From: SMITH Tara L [TaraL.Smith@dnrme.qld.gov.au]
Sent: Tuesday, 19 December 2017 9:36 AM
To: CAGNEY Justin
CC: MOOR Darren
Subject: RE: Request for DNRM briefing material
Attachments: Phase 1 & 2 New Acland EHP VERSION v3 as presented 6 Dec 17.pdf; Phase 3 New Acland Groundwater and Hydrogeology EHP v4 as presented 6 dec 17.pdf

Hi Justin,

Please find attached the two presentations used to brief Kate Bennink on New Acland Groundwater Model Report in Brisbane on 6 and 7 December 2017.

Kind regards,

Tara ☺

Tara Smith
Project Coordinator
Water Services | Central Region
Department of Natural Resources, Mines and Energy

P: 07 4999 6832 **M:** Schedule 4 - CTPI
E: TaraL.Smith@dnrm.qld.gov.au
A: 22-30 Wood Street, Mackay Qld 4740
W: www.dnrm.qld.gov.au

From: MOOR Darren
Sent: Monday, 18 December 2017 6:01 PM
To: CAGNEY Justin <Justin.Cagney@ehp.qld.gov.au>; SMITH Tara L <TaraL.Smith@dnrme.qld.gov.au>
Subject: Fwd: Request for DNRM briefing material

Tara, can you please arrange for the material used at the recent briefing to be provided to Justin. Cheers Darren

Sent from my iPad

Begin forwarded message:

> **From:** CAGNEY Justin <Justin.Cagney@ehp.qld.gov.au>
> **Date:** 18 December 2017 at 5:04:47 pm AEST
> **To:** MOOR Darren <Darren.Moor@dnrme.qld.gov.au>
> **Subject: FW: Request for DNRM briefing material**

Hi Darren,

As discussed today, the department would appreciate if you could arrange for copies of the material presented to DES in early December 2017 in relation to New Acland Coal (NAC) groundwater model to be provided to DES to assist in relation to the current EA amendment application?

I appreciate your assistance.

Regards,

Justin Cagney
Executive Director
Coal and Central Queensland Compliance
Department of Environment and Science

P 07 4837 3318

209 Bolsover Street Rockhampton 4700
PO Box 413 Rockhampton 4700

EHP Cultural capability_web graphic APPD

From: BENNINK Kate
Sent: Monday, 18 December 2017 4:19 PM
To: CAGNEY Justin
Subject: Request for DNRM briefing material

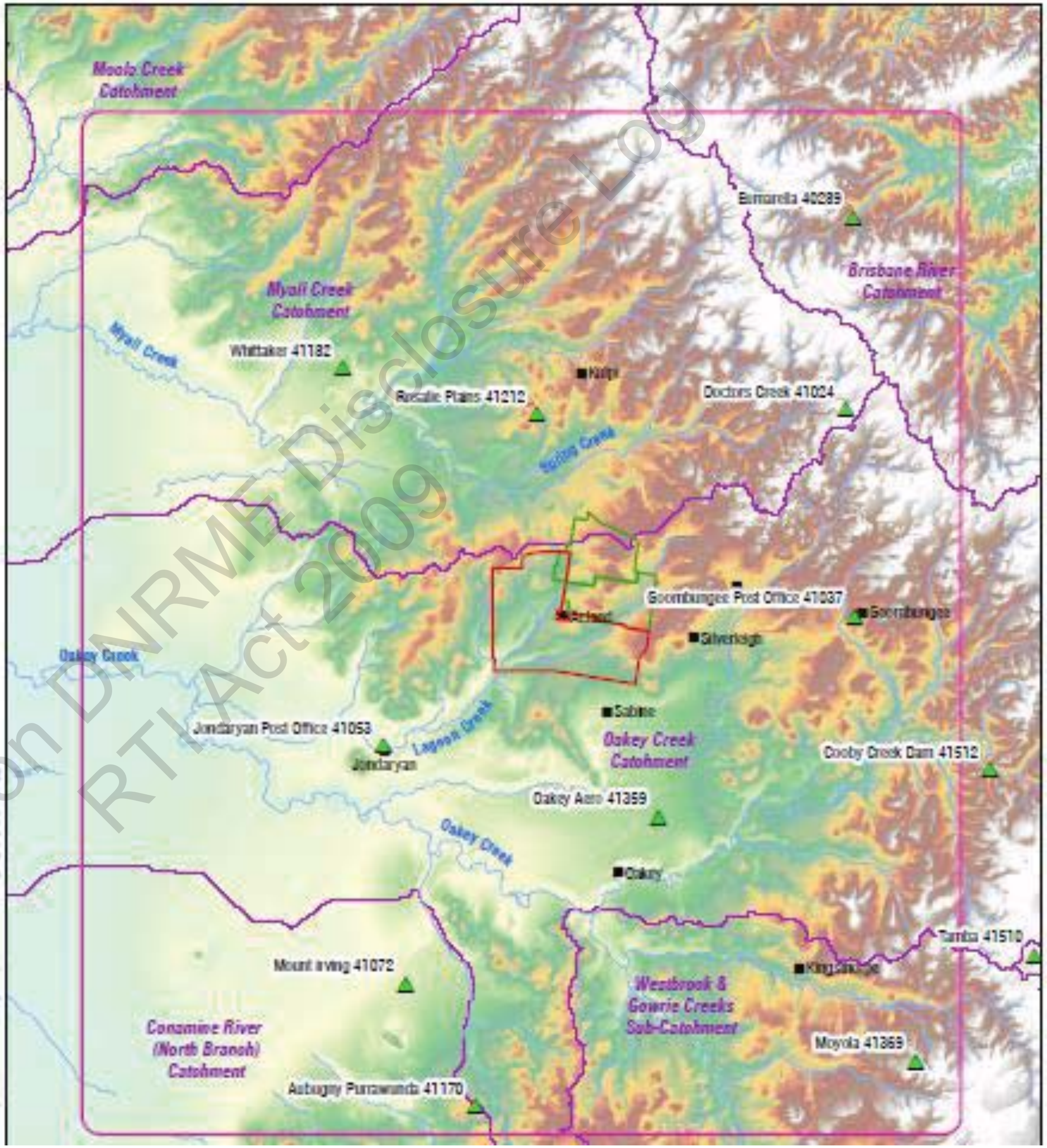
Hi Justin,

As discussed, DNRM officers provided me a briefing about groundwater in relation to NAC in early December. Could you please request that DNRM provide me with the presentations from the briefing at their earliest convenience?

Cheers
Kate

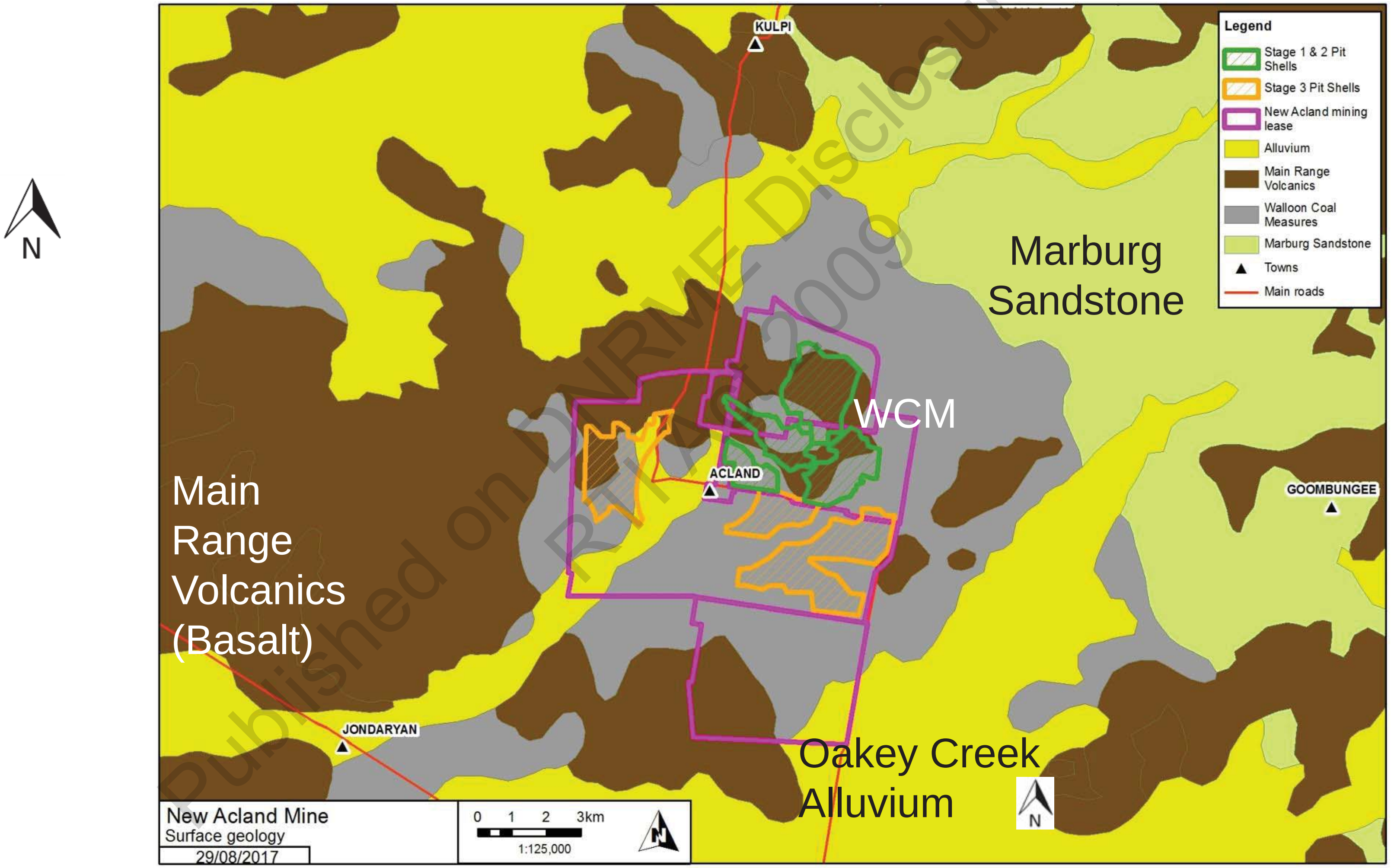
Kate Bennink
Manager
Department of Environment and Heritage Protection
Schedule 4 - CTP

Regional Setting



Regional Surface Geology

Surface geology in the area of NAC Mine



Porosity

There are two distinct types of porosity

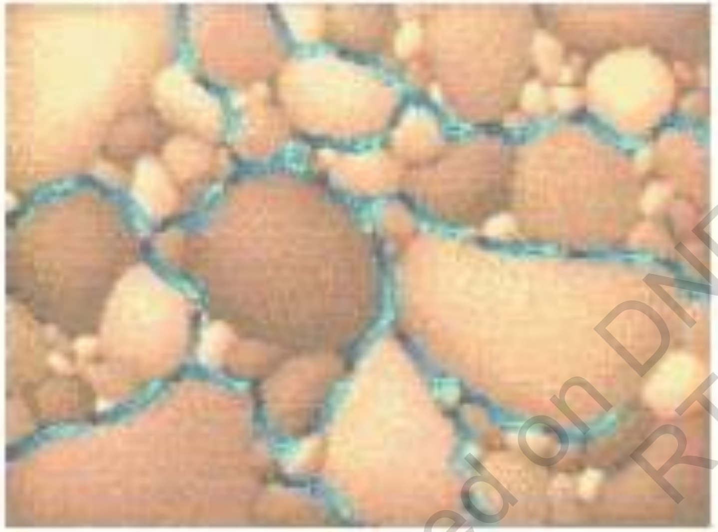
- **Primary porosity** – relates to the void spaces between the grains in granular aquifer material e.g. unconsolidated alluvium – sand, gravel, silt, clay; consolidated sediments – sandstone, shale, siltstone; also within vesicles (air/gas bubbles) in some volcanic rocks such as basalt

- **Secondary porosity** – relates to void spaces within joints, fractures, fissures, faults and cavities in a range of volcanic, metamorphic and some sedimentary rocks

Both forms of porosity can exist together – for example a fractured vesicular basalt or a fractured/jointed sandstone.

Porosity

PRIMARY POROSITY



Factors: Shape, size, sorting and packing of the grains

SECONDARY POROSITY

Factors: number, width, length (frequency and size) of the fractures, joints or other spaces in the rock

What is an aquifer (continued)

Aquifers can further be categorised by their physical properties –

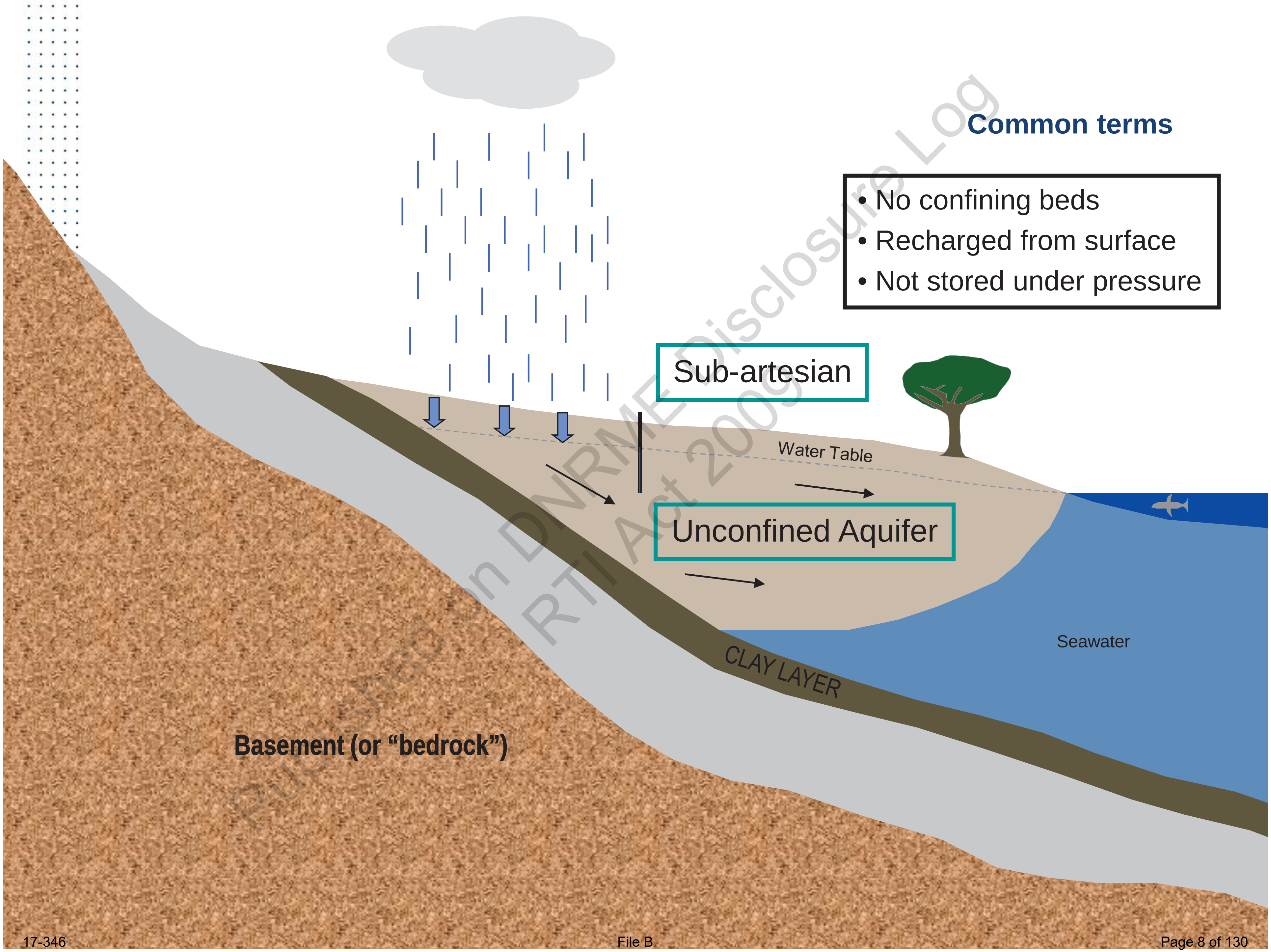
1. Unconsolidated sediments aquifer, primary porosity storage and flow between grains eg Oakey Creek alluvium

2. Fractured rock aquifer, secondary porosity storage and water moves along the fractures eg basalt (main range volcanics), coal, fractured sandstone/ shale (Walloon Coal Measures)

3. Consolidated sediments aquifer, predominantly primary porosity storage and flow between grains (porous sandstone and coal) Marburg Sandstone, Walloon Coal Measures

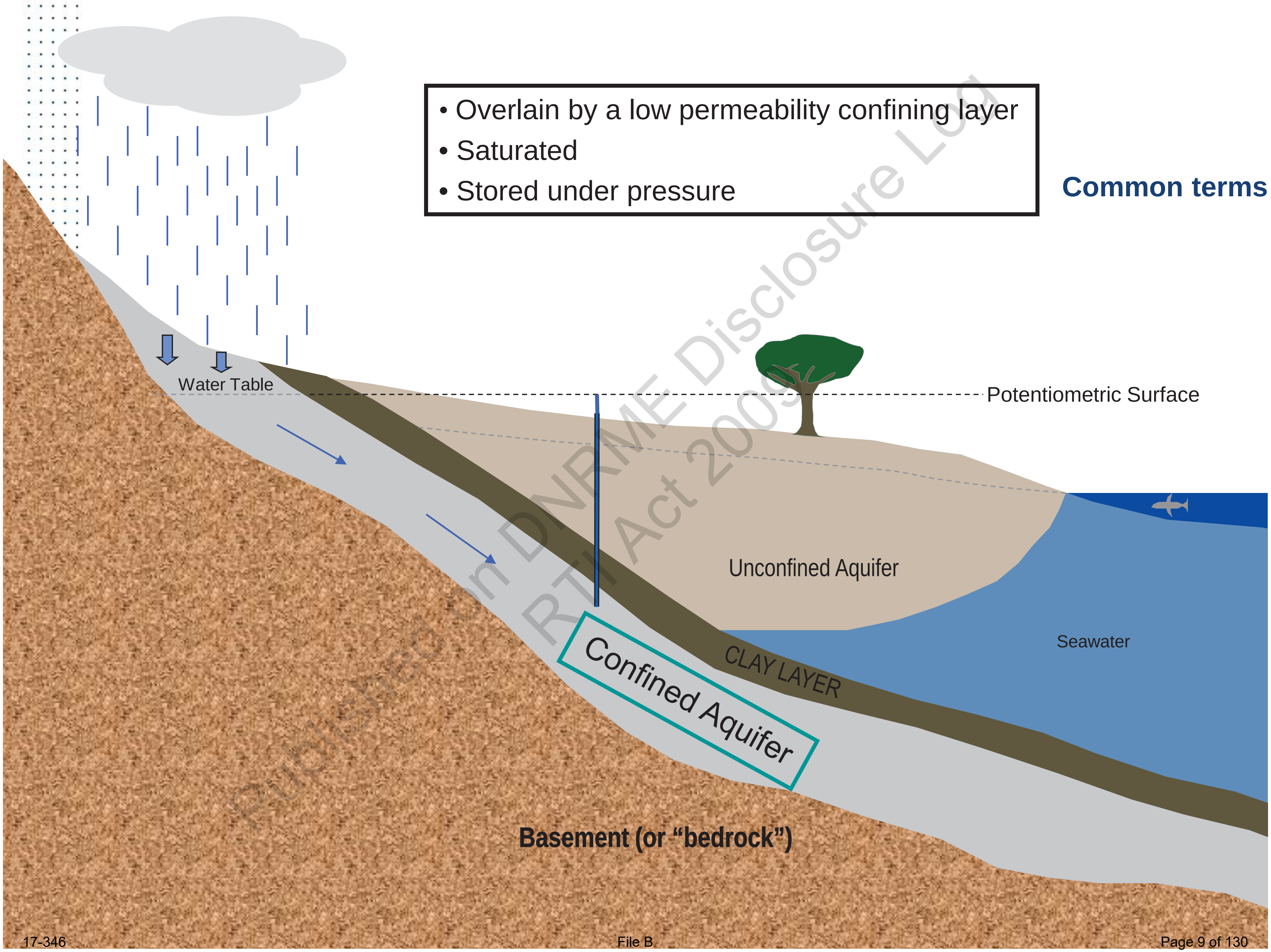
Common terms

- No confining beds
- Recharged from surface
- Not stored under pressure



Common terms

- Overlain by a low permeability confining layer
- Saturated
- Stored under pressure



Groundwater Storage

The amount of water able to be removed from an aquifer is described by two separate terms depending on whether the aquifer is unconfined or confined.

Unconfined aquifer – Specific Yield - Sy

This is represented by a percentage or decimal which describes the percentage of the saturated aquifer which is water that can be removed.

Note as the water level falls some water cannot be removed as it stays attached to particles within the aquifer.

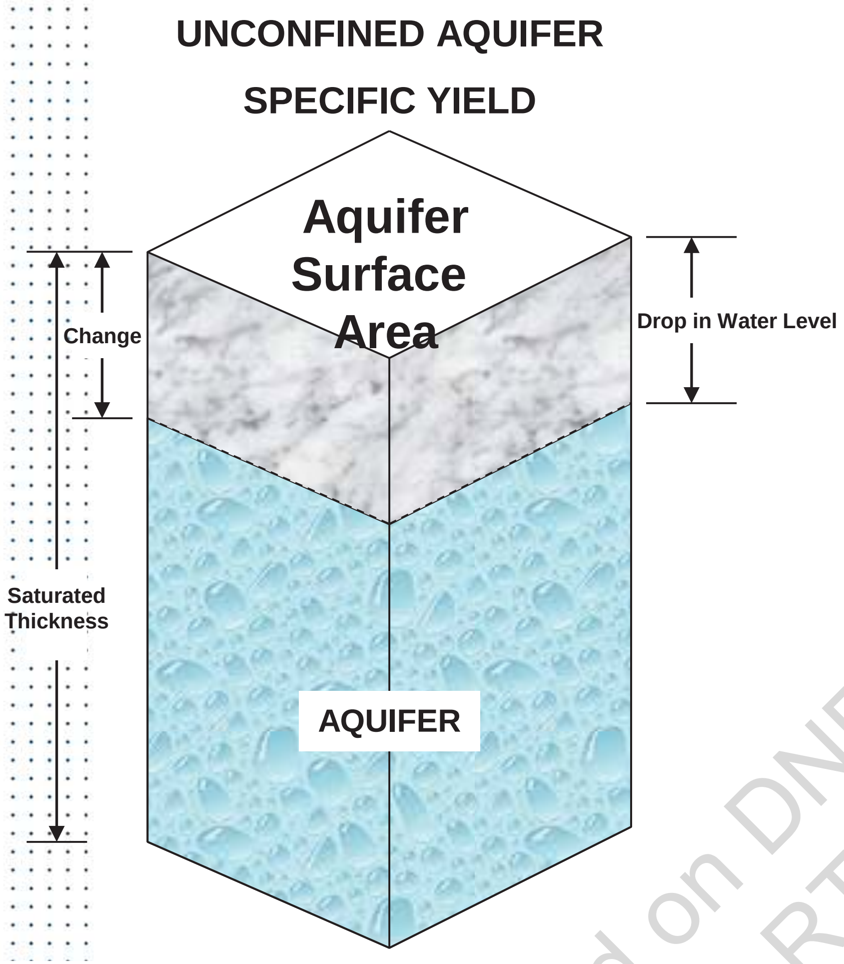
Typically the Specific yield in alluvium might be 10% or 0.10

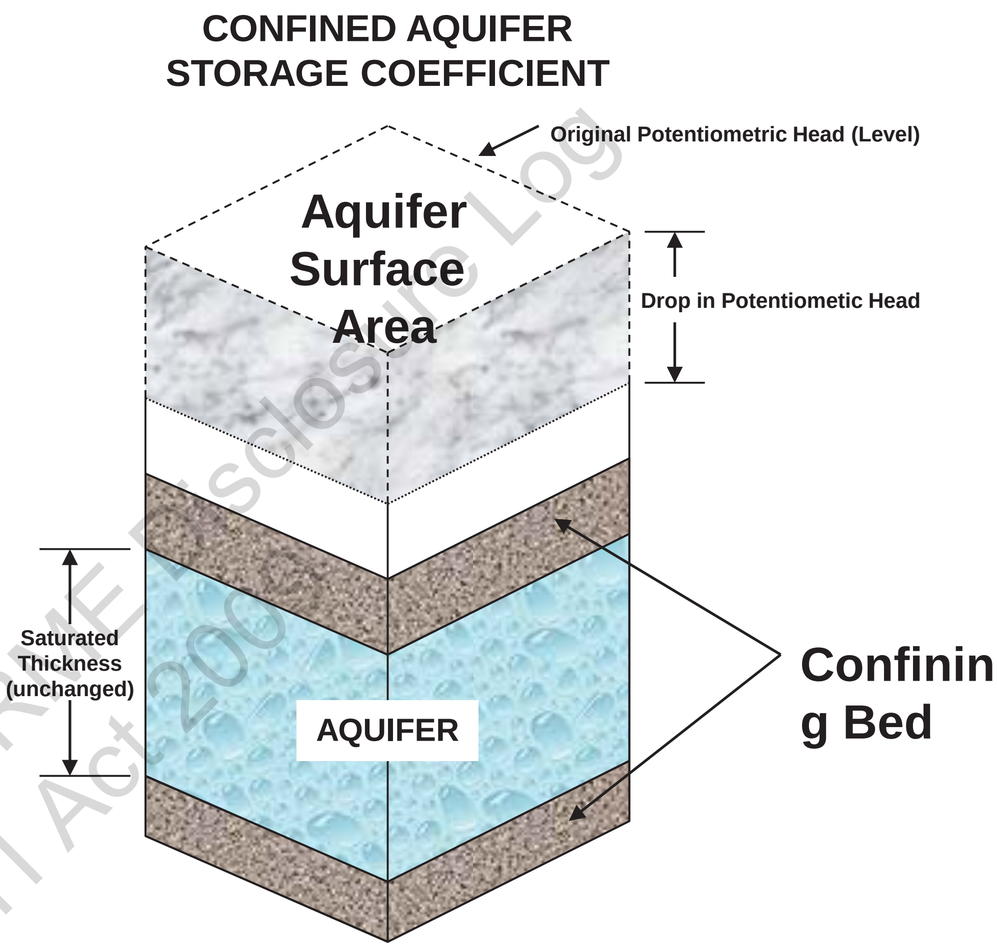
Groundwater Storage cont.

Confined aquifer – Specific Storage - Ss

Firstly the value of Specific Storage is multiplied by the thickness of the aquifer (to provide the storage coefficient) and then it applies similarly to specific yield to determine the volume of groundwater that can be removed.

But it is a factor that is applied to **the volume between the potentiometric head and the top of the aquifer.** This is some times referred to as elastic storage. Specific Storage is typically a much smaller figure than Specific Yield.





Say Area = 100Km^2 (10^8m^2)
Water Level Drop = 10m
@ Specific Yield of 5% (0.05)

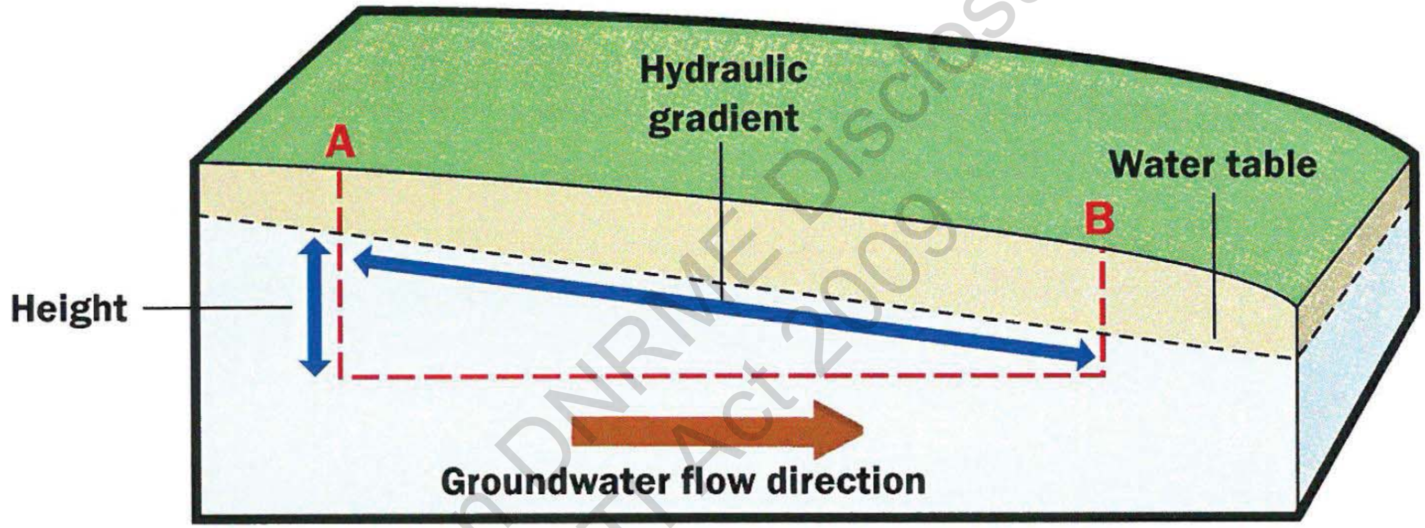
Volume Change
= 10^8x10x0.05m^3
= 10^9x0.05 x10^{-3}ML
= 10^6x0.05 ML
= 50000ML
(All From Saturated Storage)

Say Area = 100Km^2 (10^8m^2)
Head Drop = 10m
@ Storage Coefficient 10^{-4}

Volume Change
= 10^8x10x10^{-4}m^3
= 10^9x10^{-4}x10^{-3}ML
= 10^2
= 100ML
(All From Elastic Storage)

Groundwater Flow

Two factors affect how water flows through an aquifer: its hydraulic conductivity (permeability) and hydraulic gradient.

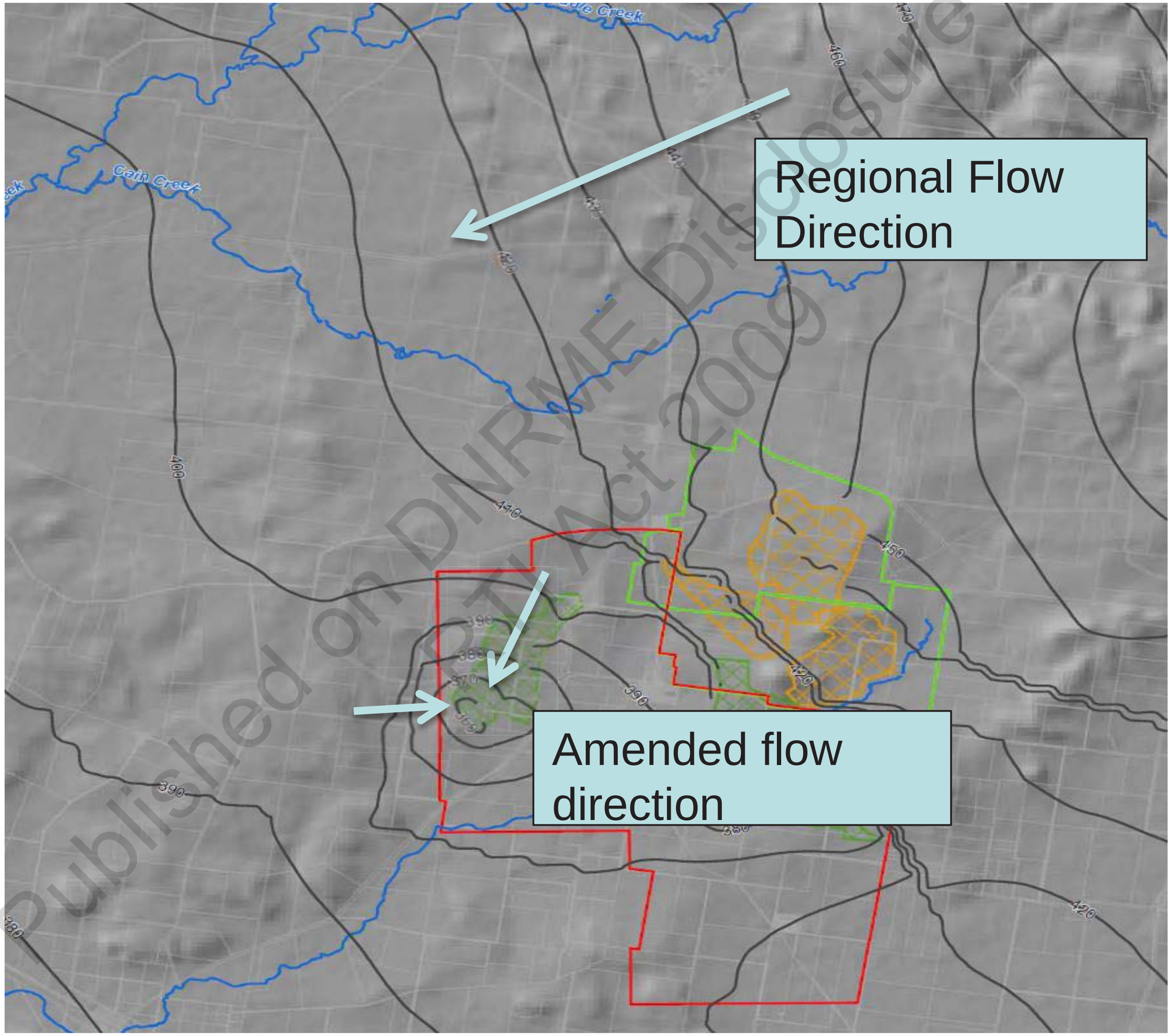


Hydraulic conductivity or K describes how easily water can move through spaces within the aquifer. (It is very similar to permeability). It can be described as Horizontal **Kh** or Vertical **Kv**

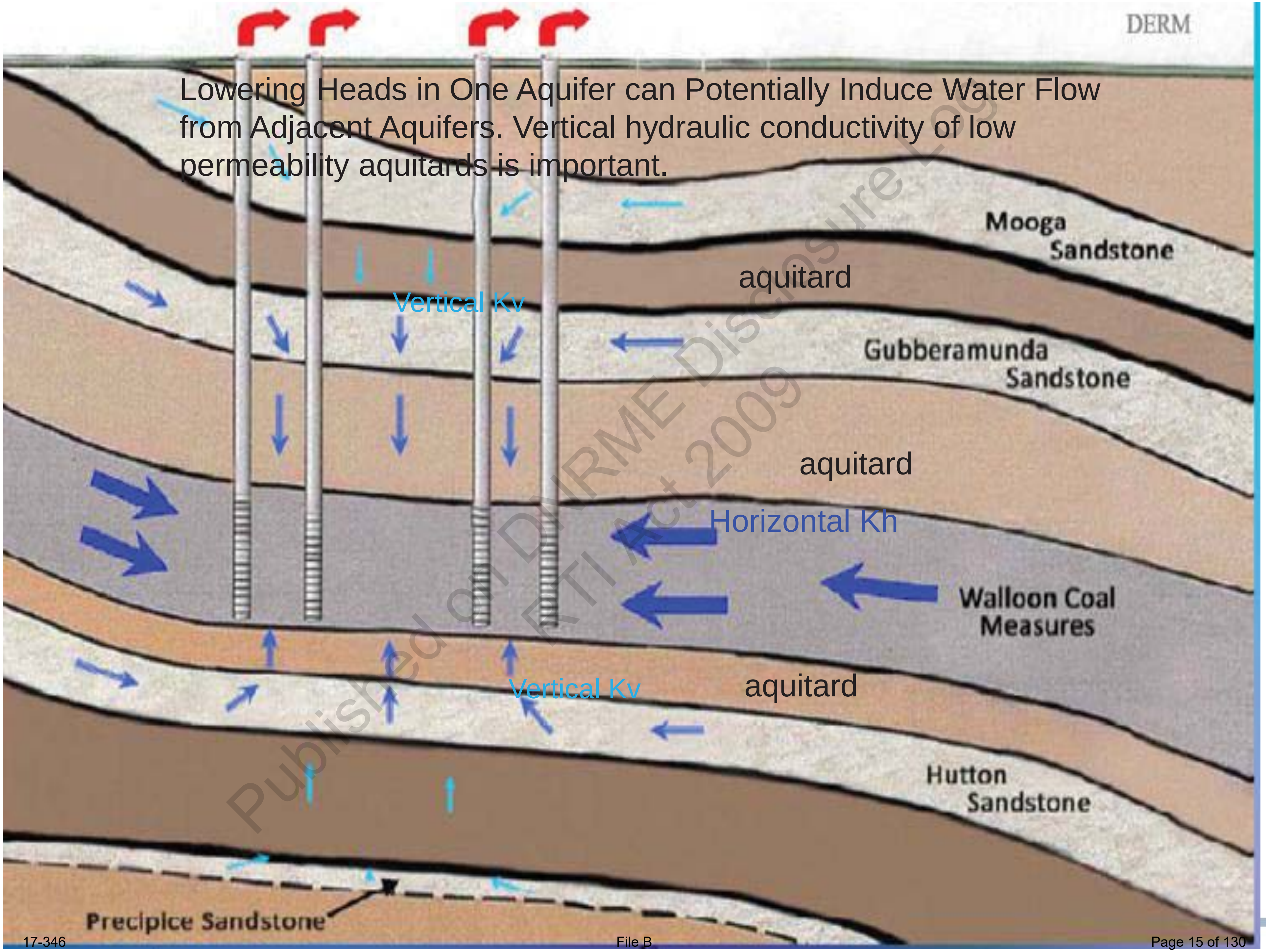
Hydraulic gradient describes the difference in groundwater height (or pressure) between two points.

Flow directions in Walloon Coal Measures

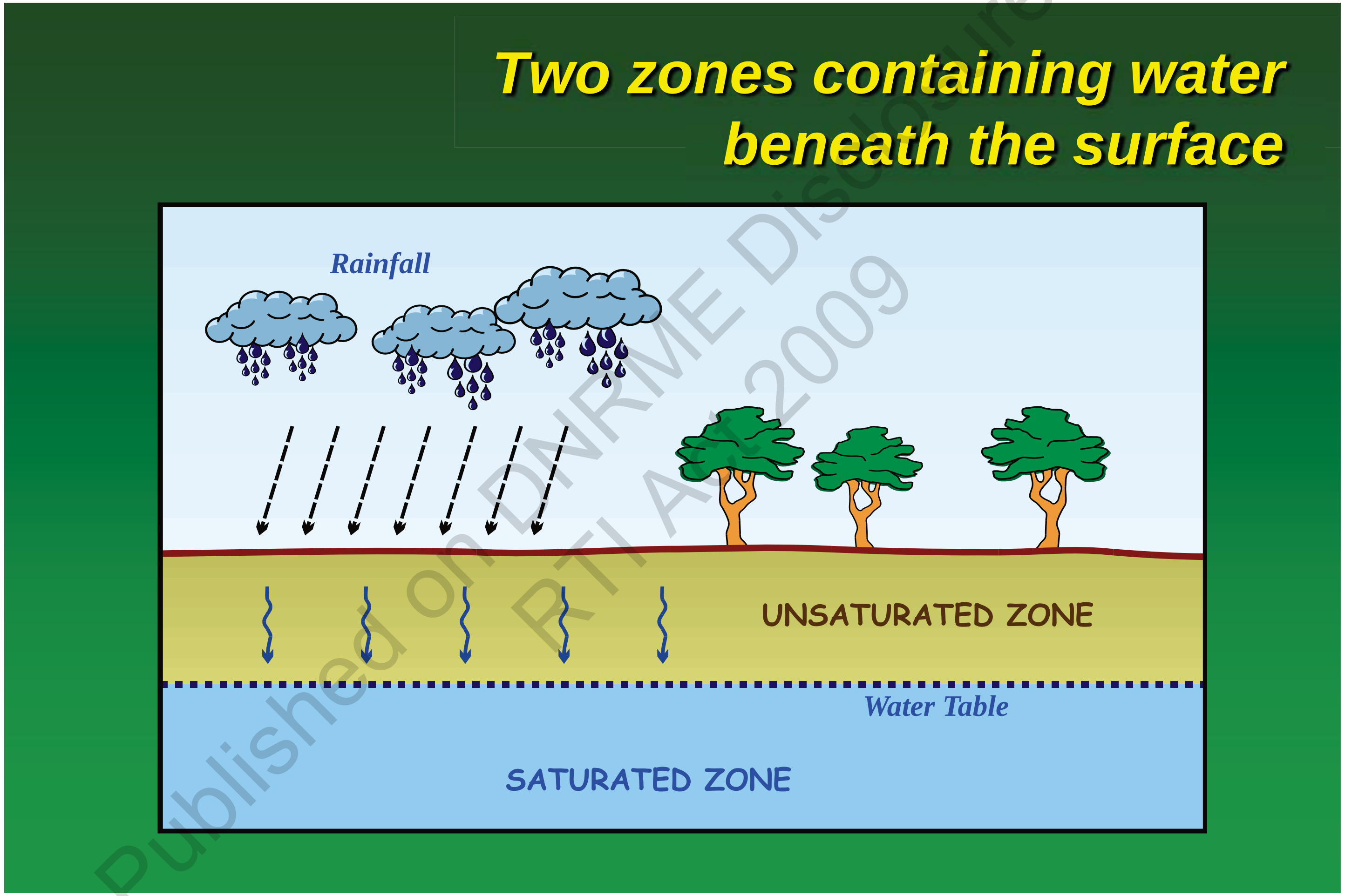
(adapted from NAC EIS 2013)



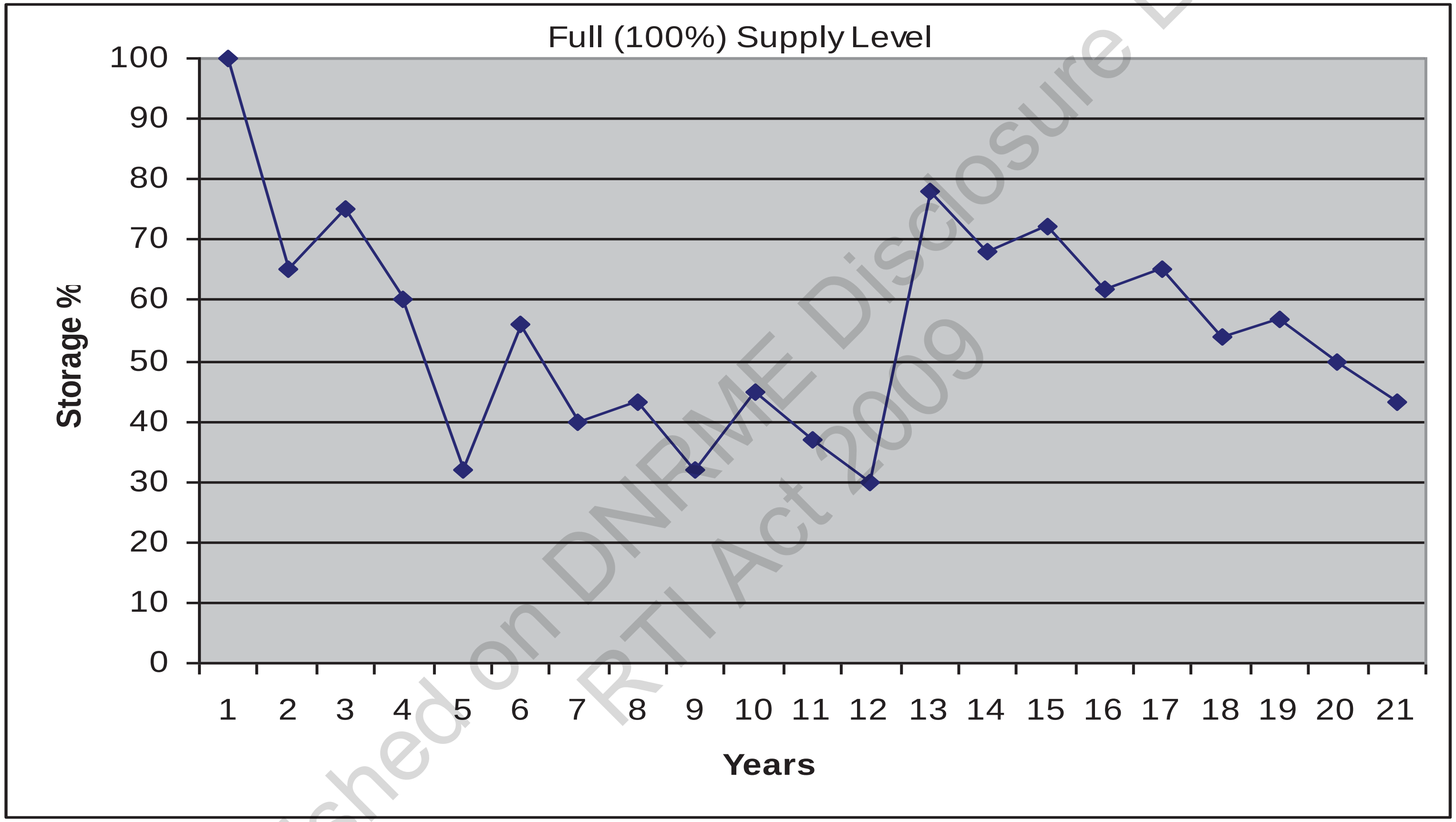
Lowering Heads in One Aquifer can Potentially Induce Water Flow from Adjacent Aquifers. Vertical hydraulic conductivity of low permeability aquitards is important.



Groundwater Storage (unconfined aquifer)



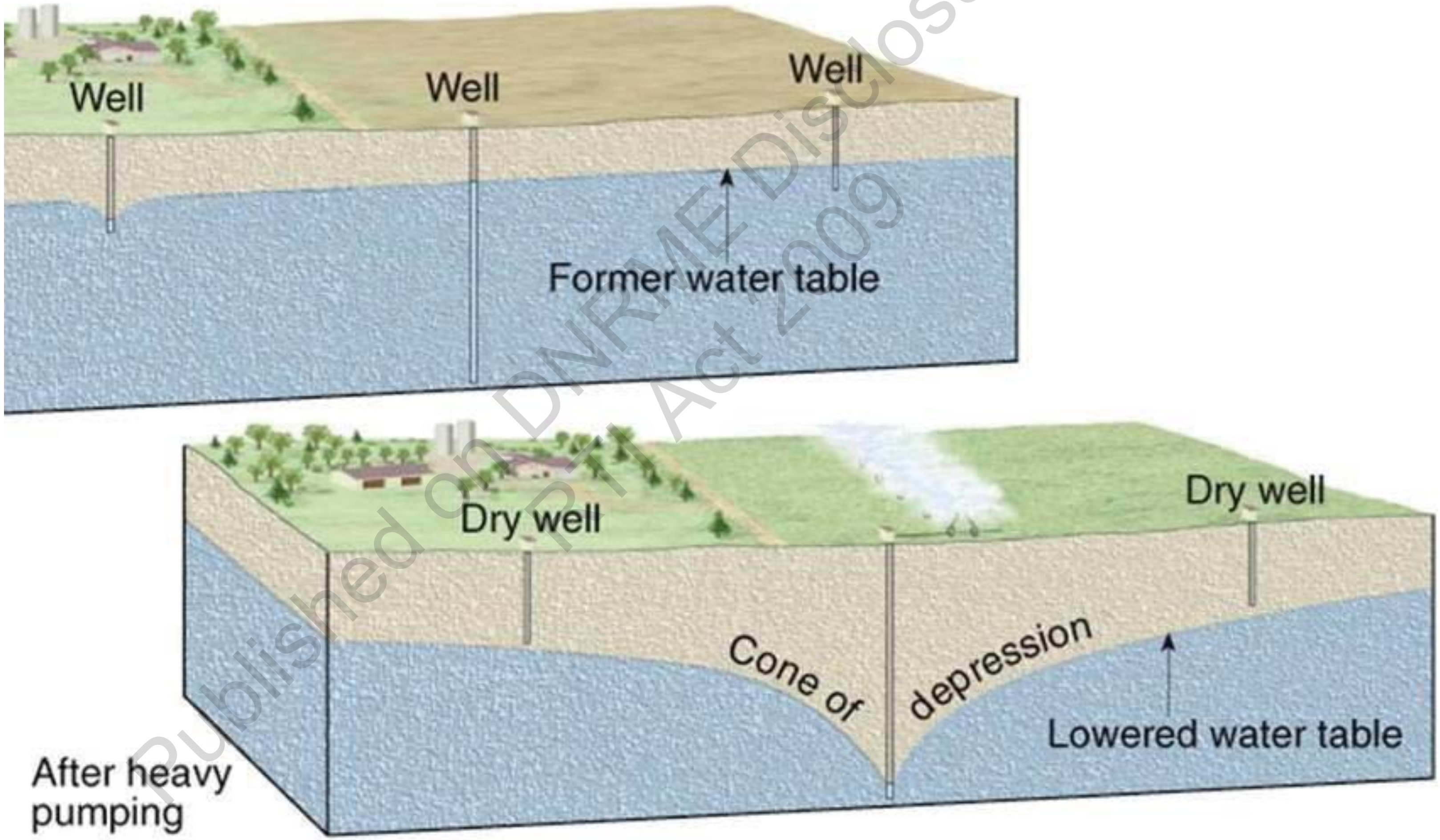
Groundwater Storage

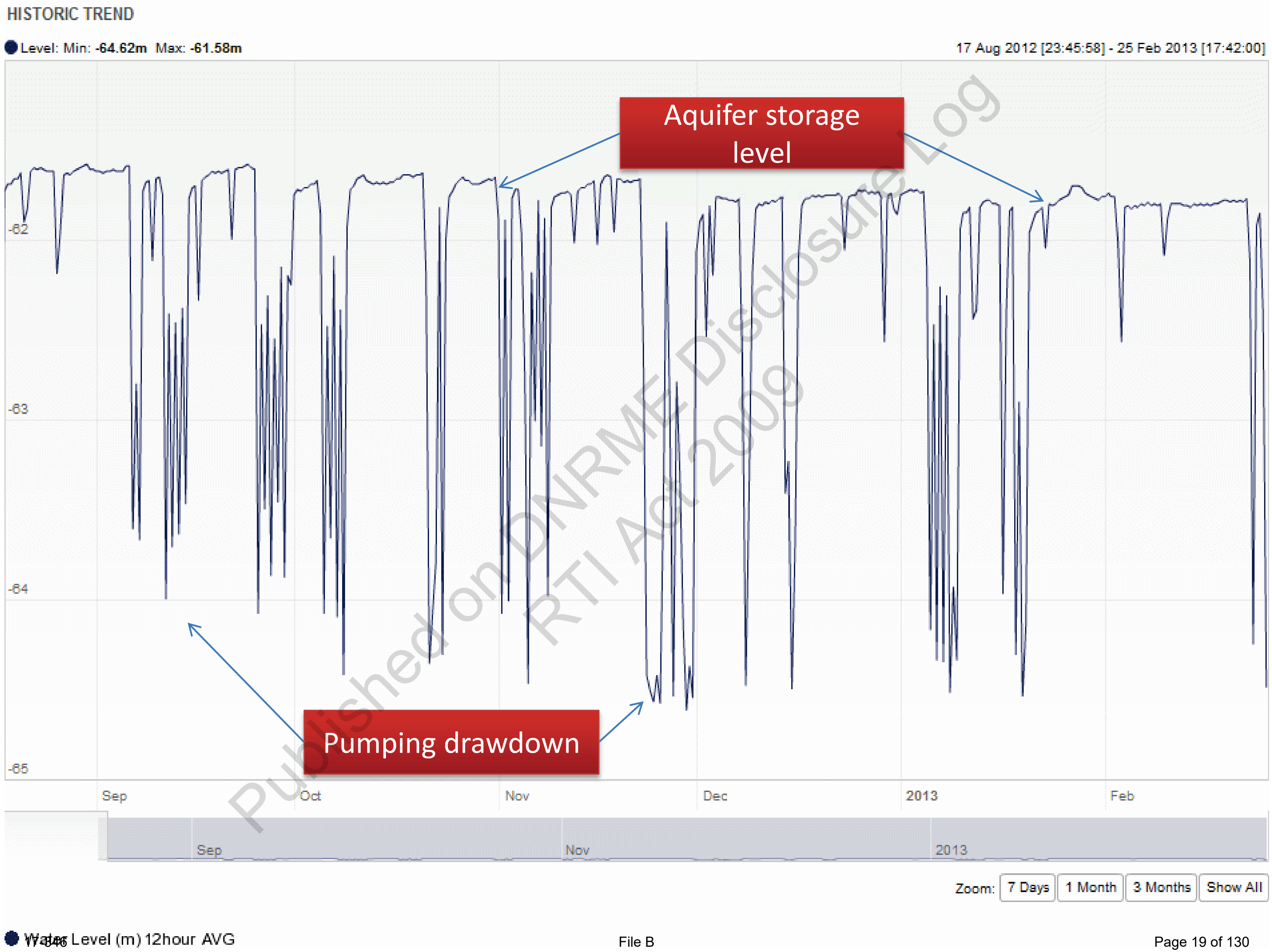


Storage rises and falls in response to inputs (Recharge) and outputs (Discharge)

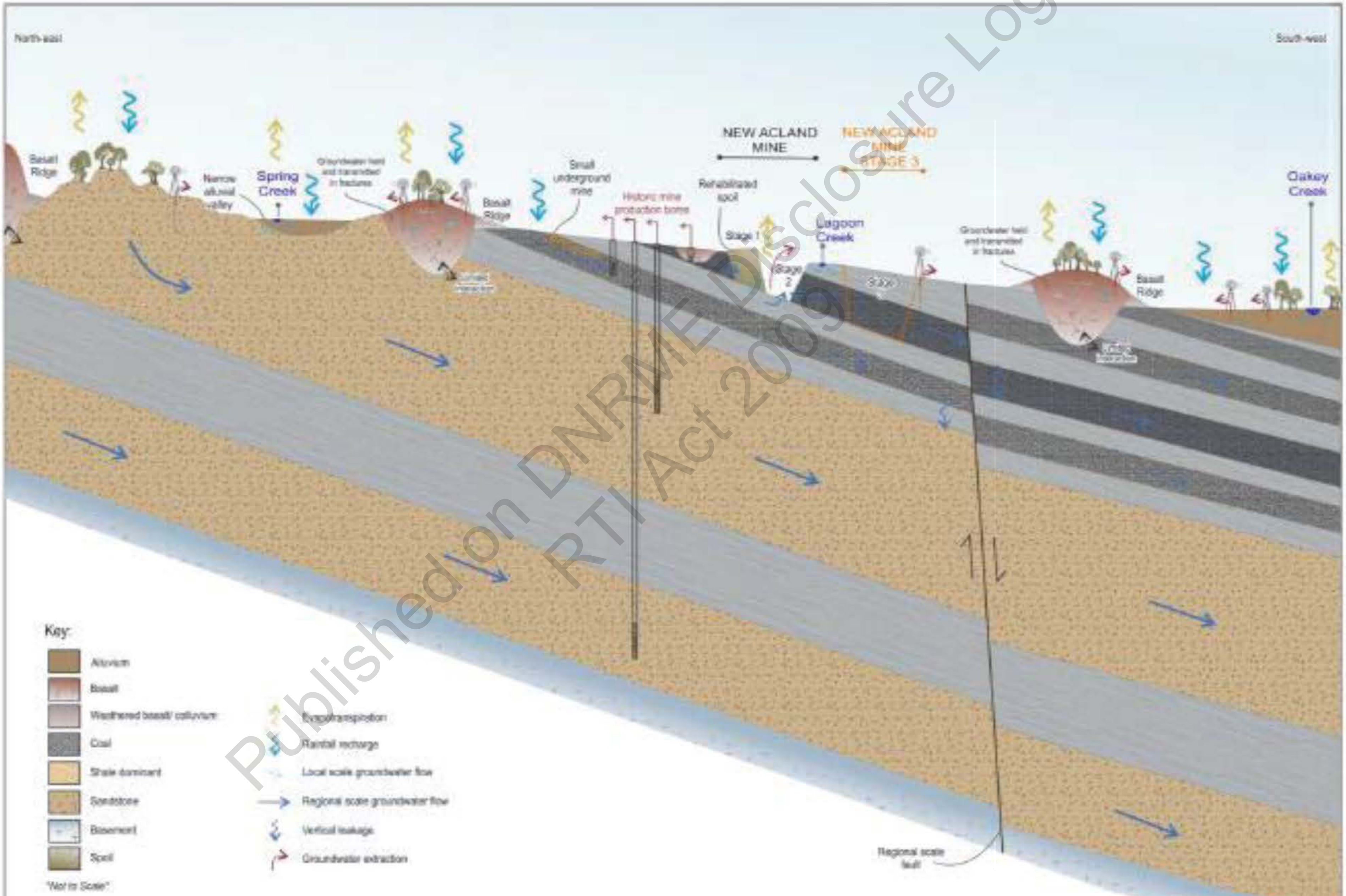
Aquifer drawdown

- Note the steep gradient near the point of take. The lower the horizontal hydraulic conductivity the steeper the gradient at the point of take



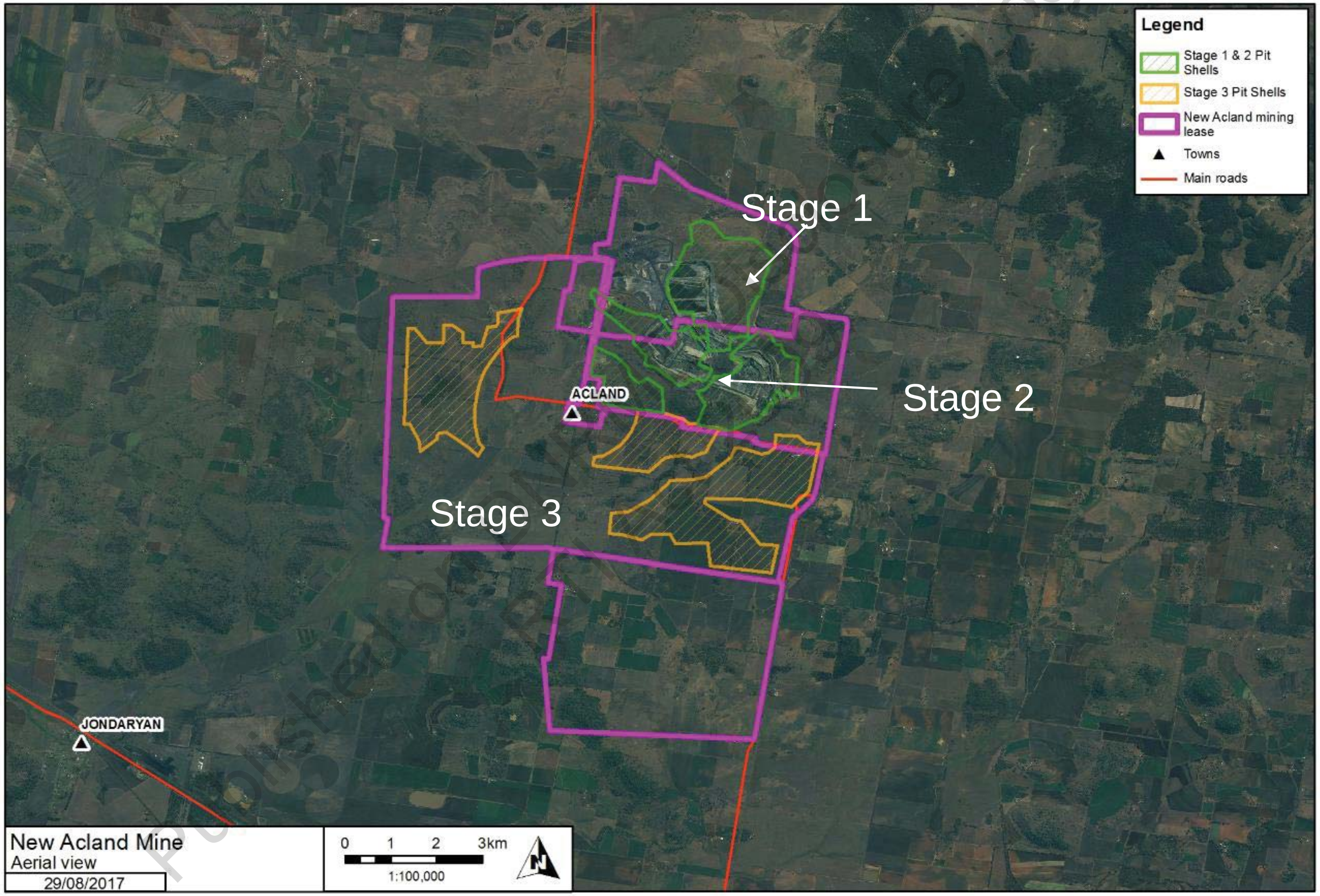

HISTORIC TREND
Level: Min: -64.62m Max: -61.58m
17 Aug 2012 [23:45:58] - 25 Feb 2013 [17:42:00]
Aquifer storage level
Pumping drawdown
-62
-63
-64
-65
Sep
Oct
Nov
Dec
2013
Feb
Sep
Nov
2013
Zoom: 7 Days 1 Month 3 Months Show All
Water Level (m) 12hour AVG

Conceptual Water Balance Diagram



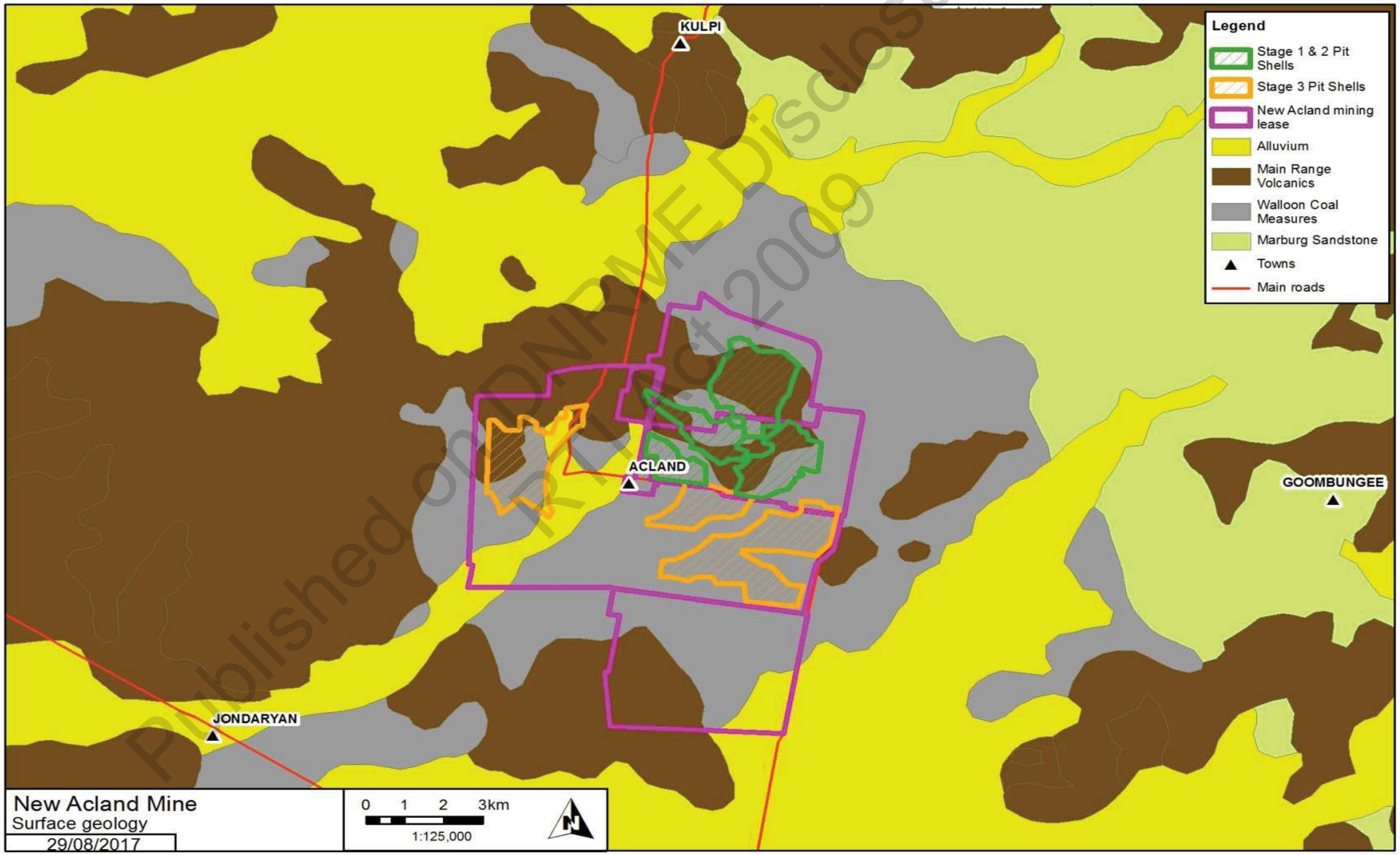
BA3

Pit Locations



New Acland mine pits on a surface geology background

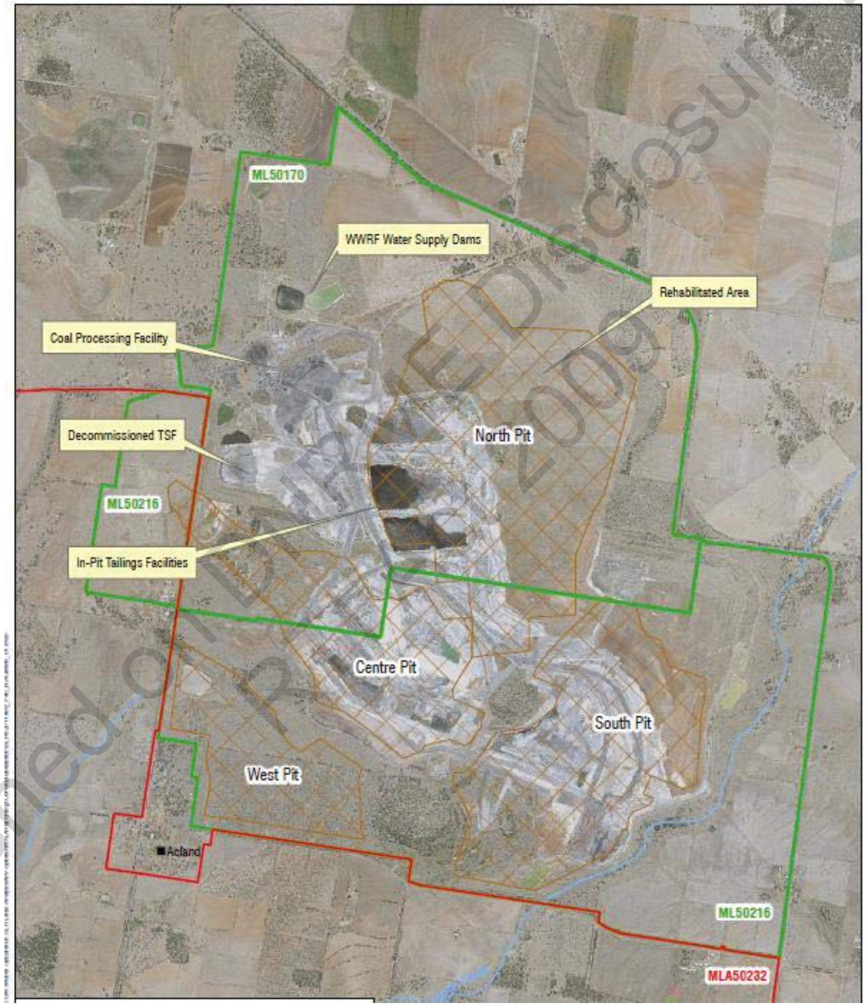
demonstrating surface geology at stage 3 pits



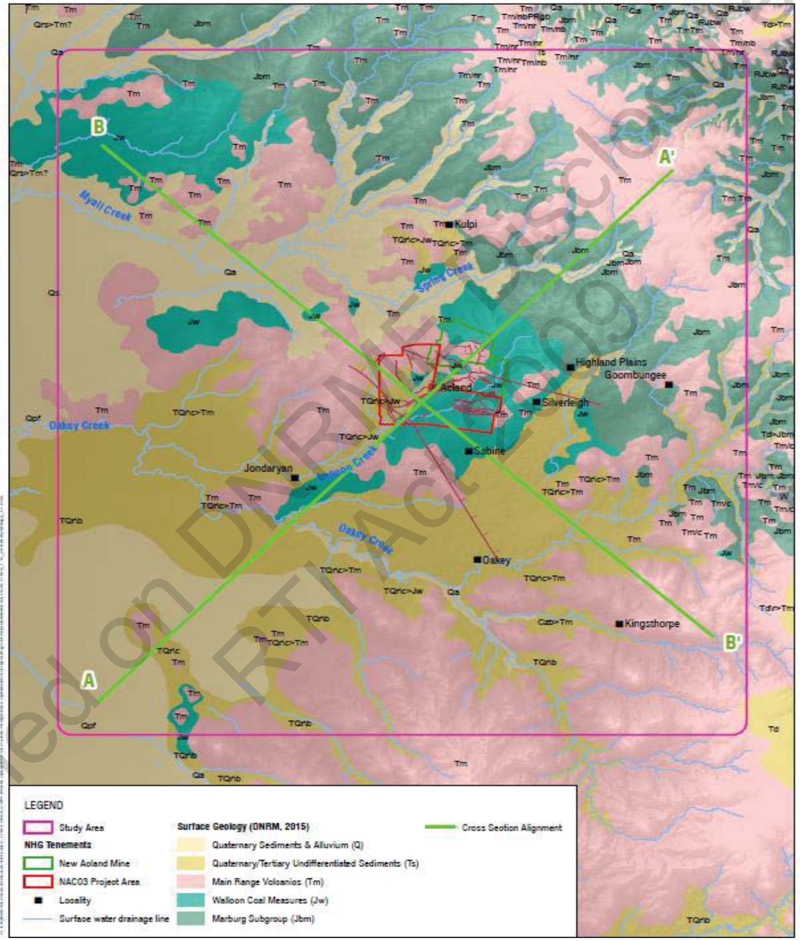
New Acland History

- **History of smaller underground coal mines at Acland from 1913 through to the 1960's.**
- **New Acland is an existing open cut coal mine**
- **Stage 1 began in 2002 – north pit**
- **Stage 2 began 2007 – centre pit, south pit and west pit. Pit depths of up to 50 metres**
- **Stage 3 will consist of 3 pits to the south and south west of stage 2, pit depths up to 60 metres**

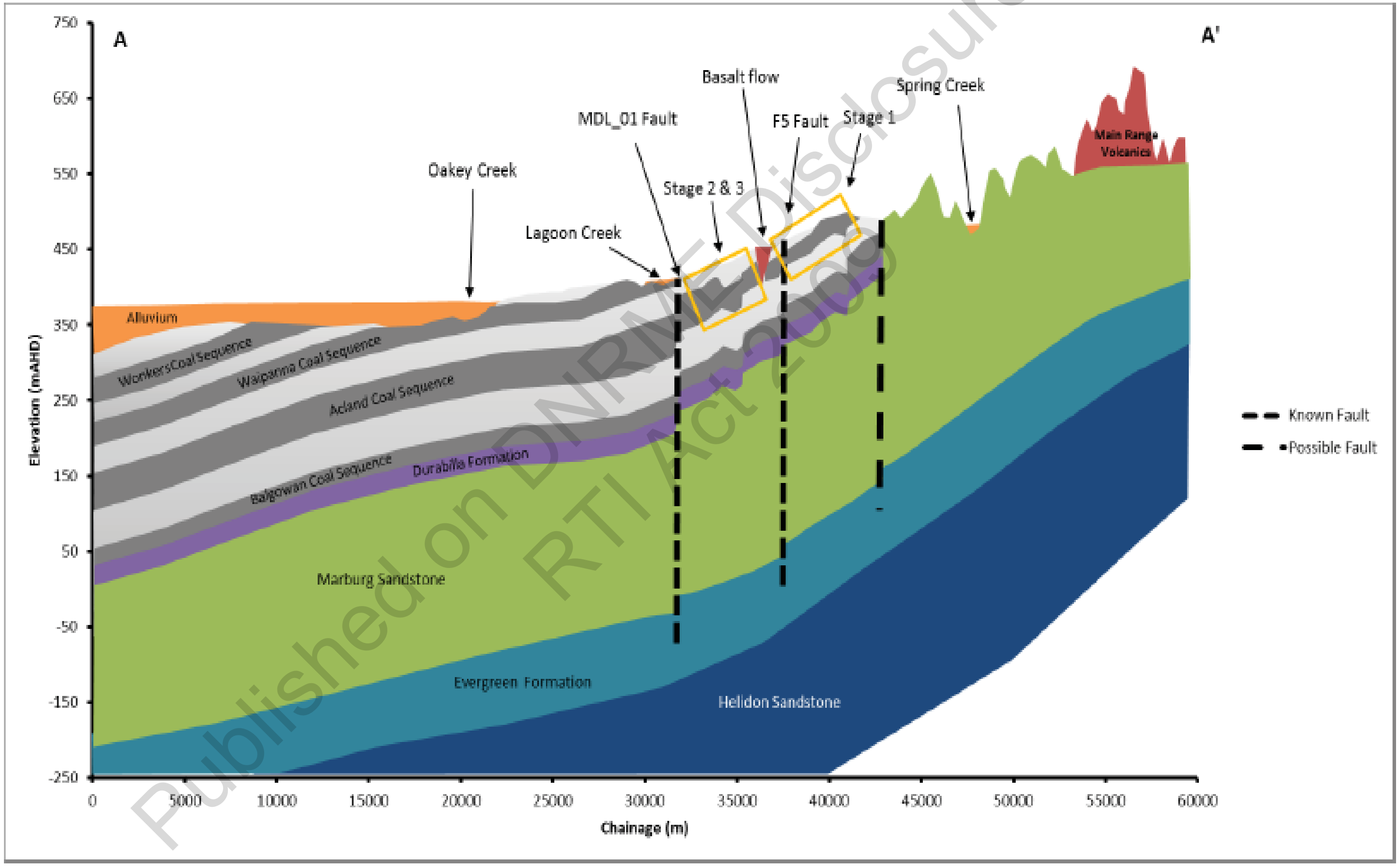
Stage 2 Pits


ML50170
WWRF Water Supply Dams
Rehabilitated Area
Coal Processing Facility
North Pit
Decommissioned TSF
ML50216
In-Pit Tailings Facilities
Centre Pit
South Pit
West Pit
Acland
ML50216
MLA50232

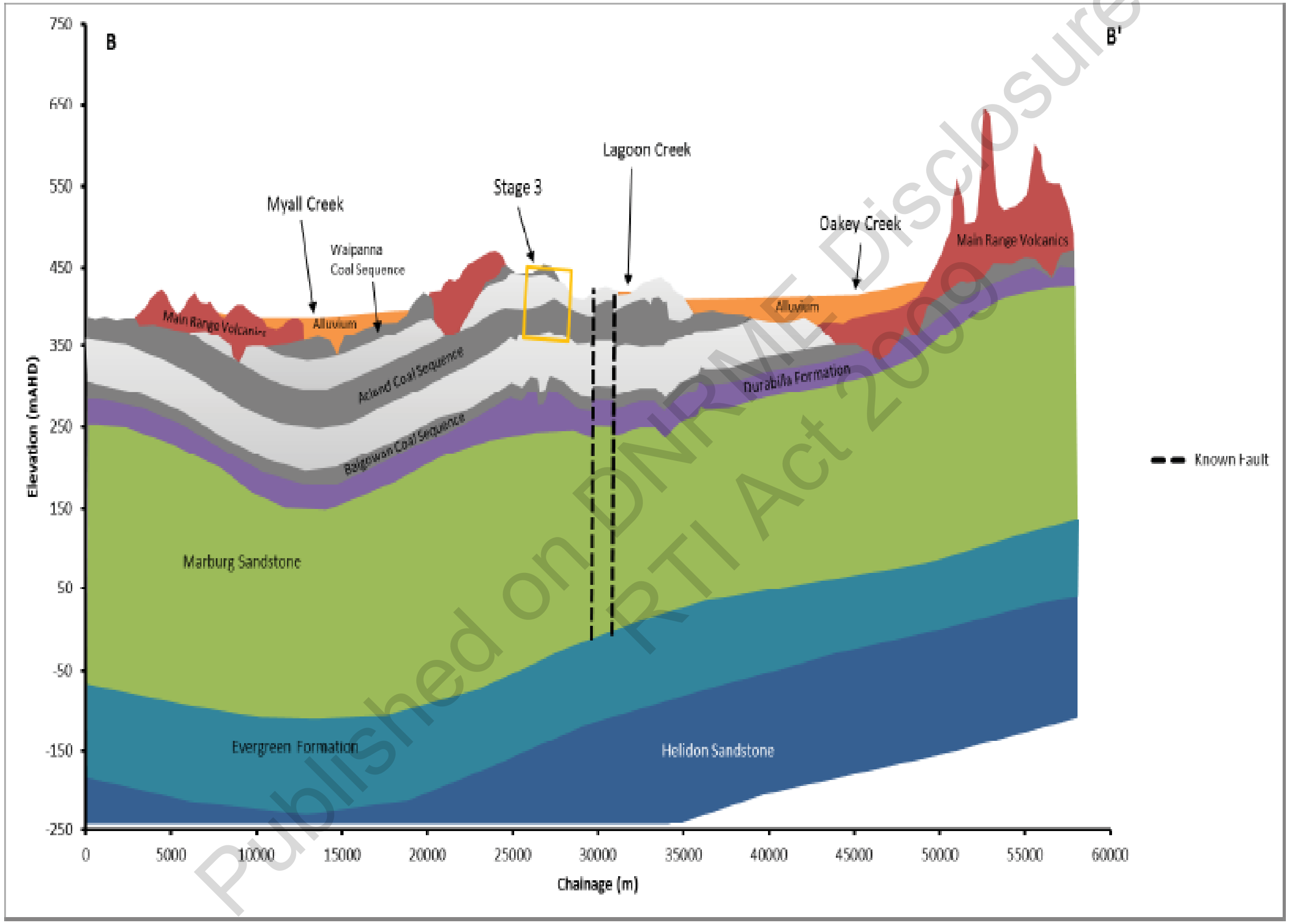
Locations of cross sections 2017 Conceptualisation report



South West to North East



North West to South East



Aquifers of interest

Alluvium porous unconfined

Basalt fractured unconfined, semi confined

Coal seams fractured confined

Marburg Sandstone porous and fractured mostly confined

Hydraulic Conductivity (permeability)
Both horizontal and vertical
Low in interburden And Durabilla Formation
- aquitards

BA5

Cross sections – Other points of Interest

Stage 1 is high in the landscape with less overburden and head of water above the base of the coal seam, so less water to remove.

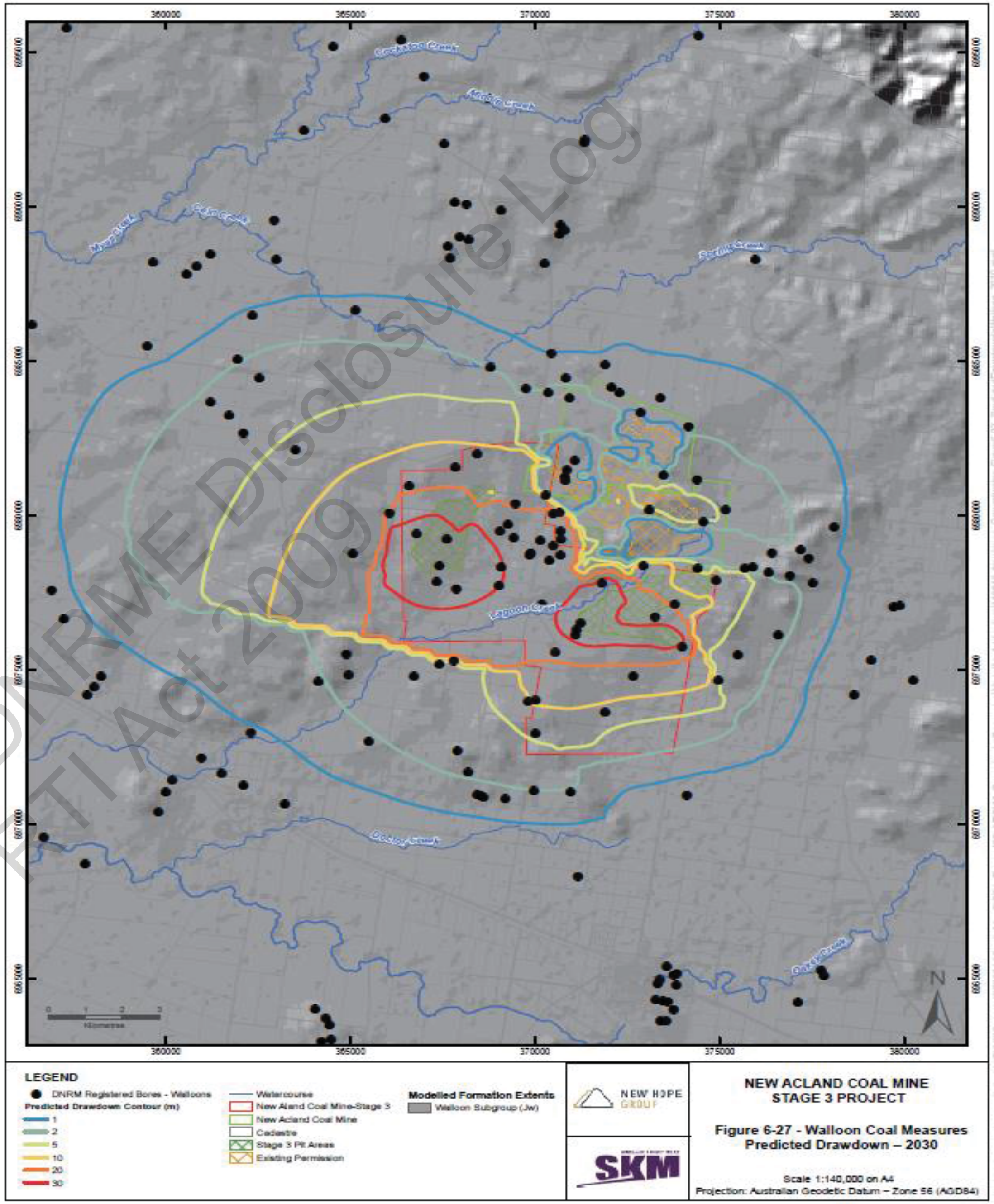
Stage 2 is further down in the landscape and dewatering requirements increase.

In places in Stage 3 there will be 30 – 50 metres of water above the base of the coal seam that requires dewatering.

BA2

2013 model predicted impacts

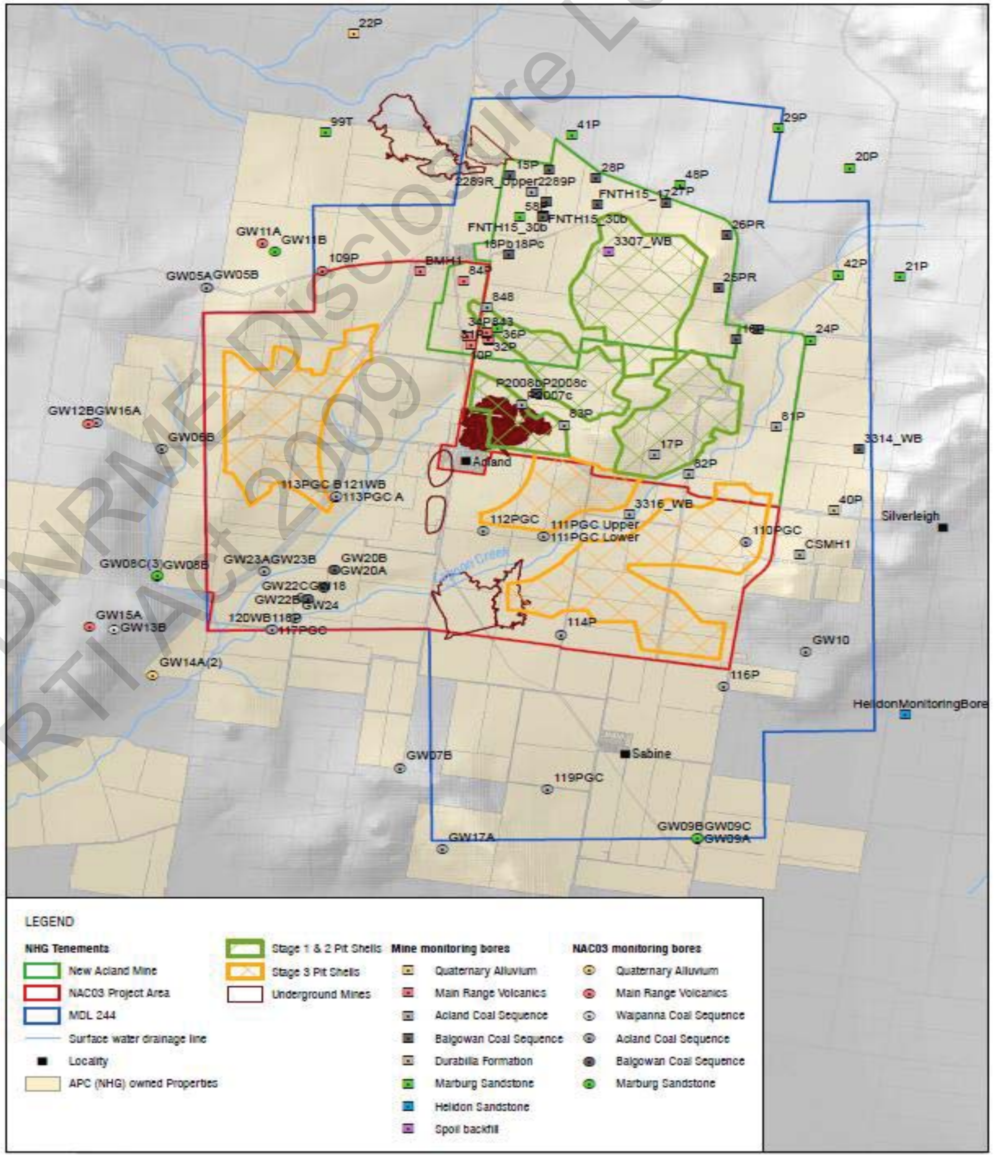
- Note 30 metre Drawdown in parts of Stage 3 pits



Department of Natural Resources and Mines

New Hope monitoring bores

The monitoring network is equally as important as the groundwater model



New Hope monitoring bores data on CSG Globe

BA4

New Hope Monitoring Bore Data on CSG Globe: Walloon Coal Measures – Acland Sequence

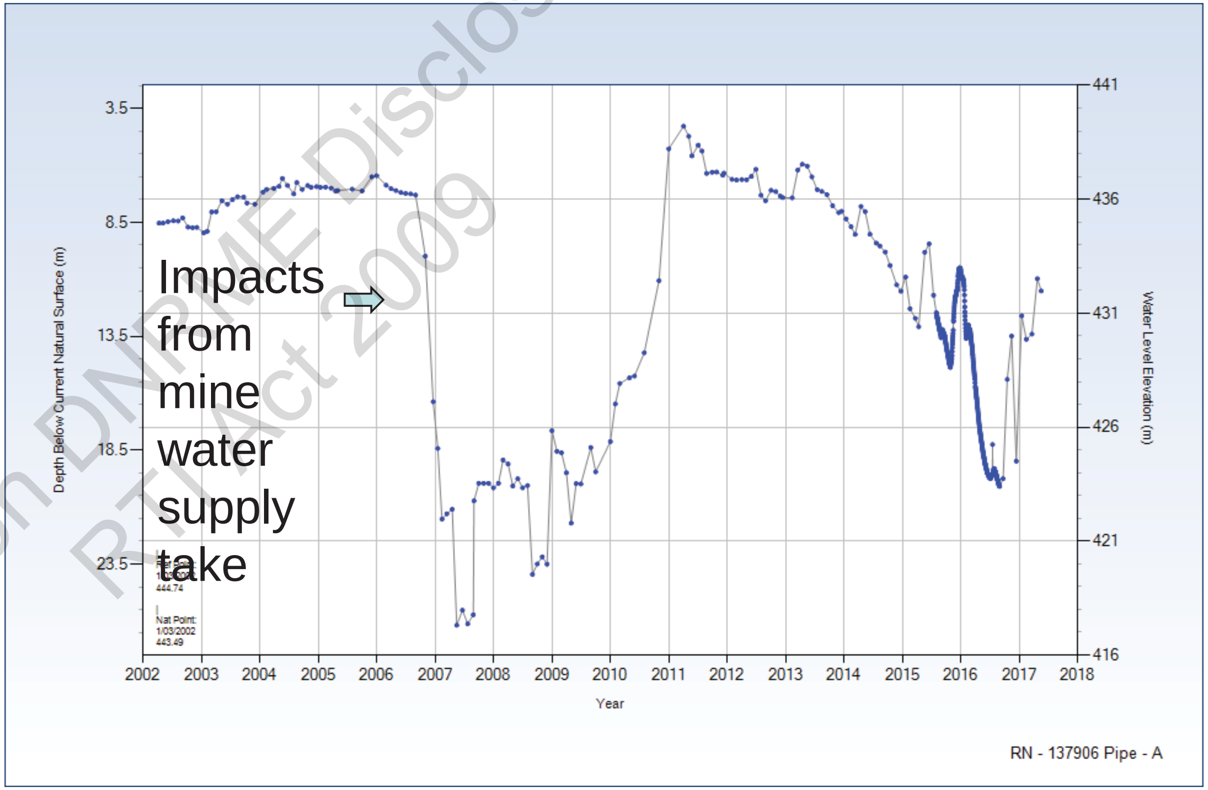
Starting level – 8.5m - April 2002

Minimum level due to mine dewatering -20.1m - Aug 2016

Drawdown of 11.6 m

As at May 2017 -11.5m

Drawdown from April 2002 level 3m



Department of Natural Resources and Mines

New Hope Monitoring Bore Data on CSG Globe: Acland Coal Sequence

Starting level – 33.4m - April 2006

Minimum level due to mine dewatering -42.4m – May 2017

Drawdown of 9m

Department of Natural Resources and Mines

New Hope Monitoring Bore Data on CSG Globe: Acland Coal Sequence

Starting level – 8.2m - April 2006

Minimum level due to mine dewatering -27.3m - Jan 2016

Drawdown of 19.1m

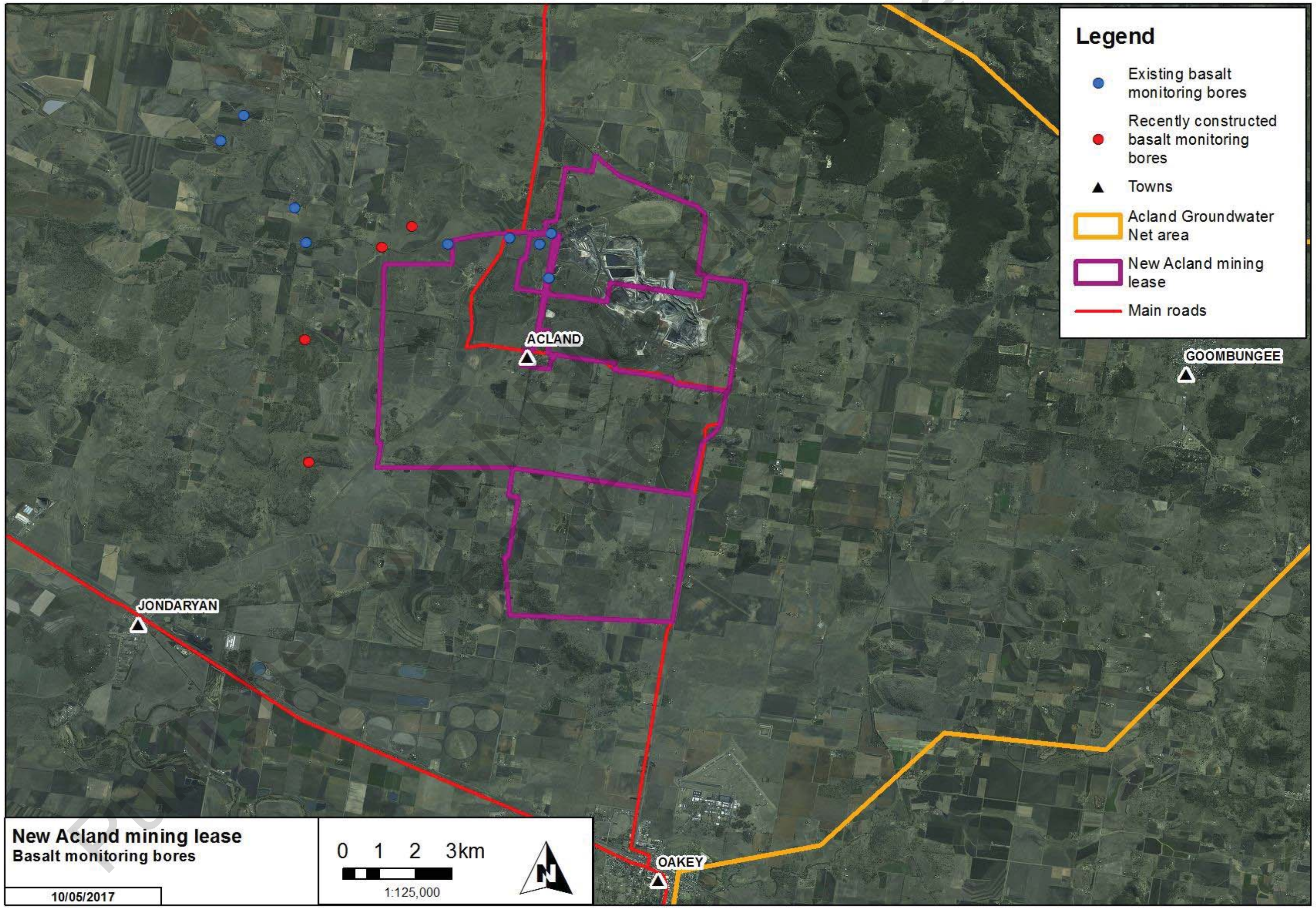
As at May 2017 -17.5m

Drawdown from April 2006 level 9.3m

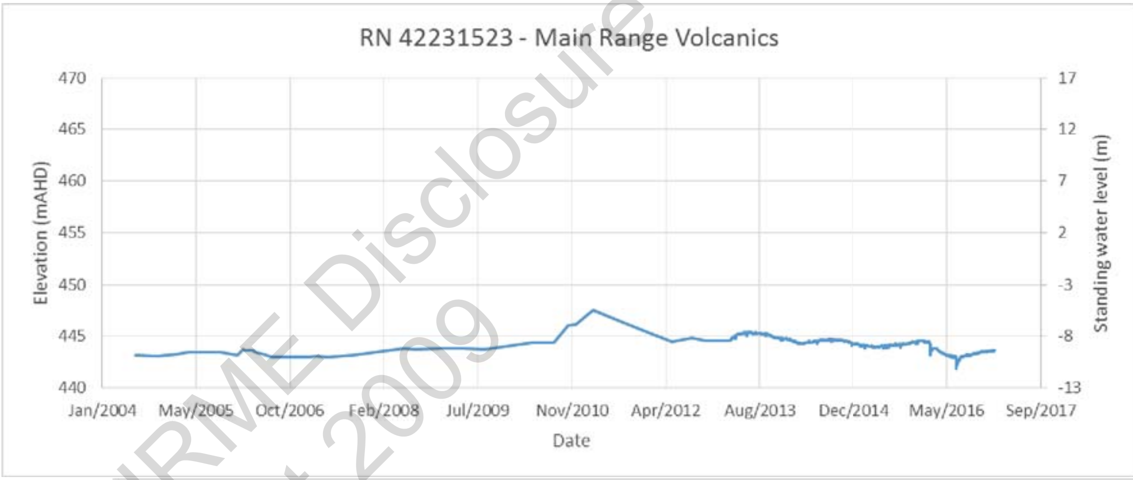
New Hope Monitoring Bore Data on CSG Globe: Acland Coal Sequence

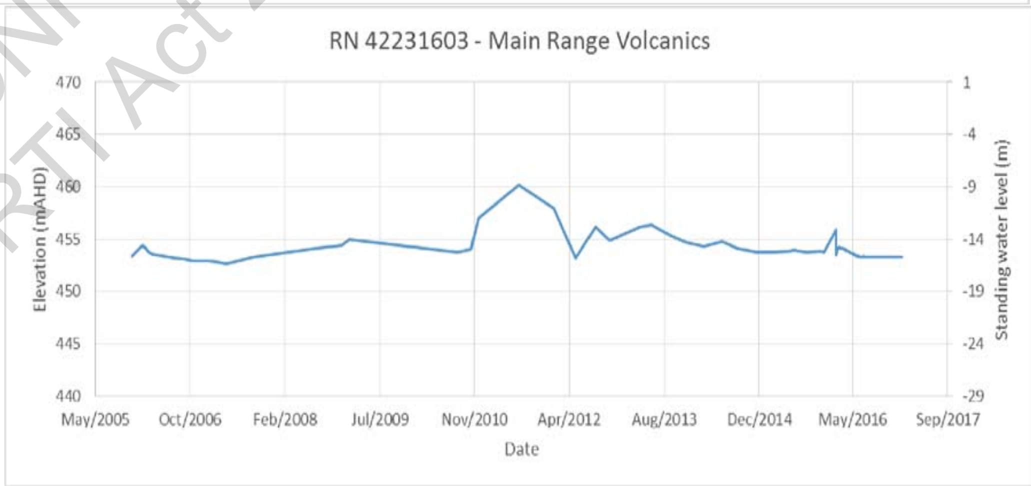
- Starting level – 32.0m - April 2006
- Minimum level due to mine dewatering -40.1m - Aug 2014
- Drawdown of 8.1m
- As at May 2017 -37.7m
- Drawdown from April 2006 level 5.7m

Basalt Monitoring Bores

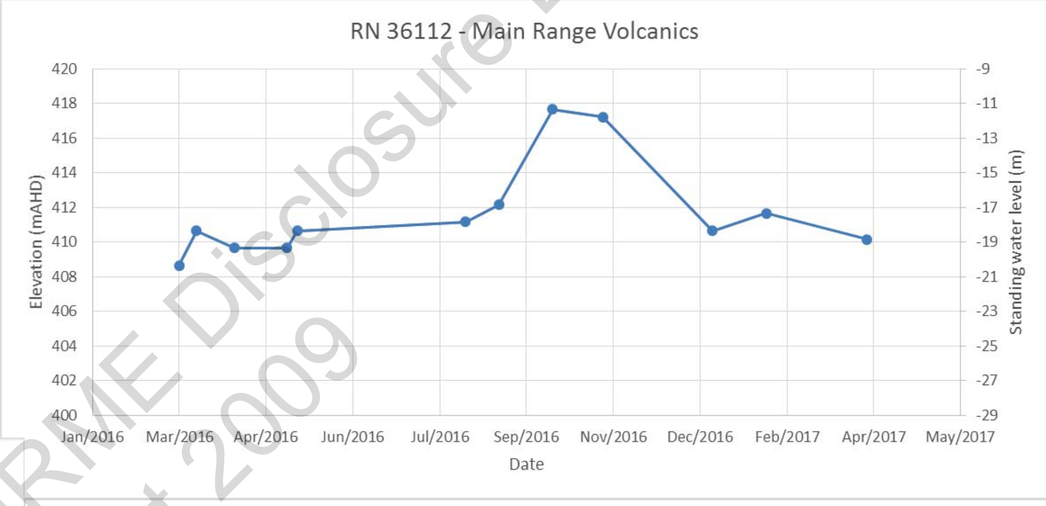


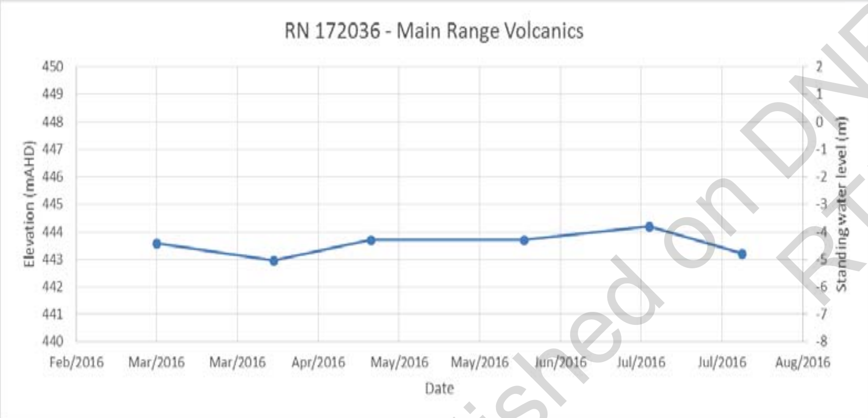
DNRM Bore 42231523 and 42231603

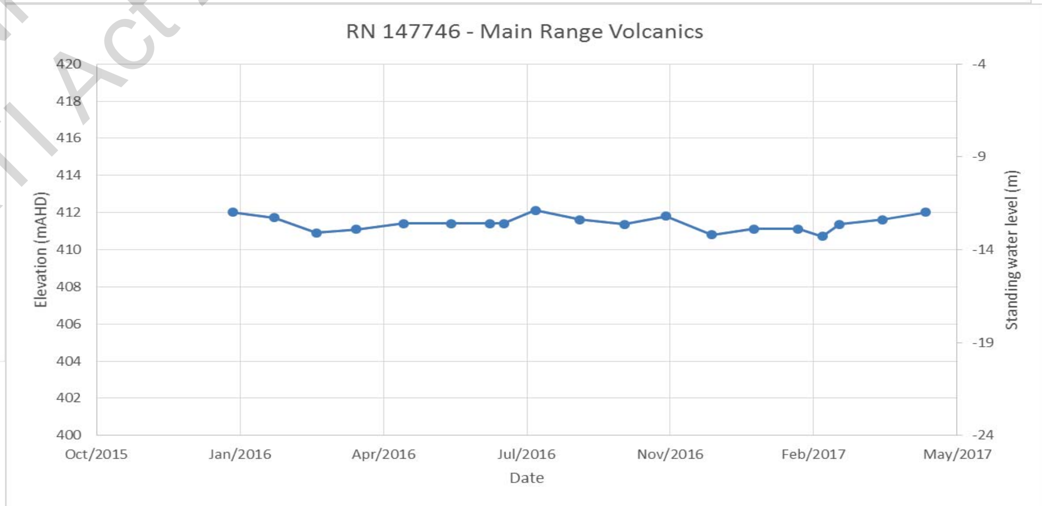




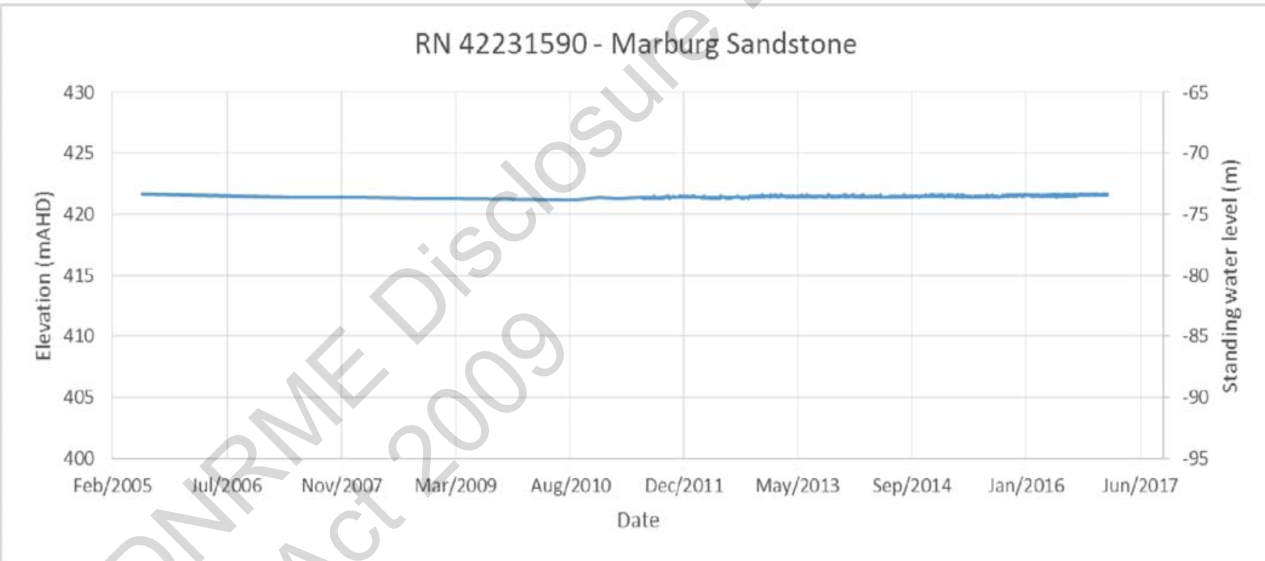
Groundwater Net Landholder bores - Basalt







DNRM Marburg Sandstone Bore 42231590

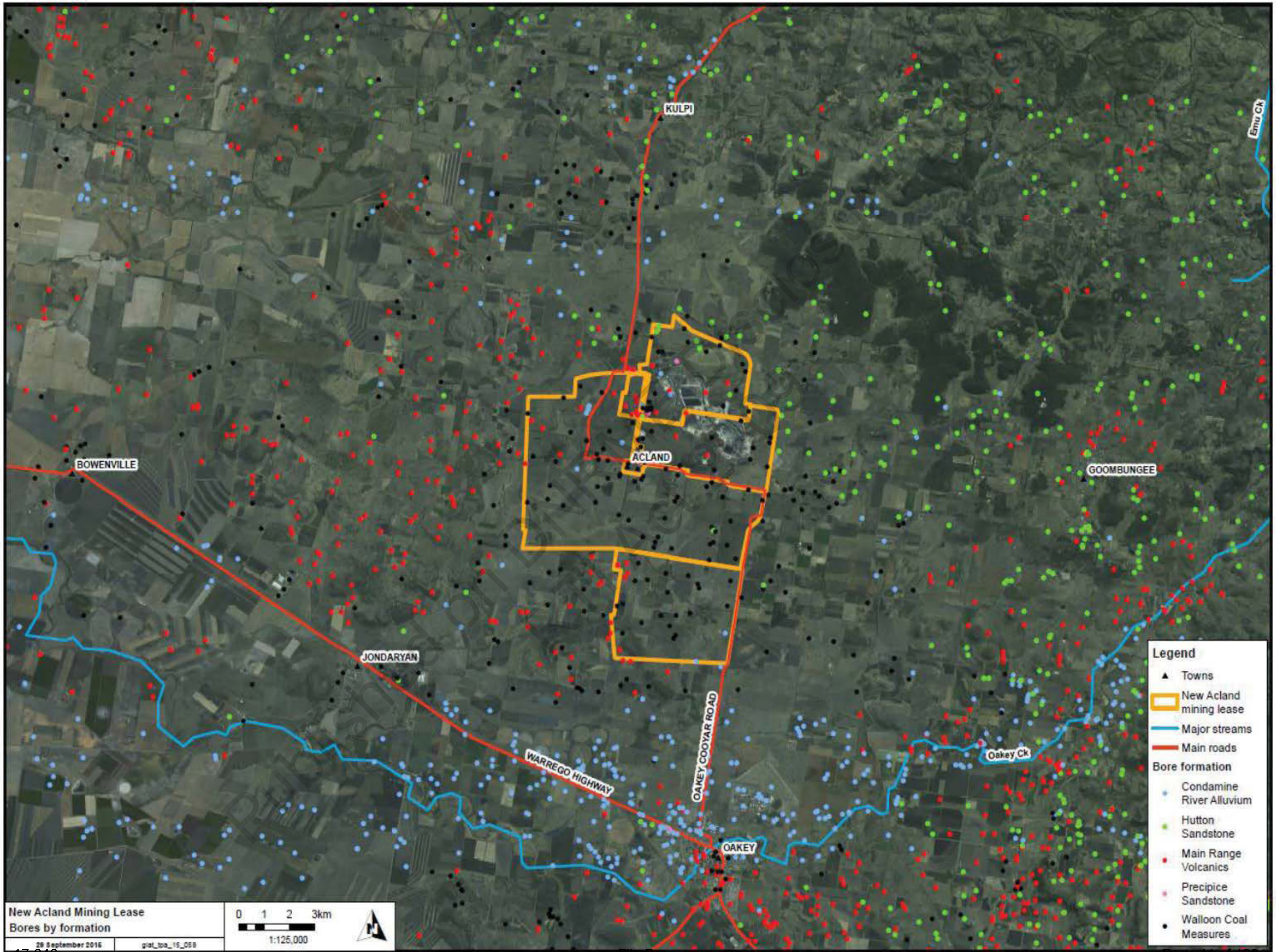


Approx. 5 km east of mine

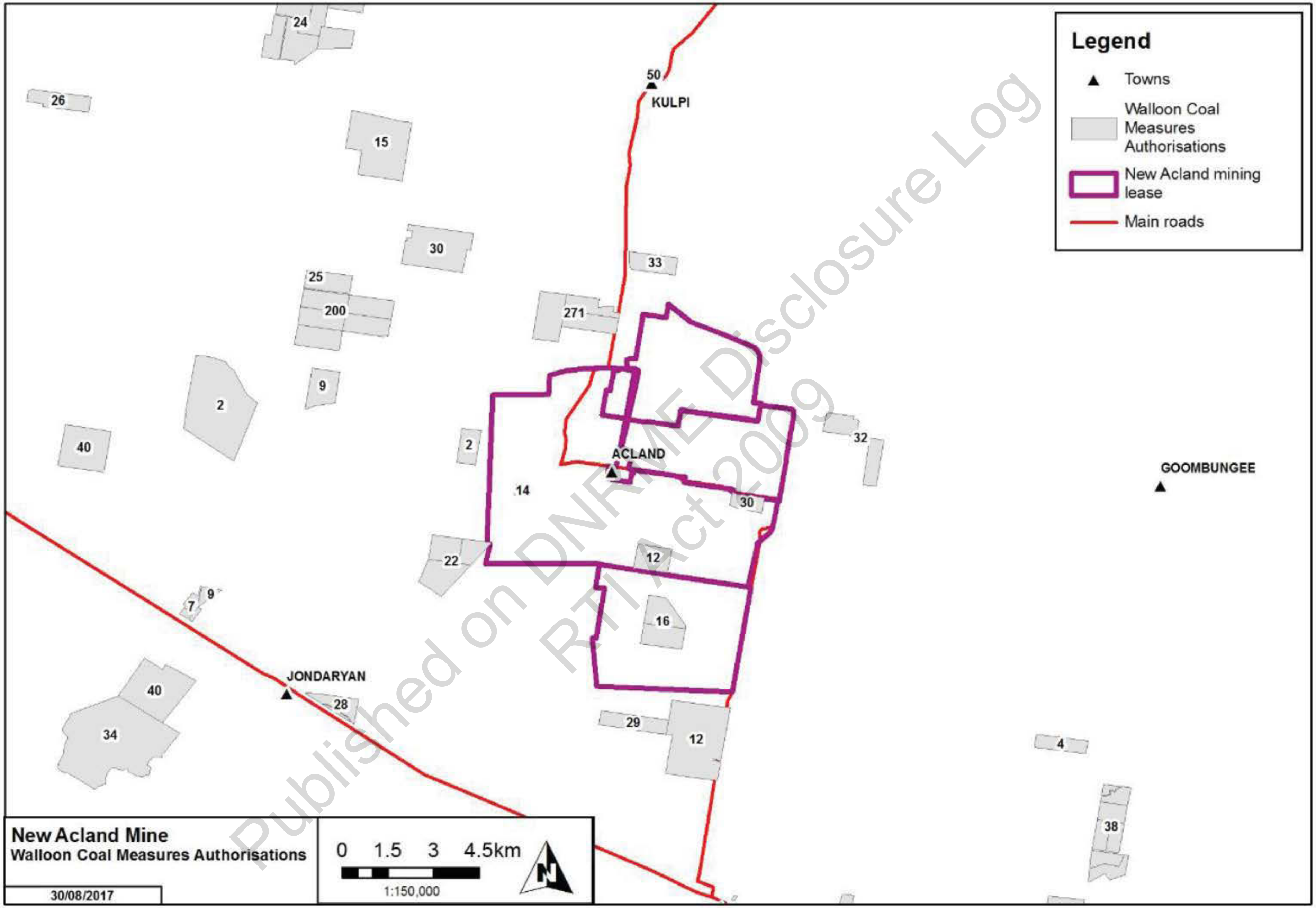
Marburg Sandstone monitoring

Water levels in two bores impacted by mine water supply take from bores 2006 – 2008.

Note little impact on bores further to the east indicating tight cone of depression – reasonably low horizontal hydraulic conductivity


KULPI
Emu Ck
BOWENVILLE
ACLAND
GOOMBUNGEE
JONDARYAN
WARREGO HIGHWAY
OAKEY COOYAR ROAD
Oakey Ck
OAKEY
Legend
Towns
New Acland mining lease
Major streams
Main roads
Bore formation
Condamine River Alluvium
Hutton Sandstone
Main Range Volcanics
Precipice Sandstone
Walloon Coal Measures
New Acland Mining Lease
Bores by formation
29 September 2016
0 1 2 3km
1:125,000

lea


Legend
Towns
Walloon Coal Measures Authorisations
New Acland mining lease
Main roads
KULPI
ACLAND
GOOMBUNGEE
JONDARYAN
50
24
26
15
30
25
200
33
271
9
2
40
14
32
30
12
22
7
9
16
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34
28
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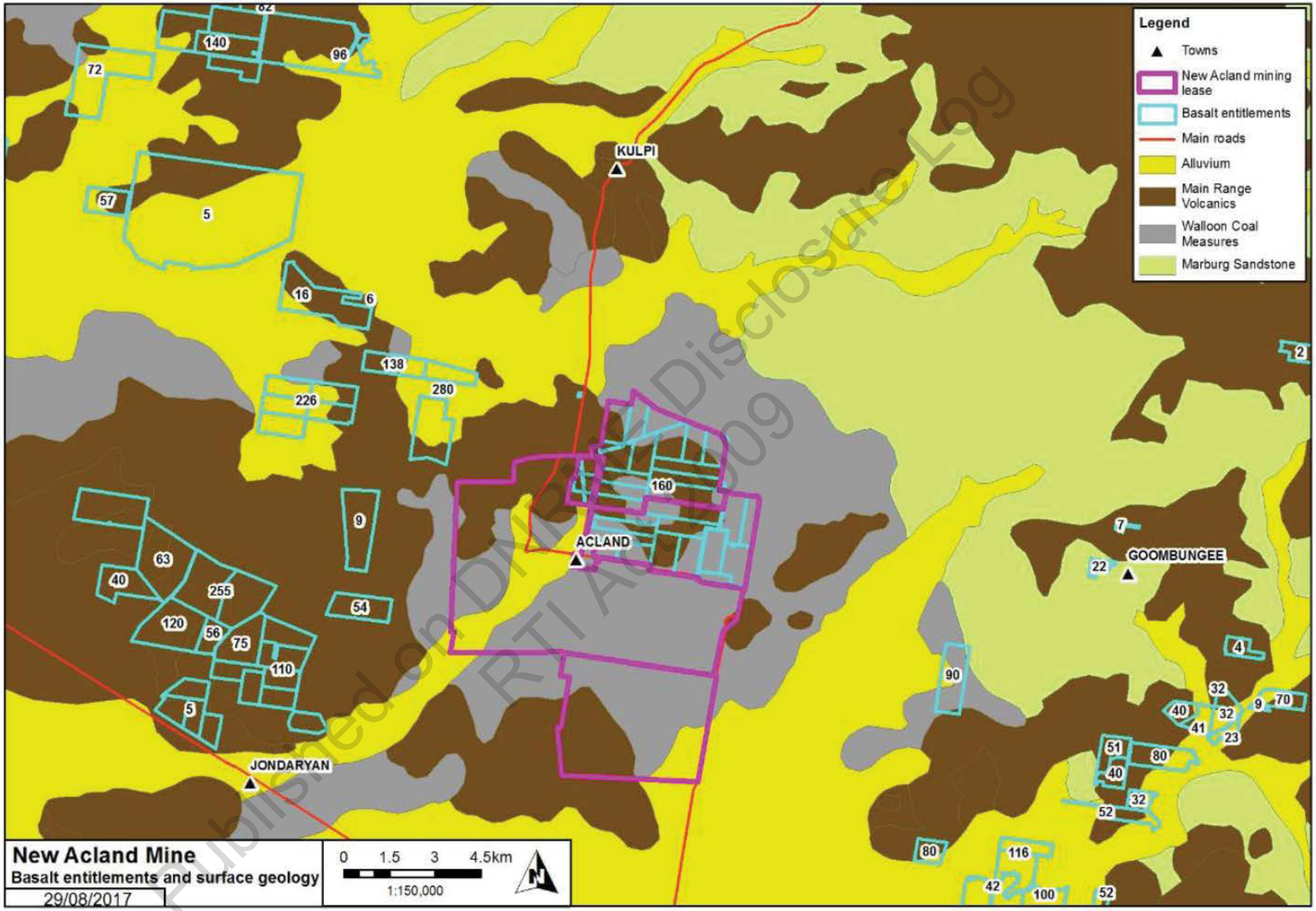
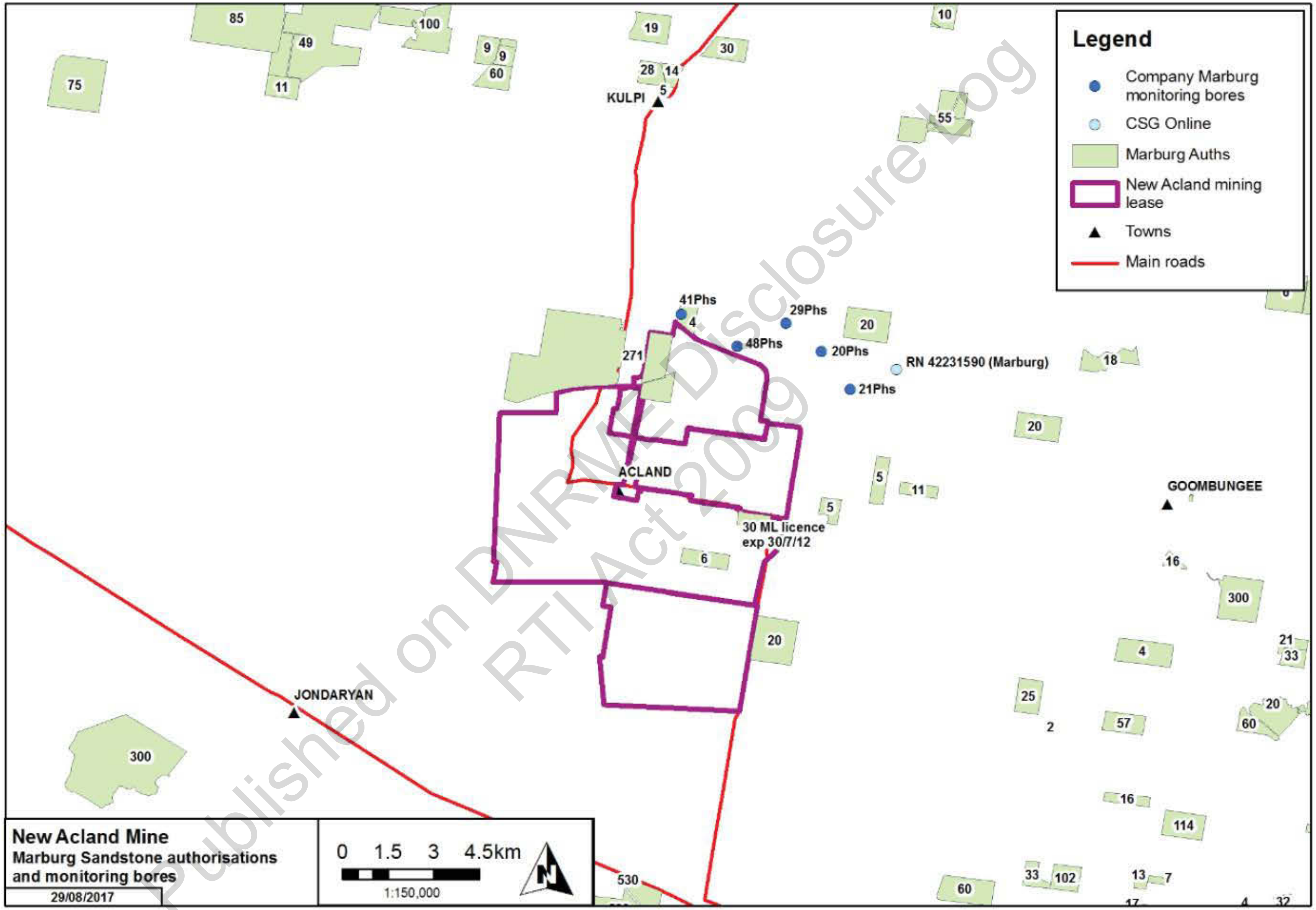
12
4
38
New Acland Mine
Walloon Coal Measures Authorisations
30/08/2017
0 1.5 3 4.5km
1:150,000
N


Legend
Towns
New Acland mining lease
Basalt entitlements
Main roads
Alluvium
Main Range Volcanics
Walloon Coal Measures
Marburg Sandstone
KULPI
ACLAND
GOOMBUNGEE
JONDARYAN
New Acland Mine
Basalt entitlements and surface geology
29/08/2017
0 1.5 3 4.5km
1:150,000
N



Legend
Company Marburg monitoring bores
CSG Online
Marburg Auths
New Acland mining lease
Towns
Main roads
KULPI
ACLAND
GOOMBUNGEE
JONDARYAN
41Phs
29Phs
48Phs
20Phs
21Phs
RN 42231590 (Marburg)
30 ML licence exp 30/7/12
New Acland Mine
Marburg Sandstone authorisations and monitoring bores
29/08/2017
0 1.5 3 4.5km
1:150,000

IESC and Land Court Outcomes

IESC Advice

December 2016, IESC advice presented to the Land Court:

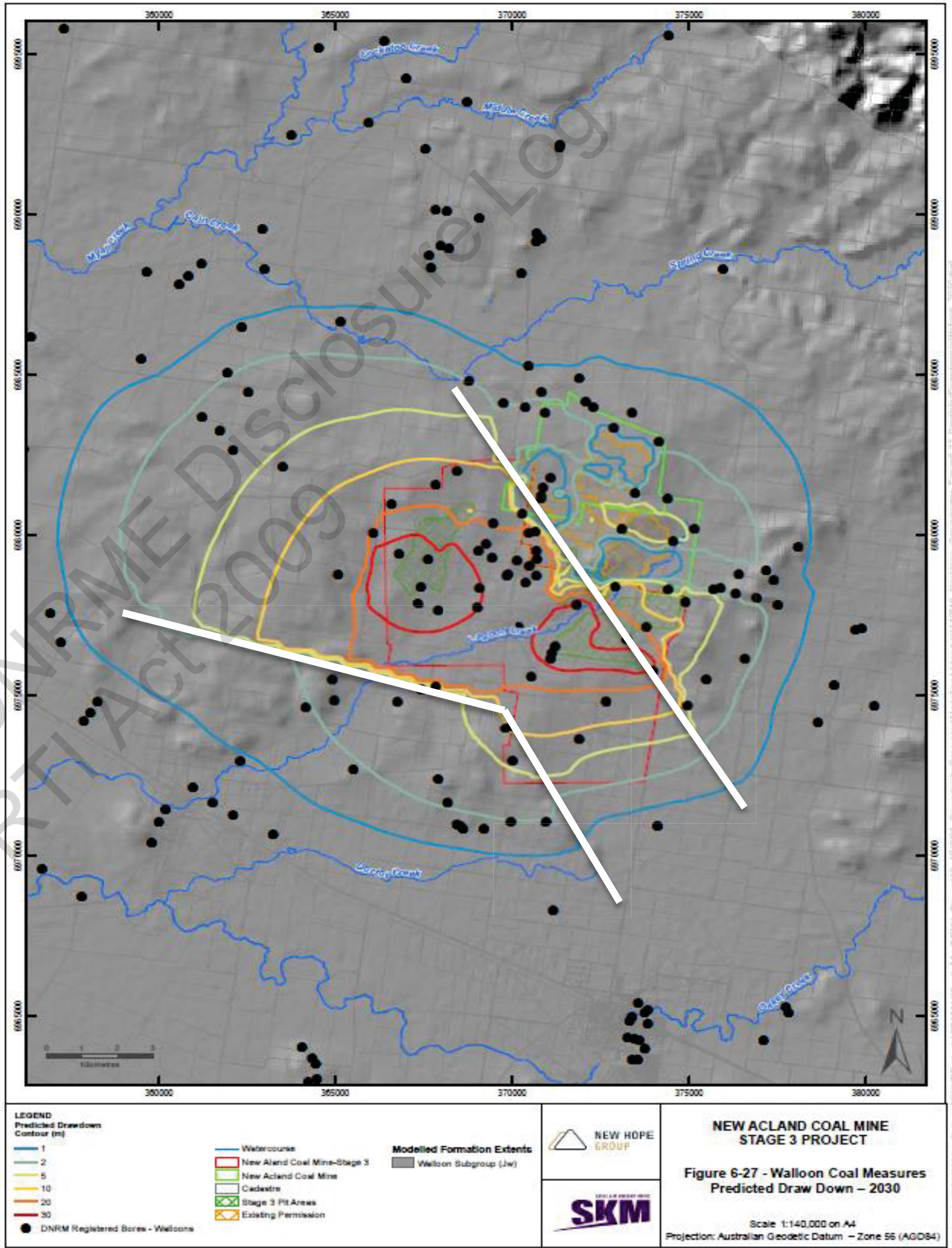
- 'The methods and data used by the proponent in their updated groundwater modelling, are appropriate for this stage of the proposed project and consistent with industry standards'
- 'Notwithstanding this, the IESC notes that all models are simplified representations of reality and therefore there will always be some residual risk of drawdown extending beyond the bounds presented in modelling. These residual risks can be addressed during the regular groundwater model update process required by the regulator and through ongoing monitoring and refining hydrogeological characterisation'

Land Court Concerns

1. **Vertical Hydraulic Conductivity:**
   - No testing was carried out on site to determine the vertical hydraulic conductivity, therefore standard multipliers were applied to the horizontal hydraulic conductivity
2. **Horizontal Hydraulic Conductivity:**
   - There are only a limited number of tests informing horizontal hydraulic conductivity
3. **Recharge:**
   - DNRM have historically used 12.7% of rainfall in the basalt aquifer for recharge in this area, which is about twice the maximum used in the study. If a recharge figure is applied which is too low it will impact on the calibrated hydraulic conductivity figures

Land Court Concerns

4. Faulting
   - Faults were placed in the model where they have not been geologically proven, and without adequate justification. Faults are only proven in some, not all, parts of the model
   - Approximate locations of faults in the model are represented by the white lines



Land Court Concerns

5. **Null Predictive Defence – Inclusion of Other Groundwater Take:**

   - Existing groundwater use had in part been left out of the existing model, and that this would impact on the calibration of the model

6. **Calibration Targets:**

   - only two calibration targets were used, groundwater head measurements and pit in-flows. 2980 models were reduced to 1836 based on head targets and from 1836 to 18 based on in flows

   - Appeared to be question marks about quality of pit inflow data given its impact on calibration

Land Court Concerns

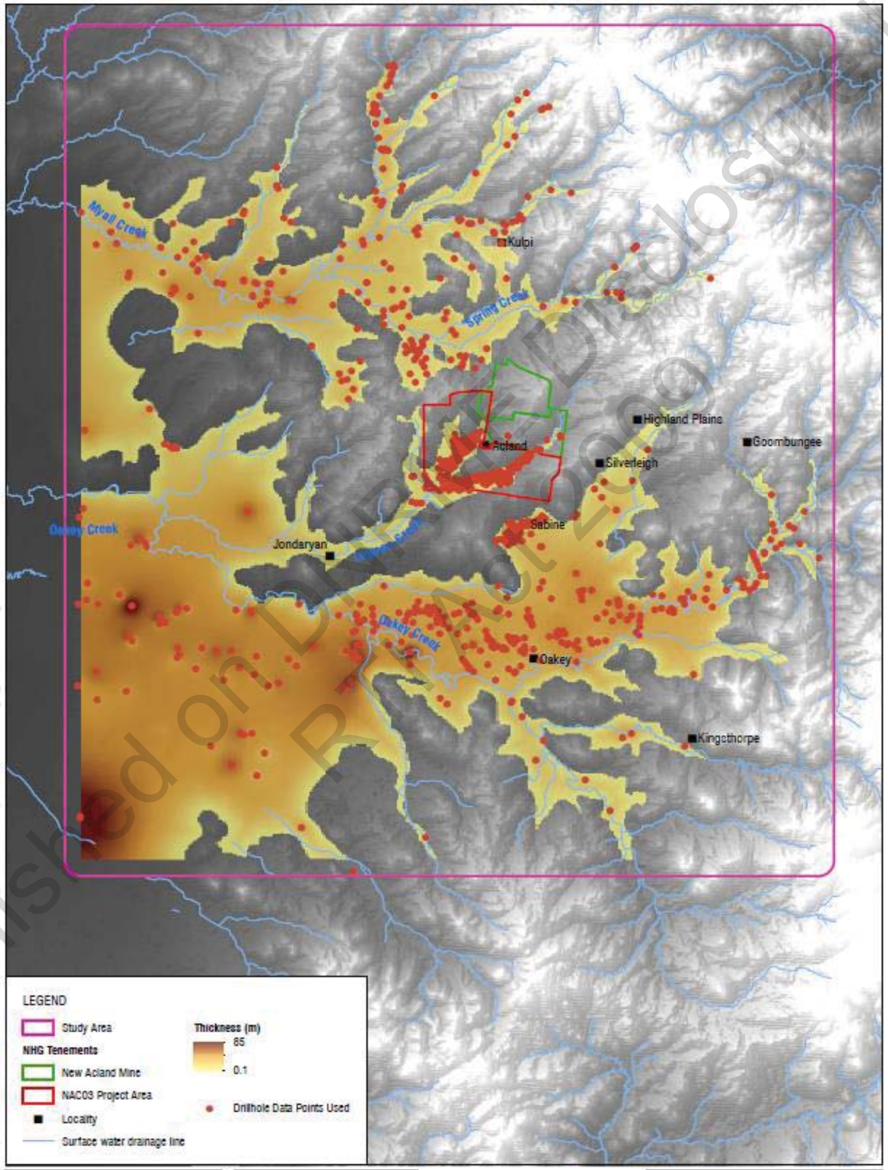
7. Make Good:

- 'Make good' agreements based on a model which is still being improved, and how landholders will be able to prove any impact caused by the mine

New Acland Mine: Stage 3
~ Actions: Land Court to Present

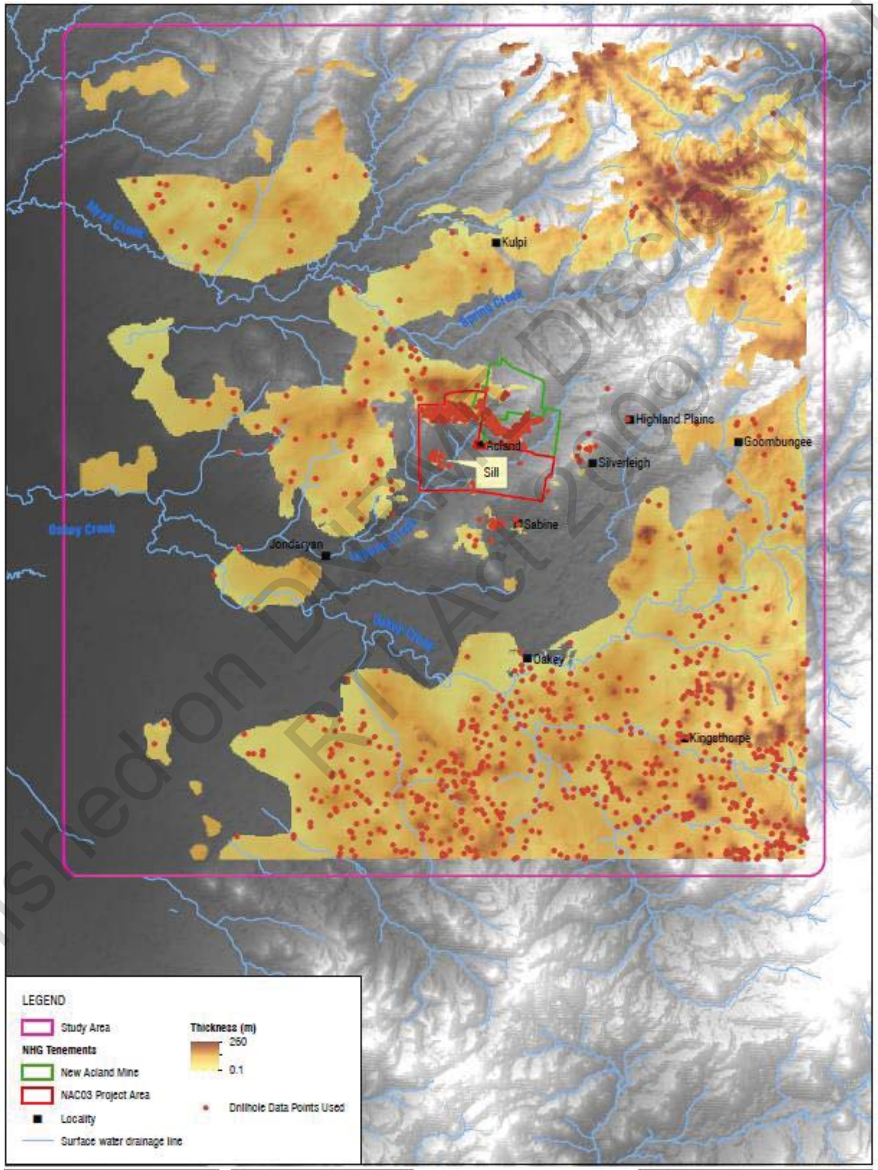
- NAC have undertaken a comprehensive new groundwater assessment to address Land Court, IESC, OCG and DNRM concerns
- This assessment comprises two components:
  1. 2017 Conceptualisation Report – new assessment work, incorporation of additional data; and
  2. 2017 Groundwater Model – new numerical model

Geological Conceptualisation - Alluvium



Department of Natural Resources and Mines

Geological Conceptualisation – Basalt



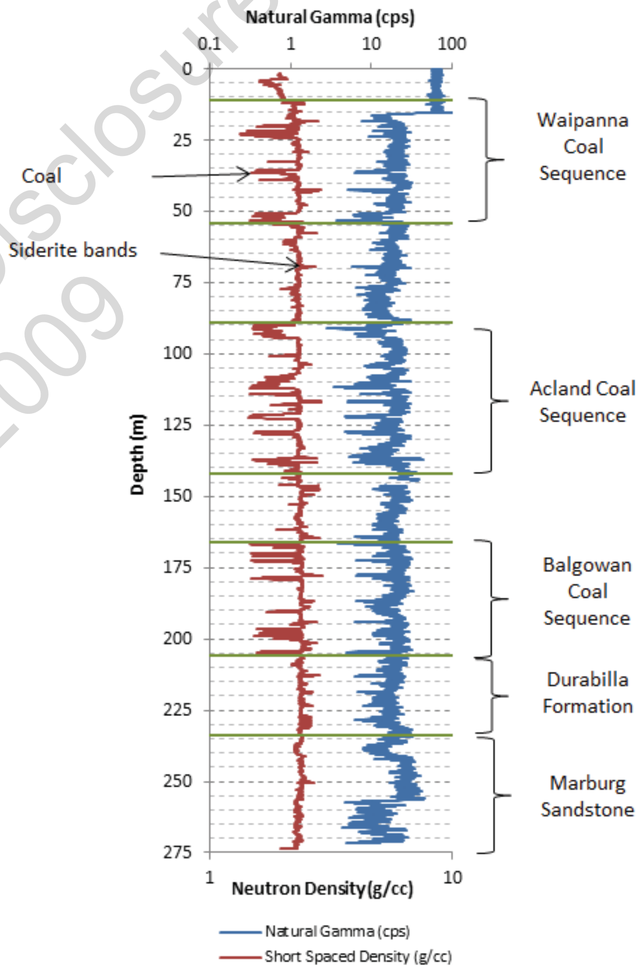
Department of Natural Resources and Mines

WCM Conceptualisation

- Walloon Coal Measures stratigraphy comprised of Coal Sequences of 30-50 m thickness separated by ~30 m thick non-coal interburden
- Consistent with OGIA Surat Basin stratigraphic conceptualisation

	Unit	Surat Basin	Clarence-Moreton Basin (Study Area)
Walloon Coal Measures	Upper Juandah Coal Measures	Kogan	*not present*
		Macalister	
		Nangram	
	Lower Juandah Coal Measures	Wambo	
		Iona	
		Argyle	
	Tangalooma Sandstone		Wonkers
	Taroom Coal Measures	Auburn	Waipanna
		Bulwer	Acland
		Condamine	Balgowan
	Durabilla Formation		

Site GW08 Downhole Geophysics



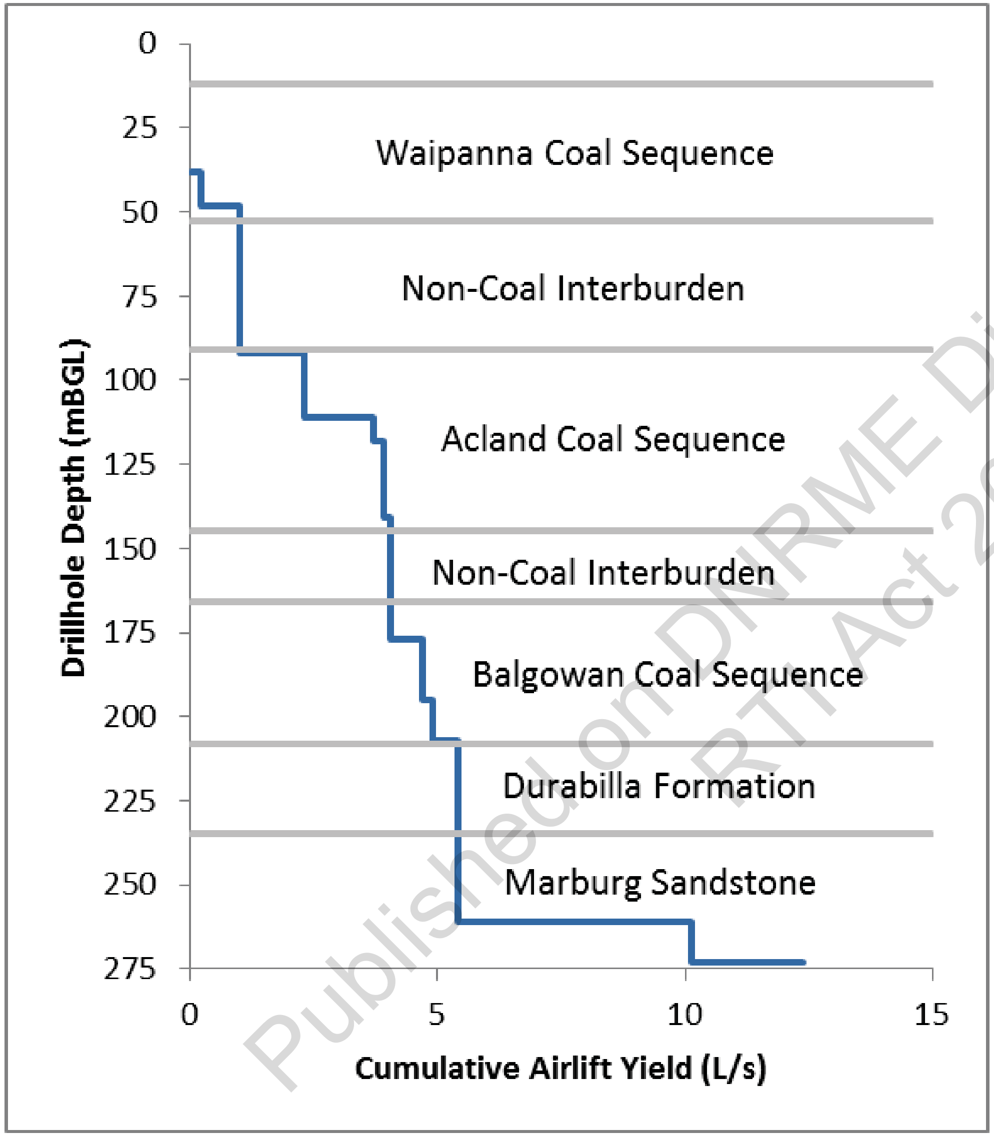
Hydrostratigraphy

- Consistent with OGIA Surat Basin hydrostratigraphic conceptualisation

Geologic Unit	Dominant Hydrostratigraphic Classification
Alluvium	Aquifer (in coarser grained horizons)
Main Range Volcanics	Aquifer (where vesicular or fractured)
Walloon Coal Measures	Aquitard (interburden between coal sequences)
	Aquifer (coal sequences)
Durabilla Formation	Aquitard
Marburg Sandstone	Aquifer
Evergreen Formation	Aquitard
Helidon Sandstone	Aquifer

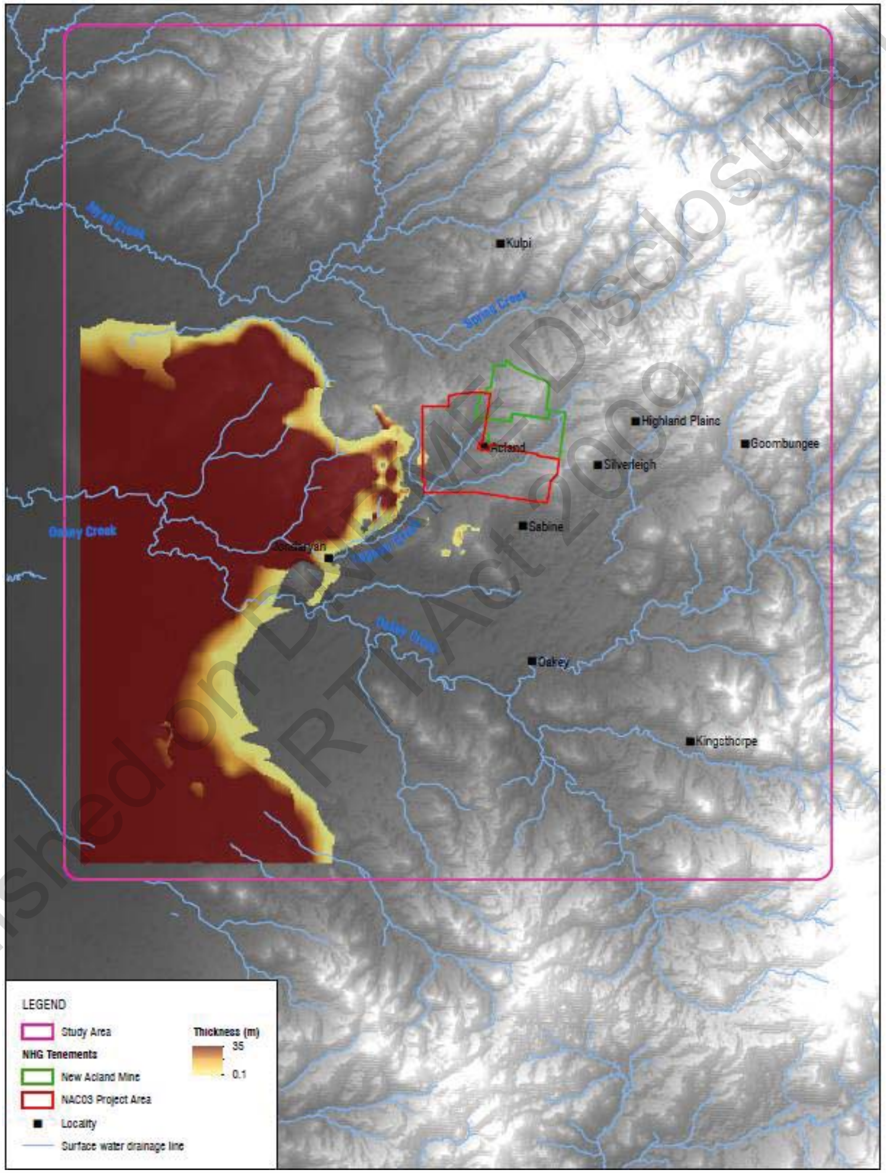
- WCM units conceptualised as separate aquifers (Coal Sequences) and aquitards (non-coal interburden)

Groundwater in units within WCM

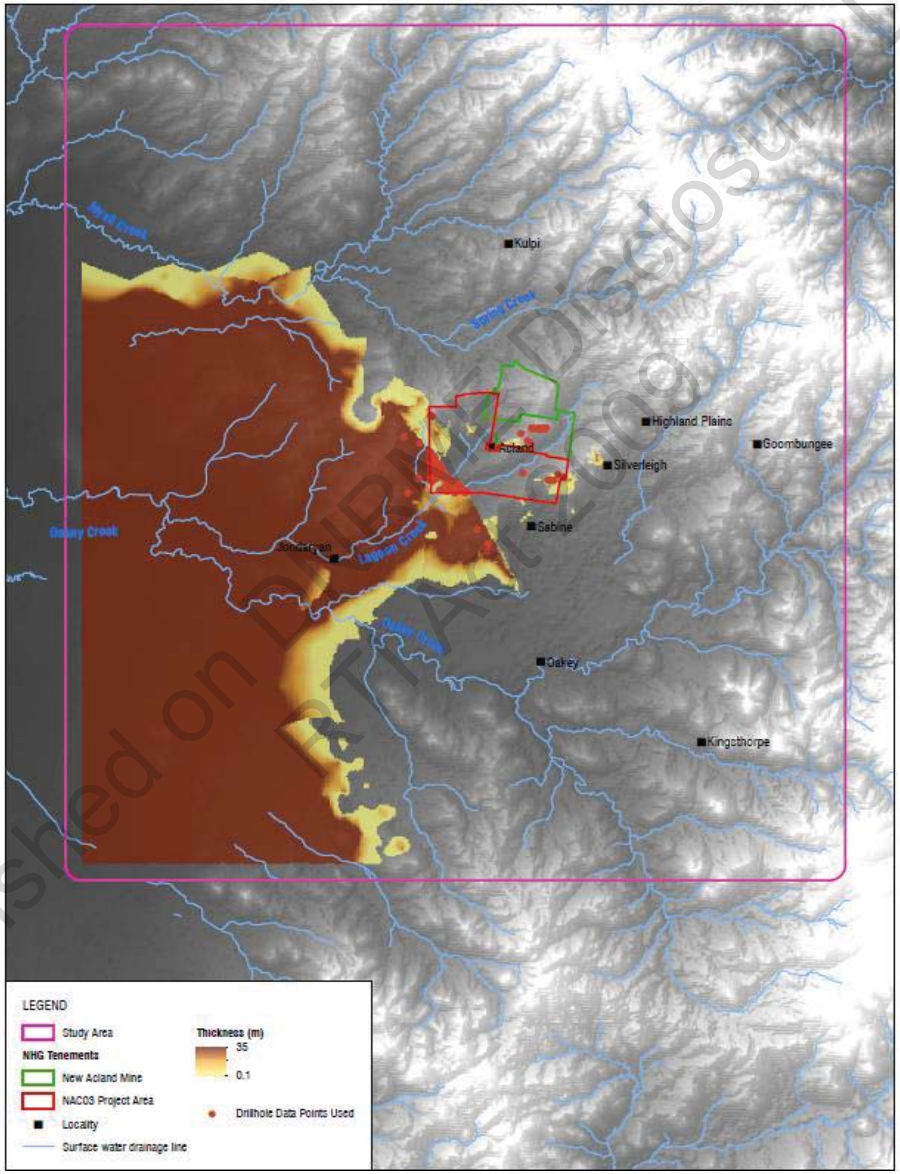


Monitoring Bore Site GW08B/GW08C Cumulative Airlift Yield

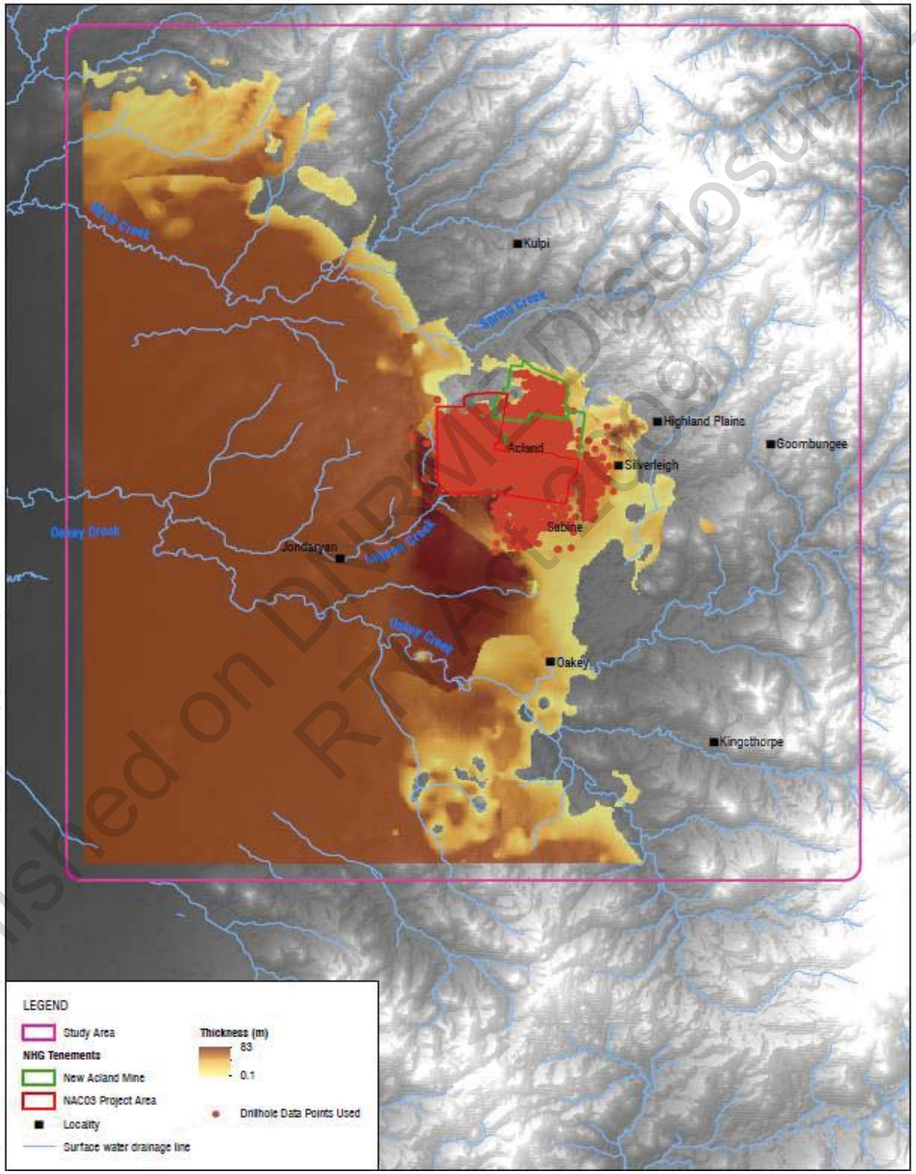
WCM Conceptualisation - Wonkers



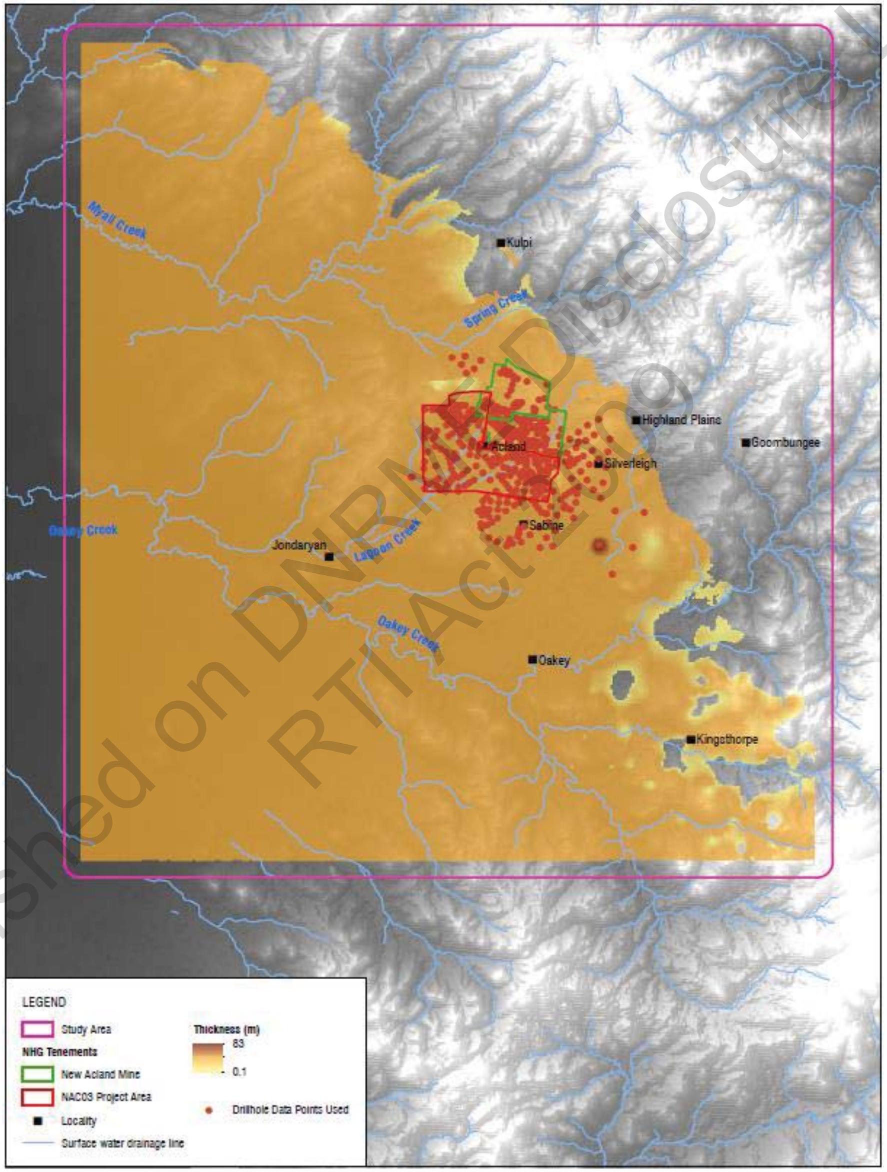
WCM Conceptualisation - Waipanna



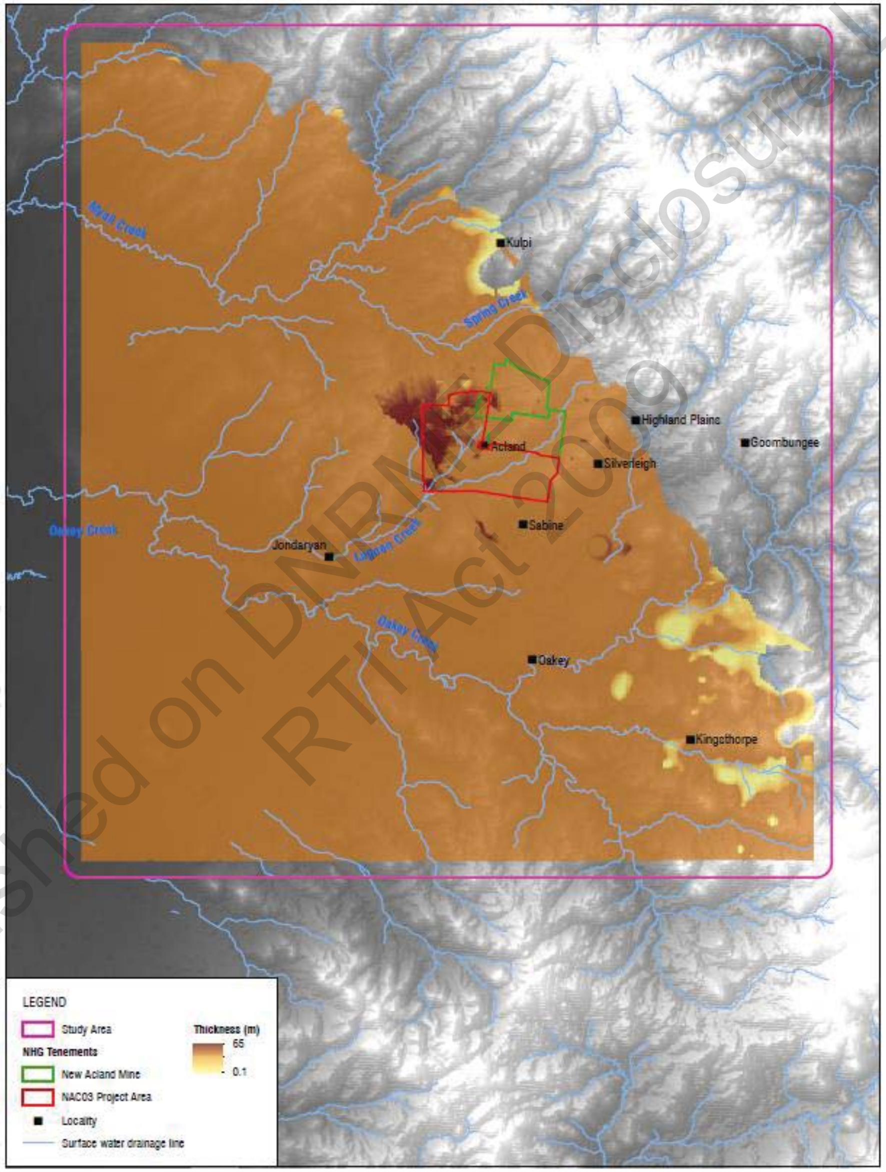
WCM Conceptualisation - Acland



WCM Conceptualisation - Balgowan



WCM Conceptualisation – Durabilla Fm



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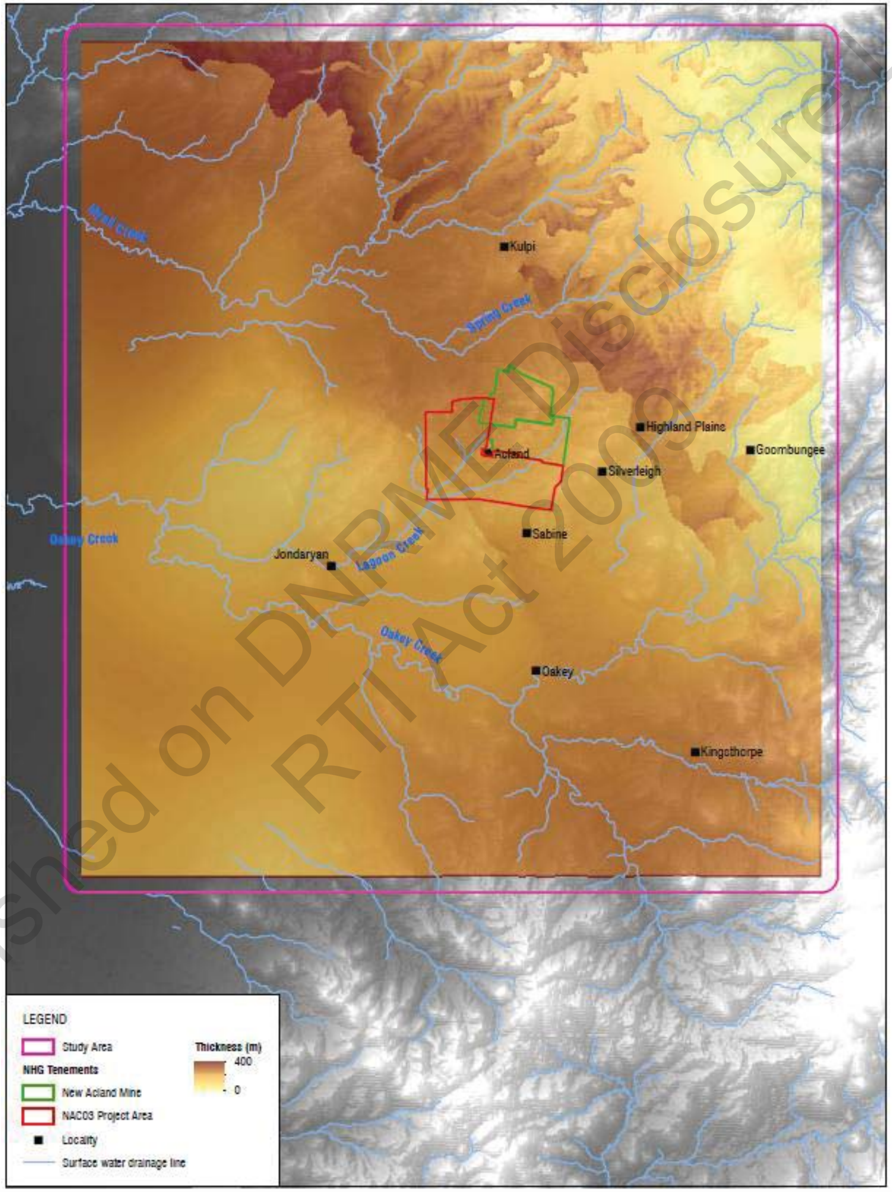
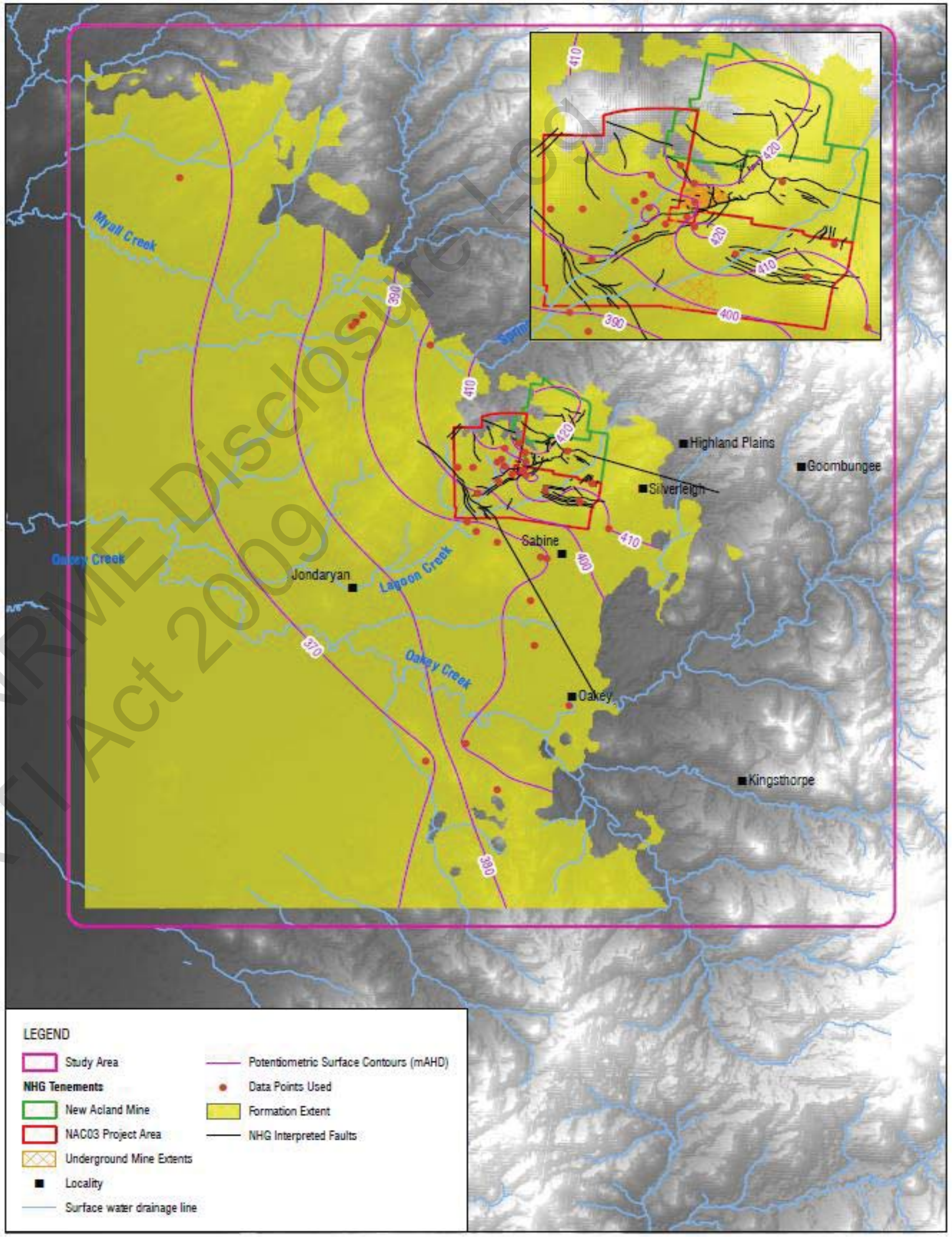
Geological Conceptualisation – Marburg Sst



Potentiometric Surface Acland Coal Sequence Pre 1990



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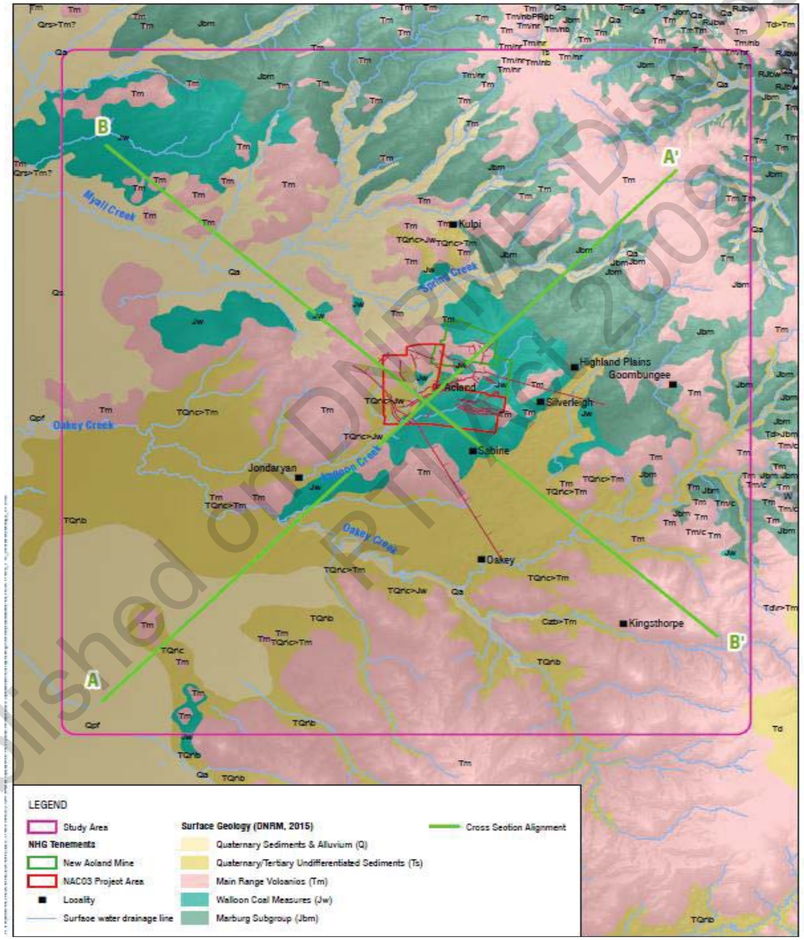
Model Layering - 2014 Model

Layer	Hydrogeologic Unit	comment
1	Alluvium	
2	Basalt	
3	Walloon Coal Measures - upper	Top of Walloon down to base of Acland sequence
4	Walloon Coal Measures - lower	Interburden below Acland down to Durabilla Formation
5	Marburg Sandstone	

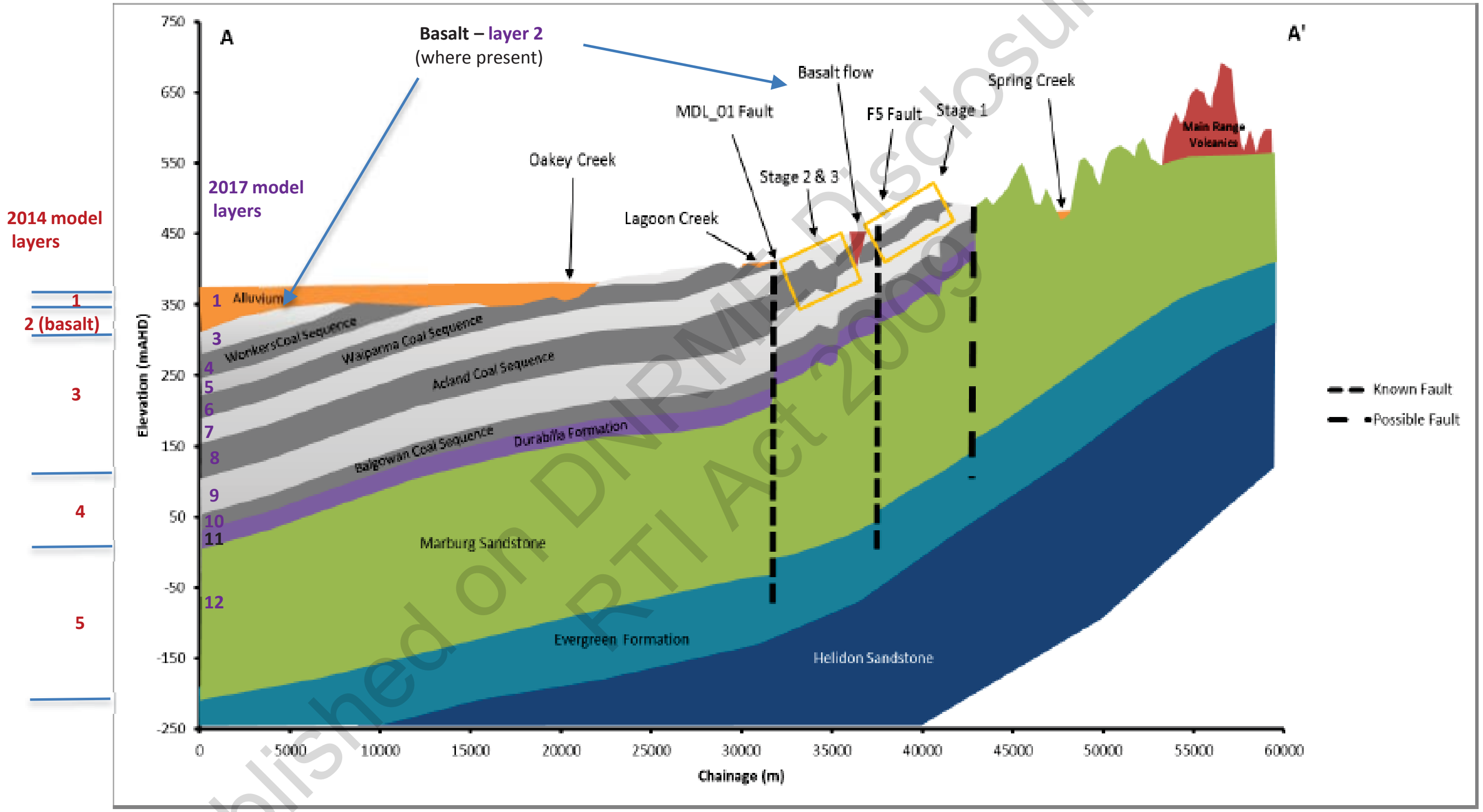
Model Layering Comparison

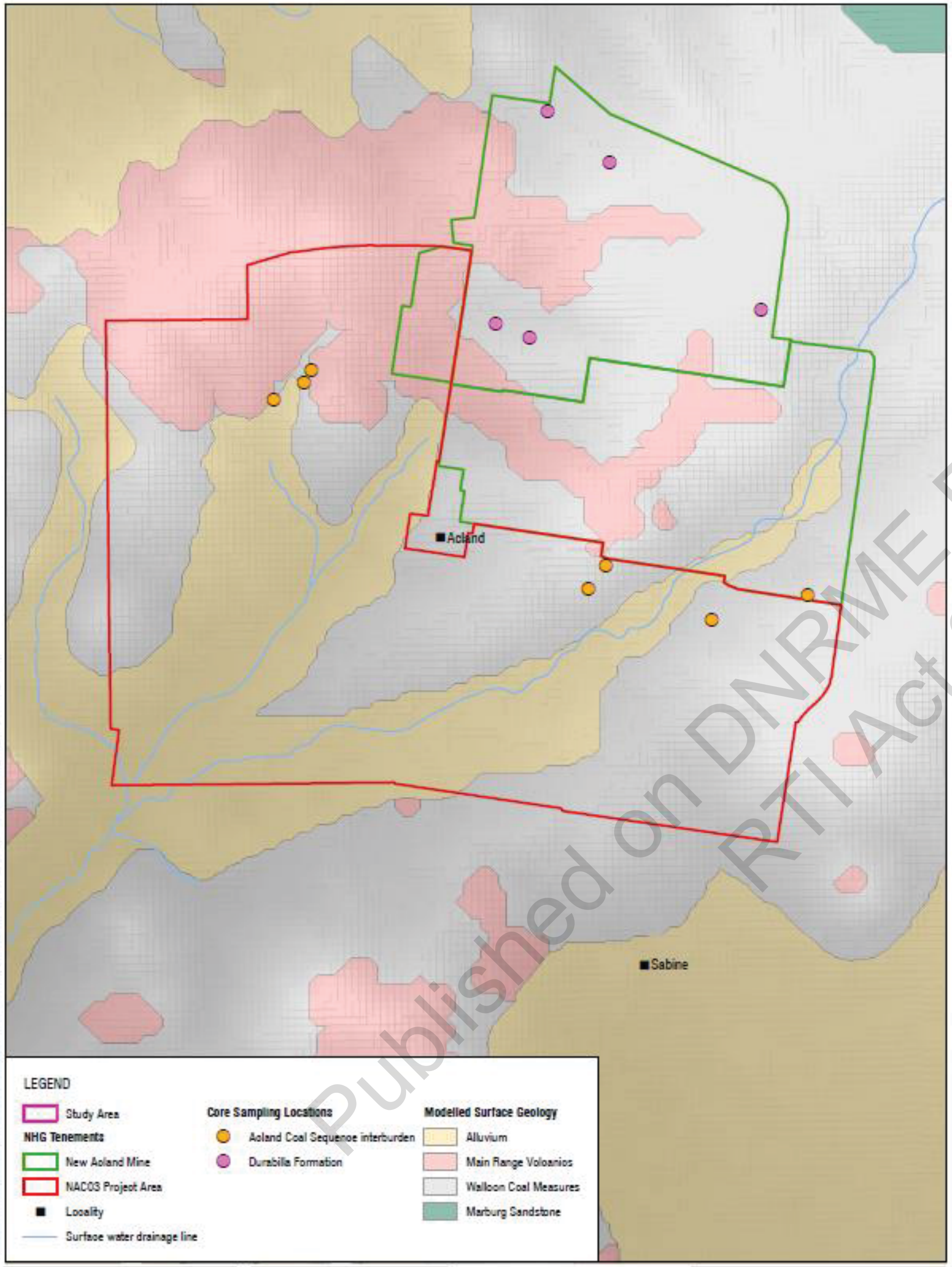
2014 Model layer	Geologic Unit	2017 model layer
1	Allluvium	1
2	Basalt	2
3	WCM above Wonkers sequence	3
3	Wonkers Sequence	4
3	interburden	5
3	Waipanna Sequence	6
3	interburden	7
3	Acland Sequence	8
4	interburden	9
4	Balgowan Sequence	10
4	Durabilla Formation	11
5	Marburg Sandstone	12

Locations of cross sections 2017 Conceptualisation report



South West to North East





Land Court Concern 1: Vertical Hydraulic Conductivity

- 29 core samples from the Walloon Coal Measures interburden (Acland sequence) were taken from 7 holes and tested for vertical hydraulic conductivity in late 2016 and early 2017.
- 11 core samples from the Durabilla formation were taken from 4 holes and tested for vertical hydraulic conductivity in late 2016 and early 2017.
- The range of results are provided in the 2017 Conceptualisation report.

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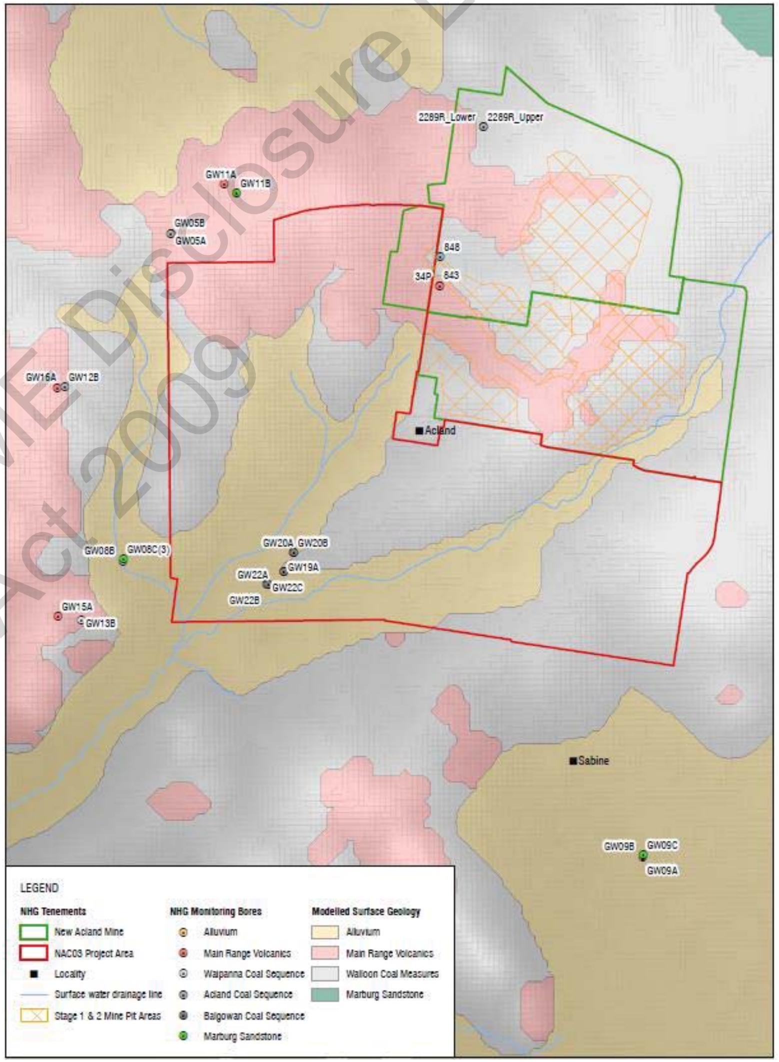
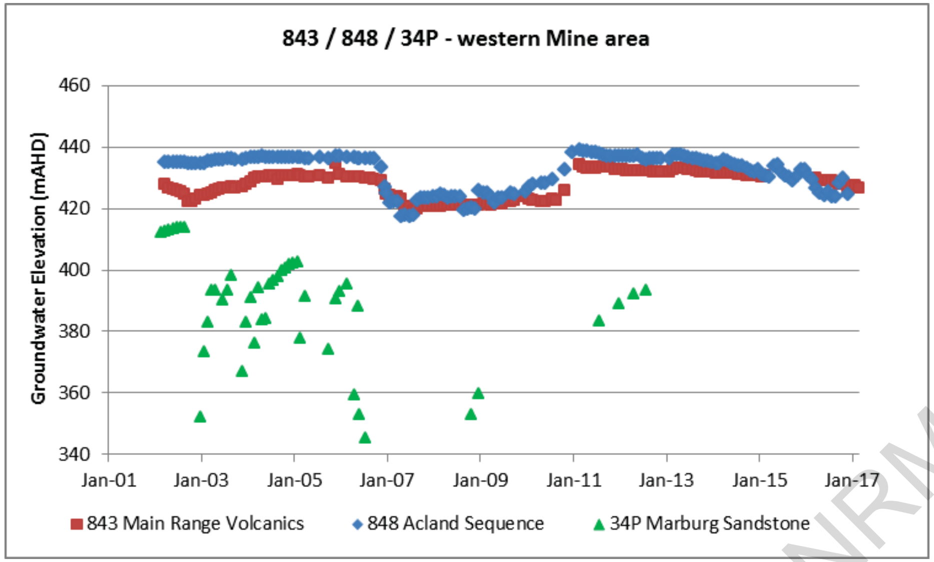
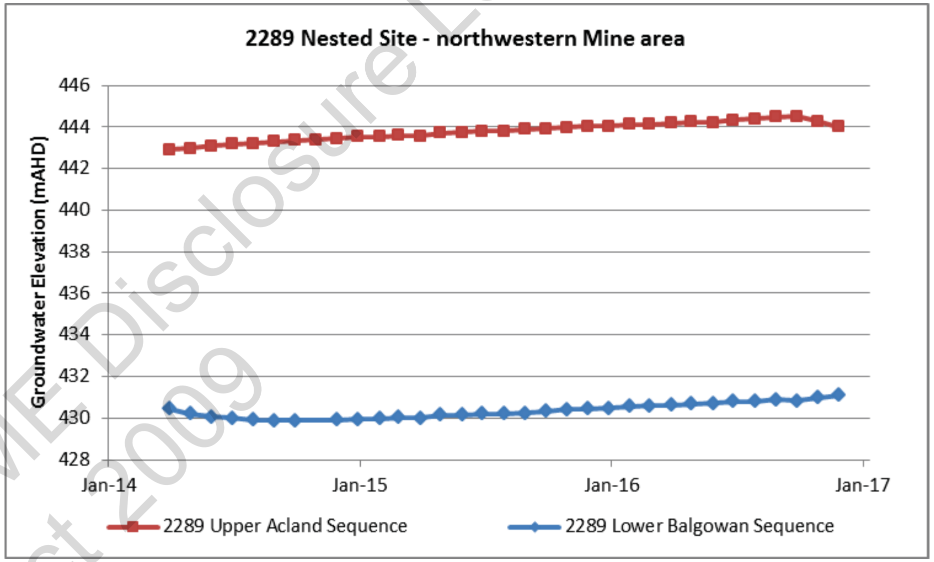
Groundwater Levels – Vertical Gradients

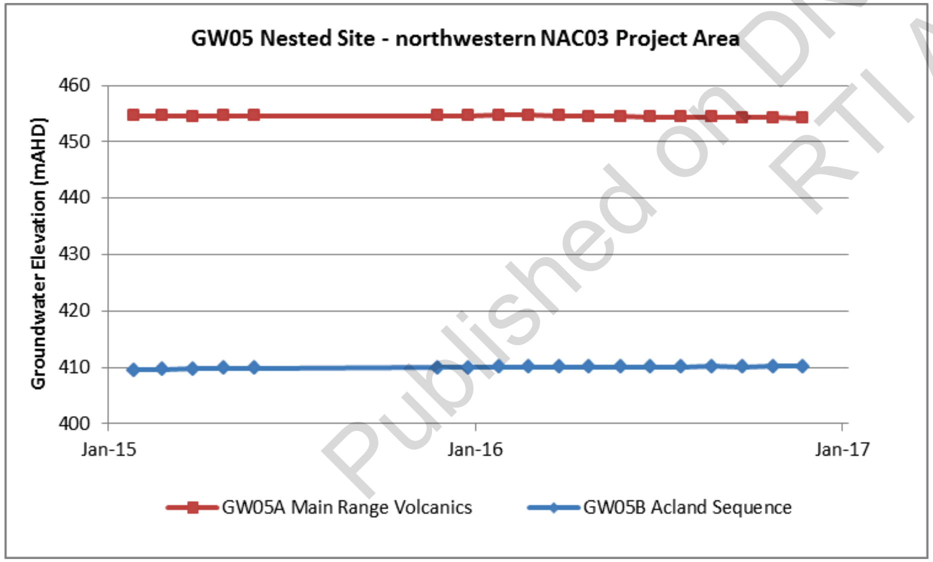
- Nested/paired bores across both existing Mine and NAC03 Project Area at multiple sites allows assessment of vertical gradients
- Results typically show:
    - Downwards gradients across aquifers
    - Significant head separation between basalt and all underlying aquifers
    - Significant head separation between WCM sequences on north side of MDL_01 fault

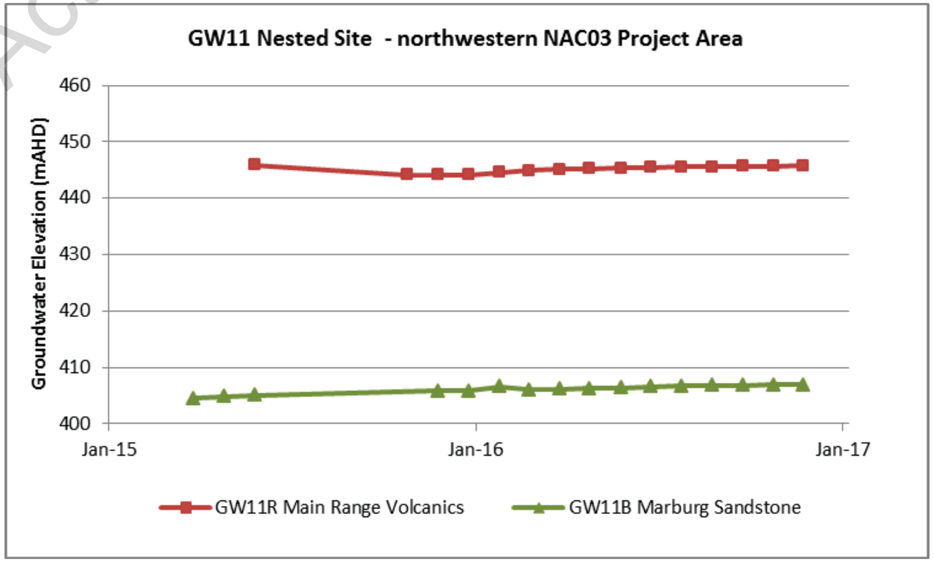


Groundwater Levels – Vertical Gradients

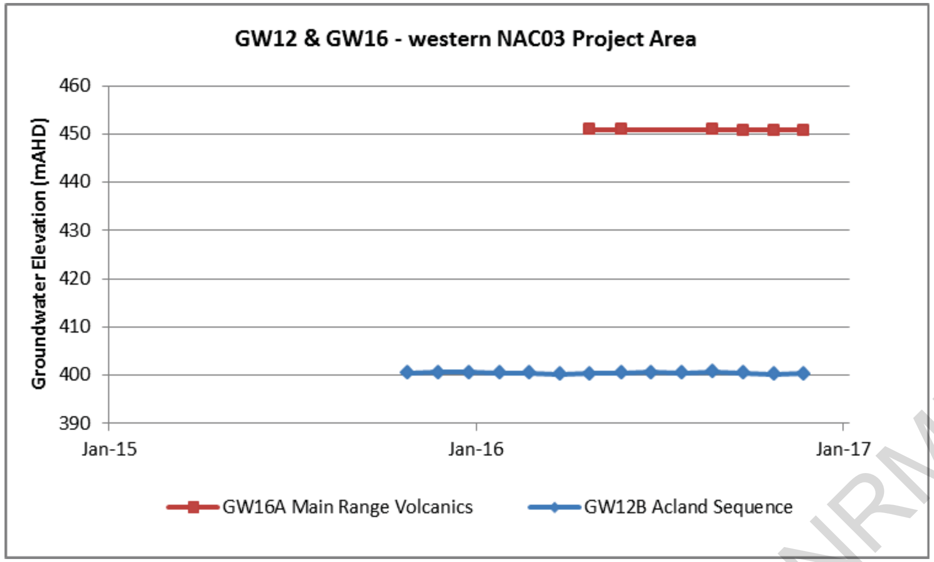


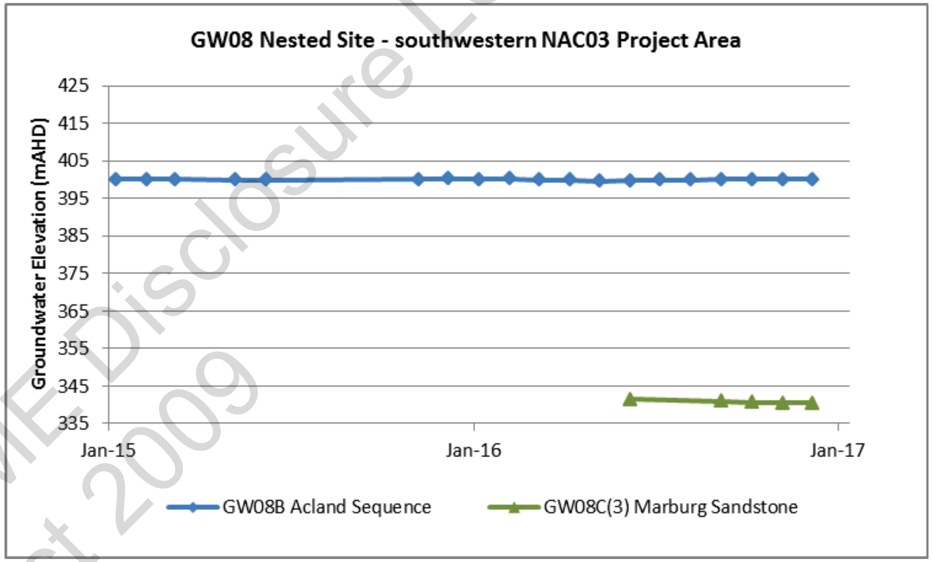


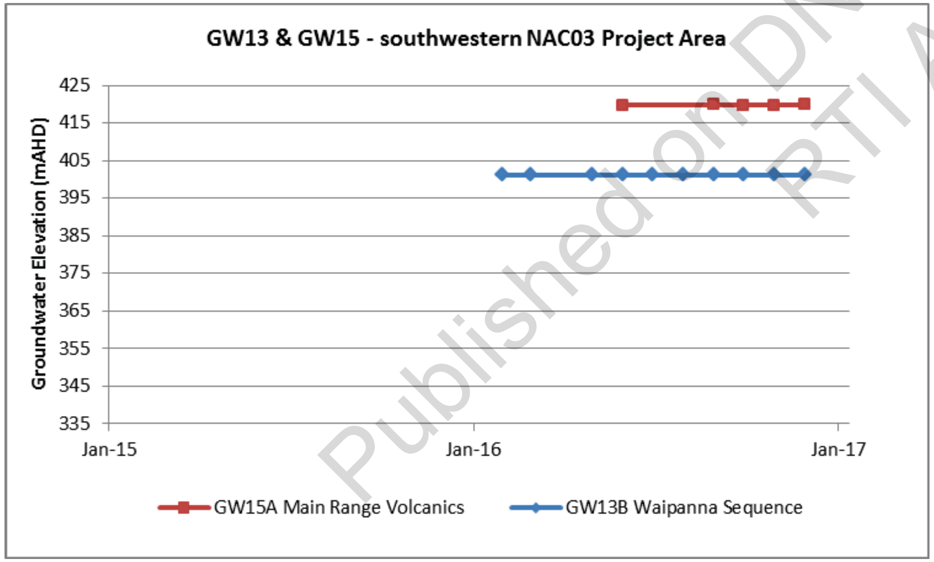


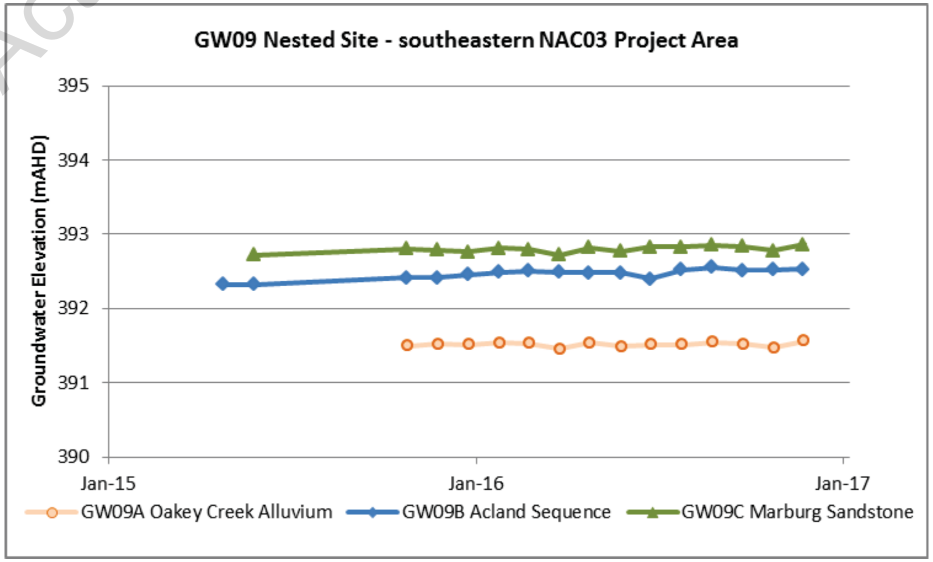


Groundwater Levels – Vertical Gradients

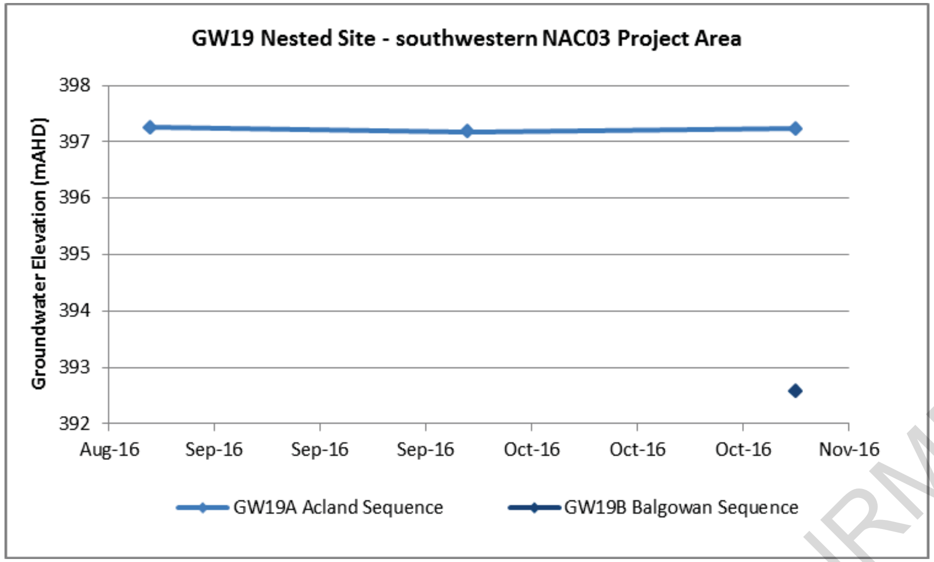


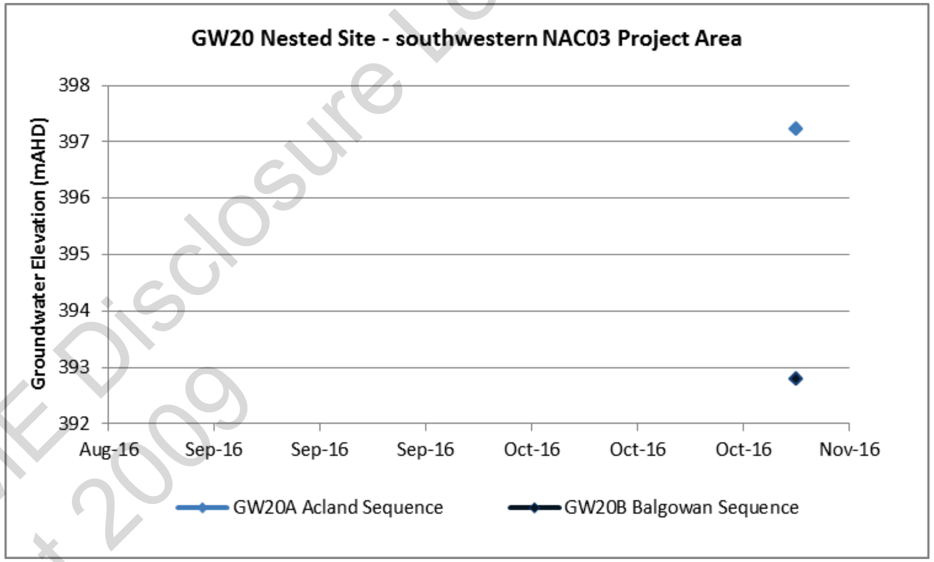


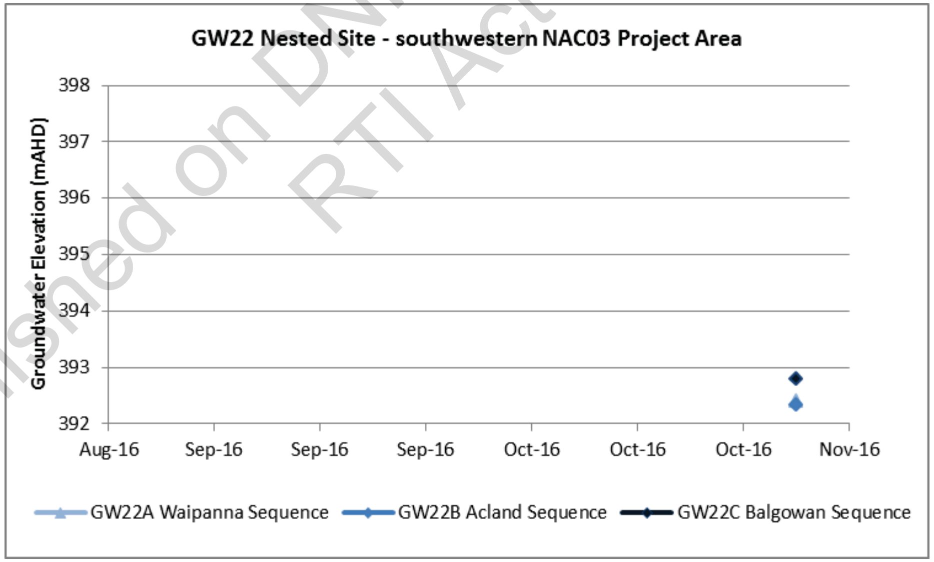




Groundwater Levels – Vertical Gradients







Land Court Concern 2: Horizontal Hydraulic Conductivity

- The 2017 Conceptual Report refers to at least 57 tests (specific number of tests are not always provided) by New Hope Group (NHG) between 2002 and 2017 to determine the horizontal hydraulic conductivity.
- Many of these tests were conducted during 2016.
- Some tests also provided data on storage characteristics.
- Currently a range of results are presented in the conceptual report.
- Note that in the updated report documents, the company advise that data from some 200 slug tests are now available.

Land Court Concern 3: Recharge

- In the 2017 Conceptual Report the proponent has presented work they have carried out using a chloride mass balance utilising 664 water samples.

- Results of this work, split up into median recharge rate calculated for each geologic unit, have been compared to that presented by the Office of Groundwater Impact Assessment (OGIA) for the Surat Cumulative Management Area (CMA) model, and results found to be similar.

- Land Court didn't accept the value for recharge used by NAC, as it didn't align with the historical figure used by DNRM to allocate water.

- However, DNRM accept the chloride mass balance approach is updated knowledge and whilst having its own limitations, is the approach most frequently used to estimate recharge in many regions.

Land Court Concern 3: Recharge

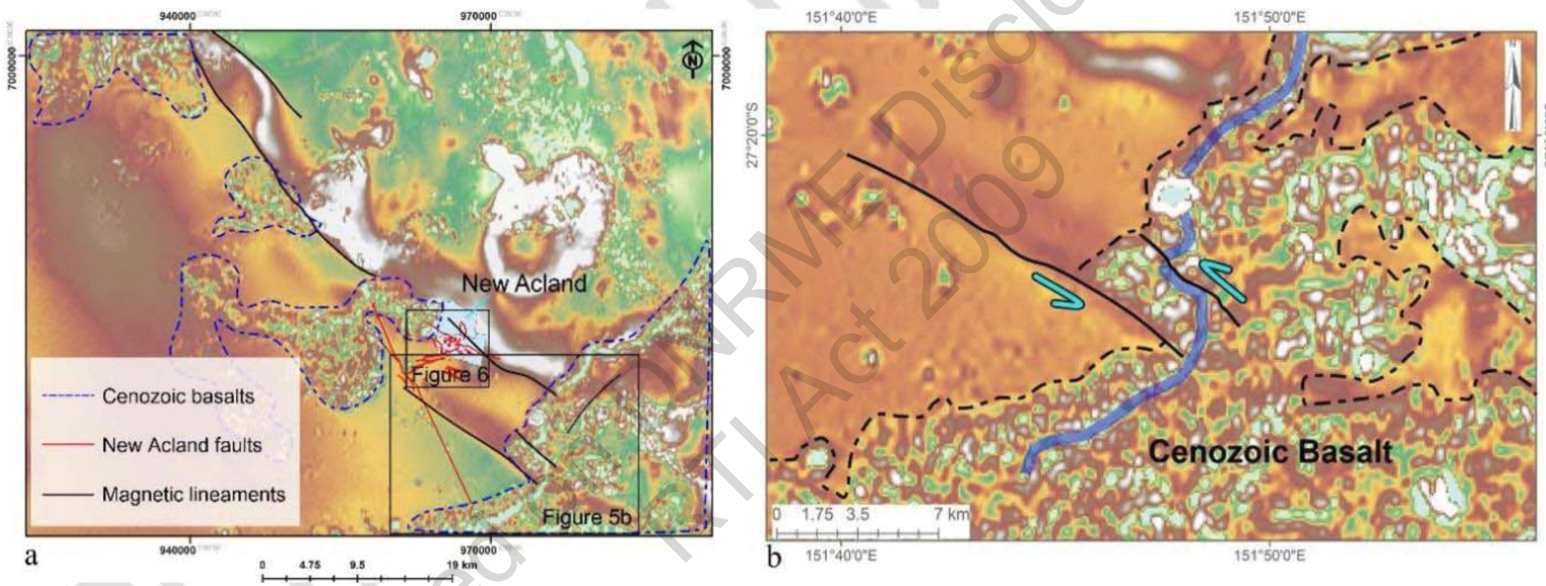
- A range of recharge values are used in the calibration process based on OGIA and SLR conceptualisation report data.

Land Court Concern 4: Faulting

Evidence of faulting in Stage 2 pits

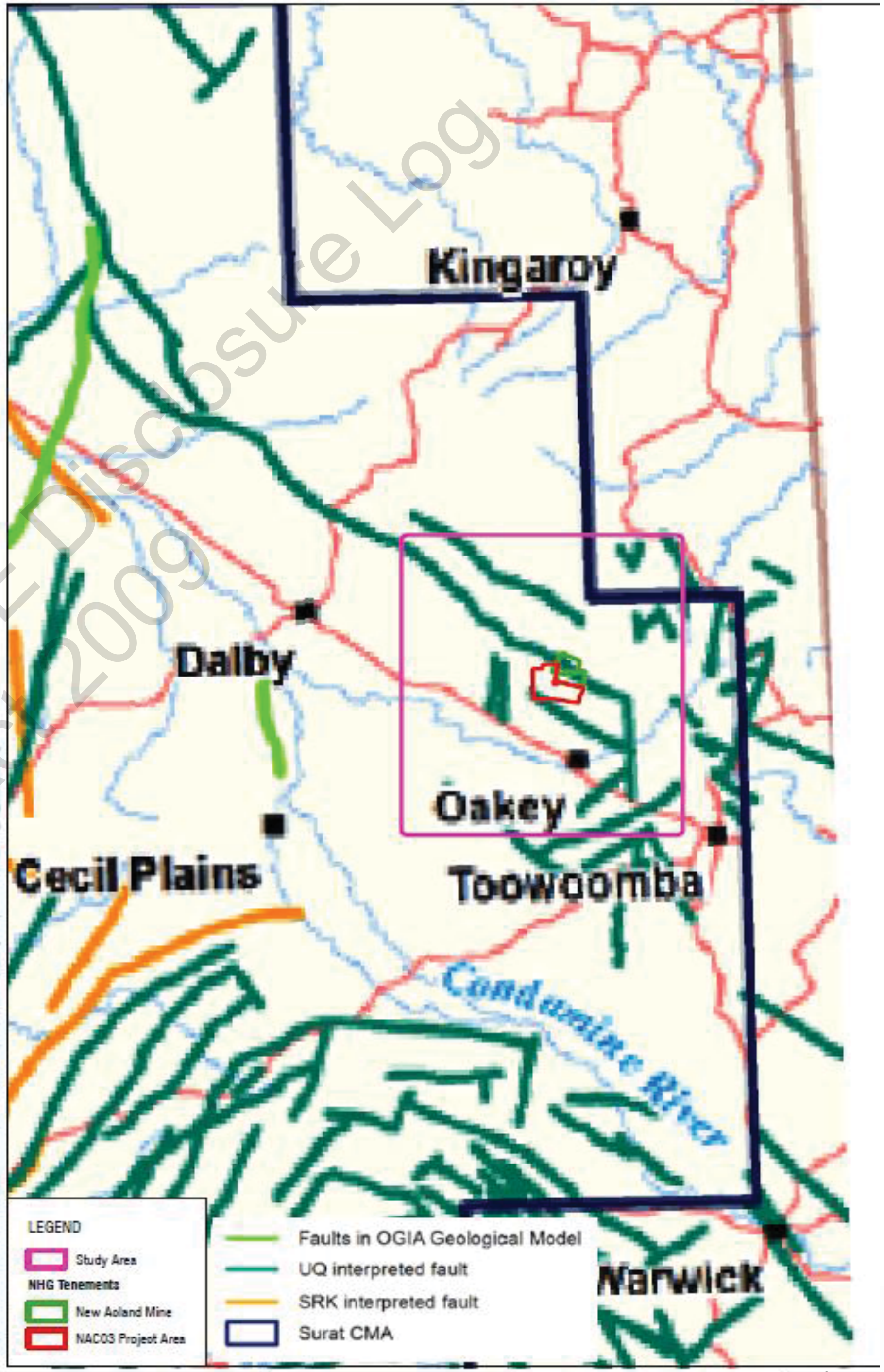
Geologic Structure

- Regional scale studies (OGIA, UQ) suggest large scale faulting of Surat/Clarence-Moreton sedimentary sequences driven by reactivation of deep basement faults



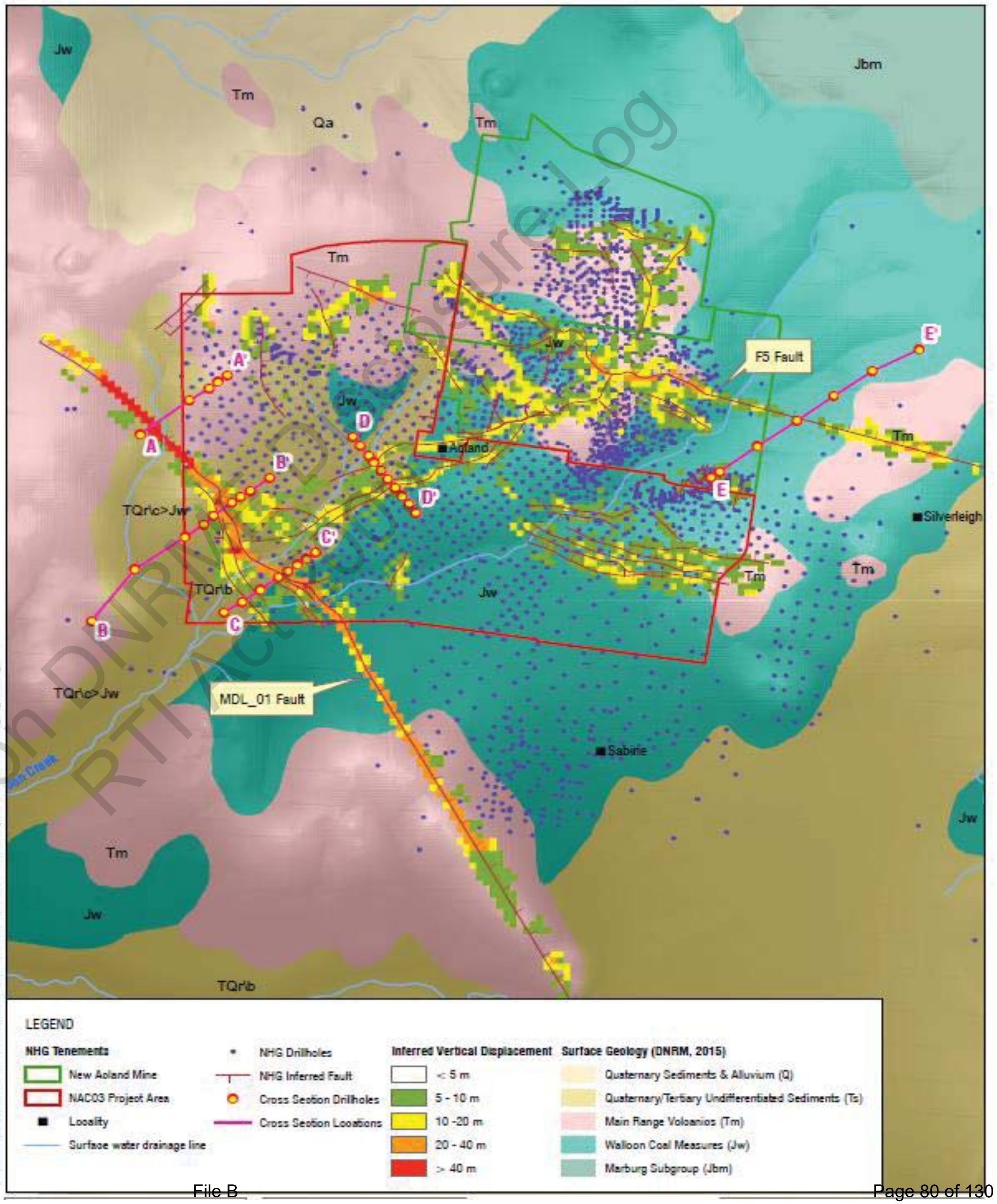
Land Court Concern 4: Faulting

- The 2017 Conceptual report references 2016 Queensland University and OGIA 2016 Surat CMA report mapping of faulting (Figure shown from OGIA 2016).
- The above fault mapping is compared to the most recent NAC fault mapping used for their geological model.
- NAC quote 'almost 3000 individual drill holes to date have been used to define the New Acland geological model and faulting contained within'.

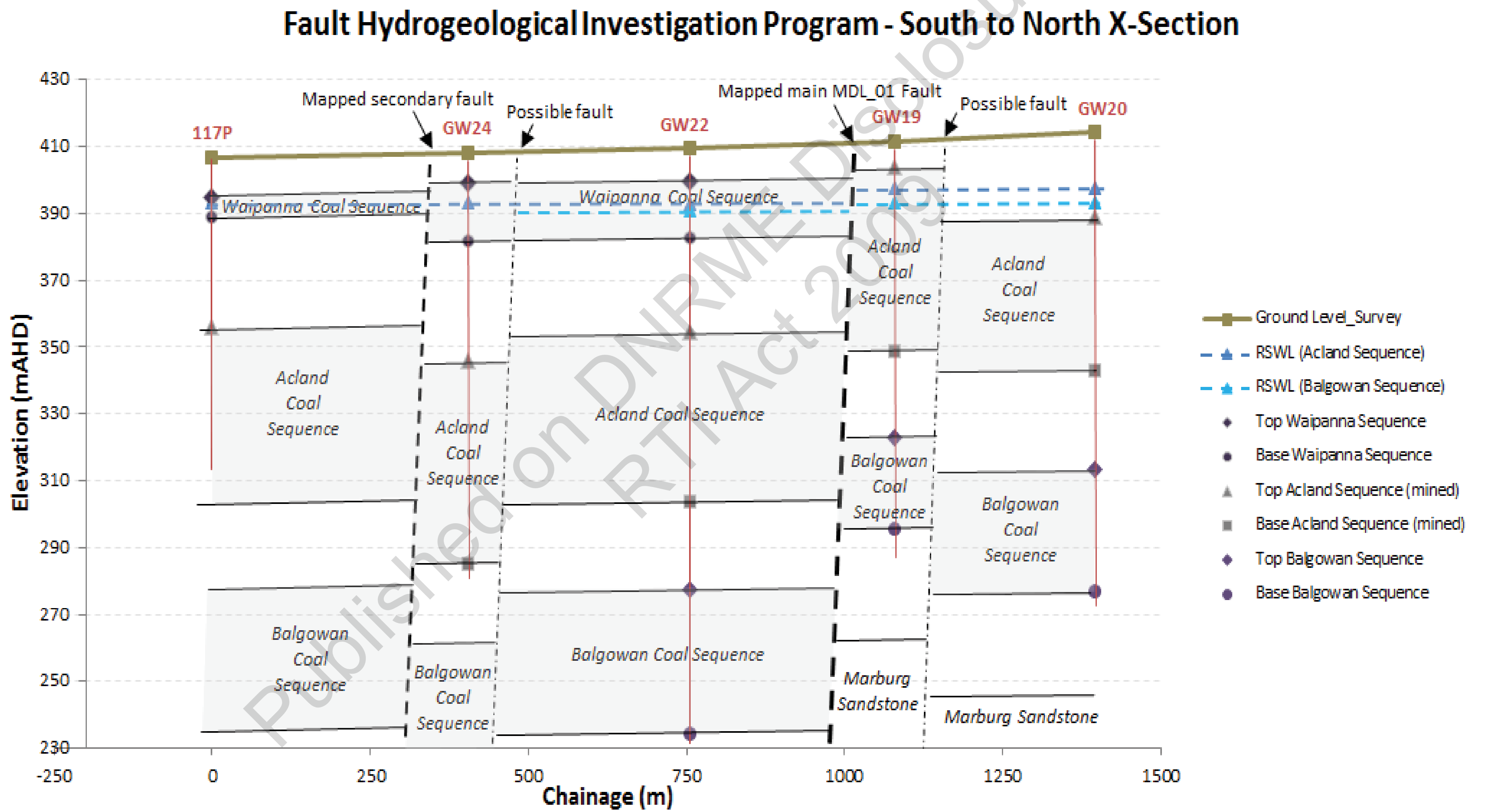


Land Court Concern 4: Faulting

The NAC mapping identifies vertical displacement at the faults based on the varying depths to the base of the Acland sequence in adjacent drill hole pairs across each fault.

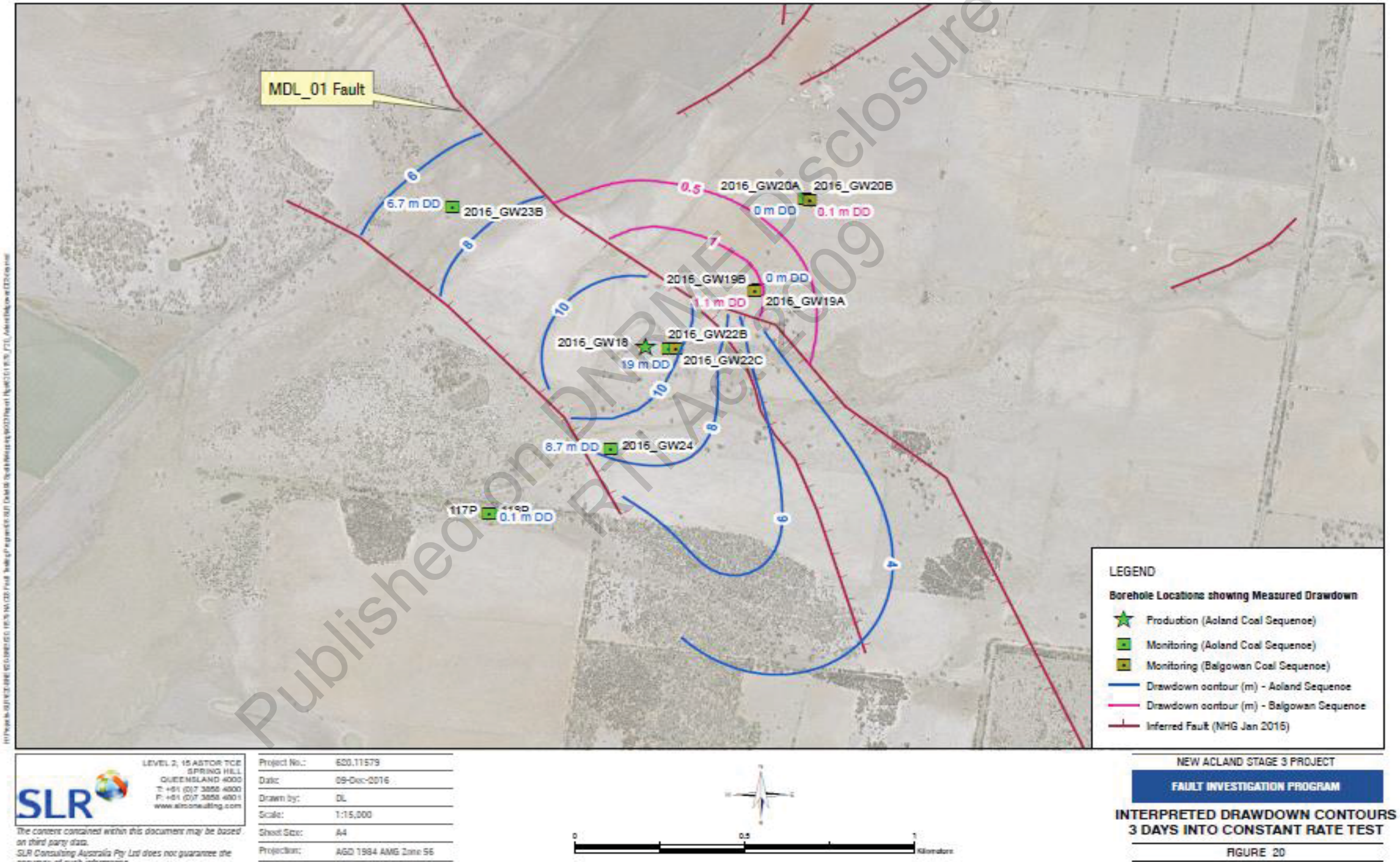


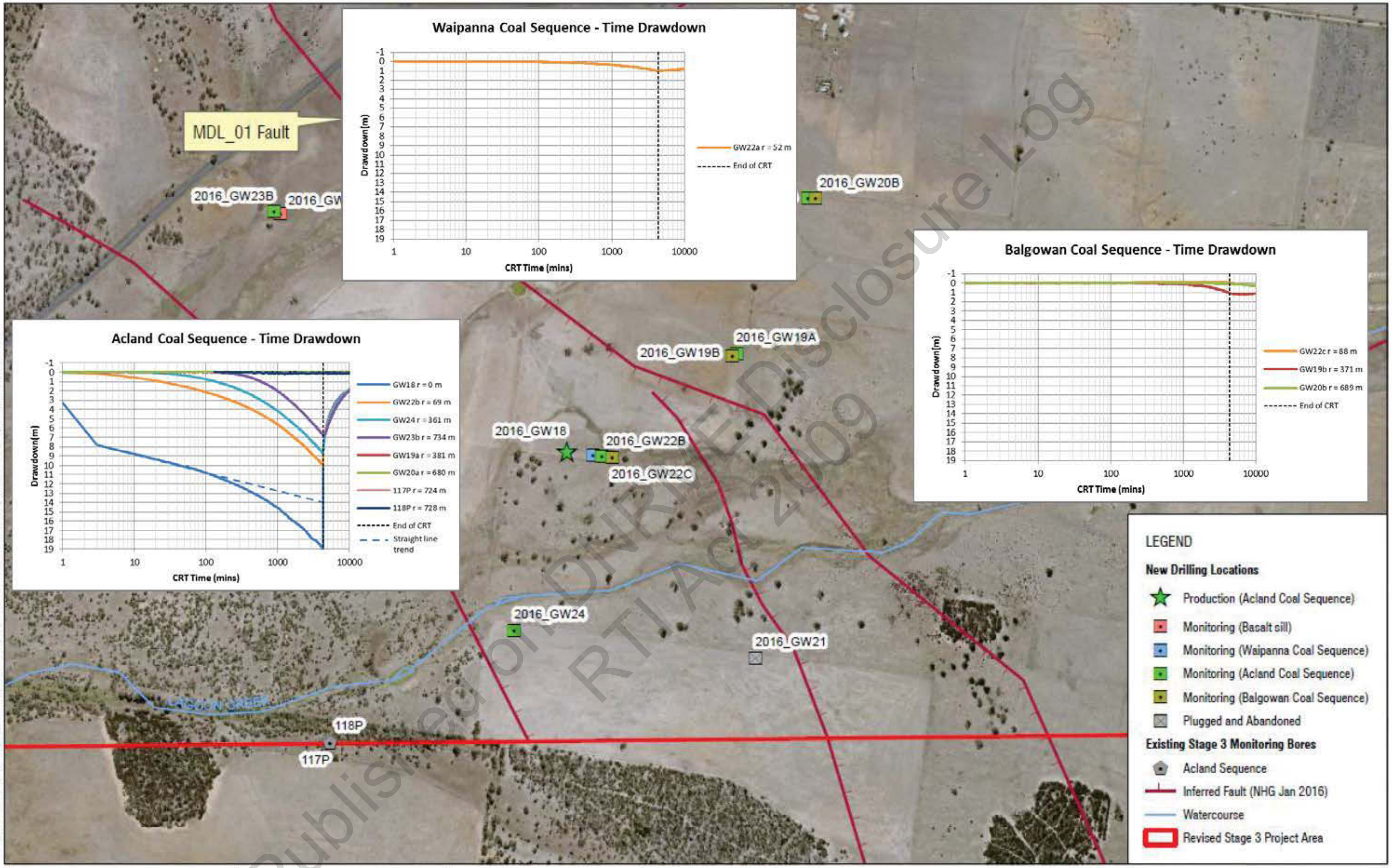
Land Court Concern 4: Faulting



Note: 1. The top of the Marburg Sandstone generally lies around 30 m below the base of the Balgowan Sequence in the Acland area, separated by the Durabilla Formation.
2. Drillhole intersections indicated in legend. NHG geological model data used for layering where specific drillhole intersection data not available (eg Balgowan Coal Sequence in bore 117P).

Land Court Concern 4: Faulting





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Project No.:	620.11579
Date:	15-Dec-2016
Drawn by:	DL
Scale:	1:10,000
Sheet Size:	A4
Projection:	AGD 1984 AMG Zone 56

N W E S
0 0.25 0.5 Kilometers

NEW ACLAND STAGE 3 PROJECT

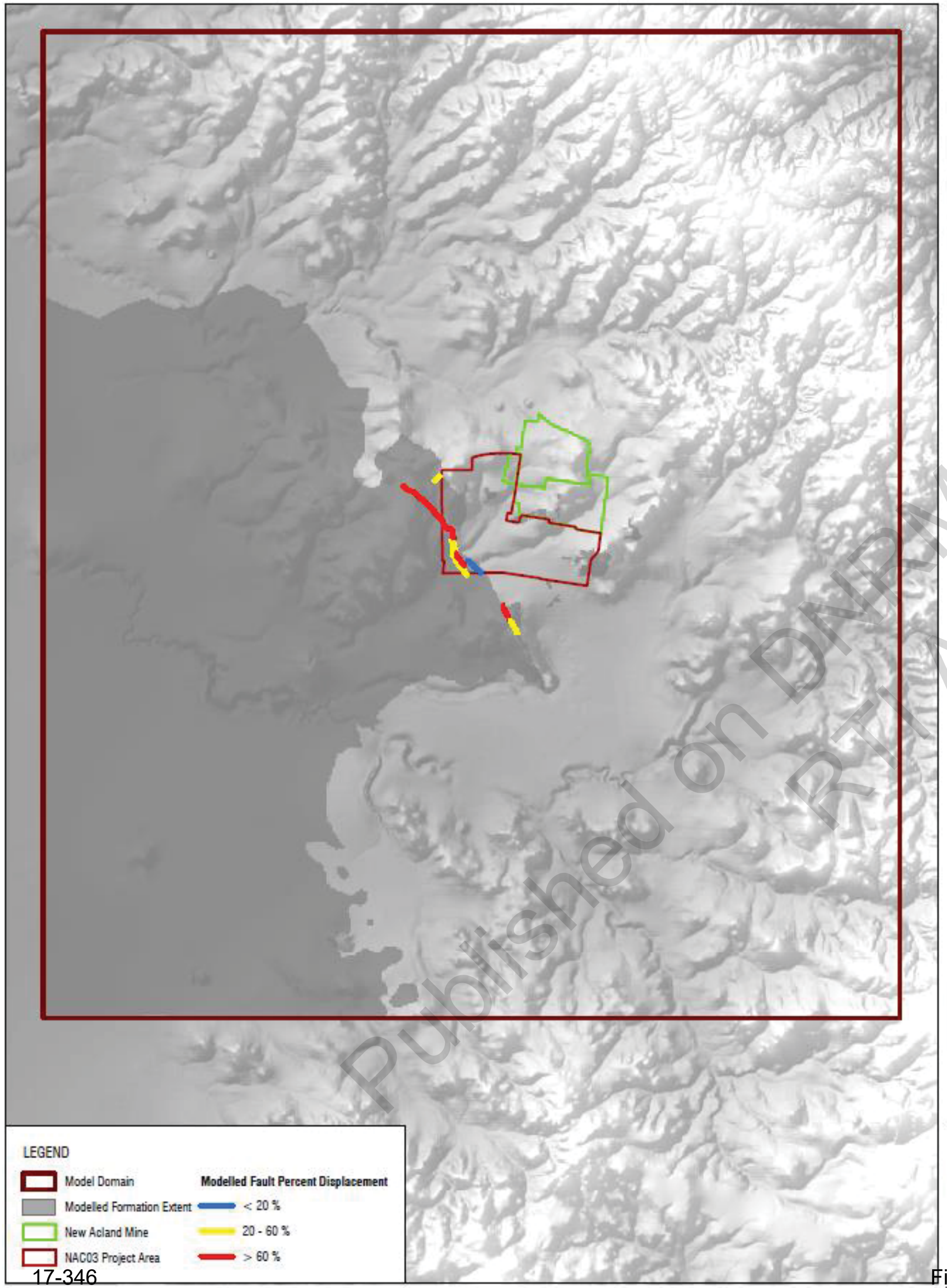
FAULT INVESTIGATION PROGRAM

FAULT INVESTIGATION BORE LOCATIONS

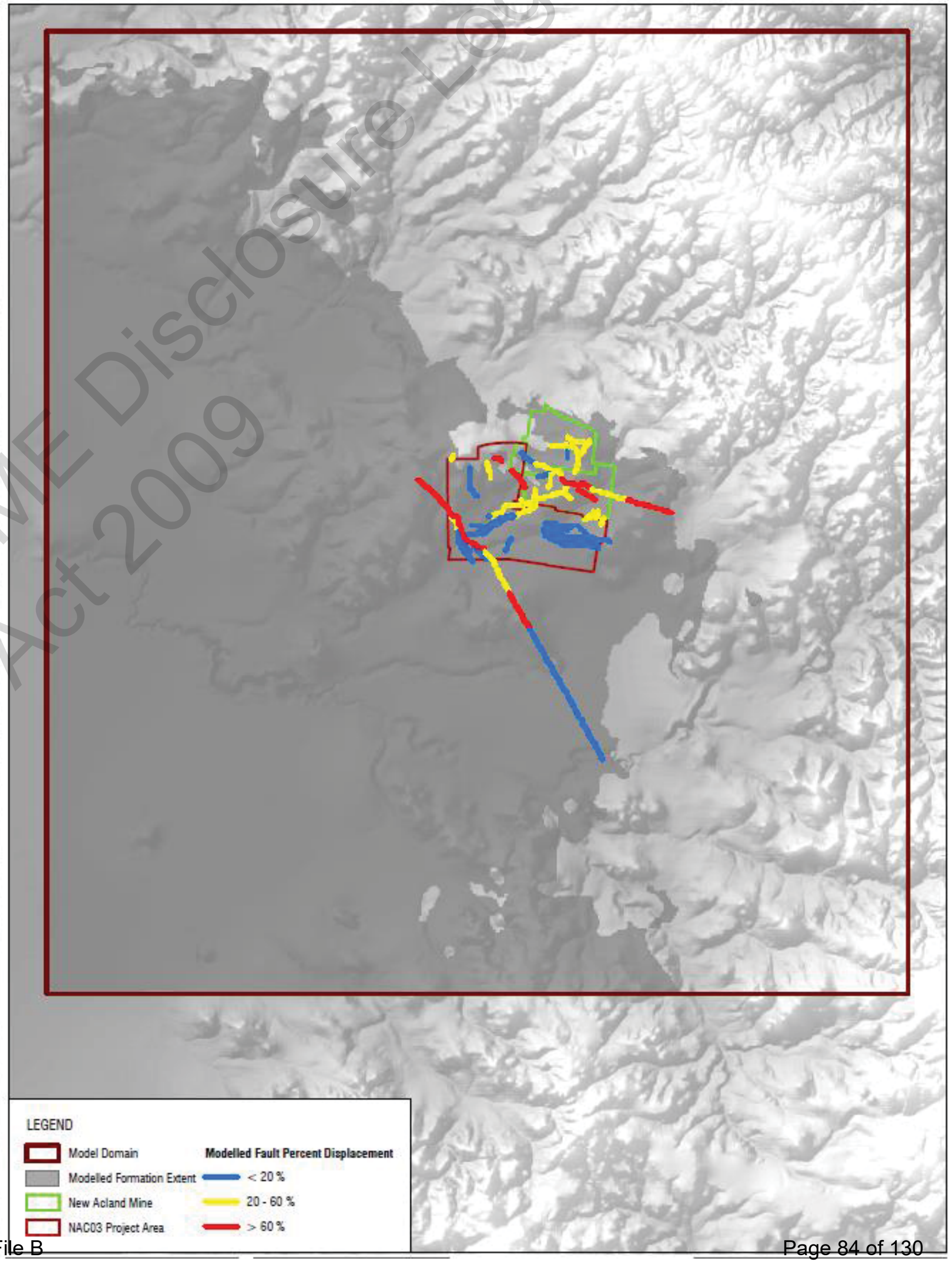
FIGURE 12

Horizontal Flow Barriers Acland Coal Sequence

Waipanna Coal Sequence

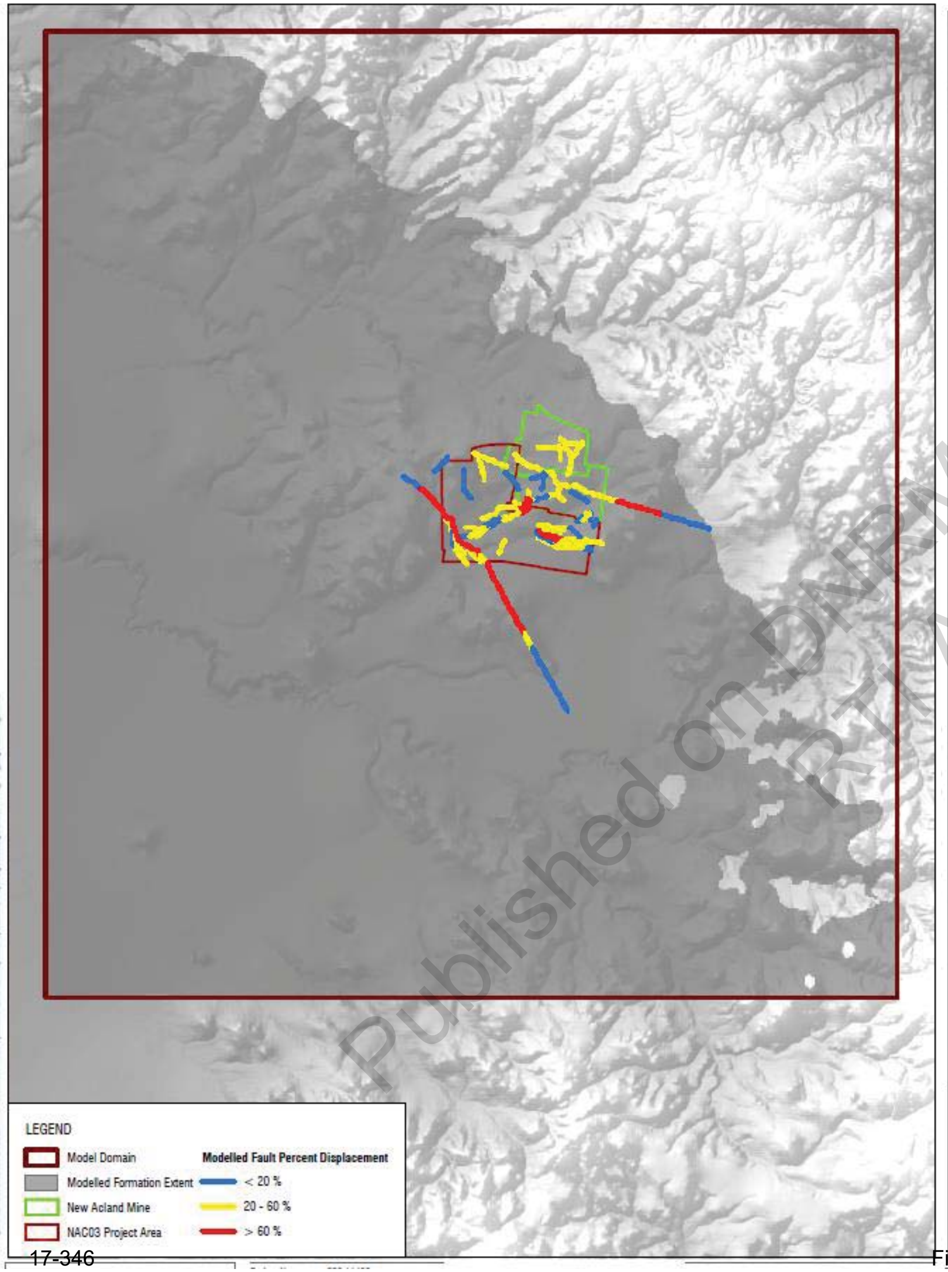


Acland Coal Sequence

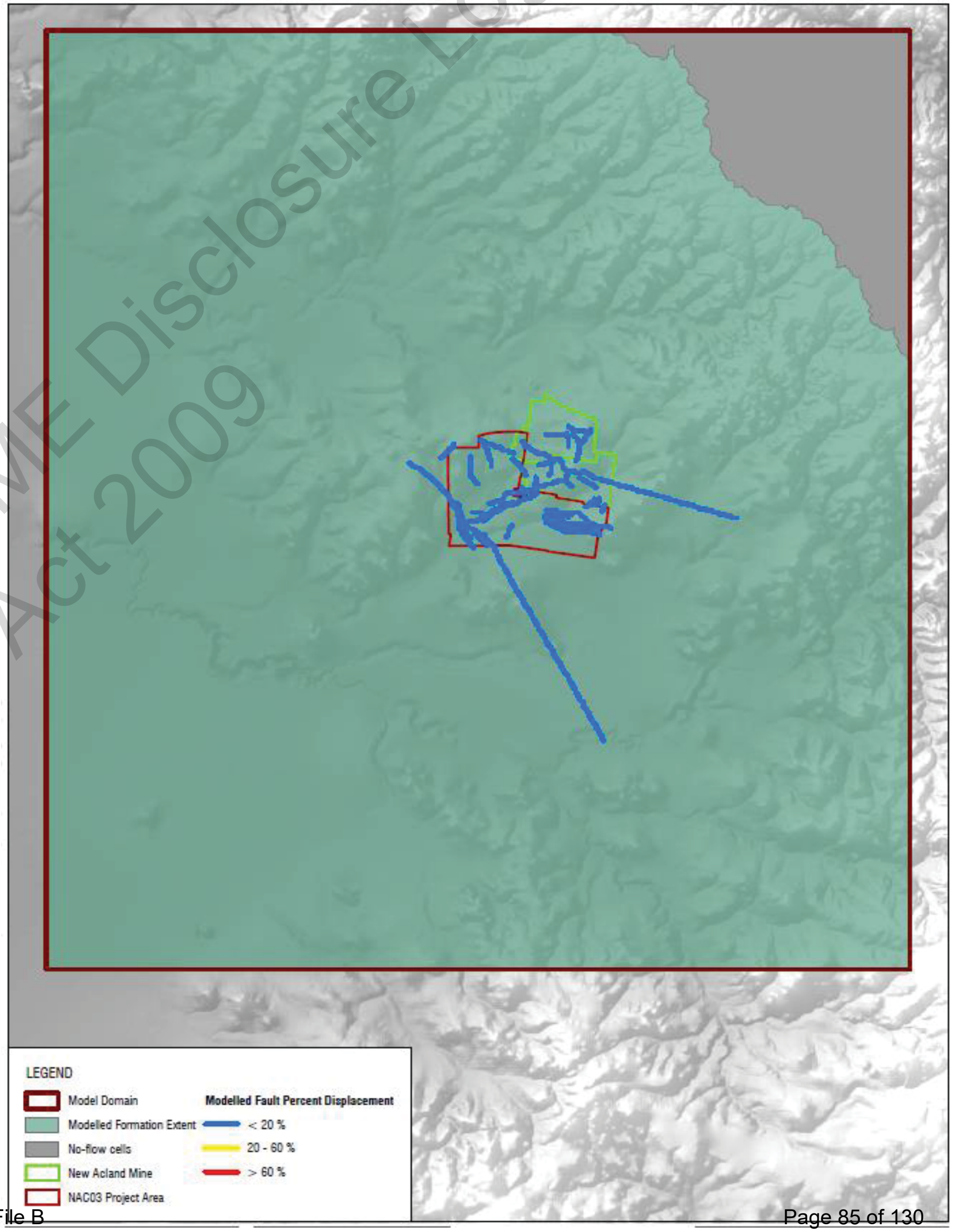


Horizontal Flow Barriers cont.

Balgowan Coal Sequence



Marburg Sandstone

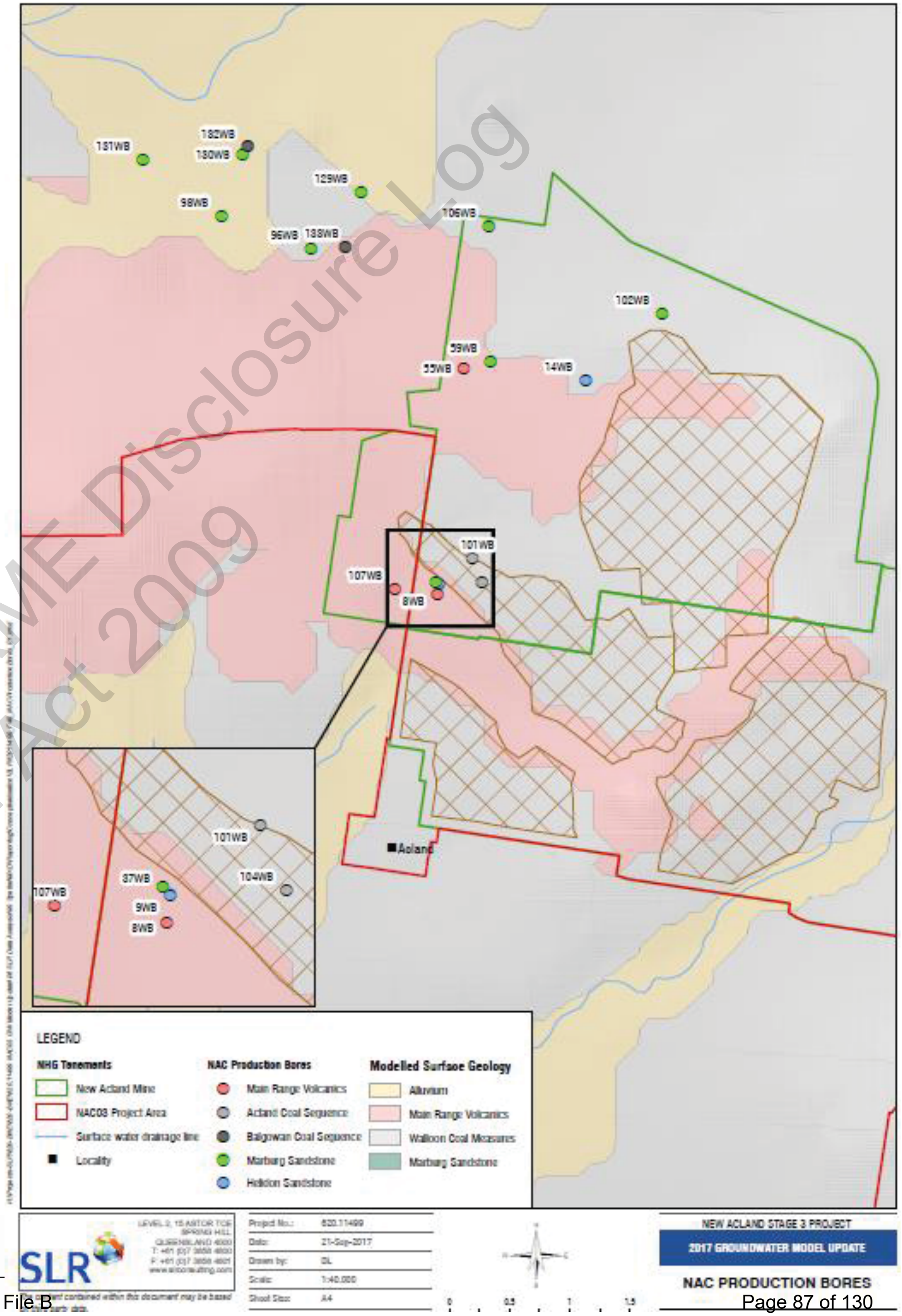


Land Court Concern 5: Null Predictive Defence – inclusion of other groundwater take

- The 2017 Conceptualisation report notes that estimates of landholders groundwater use has been obtained from OGIA as used in the Surat Cumulative Management Area model
- In areas of overlap this data has been compared with that data, which has been collected by NAC in their baseline assessment reports.
- These reports identify the landholder's estimate of water use from their own bores in areas near the mine
- NAC quote metered water use in the Oakey Creek alluvium which has been provided by DNRM
- The report also identifies water use from all mine water supply bores which impact the basalt, Walloon Coal Measures, Marburg and Helidon Sandstone aquifers
- The work provides a basis for identifying historical water use to be used in the updated model

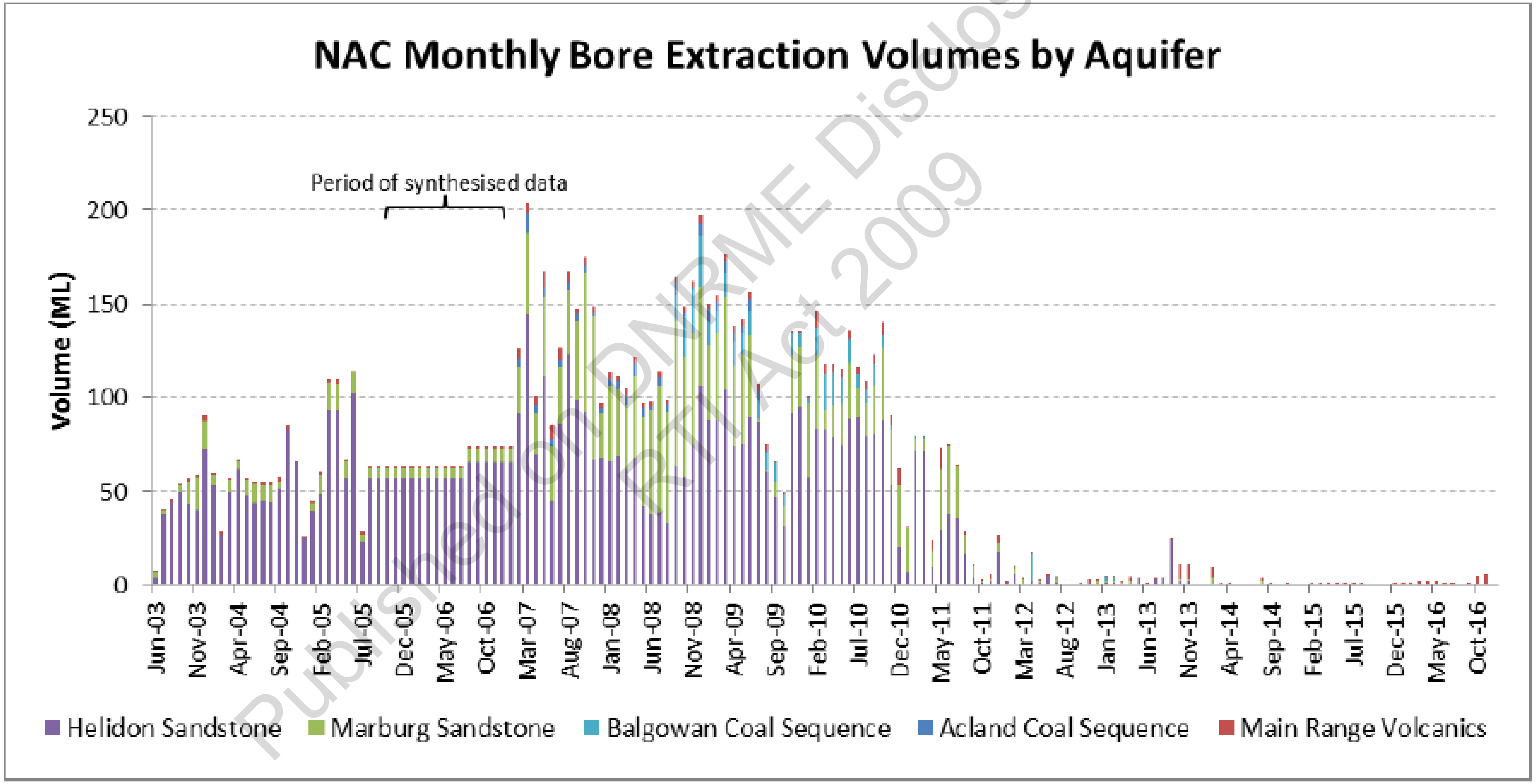
Land Court Concern 5: Null Predictive Defence – inclusion of other groundwater take

Mine water supply bores metered



Land Court Concern 5: Null Predictive Defence – inclusion of other groundwater take

Mine water supply bores metered use (most)



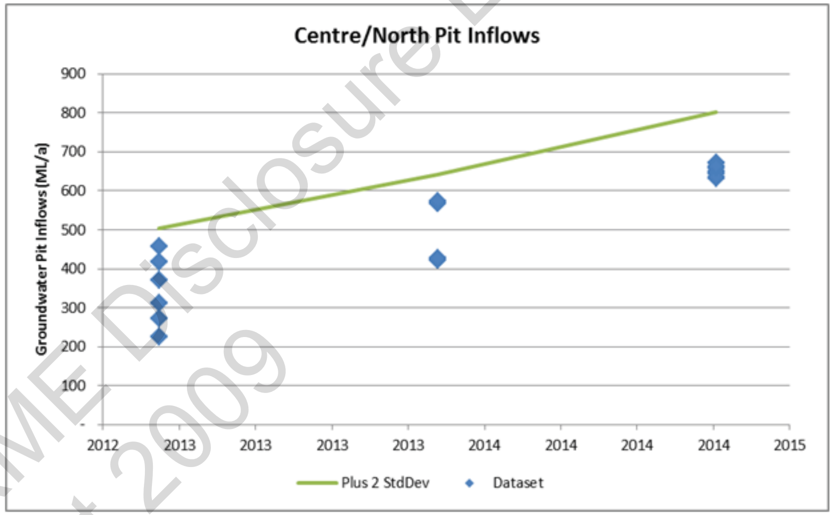
Land Court Concern 6: Calibration targets

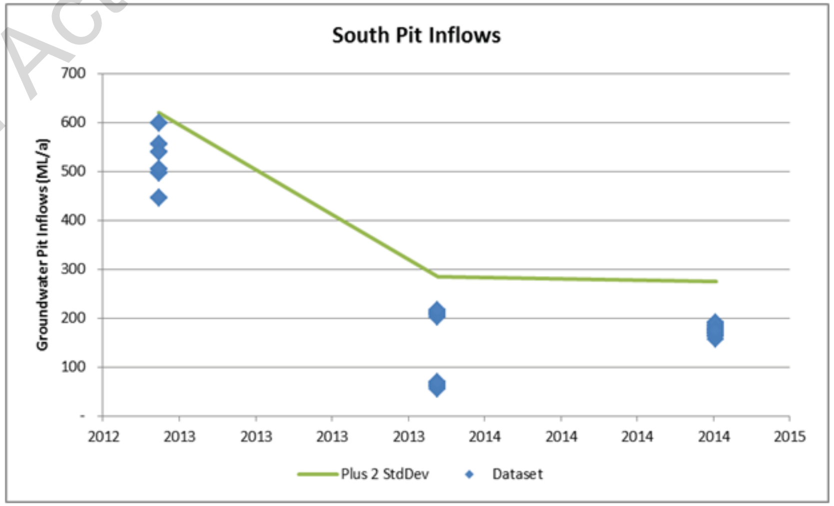
Calibration now incorporates a number of additional criteria

- Water level elevations in various bores in various geologic units both pre and post 2001
- The bores used are 'weighted' based on their construction and how likely they are to be representative of their geologic unit.
- Drawdowns in selected bores – generally closer to the mine
- The use of pit inflows but only as a cap as it was anticipated that pit inflows may be over estimated
- Oakey Creek baseflow criteria

Estimated Pit GW In-flows – New Acland Mine

- Historic mine pit inflows have been estimated by NAC using a Water Balance model for the New Acland site
- The Water Balance model incorporates in-pit pumping records as well as other relevant water fluxes
- Estimates range from 350 to 1,100 ML/a total groundwater contribution for the period 2013-2015
- Was generally considered that there may be some double accounting here as water that is used for dust suppression makes its way back into the mine. Therefore a potential overestimate





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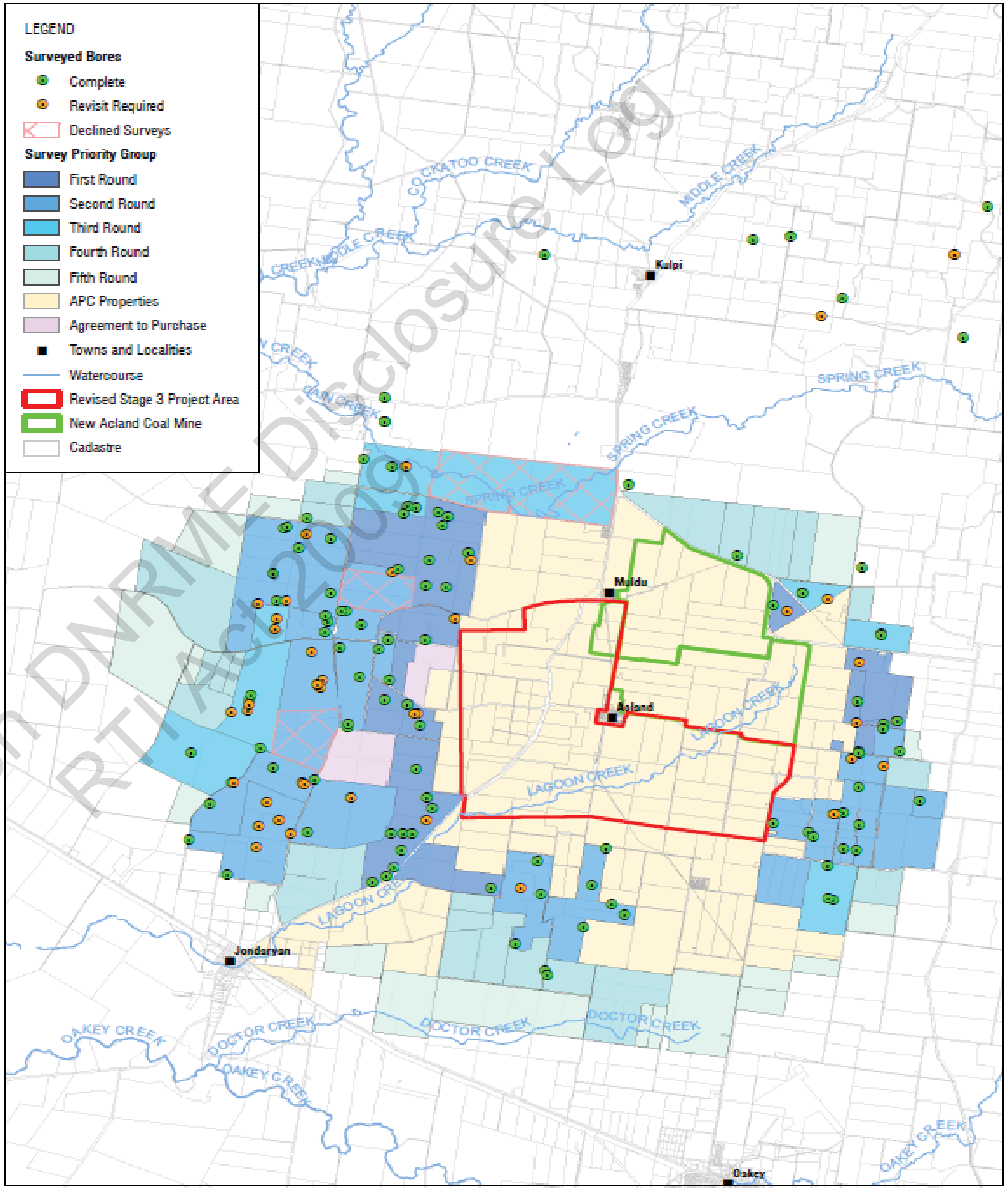
Land Court Concern 7: ‘Make Good’

- The Land Court decision appeared to disregard the assessment and review conditions imposed by the Office of Coordinator General (OCG) and the requirements under Chapter 3 to be implemented through the Associated Water Licence (AWL) process
- The groundwater monitoring program for water levels around the mine is critical to the development and ongoing review of the model and implementation of ‘Make Good’
- The OCG condition 12 requires 3 yearly reviews of the model or at other intervals if the observed groundwater levels are not consistent with those predicted by the latest version of the model
- The IESC noted in their January 2017 advice the importance of ongoing monitoring in reviewing and updating of the groundwater model

Land Court Concern 7: 'Make Good'

- An important component of 'Make Good' is the Baseline Assessment Program (BAP)
- The BAP provides a reference point to determine 'impact'.
- NAC have conducted 36 BAP's totalling 147 bores

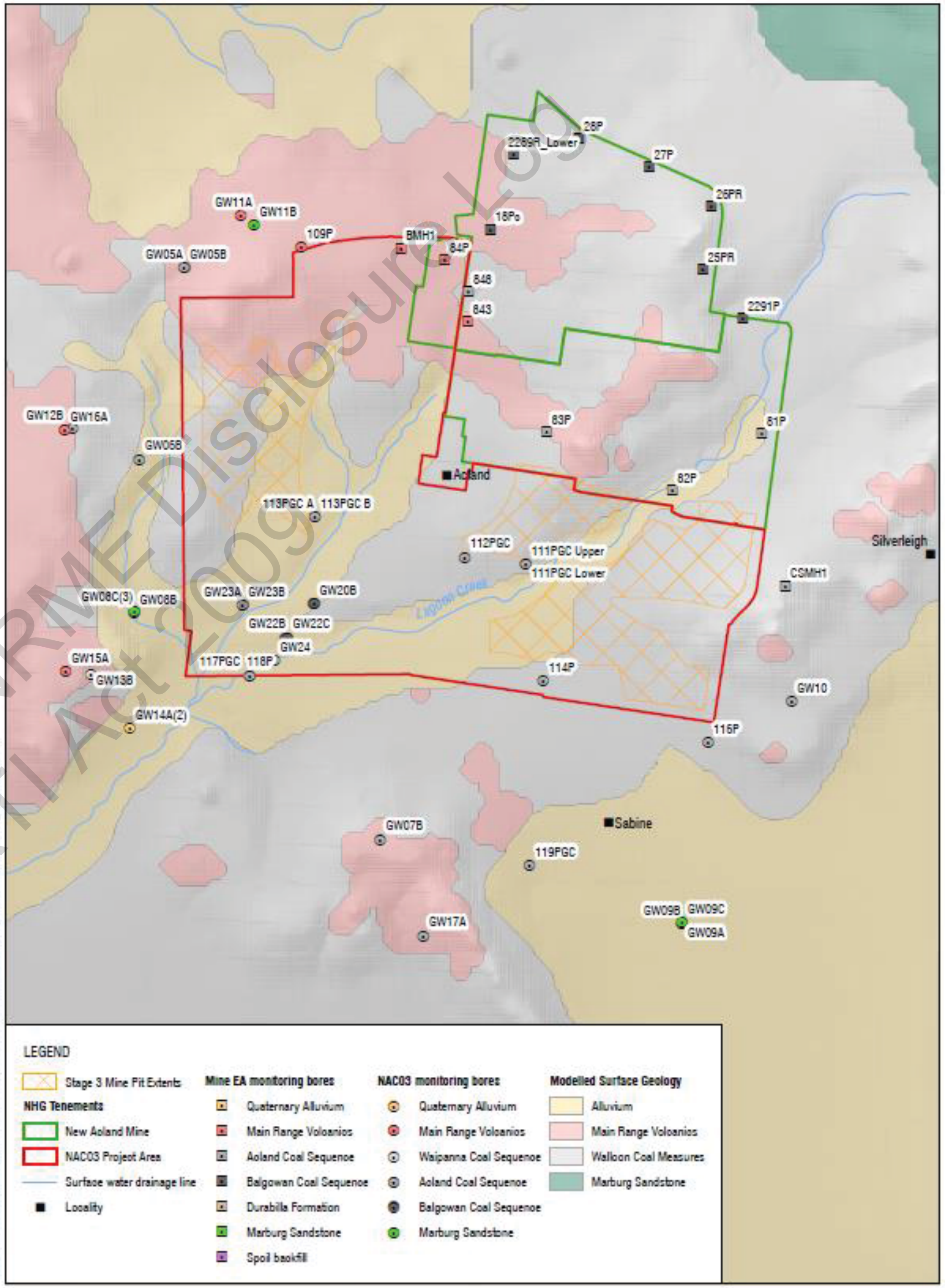


NAC Proposed ongoing monitoring network

27 Acland Sequence
9 Basalt
9 Balgowan Sequence
3 Marburg
2 Waipanna
2 alluvium

Marburg Sandstone
bores are few

Data from more NAC bores than this were used in the model develpment



2017 Model

Model setup
and additional discussion

2017 Groundwater Model Structure

3. Model Setup

- 2017 model built as new
- Significant areas where the model differs from the 2014 model. This includes;
  - modification of the mine plans
  - 3rd party extraction – landholders
  - more layers within the WCM – 2 layers to 9
  - updated fault locations and parameterisation
  - updated basalt mapping
  - modified calibration targets and weightings
  - updated likely parameter ranges
  - historical underground workings included

2017 Groundwater Model Structure

3.2 Model Complexity

- classified as a Class 2 model
- would be a Class 3 model except for;
  - Reliability of extraction data used (landholder data estimated not metered)
  - Stresses more than 2 times greater than those in calibration (pit inflows, predicted inflows for stage 3 more than 2 times greater than calibrated inflows for stages 1 and 2)

2017 Groundwater Model Structure

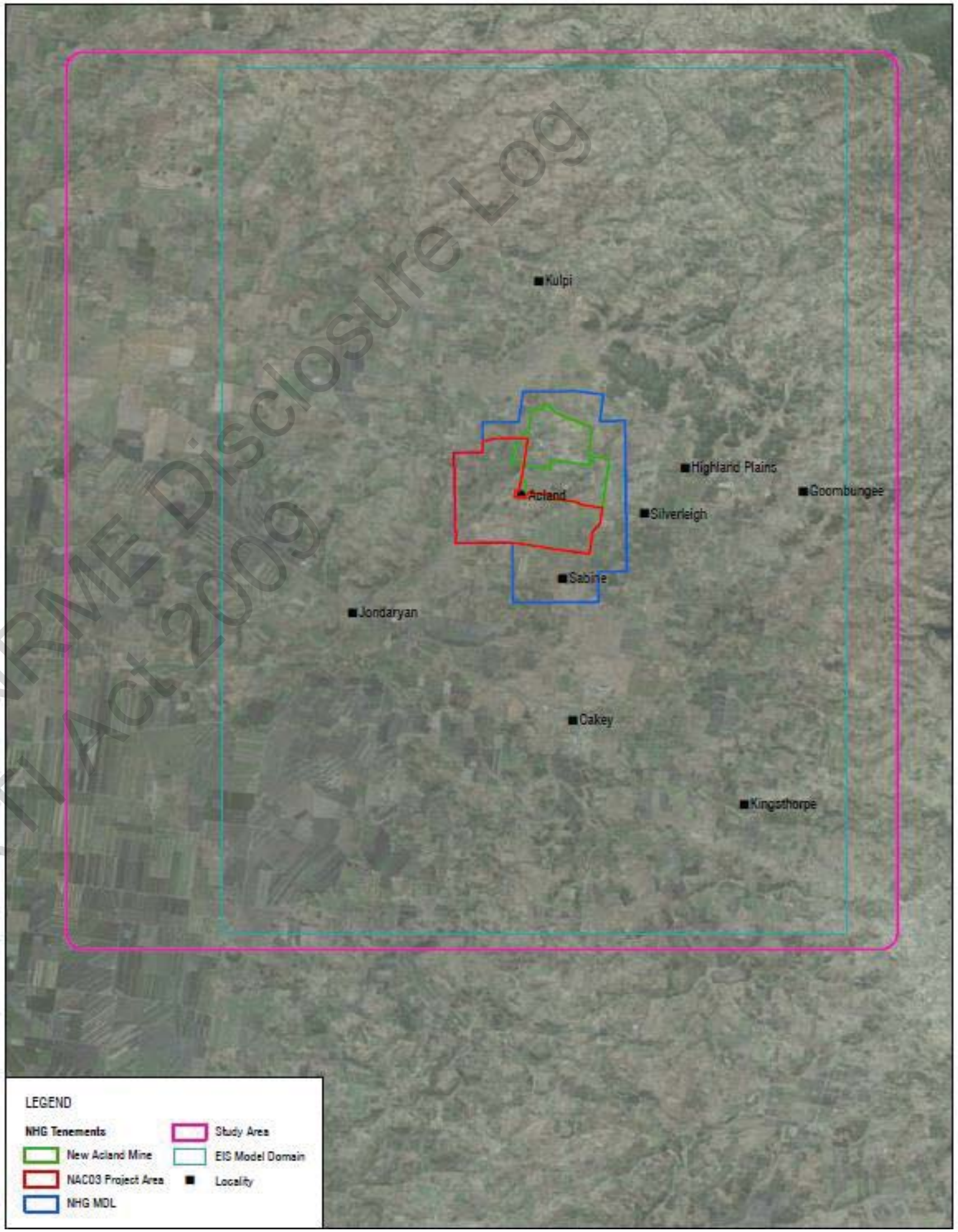
3.3 Model Exclusions

- Modelling process did not include;
  - Flood staging
  - Quantitative calibration to stream flows
  - Operational replication of historical mine workings (locations have been simulated)

2017 Groundwater Model Structure

3.4 Model Domain

- 2017 model domain extended
- Uniform grid spacing – 100m by 100m
- 2014 AEIS model 400 x 400m reducing to 200 x 200m near project
- 2017 Layers increased in WCM from 2 – 9 (as discussed)



2017 Groundwater Model Structure

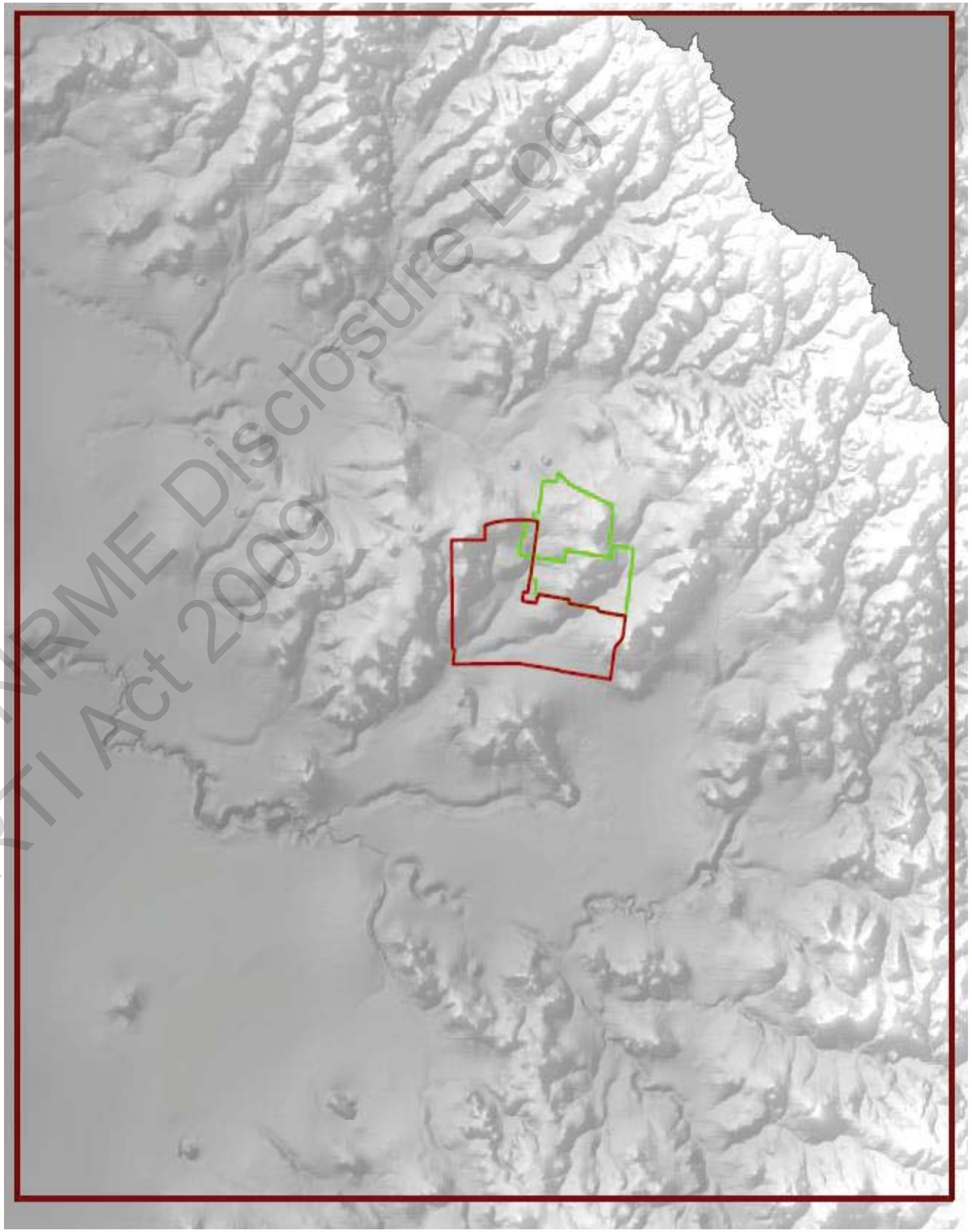
3.5 Model Boundary Conditions – inputs and outputs

- Define the groundwater flow stresses within the model
- The model requires information about groundwater head and head gradient at the boundaries
- Allows the modeller to implement boundary conditions and stresses such as :
  - Rainfall recharge
  - Interaction with surfacewater
  - Evapotranspiration fluxes
- Boundary conditions are discussed in the next slides

2017 Groundwater Model Structure

3.5.1 Inactive Areas

- Inactive areas used across all layers
- Spatially variable, depending on
  - Model configuration
  - Groundwater divide
  - Geological extent
- Example of inactive cells for the groundwater divide (NE corner)



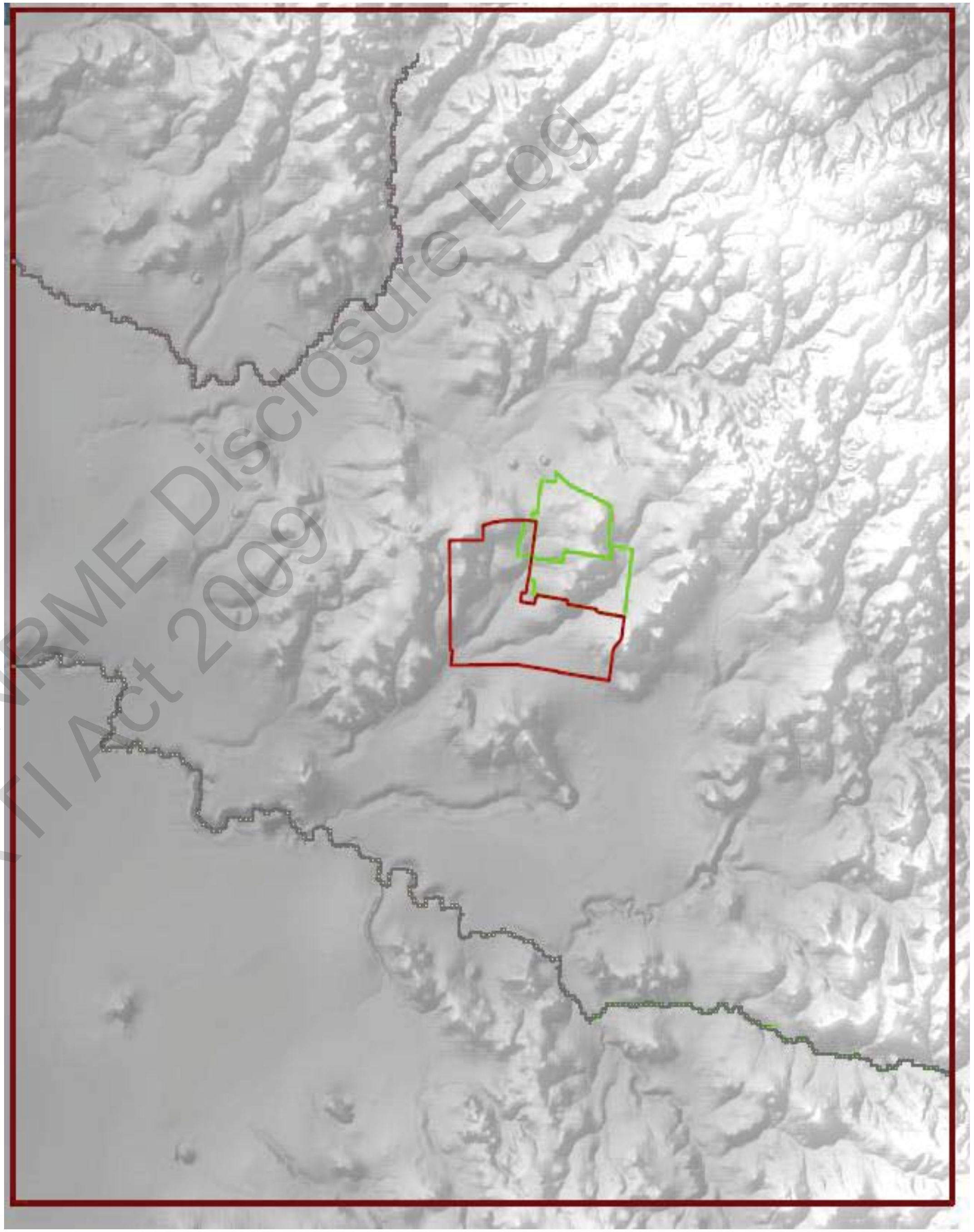
3.5.2 General Head Boundaries

- GHB's assigned to active cells where the aquifer boundary is known to extend beyond the model boundary
- Head values assigned based on pre 1990 potentiometric surface maps
- Where insufficient data was available to contour water levels to the model boundary, suitable post 1990 head values were used
- Conductance values were allowed to vary per aquifer (based on median hydraulic conductivity of unit, unit thickness at each cell and cell width of 100m)

2017 Groundwater Model Structure

3.5.3 Watercourses

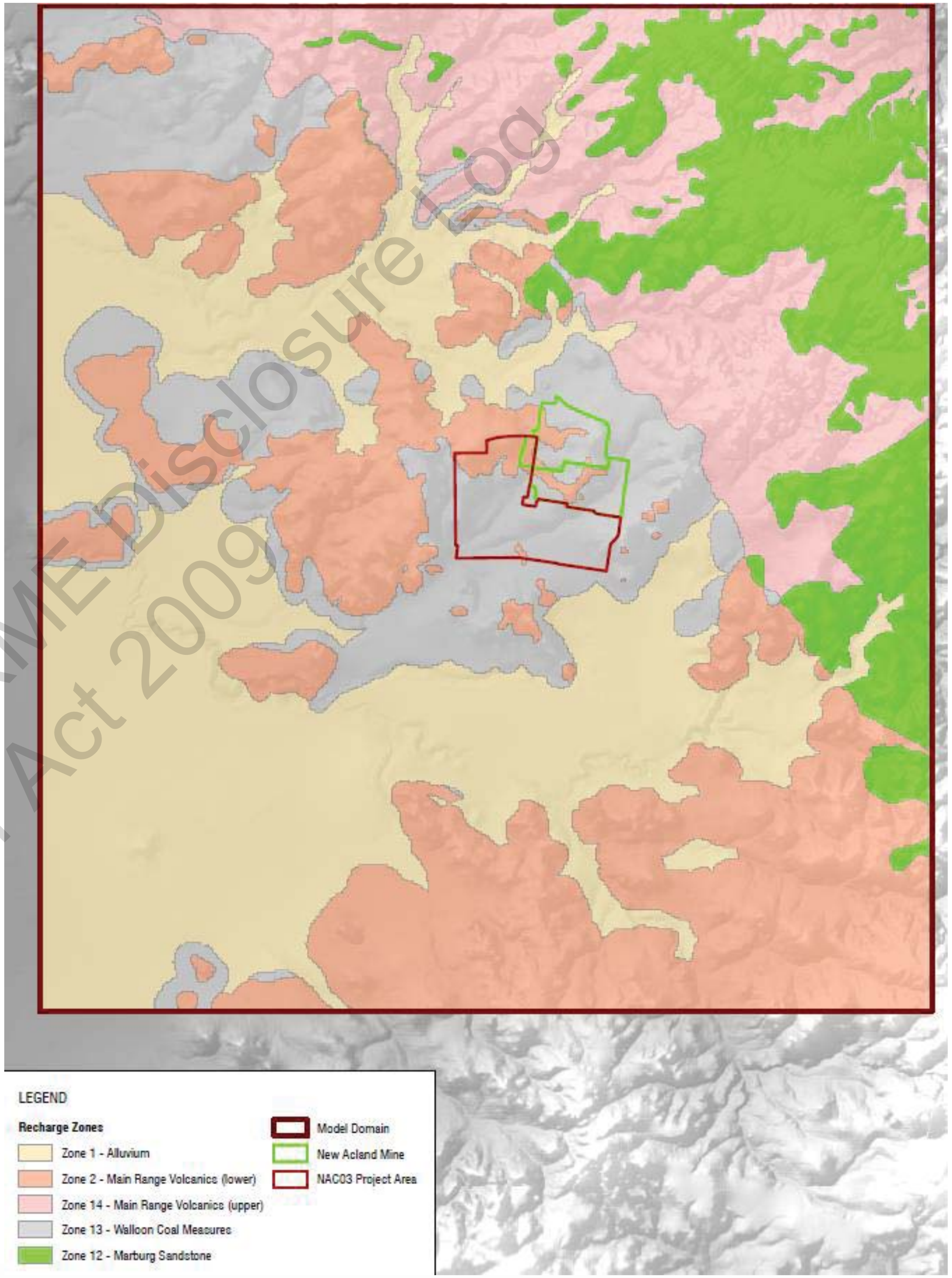
- River cells applied along watercourses where it is assessed recharge occurs greater than 50% of the time
- Watercourses are:
  - Myall Ck - north
  - Westbrook Ck - southeast
  - Oakey Ck - south
- Gowrie/Westbrook Ck have recharge occurring all the time due to Toowoomba wastewater discharge



2017 Groundwater Model Structure

3.5.4 Recharge

- Recharge zones created for each geological outcrop (note that all coal sequences and WCM interburden combined into one zone)
- Recharge is allowed to vary with rainfall (multipliers applied based on annual rainfall)
- Main range volcanics split into 2 zones to allow for higher rainfall to the east)
- Note map is still wrong, green is upper basalts



2017 Groundwater Model Structure

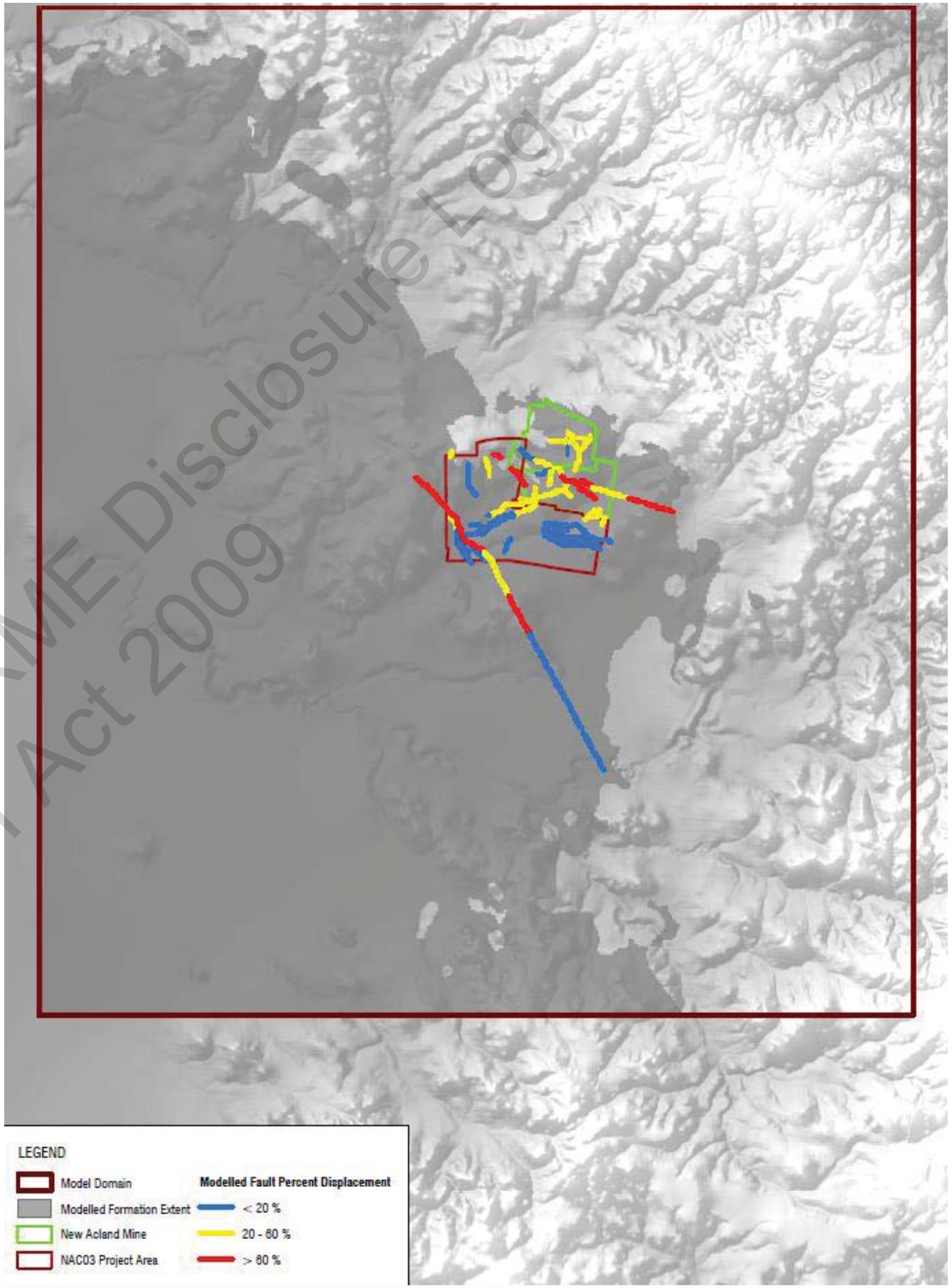
3.5.5 Evapotranspiration

- Expected as an active form of discharge in the area
- Based on corrected pan evaporation is 1530 mm/yr
- BOM estimate **Aerial Actual ET** between 600 - 800 mm/yr (used this as basis)
- Allowed to vary between 700 - 1100 mm/yr for undisturbed areas
- The package used requires an extinction depth. Linearly decreased from the surface to the extinction depth
- Extinction depth varies from 0.5 -3 m during calibration such that they are not unduly restrictive. Advised that calibrated depth did not exceed 2.5m.

2017 Groundwater Model Structure

3.5.6 Horizontal Flow Barriers

- Represent groundwater flow across the faults
- Conservative approach such that they are not overly restrictive
- Only used in more permeable layers
- Example - Acland Coal sequence – Appendix A-2



2017 Groundwater Model Structure

3.5.7 Wells

- Simulates extraction from the model area
- Landowner bore use based on the OGIA Surat CMA model with the following modifications:
  - Bores located within 1 km of the model boundary were left out to minimise interference with boundary conditions
  - Extractions rates were reduced based on NAC's assessment. To be discussed in more detail further
- Mine water supply water use as per metered records, some estimates in middle years.
- Oakey Creek alluvium bore use as per metered data supplied by DNRM
- Model can adjust the pumping rate if the water level under pumping goes below the bottom of the layer

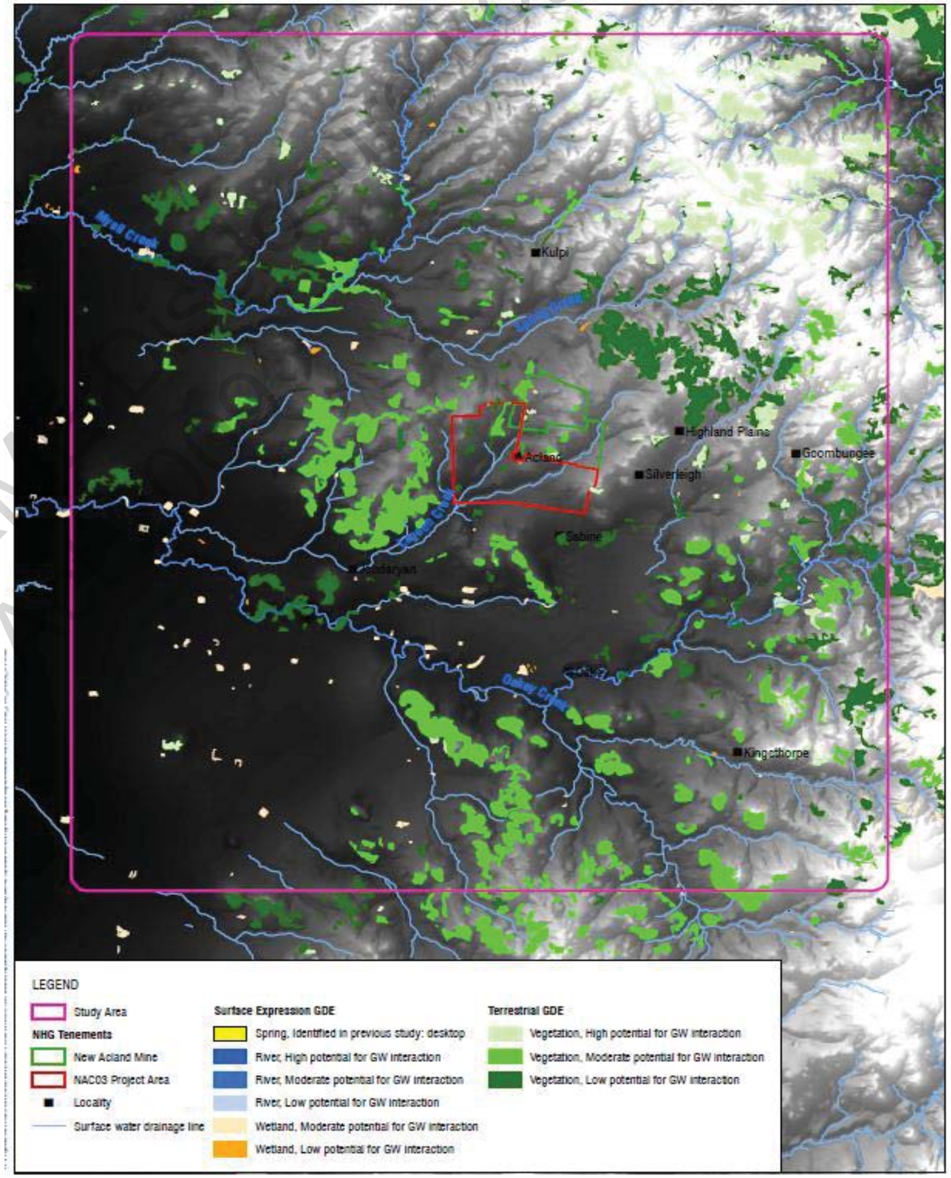
2017 Groundwater Model Structure

3.6 Model Simulation Design

- The objective of the model is to assess NAC's Stage 3 impact
- The specific outputs required from the model are:
  - Estimate mine inflows/volumes
  - Regional changes to groundwater levels during mining and post mining

Environmental - Groundwater Use

- GDE Atlas shows areas of mapped terrestrial vegetation with low to moderate likelihood of reliance on the subsurface expression of groundwater, located mainly on elevated topographic areas
- Previous NHG ecological studies prepared for the IESC have proven these to be stands of remnant vegetation of species types not likely to be reliant on groundwater
- GDEs are not considered a likely receptor of groundwater in the Study Area



Department of Natural Resources and Mines

Parameters

- Horizontal hydraulic conductivity – Kh
- Vertical hydraulic conductivity – Kv
- Specific storage Ss (confined aquifer)
- Specific Yield Sy (unconfined aquifer)
- Recharge mm/yr
- Evapotranspiration mm/yr

Parameter Ranges - Conceptualisation

Table 28 Hydraulic Parameter Summary

Unit	T (m^2/d)		Kh (m/d)		Kv (m/d)		Ss (/m)		Sy		S	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Alluvium	2	3000	0.003	88	0.19	7.5	1×10^{-4}	4×10^{-4}	6	11	3.5×10^{-4}	0.012
Main Range Volcanics	0.015	252	3.4×10^{-3}	57.4	6.2×10^{-5}	0.078	1×10^{-4}	1×10^{-4}	0.1	5	2×10^{-3}	2×10^{-3}
Walloon Coal Measures (bulk/undifferentiated)	-	-	6.6×10^{-6}	1.5	6.6×10^{-9}	0.1	1×10^{-4}	1×10^{-4}	0.5	0.5	-	-
Walloon Coal Measures (coal seams)	-	-	5.7×10^{-4}	0.9	-	-	1×10^{-7}	3.4×10^{-5}	5×10^{-3}	5×10^{-3}	-	-
Walloon Coal Measures (Waipanna Coal Sequence)	-	-	0.49	0.54	-	-	-	-	-	-	-	-
Walloon Coal Measures (Acland Coal Sequence)	6.5	69.7	4.2×10^{-3}	24.1	-	-	-	-	-	-	4.2×10^{-5}	6.6×10^{-3}
Walloon Coal Measures (Balgowan Coal Sequence)	-	-	0.04	2.5	-	-	-	-	-	-	-	-
Walloon Coal Measures (interburden)	0.4	1.8	6.5×10^{-5}	0.7	3.8×10^{-9}	2.2×10^{-4}	5×10^{-5}	5×10^{-5}	5×10^{-3}	5×10^{-3}	-	-
Durabilla Formation	-	-	3.8×10^{-6}	7.1	1×10^{-8}	0.26	-	-	-	-	-	-
Marburg Sandstone (Project Area & Surrounds)	2.7	83.4	0.24	11.4	-	-	-	-	-	-	2.5×10^{-5}	1.4×10^{-3}
Marburg Sandstone (Surat CMA)	-	-	1.2×10^{-7}	0.5	1.8×10^{-7}	0.5	-	-	-	-	-	-

Parameter Ranges – model

Table 4-10 Parameter Ranges for Independently Generated Parameter Values

Parameter	Code	Zone	Layer	Mean	Mean (log(x))	Standard Deviation (log(x))	Minimum	Maximum	Constraints
Horizontal Conductivity (m/d)	K_x	1	Alluvium	1.0E+01	1.0	0.5	3.00E-03	88	
Horizontal Conductivity (m/d)	K_x	2	Main Range Volcanics	3.2E-01	-0.5	1	3.40E-03	57	
Horizontal Conductivity (m/d)	K_x	7	Interburden	1.0E-03	-4.0	1	6.50E-05	0.7	<K_xCoal; <K_x12
Horizontal Conductivity (m/d)	K_x	12	Marburg Sandstone	1.00E+00	-3.0	0.5	1.20E-07	20	
Horizontal Conductivity (m/d)	K_x		Coal	2.1E+00	0.33	0.5		100	
Vertical Conductivity (m/d)	K_z	1	Alluvium	1.0E+00	0	0.5	0.001	7.5	
Vertical Conductivity (m/d)	K_z	2	Main Range Volcanics	1.0E-03	-3.0	1.0	6.20E-05	7.80E-02	
Vertical Conductivity (m/d)	K_z	7	Interburden	5.0E-06	-5.3	0.5	3.80E-09	2.20E-04	
Vertical Conductivity (m/d)	K_z	12	Marburg Sandstone	1.0E-05	-5.0	0.74	1.80E-07	0.5	>K_z7
Vertical Conductivity (m/d)	K_z		Coal	1.0E-01	-1.00	0.5			<K_xCoal
Specific Yield	S_y	1	Alluvium	0.06	-1.22	0.5	0.01	0.11	
Specific Yield	S_y	2	Main Range Volcanics	0.03	-1.59	0.5	0.001	0.05	
Specific Yield	S_y	7	Interburden	0.01	-2.30	0.5	0.0001	0.01	<S_yCoal
Specific Yield	S_y		Coal	0.01	-2.26	0.5	0.001	0.01	<S_y1
Recharge (rate)	R	1	Alluvium	1.0E-05	-5.0	0.2	3.16E-06	3.98E-05	
Recharge (rate)	R	2	Main Range Volcanics	2.0E-05	-4.7	0.5	3.98E-06	2.51E-04	
Recharge (rate)	R	13	Regolith	3.2E-06	-5.5	0.4	6.31E-07	3.98E-05	<R1
Recharge (rate)	R	12	Marburg Sandstone	1.6E-05	-4.8	0.4	7.94E-06	7.94E-05	
Evapotranspiration Rate (mm/yr)	ET	1	Model Domain	900			700	1,100	
Evapotranspiration Depth (m)	ED	1	Model Domain	1.75			0.5	3.0	
Specific Storage	S	1		1.0E-6	-3.5	0.25	1.0E-04	1.0E-03	
Specific Storage	S	2		1.0E-6	-4.15	0.5	5.0E-06	1.0E-03	
Specific Storage	S	3,4,6,8,10	Coal Sequences	1.0E-6	-6.0	0.5	1.0E-07	1.0E-05	

Parameter Ranges – model

Table 4-10 cont.

Parameter	Code	Zone	Layer	Mean	Mean (log(x))	Standard Deviation (log(x))	Minimum	Maximum	Constraints
Specific Storage	S	5,7,9,11	Interburden	1.0E-6	-6.0	0.5	1.0E-07	1.0E-05	
Specific Storage	S	12	Marburg Sandstone	1.0E-5	-5	0.5	1.0E-06	1.0E-04	
HFB Conductivity (%Displacement)	HFB	1	Waipanna Coal Sequence	15%			10%	20%	
HFB Conductivity (%Displacement)	HFB	2	Waipanna Coal Sequence	40%			20%	60%	
HFB Conductivity (%Displacement)	HFB	3	Waipanna Coal Sequence	80%			60%	100%	
HFB Conductivity (%Displacement)	HFB	4	Acland Coal Sequence	15%			10%	20%	
HFB Conductivity (%Displacement)	HFB	5	Acland Coal Sequence	40%			20%	60%	
HFB Conductivity (%Displacement)	HFB	6	Acland Coal Sequence	80%			60%	100%	
HFB Conductivity (%Displacement)	HFB	7	Balgowan Coal Sequence	15%			10%	20%	
HFB Conductivity (%Displacement)	HFB	8	Balgowan Coal Sequence	40%			20%	60%	
HFB Conductivity (%Displacement)	HFB	9	Balgowan Coal Sequence	80%			60%	100%	
HFB Conductivity (%Displacement)	HFB	10	Marburg Sandstone	15%			10%	20%	

Stochastic Calibration

- There are 35 independent variable parameters that relate to horizontal and vertical hydraulic conductivity , specific yield, specific storage, recharge, evapotranspiration and horizontal flow barrier conductivity.

- There are 35 variable parameters that are linked to independent parameters. Eg
  horizontal hydraulic conductivity of coal and
  horizontal hydraulic conductivity of the interburden are independent variable parameters.

  However the horizontal hydraulic conductivity of the Balgowan Sequence is dependant on these 2 independent parameters and the established percentage of coal and interburden in the sequence.

- (Kxcoal*%Coal)+(Kx7*(1-%Coal))

- Groups of parameters (one value for each parameter) are randomly (monte carlo simulation program) selected that are within the minimum and maximum requirements identified. Each group is called a realisation. Over 380 realisations are developed.

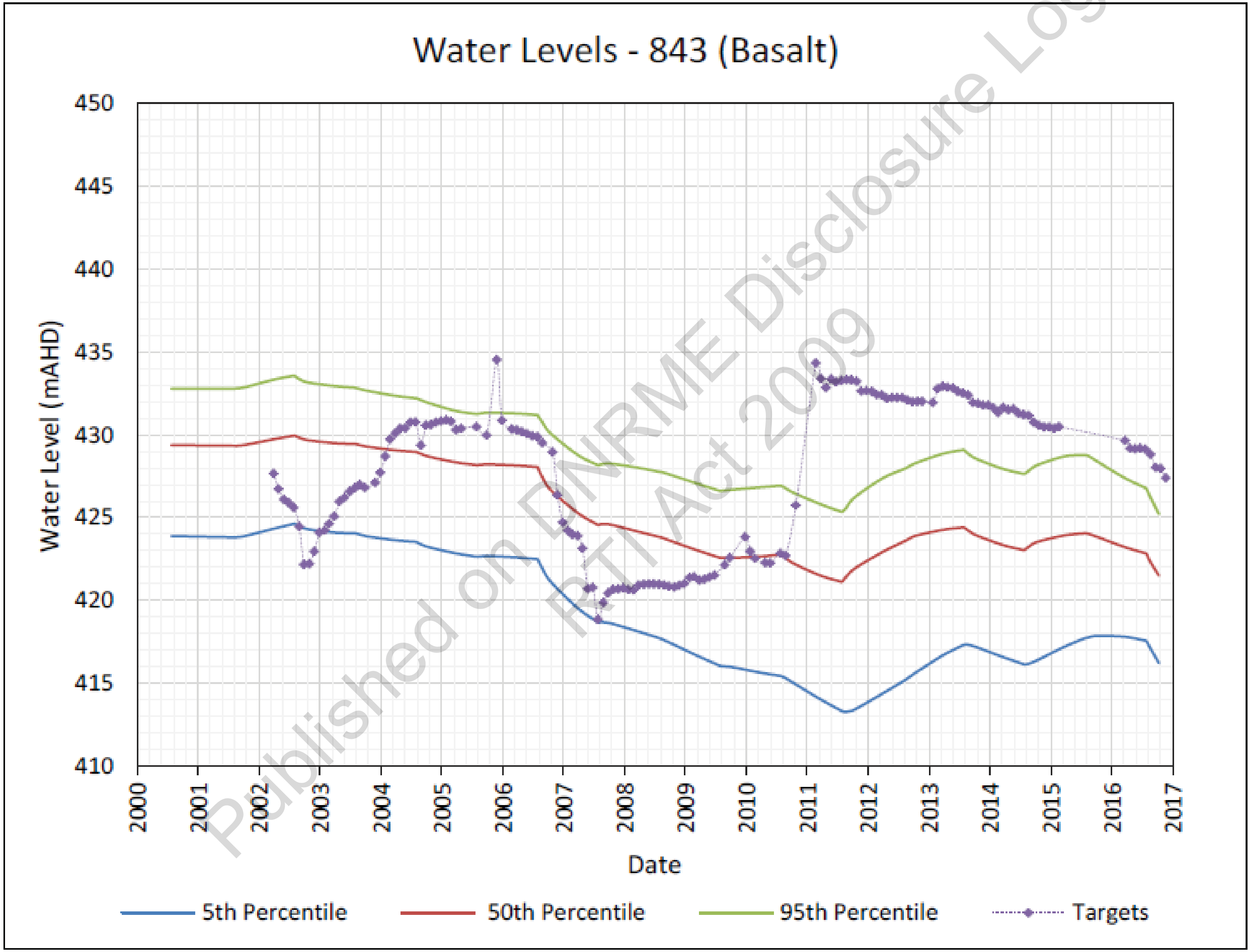
Stochastic Calibration cont.

- The model is run from 1900 to 2001 and 2001 to 2017. One group of parameters (realisation) at a time is used in the model to predict groundwater levels, drawdown, pit inflows, baseflow in Oakey Creek etc (all the target calibration criteria).
- Each target calibration criteria has a requirement eg predicted water level in certain bores must be within 2 metres of actual water level and so on.
- Where the realisation cannot meet the target calibration criteria the realisation is rejected. Through such a process 54 realisations meet all assessment or target criteria.
- These 54 realisations are then used to run the model to provide 54 independent predictions of impacts from 2017 onwards of the stage 3 activities.

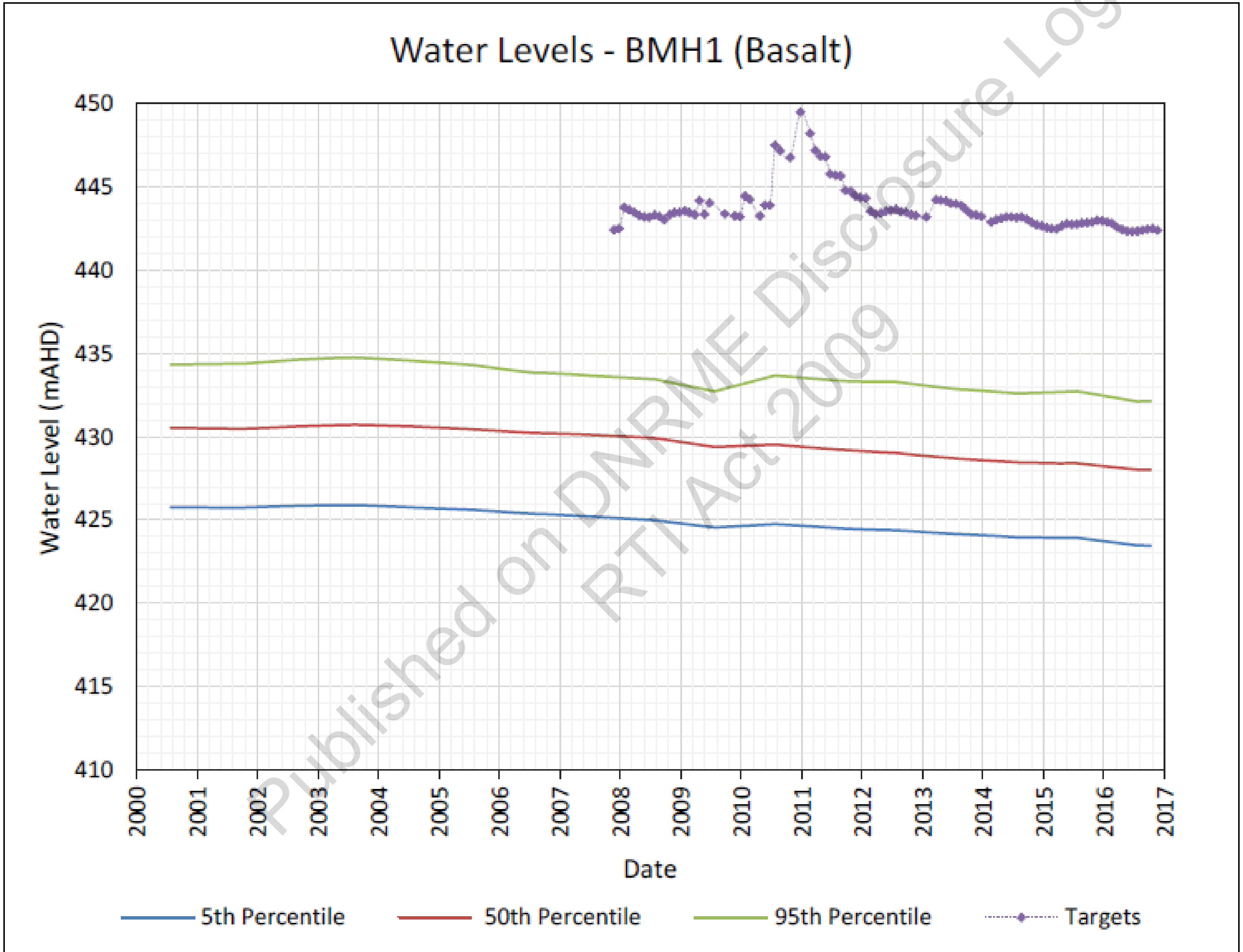
Calibrations Steady State and Transient

- A steady state model is run initially. Steady state assumes a state of equilibrium with inputs equalling outputs. Average recharge and use conditions are assumed.
- In the steady state calibration the pre 1990 water levels are used as calibration targets and heads in various layers throughout the model are predicted.
- These predicted heads from the steady state form a starting point for the transient calibration.
- A transient calibration occurs in time steps (stress periods) and allows for changing input and output conditions over time. Eg changing water use from one year to the next, the start of a mine, changing recharge conditions etc.
- A transient calibration has been run from 1900 to 2001 and then another from 2001 to 2017.
- Finally a predictive transient model has been run from 2017 onwards.

Calibration Hydrograph - close to mine and mine water supply bore
Moderate fit

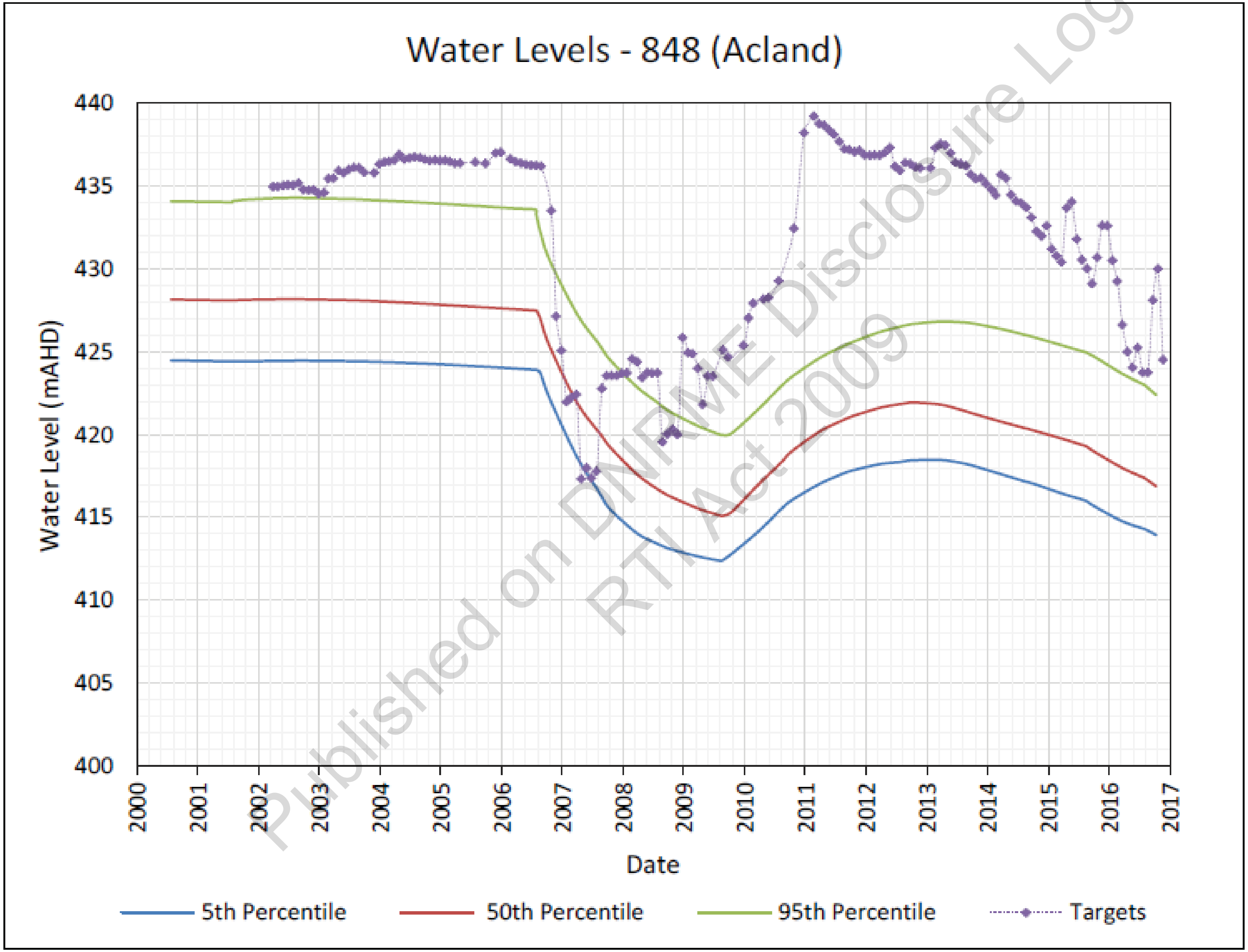


Calibration Hydrograph – west of stage 1 and 2 and north of stage 3



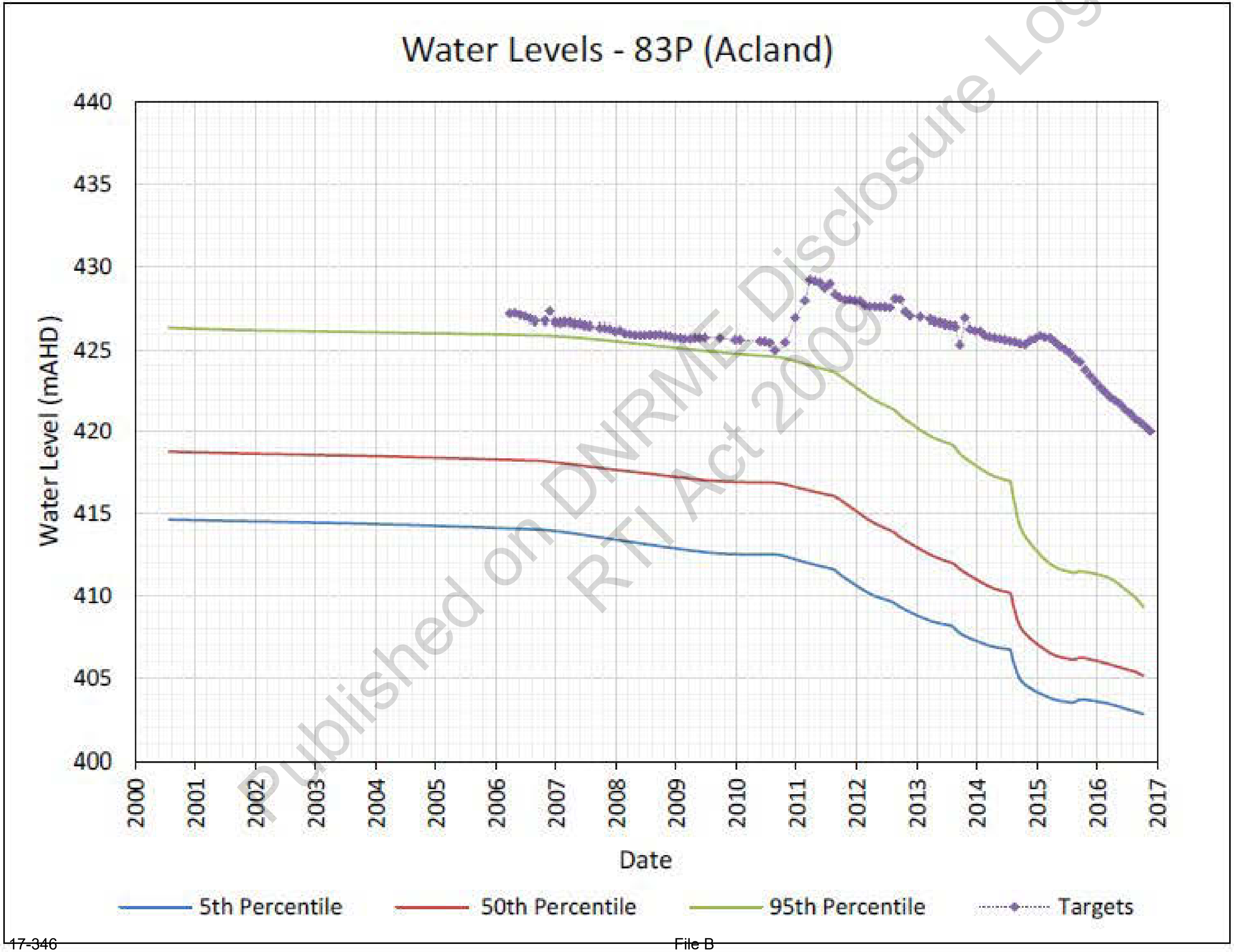
ources and Mines

Calibration Hydrograph – western edge of stage 2 and close to mine water supply bore – good fit



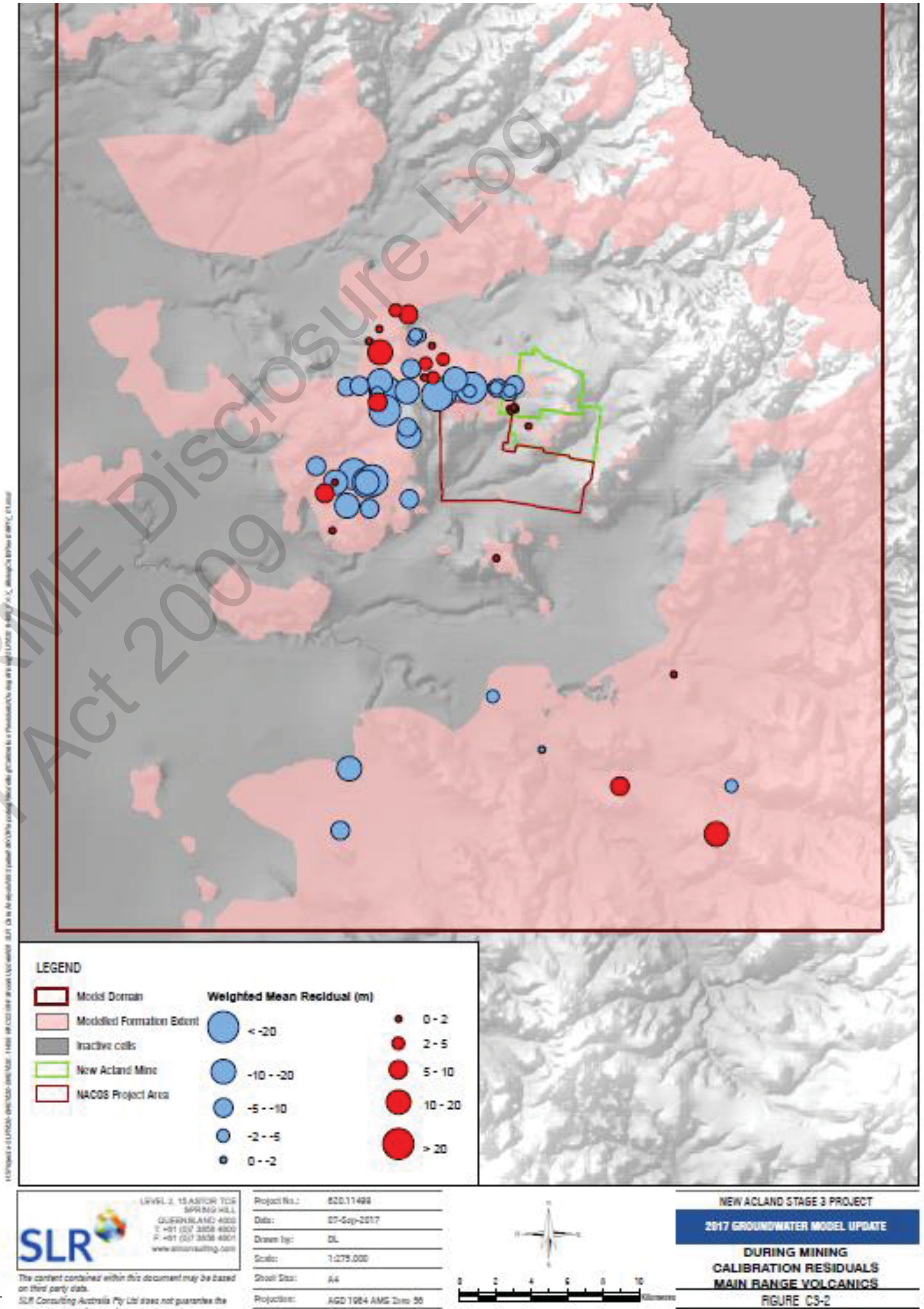
sources and Mines

Calibration Hydrograph – southern edge of stage 2 north of stage 3



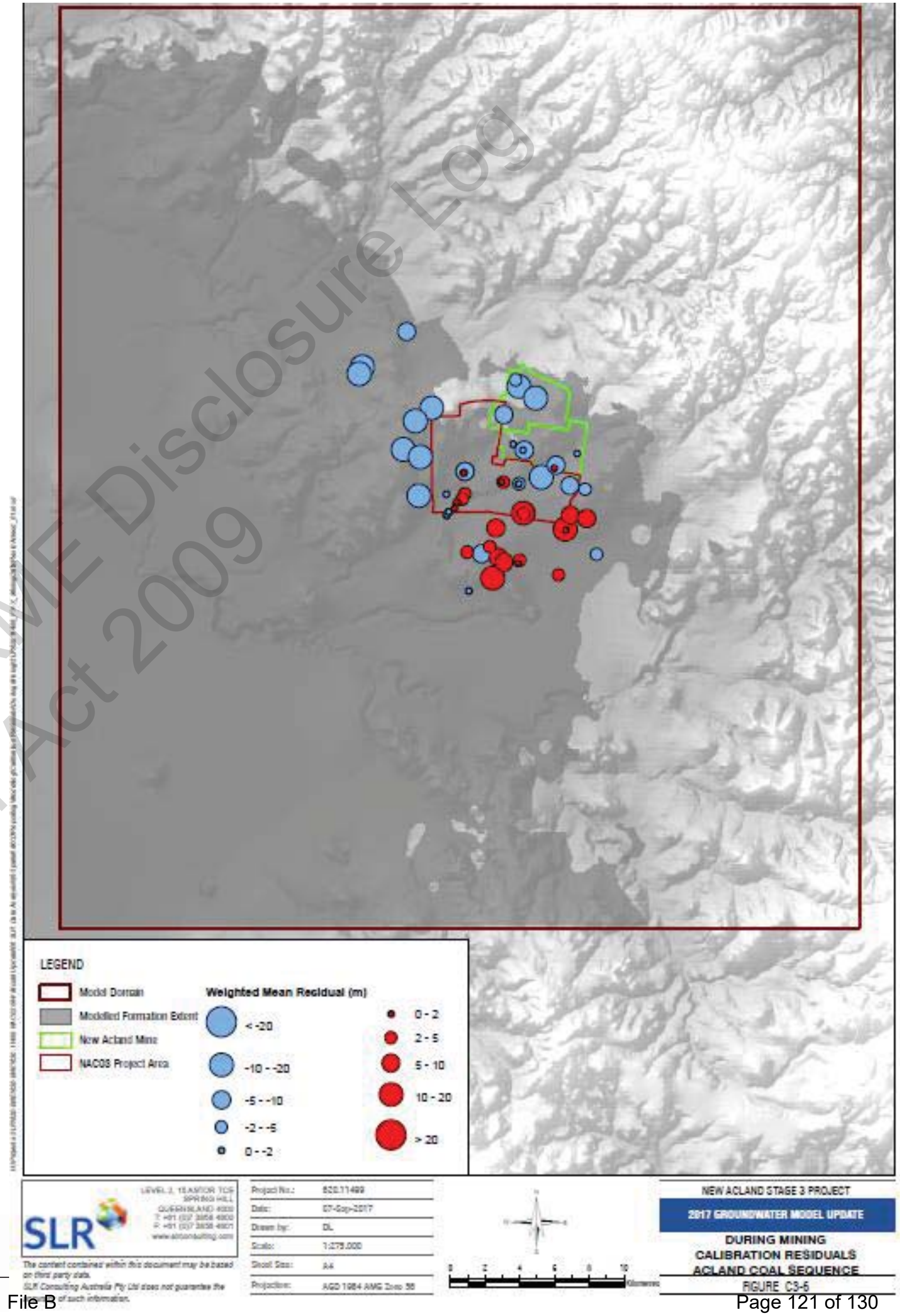
Calibration Residuals Basalt During Mining

2001-2017



Calibration Residuals Acland Sequence during mining

2001-2017



2014 model simulated the basalt layer 2 directly overlying layer 3 which included the mined Acland sequence

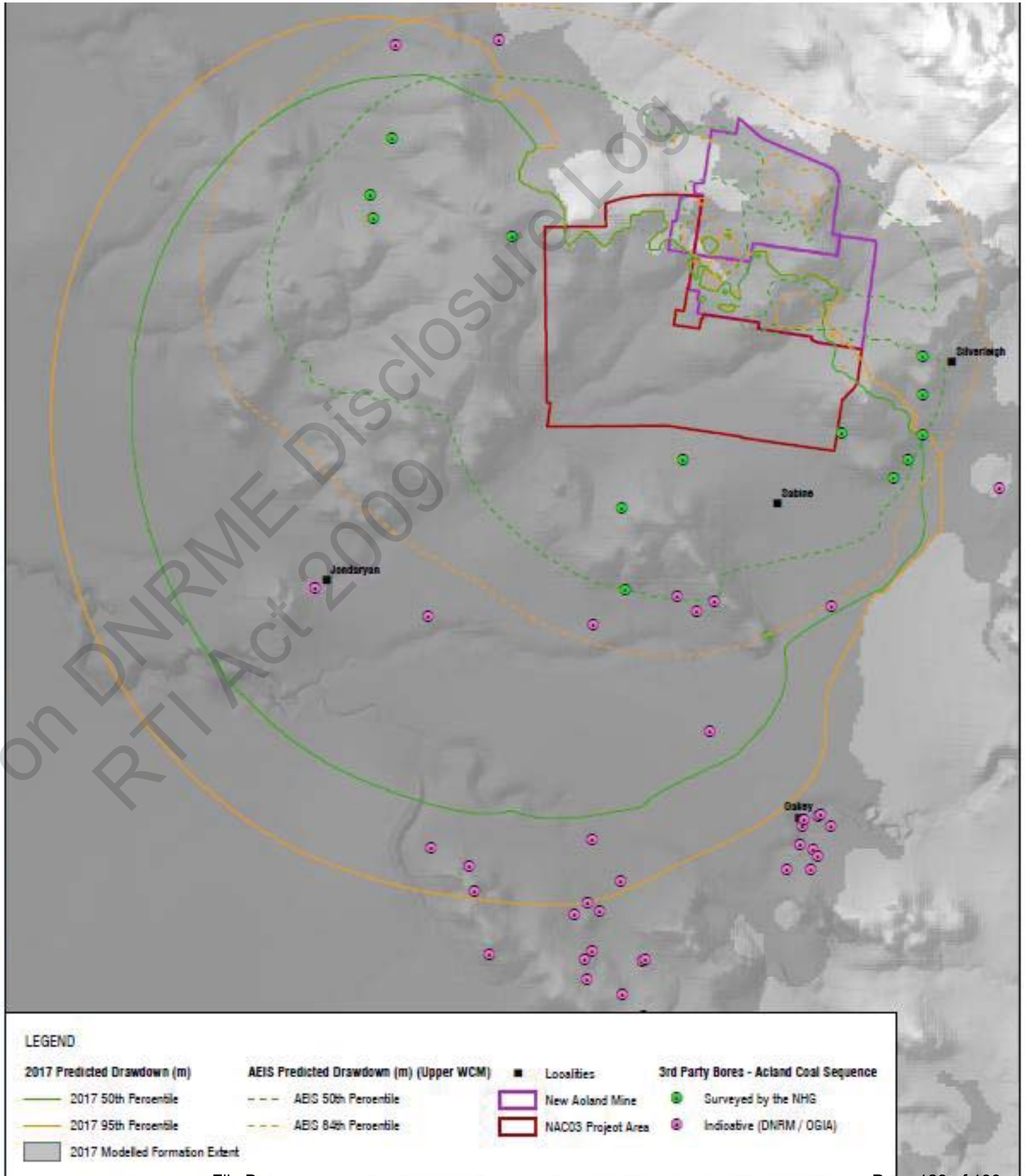
- 2017 model more accurately represents each geologic unit including the low permeability interburden layers that exist between the mined Acland sequence and the overlying basalt

- Vertical hydraulic conductivity of these interburden layers is critical and field testing data referred to by NAC has suggested a range of 2.2 x 10-4 to 3.8 x 10-9 m/day

- Different drawdown impacts are therefore predicted in various layers when comparing 2014 and 2017 outputs, including extent of propagation of these drawdowns

Comparison of Drawdowns - 2014 and 2017 model – Upper Walloon (2014) vs Acland Coal Sequence (2017) – 2m drawdown contours

- The extent of drawdown to the west is greater in 2017 model as the take of water is reasonably well confined to a thinner layer
- Additionally, the 2014 model drawdown to the south west was greatly restricted by the no flow barrier representing the MDL01 fault. In the 2017 model, the fault restricts groundwater flow, but not as much and hence drawdown propagation is greater in this direction



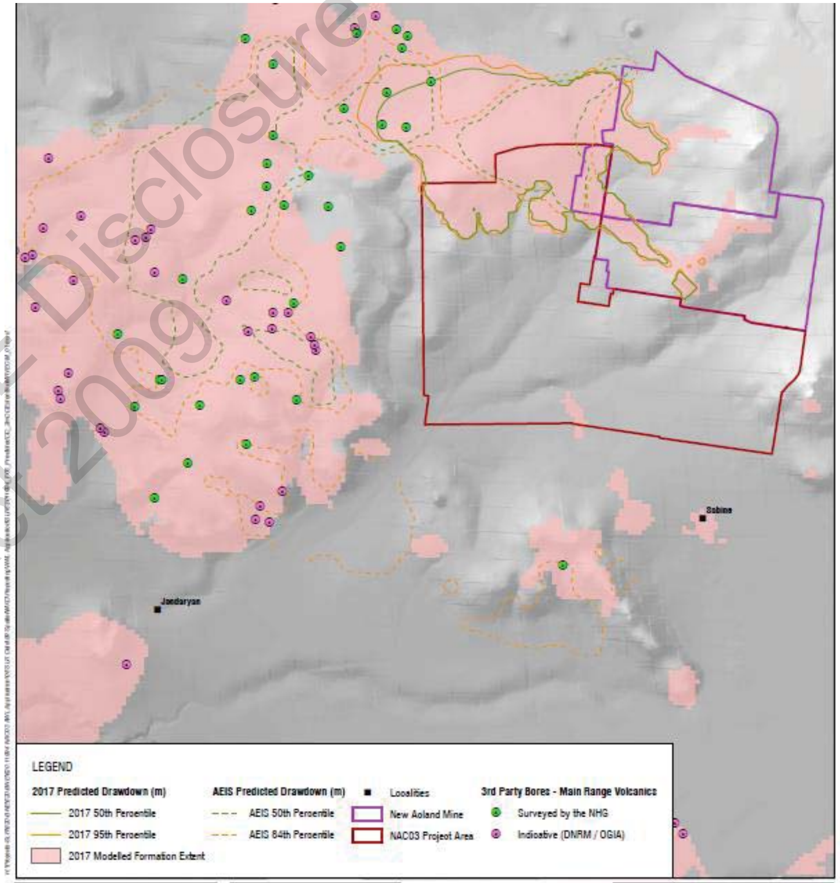
Comparison of Drawdowns between the 2014 and 2017 model – Basalt Aquifer - 2m drawdown contours

- In the 2014 model the extent of drawdown in the basalt is just inside the extent of the drawdown in the Upper Walloon Coal measures layer

- This indicates reasonably good simulated connectivity between the two layers in the 2014 model

- In the 2017 model the predicted drawdown in the basalt is restricted to those areas near the stage 3 western pit where mining will actually intercept the basalt

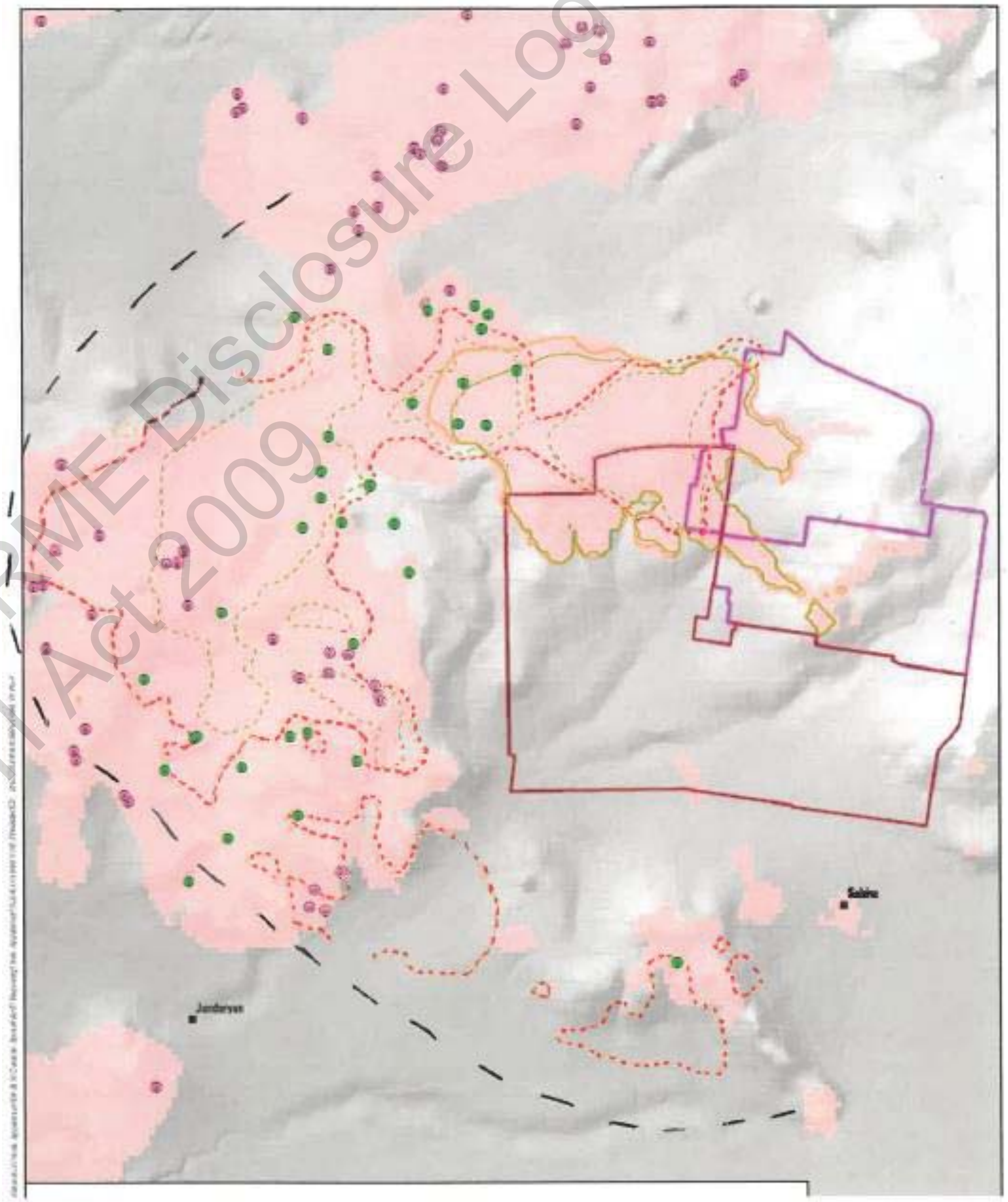
- To the west little or no propagation of drawdown vertically from dewatered Acland sequence to the basalt is simulated to occur



Comparison of Drawdowns between the 2014 and 2017 models

Black dotted line represents 84th percentile 2m drawdown extent in the Upper Walloon Coal Measures 2014 model

Red dotted line represents the 84th Percentile 2 m drawdown extent in the basalt 2014 model



Marburg Calibration issues

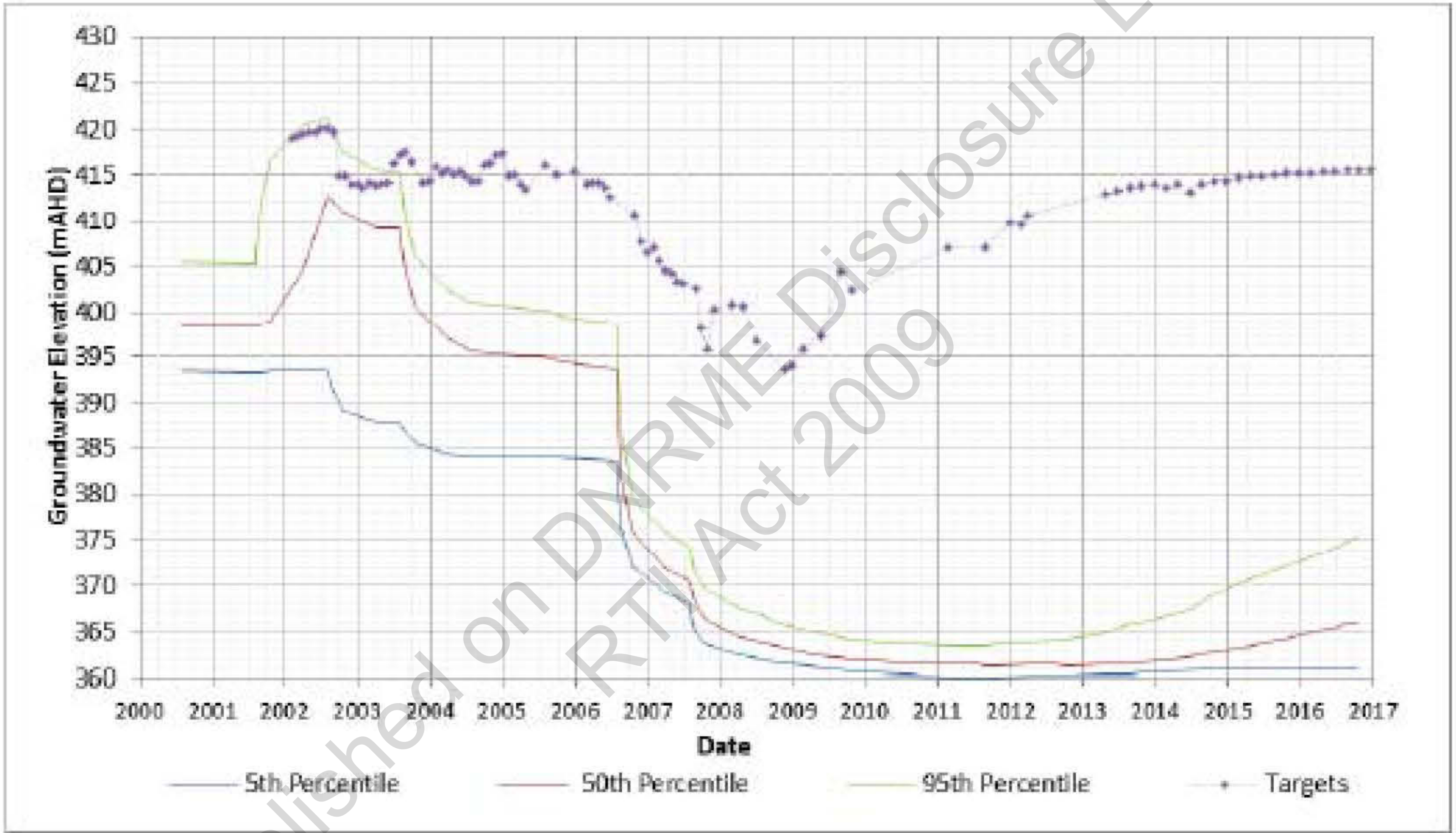


Figure 4-73 Observed and Simulated Groundwater Levels (41P)

Marburg Calibration issues

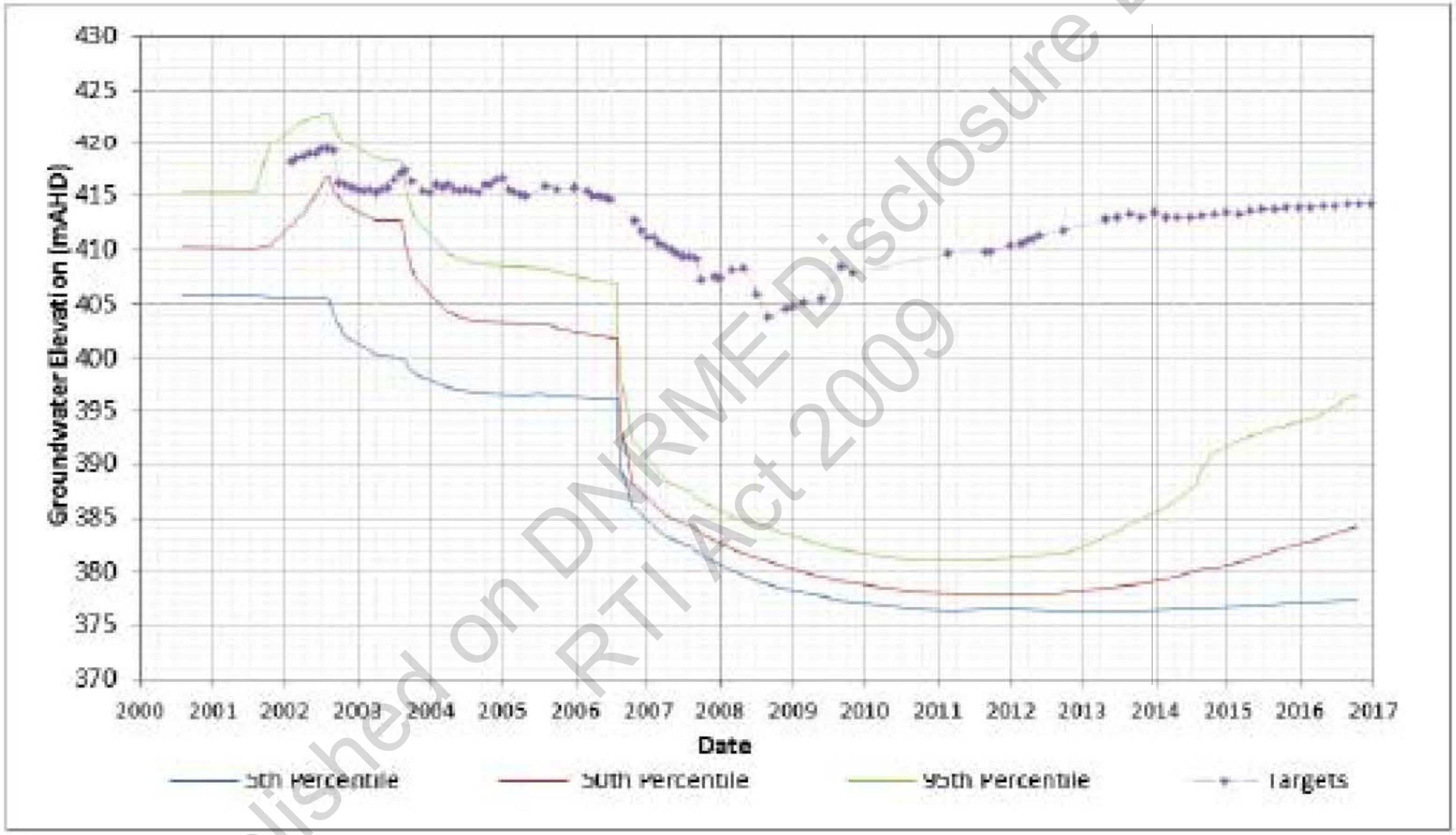
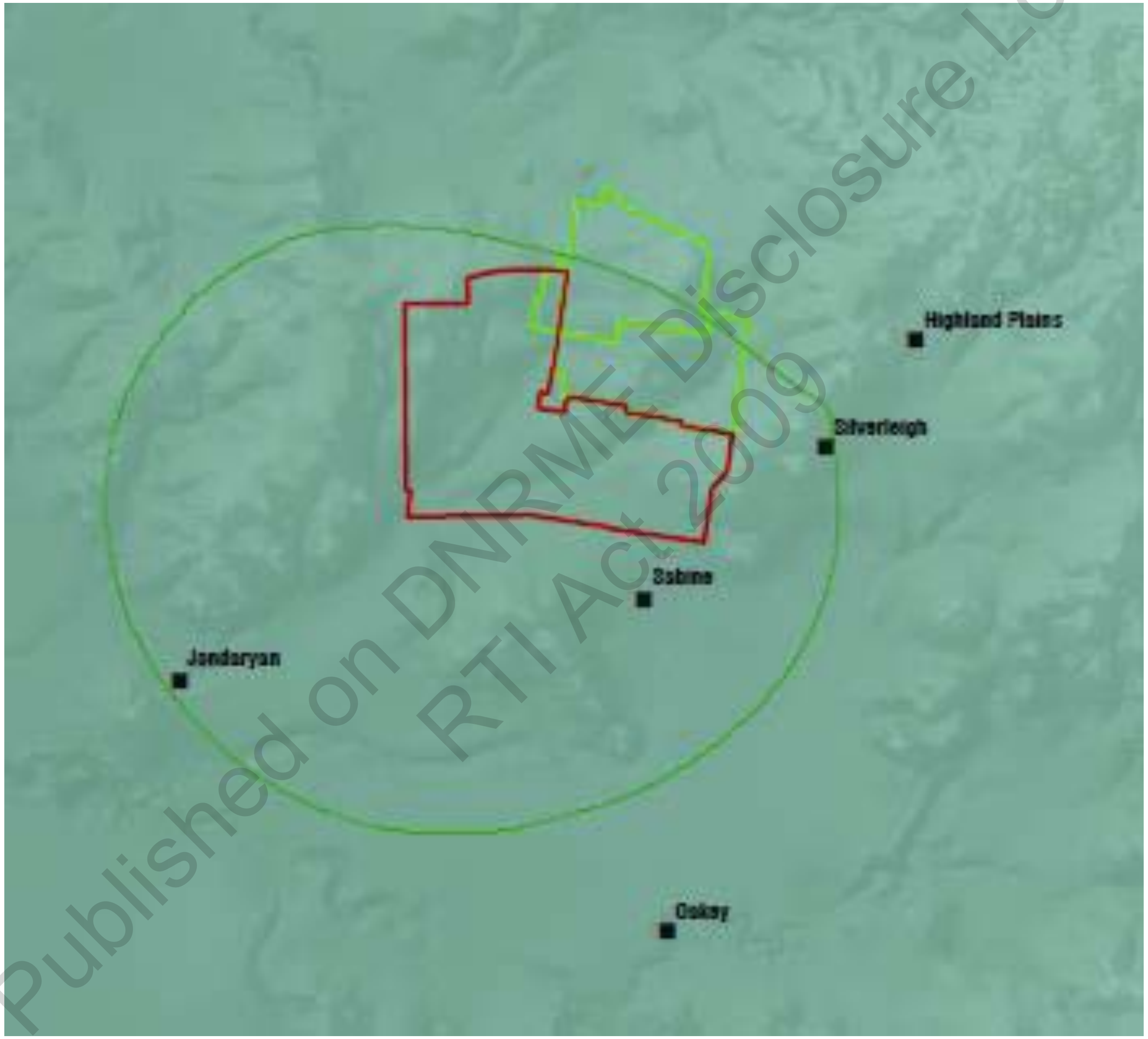


Figure 4-74 Observed and Simulated Groundwater Levels (48P)

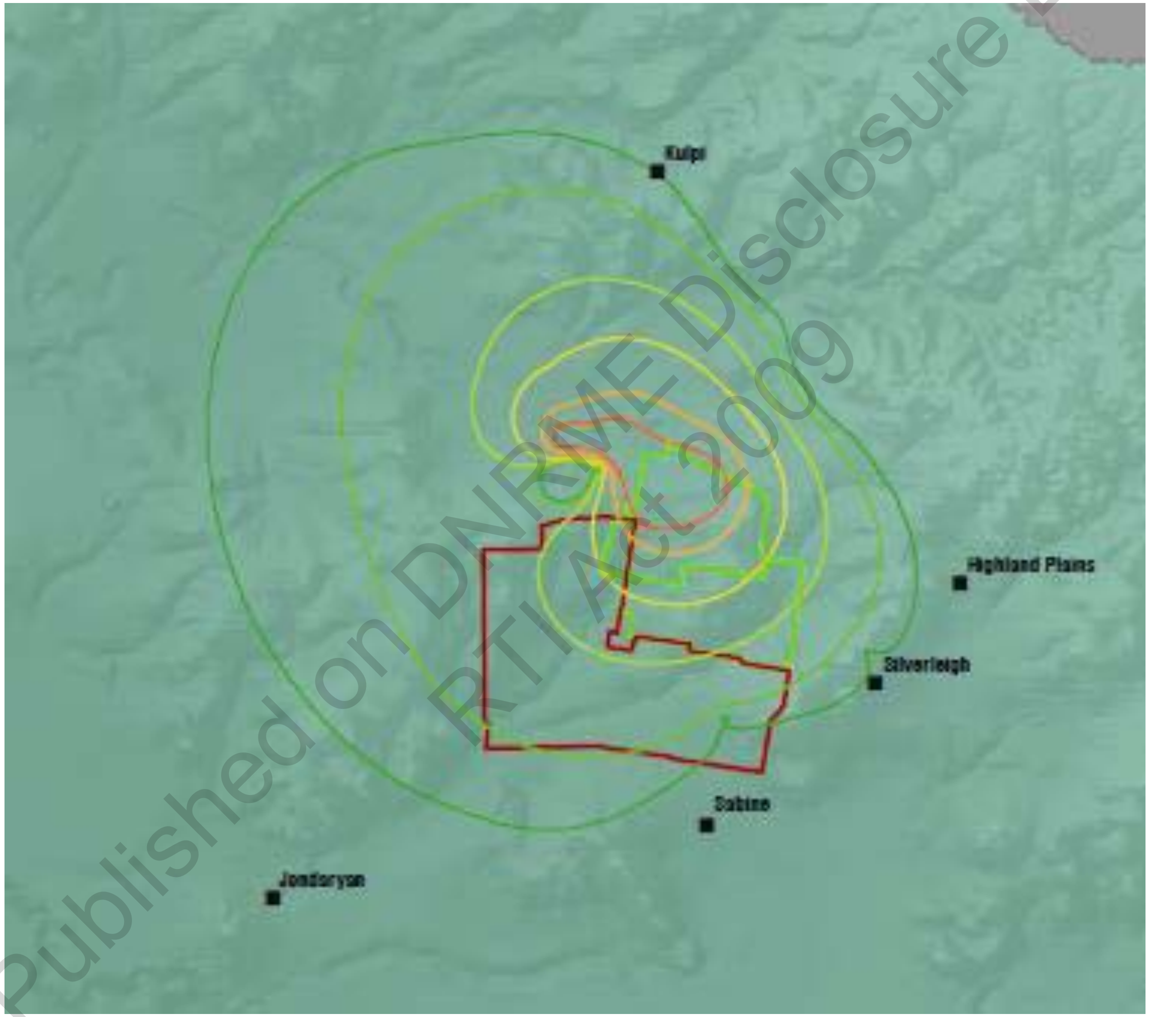
Marburg Calibration issues D3-35

INCREMENTAL MODEL (Stage 3 only) 95th percentile predicted drawdown 2018



Marburg Calibration issues D5-31

CUMULATIVE MODEL 95th percentile predicted drawdown 2018



Additional slides required

- Monitoring network enhancement
- Historical take from mine now modelled
- Some calibration matches good and bad
- Discussion of the Marburg issue in stages 1 and 2
- Richard report how do we address that, point by point or those points not already covered in our presentation.