CAGS Technical Workshop
Canberra 18th – 22nd January 2010

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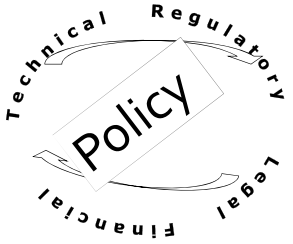
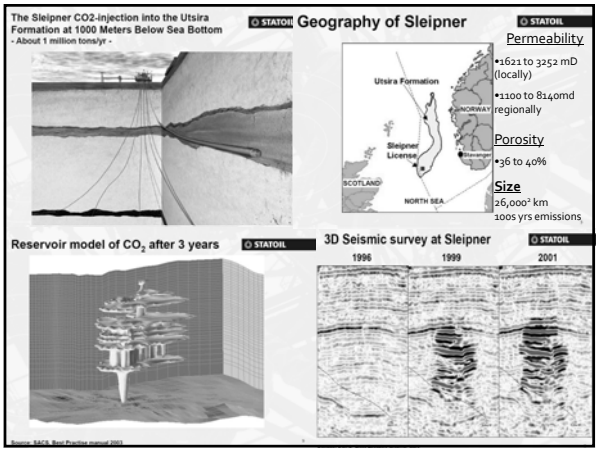
GEOLOGICAL STORAGE: CHALLENGES AND OPPORTUNITIES

"It's not just a technical problem"

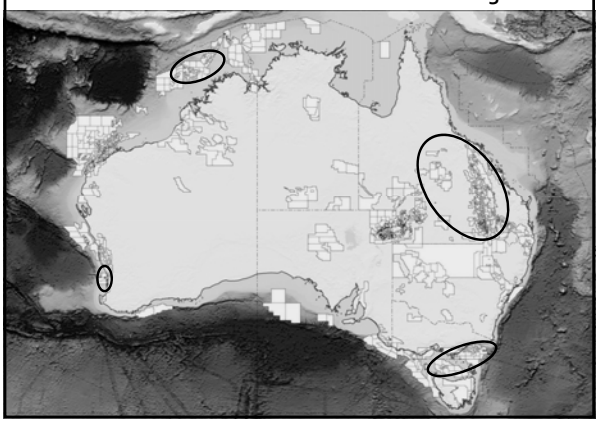




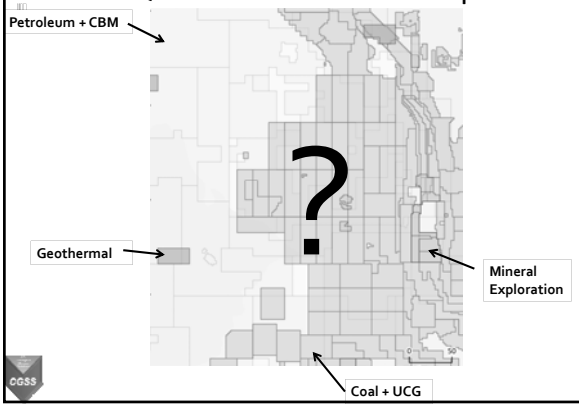
POLICY & LEGAL

Issue : Policy & legal are way bigger than people appreciate?

Petroleum Leases versus areas of interest for Storage



Queensland Permit Overlap

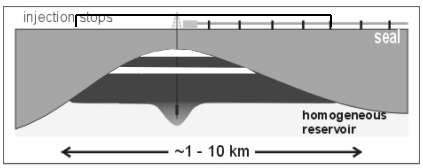


Injection scenarios?

- Consider how the following scenarios (geo-cartoons to follow) impact on;
  - technical, regulatory and legal aspects?
- Structural (physical) trapping
- Chemical trapping
- Migration pathways
- Pressure transmission

Conceptual CO_2 Storage Scenario

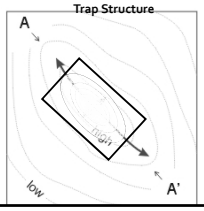
depleted field / structural trap



Assigning permits relatively easy – tightly constrained

But what if hydrocarbon discovery already exists, or believed to exist in structure? EOR - Sequenced development?

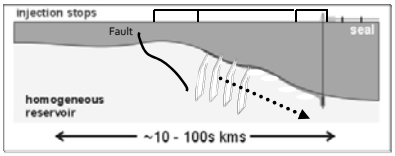
Or hydrocarbons found later - Which operator? – Who gets priority?



(template slide courtesy of Robert Root)

Conceptual CO_2 Storage Scenario

hydrodynamic / residual gas / solution trap **(MAS – Migration Assisted Storage)**

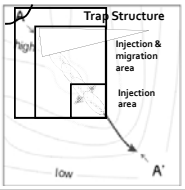


Where do you put permit boundaries ?

How big do you make permits?

What access rights do you employ?

What if there are two storage operators – co-mingling of CO_2?



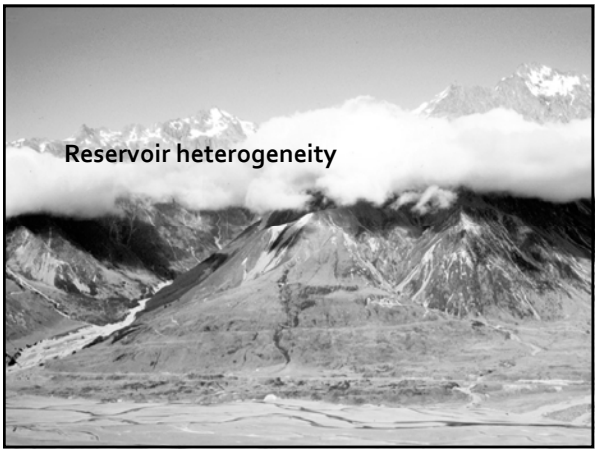
(template slide courtesy of Robert Root)

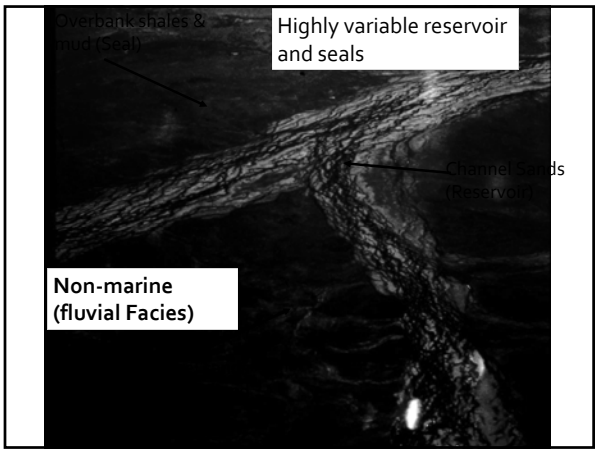
What about where Storage won't scale up locally?

- Oil & Gas Resources "uneven distribution"
- Long Pipelines
- Ship Transport
- Right strategy needs implementing based on reality of local geology
  - Long Pipelines & Ship
  - Non-coal energy source
- The value placed on CO_2 will influence the above;
- Either socially, financially or inter-generationally

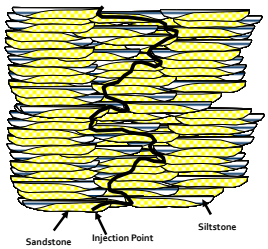
THIS IS JUST A TECHNICAL (SCIENCE & ENGINEERING) CHALLENGE .. ISN'T IT?

... plus getting the economics right to do it …





Braided Stream Deposits

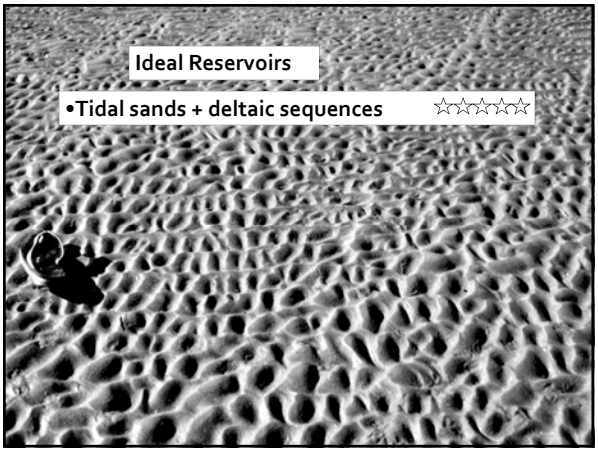


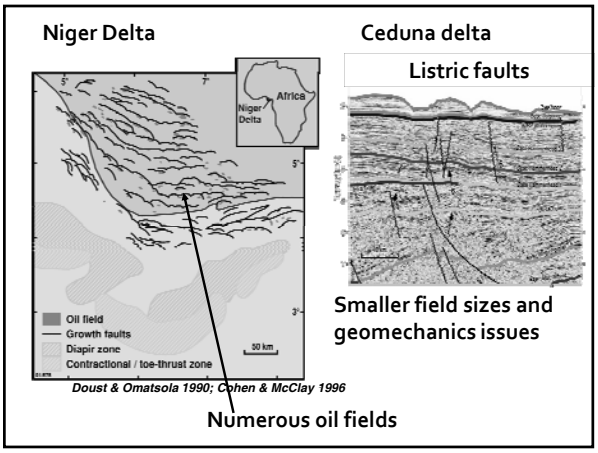
1. Channel sands
2. No continuous sealing surfaces.
3. Not sure of reservoir inter-connectivity
4. Multiple vertical migration path for buoyant fluids

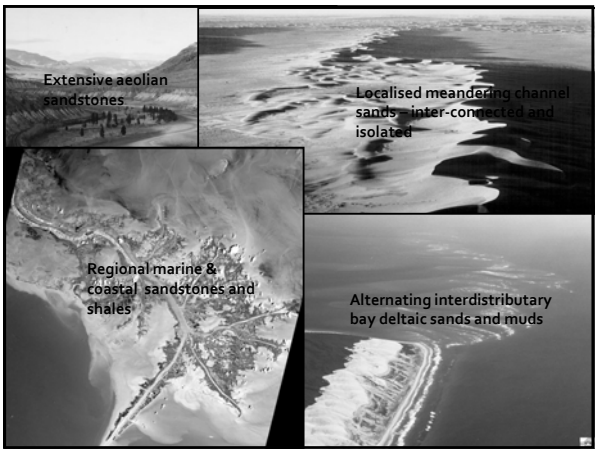
Can we model such complex and tortuous migration pathways ?

Are our reservoir simulators up to it?

How many wells required to fill this pore space







Depositional Environments

- Highly variable
- But predictable
- Need good modern analogues to compare to the ancient rocks
- Conventional Petroleum Geology production issues
- Normal Reservoir Engineering challenges
- **Again; ….. this is just doing our homework properly – normal business practices**

If we scale up – the detail in the rocks is where the real battle will be fought !

What about the number of wells required?

Issue : We must pay a lot of attention to well numbers

… it could be embarrassing (costly) if we get this one wrong ….

No.'s of Wells vs Reservoir Quality

INJECTION REQUIREMENT	Mt CO_2 / year	Environment, Age & Depth	No. of Wells	Reservoir Quality	Wells for 10 Mt CO_2 PP
"Best" Coal	0.002 to	Coal	1	ry very poor	531
		Marine: mass flow - young, 1200m	1	Superb 00 - 3000 mD	10
		Fluvial - old, ~ 2000m	3 (2) (horiz	Very Poor 5 - 45mD fractured	30
		Fluvial - 2500m		Good 50 - 250 mD	50
		Fluvial - 2500m		Good 50 - 250 mD	50
		Marine - young, 2500m		Superb multi D	2.3 (5?)
		Deltaic - 2000m		Superb multi D	2.5
		Deltaic, aeolian - 2000m		Very Good 0 mD (to D's)	5

Highly dependent on
•Depth and age
•Environment of dep
•permeability x thick
• assumption produc
• vertical vs horizont
• reservoir stimulatio
• onshore vs offshor
• reservoir heteroge
(capacity)
• multiple perforation
• pressure – build up,
• long term reliability

rates
itations
uity
????

?

Exists – Proposed – Modelled – Problematic

Conclusions

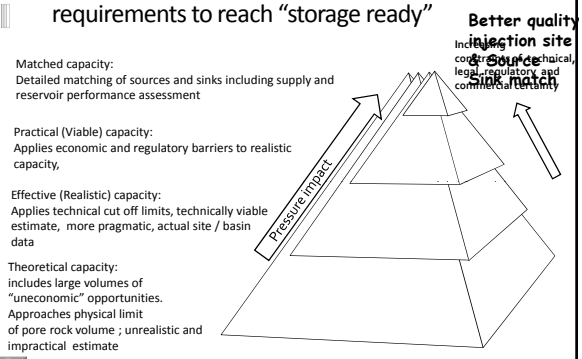
- Issues include;
- Policy, Technical, Legal, Regulatory & Financial
- … and their interactions ….
- Beware of;
- Well numbers, …. and
- Costs
- Need to;
- "*Engineer the reservoir*" due to scale of problem

Reservoir Pressure Build up

"If a site is of poor quality in terms of permeability (and thus can only accept small rates of injection), but has a lot of pore space and potential storage volume, then there will be a limit to the rate at which the CO_2 can be injected for each well. This may limit its utility as a storage site because it will require large capital costs for many wells and compressors, and, hence, quoting such a site as having large storage capacity may be extremely misleading."

Source: Bradshaw, et. al. 2007. CO_2 Storage Capacity Estimation: Issues and development of standards. International Journal Greenhouse Gas Control 2007:62-68

Storage Capacity Resource Pyramid: requirements to reach "storage ready"



Bradshaw et al 2002; Bradshaw et al 2007; Bachu et al 2007

Reservoir Pressure Build up

- Bert van der Meer (GHGT9 – November 2008)
  - Invaded space
- Van der Meer & Yavuz (2009)
  - up to a tenfold reduction in the proposed injection plan
  - threefold reduction compared with the earlier estimations of storage capacity when pressure build up was not taken into account
- Birkholzer et al (2009)
  - plume occupied a radial area of less than 2 km
  - pressure front with considerable pressure build up extended laterally for over 85 km with an area of influence of 22,000 km^2

Reservoir Pressure Build up

- Birkholzer and Zhou (2008)
  - Mt Simon Sandstone
  - pressure build-up over a large area - 15,000 km^2
  - previous theoretical storage capacity estimates based on application of storage efficiency factors and Monte Carlo simulation) ranged from 27,000 to 109,000 Mt CO_2 (USDOE, 2008)
  - geomechanical constraints are placed on by regulators, then the storage capacity may not achieve the modelled values of 5,000 to 13,000 Mt CO_2

Reservoir Pressure Build up: considerations

- fracture pressure
  - limitations that may have on storage capacity
  - Impact on injection rate, well numbers & cost
- regulatory regime
  - impact of large scale injection
- entire hydrologic regime
  - will need to be monitored
- Where pressure draw down has occurred due to production of groundwater
  - pressure build-up may be a benefit
  - provided saline water does not mix with the freshwater systems
- consider the use of pressure relief wells
  - Adds to cost

GAPS & CHALLENGES

Some Gaps & Challenges ?

- Trained staff
  - to take up the challenge
- Reliable Storage Capacity Estimates (Country level)
  - impact on Gov't policy
- Lower Capture costs (power stations)
  - up to 50 - 60% expected
- Government regulations & Storage permit access
  - Competing resources (water + hydrocarbons), Economic regime (incentive to invest), Land tenure, OHS, etc
- Access to data (digital)
  - Well, seismic, production
- Commercial Scale Sites
  - Learn by doing
- Public Acceptance
  - otherwise go nowhere
  - need Geoscientists to engage in the debate
- Gone past time for immediate action