



Government of South Australia
Department of State Development

Research Findings in Relation to the Protection of Water Resources

Update

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Regulatory Context

- Risk and Objective based regime
- Focus on risks we need to address
- Informed decision-making
- Stakeholder engagement
- Environment: natural, social and economic aspects
- Manage environmental risk to ALARP

What is Risk?

- Likelihood of an undesirable event occurring; and
- Severity of consequence of that event on the environment

Essence of Key Concerns

- No proposal has yet been made for unconventional gas extraction in South East
- Over 100's letters of concern to the Minister:
 - Fracking will contaminate aquifers;
 - Fugitive emissions will affect public health;
 - SE Green clean image will be compromised

DSD Initiatives

- Responses prepared to each letter
- FAQ Sheet
- Instigate independent research

Background/Past Studies

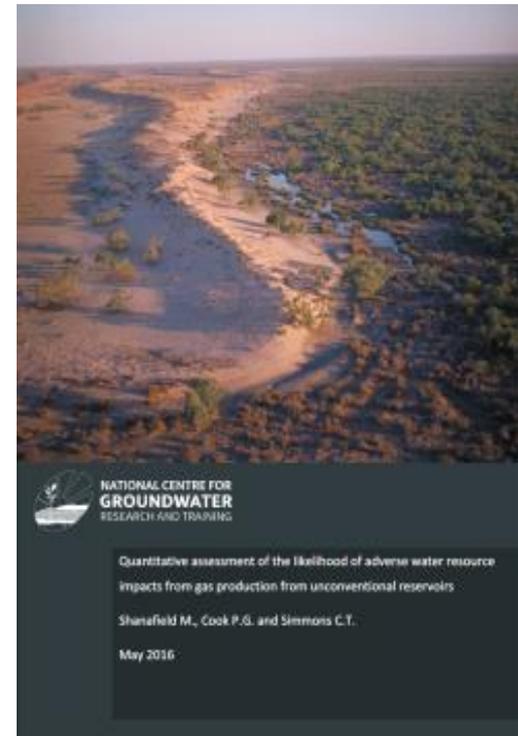
- Otway Basin Hot Sedimentary Aquifer & SEEBASE Study 2010
 - FrOGTech Report commissioned by PIRSA, VicDPI and Geoscience Australia, DEWNR, SA Water and DSD
 - <https://sarigbasis.pir.sa.gov.au/WebtopEw/ws/samref/sarig1/image/DDD/RB20100010.pdf>
 - Stage 1 provided a regional stratigraphic and structural framework over the entire Otway Basin as a baseline for characterising aquifers from surface to basement in order that government can make informed decisions and respond accordingly to all water affecting activities.
 - Stage 2 provides an opportunity for State water agencies, petroleum and geothermal explorers to develop detailed aquifer characterisation.

Research/Studies

- **National Centre for Groundwater Research and Training (NCGRT):**
Quantitative assessment of the likelihood of adverse water resources impacts from gas production from unconventional reservoirs
- **Jacobs:**
Hydrogeological consequence assessment – Unconventional gas well – South East.
- **The University of Adelaide:**
Well Cement Integrity and Cementing Practices
- **Adelaide University/Macquarie University:**
Fugitive Emissions Study

NCGRT Report

- Examines likelihood of groundwater contamination and depletion through transport of water and solutes via four pathways:
 - natural and induced fractures; leaky wells; faults; and infiltration of surface spills.
- Using statistics based on documented worldwide scientific studies and reports, assessed the likelihood of surface water contamination arising from surface spills.
- Using models to predict water flow and contaminant migration assessed the likelihood of shallow aquifer contamination.
- The draft report has been submitted following external peer review by CSIRO, Office of Water Science and DEWNR, is due to be released in early 2017.



4 Key Risk Paths

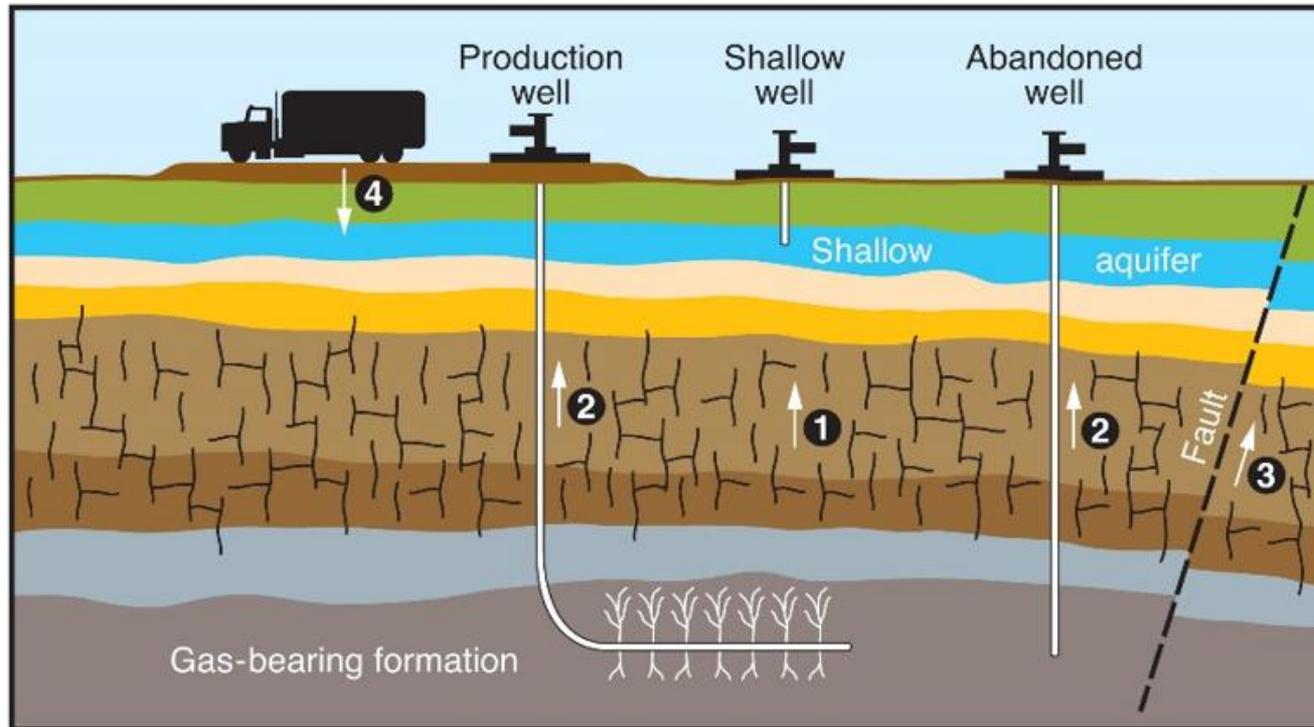


Figure 1. Pathways for contaminant transport into shallow aquifers. 1, natural and induced fractures; 2, leaky wells; 3, faults; 4, infiltration of surface spills. (Note this figure is for illustrative purposes and does not resemble true scale).

NCGRT Key Findings

Impact	Mechanism	Separation between gas-bearing formation and shallow aquifer	
		L = 500m	L = 2000m
		Coal seam gas	Shale and tight gas
Surface water contamination	Runoff from spills	1 in 10 in high rainfall areas	
Groundwater contamination	Infiltration from surface	1 in 100 #	
	Inter-aquifer leakage during hydraulic fracturing	1 in 1 million	1 in 10 million
	Inter-aquifer leakage after production ceases	1 in 400*	1 in 1 million*
Aquifer depletion †	Inter-aquifer leakage during gas production	1 in 100 billion	<1 in 1 trillion
Induced seismicity	Hydraulic fracturing and water reinjection	1 in 10,000	
Subsidence	Dewatering of formation	Not assessed	<1 in 100,000

More likely through leaky wells

Only if fracturing reactivates existing large fracture or faults and only after several hundreds or thousands of years

Resulting from formation water withdrawal

Mainly waste water injection

* Likelihood only applies if well is hydraulically fractured.

Likelihood for spills greater than 1500 litres.

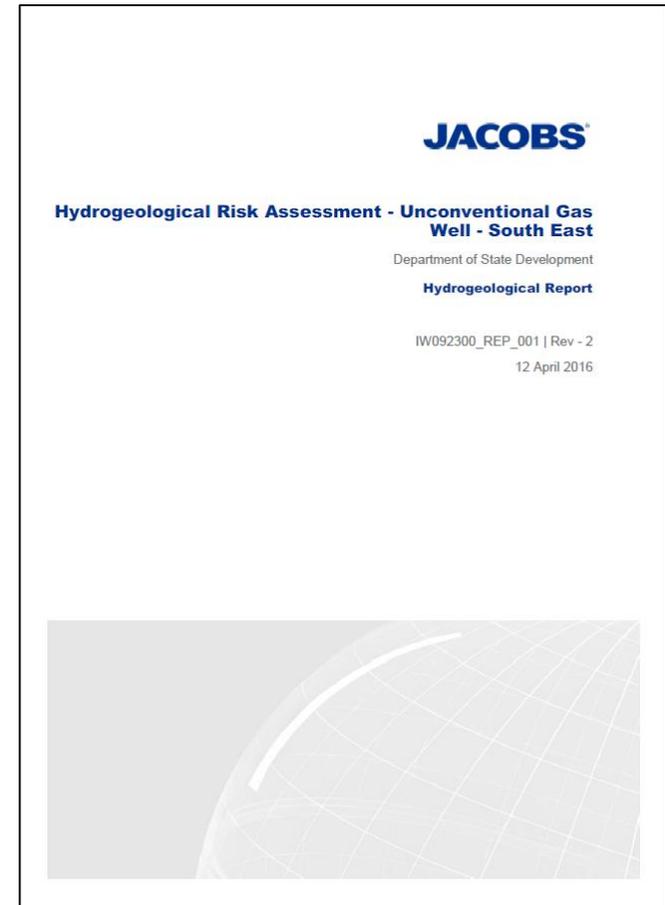
† Aquifer depletion due to direct pumping from shallow aquifers was not assessed.

Jacobs Report



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- Semi-quantitative “consequence” assessment for risks associated with the drilling of an unconventional well in the state’s South East.
- Risks associated with development of natural gas, specifically risks of hydraulic fracturing of gas reservoirs and any consequent impacts on groundwater resources
- Hydrogeological assessments to answer the “what if” questions relating to:
 - Potential consequence to aquifers as a result of fracture stimulation, i.e. frack fluid migrating via enhanced fault, fractures and fissures into aquifers used for domestic and or other supplies of water.
 - Potential consequence to aquifers as a result of a high pressure fluid (contaminant) release. This scenario is conceptually derived from the effects of a high pressure induced well casing failure in an aquifer zone.
 - Potential consequence from a failure of containment of the surface storage of fluids with potential contaminants (frack fluid, return water, hydrocarbons etc.).
- The final report will be released in early 2017.



Risk Scenarios

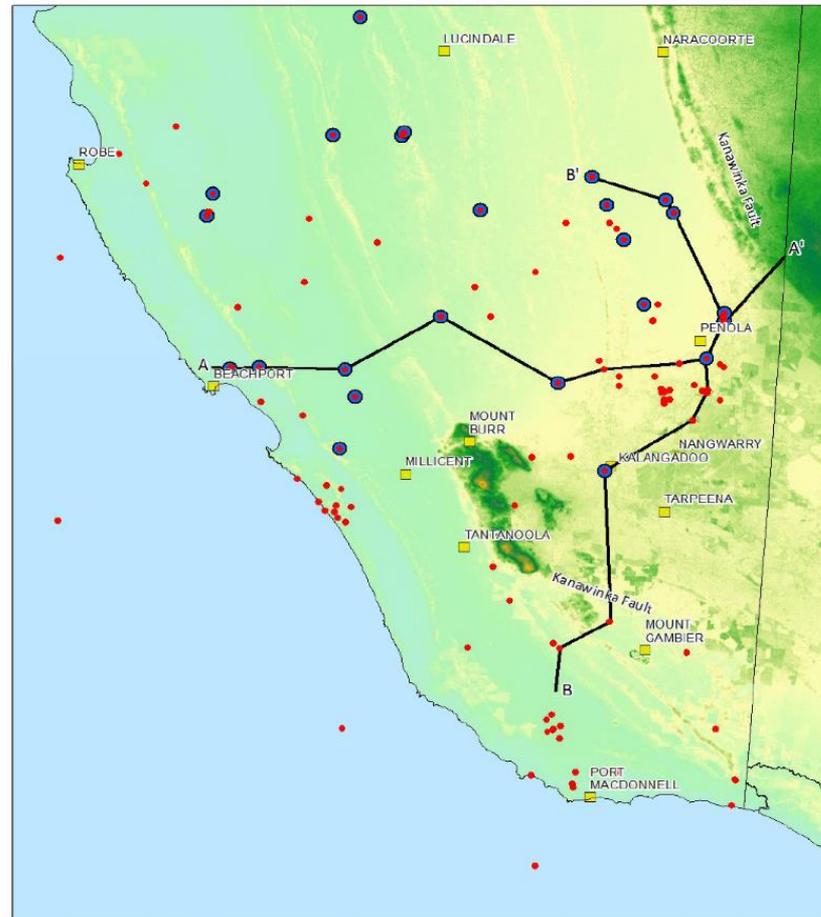


Table 3.2 : South East Unconventional Gas – Risk Identification for economic aquifers

Risk Identification for economic aquifers			
Risk	Source / Contaminant	Pathway	Receptor(s)
Contaminant Leaking from surface storage facility	Frack fluid or waste water stored in lined / unlined surface ponds	Leakage through failure in liner or overflow, migrating (through gravity flow) through unsaturated zone into unconfined aquifer (or from onsite spill or escape)	Unconfined / primary / unconsolidated aquifer
Contaminant migrating through fracture stimulation process	Frack fluid injected under pressure into gas producing reservoir rocks	Excessively stimulated fracture zones, aquitards and potential fault zones	Aquitards, shallower occurring aquifers, aquifers immediately adjacent to gas reservoirs
Contaminant migrating resulting from well failure due to high pressure	High pressure release of gas / frack fluid / saline formation waters through well casing failure point(s)	Release of contaminant under a pressure gradient into aquifers through aquitards, fault systems etc. by being released directly adjacent to the aquifer or transferring along well casing or bore-hole annulus	Aquifers adjacent to area of release (entire well column)

Hydrogeological Cross-sections

Figure 3.7 | Cross section alignments



Legend Towns All wells (DSD) Wells to basement		 Interpretated Fault SW_Vic_LandMass SW_SA_Landmass_M_GA63 State boundary North-south cross-section alignment East-west cross-section alignment		Elevation (m AHD) High: 1432 Low: -26	
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Jacobs does not warrant that this document is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information provided herein.

GDA 1984 Transverse Meridian
AG 1:80,000

0 10 20
Kilometres

A-A' Cross-section (Shallow)

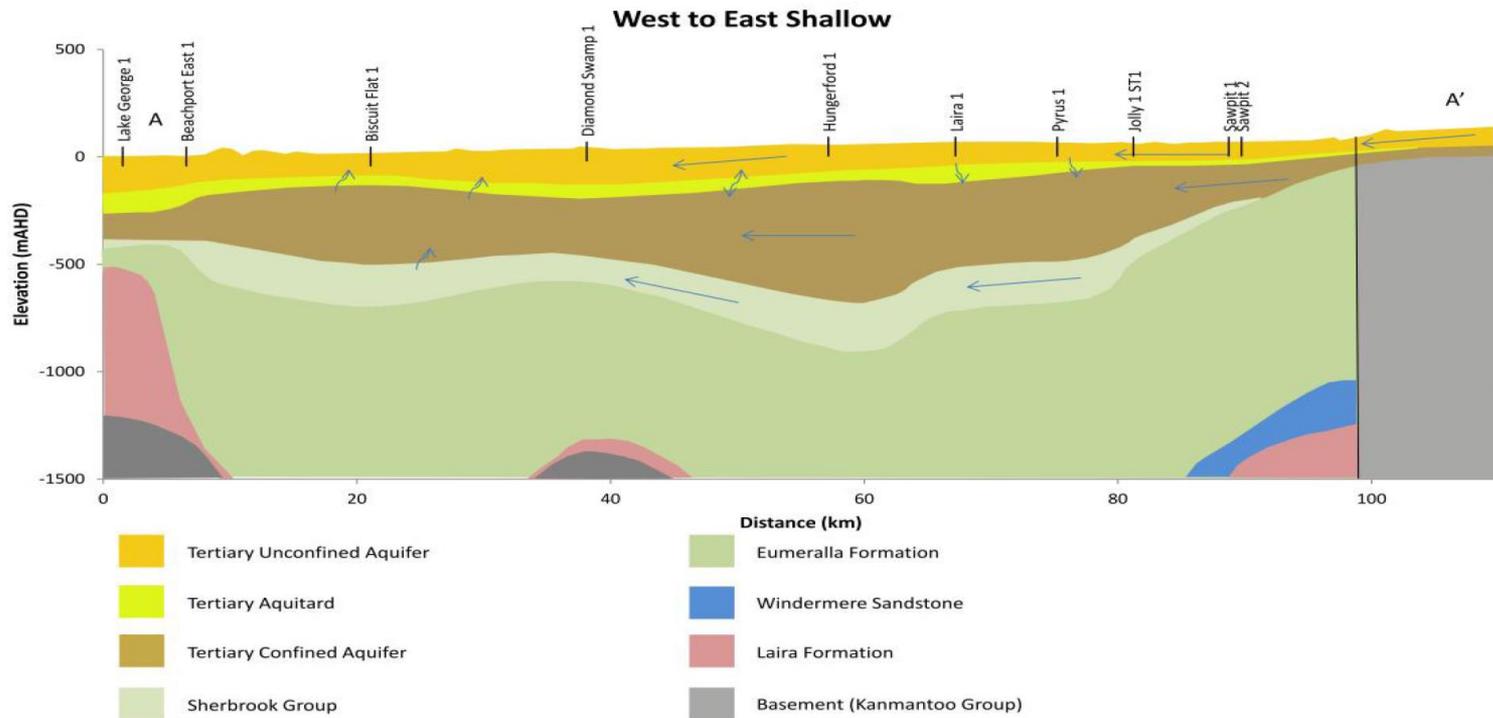


Figure 3.10 : Cross Section A-A' (West-East) – Shallower Stratigraphic Units. Arrows in blue show the inferred groundwater flow directions within and between units based on published groundwater head contours

A-A' Cross-section (Deep)

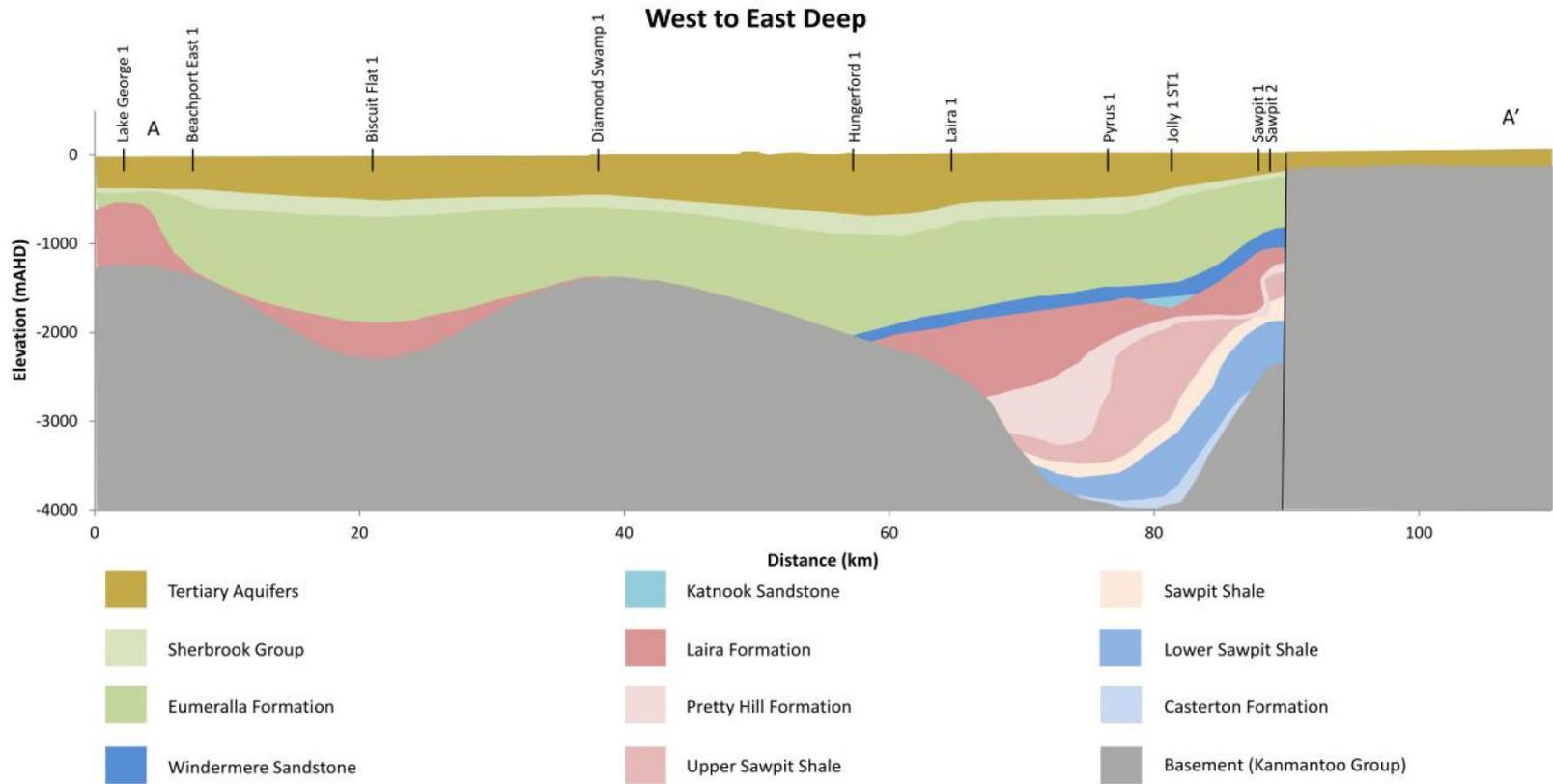


Figure 3.11 : Cross Section A-A' (West - East) – Deeper Stratigraphic Units

B-B' Cross-section (Shallow)

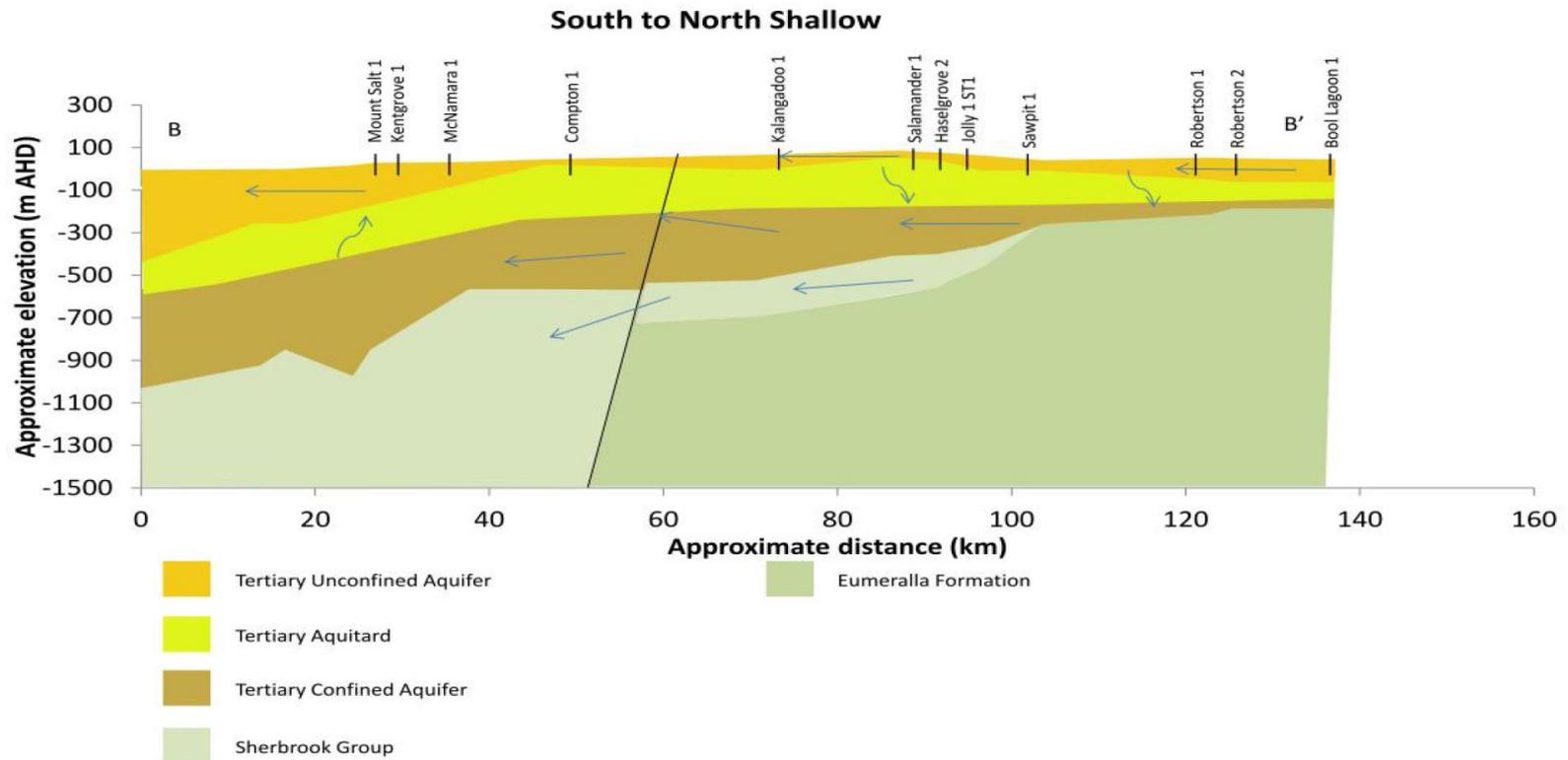


Figure 3.8 : Cross Section B-B' (South - North) – Shallower Stratigraphic Units. Arrows in blue show the inferred groundwater flow directions within and between units based on published groundwater head contours

Surface Storage Loss of Containment Event

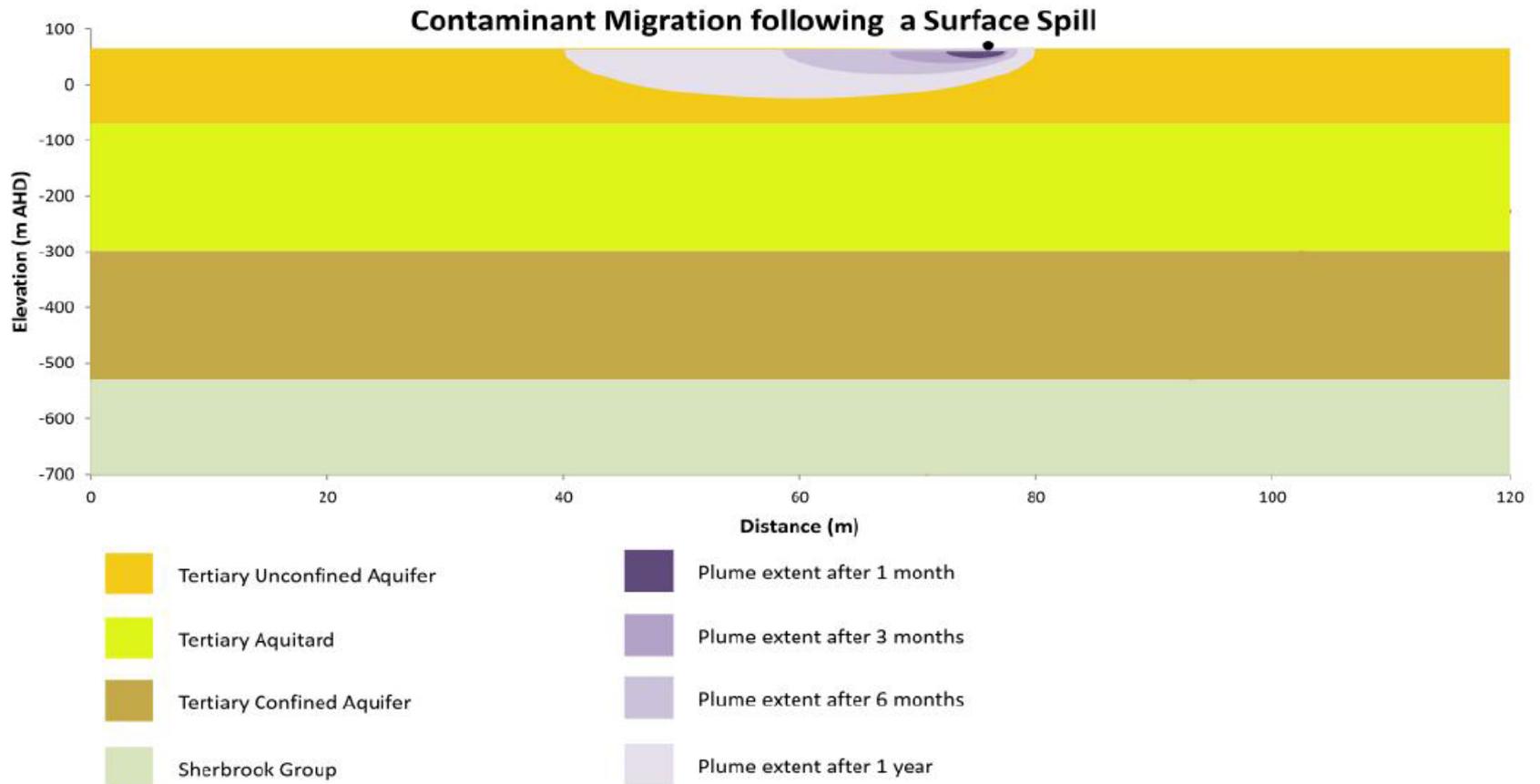


Figure A.5 : Contaminant migration following a surface contaminant spill

High Pressure Contamination Event

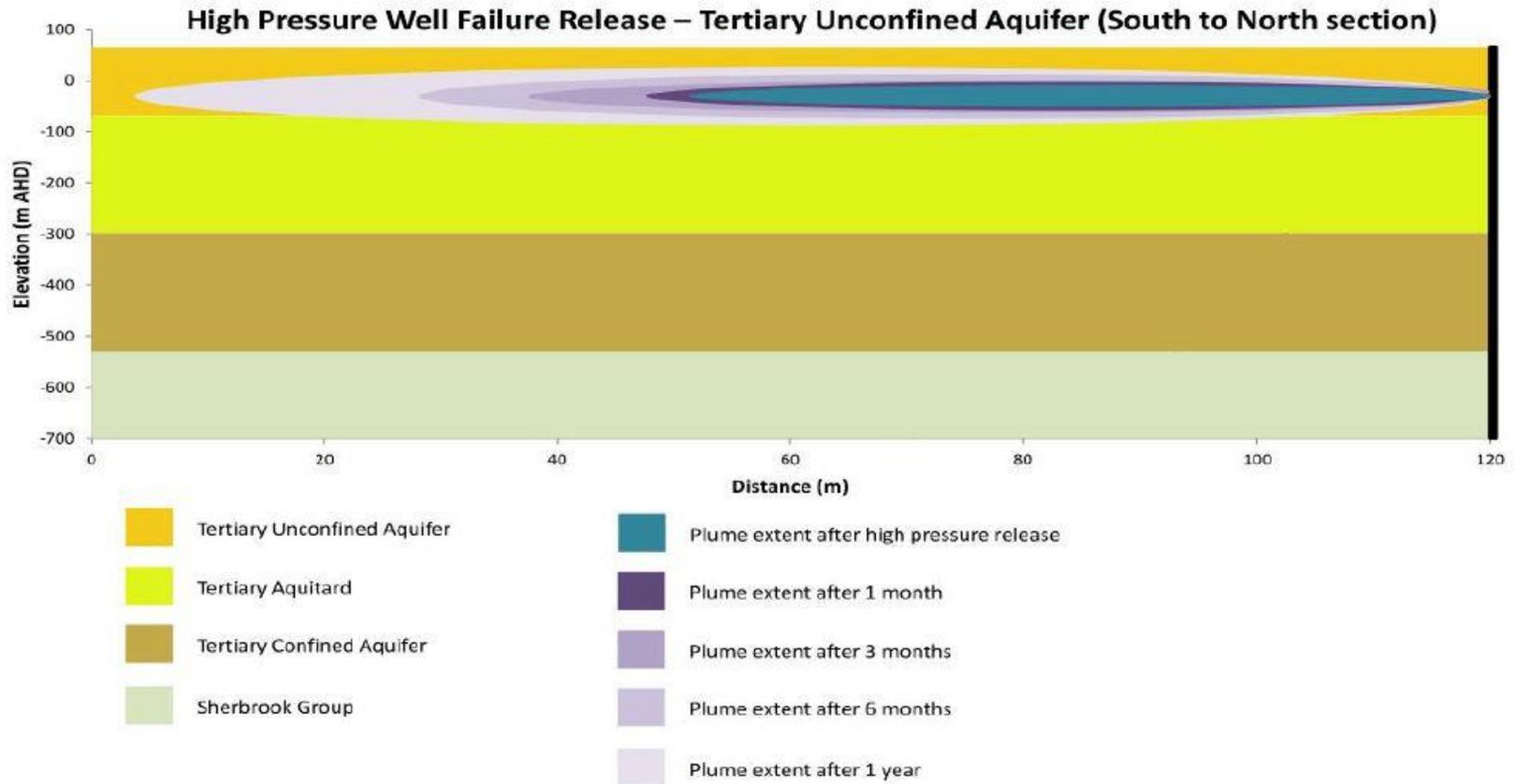


Figure A.1 : Contaminant migration following high pressure contaminant release in Tertiary Unconfined Aquifer (South to North section)

High Pressure Contamination Event

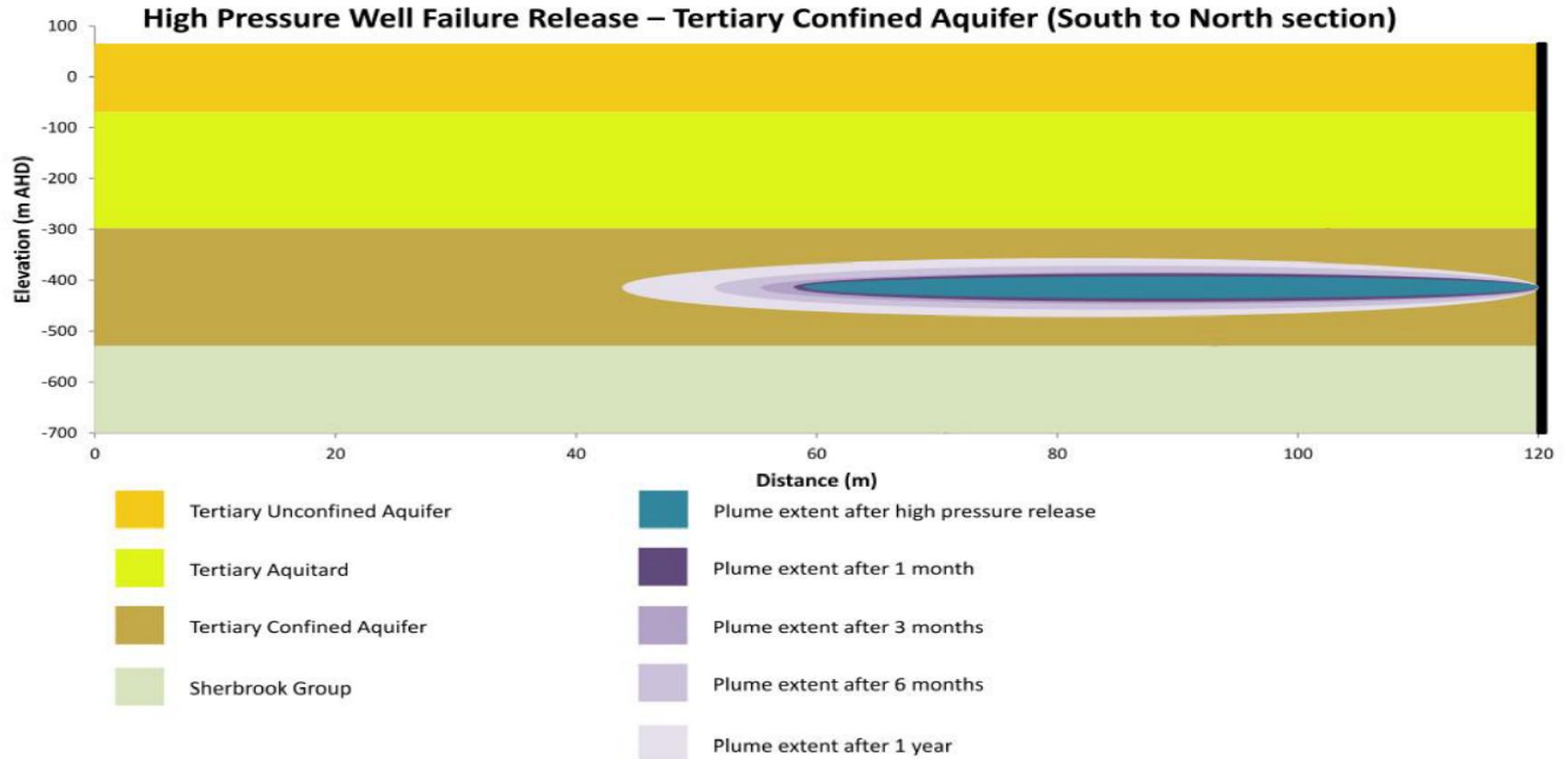


Figure A.2 : Contaminant migration following high pressure contaminant release in Tertiary Confined Aquifer (South to North section)

Inter-zonal Frac Fluid Contamination Event

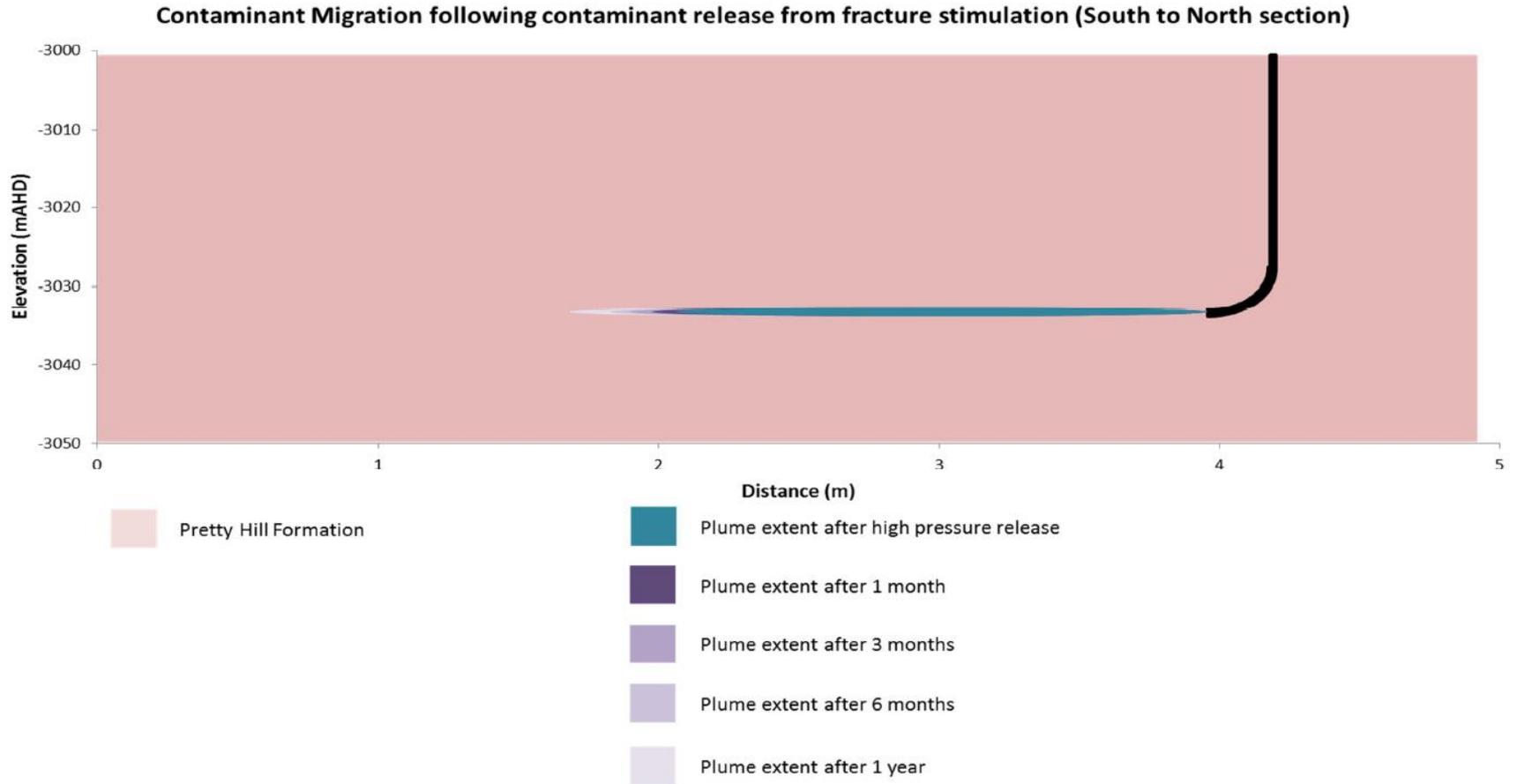


Figure A.6 : Contaminant migration in rock matrix following potential contaminant release following fracture stimulation (South to North section)

Open Fault Frac Fluid Migration Event

Contaminant migration through an open fault with aperture 0.01 mm

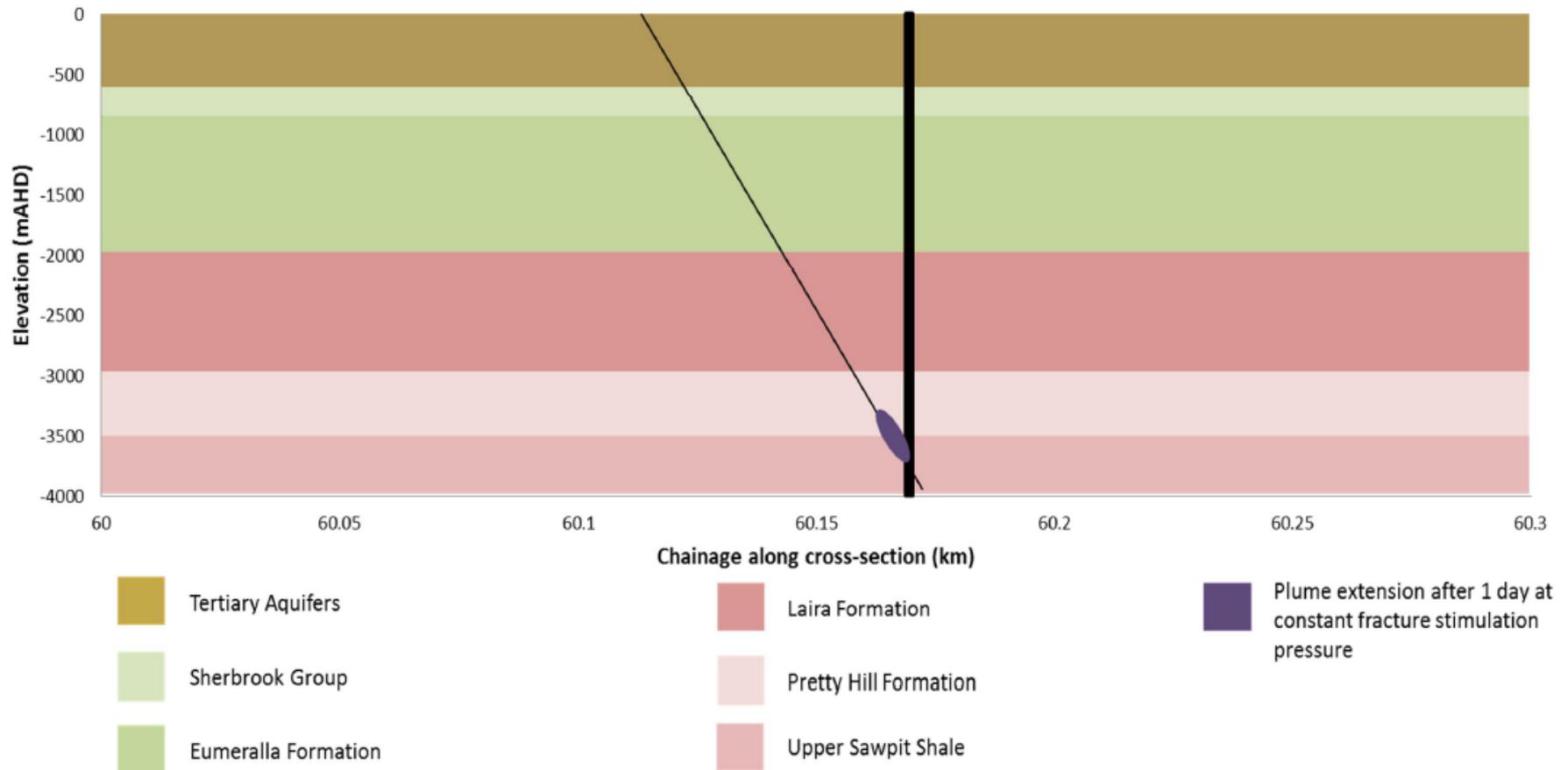
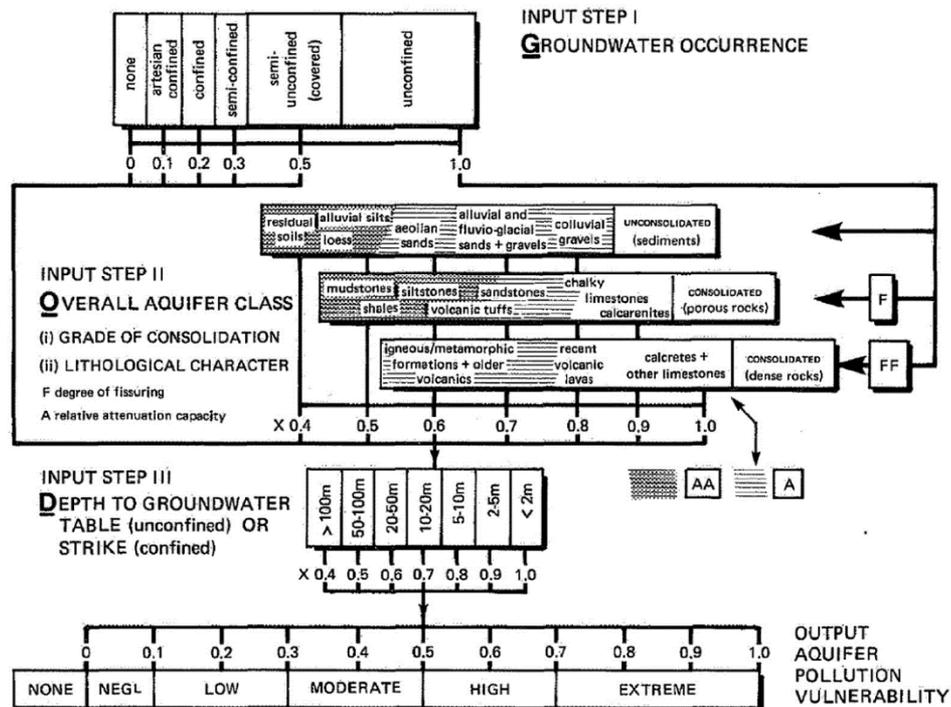


Figure A.8 : Contaminant migration through an open fracture/fault with aperture 0.01mm after 1 day at constant fracture stimulation pressure

Aquifer Vulnerability Assessment

How easy or hard for contamination event to reach and contaminate aquifer



- Groundwater (aquifer) confinement
- Overlying Strata
- Depth to Groundwater

Figure 4. GOD empirical system for the rapid assessment of aquifer pollution vulnerability.

Jacobs Report Risk Conclusions

Surface Storage Contamination

		Consequence			
		Negligible	Minor	Medium	Major
Likelihood	Almost Certain	Moderate	High	Very High	Very High
	Likely	Low	Moderate	High	Very High
	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

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		Consequence			
		Negligible	Minor	Medium	Major
Likelihood	Almost Certain	Moderate	High	Very High	Very High
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Frack Fluid Migration

		Consequence			
		Negligible	Minor	Medium	Major
Likelihood	Almost Certain	Moderate	High	Very High	Very High
	Likely	Low	Moderate	High	Very High
	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

Frack Fluid Migration

		Consequence			
		Negligible	Minor	Medium	Major
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	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

High Pressure Contaminant Release

		Consequence			
		Negligible	Minor	Medium	Major
Likelihood	Almost Certain	Moderate	High	Very High	Very High
	Likely	Low	Moderate	High	Very High
	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

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	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

High Pressure Migration via Fault

		Consequence			
		Negligible	Minor	Medium	Major
Likelihood	Almost Certain	Moderate	High	Very High	Very High
	Likely	Low	Moderate	High	Very High
	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

High Pressure Migration via Fault

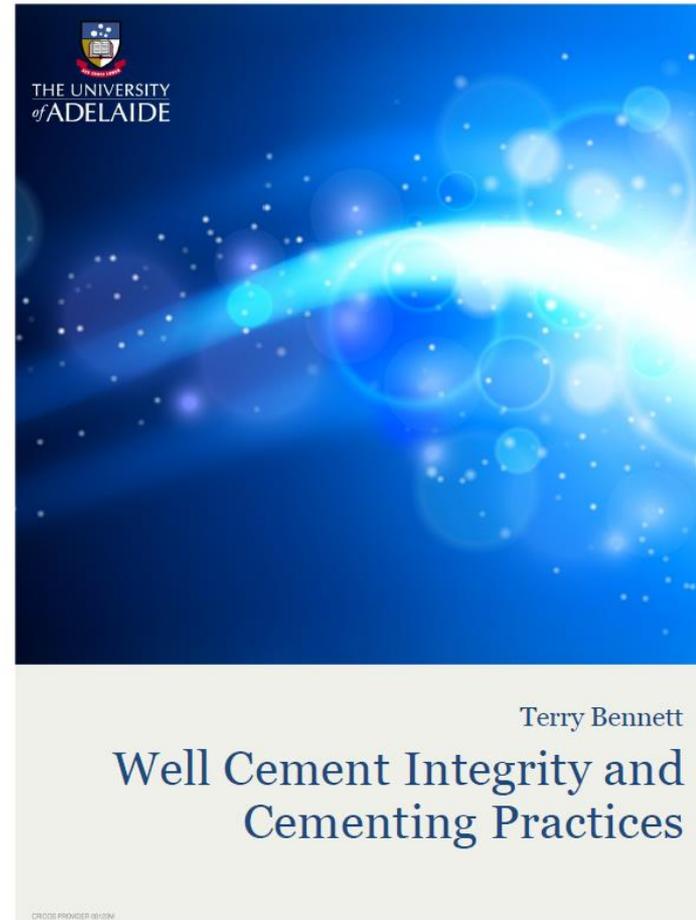
		Consequence			
		Negligible	Minor	Medium	Major
Likelihood	Almost Certain	Moderate	High	Very High	Very High
	Likely	Low	Moderate	High	Very High
	Unlikely	Low	Low	Moderate	High
	Rare	Very Low	Low	Low	Moderate

Figure 3.14 : Risk Ranking – Tertiary Unconfined Aquifer

Figure 3.15 : Risk Ranking – Tertiary Confined Aquifer

Well Cement Integrity and Cementing Practices – The University of Adelaide, Civil and Structural Engineering School

- An independent literature review into the integrity of cement.
- Key findings include the identification of factors that play an important role in the integrity of cement for long term isolation along the entire well lifecycle:
 - Design to execution (placement) and verification.
- Information derived from literature is provided together with recommendations.



Key Issues for Cement Integrity

- (a) between cement and outside of casing
- (b) between cement and inside of casing
- (c) through cement
- (d) through casing
- (e) in cement fractures
- (f) between cement and rock

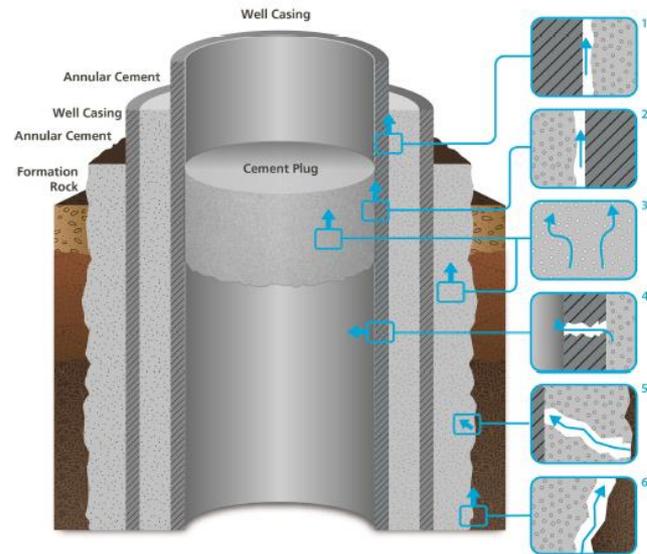


Figure 1.5: Potential leakage pathways, Celia et al. (2005)

Cement Placement

- Appropriate design, verification and placement of cement – ensuring communication between zones of fluids is isolated.
 - Objectives exist in relevant Statement of Environmental Objectives (SEO's) that focus on the protection of aquifers.
 - How objectives are to be achieved is demonstrated to DSD-ERD during the Activity Notification stage, prior to activities commencing.
 - Current practice is to cement across all aquifers with sufficient safety volume (additional amount of cement in excess of calculated requirements), with industry accepted verification methodologies (such as cement logging tools) used to confirm adequate cement coverage.
 - DSD-ERD are progressing a review of the integrity and coverage of cement behind casing for all wells (current and legacy) in the South Australian Cooper and Eromanga basins. The purpose of the project is to identify any potential noncompliance under the relevant SEO. No negative impacts to the environment have been confirmed from the reviewed wells to date. This project is ongoing.

INTEGRITY DURING SERVICE LIFE

- The report suggests little information is available in open literature on the material properties of cement blends, and hence little inference can be made to the behaviour of a cement sheath under various life cycle conditions.
 - Clarify how cement sheath strength is incorporated in existing well design procedures;
 - Compile an inventory of loading scenarios on a basin by basin basis to perform integrity analyses;
 - Develop a comprehensive experimental program for measuring the mechanical properties of cement, including curing of cement at expected in-situ conditions, compression tests at downhole temperatures and cyclic loading experiments to understand fatigue behaviour

Long Term Integrity

- The literature review indicates little information is available with respect to the long term (1000+ years) performance of well cements. Computer programs are being used to simulate long term cement performance, however additional laboratory work would benefit the calibration of these computer simulations.
- The report recommends comprehensive test program of ageing tests with different cement blends and formation water chemistries to better validate models and understand degradation mechanisms.