Particle tracking-based groundwater age and travel-time distributions in identifying aquifer connectivity linked to coal seam gas development

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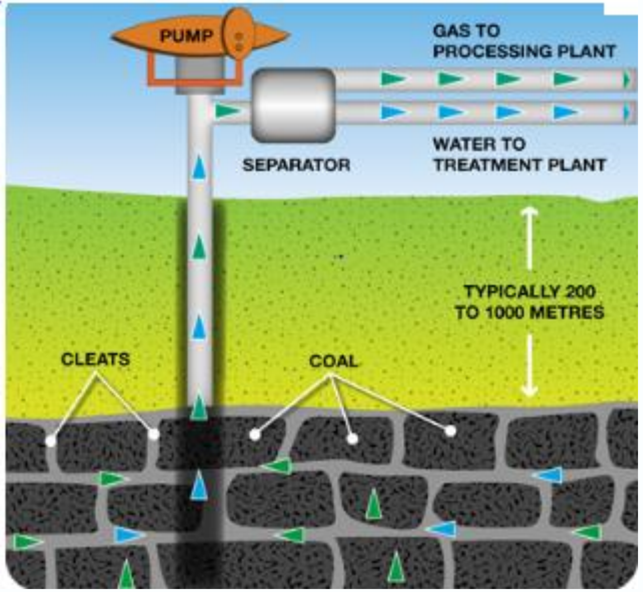
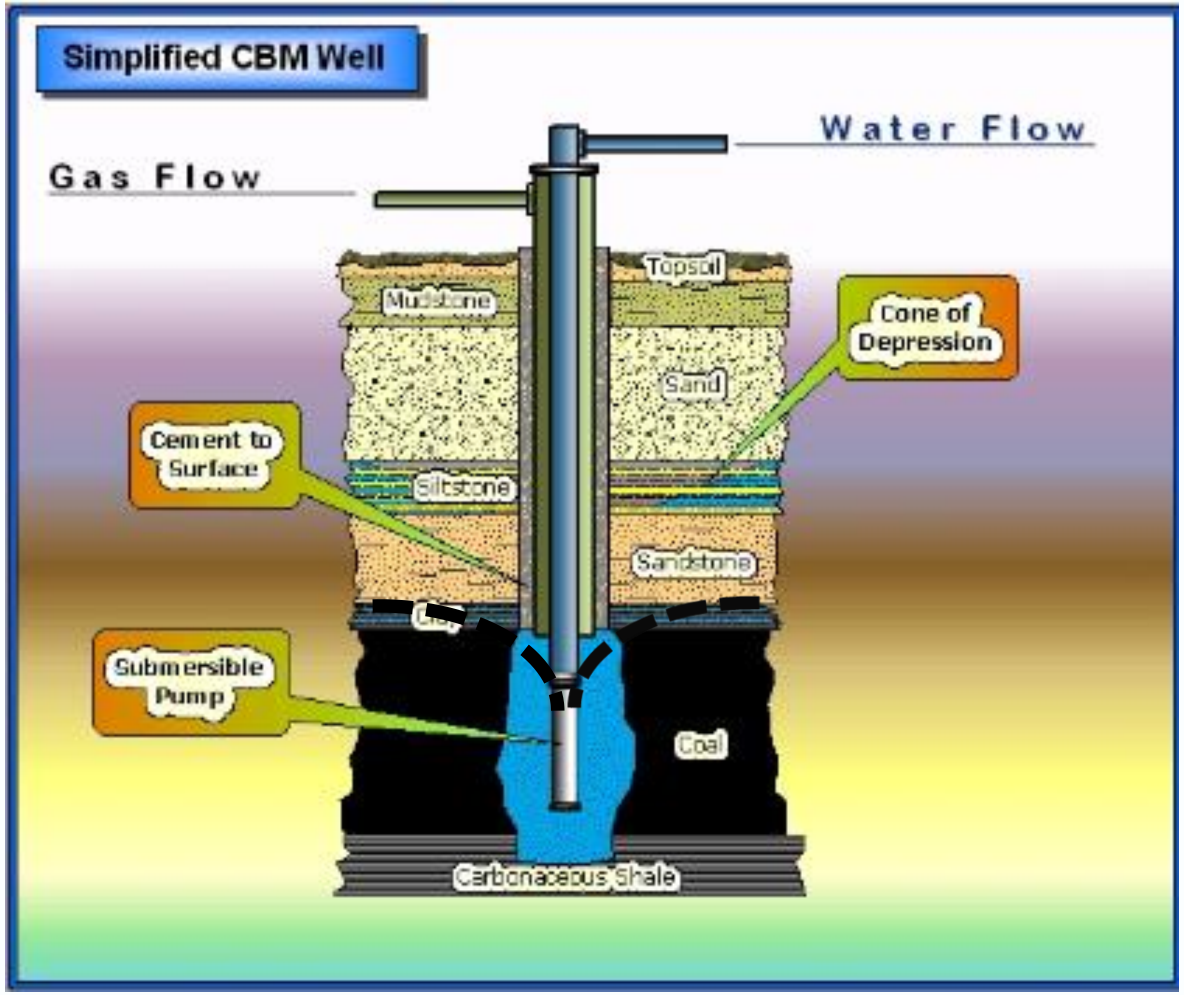
- CSIRO LAND AND WATER , AUSTRALIA

Aims of this talk

1. Coal Seam Gas development in Australia and requirement for improved understanding of deep groundwater systems
2. Regional scale modelling and uncertainty analysis for groundwater impact assessments
3. Particle tracking simulations evaluating aquifer connectivity and groundwater age

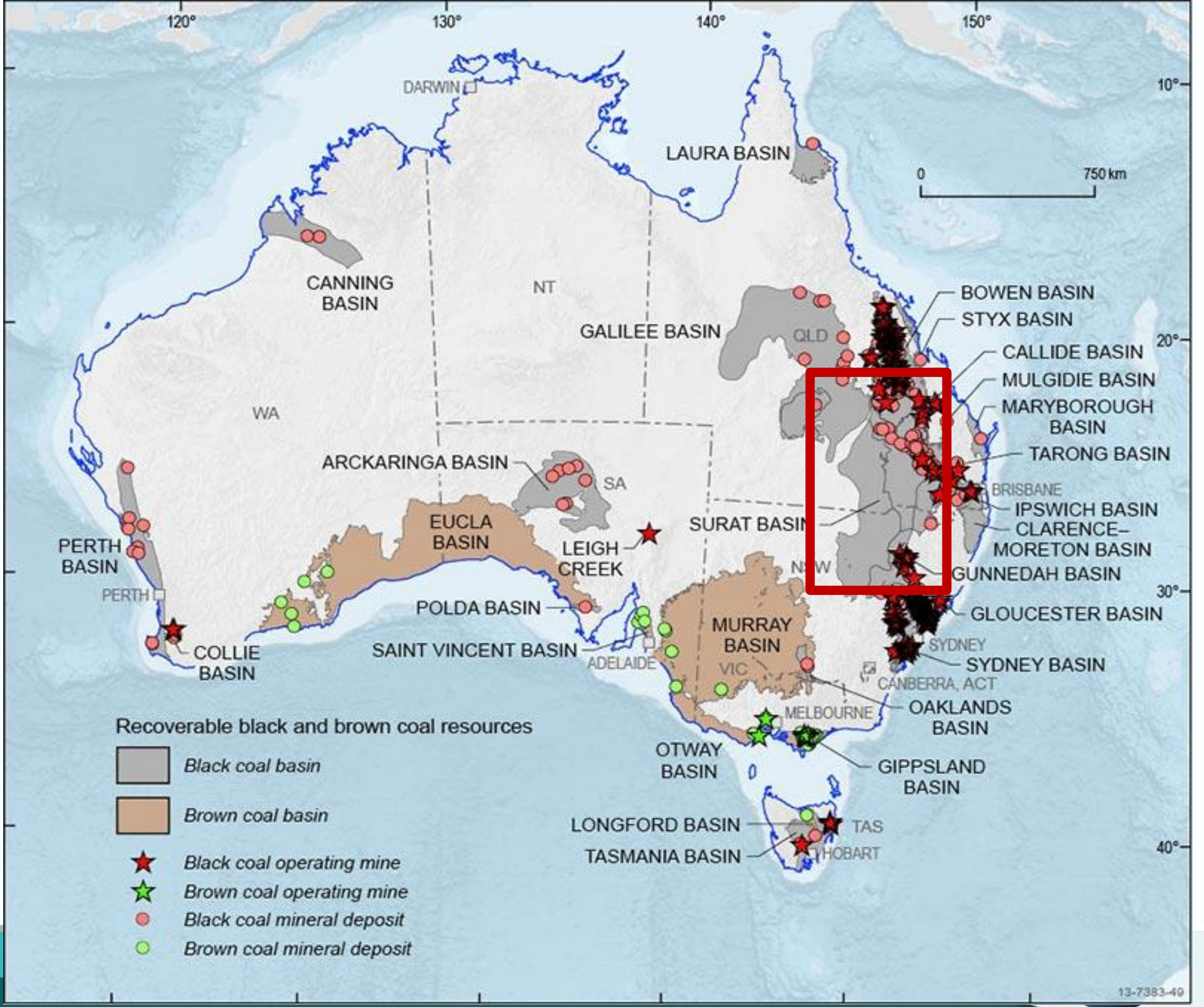
Desorption of coal seam gas requires reduced pressure





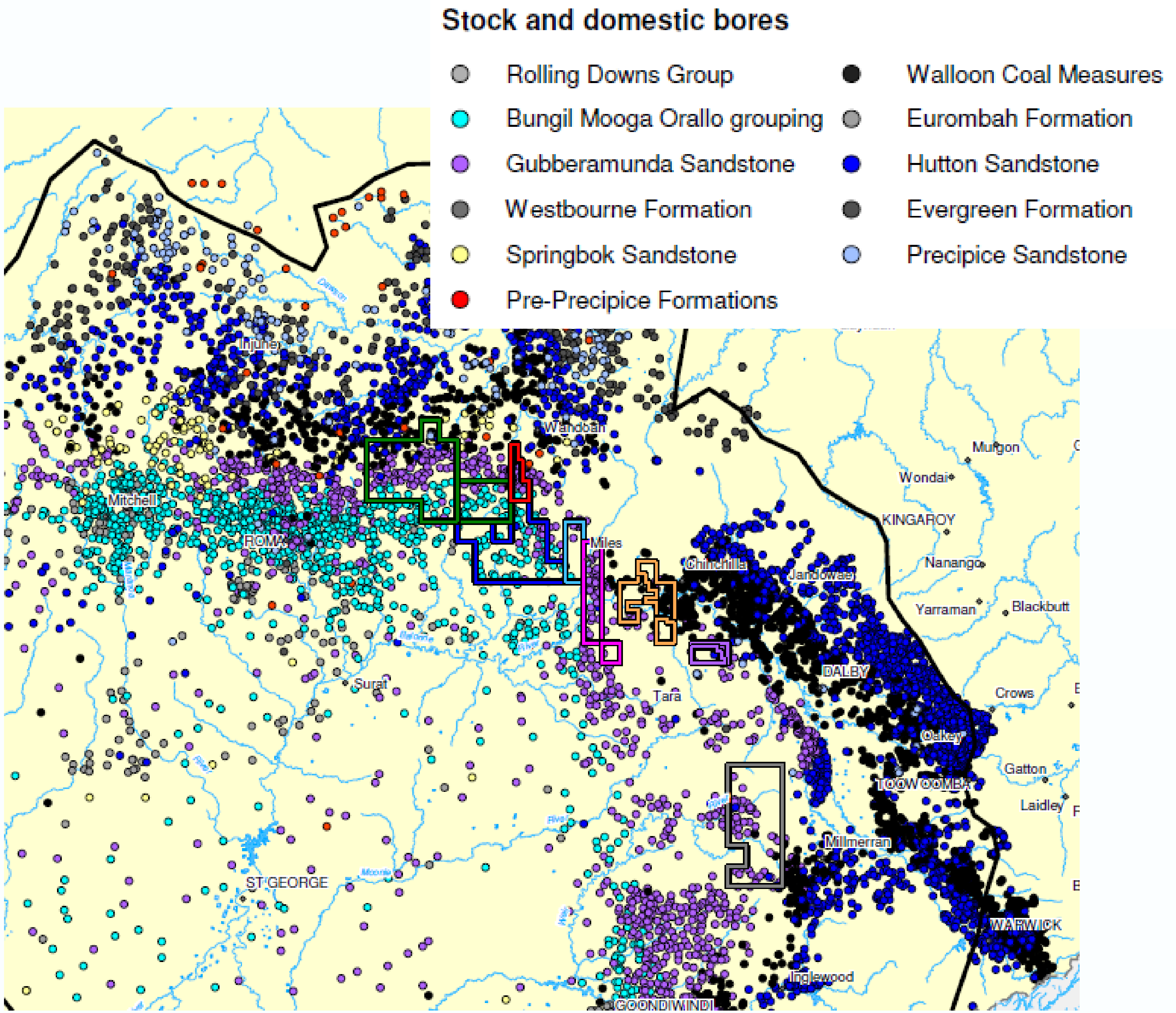
Coal Seam Gas (Coal Bed Methane) development in Australia

- CSG development planned from multiple sedimentary basins in Australia
- Commercial production has commenced from the Surat Basin in Queensland



Gas development co-located with other groundwater uses

- CSG tenements co-located with agricultural lands and beneficial aquifers are used for stock and domestic and other uses.
- Depressurization of coal seams can potentially impacts these aquifers – groundwater modelling is regularly undertaken by regulatory (and other) agencies to predict impacts
- Understanding the connectivity of aquifers to the coal seams is critical to constrain the predictive modelling of impacts to these aquifers



Source: APLNG – EIS 2010

Conceptual model for the Surat Basin

- Project on uncertainty analysis of groundwater model built for predicting CSG impacts
- Calibration constrained uncertainty analysis undertaken to quantify predictive uncertainty – using mostly groundwater head observations from different aquifers.
- Groundwater tracer data have also been collected from the Surat Basin

Hutton Sandstone – Important regional aquifer below the Walloon Coal Seams

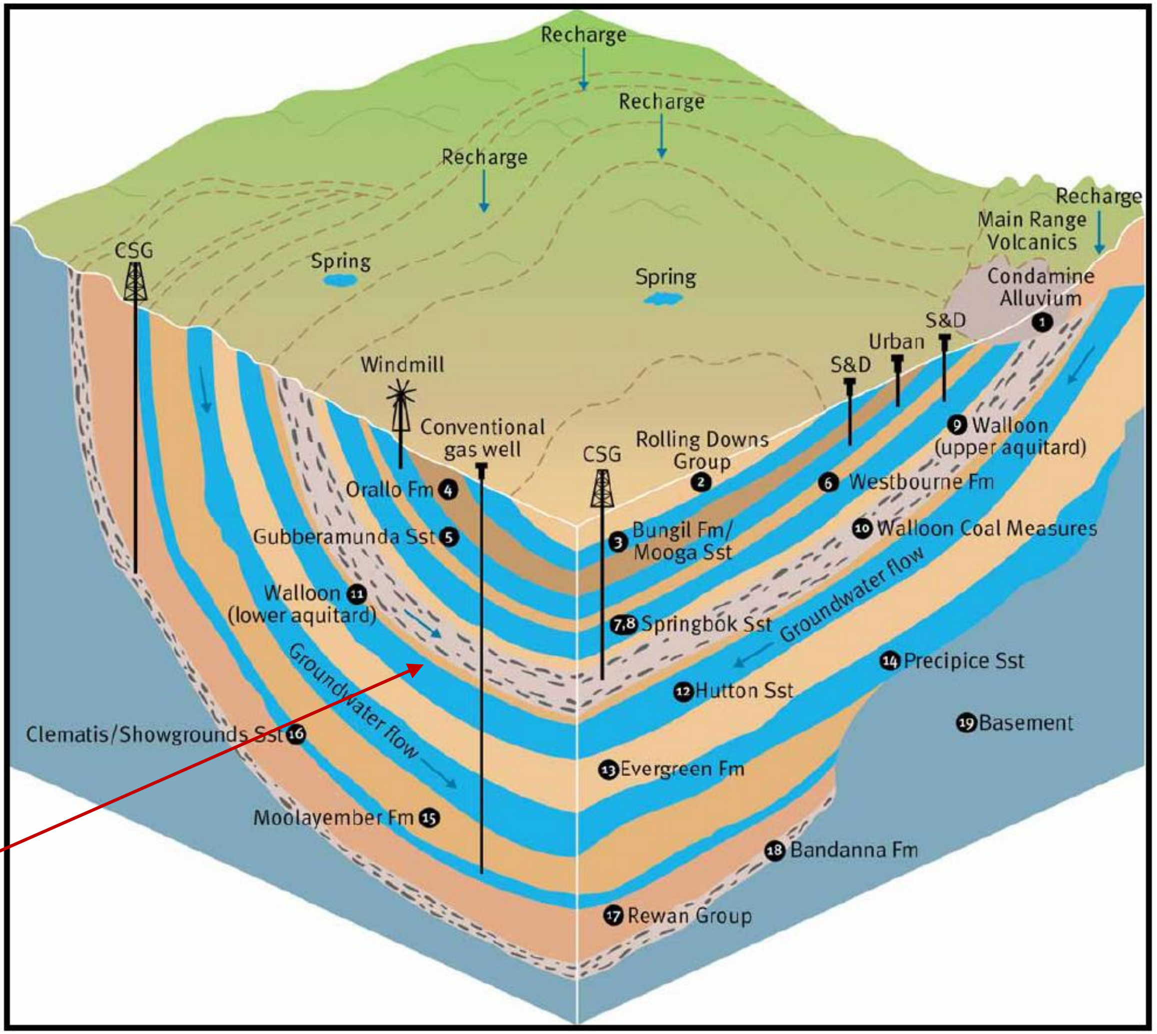
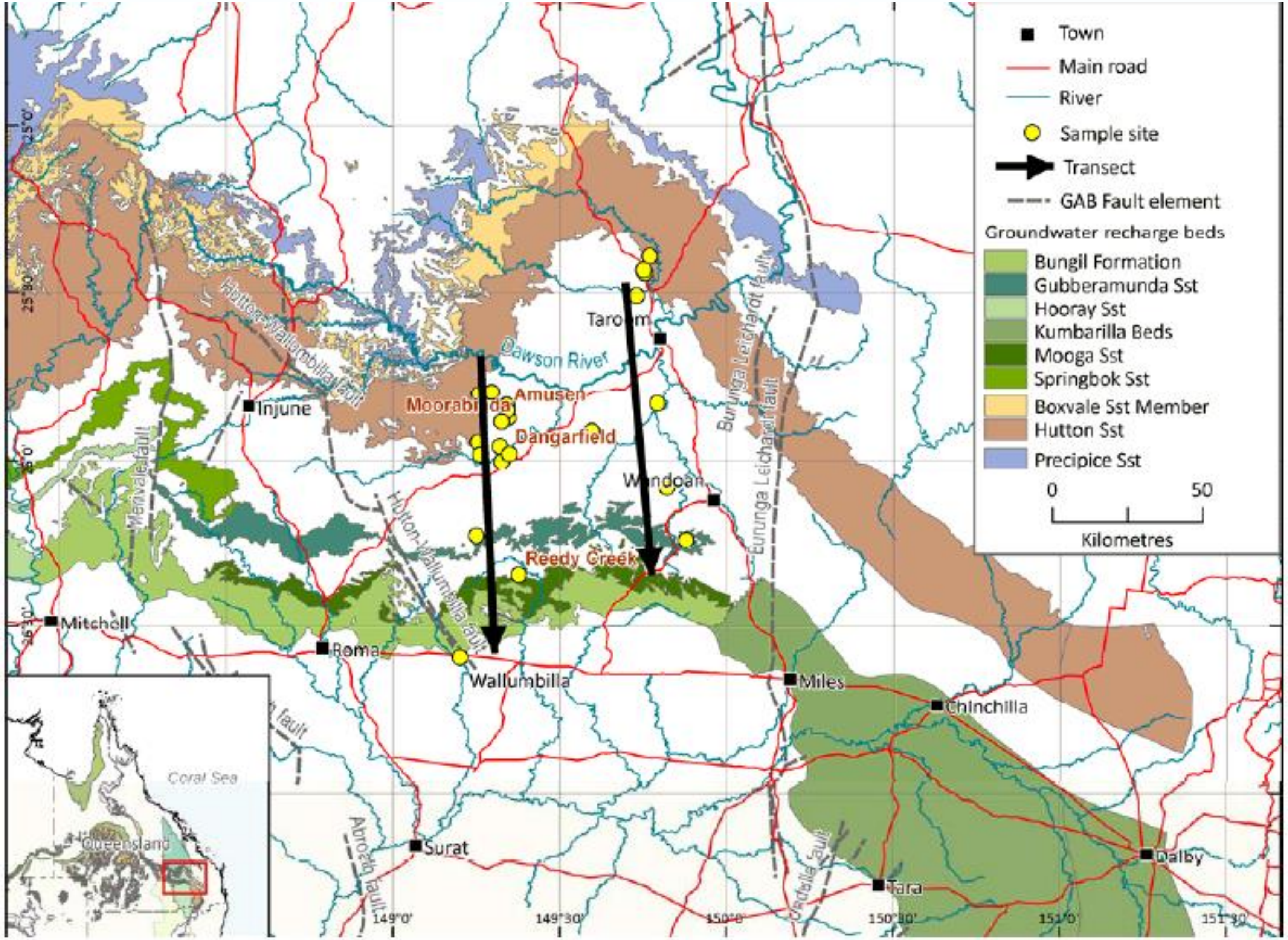


Figure 6-3 Conceptual Model of the Groundwater Systems in the Surat Cumulative Management Area

QWC (2012) Underground Water Impact Report

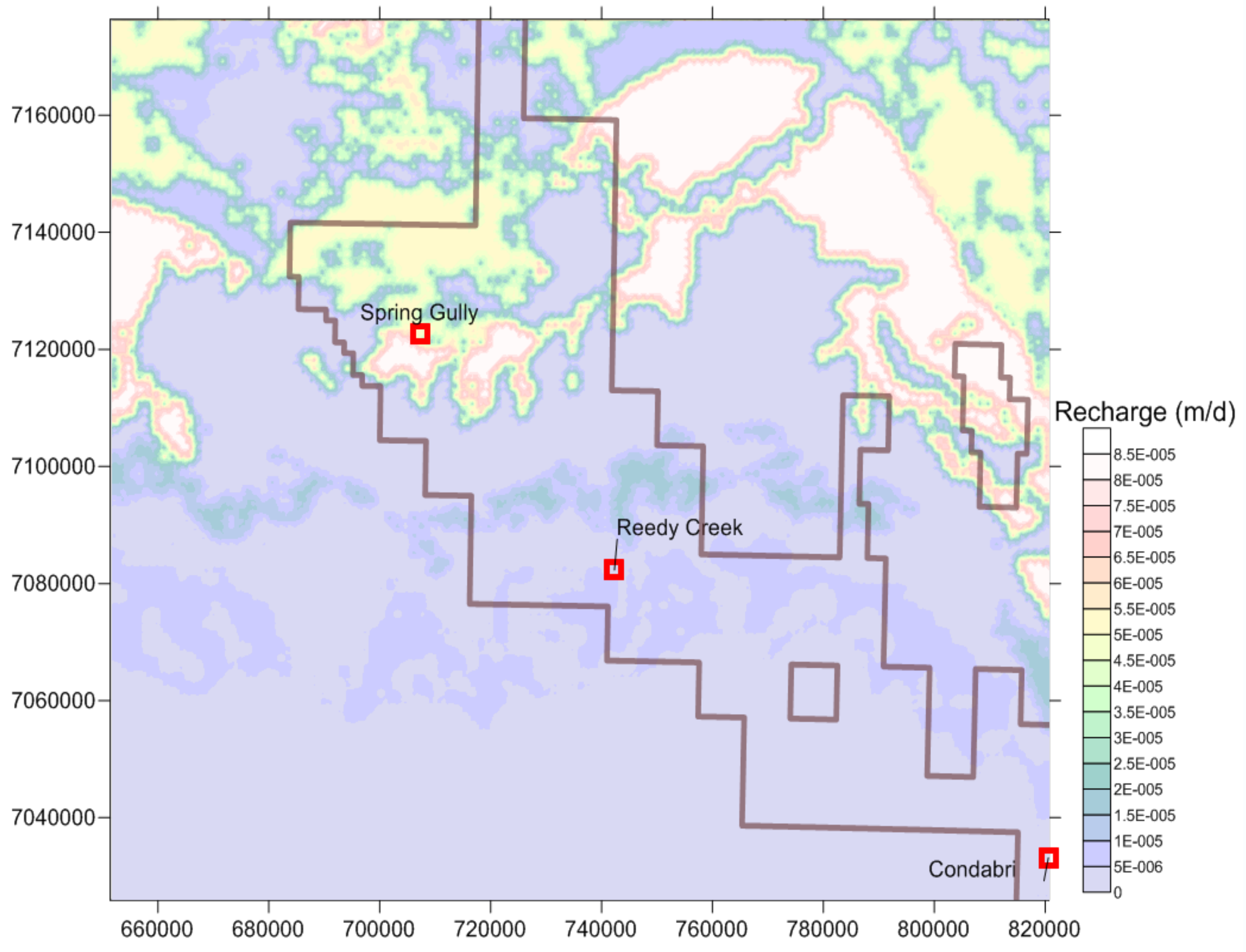
Environmental tracers

- Environmental tracers (^{2}H, ^{3}H, ^{18}O, CFCs, SF6, ^{13}C, ^{14}C, ^{36}Cl, ^{87}Sr /^{86}Sr, Noble gases) were sampled along two transects in a companion project on Geochemical Baseline Monitoring
- Stochastic particle tracking analysis was undertaken using a regional groundwater model calibrated to head observations to

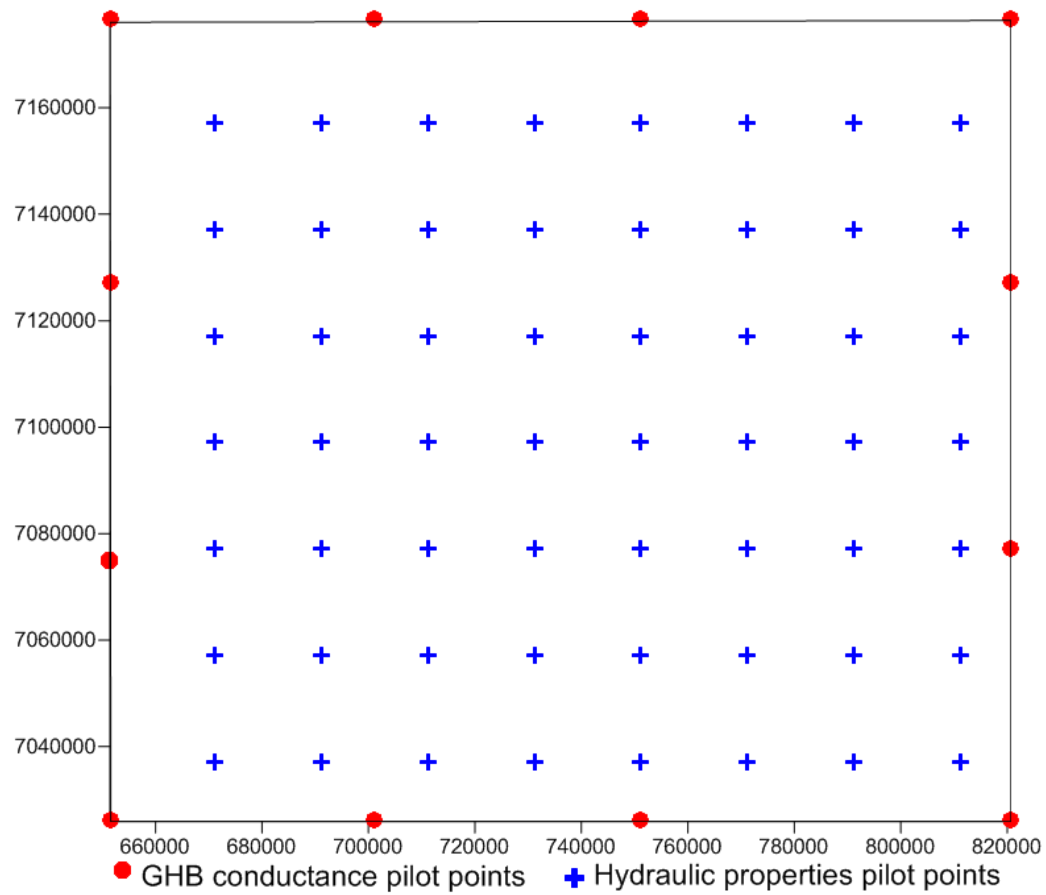


Suckow et al (2015)
http://www.gisera.org.au/publications/tech_reports_papers/GISERA-Project-4-Geochemical-Baseline-Report-V2-7182818.pdf

Model parameterization and calibration



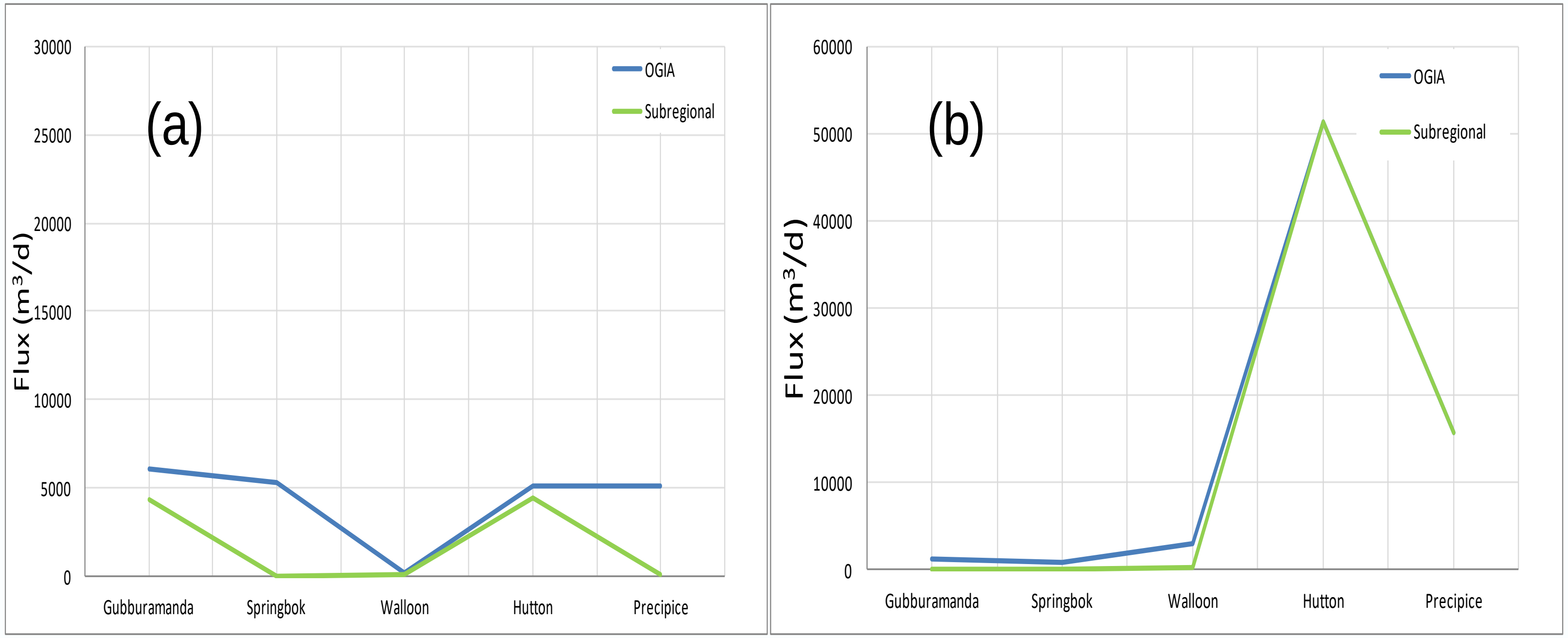
Diffuse recharge at the outcrop of multiple HSUs



Pilot points for calibration

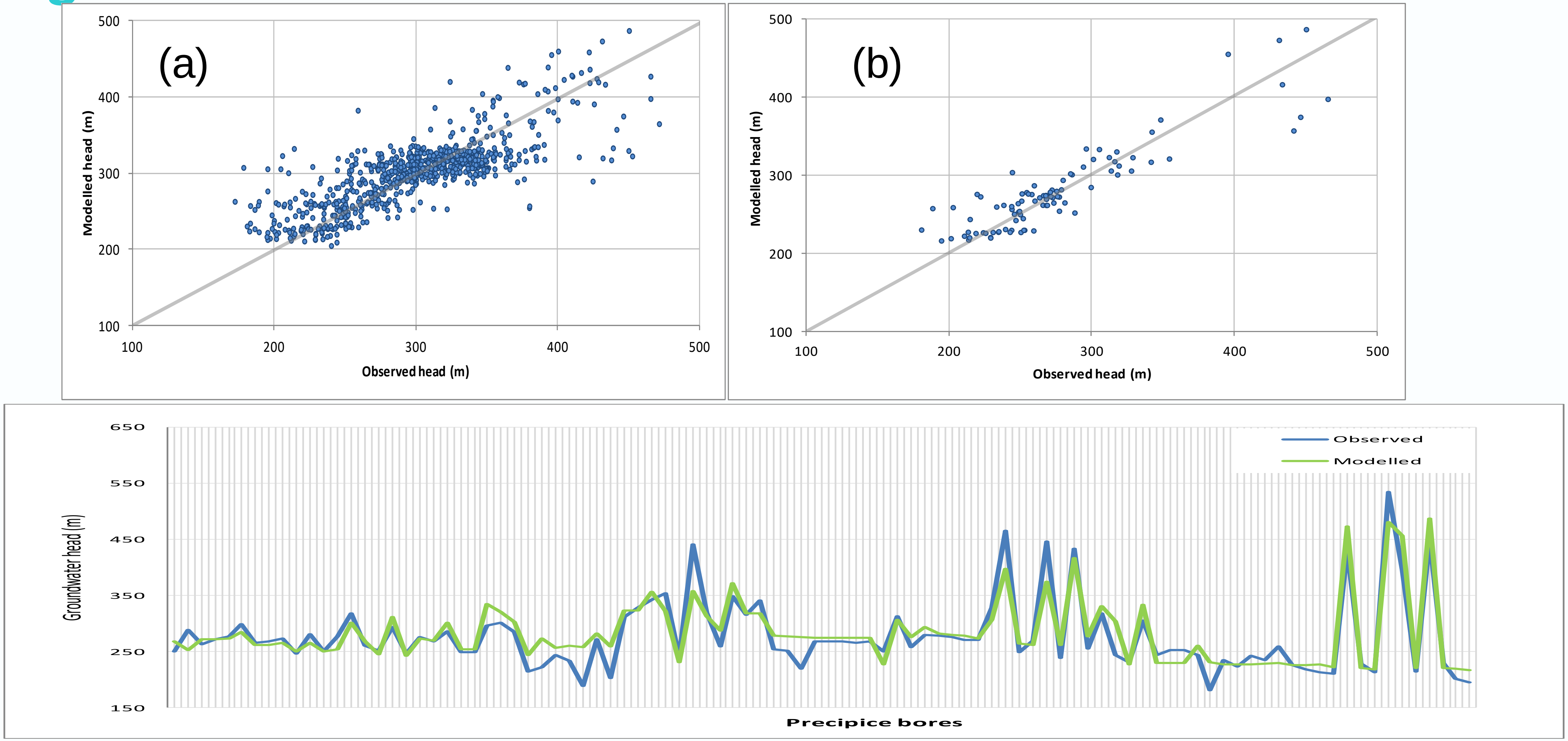
Model calibration

- Model calibrated using PEST suite of software
- Groundwater head observations from multiple aquifer layers



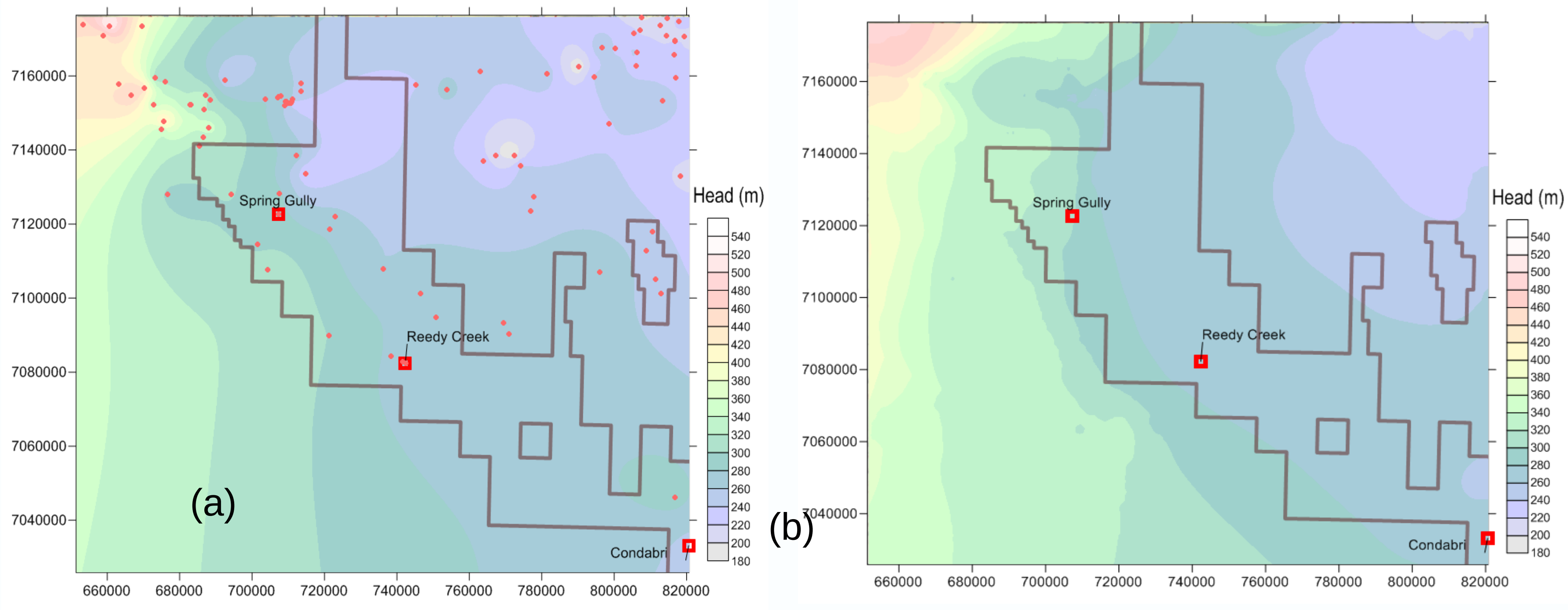
Match between the steady state boundary flux of subregional model and corresponding OGIA values: 19(a) depicts the negative flux (flux out of the model domain) and 19(b) depicts the positive flux (flux into the model domain)

Subregional model calibration…



Observed Vs subregional model simulated heads

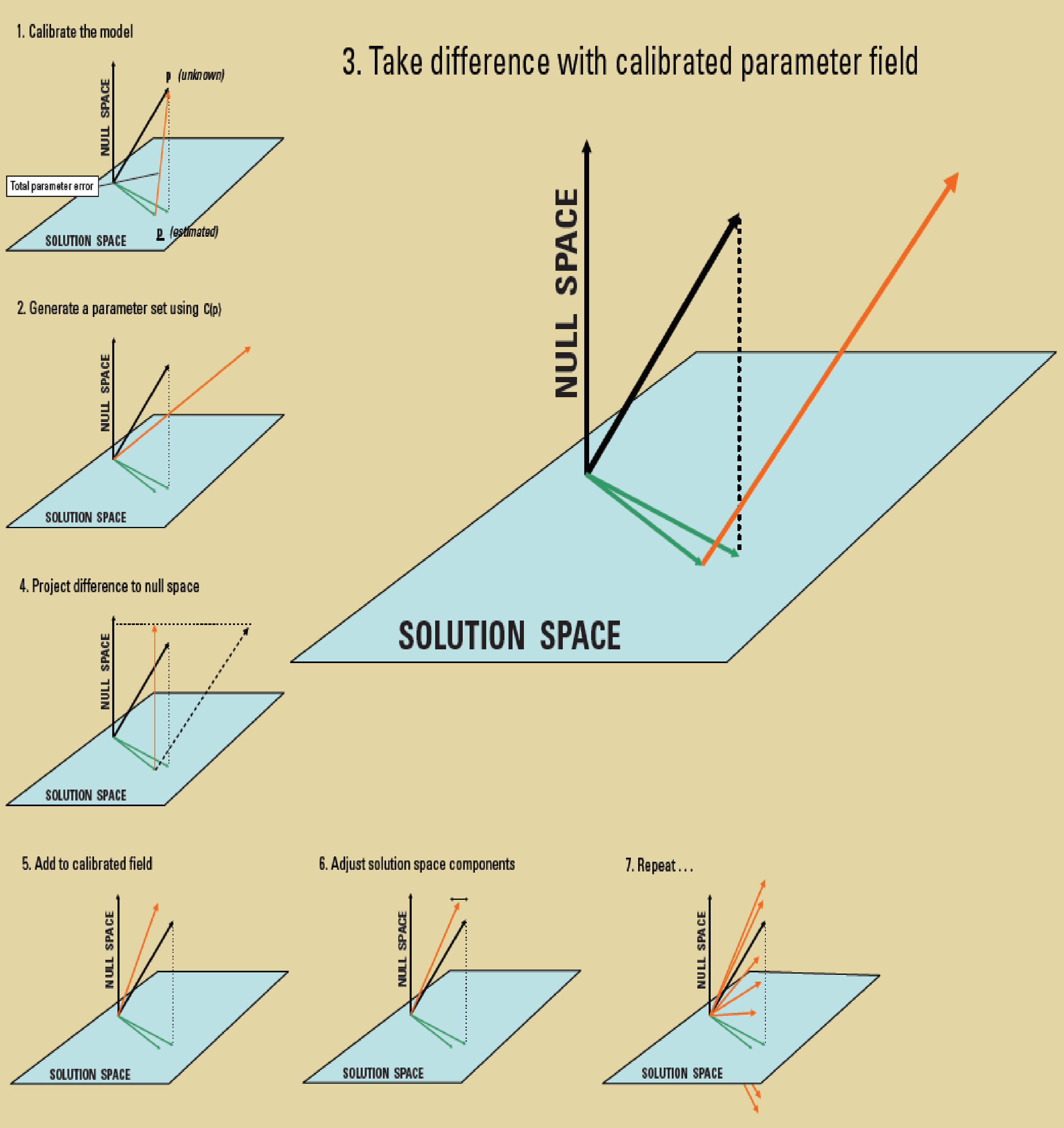
Model calibration



Contours of groundwater heads from: (a) interpolation from bore observations (the dots indicate bore locations) and (b) subregional model simulation

Calibration constrained Null-Space Monte Carlo simulation

- Model is calibrated
- Stochastic parameter fields are generated using a covariance matrix of innate parameter variability
- The calibrated parameter field is subtracted from the stochastic parameter field
- The difference is projected onto the calibration null space and the solution and the solution component is replaced by the parameter field arising from calibration exercise.



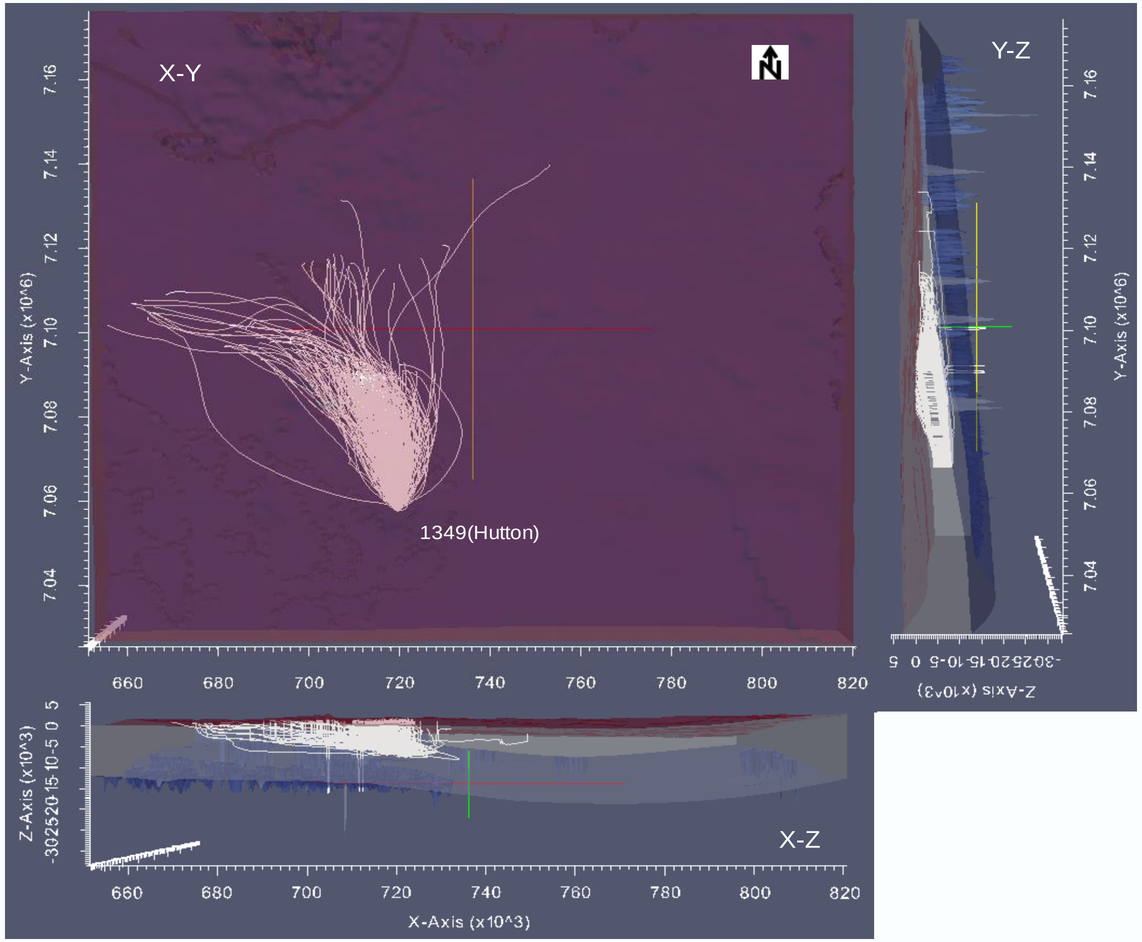
Doherty et al (2010)

Groundwater modelling used to support age tracer analyses

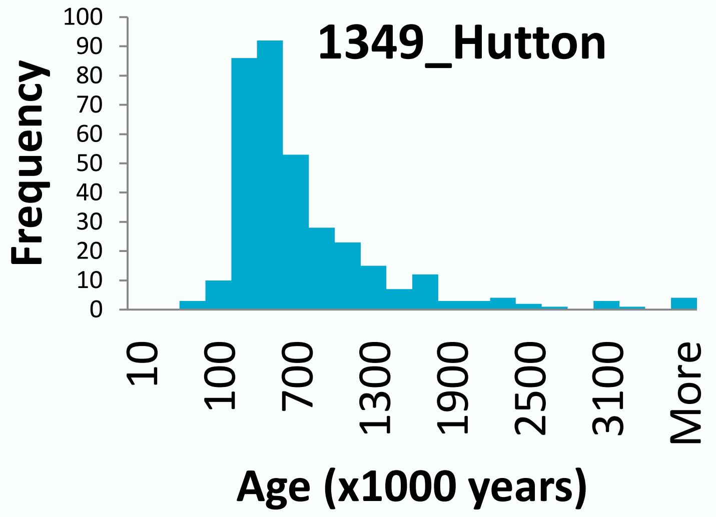
- Backward particle track simulation using Null-space Monte Carlo flow fields

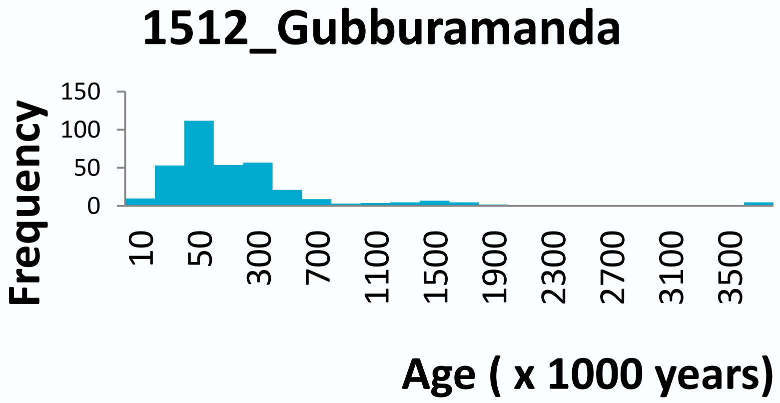
- Particle tracks simulated using 350 different combinations of model hydraulic property fields, each honoring the calibration constraints imposed by head observations
- Each particle track is obtained from an equally likely realization of the flow field

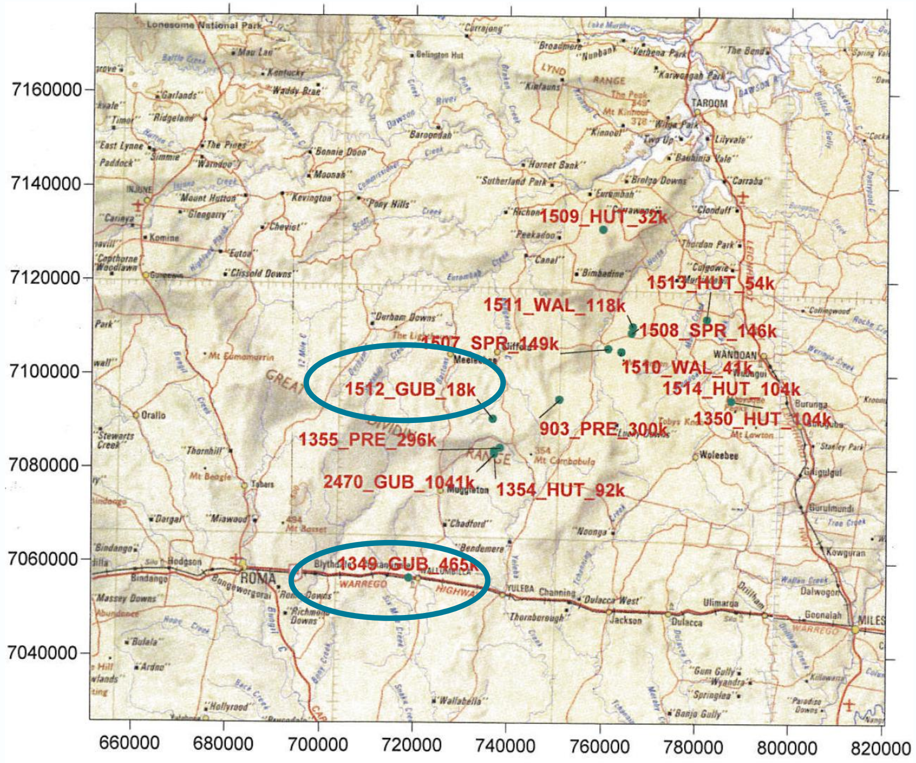
- This clearly demonstrate that the groundwater particle at a sample location could be a mixture of water recharged at different locations



Groundwater modelling used to support age tracer analyses







~350 particle tracks simulated for sampling locations in different formations

Comparison with tracer concentrations

- Age distribution was calculated for particles that tracked back to the recharge area based on the travel time
- These age distributions were used to calculate tracer concentrations using a convolution integral in a lumped parameter model [Lumpy - Suckow, 2012]
- This was used to compare to the measured values of tracers.
- The model predictions compared well with ^{14}C although inconclusive because of little or no ^{14}C in the samples
- Majority of the particle tracking results for ^{36}Cl indicated larger values than measured. This is not unexpected considering the possibility of diffusive losses of tracers to the adjacent aquitards.

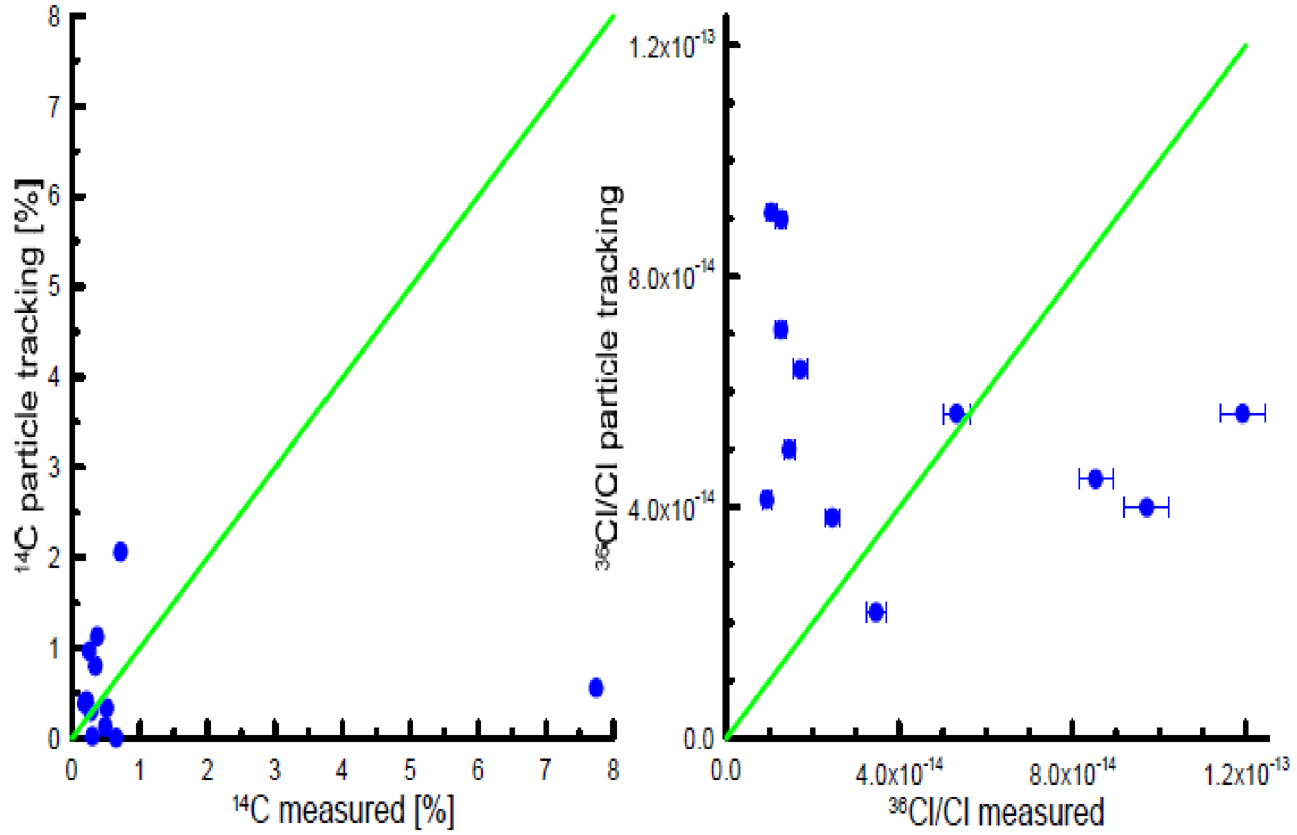


Figure 3.23: Comparison of particle-tracking derived ^{14}C (left) and $^{36}Cl/Cl$ (right) values with the actually measured tracer concentrations

Conclusions

- Large uncertainties in groundwater flow fields are possible even when constrained by large amount of groundwater head observations
- Calibration constrained stochastic particle tracking analysis was undertaken to calculate the probability distribution of travel times at locations that were sampled for environmental tracers

- Provides a quick and easy method for stochastic modelling to generate travel time distributions that can be evaluated in comparison with tracer measurements – such an approach will be particularly useful if advection is the dominant process of tracer transport.

- Comparison with multiple environmental tracers provide additional insights about the properties of aquifers and aquitards.