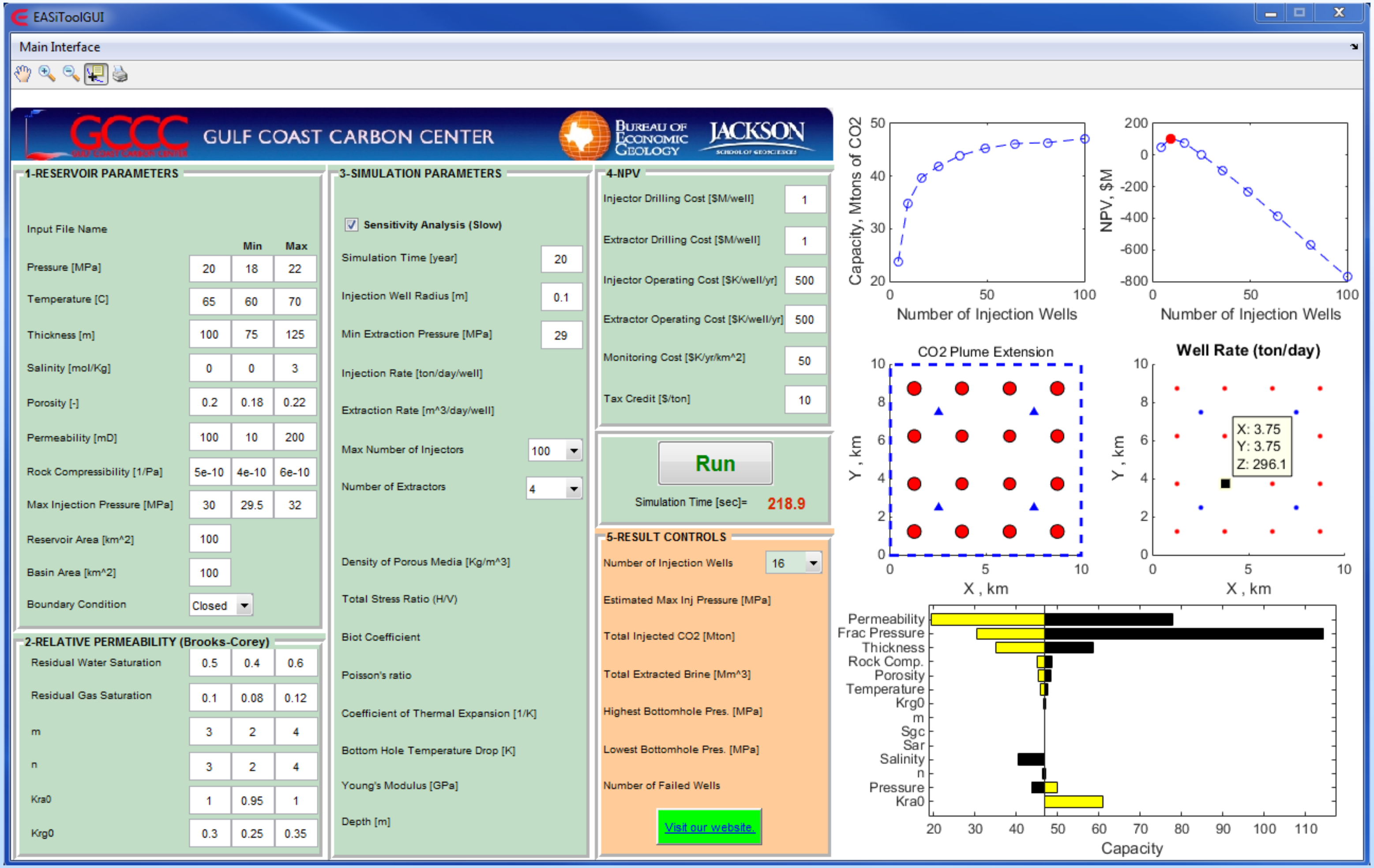


$$\begin{bmatrix} \frac{1}{2}\left(\ln(t_D)+0.80908\right)+S_a & -\frac{1}{2}E_i\left(-\frac{r_{D1-2}^2}{4t_{D,Ext}}\right) & -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D1-3}^2}{4\eta_{D3}t_D}\right) \\ -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D2-1}^2}{4\eta_{D3}t_D}\right) & \frac{1}{2}\left(\ln(t_{D,Ext})+0.80908\right) & -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D2-3}^2}{4\eta_{D3}t_D}\right) \\ -\frac{1}{2}\frac{\overline{\lambda_g}}{\overline{\lambda_w}}E_i\left(-\frac{r_{D3-1}^2}{4\eta_{D3}t_D}\right) & -\frac{1}{2}E_i\left(-\frac{r_{D3-2}^2}{4t_{D,Ext}}\right) & \frac{1}{2}\left(\ln(t_D)+0.80908\right)+S_a \end{bmatrix} \begin{Bmatrix} q^1 \\ -q^2 \\ q^3 \end{Bmatrix} = \begin{Bmatrix} \frac{2\pi hk\overline{k_{rg}}}{\mu_g}\Delta P_{\max} \\ \frac{2\pi hk\overline{k_{rw}}}{\mu_w}\Delta P_{Ext} \\ \frac{2\pi hk\overline{k_{rg}}}{\mu_g}\Delta P_{\max} \end{Bmatrix}$$

$$P_{Ext} - P_i$$

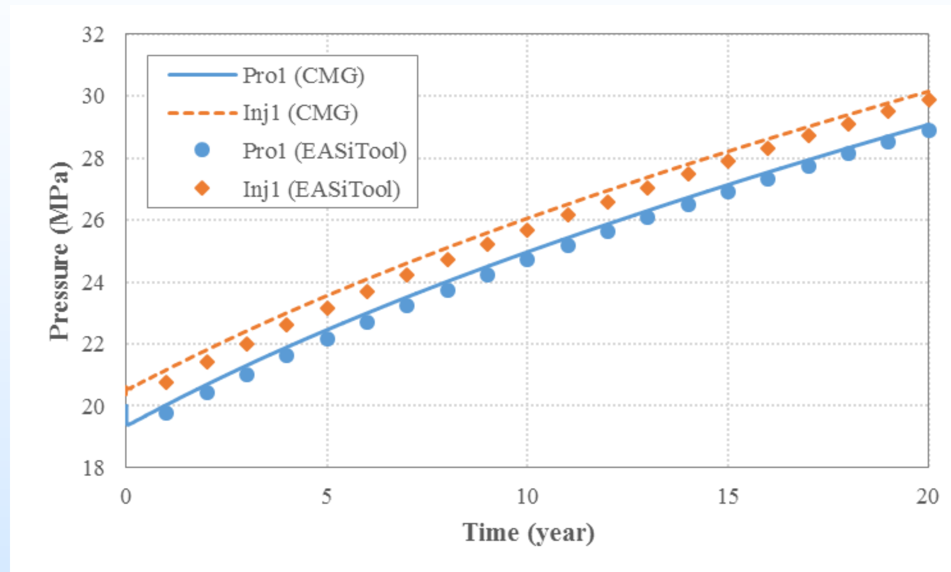
Accomplishments to Date

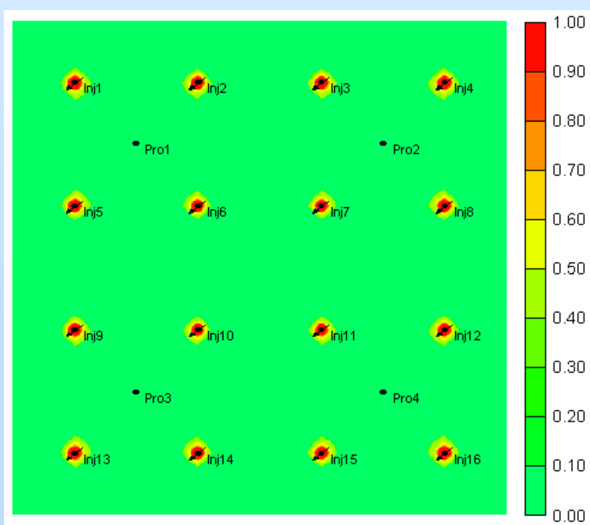
– Development and improving user interface

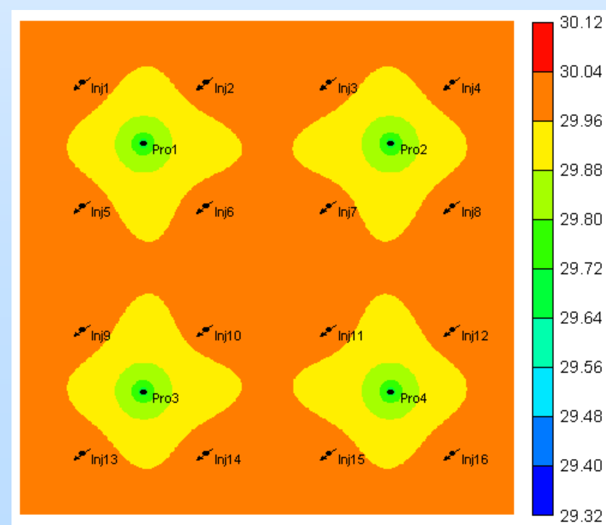


Accomplishments to Date

– Model verification

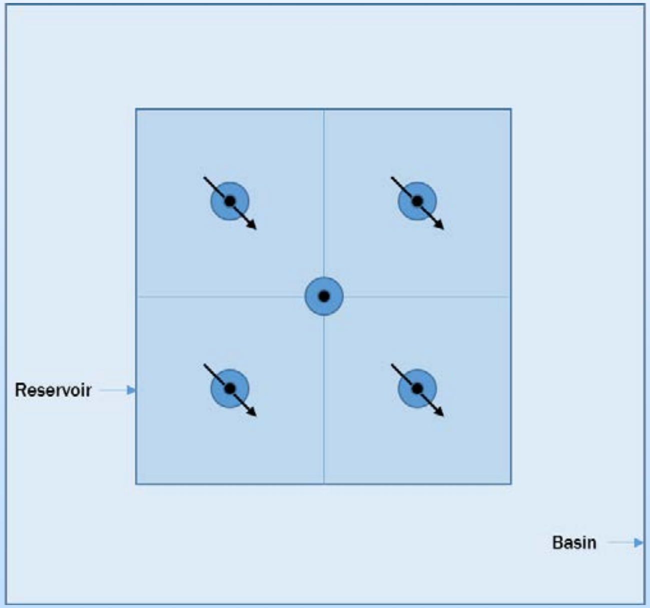


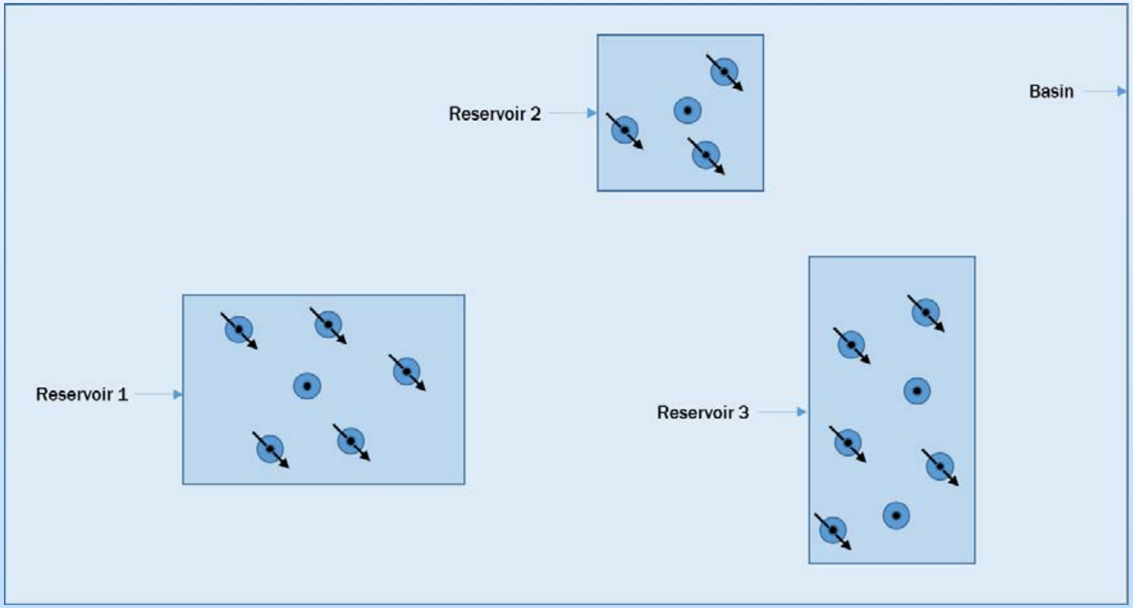




Accomplishments to Date

– User defined locations for injection and extraction wells
  - Adding multiple reservoirs within the same basin
  - Global pressure maps





Accomplishments to Date

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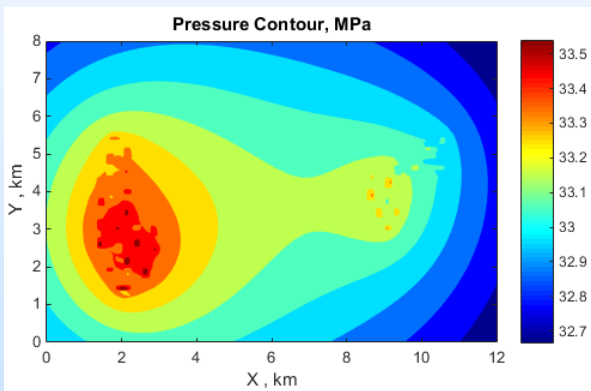
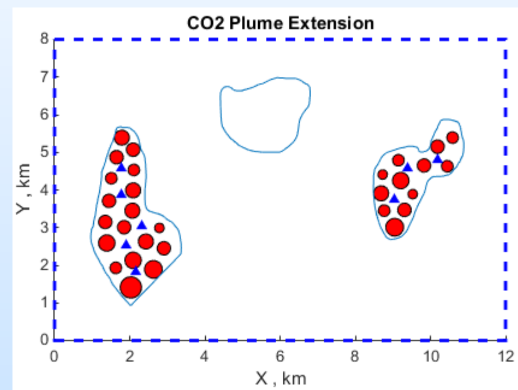
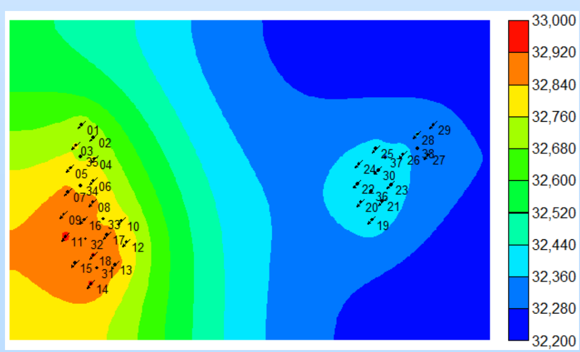
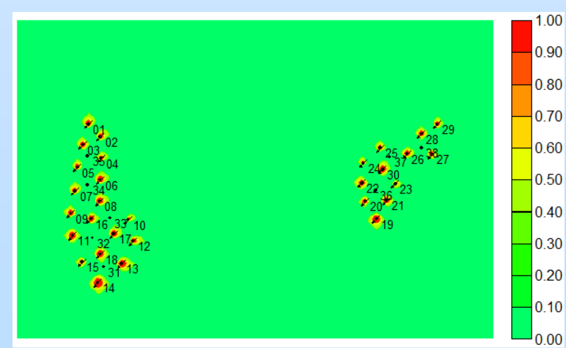




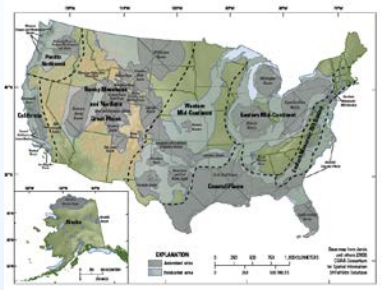


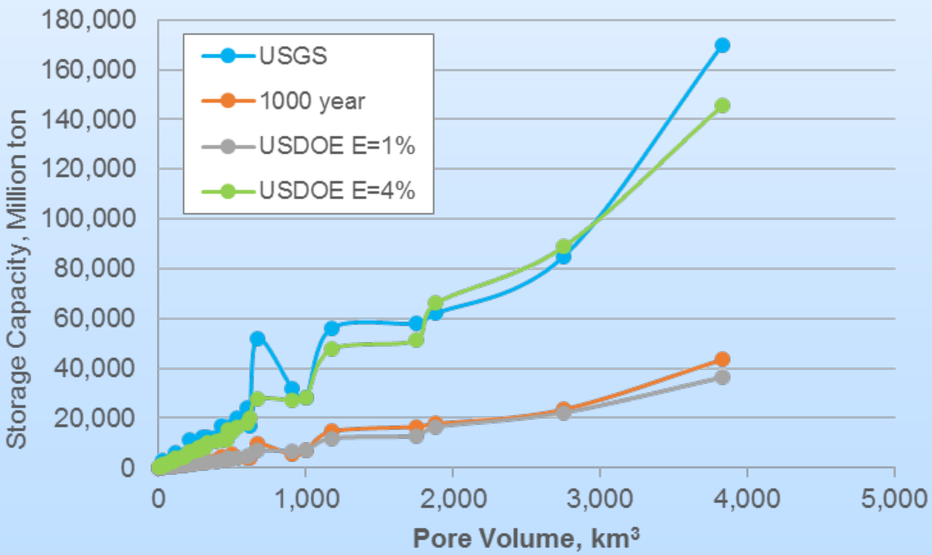


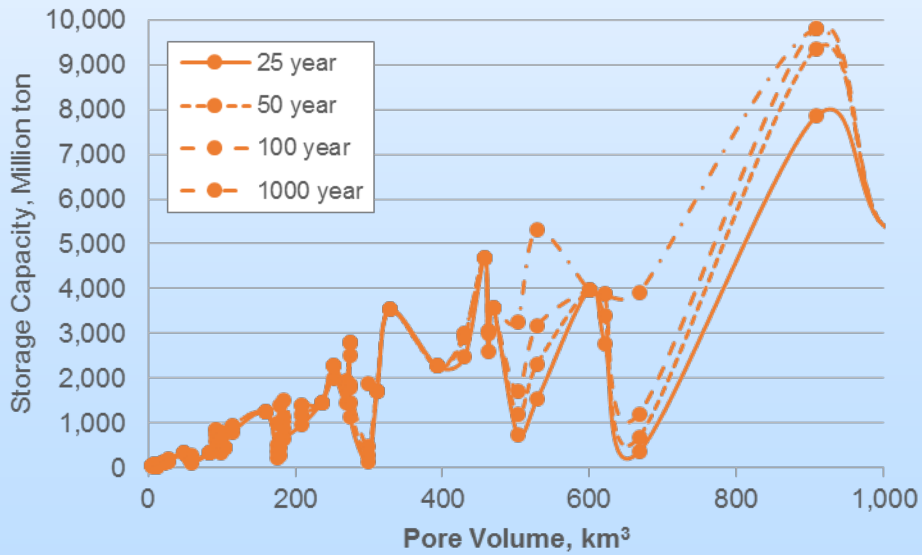
Accomplishments to Date

– Application to the USGS database

- EASiTool after 1000 years is similar to USDOE 1%.
- USGS estimation is higher (close to USDOE 4%).
- EASiTool results after 25, 50, 100, and 1000 years are different.







Synergy Opportunities

- EASiTool is an analytical simulation tool for capacity estimation in saline aquifers.

- Input data required for EASiTool is typically available for most of the projects.

- EASiTool results can be compared with the results obtained in other projects via other methods (static, simulation, etc).

Project Summary

– Fourth version of EASiTool is ready for release.
– EASiTool can be applied to large databases.
– EASiTool is available for download:
  • http://www.beg.utexas.edu/gccc/EASiTool/

Future Plans

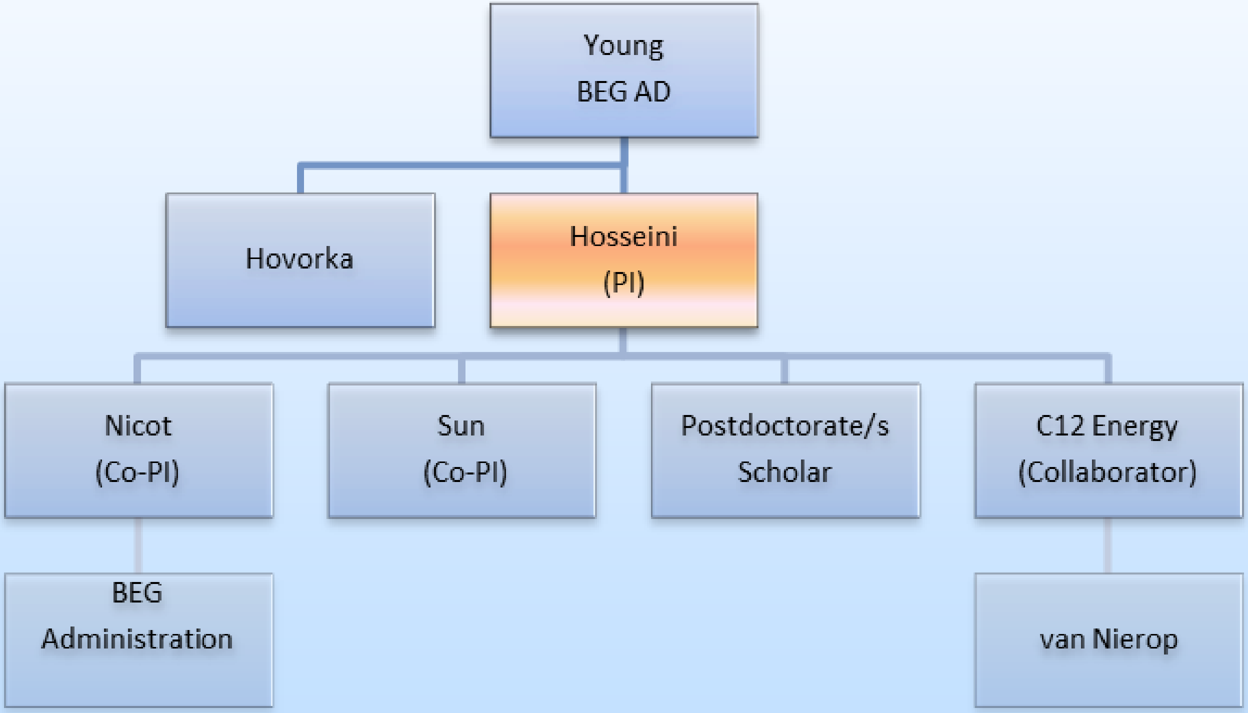
– Improving the user interface
– Application to the USGS onshore database (36 Basins)
– Application to the offshore database
– Funding to maintain and further develop EASiTool

Questions

Appendix

– Organization Chart
– Gantt Chart
– Bibliography

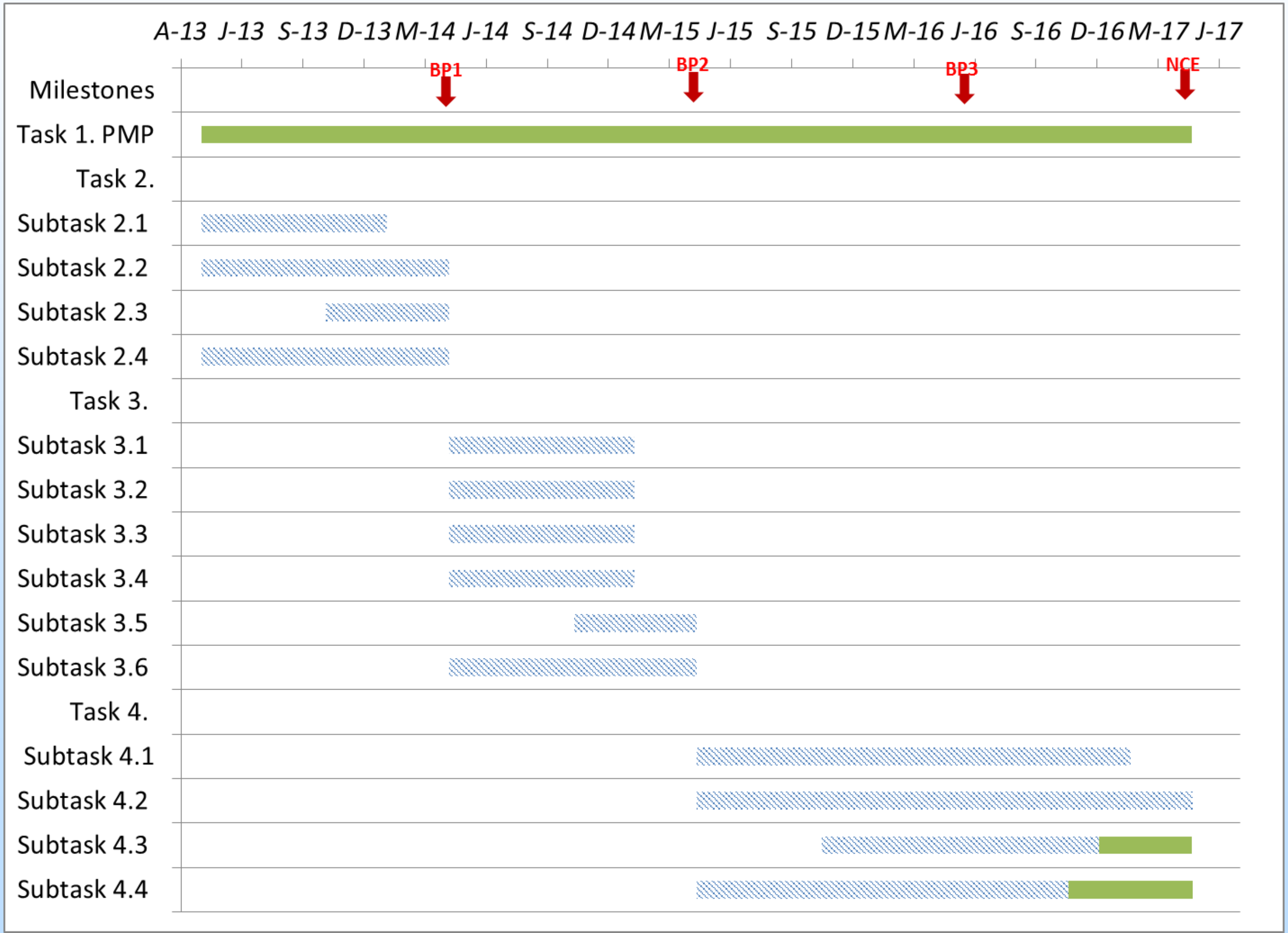
Organization Chart



Organization Chart

Project PI: Seyyed A. Hosseini			
Task 1 Project Management and Planning	**Task 2** Development of Analytical Solutions for Pressure Buildup	**Task 3** Rock Geomechanics Impact on Pressure Buildup and Capacity Estimation	**Task 4** Brine-Management Impact on CO_2 Injectivity and Storage Capacity
Task Leader/Backup Nicot/Hosseini	Task Leader/Backup Hosseini/Sun	Task Leader/Backup Hosseini/Sun	Task Leader/Backup Hosseini/Sun
Task 1 Team Nicot/Hosseini/ Young/Hovorka	Task 2 Team Subtask 2.1 Hosseini/Sun/ Postdoc/s Subtask 2.2 Hosseini/Sun/C12 Energy Subtask 2.3 Sun/Hosseini Subtask 2.4 Sun/Hosseini	Task 3 Team Subtask 3.1 Hosseini/Sun/ Postdoc/s Subtask 3.2 Hosseini/Sun/ Postdoc/s Subtask 3.3 Sun/Hosseini Subtask 3.4 Hosseini/Sun Subtask 3.5 Sun/Hosseini Subtask 3.6 Sun/Hosseini	Task 4 Team Subtask 4.1 Hosseini/Sun/ Postdoc/s Subtask 4.2 Sun/Hosseini/ Postdoc/s Subtask 4.3 Sun/Hosseini Subtask 4.4 Sun/Hosseini

Gantt Chart



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M-17
J-17
BP1
BP2
BP3
NCE
Milestones
Task 1. PMP
Task 2.
Subtask 2.1
Subtask 2.2
Subtask 2.3
Subtask 2.4
Task 3.
Subtask 3.1
Subtask 3.2
Subtask 3.3
Subtask 3.4
Subtask 3.5
Subtask 3.6
Task 4.
Subtask 4.1
Subtask 4.2
Subtask 4.3
Subtask 4.4

Bibliography

– Journals

- Kim, S., Hosseini, S.A, 2013, Above-zone pressure monitoring and geomechanical analyses for a field-scale CO_2 injection project in Cranfield, MS, Greenhouse Gases: Science and Technology, 4 (1), 81-98, DOI: 10.1002/ghg.1388

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- Kim, Seunghee, Hosseini, S. A., 2014, Effect of Pore Pressure/Stress Coupling on Geological CO_2 Storage, 13th Annual Conference on Carbon Capture Utilization & Storage.