NEW HOPE GROUP

Appendix N
IESC Submission Response

New Acland Stage 3 Project

NEW HOPE GROUP

Response to IESC Advice

QE06644.044 | Version 3

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13 August 2014

JACOBS

New Acland Stage 3 Project

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Contents

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The sole purpose of this report and the associated services performed by Jacobs is to address the IESC Advice provided as part of the New Acland Stage 3 Project EIS in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

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1. Introduction

New Acland Coal Pty Ltd (NAC), part of the New Hope Group (NHG), currently operates the existing New Acland Coal Mine (the Mine) in southeast Queensland's Clarence-Moreton Basin, as a 4.8 million tonne (product coal) per annum (Mtpa) open cut coal mine on mining lease (ML) 50170 and ML 50216 within Mineral Development Licence (MDL) 244, under the approval of Environmental Authority (EA) EPML00335713.

NAC is proposing to develop the New Acland Coal Mine Stage 3 Project (the revised Project), which involves the extension of the Mine's operating life to approximately 2029 with the inclusion and progressive development of two new resource areas within MLA 50232. These resource areas are identified as the Manning Vale and Willeroo resource areas.

NAC submitted an Environmental Impact Statement (EIS) in November 2009 for the New Acland Stage 3 Coal Mine Expansion Project (the original proposal), which involved the staged expansion of the Mine up to a capacity of 10 Mtpa. The original proposal was expected to extend coal production at the Mine until approximately 2042.

Since that time, the NHG liaised with the State and Commonwealth governments in the preparation of a Supplementary Report. Prior to the finalisation of the Supplementary Report, the NHG revised the Project's scope, in response to comments and concerns raised by Government and other stakeholders during the EIS process. The NHG understands the importance of properly securing its social licence to operate, and as a consequence, has made significant changes to the original proposal.

On 9 November 2012, the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) made a decision to accept a 'project variation' under Section 156B of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The revised Project will be assessed under the Bilateral Agreement between the Queensland and Australian governments.

An EIS has been prepared for the revised Project. This EIS has been prepared to inform decision makers, affected parties, interest groups and the public about potential environmental issues relating to the development and operation of the revised Project and how these issues will be managed. This EIS supersedes the EIS (November 2009) for the original proposal, and therefore the content of the original EIS will not be evaluated in the future assessment of the revised Project.

The final Terms of Reference (ToR) for the revised Project were issued March 2013. The proponent was requested to provide a stand-alone document to the Coordinator-General that includes details of the revised Project's potential impact on water resources. The document must be provided when the EIS is lodged. On 13 March 2013, an amendment to the EPBC Act was introduced into Federal Parliament to enable water resources to become a matter of national environmental significance in relation to coal seam gas and large coal mining development. The amendment was passed in June 2013 and is now in force, providing the Minister with the power to consider and impose conditions directly relating to impacts on a water resource itself.

A stand-alone document was provided to the Coordinator-General, as required by the ToR, at the time of EIS lodgement in February 2014. The standalone document was prepared in accordance with the *Independent Expert Scientific Committee Information Guidelines for Proposals Relating to the Development of Coal Seal Gas and Large Coal Mines where there is a Significant Impact on Water Resources* and accompanied the Coordinator-General's Request for Advice to the Independent Expert Scientific Committee (IESC).

The IESC's advice to the Coordinator-General and the Australian Government Department of the Environment was received on 10 April 2014 and included a range of comments, recommendations and requests for further information, relating to the revised Projects potential impacts on water resources. A copy of the IESC's advice statement is presented in **Appendix A** of this document.

The purpose of this document is to present the NHG's response to the IESC's advice statement.

2. Question 1: Key uncertainties and risks of the project in relation to water resources and water-related assets

2.1 Uncertainties and risks in the hydrogeological conceptualisation and numerical groundwater model

2.1.1 Item 1a: Conceptualisation and numerical representation of confining units

Updated numerical groundwater modelling has been undertaken since the EIS and details are presented as **Appendix B** of this document and **Appendix F** of the AEIS.

As described in the EIS and the original IESC request for advice submission, the Walloon Coal Measures is conceptualised as comprising two dominant units: an upper unit comprising coal seams and comparatively low permeability siltstone and mudstone interburden, and a lower unit comprising a relatively coal-barren sequence of low permeability siltstone and mudstone. The lower Walloon Coal Measures forms a confining unit between the upper Walloon Coal Measures and the underlying Marburg Sandstone. Further information regarding the conceptualisation and numerical representation of the lower Walloon Coal Measures is provided in **Section 2.1.14**.

Despite containing both relatively low permeability interburden and more groundwater transmissive coal seams, the upper Walloon Coal Measures is represented as a single composite layer in the numerical groundwater model. This layer is therefore a combination of coal seams and relatively lower permeability interburden, with the modelled hydraulic conductivity of this layer representing a bulk hydraulic conductivity across the whole thickness of the layer. Generally, the horizontal hydraulic conductivity parameterisation achieved through model calibration procedures is skewed towards the horizontal hydraulic conductivity of the coal seams themselves, as they govern (facilitate) horizontal flow in the upper Walloon Coal Measures unit. However, the vertical hydraulic conductivity parameterisation of the layer is skewed towards the vertical hydraulic conductivity of the interburden, as it is these that govern (restrict) vertical flow in the unit. This approach is consistent with that adopted in OGIA's regional groundwater model for simulating the coal bearing units of the Walloon Coal Measures.

2.1.2 Item 1b: Model Documentation – Potentiometric surface maps

The updated numerical modelling report, included in **Appendix B** of this document, presents modelled potentiometric head maps. Pre-development potentiometric head maps for the revised Project site were presented in Chapter 6 of the EIS.

Pre-mining steady state heads are not readily available and are reliant upon data collected form the DNRM registered bore database. Jacobs are unable to verify the quality of this data. In addition, the data available are not centred upon the revised Project site but are more regional and thus calibration to pre-mining water levels can best be described as a means to provide regional flow directions.

In addition to the paucity of data available for pre-mining water levels, the groundwater model does not account for other historic activities in the area that are unknown or unquantifiable to the revised Project proponent. As such the model should be judged upon its ability to replicate regional flow gradients and drawdown magnitudes where information is available. Based upon this expectation the model calibration has been considered fit for the purpose for this assessment.

Additional calibration comparisons and information are provided in Appendix A of the updated numerical modelling report, included in **Appendix B** of this document. The additional analyses include hydrographs of observed and simulated groundwater levels for all bores with more than one data point. Given that the availability of water level data for the region is both scarce and transiently sporadic in an area of intense groundwater development, it was considered that developing pre-mining potentiometric surfaces to compare with modelled potentiometric surfaces is not appropriate as outlined above. Rather, maps showing the spatial distribution of calibration SRMS error at each target bore location are also provided in **Appendix A** of the updated numerical modelling report, allowing the spatial distribution of calibration to be assessed without the need to develop highly unreliable maps of pre-mining potentiometric surfaces. The SRMS maps are provided for each model layer. As indicated by the hydrographs and SRMS maps the model is able to provide a reasonable replication of water levels across the model domain, and for most locations provides a good replication of drawdown from mining activities where information is available.

2.1.3 Item 1c: Model Documentation – Water balance

Updated water balance diagrams including post-mining, based on the results of the updated numerical groundwater modelling, are included as **Appendix B** of this document.

2.1.4 Item 1d: Boundaries – Constant heads

As described in the updated numerical modelling report, presented as **Appendix B** of this document, the setting of boundary conditions has been revised in the modelling undertaken since the EIS.

Constant head boundaries in the updated modelling have been assigned at active cells adjacent to model boundaries where the aquifer is known to extend further than the model boundary. Head values in the alluvium were based upon a typical depth to water of approximately 13.5 mbgl based on information sourced from the DNRM groundwater bore database. For all other geologic units a relationship between topography and water levels sourced from the DNRM groundwater bore database and groundwater monitoring bores at the New Acland Mine was used to assign spatially variable heads. These relationships are presented in **Figure 2-1** through **Figure 2-3**.

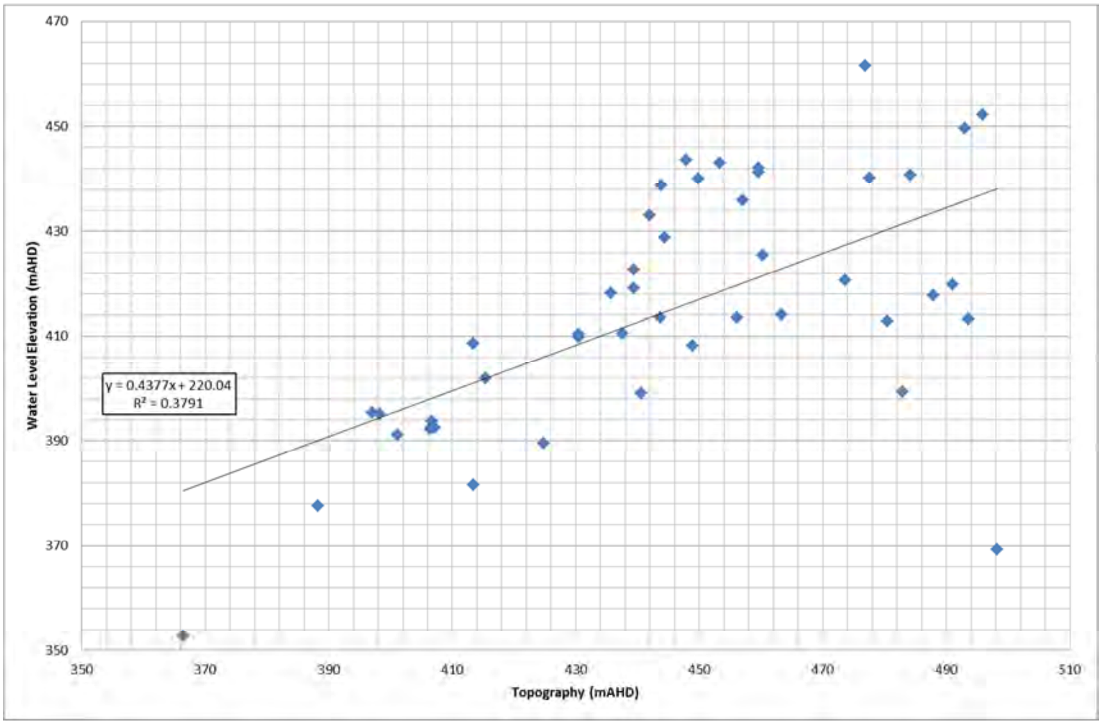


Figure 2-1 : Basalt – Relationship between topography and water levels

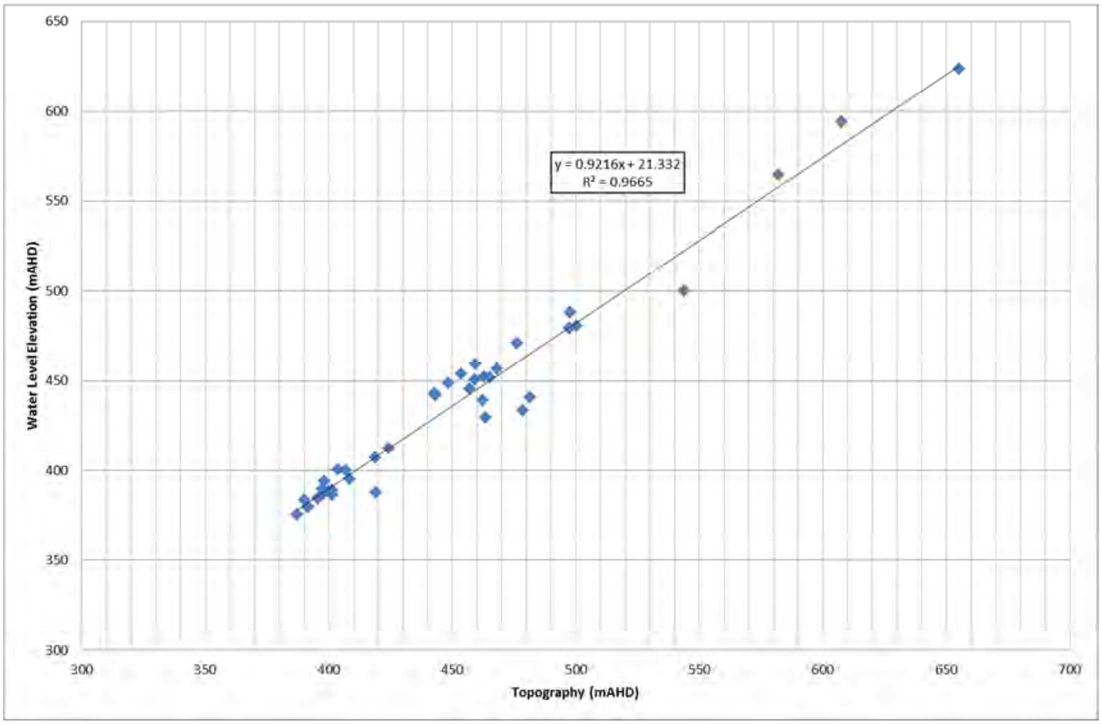


Figure 2-2 : Walloon Coal Measures – Relationship between topography and water levels

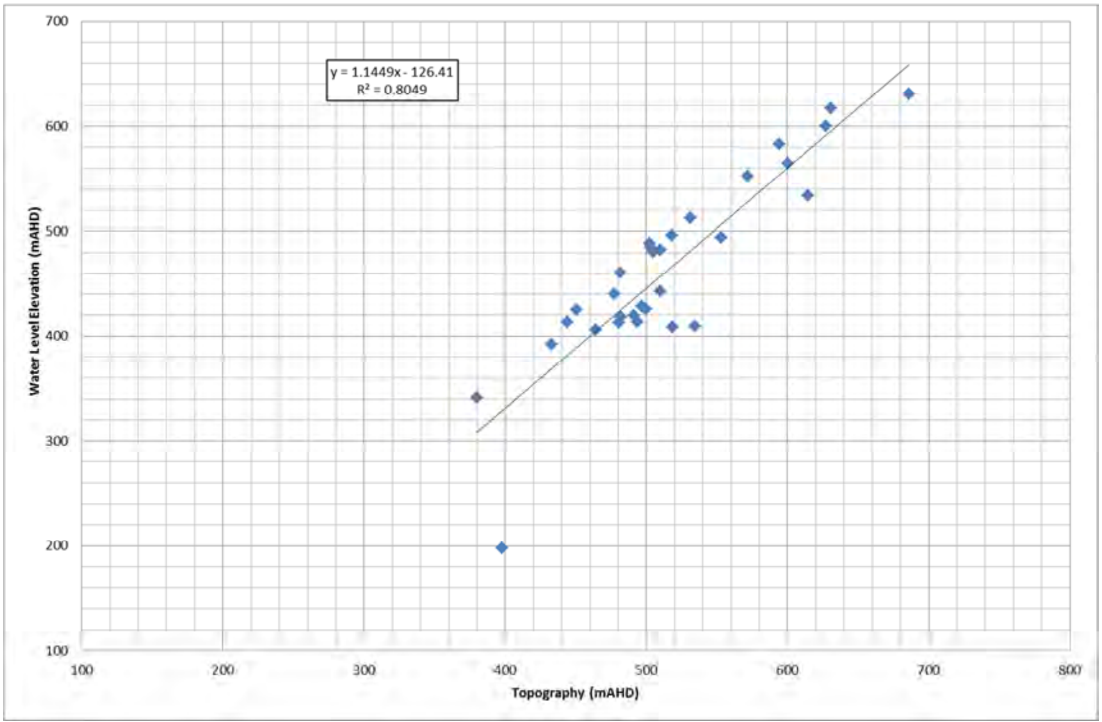


Figure 2-3 : Marburg Sandstone – Relationship between topography and water levels

2.1.5 Item 1e: Boundaries – Confidence in adopted conditions

As detailed in the response to Item 1d in **Section 2.1.4** above, model boundary conditions in the updated modelling rely on the relationship between topography and recorded water levels for each aquifer, i.e. the actual potentiometric surface.

The OGIA's regional UWIR numerical model is not at an appropriate scale for this small a project footprint and potential impact area, and therefore using that model's boundary conditions is not appropriate. However, comparison of the modelled potentiometric heads within the OGIA model with the adopted boundary conditions described in **Section 2.1.4** above shows that the OGIA model predicts heads ranging around 360 mAHD in the Walloon Coal Measures and 360 to 400 mAHD in the Marburg Sandstone in the vicinity of the New Acland model domain boundaries, compared to the New Acland model using ranges of 380 to 450 mAHD in the Walloon Coal Measures and 300 to 500 mAHD in the Marburg Sandstone in the same areas. Although the head values are similar between the two models, the broader range of modelled heads in the New Acland model reflects the more detailed assignment of heads across a much more refined model grid, based on detailed analysis of actual potentiometric level data within the model domain as described in **Section 2.1.4**.

The OGIA model has been used for model parameter constraints in the updated modelling since the EIS as described in **Appendix B**.

2.1.6 Item 1f: Boundaries – Justification of adopted conditions

Refer to the response to Item 1d in **Section 2.1.4** above.

2.1.7 Item 1g: Boundaries – Exclusion of existing groundwater entitlements

Within the groundwater model domain, there is a large number of existing groundwater entitlements as identified in the EIS, especially within the alluvial sediments associated with Oakey Creek to the south and southwest of the revised Project site. The EIS outlined that DNRM water entitlement records indicate that there are maximum allocations totalling around 11,000 ML/year within 8 km of the revised Project, including 6,660 ML/year within the alluvium of Myall and Oakey Creeks. However, the DNRM entitlement database does not identify which particular DNRM-registered bores these allocations belong to, but rather which property lot/plan number they below to. If a particular property contains more than one bore, it is not possible to assign the allocation to any particular bore. Within the EIS, it was identified that there are 939 DNRM-registered bores within 8 km of the revised Project site, however it was also identified that less than 50% of these bores have the target aquifer recorded in the DNRM database. As such, accurate representation of the water entitlements within the numerical model is currently not possible.

In addition, just because these entitlements exist does not mean that they are being fully utilised on an annual basis. Therefore, owing to a lack knowledge of where these entitlements are actually being extracted and how much of the entitlements are being utilised, these groundwater users were not explicitly replicated in the model.

The predicted groundwater drawdown impacts for the revised Project are derived from two numerical model simulations; one simulating the mine, the other without the mine. In this case, the effect on mine-related drawdown predictions owing the presence (or not) of these allocations in both simulations would be nullified.

The NHG is committed to undertaking baseline surveys at all groundwater bores within its predicted area of impact; it is envisaged that this program of works will identify the source aquifer of many of the currently ‘unknown aquifer’ bores as well as bores used in entitlements, and therefore allow more accurate groundwater modelling related to these. The NHG is committed to incorporating these third-party groundwater entitlements in future iterations of the groundwater model where possible (i.e. if the planned program of baseline assessments allows it to occur), such as the first 3-yearly review as outlined in the revised Project’s GMIMP.

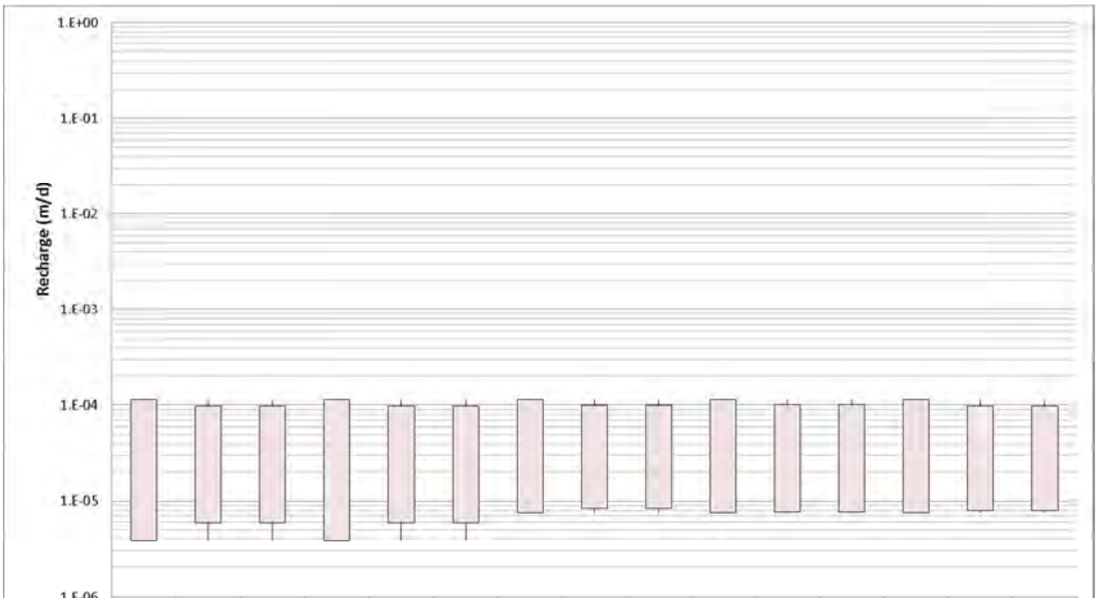
2.1.8 Item 1h: Boundaries – Modelling of Recharge

The modelling of recharge has been refined in the updated modelling since the EIS as described in **Appendix B**.

It is believed that recharge in the revised Project area and surrounds is influenced by the geological unit present at the surface; therefore, recharge zones were created for each of the different geology outcrops. From a modelling perspective this involves applying recharge to the uppermost active layer.

Recharge during transient calibration simulations was varied based on the historical rainfall record. Recharge calculation in the steady state model and for predictions relies on the long term rainfall rates. The stochastic realisations of recharge are achieved through changing the percentage of rainfall that ends up as recharge and then multiplying that percentage by the corresponding rainfall data. The use of a stochastic methodology with regards to the modelling of recharge negates the need to determine a specific likely recharge rate(s) given the range explored through the stochastic runs.

The updated modelling report, provided as **Appendix B**, describes an assessment of model sensitivity and uncertainty related to recharge. **Figure 2-4** below presents a summary of model sensitivity to recharge.



	Alluvium - SRMS	Alluvium - Inflows	Alluvium - Combined	Basalt - SRMS	Basalt - Inflows	Basalt - Combined	Walloon (upper) - SRMS	Walloon (upper) - Inflows	Walloon (upper) - Combined	Walloon (lower) - SRMS	Walloon (lower) - Inflows	Walloon (lower) - Combined	Marburg - SRMS	Marburg - Inflows	Marburg - Combined
Calibration Min	3.8E-06	6.0E-06	6.0E-06	3.9E-06	6.0E-06	6.0E-06	7.6E-06	8.3E-06	8.3E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	9.0E-06	9.0E-06
Input Max	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04
Input Min	3.8E-06	3.8E-06	3.8E-06	3.8E-06	3.8E-06	3.8E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06
Calibration Max	1.1E-04	9.7E-05	9.7E-05	1.1E-04	9.7E-05	9.7E-05	1.1E-04	9.9E-05	9.9E-05	1.1E-04	1.0E-04	1.0E-04	1.1E-04	9.7E-05	9.7E-05

Figure 2-4 : Model Parameter Sensitivity: Recharge

2.1.9 Item 1i: Boundaries – Modelling of ET

The modelling of Evapotranspiration (ET) has been refined in the updated modelling since the EIS as described in **Appendix B**.

Evapotranspiration (ET) is expected to be an active form of groundwater discharge in the model domain and has been simulated using the EVT package of MODFLOW.

Maximum ET Potential was initially estimated to be between 1400-1500 mm/yr from local meteorological data (BoM, 2011). The Australian Bureau of Meteorology estimate Aerial Actual Evapotranspiration to be between 600 to 700 mm/yr (BoM, 2011). For modelling purposes maximum ET was set to 650 mm/yr (excluding in the areas of the final voids – see **Section 2.1.22**).

The EVT package of MODFLOW requires that an extinction depth be provided, which indicates at what depth ET no longer occurs (i.e. ET rate =0). The ET rate is then linearly decreased from the maximum rate when the water level is estimated to be at the ground surface to 0 mm/year when the water level is estimated to be at the extinction depth. The extinction depth is allowed to vary during the stochastic calibration process.

2.1.10 Item 1j: Boundaries – Faults

Investigations undertaken as part of the existing Mine operations, including field investigations (e.g. WSA, 2013), have sought to identify the role that faulting within the Walloon Coal Measures plays in control on groundwater flow and aquifer compartmentalisation. These investigations have shown that these faults may play a significant role in providing barriers to groundwater flow in the Walloon Coal Measures. During the original model development as part of the EIS, the calibration procedure involved simulating the existing Mine operation with and without the inclusion of barrier faults in the model. The results of this procedure indicated that in order to best represent the compartmentalisation of the Walloon Coal Measures and the resulting monitoring bore responses, the faults which have been previously mapped by NHC's geologists based on drilling results and observations of the existing Mine's open cut pits, are best simulated as barrier 'Walls' in the model. For the updated modelling, this approach has again been adopted without specifically undertaking calibration trials without the inclusion of these Walls in the Walloon Coal Measures.

Model calibration runs were undertaken with and without barrier Wall faults applied to the Marburg Sandstone. The results of this sensitivity analysis showed that the model is relatively insensitive to the inclusion of these faults. Given that the Marburg Sandstone is conceptualised as a relatively thick, permeable and homogenous unit compared to the upper Walloon Coal Measures, it was considered that compartmentalisation of the unit is much less likely to occur than in the Walloon Coal Measures, and therefore it was decided to not apply faults to the Marburg Sandstone for the model predictions. This approach is considered conservative as it will result in further lateral propagation of drawdown away from the revised Project site in the Marburg Sandstone than would be the case with barrier faults applied.

2.1.11 Item 1k: Boundaries – Myall Creek

The modelling of both Myall Creek and Oakey Creek has been refined in the updated modelling since the EIS as described in **Appendix B**. Myall Creek is now represented as River cells rather than Drain cells.

2.1.12 Item 1l: Model Layers – General

A cross section through the model domain, and maps showing the modelled extent of each hydrogeological unit, are provided in the updated modelling report presented as **Appendix B**.

The model contains five layers, all of which are active except for in layer 1 outside the alluvial extents where cells are set as inactive. Where deeper geologic units are not present cell thicknesses are set at a minimum thickness of 0.1m and the underlying hydrogeological properties are carried up.

The hydrogeological units of relevance to the revised Project area have been simplified for incorporation into the groundwater model as discrete model layers, as described in **Table 2-1**. Layers within the model do not solely represent one individual simplified geologic unit. Geologic units are represented in the model by parameterisation of hydraulic conductivity and storage. For example, Layer 2 is intended to simulate the Basalt. Where it is estimated to exist, the cells have been assigned parameters associated with the Basalt. Where it does not exist, the next sequential geologic unit interpreted to exist is represented by a change in hydraulic conductivity and storage, and cell thicknesses are set at a minimum thickness of 0.1m. An example cross-section of the model is presented in **Figure 2-5**.

Table 2-1 : Model layering

Layer(s)	Hydrogeologic unit	Layer thicknesses (m)
1	Alluvium	0.1 - 52
2	Tertiary Basalts	0.1 - 143
2 - 3	Upper WCM	0.1 - 145
4	Lower WCM	0.1 - 153
2 - 5	Marburg Sandstone	250

The extent and, top and bottom elevations for each geologic unit were calculated based upon the following data sets:

- LiDAR digital elevation files provided by NAC
- digital elevation model (DEM) surface topography
- surface and bedrock mapping (SRK, 2006)
- DNRM database
- NAC monitoring bore geologic logs

Isopach maps and modelled extent for each geologic unit are presented in the updated numerical modelling report, provided in **Appendix B**. The extents of each geologic unit were based upon referenced geologic maps (SRK, 2006) for all consolidated units. Jacobs SKM used topography data (LiDAR and DEM) to refine the extents of the alluvium using a slope break analysis. Thicknesses were interpreted based upon available geologic logs, DRNM database and publically available interpretations of isopach and floor elevations (SRK, 2006).

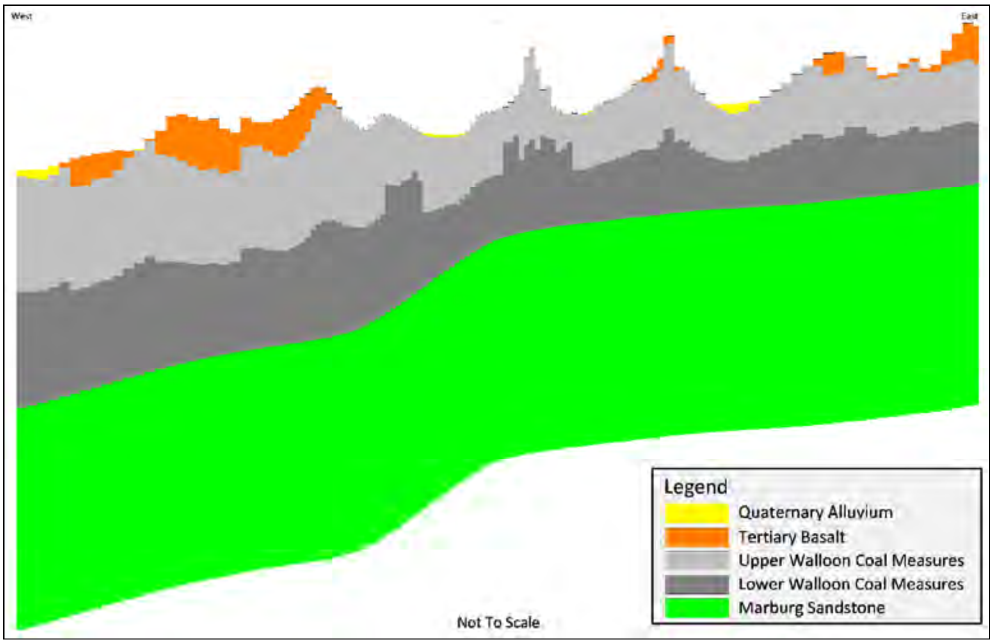


Figure 2-5 : Example cross section through the numerical model

2.1.13 Item 1m: Model Layers – Thickness and extents

Refer to the response to Item 1l in **Section 2.1.12** above.

2.1.14 Item 1n: Model Layers – Conceptualisation of Lower Walloon Coal Measures

The lower Walloon Coal Measures has been conceptualised as a separate model layer of generally lower hydraulic conductivity than the upper Walloon Coal Measures. The basis of this conceptualisation is a general lack of coal seams within geological logs for the lower parts of the Walloon Coal Measures, with a corresponding increase in the relative abundance of low permeability mudstone and siltstone sediments. This approach is consistent with the approach adopted in the OGIA UWIR model as described below.

Within the OGIA model, a similar approach is used where the lower Walloon Coal Measures is represented as layer 11 of the model, an aquitard termed the "Walloon Coal Measures (lower aquitard)". Model parameters for this layer in the OGIA show modelled with horizontal hydraulic conductivities of an order of magnitude lower than the Walloon Coal Measures coal-bearing unit.

Potentiometric head data in the vicinity of the revised Project is largely unavailable for the lower Walloon Coal Measures. Only 4 bores within the model domain have been identified for which to calibrate to for the lower Walloon Coal Measures in the numerical modelling, and no specific nested sites were identified for a direct comparison of vertical hydraulic gradients between the lower and upper Walloon Coal Measures. The numerical model is calibrated to all available head data in all units\layers of the model.

2.1.15 Item 1o: Model Parameterisation and Calibration – Adopted hydraulic conductivity and specific yield values

The updated modelling since the EIS has used revised hydraulic parameter ranges as described in **Appendix B**. Specifically, model parameterisation has been undertaken using a stochastic approach to calibration, and an uncertainty approach using the best calibrated range of hydraulic parameters has been used for model predictions. Prior to undertaking the revised model calibration, the allowed ranges of hydraulic parameters within the stochastic modelling have been constrained to those within the OGIA regional UWIR model.

2.1.16 Item 1p: Model Parameterisation and Calibration – RMS Results

The updated modelling since the EIS has provided an updated model calibration results as described in **Appendix B**.

The updated model calibration simulations resulted in 1667 model realisations (out of 2980 total possible realisations), or sets of model parameters, that simulated groundwater levels within the updated target calibration criteria of 5% SRMS (the first calibration target). Of these, 18 realisations also simulated pit inflows within the range of New Acland Mine pit inflow estimates used for calibration (the second calibration target). Therefore, these 18 realisations are considered the calibrated datasets available for an assessment of calibration sensitivity\uncertainty, as well as forming the input parameters for the predictive simulations and associated sensitivity\uncertainty assessments.

2.1.17 Item 1q: Model Predictions – Uncertainty/sensitivity analysis

The updated modelling since the EIS includes both a model sensitivity and model uncertainty analysis as described in **Appendix B**.

The results of the updated model calibration sensitivity analysis show that the model calibration is highly sensitive to the horizontal and vertical hydraulic conductivities used for the Upper Walloon Coal Measures, and relatively sensitive to the horizontal and vertical hydraulic conductivities used for the Lower Walloon Coal Measures and the horizontal and horizontal hydraulic conductivities of the alluvium and basalt. The calibration shows some sensitivity to the specific yield of the Upper Walloon Coal Measures and basalt. The model is shown to be relatively insensitive to the other model parameter variables, including recharge and ET.

2.1.18 Item 1r: Model Predictions – Restricted lateral drawdown

The updated modelling since the EIS has revised the predictions of groundwater drawdown arising from the revised Project as described in **Appendix B**.

Predicted groundwater drawdown is only laterally restricted for the Walloon Coal Measures, in a southwesterwards direction as a result of the representation of faulting and compartmentalisation by the 'Wall' package within MODFLOW.

During the original model development as part of the EIS, the calibration procedure involved simulating the existing Mine operation with and without the inclusion of barrier faults in the model. The results of this procedure indicated that in order to best represent the compartmentalisation of the Walloon Coal Measures and the resulting monitoring bore responses, the faults which have been previously mapped by NHC are best simulated as barrier 'Walls' in the model. For the updated modelling, this approach has again been adopted without specifically undertaking calibration trials without the inclusion of these Walls.

Model calibration runs were undertaken with and without barrier Wall faults applied to the Marburg Sandstone. The results of this sensitivity analysis showed that the model is relatively insensitive to the inclusion of these faults. Given that the Marburg Sandstone is conceptualised as a relatively thick, permeable and homogenous unit compared to the upper Walloon Coal Measures, it was considered that compartmentalisation of the unit is much less likely to occur than in the Walloon Coal Measures, and therefore it was decided to not apply faults to the Marburg Sandstone for the model predictions. This approach is considered conservative as it will result in further lateral propagation of drawdown away from the revised Project site in the Marburg Sandstone than would be the case with barrier faults applied.

2.1.19 Item 1s: Model Predictions – Marburg Sandstone drawdown

The updated modelling since the EIS has revised the predictions of groundwater drawdown arising from the revised Project as described in **Appendix B**.

Predicted drawdown in the Marburg Sandstone at the end of mining (**Figure 2-6**) is significantly less that the upper Walloon Coal Measures (**Figure 2-7**) across the revised Project site, however is for the most part similar in magnitude and lateral extent outside of the revised Project site, except where lateral propagation of drawdown is restricted by faulting in the Walloon Coal Measures as described in **Section 2.1.18** above. The relative flatness of the drawdown cone in the Marburg Sandstone compared to the Walloon Coal Measures is largely due to a lower overall modelled transmissivity for the Walloon Coal Measures compared to the Marburg Sandstone, and the occurrence of barrier faults in the Walloon Coal Measures that restrict lateral propagation of drawdown.

2.1.20 Item 1t: Model Predictions – Alluvium drawdown

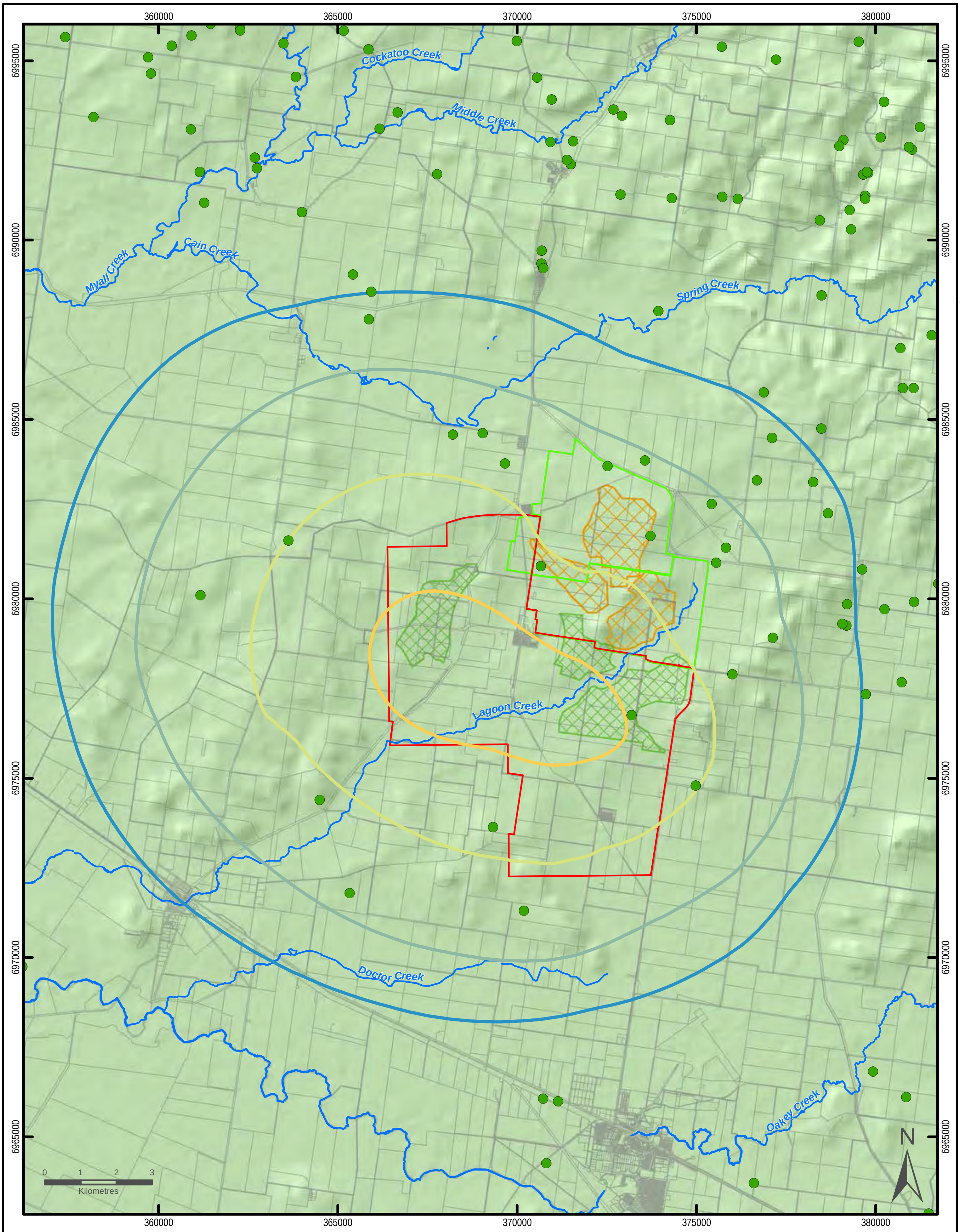
The updated modelling since the EIS has updated the predictions of groundwater drawdown arising from the revised Project as described in **Appendix B**.

Predicted drawdown in the alluvium is restricted to a small area of Lagoon Creek adjacent the southwestern edge of the revised Project site, as well as the southeastern corner of the revised Project site, as shown in **Figure 2-8**. At no time is drawdown predicted to occur in any area within 2.5 km of DNRM-registered alluvial bores or within 5 km of the main channels of the Myall and Oakey Creeks.

2.1.21 Item 1u: Model Predictions – Alluvium drawdown

The updated modelling since the EIS has included a stochastic uncertainty analysis of predicted groundwater drawdown as described in **Appendix B**.

The updated modelling predicts no reduction in streamflow in either Myall or Oakey Creek as a result of the revised Project, as described in **Appendix B**.



LEGEND

- DNRM Registered Bores - Marburg Sst

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of Marburg Sandstone

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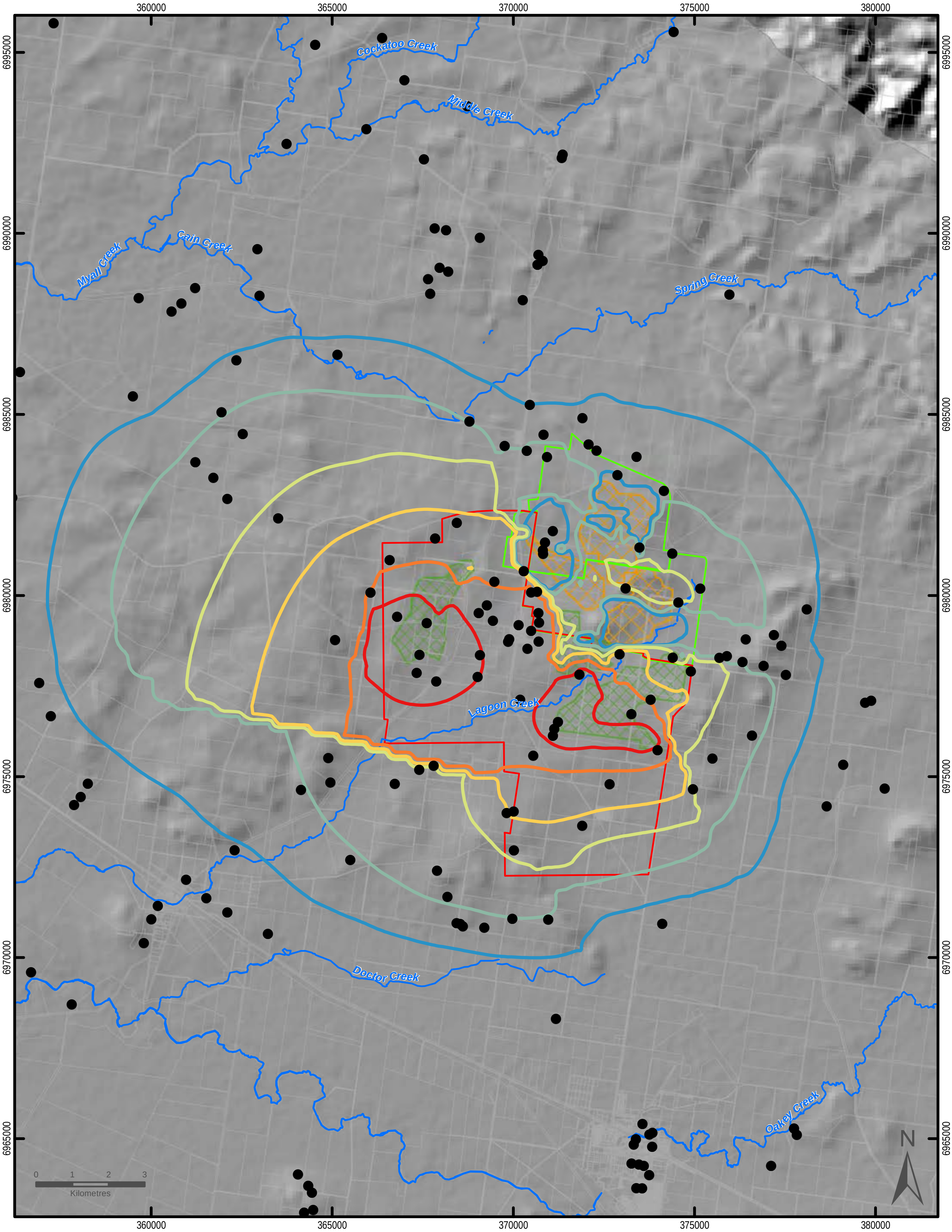
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 2-6 - Marburg Sandstone Predicted Drawdown – 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-6_PredictedDrawdownInMarburgSst_2030.mxd



LEGEND

- ● DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of Walloon Coal Measures

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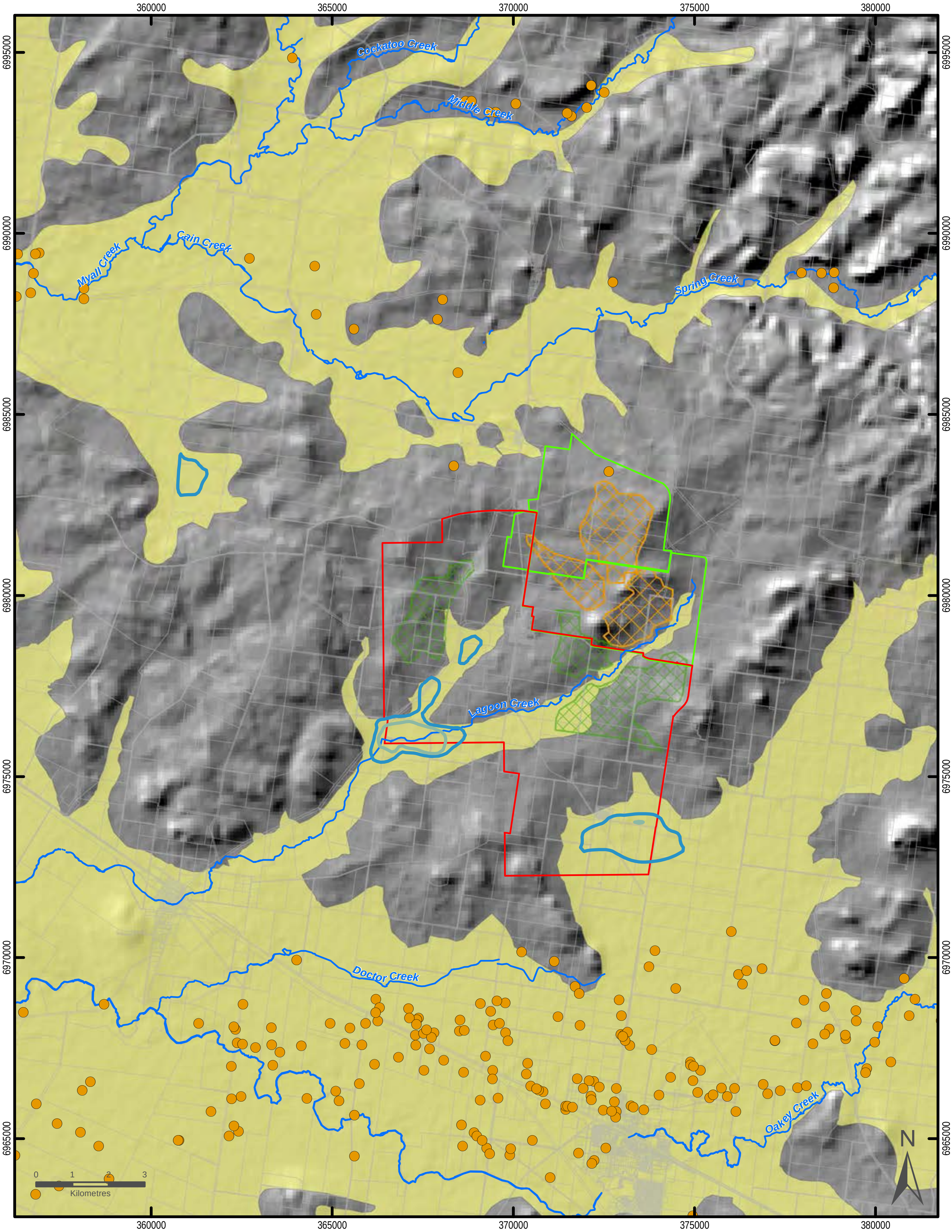
Figure 2-7 - Walloon Coal Measures Predicted Drawdown – 2030

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-7_PredictedDrawdownInWalloon_2030.mxd



LEGEND

- DNRM Registered Bores - Alluvium

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of alluvium

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Figure 2-8 - Alluvium Predicted Drawdown – 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-8_PredictedDrawdownInAlluvium_2030.mxd

Produced: 28/08/2014

2.1.22 Item 1v: Model Predictions – Post-mining simulation

The updated modelling since the EIS has included a revision to the methodology used for simulating post-mining groundwater impacts from the final depressed landforms (rehabilitated final voids) as described in **Appendix B**. The revised post-mining simulation includes an uncertainty analysis, and uses the Average Potential Pan Evaporation sourced from the Australian Government Bureau of Meteorology, factored for simulating ET from the depressed landforms. Additional recharge is supplied to the voids using 100% of average rainfall plus surface water runoff as predicted by surface water modelling as described in Chapter 5 of the revised Project's EIS.

In the long term post-mining (modelled as 300 years post-mining), the updated model predictions indicate groundwater levels in the Walloon Coal Measures will gradually recover so that for the most part there is less than 10 m residual drawdown outside the revised Project's boundary (Error! Not a valid bookmark self-reference.). Full recovery to pre-mining conditions throughout the revised Project site is limited by evapotranspirative losses from the depressed landforms (rehabilitated final voids). Drawdown adjacent the last areas to be mined is predicted to remain relatively minor (approximate maximum of 10 m drawdown) due to the ongoing evapotranspiration-driven groundwater discharge into the depressed landforms (rehabilitated final voids). The 1 m drawdown extent in the Walloon Coal Measures is predicted to remain at approximately 6 km from the revised Project boundary at its greatest (western) extent. Predicted drawdowns in both the Tertiary Basalt (**Figure 2-10**) and the Marburg Sandstone (**Figure 2-11**) in the long term are significantly less than the final year of mining, with recovery of groundwater levels occurring such that residual drawdown does not exceed 5 m for either aquifer at any location. In particular, the Marburg Sandstone is predicted to recover such that drawdown does not exceed 2 m in the long term.

Although recovery to pre-mining groundwater levels does not occur post-mining, the groundwater system recovers to a new steady-state equilibrium such that there are no additional groundwater impacts other than those that have already occurred during operation of the revised Project.

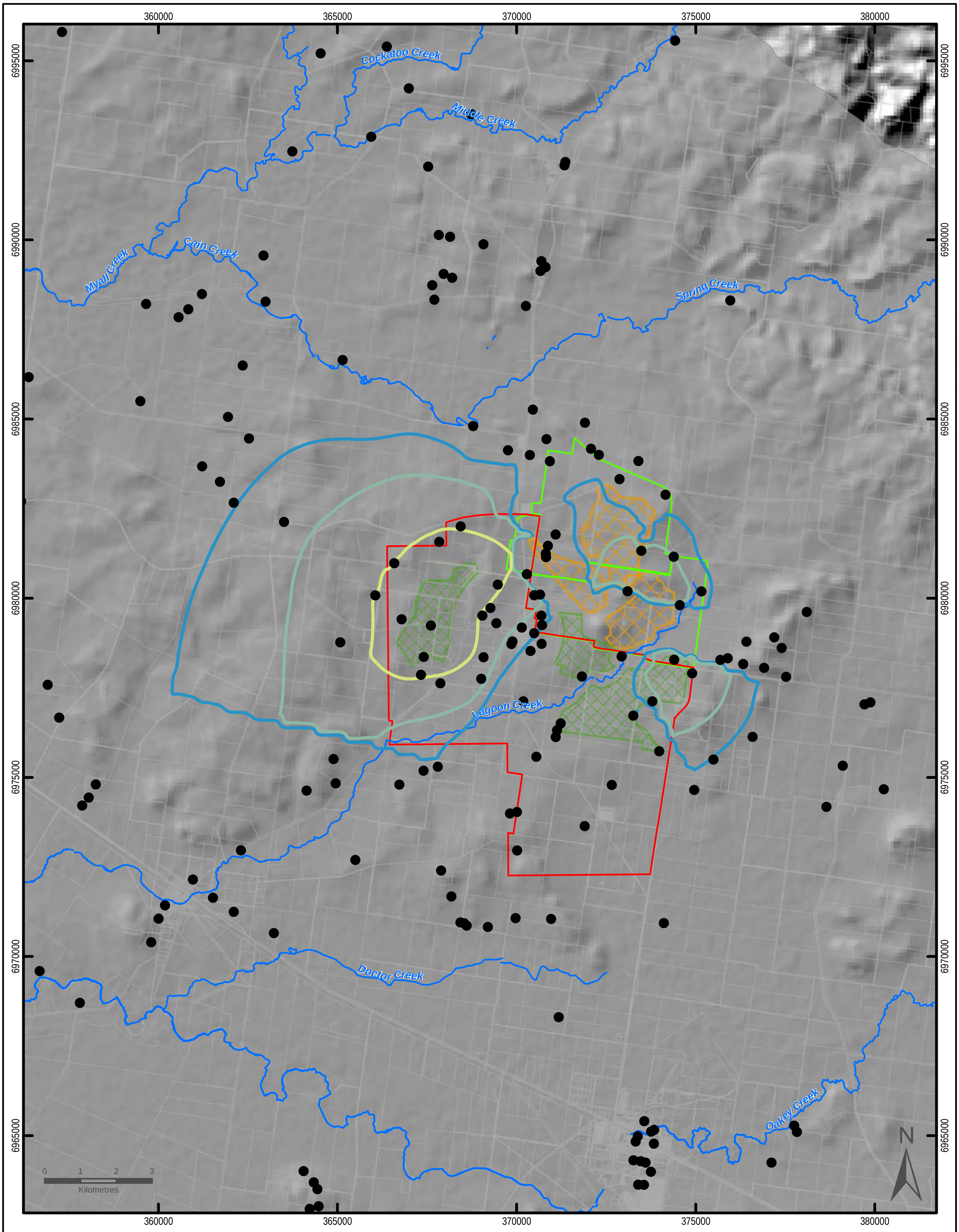
Due to the high evapotranspiration rate in the Project area, groundwater discharge to the depressed landforms (rehabilitated final voids) is predicted to continue at a combined rate of around 1 ML/day in the long term, compared to a peak of around 3.5 ML/day during mining as shown in **Figure 2-12**. Ongoing long-term discharge is driven by evaporation from permanent pit lakes; permanent lakes are predicted to form in all three depressed landforms (rehabilitated final voids) as shown in **Figure 2-13**. Recovery of groundwater levels in the depressed landforms is relatively rapid for the first few years post-mining, and stabilizes at between 2 and 6 m residual drawdown from pre-mining conditions due to ongoing evaporative discharge.

The maximum depths of the lakes that are predicted to form are around 33 m in the Manningvale West depressed landform, 18 m in the Manningvale East depressed landform, and 22 m in the Willeroo depressed landform.

Given the relatively minor long-term drawdown in the depressed landforms, it is possible that episodic large rainfall events could result in enough overland flow to the voids such that this long-term drawdown is overcome on a temporary basis, and the pits may therefore on occasion recharge the groundwater system. However, analytical salt balance modelling suggests that the depressed landform lakes are not expected to become salinized due to the effect of long term incidental rainfall and runoff, and in the long term the lakes will have salinities significantly less than native groundwater in the Walloon Coal Measures. Therefore, any groundwater recharge from the lakes will be less saline than native groundwater. In addition, NAC is committed to dedicated void lake studies as part of mine closure planning in the future, and the management strategies for the lakes will be developed in conjunction with the relevant regulators to ensure no long term water quality impacts on the groundwater system.

2.1.23 Item 1w: Model Predictions – Post-mining simulation

Refer to the response to Item 1v in **Section 2.1.22** above.



LEGEND

- DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of Walloon Coal Measures

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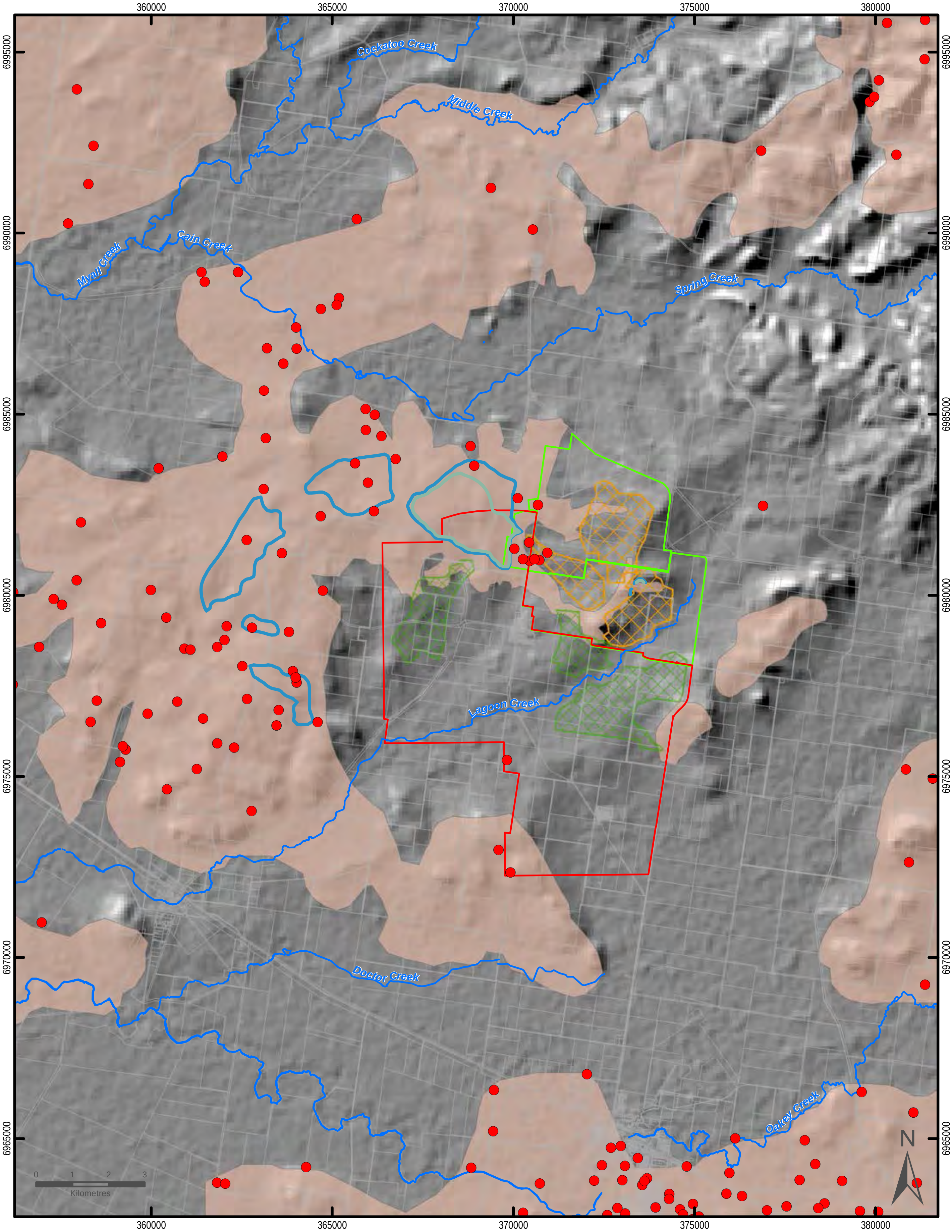
Figure 2-9 - Walloon Coal Measures Predicted Drawdown – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-9_PredictedDrawdownInWalloon_2330.mxd



LEGEND

- DNRM Registered Bores - Basalt

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of basalt

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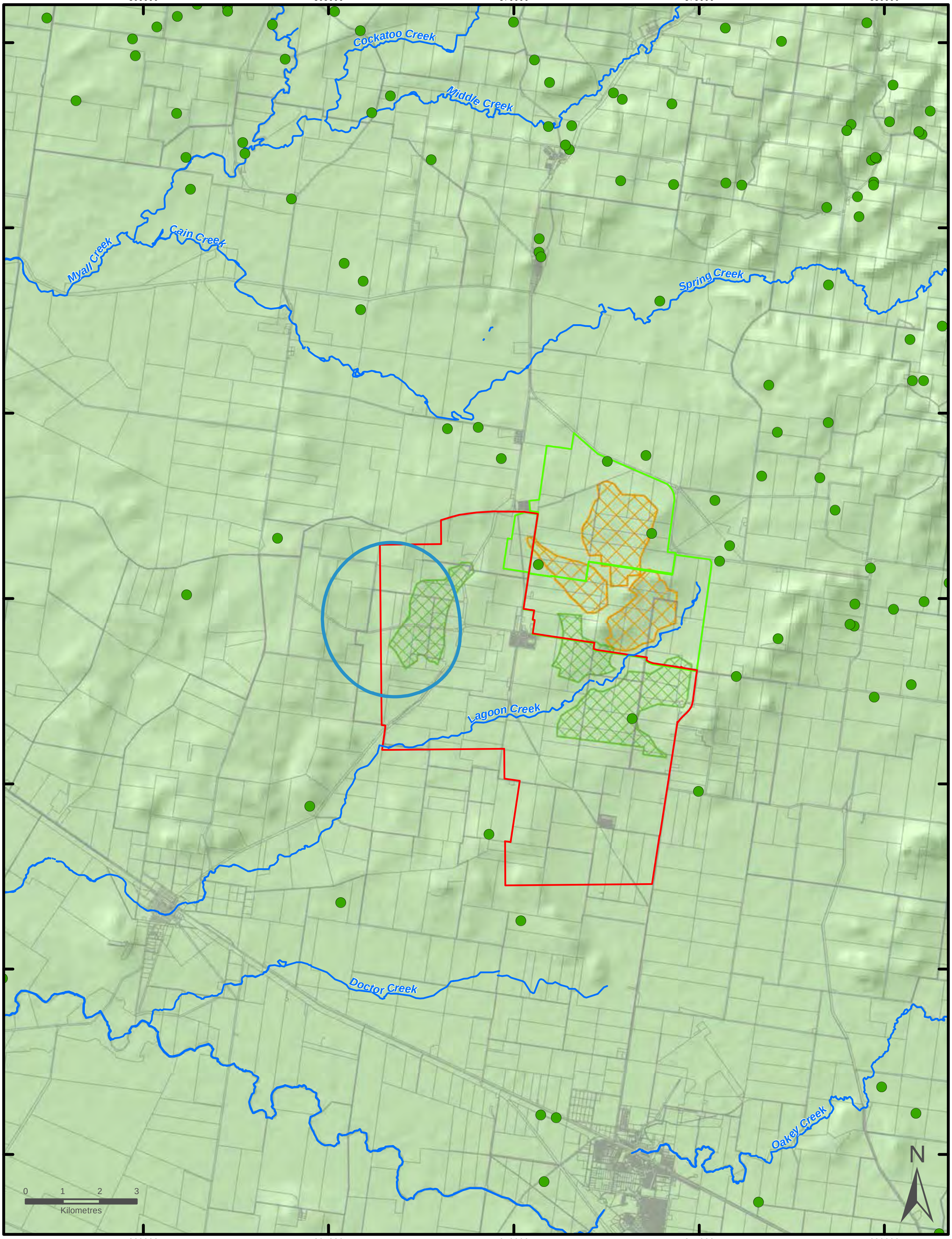
Figure 2-10 - Basalt Predicted Drawdown – Post-Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-10_PredictedDrawdownInTertiaryBasalt_2330.mxd



LEGEND

- DNRM Registered Bores - Marburg Sst

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of Marburg Sandstone

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STAGE 3 PROJECT

Figure 2-11 - Marburg Sandstone Predicted Drawdown – Post-Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ESC Response\140617_NewHope_Groundwater_Figure2-11_PredictedDrawdownInMarburgSst_2330.mxd

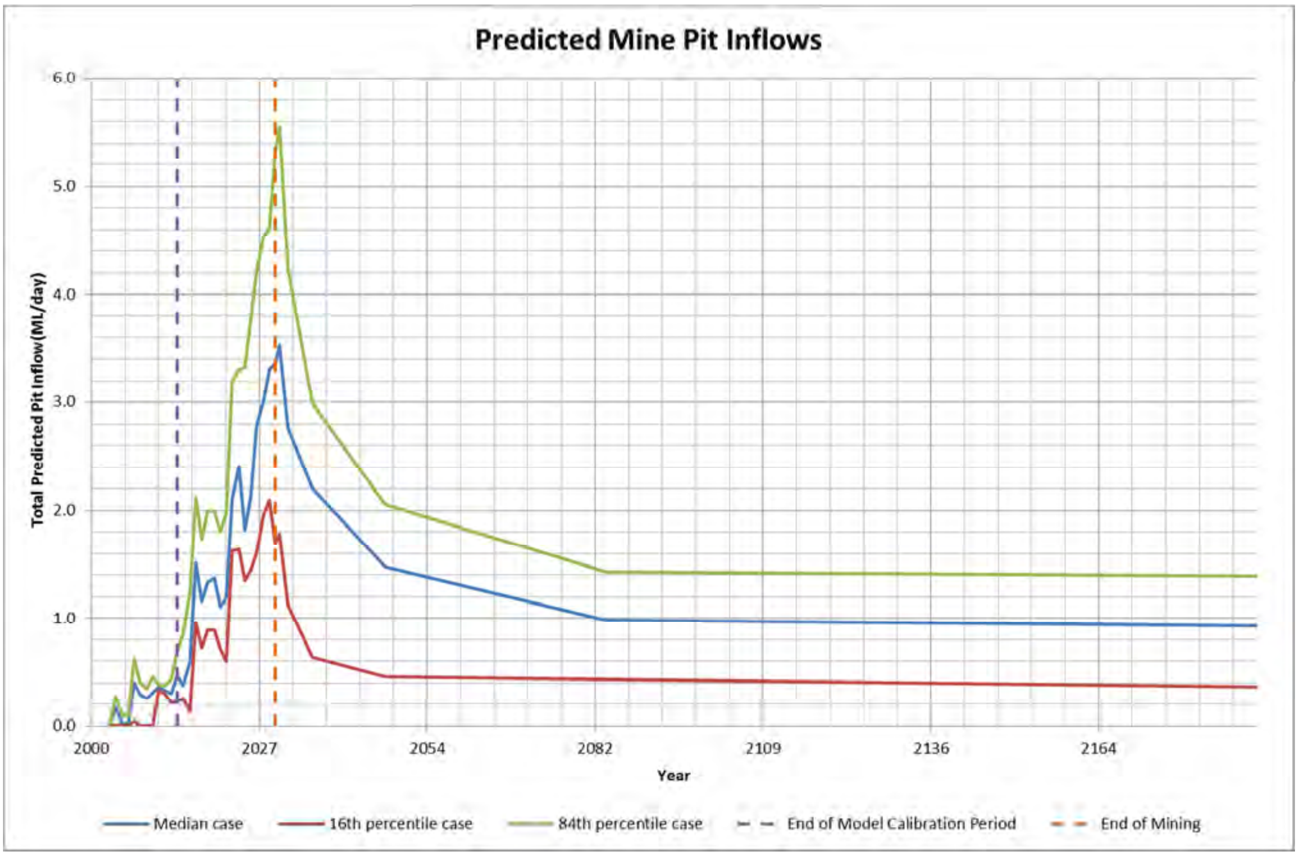


Figure 2-12 Predicted Mine Pit Inflows (median value plus one standard deviation either side)

2.1.24 Item 1x: Model Predictions – Sensitivity and Uncertainty

An assessment of model sensitivity and the uncertainty associated with model predictions is presented in the updated modelling report, provided as **Appendix B**.

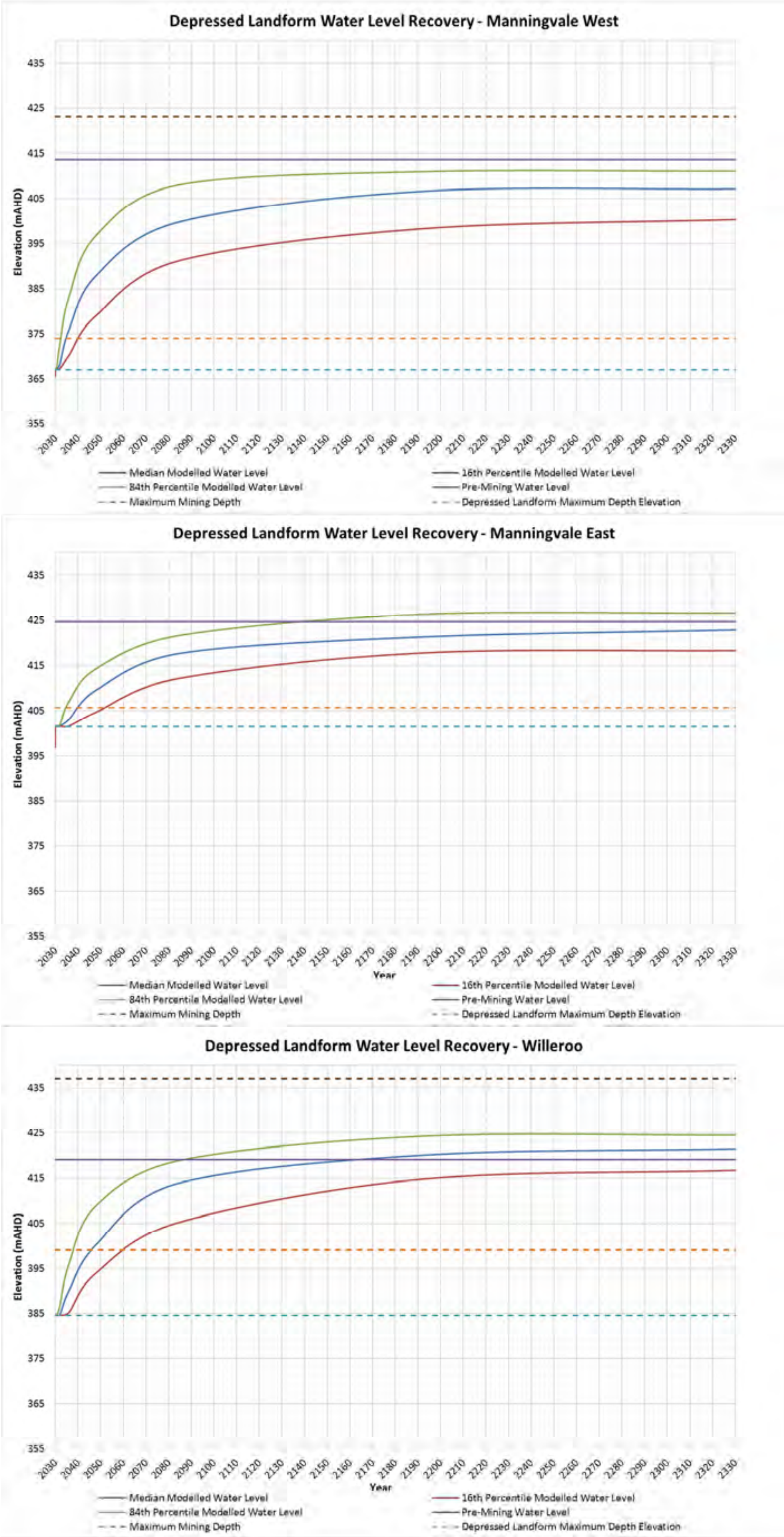


Figure 2-13 Depressed Landform Lake Evolution

2.2 Characterisation of surface water resources associated with Lagoon and Oakey Creeks

2.2.1 Item 2a: Existing Conditions – Spatial and temporal limitations of the baseline monitoring program

Baseline water quality conditions are described in the draft EIS in sufficient detail to satisfy the terms of reference (TOR) and assist in making a decision on the revised Project. NAC commits to conducting more detailed characterisation of baseline water quality conditions prior to the revised Project construction, as these additional data will be required for the purposes of monitoring compliance with Environmental Authority (EA) conditions. However, as agreed at the meeting with advisory agencies on 16 April 2014, additional baseline data are not required at this time for the purpose of impact assessment. The ephemeral flow conditions of waterways within the revised Project site requires regular monitoring involving rapid responses to rain events in order to comprehensively describe water quality conditions.

NAC commits to develop and implement a Receiving Environment Monitoring Program (REMP) in consultation with the Department of Environment and Heritage Protection (DEHP), to achieve a more detailed characterisation of baseline water quality conditions. The REMP will describe the objectives of water quality monitoring, show the location of all monitoring sites, and describe the methods that will be implemented to determine water quality in upstream reference sites, within mine storages and downstream of mining activities. The REMP will be developed in accordance with the ANZECC/ARMCANZ (2000) water quality guidelines and the Queensland Water Quality Guidelines and outline details of appropriate sensitivity of measurement, spatial and temporal sampling frequency and sample preservation and analytical methods.

2.2.2 Item 2b: Existing Conditions – Methods used to characterise macroinvertebrate diversity in Lagoon Creek

Macroinvertebrate assemblages of Lagoon Creek were characterised during a dry season aquatic ecology survey in January 2008. The aquatic ecologist completing the surveys adapted the AusRivAS survey methodology to the conditions of Lagoon Creek. It is recognised that the survey methods implemented were more suited to flowing streams rather than dams or dry season pools. The highly ephemeral nature of Lagoon Creek and general desirability to avoid macroinvertebrate sampling during times of flood (DEHP 2013, p. 102) mean that future assessments of macroinvertebrates will also most likely also take place during low or no flow conditions.

NAC commits to completing future macroinvertebrate assessments in accordance with the Queensland Monitoring and Sampling Manual (DEHP 2013). This will include the selection of sampling methods appropriate for dams or dry season pools, where they exist on site during the sampling. NAC recognises that regular monitoring of water quality and macroinvertebrates is desirable to develop a baseline of environmental conditions prior to construction works commencing, and to monitor the impacts of mining-related activities on aquatic ecology values. NAC commits to developing a Receiving Environment Monitoring Program (REMP) in consultation with DEHP, which will outline the objectives, methods and locations of future monitoring activities.

2.2.3 Item 2c: Existing Conditions – Groundwater dependent ecosystems (GDEs)

Within the EIS, the Australian Government Bureau of Meteorology's *GDE Atlas* was explored to obtain information regarding the occurrence of potential GDEs in the revised Project area and surrounds and reported in Chapter 6 of the EIS. This results of this search identified a lack of potential GDEs in and surrounding the revised Project site. In addition, comprehensive ecosystem mapping was undertaken within the revised Project site and reported in Chapter 7 – Terrestrial Ecology, and this work also identified a lack of GDEs.

Since the EIS, the Queensland Government Department of Environment and Heritage Protection's *WetlandInfo* database has been explored in order to further identify potential GDEs within the revised Project site and surrounds. The search of *WetlandInfo* extended to encompass the entire area of predicted groundwater drawdown as per the updated groundwater modelling as described in **Appendix B**.

The results of the search of the *WetlandInfo* database are shown in **Figure 2-14.** The database shows that there are several mapped terrestrial GDE occurrences (moderate confidence level) to the west and south of the revised Project site, mainly associated with outcropping and elevated basalt ridges. It is considered that these consist of remnant vegetation that has not been cleared by farming activities. The database also shows that there are several mapped terrestrial GDE occurrences (low confidence level) to the northwest, southwest, northeast and southeast of the revised Project site, associated with alluvial sediments of Oakey and Myall Creeks. Isolated surface expression GDEs (i.e. groundwater discharge zones) are identified (albeit with low confidence) to the far south and north of the revised Project site, associated with the alluvium of Oakey and Myall Creeks. It should be noted that none of the potential GDEs within the revised Project site and surrounds is mapped with a high confidence level.

Two point features (springs or waterholes) are identified in the database, one on Spring Creek (a tributary of Myall Creek) around 9 km northeast of the revised Project site, and one on Oakey Creek around 10 km southwest of the revised Project site.

It is considered that the low confidence surface expression GDEs identified in the database in the existing Mine area relate to dams and water storages associated with the Mine and are therefore not actually GDEs; it is worth considering this database error when viewing the broader results of the *WetlandInfo* search.

Regional ecosystem mapping (DEHP 2013 Version 8 QGIS) shows that the moderate confidence terrestrial GDEs to the west and south of the revised Project site, associated with outcropping basalt ridges, are likely to comprise:

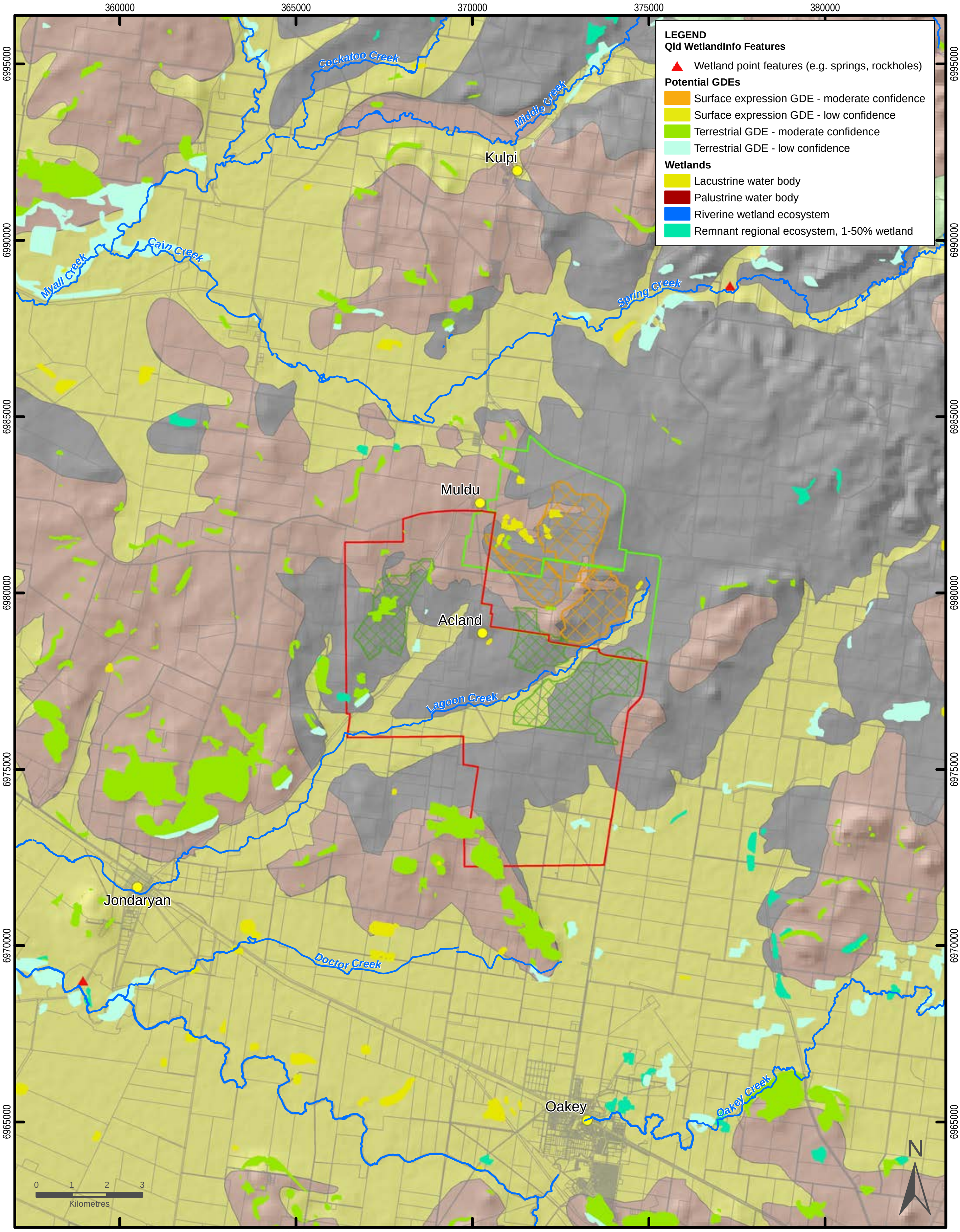
- *Dichanthium sericeum* grassland
- *Eucalyptus melanophloia* open woodland
- *Eucalyptus orgadophila* open woodland
- *Eucalyptus populnea*, *Eremophila mitchellii* shrubby woodland

The dominant ecological layer of the three woodland communities identified above comprises a range of eucalypt species including *E. populnea*, *E. melanophloia*, *E. orgadophila* and *E. crebra*. As these species form the ecologically dominant layer, these species will have the greatest rooting depth within the communities. The rooting depth of eucalypts is usually equivalent to the height of the tree. As reported in Chapter 7 of the EIS the *E. orgadophila* has a height of 18 m, while the *E. populnea* has a height of 12 m. On this basis, the rooting depth of these communities is between 12 m and 18 m, depending on the community.

The communities that are mapped as terrestrial GDEs of moderate confidence to the west and south of the revised Project site are located on basalt ridges and high points in the landscape, away from alluvial and riparian areas associated with local waterways. As such, it is expected that in these locations the depth to the watertable is greater than in the lower lying areas, and so it is considered there is only a small likelihood that these communities rely heavily on groundwater.

Model predicted groundwater drawdown, as it related to GDEs mapped within *WetlandInfo*, is presented in Figure **2-15** and **Figure 2-16**. Within the basalt aquifer, groundwater drawdown of between 1 and 3 m within zones of mapped terrestrial GDEs is expected in a small area 1 to 2 km to the northwest of the revised Project site. Within the Walloon Coal Measures, groundwater drawdown of between 10 and 20 m within zones of mapped terrestrial GDEs is expected in a small area 1 km west of the revised Project site.

At no time does predicted groundwater drawdown in the alluvium, discussed in **Appendix B**, encompass any GDEs mapped within the alluvium extent. Similarly, with no reductions in baseflow within Myall and Oakey Creeks predicted, it is not expected that the revised Project will impact on any of the mapped GDEs associated with these features.



LEGEND

- Watercourse
- Towns and Localities
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Surface Geology

- Alluvium (Qa)
- Basalt (Tm)
- Walloon Subgroup (Jw)
- Marburg Sandstone (Jbm)

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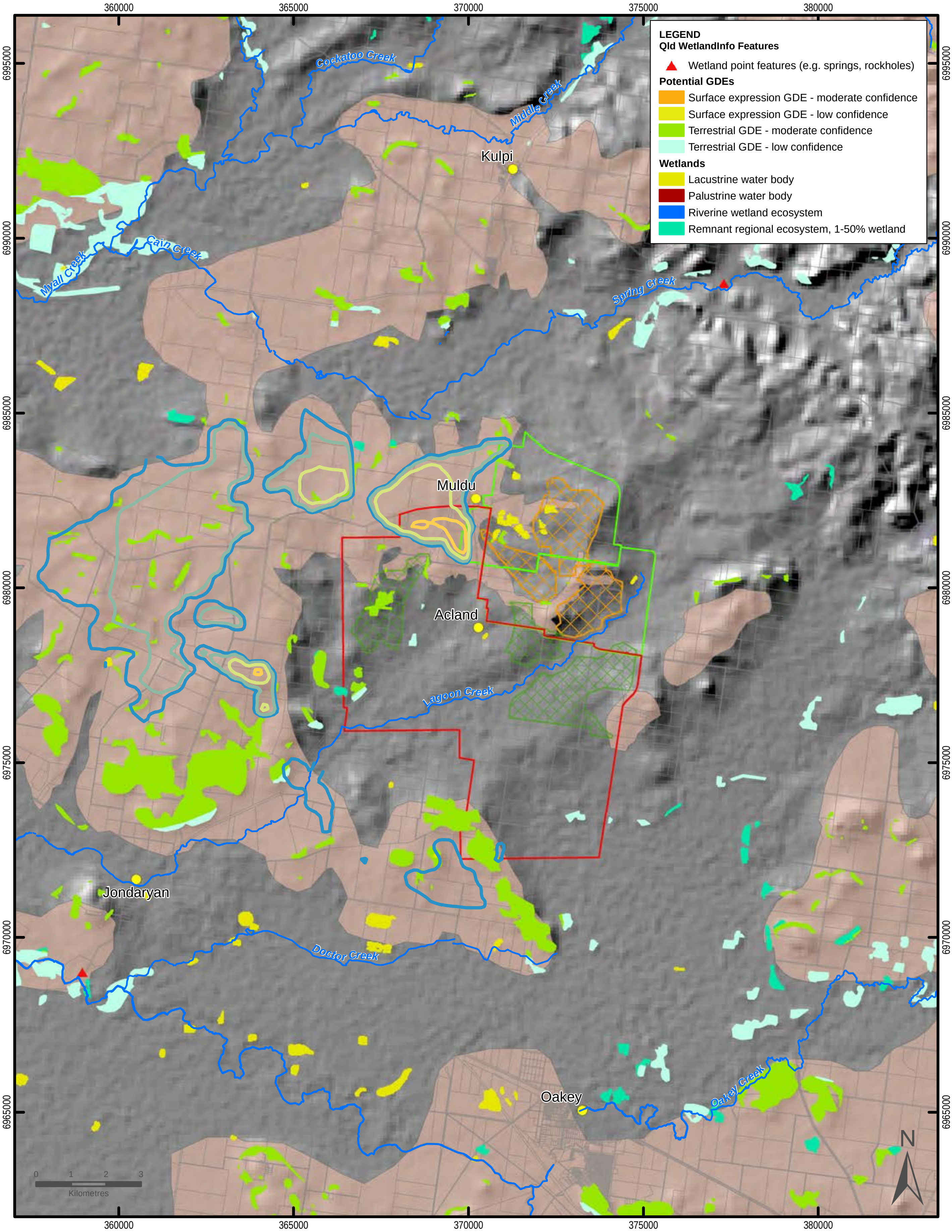
Figure 2-14 - Mapped Wetlands and GDEs (Qld WetlandInfo)

Scale 1:145,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140527_NewHope_Groundwater_Figure2-14_MappedWetlandsAndGDEs.mxd



LEGEND

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- Towns and Localities

- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission
- Modelled extent of Basalt

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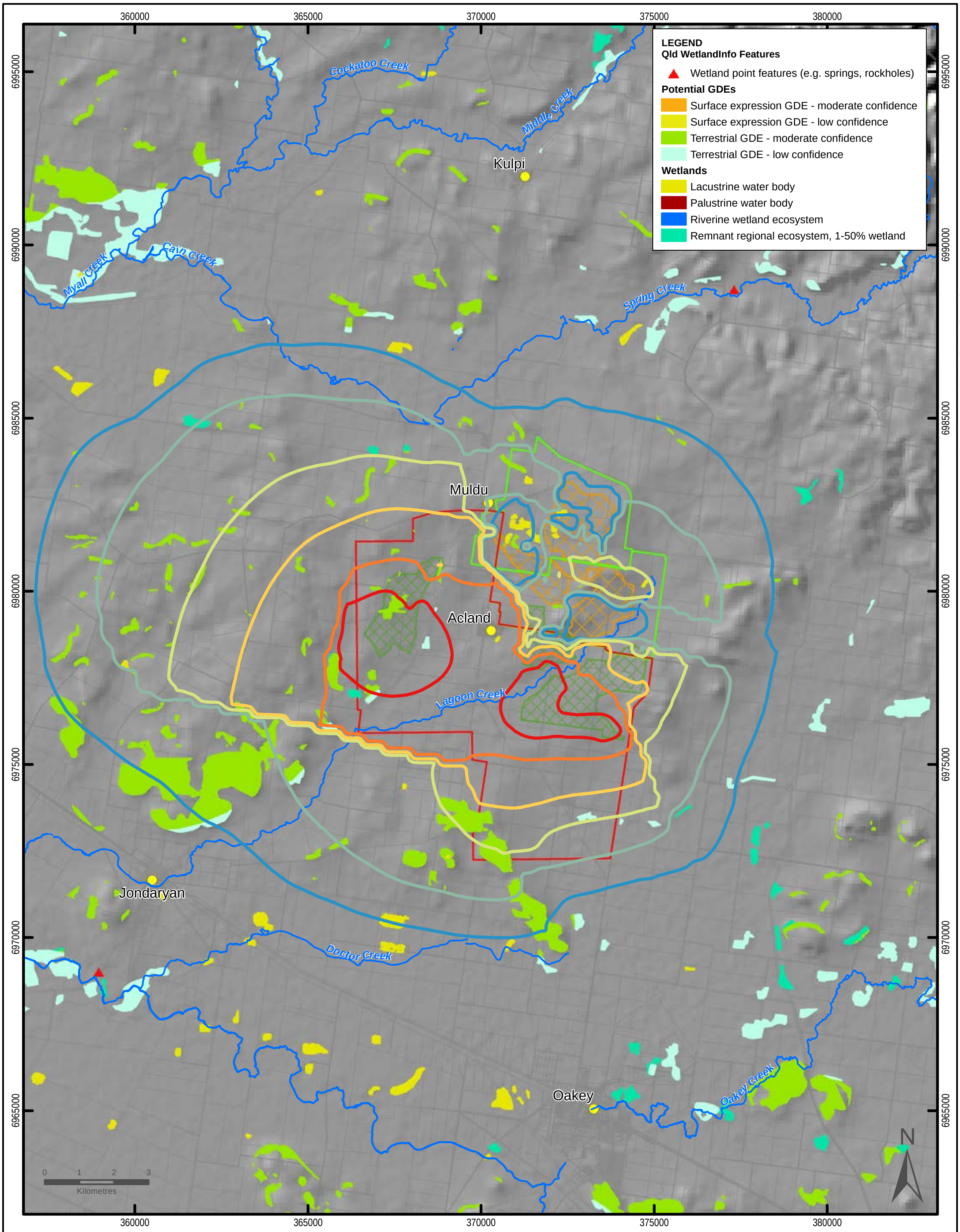
Figure 2-15 - Predicted Groundwater Drawdown in 2030 for the Tertiary Basalt in relation to Mapped Wetlands and GDEs

Scale 1:145,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-15_MappedWetlandsAndGDEs_BasaltDD.mxd



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SKM

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Figure 2-16 - Predicted Groundwater Drawdown in 2030 for the Walloon Coal Measures in relation to Mapped Wetlands and GDEs

Scale 1:145,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140617_NewHope_Groundwater_Figure2-16_MappedWetlandsAndGDEs_WalloonDD.mxd

2.2.4 Item 2d: Existing Conditions – Dependency of threatened species on groundwater dependent vegetation

Pteropus poliocephalus (Grey-headed Flying-fox) and *Phascolarctos cinereus* (Koala) have been recorded from the revised Project site, where these species make use of a wide variety of vegetation community and species. The occurrence of these species was reported in Chapter 7 of the EIS. The Grey-headed Flying-fox feeds on the nectar and fruits of a wide variety of trees and shrubs across the Acland area, including the revised Project site. The Koala has been recorded in poplar box woodlands across the revised Project site, particularly in the western areas of the site. Evidence of koala presence has also been recorded in most patches of woodland within the revised Project site, on alluvial, basalt and Walloon material. Evidence of the Koala presence has been scratches on tree trunks and scats.

Both the Grey-headed Flying-fox and the Koala make use of vegetation across the revised Project site and the Acland area and are not dependent on GDEs, specifically.

Open cut mining at New Acland has been underway for 12 years, since 2002. There is not any evidence of a decline in the quality of the vegetation that may be related to groundwater drawdown by existing mining.

2.2.5 Item 2e: Existing Conditions – Review of published literature in relation to existing aquatic and terrestrial ecosystems in the region

The results of a desktop assessment of published literature in relation to existing aquatic ecosystems of the revised Project were presented in Section 8.4.2 of the EIS (Chapter 8). This included a regional catchment overview, which described the aquatic values of waterways within the broader region, where information was available. It is noted that Cosser (1988) assessed the effects of discharges from a major sewage effluent outfall on benthic macroinvertebrates and water quality within a 105 km stretch of Gowrie Creek and Oakey Creek, between 1981 and 1984. While the study did not consider Lagoon Creek, it provided some relevant information on the environmental values of waterways downstream from the revised Project, albeit more than 30 years ago. At least 23 taxa of macroinvertebrates were identified by Cosser (1988) throughout the waterways studied, with species richness lowest near the effluent discharge point, a response to organic pollution. Creek discharge was typically stable throughout the study periods, with only occasional flood events.

The environment in the vicinity of the revised Project was described presented in Section 7.4 of the EIS (Chapter 7). There is a general lack of published literature on the terrestrial ecology values of the Acland area. The terrestrial ecology of the Acland area has been affected by clearing of vegetation. Remaining vegetation is fragmented across the Acland area, with remnants of vegetation found along waterways, on rocky outcrops and areas of poor soil quality. Flora and fauna records in a 5 k radius of the Acland, recorded by the Queensland Department of Environment and Heritage Protection, list a total of 102 species. These species comprise mostly common species that are typical of the Darling Downs region of Queensland. These records are consistent with the observations made during ecology surveys conducted for the Project. These species recorded for the Acland area and observed during the ecology surveys are those that are found in a fragmented landscape, where vegetation and habitat remain along watercourses, on areas unsuitable for agriculture and as scattered patches of vegetation in paddocks. Vegetation and habitat has been cleared from the majority of the Project site and the Acland area for agricultural purposes. Vegetation remains in small, scattered fragments along Lagoon Creek and other nearby creeks such as Spring Creek, Cain Creek and Doctor Creek. Very thin patches of vegetation are found along roadsides and fencelines across the revised Project site and Acland area. A similar pattern of vegetation distribution is seen in the general Acland area, with extensive areas of grazing and dryland cropping.

2.2.6 Item 2f: Water Quality Objectives – Adoption of aquatic ecosystem environmental value for Lagoon Creek

As described in Section 5.5 of the draft EIS (Chapter 5), the aquatic ecosystem values of Lagoon Creek have been impacted by land use practices including grazing. Much of the riparian zone and creek banks have been damaged, with obvious signs of scour and erosion observed during site surveys. Section 3.1.3.1 of the ANZECC/ARMCANZ (2000) Water Quality Guidelines describes ‘slightly to moderately disturbed’ ecosystems as including rural streams with runoff from land disturbed to varying degrees by grazing. Such a description is highly consistent with the current condition of Lagoon Creek.

The spatial distribution of aquatic ecosystem values along Lagoon Creek was described in Chapter 8 of the draft EIS. While a case could be made that some sections of Lagoon Creek are highly disturbed (e.g. Site AE1), such a classification would not be consistent with the description of ‘highly disturbed’ in the ANZECC/ARMCANZ (2000) Water Quality Guidelines, which relate to receiving runoff from intensive horticulture or urban environments. Also, the aquatic ecosystem values within degraded sections of Lagoon Creek are likely to be improved with the cessation of grazing and implementation of a conservation buffer zone around Lagoon Creek, following development of the mine. In this context, the selection of a ‘slightly to moderately disturbed’ condition was considered to be consistent with the future recovery of disturbed areas. The ‘high conservation/ecological value’ systems classification described in the ANZECC/ARMCANZ (2000) Water Quality Guidelines is clearly unsuitable for Lagoon Creek, as it relates to effectively unmodified or highly valued ecosystems, such as those occurring within national parks.

2.2.7 Item 2g: Water Quality Objectives – Rationale for water quality objectives

As described in section 5.5 of the EIS, local water quality objectives to protect the environmental values of Lagoon Creek have not been published and are currently under development. It is therefore anticipated that water quality objectives described in Chapter 5 of the EIS will be amended in the future, as further site-specific information becomes available. NAC commits to develop and implement a Receiving Environment Monitoring Program (REMP) involving regular sampling and analysis of water quality at locations upstream of, within and downstream of the revised Project. Local water quality objectives, combined with regular monitoring results, will provide additional sources of information to assess the water quality conditions within Lagoon Creek in the future. Such information will also aid in the establishment of more appropriate, site-specific water quality guidelines.

Section 3.3.2.5 of the ANZECC/ARMCANZ (2000) Water Quality Guidelines describes the default approach to deriving water quality trigger values, which is appropriate in the absence of site specific guidelines. The South-east Australia region includes South-East Queensland (Upland Rivers), and the location of the revised Project. In the absence of specific guidelines for the Condamine Catchment, guidelines from the Fitzroy catchment were also adopted for some aspects of the assessment, as they form the latest industry standards for mine water releases. The limitations associated with applying guidelines from a broad area (South-east Australia) and another catchment (Fitzroy) are acknowledged, and should be recognised in the interpretation of data.

2.2.8 Item 2h: Water Quality Objectives – Electrical conductivity water quality objective

The EC guideline of 500 µS/cm was derived from the Queensland Water Quality Guidelines (QWQG, p. 168) using the 75th percentile for the Conadmine-Macintyre Zone. As noted in the QWQG, salinity values in Queensland freshwaters show significant regional variation, arising from differences in geology and rainfall. It is agreed that further investigations at a local level, including regular flow weighted EC measurements are required to confirm the suitability of this guideline for long term application for the revised Project. Such analyses will be completed as part of the process of developing a REMP, in consultation with DEHP. As noted in Section 5.6.2 (p. 5-19) of the EIS, the available data suggest that EC concentrations in the Lagoon Creek Catchment are generally lower than those of the Oakey Creek Catchment. Such observations are consistent with the IESC suggestion that the guideline of 500 µS/cm may be high for Lagoon Creek.

2.2.9 Item 2i: Integrity and Limitations of the Data

Water quality in the vicinity of the revised Project is highly variable spatially and temporally. There is significant influence from infrequent flow events on water quality characteristics, an important consideration for interpretation of data. The most long-term and consistent water quality data for the revised Project are those obtained through Environmental Authority monitoring from the period 2008-2013 as reported in Table 5-6 of the EIS (Chapter 5). A small number of additional sampling events, during a range of flow conditions were also described, which provided further characterisation of the water quality conditions. Collectively, this information is suitable for the purpose of impact assessment. Further characterisation of water quality, involving more frequent sampling, is required to manage water quality values post approvals, including through the detailed characterisation of baseline conditions, with which water quality during construction and mining activities can be compared. The approach to such monitoring will be developed by NAC in a REMP, involving consultation with DEHP.

Limitations in the existing data include the temporal patchiness over which data were collected. Outside of the regular EA monitoring, a small number of monitoring activities were completed over a period of approximately 5 years. These data provide some indication of the water quality values under a range of flow conditions, yet do not provide a detailed data set for the purposes of developing site specific trigger values. All data were collected by suitably qualified and trained environmental staff and/or consultants. Where laboratory analysis was undertaken, it was completed by NATA-accredited laboratories. Sampling was generally conducted in a manner consistent with the Queensland Monitoring and Sampling Manual 2009 (DEHP, 2013).

2.3 Aquatic and terrestrial ecosystem assessments

2.3.1 Item 3a: Effect of baseflow reduction on Oakey and Myall Creeks aquatic and terrestrial ecosystems

An assessment of the aquatic and terrestrial ecosystems surrounding the revised Project site is provided in **Section 2.2.4** above.

The updated modelling predicts no reduction in streamflow in either Myall or Oakey Creek as described in **Appendix B**.

2.3.2 Item 3b: Effect of drawdown in the alluvium and basalt on groundwater dependant ecosystems

Refer to the response provided to Item 2c in **Section 2.2.3** above.

2.3.3 Item 3c: Impacts on threatened species associated with drawdown effects on groundwater dependant ecosystems

Refer to the response provided to Item 2c in **Section 2.2.3** and Item 2d in **Section 2.2.4** above.

2.4 Site water balance and discharge scenarios

2.4.1 Item 4a: Simulated daily flow regime in Lagoon Creek

The Department of Science, Information Technology, Innovation and the Arts (DISITA) are currently developing a daily rainfall runoff model for the upper Condamine catchment using the Sacramento model. The model has been developed to provide a long term historical flow series for the Gowrie Oakey Creek catchment to support the ROP amendment. The model was developed using upstream and downstream gauges and calibrated back to 1922. While this project was not finalised at the time of writing the EIS, DISTIA have provided the output for the flow apportioned to the Lagoon Creek catchment for use in the revised Project. This flow was apportioned based on creek catchment area.

It is acknowledged that the Lagoon Creek simulated flow shows possible inconsistencies with the Oaky Creek recorded streamflow. The simulated flow formed the basis of the assessment for the following reasons:

- Advised by DISTIA to be the best available data; and
- The Oaky Creek gauge may not be a reliable comparison as it has a short period of record with significant proportions of missing data.

The mine water management system for the Project does not rely heavily on releases from the project to Lagoon Creek. As outlined in Section 5.13.4 of the EIS, the range of releases predicted is only between 20 to 170 ML/yr. These release volumes generally account for less than 5 % of the water captured on the site annually. These volumes are considered to be very small and are unlikely to impact the water quality in Lagoon Creek.

Through the development of the REMP and the Environmental Authority conditions by DEHP the release strategy conditions will be develop to minimise potential for environmental harm. NAC is committed to collaboration with DEHP to develop appropriate release conditions

2.4.2 Item 4b: Salinity trigger values for discharge water quality

As described in section 5.5 of the draft EIS, local water quality objectives to protect the environmental values of Lagoon Creek have not been published and are currently under development. It is therefore anticipated that water quality objectives described in Chapter 5 of the EIS will be amended in the future, as further site-specific information becomes available. NAC commits to develop and implement a Receiving Environment Monitoring Program (REMP) involving regular sampling and analysis of water quality at locations upstream of, within and downstream of the revised Project. Local water quality objectives, combined with regular monitoring results, will provide additional sources of information to assess the water quality conditions within Lagoon Creek in the future. Such information will also aid in the establishment of more appropriate, site-specific water quality guidelines.

Section 3.3.2.5 of the ANZECC/ARMCANZ (2000) Water Quality Guidelines describes the default approach to deriving water quality trigger values, which is appropriate in the absence of site specific guidelines. The South-east Australia region includes South-East Queensland (Upland Rivers), and the location of the revised Project. In the absence of specific guidelines for the Condamine Catchment, guidelines from the Fitzroy catchment were also adopted for some aspects of the assessment, as they form the latest industry standards for mine water releases. The limitations associated with applying guidelines from a broad area (South-east Australia) and another catchment (Fitzroy) are acknowledged, and should be recognised in the interpretation of data.

2.4.3 Item 4c: Water release rules – water quality indicators

NAC commits to develop and implement a Receiving Environment Monitoring Program (REMP) involving regular sampling and analysis of water quality at locations upstream of, within and downstream of the revised Project. Local water quality objectives, combined with regular monitoring results, will provide additional sources of information to assess the water quality conditions within Lagoon Creek in the future. Such information will also aid in the establishment of more appropriate, site-specific water quality guidelines.

The development of release conditions under the Environmental Authority will address the key water quality indicators. NAC is committed to collaboration with DEHP to develop appropriate water quality indicators and trigger levels.

2.4.4 Item 4d: Water release rules – relation to measured ambient water quality

The development of the REMP and the site SWIMP will include monitoring upstream of the potential release point on the Lagoon Creek. This monitoring is aimed at characterising the inflowing water quality for Lagoon Creek prior to any releases from the Project. This monitoring seeks to inform the development of water quality objectives as well as an understanding of the Lagoon Creek regime to enable releases. The development of the water quality objectives and receiving water trigger levels aim to project Lagoon Creek from environmental impact.

The development of release conditions under the Environmental Authority will address the key water quality indicators and receiving water trigger levels. NAC is committed to collaboration with DEHP to develop appropriate water quality indicators and receiving water trigger levels.

2.4.5 Item 4e: Provision of verified, measured electrical conductivity values for treated wastewater proposed to be imported for operational use

It is acknowledged that the adopted value of 250 µS/cm for the imported treated effluent water quality may be potentially low. Guidelines levels for Electrical Conductivity in Queensland for recycled water for Class A+ treated effluent is 1,000 µS/cm. Electrical conductivity of the treated effluent may vary depending on a number of factors from the treatment plant. It is considered the most likely range of Electrical Conductivity is between 300 and 500 µS/cm for the treated effluent imported.

The treated effluent will not actively be released from the site and there is low probability of release due to an overflow event. If this event was to occur it would be in response to a significant rainfall event which is likely to dilute the treated effluent in the storage and the flows in the creek, unlikely to cause an environmental impact.

2.5 Elevated copper concentration in Lagoon Creek

Water quality monitoring during a flow event in 2013 detected dissolved copper concentrations at all four monitoring sites, with one site (AE4) slightly higher than the guideline value. Further monitoring is required to determine whether elevated copper concentrations regularly occur within Lagoon Creek, and if so, whether they are likely to be caused by mining-related activities or from natural processes. NAC will continue its water quality monitoring program prior to determining if the elevated copper concentrations seen in 2013 require further investigation.

2.6 Potential impacts of mine-affected water discharges on surface water users downstream of the proposed project

Modelling results indicate that in an average year only minor releases in the order of 20 ML/year will be made to Lagoon Creek with releases increasing to a maximum of 170 ML/year in the 1 % exceedance probability (very wet year). One surface water licence holder has been identified on Lagoon Creek with the next closest downstream user located after the Oakey Creek confluence 19 km downstream of the revised Project site. Therefore, the impacts of the revised Project to downstream users and the environment are expected to be negligible.

Section 5.4, page 7 of the EIS includes a spells analysis for impacts to the existing water user on Lagoon Creek. The spells analysis indicates there are some, albeit minor impacts on flow resources by reducing the duration of flow at the 90th percentile and increasing the interval between flows at the 50th and 90t percentile. However, it is noted that this analysis is conservative as it assumes the catchment removed by the revised Project is in affect for the full 117 years of data. Furthermore the analysis assumes that the catchment area is reduced by 10 km^2 for this entire period, a 5% reduction in catchment. In reality, the life of the mine's operations is only 20 years and staged mining operations combined with progressive rehabilitation further minimise the percentage of catchment disturbed by the system. This is presented in **Table 2-2** below.

Table 2-2 Reduction in catchment area as a percentage

Year	2019	2021	2023	2025	2029	Average
Reduction in catchment area	4.3%	4.0%	2.3%	1.8%	2.6%	3.0%

The event analysis in Section 5.4, page 7 of the EIS indicates that the revised Project is unlikely to impact on the Environmental Flow Objectives defined under the Water Resource Plan (Condamine and Balonne) Plan 2004.

The Water Resource Plan (Condamine and Balonne) Plan 2004 also defines Water Allocation Security Objectives (WASO) for the basin. These are defined under Division 2 Water allocation security objectives as:

13 Performance indicators for water allocation security objectives

The performance indicators for the water allocation security objectives are—

(a) the annual volume probability; and

(b) the 45% annual volume probability.

14 Water allocation security objectives

For making a decision mentioned in section 18(2), the water allocation security objectives are that—

(a) the annual volume probability for a water allocation group be not less than the annual volume probability for the group immediately before the decision is made; and

(b) the 45% annual volume probability for a water allocation group be not less than the 45% annual volume probability for the group immediately before the decision is made.

However, at the time of writing the WASO's for Lagoon Creek were still under development. In lieu of this the following commentary is provided with regards to the potential for the revised Project to impact on the volumetric probability for the water allocation group.

It has been estimated that at the peak of operation, the revised Project may lead to the 200 km^2 catchment being reduced by a maximum of 8.7 km^2, which corresponds to a 4.33% of the total catchment area. However, this will only occur for 2 years and throughout the life of the mine, with an average reduction of 3% of the life of mine.

The WSAO is that the Annual volume probability (AVP) for unsupplemented water = % simulation years that volume of water that can be taken by the group => nominal volumes for the group. Assuming the nominal volumes for the group remain the same, and that the relationship between catchment area and volume of flow is linear than we can conservatively assume that the unsupplemented AVP will be reduced by 3%. However, in reality this will only occur for the duration of the mining operations, which is 20 years.

The historical flow series for Lagoon Creek as provided by DISTIA was used to examine the influence of this 3% reduction flow volume over the 20 year life of mine. Eleven replicates of the flow series were created. In each series the mine and subsequent reduction in catchment area was simulated in a different decade. The purpose of this was to demonstrate the potential for the revised Project to impact on flow volumes and hence Annual volume probability, with allowance for climate variability. The analysis found that for the 50th percentile the mean annual volume was reduced by approximately 0.5%, with the 75th percentile (25% probability of exceedance) reducing the mean annual volume by less than 0.8%. This is considered to be a very small impact and the revised Project is considered unlikely to have a notable impact on the WSAO and volumetric reliability of water in the system.

Given the above analysis, the potential impact on downstream water users (including stock and domestic), as a result of the revised Project is considered minor. However, the NAC have also committed to the following measures to reduce the revised Project's impacts on downstream water users:

- Reducing the interference with clean catchments, undisturbed catchments will be diverted away from disturbed areas so that runoff will contribute to the Lagoon Creek flows and water resources available for downstream users.
- Proactive and progressive rehabilitation of the site. This progressive rehabilitation will enable more of the catchment to be diverted back to the creek thereby enabling runoff from this catchment area to contribute to flows in Lagoon Creek.
- Protecting and rehabilitating the creek corridor through both a no disturbance area and offset area. This will improve background water quality.
- Controlled releases from the site water management system through the proposed release condition. This will allow good quality water to be released from the site during periods of flow.

3. Question 2: Cumulative impacts with other developments in the region that may impact water resources

3.1 Confidence in the assessment of potential cumulative impacts on water resources and water-related assets

3.1.1 Item 7a: Choice of groundwater model boundaries used in the groundwater model with respect to OGIA's groundwater flow model

The OGIA's Surat CMA UWIR groundwater model (QWC, 2012) is a regional to basin-scale groundwater model designed to predict impacts on the complex groundwater systems of the Surat Basin and southern Bowen Basin as a result of multiple coal seam gas (CSG) project developments. The OGIA model domain encompasses a total area of 547.5 km (east-west) by 664.5 km (north-south), and in the southeastern corner of the model domain encompasses the New Acland revised Stage 3 Project site as shown in **Figure 3-1**. The OGIA model grid dimensions are 1,500 m by 1,500 m and it contains a significantly greater number of model layers (19 in total compared to 5 in the revised Project's model) to account for representing a large number of aquifers, both above and below the Walloon Coal Measures.

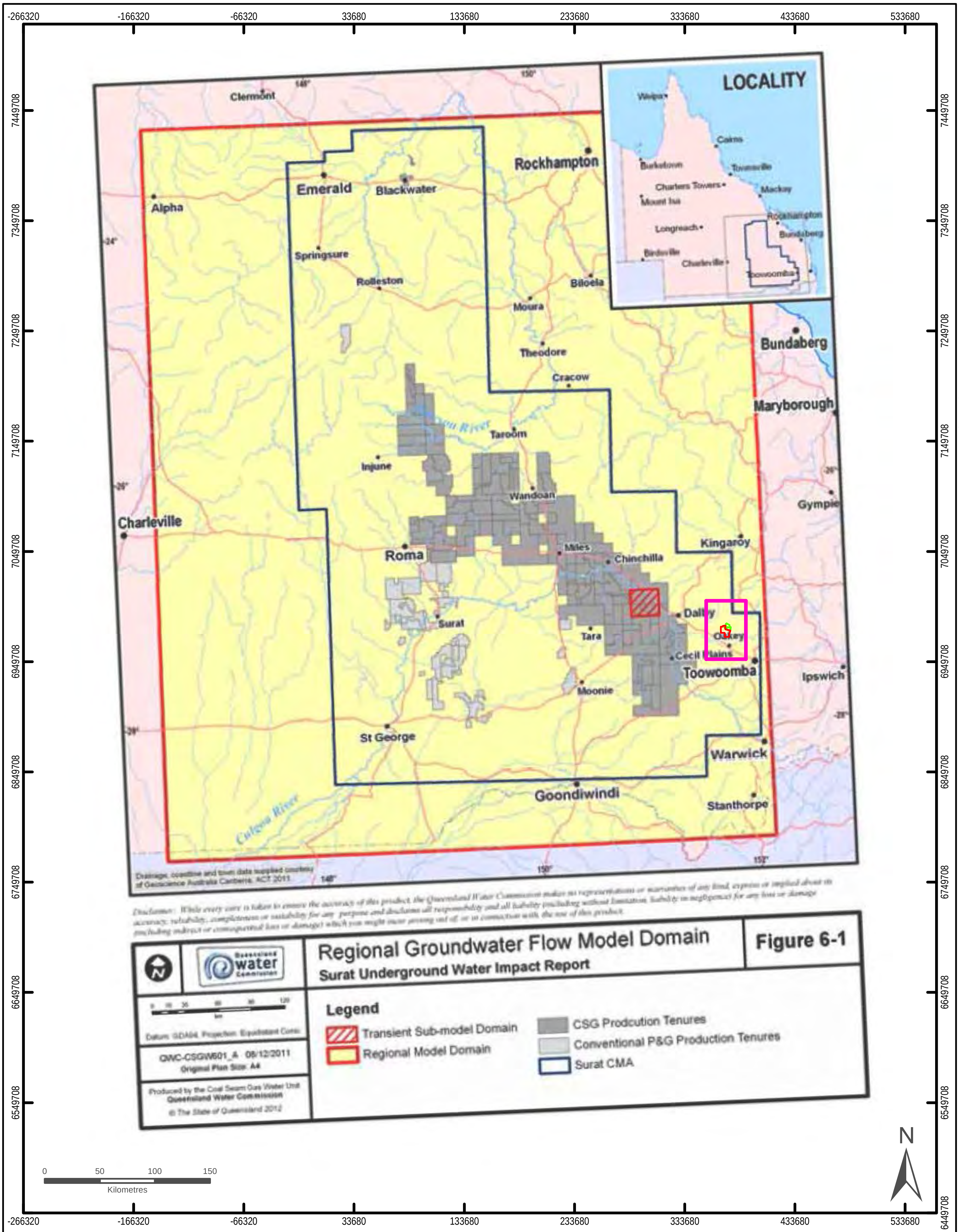
The size, complexity and model grid resolution of the OGIA model means it is inappropriate to incorporate much of the information provided by the OGIA model when setting boundary conditions for the New Acland revised Stage 3 Project model, which is designed to predict and assess groundwater drawdown of a significantly smaller development with a significantly smaller level of impact to the groundwater system.

Comparison of the modelled potentiometric heads within the OGIA model with the adopted New Acland model boundary conditions described in **Section 2.1.4** is discussed in **Section 2.1.5**. Although the head values are similar between the two models, the broader range of modelled heads in the New Acland model reflects the more detailed assignment of heads across a much more refined model grid, based on detailed analysis of actual potentiometric level data as described in **Section 2.1.4**.

Long term (30+ years from the commencement of CSG development) groundwater drawdowns predicted by the OGIA model, presented as **Figure 3-2** and **Figure 3-3**, indicate that the 1 m drawdown contour arising from CSG development extends to 18 km to the west of Oakey in the Marburg Sandstone, and 20 km to the west of Oakey in the Walloon Coal Measures. The New Acland revised Stage 3 Project model domain extends 20 km to the west of Oakey, meaning that at most, the OGIA model's predictions impact the western boundary of the revised Project's groundwater model by 1 m in the Walloon Coal Measures and 1 to 2 m in the Marburg Sandstone, in the long term (30+ years). Given that these drawdowns are relatively small and predicted to occur over a timeframe of more than twice as long as the operation of the revised Project, it is considered that incorporation of these drawdowns in the revised Project's model boundary conditions to take into account cumulative impacts is not warranted. Critically, predicted drawdown in the two models does not overlap for any aquifer, and remains at least 5 km distant (1 m drawdown contour) for the Walloon Coal Measures and 2 km distant (1m drawdown contour) for the Marburg Sandstone at all times.

3.1.2 Item 7b: Incorporation of existing groundwater entitlements into groundwater modelling

Refer to the response to Item 1g in **Section 2.1.7**. The incorporation of existing groundwater entitlements into the groundwater model has been determined to be unfeasible.



LEGEND

- New Acland Model Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

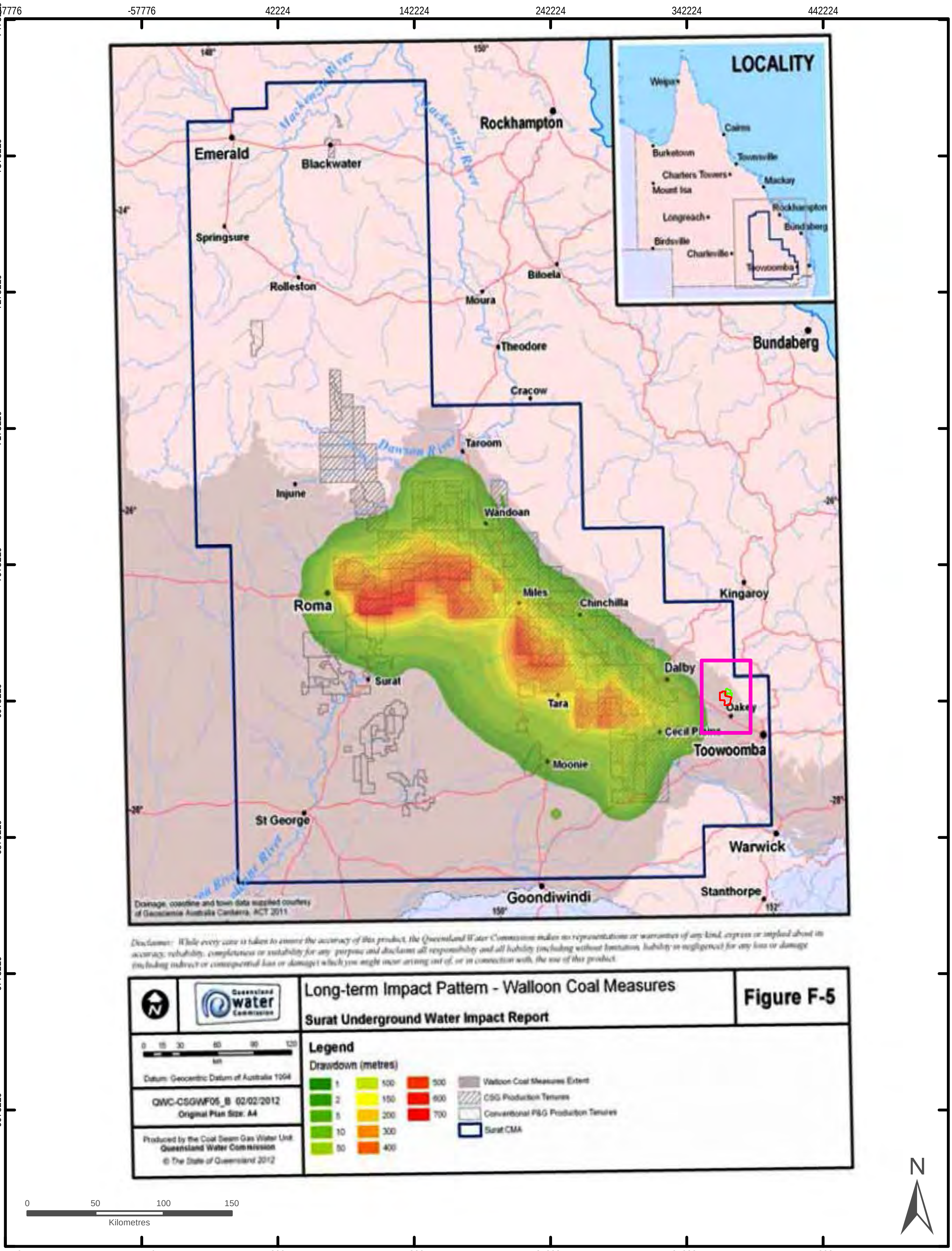
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 3-1 - Extent of the OGIA Model Domain in relation to the New Acland Stage 3 Model (QWC, 2012)

Scale 1:4,550,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_Groundwater\Resources\IESC Response\140516_NewHope_Groundwater_Figure3-1_OGIAModelDomain.mxd



LEGEND

- New Acland Model Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine

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NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 3-2 - Extent of OGIA Model Predicted Drawdown in the Walloon Coal Measures (QWC, 2012)

Scale 1:3,800,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_Groundwater\Resources\IESC Response\140516_NewHope_Groundwater_Figure3-2_OGIAModelWalloon.mxd

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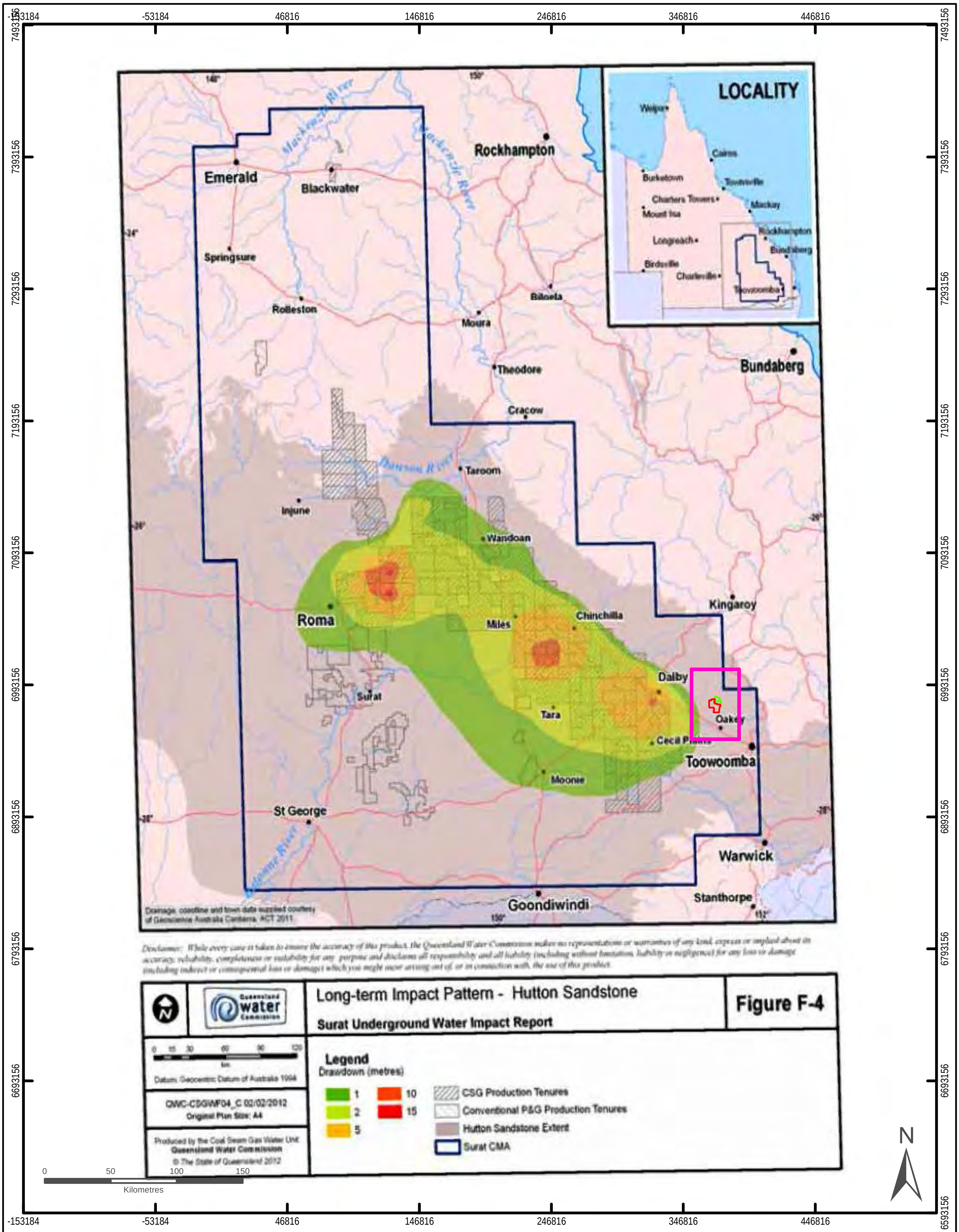


LEGEND

- New Acland Model Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine

NEW HOPE GROUP

SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 3-3 - Extent of OGIA Model Predicted Drawdown in the Marburg/Hutton Sandstone (QWC, 2012)

Scale 1:3,800,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_Groundwater\Resources\IESC Response\140516_NewHope_Groundwater_Figure3-3_OGIAModelMarburg.mxd

Produced: 28/08/2014

4. Question 3: Additional measures and commitments required to mitigate and manage impacts to water resources and water-related assets

4.1 Additional measures and commitments to mitigate and manage impacts to groundwater users

4.1.1 Item 8a: GMIMP Revisions

The proposed GMIMP presented in the revised Project's EIS was designed based on meeting the requirements of the EIS ToR and ensuring that groundwater monitoring undertaken for the revised Project adequately addresses model predictions of groundwater drawdown and impacts to existing users. In view of the updated numerical modelling undertaken since the EIS as described in **Appendix B**, the revised Project's proposed GMIMP has been revisited as suggested by the IESC in its Statement of Advice.

Assessment of the GMIMP presented in the EIS with respect to the revised predictions of groundwater drawdown and the location of groundwater receptors in the vicinity of predicted groundwater drawdown (landholder bores and potential terrestrial GDEs) has been undertaken. This assessment indicates that the proposed monitoring network remains appropriate for monitoring drawdown in all aquifers, with a good geographic spread of monitoring bores across each aquifer in the zone of predicted impacts.

The exception to this assessment is the IESC's suggestion of an additional Marburg Sandstone bore next to proposed monitoring bores 5A and 5B in the southeast corner of the revised Project site; as groundwater modelling indicates potential for drawdown in this area of between 2 and 5 m, and there is no Marburg Sandstone monitoring within 9 km of this recommended location, the IESC's suggestion is accepted. A Marburg Sandstone monitoring bore in this area will add significant information to the groundwater monitoring database, especially in the context of vertical gradients and assessment of hydraulic connection between the overlying Walloon Coal Measures and alluvial aquifers. **Figure 4-1** presents the updated proposed groundwater monitoring network. The revised GMIMP is presented as Appendix H of the AEIS.

The IESC's suggestion of an additional Walloon Coal Measures monitoring bore between existing Stage 3 monitoring bores 120WB and 114P (**Figure 4-1**) is not considered warranted, as there are already four existing Walloon Coal Measures bores within a 2 km radius of the IESC's recommended location. It is not considered that an additional monitoring bore in this location will add significant value to the GMIMP given the density of Walloon Coal Measures monitoring bores already in the GMIMP.

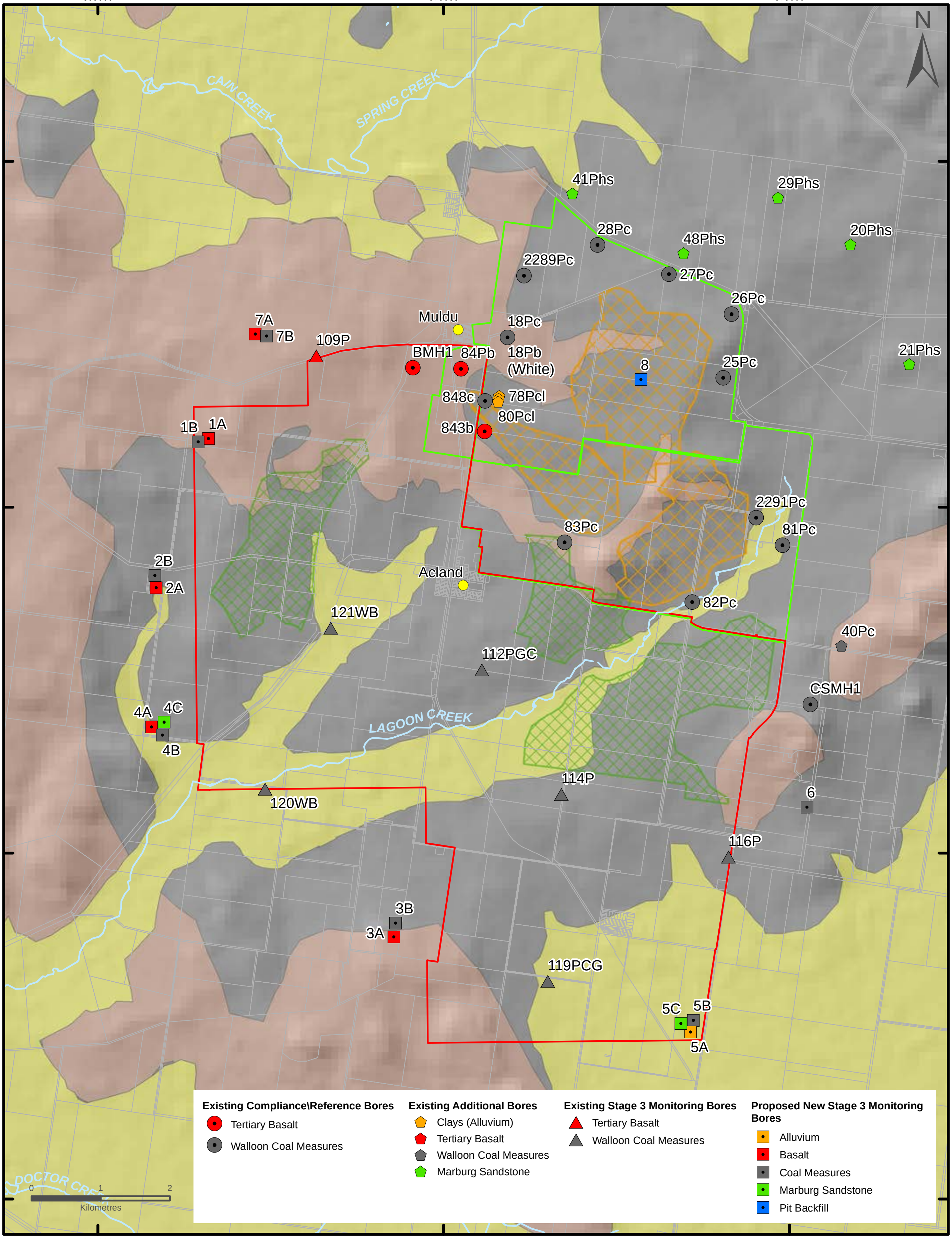
Selection of key groundwater monitoring bores and the identification of groundwater drawdown triggers at monitoring bores will occur as part of the EA process regulated by EHP should the revised Project proceed.

4.1.2 Item 8b: Real time flow and water quality monitoring stations on Lagoon Creek

NAC commits to the use of two existing real time flow and water quality monitoring stations already installed on Lagoon Creek, the locations of which are shown on **Figure 4-2**. It is noted that the stations will require upgrades prior to being suitable for the IESC's requirements. NAC considers the installation of additional stations to these two unwarranted, as additional stations will not add significant material benefit to the data collection program over and above the existing two stations.

4.1.3 Item 8c: Updated water balance modelling to incorporate a more robustly calibrated representation of the flow and quality regime within Lagoon Creek

NAC commits to undertake revised water balance modelling during the operation of the revised Project once data from the refurbished real time flow and water quality monitoring stations mentioned in **Section 4.1.2** is available.



LEGEND

- Towns and Localities
- Watercourse
- New Acland Coal Mine
- New Aland Coal Mine-Stage 3
- Existing Permission
- Stage 3 Pit Areas
- Cadastre

Modelled Surface Geology

- Alluvium (Qa)
- Basalt (Tm)
- Walloon Subgroup (Jw)
- Marburg Sandstone (Jbm)

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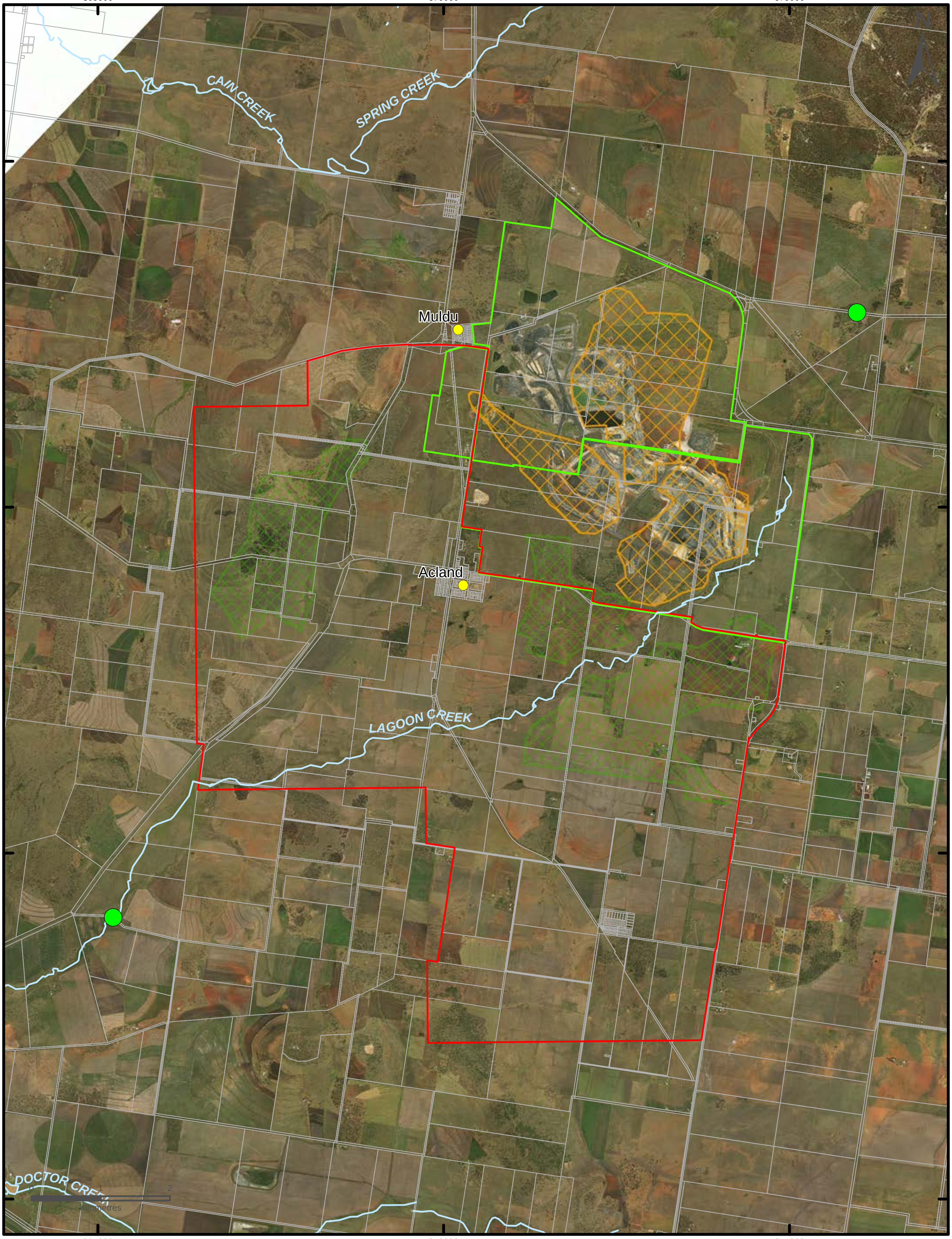
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 4-1 - Proposed Monitoring Locations

Scale 1:75,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)



LEGEND

- Surface Water Gauging Stations
- Towns and Localities
- Watercourse
- New Acland Coal Mine
- New Aland Coal Mine-Stage 3
- Existing Permission
- Stage 3 Pit Areas
- Cadastre

NEW HOPE GROUP

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NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 4-2 - Lagoon Creek Monitoring Locations

Scale 1:75,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\IESC Response\140527_NewHope_Surfacewater_Figure4-2_LagoonCreekMonitoringLocations.mxd

4.1.4 Item 8d: Regular monitoring of wastewater treatment plant effluent quality

Regular monitoring of wastewater treatment plant effluent quality is already undertaken at the Mine as part of EA conditions enforced by EHP.

4.1.5 Item 8e: Strategies to manage leachate from waste rock

A Waste Management Plan for the revised Project was included as Appendix J.13 of the draft EIS.

4.1.6 Item 8f: Certification of infrastructure design by a practising erosion control or waterway specialist

Independent certification of infrastructure design by a practicing erosion control or waterway specialist will be undertaken as part of the revised Project's detailed engineering design.

4.1.7 Item 8g: Implementation of an environmental inspection program to identify emerging erosion and sediment mobilisation issues

Implementation of an environmental inspection program to identify emerging erosion and sediment mobilisation issues will be undertaken as part of the WRMP for the revised Project, which was presented as Appendix J.4 of the draft EIS.

4.1.8 Item 8h: Presentation of commitments for surface and groundwater monitoring

Commitments for surface and groundwater monitoring are presented in the respective standalone WRMP and GMIMP for the revised Project; a combined Water Management Plan will not be prepared. The commitments of the WRMP and GMIMP are consistent with the National Water Quality Management Strategy.

4.2 Bioregional Assessment of the Northland Inland Catchment

It is noted that the Northland Inland Catchment has been identified as a Bioregional Assessment priority region. Data and relevant information from the revised Project will be made accessible for this Bioregional Assessment to assist the knowledge base for regional scale assessments.

5. Summary

The IESC's advice to the Australian Government Department of the Environment and the Queensland Office of the Coordinator-General on the New Acland Coal Mine Stage 3 Project's potential impacts on water resources can be summarised as a number of key themes as outlined on Page 2 of their Advice Statement (**Appendix A**). **Table 5-1** below outlines NHG's response to these general issues and where they are specifically addressed in this document.

Table 5-1 : Summary of IESC Advice and the NHG's Response

IESC Advice Statement		NHG Response	Document Reference
Theme	**Issue**		
Relevant Data and Information	Comparison between observed and modelled potentiometric heads is required.	Modelled potentiometric head maps are presented in **Appendix B**. Calibration hydrographs comparing modelled and observed potentiometric heads for monitoring bores are also presented in **Appendix B.**	**Section 2.1.2**
	Measured flow data is required to improve confidence in the characterisation of Lagoon Creek's flow regime. Additional monitoring data, across a greater spatial and temporal extent, is required to more robustly characterise existing surface water quality in Lagoon Creek.	The work undertaken in the EIS is appropriate to satisfy the ToR of the revised Project. The ephemeral flow conditions of waterways within the revised Project site requires regular monitoring involving rapid responses to rain events in order to comprehensively describe water quality conditions. However, NAC commits to conducting more detailed characterisation of baseline water quality conditions prior to the revised Project construction as part of Environmental Authority (EA) conditions. NAC also commits to develop and implement a Receiving Environment Monitoring Program (REMP) in consultation with the Department of Environment and Heritage Protection (DEHP), to achieve a more detailed characterisation of baseline water quality conditions. NAC also commits to the use of two existing real time flow and water quality monitoring stations already installed on Lagoon Creek.	**Section 2.2.1** **Section 4.1.2**
	Use of consistent salinity thresholds for discharges of mine-affected water to Lagoon Creek and inclusion of other key water quality indicators is required in the site water management system's release rules.	Local water quality objectives to protect the environmental values of Lagoon Creek have not been published and are currently under development. It is therefore anticipated that water quality objectives described in Chapter 5 of the EIS will be amended in the future, as further site-specific information becomes available. NAC commits to develop and implement a Receiving Environment Monitoring Program (REMP) involving regular sampling and analysis of water quality at locations upstream of, within and downstream of the revised Project. Section 3.3.2.5 of the ANZECC/ARMCANZ (2000) Water Quality Guidelines describes the default approach to deriving water quality trigger values, which is appropriate in the absence of site specific guidelines, and has been adopted for the revised Project. The development of release conditions under the Environmental Authority (EA) will address the key water quality indicators. NAC is committed to collaboration with DEHP to develop appropriate water quality indicators and trigger levels.	**Section 2.4.2** **Section 2.4.3** **Section 2.4.4**
	Assessment of ecosystems associated with Oakey Creek and Myall Creek is required.	The Queensland Government's *WetlandInfo* database has been searched for information relating to Oakey and Myall Creek's. A published literature review has also been undertaken and identifies only one existing published study relevant to the revised Project (Cosser,1988).. While the study did not consider Lagoon Creek, it provided some relevant information on the environmental values of waterways downstream from the revised Project, albeit more than 30 years ago. No impacts on Myall or Oakey Creek's from the revised Project are expected.	**Section 2.2.3** **Section 2.2.4** **Section 2.2.4** **Section 2.1.20** **Appendix B**

IESC Advice Statement		NHG Response	Document Reference
	Identification and assessment of terrestrial groundwater dependent ecosystems within the predicted cone of depression is required.	In addition to the BoM's *GDE* Atlas, the Queensland Government's *WetlandInfo* database has been searched for information relating to all types of GDEs within the predicted groundwater impact area. Some terrestrial GDEs have been identified to a moderate confidence level, mainly associated with remnant vegetation on elevated basalt ridges surrounding the revised Project site. Predicted drawdown from the revised Project is not expected to impact these potential GDEs.	**Section 2.2.3** **Section 2.2.4**
Application of appropriate methodologies	Confidence in the predictive capacity of the numerical groundwater model is low due to the adopted boundary conditions, anisotropic hydraulic conductivity and recharge values, and the lack of sensitivity testing of the model to these parameters. The exclusion of other groundwater users within the model domain further limits confidence in the model's predictions.	The numerical groundwater model has been refined, including all boundary conditions and parameterisation, and a sensitivity and uncertainty analysis has been performed. Inclusion of groundwater bore entitlements in the model is not possible as there is insufficient information to include them.	**Section 2.1.4** **Section 2.1.5** **Section 2.1.6** **Section 2.1.8** **Section 2.1.9** **Section 2.1.10** **Section 2.1.11** **Section 2.1.14** **Section 2.1.15** **Section 2.1.17** **Section 2.1.24** **Section 2.1.7**
Reasonable values and parameters in calculation	Numerical groundwater model boundary conditions.	The numerical groundwater model has been refined, including all boundary conditions.	**Section 2.1.4** **Section 2.1.5** **Section 2.1.6** **Section 2.1.8** **Section 2.1.9** **Section 2.1.10** **Section 2.1.11**
	The substantial differences between vertical and horizontal permeability values used in the numerical groundwater model.	The numerical groundwater model has been refined, including all parameterisation. Paramerisation has been tested with a stochastic sensitivity analysis during calibration. The approach adopted is consistent with other relevant groundwater models.	**Section 2.1.1** **Section 2.1.4** **Section 2.1.5**

IESC Advice Statement		NHG Response	Document Reference
	The application of a uniform percentage for recharge from rainfall for each time step in the numerical groundwater model.	The numerical groundwater model has been refined, including recharge. During model calibration recharge was allowed to vary according to the historic rainfall for the corresponding period. Multipliers, calculated by dividing the actual rainfall for the period by the average annual rainfall, are assigned for each period with records. These multipliers then correct for increased or decreased rainfall recharge by being multiplied by the calibrated percent of average annual recharge. For all other time periods, and for steady state calibration, the calibrated percent of average annual recharge is applied.	**Section 2.1.8**
	Uncertainties in the mine water balance resulting from the thresholds used for discharges of mine-affected water, which do not adequately consider ambient water quality or flow.	The Department of Science, Information Technology, Innovation and the Arts (DISITA) are currently developing a daily rainfall runoff model for the upper Condamine catchment using the Sacramento model. While this project was not finalised at the time of writing the EIS, DISTIA have provided the output for the flow apportioned to the Lagoon Creek catchment for use in the revised Project. It is acknowledged that the Lagoon Creek simulated flow shows possible inconsistencies with the Oakey Creek recorded streamflow. The simulated flow was used as formed the basis of the assessment for the following reasons: • Advised by DISTIA to be the best available data; and • The Oaky Creek gauge may not be a reliable comparison as it has a short period of record with significant proportions of missing data. The mine water management system for the Project does not rely heavily on releases from the project to Lagoon Creek. The range of releases predicted is only between 20 to 170 ML/yr. These release volumes for generally account for less than 5 % of the water captured on the site annually. These volumes are considered to be very small and are unlikely to impact the water quality in Lagoon Creek. As described in section 5.5 of the draft EIS, local water quality objectives to protect the environmental values of Lagoon Creek have not been published and are currently under development. It is therefore anticipated that water quality objectives described in Chapter 5 of the EIS will be amended in the future, as further site-specific information becomes available NAC commits to develop and implement a Receiving Environment Monitoring Program (REMP) involving regular sampling and analysis of water quality at locations upstream of, within and downstream of the revised Project. The development of release conditions under the Environmental Authority will address the key water quality indicators. NAC is committed to collaboration with DEHP to develop appropriate water quality indicators and trigger levels. The development of the REMP and the site SWIMP with will include monitoring upstream of the potential release point on the Lagoon Creek. This monitoring is aimed at characterising the inflowing water quality for Lagoon Creek prior to any releases from the Project.	**Section 2.4**
	Uncertainties in the mine water balance resulting from the assumed flow regime in Lagoon Creek, which is likely to over-estimate opportunities for discharges of mine-affected water.		

6. References

BOM, 2011 Bureau of Meteorology Average Aerial Evapotranspiration and Average Pan Evaporation Annual maps, viewed in 2011, www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp.

Cosser, 1988 Macroinvertebrate Community Structure and Chemistry of an Organically Polluted Creek in South-east Queensland, Australian Journal of Marine and Freshwater Research, 39, 671-83

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Appendix A. IESC Advice Statement

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development

Advice to decision maker on coal mining project

IESC 2014-045: New Acland Coal Mine Stage 3 (EPBC 2007/3423) – Expansion

Requesting agency	The Australian Government Department of the Environment and the Queensland Office of the Coordinator-General
Date of request	25 February 2014
Date request accepted	5 March 2014
Advice stage	Assessment

Advice

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (the IESC) was requested by the Australian Government Department of the Environment and the Queensland Office of the Coordinator-General to provide advice on the New Acland Coal Mine Stage 3 Project in Queensland at the draft Environmental Impact Statement (EIS) stage.

This advice draws upon aspects of information in the draft EIS, together with the expert deliberations of the IESC. The project documentation and information accessed by the IESC are listed in the source documentation at the end of this advice.

The proposed project is to expand and extend by up to 12 years, the New Acland Coal Mine, located approximately 35 km northwest of Toowoomba in the Lagoon Creek Catchment in the Clarence-Moreton Basin of Queensland. The proposed project involves creation of three open cut pits to increase production of coal from the Walloon Coal Measures from 4.8 Mtpa to 7.5 Mtpa of thermal product coal. Ancillary infrastructure developments would include upgrading the existing coal handling and preparation plant (CHPP) and associated stockpile areas as well as construction of an 8 km rail spur and balloon loop, and a train load-out facility.

The proposed project is located in the Lagoon Creek catchment. Lagoon Creek is an ephemeral creek flowing only after periods of significant rainfall. Lagoon Creek flows into Oakey Creek, which is part of the larger Condamine River Catchment of the Murray Darling Basin. Vegetation within the proposed project's development area provides habitat for *Pteropus poliocephalus* (Grey-headed Flying-fox) and *Phascolarctos cinereus* (Koala), which are listed as 'vulnerable' under the *Environment Protection and Biodiversity Conservation Act 1999*. Three 'endangered' and five 'of concern' regional ecosystems listed under the Queensland *Vegetation Management Act 1999* are also located within the proposed project's development area.

The IESC, in line with its Information Guidelines[1], has considered whether the proposed project assessment has used the following:

<u>Relevant data and information: key conclusions</u>

The following data and information are needed for potential impacts arising from proposed project to be fully assessed:

- A comparison between observed and modelled potentiometric heads, presented in a series of maps, to enable better assessment of the reliability of the groundwater flow model;
- Measured flow data to improve confidence in the characterisation of Lagoon Creek's flow regime;
- Additional monitoring data, across a greater spatial and temporal extent, to more robustly characterise existing surface water quality in Lagoon Creek;
- Use of consistent salinity thresholds for discharges of mine-affected water to Lagoon Creek and inclusion of other key water quality indicators in the site water management system's release rules;
- Assessment of ecosystems associated with Oakey Creek and Myall Creek; and
- Identification and assessment of terrestrial groundwater dependent ecosystems within the predicted cone of depression.

<u>Application of appropriate methodologies: key conclusions</u>

Confidence in the predictive capacity of the numerical groundwater model is low due to the adopted boundary conditions, anisotropic hydraulic conductivity and recharge values, and the lack of sensitivity testing of the model to these parameters. The exclusion of other groundwater users within the model domain further limits confidence in the model's predictions. A revised groundwater study is needed to improve confidence in the conclusions of the assessment documentation and enable development of appropriate measures to monitor and manage uncertainties and risks to water-related assets.

<u>Reasonable values and parameters in calculation: key conclusions</u>

Justification and/or further information are needed to support the proponent's approach or conclusions in relation to:

- Numerical groundwater model boundary conditions;
- The substantial differences between vertical and horizontal permeability values used in the numerical groundwater model;
- The application of a uniform percentage for recharge from rainfall for each time step in the numerical groundwater model; and
- Uncertainties in the mine water balance resulting from:
  - The thresholds used for discharges of mine-affected water, which do not adequately consider ambient water quality or flow; and
  - The assumed flow regime in Lagoon Creek, which is likely to over-estimate opportunities for discharges of mine-affected water.

The IESC recommends that the proponent develop any further project assessment documentation in line with its Information Guidelines[1].

The IESC's advice, in response to the requesting agencies' specific questions, is provided below.

Question 1: What does the Committee consider are the key uncertainties and risks of the project in relation to water resources and water-related assets? What does the Committee consider are the features of a monitoring and management framework that would address these uncertainties and risks? In responding to this question, please consider the matters raised by the State and Commonwealth (Attachments B and C) as well as additional information contained in the RFA.

1. There are uncertainties and risks in the hydrogeological conceptualisation and numerical groundwater model relating to design and implementation, which impact on the reliability of model predictions. An updated hydrogeological study that considers the following matters would enable risks to water resources to be more accurately evaluated. Suggested enhancements to the proponent's Groundwater Monitoring and Impact Management Plan (GMIMP) are provided in the response to Question 3. However, until the IESC's concerns about the groundwater model are addressed it is difficult to determine the appropriateness of the management and mitigation measures.

   Conceptualisation

   a. The absence of confining units of low hydraulic conductivity (with the exception of the Evergreen Formation) in the conceptual and numerical models will result in an unrealistic parameterisation of the hydrogeological regime. In particular, the low vertical hydraulic conductivities assigned to aquifers within the model will result in the underestimation of vertical drawdown propagation.

   Model Documentation

   b. Several predicted drawdown maps are provided; however, the pre-development head patterns have not been presented. A qualitative comparison between observed and modelled potentiometric heads, in a series of maps, would enable better assessment of model reliability. Modelled heads in each layer need to be presented, across the entire model domain, and at intervals representing pre-mining, the proposed project's operational phase, immediately post-mining, and longer term, in order to evaluate the modelled spatial and temporal pattern of groundwater flow.

   c. Extension of the water balance to include predicted post-mining groundwater levels data would enable evaluation of long term risks. An indication of fluxes by aquifer is also needed.

   Boundaries

   d. Constant head cells have been assigned along the northern, western, southern and part of the eastern margins of the model domain, which may result in unrealistic water budgets and laterally constrained drawdown within the model. Small variations in flow through these constant head boundaries may introduce large uncertainties in groundwater impact predictions.

   e. The setting of boundary conditions has relied on one potentiometric head map for the Walloon Coal Measures that is restricted to the vicinity of the proposed project. Confidence in the adopted boundary conditions could be improved by incorporating potentiometric head maps from other hydrostratigraphic units as this would help to identify groundwater flow features and provide justification for the selected model boundaries. The use of the Queensland Government's Office of Groundwater Impact Assessment (OGIA)[2] groundwater flow model would assist in determining the wider groundwater flow conditions.

f. Confidence in the groundwater model's predictive capability would be improved by providing and justifying the numerical values assigned to the constant head cells along the northern, western, southern and eastern boundaries. These values, in particular the relationship between the constant head values adopted at the same location but for different layers, may have a strong influence on the flow fields and heads, and hence the model's performance, including its predictive capability.

g. Choices for groundwater model boundaries should be described with respect to the spatial distribution of water entitlements and developments. The model excludes wells associated with other developments within the model domain; for example, the 9,000 ML/year groundwater entitlements that exist within 8 km of the proposed project. These developments are likely to invalidate the assumed boundary conditions, resulting in model constraints that produce inaccurate water budgets and model predictions.

h. Modelling of recharge as a fixed percentage of rainfall is considered simplistic in a climate where evaporation exceeds rainfall for most of the year. As recharge is the largest inflow to the model, even small variations in recharge introduce large uncertainties in groundwater impact predictions. It is recommended that the magnitude of recharge be estimated using methods other than model calibration (refer to Scanlon et al., 2002) and that a sensitivity analysis be undertaken to explore the robustness of the model predictions to variations in recharge rates.

i. The evaporation rate and extinction depth adopted in the model are not described. Evaporation appears to be the second most important contributor to flows leaving the model domain and small variations in evaporation may introduce large uncertainties in groundwater impact prediction.

j. Walls or flow barriers have been used to simulate faults in the model. While some faults may form barriers to flow, others may provide conduits for groundwater flow. Therefore, a justification for the use of flow barriers in the groundwater model is warranted.

k. Myall Creek is included in the groundwater model as a drain boundary condition despite evidence that groundwater elevations lay significantly below stream bed elevations. While it is noted that Myall Creek is situated to the north of the proposed project, justification is needed for the assumed boundary condition as it does not allow for seasonal flows to recharge groundwater.

<u>Model Layers</u>

l. An understanding of the conceptual hydrology across the entire model domain would improve understanding of lateral drawdown propagation from the Walloon Coal Measures to the Quaternary Alluvium. This may be achieved by inclusion of north-east to south-west cross-sections across the entire model domain and identification of the extent of each hydrogeological unit.

m. Information in relation to the geometry of the hydrostratigraphic units across the model, including the top, base and thickness of model layers, would aid understanding of how the numerical model parameterisation relates to the conceptual model. Individual model layers may include more than one unit which can result in an oversimplification of the hydrostratigraphy; in particular, inaccurate representation of hydraulic conductivity values. A description of how the south-west dipping conceptual hydrogeology was incorporated in the groundwater model is also needed.

n. The Lower Walloon Coal Measures are conceptualised as separated from the Walloon Coal Measures by clays with low primary porosity, rather than low vertical hydraulic conductivity.

Evidence, in the form of a potentiometric head map for the Lower Walloon Coal Measures, a comparison between heads from adjacent bores, or a head to elevation analysis within the Walloon Coal measures is needed to support this conceptualisation.

Model parameterisation and calibration

o. Calibrated model parameters indicate substantially higher horizontal and vertical hydraulic conductivity ratios than generally expected for alluvium, sandstone, and shale. Further, specific yield values are substantially lower than generally applied in groundwater models (for example, in Freeze and Cherry (1979)), which may underestimate unconfined aquifer storage. The rationale for the adopted values should be explained.

p. The information provided in the assessment documentation does not appear to support a scaled Root Mean Square (RMS) value of 8 per cent. Further explanation of the scaled RMS errors, including an analysis of those across the entire model domain, at appropriate time intervals and for each model layer, would improve confidence in model calibration.

Model predictions

q. Given the uncertainties in determining recharge and the limited documentation of the constant head boundaries across which flow occurs, there is the potential for large variations in the predicted drawdown and pit inflows, and an uncertainty/sensitivity analysis should be undertaken.

r. Predicted drawdown in 2030 indicates a steep cone of depression in the Walloon Coal Measures and basalts. Given the comparatively high hydraulic conductivity assigned to the adjoining Oakey Alluvium at this location, and the potential presence of groundwater dependent ecosystems in the Oakey Creek catchment, the cause of the restricted lateral drawdown in all hydrostratigraphic units should be clarified.

s. The presentation of drawdown contours for the Marburg Sandstone indicates that drawdown in this aquifer in the vicinity of the proposed project is greater than drawdown in the coal measures and basalts. This presentation is inconsistent with assessment documentation conclusions, which state that drawdown in the Marburg Sandstone is less that in the coal measures and basalts. This discrepancy should be reconciled.

t. The presentation of drawdown maps should be reviewed and amended to ensure that groundwater drawdown predictions in the alluvium are accurate. The assessment documentation lacks clarity around why contour lines cross the Lagoon Creek Alluvium but do not cross the alluvium associated with Oakey Creek.

u. The model predictions in terms of drawdown or stream depletion are shown in a deterministic manner; however, the model has considerable uncertainties in the calculation of the much larger components of recharge, flow across constant head boundary cells, and evapotranspiration. Inclusion of stochastic results or error/confidence intervals would better reflect the model uncertainties in the presentation of drawdown and stream depletions.

v. Use of pan evaporation to assess the final void water balance may lead to overestimation of evaporation rates as void walls can protect water in the void from wind and sunlight. It is suggested that this effect is explored in the revised hydrogeological study and alternate evaporation rate factors are adopted if applicable; for example, Castendyk and Eary (2009) use a factor of 0.7 to account for the reduced evaporation from pit lakes. If the rate of evaporation is reduced in the model, the predicted post-mining drawdown will be smaller and the predictions for the post mining water levels in the Manning Vale West, Willeroo and Manning Vale East voids would need to be revised. Inclusion of either stochastic results or error/confidence intervals would better reflect the model uncertainties in the presentation of post-mining drawdown and groundwater levels in the final voids.

w. The proponent states that the final voids will act as groundwater sinks and therefore will not permit pooled water to flow outwards into the regional groundwater system. This concept may apply to times when evaporation is larger than rainfall. If, however, episodic large rainfall events bring the pool level above that of the surrounding groundwater, there may be flow to the groundwater system; the probability of which would increase with a decreased model evaporation rate factor. Evaluation of the potential for groundwater recharge from the final voids would enable assessment of the proposed project's long term risks to groundwater quality.

x. A sensitivity and uncertainty analysis of the major components of the proponent's groundwater balance would enable evaluation of confidence limits for model outputs.

2. Additional characterisation of surface water resources associated with Lagoon and Oakey Creeks, as described below, would enable potential impacts on water quality and aquatic ecosystems to be more robustly evaluated.

<u>Existing Conditions</u>

a. Spatial and temporal limitations of the baseline monitoring program are not acknowledged in the assessment documentation. For example, characterisation of existing metals concentrations is based on one sampling event; however, the uncertainty associated with this limitation is not discussed. Consequently, existing conditions are difficult to ascertain and describe, which leads to reduced confidence levels when determining current state and condition; and attributing future impacts associated with the proposed works/activities. The following additional information would enable a more confident characterisation of the existing condition:

    i. existing and background water resource conditions, including explicit identification of processes such as different flow, mixing, chemical and redox regimes;

    ii. key water quality indicators and the appropriate sensitivity of measurement;

    iii. temporal and spatial sampling frequency; and

    iv. appropriate sample collection, sampling preservation and analytical methods.

b. Methods used to characterise macroinvertebrate diversity in Lagoon Creek are not appropriate for dams or dry season pools. It is suggested that future sampling rounds are undertaken in accordance with the Queensland Monitoring and Sampling Manual 2009 (DEHP, 2013)[3].

c. Groundwater dependent ecosystems, particularly those dependent on the alluvium and tertiary basalt aquifer, are not clearly identified in the assessment documentation. A map identifying seasonal groundwater depths and the vegetation present within the predicted area of groundwater drawdown would aid understanding of the extent and type of groundwater dependent ecosystems across the proposed project's area of influence. The identification of groundwater dependent ecosystems should be undertaken with reference to the Queensland Government's groundwater dependent ecosystem mapping in WetlandInfo.[4] Quantification of groundwater dependent ecosystem water requirements as well as the reliance of terrestrial ecosystems on shallow groundwater systems would inform the evaluation of the risks to these ecosystems posed by proposed project development.

d. Assessment of the dependency of threatened species, such as *Pteropus poliocephalus* (Grey-headed Flying-fox) and *Phascolarctos cinereus* (Koala) on groundwater dependent vegetation would provide a more comprehensive understanding of the significance of groundwater dependent ecosystems in the proposed project's development area.

e. The assessment documentation would benefit from a review of published literature in relation to existing aquatic and terrestrial ecosystems in the region; for example, see Cosser, P. (1988)[5].

<u>Water Quality Objectives</u>

a. The proponent identifies three possible descriptors of aquatic ecosystem environmental values for Lagoon Creek; however, the 'slightly to moderately disturbed' value has been adopted without explanation. Further justification for adoption of this environmental value, with due consideration of the spatial distribution of the environmental values along potentially affected watercourses, would ensure that this watercourse has been appropriately classified.

b. Explanation of the rationale for using water quality objectives developed for south-eastern Australia and the Fitzroy Basin would enable evaluation of their applicability to the Lagoon Creek and Oakey Creek catchments.

c. Evidence is needed to support the proponent's adoption of a water quality objective for electrical conductivity which is double the typical measured values in the upper reaches of Lagoon Creek. This should be informed by continuous, flow weighted electrical conductivity measurements.

<u>Integrity and Limitations of the Data</u>

d. Limitations of the monitoring data should be described in the assessment documentation; particularly in relation to: the ability of the existing data to describe the water resources both spatially and temporally; data quality; discussion on the analytes collected (for example, the suitability of some analytes as indicators or surrogates for other analytes).

3. Aquatic and terrestrial ecosystem assessments are limited to Lagoon Creek and do not acknowledge the potential for the following groundwater drawdown-induced impacts.

   a. The groundwater model predicts a reduction in baseflow for Oakey Creek and Myall Creek, indicating that there is a connection between the proposed project's operations and baseflow discharges to these watercourses. Characterisation of the existing aquatic and terrestrial ecosystems associated with Oakey Creek and Myall Creek is needed, clearly integrating the hydrological and water quality characterisations with the hydrogeological and ecological characteristics of the catchment.

   b. The assessment of potential groundwater drawdown impacts on terrestrial vegetation is based on the depth to groundwater in the Walloon Coal Measures. It is suggested that consideration of groundwater drawdown in the alluvium and tertiary basalt aquifers would more appropriately inform risks to groundwater dependent ecosystems.

   c. If the studies suggested in Paragraphs 2(c), 3(a) and 3(b) above indicate that groundwater dependent ecosystems are present and would be affected by groundwater drawdown, the consequential impacts on threatened species should be evaluated.

4. The proposed project's site water balance and proposed discharge scenarios are likely to underestimate potential impacts on water resources. The site water balance should be updated to address the following matters:

a. The simulated daily flow regime in Lagoon Creek is a poor fit in comparison to the calibration data set. The flow duration curve for Lagoon Creek is not consistent with measured data at the Oakey Creek stream gauge, which indicates that the proponent has assumed higher and more frequent flows in Lagoon Creek than are likely to be the case. This creates uncertainty with respect to the modelled mine water balance and a mine water management system that relies on releases to Lagoon Creek. Real time flow and water quality measurements on Lagoon Creek would more effectively direct the release of water from environmental dams to Lagoon Creek and inform the significance of any potential impacts;

b. Salinity trigger values for discharge water quality exceed the measured salinity within Lagoon Creek and may be expected to result in water quality exceeding the water quality objectives. This assessment is supported by model predictions which indicate that water quality downstream of the mixing zone in Lagoon Creek will exceed the 500 µS/cm water quality salinity objective proposed by the proponent. Adoption of release rules that enable water quality objectives to be achieved would minimise risks to water quality and water-related assets;

c. Inclusion in the water release rules of additional water quality indicators which can be measured reliably in the field, such as dissolved oxygen, turbidity, temperature and pH, would reduce the risk of adverse impacts to water quality and aquatic ecosystems. In addition, routine sampling of a more detailed list of analytes (e.g. metals) should be implemented to verify the effectiveness of mitigation and management measures;

d. Release rules that are specified in terms that relate to the measured ambient water quality in Lagoon Creek, in addition to flow rates during a release, could provide a more appropriate approach to avoiding environmental impacts, including changes to the flow regime; and

e. The provision of verified, measured electrical conductivity values for treated wastewater proposed to be imported for operational use by the proposed project would justify the proponent's adopted value of 250 µS/cm. This water will be managed as part of the mine water management system and potentially released to Lagoon Creek. Therefore, it is important that water quality parameters are accurately reflected within the site water balance.

5. An investigation of the cause of the elevated copper concentration in Lagoon Creek is needed to understand whether these concentrations result from natural processes. The analysis of measured data from the mine water management system would inform this assessment. If a link with existing mining operations is suspected and expected to be continued under the proposed project, water quality management and monitoring strategies would be needed to minimise water quality risks.

6. An evaluation of the potential impacts of mine-affected water discharges on surface water users downstream of the proposed project would provide a more comprehensive analysis of risks to water-related assets.

Question 2: Have cumulative impacts with other developments in the region that may impact water resources been sufficiently addressed?

7. The proponent has qualitatively considered cumulative groundwater impacts, which the IESC considers reasonably deals with 4 surrounding mines but not coal seam gas (CSG) activities, or entitlements. Confidence in the proponent's assessment of potential cumulative impacts on water resources and water-related assets would be improved by:

   a. Describing the choice for groundwater model boundaries used in this model with respect to OGIA's groundwater flow model. In particular, CSG activities may affect the heads in the proponent's groundwater model, in particular along boundaries, which could render the proponent's boundary assumptions invalid; and

b. Incorporating entitlements from other groundwater users in the model domain into an updated groundwater model. These entitlements represent over 9,000 ML/year of groundwater abstraction, which is large compared to modelled pit inflows. Therefore, their exclusion may result in inaccurate model predictions.

Question 3: Are additional measures and commitments required to mitigate and manage impacts to water resources and water-related assets?

8. A number of additional measures and commitments are suggested to mitigate and manage impacts:

   a. Following revision of the numerical groundwater model, it is suggested that the proponent's GMIMP consider and incorporate:

      i. Selection of key groundwater monitoring bores on the basis of criteria such as target aquifers, and potentially affected groundwater users and groundwater dependent ecosystems;

      ii. Selection of key groundwater monitoring bores and commencement of monitoring within a timeframe than enables seasonal and inter-annual measurement of groundwater flux;

      iii. Identification of modelled drawdowns and triggers based on the updated hydrogeological study suggested in this advice;

      iv. Groundwater data from the existing New Acland Mine's monitoring program and/or other regional monitoring programs;

      v. A bore at coordinates 370000:6976000 to monitor the predicted 20m drawdown in the Walloon Coal Measures between monitoring bores 114P and the unnamed monitoring bore to the west near Lagoon Creek; and

      vi. An additional monitoring bore in the Marburg Sandstone (near bores 5a and 5b), given the uncertainties in relation to predicted drawdown within this aquifer described in Paragraph 1(s);

   c. Real time flow and water quality monitoring stations on Lagoon Creek would enhance management of controlled releases from the proposed project's environmental dams. It is suggested that measured water quality parameters include turbidity, dissolved oxygen, pH and electrical conductivity, and that these are measured in the environmental dams, as well as near the release point and at the junction with Oakey Creek;

   d. Risks to water quality would be minimised by updating the water balance to incorporate a more robustly calibrated representation of the flow and quality regime within Lagoon Creek. Based on the results of the updated study, the size of the environment dams and frequency and duration of releases may need to be reassessed;

   e. Regular monitoring of wastewater treatment plant effluent quality would enable early detection of any changes to effluent quality over time;

   f. Incorporation of suitable strategies to manage leachate from waste rock with elevated manganese concentrations into the proponent's environmental management plan would minimise risks to water quality;

g. Independent certification of infrastructure design by a practising erosion control or waterway specialist would provide a greater level of confidence that works within the floodplain would create minimal long term impacts;

h. Implementation of an environmental inspection program to identify emerging erosion and sediment mobilisation issues would enable early detection and management of potential impacts; and

i. Commitments for surface and groundwater monitoring should be presented as part of a water monitoring plan and should be consistent with the National Water Quality Management Strategy.

9. The Northland Inland Catchment has been identified as a Bioregional Assessment priority region. Data and relevant information from the proposed project should be made accessible for this Bioregional Assessment to assist the knowledge base for regional scale assessments.

Date of advice	10 April 2014
Source documentation available to the Committee in the formulation of this advice	New Hope Group (2014) Environmental Impact Statement for the New Acland Coal Mine Stage 3 Project
References cited within the Committee's advice	[1] Information Guidelines for Proposed projects Relating to the Development of Coal Seam Gas and Large Coal Mines where there is a Significant Impact on Water Resources available at: http://iesc.environment.gov.au/pubs/iesc-information-guidelines.pdf [2] Queensland Water Commission (QWC), 2012. *Underground Water Impact Report for the Surat Cumulative Management Report* [3] Department of Environment and Heritage Protection (2013) *Monitoring and Sampling Manual 2009*, State of Queensland, Brisbane [4] Queensland Government (2014) Wetland Info. URL: http://wetlandinfo.ehp.qld.gov.au/ [5] Cosser, P. R. (1988) Macroinvertebrate Community Structure and Chemistry of an Organically Polluted Creek in South-east Queensland, *Australian Journal of Marine and Freshwater Research*, 39, 671-83

Appendix B. Updated Groundwater Numerical Modelling Report

Groundwater Modelling Technical Addendum

NEW ACLAND COAL

New Acland revised Stage 3 Project AEIS

13 August 2014

Document history and status

Revision	Date	Description	By	Review	Approved
1	4 May 2014	Draft Report	Brian Rask	Ray Hatley	Peter Smith
2	18 June 2014	Updated to include post-mining void modelling and Peer Review comments	Brian Rask	Brian Rask	Peter Smith
3	25 June 2014	Updated to include Peer Review comments	Derwin Lyons	Brian Rask	Peter Smith
4	13 August 2014	Updated following CoG review	Brian Rask	Derwin Lyons	Peter Smith

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments
1	2 May 2014	5 May 2014	NHG	
2	18 June 2014	18 June 2014	NHG	
3	25 June 2014	25 June 2014	NHG	
4	13 August 2014	13 August 2014	NHG	

JACOBS

New Acland revised Stage 3 Project AEIS

Project no:	QE06644
Document title:	Groundwater Modelling Technical Addendum
Document no:	QE06644.043
Revision:	4
Date:	13 August 2014
Client name:	New Hope Coal
Client no:	
Project manager:	Peter Smith
Author:	Brian Rask
File name:	I:\QENV2\Projects\QE06644\Phase 3 - AEIS Compilation\AEIS\04 NAP AEIS V1 Master _ Edits followng CoG Submission\00 Appendices\APP F IESC Uncertainty Analysis\App F Updated groundwater model tech report_bmr.docx

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Contents

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to provide summary documentation of the groundwater modelling assumptions, setup and results in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.
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On 12 December 2013 Jacobs announced the merger with Sinclair Knight Merz. Jacobs is one of the world's largest and most diverse providers of technical, professional and construction services.

1. Introduction

The groundwater model reported in the draft EIS is classified as a “Class 2” model (SKM 2012); commensurate with the level of input data available at the time of EIS production. This was deemed suitable for the purpose of the State level assessment of the EIS by SKM, and agreed with DNRM in his preliminary assessment regarding the groundwater model. The original model was reported in the revised Project’s draft EIS (SKM, 2013).

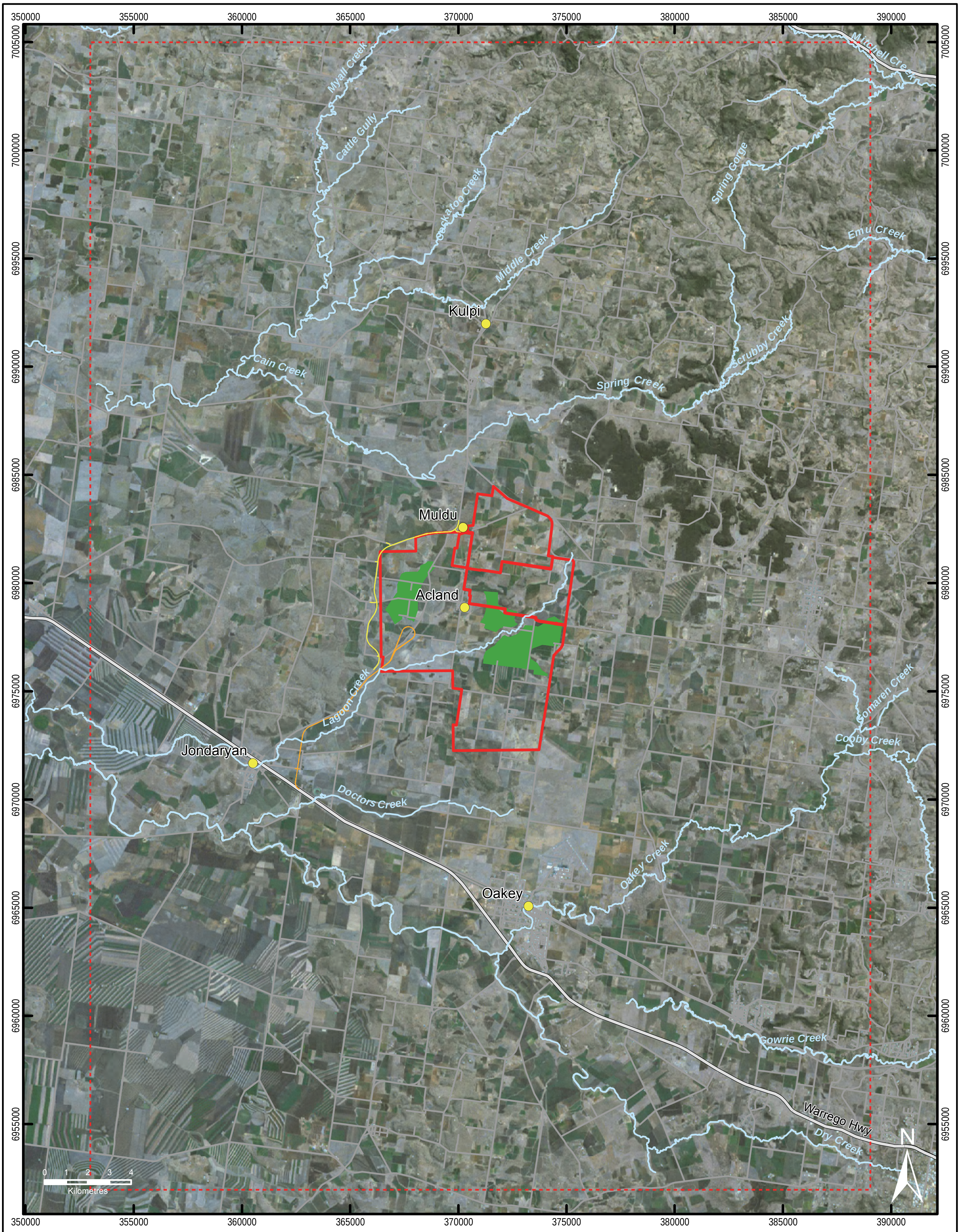
Since the original commencement of work for the EIS, additional information and data became available that if incorporated could provide additional confidence in the model and model results. Given the increased level of scrutiny and reporting requirements as a result of the introduction of the Commonwealth Water Trigger review (including a submission to the IESC), the NHG commissioned Jacobs to undertake a refinement of the numerical groundwater model used for the groundwater impact assessment for the proposed New Acland Stage 3 Project operations (the revised Project) (**Figure 1-1**).

The objective of the additional modelling was to update the model with the latest data available as well as to conduct a sensitivity and uncertainty analysis, as required for the Water Trigger review. The sensitivity and uncertainty analysis are to further assist in the quantification of the potential impacts of the proposed mining operation on the groundwater regime, and to further clarify mitigation and contingency measures, where applicable.

The confidence level of the model predictions is directly related to the availability of input data and was increased by incorporating the additional input data. The following courses of action were undertaken in order to increase model confidence:

- Reinterpretations and data analyses:
  - Update and refine the model layers based upon a review and collation of the most recent LiDAR, geologic model, and borehole logs (publically available, from landowners from recent survey, and from NAC).
  - Update model boundary conditions using the latest LiDAR, where available, for improved accuracy in water table and surface and groundwater interactions.
- Recalibration: After the refinements of model setup, the model was recalibrated. The calibration process included a stochastic based sensitivity and uncertainty analyses. Sensitivity and uncertainty assessments for calibration are key criteria for model confidence classification, as per the groundwater modelling guidelines (SKM, 2013), and are also considered a key component of the Commonwealth assessment.
- Predictive Simulations: The predictive simulations included a stochastic based sensitivity and uncertainty analyses. Sensitivity and uncertainty assessments for predictive simulations are key criteria for model confidence classification, as per the groundwater modelling guidelines (SKM, 2013), and are also considered a key component of the Commonwealth assessment.
- Updated Model report.

Models often require continuous revisions and updates as more information becomes available or when different questions are asked of it. This latest revision of the model, and the subsequent revised predictions, should be viewed as an evolution of the understanding of the system as more studies and information become available. As such the results presented herein should be considered as superseding the previously reported results as they are a better reflection of our current understanding of the system and how it behaves.



LEGEND

- Towns and Localities
- Creeks

Revised Rail & Road Infrastructure

- Revised Jondaryan-Muldu Road Diversion
- Revised Rail Spur and Balloon Loop Alignment
- Model Extent
- Mining Tenements
- Stage 3 Pit Areas

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NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 1-1 - Project Area

Scale 1:232,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140416_NewHope_Groundwater_Figure1-1_ProjectArea.mxd

Produced: 25/08/2014

2. Background Information

All information on which the model is based has either been provided by NAC, or is publicly available via the internet or literature references. A description of data sources is provided in the following sections.

2.1 Supplied Information

NAC provided the following datasets and background information:

- Surface Topography (LiDAR) grid files
- Mine Plan (Years 2017-2030 (2-yr increments) and Closure)
- Well construction and geologic logs
- Updated groundwater monitoring database
- Landowner survey database

2.2 Other Data

Additional information gathered by Jacobs were:

- Climate data
    - Annual and Monthly rainfall data at Oakey Bureau of Meteorology rainfall station (www.bom.gov.au)
    - Streamflow data at Station 422359A Oakey Creek at Jondaryan (DNRM, 2014)
    - Actual and Potential evapotranspiration rates (BOM, 2014)
- DNRM bore logs and water level data
- SRK Geology Maps (SRK, 2006)

3. Hydrogeological Setting and Conceptual Model

A conceptual model is a simplified representation of the real system. It aims to identify the most important hydrogeologic processes and geological units, and to quantify them in a manner that can then be translated into a numerical model. Thus the conceptual model forms the basis for the numerical groundwater flow model. The EIS chapter for groundwater provides a comprehensive description on the background information available and the overall conceptualisation of the hydrogeological regime. A summary of the conceptual model that forms the basis for the groundwater model are described below.

The conceptual hydrogeological model describes the aquifers present within the revised Project site, how they interact with each other and surface waters, and their attributes such as groundwater depth, thickness, transmissivity, storativity and hydraulic conductivity. The aquifers present within the revised Project site include the following:

- Quaternary Alluvial aquifer;
- Tertiary Basalt aquifer;
- Walloon Coal Measures aquifer;
- Marburg Sandstone aquifer; and
- Helidon Sandstone aquifer.

These aquifers are described further in the following Sections. **Figure 3-1** presents a schematic of the conceptual hydrogeological model for the revised Project.

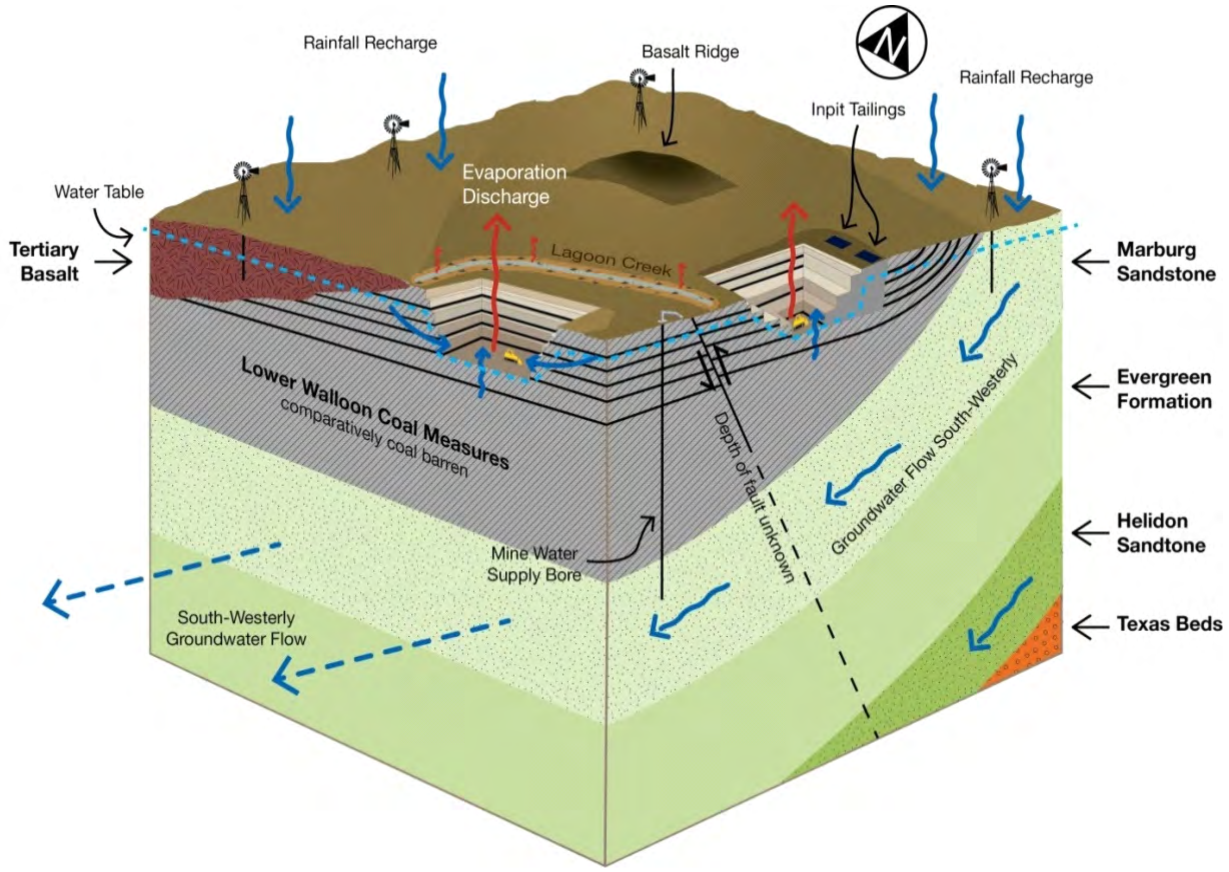


Figure 3-1 : Conceptual Hydrogeological Model

The conceptual hydrogeological model has been developed using the best available data and assumptions. The conceptual hydrogeological model will continue to be updated and refined based on the results of a targeted groundwater monitoring program and further investigations into local bore information (e.g. landholder bore surveys).

3.1 Quaternary Alluvial Aquifer

The shallow Quaternary Alluvial aquifer is limited in aerial extent and unlikely to form a major aquifer at the revised Project site. The alluvial aquifer is known to occur south of the revised Project site in association with Oakey Creek and its tributaries, where it reaches a thickness of up to 60 m and contains significant groundwater supplies. Similarly, groundwater supplies may also be developed in association with this aquifer to the northwest of the current Mine site in association with Myall Creek and its tributaries.

The predominant mechanism for recharge of the alluvial aquifer is direct infiltration. Discharge is likely to occur via evapotranspiration and infiltration to underlying aquifers.

Due to the minor nature of this aquifer within the revised Project site, data on groundwater yield and quality within the revised Project site was not obtained. Due to the lack of alluvial aquifer presence close to current mining activities, the current mine is not expected to be causing an impact to this aquifer.

3.2 Tertiary Basalt Aquifer

There is a minor occurrence of the Tertiary Basalt aquifer in the northwestern section of the revised Project site. The location of this aquifer in relation to the revised Project's mine pits means that this aquifer is unlikely to be affected by the revised Project, except where the western Manning Vale West Pit may intersect basalt to only a very minor degree. Where present in the revised Project site, the Tertiary Basalt aquifer varies in thickness from 1 m to 90 m.

Permeability within this aquifer is considered to consist of both primary and secondary porosity; however the latter is expected to dominate. The Tertiary Basalt aquifer has relatively shallow depth to groundwater at the revised Project site. Groundwater yield in the Tertiary Basalt aquifer can be up to 10 L/sec. An average bore yield of approximately 3 to 5 L/sec was reported in the Stage 2 EIS.

Pumping test data obtained from the Stage 2 EIS indicate a relatively high transmissivity of 150 m^2/day and storativity ranging from 0.001 to 0.05. The storativity values suggest that the aquifer is unconfined to semi-confined in the test locations.

The DNRM uses a uniform value of 80 mm of groundwater recharge per annum for basalt aquifers in the local area as part of water allocation assessments. This factor has been calculated to be approximately 12.7% of annual mean rainfall based on 635 mm mean annual rainfall observed at the Oakey Aero station. This suggests that recharge rates are relatively high for this aquifer.

The Mine currently draws groundwater from the Tertiary Basalt aquifer, covered under a license for 160 ML/year. However, the mine uses only approximately 11 ML/year of this allocation. Groundwater extraction from the Tertiary Basalt aquifer is also undertaken by nearby private groundwater users, mainly to the west and northwest of the revised Project site. Groundwater salinity in the Tertiary Basalt aquifer is generally lower than in the Walloon Coal Measures aquifer. This fact is reflected by a greater number of livestock and domestic users in the Tertiary Basalt aquifer.

Given that there is little occurrence of the basalt aquifer within the revised Project site, it is unlikely that mining activities will have a direct impact on the basalt aquifer. However, it is known that the basalt aquifer was deposited in palaeochannels incised into the Walloon Coal Measures palaeosurface and so the potential exists for direct hydraulic connection between the basalt aquifer and the Walloon Coal Measures, especially if a coal seam (the main water bearing units of the Walloon aquifer) were exposed in the palaeochannels.

3.3 Walloon Coal Measures Aquifer

The Walloon Coal Measures will be the main aquifer which will be affected by the revised Project. The Walloon Coal Measures outcrop across much of the revised Project site with coal seams being the principal conduit for groundwater flow.

Pumping tests undertaken in this aquifer, suggest that it is semi-confined, and of low to moderate transmissivity. Groundwater within the Walloon Coal Measures regionally flows from the north-east to south-west in accordance with the regional dip of the coal seams. Groundwater flow within this aquifer at the revised Project site is to the south, from potentiometric elevations of around 420 mAHD to potentiometric elevations of around 380 mAHD. A groundwater depression reaching around 410 mAHD exists in the vicinity of the current Mine workings, whilst a groundwater mound of around 440 mAHD exists in the vicinity of previously mined and backfilled northern Mine areas, where in-pit tailing dams now exist. The current Mine workings are likely to intercept much of this groundwater mounding given the close proximity and hydraulic gradient between the two features.

Recharge into the upper portions of the Acland-Sabine Sequence, is likely to be predominantly via coal subcrop areas on the upthrown side of faults and through deep drainage from the overlying basalt and alluvium where they occur. The comparatively higher salinity of groundwater in the lower seams of the Acland-Sabine interval and underlying Balgowan interval suggests that recharge zones for these measures are progressively more remote with depth and groundwater has longer residence times and longer migration paths. Leakage from underlying and overlying seams within the Walloon Coal Measures to these lower-lying coal seams is likely to be insignificant. Discharge from the Walloon Coal Measures aquifer occurs via mine pit dewatering and private bore extraction within the Clarence-Moreton Basin.

Significant surface water and groundwater interaction is unlikely for the Walloon Coal Measures aquifer. Groundwater has not been identified as contributing to surface water flows within nearby creeks and streams. Groundwater levels within the Walloon Coal Measures underlying the revised Project site range from around 6 to 55 mBGL.

The Walloon Coal Measures aquifers varies from being confined to semi-confined by low permeability mudstones and siltstones which occur in between the coal seams. Short term pumping tests indicate that the coal seams behave as separate aquifers. However, it is considered likely that over the long term the seams would behave as one aquifer system when stressed by dewatering in association with mining operations. Results from these tests suggest that a leaky aquifer system is likely to exist with vertical movement of groundwater occurring between seams, especially where the confining layers are thin, and via fractures within the coal measures aquifer system.

Transmissivity values within the Walloon Coal Measures were estimated to range between 7 and 47 m^2/day. Transmissivity values obtained from pumping tests undertaken for the Stage 2 EIS are consistent with those estimated from field tests undertaken for the revised Project. This result demonstrates that the transmissivity of the Walloon Coal Measures aquifer is similar from the Mine to the revised Project site.

Storage coefficients were estimated to range between 0.006 and 0.00006 for the shallow and deep coal seam aquifers respectively, suggesting the deeper seams act as confined aquifers whereas the shallow seams act as semi-confined aquifers. Bore yields for this aquifer are around 1 L/sec or less. Groundwater quality in the Walloon Coal Measures at the revised Project site is slightly acidic to slightly alkaline and is generally brackish with sodium and chloride ions dominating.

3.4 Marburg Sandstone Aquifer

The Marburg Sandstone aquifer underlies the Walloon Coal Measures and is up to 500 m thick. This aquifer exists as a confined aquifer at a depth of about 150 m within the revised Project site and is a major aquifer of the GAB.

Aquifer parameters based on pumping tests conducted for the Stage 2 EIS indicate a transmissivity of 14 m^2/day and a storativity of 0.003.

Aquitard layers separating the coal seam aquifer within the Walloon Coal Measures and the intervening lower permeability sediments of the Eurombah Formation act as effective confining layers to the Marburg Sandstone aquifer, hydraulically isolating it from the coal seams of the Walloon Coal Measures. Groundwater levels obtained from on and off site bores ranged from 410 m AHD to 425 m AHD. Typical production rates range from 5 L/sec to 25 L/sec within this aquifer. The higher yields indicate that the transmissivity of the aquifer may be larger than 14 m^2/day as indicated in the Stage 2 EIS pumping tests.

Recharge to this aquifer is likely to occur from surface water infiltration where the geological formation outcrops to the northeast of the revised Project site, with discharge via groundwater bores and throughflow to the southwest.

The mine periodically extracts groundwater from the Marburg Sandstone aquifer at a rate of approximately 10 ML/year for industrial use.

The Marburg Sandstone aquifer is a confined aquifer located more than 75m below the base of the revised Project mine pits. Therefore, the revised Project's mine pits and depressed landforms (rehabilitated final voids) are unlikely to have an effect on this aquifer.

3.5 Helidon Sandstone Aquifer

The Helidon Sandstone is the deepest aquifer at the revised Project site and is a major aquifer of the GAB. This aquifer is separated from overlying aquifers by the relatively impermeable Evergreen Formation and is up to 170 m thick.

Pumping test data indicates the transmissivity of this formation is likely to vary between 45 m^2/day to 200 m^2/day. Recharge to the Helidon Sandstone aquifer occurs where the aquifer outcrops in the northeast. This area represents the primary source of recharge to the aquifer via infiltration of rainfall and overland surface water flow, with discharge occurring mainly via groundwater bores and throughflow to the southwest.

The Mine periodically extracts groundwater from the Helidon Sandstone aquifer at a rate of 17 ML/year for industrial use and has an allocation of 710 ML/year from this aquifer. Groundwater extraction from the Helidon Sandstone aquifer for industrial use reduced greatly once the WWRF Pipeline came into operation in 2010. The Mine and other nearby private groundwater users are the main sources of groundwater extraction from the Helidon Sandstone aquifer.

The Helidon Sandstone aquifer is a confined aquifer and is located below the relatively impermeable Evergreen Formation, which in turn is located below the Marburg Sandstone aquifer. Accordingly, it is unlikely the revised Project's mine pits and depressed landforms (rehabilitated final voids) will effect on this aquifer.

4. Model setup

4.1 Modelling software

A three-dimensional finite difference model was created using the Groundwater Vistas pre-processor. MODFLOW (McDonald and Harbaugh, 1983) in conjunction with MODFLOW SURFACT (Version 4) were used to allow for saturated and unsaturated flow conditions.

A MODFLOW-based model was chosen because it is a well-documented and widely used program, and is often used for open-cut mining projects. MODFLOW-SURFACT or a finite element model such as FEFLOW is appropriate for this type of mining assessment (Mackie, 2009).

The pseudo-soil unsaturated flow option was used for the calculation of unsaturated flow conditions within MODFLOW-SURFACT. Using the MODFLOW-SURFACT package was not intended to accurately depict the unsaturated flow processes but instead to add the known stability MODFLOW-SURFACT provides. The pseudo-soil option also provides a better mass balance for post-mining void simulation. In addition, the MODFLOW-SURFACT package has an automatic time stepping program that allows for the time increments to accelerate or slow down depending upon how many iterations the solver requires to find a solution. This package was used during the calibration and predictive simulations and provided good stability.

A further feature of MODFLOW-SURFACT 4 that makes it particularly suitable for modelling mine dewatering is the Transient Material Properties (TMP) module that allows for conductivity and storage to vary with time throughout the simulation.

4.2 Model complexity

The groundwater model is classified as a “Class 2” model; commiserate with the level of input data available at the time of EIS production. This was deemed suitable for the purpose of the State level assessment of the EIS by SKM and agreed with Adrian McKay of EHP. Although the additional refinements, recalibration and sensitivity\uncertainty analyses do not bring the class of the model up to a Class 3, as per the modelling guidelines, the additional work does increase the overall confidence in the model predictions and robustness of the model.

The model is suitable for predicting the impacts of the proposed operations and post-mining recovery.

4.3 Model exclusions

The model or modelling process did not include:

- Flood or high river stage recharge.
- Quantitative calibration to baseflow.

These processes have not been explicitly included because of lack of data or they were assumed to be relatively minor influences within the groundwater regime given the existing modelling objectives and scope.

4.4 Model domain and boundary conditions

The model boundary conditions have been assigned to represent the regional groundwater flow system as described in the EIS Chapter.

The model domain (**Figure 4.1**) covers an approximate area of 36 x 53 km (1,908 km^2). The revised Project area is located within the centre of the model domain. The model area was divided into a uniform grid with spacing of 400 m by 400 m, with refined grid spacing near the revised project area of 200 x 200m, resulting in 168 rows and 132 columns. The model domain therefore consisted of 22,176 cells a layer, or 110,880 cells for the full five-layer model, of which only 96,121 were active.

The model contains five layers, all of which are active except for in layer 1 outside the alluvial extents where cells are set as inactive. Where deeper geologic units are not present cell thicknesses are set at a minimum thickness of 0.1m and the underlying hydrogeological properties are carried up.

The hydrogeological units of relevance to the revised Project area have been simplified for incorporation into the groundwater model as discrete model layers, as described in **Table 4.1**. Layers within the model do not solely represent one individual simplified geologic unit. Geologic units are represented in the model by parameterisation of hydraulic conductivity and storage. For example, Layer 2 is intended to simulate the Basalt. Where its estimated to exist, the cells have been assigned parameters associated with the Basalt. Where it does not exist, the next sequential geologic unit interpreted to exist is represented by a change in hydraulic conductivity and storage, and cell thicknesses are set at a minimum thickness of 0.1m. An example cross-section of the model is presented in **Figure 4.2**.

The alluvium is represented by its own layer (Layer 1) with inactive cells where it does not exist. This method is a simplification made during the model setup process which can decrease model size and run time, while at the same time increase numerical stability. The vertical conductivities for the alluvium are sufficiently high to allow for movement between layers, thus not unnecessarily limiting interaction between simulated geologic units.

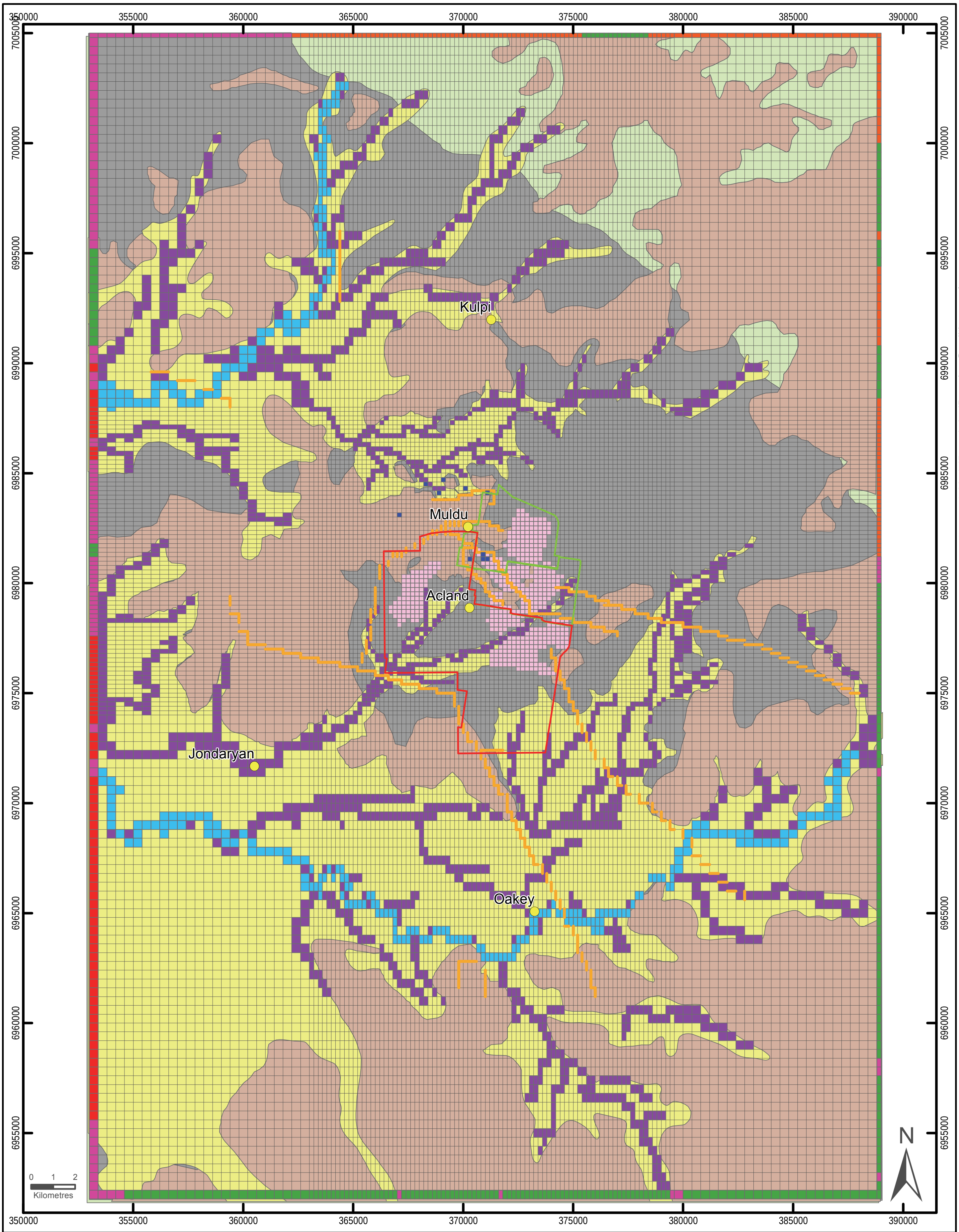
Table 4.1 : Model layering

Layer(s)	Hydrogeologic unit	Layer thicknesses (m)
1	Alluvium	0.1 - 52
2	Tertiary Basalts	0.1 - 143
2 - 3	Upper WCM	0.1 - 145
4	Lower WCM	0.1 - 153
2 - 5	Marburg Sandstone	250

The extent and, top and bottom elevations for each geologic unit were calculated based upon the following data sets:

- LiDAR digital elevation files provided by NAC
- digital elevation model (DEM) surface topography
- surface and bedrock mapping (SRK, 2006)
- DNRM database
- NAC monitoring bore geologic logs

Geologic extents for all geologic units have been modified during the latest revision. These revisions are based upon the use of more recent geologic mapping that is more consistent with bore database as well as the use additional information such as LiDAR.



LEGEND

- Towns and Localities
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Model Grid

Note: Refer to report for description of head distributions in Constant Head cells

Boundary Conditions

- Constant Heads (L1-L5)
- Constant Heads (L2-L5)
- Constant Heads (L3-L5)
- Constant Heads (L5)
- Oakey and Myall Creek (L1)
- Tributaries (L1)
- Mine Drains (L1/2/3)

Boundary Conditions

- Wells
- Modelled Faults (L3/L4)

Modelled Surface Geology

- Alluvium
- Basalt
- Walloon Subgroup
- Marburg Sandstone

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Figure 4-1 - Model Domain and Boundary Conditions

Scale 1:228,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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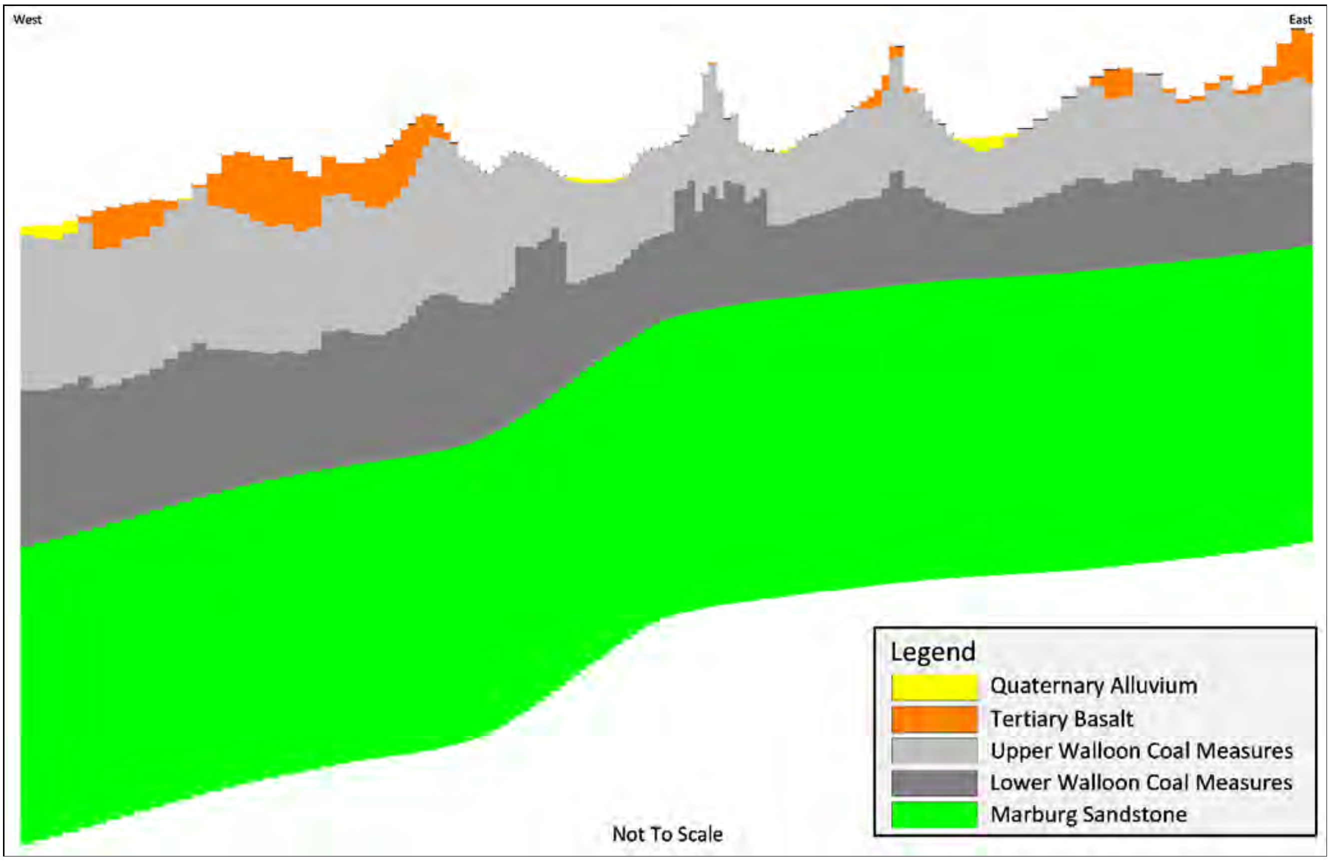


Figure 4-2 : Example Cross Section through the model domain

Isopach maps for each geologic unit are provided in **Figure 4-3** through **Figure 4-6**.The extents of each geologic unit were based upon referenced geologic maps (SRK, 2006) for all consolidated units. Jacobs SKM used topography data (LiDAR and DEM) to refine the extents of the alluvium using a slope break analysis. Thicknesses were interpreted based upon available geologic logs, DRNM database and publically available interpretations of isopach and floor elevations (SRK, 2006).

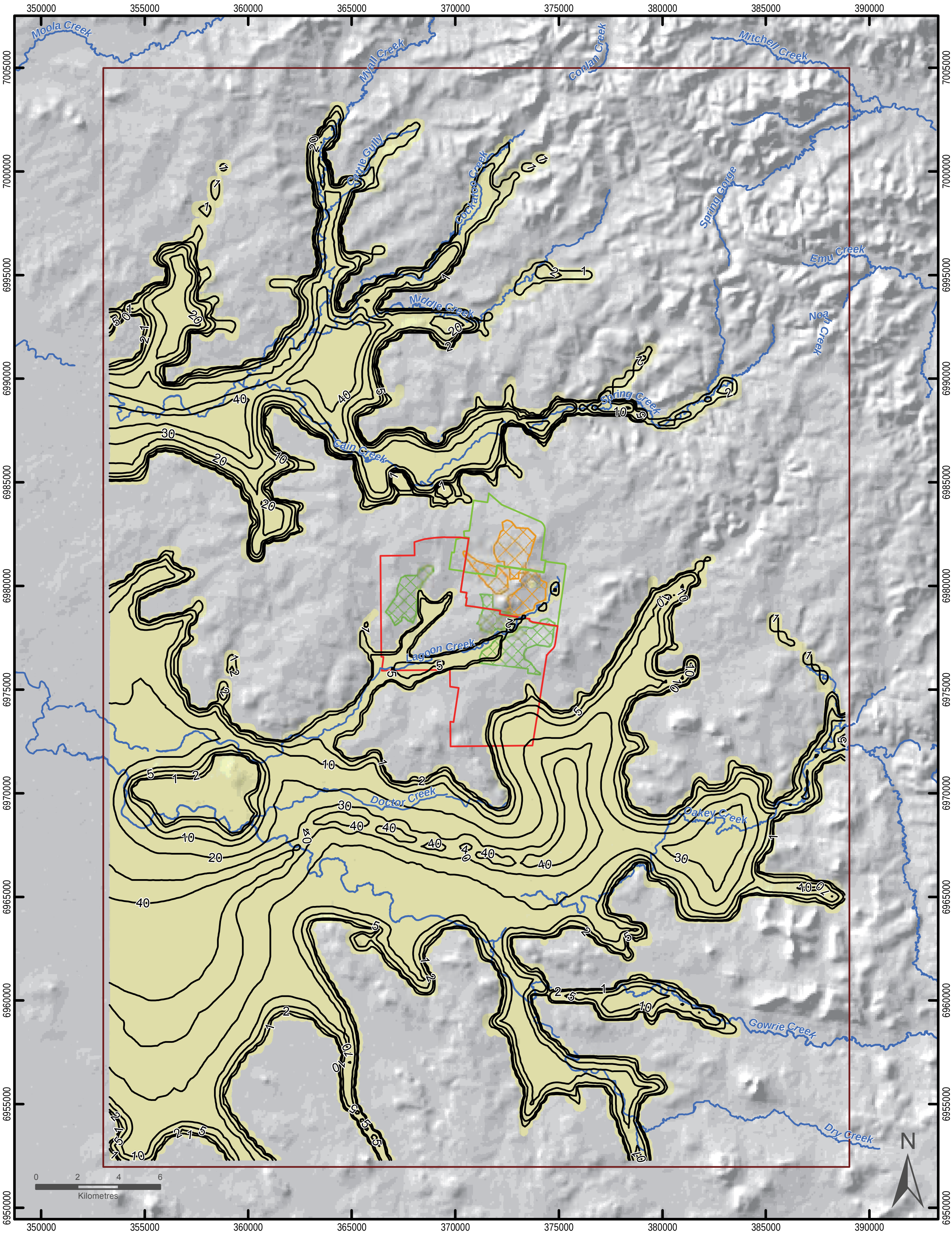
Constant head boundaries were assigned at active cells adjacent to model boundaries where the aquifer is known to extend further than the model boundary. Head values in the alluvium were based upon a typical depth to water of approximately 13.5 mbgl. For all other geologic units as relationship between topography and water levels was used to assign spatially variable heads. These relationships are presented in **Figure 4-7**through **Figure 4-9**.

The model boundary distances were chosen with the intent that drawdown in the predictive simulations would not reach the boundaries, and thus their influence would be minimised. Previous model simulations demonstrated that the extents were adequate.

Structural features, such as the faults have been explicitly simulated using the Horizontal Flow Barrier (Wall) boundary condition feature of MODFLOW within the Upper and Lower Walloon layers as well as the Basalt. The overall conductance for the faults was set at $1x10^{-10}$ m^2/d using a thickness of 1m and a hydraulic conductivity of $1x10^{-10}$ m/d. These features are shown in **Figure 4-1**.

Investigations undertaken as part of the existing Mine operations, including field investigations (e.g. WSA, 2013), have sought to identify the role that faulting within the Walloon Coal Measures plays in control on groundwater flow and aquifer compartmentalisation. These investigations have shown that these faults may play a significant role in providing barriers to groundwater flow in the Walloon Coal Measures. During the original model development as part of the draft EIS, the calibration procedure involved simulating the existing Mine operation with and without the inclusion of barrier faults in the model. The results of this procedure indicated that in order to best represent the compartmentalisation of the Walloon Coal Measures and the resulting monitoring bore responses, the faults which have been previously mapped by NHC's geologists based on drilling results and observations of the existing Mine's open cut pits are best simulated as barrier 'Walls' in the model. For the updated modelling, this approach has again been adopted without specifically undertaking calibration trials without the inclusion of these Walls in the Walloon Coal Measures.

Model calibration runs were undertaken with and without barrier Wall faults applied to the Marburg Sandstone. The results of this sensitivity analysis showed that the model is relatively insensitive to the inclusion of these faults. Given that the Marburg Sandstone is conceptualised as a relatively thick, permeable and homogenous unit compared to the upper Walloon Coal Measures, it was considered that compartmentalisation of the unit is much less likely to occur than in the Walloon Coal Measures, and therefore it was decided to not apply faults to the Marburg Sandstone for the model predictions. This approach is considered conservative as it will result in further lateral propagation of drawdown away from the revised Project site in the Marburg Sandstone than would be the case with barrier faults applied.



LEGEND

- Modelled Formation Isopach (m)
- Watercourse
- Groundwater Model Extent
- Modelled Alluvium Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

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STAGE 3 PROJECT

Figure 4-3 - Modelled Formation Isopach Quaternary Alluvium

Scale 1:245,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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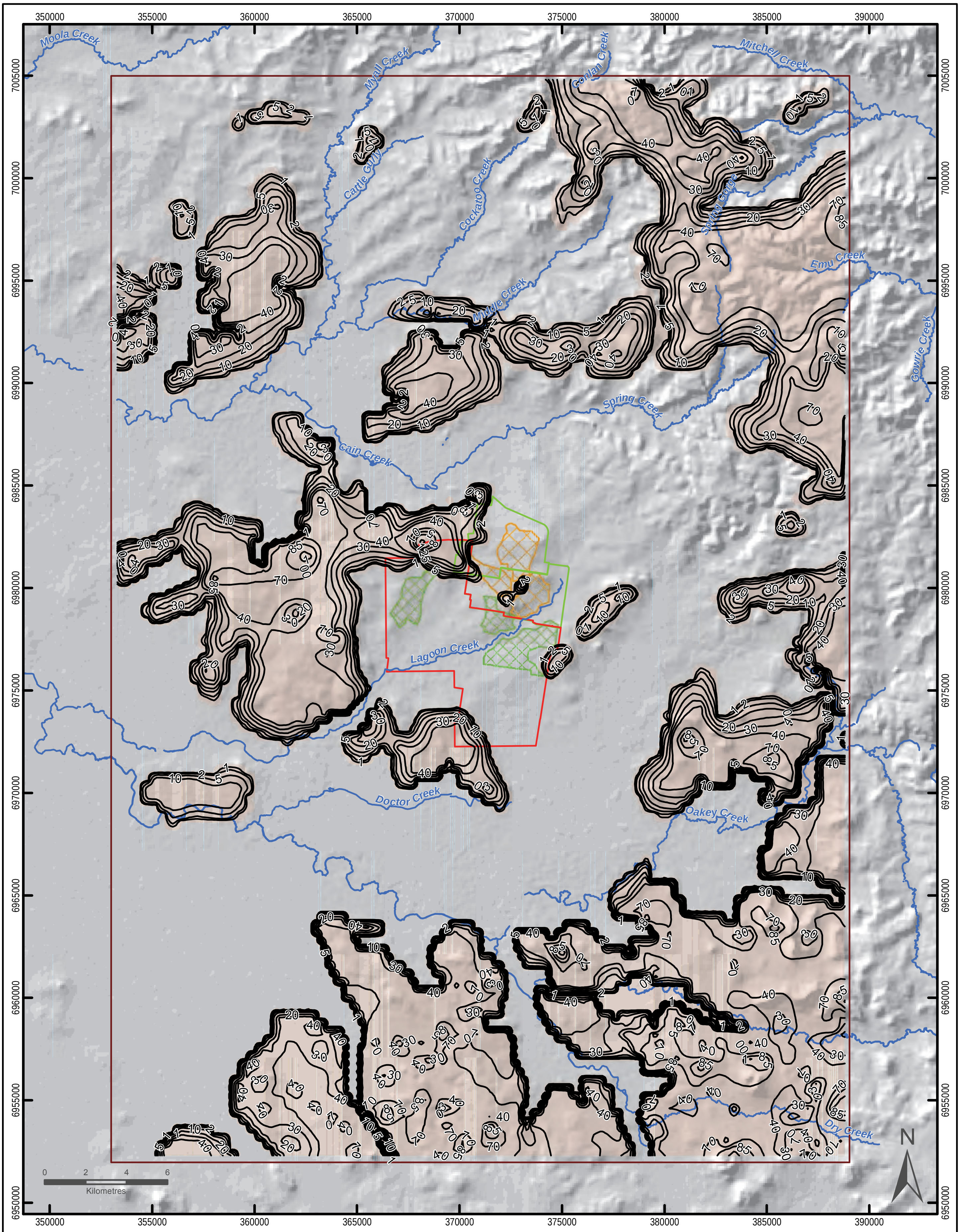

LEGEND

- Modelled Formation Isopach (m)
- Watercourse
- Groundwater Model Extent
- Modelled Basalt Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

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Figure 4-4 - Modelled Formation Isopach Tertiary Basalt

Scale 1:245,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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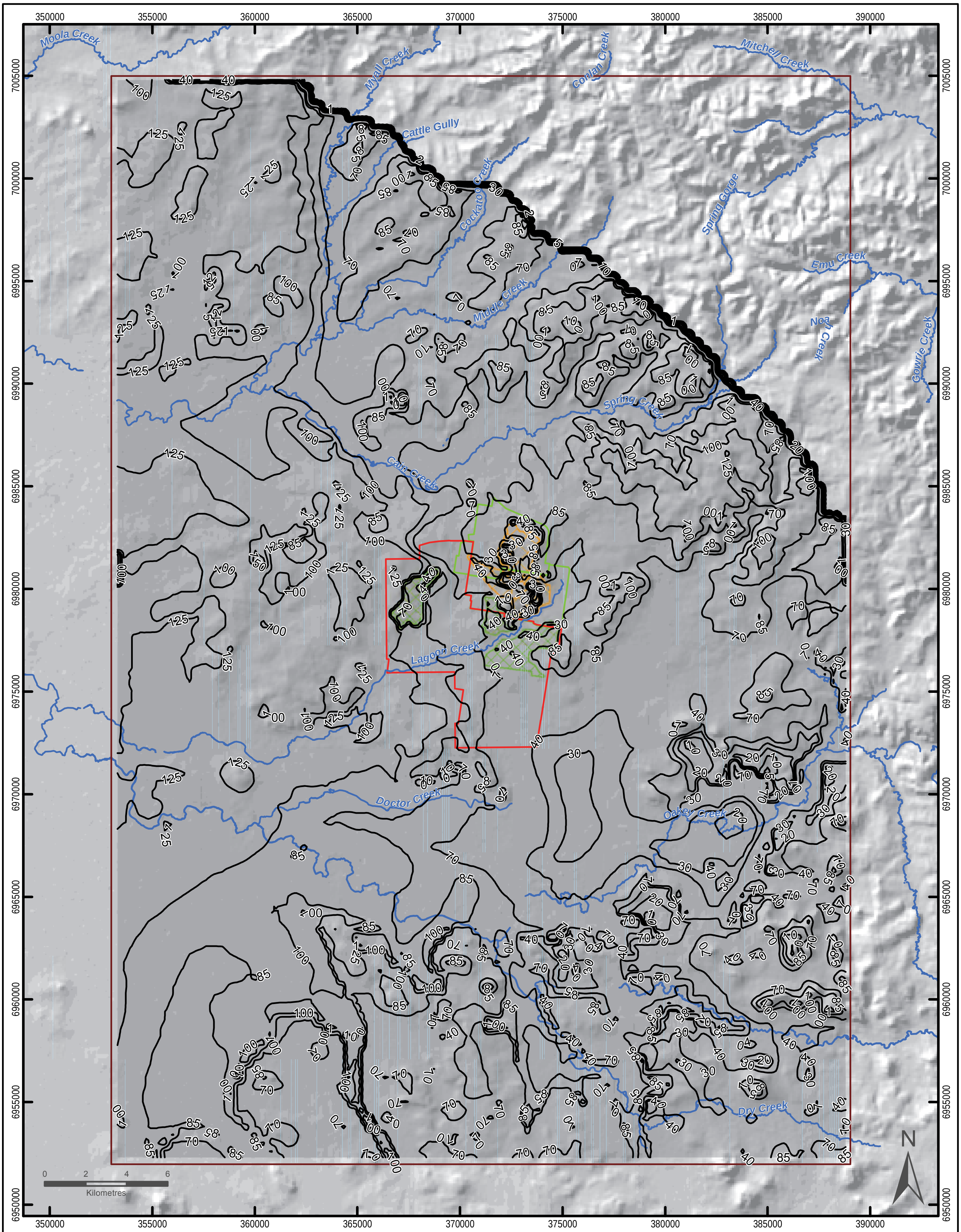

LEGEND

- Modelled Formation Isopach (m)
- Watercourse
- Groundwater Model Extent
- Modelled Upper Walloon Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

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NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure 4-5 - Modelled Formation Isopach Upper Walloon Coal Measures

Scale 1:245,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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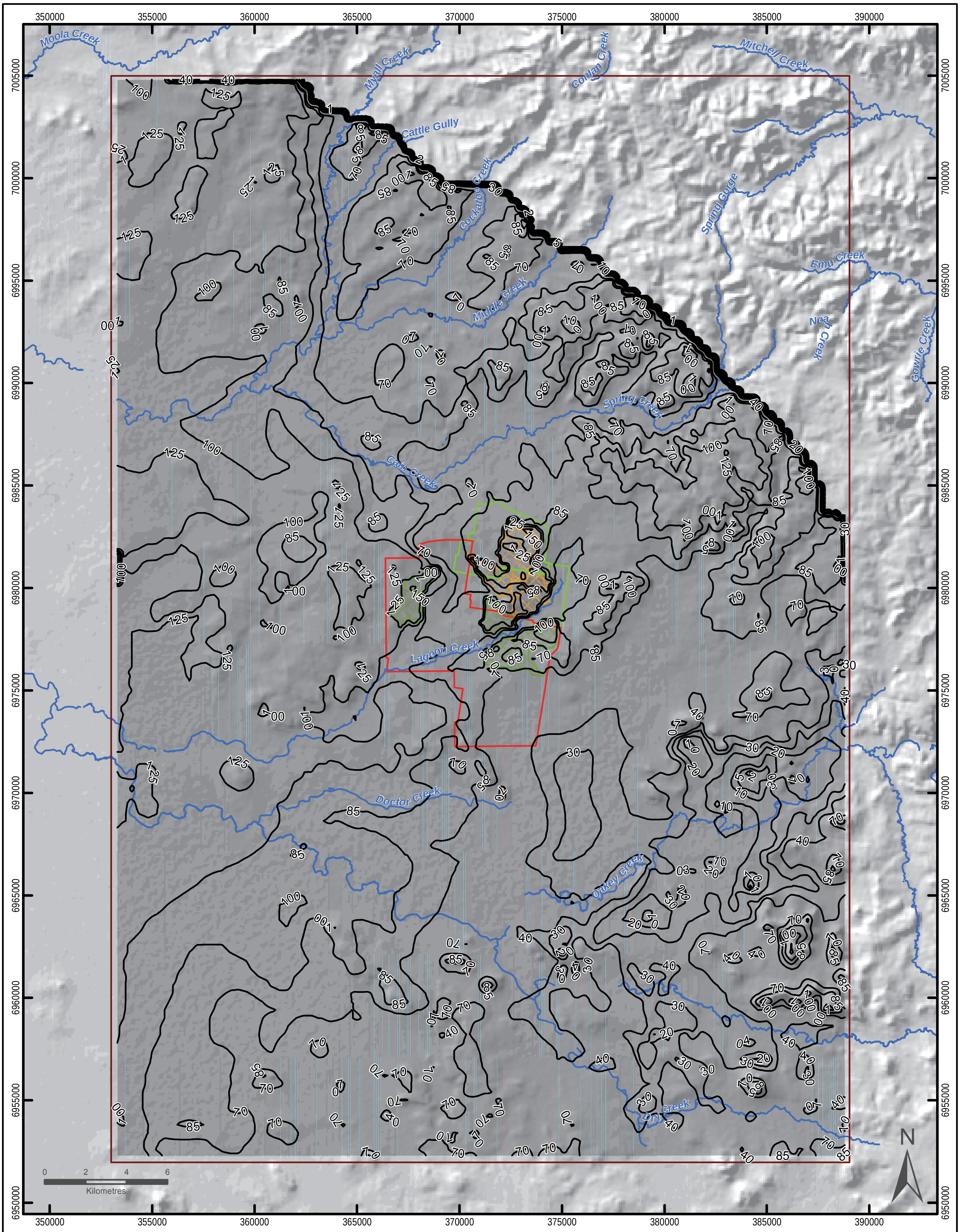

LEGEND

- Modelled Formation Isopach (m)
- Watercourse
- Groundwater Model Extent
- Modelled Lower Walloon Extent
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

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STAGE 3 PROJECT

Figure 4-6 - Modelled Formation Isopach Lower Walloon Coal Measures

Scale 1:245,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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Produced: 25/08/2014

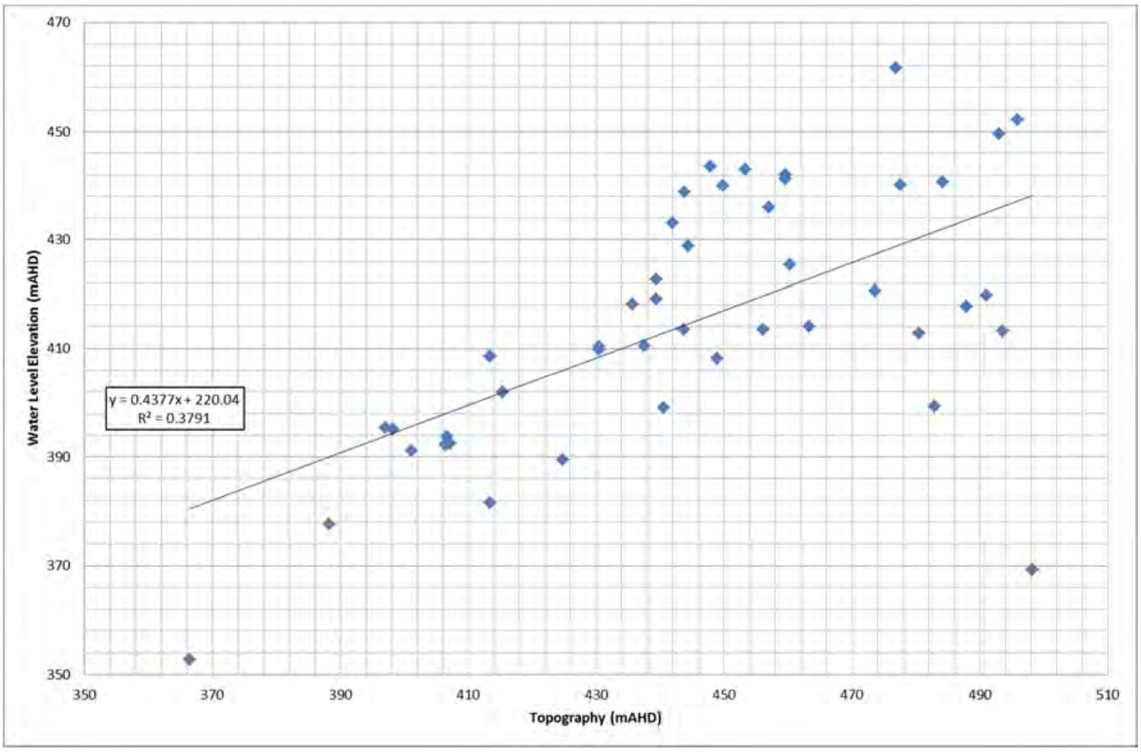


Figure 4-7 : Basalt – Relationship between topography and water levels

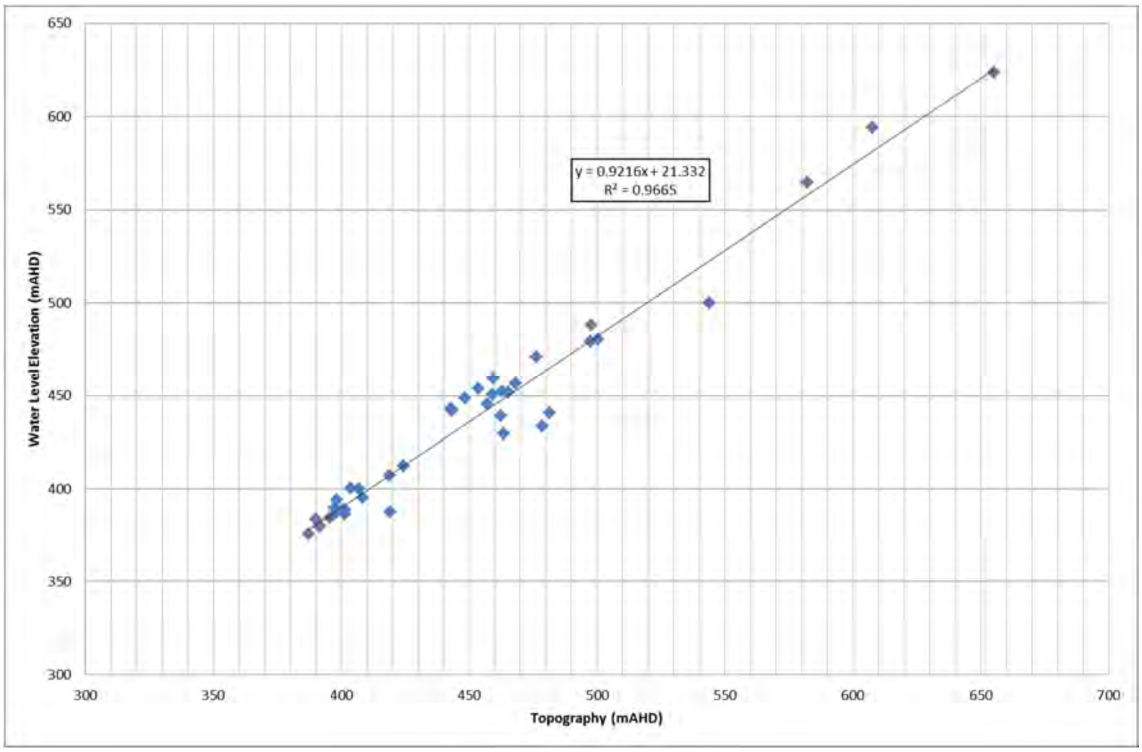


Figure 4-8 : Walloon Coal Measures – Relationship between topography and water levels

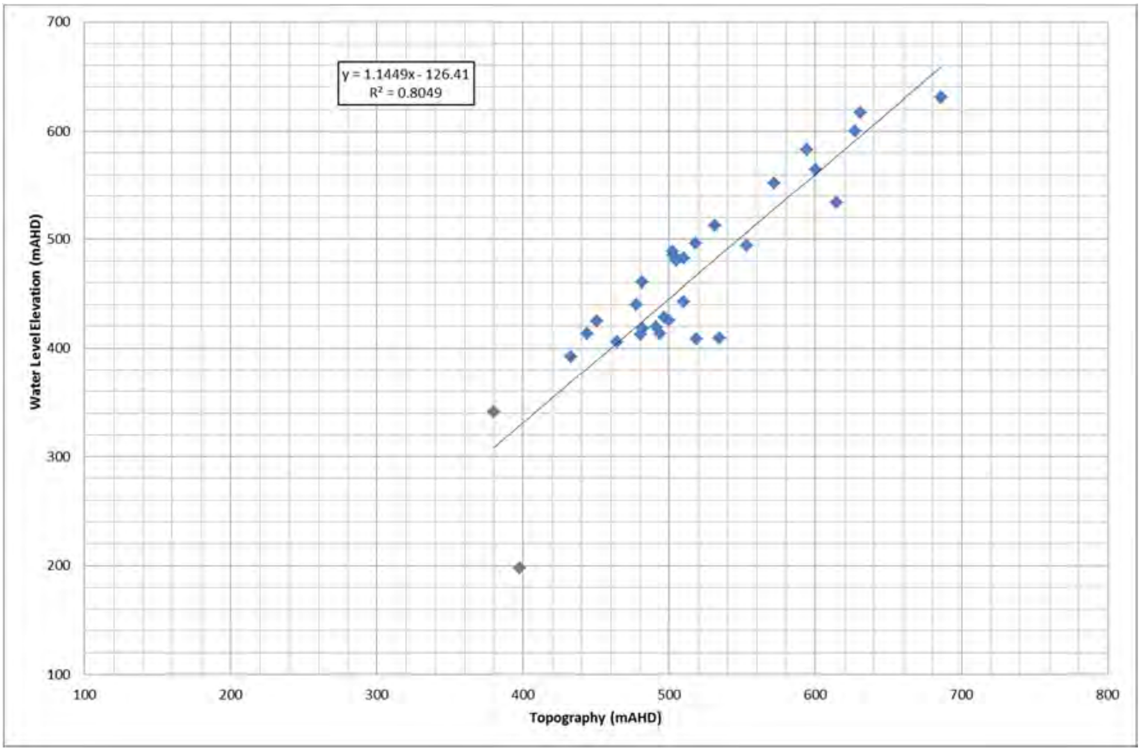


Figure 4-9 : Marburg Sandstone – Relationship between topography and water levels

4.5 Recharge

It is believed that recharge in the study area is influenced by the geological unit present at the surface. Therefore recharge zones were created for each of the different geology outcrops. From a modelling perspective this involves applying recharge to the uppermost active layer.

During calibration recharge is allowed to vary according to the historic rainfall for the corresponding period. Multipliers, calculated by dividing the actual rainfall for the period by the average annual rainfall, are assigned for each period with records. These multipliers then correct for increased or decreased rainfall recharge by being multiplied by the calibrated percent of average annual recharge. For all other time periods, and for steady state calibration, the calibrated percent of average annual recharge is applied.

4.6 Discharge/evapotranspiration

Evapotranspiration (ET) is expected to be an active form of groundwater discharge in the model domain and has been simulated using the EVT package of MODFLOW.

Maximum ET Potential was initially estimated to be between 1400-1500 mm/yr from local meteorological data (BoM, 2011). However the latest update for the AEIS uses the Australian Bureau of Meteorology estimate for Aerial Actual Evapotranspiration (AAE), estimated to be between 600 to 700 mm/yr (BoM, 2011), which is assumed to be better reflection of actual ET for areas where water is not ponded at surface. For modelling purposes, maximum ET was set to 650 mm/yr for all non-void areas consistent with the BoM AAE estimate. The maximum ET potential rate of 1450 mm/yr was assigned for all areas of voids where water has the potential to be ponded at surface, consistent with the BoM Maximum ET Potential, because it is based upon measured potential ET rates of water exposed at surface..

The EVT package of MODFLOW requires that an extinction depth be provided, which indicates at what depth ET no longer occurs (i.e. ET rate =0). The ET rate is then linearly decreased from the maximum rate when the water level is estimated to be at the ground surface to 0 mm/year when the water level is estimated to be at the extinction depth. The extinction depth is allowed to vary during the calibration process.

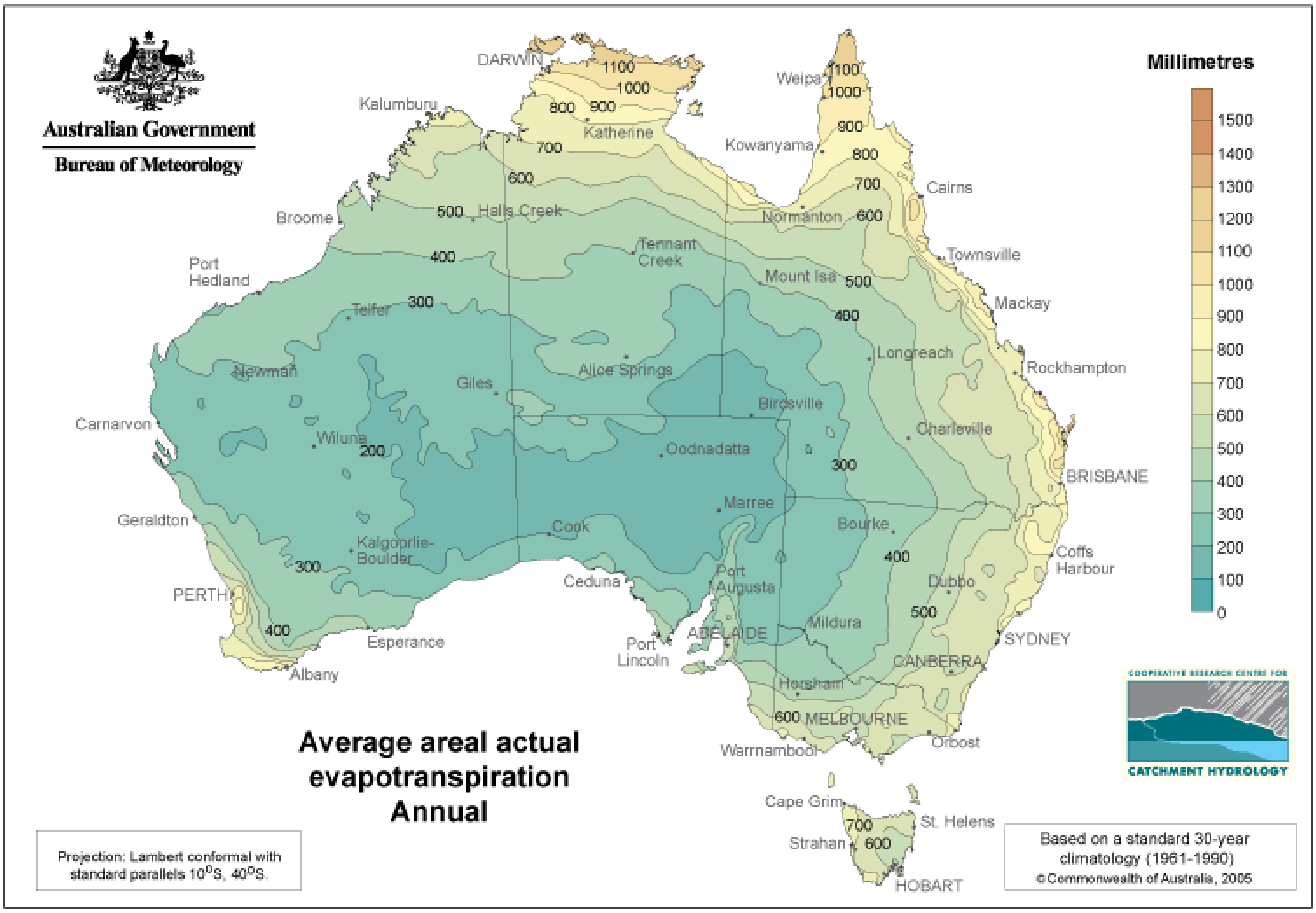


Figure 4-10 : Estimated Aerial Actual Evapotranspiration

4.7 Model simulation design

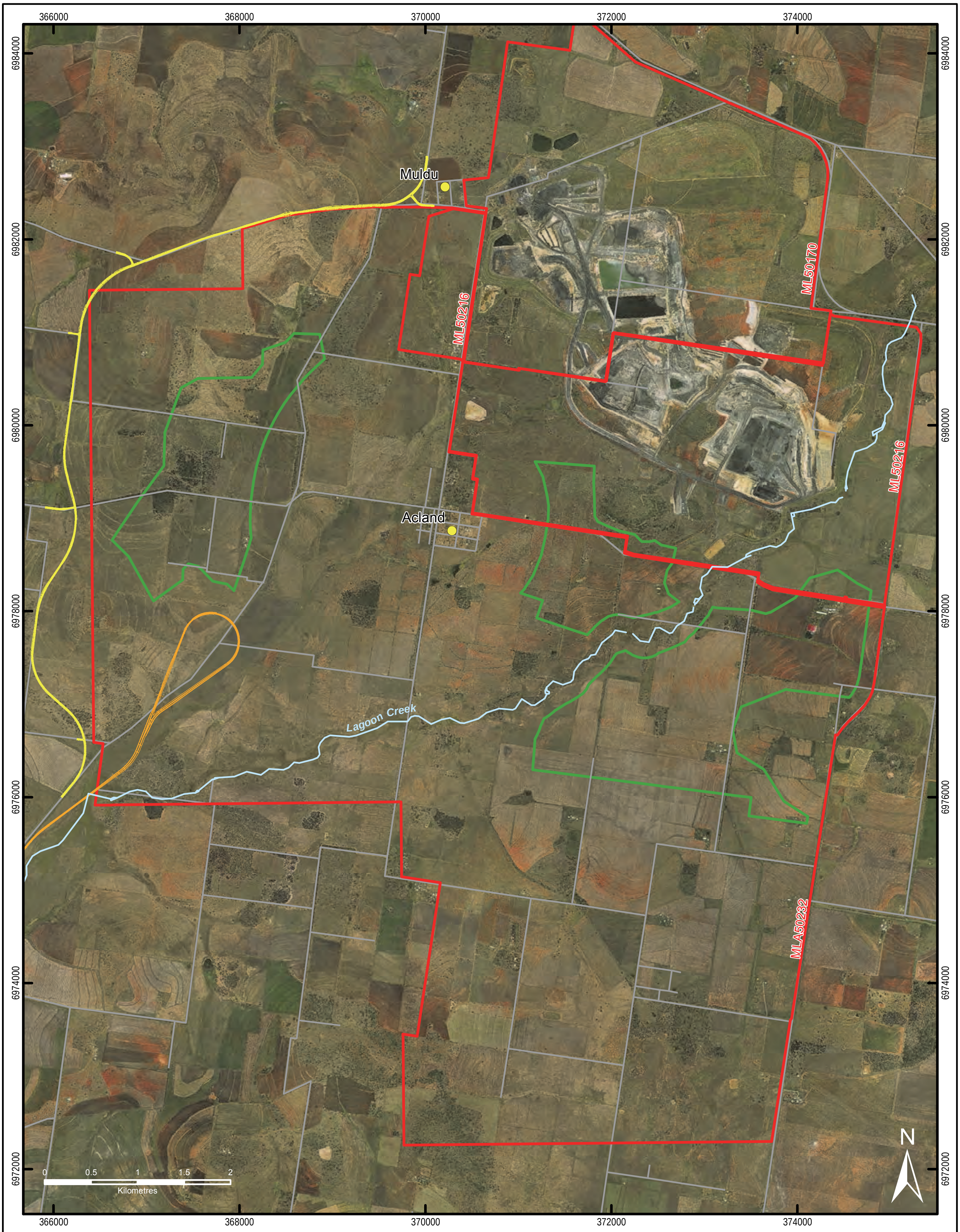
The objective of the predictive modelling was to assess the revised Project's potential impacts on the groundwater environment. The specific outputs required from the model were:

- estimated mine inflow rates/volumes
- regional changes to groundwater levels during mining and post-mining

4.7.1 Drains

Drain boundary conditions were used to replicate the sequential reduction in land surface as mining progressed throughout all layers in which mining would occur (i.e. Layers 1-3 where active). Jacobs SKM was provided with total pit depth and final landform (**Figure 4-10**, **Figure 4-11** and **Figure 4-12**) as well as a yearly mine progression map. This data was used to simulate an excavation to total depth for each year of mining. Drains remain active for 2 years.

The conductance of the drains is a product of the cell widths and a hydraulic conductivity and thickness for the "draining layer". The thickness was assumed to be 1 m and the hydraulic conductivity was assigned 200 m/day which provided numerical stability whilst still fully dewatering all actively mined areas.



LEGEND

- Towns and Localities
- Creeks
- Roads
- Mining Tenements
- Stage 3 Pit Areas

NEW HOPE GROUP

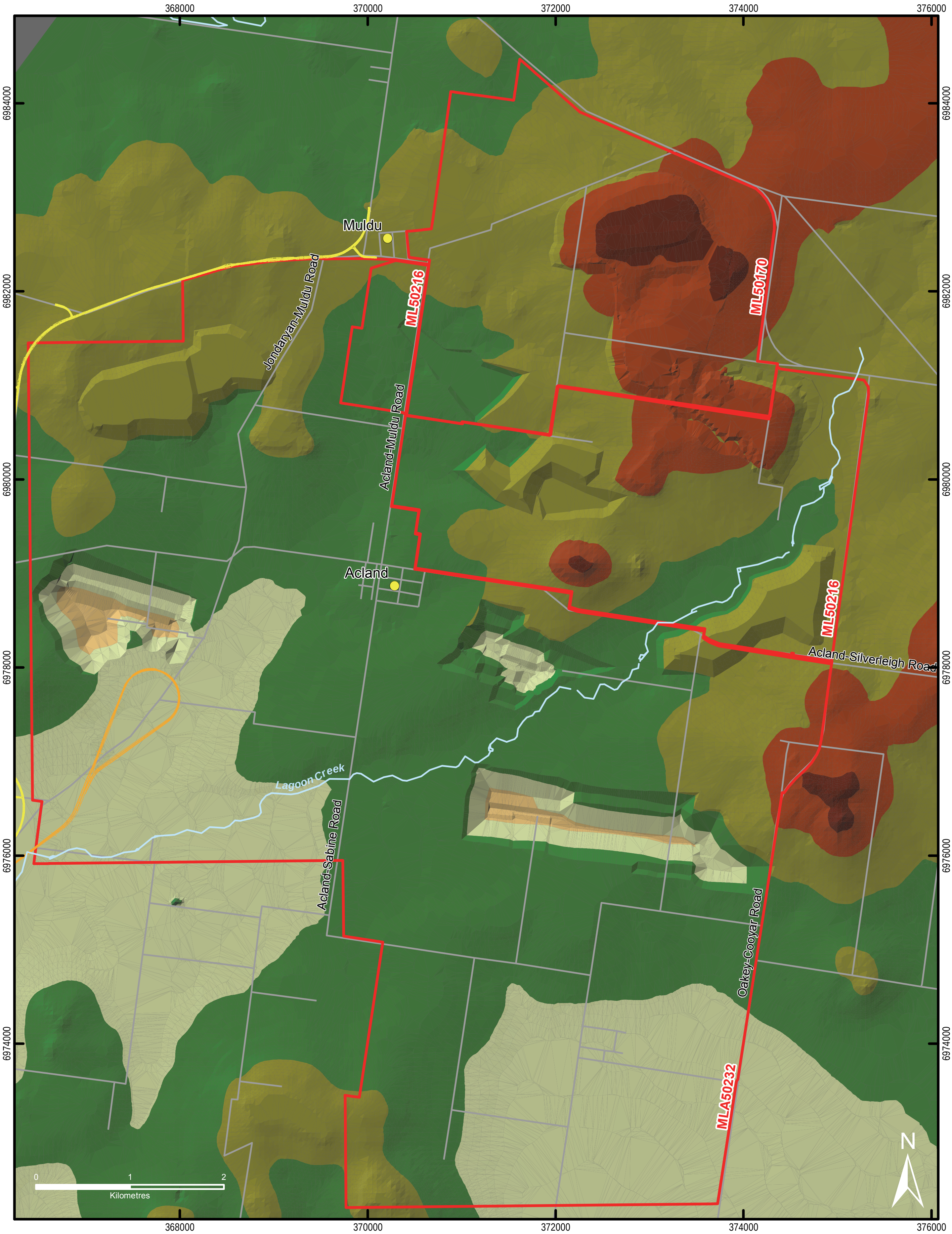
SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 4-11 - Pit Floor Elevation

Scale 1:54,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)



LEGEND

- Towns and Localities
- Roads
- Creeks
- Mining Tenements

Elevation

604 - 636	480 - 511
573 - 604	449 - 480
542 - 573	417 - 449
511 - 542	386 - 417
	355

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 4-12 - Final Landform

Scale 1:54,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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Produced: 25/08/2014

4.7.2 Time-Varying Hydrogeological Parameters

An important feature of the model was the inclusion of changing hydrogeological parameters as a result of mining and backfill sequencing. The TMP1 package implemented in MODFLOW-SURFACT allows time-varying hydrogeological parameters to be incorporated into transient simulations. When changing the hydrogeological parameters using the TMP1 package there are two key inputs:

- The timing of the changes; and
- The multiplier to be applied to the parameter starting value.

The timing and magnitude of the changes are then tied spatially to the progression of the simulated mine operation. The areas used for the drain cells depicting mine operations were used to delineate Hydrostratigraphic Units (HSUs) within the model. HSUs are used in Groundwater Vistas to group cells so that their parameters can be changed together. The TMP1 package allows for hydrogeological parameters to be varied according to HSU zones.

Since HSUs are defined by both the timing of the change and the multiplier to be applied, many different zones are required to fully represent the aerial and vertical migration of pit growth and subsequent backfilling sequences. The changes to parameters used to replicate groundwater recovery post-mining are set to take effect in the stress period after each drain cell becomes inactive. The multiplier for each HSU was calculated by dividing the new parameter(s) by the starting (i.e. calibrated) parameter(s).

In development of the post-mining prediction simulation the following assumptions were made for the backfill:

- hydraulic conductivity (x, y, and z) = 15 m/day
- specific yield = 0.15
- Maximum ET rate = 650 mm/yr.
- ET extinction depth = 2 m.

Areas within the mine pit where a void is left at the completion of mining are represent with parameters that are appropriate for a void. The property values used within the model to represent voids are as follows in **Table 4.2**.

Table 4.2 : Air Property Values

Property	Value
K_h	1,000 m/d
K_z	1,000 m/d
S_s	0.000005 m^{-1}
S_y	1

4.7.3 Transient ET Surface

Groundwater Vistas 6, allows for the simulation of transient ET surface changes. This allows ET to change in a manner that accurately reflects the changes that occur during and after mining operation. Pre-mining the ET surface is set at surface topography. In the period of mining, the ET surface elevation drops to the pit floor and post mining it is increased to the elevation of the final landform. The ET surface remains at final landform throughout the recovery period.

For areas of active mining, the extinction depth is reduced to 0.5 m.

4.7.4 Recovery recharge

Throughout the mining operations the recharge rate to the pit is assumed to be zero. Once mining operations are finished, recharge to the pit areas is assigned for the new material properties. For areas within the voids recharge is assumed to be 100% of average annual rainfall, plus estimated average annual runoff to the voids calculated as part of the surface water impact assessment. For areas of backfill, recharge is assumed to be 10% of average annual rainfall.

4.7.5 Wells

The Well Package of MODFOW is used to simulate the historic and estimated future groundwater extraction by mining operations for water supply. For more information on the rates of extraction are provided the EIS Chapter.

5. Model calibration

5.1 Methodology

Calibration of the model was undertaken using a stochastic calibration methodology designed to meet the following objectives:

- Establish datasets of model parameters that match measured groundwater levels within acceptable error limits. These parameter sets are reported collectively as the 'stochastic datasets'.
- Evaluate the sensitivity and uncertainty of model calibration
- Run the predictive simulations with the stochastic datasets to obtain an envelope of possible outcomes that also collectively represent the uncertainties associated with predictive modelling.

The stochastic approach was adopted in preference to a deterministic calibration methodology as it is capable of meeting the agreed upon objectives while offering the additional benefits of providing appropriate uncertainty analysis for predictive model results. This concept is highlighted specifically in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012):

> *"The approach taken to model calibration must be linked to the questions that all groups of stakeholders (project proponents, regulators and modellers) are trying to answer. It is important at the start of model calibration to understand the purpose of the model, that is, what the model is intended to predict. It is the desire for accuracy in future predictions that must drive the choices that are made during model calibration."*

Model calibration using the stochastic approach employed here accounts for the inherent uncertainty associated with complex models based on many inter-related parameters. Each of the 'calibrated' datasets, or realisations that generate model results within the adopted calibration acceptance criteria, is considered equally plausible. The range of model results generated using these stochastic datasets provides a good indication of the uncertainties associated with predictive modelling. Such uncertainty analysis is important in any predictive modelling exercise and is recommended in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

The stochastic calibration methodology comprised the following tasks:

- Generation of initial datasets within parameter bounds and constraints determined from the conceptual hydrogeological model and relevant data sources;
- Model simulations using each dataset;
- Comparison of model results to calibration targets, including historical groundwater levels and estimated pit inflows, when available;
- Establish the set of calibrated datasets; and
- Run predictive simulations using the calibrated datasets.

5.2 Monte Carlo Calibration Simulations

The initial datasets were generated automatically using a Monte Carlo simulation program developed by SKM. The program allows for the range of values for each parameter to be:

- Distributed as normal, log normal, random, or log random; and
- Constrained or tied to other parameters. For example, one parameter can be constrained so that it cannot exceed another parameter, or one parameter may be defined as a multiplier of another parameter (as commonly used to define a consistent level of anisotropy in hydraulic conductivity).

The generation of datasets in this method allows for flexibility in how parameters are defined and constrained, and also allows for multiple linking of parameters and constraints. These checks and constraints are important in generating datasets to ensure that datasets are not created that violate our conceptual understanding of the system (e.g. vertical conductivities exceeding horizontal conductivities, or the hydraulic conductivity of the interburden exceeding that of the coal seams).

The model parameters used as inputs for the Monte Carlo analysis included hydrogeological parameters properties (horizontal and vertical hydraulic conductivity, specific yield); conductance terms for river cells, and recharge rates.

Table 5.1 summarises of the range of values within which the model parameters were permitted to vary. The level of constraint for the parameter bounds was directly related to field-based and information available from the OGIA modelling report (GHD 2012). The ranges in parameters allowed does not necessarily reflect the expected or final values that will be selected for analysing potential inflows but are simply intended to:

- Allow for a wide range of potential values and thus possibilities to be assessed through the calibration process; and
- Evaluate the sensitivity and uncertainty in the parameterisation and calibration of the model.

Specific storage was not allowed to vary as part of the Monte Carlo process and were left at values equal to compressibility of water. The primary reasons behind this simplification are:

- For hard rock aquifers the compressibility of water is typically orders of magnitude greater than that of the material and thus any error in leaving it out is minor
- Measured values of specific storage, typically from pumping tests, do not typically account for leakage. Therefore measured values greater than the compressibility of water are often a reflection of leaky aquifers rather than the actual release of water from a drop in pressurised head. The model explicitly simulates the leakage across aquifers\aquitards. If a higher specific storage were used that included a leakage component, the resulting model simulations would either over estimate flow, under estimate drawdown or potentially underestimate the vertical connectivity between aquifers and aquitards.

5.3 Calibration Targets

Two distinct datasets were identified as appropriate calibration targets to determine which sets of model parameters represented calibrated datasets:

- The first calibration target was the matching of historical water levels recorded (steady state and transient).
- The second calibration target was set by estimated observed pit inflows between 300 and 400 m^3/d for years 2011 and 2012.

Jacobs SKM performed a qualitative assessment of data reliability based upon the information available for the bore and the sources of the data. A summary of the information and source of information are provided **Table 5.2**, along with the final weighting applied to each head target used in calculating calibration statistics.

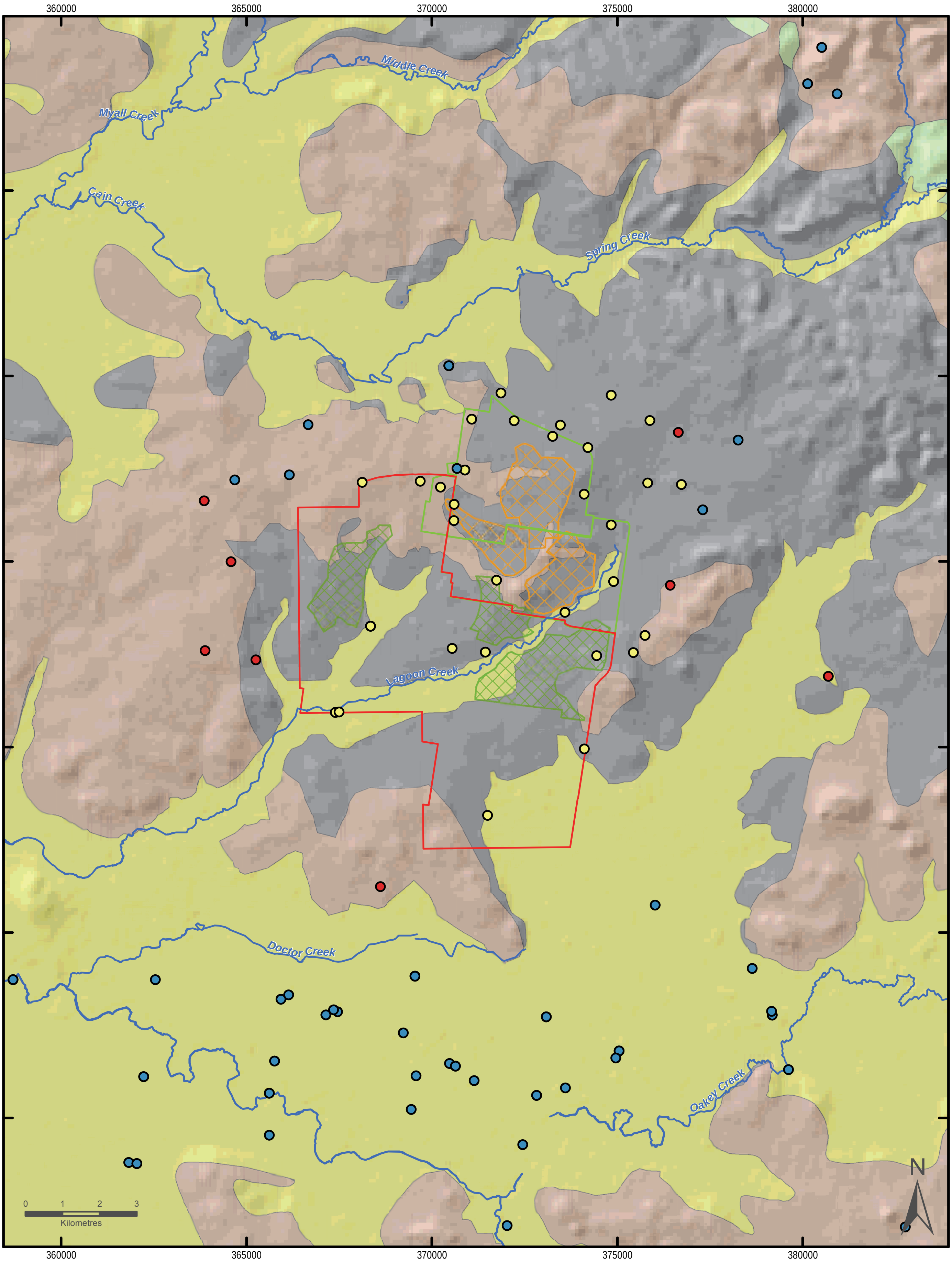
Table 5.1 : Parameter Bounds Assigned for Monte Carlo Analysis

Parameter	Geologic unit	Mean	Mean (log(x))	Standard Dev. (log(x))	Constraints
K_h (m/d)	Alluvium	8.51	0.93	0.5	None
	Basalt	0.54	-0.27	0.5	None
	Upper WCM	0.08	-1.11	0.75	None
	Lower WCM	0.01	-2.00	1	K_h Lower WCM < K_h Upper WCM
	Marburg Sandstone	0.05	-1.30	0.75	None
Parameter	**Geologic unit**		**Min. Multiplier of K_h**	**Max. Multiplier of K_h**	**Constraints**
K_z (m/d)	Alluvium		0.001	0.1	Tied to K_h Alluvium
	Basalt		0.001	0.1	Tied to K_h Basalt
	Upper WCM		0.0002	0.01	Tied to K_h Upper WCM
	Lower WCM		0.001	0.1	Tied to K_h Lower WCM
	Marburg Sandstone		0.001	1	Tied to K_h Marburg Sandstone
Parameter	**Geologic unit**	**Mean**	**Mean (log(x))**	**Standard Dev. (log(x))**	**Constraints**
S_y	Alluvium	0.01	-2.00	0.5	None
	Basalt	0.01	-2.00	0.5	None
	Upper WCM	0.005	-2.30	0.5	None
	Lower WCM	0.005	-2.30	0.5	None
	Marburg Sandstone	0.005	-2.30	0.5	None
Parameter	**Watercourse**	**Mean**	**Mean**	**Standard Dev. (log(x))**	**Constraints**
River Conductance (m^2/d)	Myall Creek	1	0	1	None
	Oakey Creek	1	0	1	None
Parameter	**Region**		**Parameter Min.**	**Parameter Max.**	**Constraints**
ET Extinction Depth (m)	Model Domain		0.5	4	None
Parameter	**Geologic unit**		**Parameter Min.**	**Parameter Max.**	**Constraints**
Recharge[1]	Alluvium and Basalt		0.2%	6.5%	None
	Upper WCM		0.4%	6.5%	None
	Marburg Sandstone		0.4%	6.5%	None
[1] Percent of annual rainfall (635 mm/yr) (www.bom.gov.au)					

Notes:

k_h - horizontal hydraulic conductivity

k_z - vertical hydraulic conductivity



LEGEND

Bores Used

- DNRM Bores
- Landholders Bores
- Project Bores
- Watercourse

- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

Modelled Surface Geology

- Alluvium (Qa)
- Basalt (Tm)
- Walloon Subgroup (Jw)
- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 5-1 - Bores Used In Calibration

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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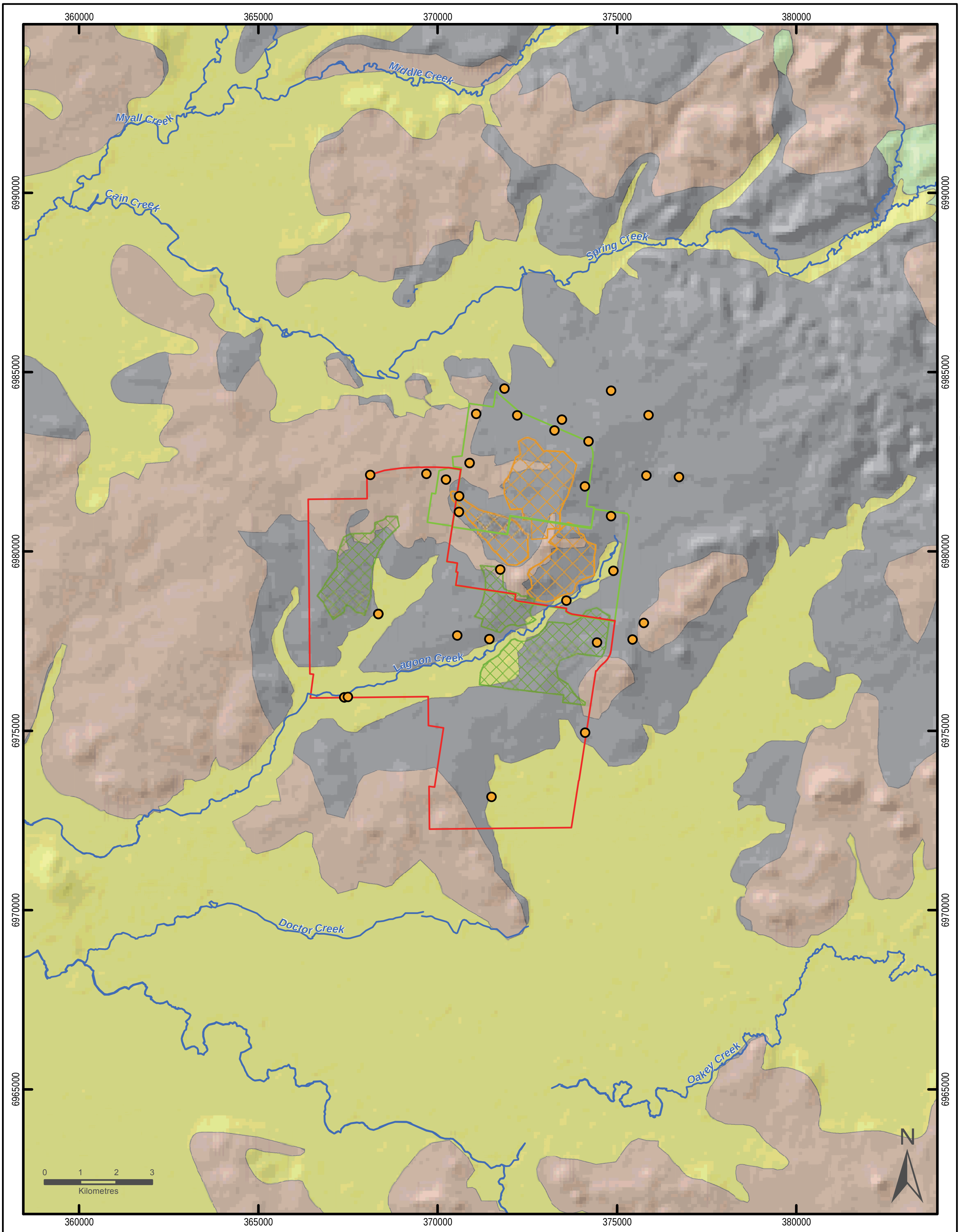

LEGEND

- Monitoring Bore Locations
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

Modelled Surface Geology

- Alluvium (Qa)
- Basalt (Tm)
- Walloon Subgroup (Jw)
- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 5-2 - Monitoring Bore Locations

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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Table 5.2 : Summary of Head Target Weighting

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
2289	NAC	N	N	Confirmed	NAC		1	Upper WCM
2291	NAC	N	N	Confirmed	NAC		1	Upper WCM
109P	NAC	Y	Y	Confirmed	NAC		1	Tertiary Basalt
110PGC	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
111PGC_Low	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
111PGC_Up	NAC	Y	Y	Confirmed	NAC		1	Lower WCM
112PGC	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
113PGCA	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
113PGCB	NAC	Y	Y	Confirmed	NAC		1	Lower WCM
114P	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
116P	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
117PCG	NAC	Y	N	Confirmed	NAC		1	Upper WCM
118P	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
119PCG	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
120WB	NAC	Y	Y	Confirmed	NAC		1	Upper WCM
18Pb	NAC	N	N	Confirmed	NAC	439.554	1	Tertiary Basalt
18Pc	NAC	N	N	Confirmed	NAC		1	Upper WCM
20Phs	NAC	N	N	Confirmed	NAC	419.8	1	Marburg Sandstone
21Phs	NAC	N	N	Confirmed	NAC	415.3	1	Marburg Sandstone
25Pc	NAC	N	Y	Confirmed	NAC		1	Upper WCM
26Pc	NAC	N	Y	Confirmed	NAC	452	1	Upper WCM
27Pc	NAC	N	Y	Confirmed	NAC	439.148	1	Upper WCM
28Pc	NAC	N	Y	Confirmed	NAC	432.56	1	Upper WCM
29Phs	NAC	N	N	Confirmed	NAC	441.63	1	Marburg Sandstone
40Pc	NAC	N	N	Confirmed	NAC	402.758	1	Upper WCM
41Phs	NAC	N	N	Confirmed	NAC	414.09	1	Marburg Sandstone
42Pc	NAC	N	N	Confirmed	NAC	415.037	1	Upper WCM
48Phs	NAC	N	N	Confirmed	NAC	415.51	1	Marburg Sandstone
81Pc	NAC	N	N	Confirmed	NAC		1	Upper WCM
82Pc	NAC	N	N	Confirmed	NAC		1	Upper WCM
83Pc	NAC	N	N	Confirmed	NAC		1	Upper WCM
843b	NAC	N	N	Confirmed	NAC	424.54	1	Tertiary Basalt
848c	NAC	N	N	Confirmed	NAC	436.89	1	Upper WCM
84Pb	NAC	N	N	Confirmed	NAC		1	Tertiary Basalt
BMH1	NAC	N	N	Confirmed	NAC		1	Tertiary Basalt
CSMH1	NAC	N	N	Confirmed	NAC		1	Upper WCM

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
52921	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
83425	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
87205	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
87282	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
129159	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
129694	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
129701	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
129708	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
129711	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143028	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143029	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143030	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143040	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143432	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143557	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
143927	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147191	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147193	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147197	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147198	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147200	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
147202	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147205	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147295	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
147296	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
147304	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147309	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147312	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147317	DNRM	N	Y	DNRM Description	Unknown		0.2	Alluvium
147342	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
147345	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
147368	DNRM	N	Y	DNRM Description	Unknown		0.2	Lower WCM
147392	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
147704	DNRM	N	Y	DNRM Description	Unknown		0.2	Lower WCM
147710	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
154313	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
42230136	DNRM	N	Y	DNRM Description	Unknown	346.14	0.2	Alluvium
42230875	DNRM	N	Y	DNRM Description	Unknown	425.16	0.2	Alluvium
42230876	DNRM	N	Y	DNRM Description	Unknown	422.49	0.2	Alluvium
42230876	DNRM	N	Y	DNRM Description	Unknown	422.49	0.2	Alluvium
42230880	DNRM	N	Y	DNRM Description	Unknown	402.48	0.2	Alluvium
42230882	DNRM	N	Y	DNRM Description	Unknown	378.69	0.2	Alluvium

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
42230883	DNRM	N	Y	DNRM Description	Unknown	378.29	0.2	Alluvium
42230883	DNRM	N	Y	DNRM Description	Unknown	378.29	0.2	Alluvium
42230884	DNRM	N	Y	DNRM Description	Unknown	375.37	0.2	Alluvium
42230886	DNRM	N	Y	DNRM Description	Unknown	377.8	0.2	Alluvium
42230934	DNRM	N	Y	DNRM Description	Unknown	371.335	0.2	Alluvium
42230934	DNRM	N	Y	DNRM Description	Unknown	371.335	0.2	Alluvium
42230935	DNRM	N	Y	DNRM Description	Unknown	386.6	0.2	Tertiary Basalt
42230936	DNRM	N	Y	DNRM Description	Unknown	382.76	0.2	Tertiary Basalt
42230937	DNRM	N	Y	DNRM Description	Unknown	379.7	0.2	Tertiary Basalt
42230937	DNRM	N	Y	DNRM Description	Unknown	379.7	0.2	Tertiary Basalt
42230938	DNRM	N	Y	DNRM Description	Unknown	393.98	0.2	Tertiary Basalt
42230953	DNRM	N	Y	DNRM Description	Unknown	390.13	0.2	Tertiary Basalt
42230954	DNRM	N	Y	DNRM Description	Unknown	440.87	0.2	Tertiary Basalt
42230954	DNRM	N	Y	DNRM Description	Unknown	440.87	0.2	Tertiary Basalt
42230959	DNRM	N	Y	DNRM Description	Unknown	483.28	0.2	Tertiary Basalt
42230960	DNRM	N	Y	DNRM Description	Unknown	507.135	0.2	Tertiary Basalt
42230981	DNRM	N	Y	DNRM Description	Unknown	386.63	0.2	Tertiary Basalt
42230981	DNRM	N	Y	DNRM Description	Unknown	386.63	0.2	Tertiary Basalt
42230982	DNRM	N	Y	DNRM Description	Unknown	379.81	0.2	Tertiary Basalt
42231183	DNRM	N	Y	DNRM Description	Unknown	400.47	0.2	Tertiary Basalt
42231229	DNRM	N	Y	DNRM Description	Unknown	378.23	0.2	Alluvium

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
42231229	DNRM	N	Y	DNRM Description	Unknown	378.23	0.2	Alluvium
42231230	DNRM	N	Y	DNRM Description	Unknown	377.89	0.2	Alluvium
42231293	DNRM	N	Y	DNRM Description	Unknown	364.37	0.2	Alluvium
42231294	DNRM	N	Y	DNRM Description	Unknown	364.42	0.2	Alluvium
42231294	DNRM	N	Y	DNRM Description	Unknown	364.42	0.2	Alluvium
42231295	DNRM	N	Y	DNRM Description	Unknown	352.12	0.2	Upper WCM
42231296	DNRM	N	Y	DNRM Description	Unknown		0.2	Alluvium
42231299	DNRM	N	Y	DNRM Description	Unknown	395.745	0.2	Alluvium
42231299	DNRM	N	Y	DNRM Description	Unknown	395.745	0.2	Alluvium
42231300	DNRM	N	Y	DNRM Description	Unknown	421.36	0.2	Alluvium
42231301	DNRM	N	Y	DNRM Description	Unknown	401.18	0.2	Alluvium
42231302	DNRM	N	Y	DNRM Description	Unknown	399.975	0.2	Alluvium
42231302	DNRM	N	Y	DNRM Description	Unknown	399.975	0.2	Alluvium
42231303	DNRM	N	Y	DNRM Description	Unknown	396.005	0.2	Alluvium
42231304	DNRM	N	Y	DNRM Description	Unknown	397.67	0.2	Alluvium
42231305	DNRM	N	Y	DNRM Description	Unknown	395.765	0.2	Alluvium
42231305	DNRM	N	Y	DNRM Description	Unknown	395.765	0.2	Alluvium
42231306	DNRM	N	Y	DNRM Description	Unknown	397.48	0.2	Tertiary Basalt
42231307	DNRM	N	Y	DNRM Description	Unknown	389.675	0.2	Alluvium
42231308	DNRM	N	Y	DNRM Description	Unknown	383.33	0.2	Alluvium
42231308	DNRM	N	Y	DNRM Description	Unknown	383.33	0.2	Alluvium

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
42231309	DNRM	N	Y	DNRM Description	Unknown	378.115	0.2	Alluvium
42231310	DNRM	N	Y	DNRM Description	Unknown	380.38	0.2	Alluvium
42231340	DNRM	N	Y	DNRM Description	Unknown	373.54	0.2	Upper WCM
42231340	DNRM	N	Y	DNRM Description	Unknown	373.54	0.2	Upper WCM
42231341	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
42231342	DNRM	N	Y	DNRM Description	Unknown	395.22	0.2	Upper WCM
42231357	DNRM	N	Y	DNRM Description	Unknown	395	0.2	Upper WCM
42231357	DNRM	N	Y	DNRM Description	Unknown	395	0.2	Upper WCM
42231358	DNRM	N	Y	DNRM Description	Unknown	394.16	0.2	Upper WCM
42231382	DNRM	N	Y	DNRM Description	Unknown	393.25	0.2	Alluvium
42231383	DNRM	N	Y	DNRM Description	Unknown	393.54	0.2	Alluvium
42231383	DNRM	N	Y	DNRM Description	Unknown	393.54	0.2	Alluvium
42231384	DNRM	N	Y	DNRM Description	Unknown	383.8	0.2	Alluvium
42231385	DNRM	N	Y	DNRM Description	Unknown	385.39	0.2	Alluvium
42231395	DNRM	N	Y	DNRM Description	Unknown	373	0.2	Alluvium
42231395	DNRM	N	Y	DNRM Description	Unknown	373	0.2	Alluvium
42231396	DNRM	N	Y	DNRM Description	Unknown	380.58	0.2	Alluvium
42231397	DNRM	N	Y	DNRM Description	Unknown	379.26	0.2	Alluvium
42231398	DNRM	N	Y	DNRM Description	Unknown	376.72	0.2	Alluvium
42231398	DNRM	N	Y	DNRM Description	Unknown	376.72	0.2	Alluvium
42231399	DNRM	N	Y	DNRM Description	Unknown	381.71	0.2	Alluvium

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
42231400	DNRM	N	Y	DNRM Description	Unknown	382.53	0.2	Alluvium
42231401	DNRM	N	Y	DNRM Description	Unknown	385.19	0.2	Tertiary Basalt
42231401	DNRM	N	Y	DNRM Description	Unknown	385.19	0.2	Tertiary Basalt
42231402	DNRM	N	Y	DNRM Description	Unknown	391.78	0.2	Tertiary Basalt
42231403	DNRM	N	Y	DNRM Description	Unknown	388.49	0.2	Tertiary Basalt
42231404	DNRM	N	Y	DNRM Description	Unknown	389.31	0.2	Tertiary Basalt
42231404	DNRM	N	Y	DNRM Description	Unknown	389.31	0.2	Tertiary Basalt
42231405	DNRM	N	Y	DNRM Description	Unknown	404.93	0.2	Alluvium
42231447	DNRM	N	Y	DNRM Description	Unknown	387.79	0.2	Tertiary Basalt
42231447	DNRM	N	Y	DNRM Description	Unknown	387.79	0.2	Tertiary Basalt
42231492	DNRM	N	Y	DNRM Description	Unknown	363.5	0.2	Alluvium
42231493	DNRM	N	Y	DNRM Description	Unknown	363.395	0.2	Alluvium
42231498	DNRM	N	Y	DNRM Description	Unknown	378.32	0.2	Alluvium
42231498	DNRM	N	Y	DNRM Description	Unknown	378.32	0.2	Alluvium
42231523	DNRM	N	Y	DNRM Description	Unknown	443.9	0.2	Tertiary Basalt
42231524	DNRM	N	Y	DNRM Description	Unknown	418.455	0.2	Upper WCM
42231529	DNRM	N	Y	DNRM Description	Unknown	590.89	0.2	Tertiary Basalt
42231529	DNRM	N	Y	DNRM Description	Unknown	590.89	0.2	Tertiary Basalt
42231590	DNRM	N	Y	DNRM Description	Unknown		0.2	Marburg Sandstone
42231593	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
42231594	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt

ID	Source	Geological log	Well construction details	Formation reliability	Sampled by	Steady State Water Level (m AHD)	Weight	Geologic Formation
42231594	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
42231603	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
42231668	DNRM	N	Y	DNRM Description	Unknown		0.2	Tertiary Basalt
Private_Bore1	Landholder Bore	y	Y	Confirmed	SKM		1	Tertiary Basalt
Private_Bore2	Landholder Bore	y	Y	Confirmed	SKM		1	Upper WCM
Private_Bore3	Landholder Bore	y	N	Confirmed	SKM		1	Marburg Sandstone
Private_Bore4	Landholder Bore	N	N	Anecdotal	SKM		0.4	Upper WCM
Private_Bore5	Landholder Bore	N	N	Anecdotal	SKM		0.4	Upper WCM
Private_Bore6	Landholder Bore	N	N	Anecdotal	SKM		0.4	Upper WCM
Private_Bore7	Landholder Bore	N	N	Anecdotal	SKM		0.4	Tertiary Basalt
Private_Bore8	Landholder Bore	N	N	Anecdotal	SKM		0.4	Tertiary Basalt

5.4 Calibration Results

The calibration simulations resulted in 1836 realisations (out of 2980), or sets of model parameters, that simulated groundwater levels within the target calibration criteria of 5% weighted SRMS (the first calibration target). Of these, 45 also simulated pit inflows within the range of inflow estimates used for calibration (between 300-400 m^3/day for 2011 and 2012) (the second calibration target). Therefore, these 45 realisations are considered the calibrated datasets available for an assessment of calibration sensitivity\uncertainty, as well as forming the input parameters for the predictive simulations and associated sensitivity\uncertainty assessments.

5.4.1 Water balance

The overall water balance for the steady state model is provided in **Table 5.3**, as represented by the realisation with the best calibration statistics. Constant Heads provide a majority of the calculated throughflow with the model, although it should be noted that constant head flows have not been filtered for flows between constant head cells. Recharge comprises the majority of total net inflows. Baseflow (Drains) to tributaries and ET are the primary outflows mechanisms.

The water balance discrepancy between calculated inflows and outflows is negligible.

Table 5.3 : Steady state water balance

	Inflows	Outflows
Well	0	-170.3
Constant Heads	213661.5	-201993
River	106.1	-93.8
Drain	0	-33082.5
Recharge	35364.0	0
ET	0	-13792.5
Total	**249131.6**	**-249132.1**
Percent Discrepancy	**-0.012**	

5.4.2 Statistics

Table 5.4 provides a summary of statistical measures used to compare results from model simulations using the calibrated datasets with observed data used as calibration targets. Plots of observed and all equivalent realisation-simulated groundwater levels for the steady state and transient calibration are presented in **Figure 5-3** and **Figure 5-4** respectively, as represented by the realisation with the best calibration statistics.

Table 5.4 : Summary of Calibration Statistics

	Minimum	Median	Maximum
Mean Residual	0.0	4.7	8.7
Absolute Residual Mean	6.6	7.9	9.3
Standard Deviation	10.6	12.5	14.1
Sum of squares	556775.8	778458.4	1218447.3
RMS Error	11.2	13.2	16.6
Min Residual	-54.2	-36.9	-22.9
Max Residual	42.2	48.9	55.9
Number of observations	4440	4440	4440
Range in observations	449.7	449.7	449.7
Scaled Standard Deviation	0.02	0.03	0.03
Scaled Abs. Mean	0.01	0.02	0.02
Scaled RMS	2.5%	2.9%	3.7%

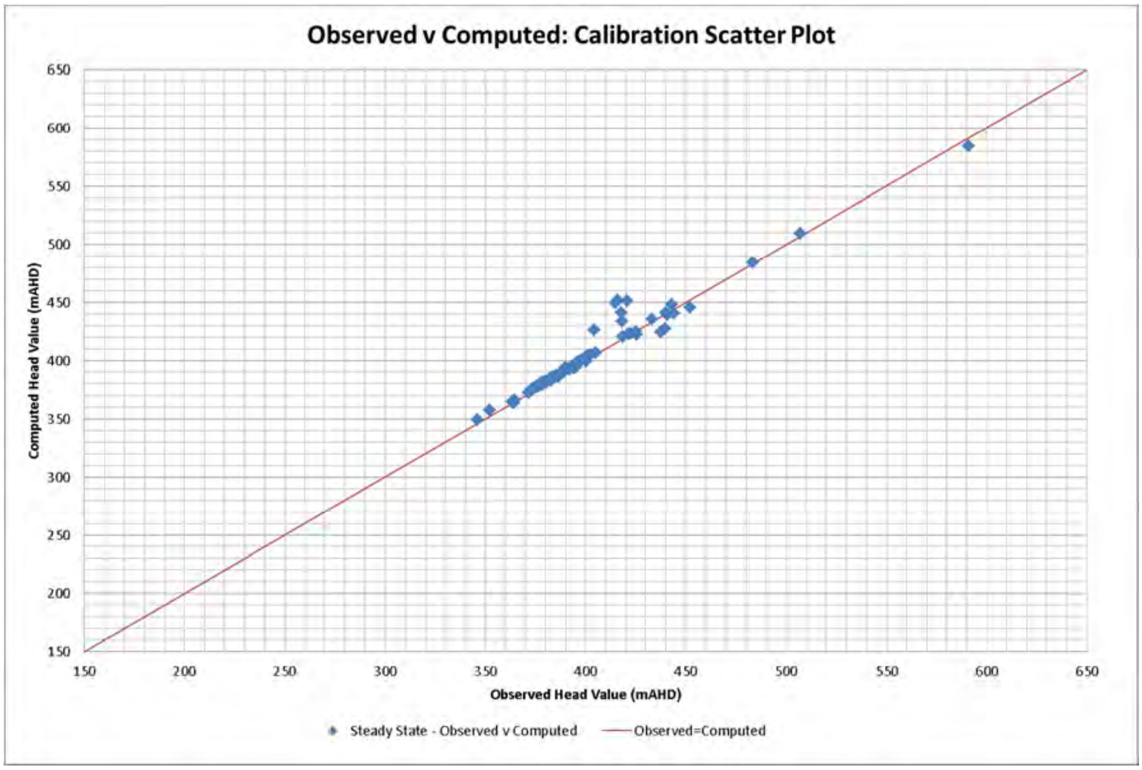


Figure 5-3 : Observed vs. Simulated Groundwater Levels (Steady State)

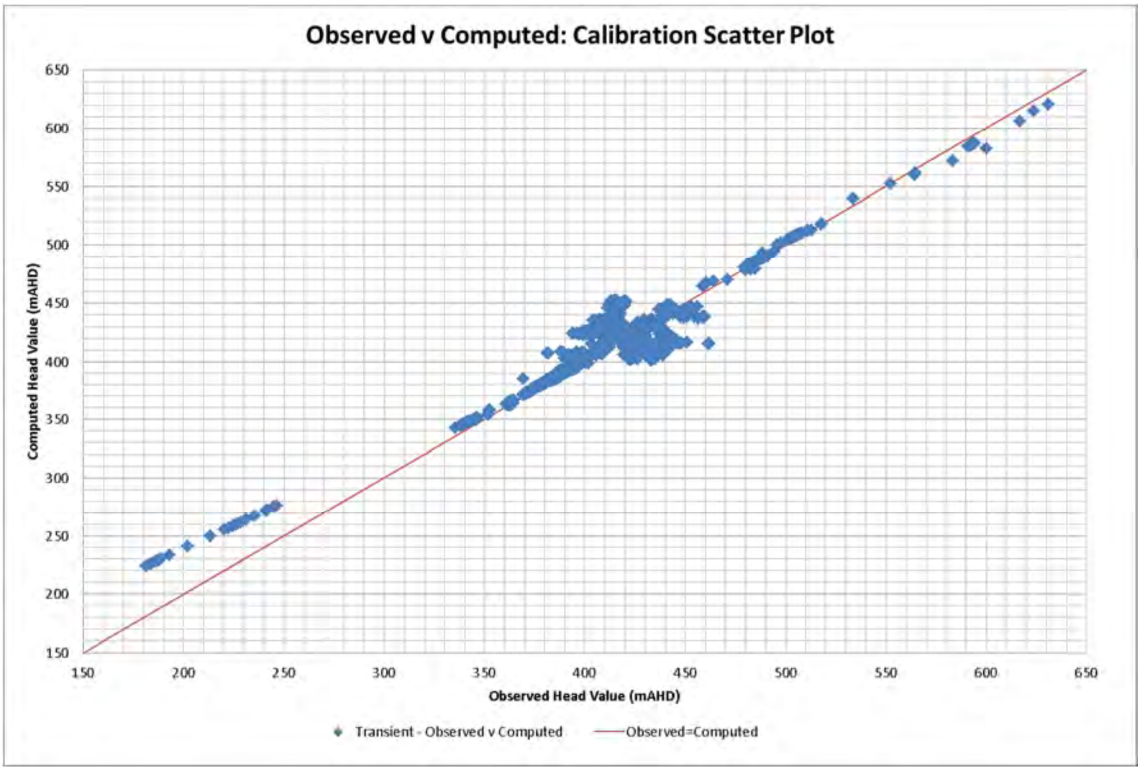


Figure 5-4 : Observed vs. Simulated Groundwater Levels (Transient)

Pre-mining steady state heads are not readily available and were reliant upon data collected form the DNRM database. As discussed previously in the report Jacobs are unable to verify the quality of this data. In addition the data available are not centred upon the project site but are more regional and thus calibration to pre-mining water levels can best be described as a means to provide regional flow directions.

In addition to the paucity of data available for pre-mining water levels, the model does not account for other historic activities in the area unknown or quantifiable to the project proponent. As such the model should be judged upon its ability to replicate regional flow gradients and drawdown magnitudes where information is available. Based upon this expectation the model calibration has been considered fit for the purpose for this assessment.

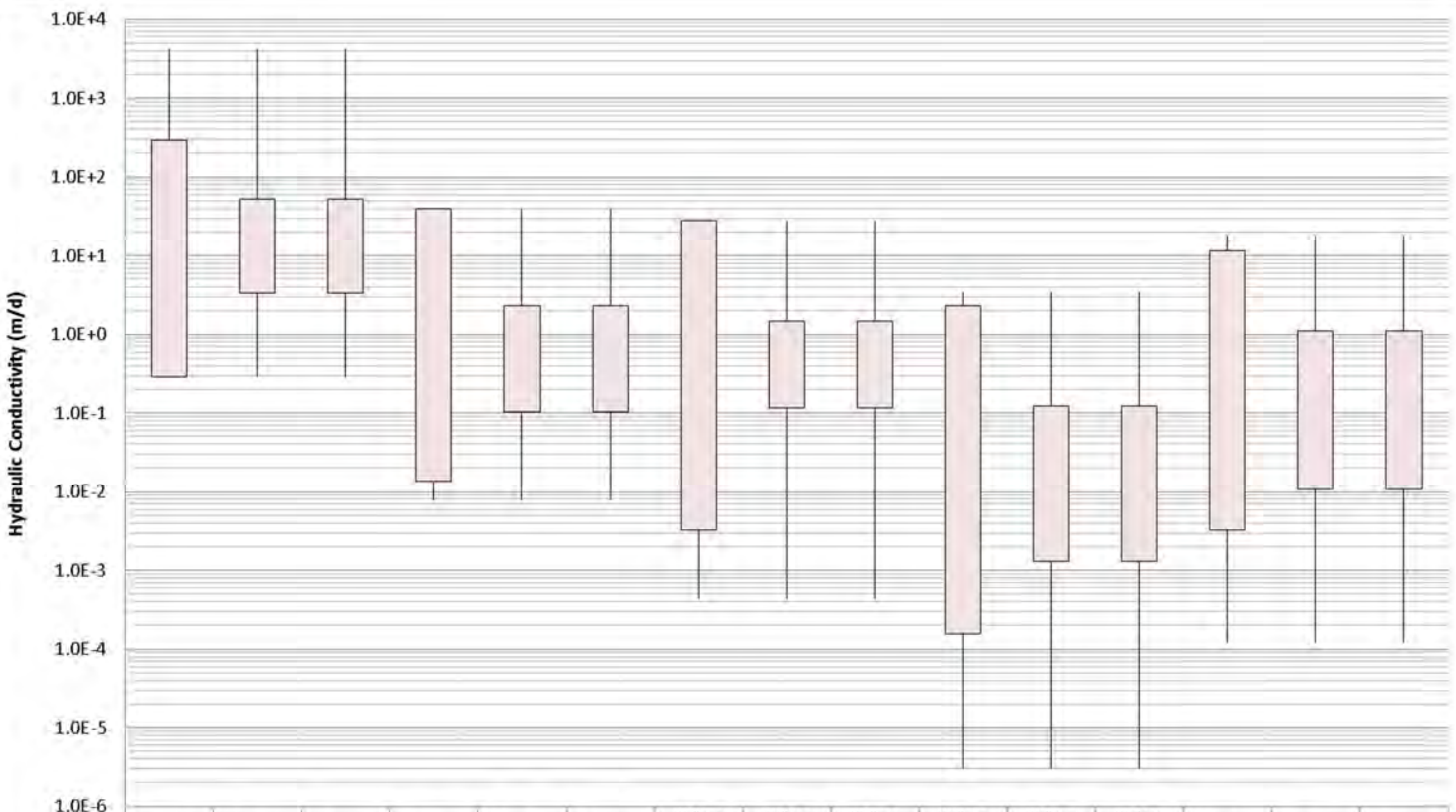
Additional calibration comparisons and information are provided in Appendix A. The additional analyses include hydrographs of observed and simulated groundwater levels for all bores with more than one data point. Given that the availability of water level data for the region is both scarce and transiently sporadic in an area of intense groundwater development, it was considered that developing pre-mining potentiometric surfaces to compare with modelled potentiometric surfaces is not appropriate as outlined above. Rather, maps showing the spatial distribution of calibration SRMS error at each target bore location are also provided in Appendix A, allowing the spatial distribution of calibration to be assessed without the need to develop highly unreliable maps of pre-mining potentiometric surfaces. The SRMS maps are provided for each model layer. As indicated by the hydrographs and SRMS maps the model is able to provide a reasonable replication of water levels across the model domain, and for most locations provides a good replication of drawdown from mining activities where information is available. .

5.4.3 Calibration Sensitivity Analysis

The input and calibrated parameter ranges are presented graphically and in tabular form in **Figure 5.5** through **Figure 5.10**. The calibrated ranges provide an indication of the model's sensitivity to changes in the parameter values while also providing an indication of the parameter value's uncertainty. For the calibrated datasets, model parameters with values that represent a lower percentage of the stochastic range indicate that model calibration is more sensitive to these parameters.

The box and whisker plots (**Figure 5.5** through **5.10**) provide three box and whiskers for each parameter. The different box and whiskers represent the dataset ranges from each calibration objective (matching SRMS and pit inflows) individually and then the final distribution with them both combined.

Additional plots are provided in **Appendix B** that provide a comparison of the distribution of parameter values before and after calibration. These graphs, in some instances, provide an indication of skewing or bias within the calibrated parameter ranges. A summary of observations for each of the parameters tested for sensitivity is provided in **Table 5.5**.

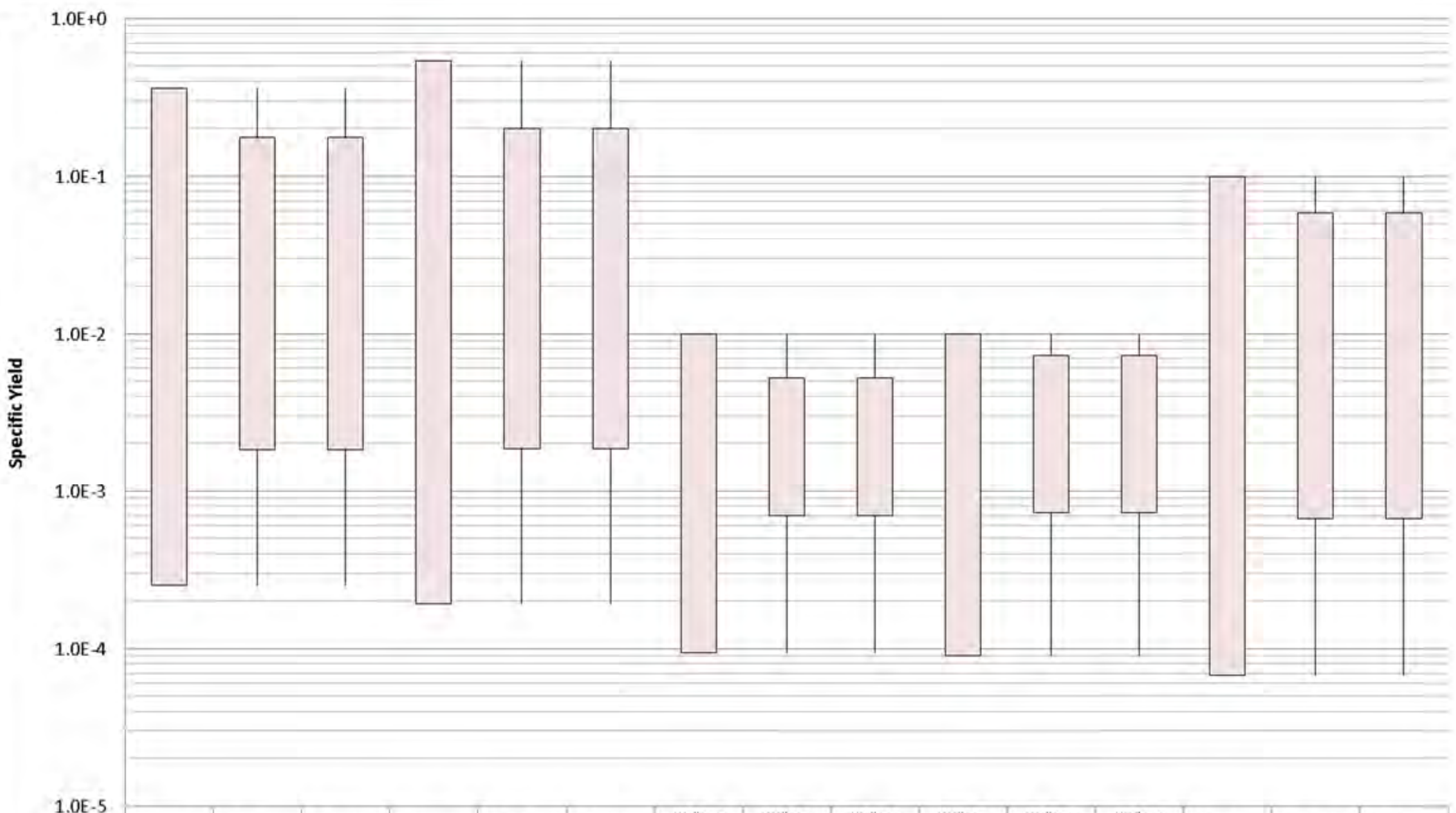


	Alluvium - SRMS	Alluvium - Inflows	Alluvium - Combined	Basalt - SRMS	Basalt - Inflows	Basalt - Combined	Walloon (upper) - SRMS	Walloon (upper) - Inflows	Walloon (upper) - Combined	Walloon (lower) - SRMS	Walloon (lower) - Inflows	Walloon (lower) - Combined	Marburg - SRMS	Marburg - Inflows	Marburg - Combined
Calibration Min	2.9E-01	3.4E+00	3.4E+00	1.4E-02	1.0E-01	1.0E-01	3.3E-03	1.2E-01	1.2E-01	1.6E-04	1.3E-03	1.3E-03	3.3E-03	1.1E-02	1.1E-02
Input Max	4.1E+03	4.1E+03	4.1E+03	4.0E+01	4.0E+01	4.0E+01	2.8E+01	2.8E+01	2.8E+01	3.5E+00	3.5E+00	3.5E+00	1.9E+01	1.9E+01	1.9E+01
Input Min	2.9E-01	2.9E-01	2.9E-01	7.9E-03	7.9E-03	7.9E-03	4.4E-04	4.4E-04	4.4E-04	3.0E-06	3.0E-06	3.0E-06	1.2E-04	1.2E-04	1.2E-04
Calibration Max	2.9E+02	5.3E+01	5.3E+01	4.0E+01	2.3E+00	2.3E+00	2.8E+01	1.5E+00	1.5E+00	2.3E+00	1.2E-01	1.2E-01	1.2E+01	1.1E+00	1.1E+00

Figure 5-5 : Model Parameter Sensitivity: Horizontal Hydraulic Conductivity

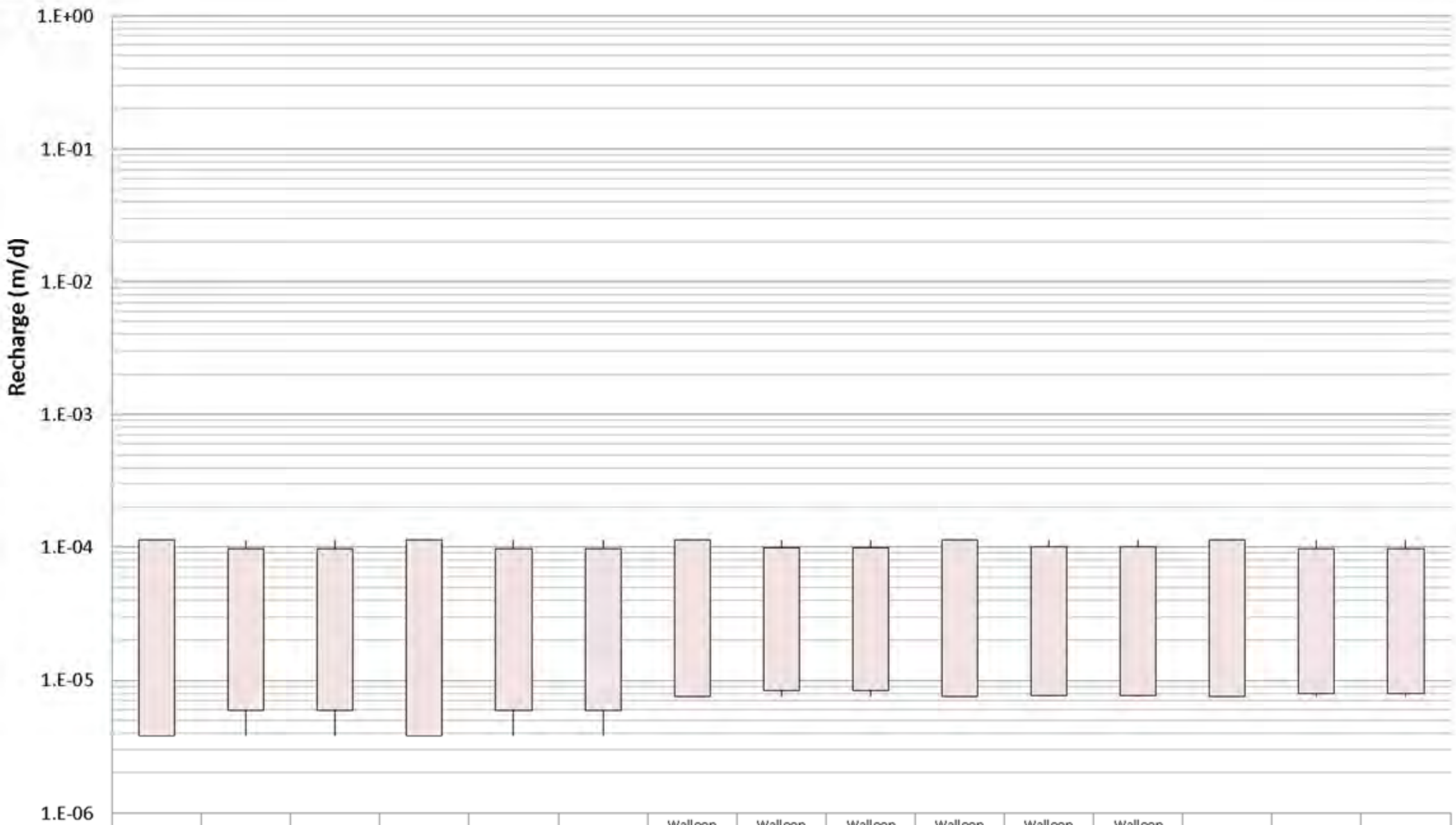
	Alluvium - SRMS	Alluvium - Inflows	Alluvium - Combined	Basalt - SRMS	Basalt - Inflows	Basalt - Combined	Walloon (upper) - SRMS	Walloon (upper) - Inflows	Walloon (upper) - Combined	Walloon (lower) - SRMS	Walloon (lower) - Inflows	Walloon (lower) - Combined	Marburg - SRMS	Marburg - Inflows	Marburg - Combined
Calibration Min	8.8E-04	1.5E-02	1.5E-02	2.1E-05	2.4E-04	2.4E-04	1.1E-05	5.5E-05	5.5E-05	2.9E-06	6.3E-06	6.3E-06	1.5E-05	5.7E-05	5.7E-05
Input Max	1.6E+02	1.6E+02	1.6E+02	1.3E+00	1.3E+00	1.3E+00	1.5E-01	1.5E-01	1.5E-01	2.2E-01	2.2E-01	2.2E-01	1.2E+01	1.2E+01	1.2E+01
Input Min	6.6E-04	6.6E-04	6.6E-04	2.1E-05	2.1E-05	2.1E-05	2.0E-07	2.0E-07	2.0E-07	2.6E-08	2.6E-09	2.6E-08	9.9E-07	9.9E-07	9.9E-07
Calibration Max	1.7E+01	1.2E+00	1.2E+00	1.3E+00	4.9E-02	4.9E-02	1.5E-01	2.8E-03	2.8E-03	2.2E-01	5.3E-03	5.3E-03	1.2E+01	2.1E-01	2.1E-01

Figure 5-6 : Model Parameter Sensitivity: Vertical Hydraulic Conductivity



	Alluvium - SRMS	Alluvium - Inflows	Alluvium - Combined	Basalt - SRMS	Basalt - Inflows	Basalt - Combined	Walloon (upper) - SRMS	Walloon (upper) - Inflows	Walloon (upper) - Combined	Walloon (lower) - SRMS	Walloon (lower) - Inflows	Walloon (lower) - Combined	Marburg - SRMS	Marburg - Inflows	Marburg - Combined
Calibration Min	2.5E-04	1.9E-03	1.9E-03	1.9E-04	1.9E-03	1.9E-03	9.4E-05	6.9E-04	6.9E-04	9.0E-05	7.3E-04	7.3E-04	6.7E-05	6.7E-04	6.7E-04
Input Max	3.6E-01	3.6E-01	3.6E-01	5.3E-01	5.3E-01	5.3E-01	1.0E-02	1.0E-02	1.0E-02	1.0E-02	1.0E-02	1.0E-02	9.9E-02	9.9E-02	9.9E-02
Input Min	2.5E-04	2.5E-04	2.5E-04	1.9E-04	1.9E-04	1.9E-04	9.4E-05	9.4E-05	9.4E-05	9.0E-05	9.0E-05	9.0E-05	6.7E-05	6.7E-05	6.7E-05
Calibration Max	3.6E-01	1.8E-01	1.8E-01	5.3E-01	2.0E-01	2.0E-01	1.0E-02	5.2E-03	5.2E-03	1.0E-02	7.2E-03	7.2E-03	9.9E-02	5.8E-02	5.8E-02

Figure 5-7 : Model Parameter Sensitivity: Specific Yield

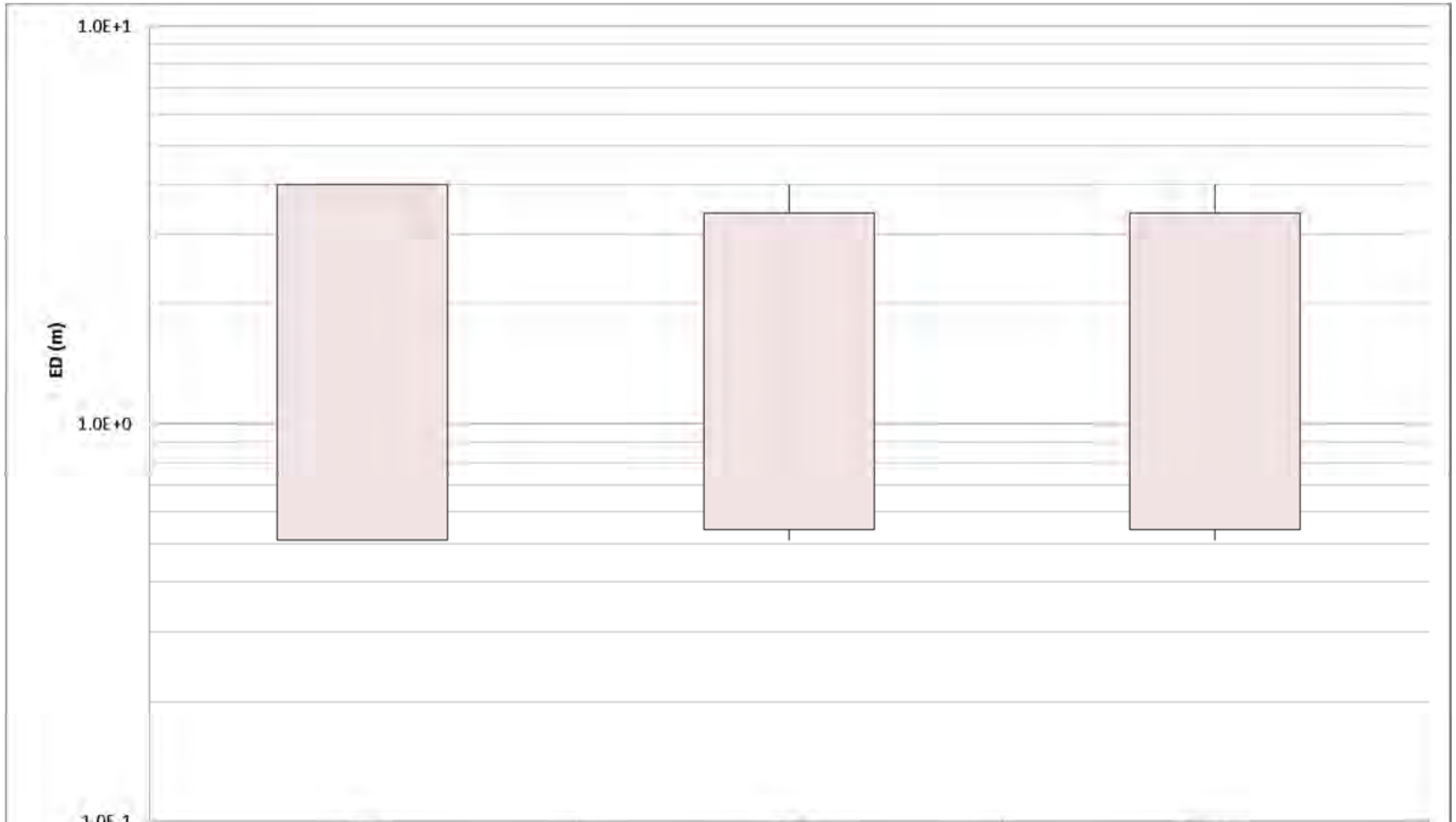


	Alluvium - SRMS	Alluvium - Inflows	Alluvium - Combined	Basalt - SRMS	Basalt - Inflows	Basalt - Combined	Walloon (upper) - SRMS	Walloon (upper) - Inflows	Walloon (upper) - Combined	Walloon (lower) - SRMS	Walloon (lower) - Inflows	Walloon (lower) - Combined	Marburg - SRMS	Marburg - Inflows	Marburg - Combined
Calibration Min	3.8E-06	6.0E-06	6.0E-06	3.8E-06	6.0E-06	6.0E-06	7.6E-06	8.3E-06	8.3E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	8.0E-06	8.0E-06
Input Max	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.1E-04
Input Min	3.8E-06	3.8E-06	3.8E-06	3.8E-06	3.8E-06	3.8E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06	7.6E-06
Calibration Max	1.1E-04	9.7E-05	9.7E-05	1.1E-04	9.7E-05	9.7E-05	1.1E-04	9.9E-05	9.9E-05	1.1E-04	1.0E-04	1.0E-04	1.1E-04	9.7E-05	9.7E-05

Figure 5-8 : Model Parameter Sensitivity: Recharge

	SRMS	Inflows	Combined	SRMS	Inflows	Combined
Calibration Min	1.2E-03	4.7E-02	4.7E-02	1.4E-04	1.7E-02	1.7E-02
Input Max	2.3E+03	2.3E+03	2.3E+03	1.1E+03	1.1E+03	1.1E+03
Input Min	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04	1.4E-04
Calibration Max	2.3E+03	1.3E+02	1.3E+02	1.1E+03	1.5E+02	1.5E+02

Figure 5-9 : Model Parameter Sensitivity: Boundary Conductance



	SRMS	Inflows	Combined
Calibration Min	5.1E-01	5.4E-01	5.4E-01
Input Max	4.0E+00	4.0E+00	4.0E+00
Input Min	5.1E-01	5.1E-01	5.1E-01
Calibration Max	4.0E+00	3.4E+00	3.4E+00

Figure 5-10 : Model Parameter Sensitivity: ET Extinction Depth

Table 5.5 : Summary of Calibration Parameter Sensitivity

Parameter	Geologic unit	Comments
K_h (m/d)	Alluvium	Horizontal conductivity for the alluvium is only slightly constrained at the low and high ranges. The distribution of calibrated values has not been skewed or biased in any direction.
K_h (m/d)	Basalt	Horizontal conductivity for the Basalt is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the higher range in values – as indicated by a minor increase in the 50th percentile value.
K_h (m/d)	Upper WCM	Horizontal conductivity for the Upper WCM is highly constrained at the low and high ranges. The distribution of calibrated values is highly skewed or biased towards the lower range in values – as indicated by a decrease in the 50th percentile value of nearly an order of magnitude.
K_h (m/d)	Lower WCM	Horizontal conductivity for the Lower WCM is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the lower range in values – as indicated by a minor decrease in the 50th percentile value.
K_h (m/d)	Marburg Sandstone	Horizontal conductivity for the Marburg Sandstone is only slightly constrained at the low and high ranges. The distribution of calibrated values has not been skewed or biased in any direction.
K_z (m/d)	Alluvium	Vertical conductivity for the alluvium is only slightly constrained at the low and high ranges. The distribution of calibrated values has not been skewed or biased in any direction.
K_z (m/d)	Basalt	Vertical conductivity for the Basalt is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the higher range in values – as indicated by a minor increase in the 50th percentile value.
K_z (m/d)	Upper WCM	Vertical conductivity for the Upper WCM is highly constrained at the low and high ranges. The distribution of calibrated values is highly skewed or biased towards the lower range in values – as indicated by a decrease in the 50th percentile value and a reduction in the maximum value by nearly three orders of magnitude.
K_z (m/d)	Lower WCM	Vertical conductivity for the Lower WCM is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the lower range in values – as indicated by a minor decrease in the 50th percentile value.
K_z (m/d)	Marburg Sandstone	Vertical conductivity for the Marburg Sandstone is only slightly constrained at the low and high ranges. The distribution of calibrated values has not been skewed or biased in any direction.
S_y	Alluvium	Specific yield for the alluvium is only slightly constrained at the low and high ranges. The distribution of calibrated values has not been skewed or biased in any direction.
S_y	Basalt	Specific yield for the Basalt is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the higher range in values – as indicated by a minor increase in the 50th percentile value.
S_y	Upper WCM	Specific yield for the Upper WCM is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the lower range in values – as indicated by a minor decrease in the 50th percentile value.
S_y	Lower WCM	Specific yield for the Lower WCM is not constrained at the low and high ranges. The distribution of calibrated values is not skewed or biased in any direction.

Parameter	Geologic unit	Comments
S_y	Marburg Sandstone	Specific yield for the Marburg Sandstone is not constrained at the low and high ranges. The distribution of calibrated values is not skewed or biased in any direction.
River Conductance (m^2/d)	Myall Creek	River Conductance for Myall Creek is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the lower range in values – as indicated by a decrease in the 50th percentile value.
River Conductance (m^2/d)	Oakey Creek	River Conductance for Oakey Creek is slightly constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the middle and higher range in values – as indicated by the significant increase in the 10th and 40th percentile values.
ET Extinction Depth	Model Domain	ET Extinction Depth is not constrained at the low and high ranges. The distribution of calibrated values is slightly skewed or biased towards the higher range in values – as indicated by an increase in the 50th percentile value.
Recharge	Alluvium and Basalt	Recharge to the alluvium and Basalt is not constrained at the low and high ranges. The distribution of calibrated values is skewed or biased towards the lower range in values – as indicated by a decrease in the 50th percentile value.
Recharge	Upper WCM	Recharge to the Upper WCM is not constrained at the low and high ranges. The distribution of calibrated values is skewed or biased towards the lower range in values – as indicated by a decrease in the 50th percentile value.
Recharge	Marburg Sandstone	Recharge to the Upper WCM is not constrained at the low and high ranges. The distribution of calibrated values is skewed or biased towards the higher range in values – as indicated by an increase in the 50th percentile value.

6. Predictive simulation results

The parameters sets from the stochastic calibration were used for the predictive simulations in order to provide a stochastic based prediction of potential impacts. All results, where practical, are reported using the median results to present the most likely impacts. Uncertainty bounds are presented using plus and minus one standard deviation. For results, such as potentiometric maps, that are not conducive to this type of presentation the results from the best calibrated realisation is presented.

6.1 Prediction of mine dewatering

The predictive simulation allows all water to flow into the mine pit, from where the water would then be managed. The seepage into the pit was simulated with the lowering of Drain cells to the pit floor according to the mine plans provided. Evapotranspiration surface elevations are also adjusted with the mining depth, along with an extinction depth of 0.5m to account for evaporative losses within the pit. Final estimated pit inflow (all pits combined) is provided in **Figure 6-1**.

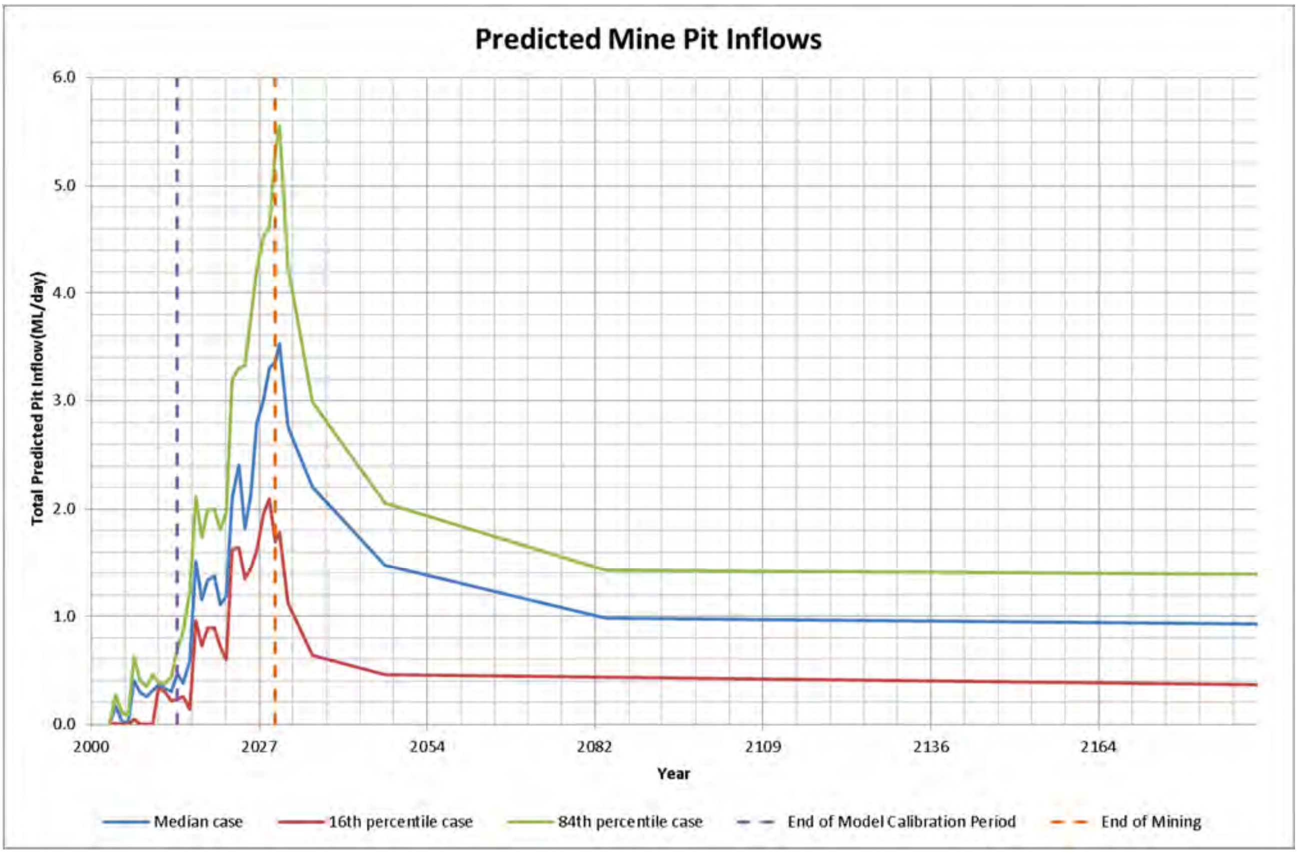


Figure 6-1 : Estimated Pit Inflows

6.2 Water balance

A transient water balance for the best calibrated realisation is provided in **Figure 6-2**. Percent discrepancy is within acceptable bounds (<2%) for the entire model simulation (i.e. time steps and stress periods).

Recharge to model domain is the primary source of net inflow, with ET and flow to drain features (mining and tributaries) comprising the majority of outflow from the model.

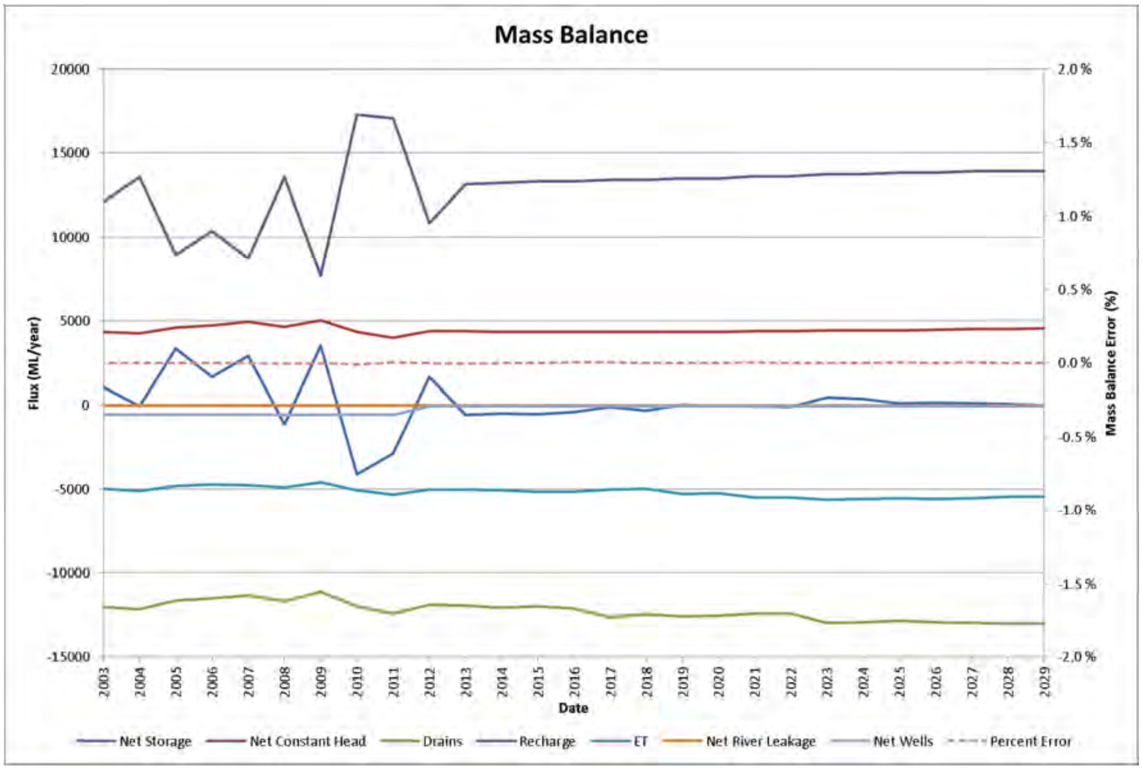


Figure 6-2 : Predictive Mass Balance

The mass balance for the River cells representing Myall Creek and Oakey Creek were assessed for potential induced losses associated with the revised Project. The results indicate that no additional losses are expected to occur above any historic or current impacts as shown in **Figure 6-3**.

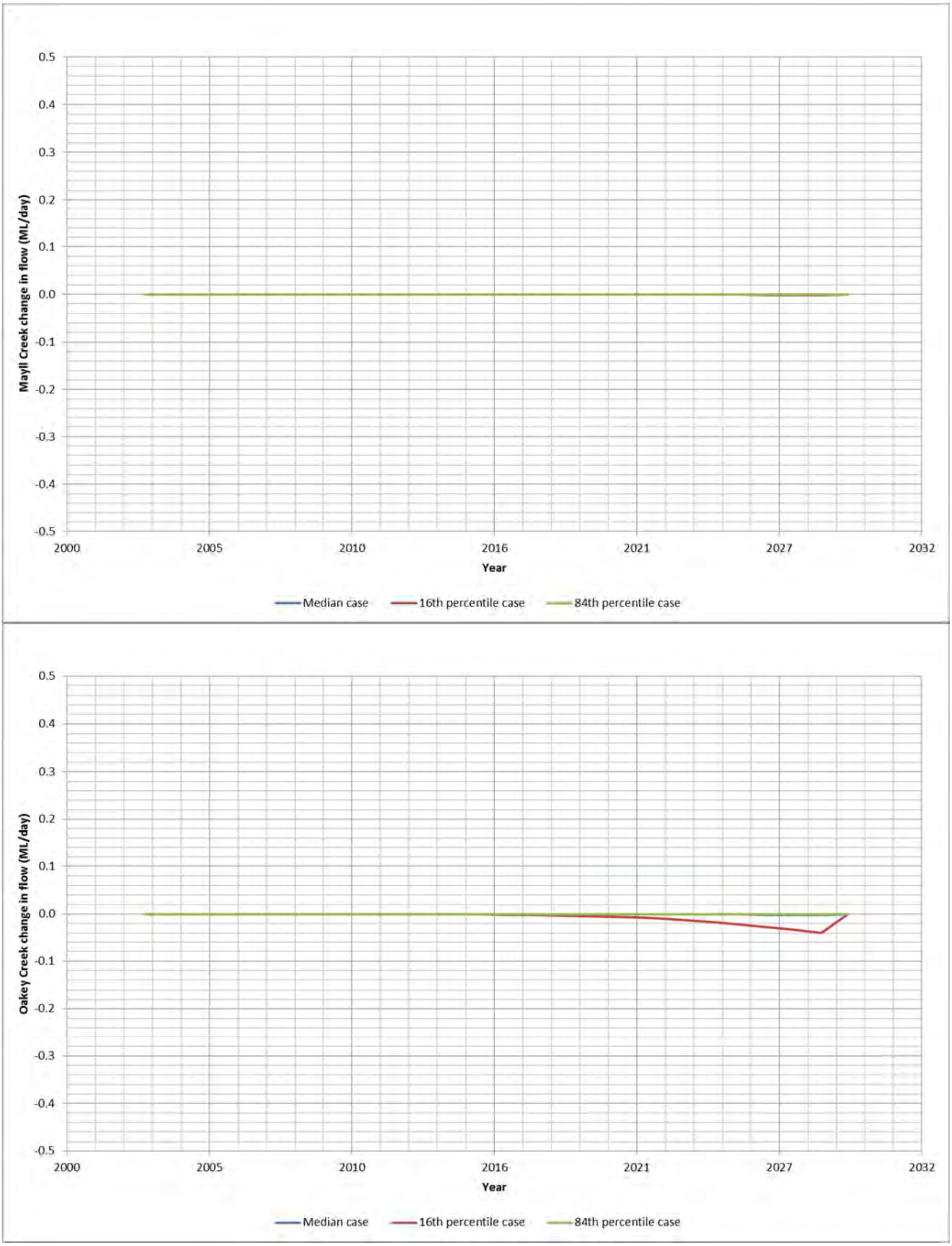


Figure 6-3 : Summary of Potential Baseflow Losses

6.3 Predicted water levels, drawdown and potential impact areas

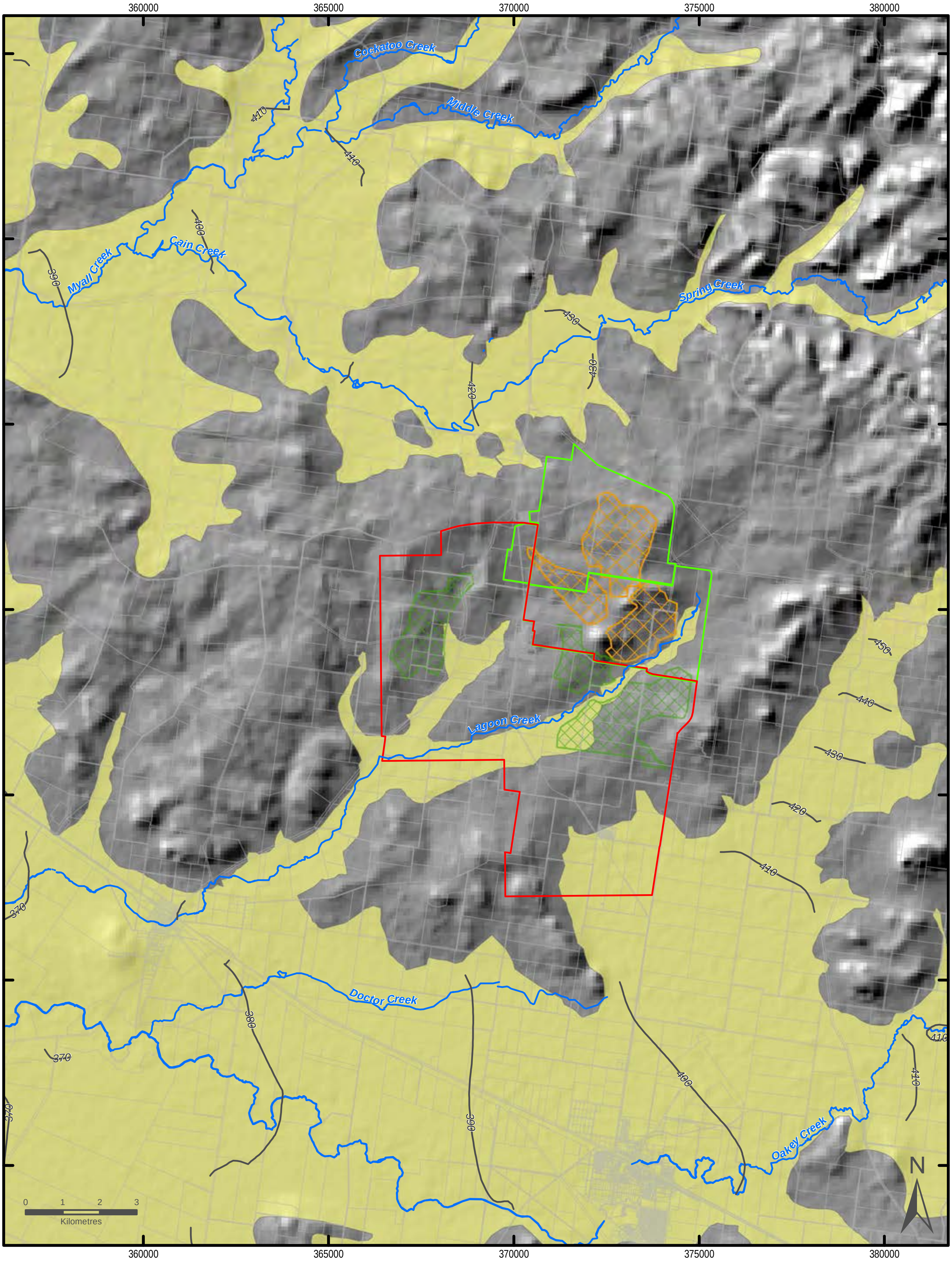
Predicted water level maps for selected periods of mining and post mining for each geologic unit represented in the model are provided in **Figure 6-4** through **Figure 6-19**. The water levels presented are from the best calibrated realisation.

Drawdown maps for selected periods of mining and post mining for each geologic unit represented in the model are provided in **Figure 6-20** through **Figure 6-31**. The drawdown presented is the most *likely* (i.e. median) drawdown based upon the stochastic results.

Potential impact zones for selected periods of mining and post mining for each geologic unit represented in the model are provided in **Figure 6-32** through **Figure 6-42**. The potential impact zones are presented with the most likely case (i.e. median results) and an upper and lower bound (plus and minus one standard deviation) based upon the stochastic results.

Predicted water level recovery within the final depressed landforms (voids) is provided in **Figure 6-43**. Again the results are presented with the most likely case (i.e. median results) and an upper and lower bound (plus and minus one standard deviation) based upon the stochastic results.

Figure 6-4 : Alluvium - Predicted Water Levels – 2017



LEGEND

Alluvium - Predicted Water Levels (mAHD)
Watercourse
New Aland Coal Mine-Stage 3
New Acland Coal Mine
Cadastre
Stage 3 Pit Areas
Existing Permission

Modelled Formation Extents
Alluvium (Qa)

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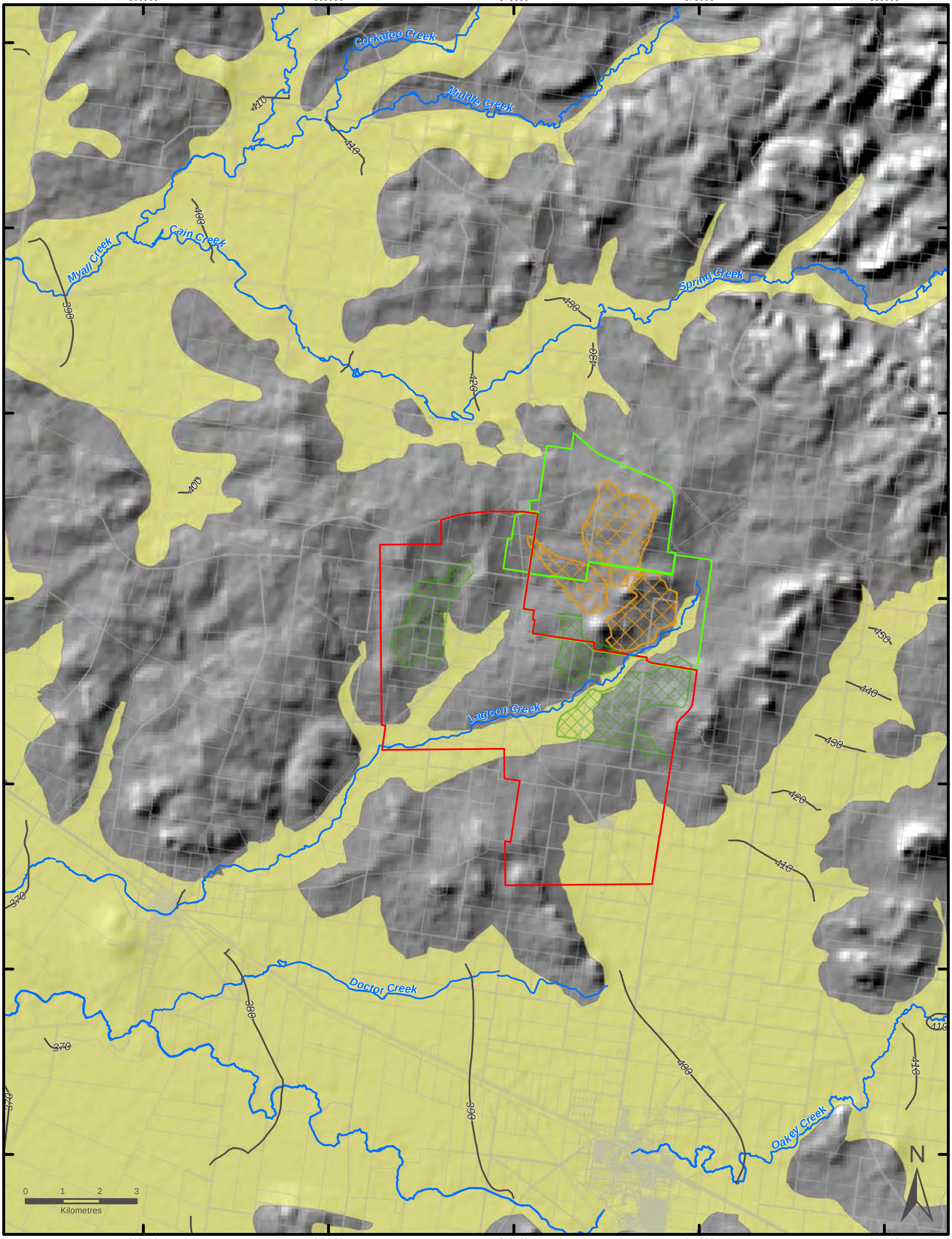
Figure 6-4 - Alluvium Predicted Water Levels – 2017

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-4_PredictedWaterLevelsAlluvium_2017.mxd

Produced: 28/08/2014



LEGEND

- Alluvium - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

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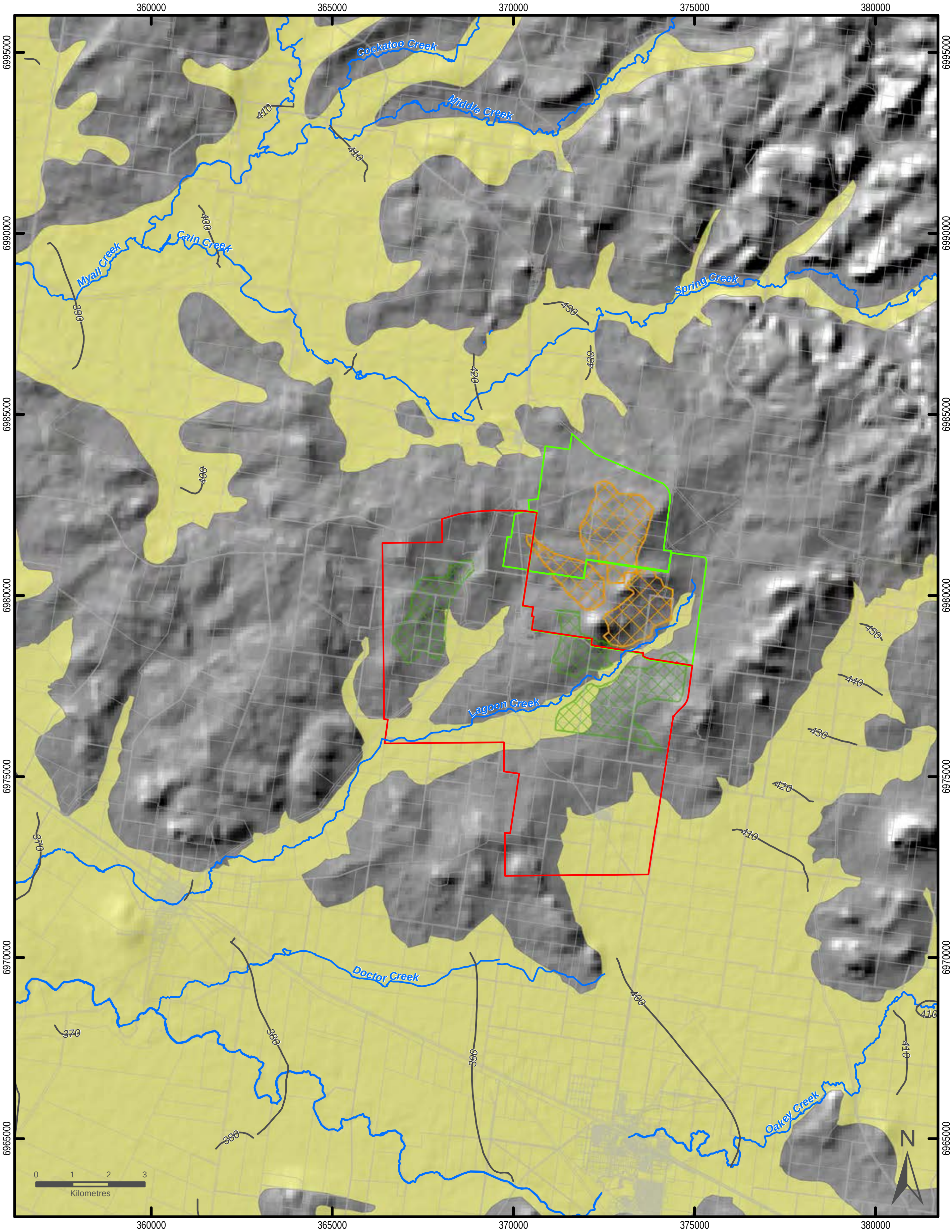
Figure 6-5 - Alluvium Predicted Water Levels – 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-5_PredictedWaterLevelsAlluvium_2021.mxd

Produced: 28/08/2014



LEGEND

- Alluvium - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

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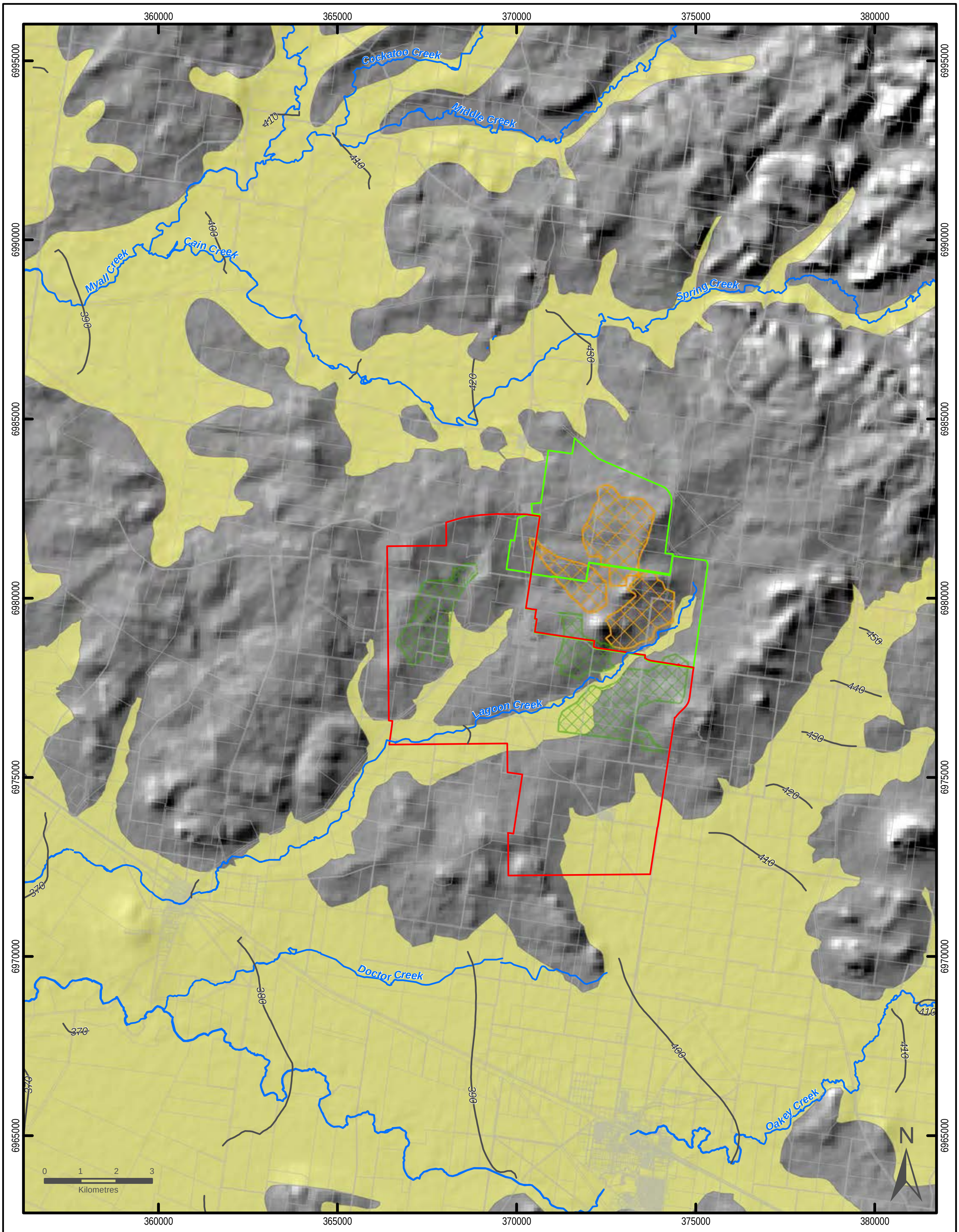
Figure 6-6 - Alluvium
Predicted Water Levels – 2030

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)



LEGEND

- Alluvium - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

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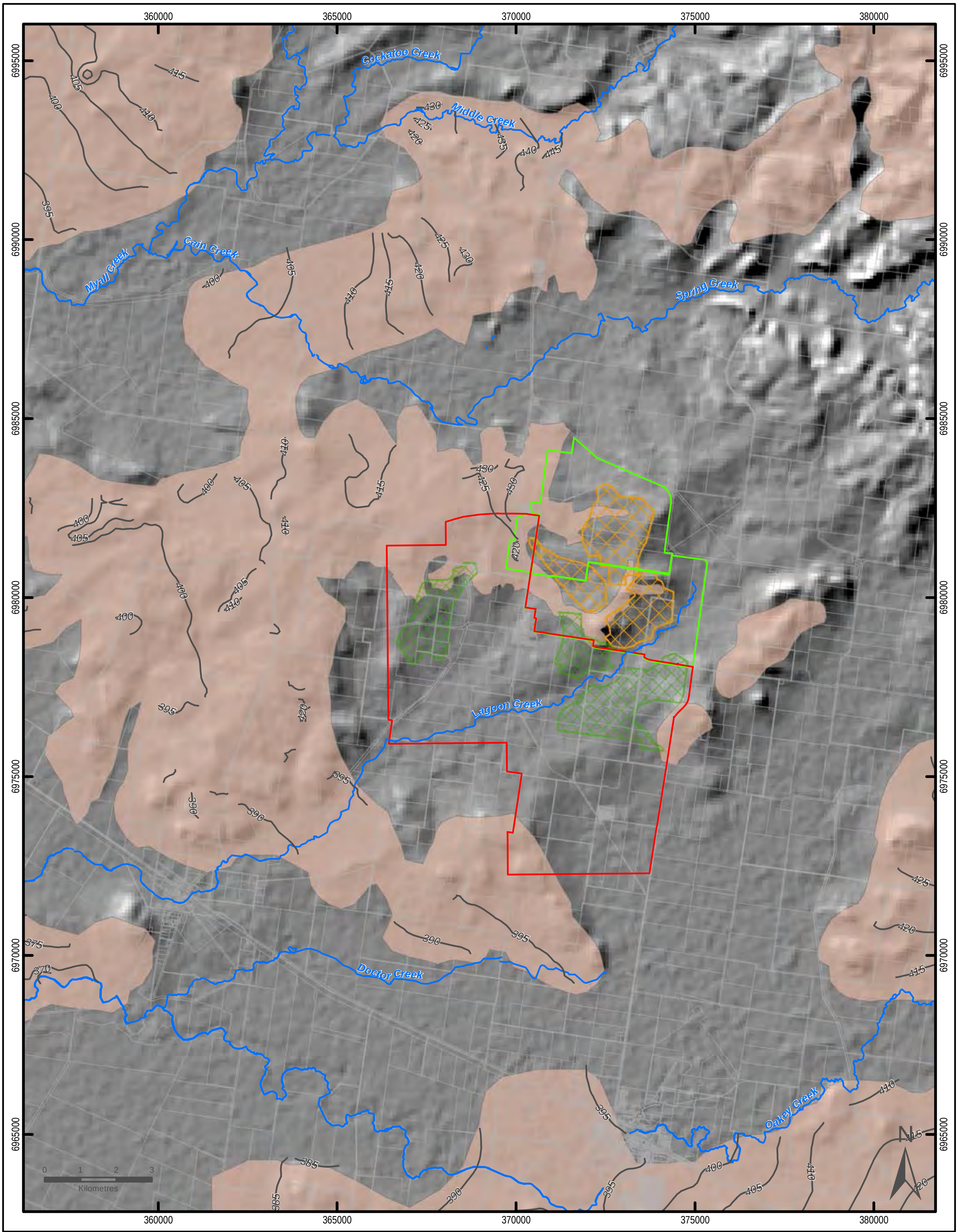
Figure 6-7 - Alluvium Predicted Water Levels – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-7_PredictedWaterLevelsAlluvium_PostMining.mxd

Produced: 28/08/2014



LEGEND

- Basalt - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

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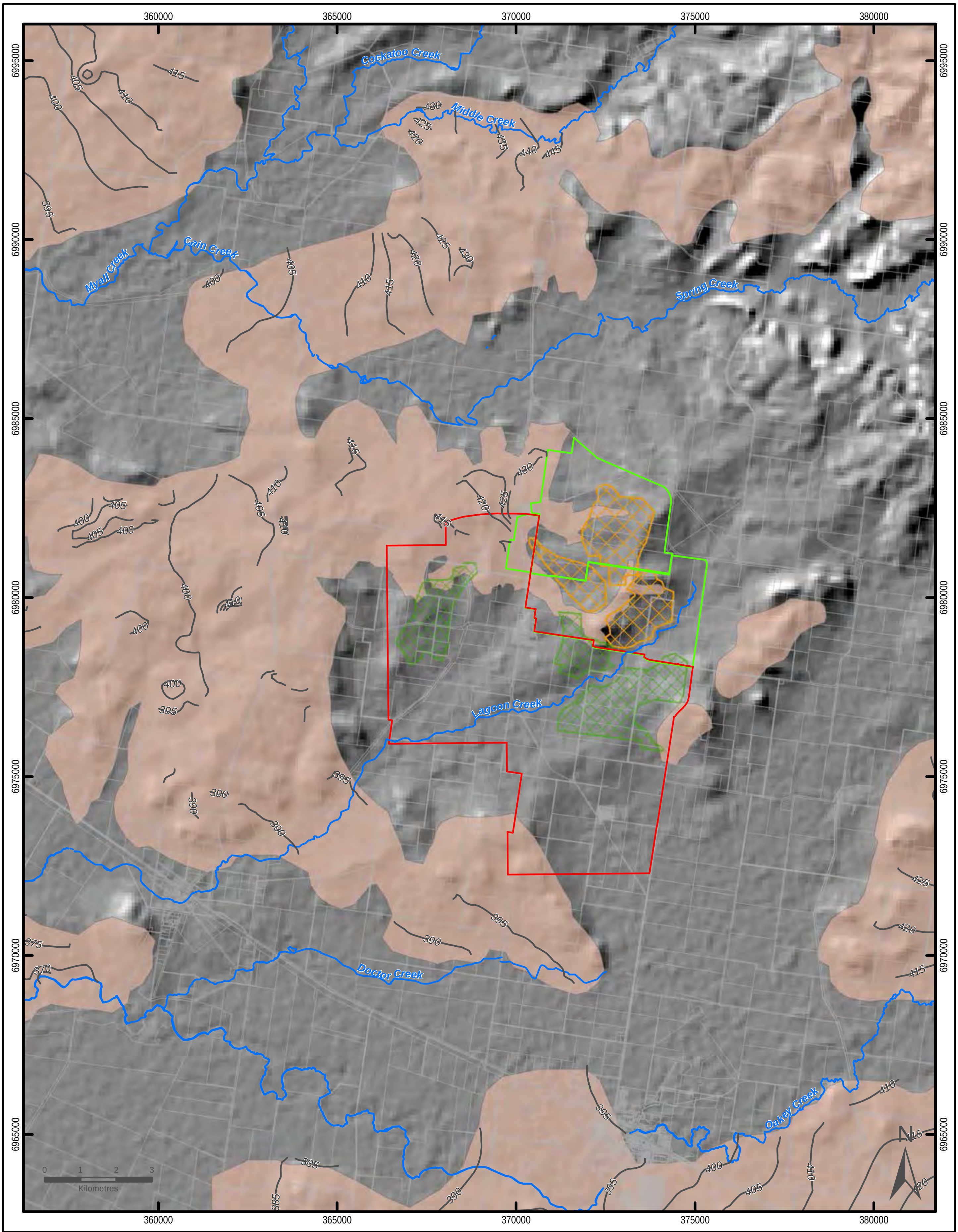
Figure 6-8 - Basalt
Predicted Water Levels – 2017

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-8_PredictedWaterLevelsBasalt_2017.mxd



LEGEND

- Basalt - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

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Figure 6-9 - Basalt Predicted Water Levels – 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140617_NewHope_Groundwater_Figure6-9_PredictedWaterLevelsBasalt_2021.mxd

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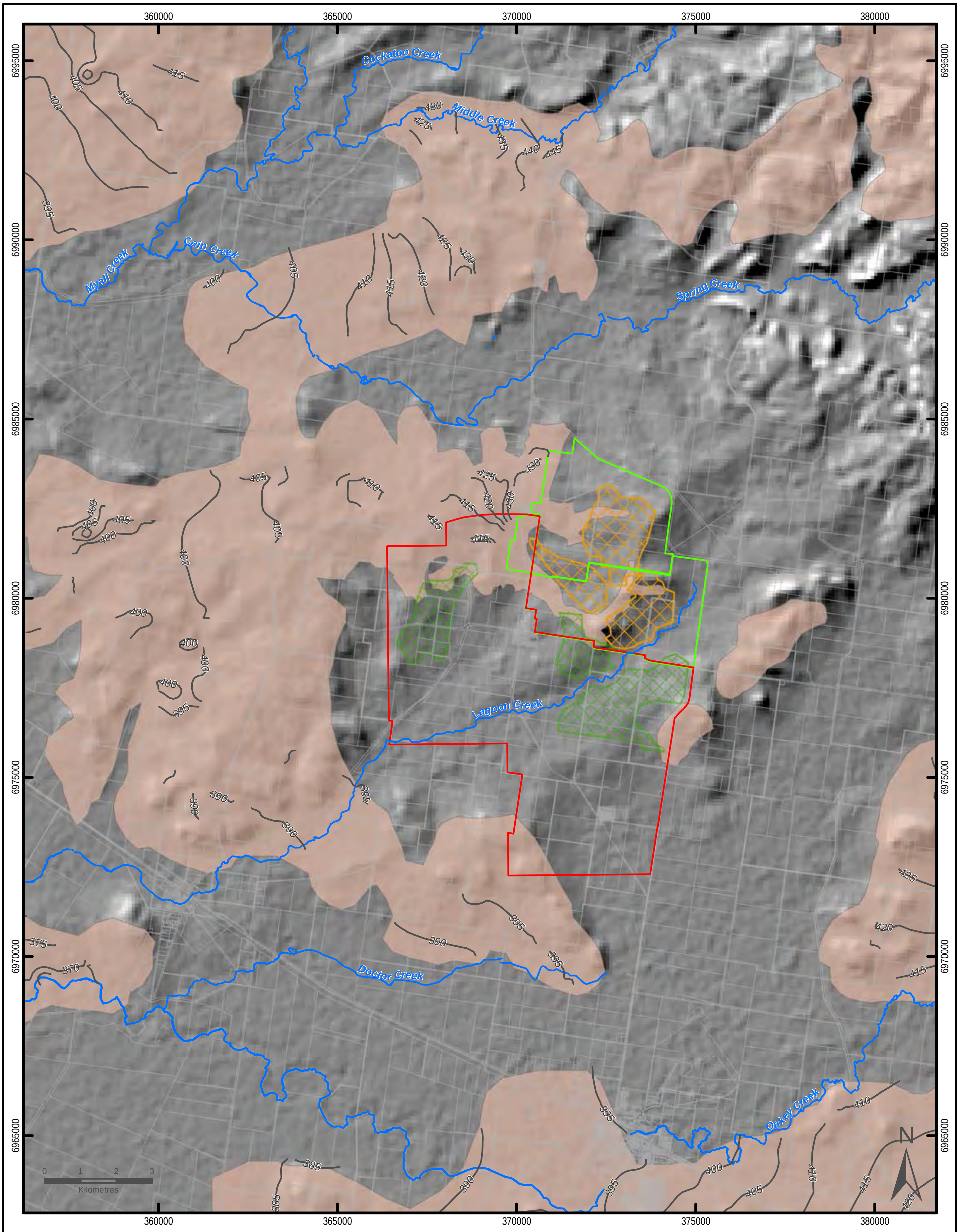

LEGEND

- Basalt - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

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Figure 6-10 - Basalt
Predicted Water Levels – 2030

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-10_PredictedWaterLevelsBasalt_2030.mxd

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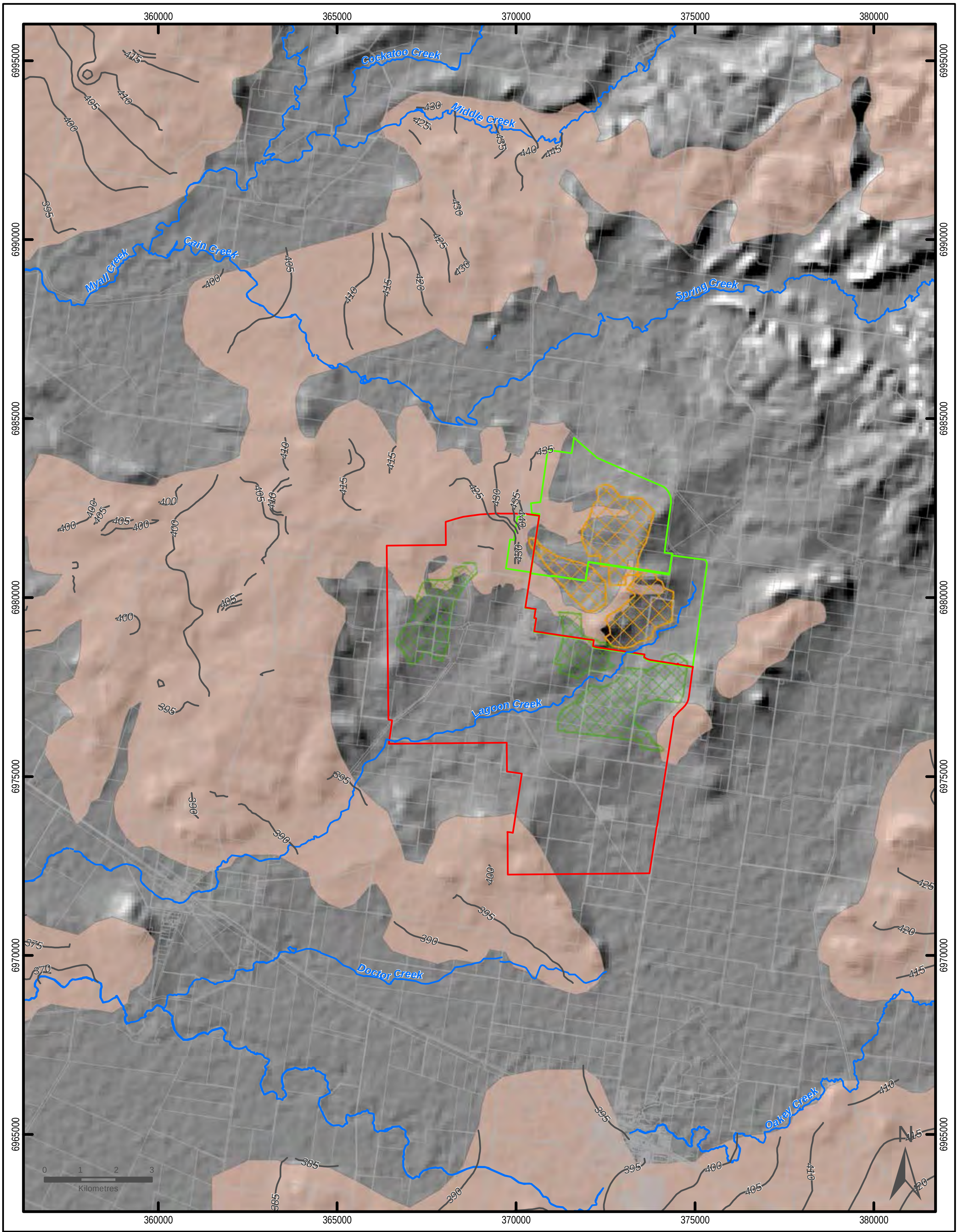

LEGEND

- Alluvium - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

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Figure 6-11 - Basalt Predicted Water Levels – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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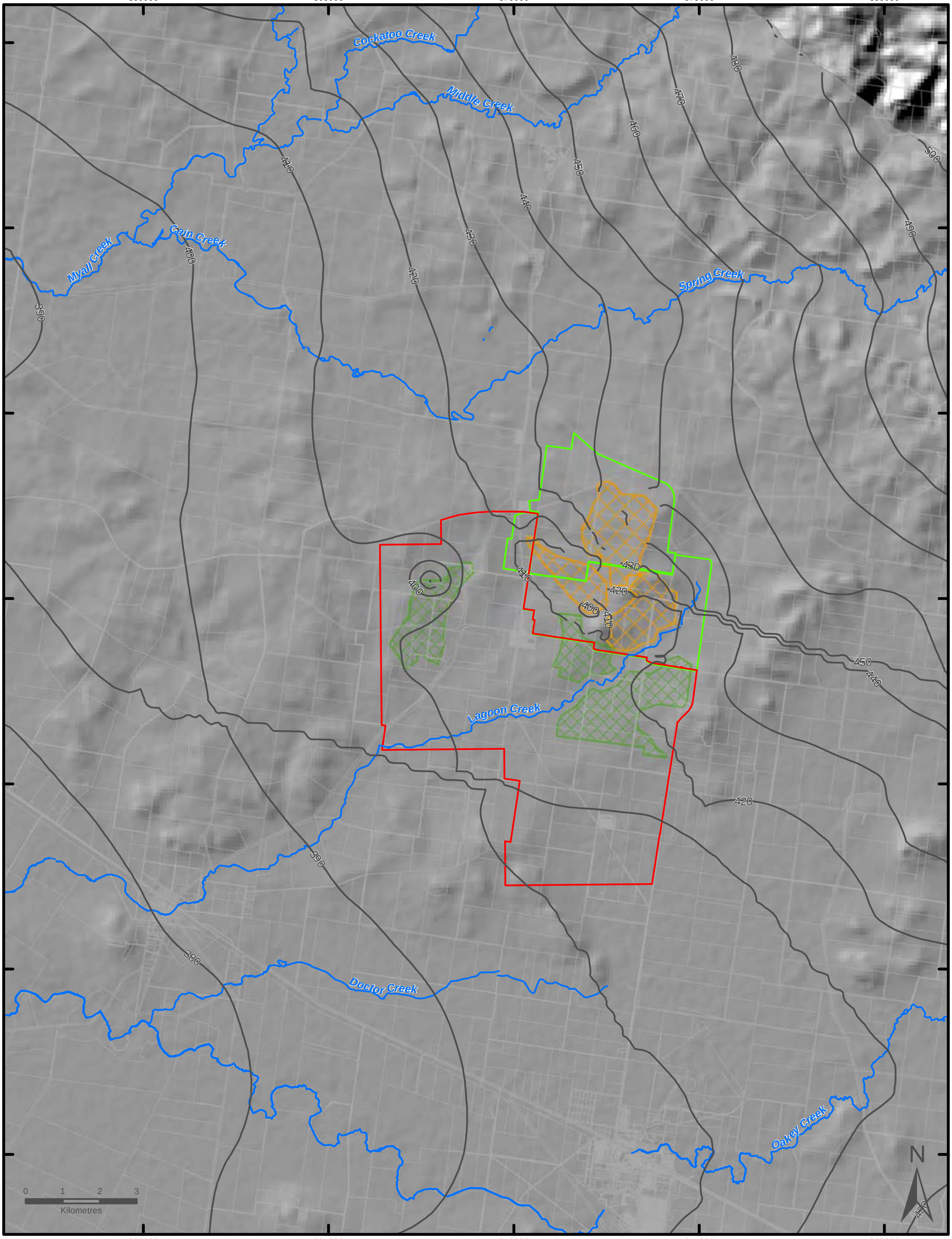

LEGEND

- Walloon Coal Measures Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

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Figure 6-12 - Walloon Coal Measures Predicted Water Levels – 2017

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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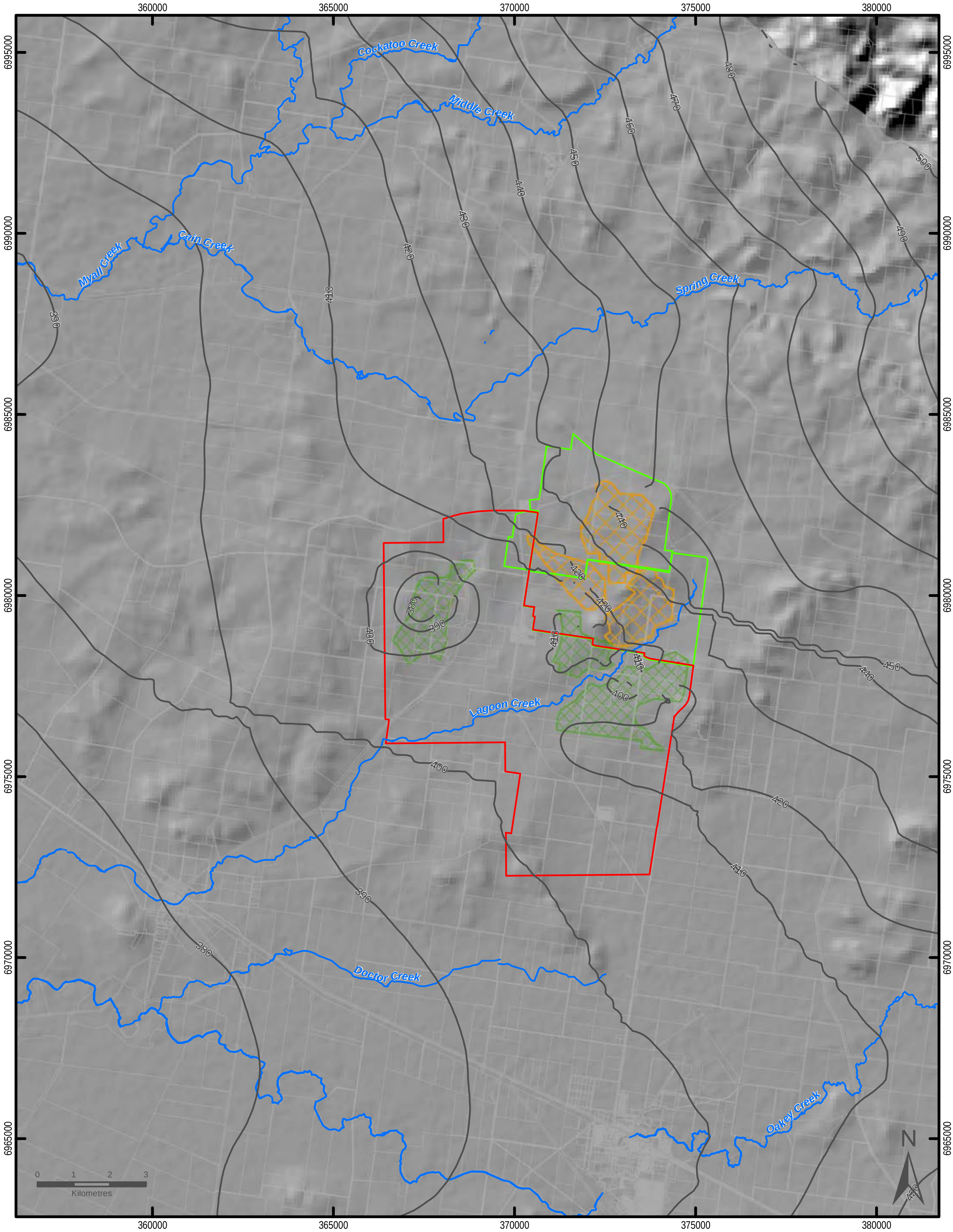
Produced: 28/08/2014



LEGEND

- Walloon Coal Measures Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

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Figure 6-13 - Walloon Coal Measures Predicted Water Levels – 2021

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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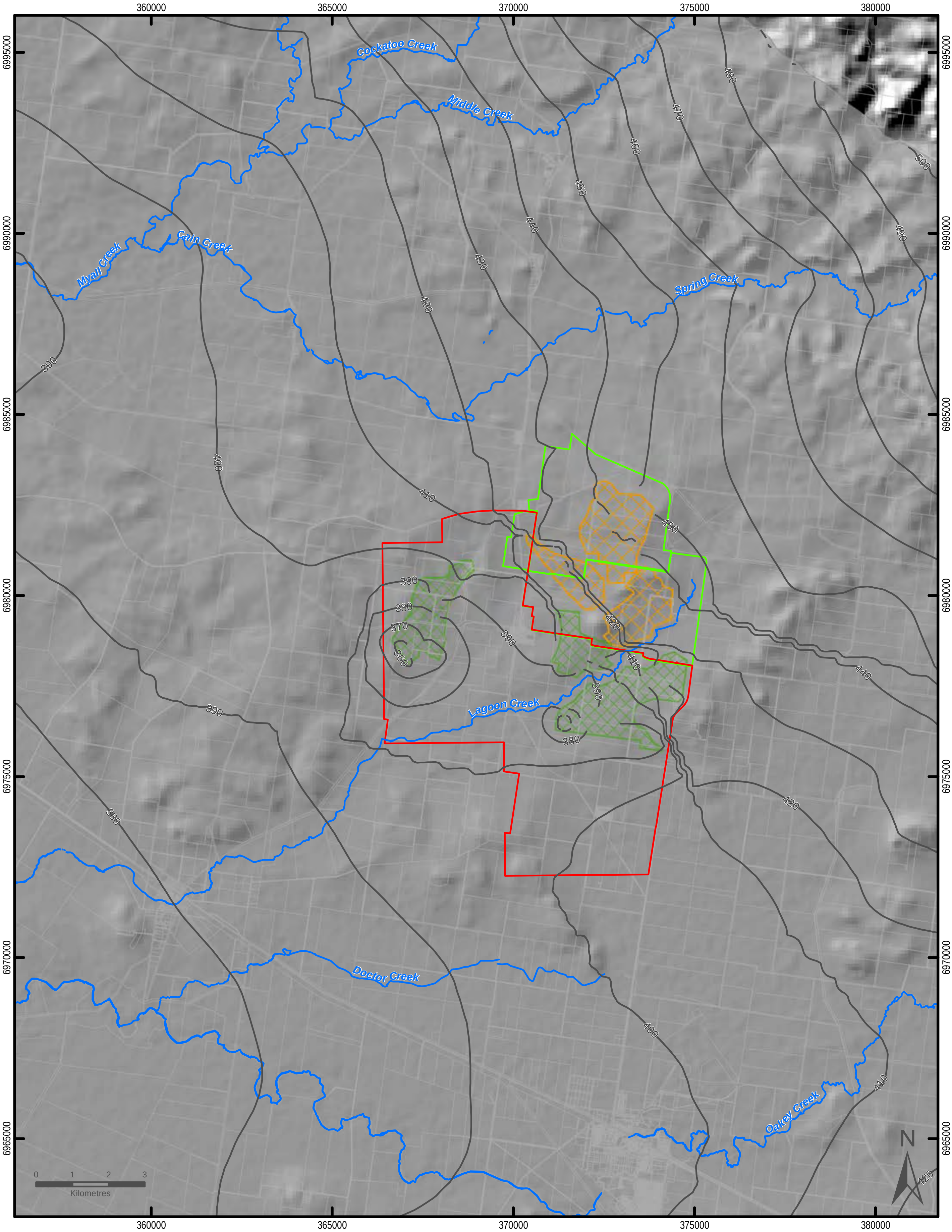

LEGEND

- Walloon Coal Measures Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

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Figure 6-14 - Walloon Coal Measures Predicted Water Levels – 2030

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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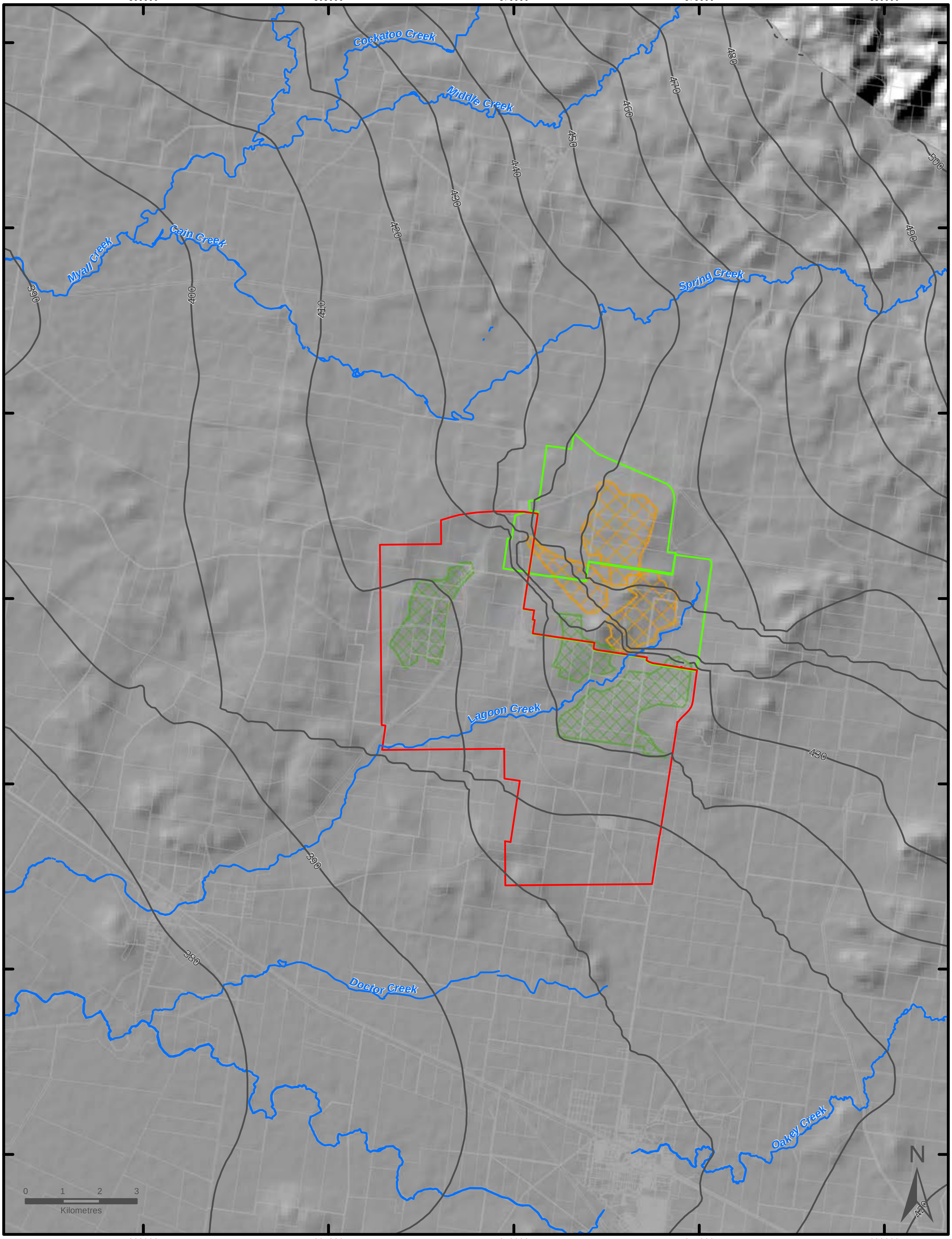

LEGEND

- Walloon Coal Measures Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

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Figure 6-15 - Walloon Coal Measures Predicted Water Levels – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-15_PredictedWaterLevelsWalloon_PostMining.mxd

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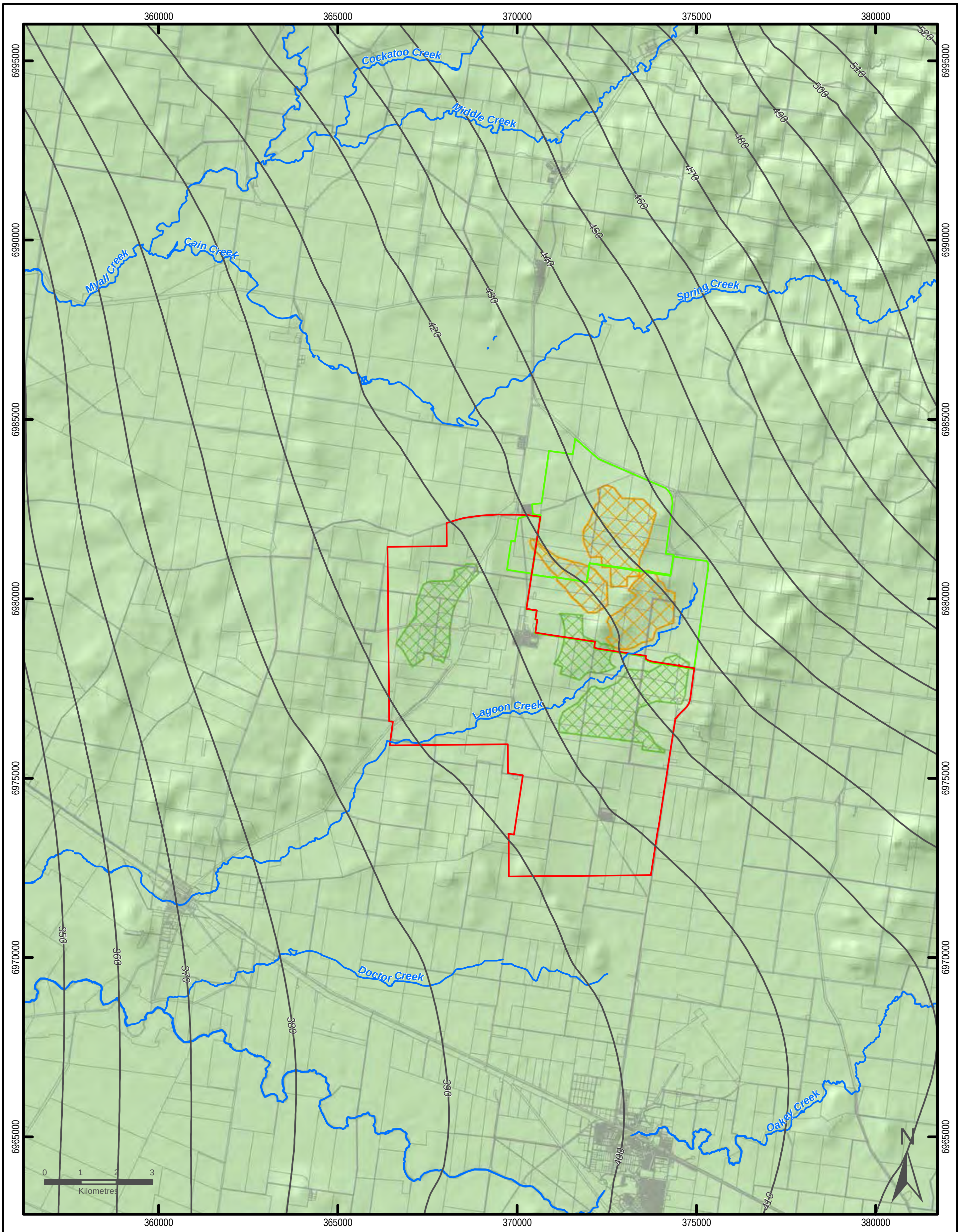

LEGEND

- Marburg Sandstone - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

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Figure 6-16 - Marburg Sandstone Predicted Water Levels – 2017

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140617_NewHope_Groundwater_Figure6-16_PredictedWaterLevelsMarburgSandstone_2017.mxd

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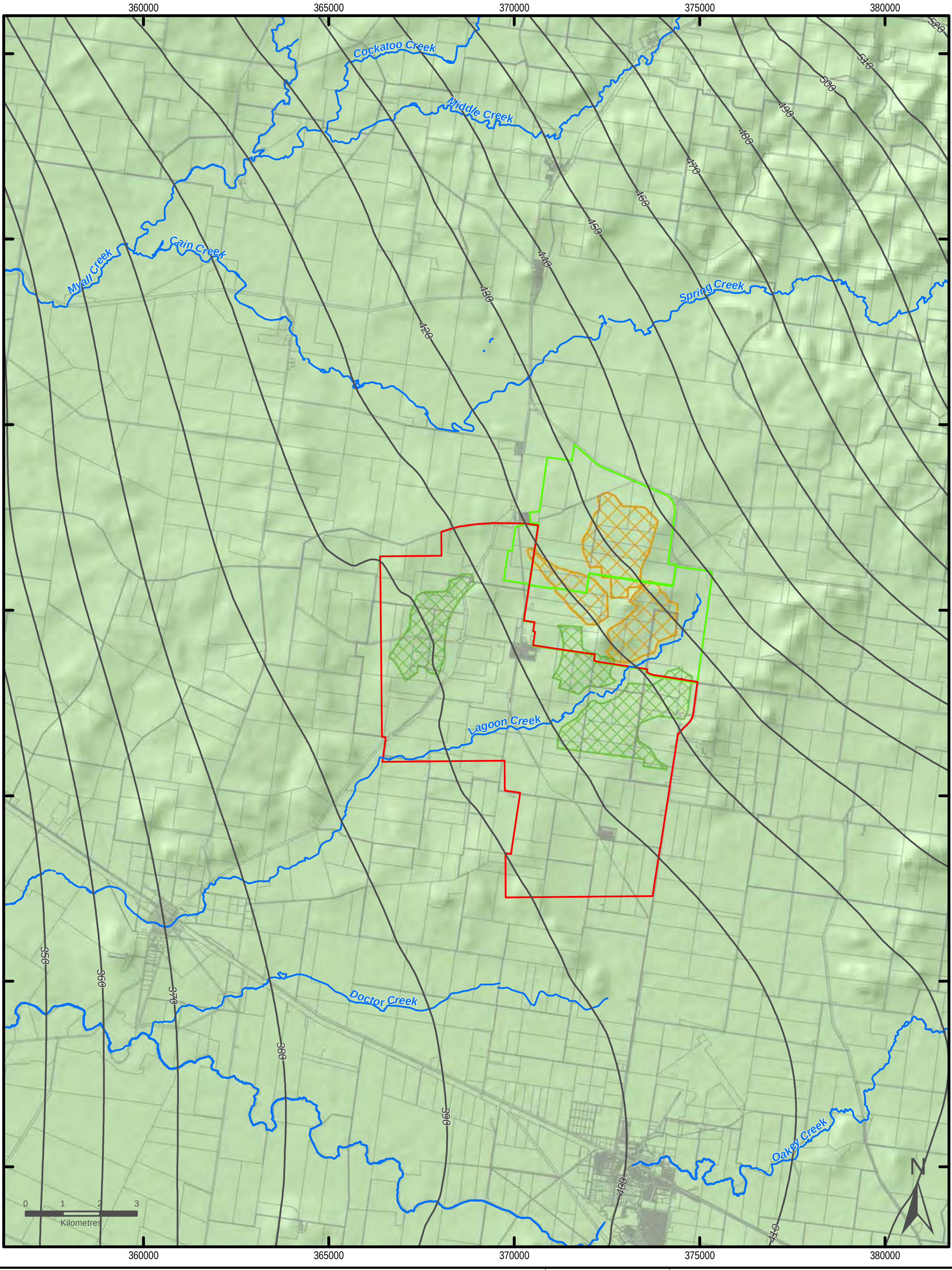

LEGEND

- Marburg Sandstone - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

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NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-17 - Marburg Sandstone Predicted Water Levels – 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-17_PredictedWaterLevelsMarburgSandstone_2021.mxd

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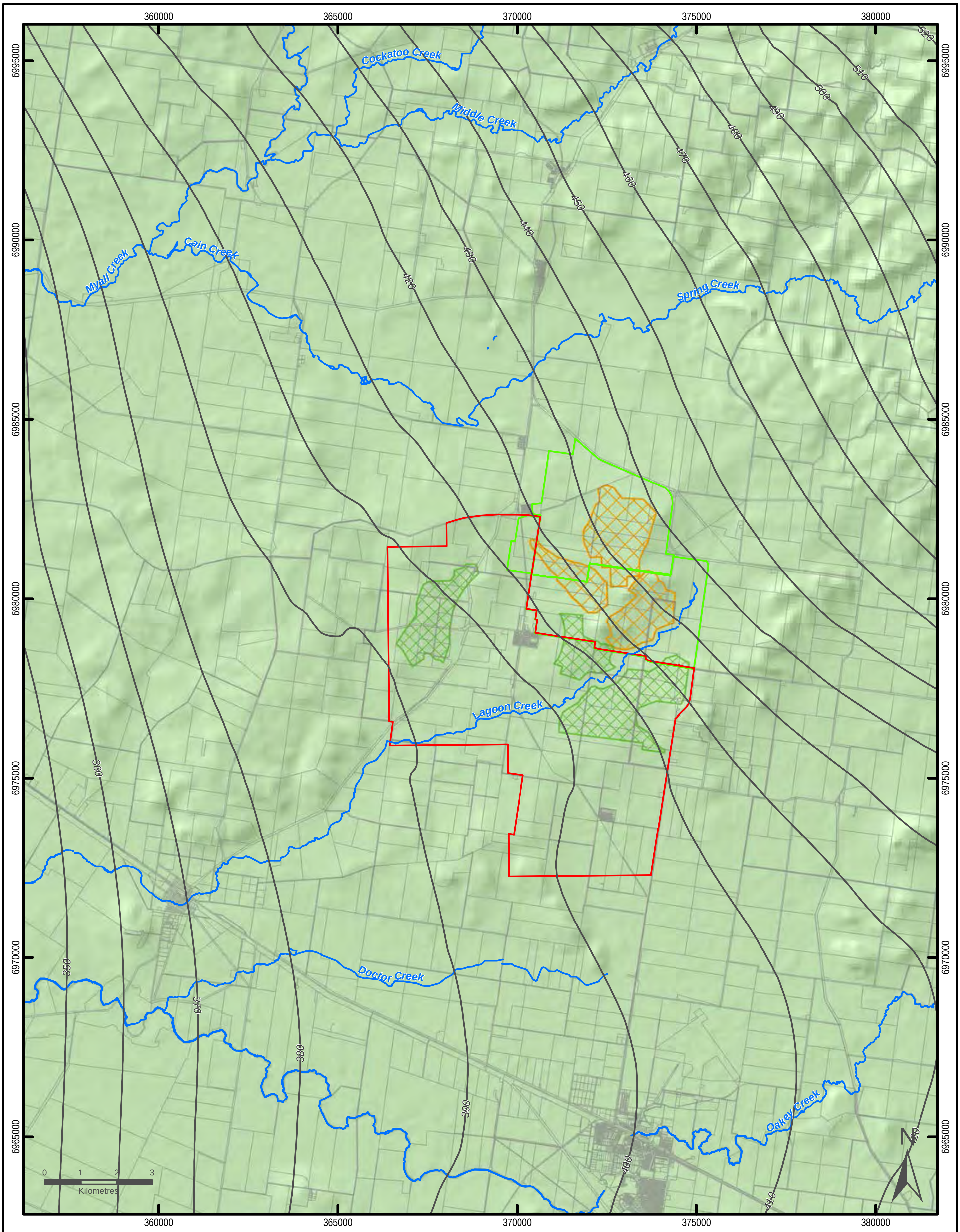

LEGEND

- Marburg Sandstone - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

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NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-18 - Marburg Sandstone Predicted Water Levels – 2030

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140617_NewHope_Groundwater_Figure6-18_PredictedWaterLevelsMarburgSandstone_2030.mxd

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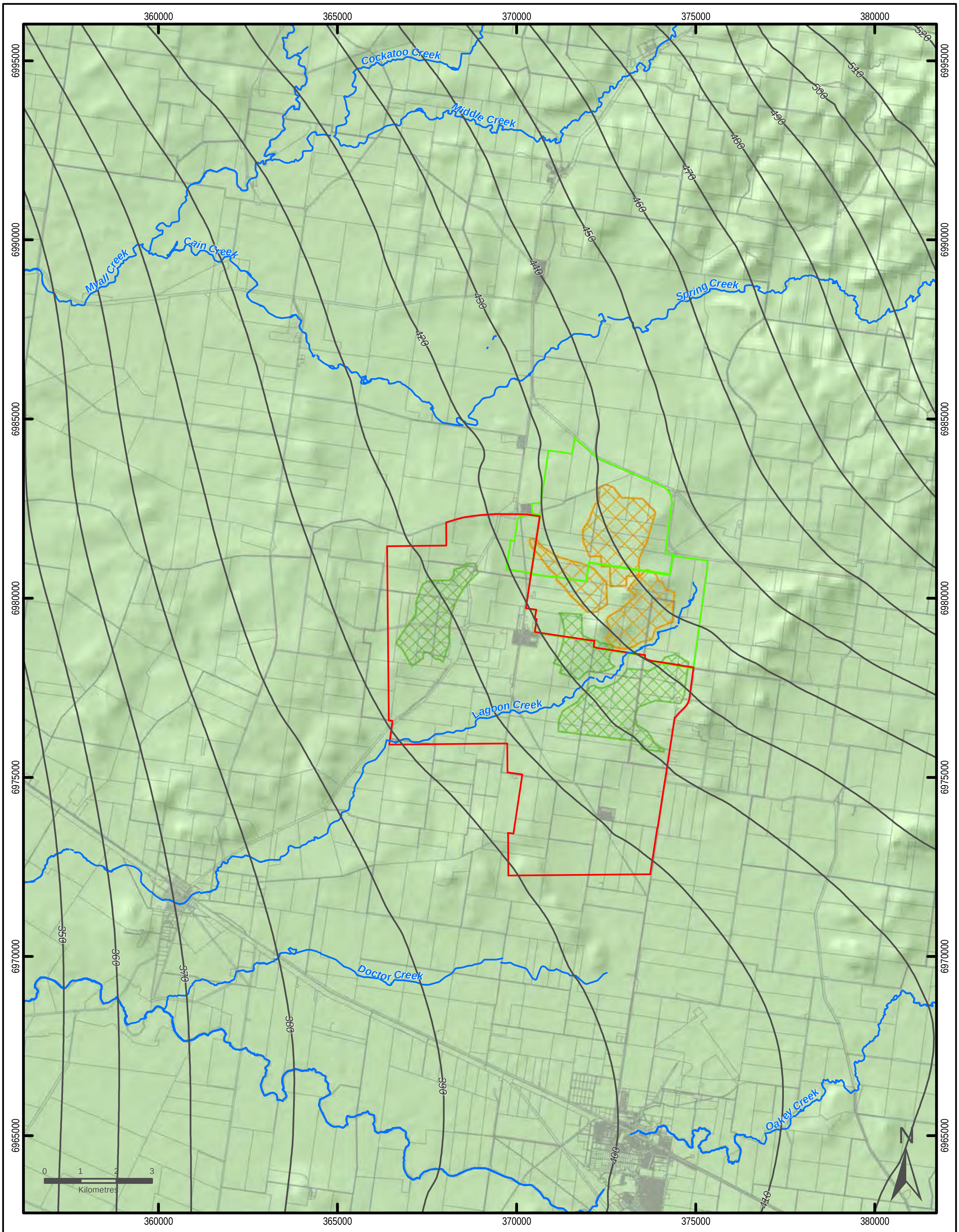

LEGEND

- Marburg Sandstone - Predicted Water Levels (mAHD)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

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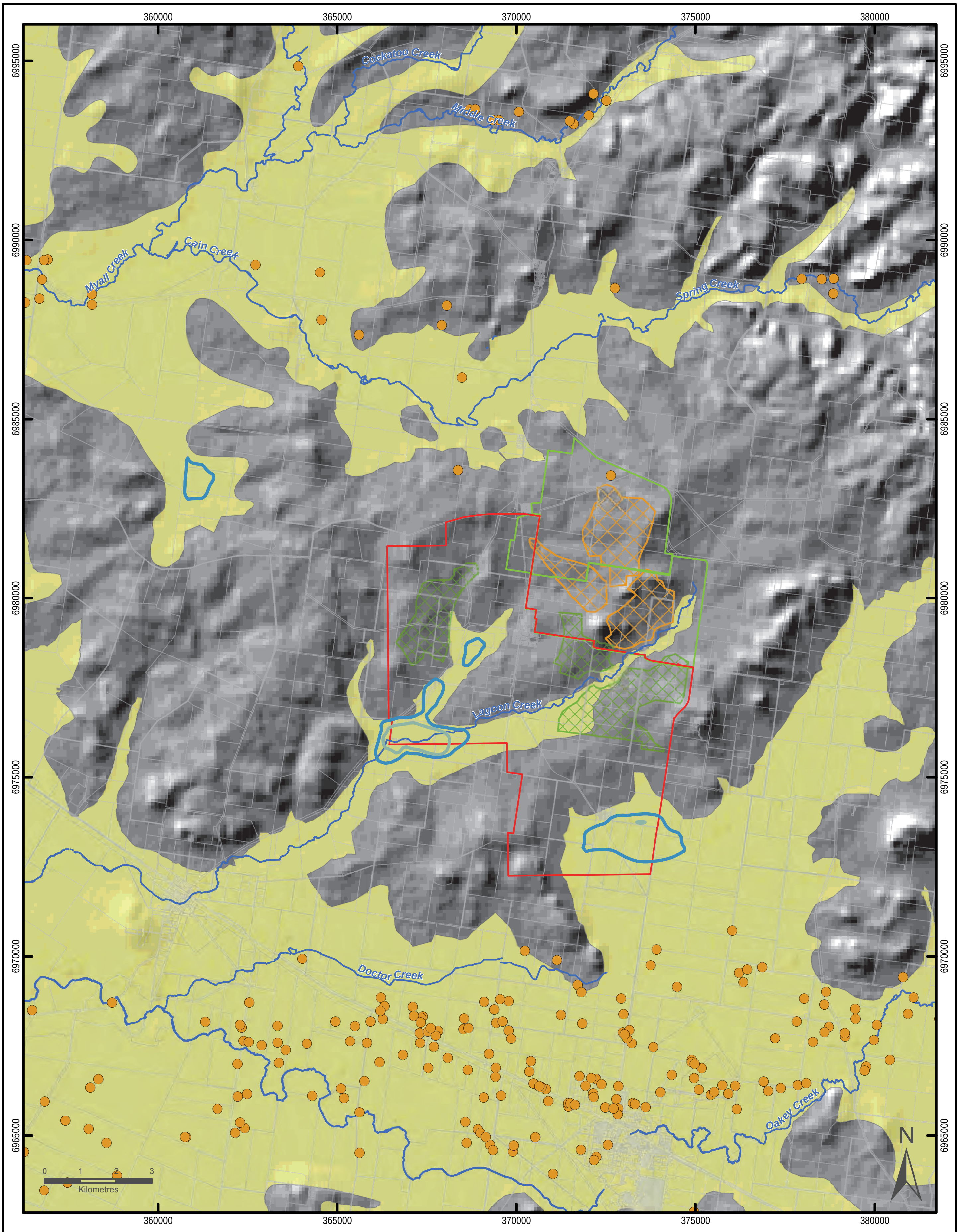
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-19 - Marburg Sandstone Predicted Water Levels – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)



LEGEND

DNRM Registered Bores - Alluvium

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

Watercourse

New Aland Coal Mine-Stage 3

New Acland Coal Mine

Cadastre

Stage 3 Pit Areas

Existing Permission

Modelled Formation Extents

Alluvium (Qa)

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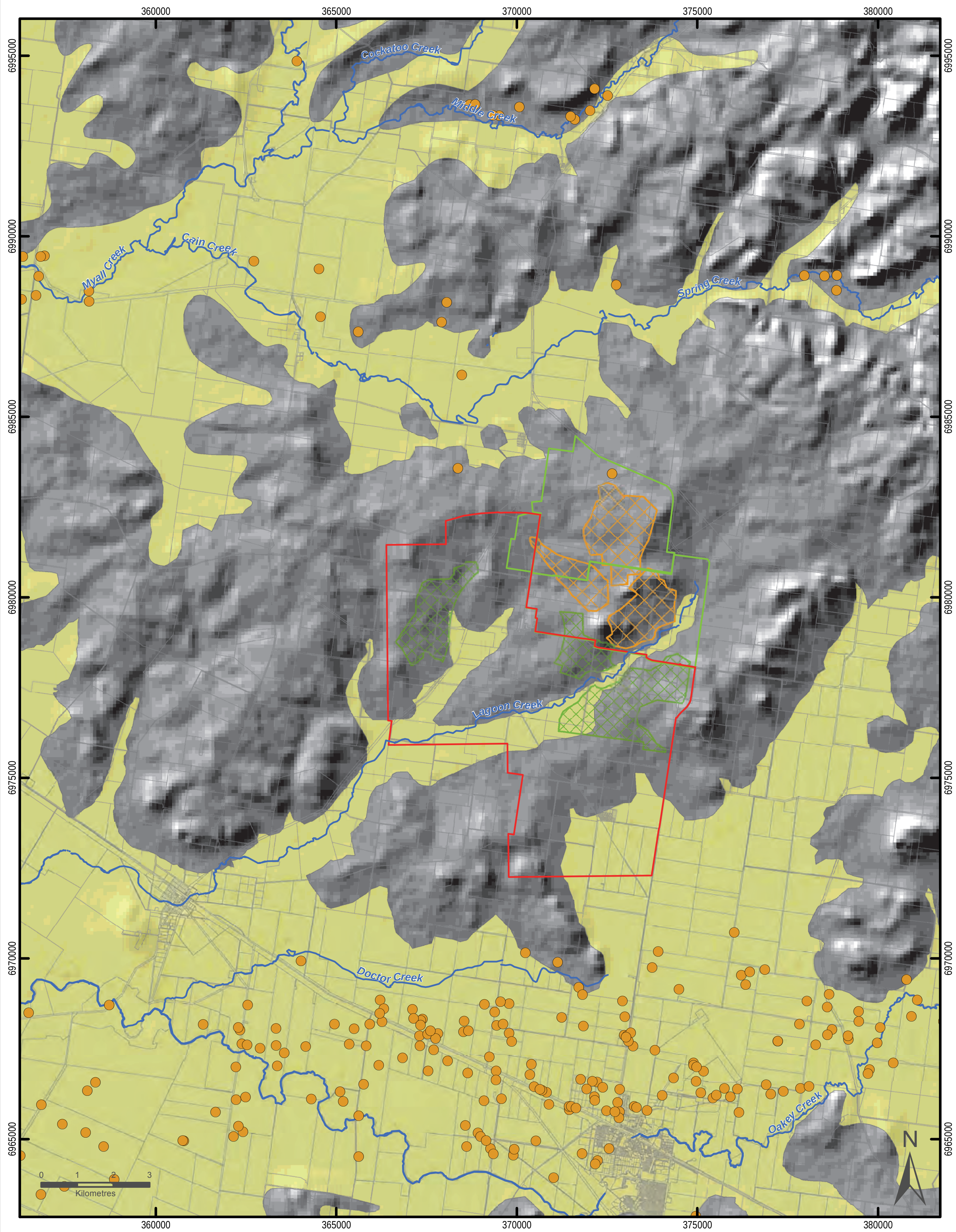
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-20 - Alluvium Predicted Drawdown – 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-20_PredictedDrawdownInAlluvium_2030.mxd



LEGEND

- DNRM Registered Bores - Alluvium

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

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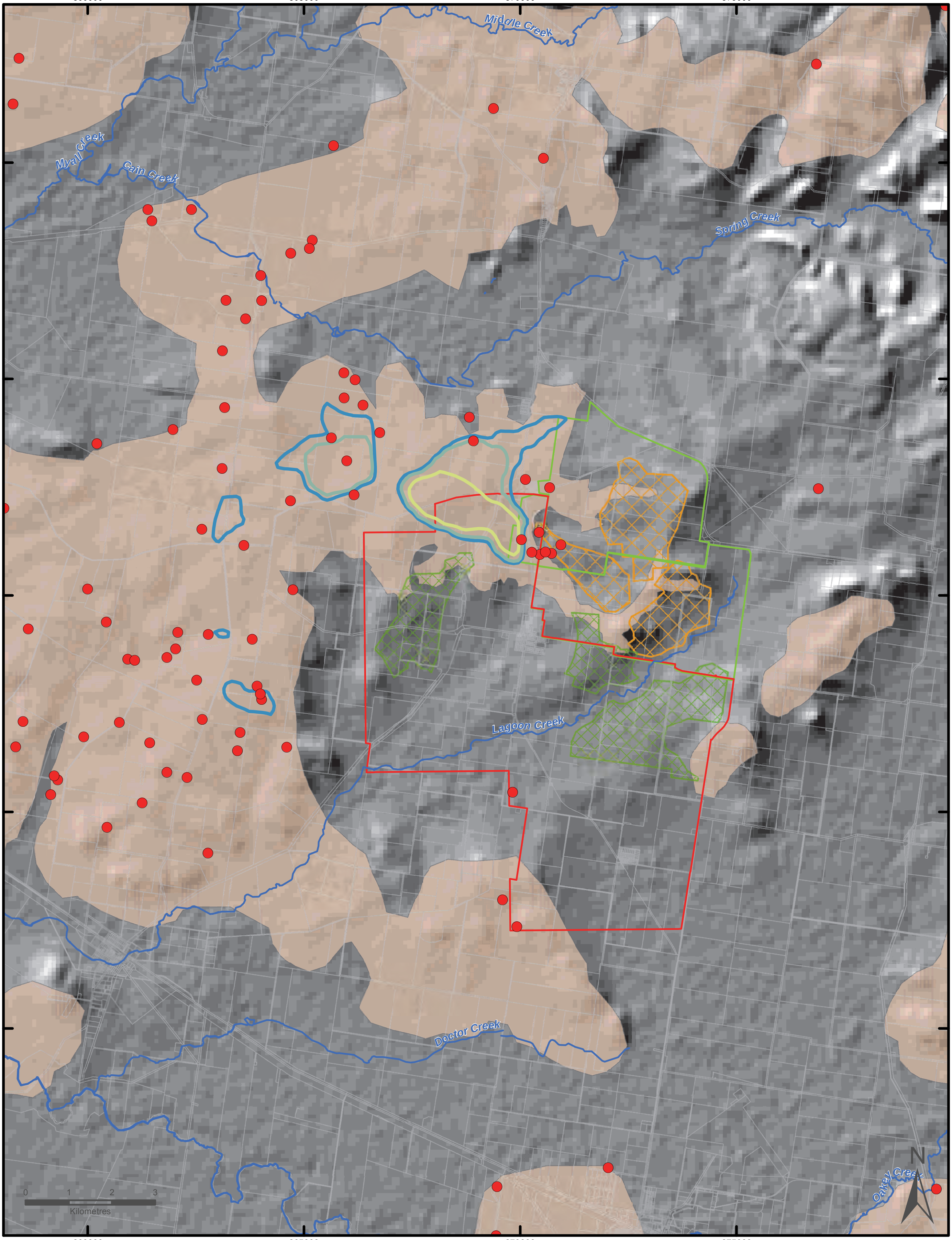
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-21 - Alluvium Predicted Drawdown – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)



LEGEND

- DNRM Registered Bores - Basalt

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

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NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-22 - Basalt Predicted Drawdown – 2021

Scale 1:120,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\SpatialArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-22_PredictedDrawdownInTertiaryBasalt_2021.mxd

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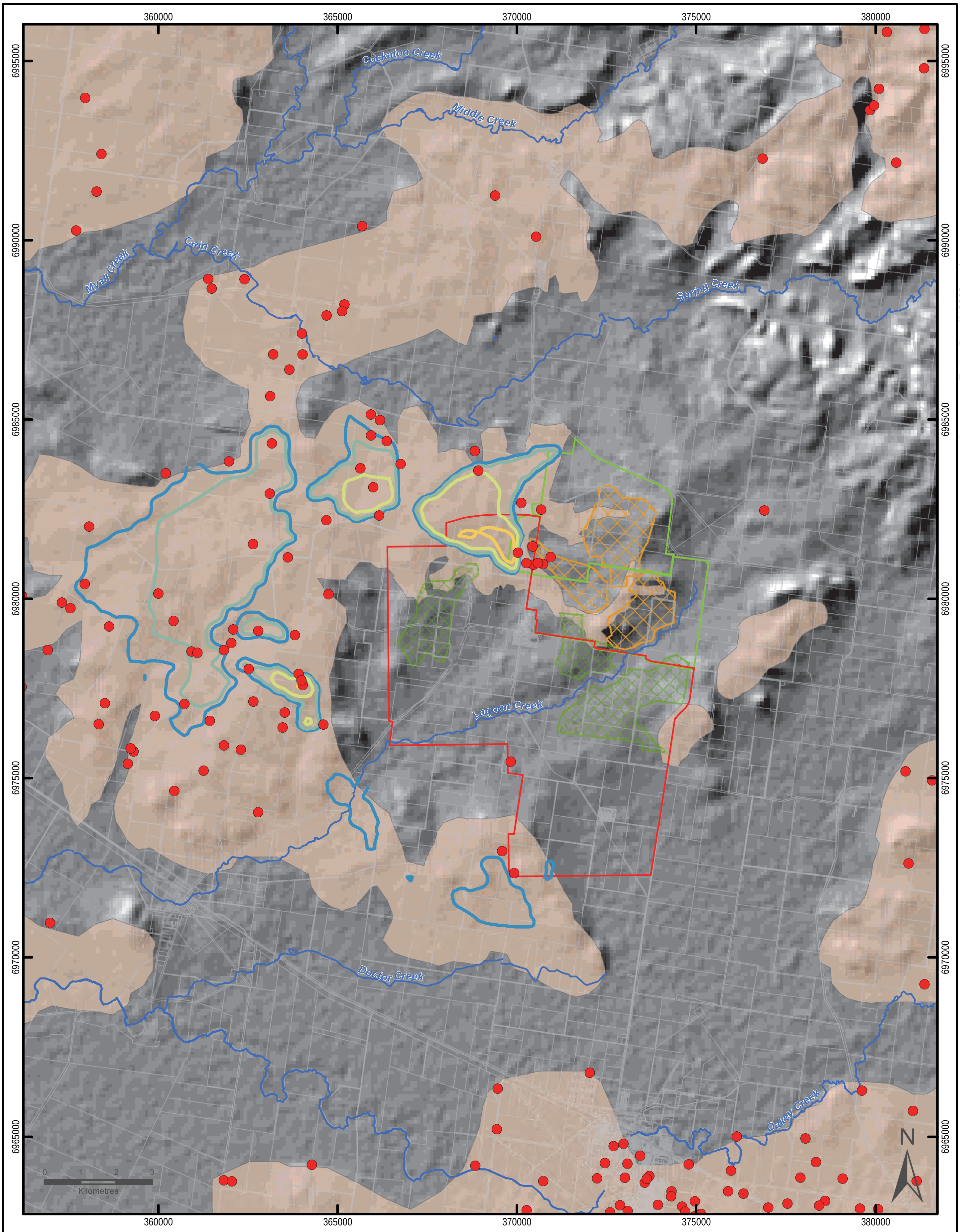


LEGEND

- DNRM Registered Bores - Basalt

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

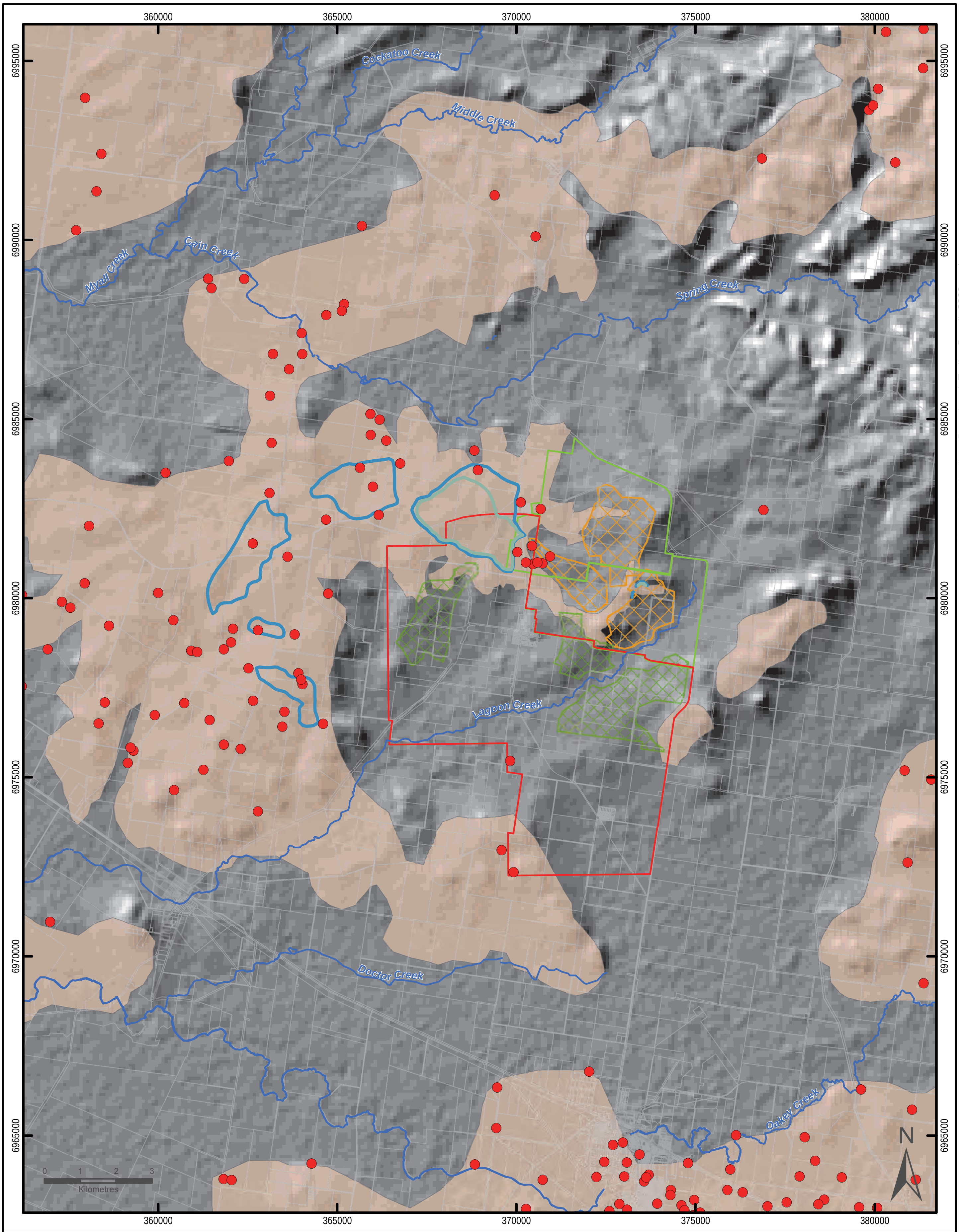
NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure 6-23 - Basalt Predicted Drawdown – 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\SpatialArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-23_PredictedDrawdownInTertiaryBasalt_2030.mxd



LEGEND

- DNRM Registered Bores - Basalt

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure 6-24 - Basalt
Predicted Drawdown – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-24_PredictedDrawdownInTertiaryBasalt_2330.mxd

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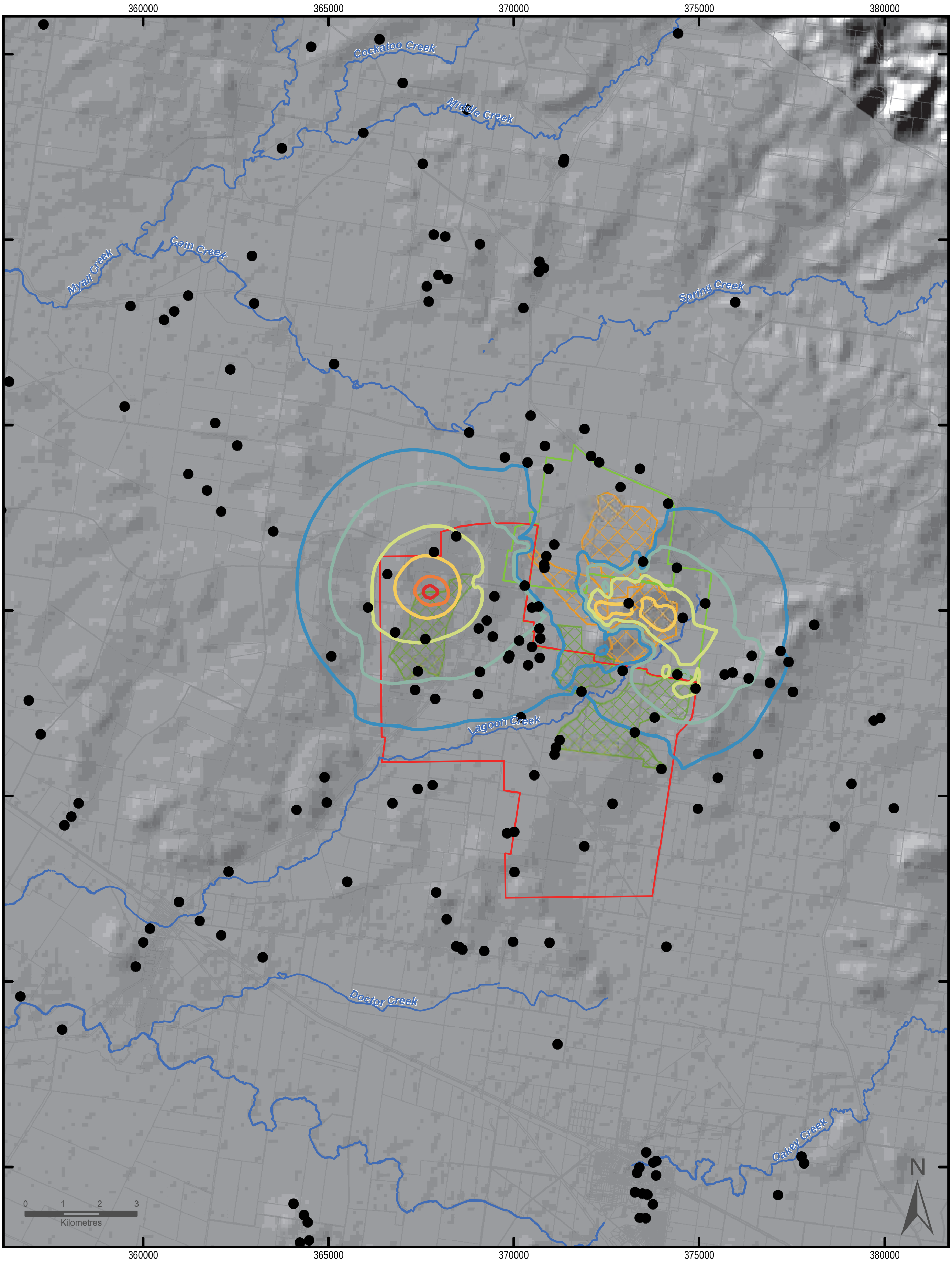

LEGEND

- DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extent

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-25 - Walloon Coal Measures Predicted Drawdown – 2017

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-25_PredictedDrawdownInWalloon_2017.mxd

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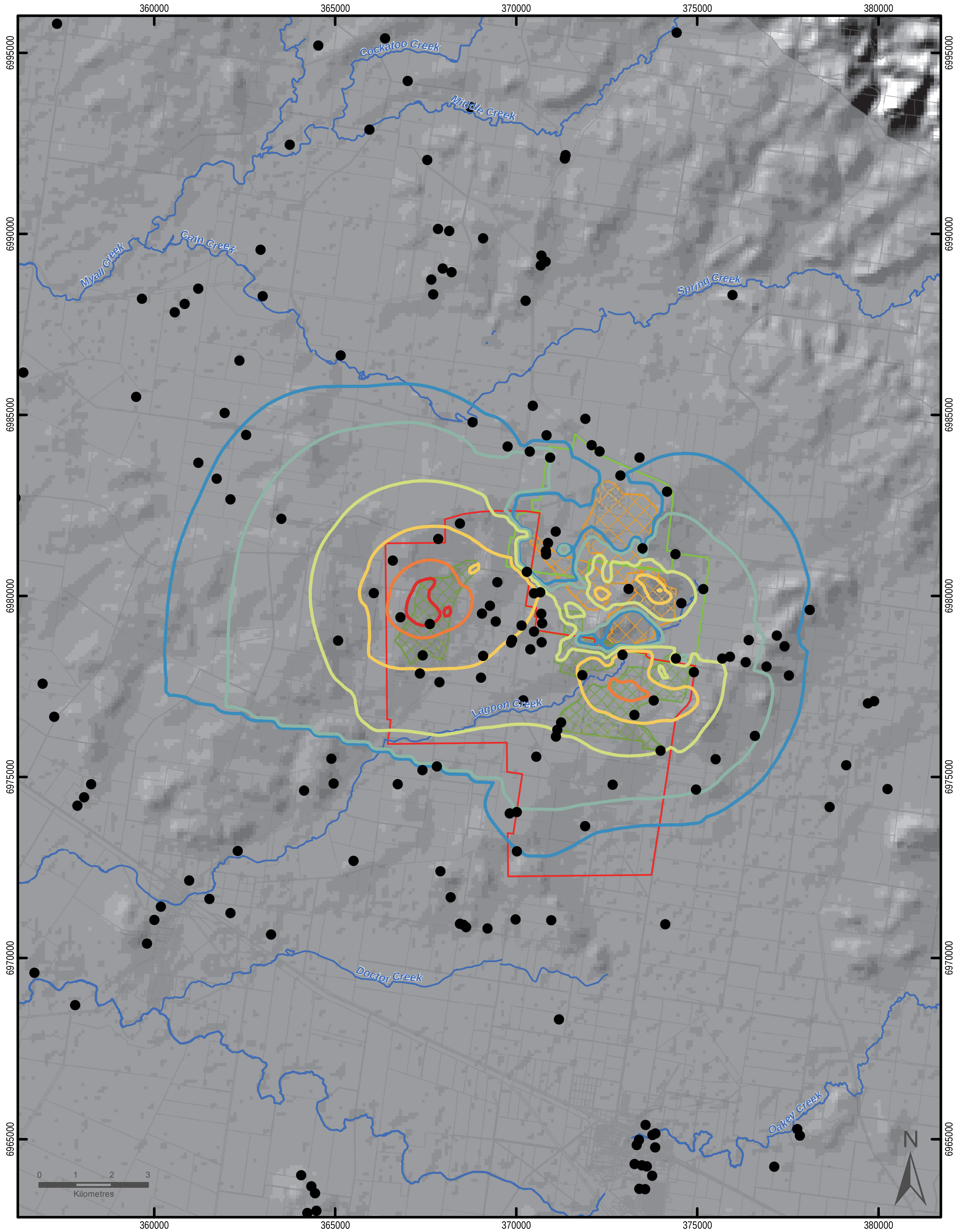

LEGEND

- ● DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-26 - Walloon Coal Measures Predicted Drawdown – 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\SpatialArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-26_PredictedDrawdownInWalloon_2021.mxd

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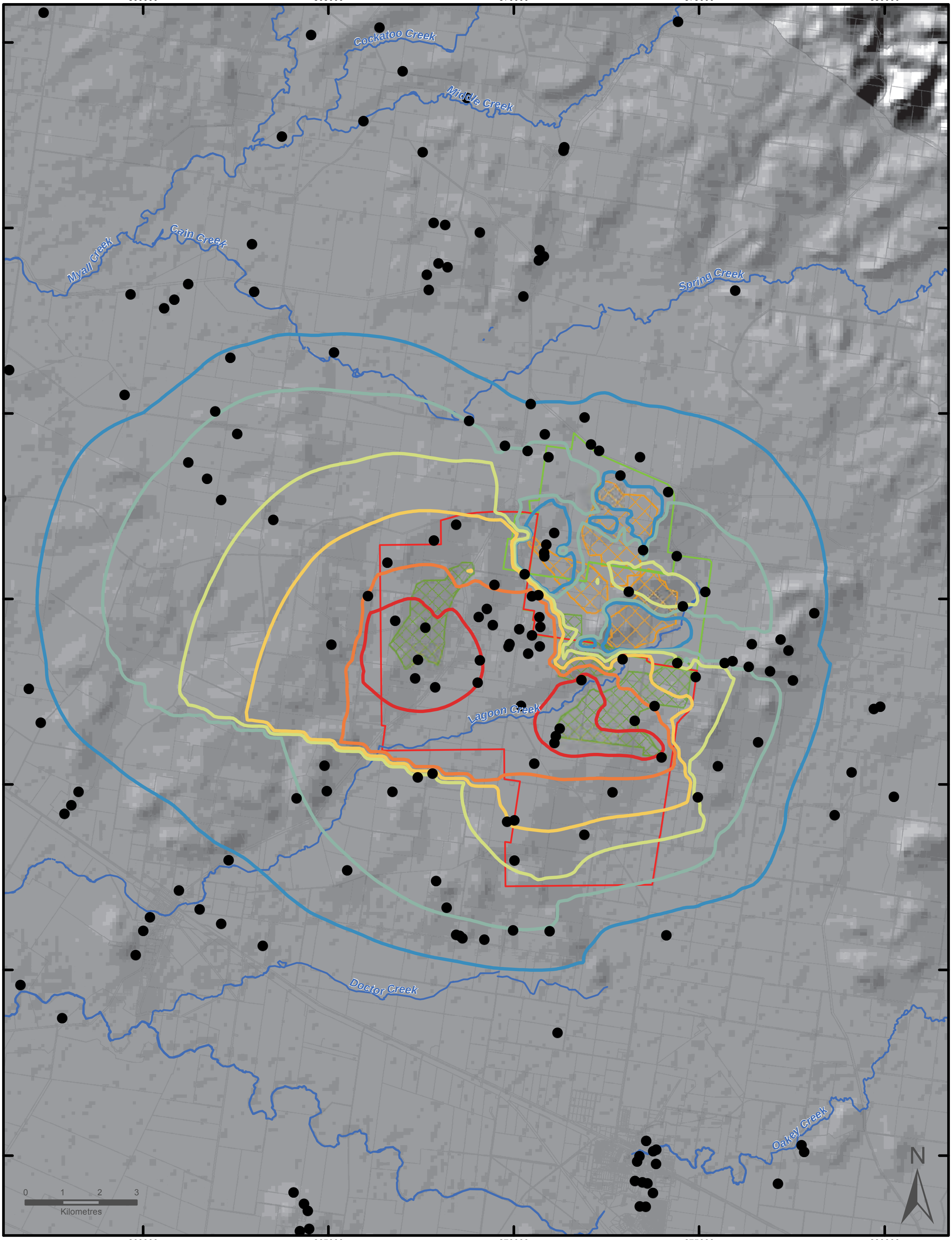


LEGEND

- ● DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

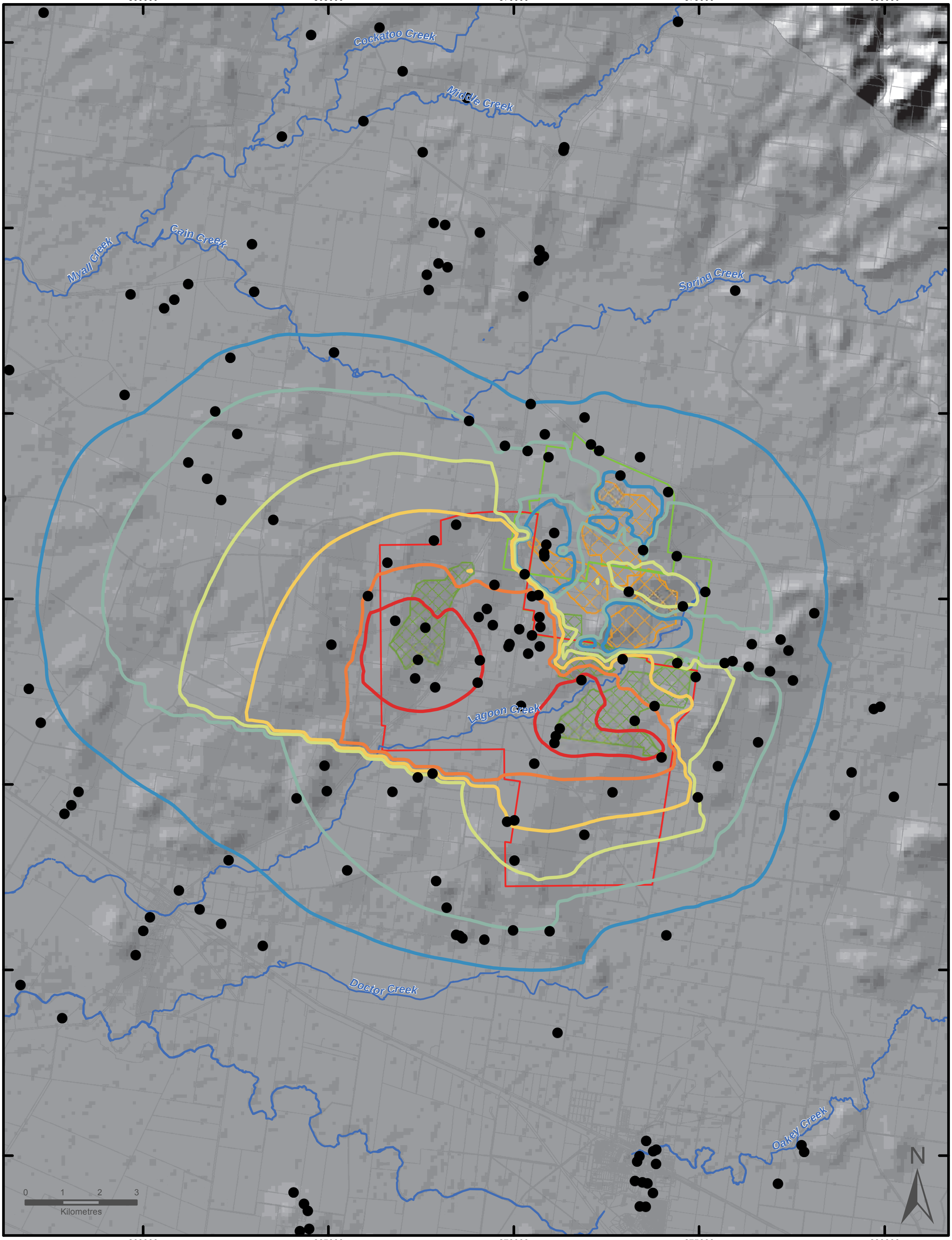
SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure 6-27 - Walloon Coal Measures Predicted Drawdown – 2030

Scale 1:140,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-27_PredictedDrawdownInWalloon_2030.mxd



LEGEND

- ● DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

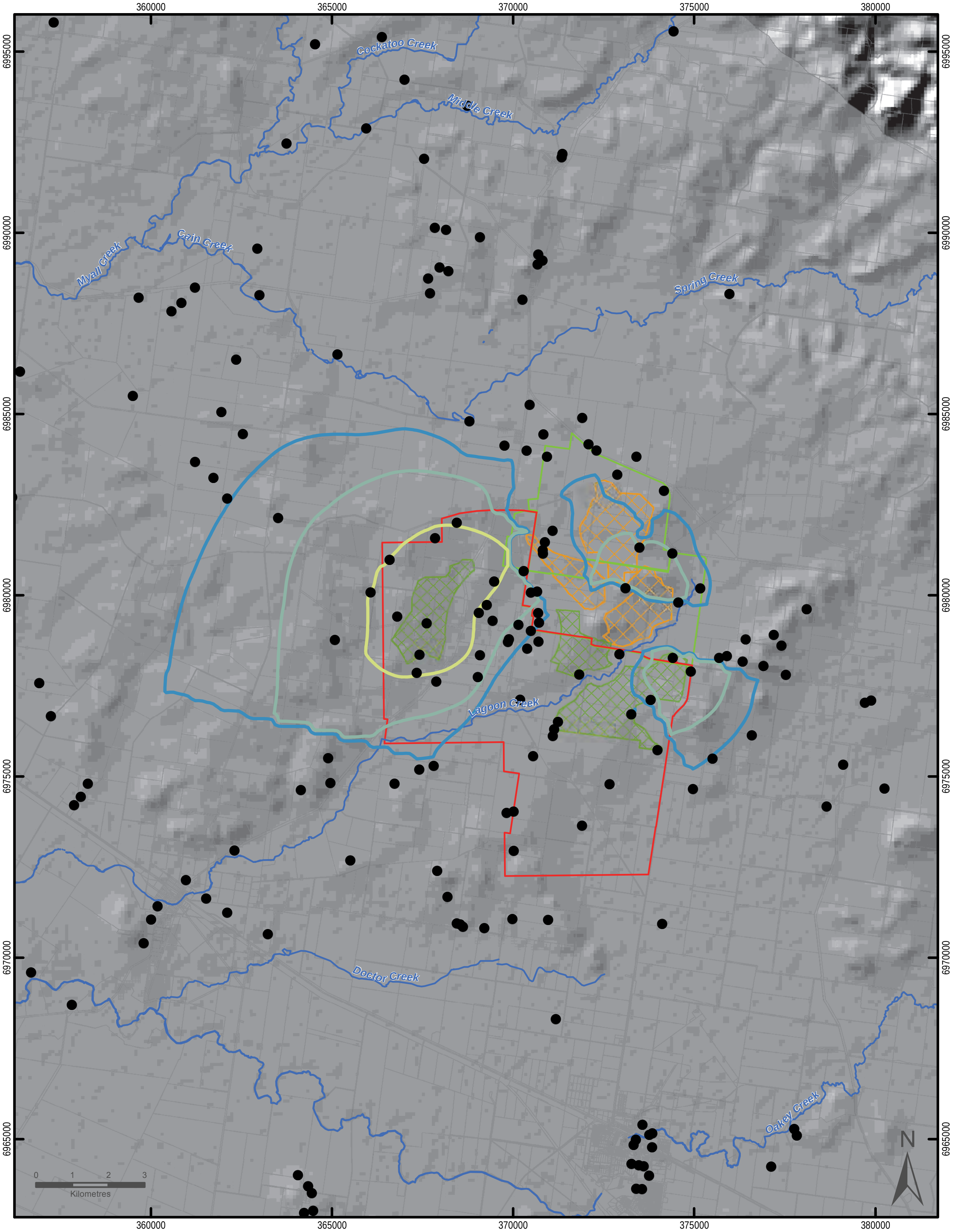
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-27 - Walloon Coal Measures Predicted Drawdown – 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\SpatialArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-27_PredictedDrawdownInWalloon_2030.mxd



LEGEND

- ● DNRM Registered Bores - Walloons

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-28 - Walloon Coal Measures Predicted Drawdown – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-28_PredictedDrawdownInWalloon_2330.mxd

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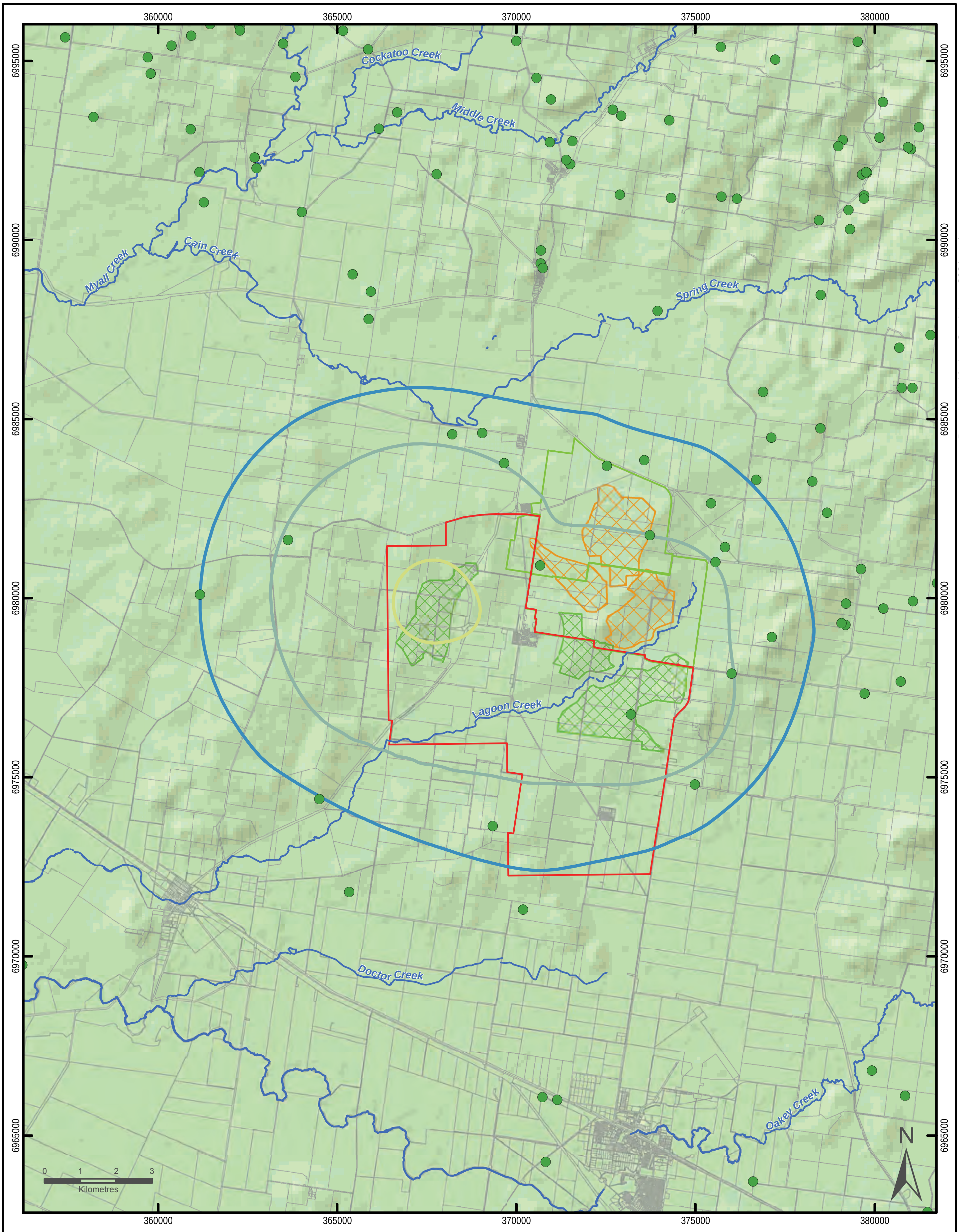


LEGEND

- DNRM Registered Bores - Marburg Sst

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

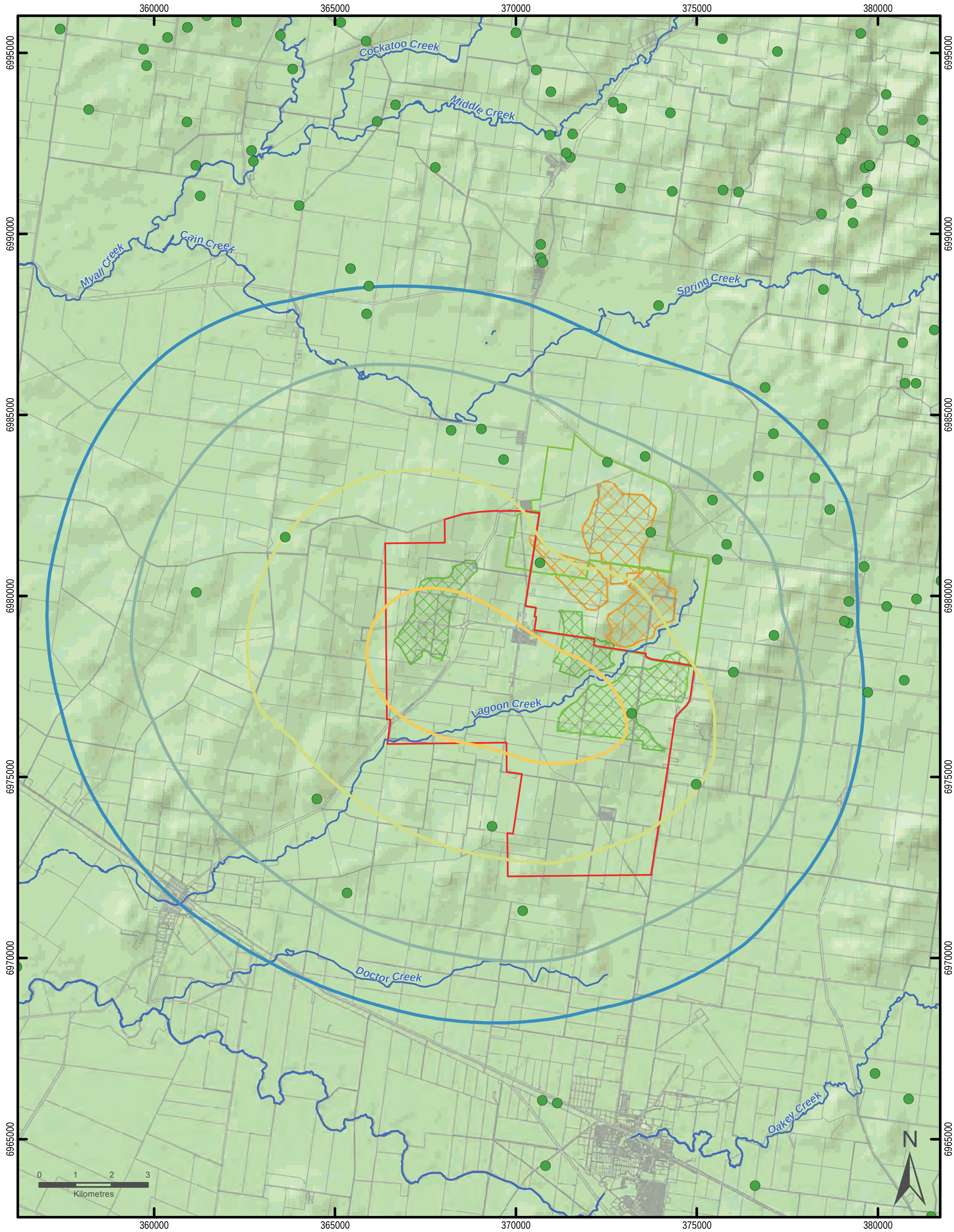
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-29 - Marburg Sandstone Predicted Drawdown – 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-29_PredictedDrawdownInMarburgSandstone_2021.mxd



LEGEND

- DNRM Registered Bores - Marburg Sst

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

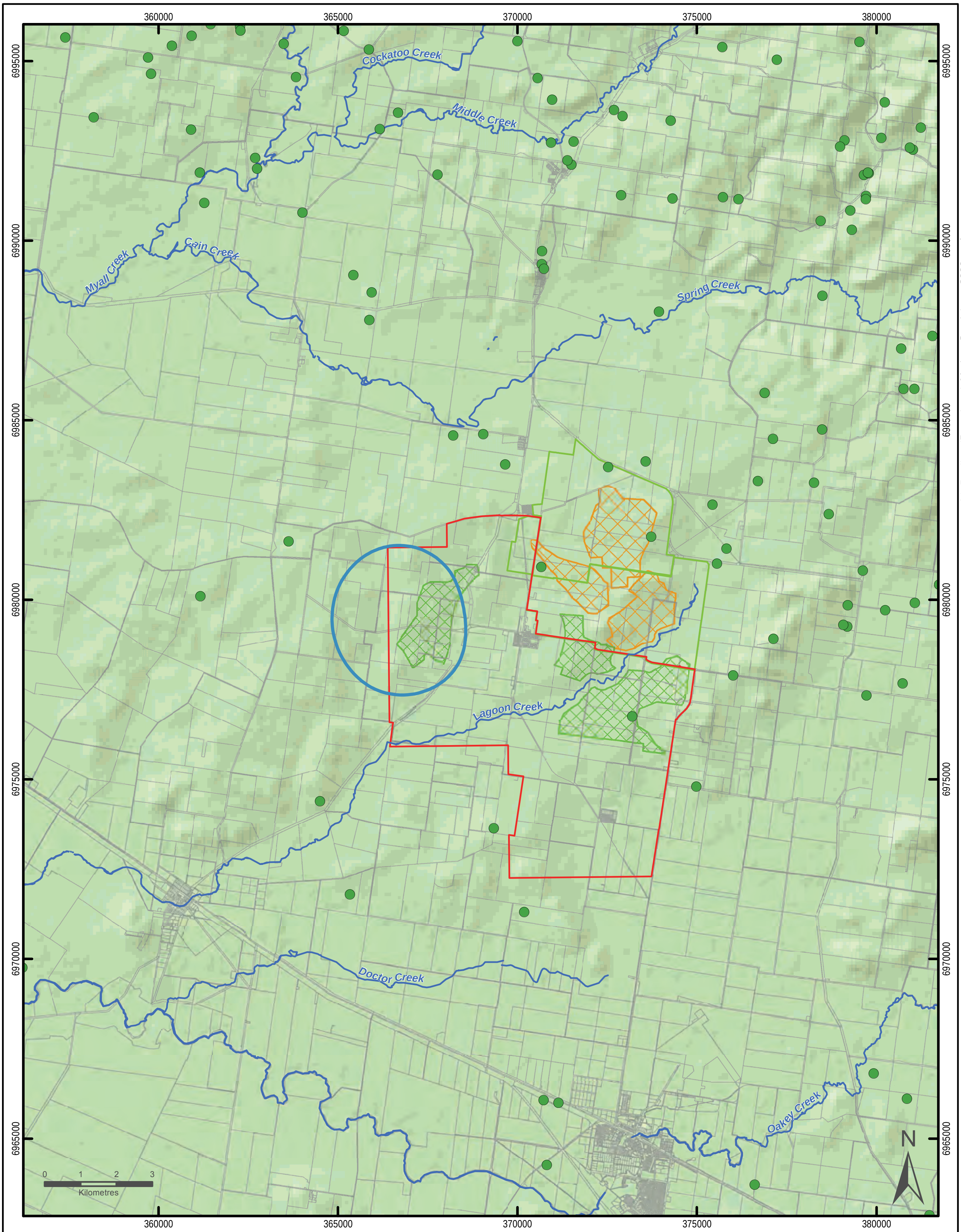
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-30 - Marburg Sandstone Predicted Drawdown – 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-30_PredictedDrawdownInMarburgSandstone_2030.mxd



LEGEND

- DNRM Registered Bores - Marburg Sst

Predicted Drawdown Contour (m)

- 1
- 2
- 5
- 10
- 20
- 30

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure 6-31 - Marburg Sandstone Predicted Drawdown – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-31_PredictedDrawdownInMarburgSandstone_2330.mxd

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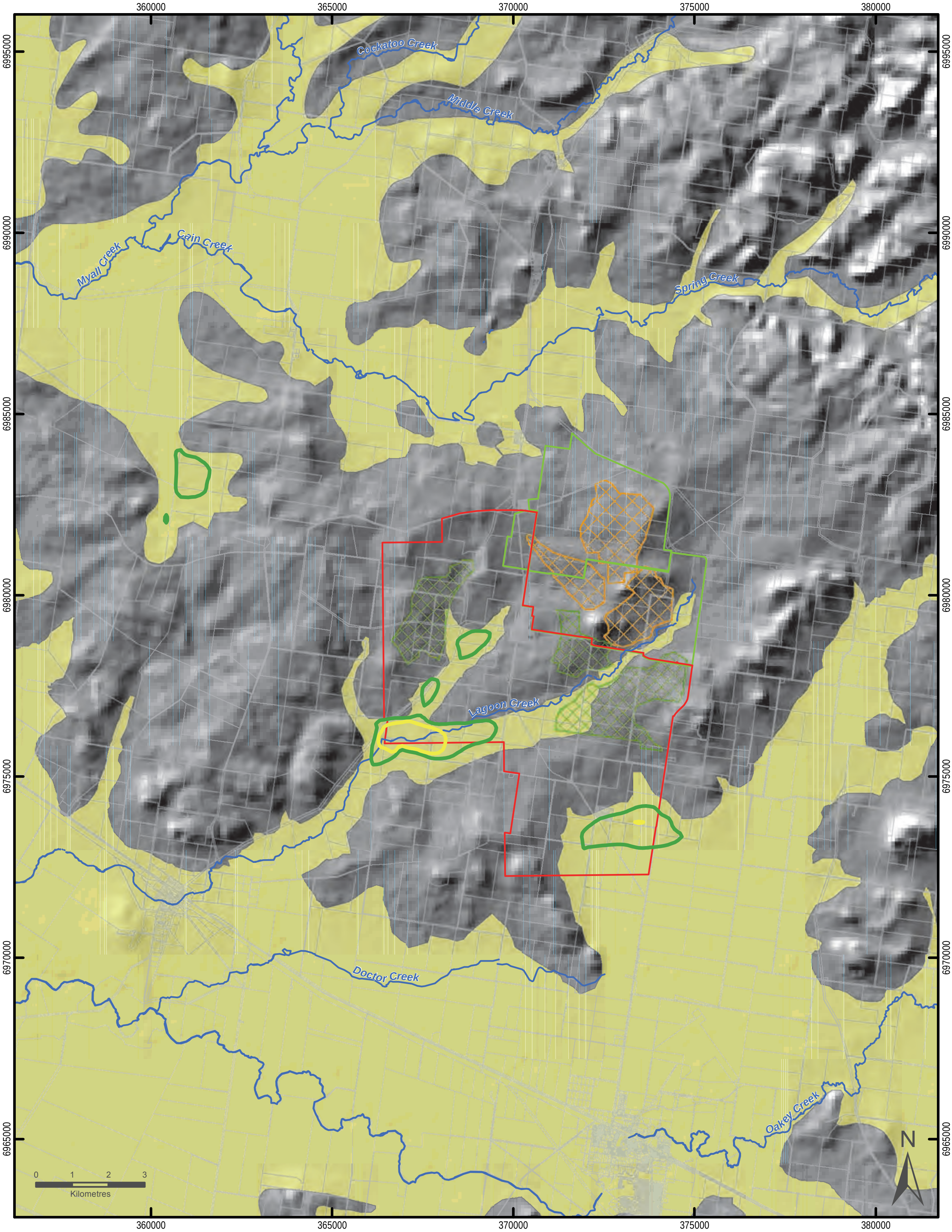


LEGEND

Maximum impact extent in the Alluvium

- 2 metre contour (50th Percentile)
- 2 metre contour (84th Percentile)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

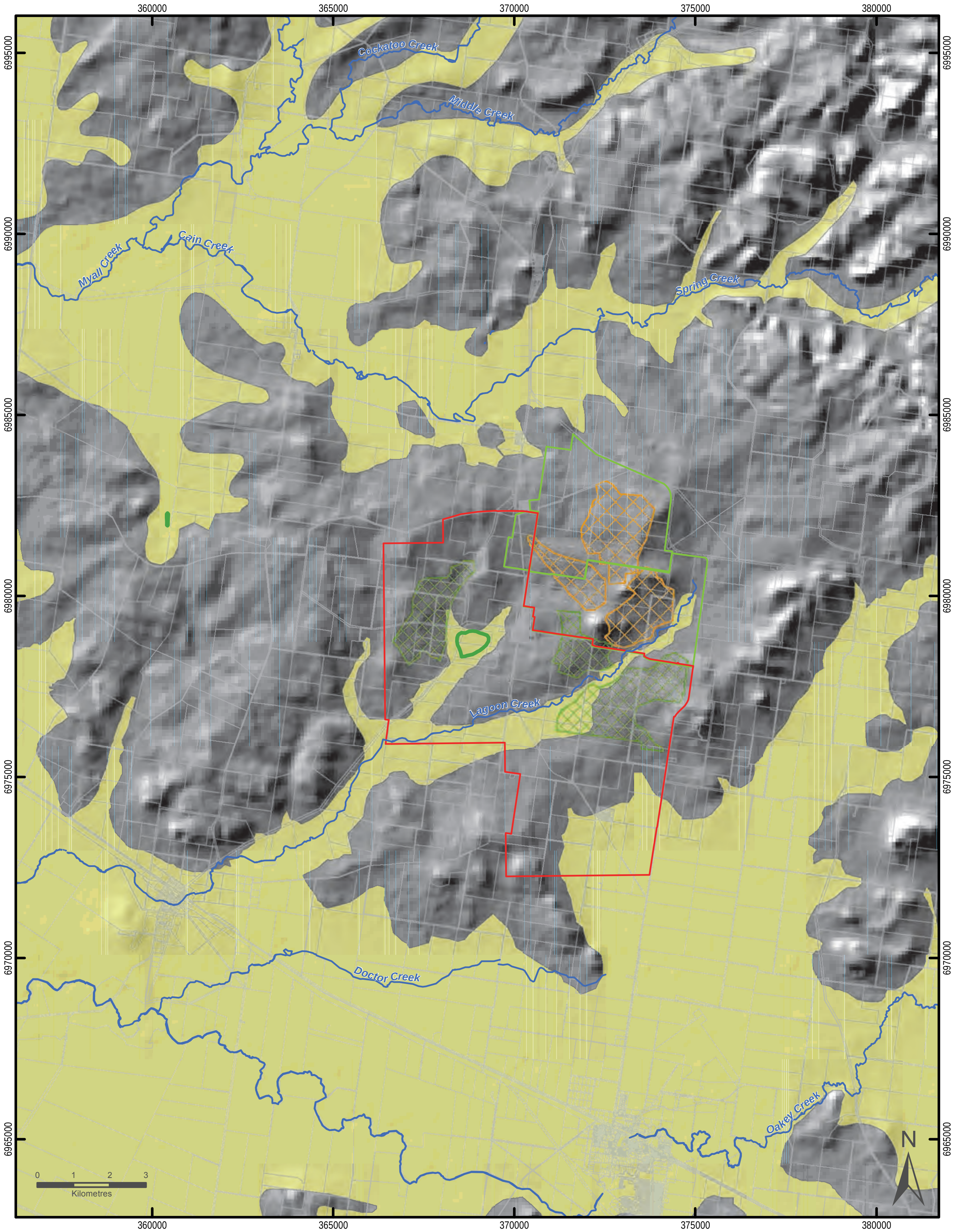
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-32 - Alluvium Maximum Impact Extent - 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-32_MaxImpactExtentAlluvium_2030.mxd



LEGEND

Maximum impact extent in the Alluvium

- 1 metre contour (84th Percentile)
- Watercourse
- Cadastre
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-33 - Alluvium Maximum Impact Extent – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

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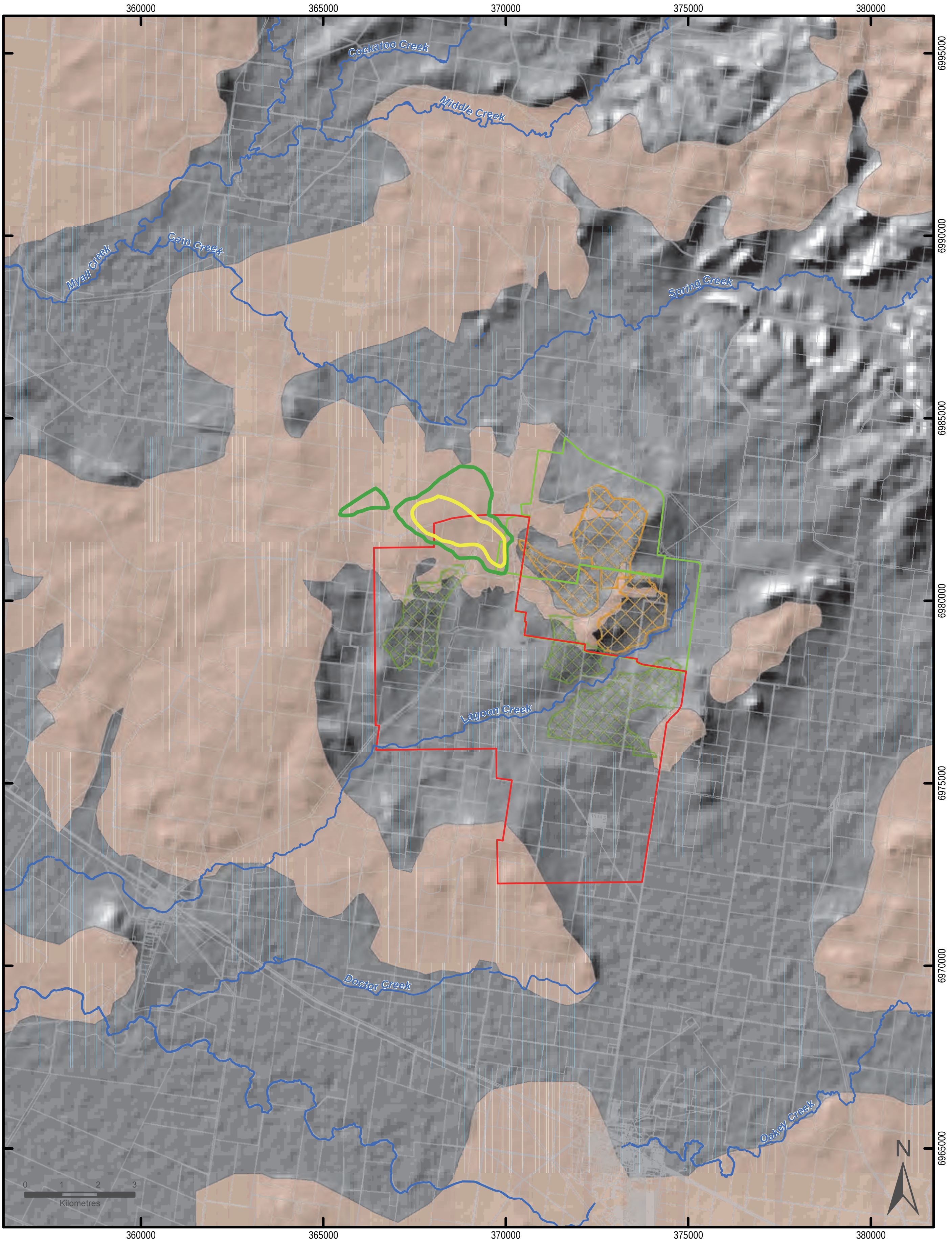


LEGEND

Maximum impact extent in the Tertiary Basalt

- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)
- Watercourse
- New Aland Coal Mine- Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

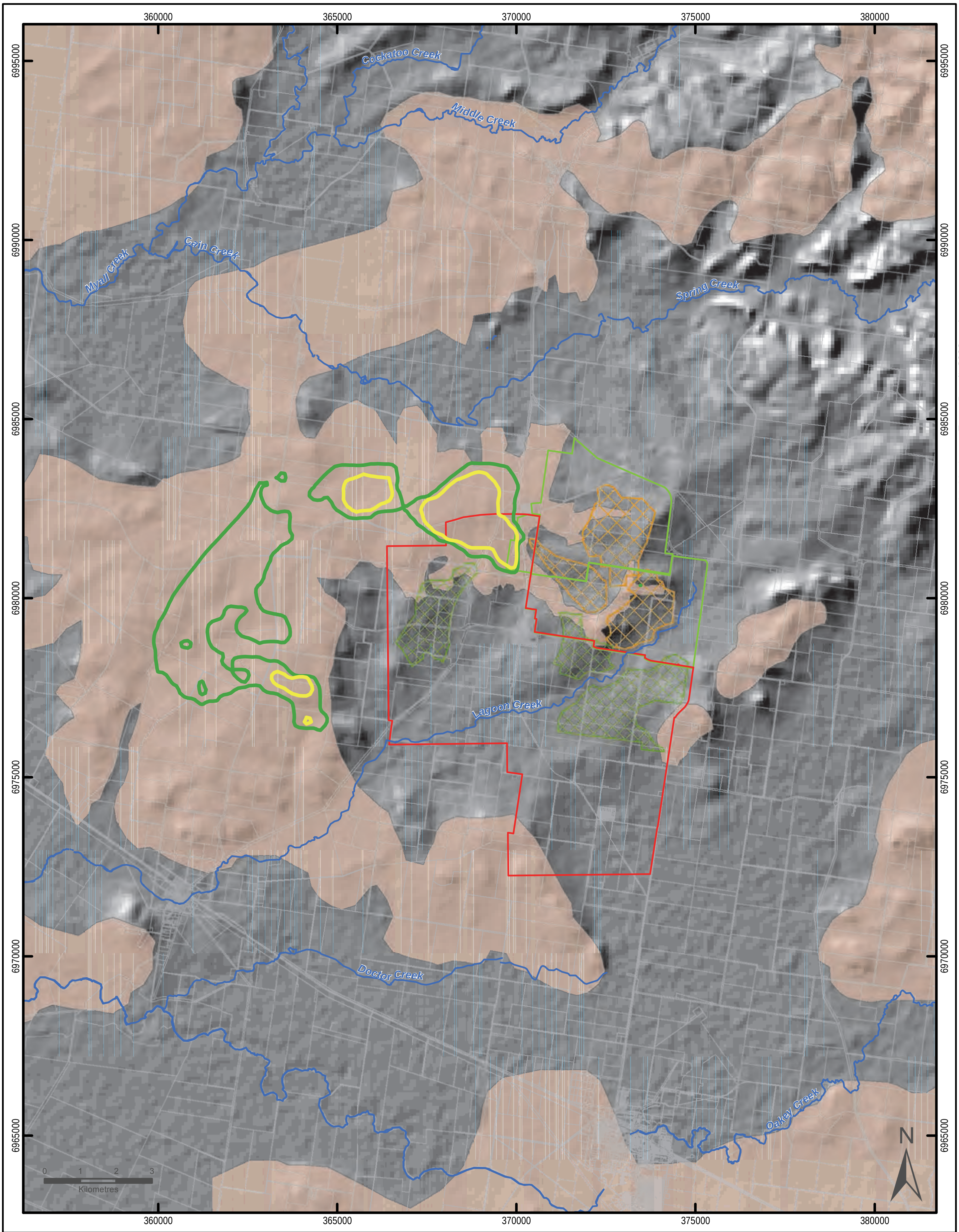
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-34 - Basalt Maximum Impact Extent - 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-34_MaxImpactExtentBasalt_2021.mxd



LEGEND

Maximum impact extent in the Tertiary Basalt

- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

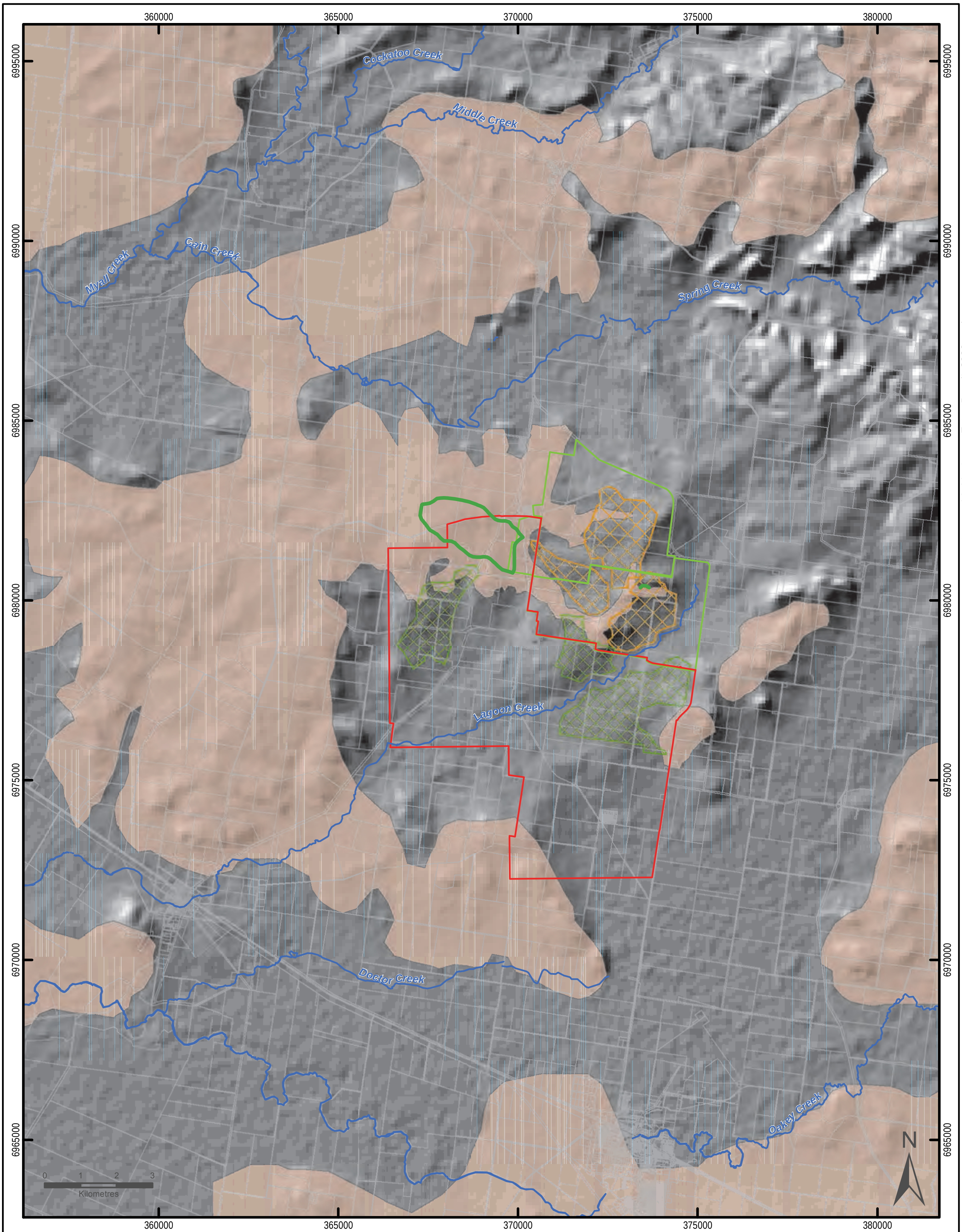
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-35 - Basalt Maximum Impact Extent - 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-35_MaxImpactExtentBasalt_2030.mxd



LEGEND

Maximum impact extent in the Tertiary Basalt

- 5 metre contour (84th Percentile)
- Watercourse
- Cadastre
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Basalt (Tm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

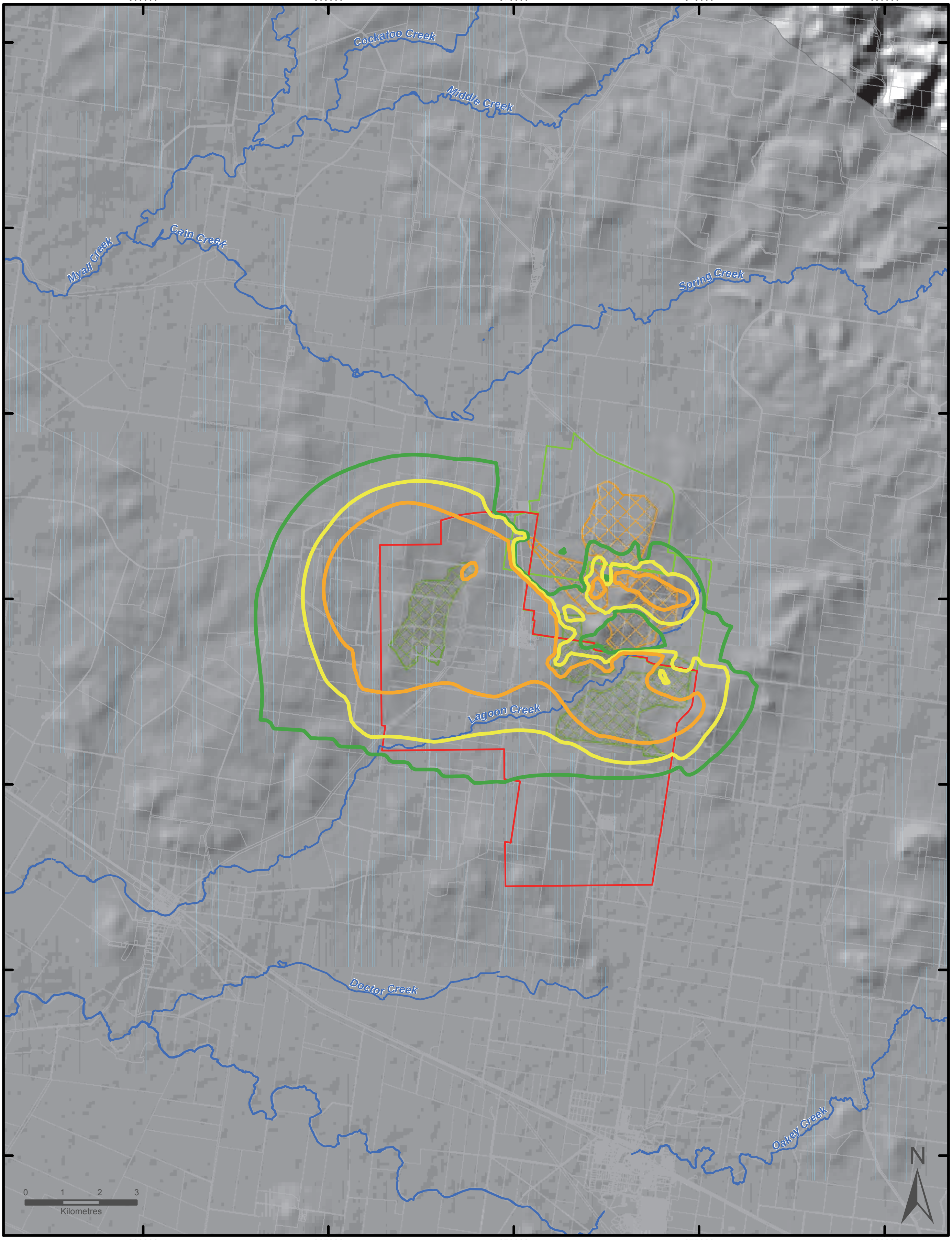
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-36 - Basalt Maximum Impact Extent – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-36_MaxImpactExtentBasalt_2330.mxd



LEGEND

Maximum impact extent in the Walloon Coal Measures

- 5 metre contour (16th Percentile)
- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal
- Cadastre
- Stage 3 Pit
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

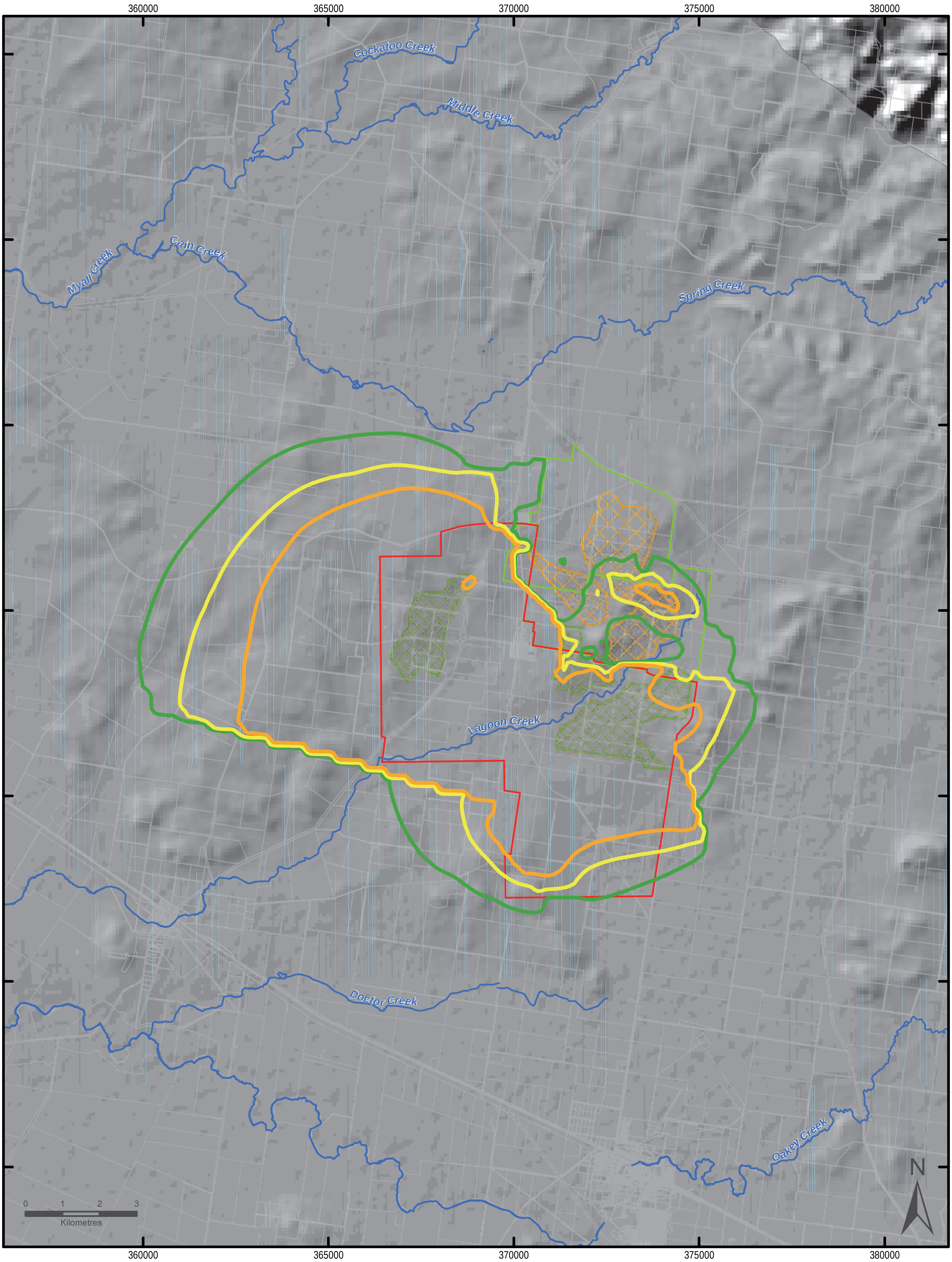
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-37 - Walloon Coal Measures Maximum Impact Extent - 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-37_MaxImpactExtentWalloon_2021.mxd



LEGEND

Maximum impact extent in the Walloon Coal Measures

- 5 metre contour (16th Percentile)
- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal
- Cadastre
- Stage 3 Pit
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

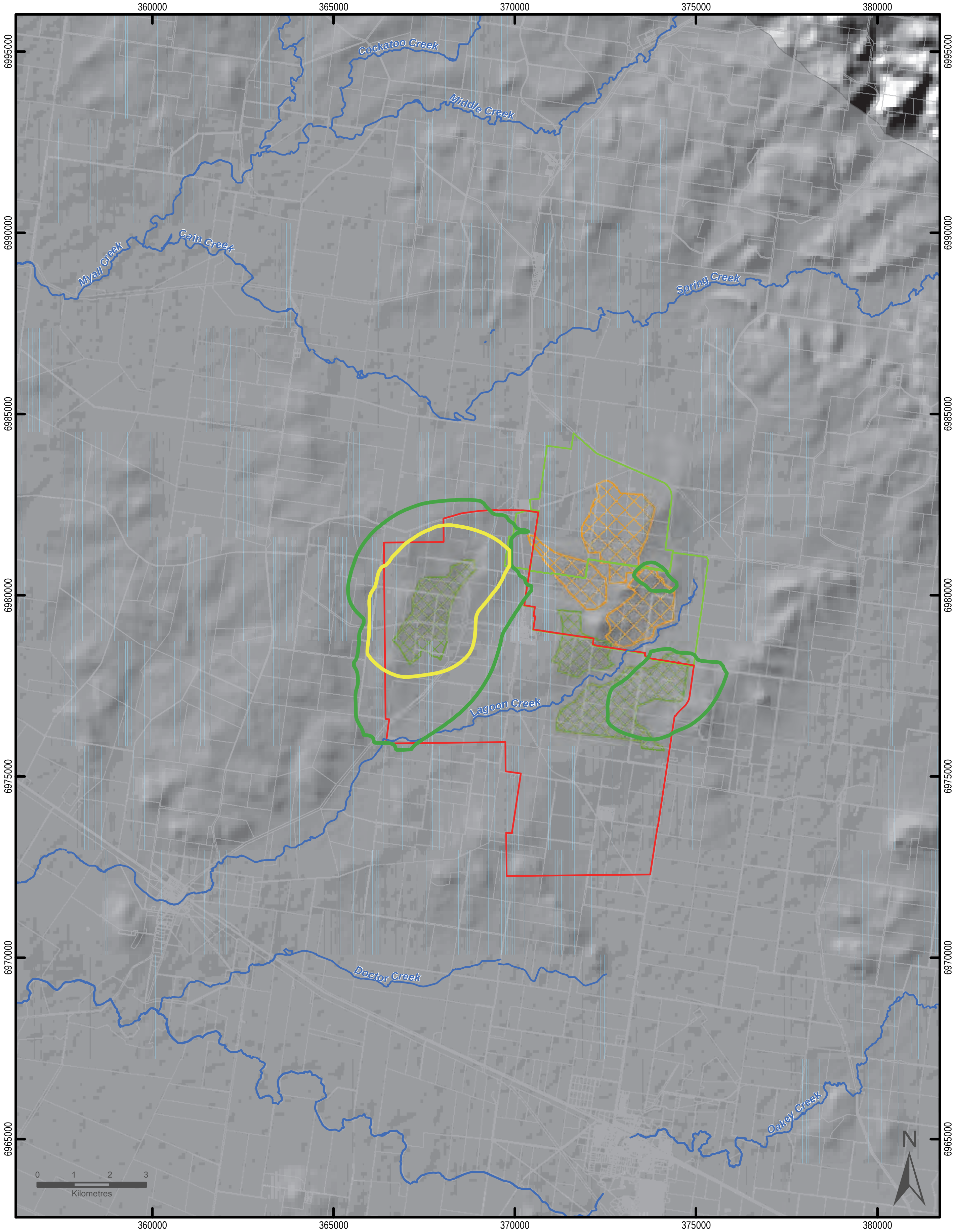
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-38 - Walloon Coal Measures Maximum Impact Extent - 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-38_MaxImpactExtentWalloon_2030.mxd



LEGEND

Maximum impact extent in the Walloon Coal Measures

- 5 metre contour (16th Percentile)
- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)

- Watercourse
- New Aland Coal Mine- Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-39 - Walloon Coal Measures Maximum Impact Extent – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-39_MaxImpactExtentWalloon_2330.mxd

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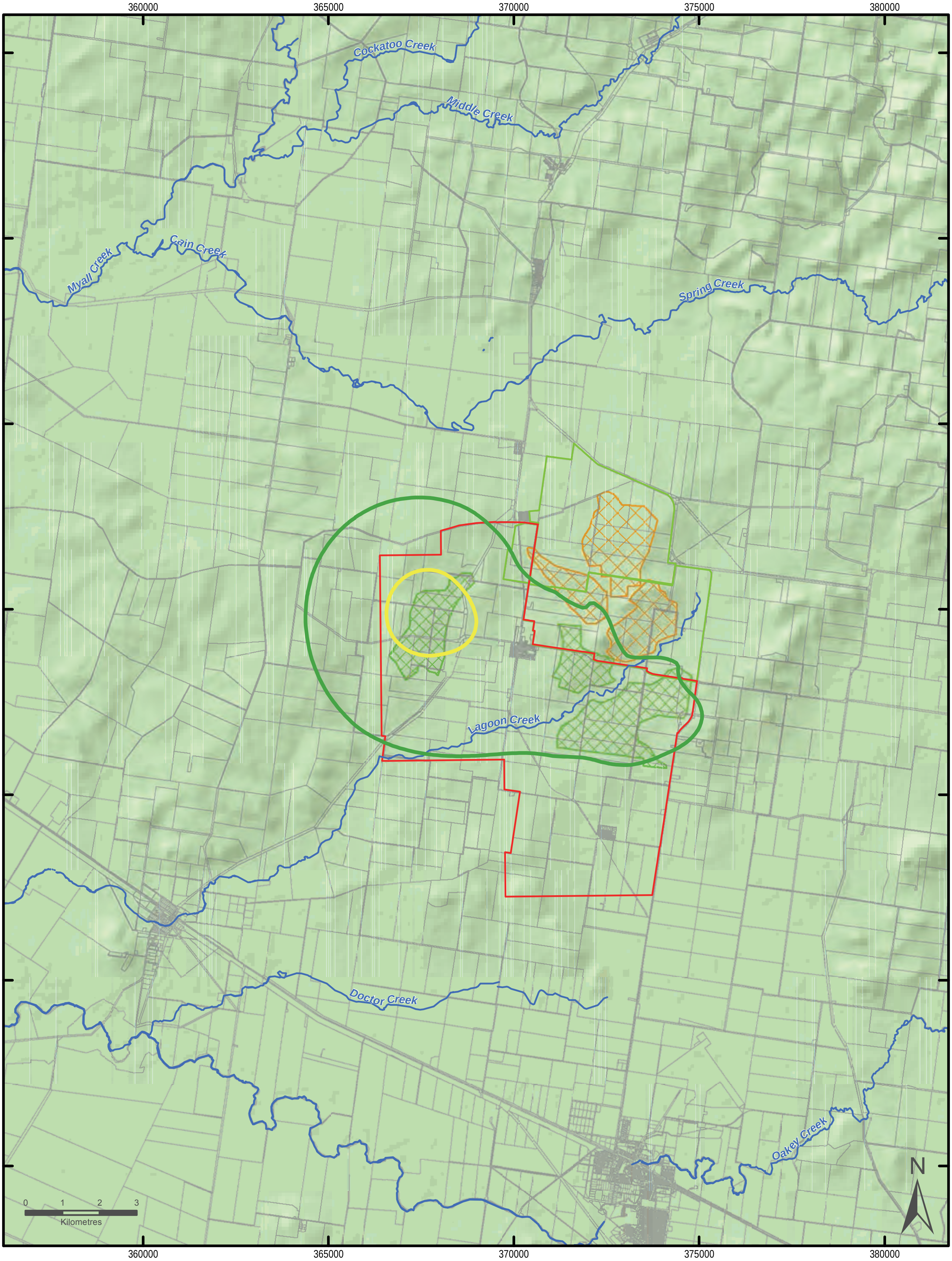


LEGEND

Maximum impact extent in the Marburg Sandstone

- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)
- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

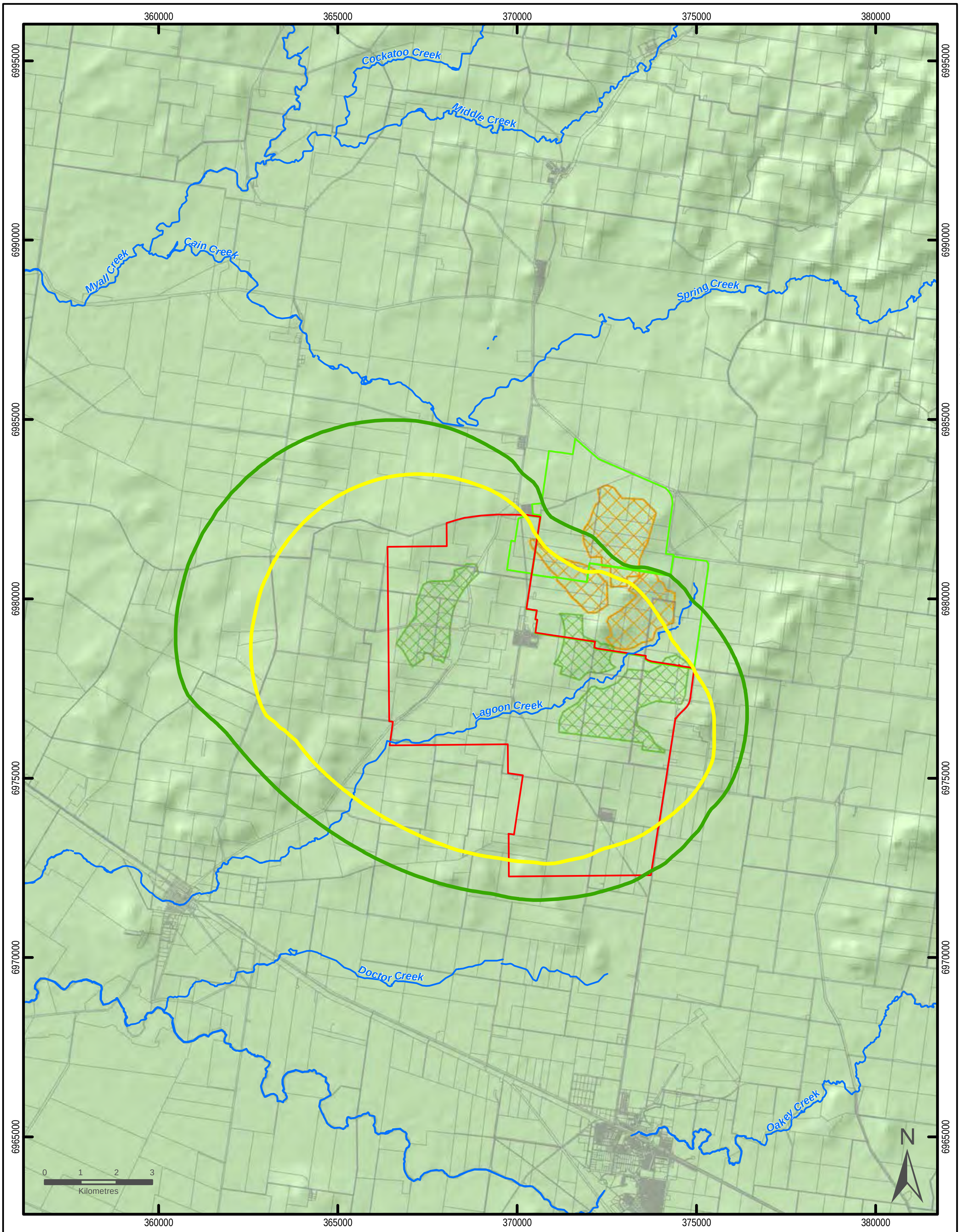
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-40 - Marburg Sandstone Maximum Impact Extent - 2021

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 26/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140616_NewHope_Groundwater_Figure6-40_MaxImpactExtentMarburg_2021.mxd



LEGEND

Maximum impact extent in the Marburg Sandstone

- 5 metre contour (50th Percentile)
- 5 metre contour (84th Percentile)
- Watercourse
- New Aland Coal Mine- Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

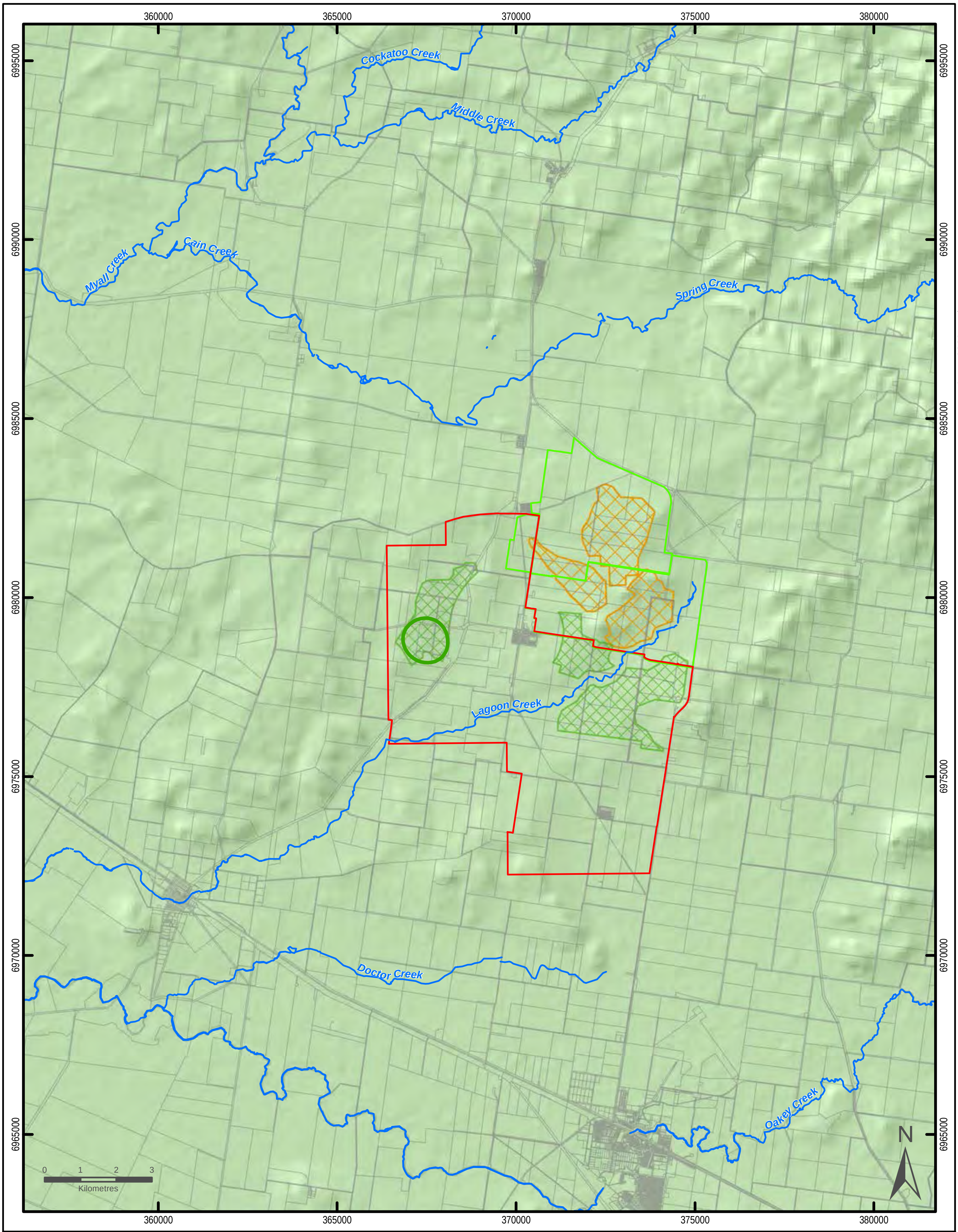
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-41 - Marburg Sandstone Maximum Impact Extent - 2030

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140616_NewHope_Groundwater_Figure6-41_MaxImpactExtentMarburg_2030.mxd



LEGEND

Maximum impact extent in the Marburg Sandstone

- 5 metre contour (84th Percentile)
- Watercourse
- Cadastre

- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure 6-42 - Marburg Sandstone Maximum Impact Extent – Post Mining

Scale 1:140,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 28/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140616_NewHope_Groundwater_Figure6-42_MaxImpactExtentMarburg_2330.mxd

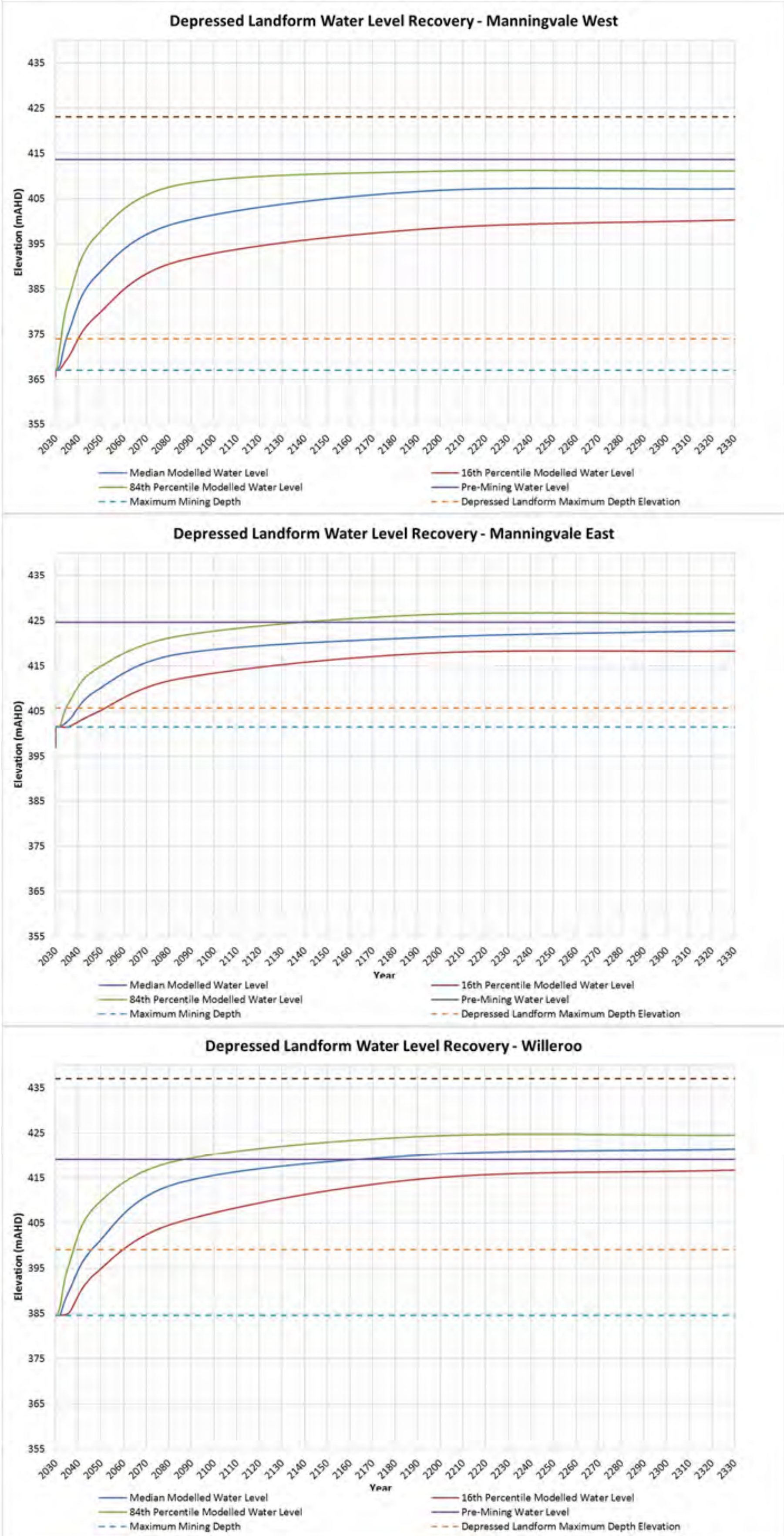


Figure 6-43 : Pit Lake Evolution

A mass balance for the model domain for post-mining recovery and pit lake evolution is provided in **Figure 6-44 : Post-Mining Mass BalanceFigure 6-44**. The primary source of inflow to the model is recharge. The main sources of outflow across the entire model are flows to tributaries and evapotranspiration. Evapotranspiration and change in storage have a relatively equal and opposite trend as the voids fill during the first 90-100 years. Once the voids have reached equilibrium, as indicated by a zero net change in storage, evapotranspiration also reaches a long-term equilibrium.

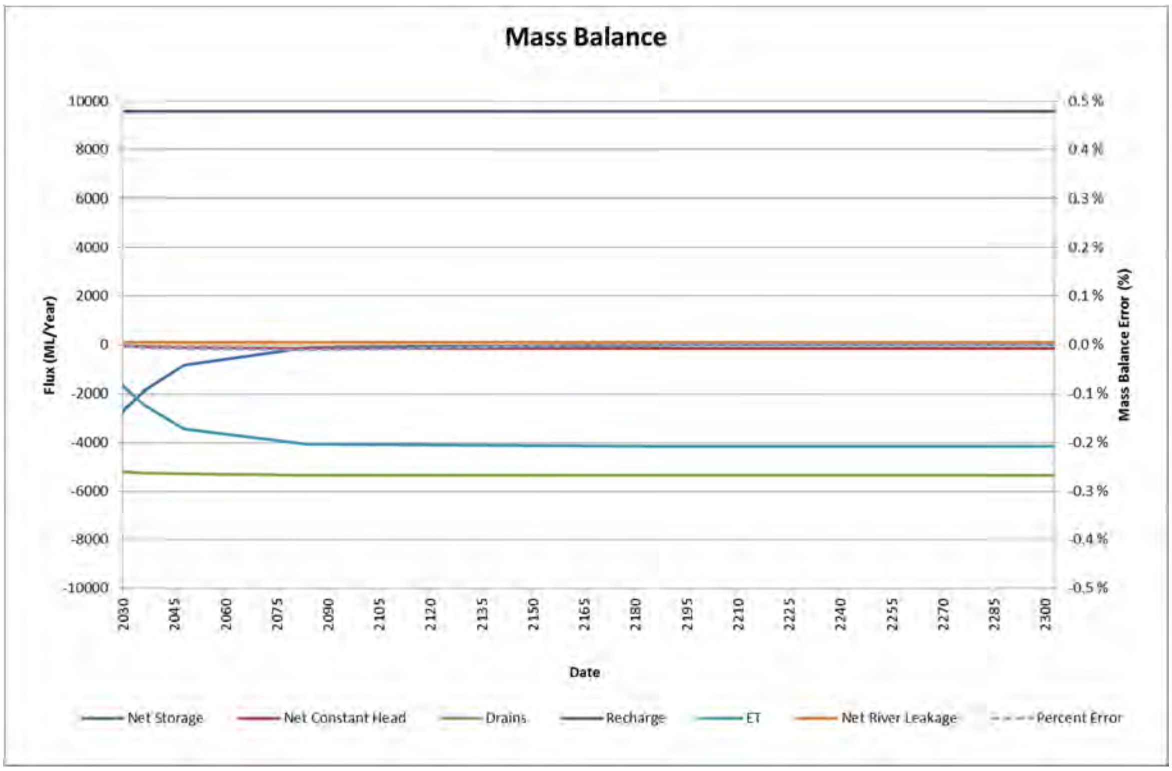


Figure 6-44 : Post-Mining Mass Balance

7. Uncertainty analysis

Understanding uncertainty is an inherent part of any qualitative and/or quantitative assessment. It is as important to understand the uncertainty of the assessments as it is to understand the conclusions derived from the results of the assessment, as it will put those conclusions into context.

To understand the uncertainty in this assessment, a comparison/evaluation was made for the following estimated output requirements:

- pit inflow and/or dewatering rates associated with the proposed mine plan
- drawdown, as indicated by potential impact zones, during and after the proposed mine operations.

7.1 Inflows

The uncertainty of inflow predictions, as indicated by the upper and lower bounds, is relatively small (< +/- 20% the median). These results are most likely a result of the restriction of parameter values for the Walloon Coal Measures during calibration. These results also indicate that inflows are much less sensitive to other parameters.

7.2 Drawdown

Drawdown extent, as indicated by the potential impacts zones **in Figure 6-32** through **Figure 6-42**, indicate a relatively minor uncertainty in areal extent of uncertainty for drawdown propagation. The level of uncertainty in each aquifer is relative to the level of constraint provided in the calibration process. For example, the uncertainty in impact zone extent for the Walloon Coal Measures is much less than that of the Marburg sandstone, as is the constraint in calibrated parameter values (**Figure 5.5** through **Figure 5.10**).

8. Summary and Conclusions

The level of constraint calibration has provided on parameter values is evident in the level of uncertainty indicated in the predictive results. Given that calibration is considered within acceptable limits and the level of uncertainty in the predictive results is considered minor, in hydrogeologic modelling terms, it is then concluded that the calibration process has provided enough rigor for predictive results to be considered fit for purpose and suitable for the assessment of potential impacts associated with the proposed project. .

9. References

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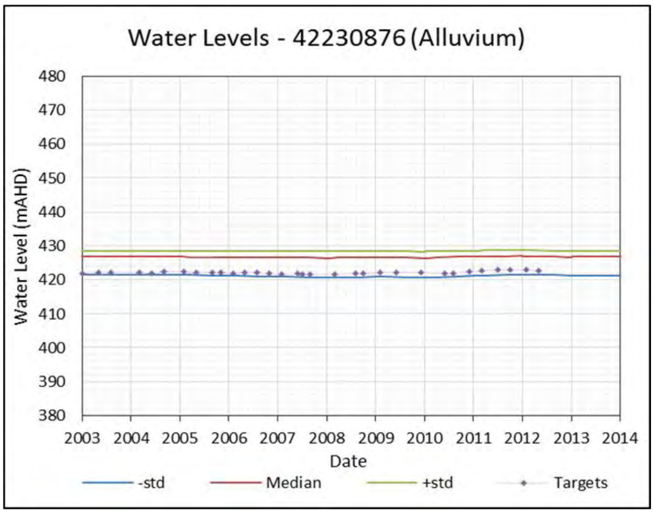
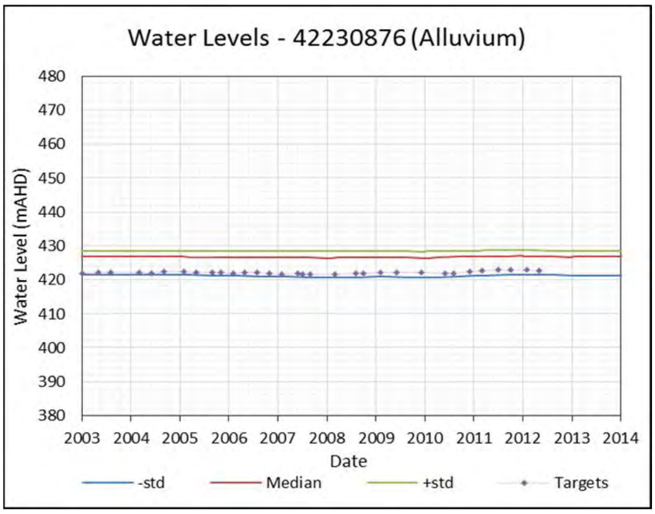
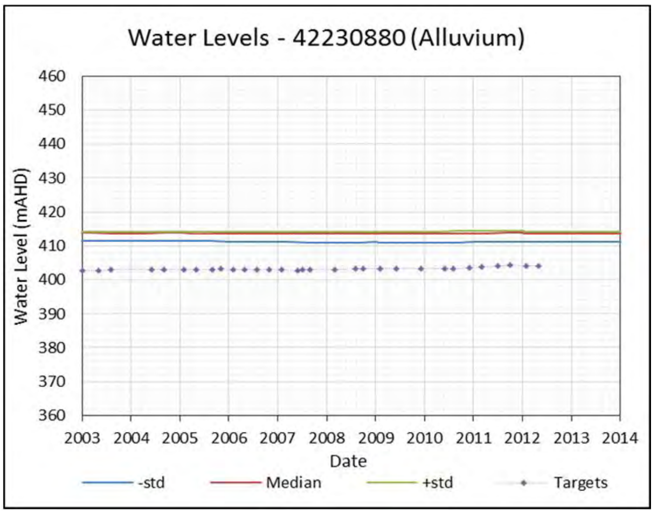
Appendix A. Calibration Information

Appendix A.1 Calibration Hydrographs

Alluvial Bores


Water Levels - 42230876 (Alluvium)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42230876 (Alluvium)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42230880 (Alluvium)
Water Level (mAHD)
460
450
440
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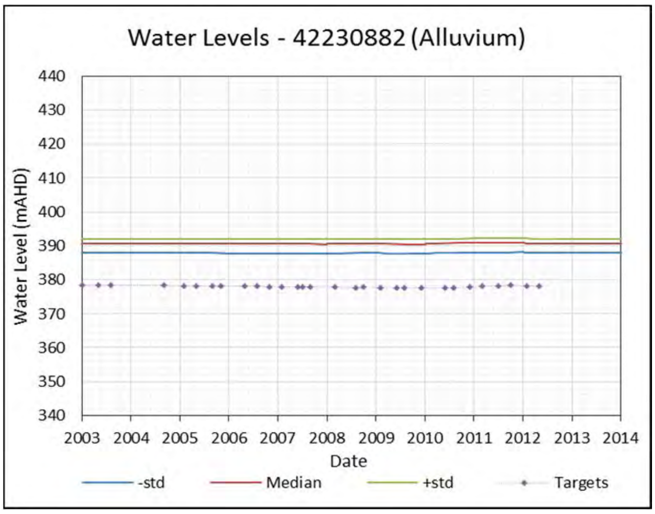
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42230882 (Alluvium)
Water Level (mAHD)
440
430
420
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400
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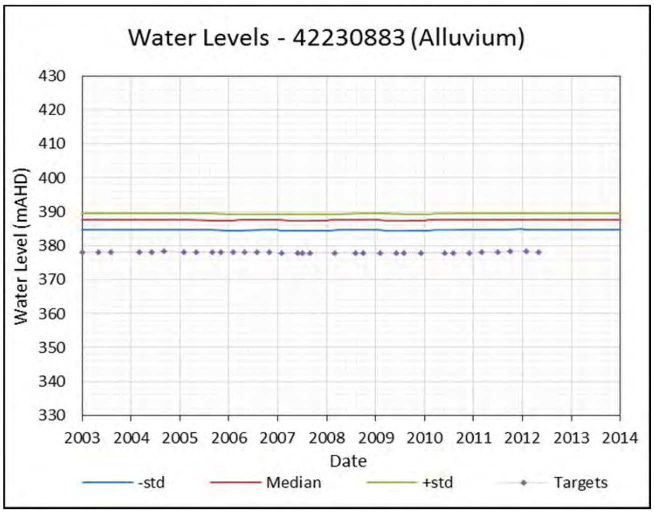
380
370
360
350
340
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42230883 (Alluvium)
Water Level (mAHD)
430
420
410
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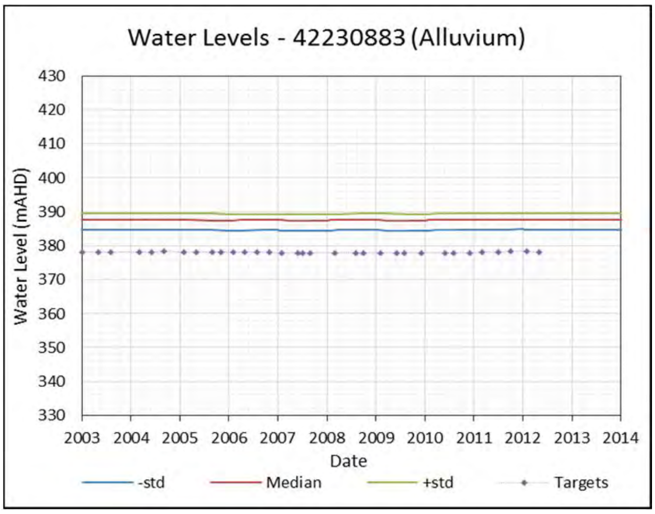
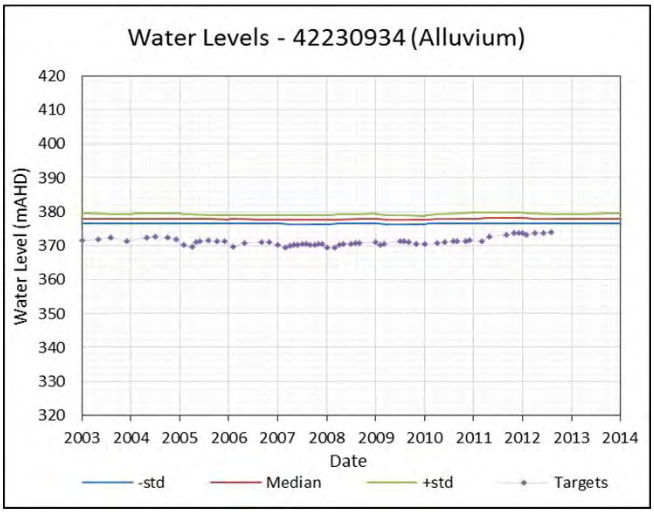
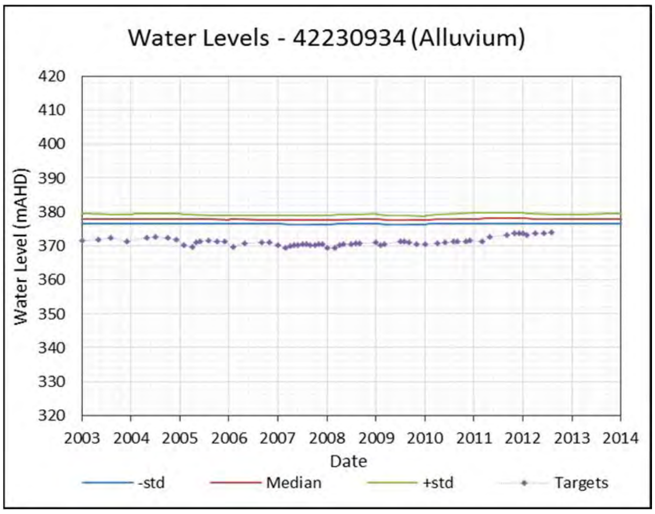
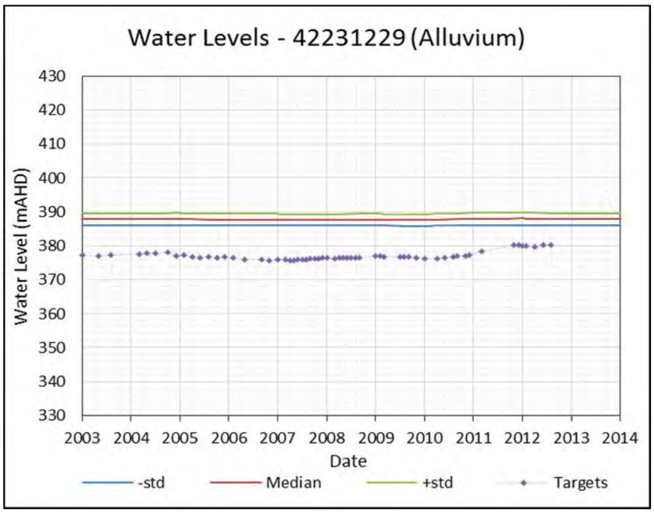
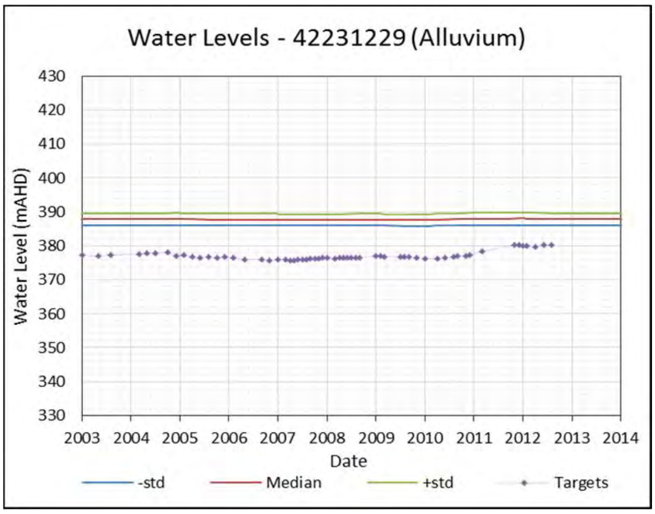
390
380
370
360
350
340
330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

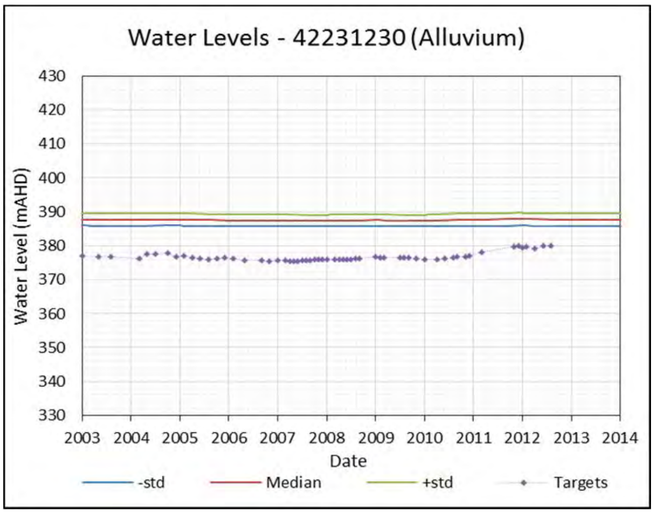

Water Levels - 42230883 (Alluvium)
Water Level (mAHD)
430
420
410
400
390
380
370
360
350
340
330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

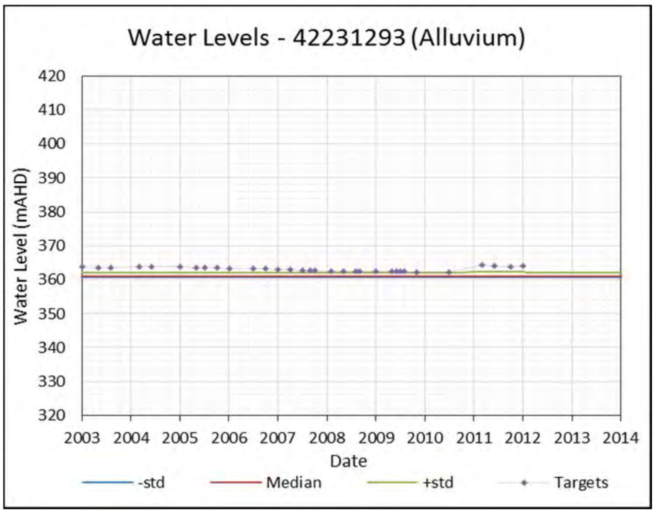

Water Levels - 42230934 (Alluvium)
420
410
400
390
380
370
360
350
340
330
320
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

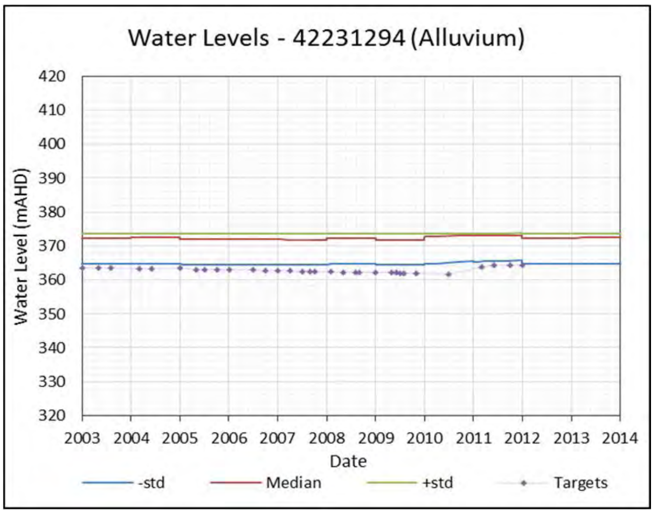

Water Levels - 42230934 (Alluvium)
420
410
400
390
380
370
360
350
340
330
320
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231229 (Alluvium)
430
420
410
400
390
380
370
360
350
340
330
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231229 (Alluvium)
430
420
410
400
390
380
370
360
350
340
330
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231230 (Alluvium)
430
420
410
400
390
380
370
360
350
340
330
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231293 (Alluvium)
420
410
400
390
380
370
360
350
340
330
320
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231294 (Alluvium)
420
410
400
390
380
370
360
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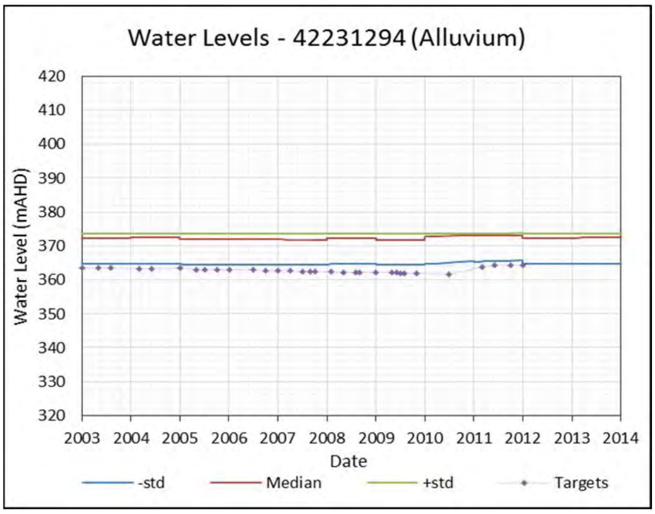
340
330
320
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231294 (Alluvium)
420
410
400
390
380
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360
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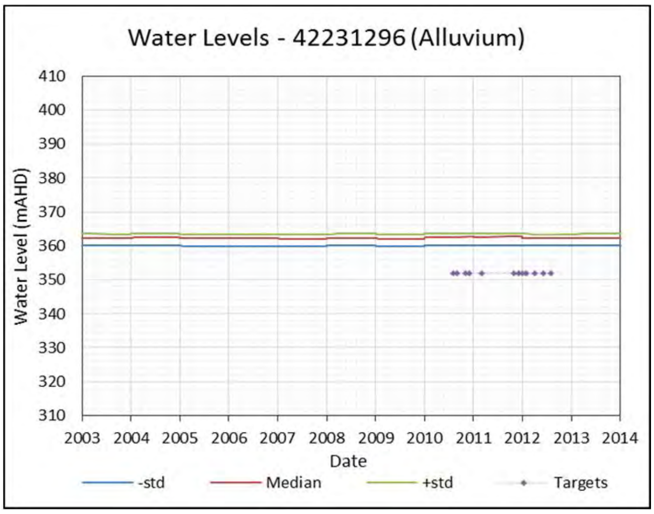
340
330
320
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231296 (Alluvium)
410
400
390
380
370
360
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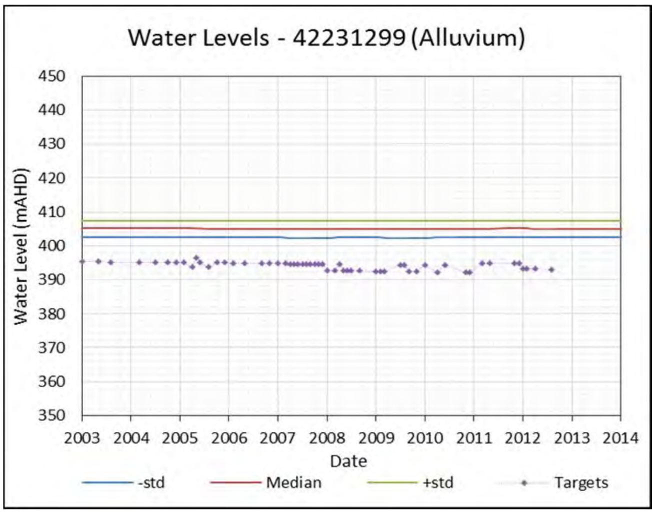
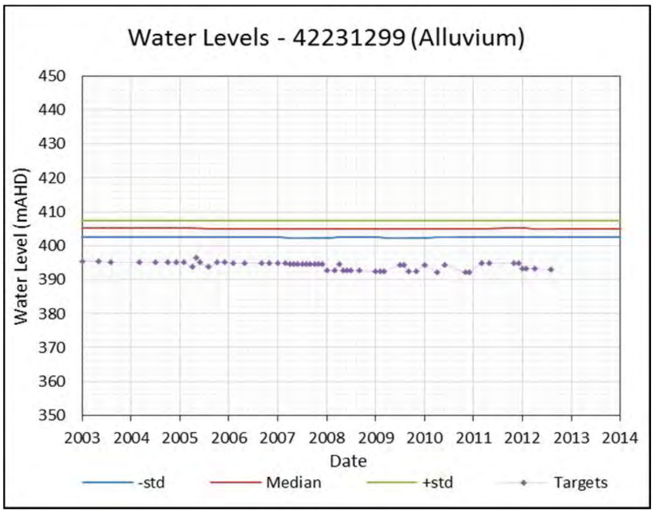
330
320
310
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231299 (Alluvium)
450
440
430
420
410
400
390
380
370
360
350
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231299 (Alluvium)
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440
430
420
410
400
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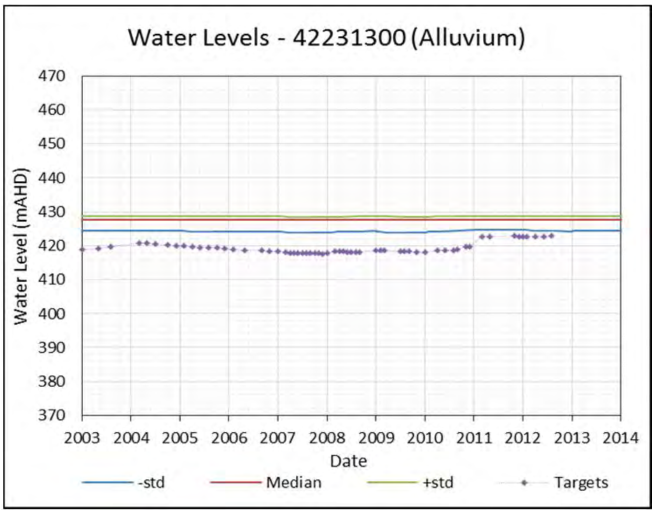
360
350
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231300 (Alluvium)
470
460
450
440
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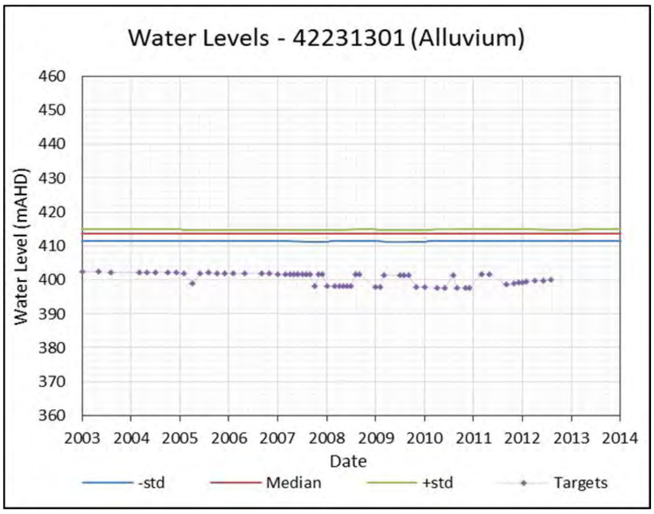
400
390
380
370
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets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Water Level (mAHD)
Date
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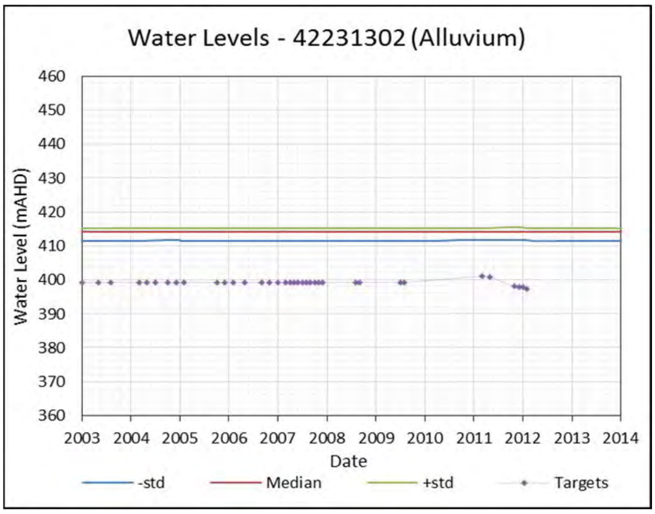
Median
+std
Targets


Water Levels - 42231302 (Alluvium)
Water Level (mAHD)
Date
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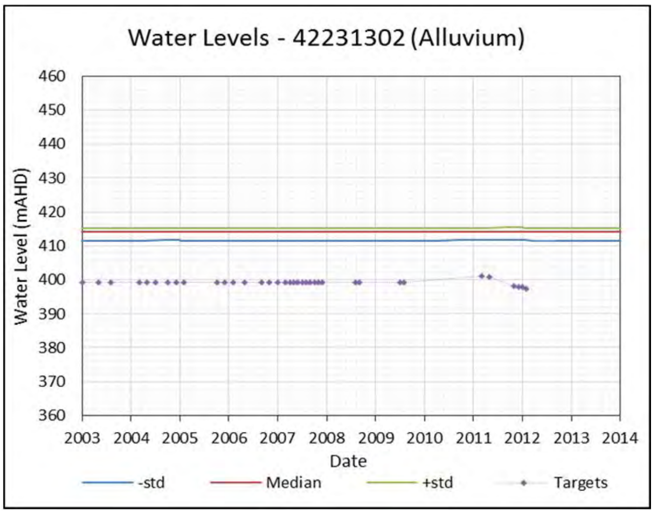
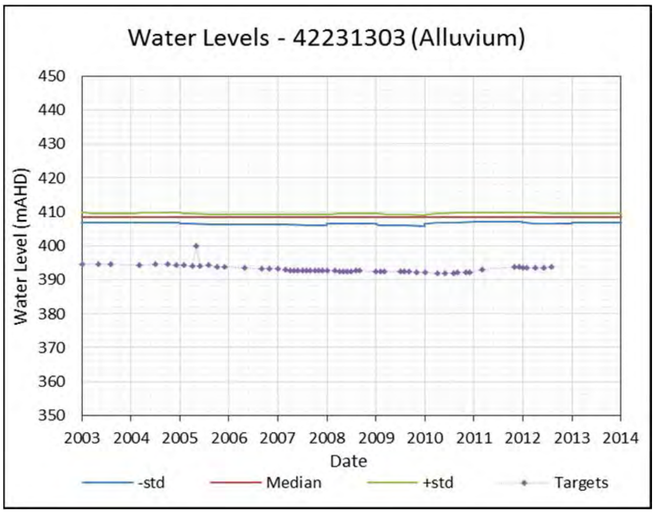
Median
+std
Targets


Water Levels - 42231302 (Alluvium)
Water Level (mAHD)
Date
-std
Median
+std
Targets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Water Level (mAHD)
Date
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Median
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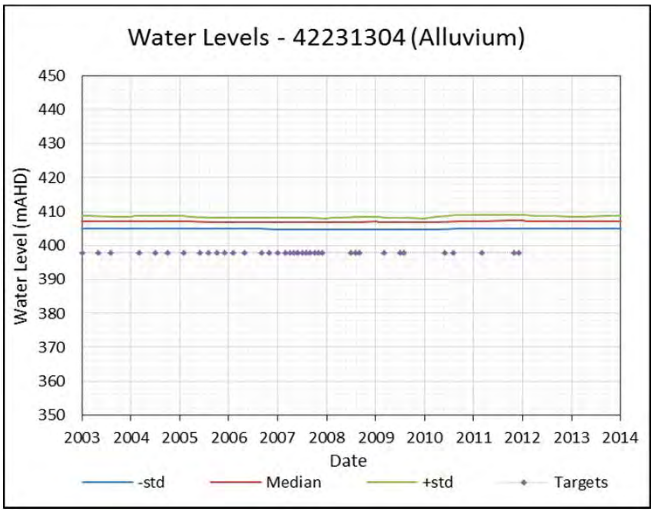
Targets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Water Level (mAHD)
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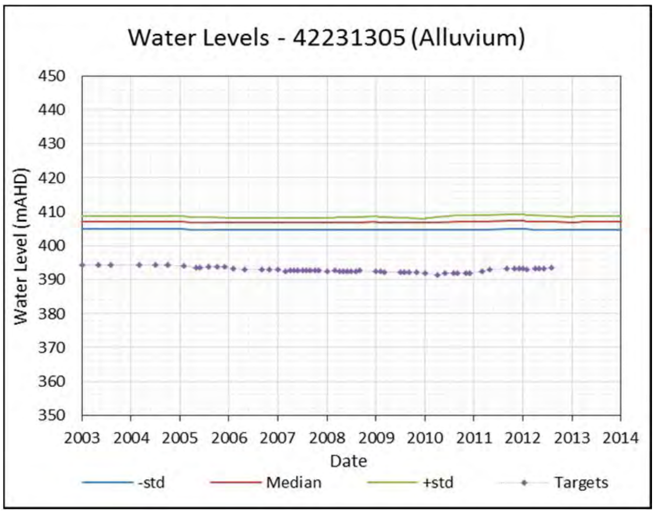
Median
+std
Targets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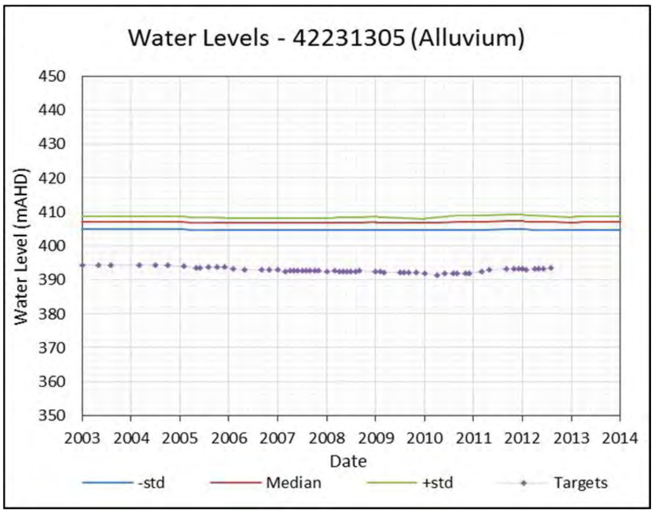
Water Level (mAHD)
Date
-std
Median
+std
Targets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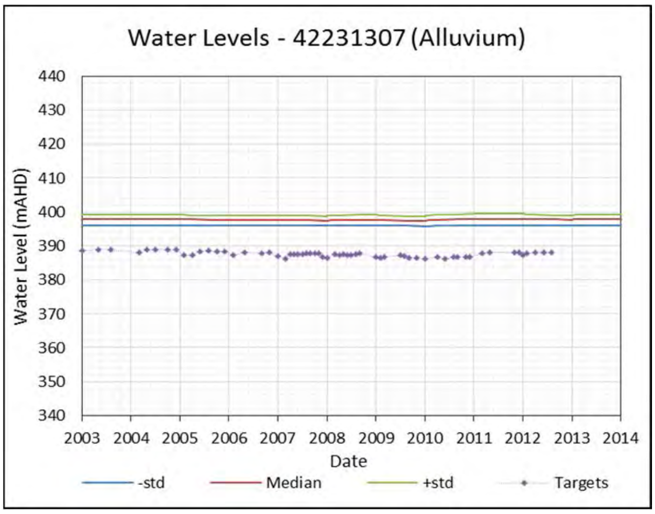
Water Level (mAHD)
450
440
430
420
410
400
390
380
370
360
350
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets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Water Level (mAHD)
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370
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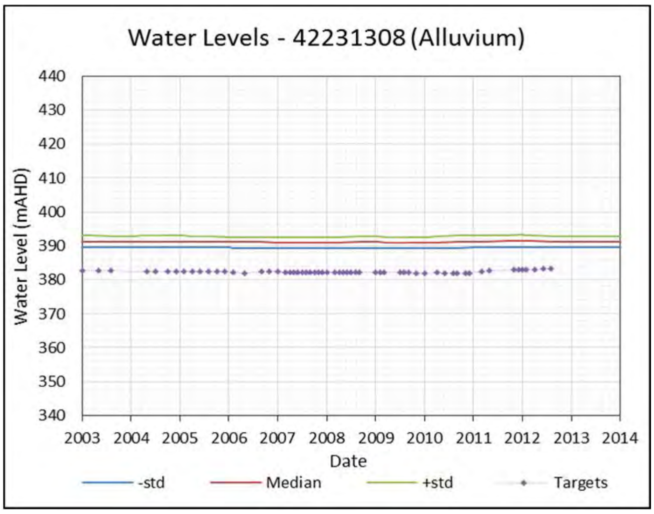
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231308 (Alluvium)
Water Level (mAHD)
440
430
420
410
400
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380
370
360
350
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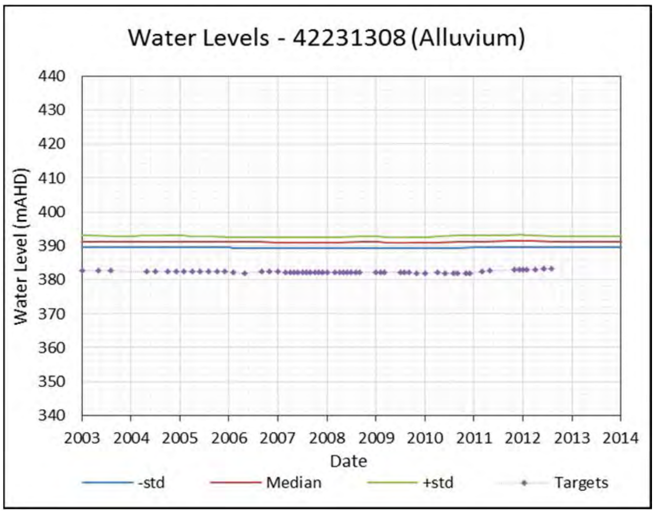
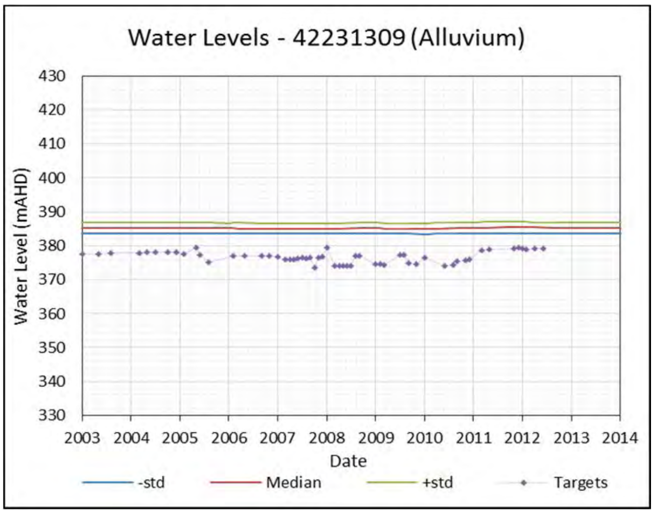
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231308 (Alluvium)
Water Level (mAHD)
440
430
420
410
400
390
380
370
360
350
340
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231309 (Alluvium)
Water Level (mAHD)
430
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400
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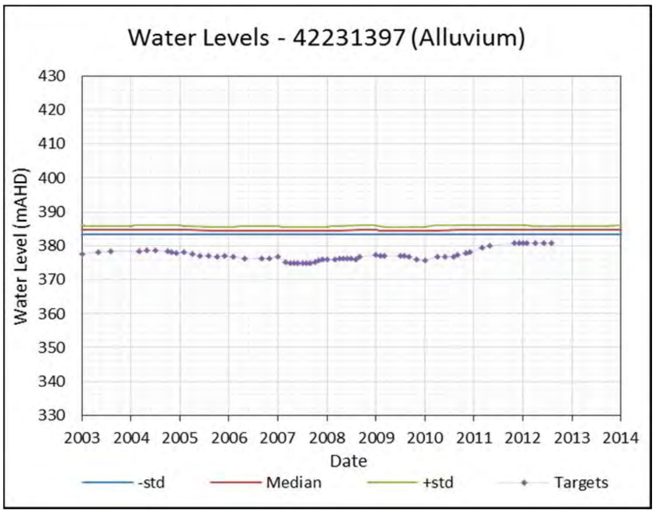
380
370
360
350
340
330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231397 (Alluvium)
Water Level (mAHD)
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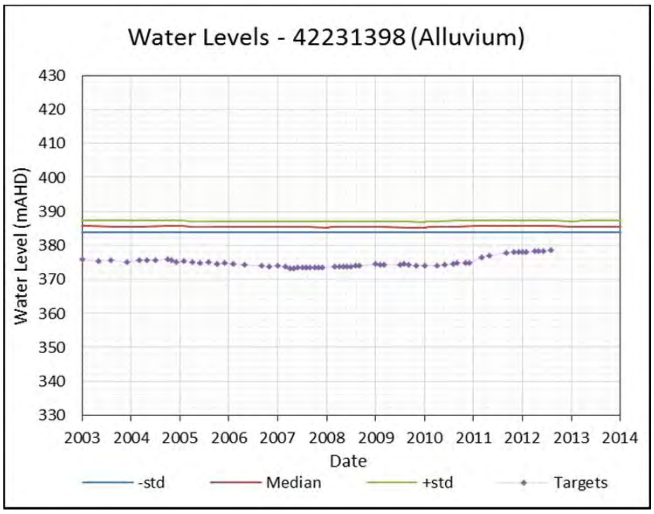
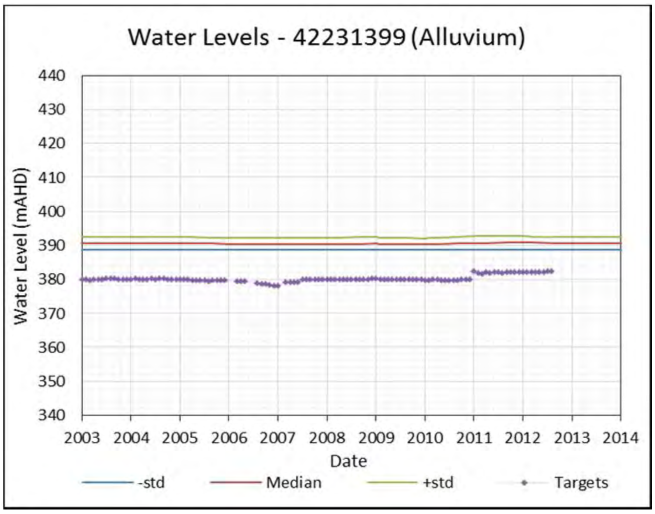
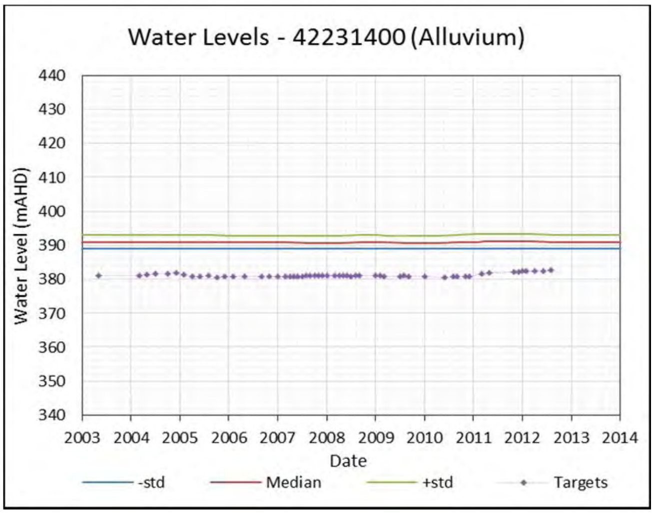
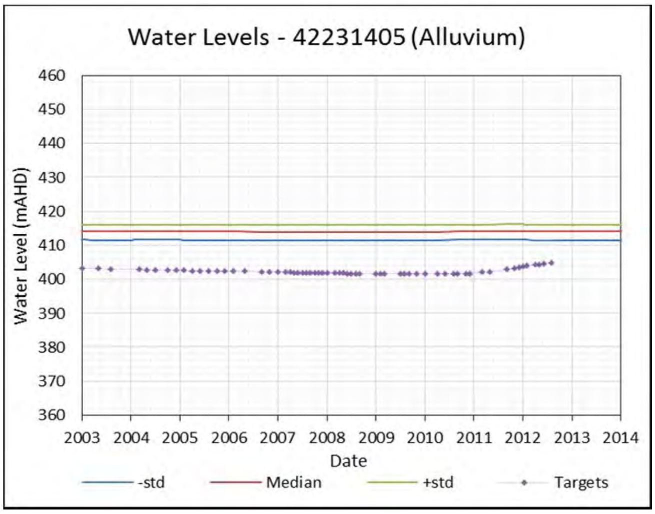
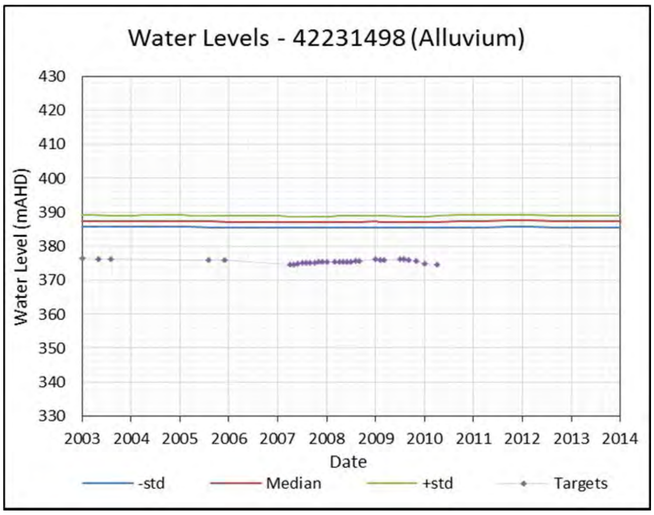
370
360
350
340
330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231398 (Alluvium)
Water Level (mAHD)
430
420
410
400
390
380
370
360
350
340
330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231399 (Alluvium)
Water Level (mAHD)
440
430
420
410
400
390
380
370
360
350
340
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231400 (Alluvium)
Water Level (mAHD)
440
430
420
410
400
390
380
370
360
350
340
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231405 (Alluvium)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231498 (Alluvium)
Water Level (mAHD)
430
420
410
400
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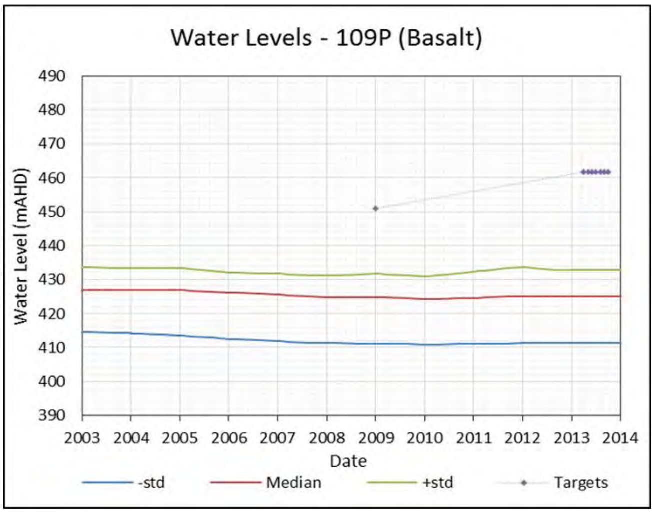
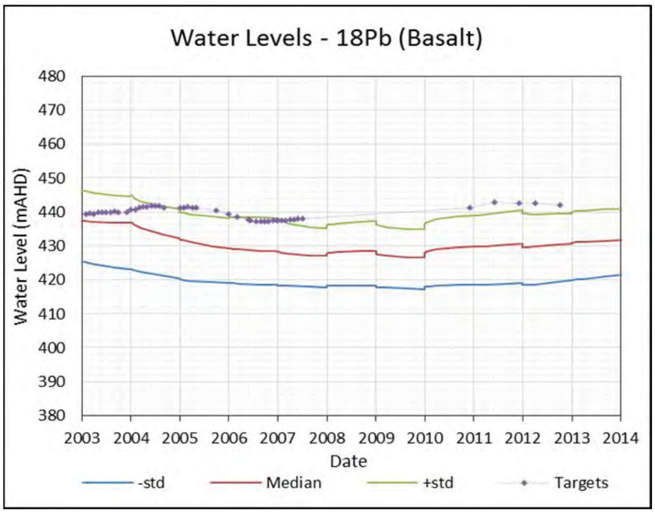
380
370
360
350
340
330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

Basalt Bores


Water Levels - 109P (Basalt)
Water Level (mAHD)
490
480
470
460
450
440
430
420
410
400
390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 18Pb (Basalt)
Water Level (mAHD)
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470
460
450
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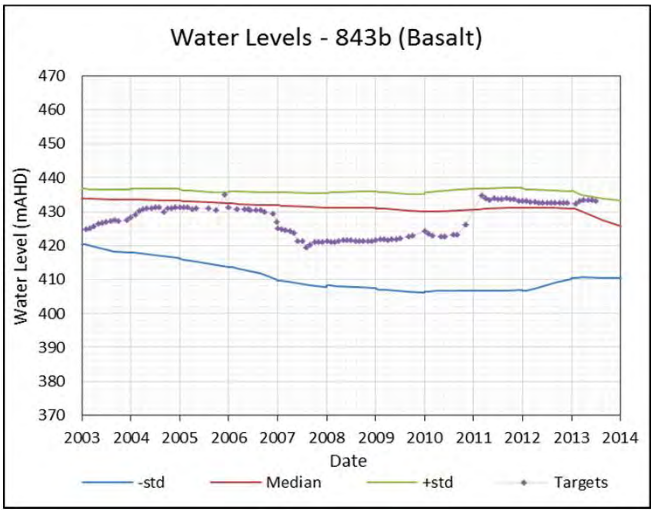
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 843b (Basalt)
Water Level (mAHD)
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460
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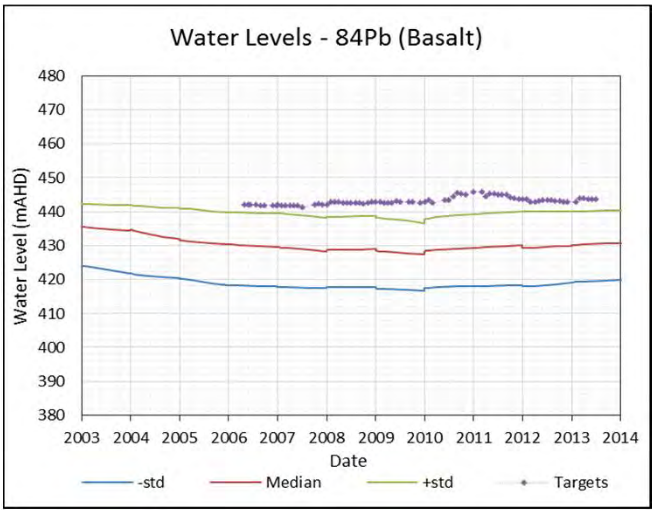
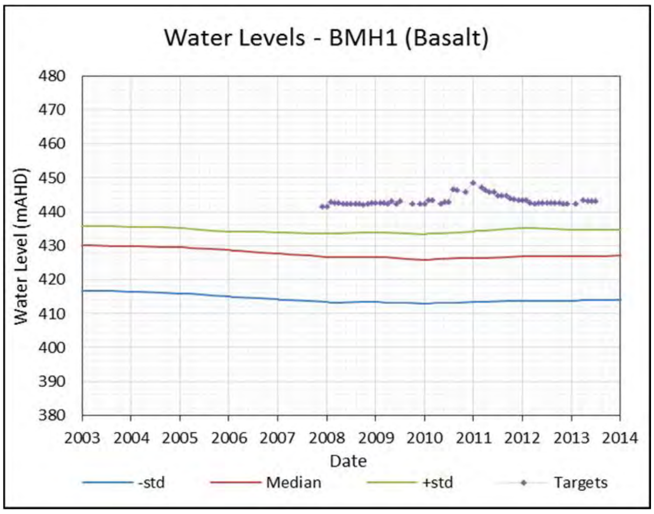
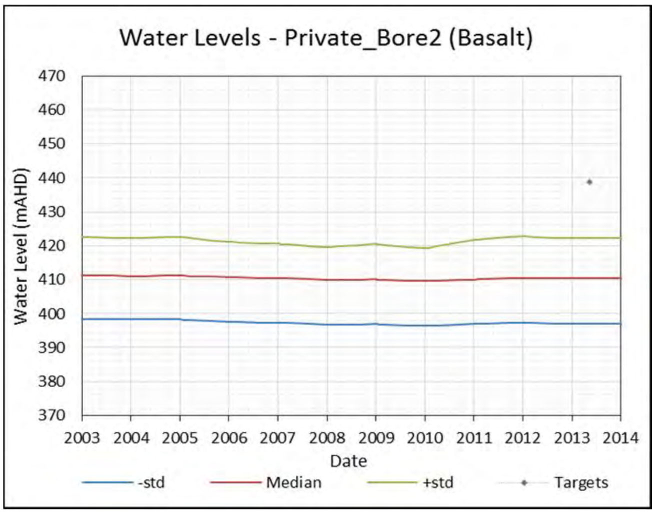
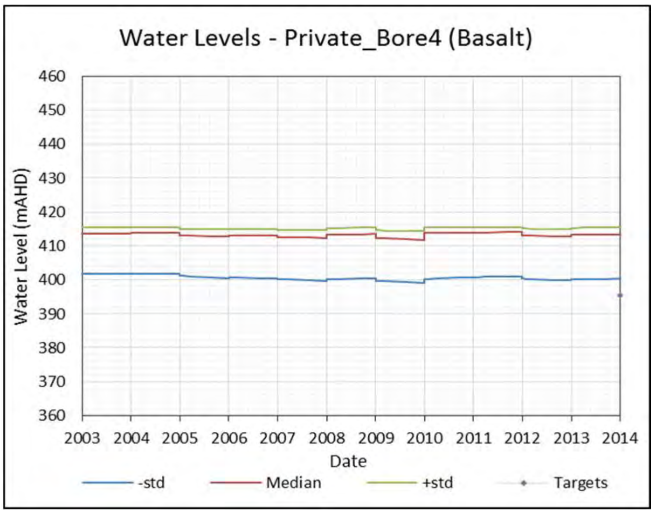
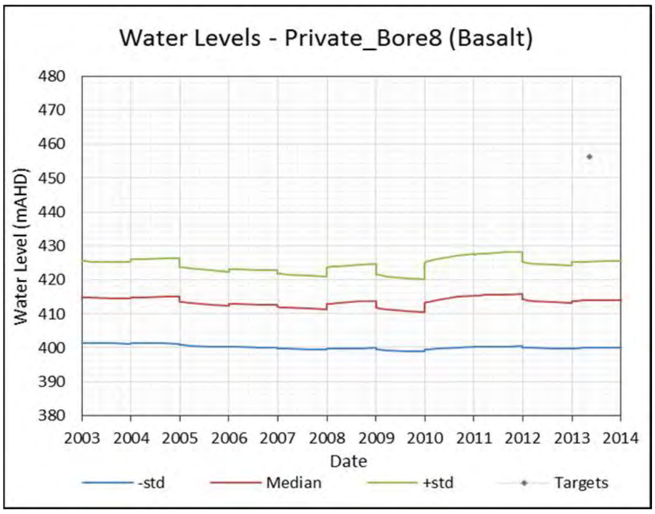
420
410
400
390
380
370
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

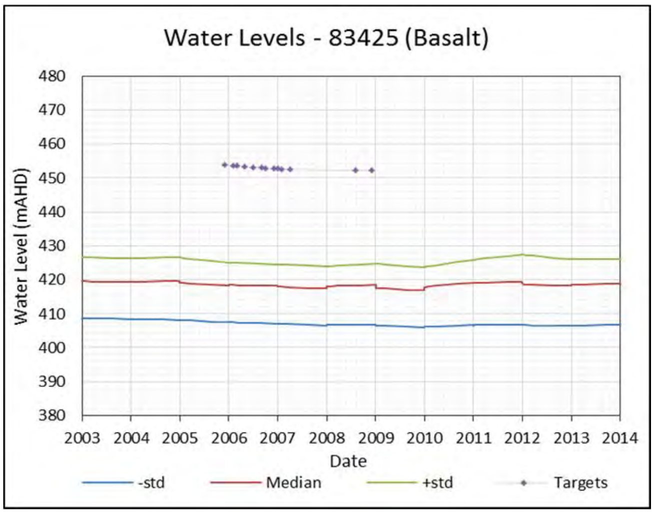

Water Levels - 84Pb (Basalt)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

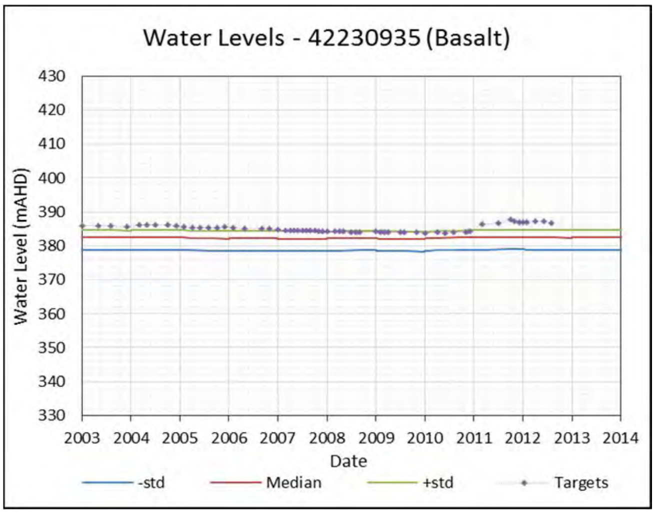

Water Levels - BMH1 (Basalt)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

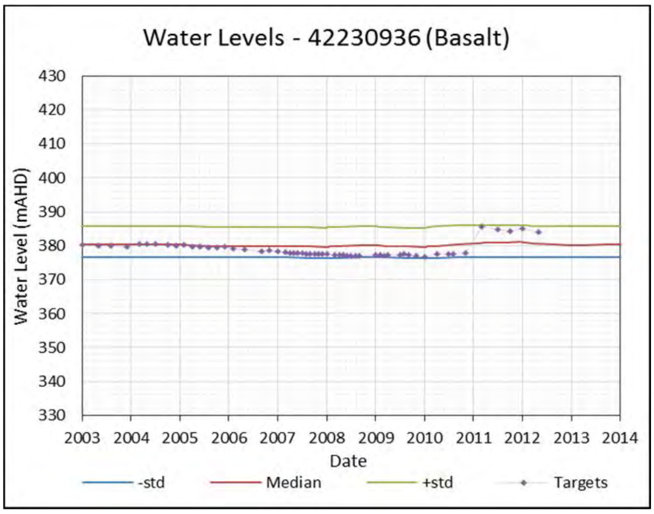

Water Levels - Private_Bore2 (Basalt)
Water Level (mAHD)
470
460
450
440
430
420
410
400
390
380
370
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

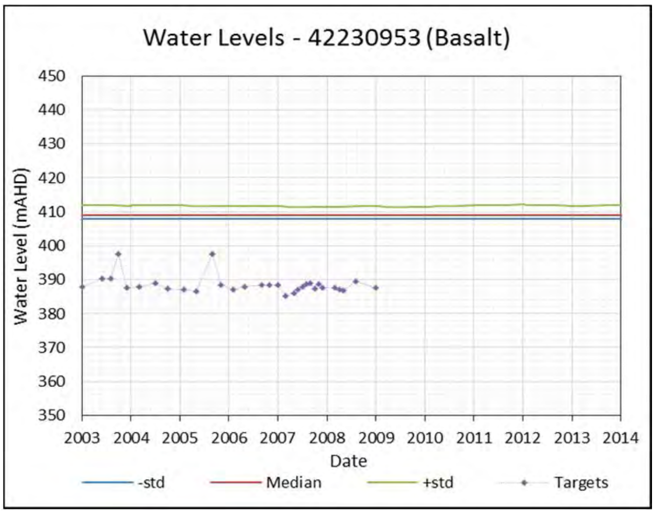

Water Levels - Private_Bore4 (Basalt)
Water Level (mAHD)
Date
-std
Median
+std
Targets

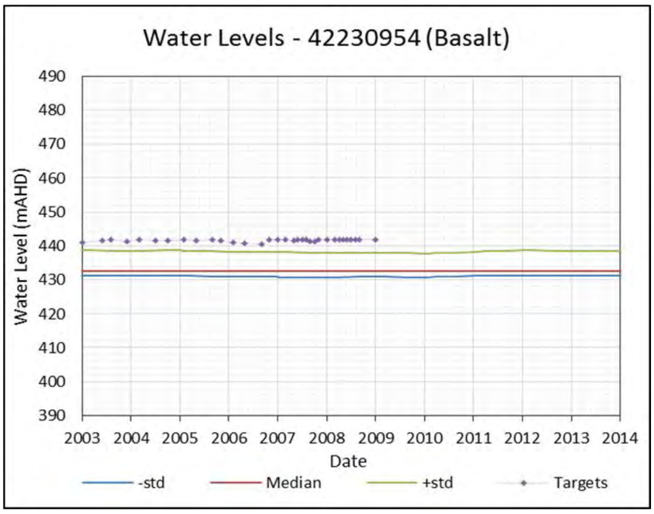

Water Levels - Private_Bore8 (Basalt)
Water Level (mAHD)
Date
-std
Median
+std
Targets

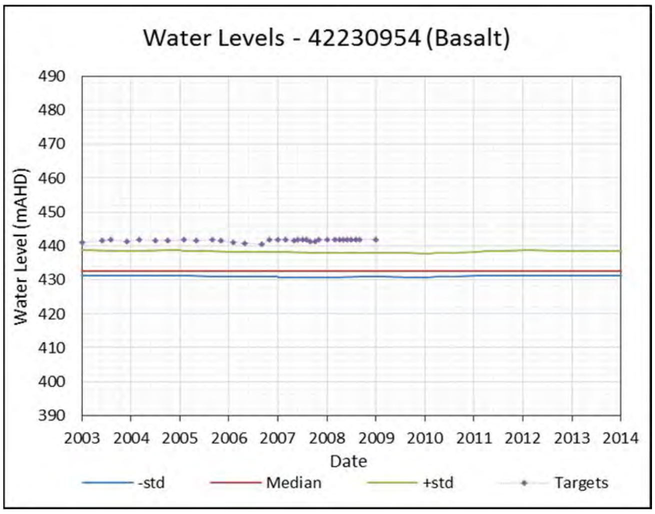

Water Levels - 83425 (Basalt)
Water Level (mAHD)
Date
-std
Median
+std
Targets

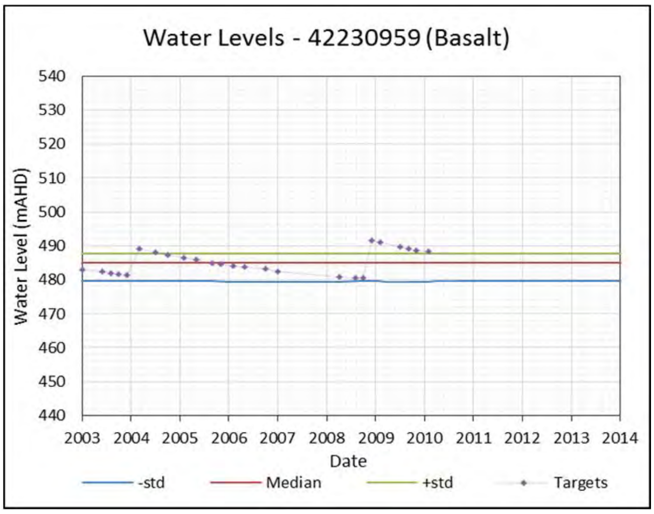

Water Levels - 42230935 (Basalt)
Water Level (mAHD)
Date
-std
Median
+std
Targets

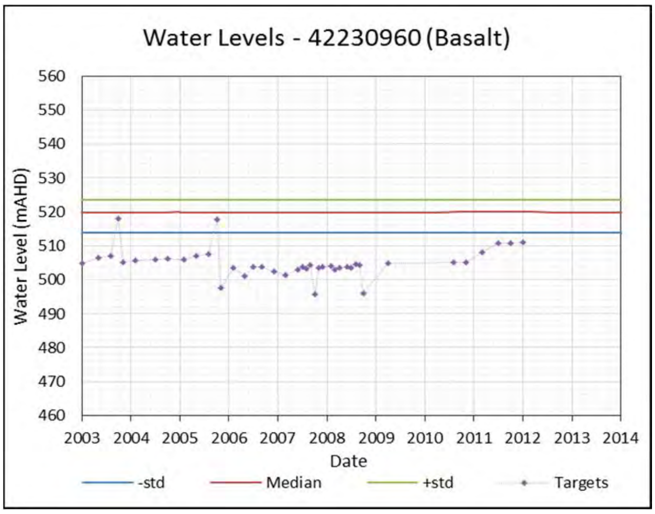

Water Levels - 42230936 (Basalt)
Water Level (mAHD)
Date
-std
Median
+std
Targets

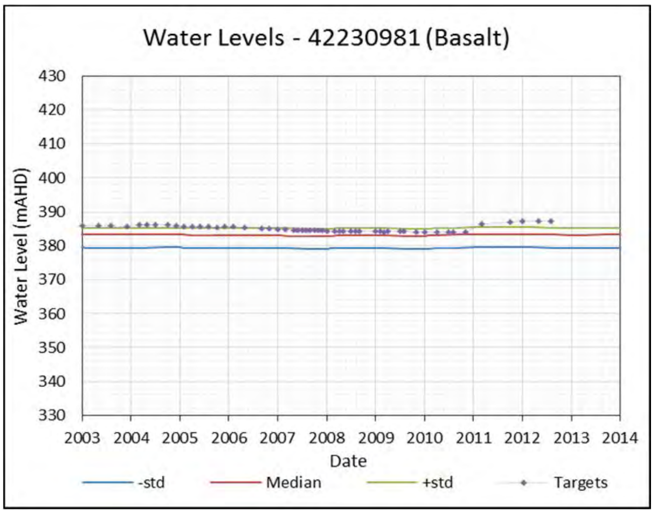

Water Levels - 42230953 (Basalt)
Water Level (mAHD)
Date
-std
Median
+std
Targets

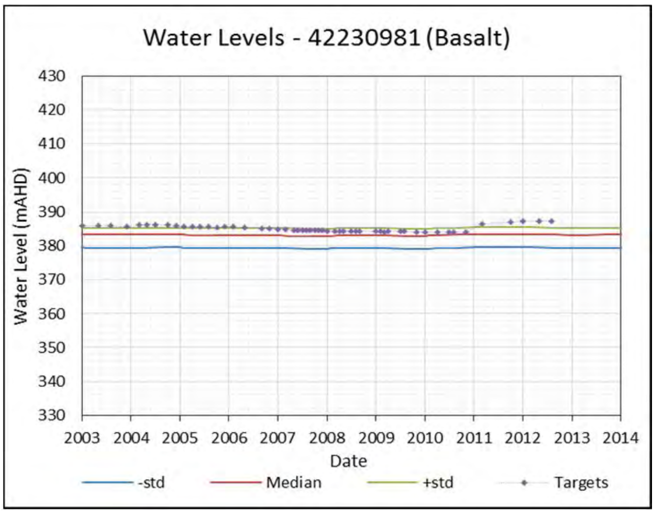

Water Levels - 42230954 (Basalt)
Water Level (mAHD)
490 480 470 460 450 440 430 420 410 400 390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

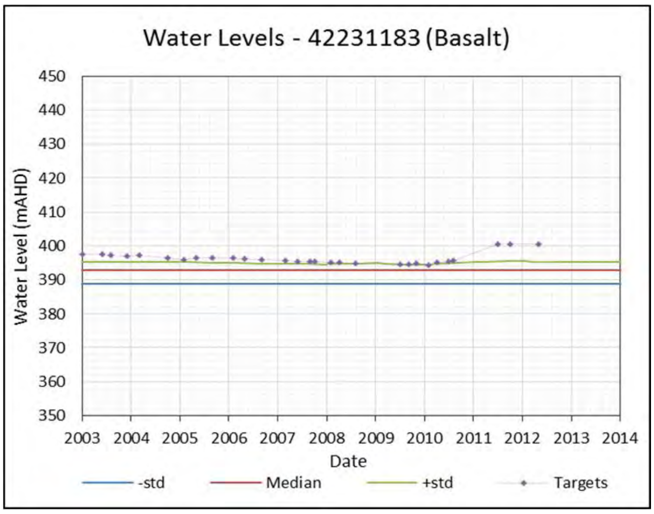

Water Levels - 42230954 (Basalt)
Water Level (mAHD)
490 480 470 460 450 440 430 420 410 400 390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42230959 (Basalt)
Water Level (mAHD)
540 530 520 510 500 490 480 470 460 450 440
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

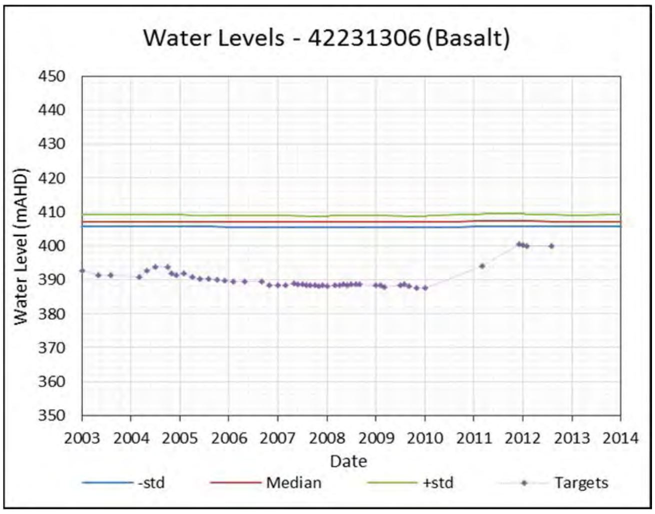

Water Levels - 42230960 (Basalt)
Water Level (mAHD)
560 550 540 530 520 510 500 490 480 470 460
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42230981 (Basalt)
Water Level (mAHD)
430 420 410 400 390 380 370 360 350 340 330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

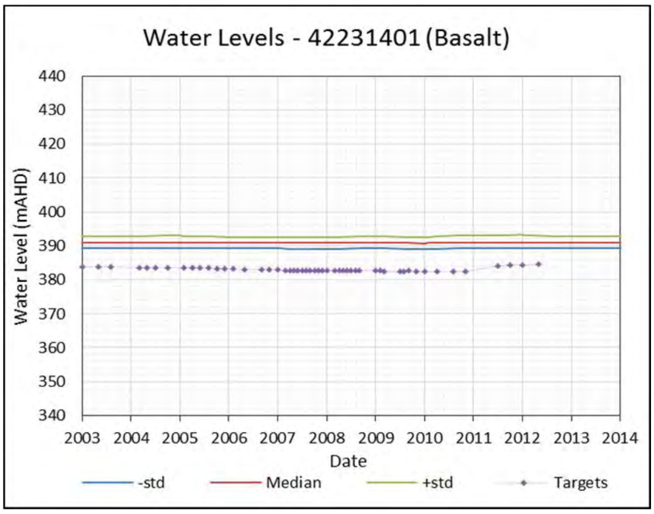

Water Levels - 42230981 (Basalt)
Water Level (mAHD)
430 420 410 400 390 380 370 360 350 340 330
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets



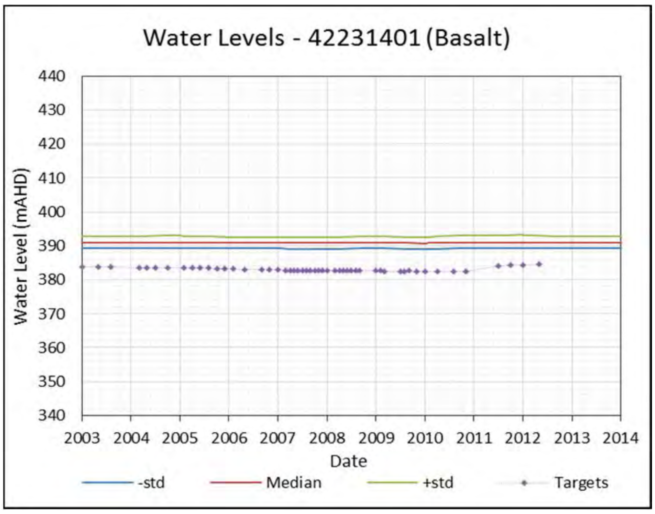
Water Levels - 42231183 (Basalt)
450
440
430
420
410
400
390
380
370
360
350
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets



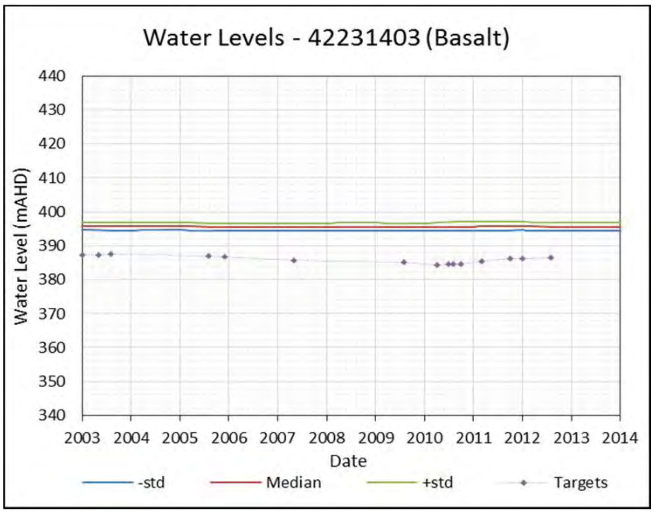
Water Levels - 42231306 (Basalt)
450
440
430
420
410
400
390
380
370
360
350
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets



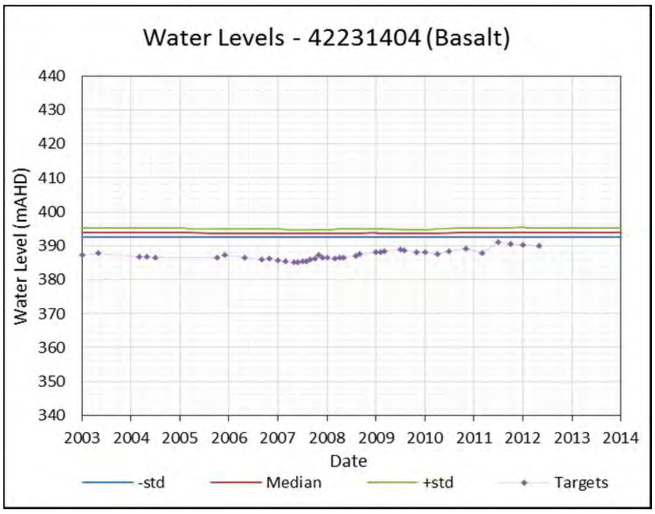
Water Levels - 42231401 (Basalt)
440
430
420
410
400
390
380
370
360
350
340
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets



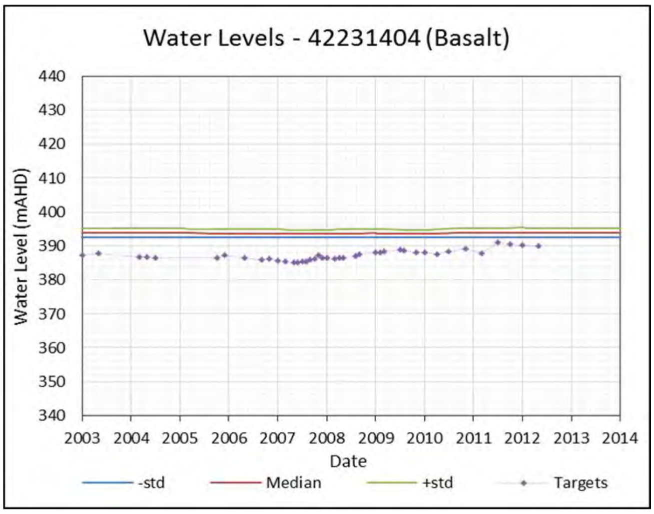
Water Levels - 42231401 (Basalt)
440
430
420
410
400
390
380
370
360
350
340
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

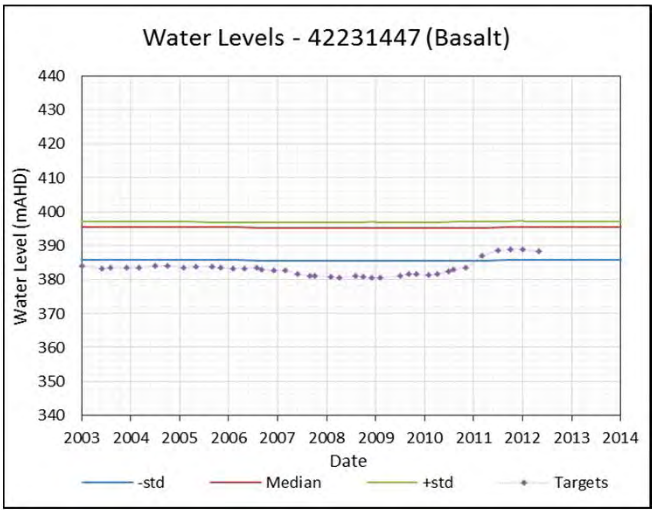


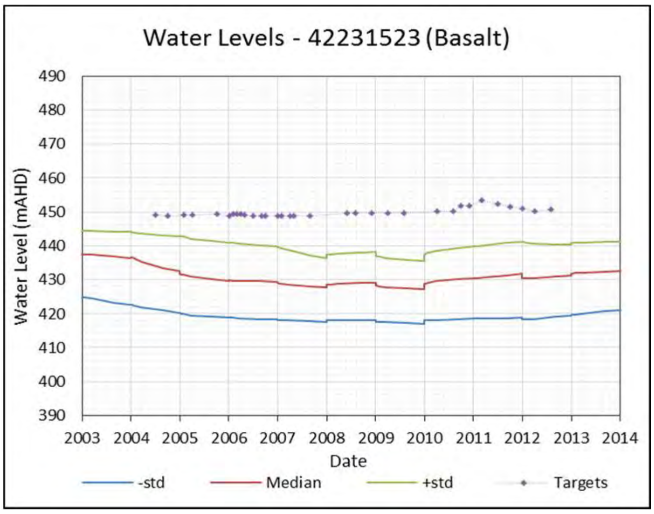
Water Levels - 42231403 (Basalt)
440
430
420
410
400
390
380
370
360
350
340
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

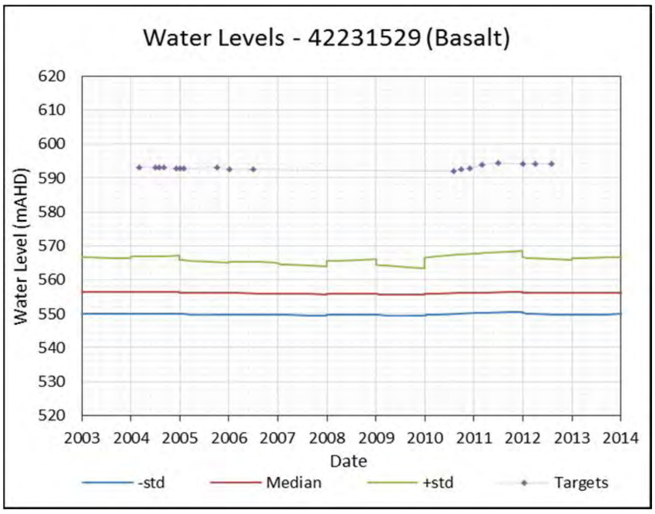


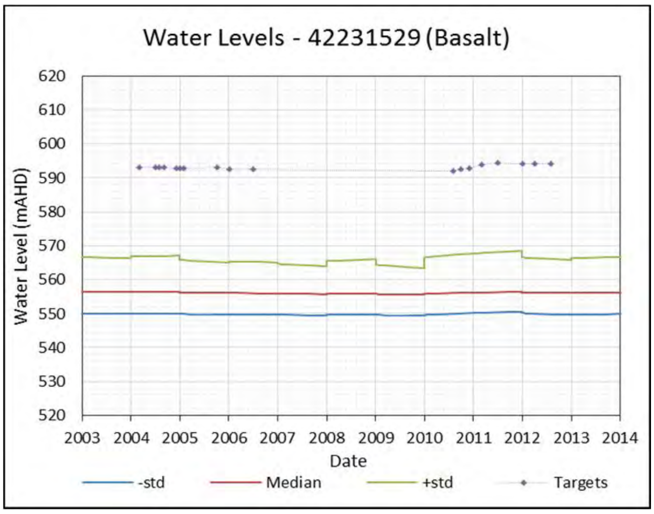
Water Levels - 42231404 (Basalt)
440
430
420
410
400
390
380
370
360
350
340
Water Level (mAHD)
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

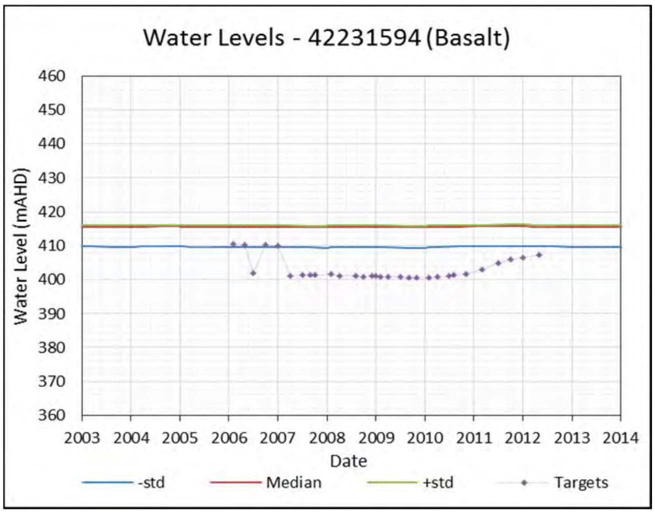

Water Levels - 42231404 (Basalt)
Water Level (mAHD)
440
430
420
410
400
390
380
370
360
350
340
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

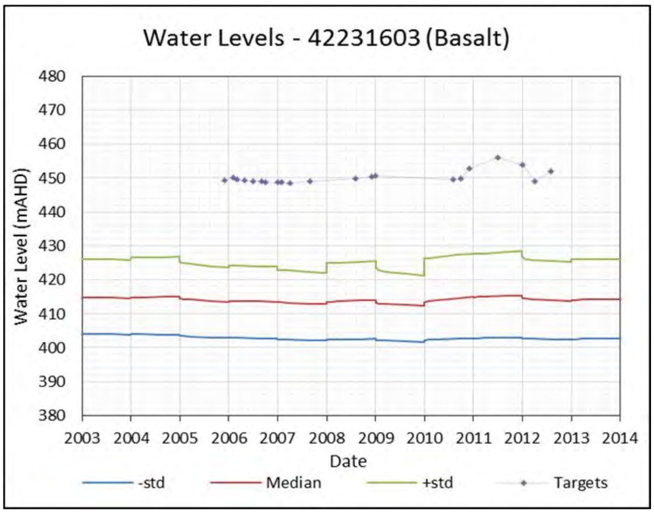

Water Levels - 42231447 (Basalt)
Water Level (mAHD)
440
430
420
410
400
390
380
370
360
350
340
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231523 (Basalt)
Water Level (mAHD)
490
480
470
460
450
440
430
420
410
400
390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

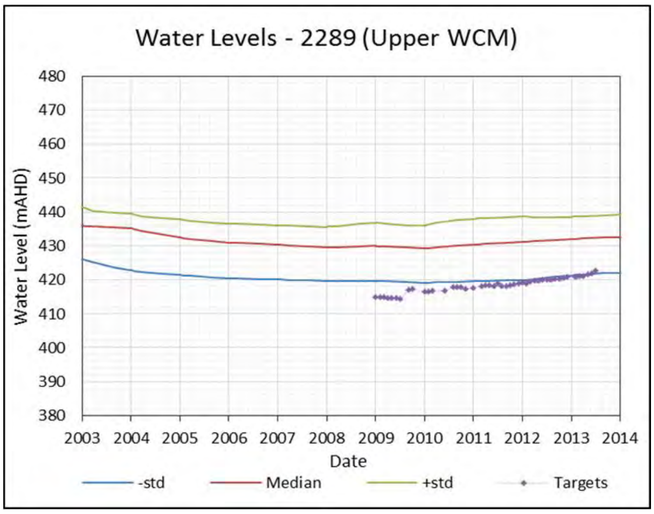

Water Levels - 42231529 (Basalt)
Water Level (mAHD)
620
610
600
590
580
570
560
550
540
530
520
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

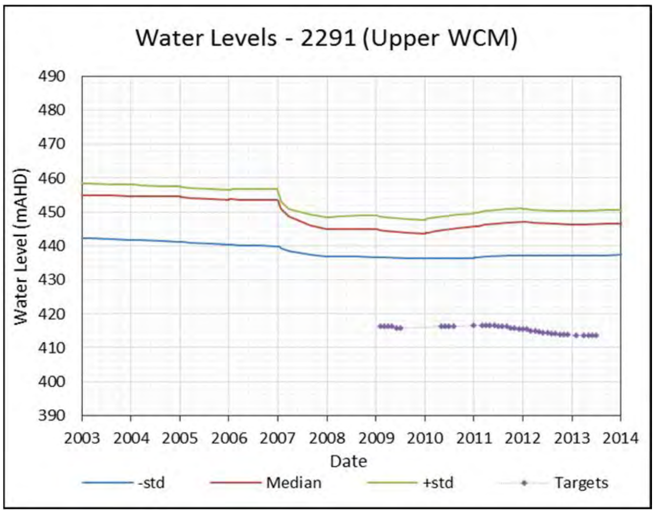

Water Levels - 42231529 (Basalt)
Water Level (mAHD)
620
610
600
590
580
570
560
550
540
530
520
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

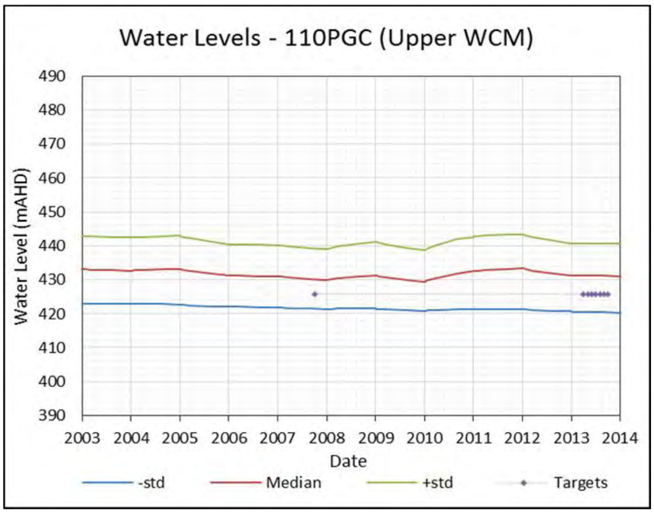

Water Levels - 42231594 (Basalt)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

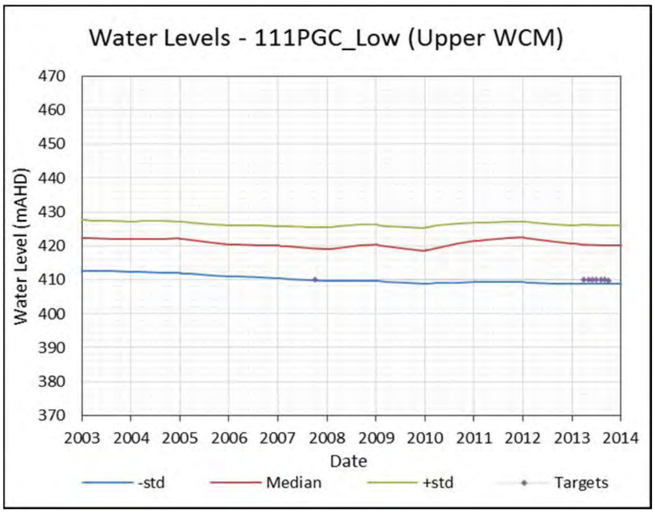

Water Levels - 42231603 (Basalt)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Date
-std
Median
+std
Targets

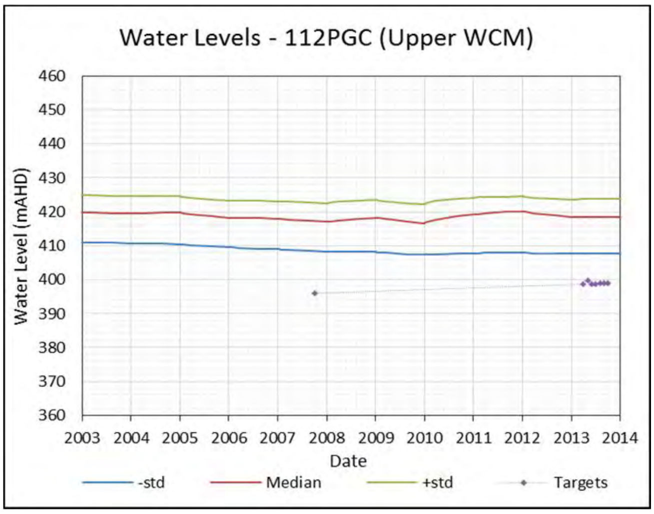
Upper Walloon Coal Measures Bores

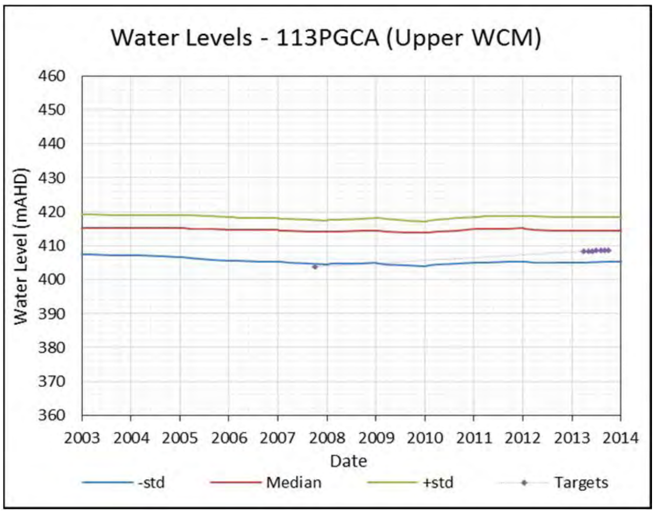

Water Levels - 2289 (Upper WCM)
Water Level (mAHD)
Date
-std
Median
+std
Targets

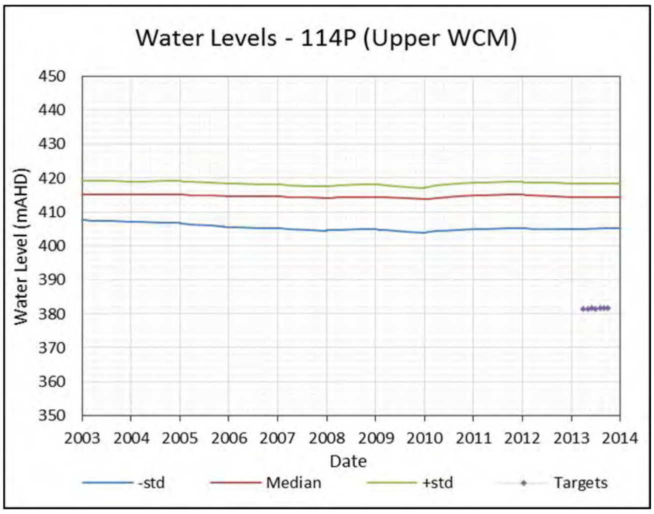

Water Levels - 2291 (Upper WCM)
Water Level (mAHD)
Date
-std
Median
+std
Targets

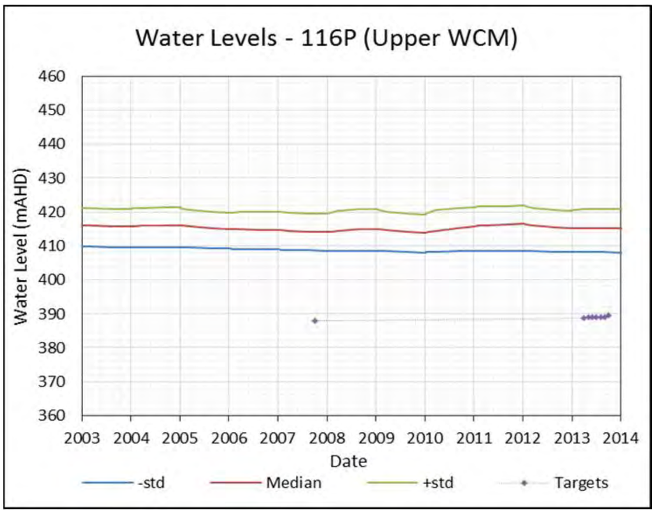

Water Levels - 110PGC (Upper WCM)
Water Level (mAHD)
Date
-std
Median
+std
Targets

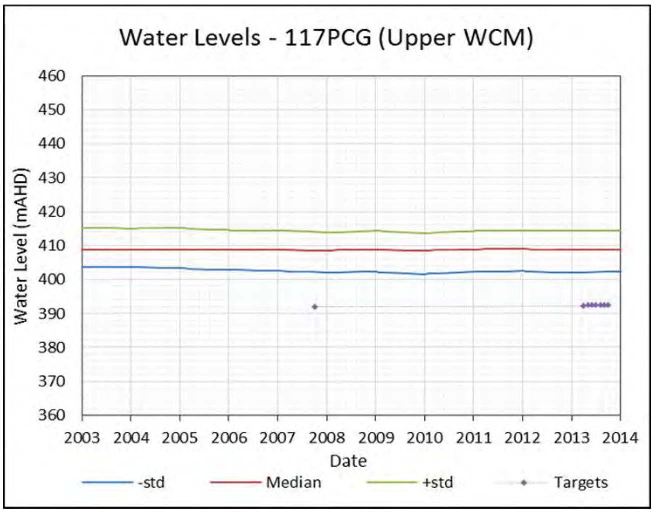

Water Levels - 111PGC_Low (Upper WCM)
Water Level (mAHD)
Date
-std
Median
+std
Targets

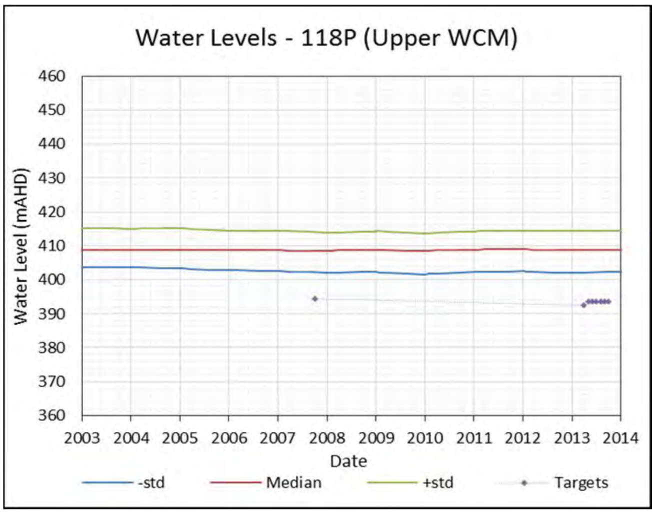

Water Levels - 112PGC (Upper WCM)
Water Level (mAHD)
Date
-std
Median
+std
Targets

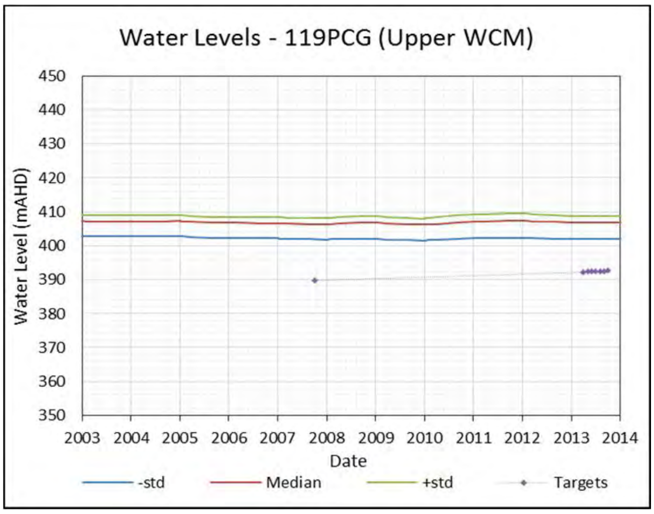

Water Levels - 113PGCA (Upper WCM)
Water Level (mAHD)
Date
-std
Median
+std
Targets

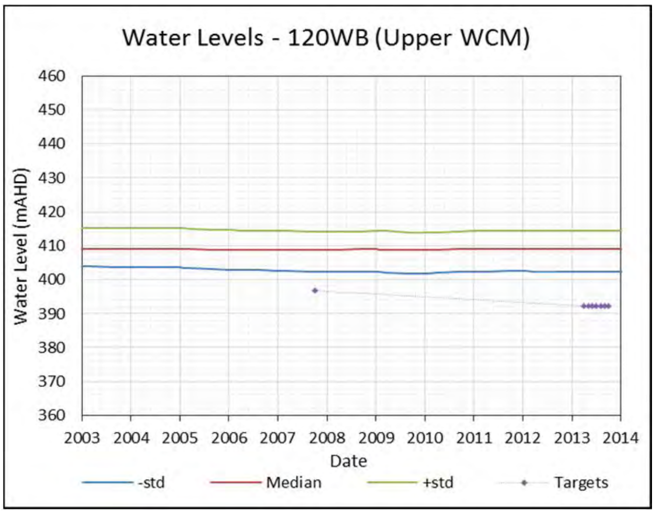

Water Levels - 114P (Upper WCM)
Water Level (mAHD)
450
440
430
420
410
400
390
380
370
360
350
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

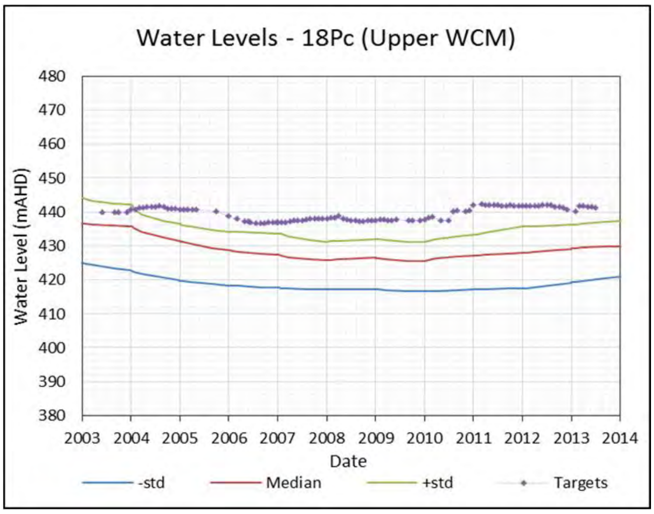

Water Levels - 116P (Upper WCM)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

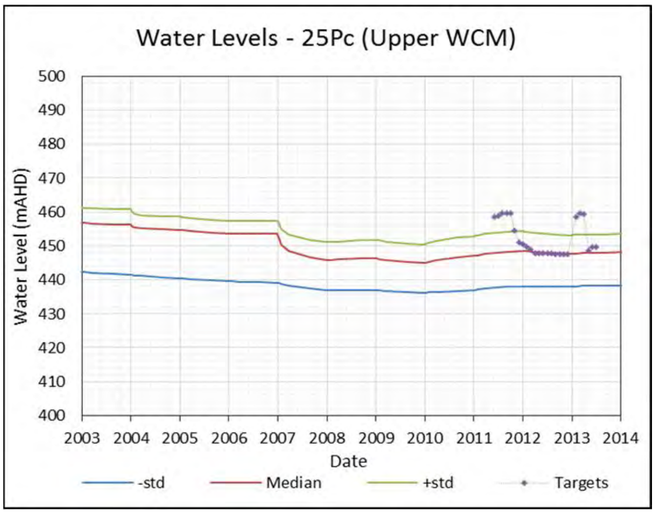

Water Levels - 117PCG (Upper WCM)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

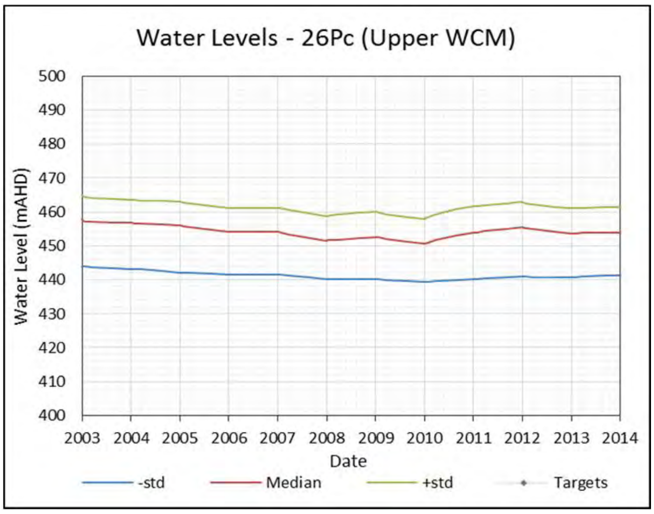

Water Levels - 118P (Upper WCM)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

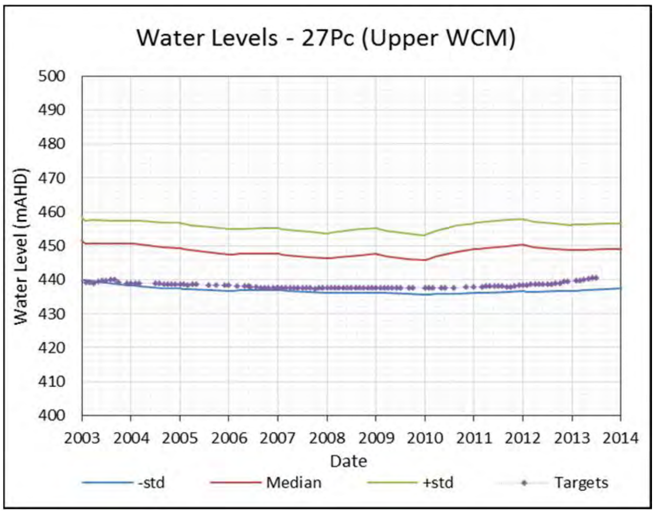

Water Levels - 119PCG (Upper WCM)
Water Level (mAHD)
450
440
430
420
410
400
390
380
370
360
350
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

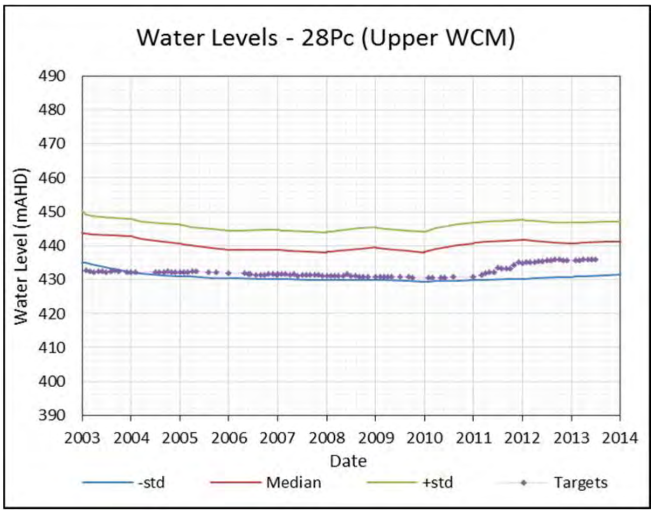

Water Levels - 120WB (Upper WCM)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

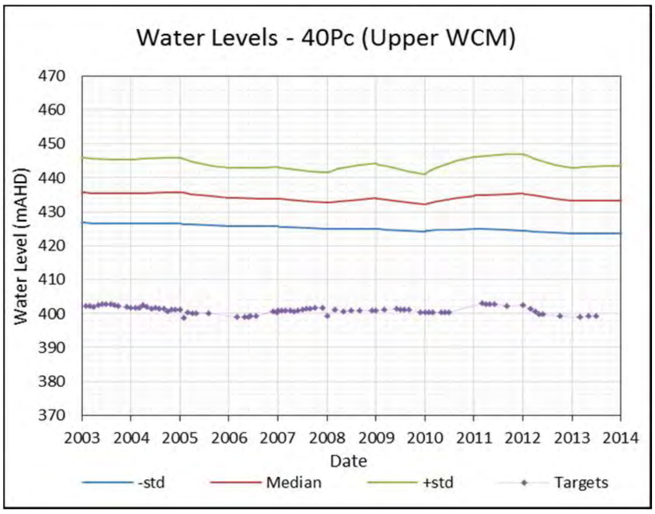

Water Levels - 18Pc (Upper WCM)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

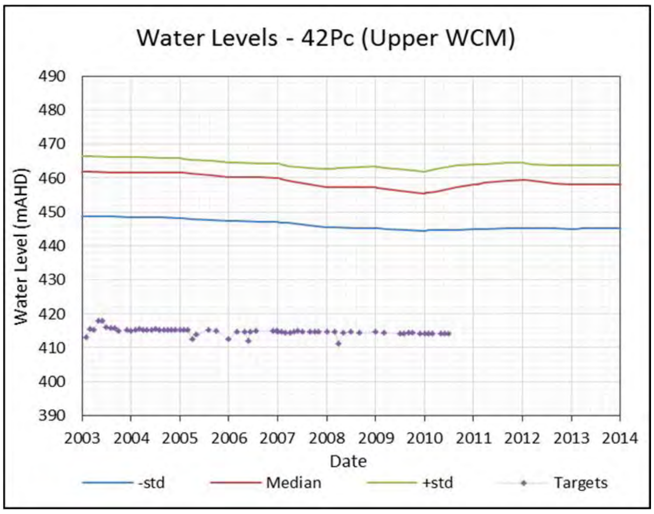

Water Levels - 25Pc (Upper WCM)
Water Level (mAHD)
500
490
480
470
460
450
440
430
420
410
400
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

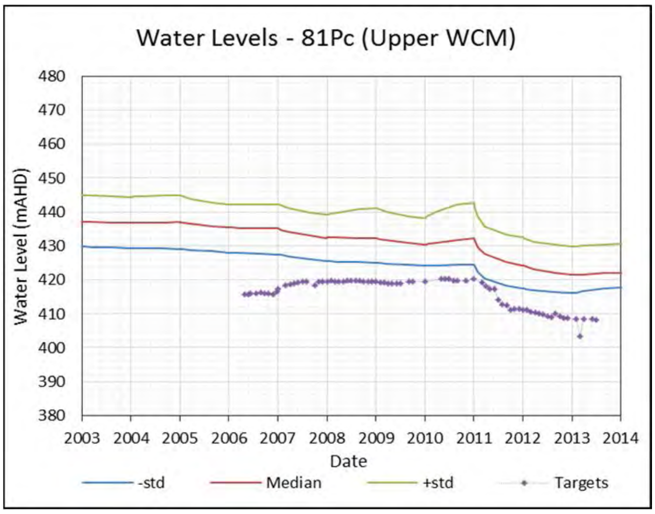

Water Levels - 26Pc (Upper WCM)
Water Level (mAHD)
500
490
480
470
460
450
440
430
420
410
400
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

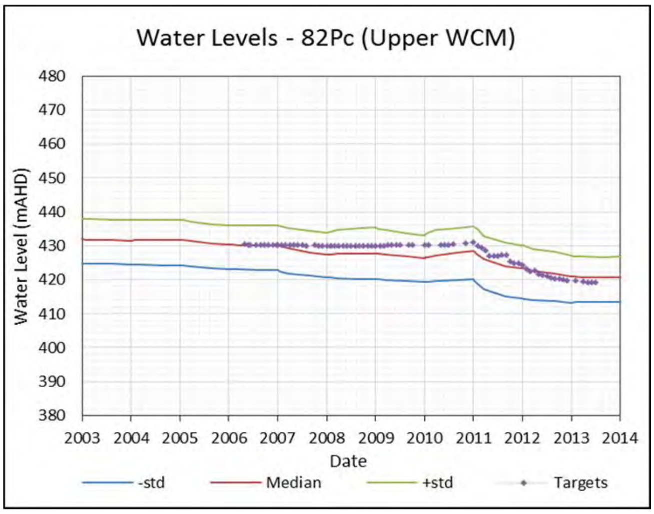

Water Levels - 27Pc (Upper WCM)
Water Level (mAHD)
500
490
480
470
460
450
440
430
420
410
400
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

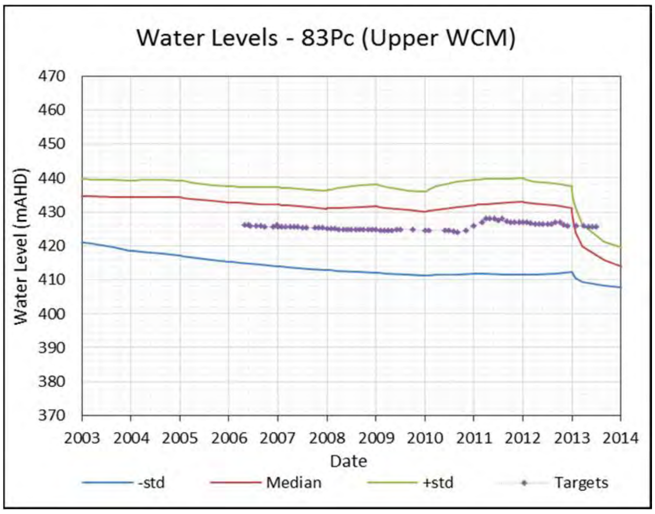

Water Levels - 28Pc (Upper WCM)
Water Level (mAHD)
490
480
470
460
450
440
430
420
410
400
390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

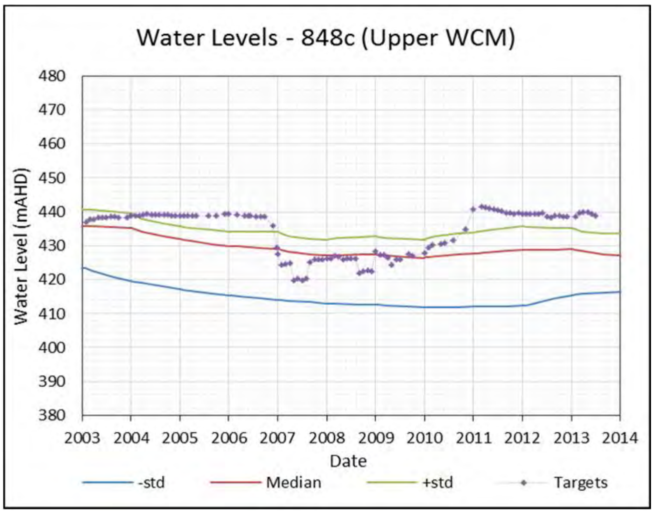

Water Levels - 40Pc (Upper WCM)
Water Level (mAHD)
470
460
450
440
430
420
410
400
390
380
370
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

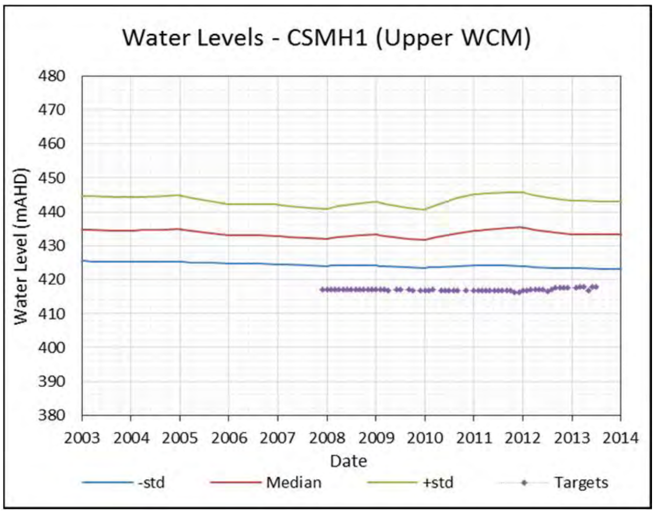

Water Levels - 42Pc (Upper WCM)
Water Level (mAHD)
490
480
470
460
450
440
430
420
410
400
390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

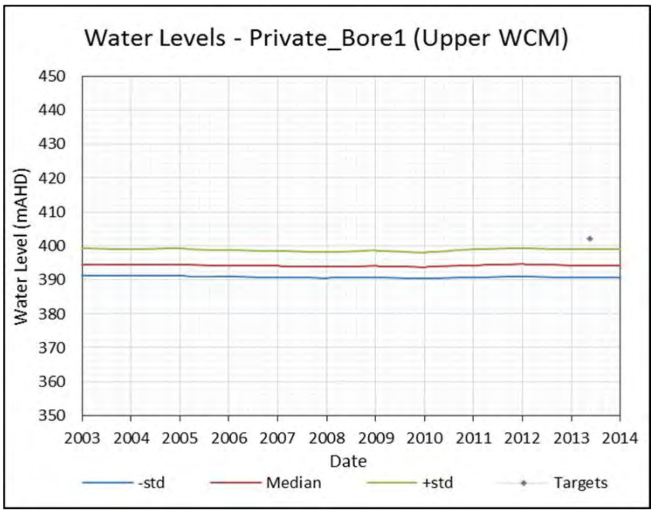

Water Levels - 81Pc (Upper WCM)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

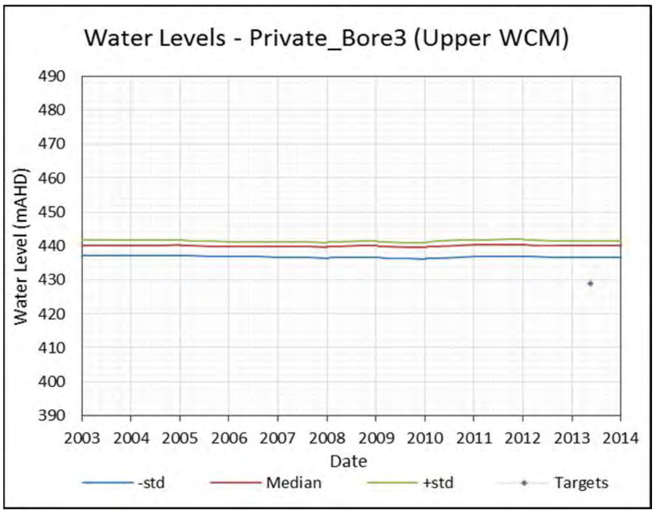

Water Levels - 82Pc (Upper WCM)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

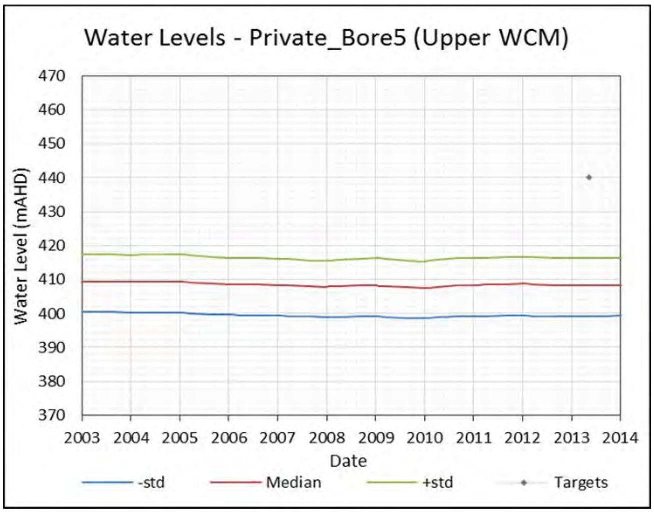

Water Levels - 83Pc (Upper WCM)
Water Level (mAHD)
470
460
450
440
430
420
410
400
390
380
370
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

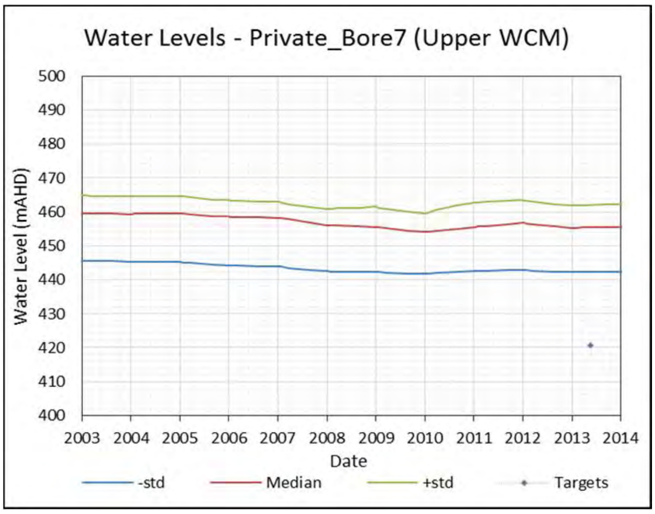

Water Levels - 848c (Upper WCM)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

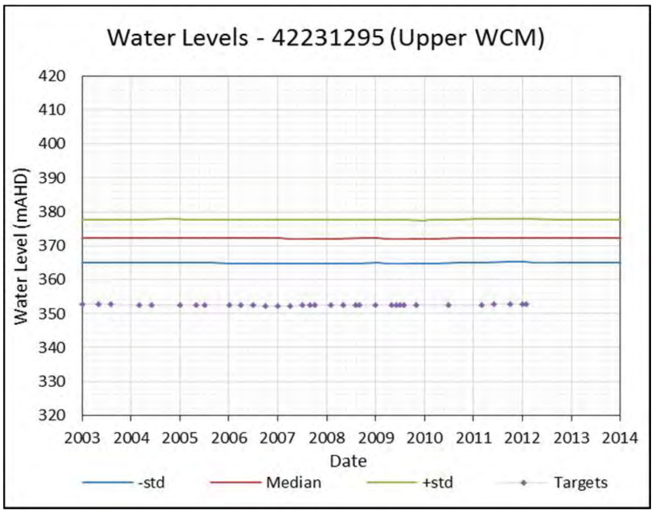

Water Levels - CSMH1 (Upper WCM)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

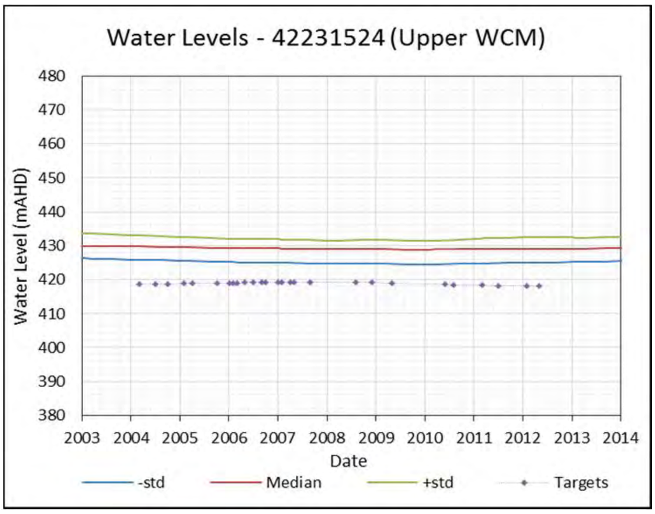

Water Levels - Private_Bore1 (Upper WCM)
Water Level (mAHD)
450
440
430
420
410
400
390
380
370
360
350
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - Private_Bore3 (Upper WCM)
Water Level (mAHD)
490
480
470
460
450
440
430
420
410
400
390
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

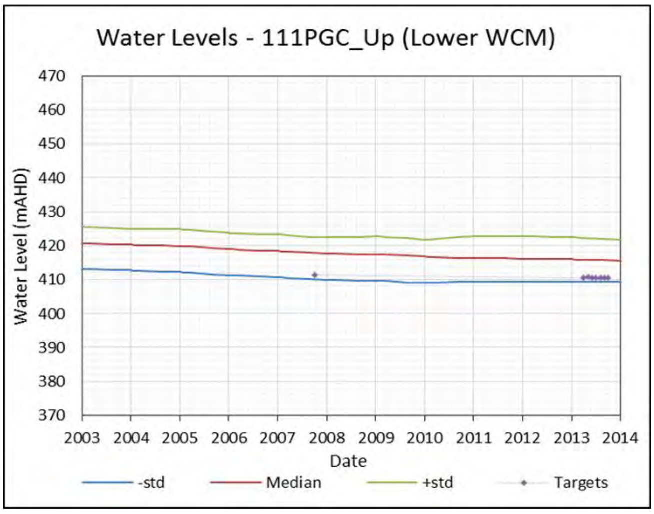

Water Levels - Private_Bore5 (Upper WCM)
Water Level (mAHD)
470
460
450
440
430
420
410
400
390
380
370
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

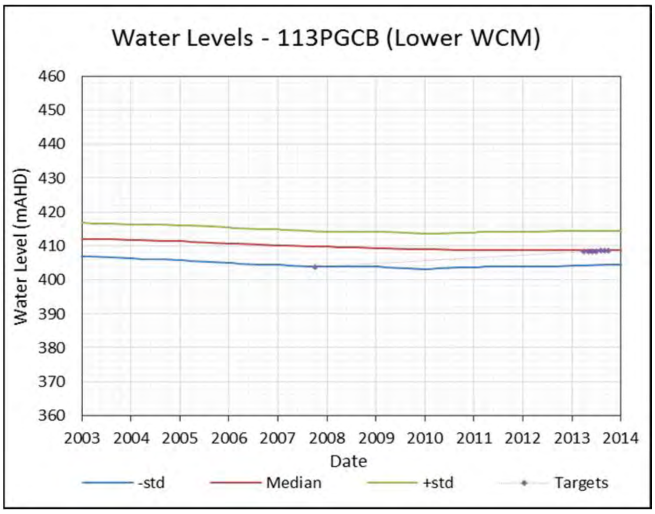

Water Levels - Private_Bore7 (Upper WCM)
Water Level (mAHD)
500
490
480
470
460
450
440
430
420
410
400
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets


Water Levels - 42231295 (Upper WCM)
Water Level (mAHD)
420
410
400
390
380
370
360
350
340
330
320
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

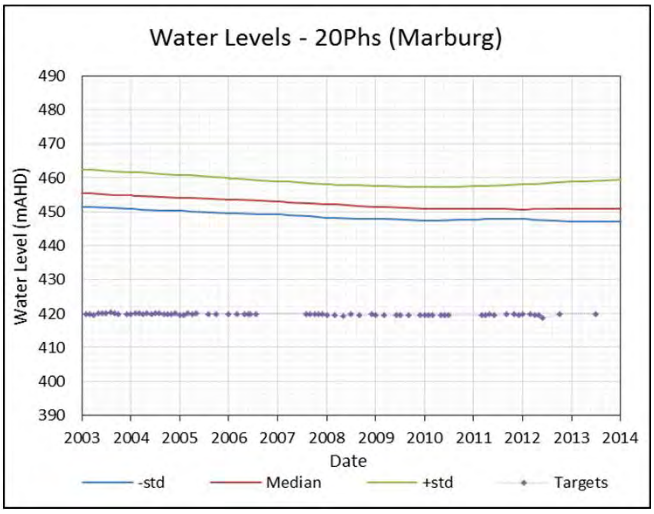

Water Levels - 42231524 (Upper WCM)
Water Level (mAHD)
480
470
460
450
440
430
420
410
400
390
380
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

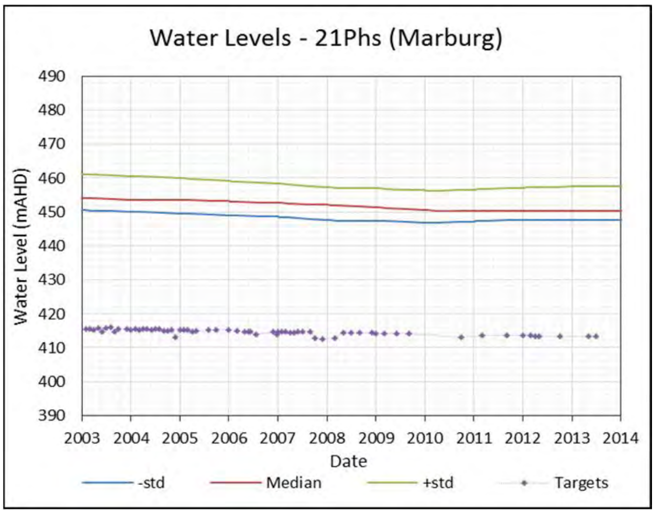
Lower Walloon Coal Measures Bores

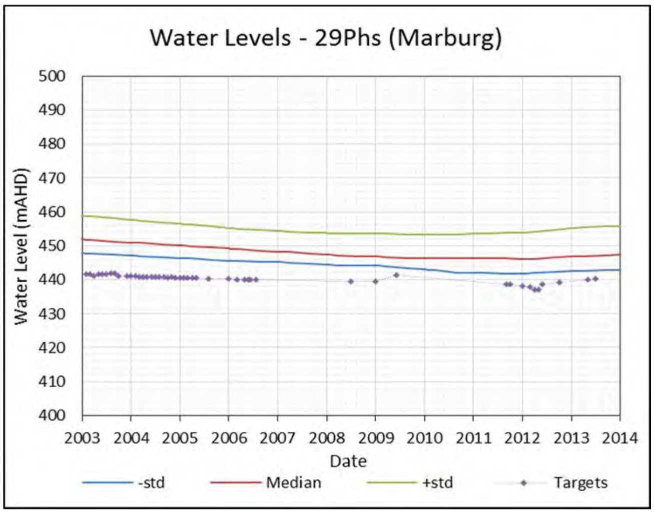

Water Levels - 111PGC_Up (Lower WCM)
Water Level (mAHD)
470
460
450
440
430
420
410
400
390
380
370
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

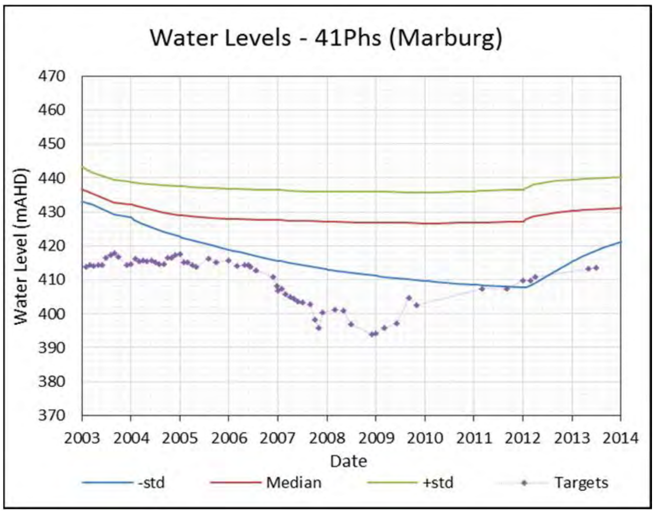

Water Levels - 113PGCB (Lower WCM)
Water Level (mAHD)
460
450
440
430
420
410
400
390
380
370
360
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Date
-std
Median
+std
Targets

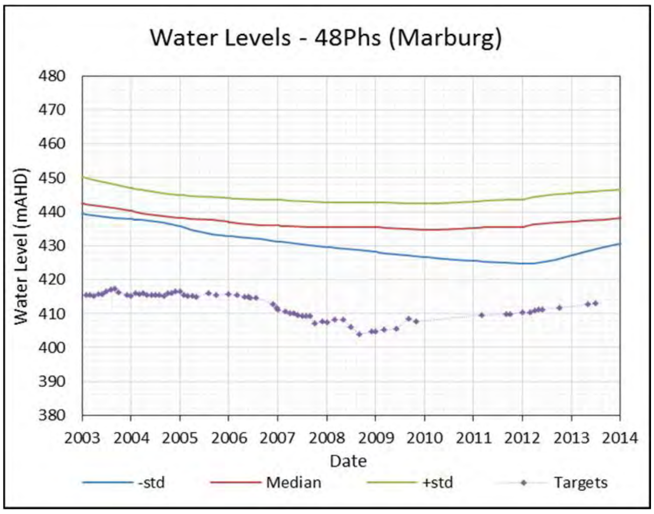
Marburg Sandstone Bores

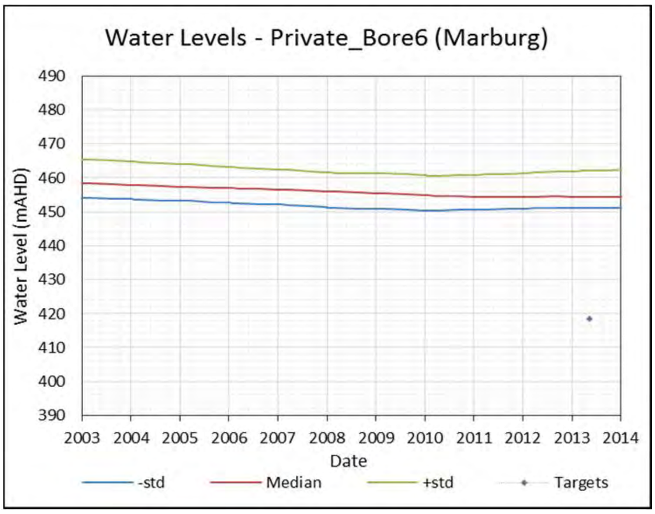

Water Levels - 20Phs (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets

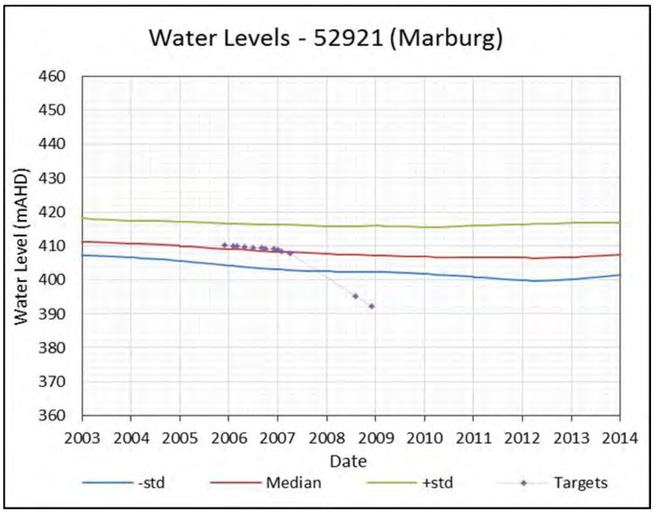

Water Levels - 21Phs (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets

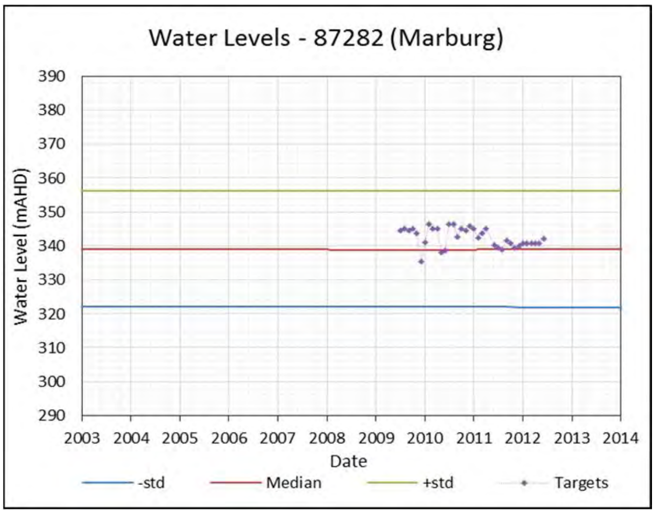

Water Levels - 29Phs (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets

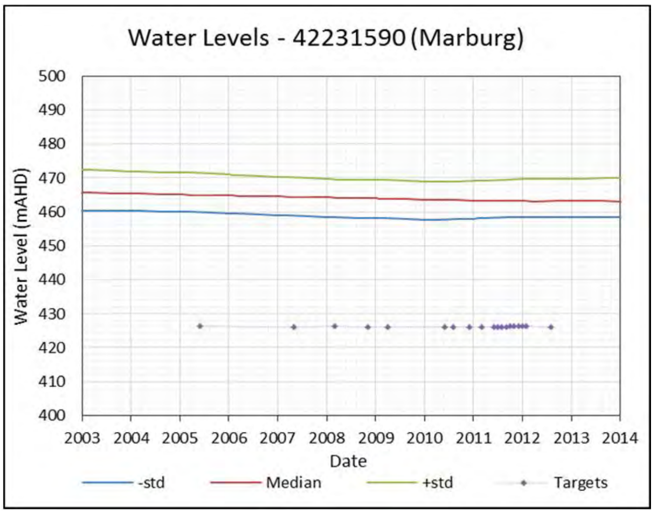

Water Levels - 41Phs (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets


Water Levels - 48Phs (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets

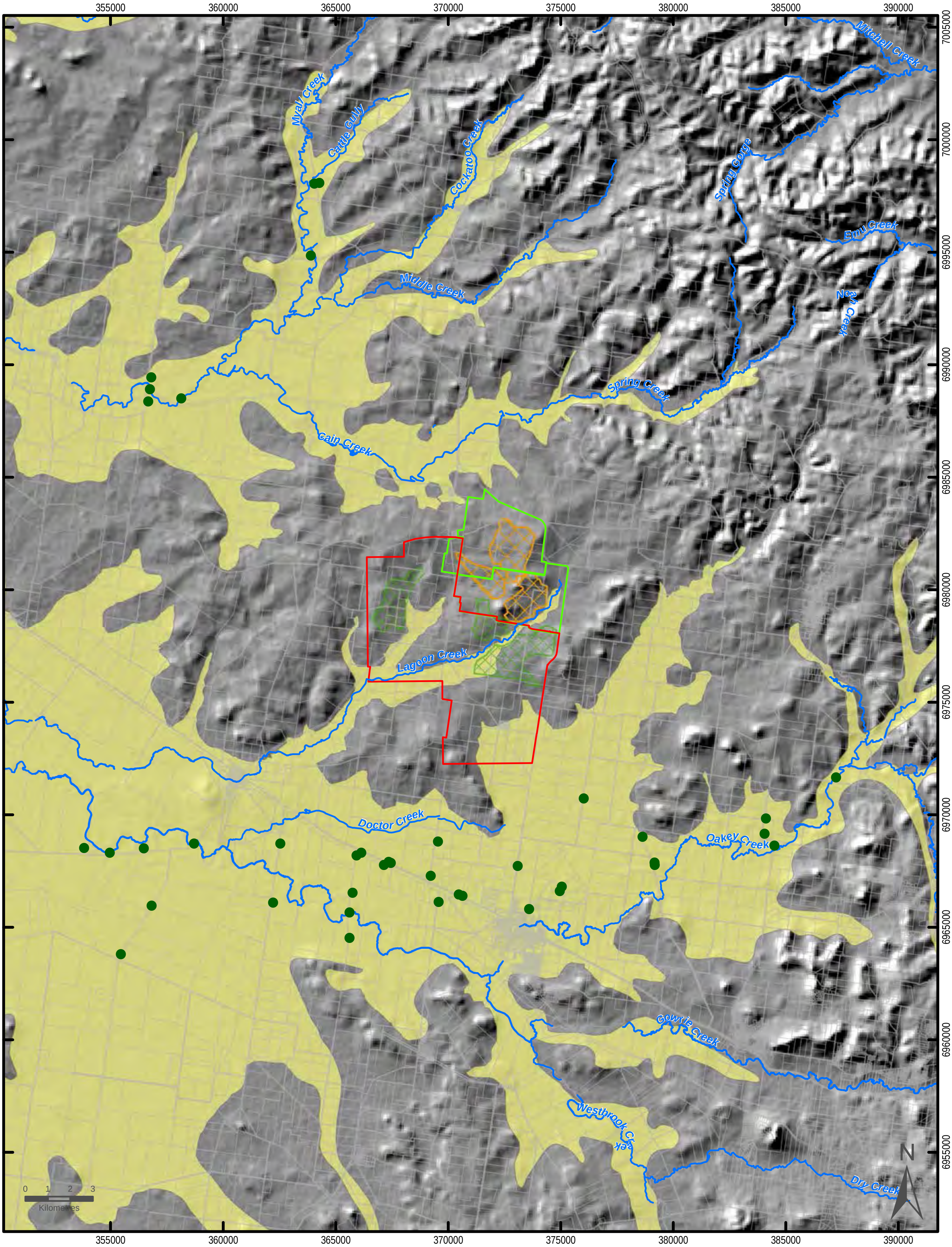

Water Levels - Private_Bore6 (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets


Water Levels - 52921 (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets


Water Levels - 87282 (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets


Water Levels - 42231590 (Marburg)
Water Level (mAHD)
Date
-std
Median
+std
Targets

Appendix A.2 Calibration Maps



LEGEND

Alluvium Calibration Points (Bores)
Best Model Calibration Result

- < 5% SRMS
- 5 - 10% SRMS
- 10 - 25% SRMS
- 25 - 50% SRMS

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Alluvium (Qa)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

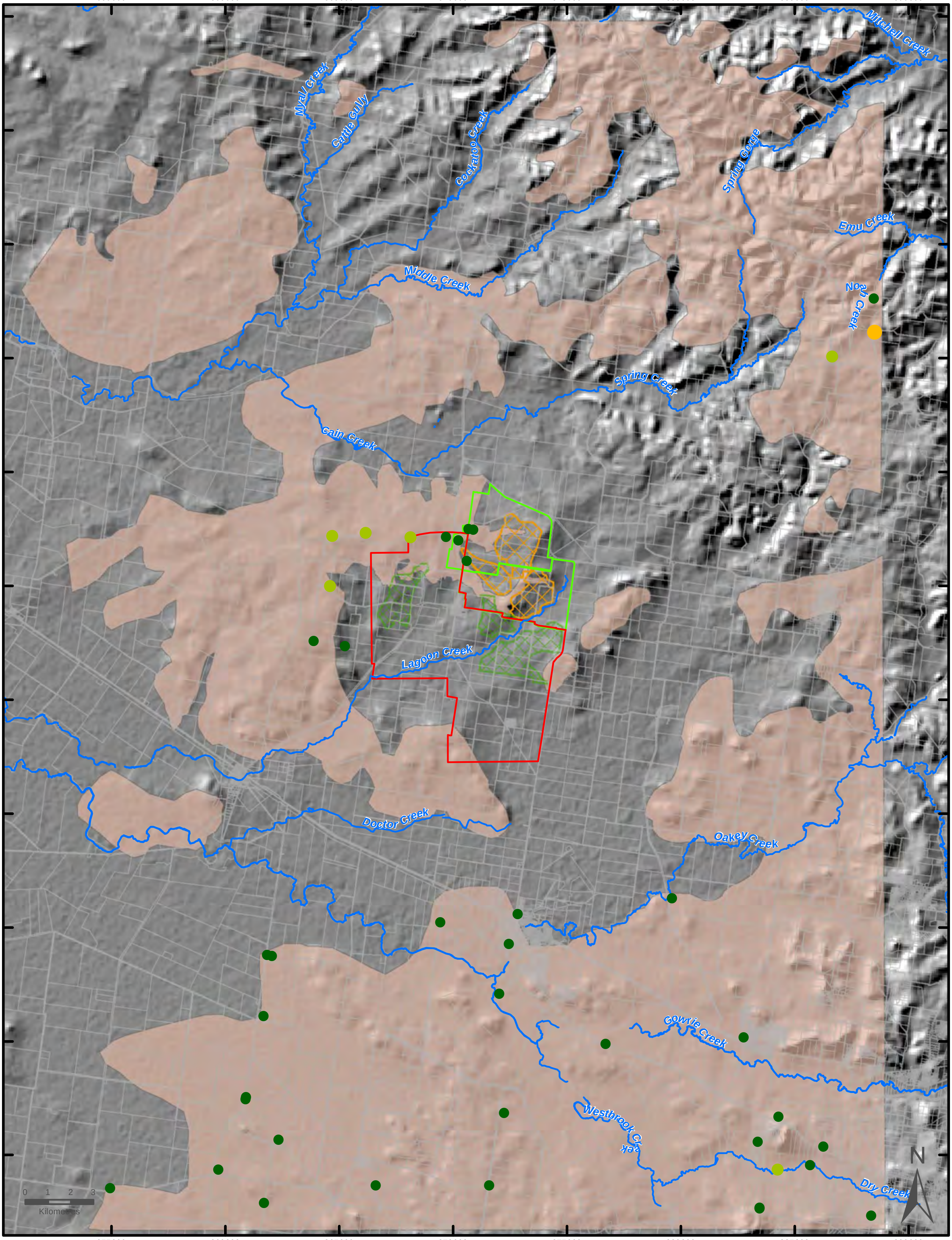
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure A2.1
Alluvium Calibration Map

Scale 1:228,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140813_NewHope_Groundwater_FigureA2.1_CalibrationAlluvium.mxd

Produced: 28/08/2014



LEGEND

Basalt Calibration Points (Bores)

Best Model Calibration Result

- < 5% SRMS
- 5 - 10% SRMS
- 10 - 25% SRMS
- 25 - 50% SRMS

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Tertiary Basalt (Tm)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

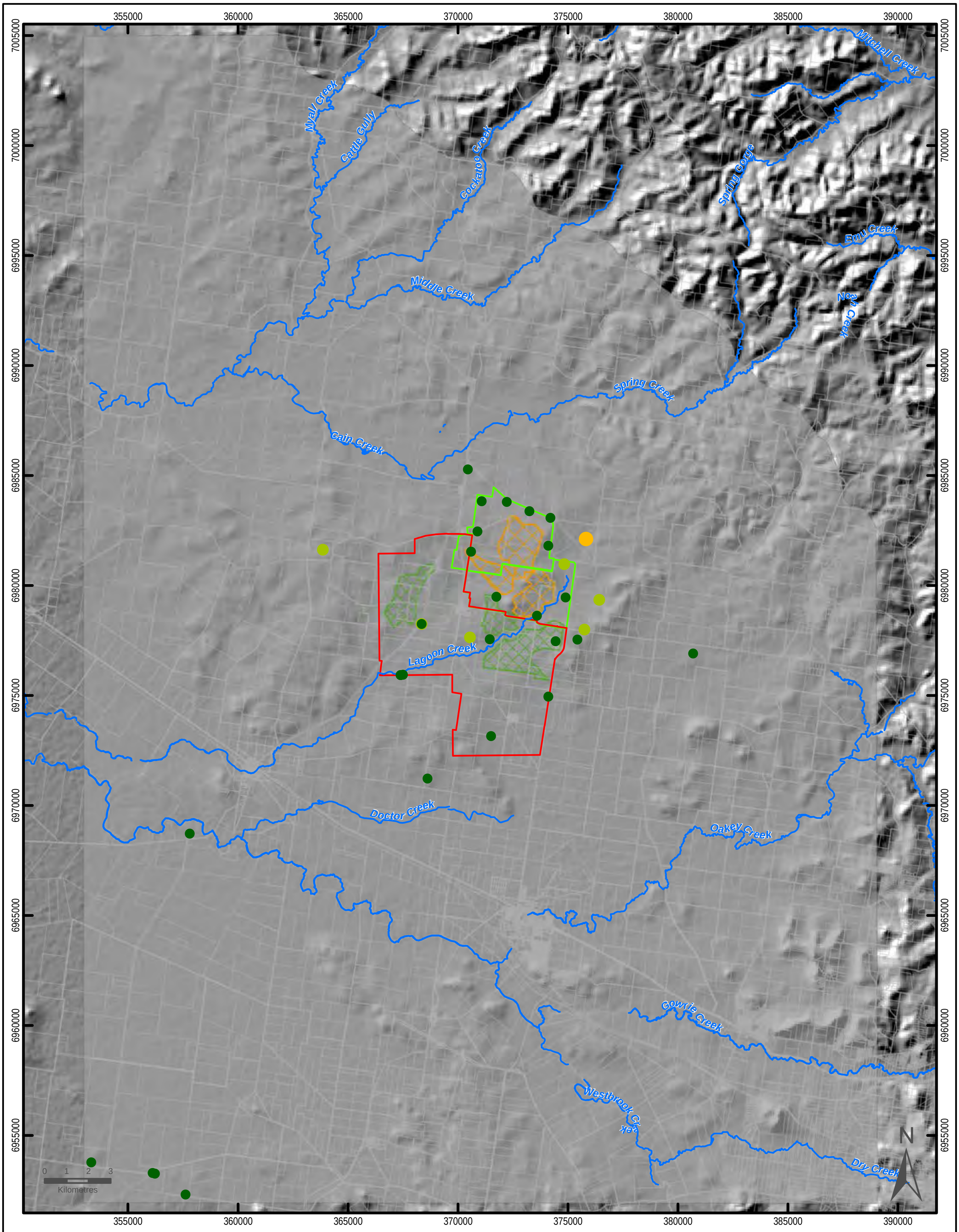
NEW ACLAND COAL MINE STAGE 3 PROJECT

Figure A2.2
Tertiary Basalt Calibration Map

Scale 1:228,000 on A4

Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Produced: 29/08/2014 Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140813_NewHope_Groundwater_FigureA2.2_CalibrationBasalt.mxd



LEGEND

Upper WCM Calibration Points (Bores)
Best Model Calibration Result

- < 5% SRMS
- 5 - 10% SRMS
- 10 - 25% SRMS
- 25 - 50% SRMS

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

NEW HOPE GROUP

SINCLAIR KNIGHT MERZ SKM

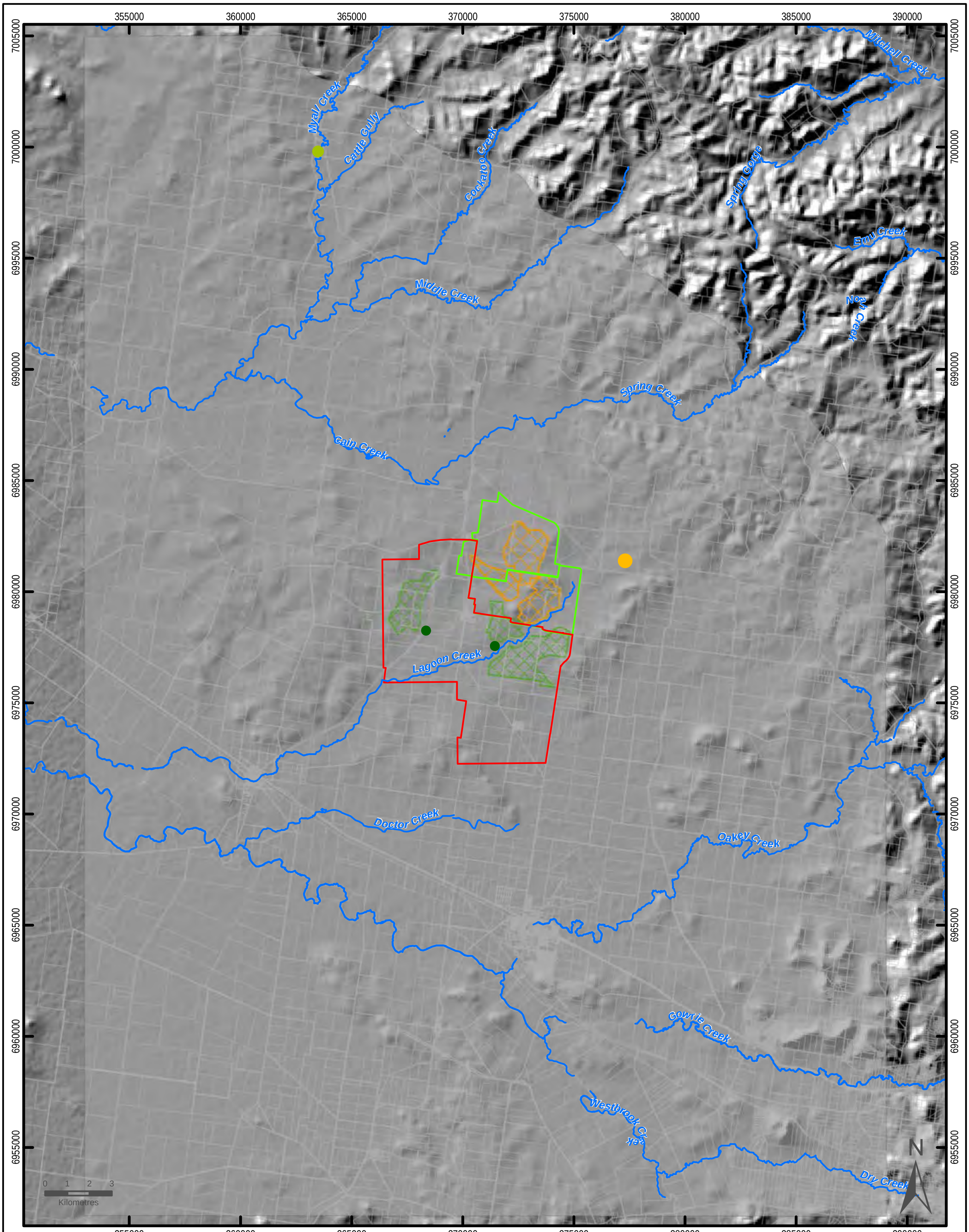
NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure A2.3
Upper Walloon Coal Measures Calibration Map

Scale 1:228,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum140813_NewHope_Groundwater_FigureA2.3_CalibrationUpperWCM.mxd

Produced: 28/08/2014



LEGEND

Lower WCM Calibration Points (Bores)
Best Model Calibration Result

- < 5% SRMS
- 5 - 10% SRMS
- 10 - 25% SRMS
- 25 - 50% SRMS

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Walloon Subgroup (Jw)

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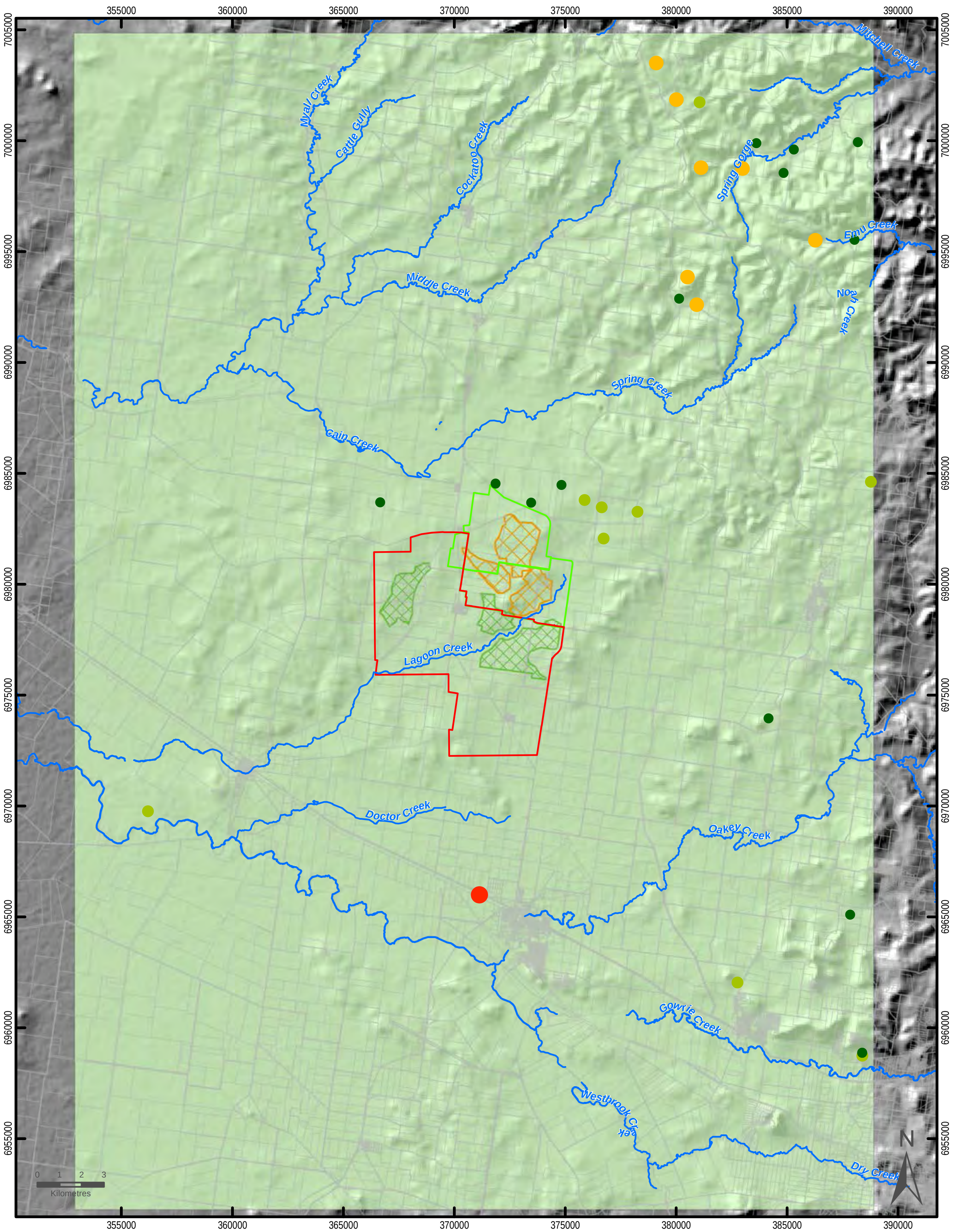
SKM

NEW ACLAND COAL MINE
STAGE 3 PROJECT

Figure A2.4
Lower Walloon Coal Measures
Calibration Map

Scale 1:228,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140813_NewHope_Groundwater_FigureA2.4_CalibrationLowerWCM.mxd
Produced: 28/08/2014



LEGEND

Marburg Sst Calibration Points (Bores)
Best Model Calibration Result

- < 5% SRMS
- 5 - 10% SRMS
- 10 - 25% SRMS
- 25 - 50% SRMS

- Watercourse
- New Aland Coal Mine-Stage 3
- New Acland Coal Mine
- Cadastre
- Stage 3 Pit Areas
- Existing Permission

Modelled Formation Extents

- Marburg Sandstone (Jbm)

NEW HOPE GROUP

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NEW ACLAND COAL MINE STAGE 3 PROJECT

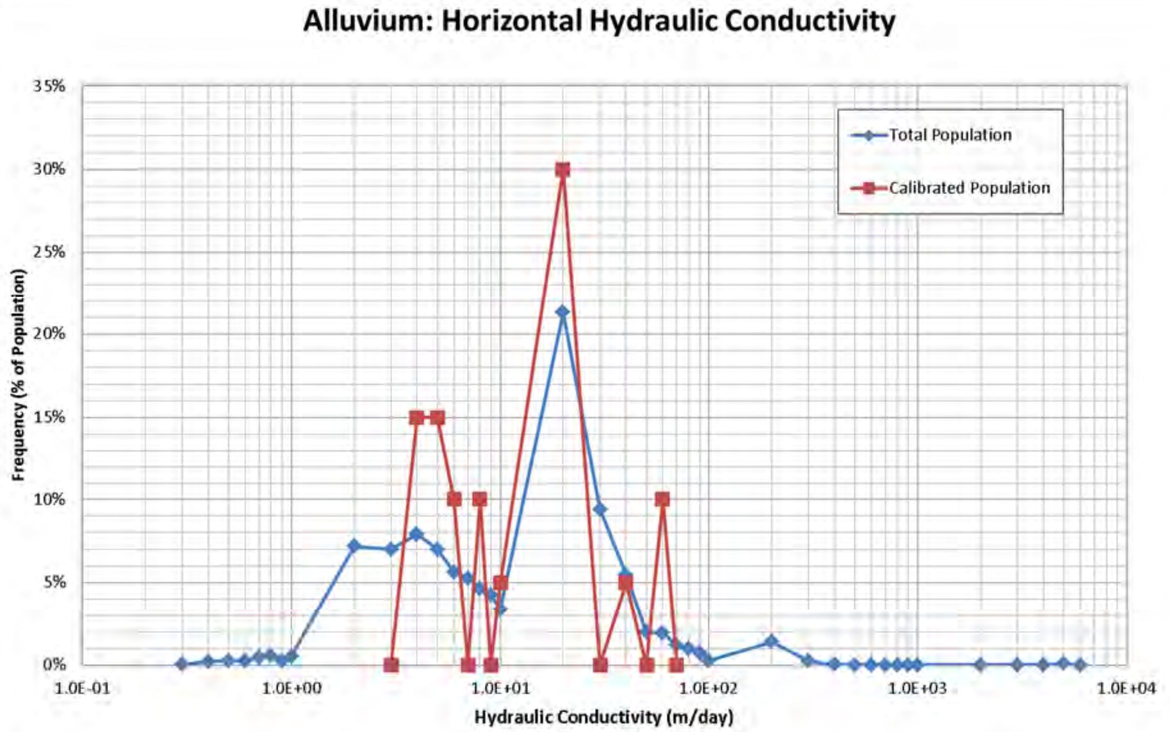
Figure A2.5 Marburg Sandstone Calibration Map

Scale 1:228,000 on A4
Projection: Australian Geodetic Datum – Zone 56 (AGD84)

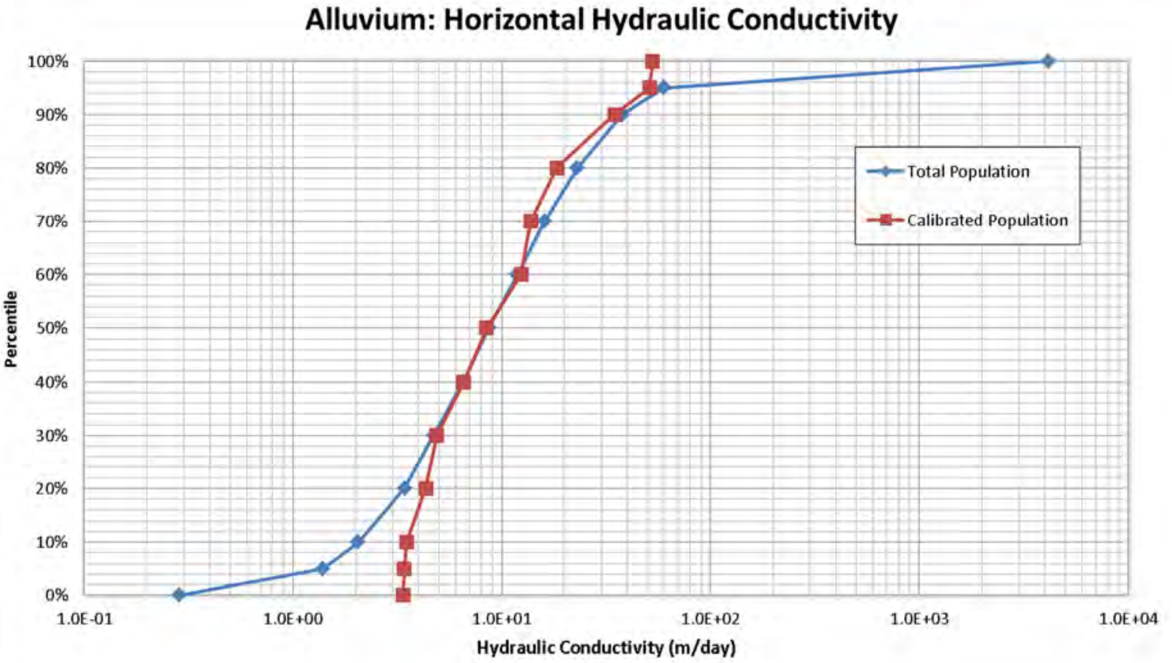
Path: I:\QENV2\Projects\QE06644\Spatial\ArcGIS\01_Figures\03_AEIS\06_GroundwaterResources\ModellingAddendum\140813_NewHope_Groundwater_FigureA2.5_CalibrationMarburg.mxd

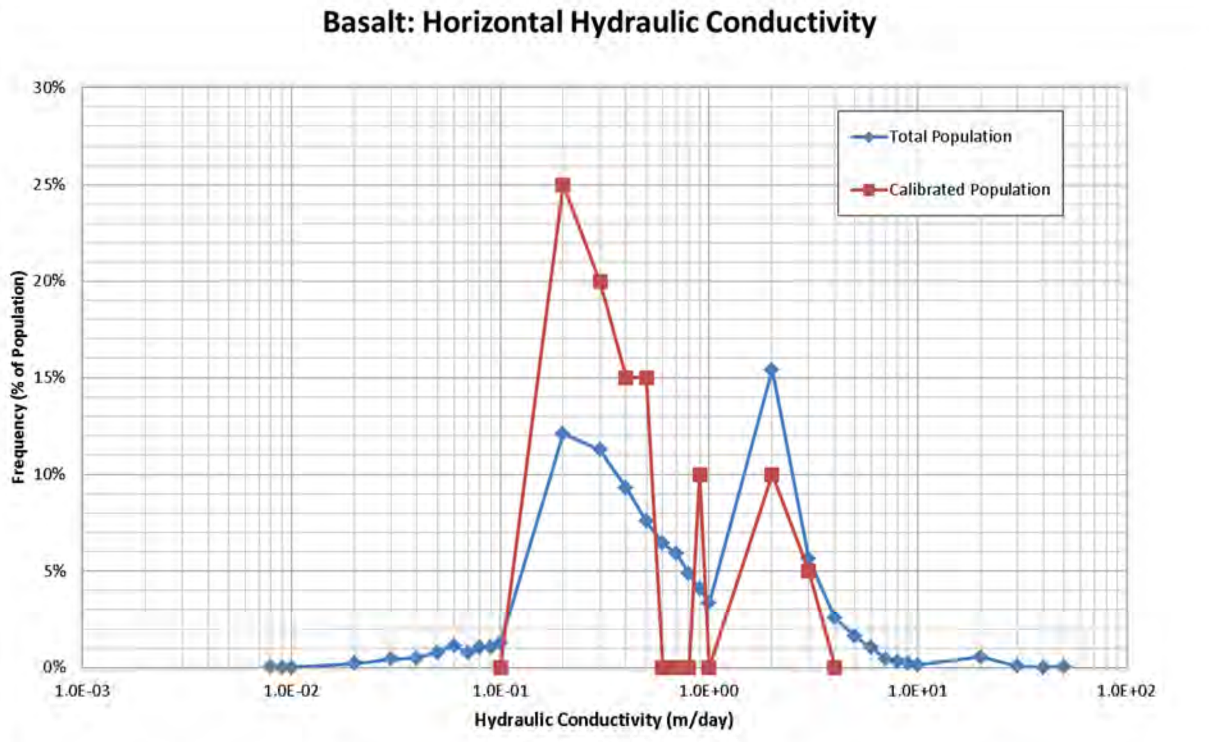
Produced: 28/08/2014

Appendix B. Calibration Parameter Sensitivity Plots

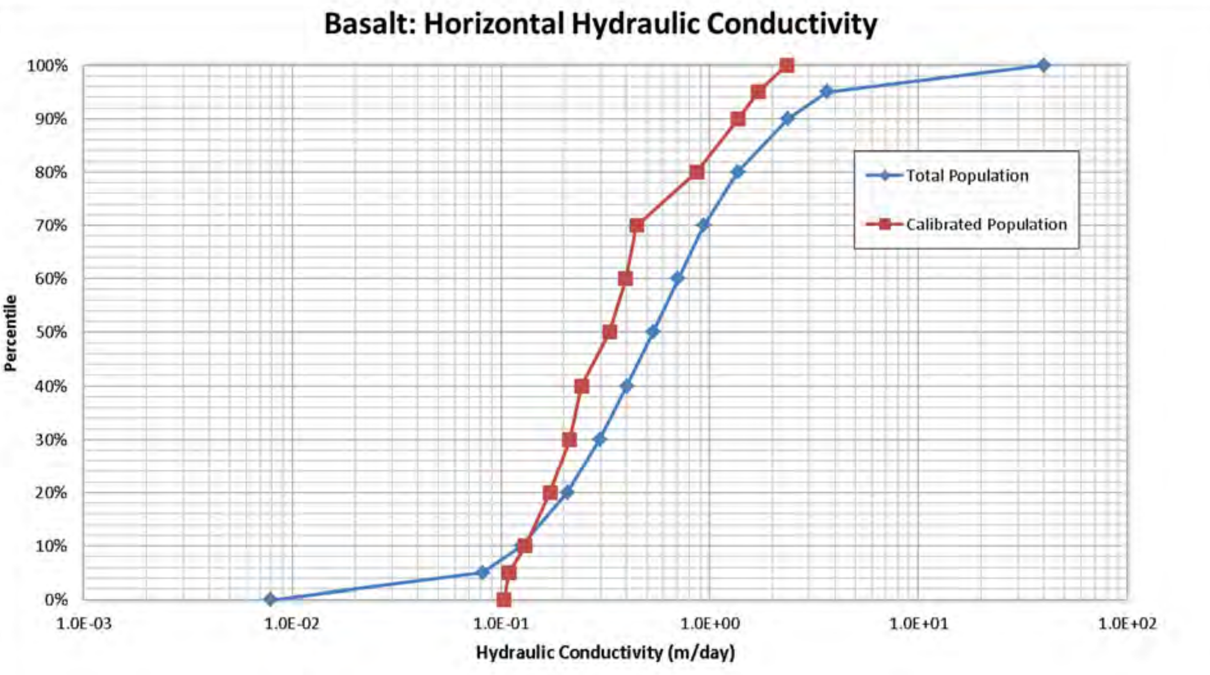


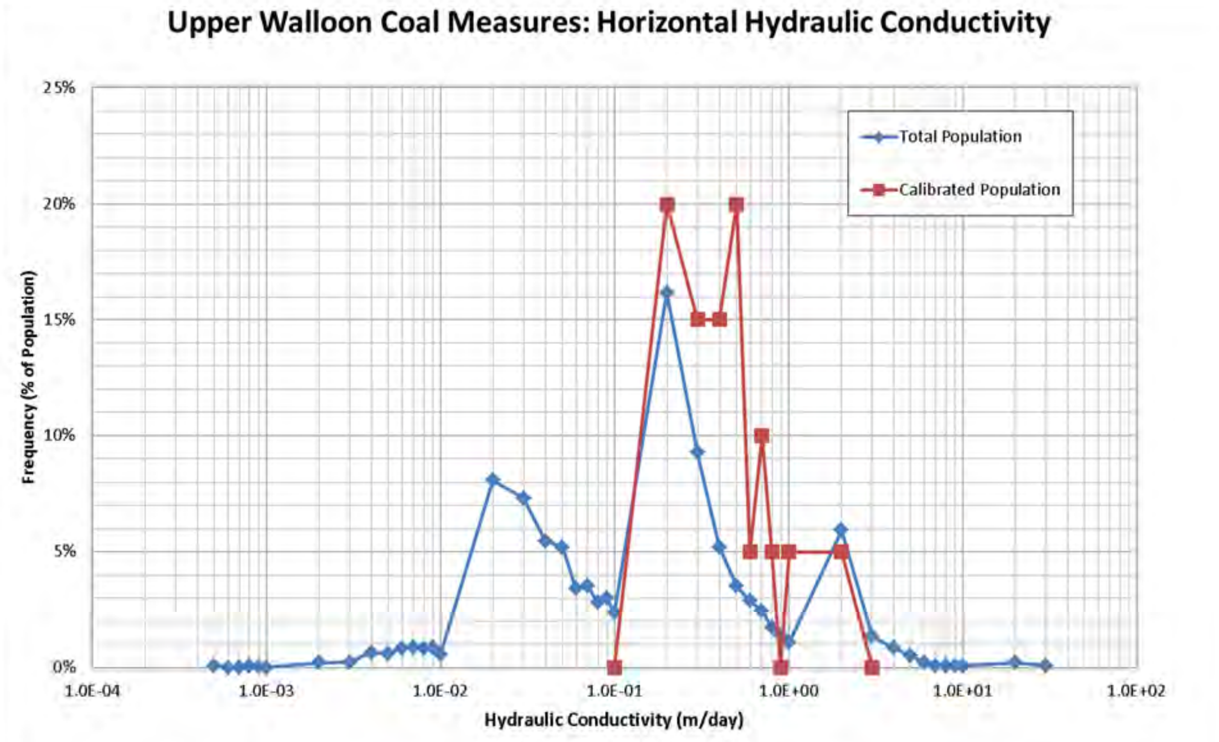
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.



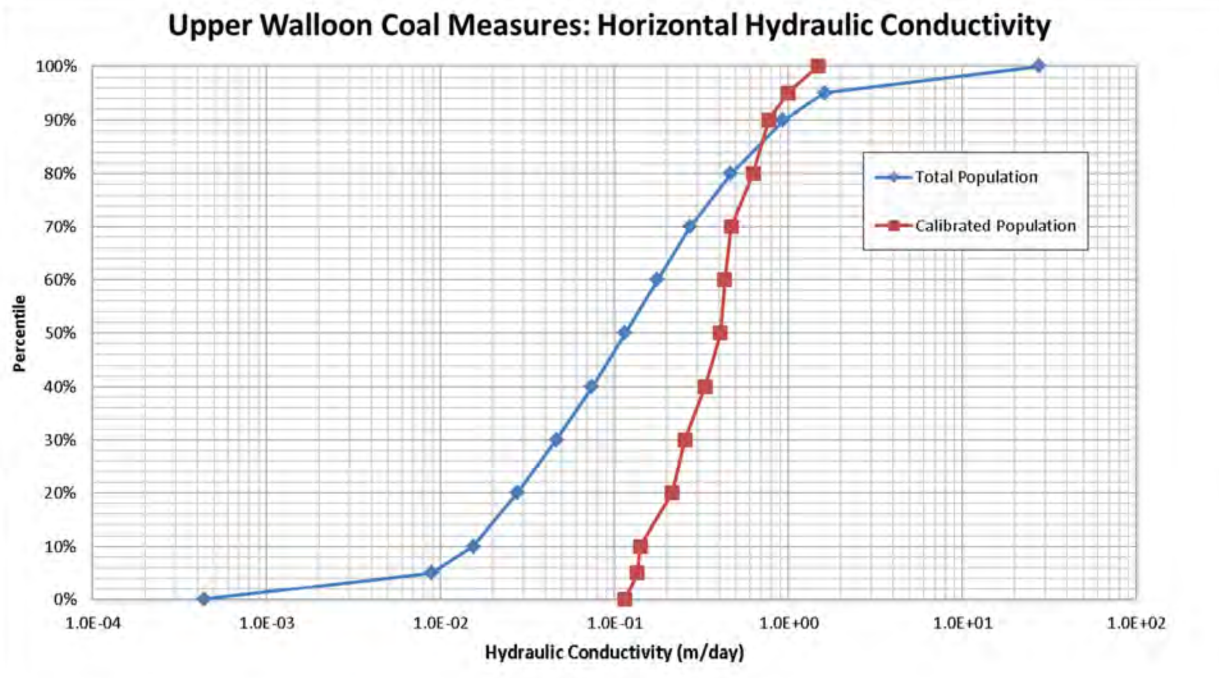


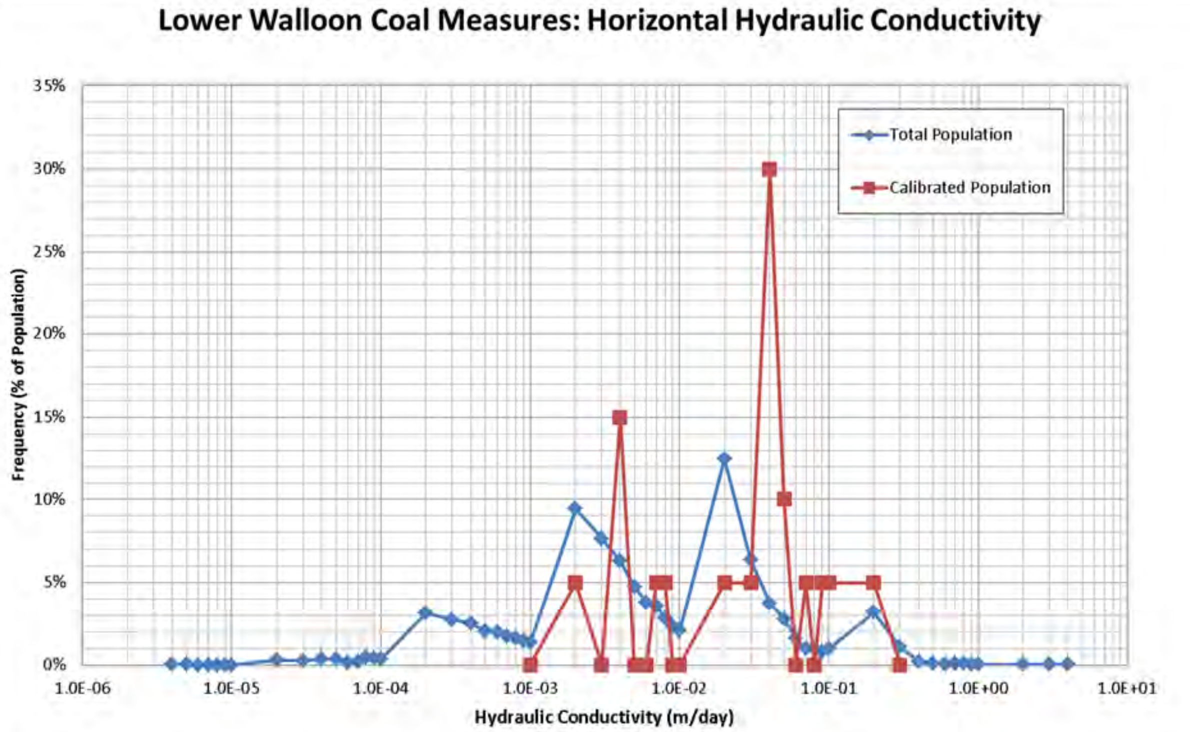
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.



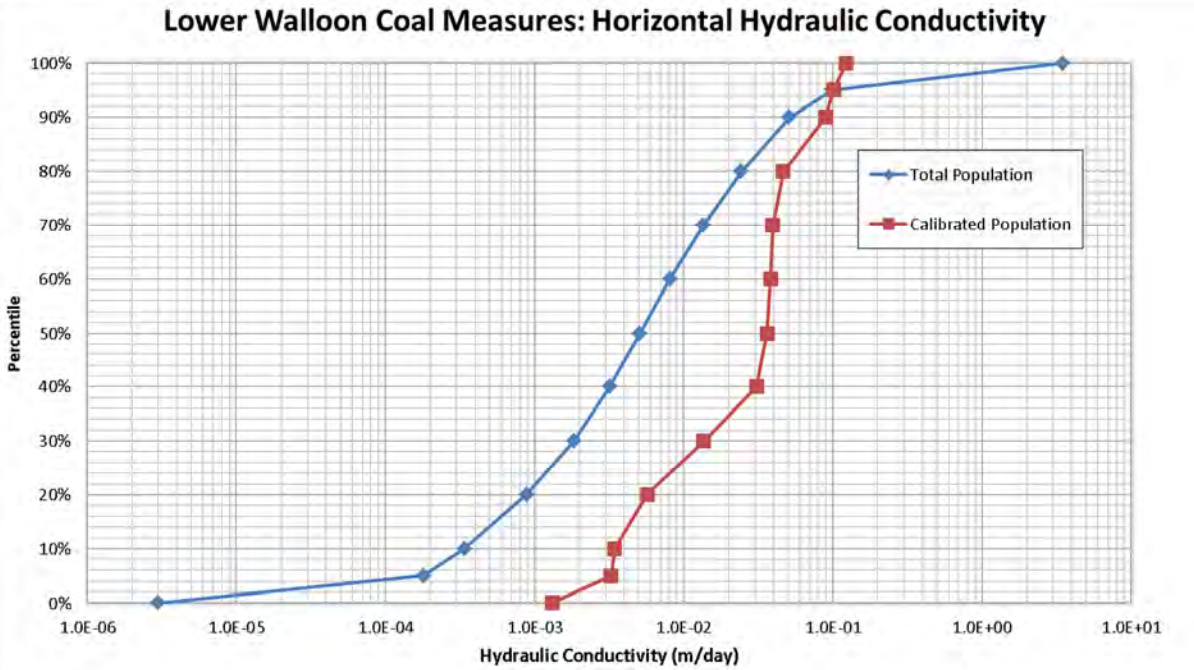


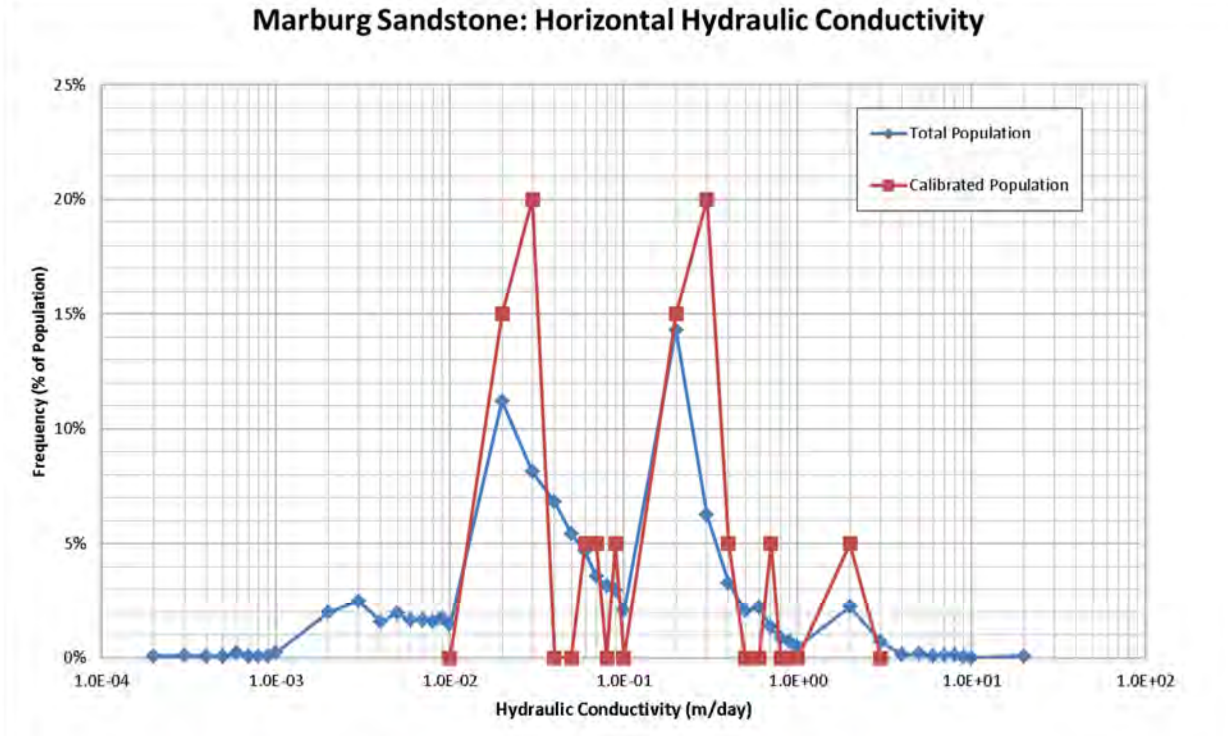
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.



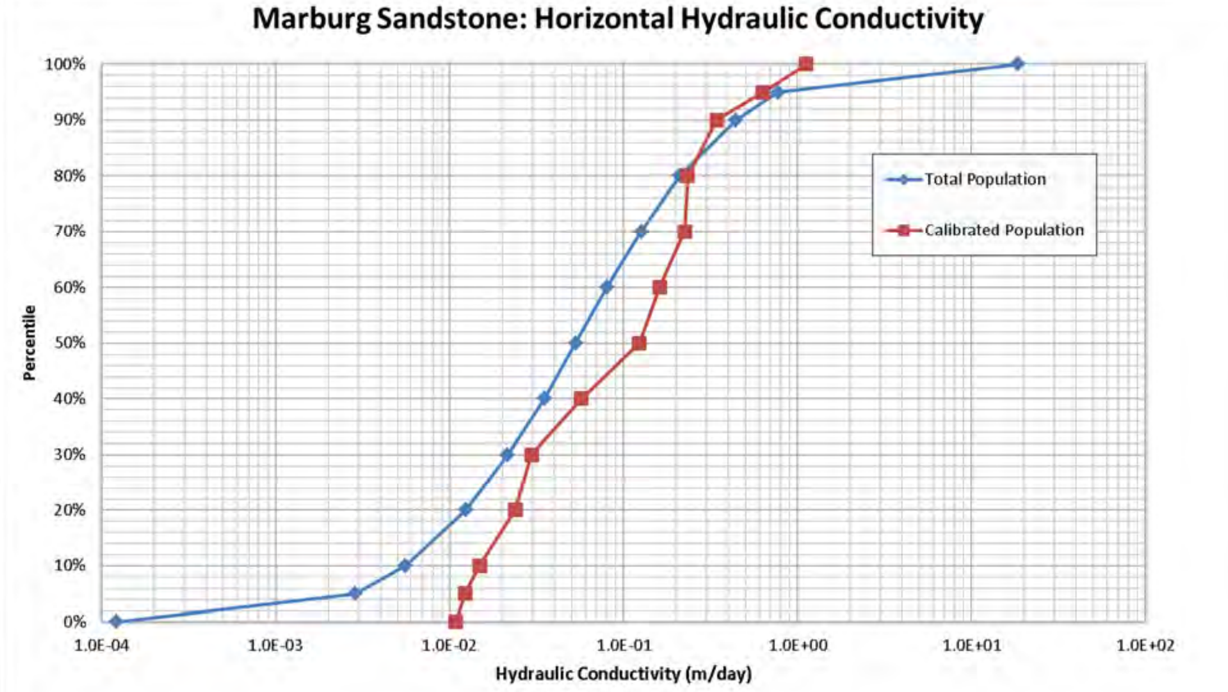


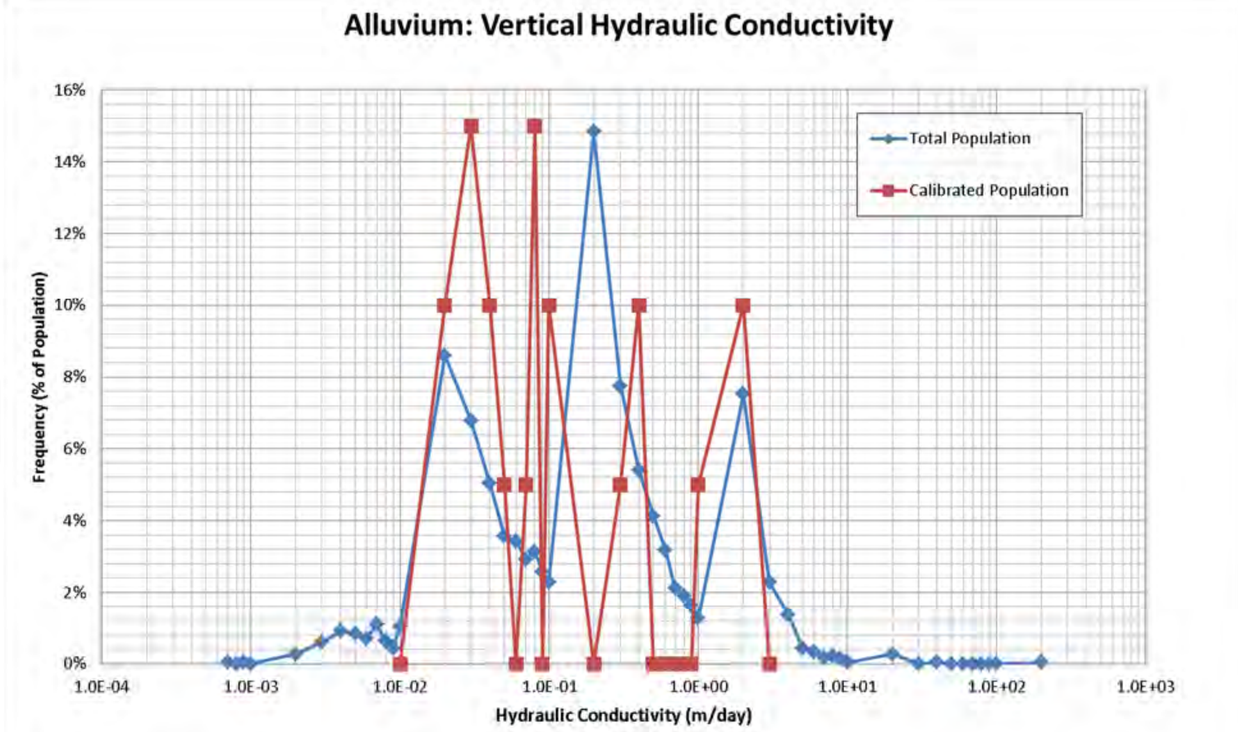
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.



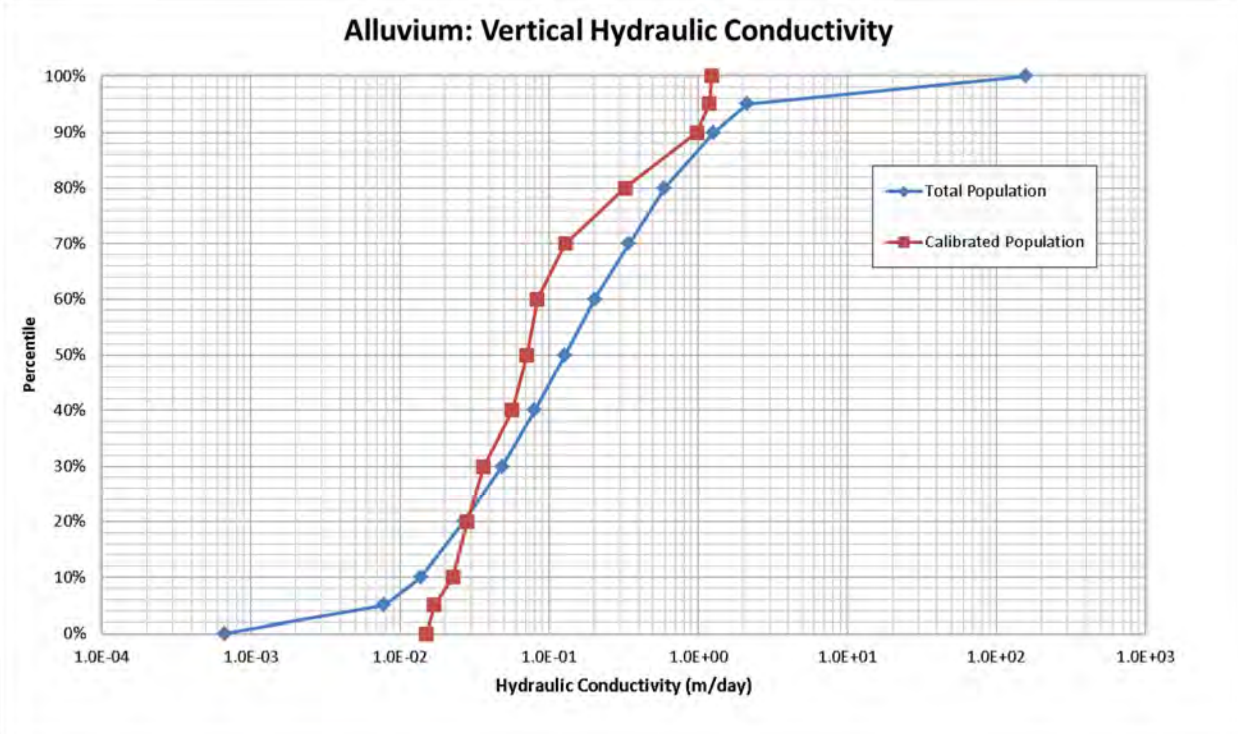


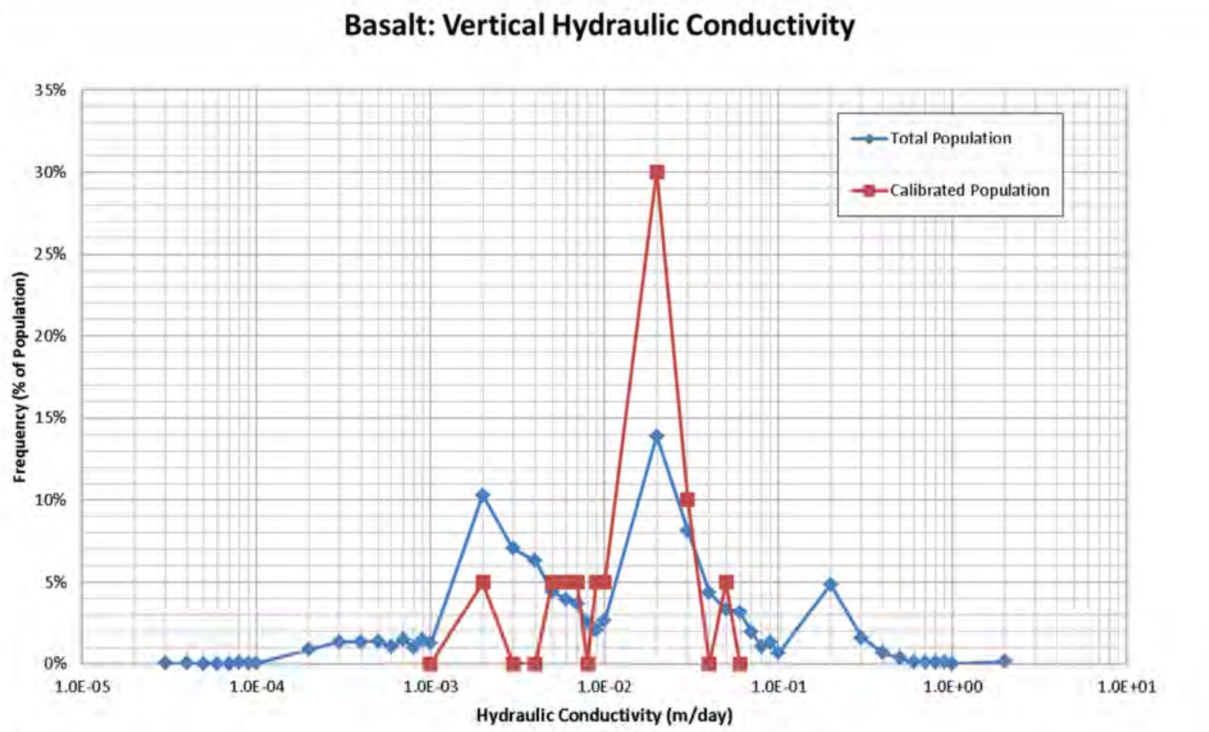
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.



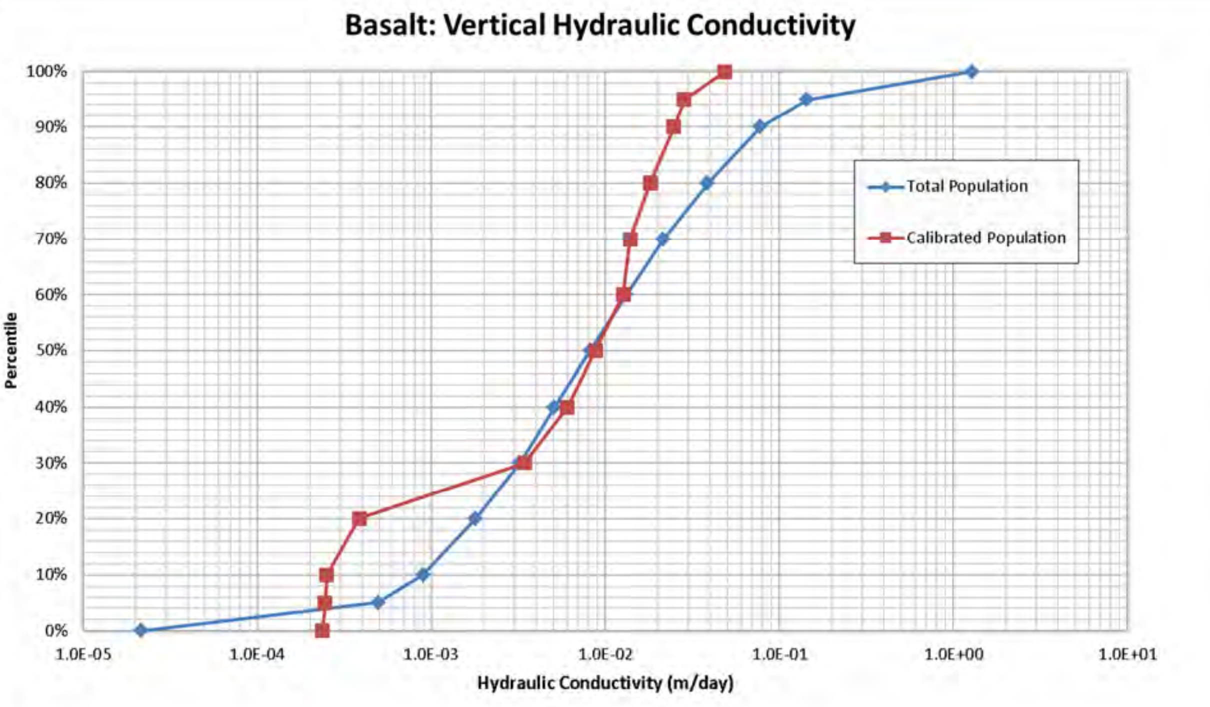


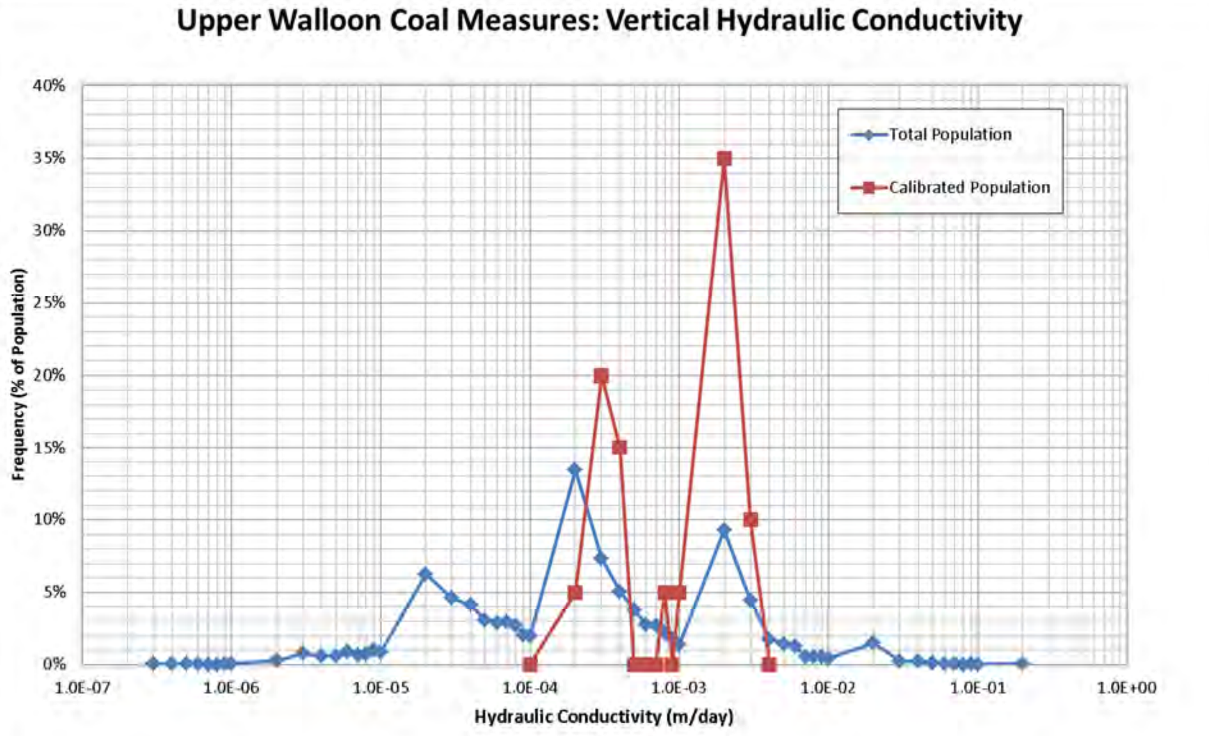
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.



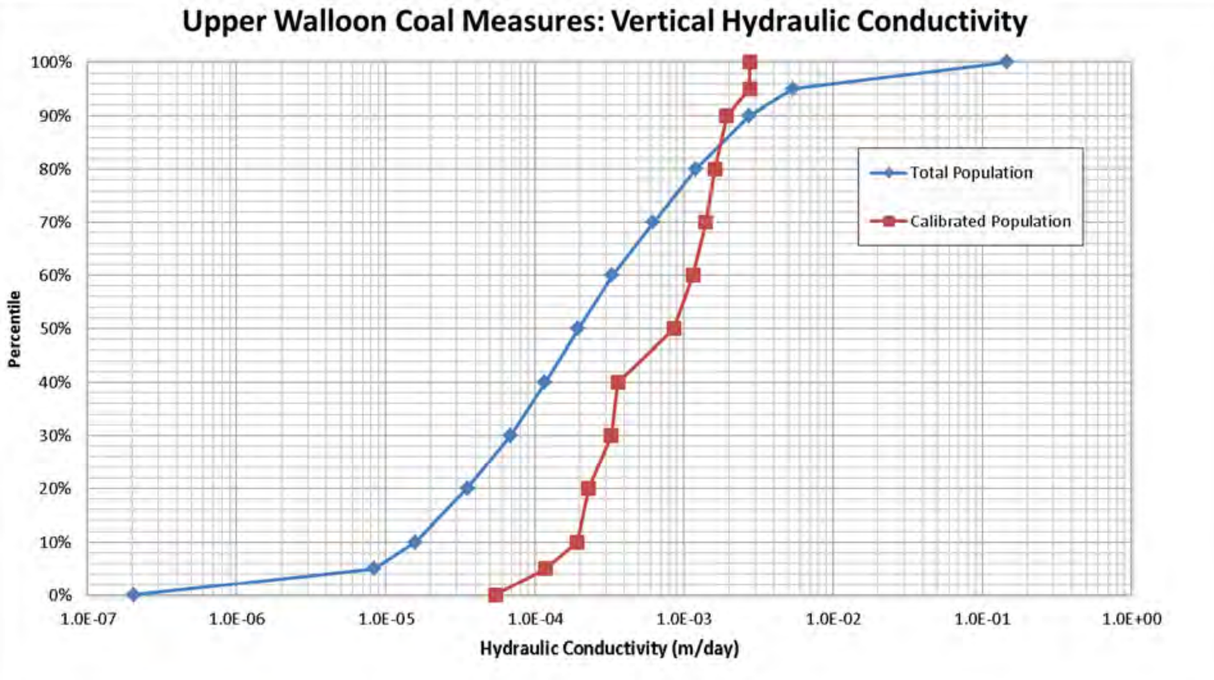


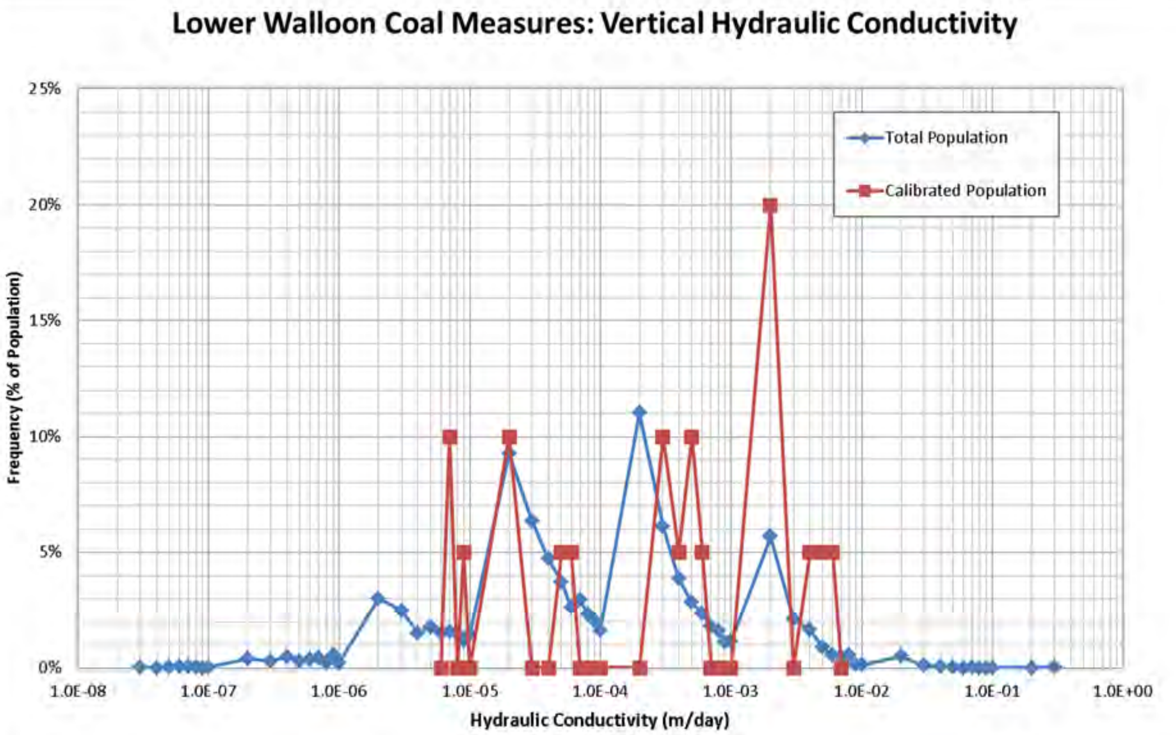
Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.





Note: The "Total Population" (blue line) frequency is calculated by dividing the total number of models simulated within the above parameter ranges by the total number of models simulated. For the "Calibrated Population" (red line) the frequency is calculated by dividing the number of models simulated within the above parameter ranges that meet calibration criteria, by the total number of models simulated that meet calibration criteria.





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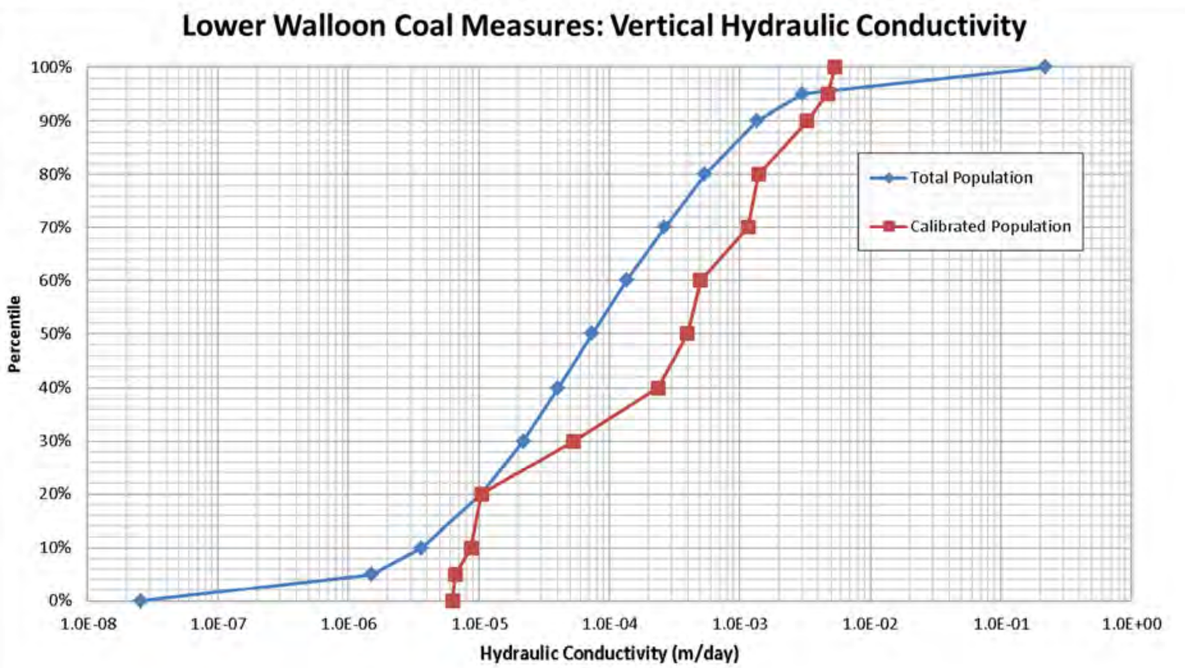

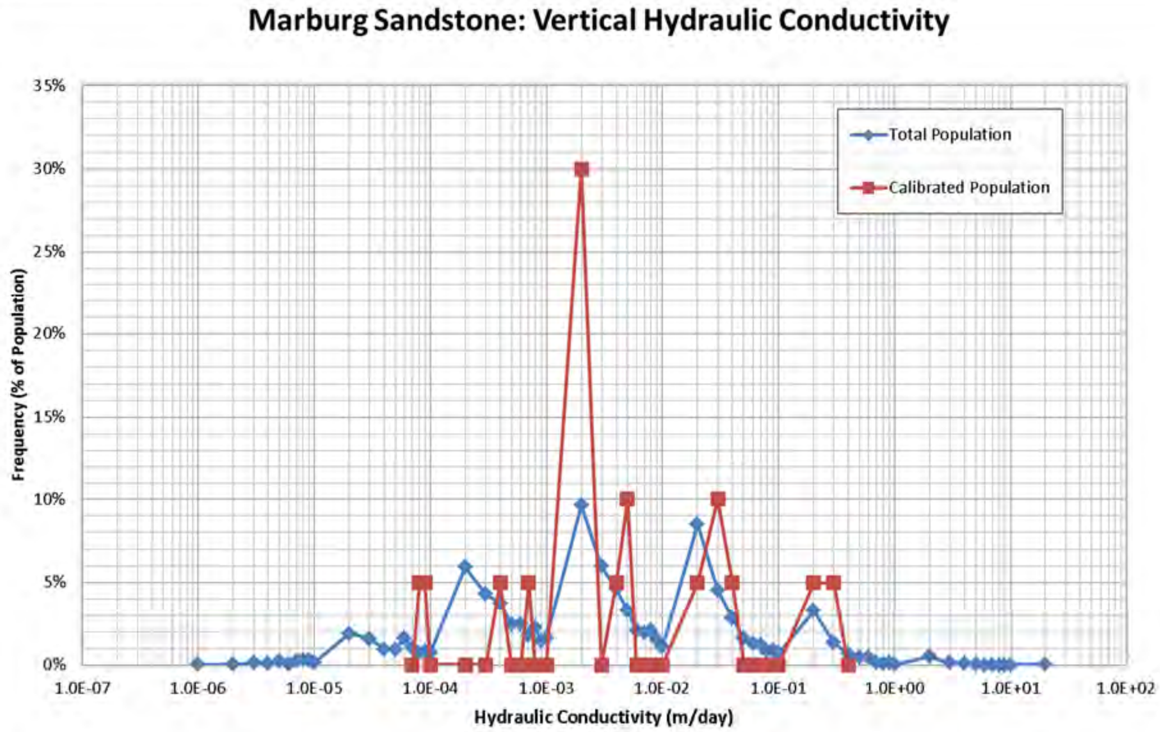

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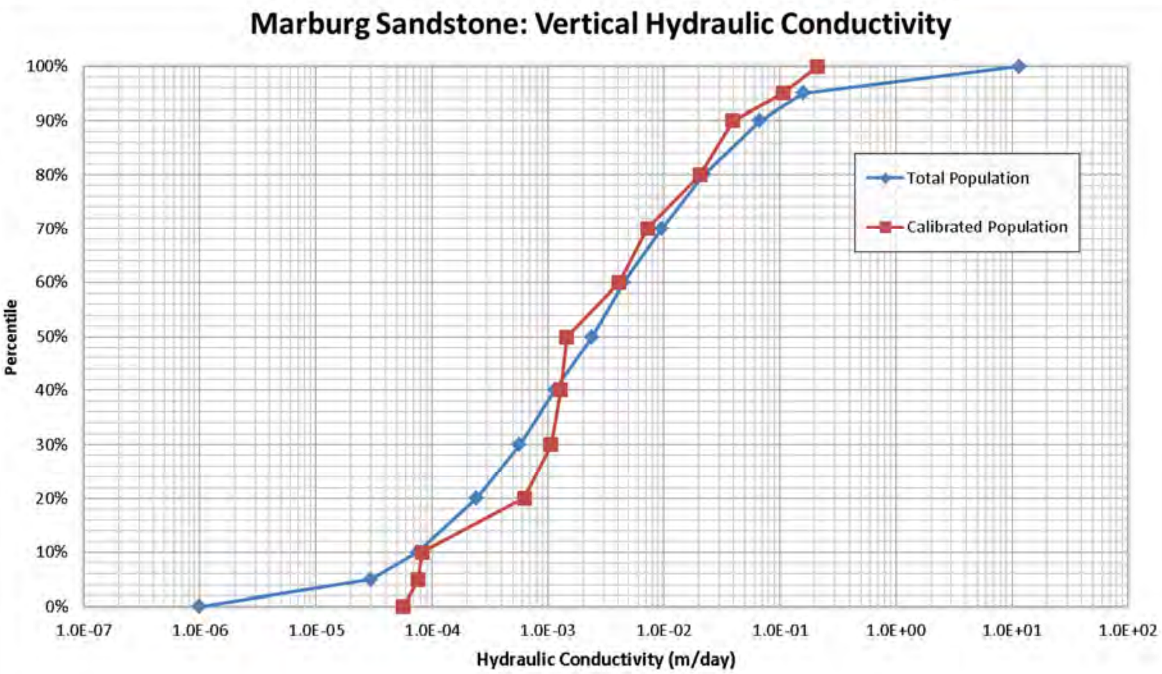

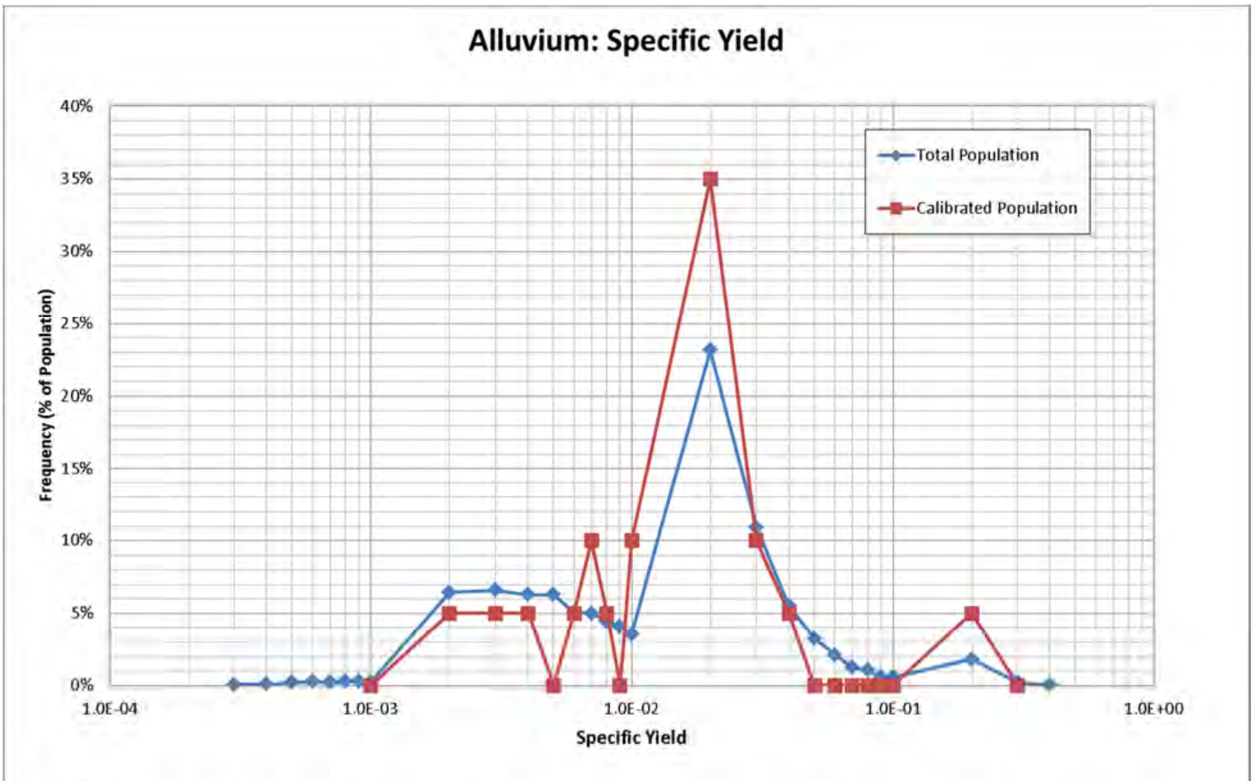

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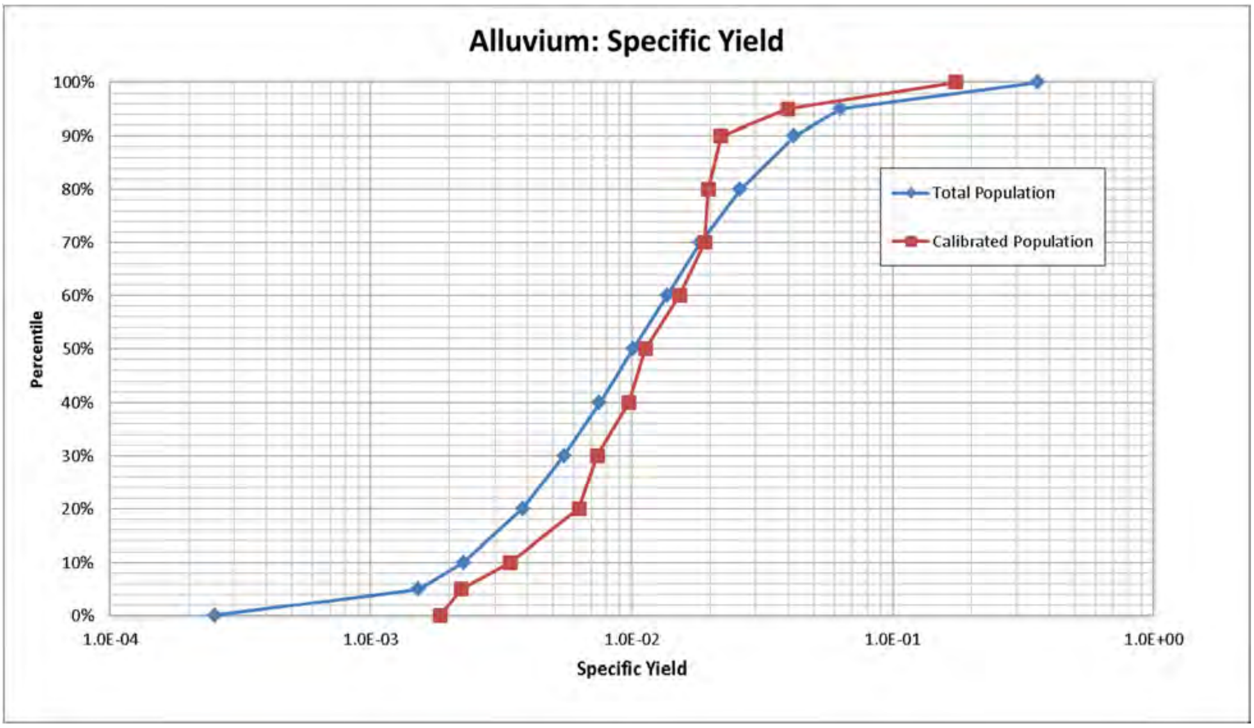

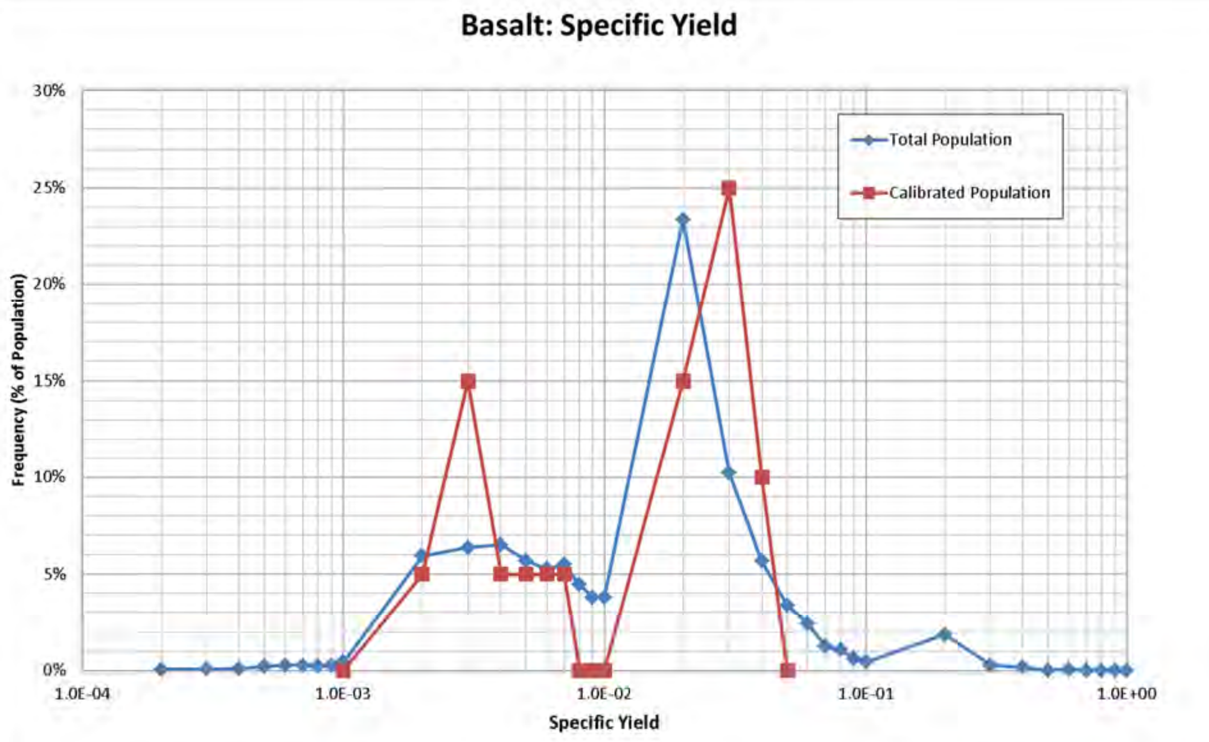

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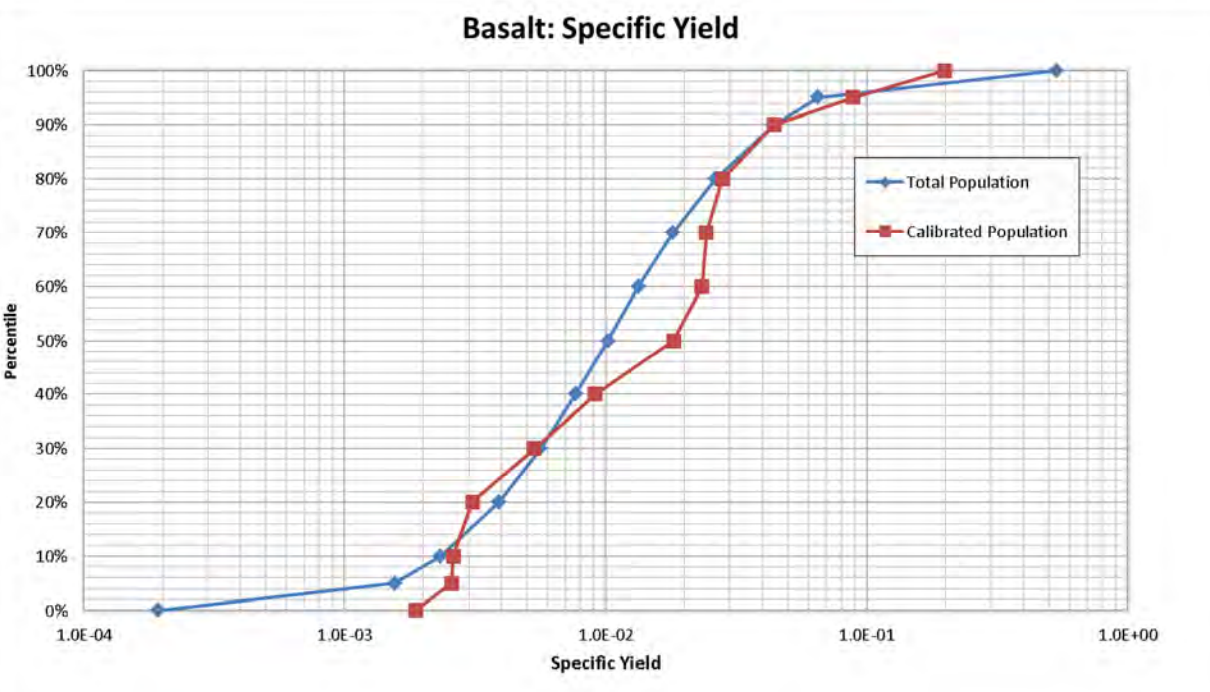

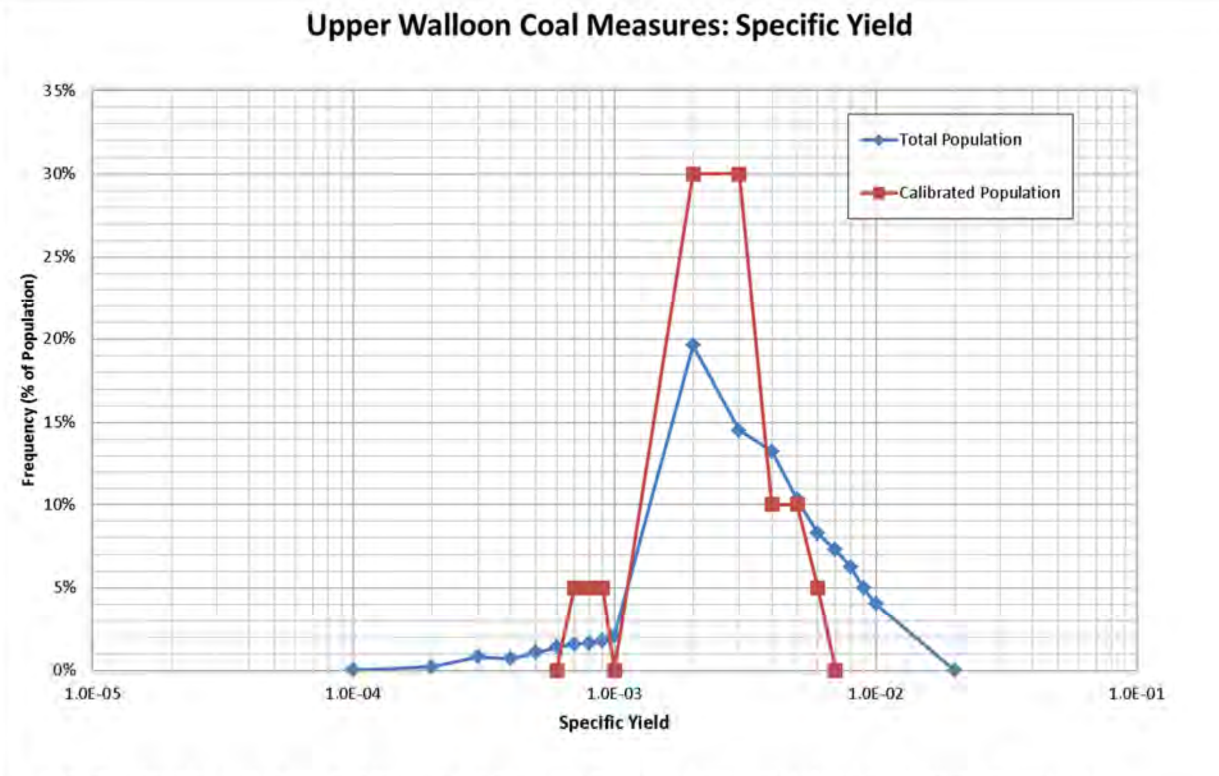

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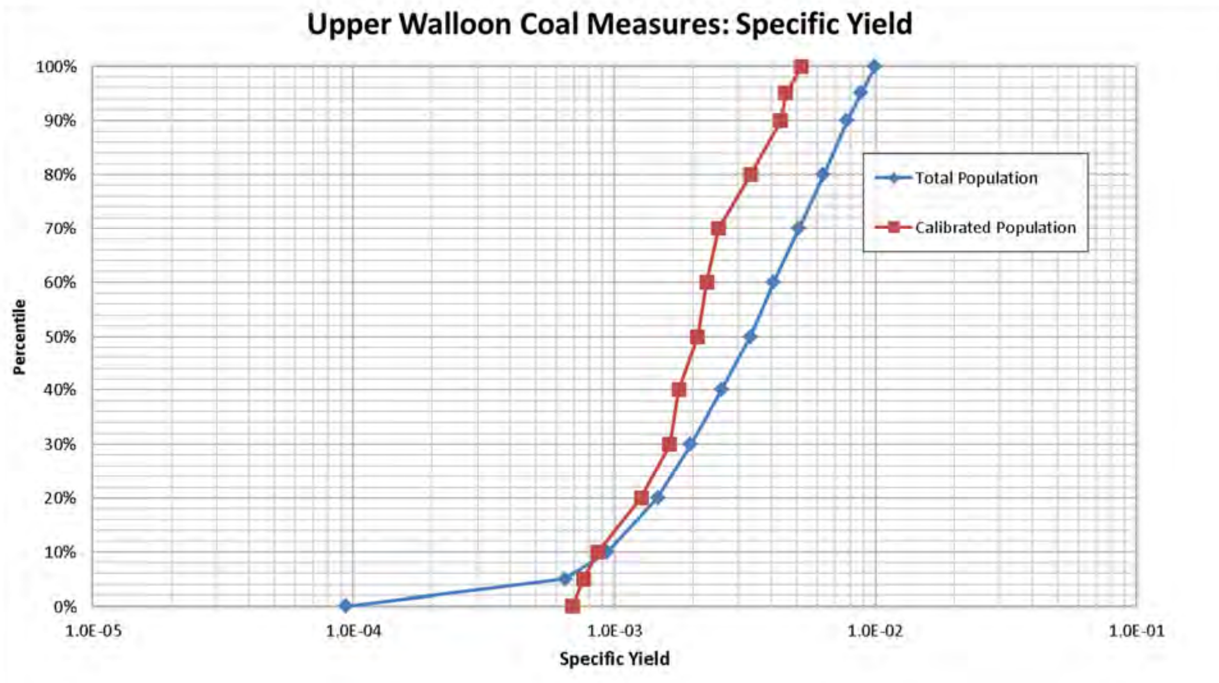

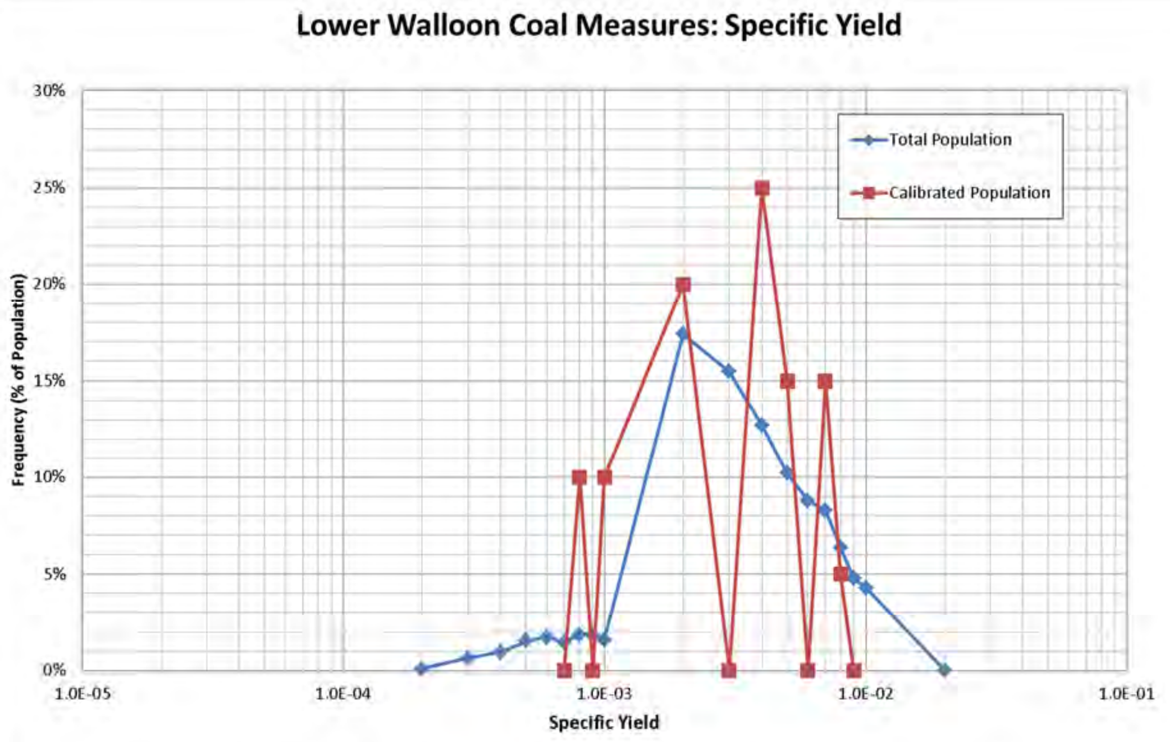

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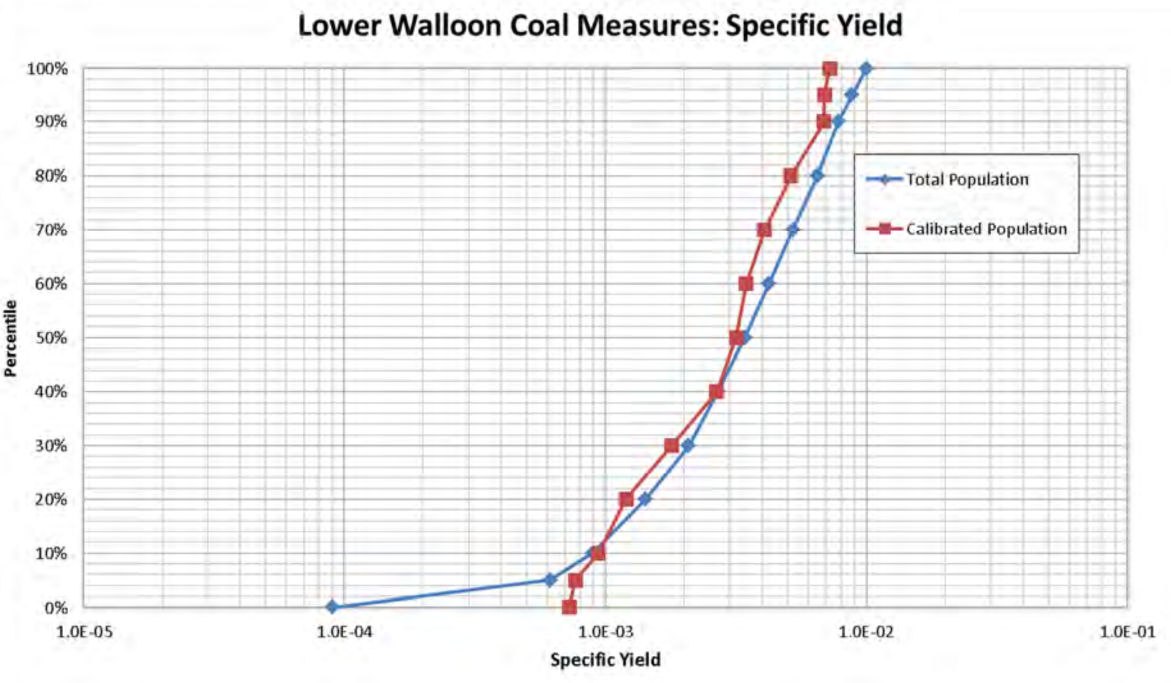

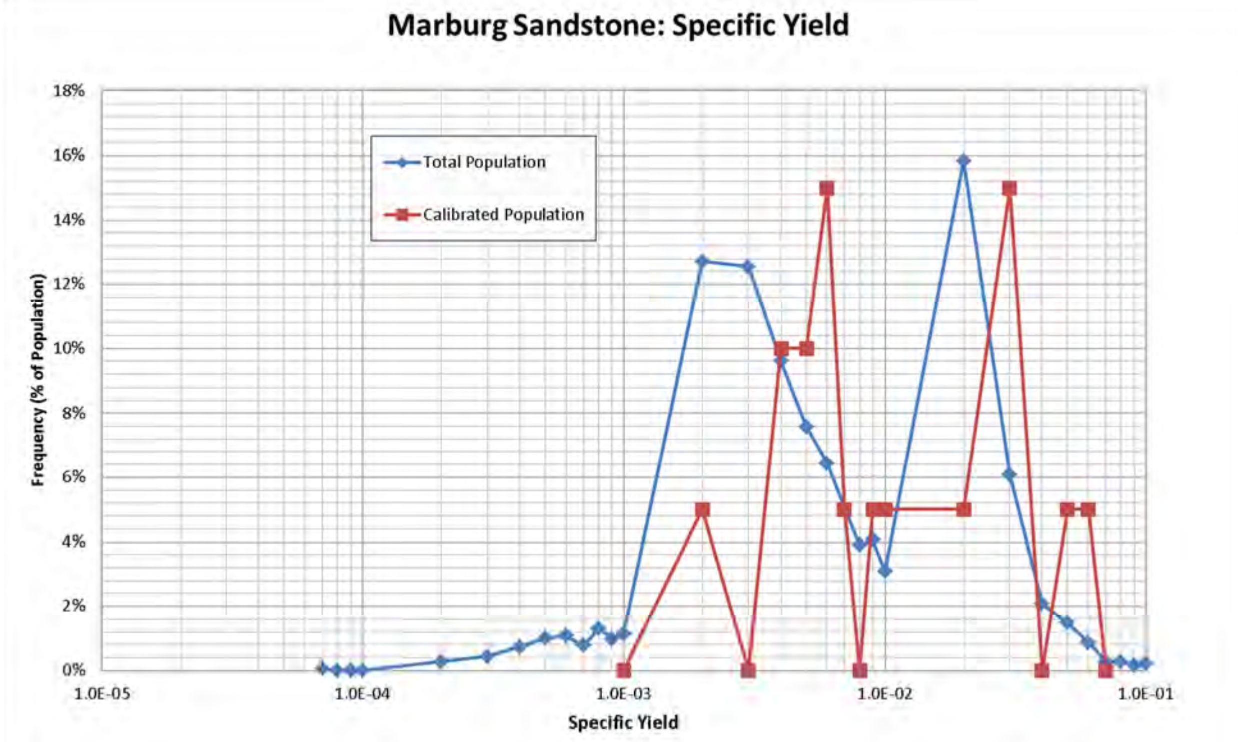

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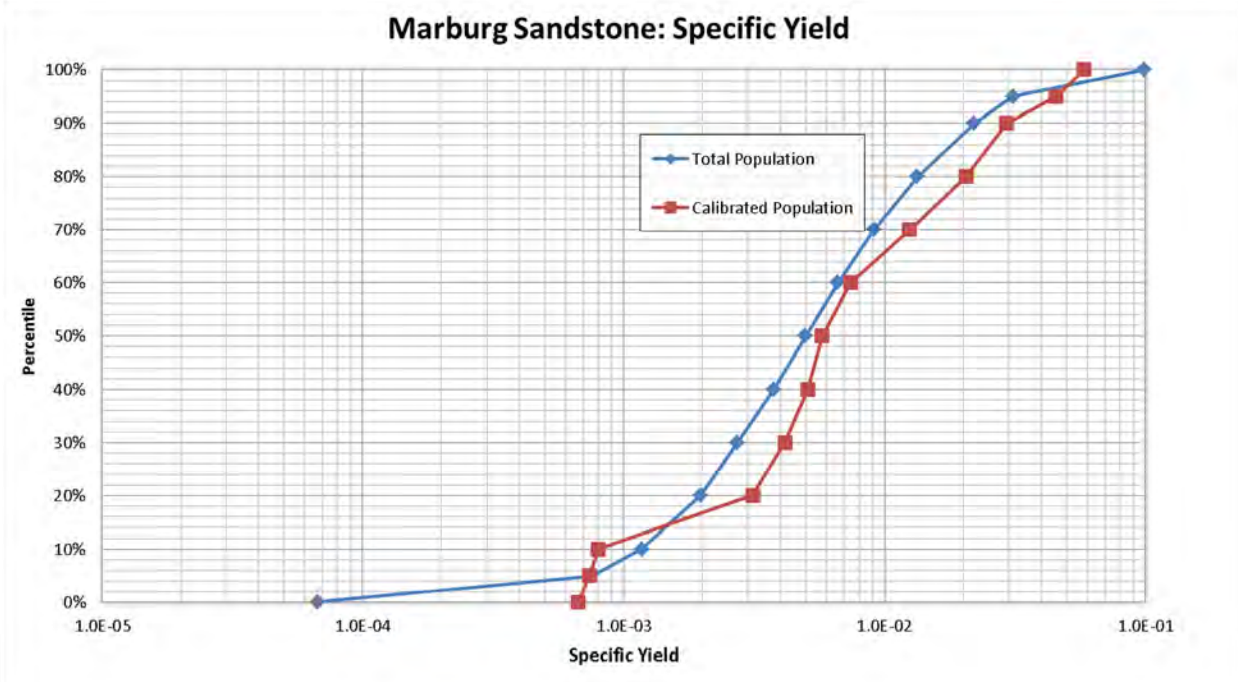

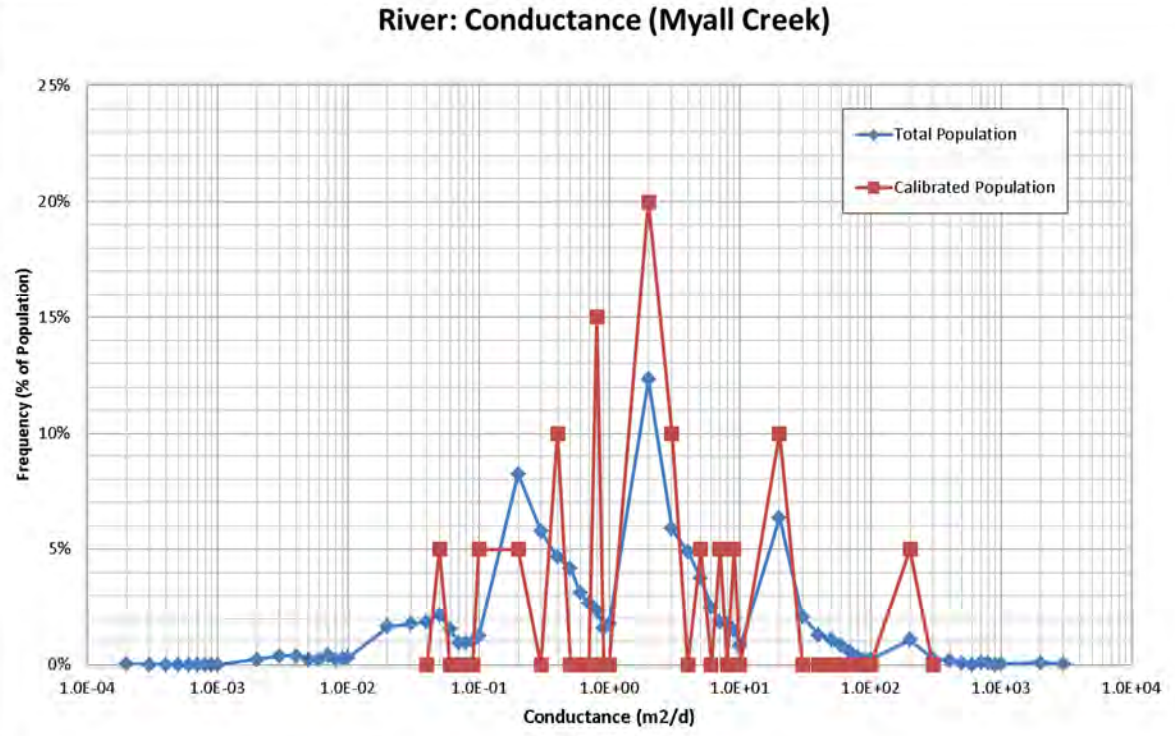

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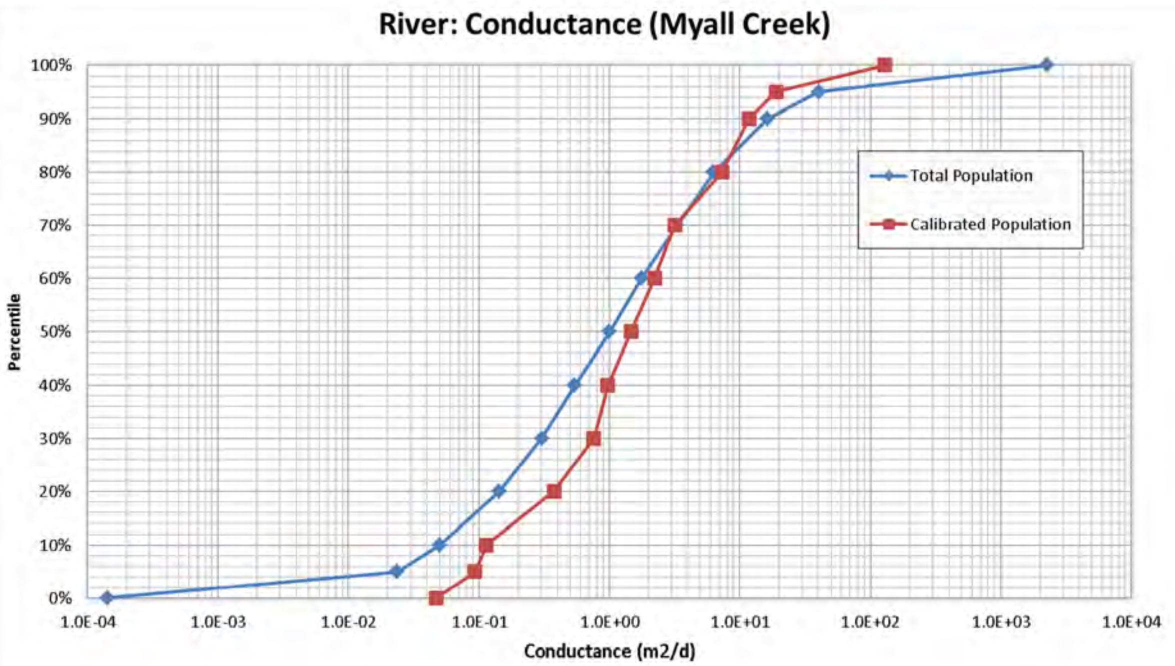

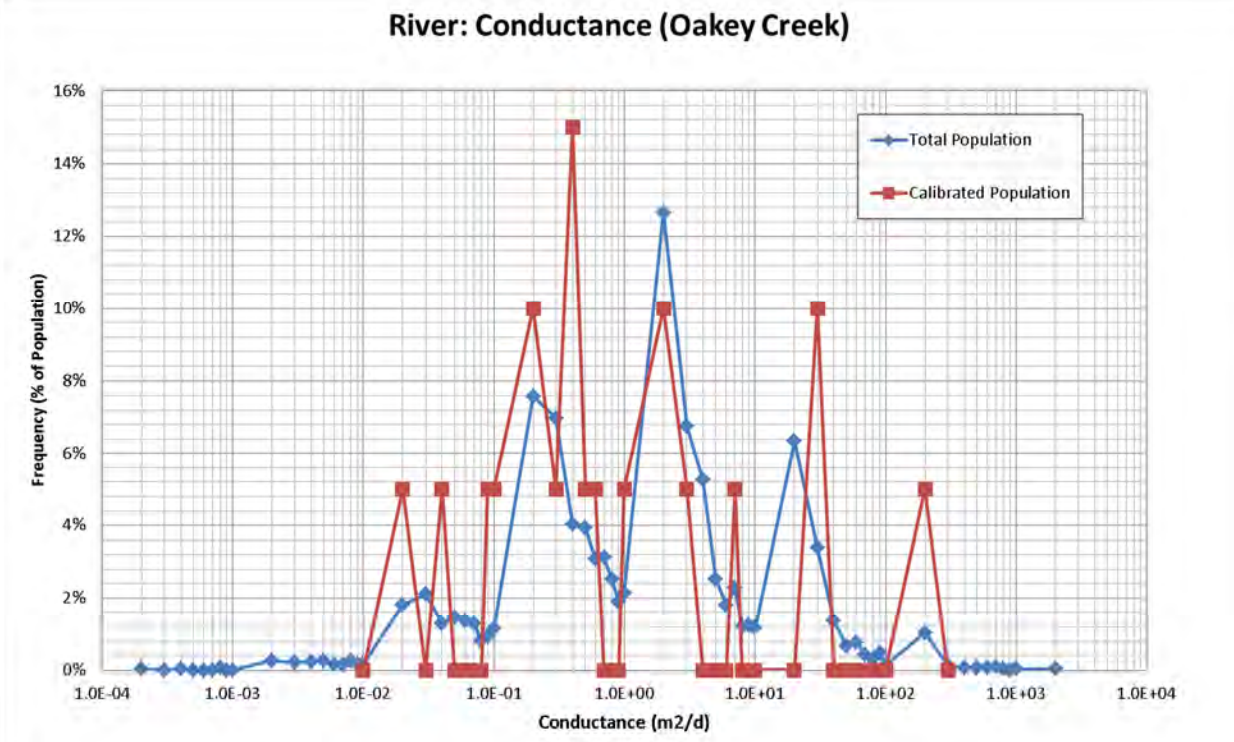

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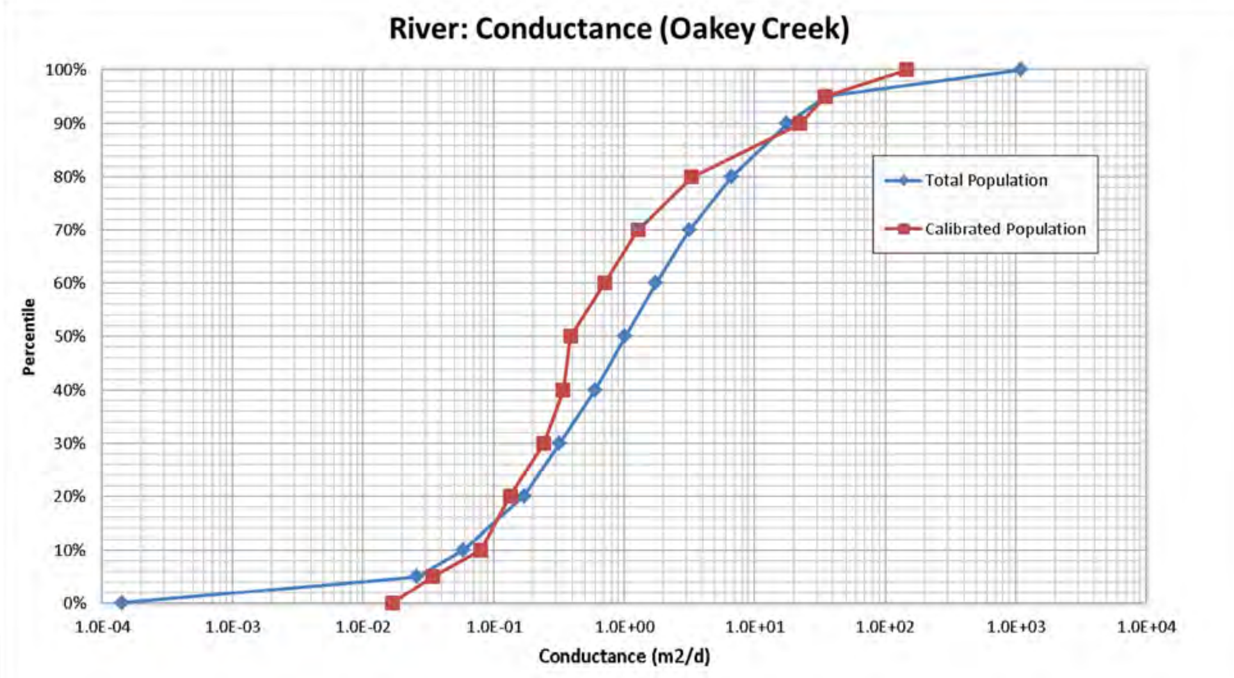
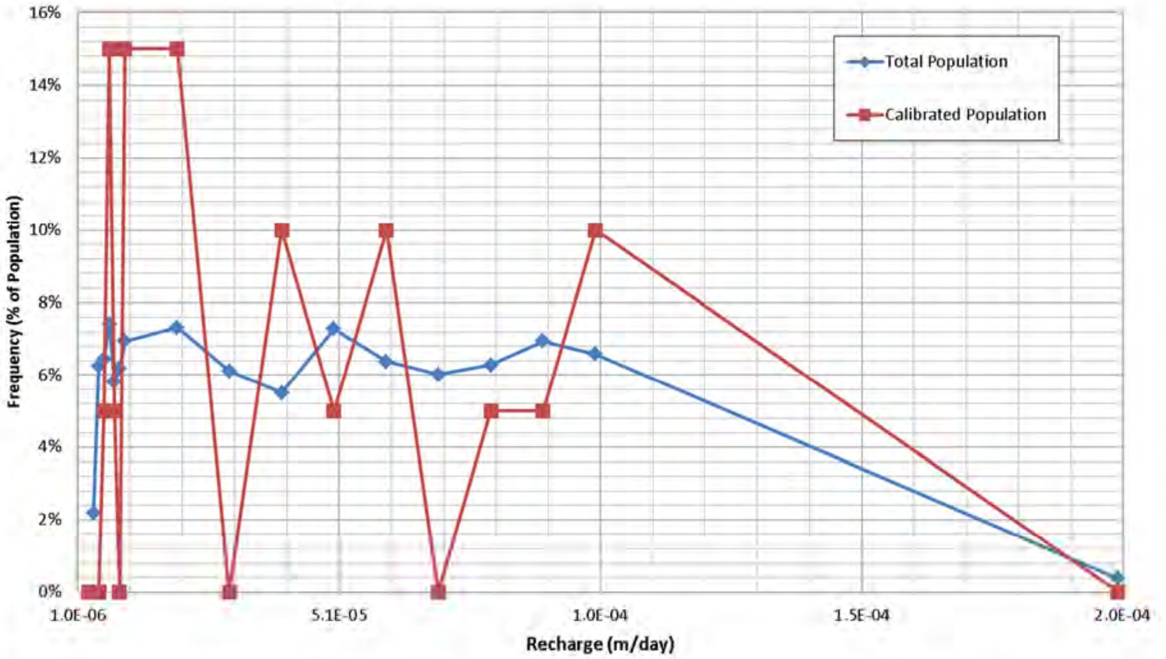


Alluvium: Recharge



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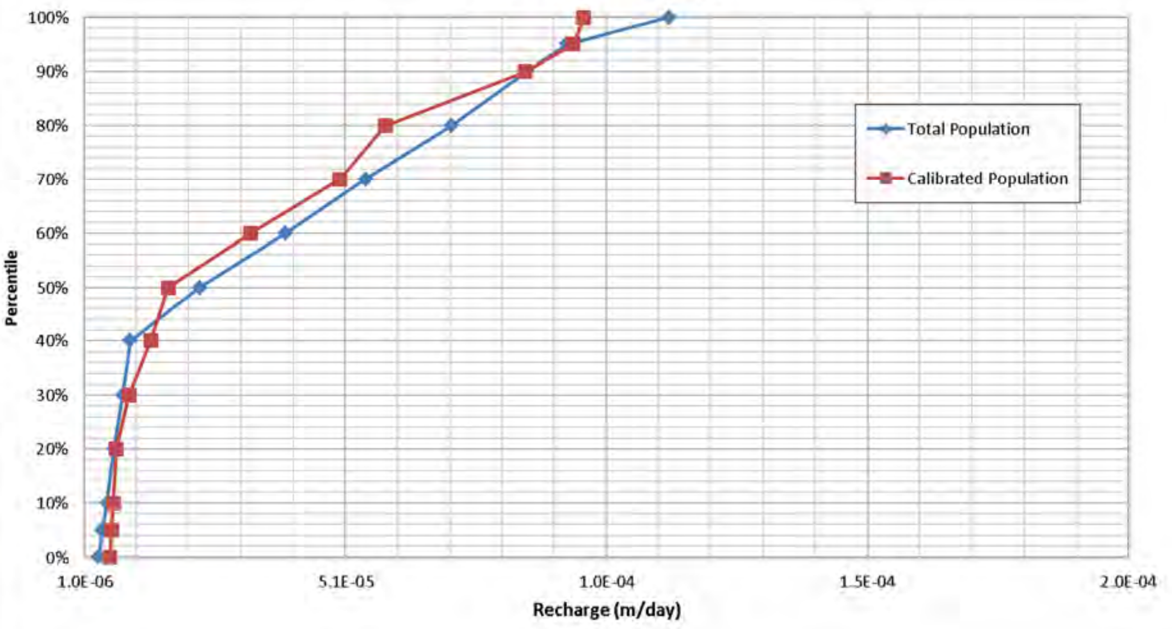
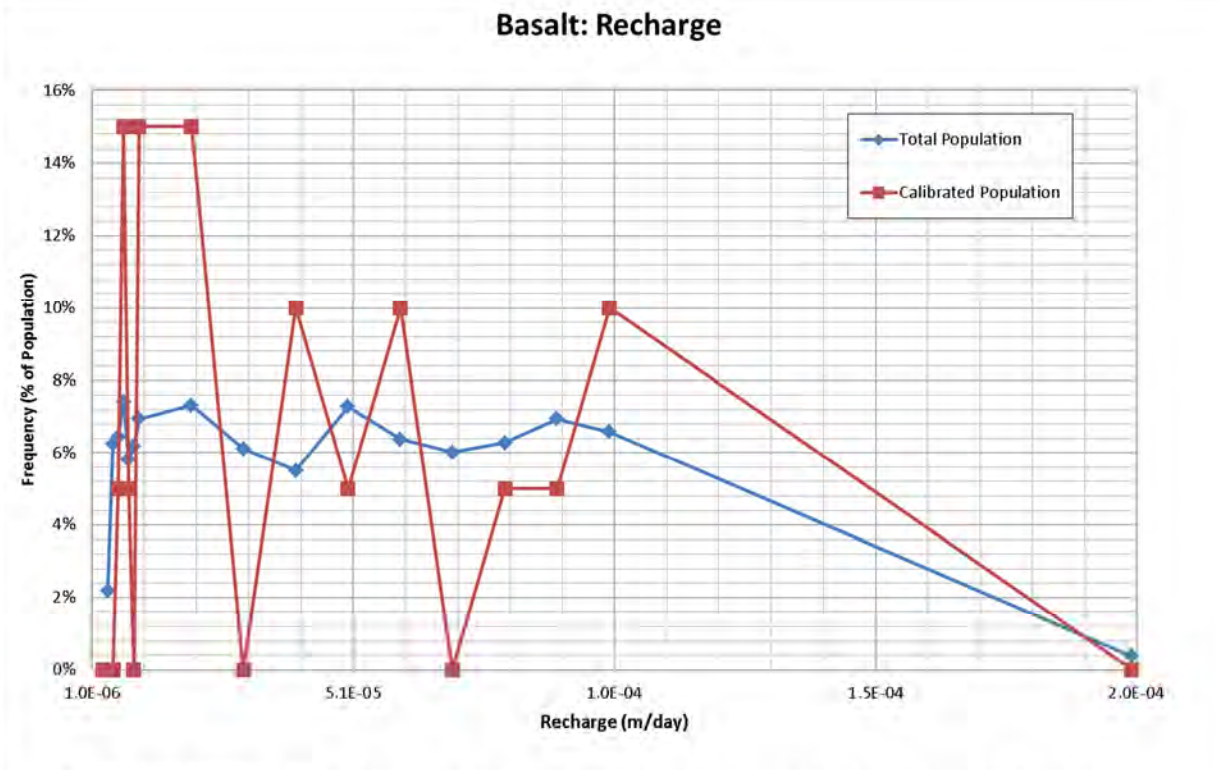
Alluvium: Recharge





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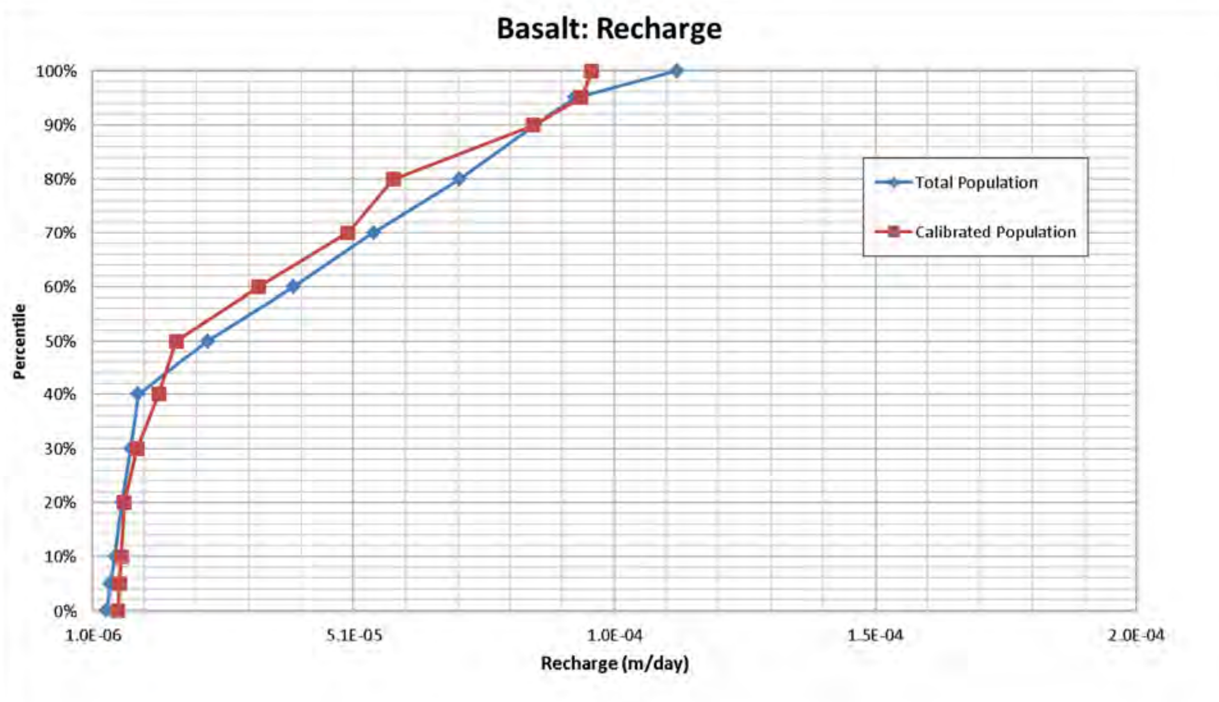

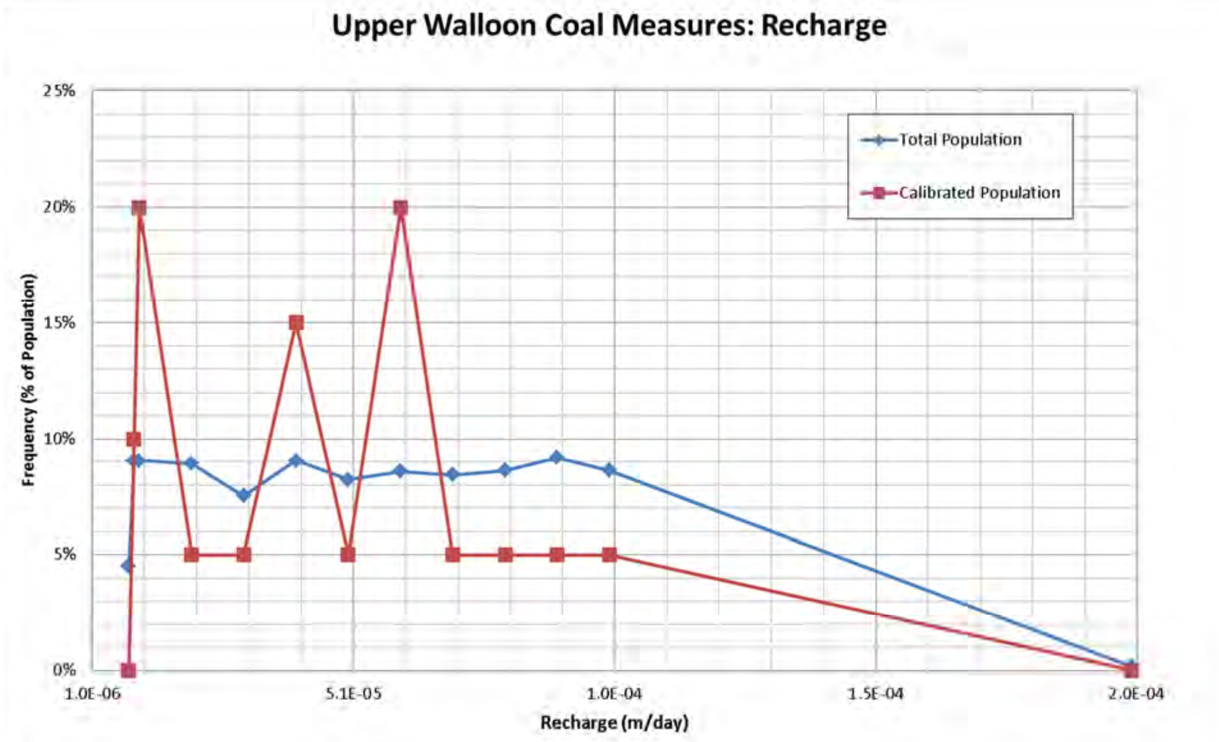

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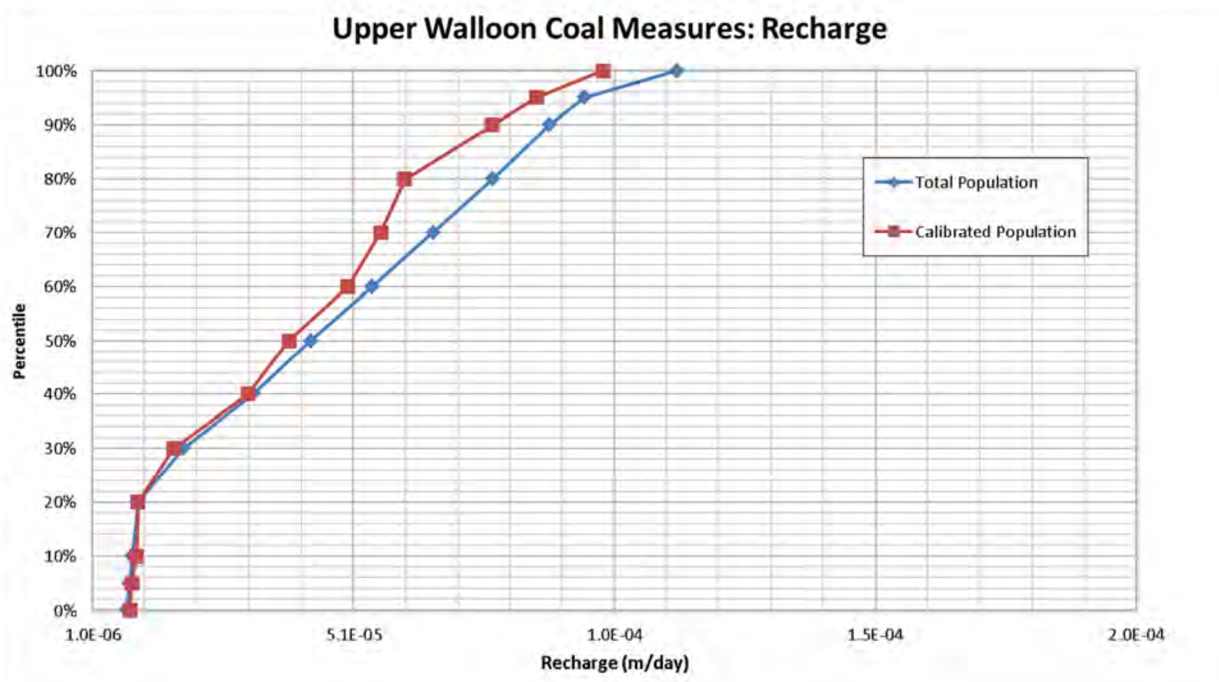

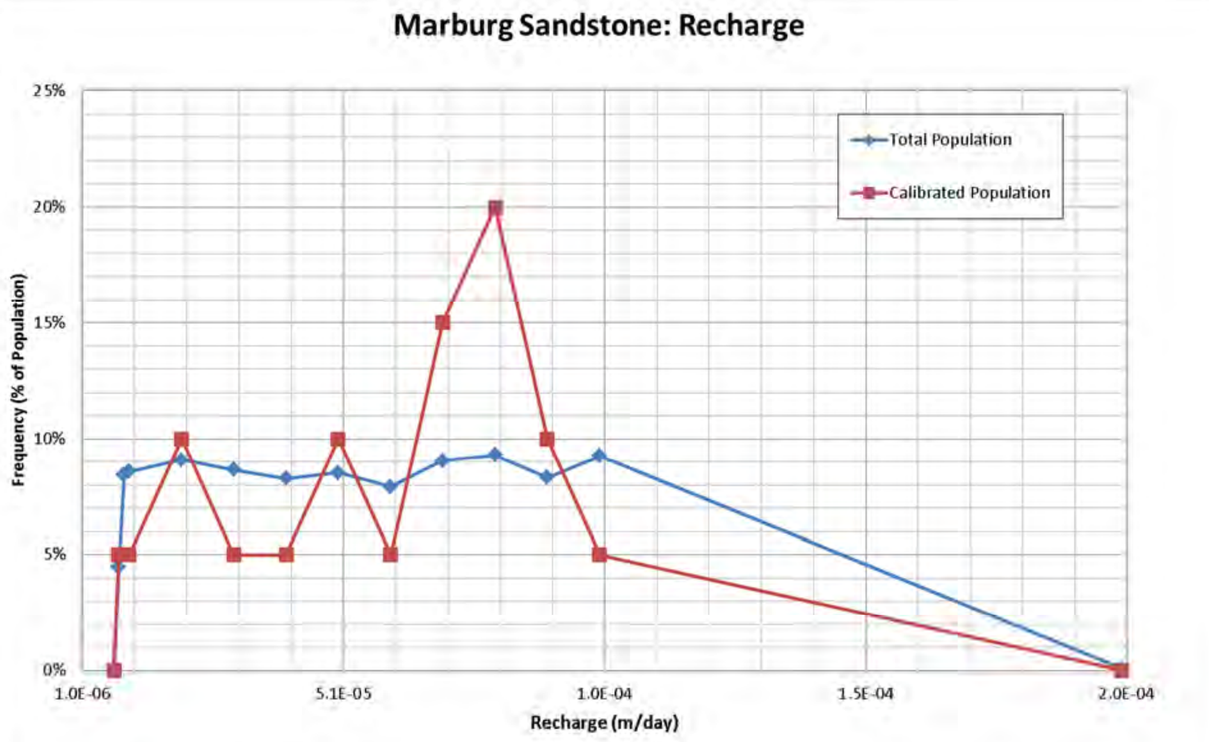

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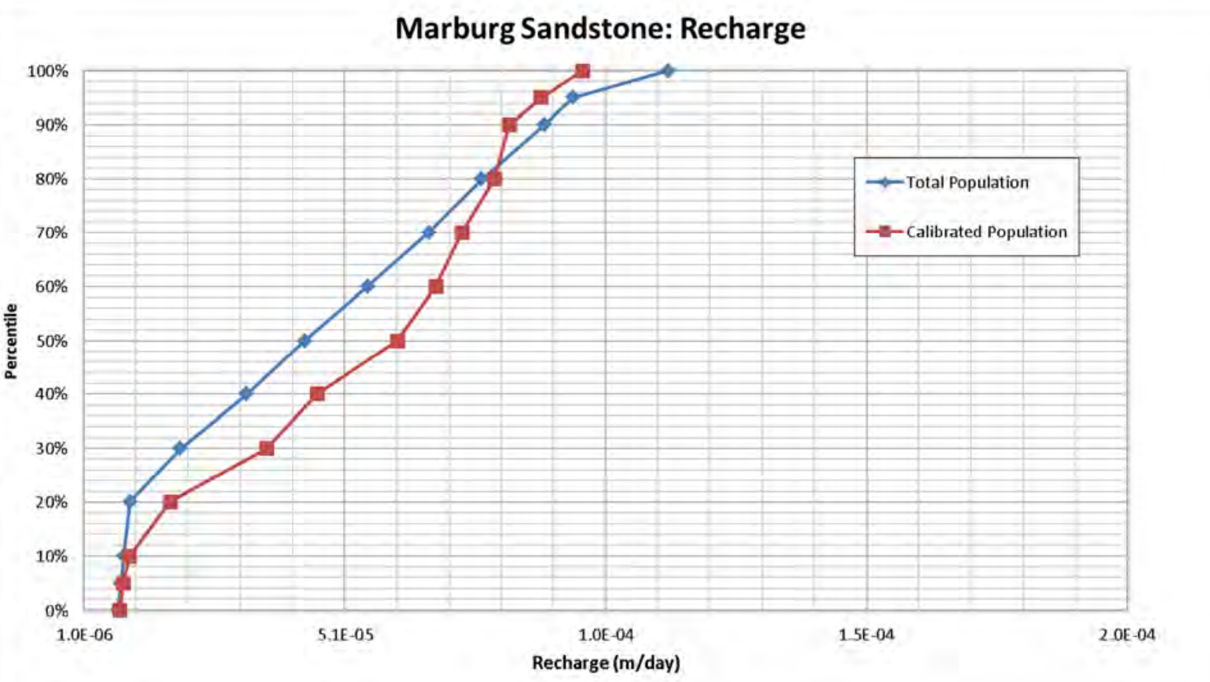

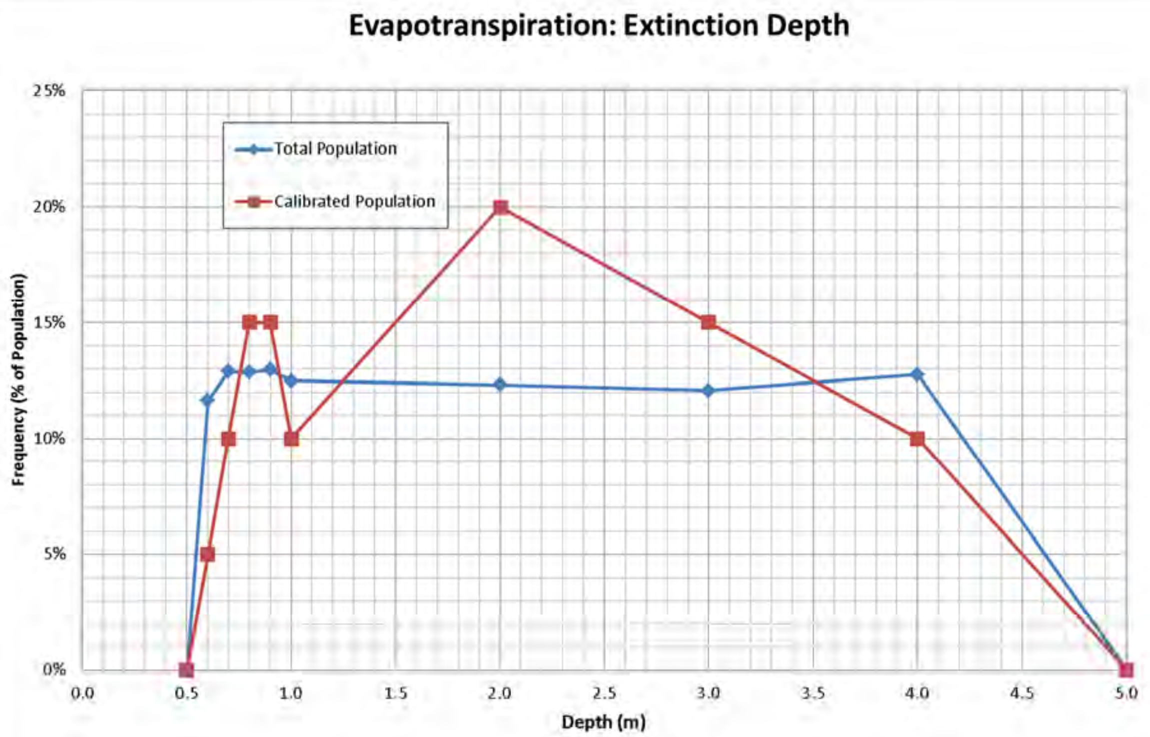

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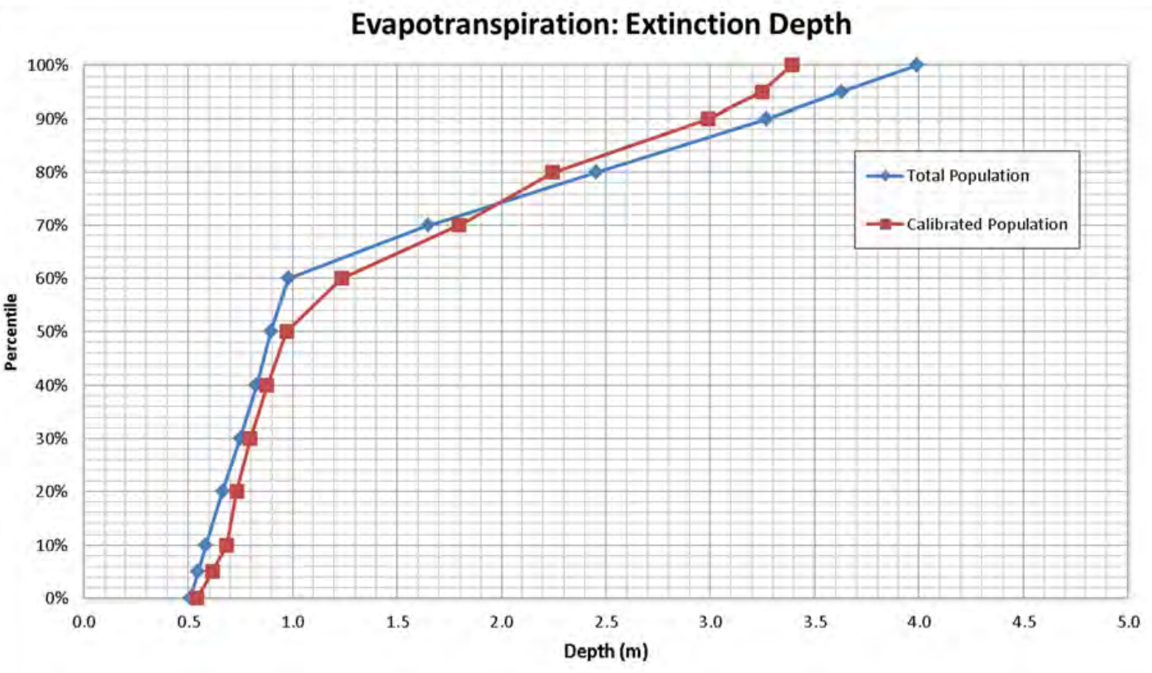
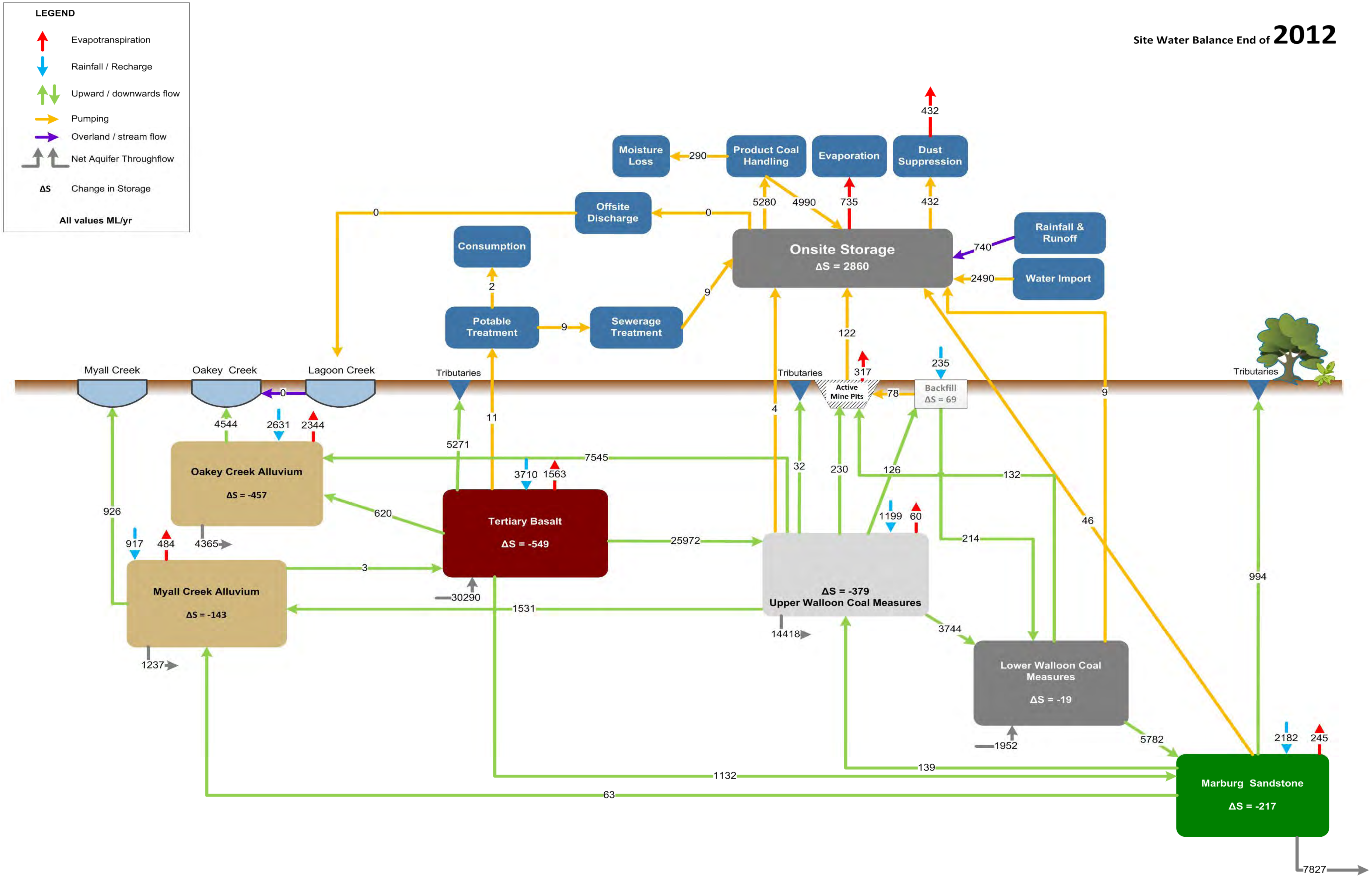


Appendix C. IESC Water Balance Diagrams


LEGEND
Evapotranspiration
Rainfall / Recharge
Upward / downwards flow
Pumping
Overland / stream flow
Net Aquifer Throughflow
ΔS Change in Storage
All values ML/yr
Site Water Balance End of 2012
Moisture Loss
Product Coal Handling
Evaporation
Dust Suppression
Offsite Discharge
Consumption
Onsite Storage
ΔS = 2860
Rainfall & Runoff
Water Import
Potable Treatment
Sewerage Treatment
Myall Creek
Oakey Creek
Lagoon Creek
Tributaries
Active Mine Pits
Backfill ΔS = 69
Oakey Creek Alluvium
ΔS = -457
Tertiary Basalt
ΔS = -549
ΔS = -379
Upper Walloon Coal Measures
Myall Creek Alluvium
ΔS = -143
Lower Walloon Coal Measures
ΔS = -19
Marburg Sandstone
ΔS = -217
432
290
5280
4990
735
432
0
0
740
2490
2
9
9
122
317
235
78
4
9
46
11
5271
4544
2631
2344
7545
3710
1563
32
230
126
132
620
926
917
484
4365
25972
1199
60
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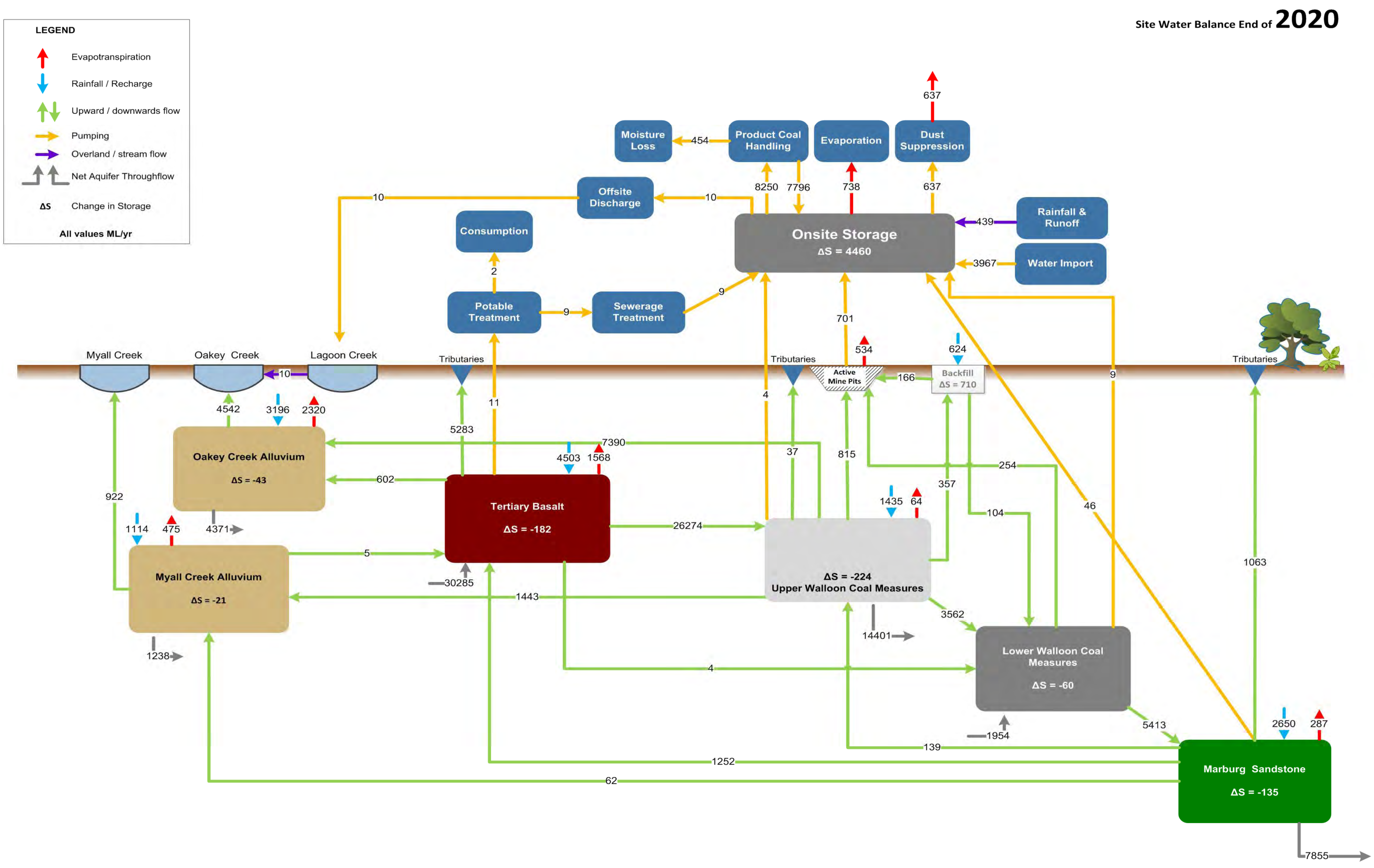
245
139
1132
63
7827


Site Water Balance End of 2020
LEGEND
Evapotranspiration
Rainfall / Recharge
Upward / downwards flow
Pumping
Overland / stream flow
Net Aquifer Throughflow
ΔS Change in Storage
All values ML/yr
Moisture Loss
Product Coal Handling
Evaporation
Dust Suppression
Offsite Discharge
Consumption
Onsite Storage ΔS = 4460
Rainfall & Runoff
Water Import
Potable Treatment
Sewerage Treatment
Myall Creek
Oakey Creek
Lagoon Creek
Tributaries
Active Mine Pits
Backfill ΔS = 710
Oakey Creek Alluvium ΔS = -43
Tertiary Basalt ΔS = -182
Upper Walloon Coal Measures ΔS = -224
Myall Creek Alluvium ΔS = -21
Lower Walloon Coal Measures ΔS = -60
Marburg Sandstone ΔS = -135
637
454
8250
7796
738
10
439
3967
2
9
701
534
624
166
4542
3196
2320
5283
11
4
37
815
254
7390
4503
1568
602
922
1114
475
4371
26274
357
1435
64
104
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2650
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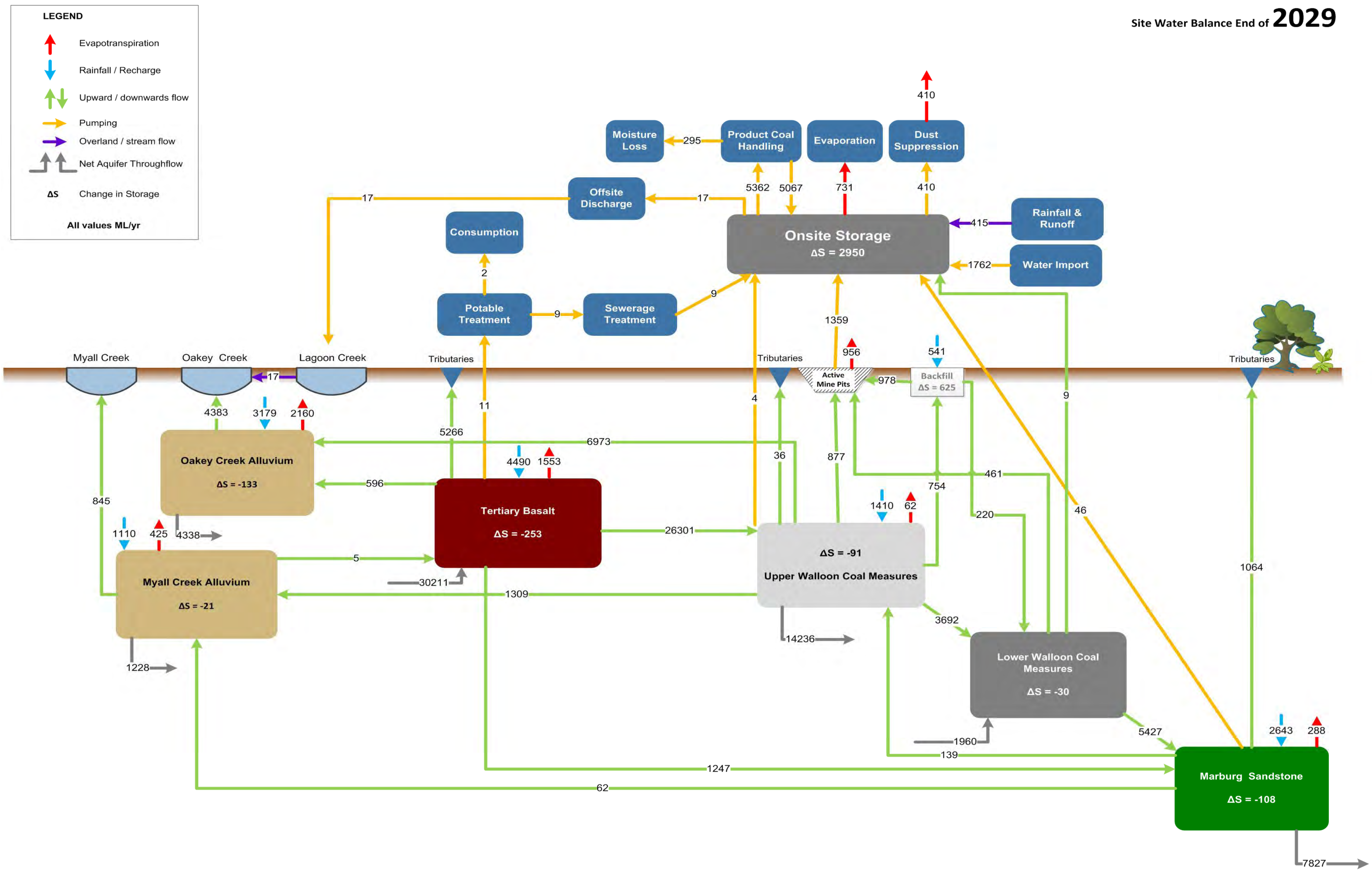
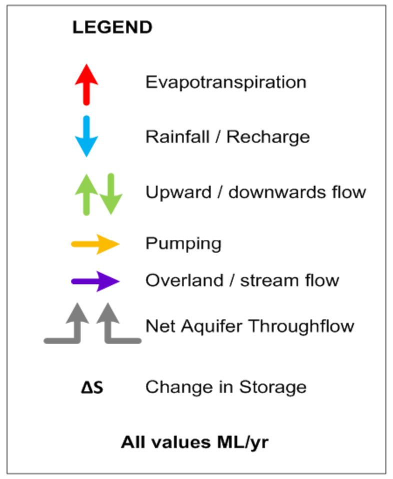
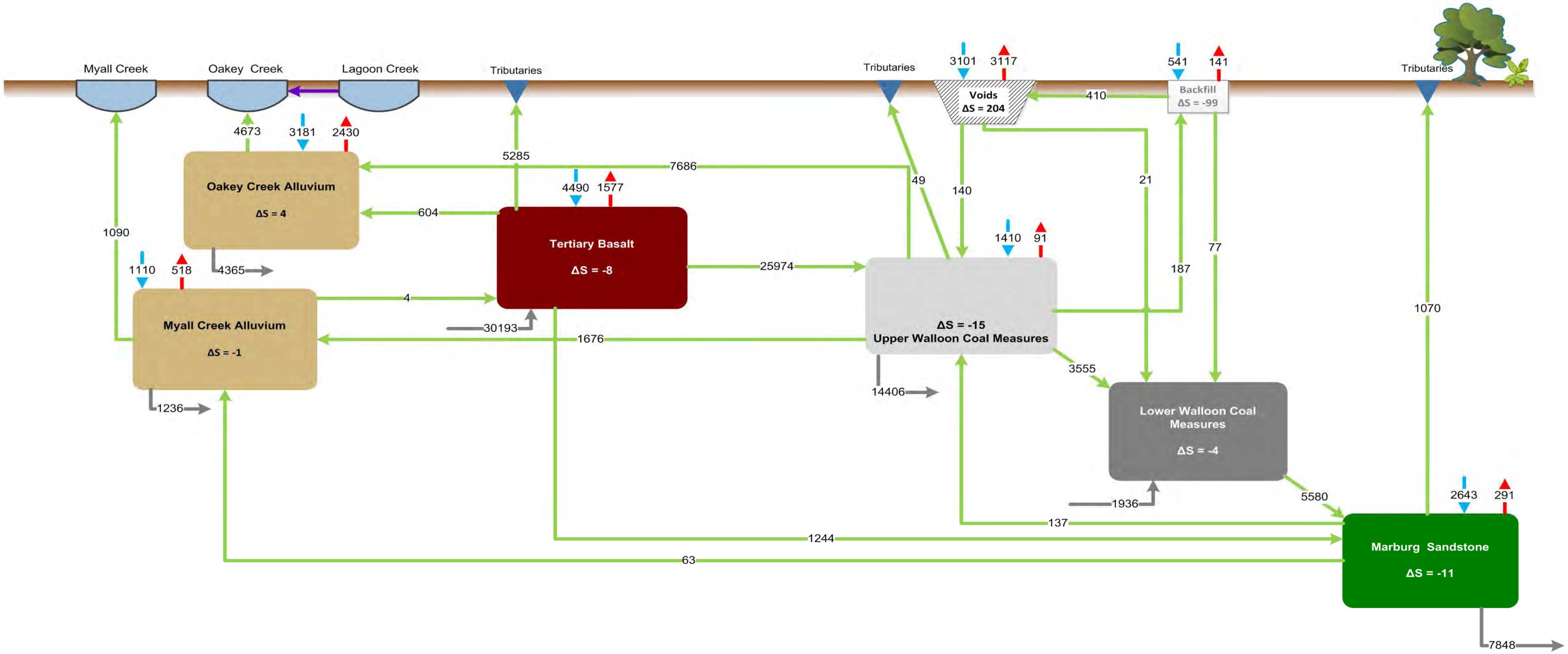
1954
139
1252
62
7855


LEGEND
Evapotranspiration
Rainfall / Recharge
Upward / downwards flow
Pumping
Overland / stream flow
Net Aquifer Throughflow
ΔS
Change in Storage
All values ML/yr
Site Water Balance End of 2029
Moisture Loss
295
Product Coal Handling
Evaporation
Dust Suppression
410
5362
5067
731
410
Offsite Discharge
17
17
Consumption
Onsite Storage
ΔS = 2950
415
Rainfall & Runoff
1762
Water Import
2
Potable Treatment
9
Sewerage Treatment
9
1359
Myall Creek
Oakey Creek
Lagoon Creek
17
Tributaries
Tributaries
Tributaries
956
541
Active Mine Pits
978
Backfill
ΔS = 625
9
4383
3179
2160
11
4
5266
6973
36
877
461
4490
1553
Oakey Creek Alluvium
ΔS = -133
596
Tertiary Basalt
ΔS = -253
754
1410
62
220
46
845
1110
425
4338
26301
ΔS = -91
Upper Walloon Coal Measures
1064
5
Myall Creek Alluvium
ΔS = -21
30211
1309
3692
14236
1228
Lower Walloon Coal Measures
ΔS = -30
1960
5427
2643
288
139
1247
Marburg Sandstone
ΔS = -108
62
7827



Site Water Balance End of **Post Mining**



Appendix C. Groundwater Numerical Modelling Peer Review Report

Australasian Groundwater and Environmental Consultants Pty Ltd (AGE)

Report on

Groundwater Model Peer Review New Acland Mine - Stage 3

Prepared for

New Acland Coal Pty Ltd

Project No. G1680 June 2014

www.ageconsultants.com.au ABN 64 080 238 642

Edition	Comments	Author	Authorised by	Date
Ver 1	First draft	AMD	AMD	27/06/2014

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GROUNDWATER MODEL PEER REVIEW

NEW ACLAND MINE – STAGE 3

1 INTRODUCTION

New Acland Coal Pty Ltd (NAC) are the proponent of the New Acland Coal Mine Stage 3 Project and a wholly owned subsidiary of New Hope Corporation Ltd (New Hope). NAC currently operate the New Acland Coal Mine which is an open cut mine located approximately 35 km northwest of Toowoomba in the Darling Downs. Under the current approval, mining will cease in 2017. The proposed Stage 3 Project will extend the mine's operation to approximately 2029. The expansion area includes three mine areas (pits), Manning Vale West, Manning Vale East and Willeroo. All are located within MDL 244 and are subject of Mining Lease Application (MLA) 50232.

To undertake this extension, NAC are preparing an Environmental Impact Statement (EIS). The assessment of groundwater is an important aspect of the environmental assessment, and groundwater modelling forms a major input into the groundwater assessment for the EIS.

After a number of iterations, NAC have revised the Project to what they have termed as a 'reduced mine plan'. This peer review focuses on the revised modelling that simulates the reduced mine plan in a model that has significant improvements over the previous model.

This peer review has been conducted by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) after the modelling has taken place. AGE has not been part of the initial model planning, conceptualisation or development. AGE has provided feedback to the modelling team prior to the completion of the review, however this advice was mostly editorial and did not alter the outcomes of the modelling exercise.

2 REVIEW PROCESS

The scope of work is to carry out and undertake a technical review of the modelling. The review has utilised the Australian Groundwater Modelling Guidelines (Barnett *et al*., 2012)[1], the most current framework available to undertake the assessment.

The evidentiary basis for the review has primarily been the model report:

- Groundwater Modelling Technical Addendum, New Acland Coal, New Acland revised Stage 3 Project AEIS, 18 June 2014, Jacobs SKM – Revision 2.

[1] Barnett et al, (2012), Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra

This report is an addendum and update to the original modelling undertaken for the EIS. The report is just over 120 pages in length including numerous full page figures and three appendices. The addendum nature of the report has resulted in the absence or limited quantity of some components usually presented in a modelling report.

The reviewer has also used the following documents to provide additional information throughout the review process:

- New Acland Coal Mine Stage 3 Project – Environmental Impact Statement;
  - Chapter 6 – Groundwater;
  - Appendix G.4 Groundwater;
  - Appendix G.4.2 Landholder Bore Survey Results;
  - Appendix G.4.3 WSAA Water Quality Monitoring Report;
  - Appendix G.4.5 Groundwater Numerical Modelling Report; and
  - Appendix J.5 Groundwater Monitoring and Impact Management Plan.
- Advice to decision maker on coal mining project, IESC 2014-045, 10 April 2014; and
- New Acland Stage 3 Project, Response to IESC Advice, QE6644.044 | Version 1, 18 June 2014, Jacobs.

The review has focused on whether the model is 'fit for purpose' for the stated objectives. It examines the modelling approach and model results to determine if it is an appropriate tool for the predictions being made.

This review uses the peer review checklist provided in (Barnett *et al*., 2012)[1] and this in included in Appendix A.

3 MODEL REVIEW DETAILS

The following discussions are provided on key model components and provide background for the decisions made in the checklist (Appendix A).

The objectives for the 'updated' modelling are presented in Section 1 (Introduction of the modelling report). What is missing here is the overall objective of the modelling, for example: "to predict groundwater impacts from the proposed mining extension to the New Acland Project". Further objectives relating specifically to the model calibration are provided in Section 5.1 of the modelling report. It is suggested that clearly defined modelling objectives, not only for the specific model details, but also for identifying how the work achieves the EIS requirements would be of benefit to the report.

The key aspect to this updated modelling (over the previous EIS model) is the stochastic approach to calibration and predictions, which provide a measure of uncertainty in the range of predictions. This approach is becoming industry best practice in groundwater modelling. The resulting outputs are more appropriate for presenting modelling results to decision makers, whereby uncertainty in the model predictions can readily be evaluated.

The alternative method to the stochastic approach is the deterministic approach. This involves only one realisation of parameters, usually determined through calibrating to the observed dataset. This calibration can result in a parameter set that is non-unique, in that various combinations of correlated parameters can be assigned to arrive at the same 'level of calibration'. While the level of calibration can be consistent, there is no guarantee that this consistency will flow through to the predictions. This is particularly the case where the stresses applied in the predictive phase are not present during the calibration phase, as is usually the case with models simulating impacts from new developments and mining.

The stochastic approach accounts for this non-uniqueness by providing a number of parameter realisations that all calibrate the model. These realisations are then used as parameter sets through the predictive phase. This approach, as adopted by Jacobs, provides measure on the uncertainty in the predicted impacts.

Based on the criteria set out in Barnett *et al*. (2012)[1], the modeller has correctly identified this model as a Class 2 model – a model suitable for undertaking impact assessments. The criteria that the report quotes focuses on available data, however there are two other categories for which the assessment should be done and each category should be at least Class 2. The categories are data, calibration and prediction. The key indicators for the class definitions of the three categories can be seen in Table 2-1 of Barnett *et al*. (2012)[1]. After assessment of these criteria, it is the reviewer's opinion that the model does satisfy at least Class 2 for all three categories. Evidence for this assessment is provided throughout the following discussions.

3.1 Conceptual Model

The chosen model layers are adequate for the discrete simulation of the key identified geological units. The key hydrogeological processes that form the discharge and recharge components of the water balance are identified and captured, and these are discussed below in Section 3.4.

The model report provides a conceptual block diagram highlighting the system inputs and outputs (see Fig 3-1 of the model report). It does not provide quantification of the estimated bulk water movements into and out of the model domain. Ideally these inputs and outputs are quantified to identify the range of likely flows. This aids in assessing the numerical model's success in representing the conceptual model.

The conceptual model has been developed on geological data sourced from drilling logs and from the SRK geological model. The SRK data is currently considered the most comprehensive dataset for the Surat Basin. The division of this multilayered geology into only five layers may be considered an over simplification, however it does provide a model with more vertical connection than is likely and hence provides conservative estimates of drawdowns in the units above a below the target coal measures.

The identified boundary conditions interacting with the model domain (recharge, surface drainage, rivers, and evapotranspiration) cover the key bulk water movements. The report indicates that flooding has not been simulated. The transient observation data confirms this to be an appropriate assumption as none of the water level records show significant or sudden increases due to such an event.

Available data to undertake the conceptualisation satisfies all the characteristics suggested for a Class 2 confidence level.

3.2 Software

The groundwater flow modelling is undertaken using MODFLOW SURFACT. This is a commercial version of the industry standard MODFLOW code (distributed by the United States Geological Survey – USGS), with additional functionality. SURFACT is distributed by HydroGeoLogic (HGL). One key function of SURFACT is the ability to simulate unsaturated conditions, which is critical for mine dewatering simulation in most cases. It also comes with more robust numerical solvers and adaptive time-stepping to assist in progressing the numerical solution through difficult situations.

The report also indicates the use of in-house programs for the generation of the stochastic parameters and the constraints. The reviewer has not assessed this software as it is a simple data processing program and it does not require review.

3.3 Model Grid and Structure

The model grid adopted by Jacobs is appropriate for impact prediction from the proposed mine. The model dimensions suggest external boundaries are located a sufficient distance to limit the constant heads from influencing predictions. The model grid comprises 168 rows and 132 columns, with 22,176 cells per layer. The grid dimensions vary with cells around the mine refined to 200 m x 200 m, increasing to 400 mx 400 m. The refined cells around the mine are likely to be sufficiently small enough to represent annual mining in adequate detail.

3.4 Boundary Conditions

3.4.1 Extent of Model and Constant Heads

Constant head cells have been applied surrounding the majority of the model domain. This is a necessary assumption supported by the fact that the geology is continuous and extensive outside the model domain. The continuous groundwater movement (either into or out of the model domain) is captured by the application of constant head cells.

Constant head boundary conditions have been derived from the relationship between the observed water level and natural surface elevation. This is an appropriate assumption as undisturbed groundwater water levels often follow topography. For the Walloon Coal Measures and the Marburg Sandstone this relationship is strong. However, for the Tertiary basalt the relationship is not as strong. This is a function of the heterogeneity of the fracture zones within the basalt, and the potential for groundwater in the basalt to perch above the regional water table. It is noted that the adopted line of best fit (Figure 4-7 of the modelling report) accounts for the potential for higher water levels to be perched, and also avoids lower water levels that could be impacted by pumping. This assumption for the basalt is considered appropriate despite the low correlation.

One further confirmation for the limited influence of the fixed heads on model predictions is the change in boundary flows throughout the model run (calibration and predictions). The inflow and outflow components are not presented in the report beyond the steady state model, as only the net of the fixed head is supplied for the predictions (Figure 6-2 of the modelling report). Given that the net constant head cells do not show a response to the predicted mining, it is reasonable to conclude the constant head boundary conditions are not influencing the model predictions unduly.

The steady state budget shown in Table 5.3 of the modelling report shows an obvious dominance of the constant heads within this balance. It should be noted that these large volumes (200+ ML/day) include the flow between adjacent fixed head cells, and are not indicative of the true interaction with the internal model domain. There is a switch within the SURFACT code that removes this from the modelled water budget. Details of this have been provided to Jacobs and the water budget will likely be corrected in subsequent versions of the model report.

3.4.2 Faults

Horizontal flow barriers (referred to by Jacobs as ‘Walls’) are used to represent the influence of faults in compartmentalisation of the geological units. They have been conservative by not applying these to the model layer representing the Marburg Sandstone, and this approach is considered appropriate.

However, what is not clear from the report is the source used for determining the location of the faults. It is assumed that these are based on geological data; however the report is lacking a map to show the location of these faults.

It is often difficult to determine the hydraulic nature of fault, particularly whether it is a barrier to flow or a conduit to flow, without a detailed geological investigation. Jacobs have justified the inclusion of faults as barriers based on the initial calibration of the model and the ability to better match observation data with the faults simulated rather than removed.

3.5 Parameters

The ranges of parameters tested for the calibration are shown in Figures 5-5 to 5-10 of the modelling report. This data is also presented in Appendix B of the modelling report, where the frequency distributions of the tested parameters are provided. These ranges are considered appropriate and typical of the parameter ranges applied in similar models within the Surat Basin, such as the parameters adopted for the OGIA groundwater model[2].

The approach to generating random parameter sets for use in the stochastic analysis has been supported by the inclusion of rules to appropriately constrain relative parameters based on the conceptualisation. For instance the vertical hydraulic conductivity of the alluvium should be less than the horizontal hydraulic conductivity. Likewise the recharge to the alluvium is likely to be higher than the recharge rate to the Walloon Coal Measures. This application of constraints has occurred through Jacob's own in-house software.

3.6 Calibration

Rather than undertake a standard deterministic approach to the calibration of the model, stochastic techniques have been used to provide a range of parameters that satisfy calibration criteria. The criterion is a scaled RMS of less than 5%. This measure is adequate for the definition of calibration.

The target observation data used for the steady state and transient calibration is ideal as it offers a mix of water levels and flows to calibrate against. Mixing the observation types reduces non-uniqueness of the parameter set. The water level observation data has been analysed and each observation has been assigned a weighting based on confidence in the measurement (Table 5.2 of the modelling report). The flow observations are limited to estimated pit inflows for two observations.

Jacobs have provided the steady state and transient scatter diagrams for the 'best calibration' set of parameters. Subjectively, it can be concluded that the model is adequately calibrated. It would be worthwhile to see the corresponding 'worst calibrated' set of parameters that still meet the criteria to assess the potential spread or scatter of the calibrated data.

The best calibrated steady state water budget shows a dominance of flow to the constant head boundary. As discussed earlier, this is likely to be an accumulation of flow between adjacent constant head cells, and is therefore not indicative of the true transfer of water between the model domain and these external boundary conditions.

The calibration has not matched all observation data across the model domain, as indicated in the transient hydrographs presented in Appendix A of the modelling report. No detailed discussion on these hydrographs is provided in the report, though it appears that some of the hydrographs are

[2] GHD, 2012, *Surat Cumulative Management Area Groundwater Model Report*. Prepared for the Queensland Water Commission.

showing impacts from mining, and generally this aspect is replicated in magnitude and timing (not always in absolute elevation). Given these results, the calibration component of the confidence level classification can be assigned to Class 2.

3.7 Predictions

3.7.1 Representation of Mining within the Model

Open cut mining proposed for the Project will result in the storage of spoil in pit. These changes to the groundwater regime have been simulated within the model through the SURFACT Time Variant Parameter (TMP) package. The documented changes for the spoil and the void are plausible, although the spoil properties are at the upper end of the likely range. The true value will depend on how the spoil is deposited and how much compaction takes place as it is built up over time. This technique of changing parameters throughout the simulation is considered appropriate.

At the completion of mining the remaining voids will start recovering to form a pit lake. This has been simulated in the model using the ‘high-k’ lake approach. There are other options for representing these voids, however the high-k lake simulation is considered appropriate for this impact assessment.

The predictions made by the model are over a 17 year period (for mining), while the calibration period is 11 years. The model run time is less than 3 times the calibration period, meaning that this aspect of the modelling has exceeded the Class 2 requirements and achieved a confidence level classification of Class 3.

3.7.2 Presentation of Results

To assess the extent of impact from the Project, Jacobs have simulated a ‘null’ model to provide a background from which the predicted impacts for the proposal can be isolated. This ‘no-mine’ simulation means that some of the simplifying assumptions made in the conceptualisation are nullified, as these assumptions exist in both models. This is likely true of the groundwater extraction from the alluvium that was not simulated due to uncertainty in the true pumping rates. Whether in or out of the model, if the approach is consistent in both ‘mine’ and ‘no-mine’ models then the predicted drawdowns would show no material difference.

The predictions are provided for the key model layers for key model output times. While there is a lot of model output presented graphically, there are no qualifying statements and no critical discussion of the results. During the review phase, questions were raised regarding the predicted drawdown in the Lagoon Creek alluvium away from the mine. It was only after discussion with the modelling team that it was apparent that the upper parts of the alluvium were dry.

The same issue occurs in the basalt, where initially the drawdown presented seems erroneous given it is isolated from the mining areas. However, careful examination of the water level contours for the basalt (Figures 6-8 to 6-11 from the modelling report) indicates that there are large parts of the basalt that are normally dry. This aspect could have been better communicated to the reader through some discussion in the report text.

Some discussion on model results has been provided in the response to IESC Advice, however this is limited, and does not contain the detail required for the reader to appreciate the predictive capacity of the model and to understanding any anomalous results being presented.

Where possible, Jacobs have presented the median (most likely) result from the stochastic simulations, as well as results representing one standard deviation above and below these results.

This provides the decision makers with a sense of the prediction capacity of the model and reliability of the results.

The use of one standard deviation for the presentation of the results is appropriate, as beyond this the model parameter sets become more extreme and less likely. This is a compromise between presenting the most likely scenario, while not giving undue credence to extreme parameter values.

Impacts on existing users are not presented in the report. There are tables that appear in more recent responses to government agencies that present this data; therefore it is unclear why it does not appear in this report. It is assumed that the model has been used for this analysis and it is an output of this model.

The current modelling predicts recovery in the void areas post mining. Once mining and dewatering activities cease, the groundwater levels in the adjacent areas recover. The model simulates the groundwater recovery post mining for a period of 300 years. This provides sufficient time for the lakes that will form in the voids to reach equilibrium (generally within 200 years). The recovery rates are provided for the most likely and for one standard deviation either side, and these seem realistic given a uniform climatic assumption. The surprising result from this is that the Willeroo pit will more than likely recover to a higher groundwater level than the predicted pre-mining level. There is also a possibility that the Mannering East pit lake will reach an equilibrium level that is above the pre-mining level. Key to this result is the amount of potential runoff applied. The adopted values for runoff to each final void are not reported, though it is noted that these estimates have been sourced from the surface water assessment.

The high recovered post mining water levels are recognised in the report text, and context is added indicating that the model will undergo further updates as more data is collected through mining. Subsequent to this, a more detailed final void study will be undertaken and management strategies will be derived to ensure there is no long term effect to surrounding water quality.

The inclusion of faults in the model has had an obvious control on the shape and extent of the predicted drawdowns in the Walloon Coal Measures. However, this restriction does not seem to impact the shape and extent of drawdown in the Marburg Sandstone, nor the predicted drawdown occurrence in the overlying basalt and alluvium.

3.8 Uncertainty Analysis

The stochastic approach to the modelling has provided the outcomes to assess the model uncertainty. Instead of providing a single deterministic solution, a plausible range of predictions have been presented, with the recognition that there is uncertainty in any model parameter set adopted by the model.

Jacobs have provided model predictions for the median simulation of the range of predictions undertaken. They have also presented the 16th and 84th percentile simulations runs (i.e. one standard deviation) to provide an indication of the likely uncertainty of the median prediction. This provides decision makers with a gauge to the model's performance and potential error.

Uncertainty has been presented for the key model outputs, those being the extent of predicted drawdown, the predicted inflow to the void, and the long term water level recovery (although this was not strictly discussed in the Section 7 of the modelling report).

3.9 Conclusions to Model Report

The conclusions to the modelling report are considered limited and there is not enough discussion about the results. The conclusions require a clear link back to the model objectives and discussion on how the outcomes address the model objectives. This can be inferred to some extent, however it should not be left up to the reader.

The lack of discussion may be due to the nature of the report (that is an addendum) where discussion appears elsewhere. However, the report should still summarise the modelling with a proper discussion of results. Value judgements need not be made, but factual discussion would assist readers to understand the results of the modelling.

4 CONCLUSION

Assessment of the modelling approach, calibration and predictions (including provisions of uncertainty in the presented predictions) leads to the conclusion that the model is appropriate and 'fit for purpose' for the objective of assessing the potential groundwater impacts resulting from the New Acland Stage 3 Project.

The model has been built on appropriate assumptions given the data that is available. The extent of predicted drawdown and the magnitude of predicted pit inflows are plausible, and typical of the magnitudes seen in other models simulating similar developments in similar layered hydrogeological regimes.

Numerical modelling generally results in numerous realisations and simulations and it is often difficult to determine what results to present. Identifying the best calibrated parameter for the presentation of water budgets and scatter diagrams, and using the median and one standard deviation simulations was considered appropriate.

The reporting of the model would be improved by providing more critical discussion on the model results and clearer definition of objectives. However, this does not change the appropriateness of the model development, calibration and predictions for the groundwater impacts assessed for the New Acland Stage 3 Project.

AUSTRALASIAN GROUNDWATER AND ENVIRONMENTAL CONSULTANTS PTY LTD

ANDREW DURICK
Principal Groundwater Modeller / Director

Appendix A

PEER REVIEW CHECK LIST

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
1. PLANNING		
1.1 Are the project objectives stated?	Yes	The objectives of the additional modelling that the addendum addresses are stated in the introduction.
1.2 Are the model objectives stated?	Yes	Stated throughout the report, but should be clearly identified in a separate section for more clarity
1.3 Is it clear how the model will contribute to meeting the project objectives?	Yes	Not stated clearly in the addendum modelling report, but the framework is presented in the Groundwater Chapter of the EIS where it states "the undertaking of numerical modelling to estimate the likely effects of the revised Project on groundwater levels".
1.4 Is a groundwater model the best option to address the project and model objectives?	Yes	Need to identify potential impacts from the proposed mining on the adjacent groundwater regimes.
1.5 Is the target model confidence-level classification stated and justified?	Yes	Stated in reference to the previous model – assigned a Class 2 based on available data and model approach. Class 2 is suitable for impact assessment. Peer review agrees that the current model satisfies the conditions of a Class 2 model – aquifer impact assessment model.
1.6 Are the planned limitations and exclusions of the model stated?	Yes	Simulation did not include the simulation of floods and quantitative calibration to baseflow.
2. CONCEPTUALISATION		
2.1 Has a literature review been completed, including examination of prior investigations?	No	Not available in the model report, and limited in the original groundwater chapters of the EIS.
2.2 Is the aquifer system adequately described?	Yes	
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Yes	The key hydrogeological units have been identified
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Yes	The surface geology is available as backgrounds to numerous maps in the report. There is no mapping provided for the adopted faults, only their locations on a map showing model boundary conditions.
2.2.3 aquifer geometry including layer elevations and thicknesses	Yes	Isopachs of the assigned geological units are provided

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Yes	Discussed in Section 3 for the various hydrogeological units
2.3 Have data on groundwater stresses been collected and analysed?	Yes	
2.3.1 recharge from rainfall, irrigation, floods, lakes		Recharge mechanisms for the various geological units has been discussed.
2.3.2 river or lake stage heights	Yes	It is assumed that gauge data has been used in the preparation of the RIV package, however the report does not provide details on the RIV package beyond its location and the calibration of the conductance terms for the two major creeks. The report does note the use of streamflow data from gauge 422359A on Oakey Creek.
2.3.3 groundwater usage (pumping, returns etc)	Yes	Given difficulty in assigning extraction rates from the allocation data from DERM, and the approach to the predictions using a corresponding 'no-mine' simulation, the extraction for existing users was not simulated. Extraction at the minesite was included in the model for the transient calibration.
2.3.4 evapotranspiration	Yes	Data from the BOM has been processed and used in the model for the generation of the EVT package.
2.3.5 other?		
2.4 Have groundwater level observations been collected and analysed?	Yes	Data has been tabulated and assigned weighting for the calibration.
2.4.1 selection of representative bore hydrographs	No	All available data has been used
2.4.2 comparison of hydrographs	No	Not discussed
2.4.3 effect of stresses on hydrographs	No	Not discussed
2.4.4 watertable maps/piezometric surfaces?	No	The model report does not contain any contour maps of observed water levels.
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	NA	
2.5 Have flow observations been collected and analysed?	Yes	Mine inflow rate estimates have been used as calibration targets for the calibration
2.5.1 baseflow in rivers		
2.5.2 discharge in springs	NA	
2.5.3 location of diffuse discharge areas?		

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
2.6 Is the measurement error or data uncertainty reported?	No	Not discussed
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	No	Not discussed
2.6.2 spatial variability/heterogeneity of parameters	Yes	Considered when assigning the constraints to the parameter ranges for the stochastic calibration.
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	No	Not discussed
2.7 Have consistent data units and geometric datum been used?	Yes	
2.8 Is there a clear description of the conceptual model?	Yes	
2.8.1 Is there a graphical representation of the conceptual model?	Yes	
2.8.2 Is the conceptual model based on all available, relevant data?	Yes	
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Yes	
2.9.1 Are the relevant processes identified?	Yes	
2.9.2 Is justification provided for omission or simplification of processes?	Yes	
2.10 Have alternative conceptual models been investigated?	Yes	On a parameter / calibration basis through the stochastic approach
3. DESIGN AND CONSTRUCTION		
3.1 Is the design consistent with the conceptual model?	Yes	
3.2 Is the choice of numerical method and software appropriate?	Yes	MODFLOW SURFACT is the industry standard approach to simulation of mining impacts on a regional scale.
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	There is an indication on Figure 4-1 that the transition zone from the refined grid to the larger grid has adjacent cells that are greater than the 1.5x rule of thumb, but the model is stable. The solver used is not reported, however the percent discrepancy from key simulations indicates adequate convergence and solutions are achieved.
3.2.2 Is the software reputable?	Yes	SURFACT is industry standard. Jacobs have applied in-house code for preparation and management of the stochastic simulations that does not need verification.

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
3.2.3 Is the software included in the archive or are references to the software provided?	NA	
3.3 Are the spatial domain and discretisation appropriate?	Yes	
3.3.1 1D/2D/3D	Yes	Pseudo 3D modelling has been undertaken with SURFACT.
3.3.2 lateral extent	Yes	Domain has been chosen to extend beyond the expected impacts and has encapsulated the nearest groundwater users and groundwater systems for evaluation of impacts.
3.3.3 layer geometry?	Yes	Geological information has been taken from the SRK dataset which is the most appropriate dataset available.
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Yes	Refinement across the mining area at 200 metres provides enough detail to simulate the mine progression on a yearly basis.
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Yes	The Walloon Coal Measures are divided into upper and lower sections.
3.4 Are the temporal domain and discretisation appropriate?	Yes	
3.4.1 steady state or transient	Yes	Both simulations are undertaken
3.4.2 stress periods	Yes	Not mentioned in report – but confirmed through discussions with modeller. Transient stress periods for the historical and predictive mining simulations are yearly. This is appropriate as the observation data being calibrated to does not contain a seasonal pattern. The recovery simulation uses one stress period of 300 years.
3.4.3 time steps?	Yes	Not mentioned in report – but confirmed through discussions with modeller to be controlled by the ATO package of SURFACT.
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Yes	At the model extent, constant head conditions are sufficiently distant from the area of key predictions and well outside of the extent of impacts.
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Yes	

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Yes	Fixed boundary conditions are located sufficiently distant to the areas of key predictions. Other boundary conditions are varied in the stochastic approach; therefore their values vary within the range of parameters adopted in the calibration set.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	The zonation of recharge is based on surface geology and the assigned value is variable within the calibrated datasets, but constrained to plausible ranges.
3.5.4 Are lateral boundaries time-invariant?	No	Constant head elevations do not vary, but the volume removed or added to the model domain changes with time as the heads within the model domain vary with other
3.6 Are the initial conditions appropriate?	Yes	Represent pre mining water levels, though the resulting heads are not presented for any of the calibrated realisations
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?		Groundwater modelling (steady state)
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	Yes	Initial conditions are generated through steady state simulation, which is then followed by a transient simulation before the predictions are made.
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	NA	
3.7 Is the numerical solution of the model adequate?	Yes	Details of the solver and solver settings are not documented, however the percent discrepancy of the steady state and a transient simulations are reported and indicate adequate numerical solution
3.7.1 Solution method/solver	No	Not documented
3.7.2 Convergence criteria	No	Not documented
3.7.3 Numerical precision	No	Not documented
4. CALIBRATION AND SENSITIVITY		
4.1 Are all available types of observations used for calibration?	Yes	
4.1.1 Groundwater head data	Yes	All water level observations available are used in the calibration of both a steady state and transient model simulation.

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
4.1.2 Flux observations	Yes	Estimated mine inflows for a short period of the calibration
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	NA	
4.2 Does the calibration methodology conform to best practice?	Yes	Stochastic instead of deterministic.
4.2.1 Parameterisation	Yes	Parameters are distributed uniformly within each geological unit, which is appropriate for regional scale impact modelling
4.2.2 Objective function	Yes	A target scaled RMS (< 5%) has been used as criteria to define calibration for the stochastic simulations.
4.2.4 Which methodology is used for model calibration?		Calibration is stochastic rather than deterministic, resulting in a number of parameter realisations that calibrate the model
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Yes	Through the stochastic approach to the calibration a range of parameters are assessed against
4.3.2 boundary conditions	Yes / No	Boundary conditions involved in the calibration have consequently addressed sensitivity through the modelling approach
4.3.3 initial conditions	Yes	Initial conditions are generated through steady state runs. Changes in hydraulic conductivity and some boundary conditions are propagated through the whole model during the stochastic simulations.
4.3.4 stresses	Yes	Recharge and some boundary condition fluxes are varied during the calibration and consequently through the predictions
4.4 Have the calibration results been adequately reported?	Yes	Partially reported – calibrated parameter sets satisfying criteria are presented in Appendix B, however the parameter dataset that provides the best calibration is not presented. The statistical summaries for the min, max and median datasets that satisfy calibration are tabulated and the steady state and transient scatter diagrams are presented.
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	Yes	Appendix A for transient hydrographs

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	No	It is not clear. Some transient hydrographs have not calibrated well, but it isn't readily apparent where these are to determine if this is a vertical gradient issue.
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	Statistics are provided for the best achieved calibration and across the range of calibrated models. The best calibration fit is also shown in scatter diagrams
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Yes	Both scatter diagram and transient hydrographs are presented. The level of transient calibration achieved is not ideal, however a lot of these transient
4.5.1 spatially	Yes	Scatter diagrams are presented, but no maps of residuals. – Difficult as the "calibrated" model involves numerous runs.
4.5.2 temporally	Yes	Transient hydrographs
4.6 Are the calibrated parameters plausible?	Yes	The ranges of possible parameter values to calibrate the model are constrained to plausible values. The relative ranges between parameters are also constrained so unrealistic combinations of parameters are avoided.
4.7 Are the water volumes and fluxes in the water balance realistic?		Steady state water budgets are tabulated and the transient calibration period water balance net values are plotted against time. The dominance of the throughflow in the water balance is concerning, though this is likely includes the accounting of flow between neighbouring fixed heads. The net throughflow from the fixed heads is plausible.
4.8 has the model been verified?	No	No verification runs were undertaken.
5. PREDICTION		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Yes	DRN boundary condition is used to simulate the dewatering
5.2 Is predictive uncertainty acknowledged and addressed?	Yes	The stochastic approach to the calibration is followed through to the predictions where the parameter sets that met the calibration criteria are used to undertake the predictions
5.3 Are the assumed climatic stresses appropriate?	Yes	

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
5.4 Is a null scenario defined?	Yes	A corresponding 'no mine' simulation is used to predict the groundwater behaviour of ;no-mining'. This is then used with the corresponding 'mine' prediction to identify the extent of impacts due to the proposal
5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Yes	
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	NA	
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	NA	
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	Yes and No	The transient calibration period is 2003 to 2013 (11 years), while the predictions for mining are from 2013 to 2029 (17 years), therefore these periods are considered comparable. The model also simulates groundwater recovery which extends the simulation out to 2330 (300 years of recovery). There is no reference to the reduced certainty of these later recovery predictions, however Jacobs have supplied the predictions for a range of parameters.
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Yes	Propagation of the impacts are expected to be slow and the annual stress periods that have been chosen are appropriate for this.
5.6 Do the prediction results meet the stated objectives?	Yes	Predictions of the potential range of impacts from the proposed project are produced from the modelling
5.7 Are the components of the predicted mass balance realistic?	Yes	Only the transient water balance for the simulation with the best calibration is provided and this is plausible. It is not known if the water budgets for the other calibrated parameter realisations are comparable to the presented data.
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	NA	
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	NA	No impacts are predicted on the adjacent creeks, although it is noted that no magnitude of total stream flow is reported.

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	No	In the water budget data provided in the report there is nothing that stands out as anomalous. It is possible that the EVT package has been assigned to areas where surface drainage (RIV or DRN package) is applied. The EVT extinction depth is variable within the stochastic runs and some of the deeper extinction depths could intercept water that would be exchanged if the RIV heads and DRN reference elevations are shallower. However the range of possible budgets for all simulations are not presented in the report.
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	The possible depths of recharge are capped at an upper limit of $1e^{-4}$ m/day. This means it is less than or equal to 0.1 mm/day, which at most would equate to 36.5mm/year – well below annual rainfall (~630mm/year)
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	No	
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	NA	
6. UNCERTAINTY		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Yes	The stochastic approach to calibration of the model has been applied to the predictions and the resulting range of predictions (± 1 SD) are presented for key outputs.
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	No	All simulations the satisfy the calibration criteria for the stochastic simulations undertaken were used for providing the reported prediction range.
6.3 Are the sources of uncertainty discussed?		
6.3.1 measurement of uncertainty of observations and parameters	No	
6.3.2 structural or model uncertainty	No	
6.4 Is the approach to estimation of uncertainty described and appropriate?	No	
6.5 Are there useful depictions of uncertainty?	No	
7. SOLUTE TRANSPORT		

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	NA	
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	NA	
7.3 Is the choice of numerical method and software appropriate?	NA	
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	NA	
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	NA	
7.6 Are the solver and its parameters appropriate for the problem under consideration?	NA	
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	NA	
7.8 Has an assessment been made of the need to consider variable density conditions?	NA	
7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	NA	
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	NA	
7.11 Is the calibration based on meaningful metrics?	NA	
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	NA	
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	NA	
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	NA	
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	NA	
8. SURFACE WATER–GROUNDWATER INTERACTION		
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	

Table A- 1: PEER REVIEW CHECK LIST		
REVIEW QUESTIONS	**YES/ NO**	**COMMENT**
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Yes	Limited data available. Given the given proximity to impacts, the representation through the RIV package of the major creeks (Myall and Oakey) is considered appropriate.
8.3 Is the groundwater model coupled with a surface water model?	No	No need in this instance
8.3.1 Is the adopted approach appropriate?	NA	
8.3.2 Have appropriate time steps and stress periods been adopted?	NA	
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	NA	