Summary of results and conclusions

High Prospectivity Basins

- Contain at least one reservoir-seal interval with demonstrated effectiveness for injection, storage and containment of CO₂ (i.e. have a total ranking score ≥ 13).
- Twenty reservoirs from five basin areas (Bowen, Cooper, Eromanga, Galilee and Surat basins).
- Most reservoirs have either produced hydrocarbons, and/or are major groundwater aquifers.
- Have sufficient data sets to establish their prospectivity.

Southern Bowen Basin

- Most basin area >60 mCDL and at suitable depth for supercritical CO₂ storage.
- Moolayember Formation & Snake Creek Mudstone form regional seal for the underlying Triassic reservoirs (Showgrounds Sandstone & Bowen Group).
- Some large faulted anticlines on eastern flank. Containment issue due to truncated, steeply dipping strata and large thrust faults. Poor reservoir quality due to proximity to eastern volcanic arc.

Outline - Results

1. Description of the 5 High prospectivity basins in detail
2. Summary of low prospectivity basins
3. Discussion of potential for storage in unmineable coals and ECBM
4. Discussion of storage in depleted oil & gas fields
Southern Bowen Basin

- Volumetric calculations were completed for 3 reservoir units (Showgrounds Sandstone, Rewan Formation and Timowan Formation).
- Reservoir net pay zone thicknesses from WCRs and average porosity from QPED database used in calculations.
- Total theoretical storage volume 365 Mt
- Greatest theoretical capacity in Showgrounds Sandstone (98 Mt)

Western Bowen Basin

- Structural elements on depth to base Peawaddy Fm equivalent. SRA map series from QPPE/PSU.

Northern Denison Trough

- 9 reservoir units were assessed – only high potential unit is the Aldebaran Sandstone.
- Reservoir well sealed but highly variable, generally low permeability sandstones.

Western Denison Trough

- Volumetric calculations were completed for 4 reservoir units (Aldebaran Sandstone – nth Denison Trough; Aldebaran Sandstone nth Denison Trough; Freitag Fm; Catherine Sandstone).
- Reservoir net pay zone thicknesses from WCRs & average porosity from QPED database used in calculations.
- Total theoretical storage volume 250 Mt
- Greatest theoretical capacity in Aldebaran Sandstone over southern Denison Trough (100 Mt).
- Injectivity into low permeability reservoirs main uncertainty.
Cooper Basin

Potential geological storage area in the Cooper Basin (blue polygon) & locations of major emissions nodes

Depth structure map (mSS) of ‘P’ horizon (top Toolachee Fm/base Nappamerri).

Cooper Basin

High prospectivity potential geological storage area in the Cooper Basin (blue polygon) & locations of major emissions nodes.

Depth structure map (mSS) of ‘P’ horizon (top Toolachee Fm/base Nappamerri).

Cooper Basin

• Basin at suitable depths for supercritical injection of CO₂, and has trapped hydrocarbons
• Reservoir tight (80% failure at depths >2400 mSS) - heat in regional fluvial sandstones from Toolachee sealed by Callamurra Member.
• Dry structures may provide opportunities if fault seal issues resolved, depleted fields aren’t likely to be available in the near future but Challum field has the largest capacity.

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Cooper Basin

• Volumetric calculations were completed for one reservoir unit the Toolachee Formation
• Reservoir thickness was derived from isopach mapping (using Interpretation from Draper et al. 2002)
• Calculated theoretical storage volume: 172 Mt.
• No estimate is made for the Patchawarra Fm but it is likely to be similar to the Toolachee Formation.

Cooper Basin

• The occurrence of regionally extensive, vertically stacked reservoirs and a thick regional seal succession indicates that the Eromanga Basin has the geological components suitable for the storage of the CO₂.
• The presence of large anticlinal structures as well as flat-shallow dipping synclines and monoclines indicate that a range of both structural and residual gas saturation trapping mechanisms could be utilised.
• The location of the 800mGL level at the base of the regional seal succession indicates that a large proportion of the basin is suitable for supercritical CO₂ storage.

Eromanga Basin

Potential geological storage area in the Eromanga Basin (blue polygon) & locations of major emissions nodes

Depth structure map (mSS) of the ‘C’ horizon (top Cadna-owie Formation).

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• The location of the 800mGL level at the base of the regional seal succession indicates that a large proportion of the basin is suitable for supercritical CO₂ storage.
A thick regional seal succession and multiple intraformational seal units are present over the entire basin. The regional seal succession is 400–700 m thick, comprises the Wallumbilla Formation, Toolebuc Formation and the Allara Mudstone and consists predominantly mudstone interbedded with varying amounts of sandstone, limestone and siltstone.

The potential storage area is derived from the 490 mSS contour (top CO₂ supercritical zone) on the base of the regional seal succession (using the C horizon). Volumetric calculations were completed for 5 reservoir units. Reservoir thickness was derived from isopach mapping (using QPED formation top data). The combined theoretical capacity for these reservoirs is massive (46.49 Mt CO₂) – reflects the extensive nature and thicknesses of reservoir units. Hutton Sandstone capacity is estimated at 12.26 Mt of CO₂.

Potential geological storage areas in the Galilee Basin (blue polygons) & locations of major emissions nodes

Triassic & Late Permian strata from relatively continuous reservoir-seal units, and are potentially suitable for geological storage of CO₂ where they are preserved beneath the Eromanga Basin (truncated to the south). Main storage mechanism is residual gas migration trapping using low regional dip of strata in Koburra Trough, and southwest plunging faulted edges in early Galilee Basin – potential fault seal breaching. Anticlinal with fault-independent closures provide smaller storage options. Potential stratigraphic trapping in Early Permian strata.

Potential units were ranked – 5 of these are the ‘traditional’ reservoirs targeted for oil exploration and are below the regional seal units; 2 units are above the regional seal and ‘rest’ due to a number of factors. These units below the regional seal are generally characterised by mediocre-excellent reservoir quality. Bulk seal effectiveness of the intraformational seals (Birkhead, Westbourne etc) may be limited on a regional scale but may be effective locally (as is demonstrated by the occurrence of hydrocarbon accumulations).
7 reservoir units were ranked – best potential units are the Clematis/Rewan Fm sealed by Moolayember Formation; Betts Creek beds with unconventional Rewan Formation seal.

These reservoirs have good-excellent & moderate-good measured porosity & permeability; however well data coverage too sparse to map reservoir fairways.

Early Permian units ranked as unsuitable-low potential - generally poor reservoir quality.

7 reservoir units were ranked – unsuitable to due to poor reservoir quality and absence of an effective seal (coal measures more likely to form baffles rather than unconventional seals).

Volumetric calculations were completed for 4 reservoir units.

Not possible to define reservoir fairways or gas zones with regional well data coverage; measured data is largely reconstrсан, storage volumes should therefore be used with caution.

Large theoretical storage volumes: Southern Galilee 3.69 Mt; Koburra Trough 3.8 Mt.

Clematis Sandstone/Rewan Formation in Southern Galilee has estimated capacity of ~5.6B.

Seal capacity & faults through seal key uncertainty – needs addressing through 3D seismic & updated seismic.

Potential geological storage areas in the Surat Basin (blue polygons) & locations of major emissions nodes

Depth-structure map to top Evergreen Fm regional seal. Dry structures also shown.

A broad structural depression “the Mimosa Syncline” basement dipping strata to the W & NW providing a structural architecture that favours slow, long-range migration of CO₂, maximising the potential for residual gas saturation trapping.

The upper Evergreen Formation acts as a regional seal for the underlying Early Jurassic reservoirs (Precipice, Boral Evergreen & Boreale sandstones).

The location of the 800 mGL level at the base of the regional seal succession indicates that a large proportion of the basin is suitable for supercritical CO₂ storage.

Two potential regional conventional seals for CO₂; the Early Jurassic upper Evergreen Formation and the Late Jurassic Westbourne Formation.

There are also intervals of low- or non-porous/impermeable units sands associated with siltstone, shales and occasional coal that act as intrasformational seals within the Precipice Sandstone, Hutton Sandstone and Wallloon Coal Measures.

Regionally-extensive sandstone units provide potential reservoirs throughout the basin.
The Precipice, Basal Evergreen, Boxvale, Hutton and Springbank (ranked 7–9) are the most important reservoir units in the basin. Those are the traditional reservoirs targeted for oil exploration and are below the regional seal units.

Reservoirs that ranked 10–12 have good reservoir quality but they are too deep.

Seams failed due to lack of regional seal.

### Estimated Storage Volumes

- The Precipice Sandstone reservoir map showing depth (m) structure surface. Also shown are drainage cell interpretations and gas fields (red outlined) in the Surat Basin.

### Low Prospectivity Basins

- Most appear to have unfavorable geological settings for large-scale CO<sub>2</sub> storage, but cannot be ranked as unsuitable due to insufficient data on reservoir and seal effectiveness.
- Several are located near major emissions nodes and may warrant acquisition of new well and seismic data.
- Although maximum theoretical storage volumes have been estimated, these have generally been calculated over multiple reservoir units and with insufficient constraints to assign any level of subjective estimated accuracy.
- It is likely that additional data would significantly decrease the size of potential storage areas and reduce the theoretical storage volumes for most low prospectivity basins.

### Volumetric Calculations

- Volumetric calculations were completed for 4 reservoir units (i.e. Precipice, Basal Evergreen, Boxvale, Hutton)
- Theoretical storage capacity using residual gas saturation trapping totals 1,962 Mt in the evaluated reservoirs – greatest capacity in Precipice Sandstone (1,289 Mt).
- Other storage options are limited to depleted oil and gas fields, which only provide ~6 Mt of storage capacity.

### Low Prospectivity Basins

- Contain reservoir-seal intervals with uncertain effectiveness due to either limited data to evaluate their prospectivity, or high variability in the quality of reservoirs and seals.
- The total ranking score of the best reservoir-seal intervals in low prospectivity basins ranges from 6–12.
- 48 low prospectivity reservoirs from these 13 basins

### Adavale Basin

- Devonian rift-depo centre in central QLD
- Variable lithologies and reservoir quality, western margin different from the eastern margin
- Lissoy Sandstone main interval of interest - 2 dry gas accumulations
- Both structural and stratigraphic traps present
- 135 wells in Adavale and Warrabin but only 83 of these penetrate reservoir of Devonian section

### Adavale Basin and Warrabin

- Well cross-section B-F displayed at the top of the Cooladdi Dolomite/Burra Salt seal units.
- Adavale Basin and Warrabin Trough location map showing wells and cross-section locations.
Adavale Basin

A basic storage capacity estimate was made using the following parameters (note this is not the same methodology as used for the High Prospectivity basins):

- Area: 3,996,887 km²
- Injection depth: 3,915 m
- Estimated net-to-gross: 30%
- Average net pay thickness: 94 m
- Average porosity: 20%
- Equilibrium CO₂ density: 550 kg/m³
- Residual gas saturation: 0.17
- Storage efficiency factor: 0.12

The resulting CO₂ storage capacity is 286 Mt (5 TCF) of CO₂.

This estimate is considered to be grossly larger than the actual CO₂ storage capacity, since it does not consider the expected large variations in reservoir quality in terms of thickness, net-to-gross, porosity, and permeability.

Potential storage area map for the Lissoy Sandstone (after Paton, 1977). Other reservoir units may exist along the eastern and western margins.

Clarence-Moreton Basin

- Mesozoic basin in SE QLD
- Mostly too shallow
- Insufficient data to determine reservoir quality and extent
- Insufficient data to determine seal quality

Regional schematic cross-section showing the relationship of the Clarence-Moreton Basin to other older basins (modified from Kukull et al., 1986).

Clarence-Moreton Basin

There is insufficient data to accurately calculate the CO₂ storage capacity in the Clarence-Moreton Basin. However, an estimate has been made using the following inputs:

- Area: 2,772
- Injection depth: 800–1,000 m BGL
- Gross thickness: 200 m
- Estimated net: gross 70%
- Equilibrium CO₂ density: 275 kg/m³
- Average porosity: 22.5%
- Residual gas saturation: 0.03;
- and
- Storage efficiency factor: 0.08

Estimated storage volume of approximately 193 Mt CO₂.

Maximum potential storage areas in the Clarence-Moreton basin. There is not enough information to map reservoir fairways.
Unsuitable Basins

- 19 unsuitable basins are known to be unsuitable as their reservoirs and/or seals are all below the minimum criteria.
- Most of these basins are located in eastern and northern Queensland, often in close proximity to major CO₂ emissions nodes.
- Most fail on containment due to highly deformed basin fills that lack regional seals or because they have a shallow basin fill that lacks a regional seal.
- The shallowness of the sedimentary fill in many of the basins prevents the storage of CO₂ in its supercritical state.

Biloela and Callide Basins

Schematic geological cross-section of the Biloela and Callide basins (modified from Monte Carlo cross-section). Note that the both basins are entirely unsuitable.

Burdekin Basin

- Example of unsuitable basin failing on seal effectiveness and containment.
- Most of these basins are ranked A for reservoir effectiveness due to lack of data.

CO₂ Storage in Coal

- Potential storage areas have been defined in major coal basins (Bowen, Surat & Galilee basins).
- Depth structure maps to top of major coal measures generated to define potential storage areas (400 – 1,000 m).
- Storage volumes have not been calculated - know that these will be unrealistically large - injectivity is real issue.
- Gross coal thickness maps superimposed on storage area maps to highlight areas with likely greatest capacity.
- Results show best potential is in CBM exploration sweet spots – mainly an option for ECBM recovery.

Potential Coal Storage Areas

Location of thick extensive coal measures at depths >400 m and <400 m (grey hatched polygons). Also shown are CSG fields and IP measures (June 2008).

Example - Bowen Basin

- Contains world-class CSG resources (Harrow and Spring Gully fields).
- Contains large southeast-plunging antiforms with enhanced permeability (generally >90 mD) at the crest of structures.
- These fields occur at depths of 900–1,000 m.

- Dimsen Valley (Eastern Tensam trough)
  - Depths from 300–3000 m but is mainly at depths 900–1,000 m below.
  - CSG production occurs within the Berauda Coal Measures.
  - Low permeabilities (<0 mD)

- Beringa Anticline (Eastern Tensam trough)
  - CSG production inoce in the Lockyer and Freec fields.
  - Depths 900–1,000 m.
  - Loss of permeability with depth, with some/helene gas in are considered sub-economic.
**CO₂ Storage in Depleted fields**

- A maximum theoretical replacement volume (MTRV) calculated on original in place resources as reported by QDEEDI 2008.
- A MTRV of 279 Mt CO₂ is estimated for 295 gas and/or oil fields and ~498 reported producing reservoir pools in Queensland.
- However, most large fields are still producing and are unlikely to be available for CO₂ storage in the near future. Only 99 fields are either depleted or near depleted (75% original all reserves remaining) which have a combined MTRV of 64.6 Mt CO₂.

Location of oil, gas and oil and gas fields scaled by MTRV. Also shown are major extension nodes and gas (red lines) and oil (green lines) pipelines.

**Challum field**

- Has the largest potential CO₂ storage of all the Queensland oil and gas fields, with a combined 52.4 Mt.
- 5.8 Megatonnes in the Hutton Sandstone, 43.2 Megatonnes in the Toolachee Formation and 3.4 Megatonnes in the Patchawarra Formation.

Above: Depth structure map of top Toolachee Fm 39.8 sandstones.

**Summary**

- This atlas is the first step in targeting basins or parts of basins in onshore Queensland where more detailed studies will help evaluate and characterise future storage sites.
- Good opportunities for geological storage are most evident in the Bowen, Cooper, Eromanga, Galilee and Surat basins.
- But further drilling and exploration is required in many parts of these basins to fully document the quality of their storage prospectivity.

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