Reservoir Modeling for Wabamun Area CO_2 Sequestration Project (WASP)

Davood Nowroozi

Don Lawton

Effect of production/injection on Geophysical parameters

- Production or injection makes change in fluid parameters as saturation and pressure and they cause changes in **wave velocities and amplitude**

- Geomechanical changes in a reservoir can make new **fractures** or physical movement in reservoir formations (collapse/swell is detectable if within seismic resolution).

Research steps

- Reservoir simulation
- Prediction of plume fate and dynamic parameters in a real reservoir
- Seismic modeling for each separate part (cell) of reservoir considering changes in dynamic parameters
- Predicting geophysical behavior of whole reservoir considering injection or production

Work Flowchart

- Gathering geological, petrophysical and reservoir data
- Create geo model files for simulation
- Schedule for production or injection
- Choosing suitable simulator (Black oil or Compositional)
- Simulation
- Develop dynamic parameters for seismic modeling and interpretation

Reservoir simulation

- A numerical modeling method that interprets physical phenomena for discrete cells in reservoir, extending in:
  - (a) time
  - (b) space
- The equation is solved for each cell and each time step (combination of the material balance and Darcy's law)

Simulators

Function of Pressure , Isothermal, Fast, Inexpensive

Black-oil Simulators

•*Three-phases (oil, gas, and water)*

•*Three components (oil, gas, and water)*

•*All fluid properties are functions of pressure*

Suitable for cases with recovery mechanics not sensitive to composition changes in the reservoir fluids such as primary recovery, solution gas drive, gravity , drainage, gas cap expansion, water drive, water injection and gas injection without mass transfer

Multi phase, Complicated, Expensive

Compositional simulator

Multi-component and multi-phase reservoir simulators based on EOS modeling.

Suitable for cases sensitive to compositional change in reservoir fluids such as primary depletion of volatile oil, gas condensate reservoirs and pressure maintenance in such reservoirs. In addition multiple contact miscible gas injection, CO_2 and N_2 injection

Reservoir Simulation

1) Darcy's law $$q = -\frac{k}{\mu}\nabla P$$

q: The flux , ∇P:pressure gradient , µ:Viscosity, k: Permeability

2) Material Balance

$$-\frac{\partial J_x}{\partial x} - \frac{\partial J_y}{\partial y} - \frac{\partial J_z}{\partial z} - q = \frac{\partial C_l}{\partial t}$$

or $$-\nabla . M = \frac{\partial}{\partial t}(\emptyset\rho) + q$$

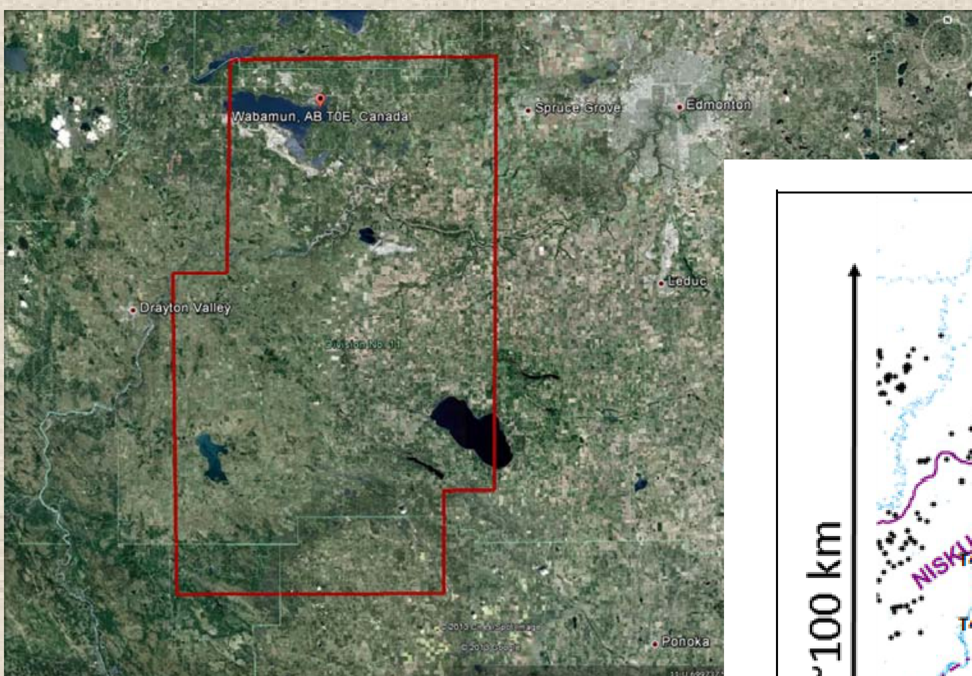
Mass flux =Accumulation + injection/production

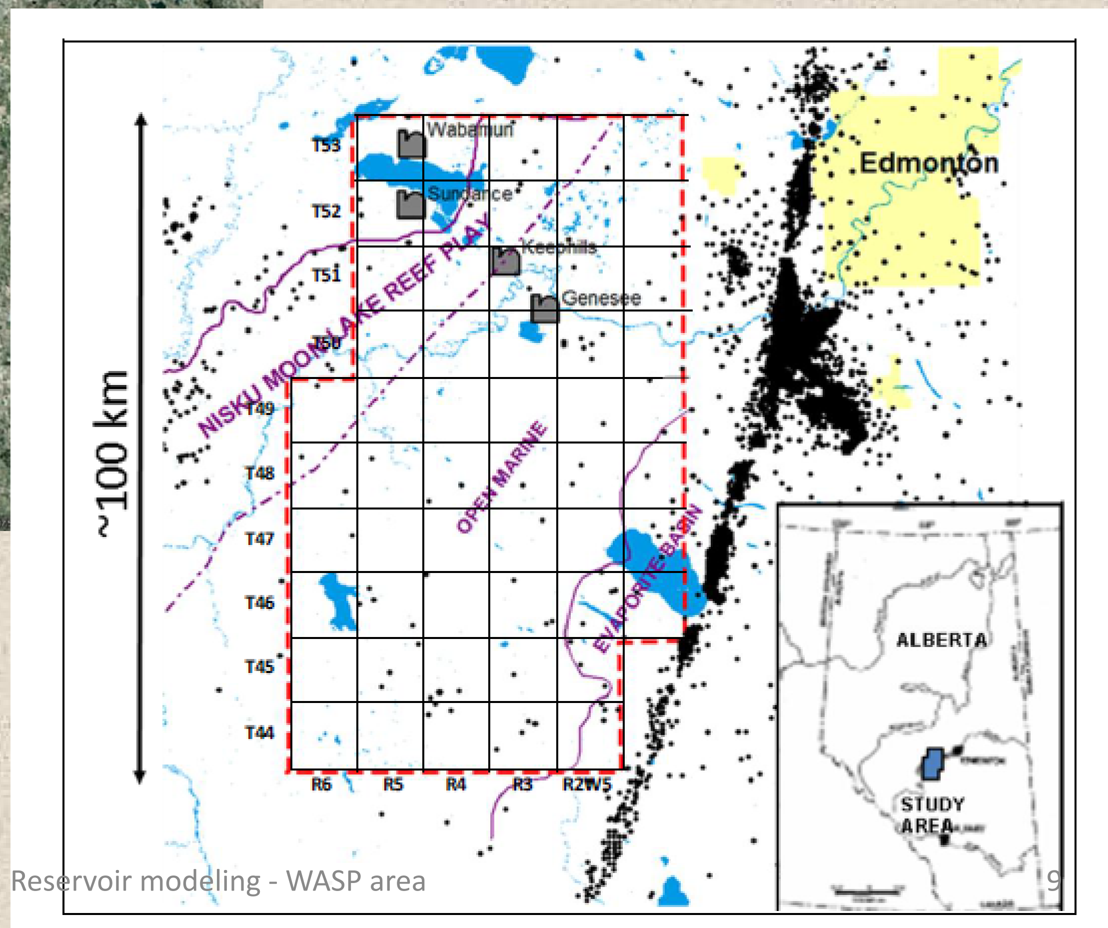
3) and simulator flow equations

Requirements for effective storage

- Capacity or Porosity of reservoir,
- Injectivity or Permeability of reservoir
- A secure volume or good cap-seal condition

WASP Project area



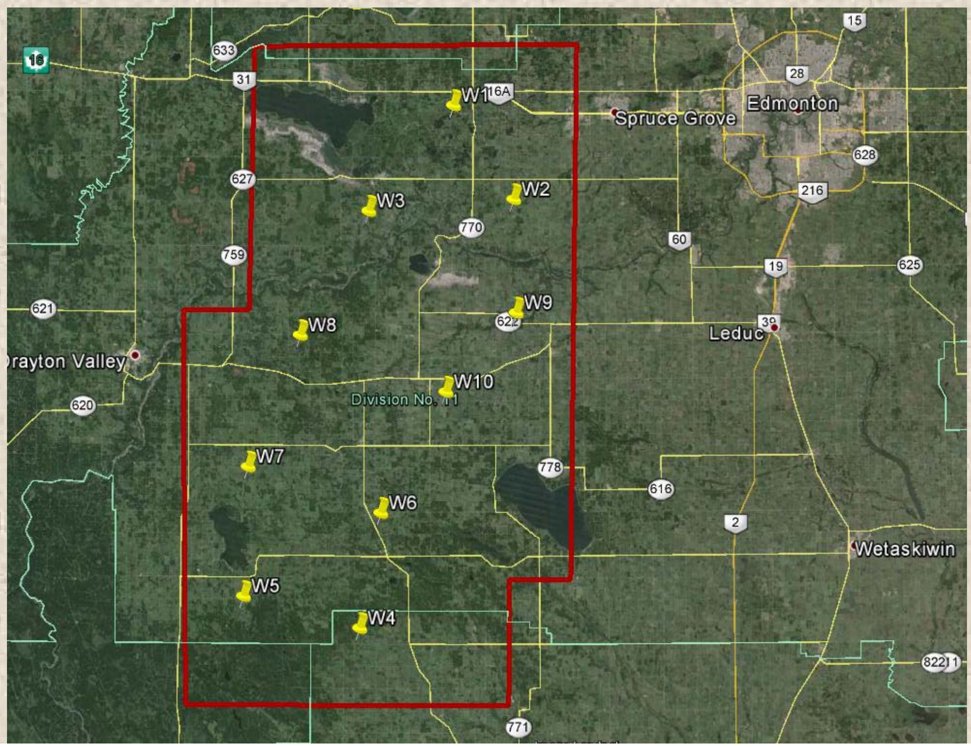


Wabamun project

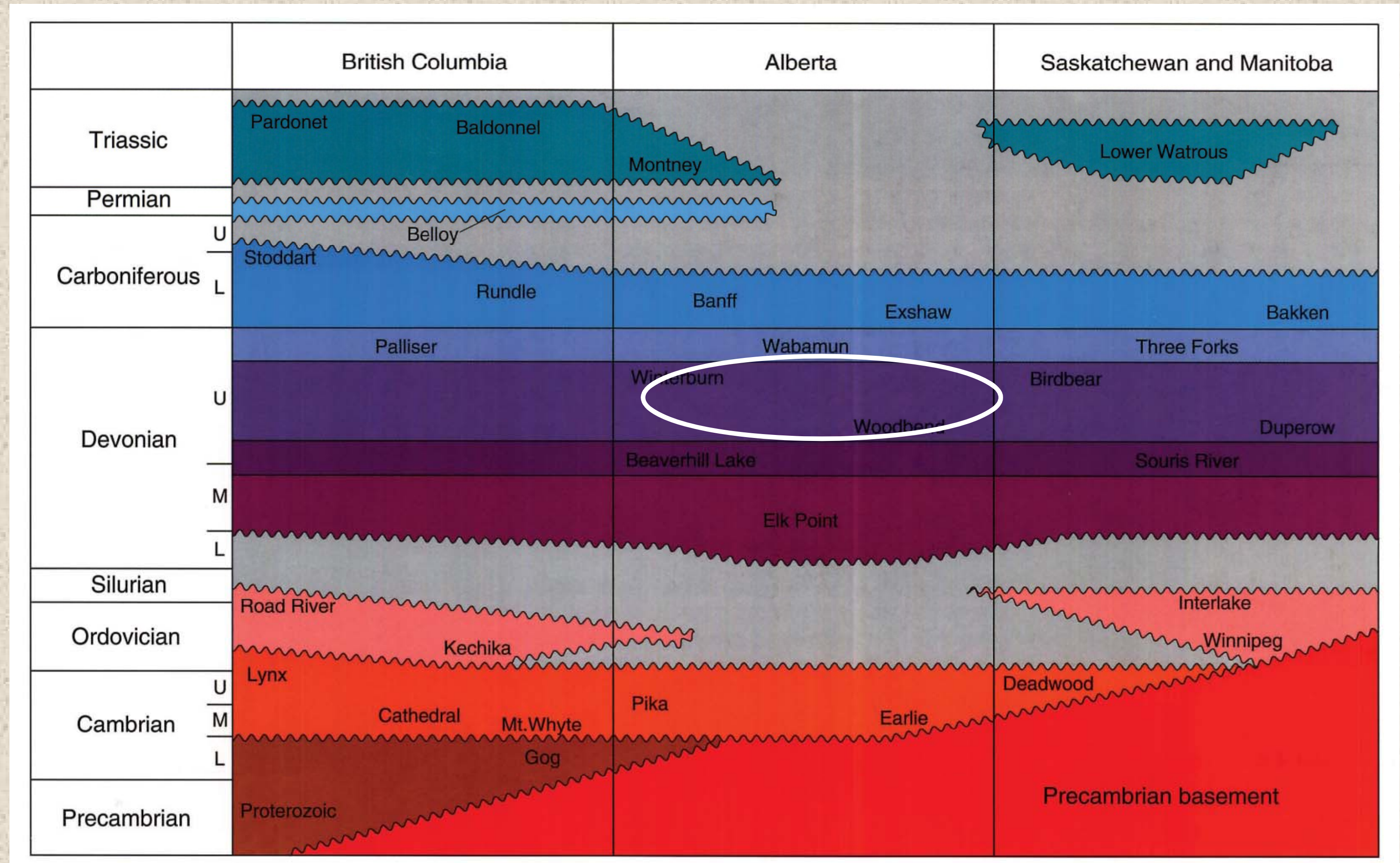
- Area ~ 5030 Km^2
- Aquifer : Nisku formation – Dolomite
- Cap: Calmar – Dolomitic shale
- Data sources for creating geomodel: 79 well logs, 13 core data, 199 2D seismic line, 22 Drill stem test (DST) and mineralogy data (C.L. Eisinger et al., 2009)
- No of Cells: 193*122*30 (over 706380 cells)
- Cell size :500*500*(2-6)m

Injection plan

- Injection schedule :No of injectors (Wells) : 10
- Bottom hole pressure: 40 MPa (constant)
- Injection duration: 50 years



Stratigraphy around the Nisku aquifer



Injection goal

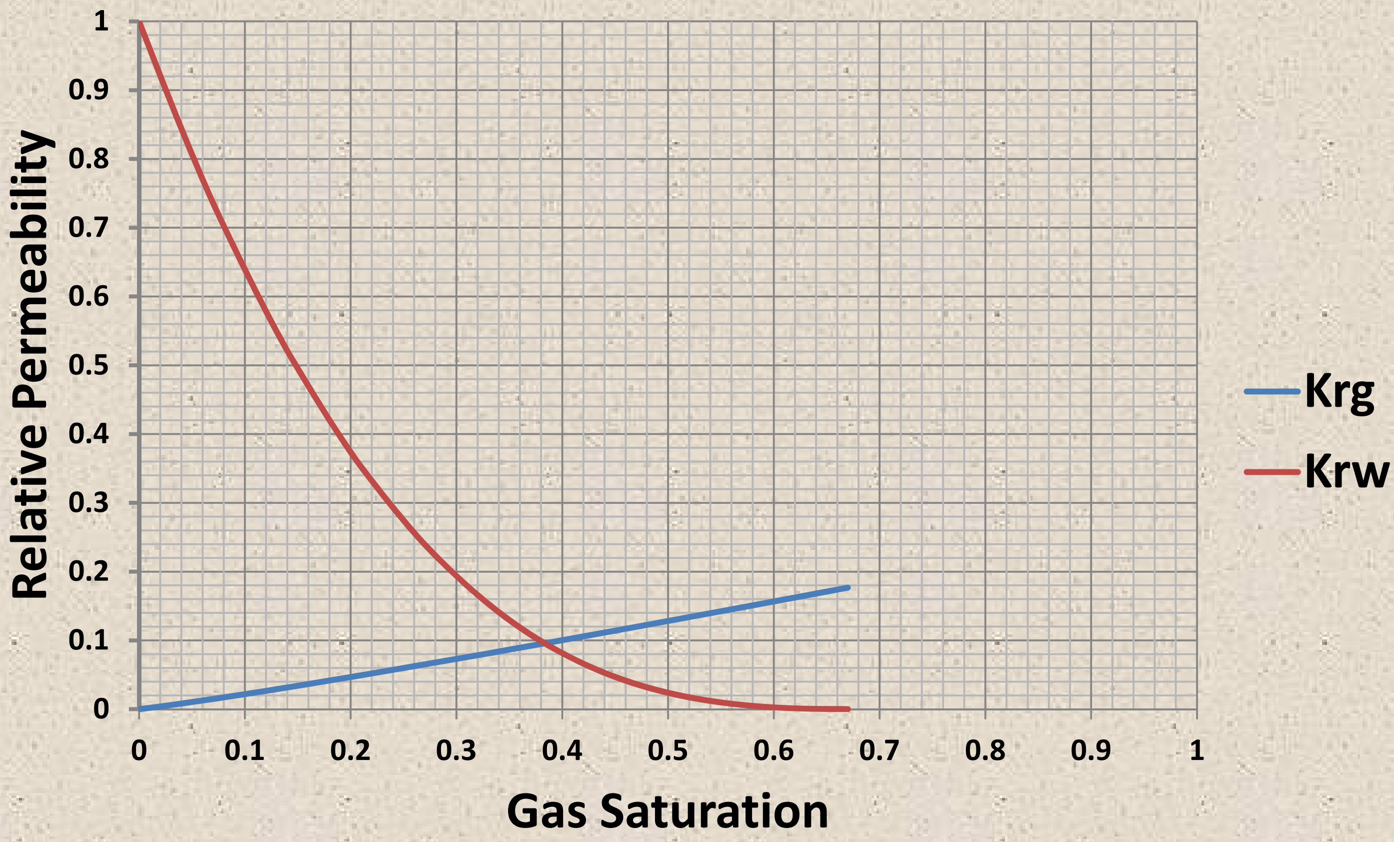
- 20Mt/year storage capacity for all the wells

Total one Gt for 50 years

Simulation goal

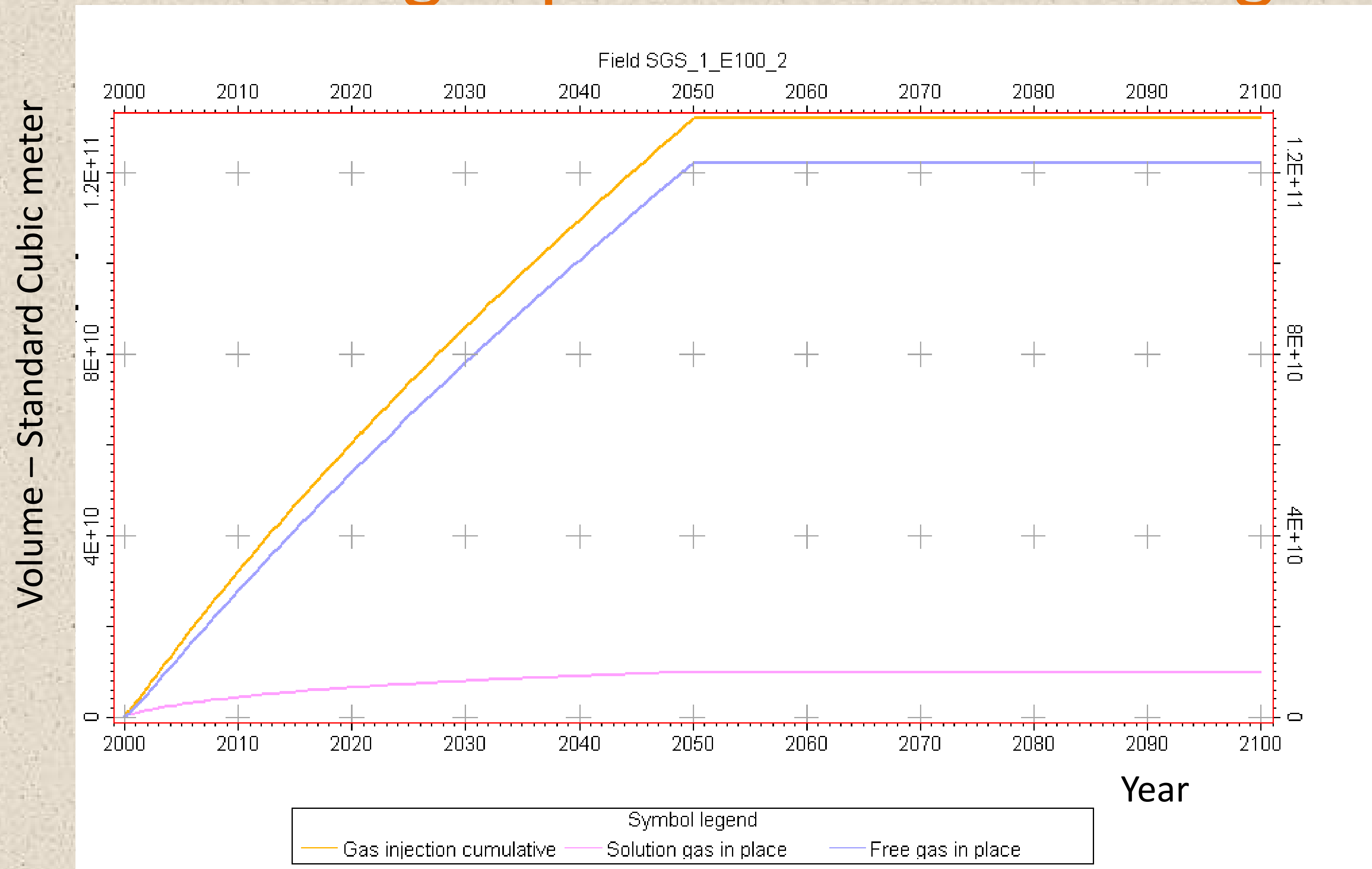
- Capacity for CO2 on the present schedule
- Distribution of pressure and Gas Saturation in reservoir
- Distribution of reservoir parameters after discontinuing injection
- Create usable output for 4D and AVO models

Relative permeability

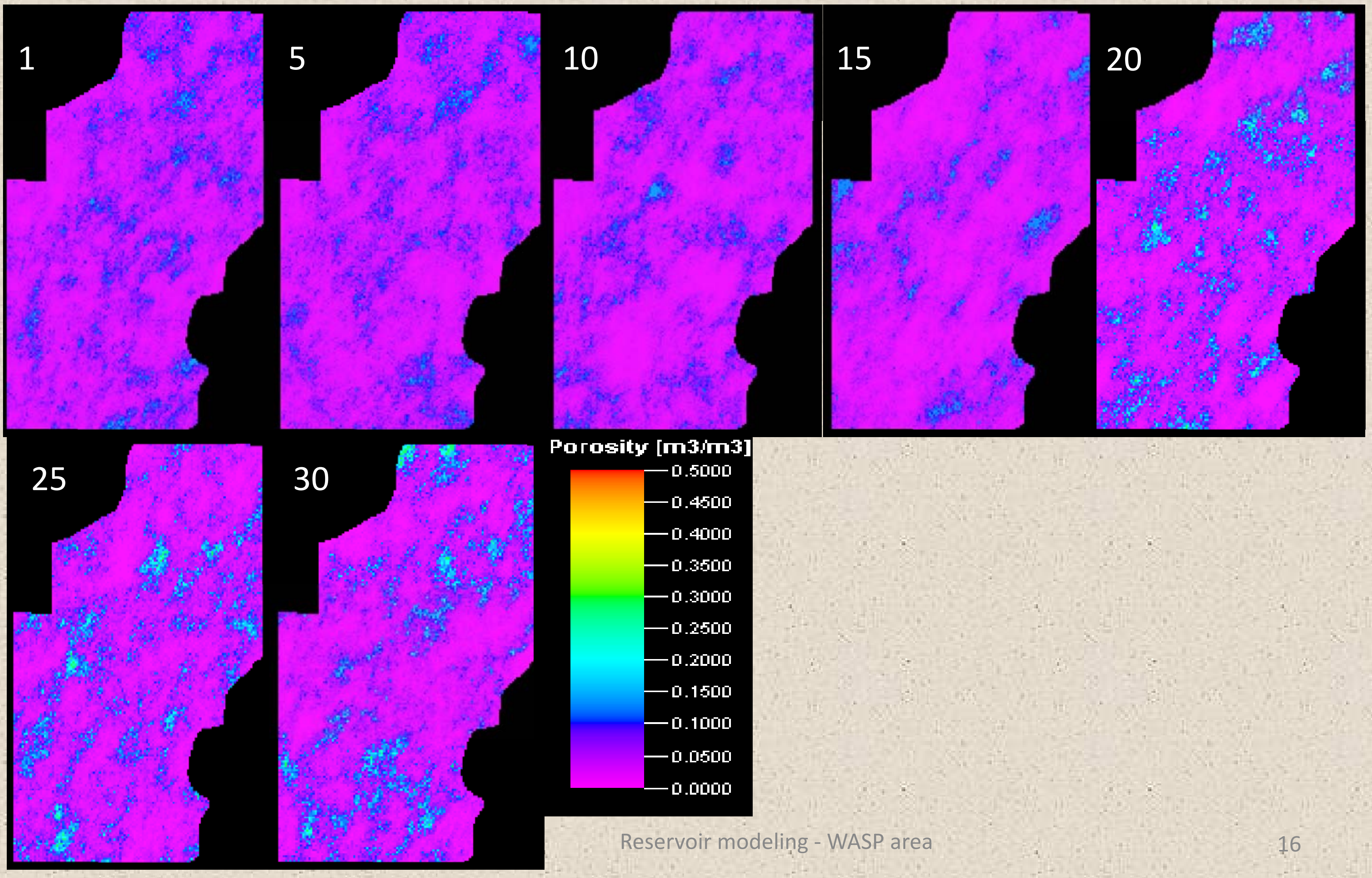


Gas-Water relative permeability diagram for Nisku acquifer (WASP area) (Bennion and Bachu, 2005)

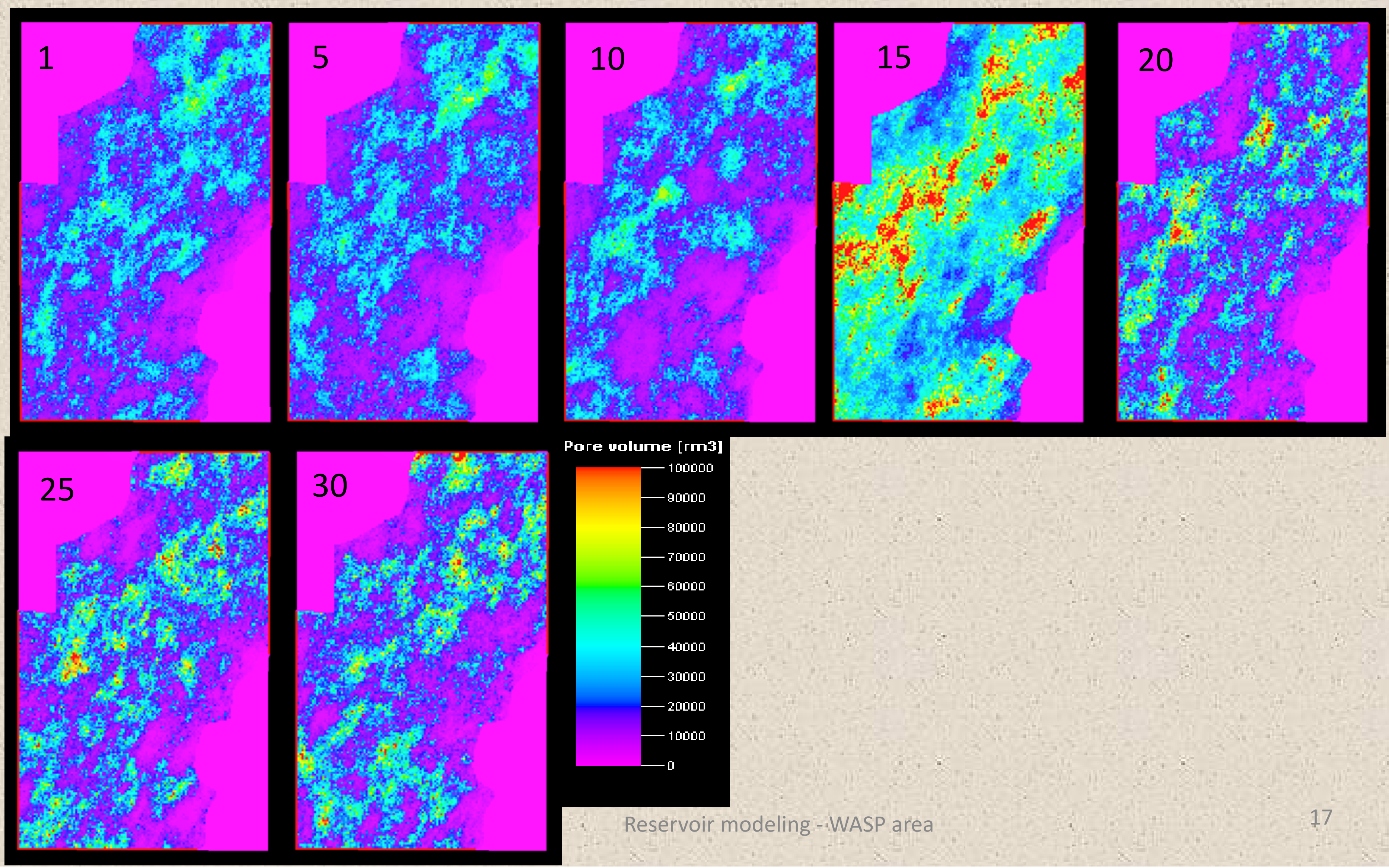
Total gas injection volume and portion of free gas phase and solution gas



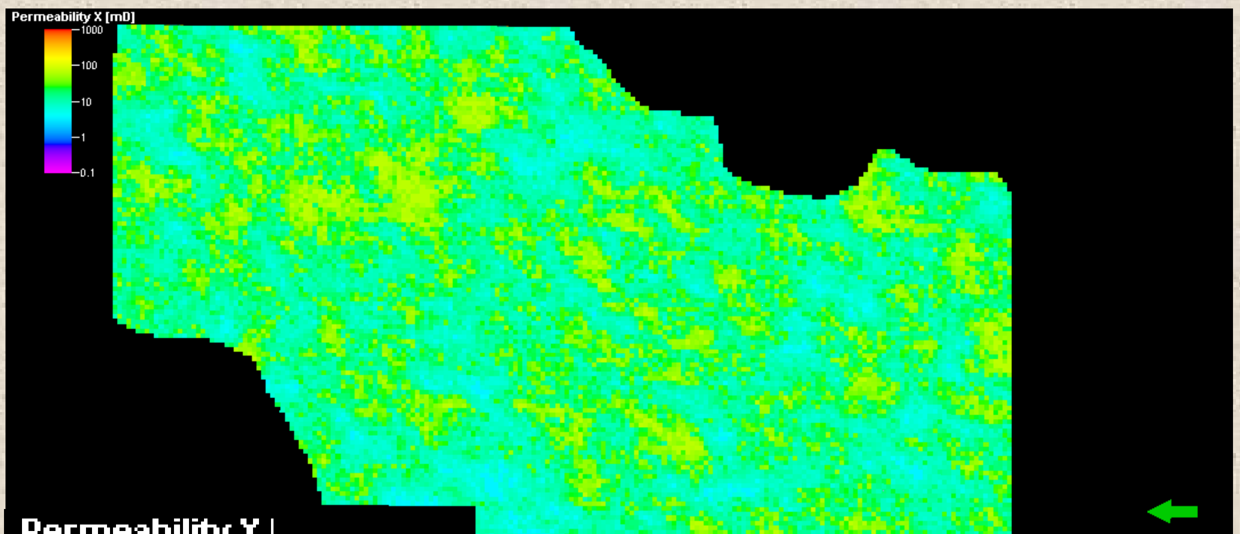
Porosity map in different horizons

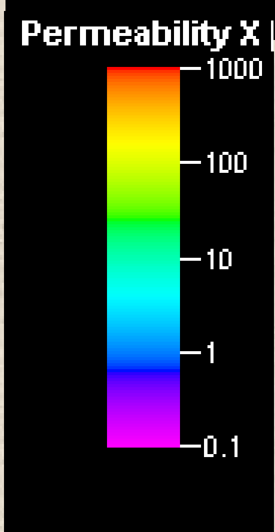


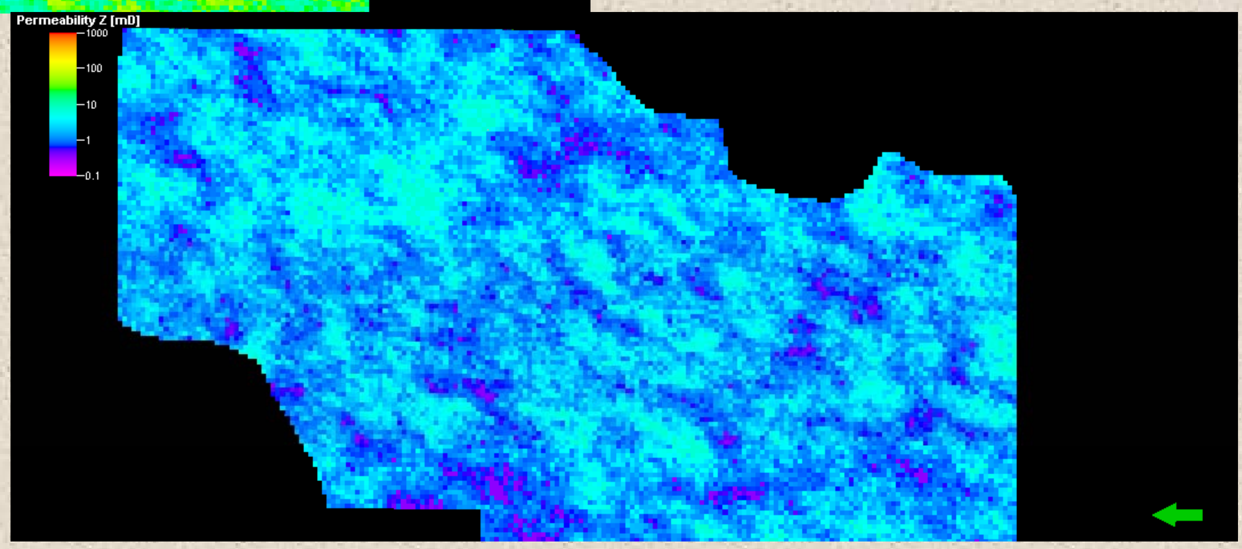
Pore Volume at reference conditions



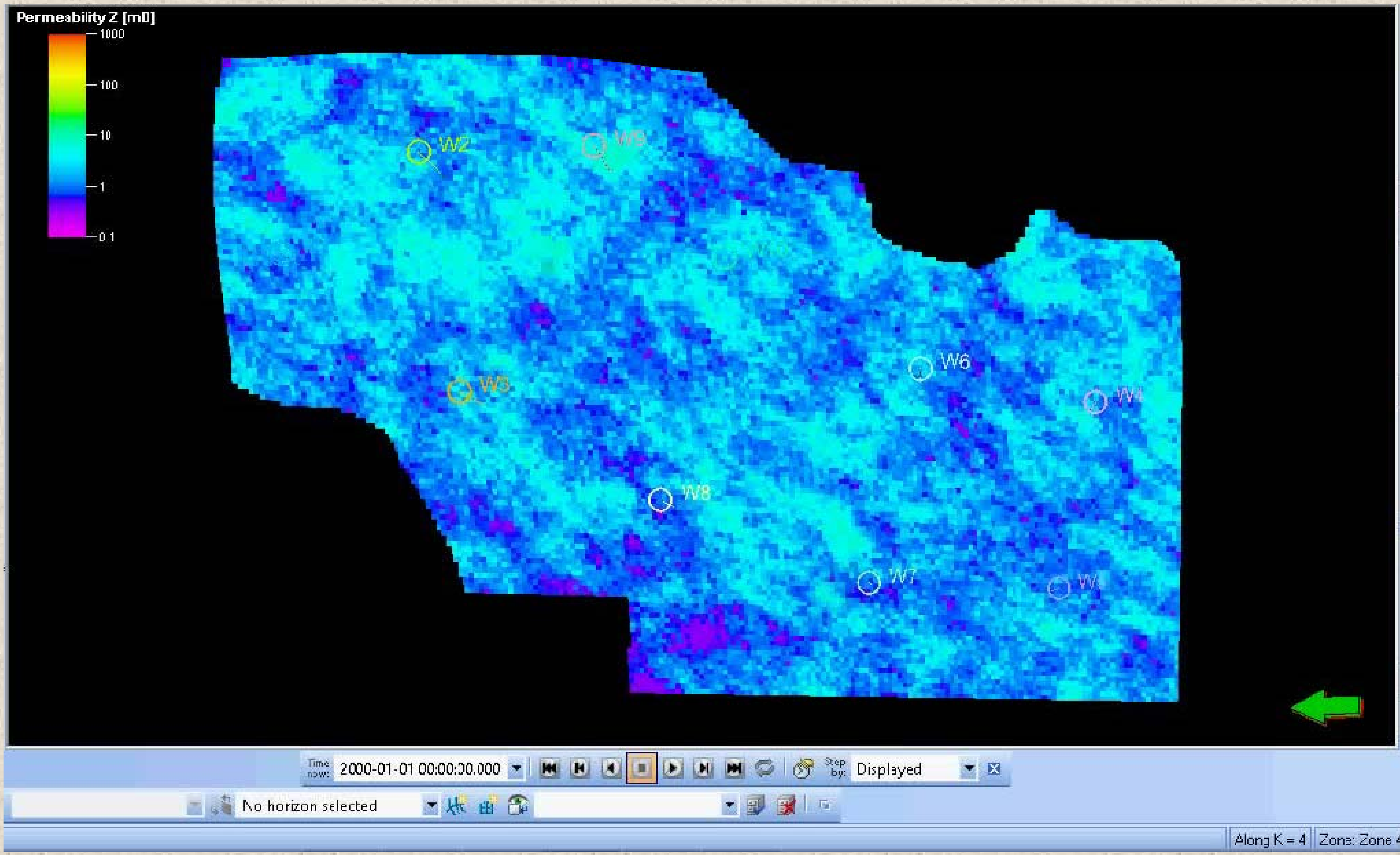
Permeability map



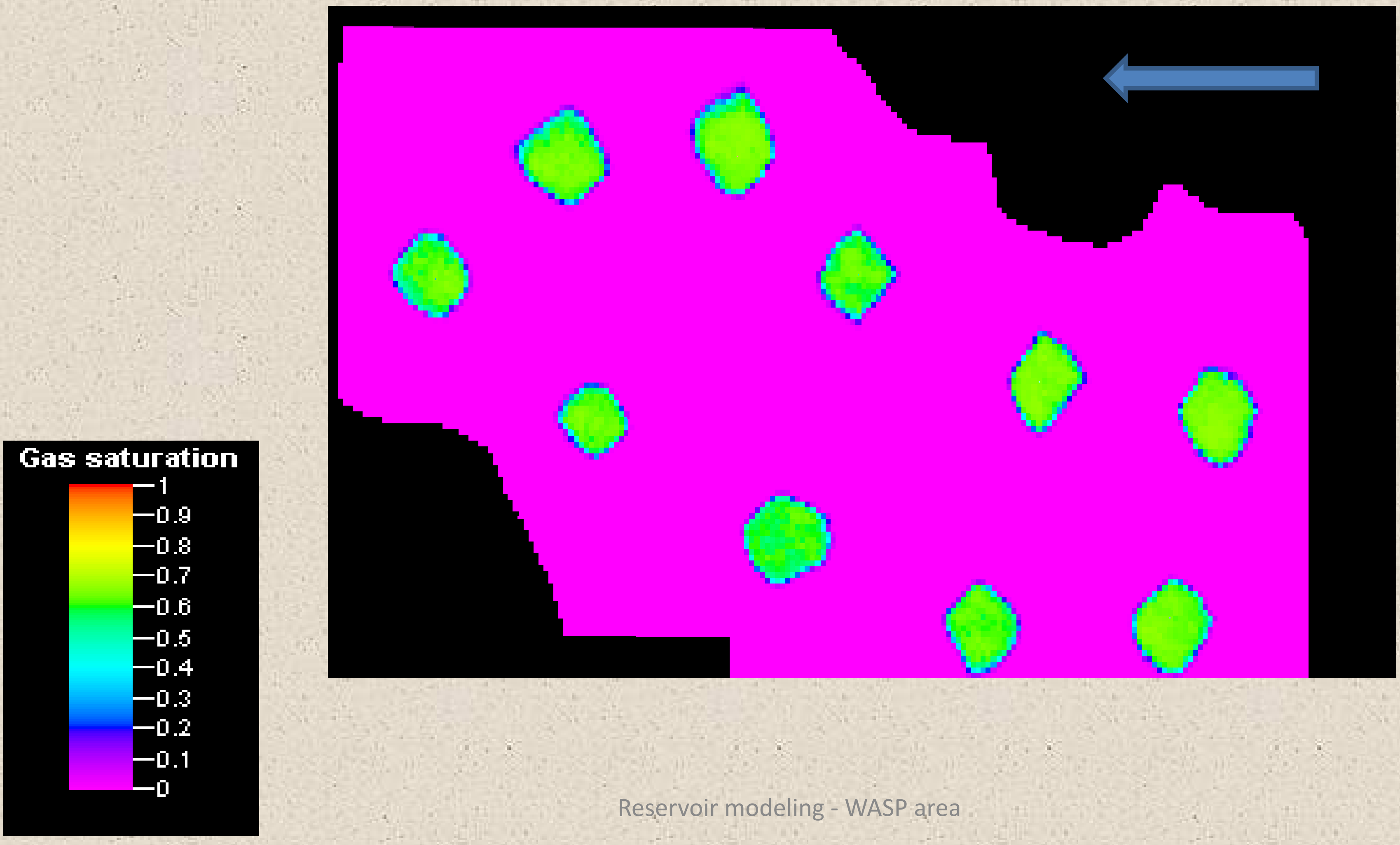




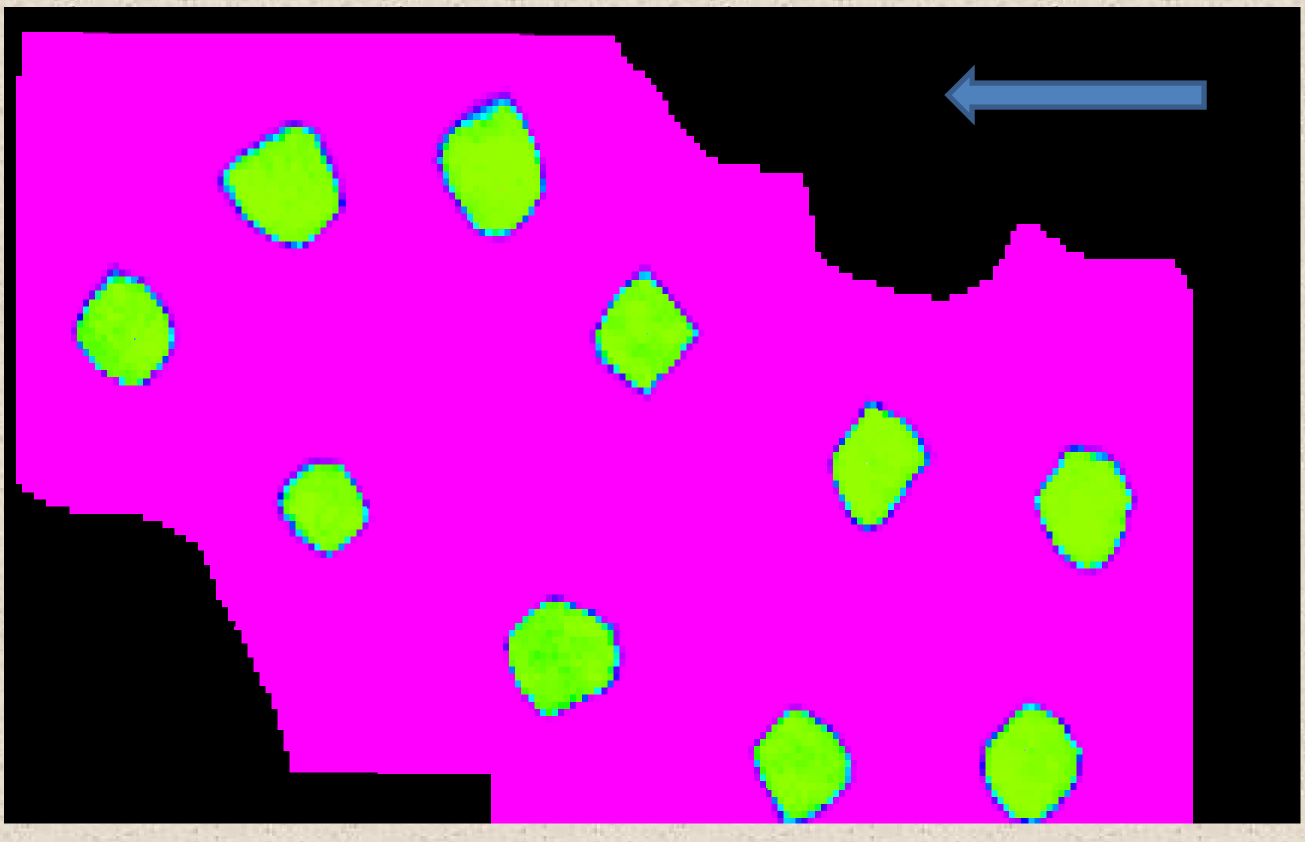
Z permeability in 30 horizons

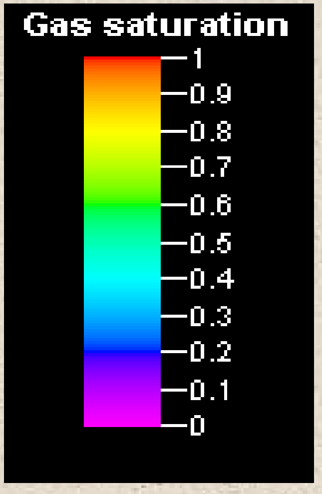


Gas saturation map, 50 years after injection

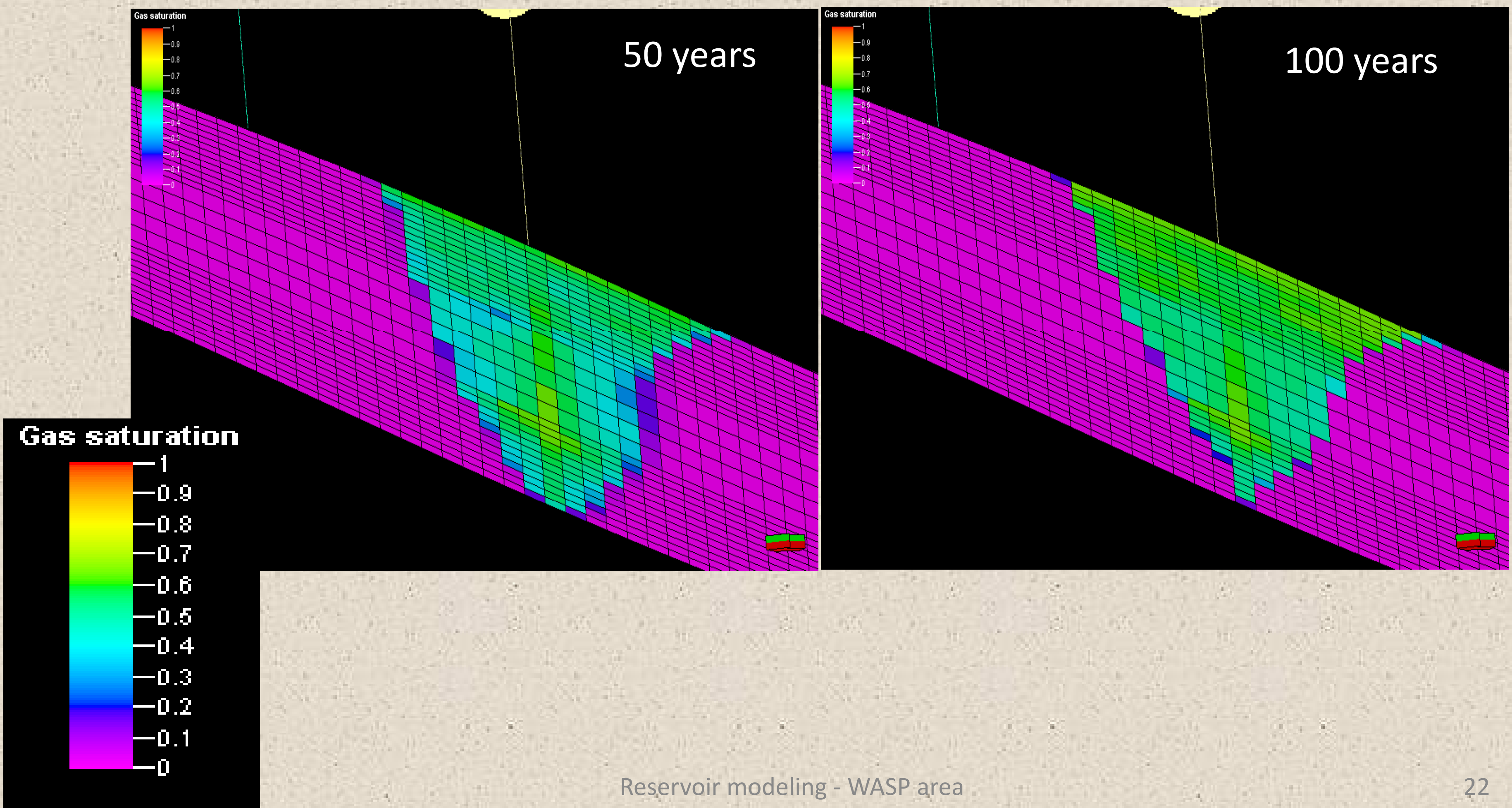


and 100 years after injection

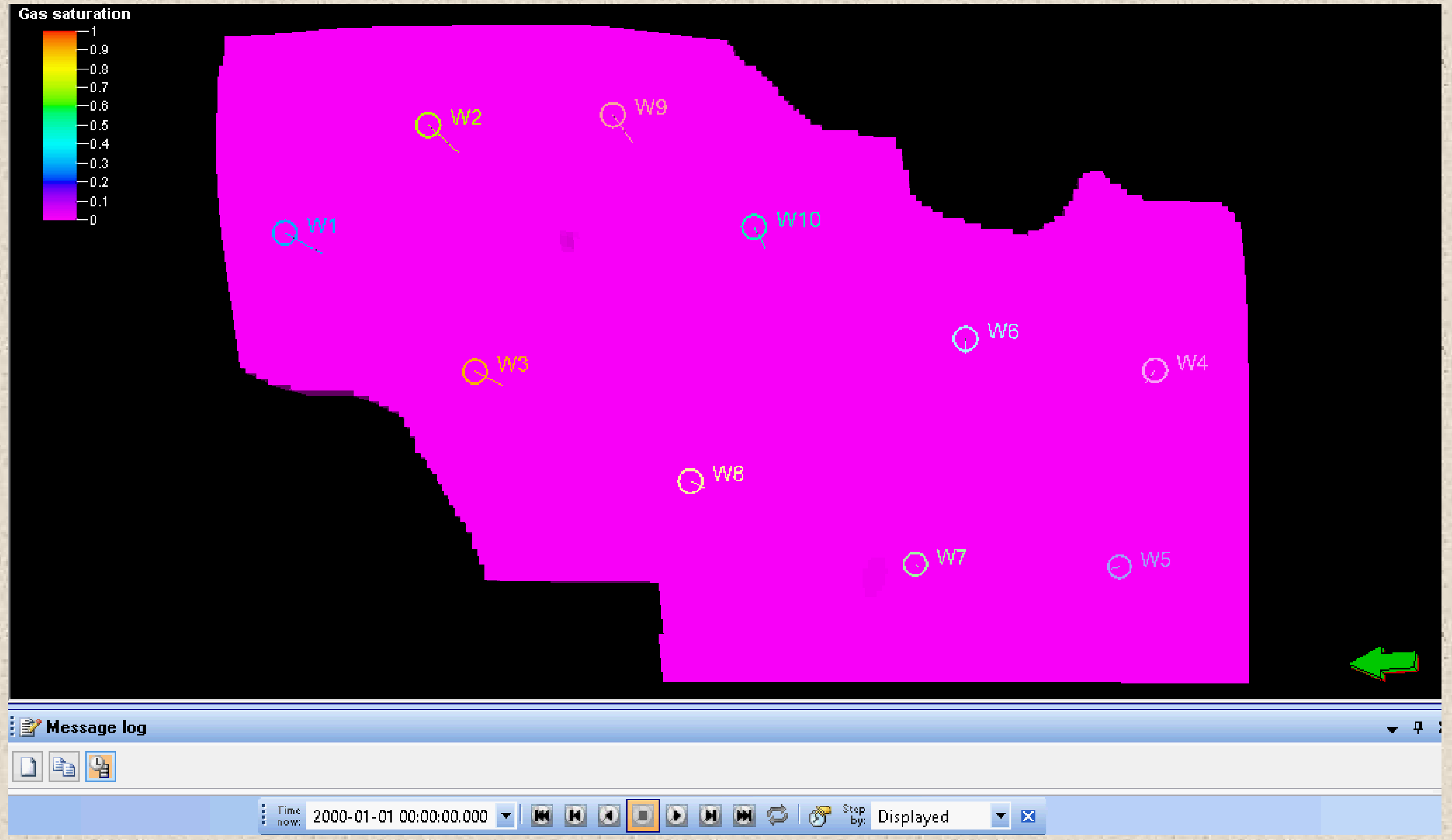




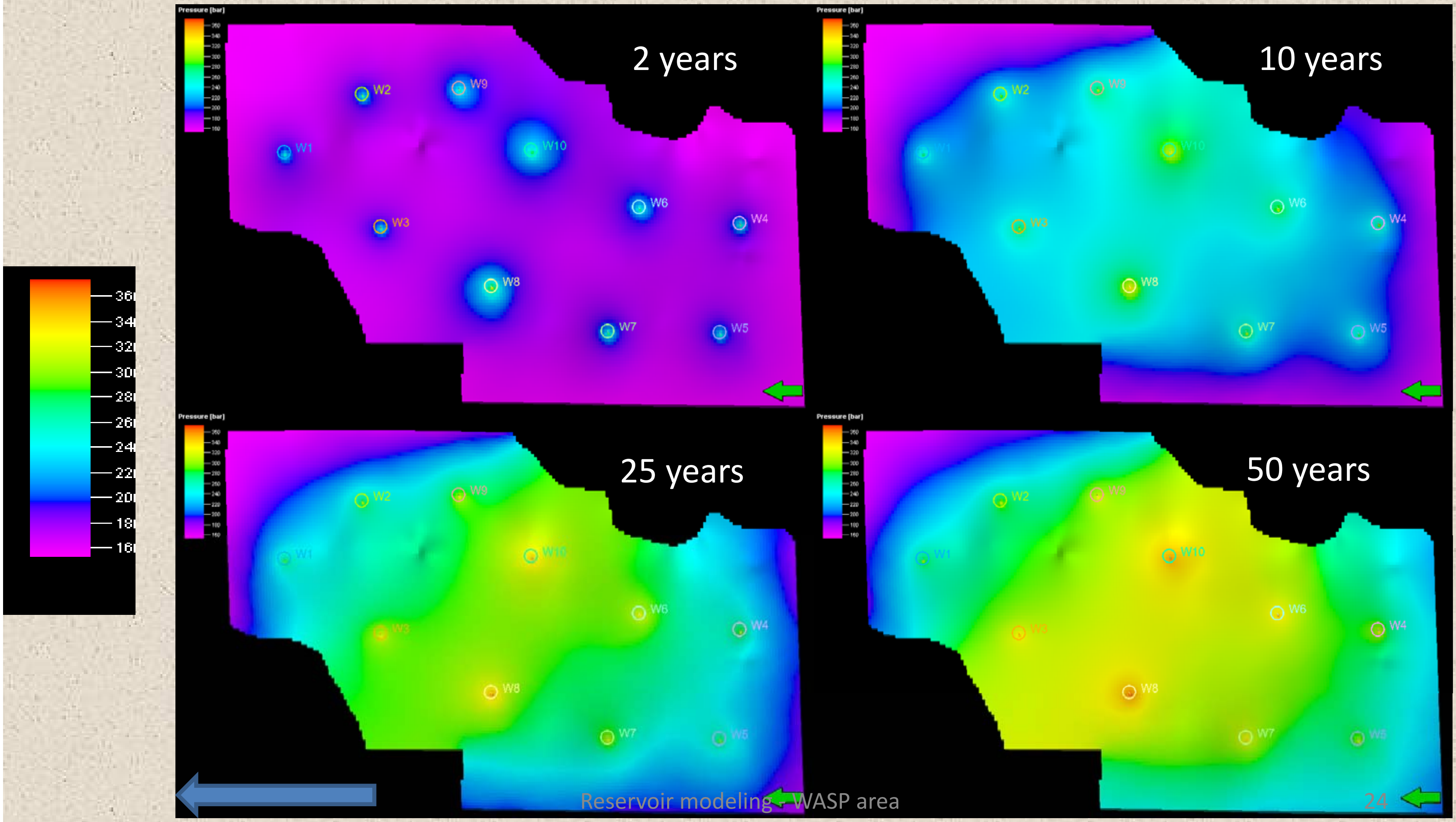
Gas saturation in well8 (XZ section) in 50 and 100 years



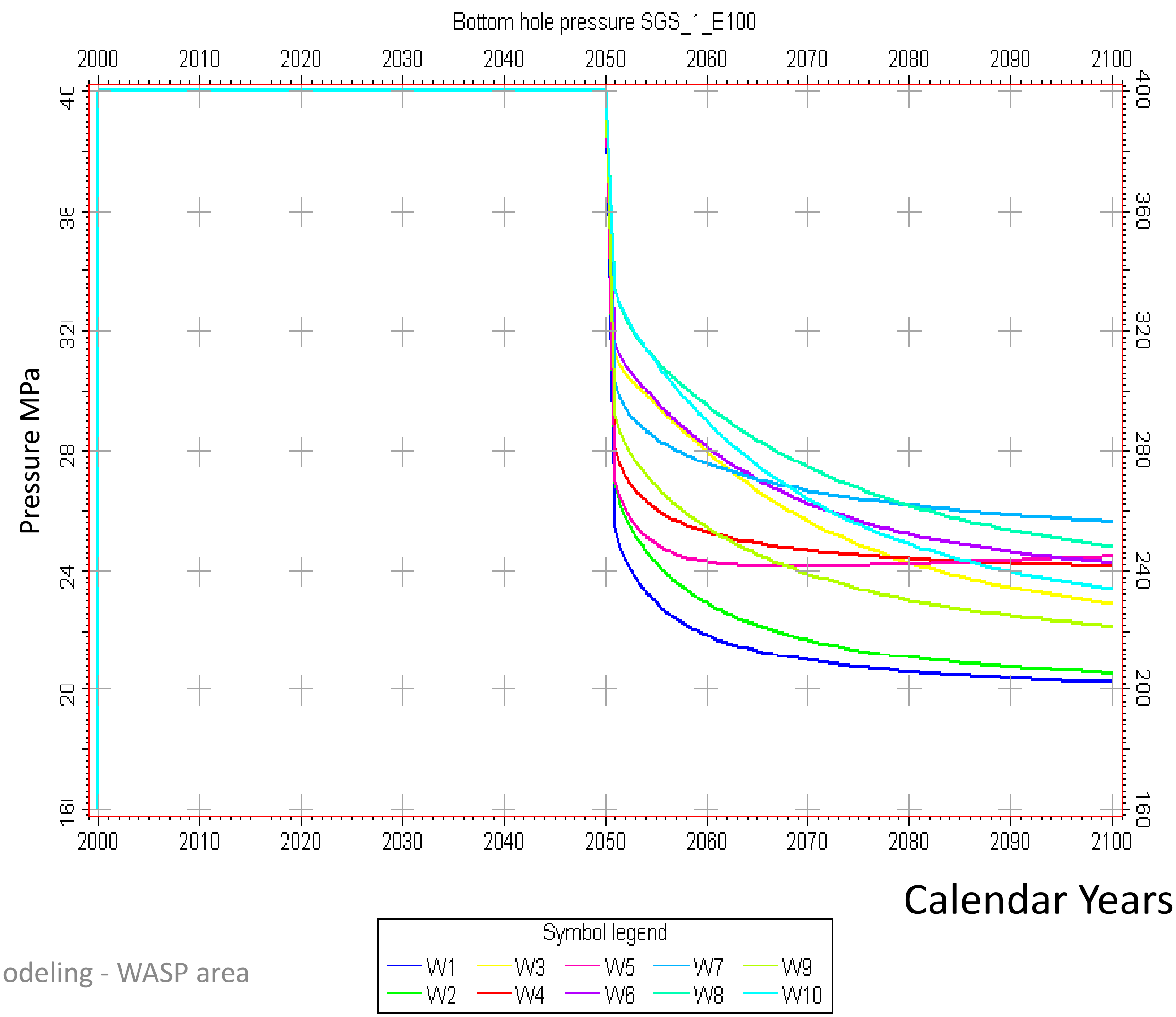
Gas Saturation change for 100 years(Animation)



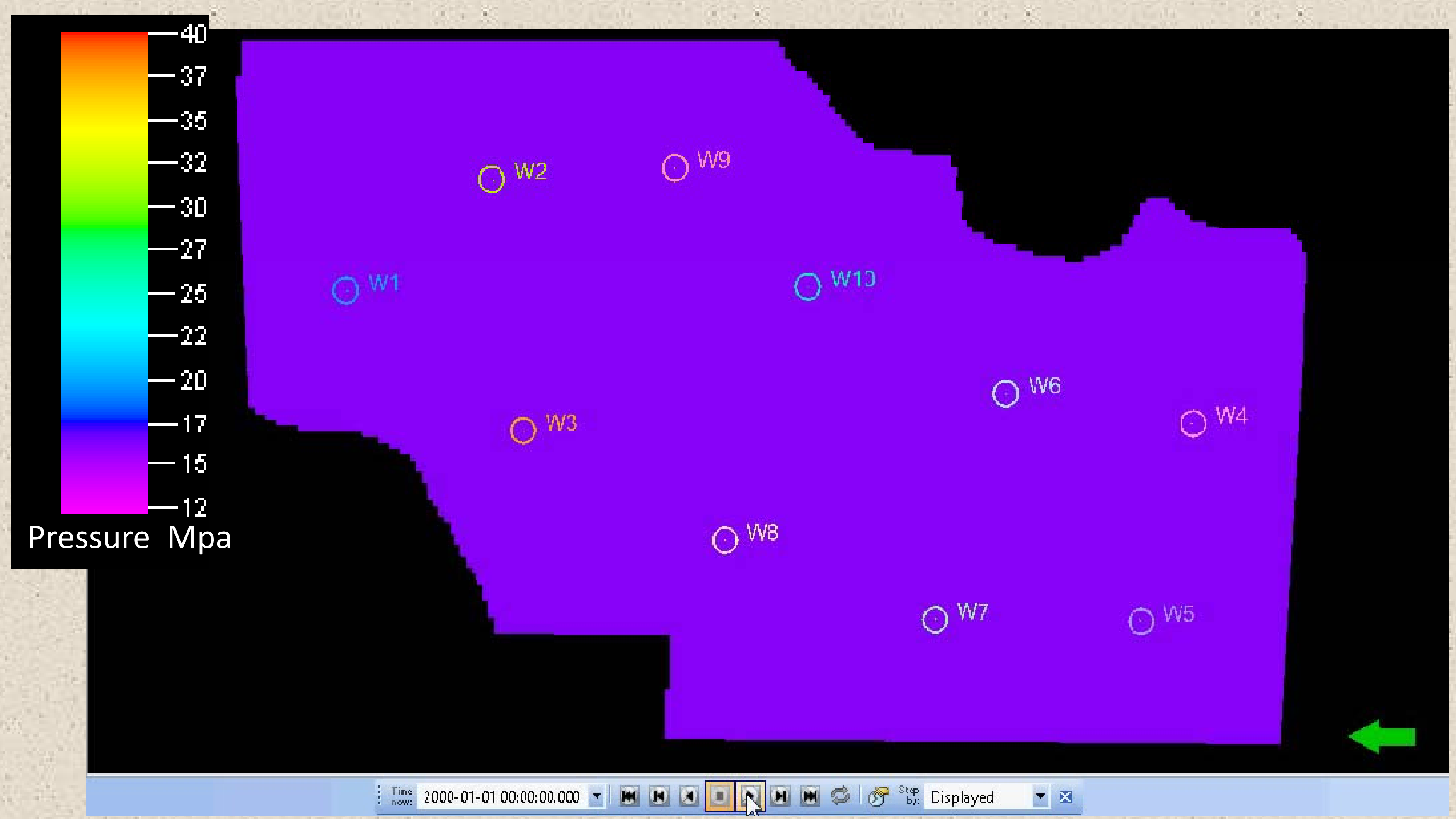
Pressure change during injection



Pressure change after injection in wells



Pressure change in reservoir during injection (Animation)



CO_2 Capacity

Well	Cumulative injection (Billion sm^3)	Cumulative injection (Million Ton)	Portion of each well
Total Field	132	244	100.0
W1	17	32	13.2
W2	12	23	9.5
W3	6	12	4.9
W4	11	20	8.0
W5	15	27	11.1
W6	8	15	6.3
W7	11	20	8.2
W8	22	41	16.9
W9	12	23	9.4
W10	16	30	12.4

Conclusions

- Current schedule can inject 25% of CO2 that power plants produce
- Pressure transmission is faster than gas phase and affected the whole reservoir

Next steps

- Check other injection scenarios
- Integrating reservoir data for create geophysical model for each cell , and make a synthetic model for whole reservoir
- Reservoir geomechanical study and numerical time lapse geophysical monitoring

Acknowledgments

- Dr. D.C. Lawton
- Dr. H. Hassanzadeh
- Dr. S.A. Ghaderi
- CREWES Team and sponsors
- Schlumberger for software (Petrel and ECLIPSE)

Thank you