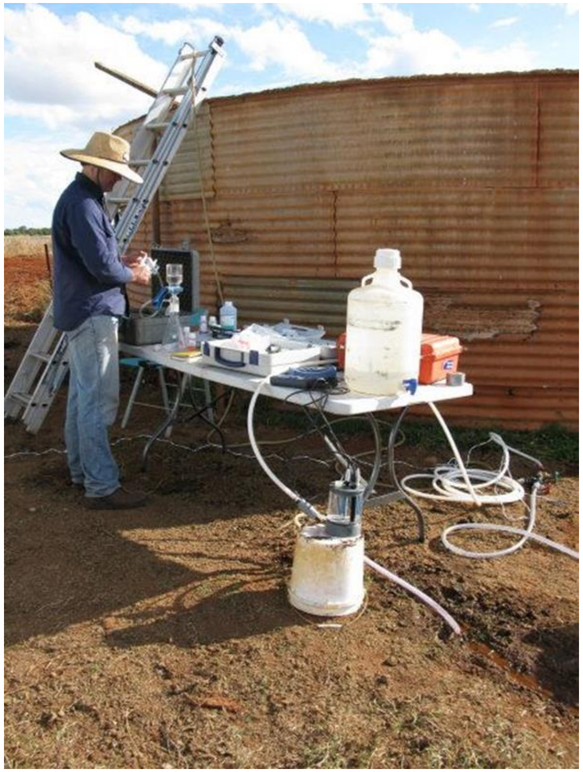
Australian Government
Geoscience Australia

Monitoring for CO_2 impacts on groundwater

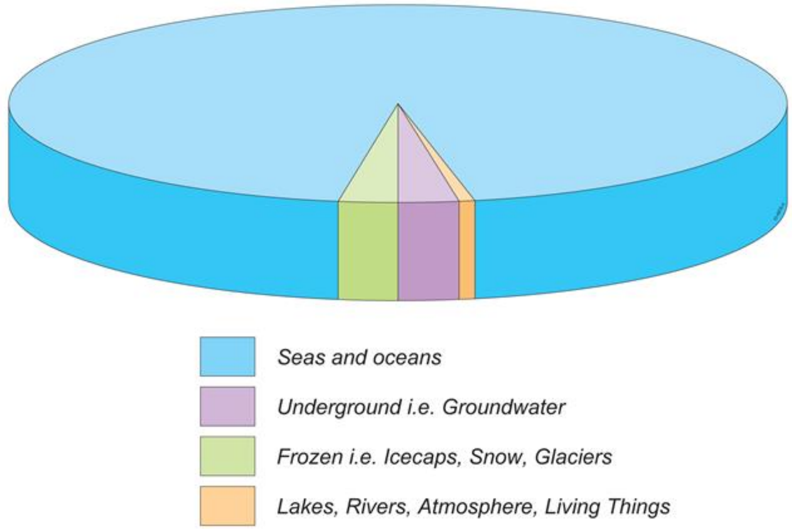
Dr Andrew Feitz



Monitoring for Geological Storage of CO_2 Workshop

7-10 May 2013

Global Water Resources



~93.97% Seas and oceans

~2.4% Underground i.e. Groundwater

~2.4% Frozen i.e. Icecaps, Snow, Glaciers

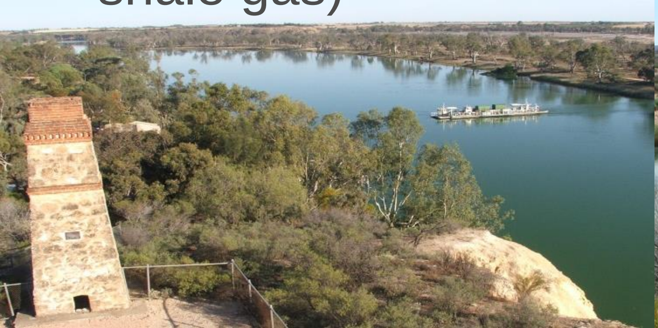
<0.1% Lakes, Rivers, Atmosphere, Living Things

Groundwater in Australia

Groundwater usage:

- 17% of available water
- 30% of high security water in drought
- ***<u>Only</u>*** source of water for many regional towns, mining and remote indigenous communities
- 70% of rivers are dependent on baseflow
- Groundwater is essential for groundwater dependent ecosystems – but poorly understood

Groundwater is also a critical issue in national energy security (coal seam gas, geothermal, shale gas)



Groundwater in China

Groundwater usage:

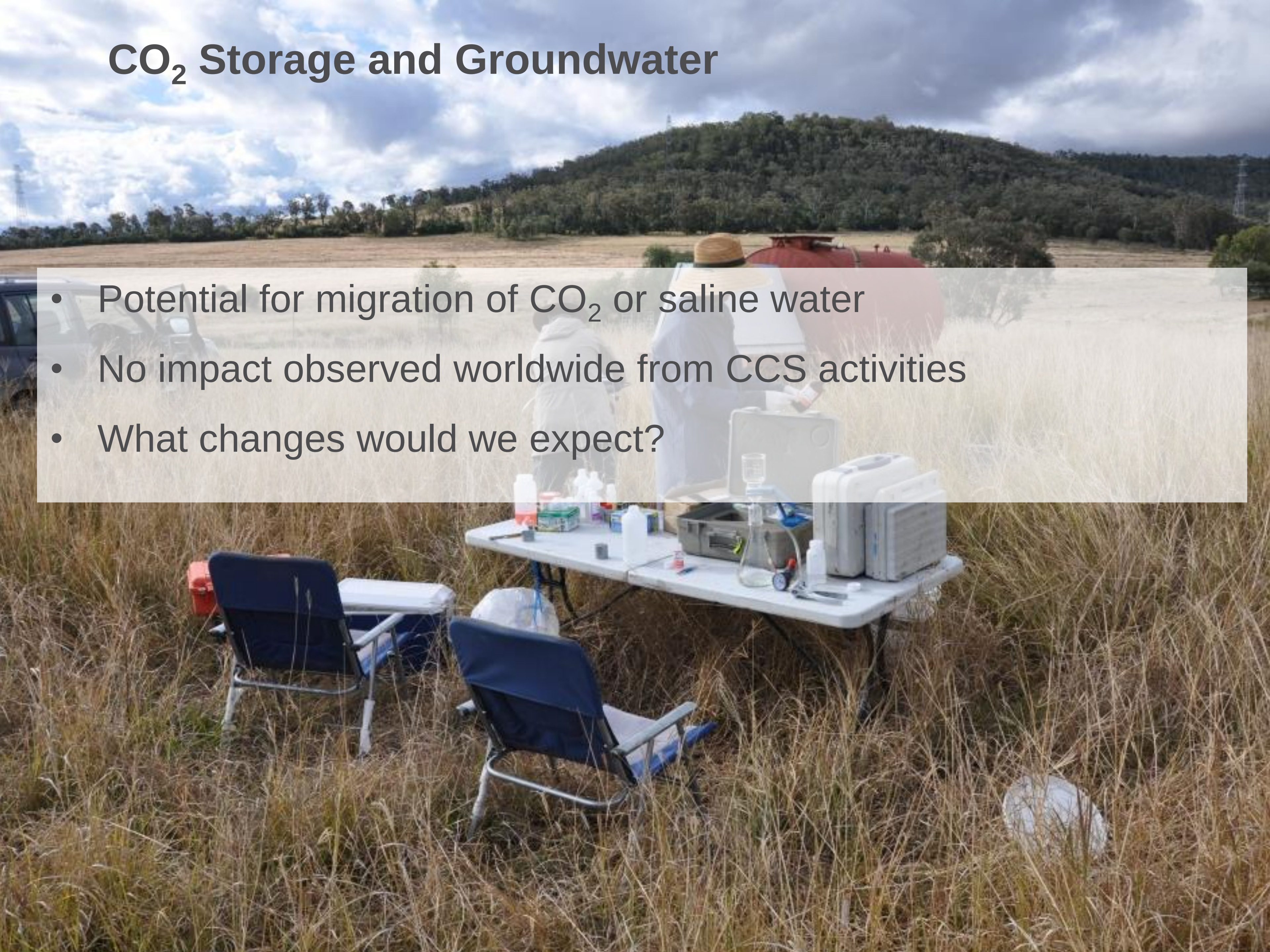
- Groundwater used extensively
- 40% farmland uses groundwater for irrigation
- 70% drinking water supplies from groundwater in Northern/northwest China
- Issues of groundwater contamination (especially in the south (90%)) and rapidly decreasing groundwater levels across China
- 2/3 of China's 660 cities suffer from water scarcity
- Projected water use to rise from ~600 to 750 billion m^3/yr (2030)
- Total groundwater resources in China presently unknown

Sustainable use and protection of groundwater quality is a critical for both Australia and China!

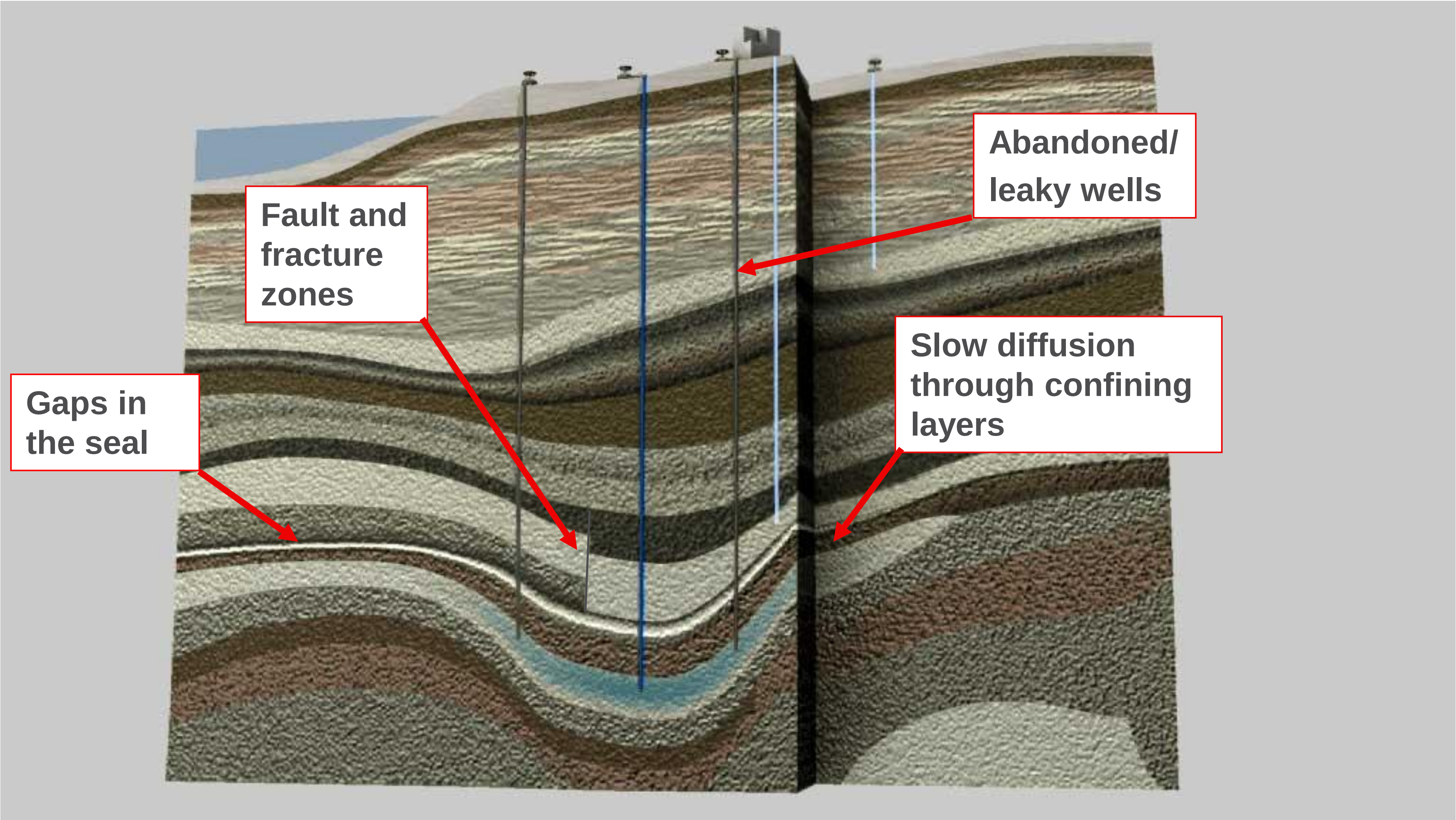
Qui (2010) Nature 466, 308

CO_2 Storage and Groundwater

- Potential for migration of CO_2 or saline water
- No impact observed worldwide from CCS activities
- What changes would we expect?



Potential leakage pathways



Step 1: Dissolution (Henry's Law)

CO_2 Pressures

Atmosphere: 0.0003 atm

Soil: 0.1 atm

Groundwater: 0.001 – 0.1 atm

Geological storage: ~100 atm

$$CO_2(aq) = K_H P_{CO_2}$$

Step 2: CO_2 reactions with water

- Carbonic acid formation and dissociation
- Generation of acid (H^+)

$$CO_2(aq) + H_2O \rightarrow H_2CO_3$$

$$H_2CO_3 \rightarrow H^+ + HCO_3^- \rightarrow H^+ + CO_3^{2-}$$

Accelerated Weathering

- Acid reacts with rocks, releases metals and increases alkalinity

Calcite

$$CaCO_{3(s)} + CO_2 + 2H_2O \rightarrow Ca^{2+} + 2HCO_3^-$$

Dolomite

$$CaMg(CO_3)_{2(s)} + 2CO_2 + 2H_2O \rightarrow Ca^{2+} + Mg^{2+} + 4HCO_3^-$$

Siderite

$$FeCO_{3(s)} + CO_2 + H_2O \rightarrow Fe^{2+} + 2HCO_3^-$$

Silicates

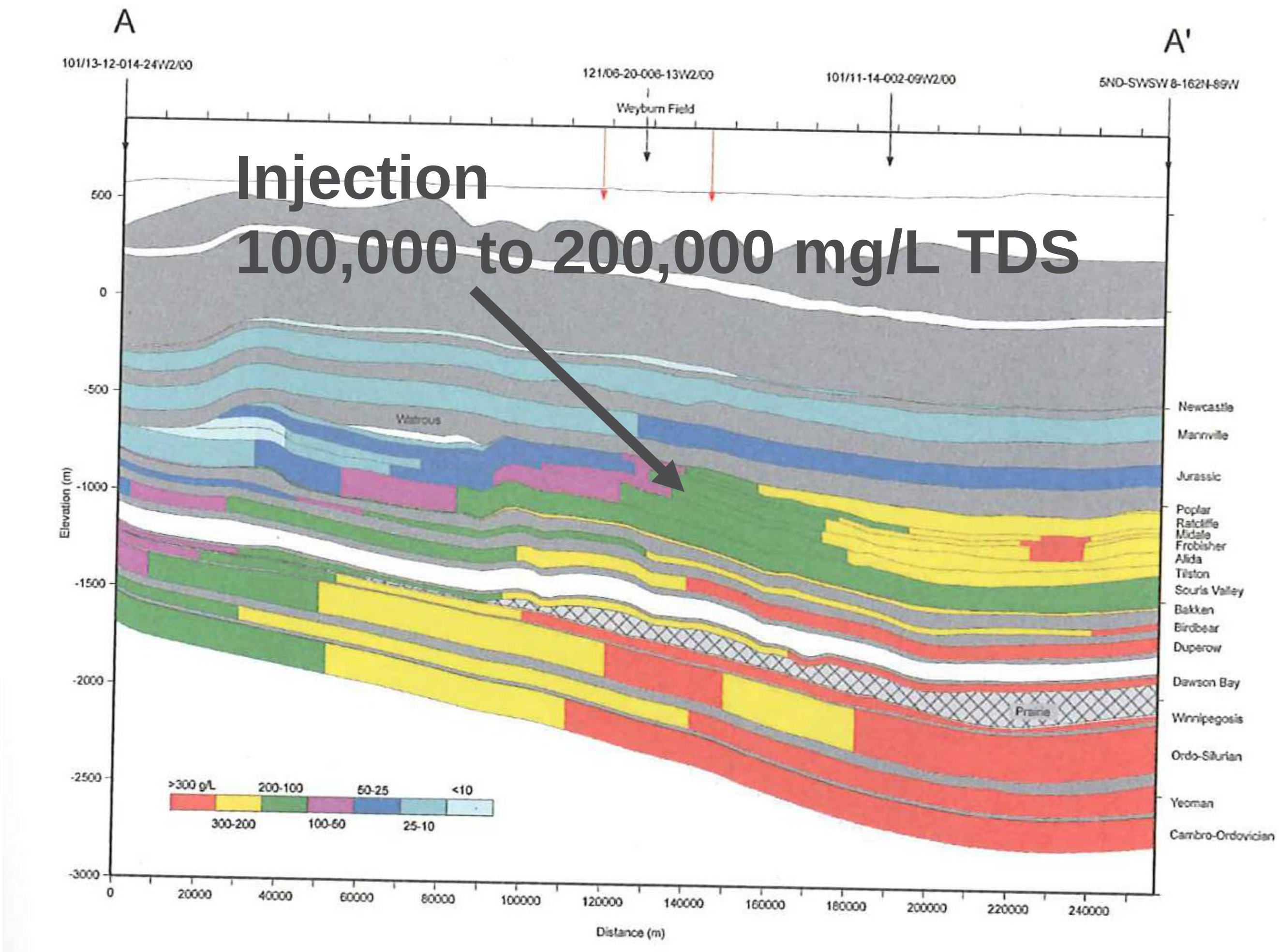
$$KAlSi_3O_{8(s)} + 4CO_2 + 8H_2O \rightarrow K^+ + Al^{3+} + 3H_4SiO_4 + 4HCO_3^-$$

Potential impacts on groundwater chemistry

- pH decrease (immediate)
- Weathering will lead to increased alkalinity/TDS
- Increase in major ions (Ca, Mg, Fe, K, Na, Al and Mn)
- Major concern is movement of saline water into freshwater aquifers
- Other concerns
  - Trace metals (esp. As, Pb, Ni, Cr)
  - Trace organic contaminants
  - Boron (agriculture)
  - Si and Br (water treatment plants)
- Note metal leaching not only related to direct contact with CO_2, could occur outside permit

Is the groundwater system fresh or saline?

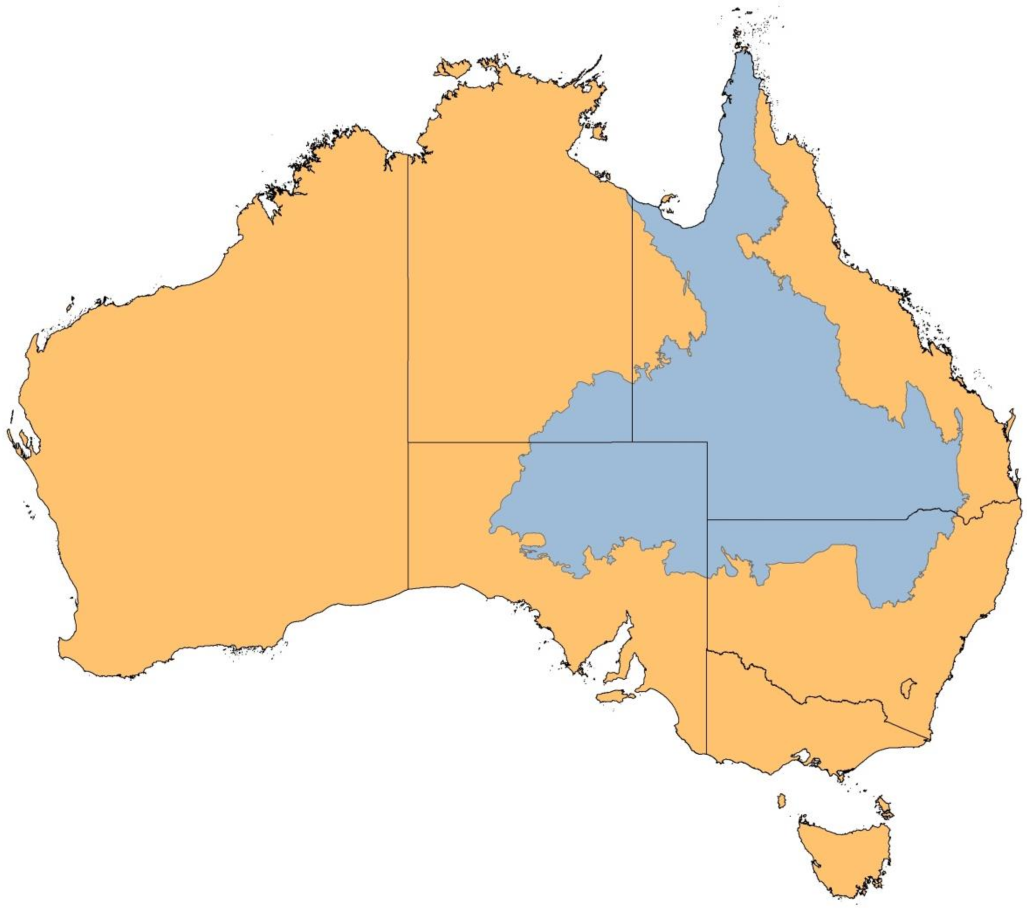
North American saline example - Weyburn hydrostratigraphy (Canada)



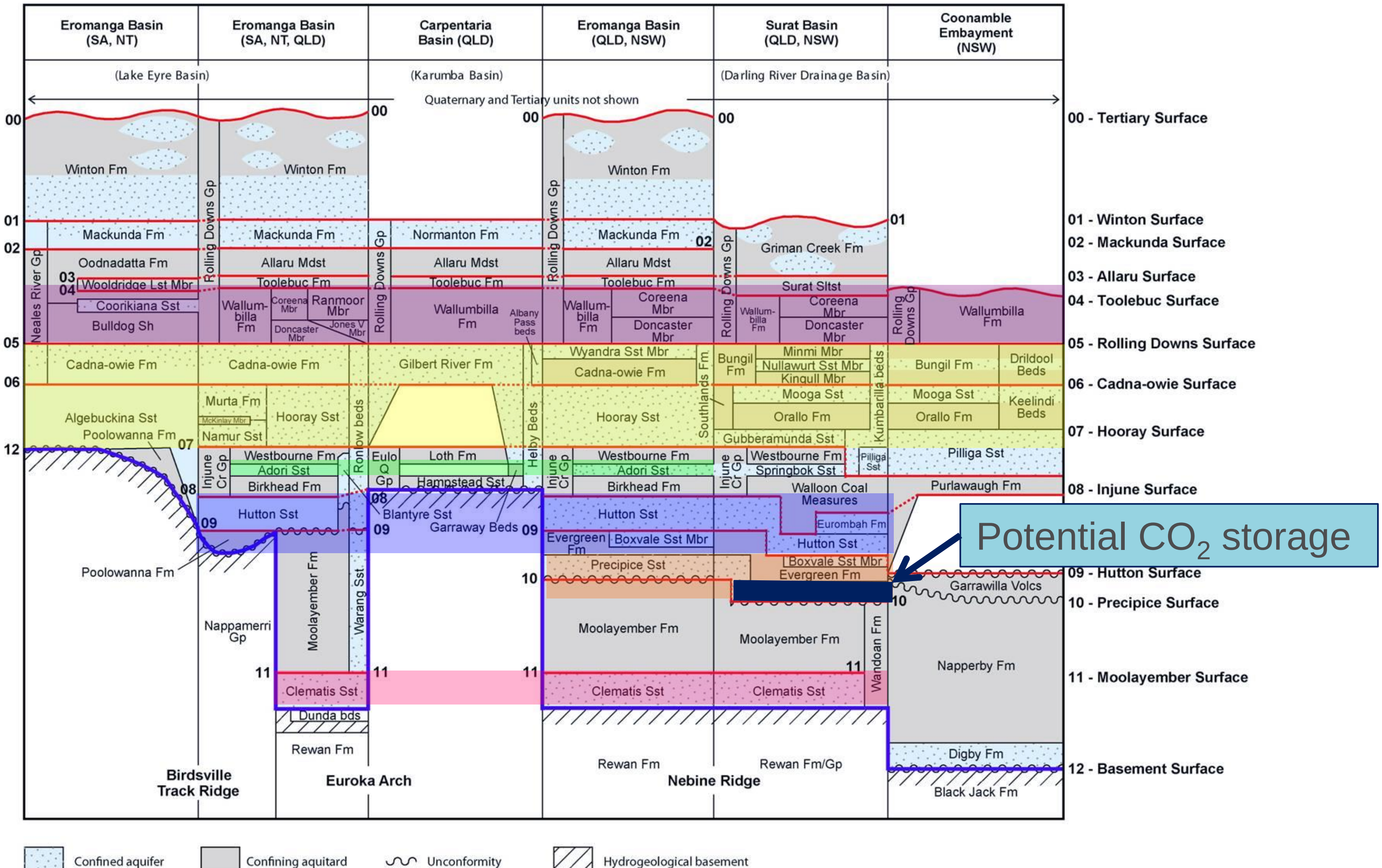
PTRC, 2004

Great Artesian Basin

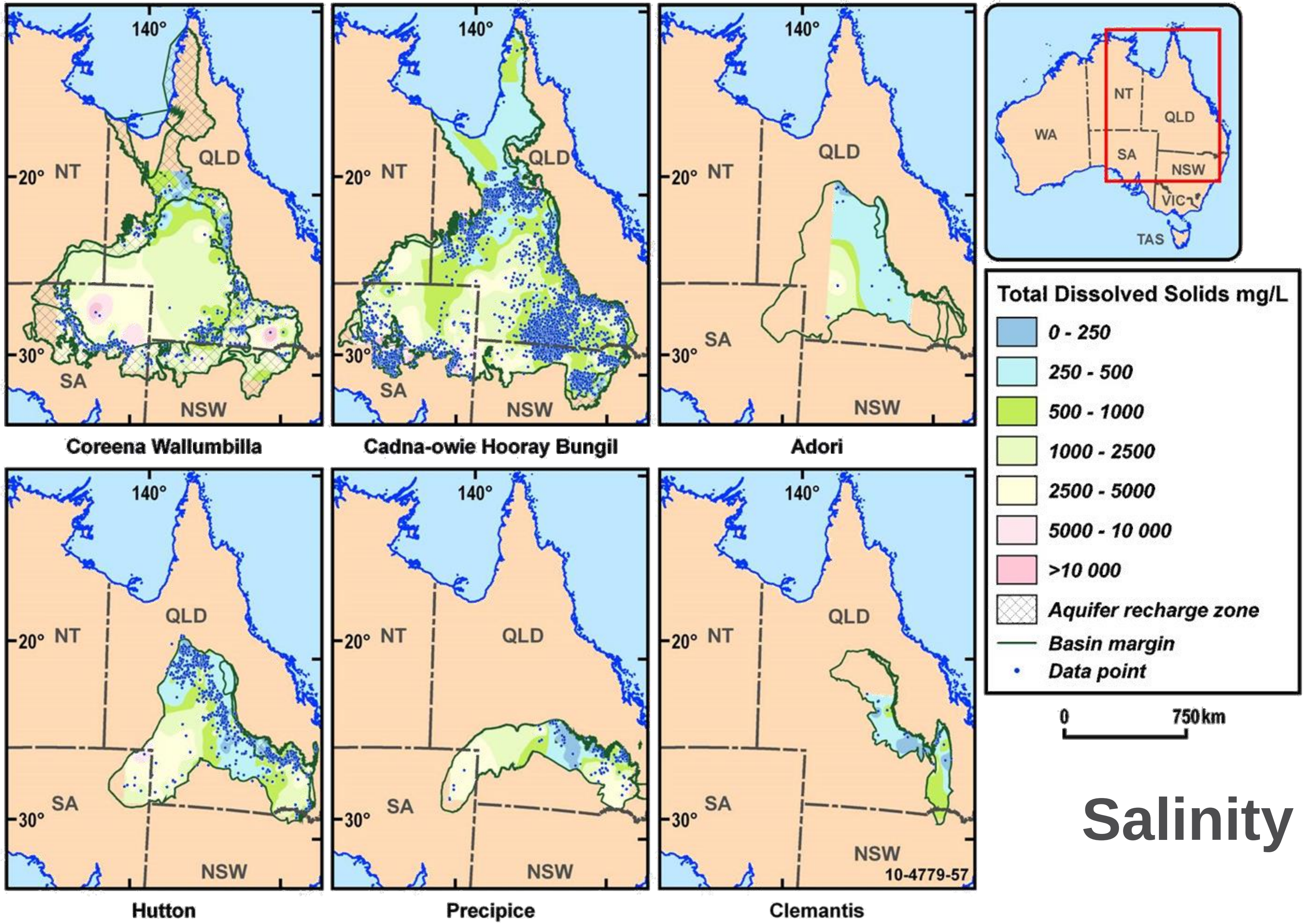
- One of the world's largest freshwater aquifer systems
- 1.7 million km^2
- Up to 3000m deep
- 30 - 100°C
- 65,000,000 GL
- Extraction 570 GL/yr



Developing hydrogeochemical maps for the GAB



Source: Radke et al., 2000


140°
20°
30°
NT
QLD
SA
NSW
WA
VIC
TAS
Total Dissolved Solids mg/L
0 - 250
250 - 500
500 - 1000
1000 - 2500
2500 - 5000
5000 - 10 000
>10 000
Aquifer recharge zone
Basin margin
Data point
0
750 km
10-4779-57
Coreena Wallumbilla
Cadna-owie Hooray Bungil
Adori
Hutton
Precipice
Clemantis

Salinity

Groundwater systems in China?

- Is groundwater in potential CO_2 storage basins in China fresh/brackish like Australia or more saline/hypersaline like North America?
- Preliminary data suggests groundwater systems in China more like Australia
  – Large stocks of fresh to brackish (somewhat salty) groundwater
  – Often good quality water at depth (e.g. 500 - 1000m)
- Establishing a baseline is critical (how much groundwater, pressures, how saline?)

What to measure?

- **Essential: Field pH and total dissolved solids (salinity)/ Electrical conductivity**
- Lab pH can be quite different to actual (field) pH due to rapid equilibrium with atmosphere
- Field analysis (pH, redox, temperature, EC; also helpful is Fe^{2+})
- Cations (Na, Mg, Ca, K) and anions (Cl, SO4, HCO3, F)
- Trace metals and metalloids (e.g. Pb, As, Al, B, Ni, Mn, Hg, Sr, Rb)
- Isotopes useful for aquifer characterisation (e.g. d^2H, $d^{18}O$, $d^{13}C$, ^{14}C, ^{36}Cl, $^{87}Sr/^{86}Sr$) but analysis is expensive
- Trace organics if mobilisation of oil/condensate a concern (e.g. BTEX, napththalene and total recoverable hydrocarbons)
- Analysis of exsolved gases including composition and isotopic d^2H and $d^{13}C$ analysis (methane and CO_2)

Gas isotopes

Field collection of exsolved gases from groundwater for isotopic analysis useful for detecting small leaks in overlying aquifers

Issues

- Whether a groundwater system is hypersaline or brackish/fresh determines key contamination risks
- Groundwater data coverage often limited, especially for the deeper aquifers
  - i.e. field parameters (e.g. Eh, pH), isotopes, trace metal and organics
- Isotopes (water and gas) will be key for investigating potential leaks and connectivity
- Risk of CO_2 waters intersecting groundwater used for agriculture/potable supplies is higher in Australia (and probably also for China) than North America/Europe
- Agricultural and petroleum/gas bore integrity

Summary

- Establishing a baseline for aquifers in the basin is essential
- Salinity contamination may be less of a concern than in North America/Europe
- If not storing in a saline or hypersaline formation, a major risk is trace metal/organic contamination
- Seal integrity of overlying geological unit critical

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Earth Resources Australia

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Qld Department of Environment and Resource Management (DERM)

Bureau of Rural Sciences (BRS)

Australian Government
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