Identification of Residual Oil Zones (ROZs) in the Williston and Powder River Basins

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Transforming Technology through Integration and Collaboration
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Presentation Outline

- Benefit to the program
- Project overview
- Technical status
- Accomplishments to date
- Synergy opportunities
- Summary

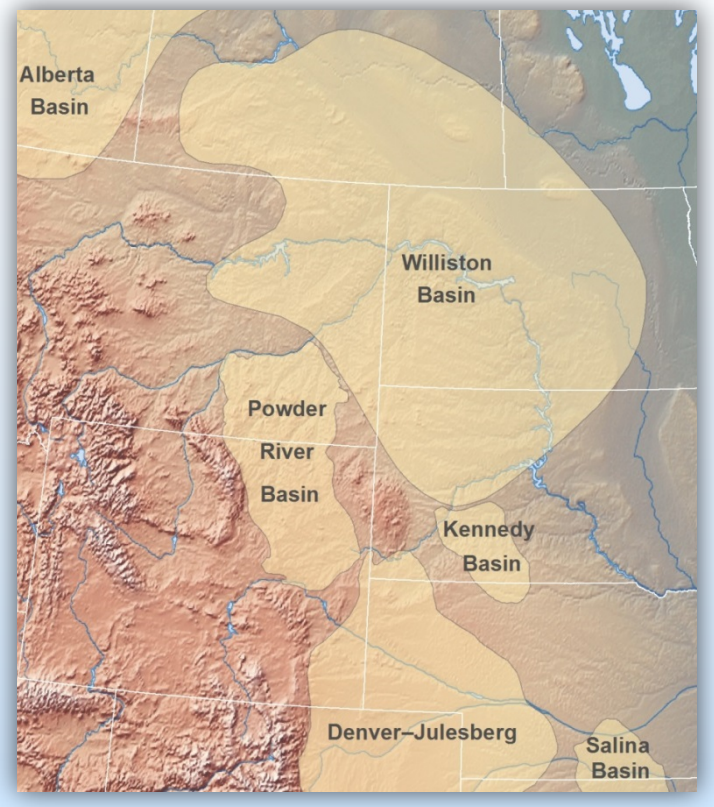
Benefit to the Program

- Second and fourth goals of Carbon Storage Program:
  - Improve reservoir storage efficiency while ensuring containment effectiveness.
  - Develop best practices manuals (BPMs).
- Potential ROZs will be identified and evaluated for oil recovery and CO_2 storage resource potential.
  - CO_2 storage efficiency is improved through CO_2 EOR.
- A repeatable methodology will be developed and presented in a BPM.

Project Overview:
Goals and Objectives

Objectives:

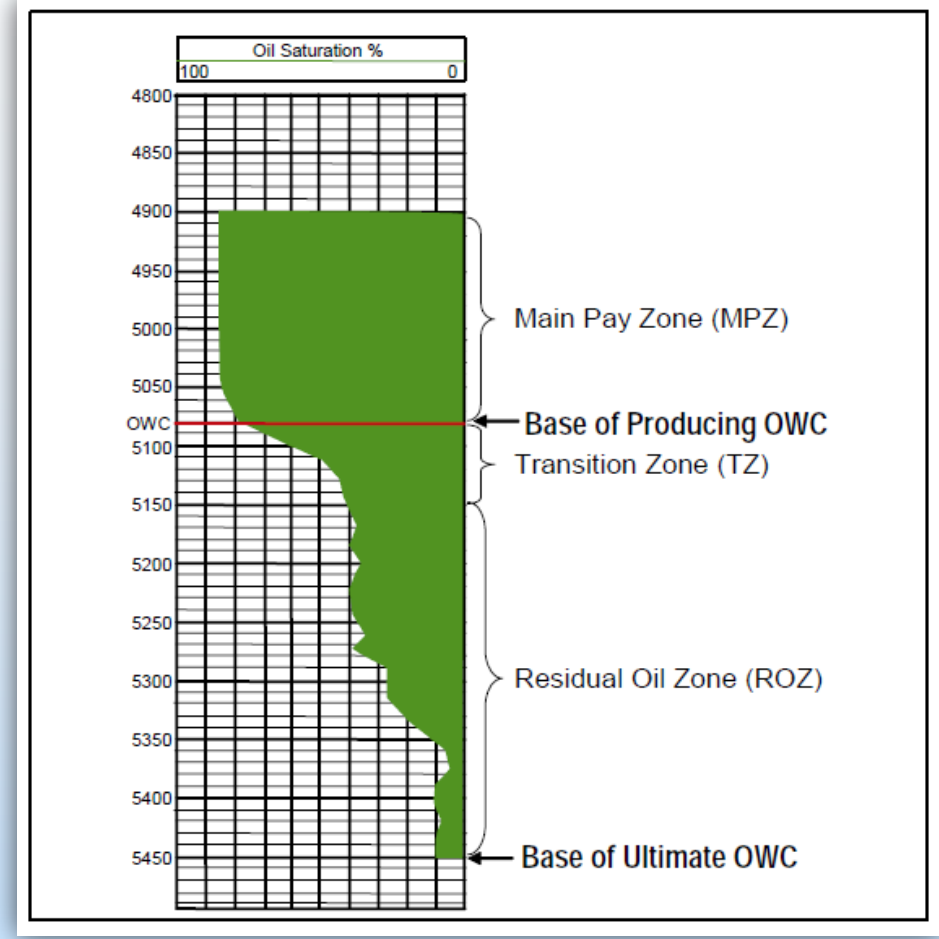
- Identify and characterize the presence and extent of potential ROZs in the Williston Basin (WB) and Powder River Basin (PRB).
- Estimate residual oil in place and CO_2 storage potential (Goal 2).
- Determine feasibility of CO_2 enhanced oil recovery (EOR) in identified ROZs (Goal 2).
- Develop repeatable methodology for sedimentary basins to be included in a BPM (Goal 4).



What Is a ROZ?

Residual Oil Zones

- "Mother Nature's waterflood"
- Oil zones have already been swept:
  - Oil shows but does not produce (20%–40% S_o).
  - Waterflood will not extract additional oil.
  - Skip to tertiary recovery (CO_2 flood).

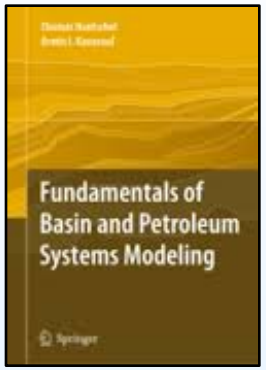


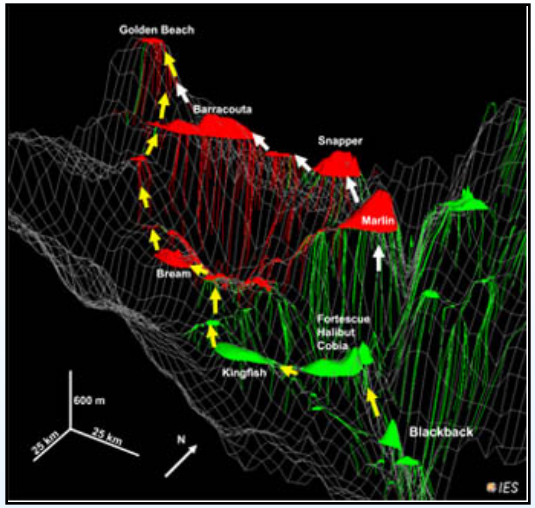
Koperna and Kuuskraa (2006)

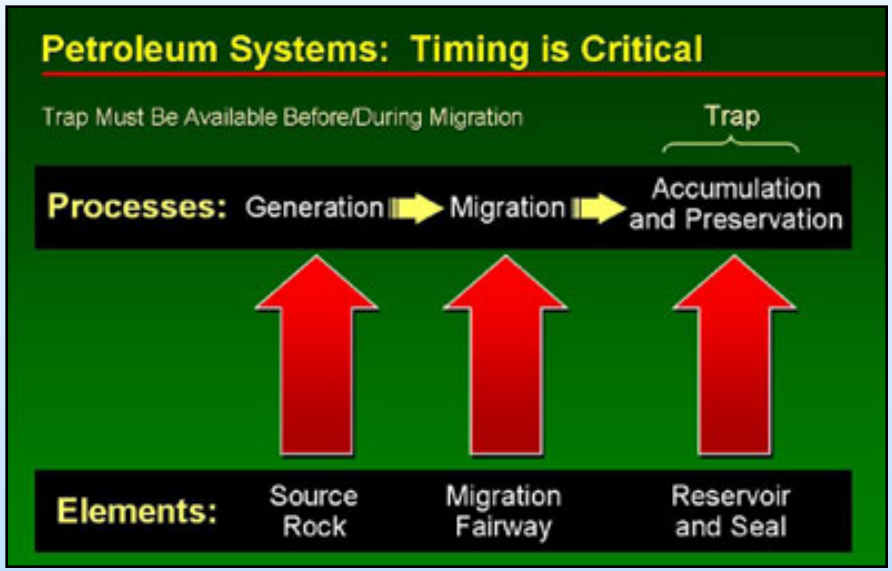
Methodology – Basin Modeling

Provide a complete record of the evolution of a petroleum system, including:

- Deposition and erosion.
- Pressure and compaction.
- Heat flow analysis.
- Petroleum generation.
- Fluid pressure, volume, temperature analysis.
- Reservoir volumetrics.
- Structural evolution.
- Generation, migration, and accumulation of hydrocarbons.



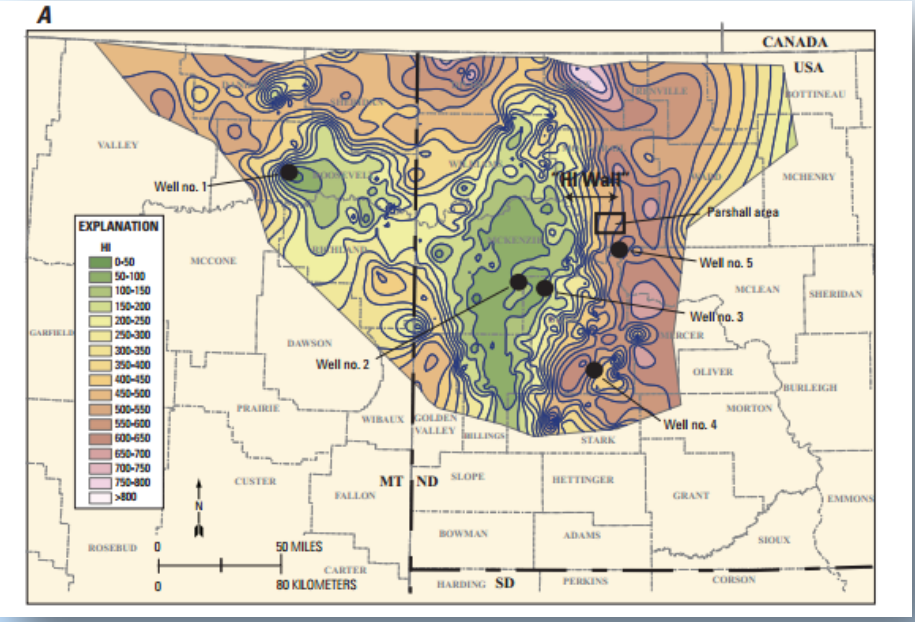


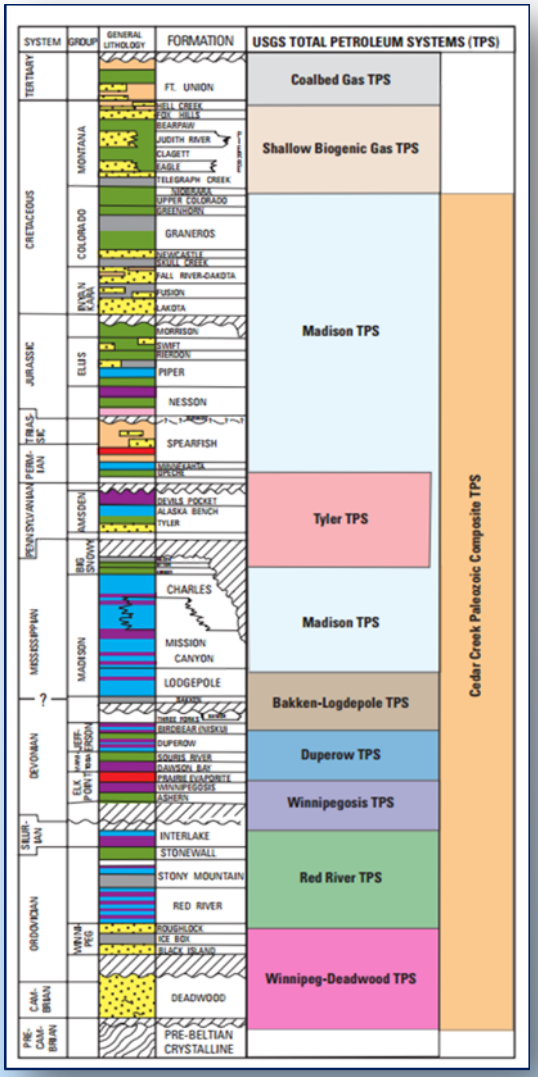


Literature Review

Goals of Literature Review

- Understand ROZs and previous work in basin modeling, both local and abroad.
- Translate geologic history of basins into an input for modeling.
- Gather data required for model construction.
- **Status**: In progress.

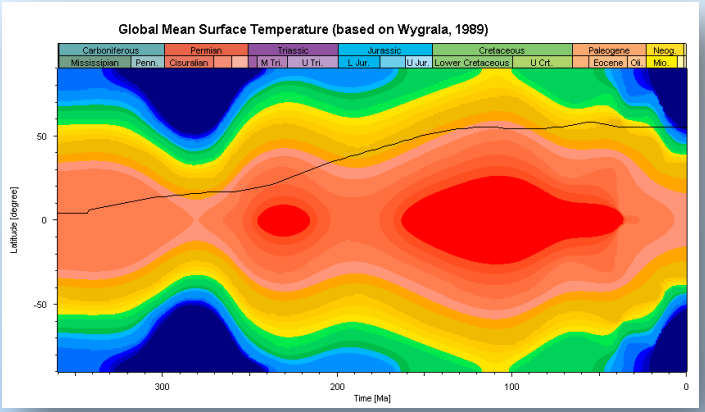




1-D and 2-D Modeling

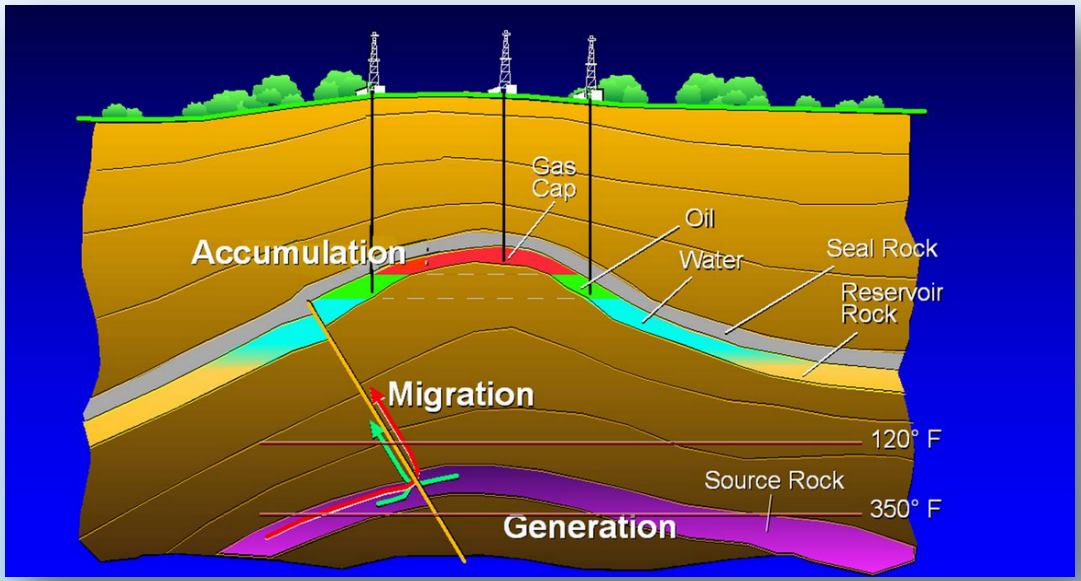
1-D Models

- Point location examination of:
  - Burial history.
  - Temperatures.
  - Boundary conditions.
  - Generation.
- **Status**: Ongoing.
  - Completed, simulated, and calibrated several 1-D models.



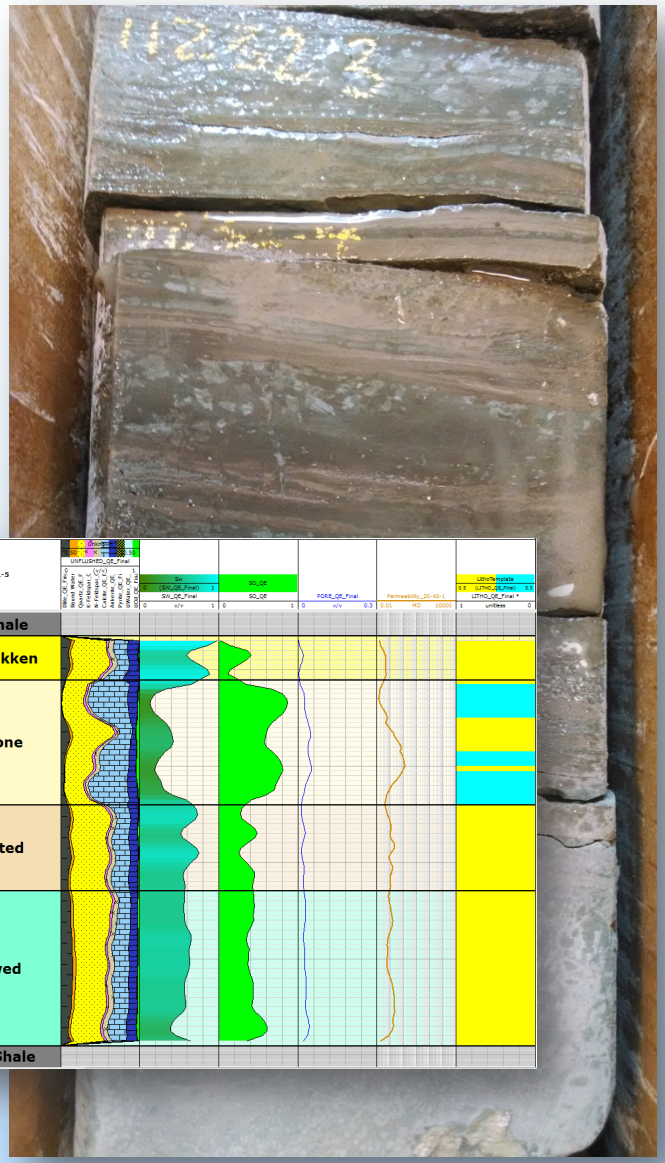
2-D Models

- Investigate generation and lateral migration.
- Faster than 3-D.
- **Status**: Ongoing.
  - Completed, simulated, and calibrated for one oil field.



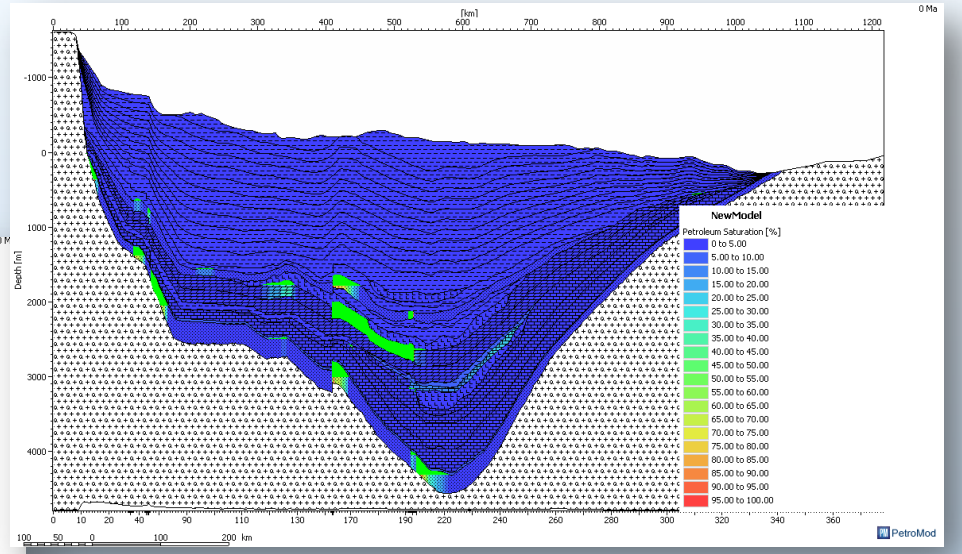
Fresh Core Analysis and Petrophysics

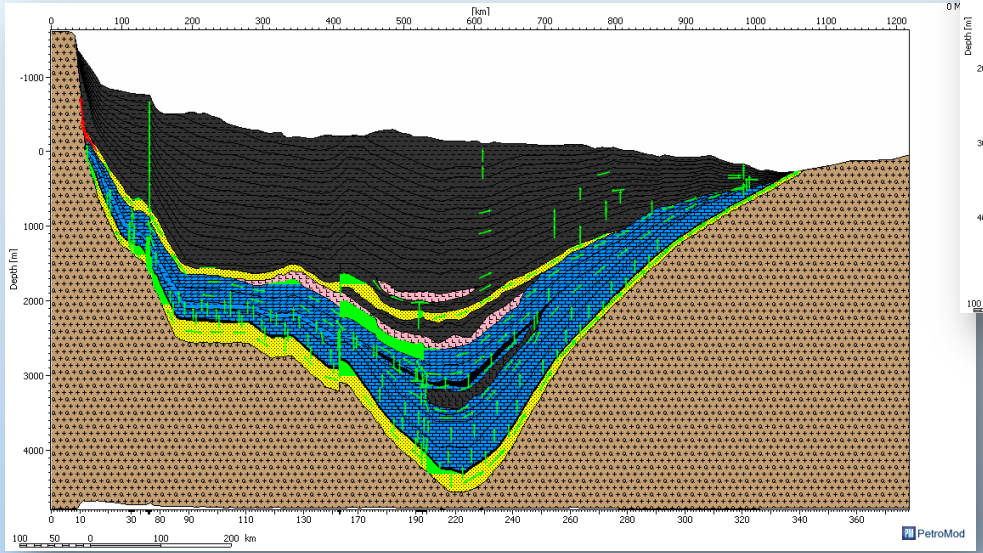
- Multiple wells will be chosen based on 2-D modeling results and fresh core availability.
- Combine core data and well log analysis to estimate fluid saturations in potential ROZs.
- Means of model validation.
- **Status**: Initiating.



Update 2-D Models

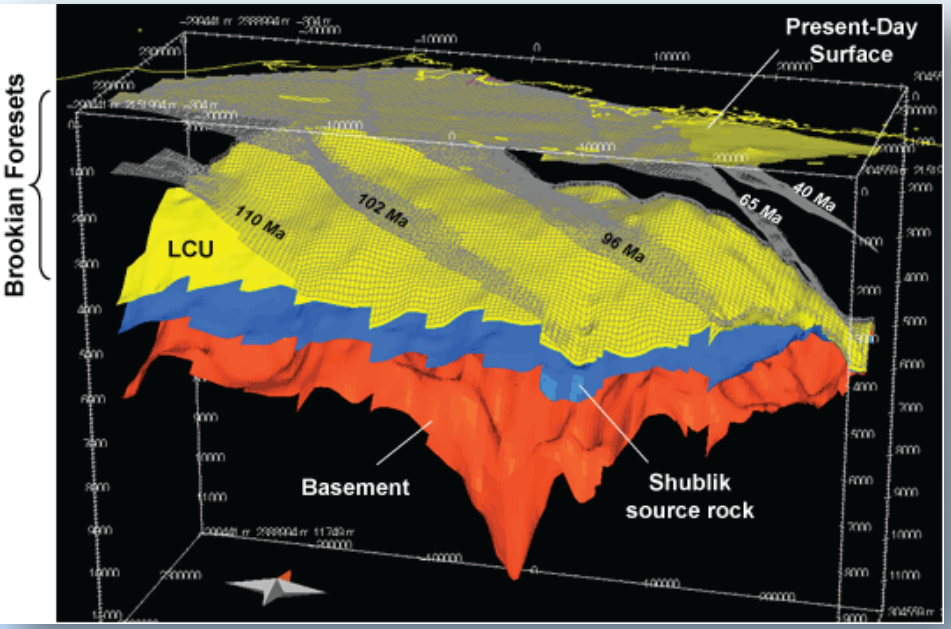
- Using fresh core fluid saturations and petrophysics, the 2-D cross-sectional models will be updated to reflect the actual field results.
- Provides model calibration and validation before building more complex 3-D models.

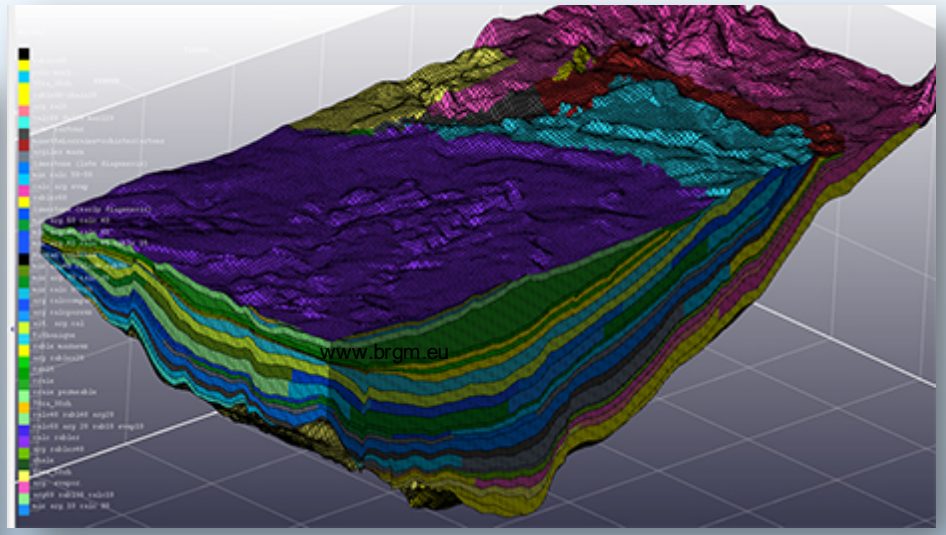




3-D Models

- Robust basin analysis that provides more detail than a simplified 2-D model.
- **Status**: Structural models being developed.
  - One area completed and simulated.





Methodology – Select Submodels

- Create detailed models to investigate:
  - ROZ genesis and indicators.
    - Salt movement
    - Hydrogen sulfide existence
    - Free sulfide migration
  - CO_2 EOR.
    - Fields with tilted oil–water contacts
    - Brownfield ROZs
    - Geologic modeling and simulation
- **Status:** Scheduled to begin next budget period.

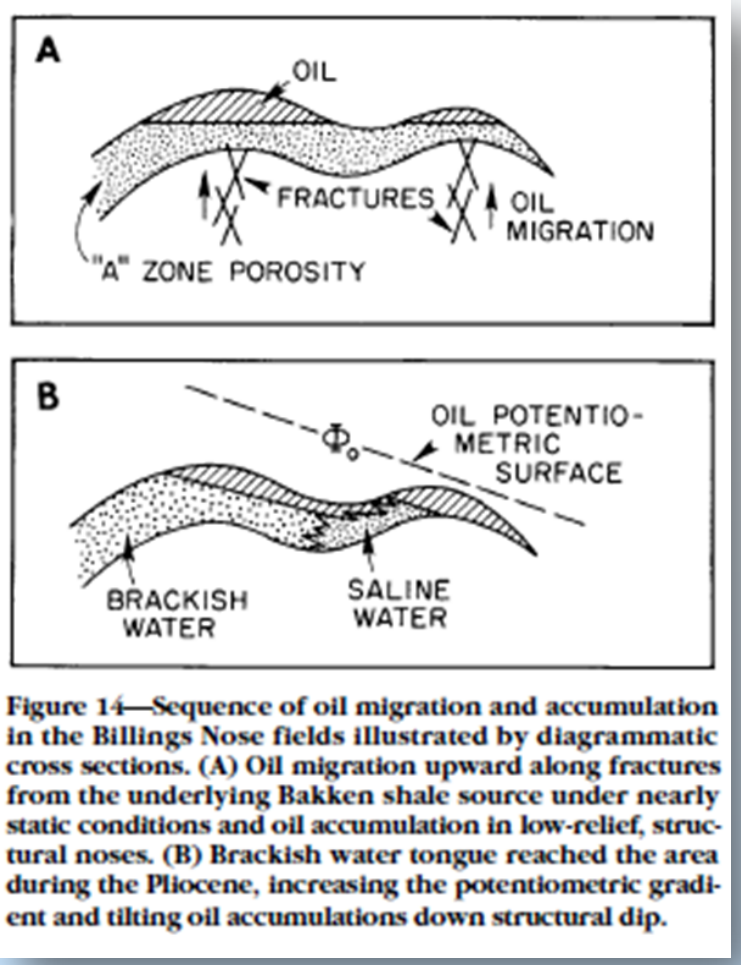
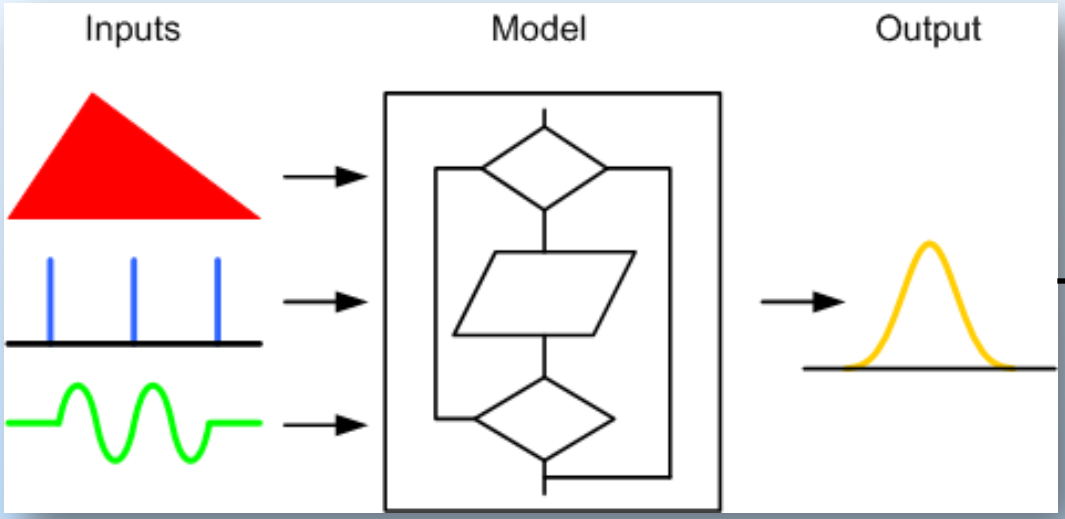


Figure 14—Sequence of oil migration and accumulation in the Billings Nose fields illustrated by diagrammatic cross sections. (A) Oil migration upward along fractures from the underlying Bakken shale source under nearly static conditions and oil accumulation in low-relief, structural noses. (B) Brackish water tongue reached the area during the Pliocene, increasing the potentiometric gradient and tilting oil accumulations down structural dip.

Berg and others (1994)

Methodology – Risk Analysis

- Uncertainty analysis using Monte Carlo simulations will be performed to better understand the impact of key variables:
  - PetroRisk
- Range of data for each variable will come from literature review database.
- Probabilities, confidence intervals, error bars, correlations, and calibration will be considered to find the best model fit.
- High-, mid-, and low-probability models will be used in fairway mapping.
- **Status:** Scheduled to begin next budget period.



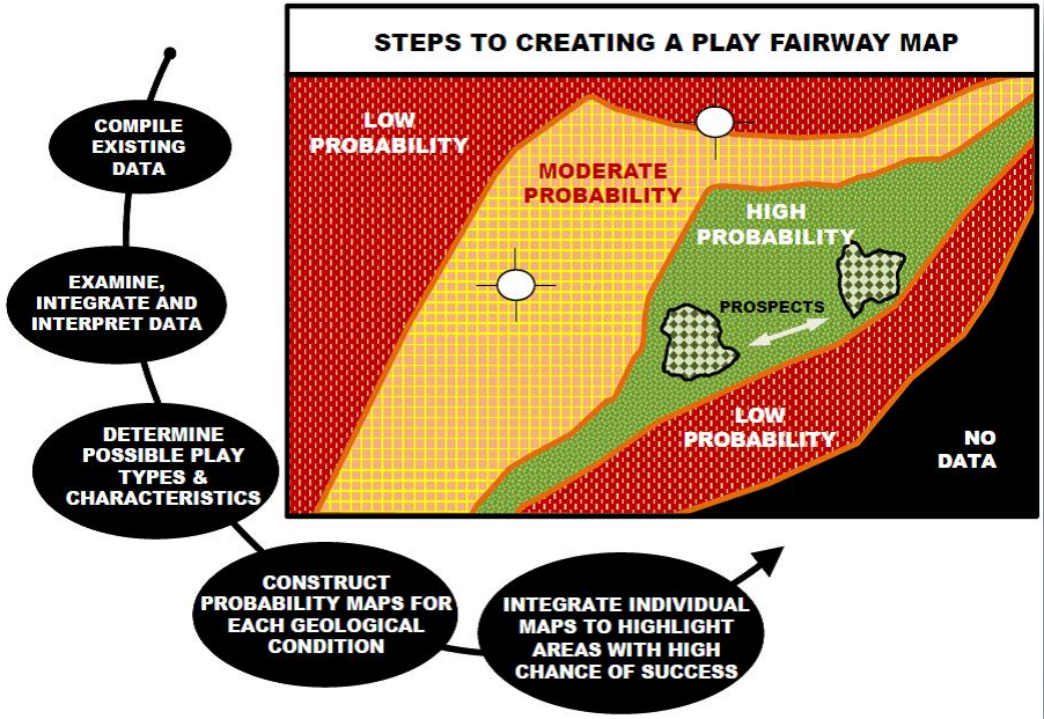
www.brighton-webs.co.uk/montecarlo/simulation.aspx

Analyze

- Histograms
- Tornado plots
- Crossplots
- Distributions

Output – ROZ Fairway Mapping

- Create play fairway maps showing discovered brownfield (existing fields) and greenfield (new fields) ROZs.
- Display high, mid, and low probabilities.



Output – CO_2 EOR Feasibility Study

- Analyze potential ROZs to determine feasibility for enhanced recovery using CO_2.
- Use published ranges for recovery and utilization factors for conventional CO_2 EOR projects.
- Make high, mid, and low estimates.

www.aogr.com

Accomplishments to Date

- Literature review well under way.
- Several 1-D models completed, simulated, and calibrated.
- 2-D model of Elkhorn Ranch Field (in North Dakota) completed and simulated.
- Potential ROZ identified near Elkhorn Ranch Field.
- 3-D model of Elkhorn Ranch Field completed and simulated.
- An overview of this project and its goals was presented at the Williston Basin Petroleum Conference in Regina, Saskatchewan, on April 29, 2015.

Synergy Opportunities
Associated Storage (EOR)

- The basin evolution modeling could be used to identify future unconventional or conventional targets.
- Collaboration between projects investigating CO_2 EOR in unconventional reservoirs and ROZs will help further the understanding of CO_2 storage associated with EOR.

Summary

- Key findings
  - Current PetroMod models predict hydrocarbon accumulations that largely agree with known pools.
- Lessons learned
  - Much greater understanding of PetroMod software and relationships among variables.
  - Improved structural frameworks for the WB and PRB.
  - Delicate balance between not enough detail and too much when collecting data.
- Future plans
  - Streamline and calibrate.

Appendix

Supplemental Slides

Appendix
ROZ Classification

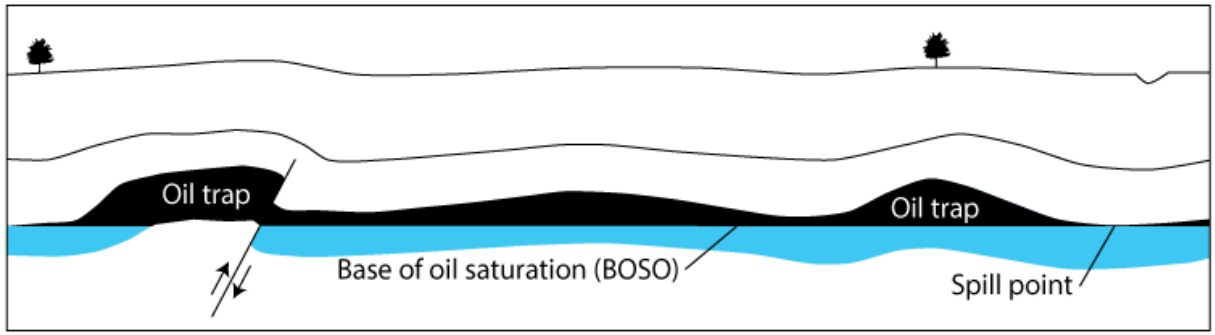
ROZ Setting

- Brownfield – associated with (below) known oil fields.
- Greenfield – residual oil accumulations in new areas.

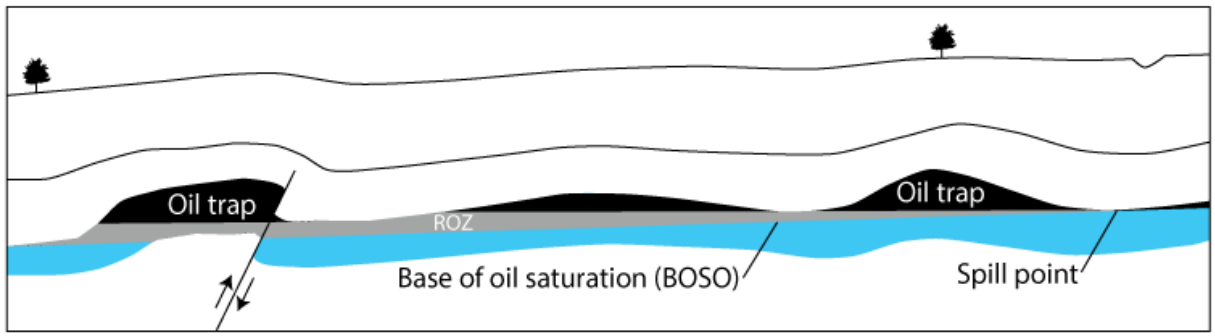
ROZ Genesis

Type I – Regional tilt
Type II – Breached seal
Type III – Hydrodynamic tilt

Original

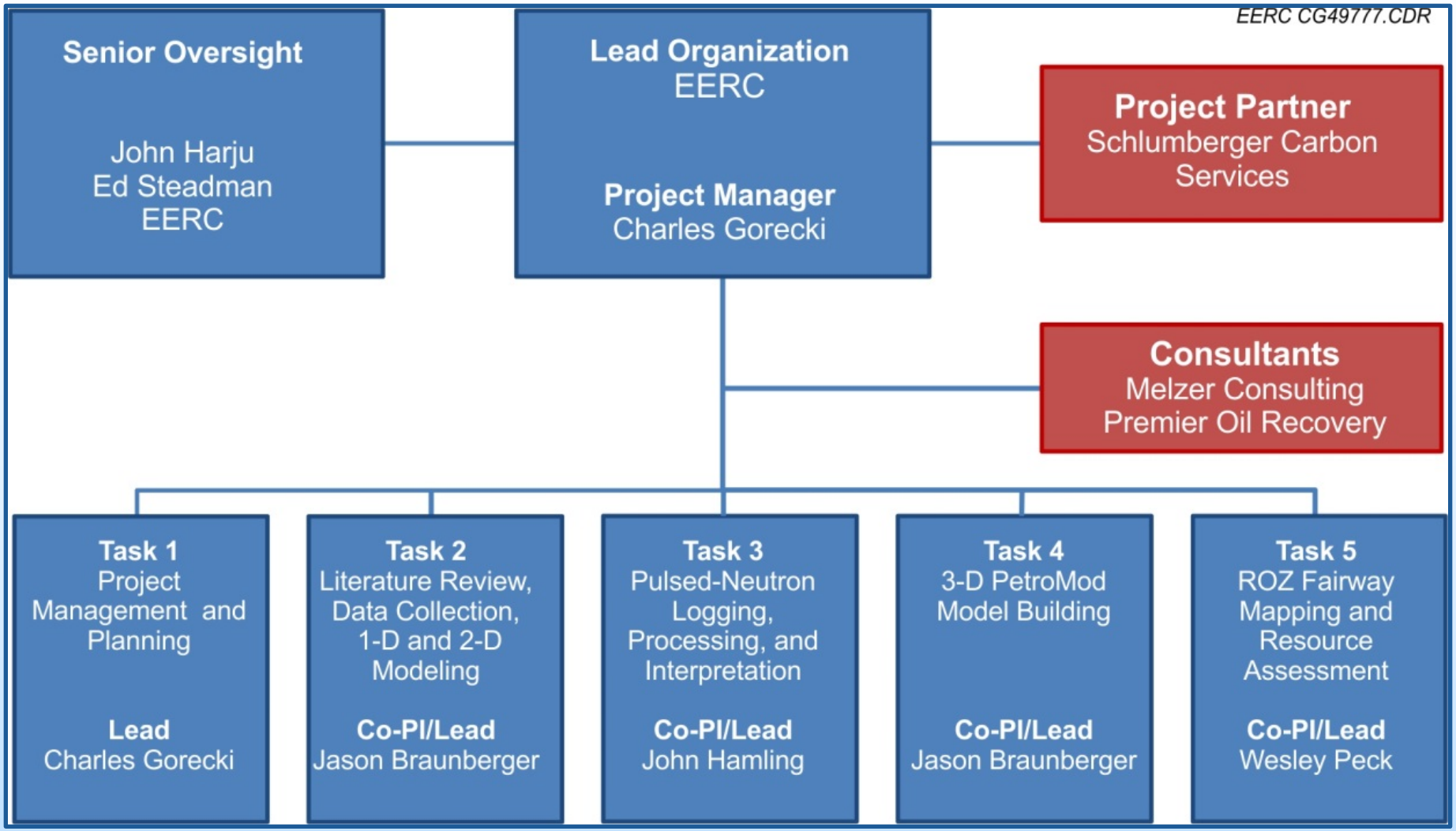


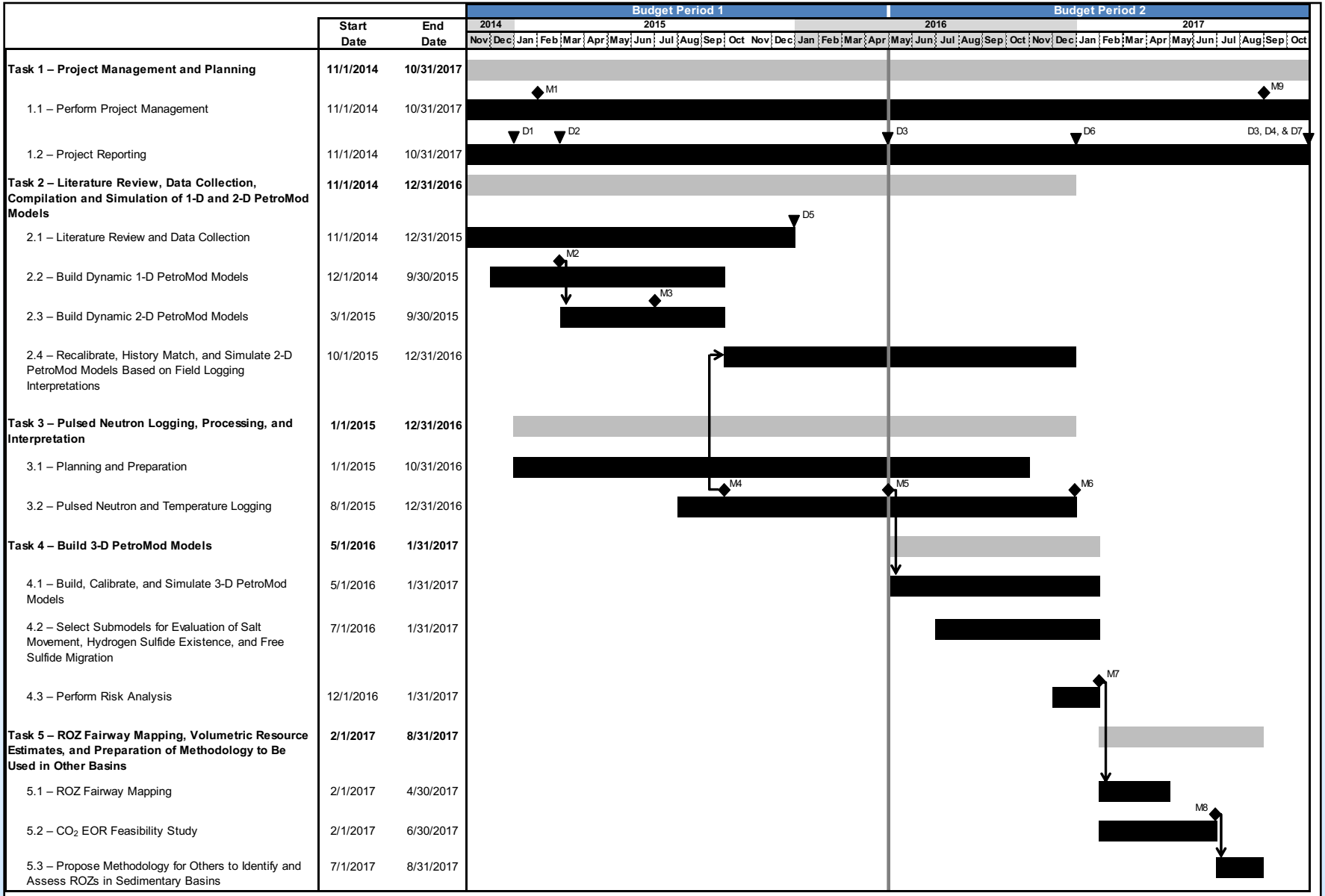
ROZ



Modified from Melzer (2011)

Organization Chart





Summary Task
Activity Bar
Milestone (M)
Deliverable (D)
Critical Path

Key for Milestones (M)	
M1 – Project Kickoff Meeting Held	M8 – Resource Assessment Completed
M2 – First Cross Section of 1-D Model Completed	M9 – Debriefing Meeting with Operators Held
M3 – Potential ROZ Indentified	
M4 – First PNL Interpretation Completed	
M5 – First Round of PNL Collection Completed	
M6 – Second Round of PNL Collection Completed	
M7 – Risk Analysis Completed	

Key for Deliverables (D)
D1 – Updated PMP
D2 – Project Fact Sheet
D3 – Data Submission to EDX
D4 – Final Report
D5 – Literature Review Summary
D6 – Conference Paper
D7 – Peer-Reviewed Journal Article

Rev. December 17, 2014

Bibliography

- No peer-reviewed literature to date.