KEPCO KOREA ELECTRIC POWER CORPORATION
BYLONG AUSTRALIA

BYLONG COAL PROJECT

Environmental Impact Statement

Supplementary Response to Submissions

August 2016

2

Appendices
J-M

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

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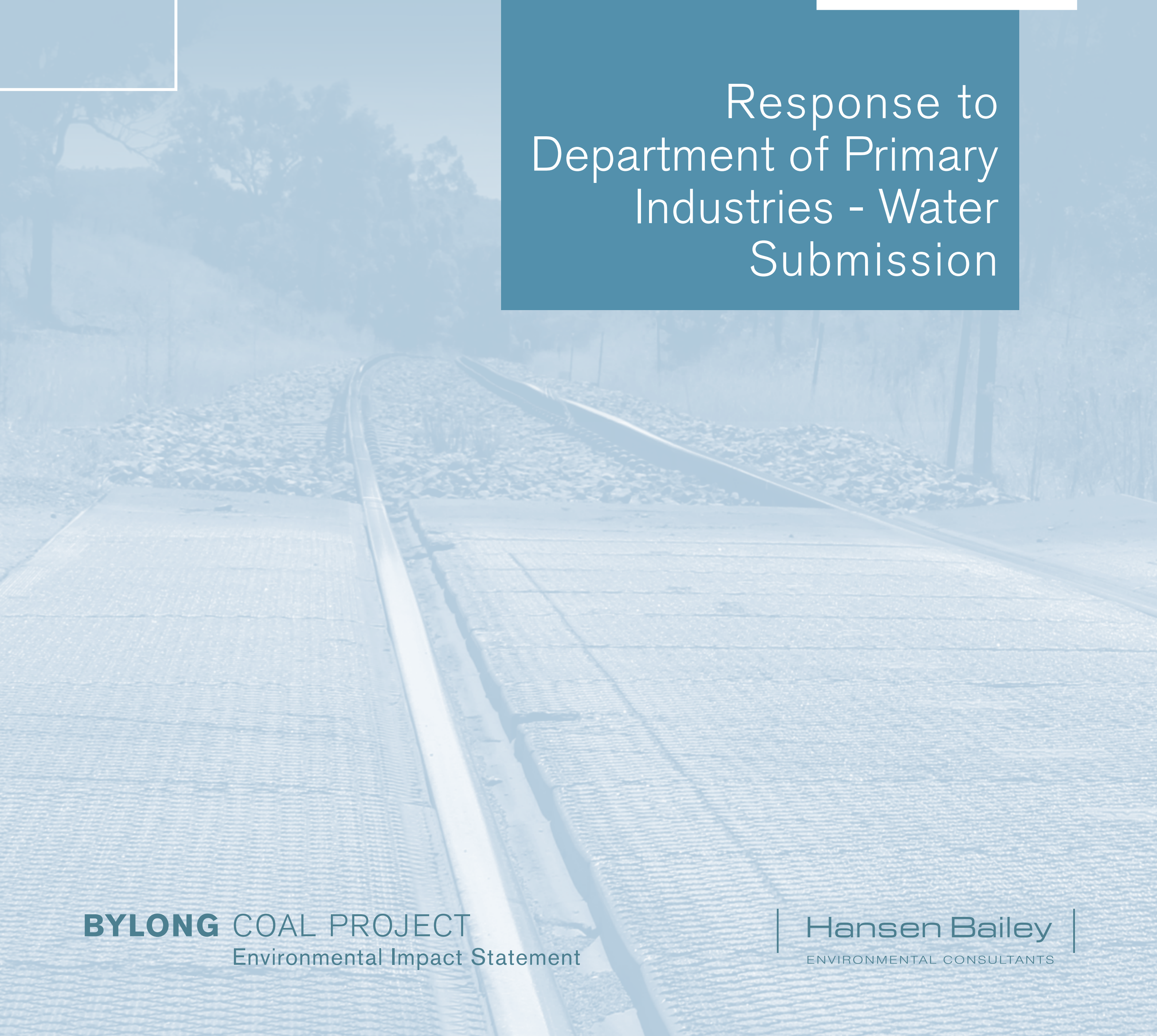
Response to Department of Primary Industries - Water Submission



17 August 2016

Team Leader
Planning Assessment
22-33 Bridge Street
SYDNEY NSW 2000

Attention: Mr Stephen O'Donoghue

Dear Steve,

Bylong Coal Project
Response to Department of Primary Industries – Water Submission, Dated 12 May 2016

1. INTRODUCTION

The '*Bylong Coal Project Environmental Impact Statement*' (EIS) which supported Development Application (SSD) 14_6367 for the Bylong Coal Project (the Project) was placed on public exhibition between 23 September and 6 November 2015.

Hansen Bailey prepared the document '*Bylong Coal Project Response to Submissions*' (RTS) dated 23 March 2016 to address comments received from agencies and other stakeholders during the exhibition of the EIS. The RTS included responses to the NSW Department of Primary Industries – Water (DPI–Water) submission dated 11 November 2015 in relation to water matters. During the period of preparing the RTS, a phone conference meeting was held with DPI–Water on 25 November 2015 to clarify issues raised in its submission.

DPI-Water reviewed the RTS and provided a further letter dated 12 May 2016 to the Department of Planning and Environment (DP&E) over various matters addressed in previous correspondence and queries remaining with the RTS. This letter has been prepared to respond to DPI–Water comments within letter of the 12 May 2016. It should be noted that a separate response has been provided to the comments made by DPI–Agriculture, which are also included in DPI's letter of 12 May 2016.

A meeting was held with DPI-Water on 27 May 2016 to present the results of the borefield pump testing program as explained within the RTS document and to discuss the DPI-Water submission dated 12 May 2016. A further meeting was held with DPI-Water via phone conference on 25 July 2016 to provide an update on the additional groundwater modelling undertaken to address DPI-Water and DP&E's Peer Reviewers comments. This letter includes reference to the discussions held during these meetings where relevant.

2. RESPONSE TO DPI-WATER SUBMISSION

2.1 DPI-WATER OUTSTANDING ISSUES

DPI Water has reviewed the information provided by the proponent and considers the entire body of work presents an adequate understanding of the project, along with the hydrology and hydrogeology. The associated impacts on water dependent assets were previously assessed against the minimal impact considerations of the Aquifer Interference Policy. No registered water users were indicated to fall within a Category 2 minimal impact consideration (less productive) and the independent groundwater modelling reviewer has assessed the model and concluded the model to be fit for purpose according to the framework of the Australian Groundwater Modelling Guidelines.

Notwithstanding, several issues that DPI Water noted previously remain and require further clarification or work – these are described hereunder. The issues are reproduced from DPI Water's comments regarding the Environmental Impact Statement. Additional issues raised by DPI Water hydrogeologists as part of this review of the latest reports and data are also included and the latest DPI Water response to the RTS is provided.

Response

Noted. Each issue is responded to below.

Issue A

The proponent should provide a more comprehensive assessment of the potential impacts that may result from the reduction in availability of groundwater to agriculture during dry years.

DPI Water advises that the water security to the project during extended drought periods remains uncertain and this warrants further consideration by the proponent.

DPI Water Response to RTS:

Further information required.

The Proponent has performed additional modelling including a new sensitivity analysis and has agreed that the potential to reduce the availability of groundwater to agriculture during dry years is likely.

The analysis in Figure 41 showed that the impacts on other landholders' bores can exceed 2 m drawdown and on the Tinka Tong property (can attain between 2m and 10 m drawdown. The model is sensitive to a number of parameters and there remains uncertainty as to the validity of its outputs and the degree of fitness for purpose.

In relation to other water users DPI Water asserts the model cannot be relied upon to make satisfactory predictions about reliability of supply to other users and therefore the proponent should commit to proposed make good measures for affected properties at the onset of mining.

The reasons for uncertainty about modelling outputs are further discussed in relation to Issue G, below.

The proponent has provided the following response in relation to project water supply which is considered satisfactory:

Ultimately if the borefield cannot sustainably supply the required make up water during drought then KEPCO will implement measures described within the Water Management Plan. This may include purchasing additional entitlements on the water market if available, the redundancy of KEPCO agriculture activities that extract water from bores to progressive reduction in the mining activities that consume water. (p 80, Response to Submissions on Groundwater, AGE)

Response

KEPCO and its groundwater consultants have undertaken an extensive work program over the last few years to provide improved certainty in relation to the groundwater modelling predictions, including reliability of the alluvial borefield. The RTS groundwater modelling built on the modelling undertaken within the EIS and made a number of refinements to the modelling based on stakeholder comments and additional groundwater monitoring data.

The RTS groundwater modelling also investigated the ability of the proposed borefield to generate the required makeup water for the Project during periods of extreme drought conditions. This analysis focussed on an extreme drought condition scenario and tested a wide range in hydraulic parameters within the modelling utilising a linear uncertainty analysis. This uncertainty modelling demonstrated that under the extreme dry climatic condition scenario and utilising conservative hydraulic parameters, there were numerous occasions where the alluvial borefield would be able to sustain the makeup water demands for the Project. However, there remained the potential under extreme uncertainty scenarios where the proposed alluvial borefield may not be able to sustain the makeup water demands for the Project. It should be noted that all predictive model scenarios assessed for the RTS simulated the continued landholder pumping according to 100% water access licence volumes. Therefore, drawdown experienced at landholder bores has the consideration of cumulative drawdown included within all predictions.

It is noted that the optimised borefield layout within the RTS was developed based on the extreme dry climatic conditions and comprised 16 bores within the alluvium on KEPCO land.

The extent of this borefield to the north was the main reason for the identified drawdown impacts to neighbouring privately owned bores within the alluvium in the RTS. It is noted that since the submission of the RTS, KEPCO has acquired the Tinka Tong property. KEPCO advised DPI-Water of this acquisition in letter dated 12 August 2016.

As referred to within Section 4.3.7 of the RTS and described within the response to Issue B below, KEPCO has now finalised the additional work on the alluvial borefield (i.e. pump testing work on alluvial aquifer) to further validate and refine the hydraulic parameters being utilised within the groundwater model. This work is described within Section 4 of the Response to Submissions on Groundwater report prepared by AGE which is included within **Appendix A**. The pump testing work identified that the permeability of the alluvial aquifer was higher than that previously measured by conducting rising and falling head tests within the monitoring bores installed within the alluvial aquifer. This additional monitoring information has been utilised within the latest round of groundwater modelling and has enabled a further refinement to the proposed borefield down to eight bores.

Whilst complex groundwater models do attract some level of uncertainty, KEPCO and its consultants have investigated the likely magnitude of uncertainty and identified the potential range in environmental impacts associated with the Project. Therefore, the groundwater model is considered a useful tool for informing decisions regarding water management for the Project.

A response to the issues raised by DPI-Water concerning uncertainty around groundwater modelling outputs are further provided as part of the response to Issue G below.

As noted by DPI-Water and consistent with Section 7.6.4 of the EIS and Section 4.3.1 of the RTS, should groundwater monitoring indicate that the Project has resulted in changes in groundwater levels and/or quality more extensively than predicted at any privately owned bore, then KEPCO will discuss mitigation measures with the landholders. This may include the implementation of "*make good provisions*" to compensate for any adverse impacts to neighbouring landholder bores determined to be a result of the Project.

Issue B

> *Drawdown impacts from the mine related impacts onto nearest users cannot be reliably predicted. This issue is compounded in that the details of the proposed borefield location have not been presented and it is unclear how this extraction is considered within the groundwater model. Further, the alluvial aquifer is of limited thickness and any additional decline in water levels, particularly during a drought would impact significantly on adjoining groundwater users. Any additional water table decline as a consequence of the mine, particularly during a drought, could make many wells non-viable.*
>
> *To address this concern, prior to commencement of mining "make good provisions" should be determined for all impacted users within the alluvial area of the project boundary.*

DPI Water Response to RTS:

Further information required

This issue is also related to Issue A and the relevance was discussed above.

With regards to the additional borefield location the Proponent has provided the following response:

Whilst stakeholders requested locations for any additional bores required to maintain yields from the alluvial borefield during drought, at this stage it is not appropriate to provide locations of additional bores. The locations of additional bores will depend on the results of test pumping commencing in mid-March 2016, as well as climatic conditions at the time of mining. KEPCO owns a large landholding within and adjacent to the Project Boundary and this area remains a potential location for additional water supply bores if expanding the Projects borefield is necessary to maintain make up water volumes during drought. (p 80, Response to Submissions on Groundwater, AGE)

As discussed with respect to Issue A DPI Water maintains concerns regarding the reliability of supply to other users and therefore recommends the proponent commit to proposed make good measures for affected properties at the onset of mining.

Response

Noted. See response to Issue A.

As noted within the RTS, KEPCO commissioned a test pumping program to evaluate the yield of bores within the alluvial aquifer and its hydraulic properties to reduce the uncertainty associated with groundwater modelling predictions. The testing program was undertaken between March and May 2016 and comprised the installation of trial test bores at four sites (see **Appendix A**). The test bores were pumped continuously at rates of between 0.4 ML/day and 1.2 ML/day for up to 100 hours. Analysis of the test results indicated the alluvial groundwater system is more permeable than assumed in previous modelling and the groundwater model was updated to reflect this. The proposed borefield to supply the required makeup water to the Project was further refined. The borefield incorporates three of the four existing trial bores and five new bore sites within the alluvial aquifer system.

Table 1 provides the coordinates for each of the optimised bores proposed as part of the makeup water supply borefield.

Table 1
Existing and Proposed Bores for the Project Borefield

Bore ID	Status	Easting (GDA94 Z56)	Northing (GDA94 Z56)	Ground Elevation (mAHD)
AGE21P	Existing	230403	6407018	275.6
AGE24P	Existing	230336	6408250	267.3
AGE28P	Existing	232023	6406187	284.0
AGE34P	Proposed	230130	6408513	259.8
AGE35P	Proposed	230910	6407716	267.2
AGE36P	Proposed	232059	6406605	271.3
AGE37P	Proposed	233416	6405768	282.0
AGE38P	Proposed	233168	6405531	280.3

Each proposed bore location within the alluvium has been situated to comply with buffer zones specified within the water sharing plan rules. It is noted that since the submission of the RTS, KEPCO has acquired the Tinka Tong property. KEPCO advised DPI-Water of this acquisition in letter dated 12 August 2016. The closest private non-mine owned water supply bores are now located on the Eagle Hill property and are remote at over 2 km from the nearest pumping bore proposed within the borefield.

Updated modelling (including uncertainty modelling) has indicated the risk of impact to the bores located on the Eagle Hill property is low with no modelling scenarios predicting a drawdown of more than one metre at these bores.

It should be acknowledged that the groundwater model simulates cumulative impacts to landholder bores by representing continued landholder abstraction alongside mine depressurisation in 'drought conditions'.

Issue C

> *There is potential for salinity change and contamination transport from overburden emplacement areas. Whilst the geochemistry has been thoroughly addressed, the supporting documentation to mark the boundary between colluvium and alluvium is minimal. This is because the soil mapping is produced at a broad scale and will have inaccuracies. The consequence being that there is potential for mining and mine spoil emplacement to be located within alluvial boundary where such inaccuracies exist.*

To address this concern further supporting documentation is required delineating at a local scale the alluvial/colluvial boundary from which the 150m setback will apply. This should therefore be verified by field work using the proponents mine plans to ensure the alluvium setbacks are maintained in the field.

DPI Water Response to RTS:

Response satisfactory.

The proponent has detailed further work by Douglas Partners and has provided updated maps with appropriate setbacks of mining areas.

The Proponent has also responded with the following with regards to salinity contamination:

It is agreed with the comment in the submission that a contaminant transport model can better represent the formation of any plumes emanating from the buried rejects materials, however it is considered that contaminant transport modelling is not warranted at this stage of the Project. This is because the EIS which used conservative assumptions on salinity released from the rejects materials indicated a low risk to water quality. As the risk was identified to be low, more sophisticated methods were not considered to be warranted at this stage. Section 7.2.8. discusses measures to be documented within the Water Management Plan for ongoing monitoring of waters that come in contact with the rejects materials and a post closure monitoring program. (p 84, Response to Submissions on Groundwater, AGE)

The proponent must implement agreed setback distances from the alluvial boundary and perform ongoing monitoring of the setback during project construction to ensure the setback is maintained. The proponent should arrange the supplementation of the groundwater modelling by including a contaminant transport model as part of a model refinement and enhancement program undertaken as part of the Water Management Plan for the operation.

Response

As described in Section 4.3.1 of the RTS investigations completed by Douglas Partners in 2011 to improve the definition of the alluvial/colluvial boundary were included as a mine planning constraint to ensure that the adopted mine plan was set back by a minimum of 150 m from the edge of the alluvial boundary. KEPCO will perform ongoing investigations to ensure the 150 m setback from the open cut mining areas to the alluvial boundary is not breached.

The Water Management Plan will provide a decision tree for management of groundwater quality. The decision tree will identify appropriate actions should groundwater quality decline and there is potential for a plume of brackish water to move from the open cut mining area into the surrounding environment.

Where appropriate the decision tree will specify methods to quantify the movement of solutes in groundwater including contaminant transport modelling.

Issue D

Water supply reliability of the proposed borefield including planned expansions during extended drought periods is unknown and insufficient detail about the borefield was provided for review. Section 13.6 from the EIS summarises the precarious capacity of the alluvial aquifer to meet mine water demands.

During the dry season, it is likely that many of the irrigation wells are unable to sustain high abstraction volumes, and the groundwater modelling confirms this.

The security of the mine's water supply warrants detailed consideration and reporting.

DPI Water Response to RTS:

See response at Issue A and Issue G.

Response

Response to the issues raised concerning uncertainty around modelling outputs is provided in response to Issue G below.

Issue E

Conceptual hydrogeology could not be adequately assessed due to the proponent not providing bore logs and groundwater contour maps for each aquifer.

DPI Water Response to RTS:

Further information required.

DPI Water had difficulty interpreting the borelogs provided by the proponent due to the resolution of the documentation. Certain maps were also of poor resolution and could not be adequately assessed. DPI Water did not have sufficient time to conduct a detailed review of the borelogs to understand pertinent detailed aspects of the hydrogeology. Updated maps, shapefiles and borelogs with higher resolution were requested for use during the Water Management Planning stage, but were not made available to DPI Water staff assessing the RTS.

The proponent did provide very useful groundwater contour maps for each aquifer which yielded greater understanding however there were in certain cases questions on the interpretation of the data used to derive the contours and the conclusions drawn in the groundwater assessment.

DPI Water interpreted from the maps that a hydraulic connection between the Quaternary alluvial aquifer and the main Coggan Coal seam aquifer was likely to exist. The groundwater contour information also provided confirmation regarding the poor state of calibration for the deeper layers in the model that was alluded to during the preceding EIS review.

DPI Water requests the proponent facilitate a workshop discussion between the independent model reviewer, the modeller and DPI Water staff to improve the model for the Water Management Planning stage. The proponent is to provide higher resolution maps and borelog data and a 3D conceptual hydrogeological model with details including layer thicknesses and hydraulic conductivity distributions to DPI Water prior to the workshop discussion.

Response

As explained in Section 3.12.5 of the RTS, the Response to Submissions on Groundwater prepared by AGE (Appendix H of the RTS) provided further detail in relation to the site geological conditions and items relating to aquifer conceptualisation. Higher resolutions files of the borelogs and other requested information was provided to DPI-Water on 18 April 2016.

Further to this, DPI-Water were also provided a copy of the Leap Frog Hydro model on 22 July 2016 which was developed to graphically illustrate (in 3D) the various layers from the numerical flow model.

It is agreed that the available data does indicate in some areas where there is a direct and indirect hydraulic connection between the alluvium and the coal seams proposed to be mined. Figure 5-19 of **Appendix A** illustrates where the Coggan Coal seam either subcrops below the alluvium, or outcrops close to the land surface. The areas where the coal seam subcrops directly beneath the alluvium, or is separated by a thin layer of weathered Permian sediments will be areas where the connectivity is enhanced. The MODFLOW USG model has appropriate represented this hydraulic connection between the Coggan Coal seam and the alluvium in these distinct areas.

KEPCO is committed to facilitating ongoing discussions with DPI-Water throughout the development of the post approval Water Management Plan. It is understood that DPI-Water now has the information required to facilitate this workshop.

Issue F

Under the Water Sharing Plan (WSP) ongoing security of access is required to the DPI Water network infrastructure which is situated within the Project area. These bores are to be used as part of the ongoing regulation of the Bylong River Water Source.

DPI Water Response to RTS:

Response satisfactory.

The proponent has provided the following response:

The Water Management Plan will also provide a commitment by KEPCO to maintain access to the government monitoring bores that occur with the Project Boundary or on KEPCO owned land outside Project Boundary. (p 87, Response to Submissions on Groundwater, AGE)

Response

Noted.

Issue G

No groundwater level outputs from the model for layers between the alluvium and Coggan seams were provided to understand the model behaviour in these layers.

The sensitivity analysis was not thorough enough in terms of varying the ratio between horizontal to vertical hydraulic conductivity nor was justification for the magnitude of difference provided.

The model is over predicting water levels which means there is too much water in the model that is then potentially available to attenuate the water levels in the alluvium aquifer (with low vertical K values) resulting in dampened drawdown predictions due to mining.

The likely presence of multiple semi-confined aquifers separated by aquitards and the potential for several distinct, largely unrelated shallow water tables to be present within the modelling domain suggests that other model codes could be better suited to the site.

It is suggested therefore that the model should be used with care when assessing drawdown effects and the propagation of the drawdown cone outwards from open cut and underground mines.

DPI Water Response to RTS:

Further information required.

The proponent satisfied the first point.

The proponent performed a much improved and very useful sensitivity analysis which revealed how sensitive the model was to certain parameters. However the uncertainty was never quantified by varying the sensitive parameters on the actual updated model. The model was also sensitive to recharge.

The issue of greatest concern is the mismatch between the hydraulic conductivities obtained from Packer testing and those used in the model. This was especially the case for the Ulan and Coggan coal seam layers but was not limited exclusively to just these units. The distribution of the hydraulic conductivity in the model was not provided as a figure and the range of magnitude of hydraulic conductivity values applied to the model was very wide, resulting in critical uncertainty as to locations where excessively low hydraulic conductivity may have been applied. The sub-cropping Ulan and Coggan seams (that are recognised as important aquifers) may have an unreasonably low hydraulic conductivity applied in the model in close proximity to the stream and *alluvial aquifer or close to the surface beneath the weathered interburden (both are recharge areas). This could result in the inability of the model to allow realistic and representative volumes of water to enter into the deeper aquifer. Under the conditions of modelling mining induced drawdowns, the impact on the alluvial aquifer may be greatly diminished if a low hydraulic conductivity is applied to aquifers connected to the alluvium.*

The conceptual hydrogeological model did not adequately consider the initial draining of the Ulan and Coggan layers by the open cut and underground mines (facilitated by down-dip flow within the seams) and then the subsequent depletion of the alluvial aquifer via leakage through hydraulic connections between the different layers.

The risk to the project and neighbouring authorised users is that the full thickness of the alluvial aquifer in the vicinity of the mine may be entirely depleted of groundwater and potentially harmed.

During discussions with the proponent, DPI Water requested that the 3D conceptual model be provided and this has not yet occurred.

On the basis of the hydrogeology and modelling work reviewed thus far, DPI Water considers that the proposal should currently be considered based on a worst case scenario that assumes that the full thickness of the alluvial aquifer in the vicinity of the mine will be drained if the proposal goes ahead, thus diminishing the water supply to the project itself and to other authorised users. To better define the conditions under which this will occur, and the spatial extent where this could occur, DPI Water considers that the proponent should be required to do further modelling with appropriate refinements.

In addition, the proponent should arrange additional aquifer pumping tests with monitoring of adequately located observation bores to thoroughly characterise all of the layers that have the potential to drain the alluvium aquifer – this includes the Ulan and Coggan Coal seams.

Response

As discussed previously, KEPCO have completed the installation and testing of trial pumping bores at four sites within the alluvial aquifer. This work has indicated a more permeable and productive aquifer system occurs within the alluvials than previously represented within numerical models.

The Project's numerical model has been updated to reflect this new information and the remodelling has confirmed that the proposed borefield within the alluvium will not completely drain the aquifer. It will of course induce some drawdown, however extraction from the bores will remain below the currently licensed limits and the predicted drawdown is therefore accounted for in DPI-Water's calculations of sustainable yield for the alluvial groundwater system.

The coal seams within the groundwater model were represented as being moderately permeable where they occur close to the surface and becoming less permeable with depth due to increasing stress and mineralisation filling cleats. This declining permeability with depth in coal seams is a relationship well documented in literature. Within the numerical model, the Ulan seam and Coggan seam were assigned a hydraulic conductivity of 0.05 m/day and 0.1 m/day respectively at a depth of 10 m below the surface. Whilst some packer tests yielded higher values than these, it is not considered appropriate to apply upper values to a groundwater model that aims to represent the effective regional average permeability of the coal seams. The assigned values allow for the movement of groundwater through the coal seams and from the alluvial groundwater systems as demonstrated by the predicted influx of water to the mining areas and take of water from the alluvial groundwater systems. These assigned values are therefore considered appropriate. This is further discussed in Section 6.3.1 of **Appendix A**.

As mentioned above, it is recognised that there is a direct and indirect hydraulic connection between some parts of the alluvium and the coal seams proposed to be mined and this has been appropriately represented within MODFLOW USG model. However, as explained within Section 6.3.1 of **Appendix A**, the impacts resulting from the depressurisation of the coal seams below the alluvial aquifers do not extend as far as the areas where there is a direct connection between the alluvium and coal seams. This is a result of several factors, including:

- The alluvial aquifers ability to recharge the Permian groundwater system;
- The hydraulic properties of the coal seams; and
- The presence of a hydraulic buffer between the mining areas.

The alluvium acts as a recharge zone for localised Permian groundwater. Mine dewatering reduces the pressures below the alluvium; however, induced flow loss must be greater than surface water recharge, lateral through-flow, and storage to invoke significant drawdown to the alluvium. The groundwater model simulates this delicate balance for the base case, sensitivity runs, and uncertainty analysis simulations.

Results demonstrate that coal seam depressurisation does not invoke significant alluvial aquifer drawdown. In fact, a significant quantity of abstracted groundwater is required to drain the alluvial aquifer entirely, demonstrated by the sustainable yield of the proposed borefield.

The EIS model simulated a ‘highly connected’ setup of the shallow aquifer units with the ‘vadose zone’ option in SURFACT. This setting invokes lateral depressurisation across ‘dry’ aquifer units. The Pseudo-soil setting (or ‘Upstream-weighting’ setting in MODFLOW USG) simulates this interaction more sensibly, and does not allow lateral depressurisation between ‘dry’ model cells.

The latest version of the numerical model was recalibrated to reduce the overly high groundwater levels in the alluvial and Permian groundwater units. This has slightly increased the number of dry cells along the alluvial-Permian interface, and has reduced the flow transfer rates between the Permian into the alluvium.

All of the aforementioned factors combined have resulted in the reduction of alluvial aquifer drawdown compared to results defined in the EIS.

In regards to the suitability of the modelling code, MODFLOW-USG is becoming quickly regarded as an industry standard and preferred approach to complex regional mining projects. MODFLOW-USG uses a control-volume finite difference approach, which combines the benefits of finite element modelling (e.g. FEFLOW) with the numerical stability of finite difference simulations (e.g. standard MODFLOW). It was imperative that groundwater flow budget discrepancies derived from modelling predictions were as low as possible, so that flux changes between units could be accurately quantified. The ability to 'pinch-out' layers, and the use Voronoi shaped cells allowed for efficient model run times, which was essential to undertake the uncertainty analysis in a timely fashion. KEPCO strived to replicate the recommended approach of coupling a finite-element approach with a hydrological model (e.g. FEFLOW + MIKESHE) as closely as reasonably possible with MODFLOW-USG equivalents.

DPI-Water were provided a copy of the Leap Frog Hydro model on 22 July 2016 which was developed to graphically illustrate (in 3D) the various layers from the numerical flow model.

Whilst KEPCO respects DPI-Water's suggestion, it does not support the requirement to complete pumping tests for bores within the Ulan and Coggan coal seams. During the initial baseline monitoring period, KEPCO commissioned Douglas Partners to complete a significant program of packer testing within the Triassic and Permian bedrock units for the purposes of characterising the hydraulic conductivity of these units. This information has provided useful information to guide the development of the numerical model.

KEPCO's groundwater consultants have advised that pumping tests are not practically appropriate within any other units except the alluvium. This is because the yield from the bedrock units is typically too low to sustain pumping at any useful rate. In this case, the packer testing methodology has been utilised as a more appropriate technique for measuring hydraulic conductivity within the coal seams and other bedrock units.

Issue H

> *The proponent does not currently hold a licence under Part 5 of the Water Act to account for the take of water from the Permian aquifer.*
>
> ***DPI Water Response to RTS:***
>
> *Response satisfactory.*
>
> *The proponent has submitted an application for a licence under Part 5 of the Water Act 1912 which is currently under assessment.*

Response

Noted.

As discussed during the phone conference meeting held with DPI-Water on 25 July 2016, the latest version of the groundwater modelling has predicted a larger inflow to the mining areas than predicted within the EIS. Accordingly, KEPCO proposes to hold further discussions with DPI-Water in relation to varying the water allocation sought within the *Water Act 1912* licence application to correspond with the revised groundwater inflow predictions.

Issue I

No remediation technique has been proposed for sections of creek that are not accessible by machinery. It is requested that additional strategies be identified to avoid, minimise and manage surface cracking in less-accessible sections of Dry Creek.

DPI Water Response to RTS:

Response satisfactory.

The proponent has provided the following response However, KEPCO will monitor cracking and surface impacts during operations to ensure the cracks do not pose an unacceptable risk to water flows, wildlife or livestock.

When cracks appear in areas inaccessible to machinery, any attempt to provide access for machinery to the site will likely cause more damage to the vegetation and soils than the subsidence impacts. Therefore, if deemed appropriate, the crack will be left to self-repair over time.

Surface cracking which has been assessed to pose unacceptable risk to the condition of Dry Creek and associated tributaries, alternate remediation measures will be considered for implementation. This may include attempts for personnel to access the impact site by foot and attempt to remediate the cracking without mobile equipment. (p 79, Response to Submissions, Hansen Bailey)

Response

Noted.

Issue J

A sufficient number of legible cross-sections to be provided in all orientations to adequately describe the geology.

DPI Water Response to RTS:

Further information required

While the proponent has provided improved cross-sections, there are not a sufficient number to understand the 3D conceptual geology along the groundwater flow paths from recharge areas towards open-cut or underground mines or beneath coal spoil emplacement areas and towards other water users. The sections across the alluvium do not depict the dipping Permian beds.

The proponent should liaise with DPI Water to obtain information about specific layer and cross-section requirements.

Response

Section 3 of the Response to Submissions on Groundwater Report (**Appendix A**) presents a series of additional cross sections through the key stratigraphic units and proposed mining areas. The cross sections through the alluvium provided in the RTS have been increased both laterally and vertically to incorporate the Permian strata, the catchment area contributing streams and the proposed mining and emplacement areas. A new cross section is also provided through the proposed open cut and underground mining areas further south and upstream.

The cross sections are based on the layers within the groundwater model and therefore show the layers and stratigraphic unit each layer represents. Adjacent monitoring bores are also illustrated on each cross section.

In addition to these cross sections, DPI-Water were provided a copy of the Leap Frog Hydro model on 22 July 2016 which was developed to graphically illustrate (in 3D) the various layers from the numerical flow model. Utilising this Leap Frog Hydro model tool, DPI-Water is able to explore any additional cross sections from the numerical flow model that they would like to review.

2.2 AIP "MINIMAL IMPACT CONSIDERATIONS"

Issue

> *With regard to the AIP "minimal impact considerations", in respect of water quality issues the following is recommended.*
>
> *To manage contamination transport from the coal spoils areas, the proponent must implement the management measures recommended by the independent geochemical assessor, RGS Environmental Pty Ltd, with additional regard to appropriate groundwater and spoil seepage monitoring.*

Response

As explained within Section 7.20.4 of the EIS, KEPCO will develop and implement a Mine Waste Management Plan to appropriately manage the waste materials generated throughout the mining process to minimise potential risk of impact to the neighbouring environment.

This Mine Waste Management Plan be prepared consistent with the recommendations from the Geochemical Impact Assessment (Appendix AB of the EIS) and will include provisions for the monitoring of runoff and seepage from overburden, interburden and coal rejects on a regular basis during the operations phase of the Project.

As explained within Section 4.3.12.3 of the RTS, the Water Management Plan for the Project will include further details on the monitoring program to be implemented to monitor potential contamination from the overburden emplacement areas.

2.3 MINE WATER SECURITY

Issue

With regard to mine water security, it is recommended,

That intensive and extensive borehole water level monitoring is continually undertaken by the Proponent during mining to monitor drawdown impacts and inform the management responses adopted by the Proponent.

Response

KEPCO has installed an extensive network of groundwater monitoring bores to characterise the regional groundwater regime as part of the baseline monitoring period. A number of these bores will be suitable for long term monitoring of groundwater levels and quality during mining and beyond. However, it is recognised that some of these bores will be removed by open cut or underground mining and replacement monitoring bores will be required. This includes bores (or vibrating wire piezometers) which are located within the strata overlying the proposed underground mine or within the footprint of the open cut mining areas.

Additional monitoring bores are also proposed in the vicinity of the proposed pumping bores as part of the borefield in order to monitor the drawdown within the alluvial aquifer.

The Water Management Plan will identify where gaps within the existing or future monitoring network are present, and provide a staged plan for the installation of additional monitoring sites as required. The Water Management Plan (to be prepared as a post approval) will be prepared in consultation with the key regulatory stakeholders, including DPI-Water.

2.4 OUTSTANDING PRIOR RECOMMENDATIONS

Issue

Outstanding prior recommendations yet to be addressed

- *The proponent should provide a map depicting the depth of the weathered zone within the Project boundary and comment in greater detail on the water bearing capacity of this zone.*
- *The proponent should provide a separate groundwater contour map for the basalt aquifer beneath Dry Creek. The thickness of the saturated zone and unsaturated zones in the Basalt is also to be provided.*
- *The proponent should provide a water balance for each of the aquifers in the project area and quantify the volumes available for use as a water supply source to understand the availability of water during extended drought periods.*
- *Due to uncertainty with the current hydrogeological conceptual model, future drilling and construction of a limited and reasonable number of monitoring bores into sandstones may be required should a data gap be*

recognised (Farmers Creek Formation, the Gap Sandstone, Watts Sandstone or other aquifers)

- *An automated Class A pan for measuring evaporation should be installed on site*

Response

As explained earlier, DPI-Water has been provided a copy of the Leap Frog Hydro model on 22 July 2016 which was developed to graphically illustrate (in 3D) the various layers from the numerical flow model. The weathered zone across the numerical model domain is able to be viewed utilising this tool.

During the early stages of the groundwater investigations for the Project, a network of monitoring bores were installed into the weathered zone. The bores were located to measure hydraulic properties and monitor groundwater levels adjacent to potential open cut mining areas, and to understand the potential for the weathered zone to indirectly connect the mining areas with the alluvial aquifer.

The Response to Submissions on Groundwater report included as Appendix H of the RTS included maps (Figure 18) indicating the thickness of the weathered zone and discussed the measured hydraulic properties. Section 5.3.1 of **Appendix A** provides further information on the hydraulic properties and water levels fluctuations measured within the weathered zone. The weathered zone has been conservatively represented within modelling as a permeable zone that will allow transmission of groundwater according to hydraulic gradients and permeability.

Sections 4.1 and 4.2 of the Appendix H of the RTS outlined the installation of five additional monitoring bores along Dry Creek to characterise the nature of any alluvial sediments along the creek line, and the potential for this material to form an aquifer that could support deep rooted vegetation. It was identified during the installation of these monitoring bores that the material adjacent to Dry Creek was dry.

Section 5.2 of **Appendix A** outlines further investigation into the potential for the Tertiary basalt to form an aquifer system. Geophysical logs collected during the coal exploration program indicated at five sites that the Tertiary basalt was dry with the water table occurring in underlying strata. The conceptual hydrogeological model for the basalt is that it remains unsaturated although may support short-term perching as part of normal recharge mechanisms as rainfall drains to deeper units.

Section 6 of **Appendix A** describes the latest round of numerical modelling and provides model water budgets and balance tables.

The Water Management Plan will determine where there are potential gaps in the monitoring bore network and will include consideration of all geological units overlying the proposed underground mining area including the Farmers Creek Formation, the Gap Sandstone, Watts Sandstone or other units.

The Water Management Plan will outline the methods to be utilised for monitoring evaporation at the Project site.

2.5 DPI-WATER RECOMMENDED CONDITIONS OF APPROVAL

DPI Water recommends the following conditions be included in any determination issued for the Bylong Coal Project:

1. Prior to commencement of operations the proponent must prepare a Water Management Plan in consultation with DPI Water, which is to incorporate the following (not exclusive):

Issue

- *A procedure for the implementation of make good provisions for water supply to the Tinka Tong property in general accordance with the NSW Aquifer Interference Policy at the onset of mining.*

Response

KEPCO notified DPI-Water (in letter dated 12 August 2016) that the property known as Tinka Tong was acquired by KEPCO in June 2016 and is therefore no longer a private freehold property.

However, as explained in Section 7.6.4 of the EIS and Section 4.3.1 of the RTS, should groundwater monitoring indicate that the Project has resulted in changes in groundwater levels and/or quality at any privately owned bore more extensive than predicted at any privately owned bore, then mitigation measures will be discussed with the landholders. This may include the implementation of "*make good provisions*" to compensate for any adverse impacts to neighbouring landholder bores determined to be a result of the Project.

Issue

- *A monitoring program to enable the continuing assessment of impacts to the reliability of groundwater supply at all potentially affected properties using appropriately located and constructed bores equipped with automatic water level loggers.*

Response

The Water Management Plan will detail the monitoring program to be implemented to identify the impacts of the Project on the regional groundwater regime. The Water Management Plan will outline trigger levels to which the monitoring data will be compared. If these trigger levels are exceeded, further investigations will take place to confirm the reasons for the exceedance and identify any response required. The trigger levels will be established to ensure that monitoring will identify any unforeseen drawdown impacts to the alluvial aquifer as a result of the Project, before any neighbouring landholder bore is adversely impacted.

As outlined in Section 4.3.13 of the RTS, all KEPCO bores will have flow meters and water level loggers installed. Water levels and flow velocity will also continue to be monitored in the key streams within the Project Boundary. The WMP will outline these monitoring measures in more detail.

Issue

- *A procedure for the implementation of make good provisions for water supply to any properties identified as impacted as a result of the mining operations in general accordance with the NSW Aquifer Interference Policy.*

Response

Should groundwater monitoring indicate that the Project has resulted in changes in groundwater levels and/or quality at any privately owned bore more extensive than predicted, then mitigation measures will be discussed with the landholders. This may include the implementation of "*make good provisions*" to compensate for any adverse impacts to neighbouring landholder bores determined to be a result of the Project.

Issue

- *A program for the update and refinement of the groundwater model in consultation with DPI Water to enable future refinement of the Water Management Plan in accordance with the principles of adaptive management. This program should include (not exclusive):*
    - *a workshop discussion between the independent model reviewer, the modeller and DPI Water staff. The proponent is to provide beforehand (i.e. prior to the workshop discussion) higher resolution maps and borelog data, a 3D conceptual hydrogeological model with details including layer thicknesses and hydraulic conductivity distributions, and all of the measured data and analysis corresponding to the pumping tests performed in March 2016, and any subsequently undertaken;*
    - *updated model runs with alternative hydraulic conductivity values in both horizontal and vertical orientations (KH and KV), determined in consultation with DPI Water, applied to the Permian aquifers in contact with the identified recharge areas;*
    - *additional uncertainty analysis on these model scenarios by applying the range of values obtained from hydraulic conductivity assessments across the Project area, including any additional aquifer pumping tests;*

  - *modelling of both the open cut mine void and underground mine as scenarios that drain water from the Permian aquifers in contact with the identified recharge areas; and*
  - *supplementation of the groundwater modelling by inclusion of a contaminant transport model to assess potential for salinity change and contaminant transport from overburden emplacement areas.*

Response

The Water Management Plan will outline a program for the update, verification and refinement of the groundwater model. DPI-Water will be consulted during development of the Water Management Plan.

The Water Management Plan will consider where there are any gaps in the monitoring network and define a plan for installation of additional monitoring sites. This process will generate new data and it is likely only after such data is available that any updates to the groundwater model would be warranted.

Issue

- *The proponent must implement agreed setback distances from the alluvial boundary and perform ongoing monitoring of the setback during project construction to ensure the setback is maintained.*

Response

As noted in the response to Issue C, KEPCO will perform ongoing investigations to ensure the 150 m setback from the open cut mining areas to the alluvial boundary is not breached.

Issue

- *All works on waterfront land are to be conducted in accordance with DPI Water's Guidelines for Controlled Activities on Waterfront Land as amended from time to time.*

Response

The Project proposes a number of activities adjacent to and within the vicinity of waterways as outlined within Section 3 of the EIS. KEPCO will conduct these activities on waterfront land in general accordance with DPI-Water's *Guidelines for Controlled Activities on Waterfront Land* as amended from time to time.

2.6 REVISED SURFACE WATER BALANCE

A revised mine water balance has been undertaken by WRM Water and Environment in light of the revised groundwater inflows which have been predicted through the latest round of groundwater modelling and is provided in **Appendix B**. The revised mine water balance comprised an update to the EIS modelling by utilising the base case groundwater inflows into the open cut and underground mining areas from the latest groundwater modelling undertaken by AGE (as presented within **Appendix A**). Otherwise, the revised mine water balance utilised the same methodology and assumptions that were utilised within the EIS modelling.

The revised water balance modelling indicated that for very dry climatic conditions, there is less than a 1% chance that more than 1,268 ML of water would be required from the Project borefield. This is marginally more than the 1,170 ML predicted within the EIS mine water balance modelling.

The revised water balance modelling demonstrated (similar to the EIS results) that prior to the commencement of underground mining, there is a low risk of significant volumes of water accumulating within in the open cut mining areas. Once the underground operations commence, groundwater inflows increase significantly. This may result in the potential for water accumulating within the mining voids if wet climatic conditions occur.

During the combined operations and underground only (i.e. PY 7 to PY 25), there is a

- 1% chance of storing more than 6,940 ML in the Eastern open cut mining area;
- 10% chance of storing more than 6,420 ML in the Eastern open cut mining area; and
- 50% chance of storing up to 5,540 ML in the Eastern open cut mining area.

The model results show that during open cut only operations, the accumulation of water with the open cut mining areas is manageable. However, once the underground operations commence, the additional groundwater inflows and reduction in site water demands increase the risk of water accumulation within the mining areas. This water will need to be managed within the water management system, most likely within one or both of the Eastern Open Cut voids.

The results of the revised mine balance modelling show that the site water management system can be operated to ensure with at least a 99% probability that no uncontrolled release of saline water over the Project life. The only uncontrolled offsite releases will be from sediment dams during periods of rainfall above the relevant design criteria.

The Water Management Plan will outline the requirement for the validation of both the groundwater modelling as well as to complete regular updates of the site mine water balance to understand the risks associated with the management of water on the site. Whilst there is a potential for a substantial quantity of water to accumulate within the open cut mining voids during the underground period under very wet climatic conditions, the revised mine water balance modelling has demonstrated that based on these extreme worst case conditions it can be contained within the mine water management systems. There are numerous other mechanisms which may be available to generate further capacity within the water management system to manage water onsite. This could include measures such as adjusting the final years of open cut operations to maintain a greater void capacity remaining at the end of the open cut mining life or by managing some of the mine water within the mined underground goaf areas. These mechanisms will be further investigated following the validation and updates to the groundwater and mine water balance models as part of the Water Management Plan.

3. CONCLUSION

We trust this response addresses the issues raised in the DPI-Water submission. Should you have any queries in relation to this letter, please contact us on 6575 2000.

Yours faithfully

HANSEN BAILEY

James Bailey
Director

Nathan Cooper
Senior Environmental Scientist

APPENDIX A

RESPONSE TO SUBMISSIONS ON GROUNDWATER REPORT

Australasian
Groundwater
and Environmental
Consultants Pty Ltd
(AGE)

Report on

Bylong Coal Project

Response to Submissions on Groundwater

Prepared for
Hansen Bailey Pty Ltd

Project No. G1606   September 2016
www.ageconsultants.com.au   ABN 64 080 238 642

Document details and history

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Table of contents

Page No.

Table of contents
(continued)

Page No.

List of figures

Table of contents
(continued)

Page No.

Table of contents
(continued)

Page No.

List of tables

List of appendices

Report on

Bylong Coal Project
Response to Submissions on Groundwater

1 Introduction and background

KEPCO Bylong Australia Pty Ltd (KEPCO) is planning to develop an open cut and underground coal mine in the Bylong Valley (the Project), which is located in Mid-Western Region of New South Wales (NSW). The Project has been subject to two levels of groundwater assessment, according to the NSW Regulatory Regime. The first was an initial groundwater assessment addressing the requirements of the NSW Gateway Certificate Assessment process. The second stage of work was a groundwater impact assessment prepared for the Environmental Impact Statement (EIS), which described the field investigations and impact assessment using numerical modelling. Major milestones for the EIS process have included:

- July-2015 EIS submitted to the NSW Government agencies;
- March 2016 Response to submissions (RTS) document submitted; and
- May 2016 Additional submissions from NSW Government agencies received.

This supplementary report provides additional information and analysis requested in submissions from the NSW Government agencies. It describes the results of further monitoring, field investigations and numerical modelling. For consistency with previous work, sections of this report refer to modelling work by AGE (2015) as the 'EIS' and AGE (2016) as the 'RTS', with the most recent updated modelling referred to as the 'RTS2'.

Hansen Bailey Environmental Consultants Pty Ltd (Hansen Bailey) engaged Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) to respond to the submissions on behalf of its client WorleyParsons Services Pty Ltd (WorleyParsons).

2 Objectives and scope of work

The Department of Primary Industries - Water (DPI Water) and the Department of Planning and Environment (DP&E) responded to the RTS submitted in March 2016 requesting additional information and investigation. The DPI Water requested further information and clarity on the:

- sustainability of extraction from the alluvial aquifer during drought conditions;
- impacts on neighbouring agricultural bores during drought conditions;
- the geology and hydrogeology datasets; and
- model calibration and water levels.

The DP&E commissioned Kalf and Associates (KA) to review the groundwater modelling on their behalf, with KA requesting further information:

- comparing outputs from the two numerical modelling codes used on the Project being MODFLOW SURFACT and MODFLOW USG;
- on the MODFLOW USG model mesh at the Goulburn River; and
- on the approach to modelling the surface water and groundwater interaction along the Bylong River and Lee Creek.

This report responds to the further requests from DP&E and DPI Water as follows:

- Section 3 presents a series of cross sections through the key stratigraphic units and proposed mining areas;
- Section 4 describes the pumping test program undertaken within the alluvial aquifer system;
- Section 5 presents additional information collected from the main groundwater systems including analysis of the pumping test data, recharge and saturated thickness;
- Section 6 describes further numerical modelling including calibration, predictions and uncertainty; and
- Section 7 discussed the results of the additional investigations and water management measures.

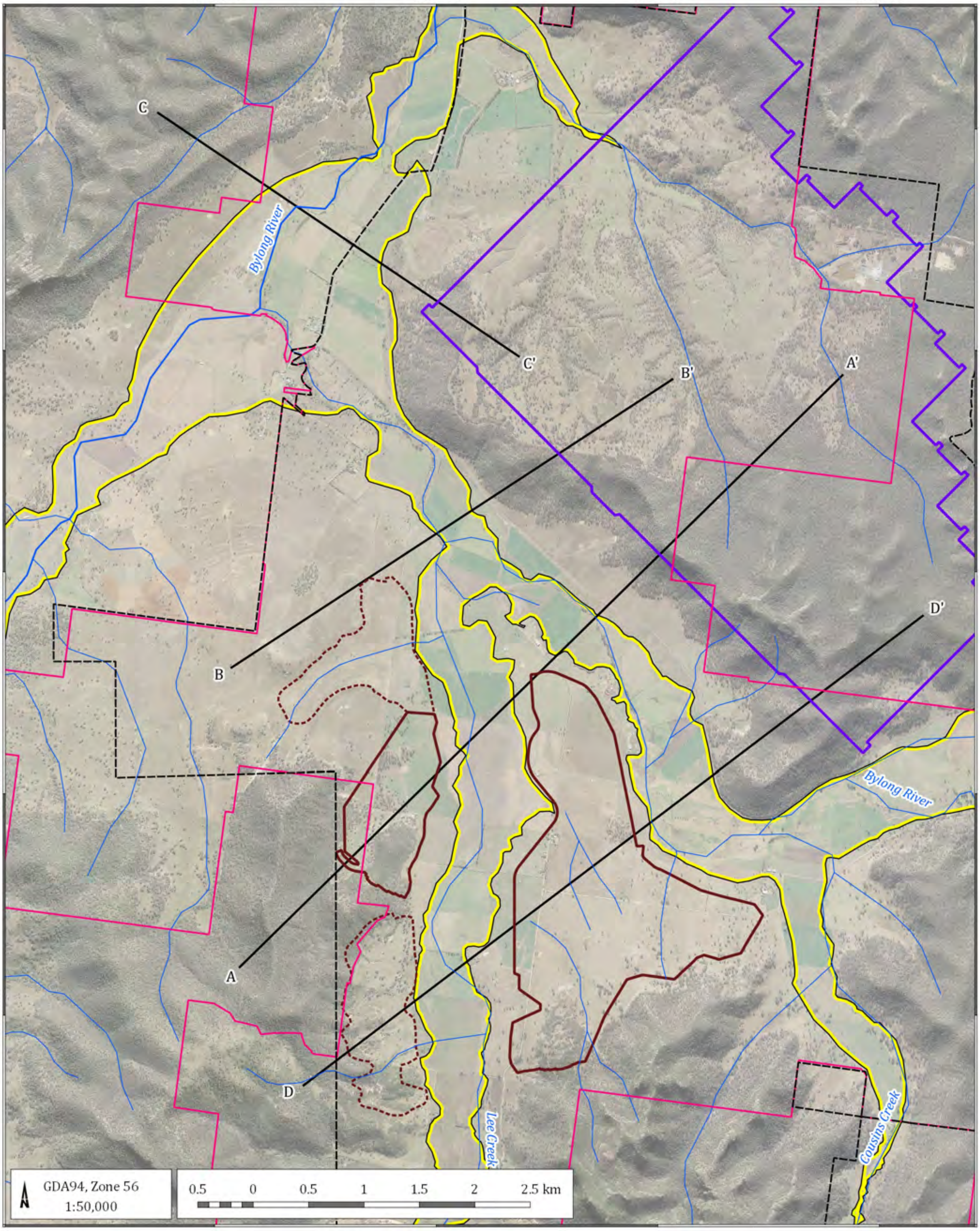
3 Geology

In response to previous requests the RTS document provided a series of geological cross sections. The first set of sections were developed through the alluvial aquifer and showed detailed lithological layers within the alluvial sediments (AGE 2016 - Section 4.2.1). The second set of cross sections were at a larger scale and developed from the sites geological model showing the key geological units (AGE 2016 - Appendix B).

In DPI Water's submission on the RTS it requested additional cross-sections to understand the 3D conceptual geology along the groundwater flow paths from recharge areas towards open-cut or underground mines or beneath coal spoil emplacement areas and towards other water users with detail on the dipping Permian beds.

To address this request the cross sections through the alluvium provided in the RTS were increased both laterally and vertically to incorporate the Permian strata, the catchment area contributing streams and the proposed mining and emplacement areas. A new cross section was also provided through the proposed open cut and underground mining areas further south and upstream.

Figure 3-1 shows the locations of the cross sections, whilst Figure 3-2 to Figure 3-5 shows the geological units along each cross section line. The cross sections are based on the groundwater model and therefore show the stratigraphic unit(s) each model layer represents. Adjacent monitoring bores are projected onto each cross section.



LEGEND

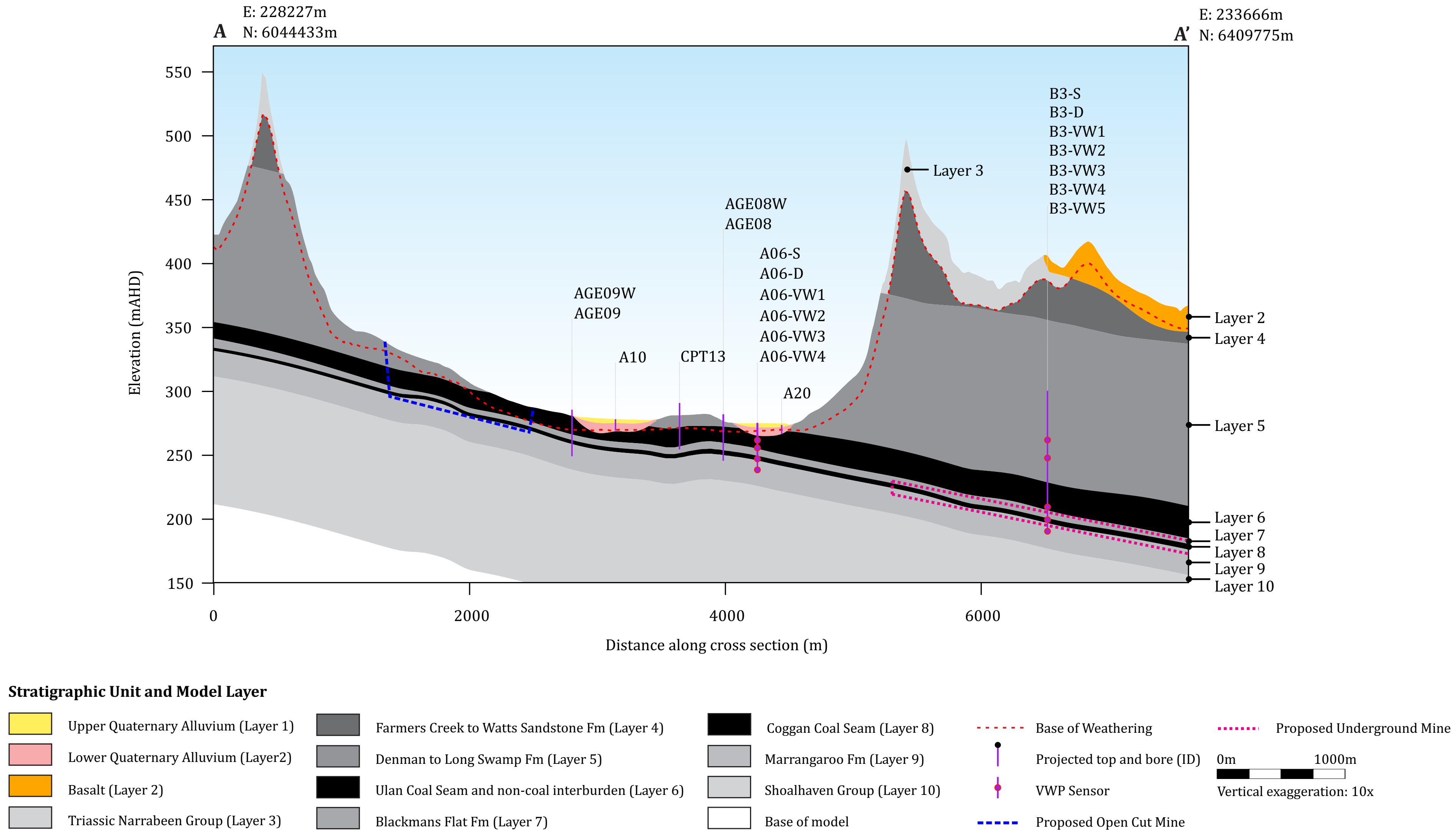
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Project Boundary
- Quaternary alluvium
- Cross section line
- Major drainage
- Minor drainage

Bylong Coal Project (G1606G)

Location of cross sections through alluvium

DATE 15/07/2016

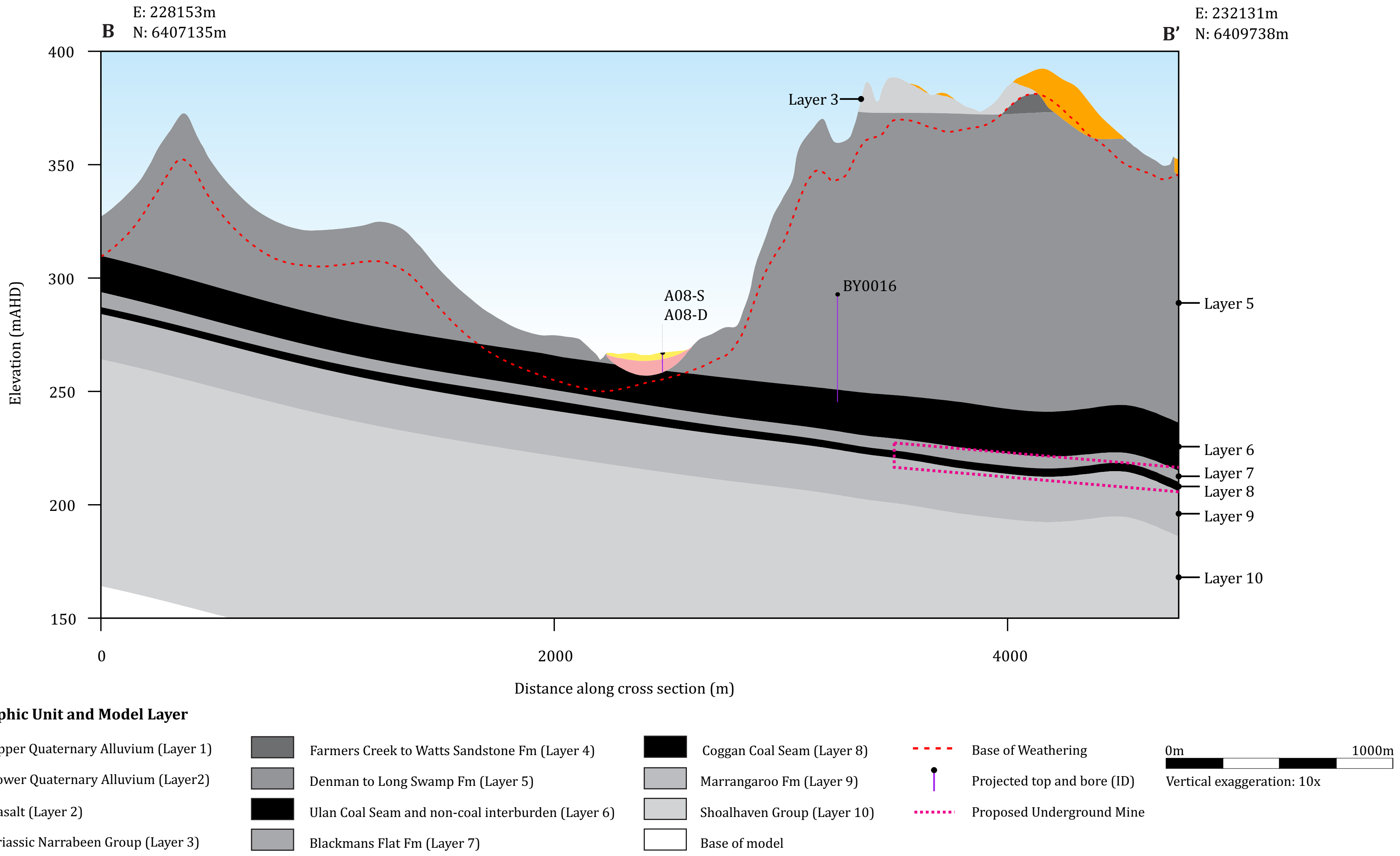
FIGURE No: **3-1**



Geological cross section A - A'

Figure 3-2

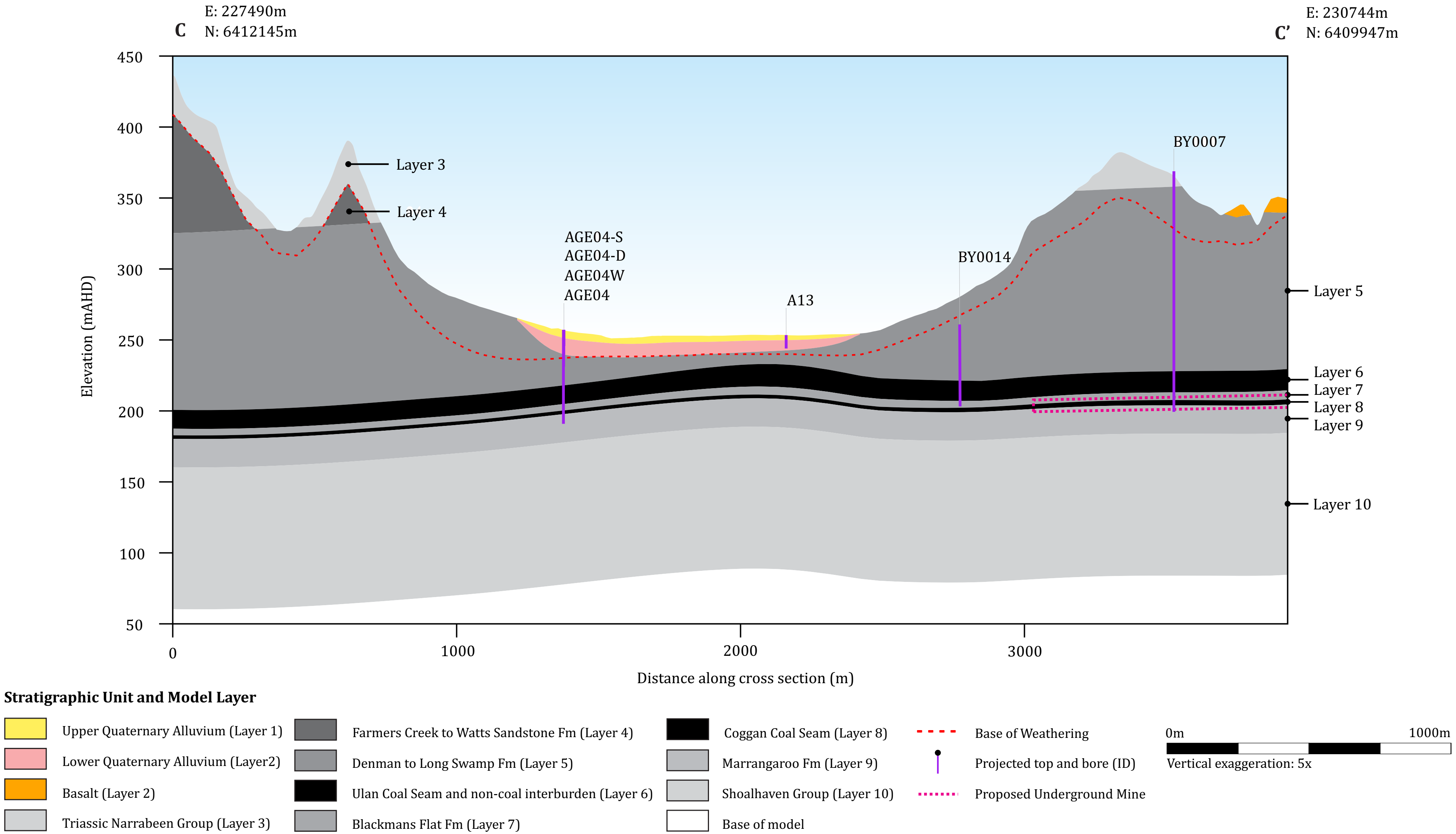
Bylong Coal Project (G1606G)



Geological cross section B - B'

Figure 3-3

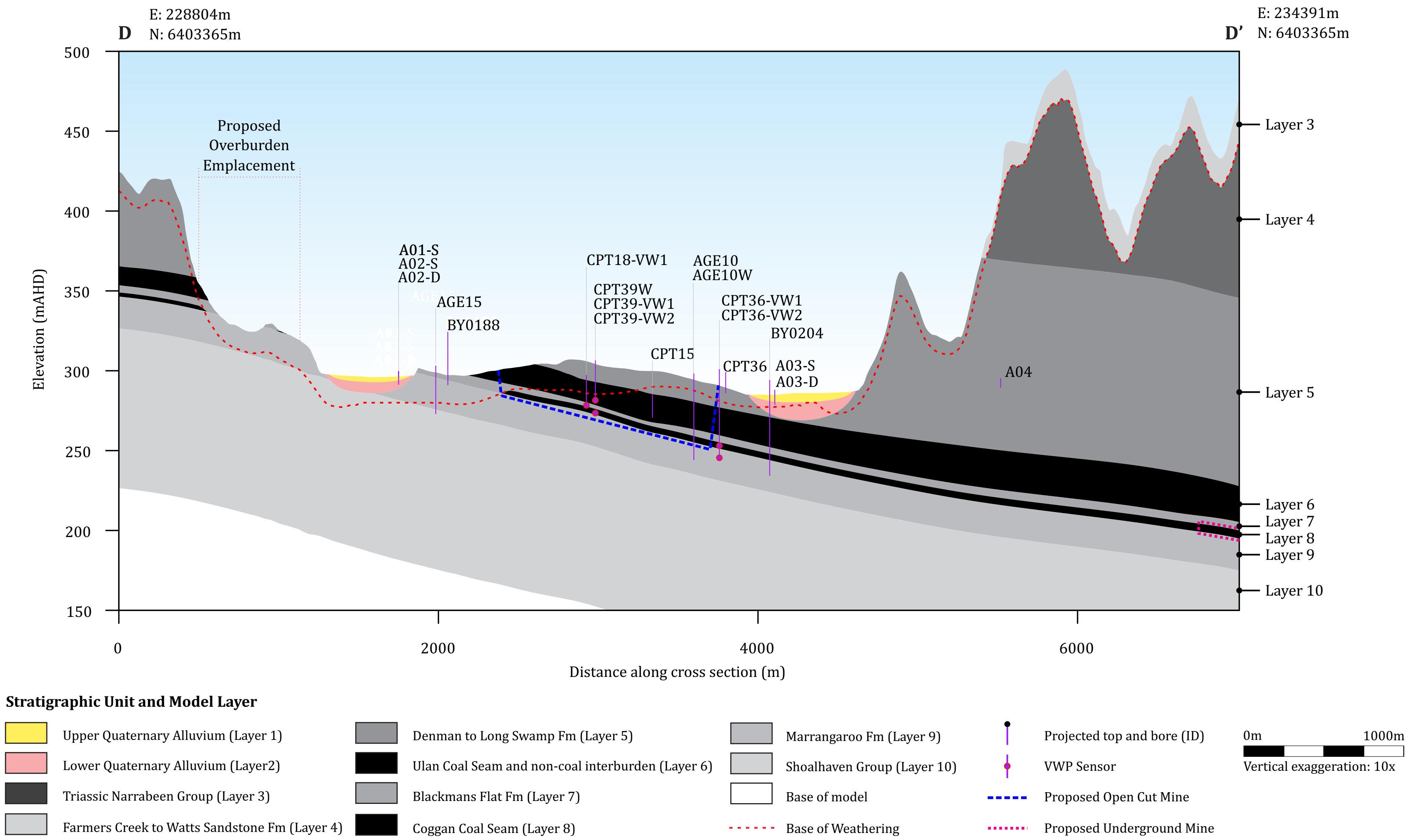
Bylong Coal Project (G1606G)



Geological cross section C - C'

Figure 3-4

Bylong Coal Project (G1606G)



Geological cross section D - D'

Figure 3-5

Bylong Coal Project (G1606G)

4 Pumping Test Program

A number of submissions on the EIS recommended the installation of trial pumping bores to measure the yield of the alluvial aquifer. This work was undertaken by KEPCO in early 2016. The work program is outlined in the following sections:

- Section 4.1 describes the installation of the trial pumping bores; and
- Section 4.2 outlines the yield testing program.

Section 5.1 describes the hydraulic properties and water quality data collected from the testing program and a revised description of alluvial aquifer properties.

4.1 Location and bore design

Four sites were selected to test the yield from the alluvium and to measure the hydraulic properties of the alluvial sediments. At each of the four trial sites, a pumping bore and two or three monitoring bores were installed. Fieldwork for the Project commenced mid-March 2016 and was completed in early May 2016. Large diameter drilling for the pumping test bores was completed by Gricks Drilling Pty Ltd, whilst monitoring bore works were completed by Hagstrom Drilling Pty Ltd. AGE supervised the drilling and pumping tests.

Figure 4-1 shows the locations of each of the trial testing sites in relation to the proposed mining areas, with Figure 4-2 to Figure 4-5 showing the detailed test layout at each site. Table 4-1 summarises the construction details for each of the bores. The geology and construction details (composite logs) are contained within Appendix A.

LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area

Bore locations

- Monitoring bore
- Pumping bore
- Monitoring bore abandoned after testing
- Major drainage
- Minor drainage

Bylong Coal Project (1606G)

Pumping and monitoring bore locations

DATE 15/07/2016

FIGURE No: **4-1**

LEGEND

Bore locations

- Monitoring bore
- Pumping bore
- Monitoring bore abandoned after testing
- Major drainage
- Minor drainage

Bylong Coal Project (1606G)

Pumping and monitoring bore locations - Site 1

DATE 15/07/2016

FIGURE No: **4-2**

LEGEND

Open Cut Mining Area

Bore locations

- Monitoring bore
- Pumping bore
- Major drainage
- Minor drainage

Bylong Coal Project (1606G)

Pumping and monitoring bore locations - Site 2

DATE
15/07/2016

FIGURE No:
4-3

LEGEND

Bore locations

- Monitoring bore
- Pumping bore
- Major drainage
- Minor drainage

Bylong Coal Project (1606G)

Pumping and monitoring bore locations - Site 3

DATE 15/07/2016

FIGURE No: **4-4**

LEGEND

Bore locations

- Monitoring bore
- Pumping bore
- Major drainage
- Minor drainage

Bylong Coal Project (1606G)

Pumping and monitoring bore locations - Site 4

DATE 15/07/2016

FIGURE No: **4-5**

Table 4-1 Summary of bore construction details

Well ID	Location	Bore type	Completion date	Easting (GDA94 Z56)	Northing (GDA94 Z56)	Collar – ground level (mAHD)	Collar – top of PVC / steel (mAHD)	Screen depth (mbgl)	Filter depth (mbgl)	Alluvium depth (mbgl)	SWL mTOC[1] / Date of measurement	Monitoring bore distance (metres from pumping bore)
AGE21P	Site 3	Pumping	19/03/2016	230399.86	6407017.74	275.42	276.32	8.6 - 10.6	3 - 16	11	7.615: 06/05/2016	-
AGE22M	Site 3	Monitoring	21/03/2016	230408.92	6406988.41	275.67	276.45	8 - 11	3 - 18	12	7.685: 06/05/2016	30.7
AGE23M	Site 3	Monitoring	23/03/2016	230404.43	6407002.98	275.5	276.25	8 - 11	3 - 18	12	7.492: 06/05/2016	15.45
AGE24P	Site 1	Pumping	23/03/2016	230335.86	6408250.32	267.07	267.77	9.46 - 11.46	3 - 11.5	13	3.44: 06/05/2016	-
AGE25M	Site 1	Monitoring	30/03/2016	230333.75	6408262.60	267.21	268.02	7 - 10[2]	N/A	N/A	-	5.5
AGE26M	Site 1	Monitoring	01/04/2016	230340.37	6408245.85	267.19	267.8	9 - 12	3 - 12	N/A	3.45: 06/05/2016	6.35
AGE27M	Site 1	Monitoring	02/04/2016	230344.68	6408241.39	267.34	268.06	9 - 12	3 - 12	N/A	3.69: 06/05/2016	12.55
AGE28P	Site 4	Pumping	02/04/2016	232022.00	6406184.64	283.91	284.42	13 - 15	3 - 20	15	1.88: 26/04/2016	-
AGE29M	Site 4	Monitoring	03/04/2016	232044.99	6406165.16	284.19	284.93	12 - 15	3 - 19	15	2.24: 05/05/2016	30.13
AGE30M	Site 4	Monitoring	05/04/2016	232033.68	6406174.91	284.03	284.88	12 - 15	3 - 19	15	2.197: 05/05/2016	15.2
AGE31M	Site 2	Monitoring	13/04/2016	231762.56	6406941.95	279.03	279.7	13 - 16	3 - 16.9	16	2.112: 04/04/2016	13.54
AGE32P	Site 2	Pumping	15/04/2016	231768.38	6406929.72	279.08	279.79	13 - 15	3 - 17.7	16	2.07: 04/04/2016	-
AGE33M	Site 2	Monitoring	16/04/2016	231774.97	6406915.71	279.14	279.85	13 - 16	3 - 18.6	16	2.082: 04/04/2016	29.03

Notes: *1. SWL mTOC = Standing water level metres below top of casing*

2. Temporary screen for pumping test – bore abandoned after testing

4.1.1 Site 1 – Downstream at Bylong River - Lee Creek Confluence

Site 1 is located downstream of the open cut mine, about 300 m east of the Bylong River and 500 m downstream of the confluence of the Bylong River with Lee Creek. The site consisted of one pumping bore (AGE24P) and three monitoring bores (AGE25M, AGE26M, AGE27M). Figure 4-6 below shows installation of a bore at Site 1 looking to the north-west towards the Bylong River.

Figure 4-6 Drilling at Test Site 1

The pumping bore intersected relatively clean alluvial sands and gravels from 4 m to 13 m below surface during drilling. Tertiary basalt derived gravels occurred from 11 m to 13 m, creating difficult drilling conditions. This resulted in the hole collapsing from 11 m to 13 m, preventing the screen from being installed to the base of the alluvial aquifer.

The monitoring bore AGE25M encountered drill bit refusal due to igneous cobbles / boulders at a depth of 10 m. A temporary PVC casing was installed within this bore for monitoring during the pumping test and later abandoned. Monitoring bores AGE26M and AGE27M also encountered igneous gravels towards the base of the alluvial sequence and both bores were constructed at a depth of 12 m, where drilling chips suggested weathered rock had been intersected.

Groundwater levels at this site stabilised at about 3 m below ground surface indicating a saturated thickness of around 10 m to 11 m in this area.

4.1.2 Site 2 – East of proposed open cut mining area

Site 2 was located about 60 m to the east of the Bylong River approximately 2.3 km upstream of the Lee Creek confluence. The site consisted of one pumping bore (AGE32P) and two monitoring bores (AGE31M and AGE33M). The boreholes at this site intersected 16 m of alluvial sediments comprising clean sand and gravel, underlain by sandstone at about 16 m. Groundwater levels at this site were about 1 m below ground surface indicating a saturated thickness of around 15 m in this area. Figure 4-7 shows the location of a bore at Site 2 looking to the east.

Figure 4-7 Drilling Test Site 2 east of Bylong River

4.1.3 Site 3 – Lee Creek

Site 3 was located on the Lee Creek flood plain between the proposed Eastern and Western open cut mining areas. The site was within an area of pasture previously irrigated with a centre pivot, which is clearly visible within aerial photography. The site consisted of one pumping bore (AGE21P) and two monitoring bores (AGE22M and AGE23M). Figure 4-8 below shows drilling undertaken at Site 3 looking to the west.

Site 3 intersected sand and gravel to between 11 m and 12 m in depth. This was underlain by a dull black coal seam of about 1 m in thickness. Groundwater levels at this site were about 6 m to 7 m below ground surface indicating a more limited saturated thickness of around 4 m to 8 m in this area. The pumping bore AGE21P lifted slightly (~300 mm) as the surface casing was extracted, reducing slightly the installation depth. Subsequent hole development indicated the casing remained undamaged.

Figure 4-8 Drilling rigs setting up at Test Site 3 on Lee Creek flood plain

4.1.4 Site 4 – Upstream Bylong River

Site 4 was located on the Bylong River floodplain. The site again consisted of one pumping bore (AGE28P) and two monitoring bores (AGE29M and AGE30M). Figure 4-9 shows the site viewed from the west.

The boreholes at this site intersected 15 m of alluvial sediments comprising clean sand and gravel, with clay present within the drilling chips suggesting lenses of finer sediment. The alluvial sediments were underlain by a dull to bright banded, highly weathered coal seam of about 3 m in thickness. Groundwater levels at this site were about 1 m below ground surface indicating a saturated thickness of around 14 m in this area.

Figure 4-9 Drilling at Test Site 4 adjacent to Bylong River

4.2 Testing program

4.2.1 Test set-up

Pumping tests were undertaken at each site to assess the hydraulic properties of the alluvial aquifer and the long term yield from each bore. Each test consisted of an initial stage of equipment testing to determine pump flow rate at a given pressure. This was followed by a step draw down test which comprised of a series of steps with increasing flow rates over identical time periods. These measured flow rates and associated drawdown were used to determine a maximum flow rate for the 100 hour constant rate test. The constant rate tests were conducted on each site the day after the step drawdown test. After the test, the water level was recorded until the aquifer had fully recovered, which was usually within a day.

Data loggers were installed prior to the tests in the pumping bore and the two associated observation bores to record the water levels. The water levels were also manually checked in the pumping and monitoring bores and in any surrounding existing private wells and surface water features, where these were present. Table 4-2 summarises the dates the testing was undertaken.

Table 4-2 Summary of test dates

Site	Test dates		
	Step drawdown	Constant rate	Recovery
1	9 April 2016	12 - 16 April 2016	17 April 2016
2	4 May 2016	5 - 8 May2016	9 May 2016
3	18 April 2016	19 - 23 April 2016	24 April 2016
4	25 - 26 April 2016*	27 April - 1 May 2016	2 May 2016

Note: ** The pump capacity was insufficient to stress the aquifer and another test with three steps was conducted on 26th April with a higher capacity pump*

Two pumps were used for testing, depending on the yield of the bores as follows:

- lower yield bores – Lowara 16GS75, 4" submersible pump; and
- higher yield bores – Lowara Z646, 6" submersible pump (50Hz).

A mobile generator powered the pumps with water delivery through 4" diameter lay flat pipe. Flow rates were measured with an in-line impeller flow meter. Figure 4-10 shows the headworks and flow meter setup used for each pumping test.

Figure 4-10 Headworks and flow meter setup

Monitoring of bores on the Tinka Tong property was undertaken whilst pumping tests at Site 1 were in progress. No influence from the pumping test was evident at the two bores on this property. It is noted since completion of the pumping tests KEPCO has acquired this property.

4.2.2 Step tests

Table 4-3 summarises the pumping rate and duration for each of the steps undertaken during the step tests.

Table 4-3 Step test summary

Bore ID	Step	Rate (L/s)	Duration (min)
AGE21P	1	2.26	30
	2	2.93	45
	3	4.2	45
	4	5.1	45
	5	5.6	45
AGE24P	1	2.6	45
	2	4.3	45
	3	6.1	45
	4	7.3	45
AGE28P	1	2.16	45
	2	3.16	45
	3	4.16	45
	4	5	45
	5	6.16	45
	6	7.83	45
AGE28P*	1	8	45
	2	10	45
	3	11	45
AGE32P*	1	7.83	45
	2	10	45
	3	11.3	45
	4	12.83	45
	5	14	45

4.2.3 Constant rate test set-up

Table 4-4 below summarises the details of the constant rate test at each site.

Table 4-4 Constant rate test summary

Bore ID	Bore type	Distance from pumping well (m)	Standing Water Level (mbgl)	Maximum drawdown (m)	Site	Pumping rate (L/s)	Duration (hrs)
AGE21P	Pumping	-	6.64	1.81	3	4.6	100
AGE22M	Observation	30.7	6.95	0.18			
AGE23M	Observation	15.45	6.78	0.21			
AGE24P	Pumping	-	2.9	3.44	1	4.6	103
AGE26M	Observation	6.35	2.9	0.31			
AGE27M	Observation	12.55	2.99	0.24			
AGE28P	Pumping	-	1.41	8.28	4	8.3	100
AGE29M	Observation	30.13	1.65	0.23			
AGE30M	Observation	15.2	1.48	0.38			
AGE32P	Pumping	-	1.5	11.53	2	13.9	79
AGE31M	Observation	13.54	1.43	1.21			
AGE33M	Observation	29.03	1.43	0.84			
REG3005005	Observation	57.98	1.405	0.53			

The constant rate test for Site 2 was interrupted at 79 hours as a substantial rain event was forecast for the following evening. 15 mm of rainfall was measured on 10th May at the Bylong (Glenview) weather station (Number 62107), but given the limited rainfall and the fact it occurred after the test was completed indicates the testing program was not influenced by this event.

Section 5.1.1 describes the analysis of the data collected during the pumping test program.

5 Groundwater regime

The following sections provide further information on the groundwater regime as follows:

- Section 5.1 presents new information collected on the alluvial aquifers;
- Section 5.2 discusses the potential for the Tertiary basalt to form an aquifer; and
- Section 5.3 provides further information on the Permian weathered zone and coal seam connectivity with the alluvium.

5.1 Alluvial aquifer

5.1.1 Hydraulic properties

Drawdown and recovery data from pumping and monitoring bores provides an estimate of the hydraulic parameter of aquifer transmissivity and storage coefficient (Ss). The coefficient of hydraulic conductivity (K) is obtained by dividing the transmissivity by the aquifer thickness. The hydraulic properties of the alluvial aquifer system were estimated from the pumping test data using a variety of methods including a small numerical model and analytical equations.

A simple 'sand box' numerical model was constructed for the purposes of estimating the hydraulic properties of the alluvial aquifer. The model was constructed using the Groundwater Vistas 6 graphical user interface and MODFLOW and comprised:

- a single layer with 1 m x 1 m cells spanning 200 rows and 100 columns;
- a uniform thickness adjusted to match the thickness of the saturated aquifer at each pumping test site;
- constant head cells at rows 1 and 200 of the model with an elevation of 0.0 m and -0.001 m respectively to create a slight gradient across the model under non-pumped conditions;
- a single pumping well placed in the centre of the model grid, and the monitoring bores spaced accordingly; and
- two stress periods, the first for the 100 hour pumping tests and the second for the recovery period.

An automated parameter estimation program (PEST) was used to determine the optimal values of hydraulic conductivity and specific yield in the sand box model. Figure 5-1 shows the measured and modelled drawdowns and the optimised parameters for each monitoring bore site.

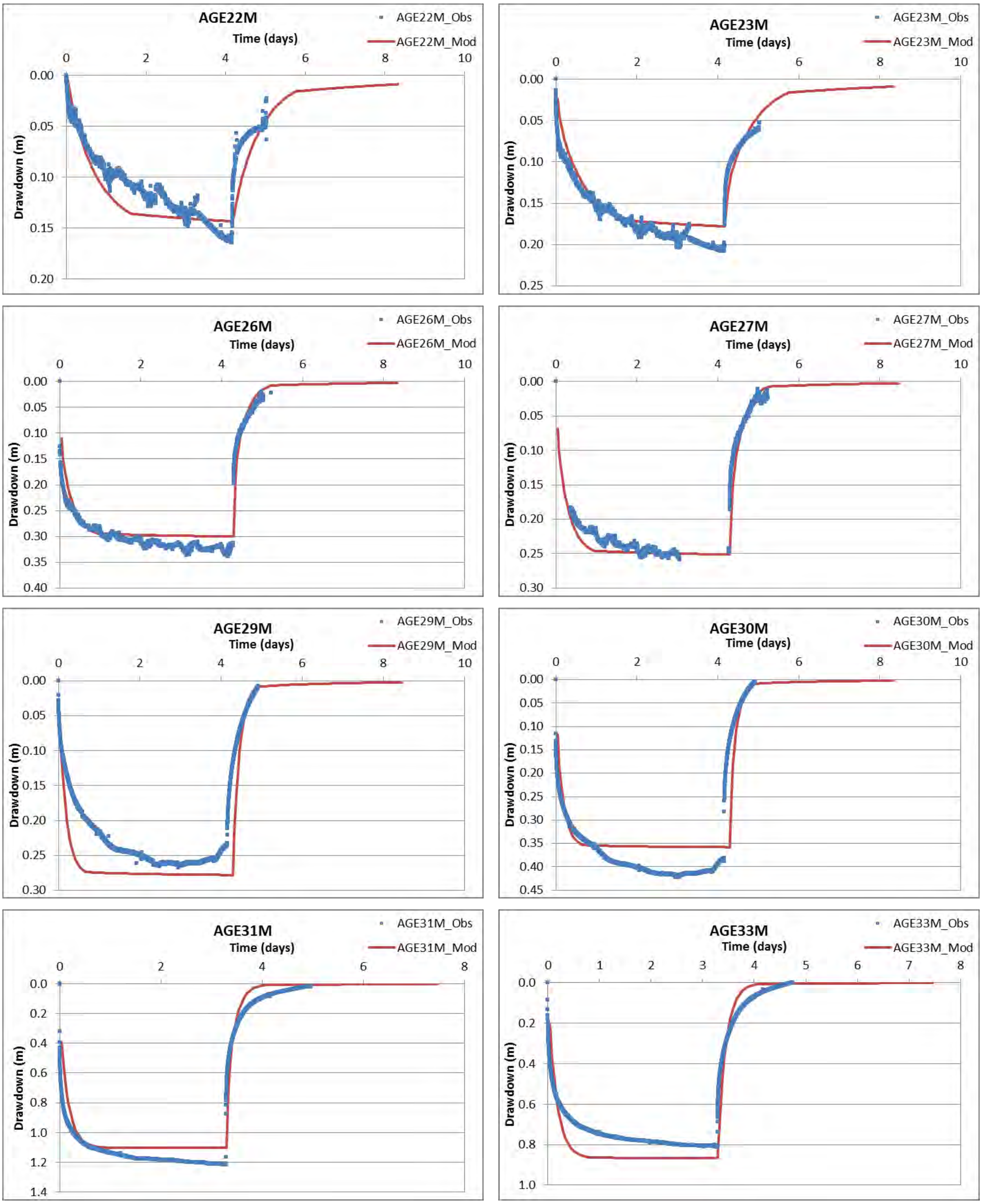


Figure 5-1 Simulated and measured groundwater levels from pumping and recovery tests

The data was also analysed using standard analytical methods (Theis, Cooper-Jacob and Neuman). The "Aquifer Test Version 2.0"[1] software package was used for this task. Table 5-1 summarises the hydraulic properties estimated from the analytical and numerical methods.

Table 5-1 Constant rate test results

Bore ID	Site	Theis		Cooper - Jacob		Neuman		Theis Recovery	Numerical model	
		k	Ss	k	Ss	k	Ss	k	k	Sy
AGE21P	3	106	-	165	-	85.6	-	230	235	19
AGE22M	3	153	19.2	191	12.9	192	9.9	374		
AGE23M	3	171	11.8	171	14.2	214	4.1	286		
AGE24P	1	78.6	-	102	-	70.7	-	110	97.4	5.5
AGE26M	1	1050	0.4	97.2	1.8	108	0.9	82.4		
AGE27M	1	-	0.001	139	0.3	236	0.001	76.9		
AGE28P	4	18.6	-	34.6	-	11.8	-	13.2	102.7	3.7
AGE29M	4	88.2	3.3	80.9	4.5	69.9	5.9	25.7		
AGE30M	4	78.7	1.1	88.2	0.7	73.5	1.5	24.3		
AGE31M	2	67.2	0.6	78.6	0.3	66.1	0.7	45.3		
AGE32P	2	19.2	-	64.9	-	19.9	-	47.9	38.8	2.0
AGE33M	2	65	0.2	78.8	0.05	65.1	2.7	41.1		

***Notes**:* *k – hydraulic conductivity (m/day)*
Ss – storage coefficient (m^{-1} x 100)
Sy – specific yield (%)

[1] Waterloo Hydrogeologic, (1996), *"Aquifer Test Version 2.0"*

Figure 5-2 shows the optimised values compared with the ranges generated from analytical pumping test.

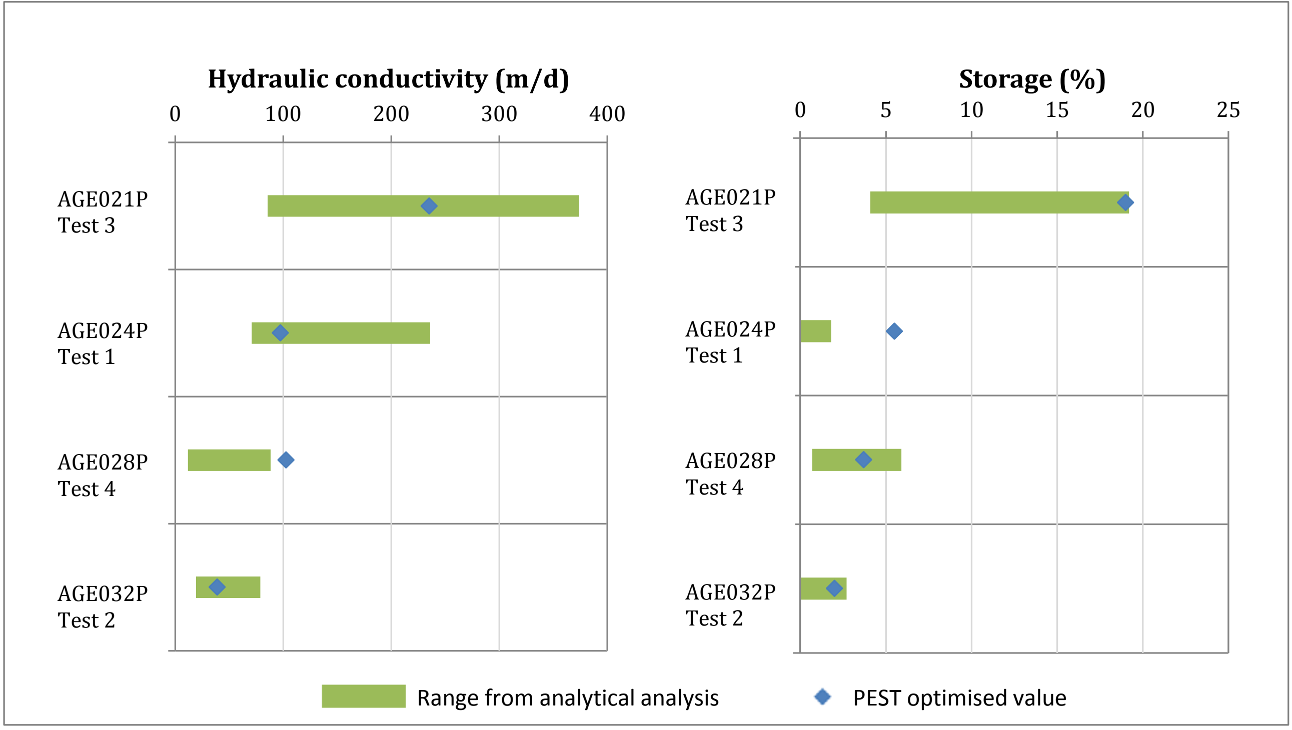


Figure 5-2 Aquifer properties estimated from analytical and numerical methods

The pumping test analyses indicate a high to very high hydraulic conductivity within the alluvial aquifer at each of the sites chosen for the pumping tests. The results are also higher than previous measurements of hydraulic conductivity obtained by conducting rising and falling head tests within the monitoring bores installed within the alluvial aquifer. Figure 5-3 shows graphically the range in hydraulic conductivity measured within each bore installed within the alluvial aquifer as well as the values adopted within the numerical modelling.

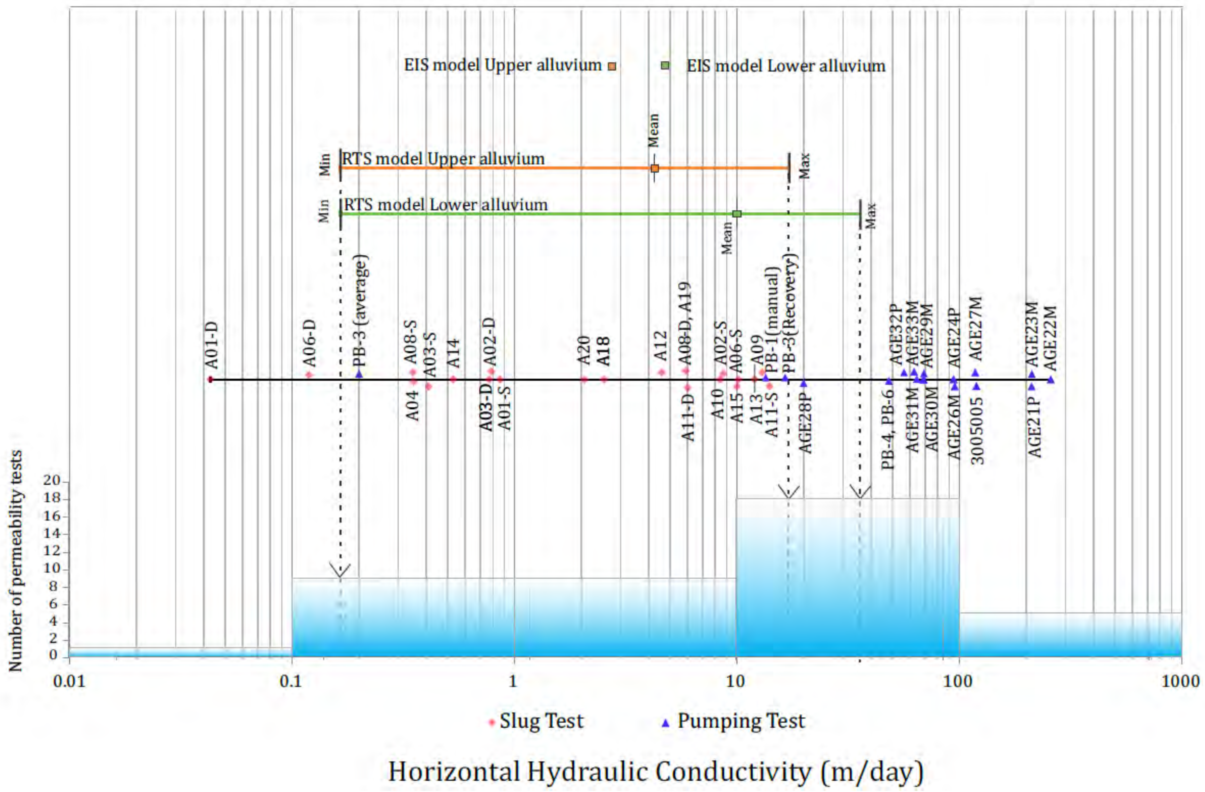


Figure 5-3 Range of hydraulic conductivity estimates within alluvium

The range within the data suggests either, a heterogeneous aquifer system, or the estimate of hydraulic conductivity depends on the testing method chosen. The pumping tests are considered more likely to have captured an appropriate estimate of hydraulic conductivity, as they are less likely to be subject to influences from 'skin effects' that may have retarded the flow of water from the formation during the rising and falling head tests.

Figure 5-3 shows the majority of hydraulic conductivity estimates fall within the range 10 m/day to 100 m/day. Figure 5-3 also shows the hydraulic conductivity range assumed for numerical models developed for the EIS and RTS and indicates the adopted values did not represent the upper end of the data range.

Figure 5-4 shows the range of storage estimates from the alluvial aquifer derived from the pumping test analysis. Like the hydraulic conductivity, the storage estimates show a relatively wide range. Storage is not estimated from the rising and falling head tests, and therefore the adopted methodology potentially does not explain the measured range, with heterogeneity in the aquifer being the only reason. Figure 5-4 also shows the storage range assumed for numerical models developed for the EIS and RTS and indicates, unlike hydraulic conductivity, the adopted values did likely consider an appropriate range based on available data.

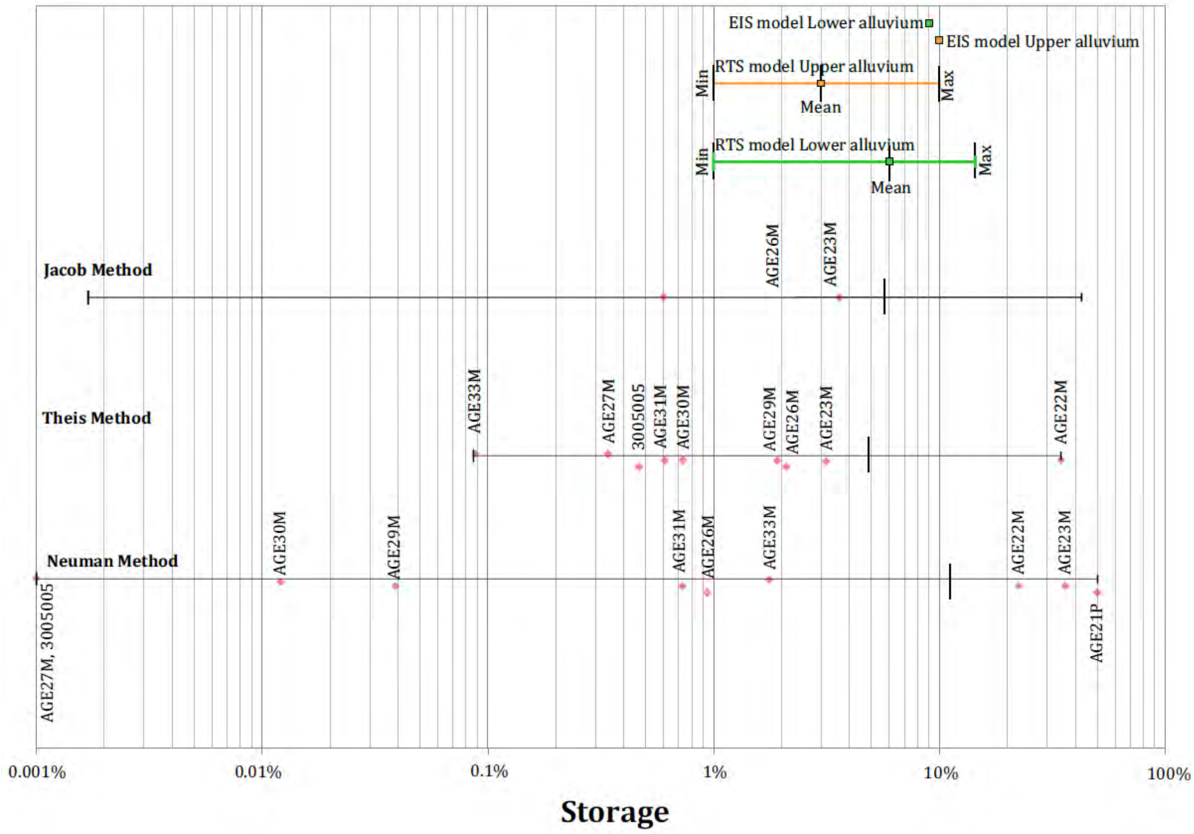
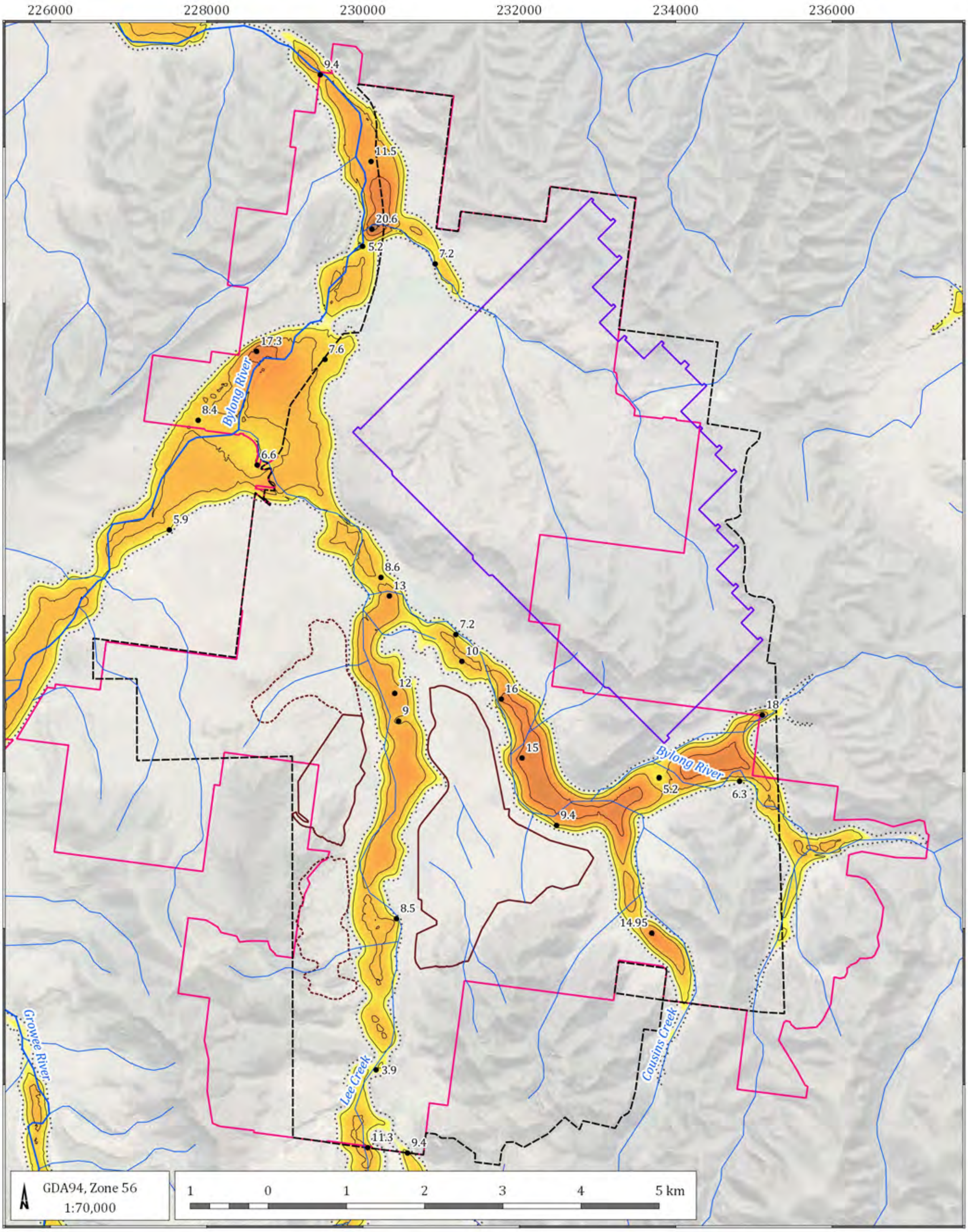


Figure 5-4 Range of storage estimates within alluvium

5.1.2 Alluvium thickness and water budget

As described above, the pumping test program provided further information on the properties of the alluvial aquifer surrounding the open cut mining area. This included estimates of hydraulic conductivity, storage and saturated thickness. The new geological data from drilling the new pumping and monitoring bores was used to update the mapping of the saturated thickness of the alluvial aquifer and to derive a simple water budget for the system.

During the EIS, the thickness of the alluvium was mapped using available borehole data and the limit of the alluvium was determined by Douglas Partners (refer AGE 2016 – Section 6.4). Control points were used where no data existed. The mapped thickness of the alluvium was updated using data from the newly installed pumping and monitoring bores. Figure 5-5 shows the mapped thickness of the alluvial sediments. The thickness of the saturated zone was determined by interpolating water levels measured in March 2016 and subtracting the depth to the water table from the total saturated thickness. A similar figure (Figure 7.1) was provided in the EIS based on information available at that time. The newer information indicates a larger thickness of alluvial sediment, in the Bylong River flood plain to the east of the Eastern open cut mining area. Figure 5-6 shows the mapped saturated thickness within the alluvial aquifer. It highlights the areas of most significant saturated thickness within the Bylong River alluvium occurs between the open cut and underground mining areas.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- KEPCO owned land
- Quaternary alluvium
- Major drainage
- Minor drainage

Interpolated thickness of alluvial sediments (m)

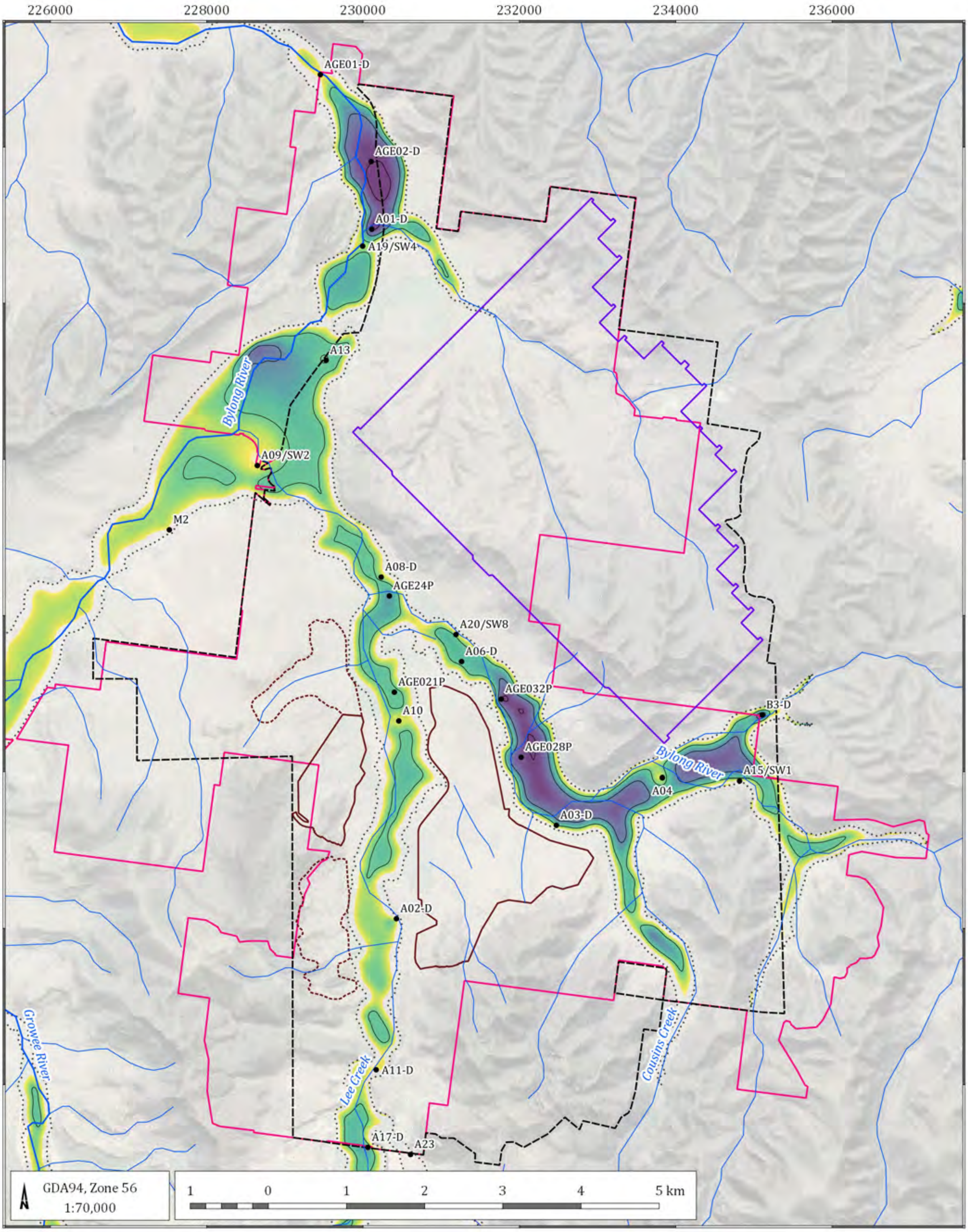
- 1
- 5
- 15
- 22
- Interpolated thickness contour of alluvial sediments (m, 5m interval)
- • Drillholes used for interpolation of alluvial sediments thickness (m)

Bylong Coal Project (G1606G)

Revised interpolated thickness of alluvial sediments

DATE 15/07/2016

FIGURE No: **5-5**



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- KEPCO owned land
- Quaternary alluvium
- Major drainage
- Minor drainage

Interpolated thickness of saturated alluvial sediments (m)

- 1
- 5
- 10
- 15
- Interpolated thickness contour of saturated alluvial sediments (m, 5m interval)
- • Drillholes used for interpolation of alluvial sediments water level

Bylong Coal Project (G1606G)

Revised interpolated saturated thickness of alluvial sediments

DATE
15/07/2016

FIGURE No:
5-6

As discussed, the figures show the maximum saturated thickness occurs within the Bylong River alluvium, particularly east of the open cut mining area, and also in a location downstream of the underground mine where the saturated thickness reaches a maximum of about 16 m. The maps suggest the areas of thicker alluvium are separated by rock bars that effectively create groundwater pools, separated by bedrock highs. The maps indicate that Lee Creek and the Growee River hold significantly less groundwater than the Bylong River with the saturated thickness, varying from around 2 m to 6 m and 2 m to 3 m respectively in each of these systems. This suggests the rock bars that hold back water and promote the collection of groundwater in the Bylong River alluvium, are less prominent in the bedrock underlying Lee Creek in the project area. Growee River is relatively distant from the project area and therefore there is less information on the bedrock morphology.

The mapped saturated thickness was used to estimate the volume of water in storage within the alluvium at March 2016. Rainfall recharge was also estimated using the surface area of the alluvial aquifer and proportions of average annual rainfall. Table 5-2 summarises the water budget for the alluvial aquifer system for March 2016.

Table 5-2 Alluvial aquifer water budget ~ March 2016

Alluvial aquifer	Saturated volume (m^3)	Surface area (m^2)	Estimated volume of water in storage (ML)		Estimated annual recharge (ML/year)	
			5%*	15%*	3%#	20%#
within Project boundary	95,232,427	11,280,780	4,762	14,285	73	1,467
within KEPCO land ownership^	126,741,570	14,808,926	6,337	19,011	96	1,925

Notes: ** assumed specific yield*

 # assumed % of annual rainfall that reaches the water table as recharge – average annual rainfall assumed to be 650 mm (refer AGE [2015] Figure 5.2 EIS)

^ area calculated prior to the acquisition of the Tinka Tong property

The assumed range for specific yield shown in Table 5-2 used to estimate the volume of water in storage was estimated from the results of the pumping test analysis. Table 5-2 shows the volume of groundwater in storage within the alluvial aquifer system within the project area is estimated to range from about 5,000 ML to 14,000 ML. The land owned by KEPCO extends beyond the Project Boundary, and when this increased area is considered the volume in storage within the alluvial aquifer increases to about 6,000 ML to 19,000 ML.

It should be noted that these estimates are based on groundwater levels measured largely in March 2016. Monitoring shows groundwater levels are historically relatively low and during periods of higher rainfall the water levels in storage can increase by 1.5 m to 3 m above the levels measured in March 2016 (AGE 2016). If groundwater levels were to rise by 1.5 m to 3 m the volumes of groundwater in storage would increase by about 20% to 50%.

Table 5-2 shows the potential range in groundwater recharge is wide depending on the proportion of annual rainfall adopted as entering the alluvial aquifer. This indicates rainfall recharge could vary between <100 ML/year and 1,500 ML/year within the Project Boundary, and up to 1,900 ML/year within KEPCOs land ownership.

Table 5-2 demonstrates that the volume of water required from the bore field to account for potential deficits in surface water could exceed the annual recharge rates. Where groundwater extraction exceeds recharge then groundwater is removed from aquifer storage and declines in groundwater levels will occur. However, when recharge rates are higher they are likely to exceed the demand from the bore field, then reduction in aquifer storage would not occur. It is also important to note there are other sources of groundwater recharge to the alluvial aquifers. These are seepage from flows in creeks and rivers, groundwater flow from upstream and flow from the underlying Permian bedrock into the alluvium, which all serve to recharge the alluvial aquifer.

5.1.3 Groundwater levels and recharge

The numerical modelling undertaken for the EIS and RTS utilised a simple soil moisture balance to estimate rainfall recharge rates to the shallow groundwater systems. The EIS utilised daily rainfall measurements from the rainfall gauge installed at the Project, along with data from the Wollar rainfall gauge (BOM station 62032), whilst the RTS used interpolated data from the SILO data source to estimate recharge.

Observations over the baseline monitoring period has indicated small high intensity storm events can move through the catchment resulting in significant variability in rainfall recorded in rain gauges across the catchment. To further estimate recharge, a combination of interpolated SILO data and measurements from the Project rain gauge were used. Figure 5-7 shows the daily rainfall and the periods the soil moisture budget indicates potential for the soil profile to become fully saturated, resulting in recharge to the water table of alluvial aquifer. It was assumed that 40 mm of rainfall excluding evaporation was required to accumulate in the profile for the soil to be fully saturated and promote deep drainage to the water table. Therefore rainfall must exceed evaporation to allow accumulation of water in the soil profile and accumulate over time to 40 mm in total.

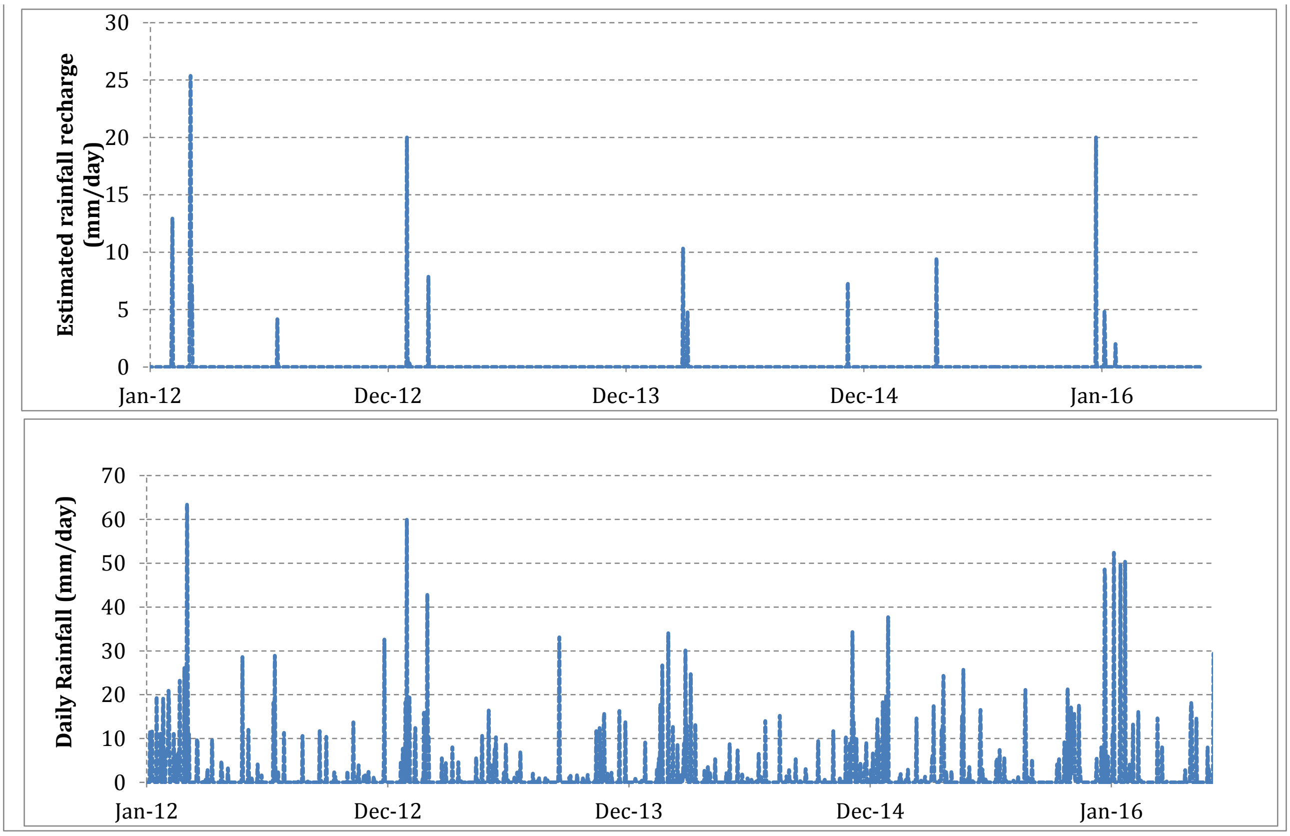


Figure 5-7 Daily rainfall and estimated rainfall recharge events

Figure 5-7 indicates over the baseline monitoring period significant recharge to the alluvial aquifer has generally occurred only during the summer months when rainfall has been sufficient to saturate the soil profile. The figure shows that a significant recharge event appears to have occurred during December 2015 and January 2016. The RTS document reviewed groundwater level data collected up to early December 2015, and therefore did not consider the influence of this recent recharge event. Review of the most recent groundwater monitoring data indicates there has been some recovery in groundwater levels within the alluvial aquifer due to rainfall events in late December 2015 and January 2016. Updated groundwater level hydrographs for bores within the monitoring network are included within Appendix B. Figure 5-8 to Figure 5-10 show groundwater levels recorded within the alluvial aquifer from selected bores over the baseline monitoring period. The RTS document includes a borehole location map (AGE 2016 - Figure 2).

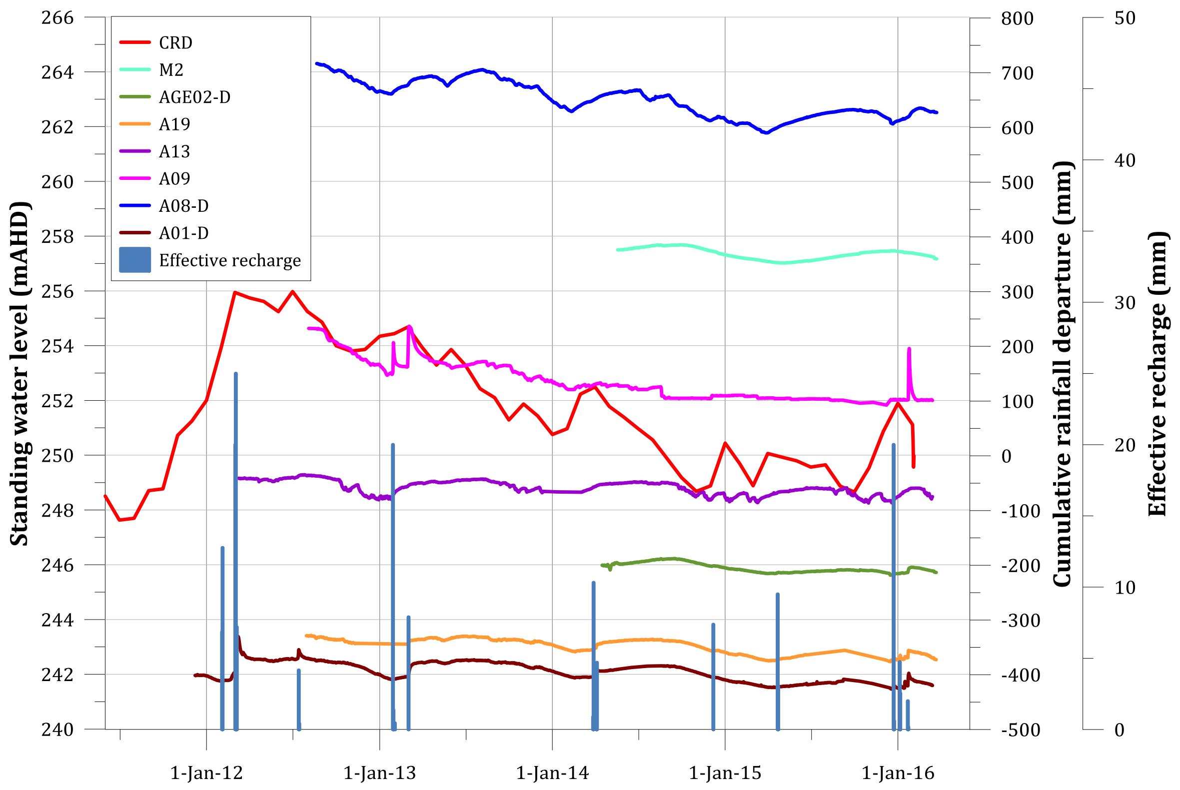


Figure 5-8 Alluvial aquifer hydrographs – bore located down stream of proposed open cut mining area

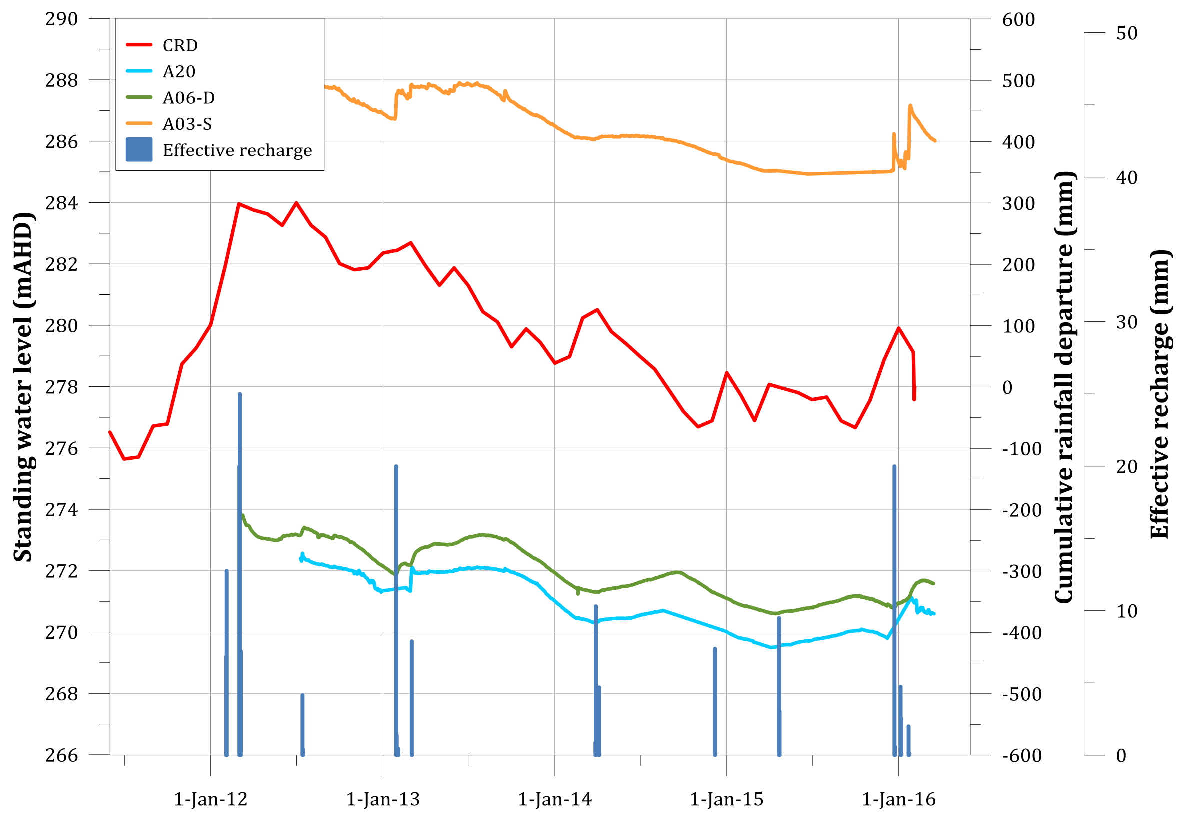


Figure 5-9 Alluvial aquifer hydrographs – within Bylong River alluvium adjacent to proposed open cut mining area

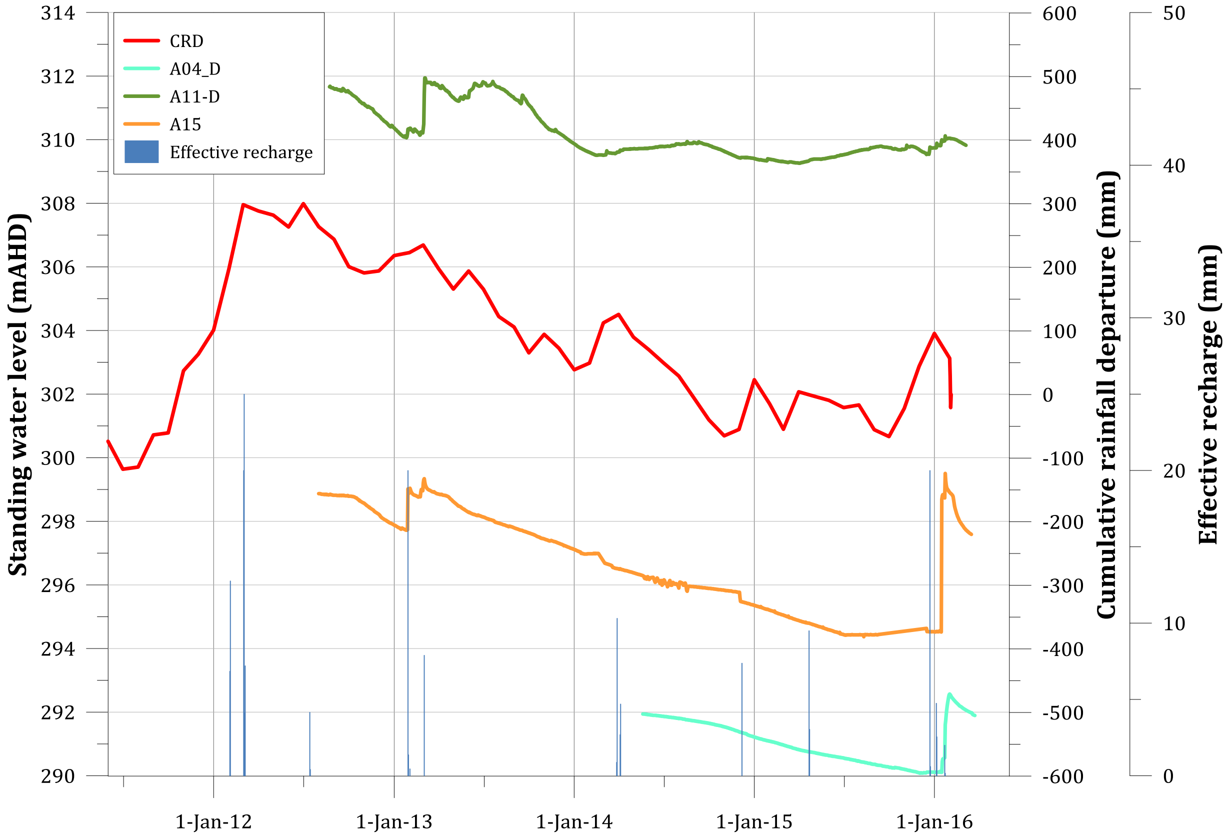


Figure 5-10 Alluvial aquifer hydrographs- up stream of proposed mining areas

The hydrographs generally show rising groundwater levels when rainfall recharge has been estimated, indicating estimates of recharge using the soil moisture spreadsheet are appropriate. The monitoring bores show a variety of responses to the rainfall event in December 2015 and January 2016. At some bores, water levels increased slowly over a period of about three weeks, where as in others water levels increased rapidly over a period of 24 hours. The most rapid response was recorded upstream of the proposed mining area in bores A15 that is located within relatively close proximity to the Bylong River which recorded a 4 m rise in water level on 15 January 2016. The rapid rise in water levels can only be explained by recharge to the alluvial aquifer due to seepage through the bed of the Bylong River. Interestingly other bores peaked about nine days later rising between 1 m and 2 m in a day (eg. A20, A09). These bores are located downstream of bore A15, suggesting runoff from the upstream catchments recharges the groundwater systems further downstream.

A much slower and gradual rise in groundwater levels was observed in other bores more distant from the rivers and creeks for example A08D and A04, suggesting rainfall recharge, or down valley flow as the primary recharge mechanisms. Using the assumptions for recharge presented previously in Table 5-2 and assuming an average water level rise of 1 m within the alluvial aquifer indicates the recharge observed in January 2016 would range from about 600 ML to 1,700 ML.

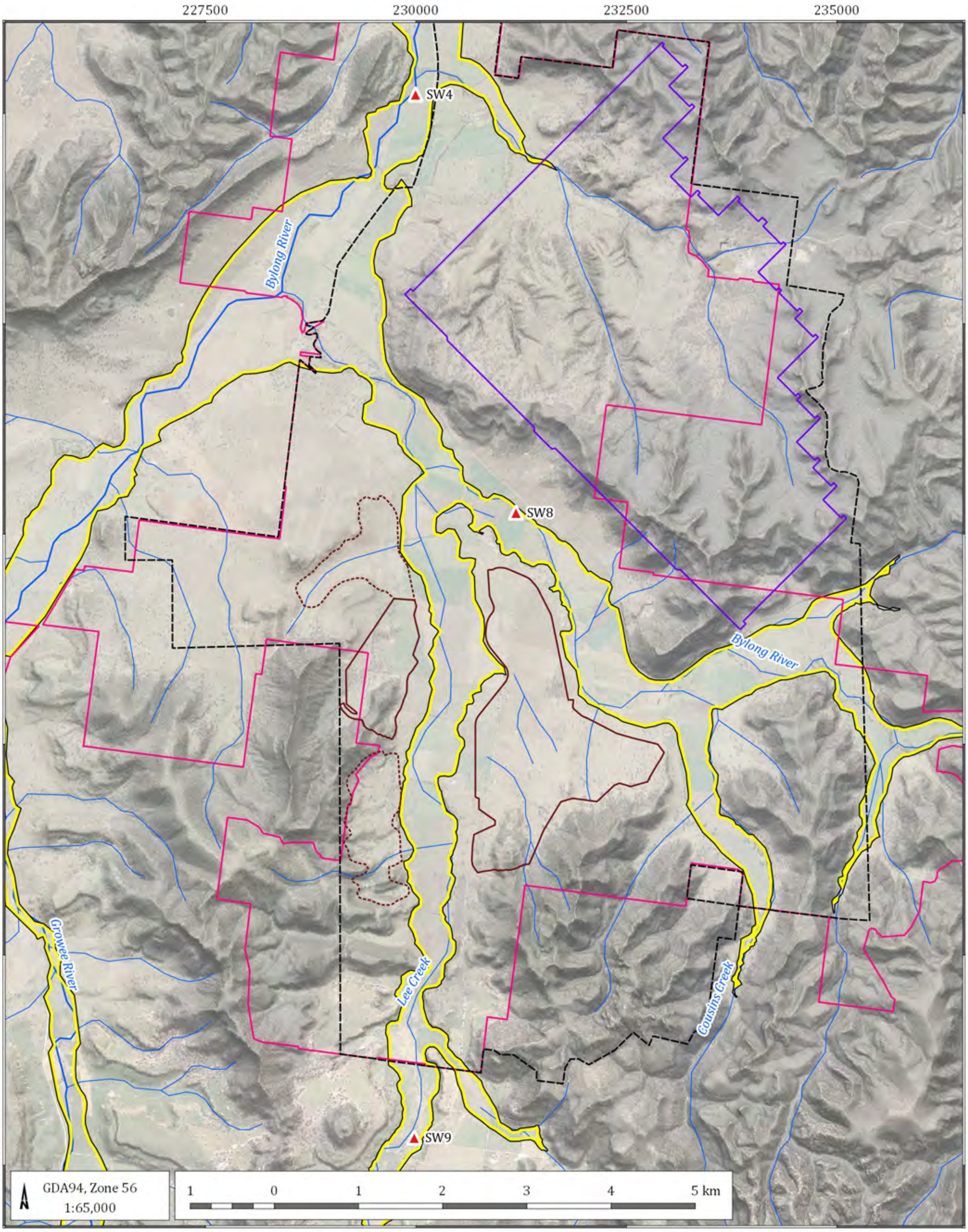
Section 6.3.2 describes how the rainfall recharges from the soil moisture spreadsheet were used to calibrate the groundwater model to the baseline data. Section 6.4.2 describes the assumptions used when determining rainfall recharge rates for the predictive model representing the proposed mining activities.

5.1.4 Streamflow

KEPCO have installed stream gauges to monitor stream flow levels, volumes and water quality at three sites within the Study Area. The gauges are located as follows:

- SW4 – Bylong River downstream of the confluence with Growee River;
- SW8 - Bylong River downstream from the proposed Eastern Open Cut Mining Area and adjacent to the proposed underground extraction area; and
- SW9 - Lee Creek upstream of the proposed Open Cut Mining Areas.

Figure 5-11 shows the locations of the stream gauges. The data from the three stream gauges show that the river systems within the Study Area are ephemeral, and have not flowed continuously over the baseline monitoring period. Measuring stream flow has been problematic at the gauges due to the intermittent flows. To provide a continuous estimate of stream flows, WRM developed an AWBM rainfall runoff model for the Project catchments as part of the EIS process. This model was used to simulate surface water flow within the catchments over the baseline monitoring period. Figure 5-12 shows the stream flow events simulated by the AWBM model at gauges SW4 to SW9, as well as flow recorded by the government stream gauge located downstream on the Goulburn River.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Quaternary alluvium
- Stream gauging stations
- Major drainage
- Minor drainage

Bylong Coal Project (1606G)

Stream gauging stations

AGE GROUNDWATER & ENVIRONMENTAL

DATE 15/07/2016

FIGURE No: **5-11**

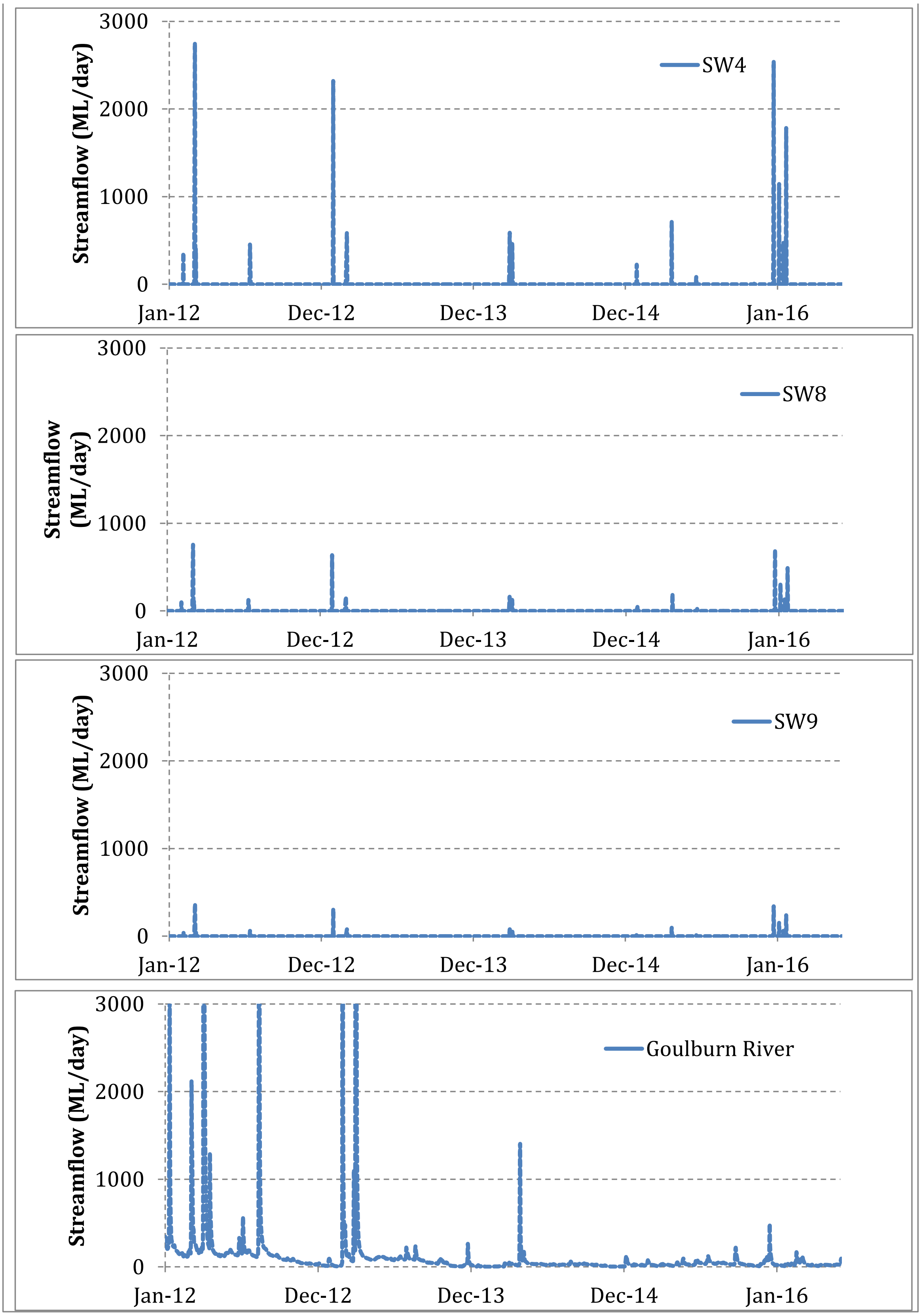


Figure 5-12 Stream flow hydrographs

Figure 5-12 shows stream flows increase with distance downstream as the contributing catchment area increases. At site SW8 adjacent to the open cut and underground mining areas stream flow events occur for only one day, with five separate stream flow events during December 2015 and January 2016, ranging from about 100 ML/day to 700 ML/day. Interestingly the stream flow events predicted using the AWBM model are higher than streamflow observed downstream at the Goulburn River gauge (No. 210006). This suggests streamflow is lost as recharge into the alluvial aquifers as it flows downstream. This is not unexpected given the water table is known to be below the bed of the streams in many areas, and therefore would allow water to flow into the underlying aquifer.

5.1.5 Water quality

Groundwater samples were collected from the eight monitoring bores installed for the pumping trials between 4th and 9th May 2016. Sampling was undertaken after the test pumping was completed. Samples were collected using an electro-submersible pump and low-flow technique, where field water quality parameters were allowed to stabilise before samples were collected.

Samples were analysed by Australian Laboratory Services in Sydney for a suite of parameters consistent with the baseline groundwater assessment and included:

- pH, electrical conductivity (EC) and turbidity;
- major cation / anions (calcium, magnesium, sodium, potassium, chloride, sulphate, alkalinity and ionic balance);
- nutrients (nitrate, nitrite, ammonia and total phosphorous); and
- dissolved metals (beryllium, barium, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, vanadium and zinc).

Table 5-3 presents the results of the laboratory analyses. The samples recorded neutral pH values ranging between 7.25 and 7.43. The EC measurements indicated relatively fresh water ranged from 395 µS/cm to 1670 µS/cm. The samples indicate the water is suitable for livestock, and potable in some locations, but with palatability issues at AGE26M and AGE27M.

Table 5-3 Groundwater analysis results

			Sample ID	AGE22M	AGE23M	AGE26M	AGE27M	AGE29M	AGE30M	AGE31M	AGE33M
			Sample date	09/05/2016	09/05/2016	09/05/2016	09/05/2016	05/05/2016	05/05/2016	04/05/2016	04/05/2016
Analyte	Units	LOR	ANZECC guidelines - livestock								
Physical properties											
pH Value	pH Unit	0.01		7.33	7.25	7.40	7.36	7.39	7.42	7.40	7.43
Electrical Conductivity @ 25°C	µS/cm	1		644	640	1370	1670	395	401	459	447
Cation / Anions											
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	mg/L	1		172	164	319	324	132	135	157	149
Total Alkalinity as CaCO3	mg/L	1		172	164	319	324	132	135	157	149
Sulfate as SO4 - Turbidimetric	mg/L	1		59	60	62	107	9	9	10	11
Chloride	mg/L	1		58	58	234	308	38	38	42	42
Calcium	mg/L	1		46	47	81	101	21	21	26	25
Magnesium	mg/L	1		28	29	57	77	17	17	20	20
Sodium	mg/L	1		48	41	118	130	31	31	35	34
Potassium	mg/L	1		4	4	6	7	4	4	3	3
Ionic Balance	%	0.01		3.73	3.56	0.87	0.52	<0.01	0.76	0.13	0.65
Dissolved Metals											
Aluminium	mg/L	0.01	5	0.02	0.02	<0.01	<0.01	0.01	<0.01	0.01	0.02
Arsenic	mg/L	0.001	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

			Sample ID	AGE22M	AGE23M	AGE26M	AGE27M	AGE29M	AGE30M	AGE31M	AGE33M
			Sample date	09/05/2016	09/05/2016	09/05/2016	09/05/2016	05/05/2016	05/05/2016	04/05/2016	04/05/2016
Analyte	Units	LOR	ANZECC guidelines - livestock								
Beryllium	mg/L	0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	mg/L	0.001	-	0.120	0.101	0.076	0.088	0.021	0.027	0.035	0.030
Cadmium	mg/L	0.0001	0.01	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	1	0.001	<0.001	0.001	0.001	<0.001	<0.001	0.002	0.001
Copper	mg/L	0.001	1	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead	mg/L	0.001	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	-	0.177	0.025	0.096	0.133	0.105	0.092	0.281	0.211
Nickel	mg/L	0.001	1	0.002	0.005	0.002	0.002	0.002	0.002	0.002	0.002
Selenium	mg/L	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium	mg/L	0.01	-	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	mg/L	0.005	20	0.008	0.006	<0.005	<0.005	0.005	<0.005	<0.005	0.019
Iron	mg/L	0.05	-	0.24	<0.05	<0.05	<0.05	<0.05	0.07	0.18	0.13
Mercury	mg/L	0.0001	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nutrients											
Ammonia as N	mg/L	0.01	-	0.02	<0.01	<0.01	<0.01	0.01	0.02	0.04	0.04
Nitrite as N	mg/L	0.01	9.1	<0.01	<0.01	0.03	0.04	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	90.3	0.91	1.50	0.42	0.87	0.04	0.04	0.03	0.03
Nitrite + Nitrate as N	mg/L	0.01	99.4	0.91	1.50	0.45	0.91	0.04	0.04	0.03	0.03
Total Phosphorus as P	mg/L	0.01	-	0.05	0.05	0.10	0.08	0.02	0.03	0.03	0.04

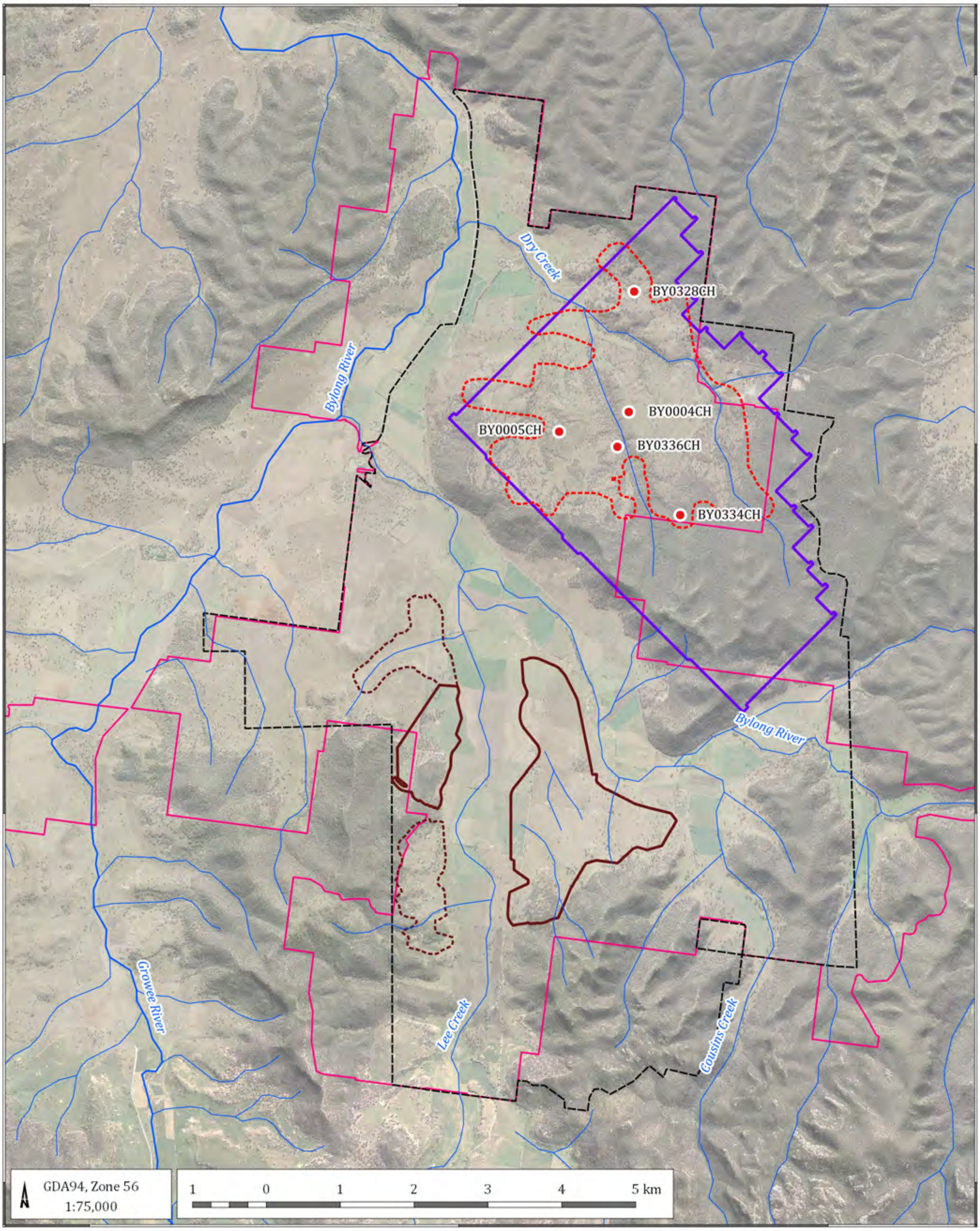
5.2 Tertiary basalt

Tertiary basalt flows occur as capping overlying Triassic sediments of the Narrabeen Group above the area where longwall mining is proposed. Exploration drilling indicates the thickness of the basalt averages 25 m.

KEPCOs geologists conducted field mapping as part of the exploration program and identified basalt outcrops occurring predominantly along creek lines on top of the plateau where underground mining is proposed and along Dry Creek. Colluvium comprising a proportion of basalt material often makes up the overburden lithological material in the valley areas. In some drill holes igneous rocks have been identified beneath weathered coal layers.

In the RTS, the potential for the basalt to form an aquifer was discussed using water level data collated across a vertical profile of units at a single location. This included a monitoring bore that is screened within the basalt (BY0091-B). This bore was found to be dry throughout the three year monitoring period. It is currently the only monitoring bore screened within the basalt unit. The RTS also referred to a deeper bore (BY0091-S) installed in the State Mine Formation, located directly beneath the basalt. Water level information from this bore, relative to the base of the basalt, indicated that the basalt was dry in the monitored area. The RTS concluded the basalt could potentially become partially saturated in areas where the base of the basalt is below 328 m RL. More recent assessment indicates that this is unlikely and that the basalt probably remains wholly unsaturated, as discussed below.

To further confirm the basalt does not form a permanent aquifer, the limited basalt groundwater data was augmented by reviewing and interpreting geophysical logging results obtained from exploration drill holes that penetrated the basalt. Five bore logs with sonic logging were assessed. These logs were run in open cored exploration holes. The principle of sonic (acoustic) logging requires that there be fluid present in the bore for the technique to work and a response to be measured. Therefore, the depth where the sonic log begins indicates the fluid level in that hole at the time. A potential problem with this method is that the fluid level may not be representative of the standing groundwater level due to the use of drilling muds. However, conservatism is introduced because a recorded drilling mud level would most likely be more elevated than the equilibrium water table level. It should also be noted that the fluid levels if at equilibrium with the groundwater systems represent an average levels controlled by the relative water levels in all water-bearing units intersected by the borehole because they are uncased. Each bore was drilled to between approximately 100 m and 200 m below the surface. A location plan for the exploration bores is presented as Figure 5-13.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Kepco owned land
- Basalt extent
- Exploration bore
- Major drainage
- Minor drainage

Bylong Coal Project (G1606G)

Location of exploration bores with sonic logs

DATE 15/07/2016

FIGURE No: **5-13**

The water levels from the sonic logs were compared against the inferred groundwater levels and the base of the basalt to investigate the vertical relationship. In all cases, the base of the basalt was recorded as being above the fluid level, indicating the basalt is likely to be unsaturated. Table 5-4 presents the water level data. The smallest height difference between base basalt and fluid level is observed in bore BY0328CH. This is expected as the bore is located in a relative topographic low.

Table 5-4 Sonic-inferred fluid levels and logged basalt horizons

Bore ID	Sonic start (mbgl)	Top basalt (mbgl)	Bottom basalt (mbgl)	Top borehole elevation (mRL)	Sonic water level start (mRL)	Top basalt (mRL)	Bottom basalt (mRL)
BY0004CH	80.5	1	39.5	370.88	290.38	369.88	331.38
BY0005CH	92	1	23.8	356.00	264.00	355.00	332.20
BY0328CH	38	6	35	342.17	304.17	336.17	307.17
BY0334CH	116	1	10	404.41	288.41	403.41	394.41
BY0336CH	36	5	11	339.78	303.78	334.78	328.78

The RTS concluded that additional monitoring bores would be required to fully define the saturated and unsaturated characteristics of the basalt. These bores would target potentially deeper and thicker zones within the basalt where there is potential for groundwater to occur. The floor of the basalt appears to generally conform with the topography and therefore the highest potential for statured zones was considered likely to be in topographically lower lying areas.

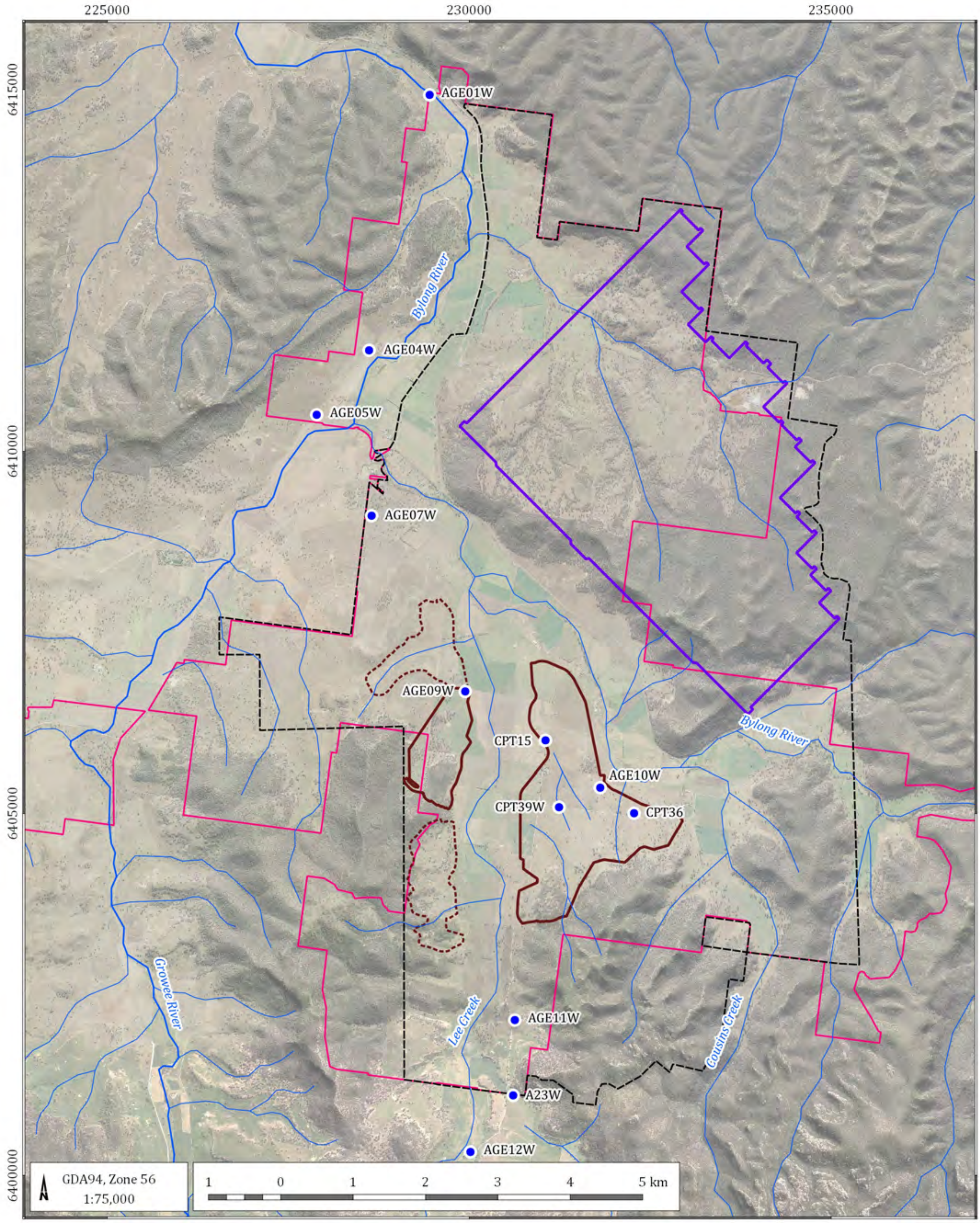
A methodology for installation of additional bores will be documented within the Water Management Plan. At this stage, however, the conceptual hydrogeological model for the basalt is that it remains unsaturated although may support short-term perching as part of normal recharge mechanisms as rainfall drains to deeper units.

5.3 Permian / Triassic

5.3.1 Weathered zone

The weathered zone and its hydraulic properties have been investigated and assessed largely due to its potential impact on groundwater ingress to the proposed open cut mine areas. The unit underlies the alluvium and will act as a pathway for flow from the alluvium to the proposed open cut mining areas in some parts. Section 4.4.1 of the RTS document presented further information on the weathered zone. The report provided thickness maps of the units and discussed the conservatism of assigned hydraulic properties used in the model. Subsequent stakeholder submissions requested further information regarding the aquifer properties of the weathered zone to increase the understanding of the potential for it to yield groundwater to the open-cut mining areas.

During the early stages of groundwater investigations for the Project, a network of monitoring bores were installed into the weathered zone. The bores with the prefix AGE, and suffix W (e.g. AGE01W) were located to measure hydraulic properties and monitor groundwater levels adjacent to potential open cut mining areas, and to understand the potential for the weathered zone to indirectly connect the mining areas with the alluvial aquifer. Figure 5-14 shows the location of AGE_W series and other bores installed within the weathered zone. The bores were relatively wide spread as other potential open cut mining areas were being considered at that time.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Kepco owned land
- Monitoring bore
- Major drainage
- Minor drainage

Bylong Coal Project (G1606G)

Monitoring bores targeting weathered zone

AGE GROUNDWATER & ENVIRONMENTAL

DATE 15/07/2016

FIGURE No: **5-14**

Douglas Partners (DP) supervised the drilling of the bores and carried out rising head tests to estimate hydraulic conductivity. Each rising head test was performed three times in each respective well to allow an average hydraulic conductivity to be assessed. Figure 5-15 presents the measured range in hydraulic conductivity obtained from this assessment as a box and whisker plot.

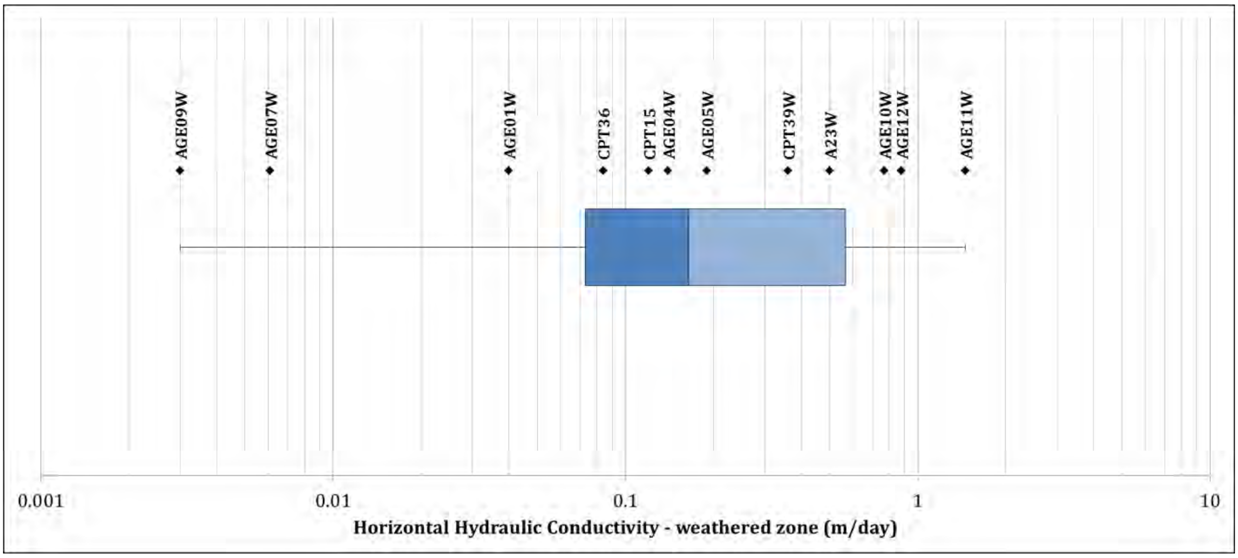


Figure 5-15 Weathered zone hydraulic conductivity range

The plot shows that values for hydraulic conductivity range over three orders of magnitude. This is to be expected given the heterogeneity of the weathered zone, related to the weathering and associated changes in mineralogy, particularly the formation of clays. The 0.003 m/day to 1.46 m/day range is characteristic of a silt to silty sand type lithology and is several orders of magnitude lower than that assessed for the alluvium. The majority of the test results fall within the 0.1 m/day to 1.0 m/day range (0.2 m/day was used for the unit in the numerical model). There is no clear geographic trend in the hydraulic conductivity estimates across the Project Boundary.

Figure 5-16, Figure 5-17 and Figure 5-18 below present groundwater level measurements from a subset of the weathered zone monitoring bores. Each figures presents groundwater levels from pairs of bores, where one bore is screened within the weathered zone, and the other within the overlying alluvial aquifer. These paired bores allow the water level fluctuations within weathered zone and alluvium to be compared.

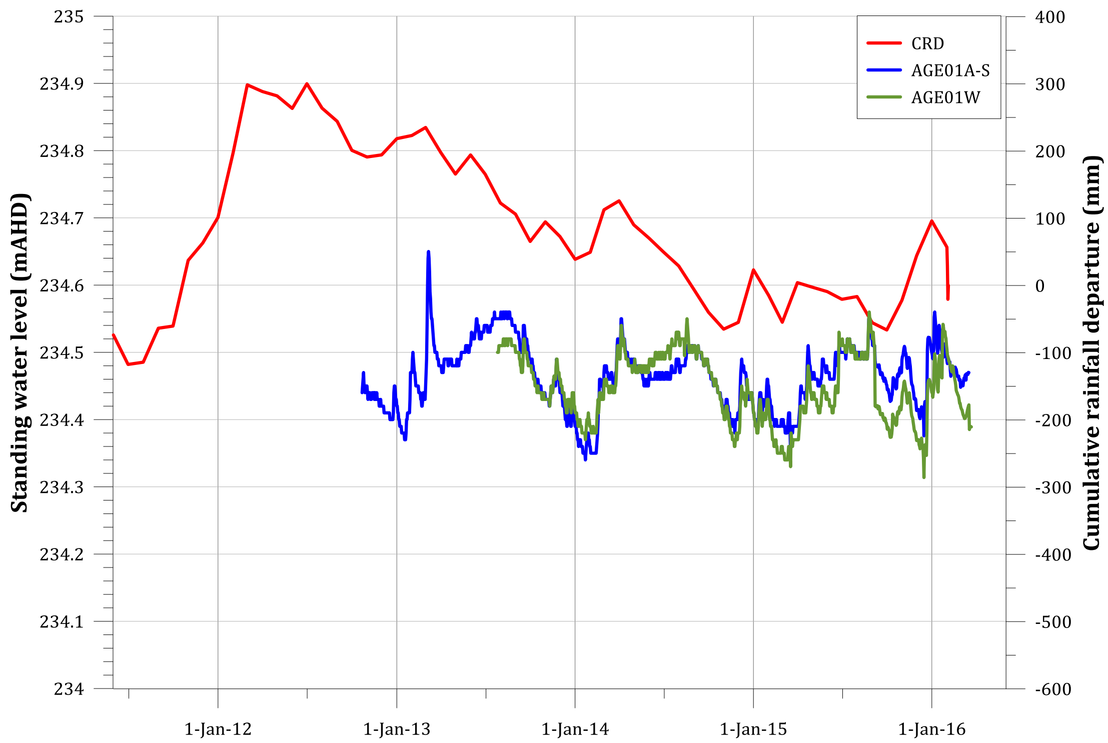


Figure 5-16 Groundwater levels – AGE01A-S and AGE01W

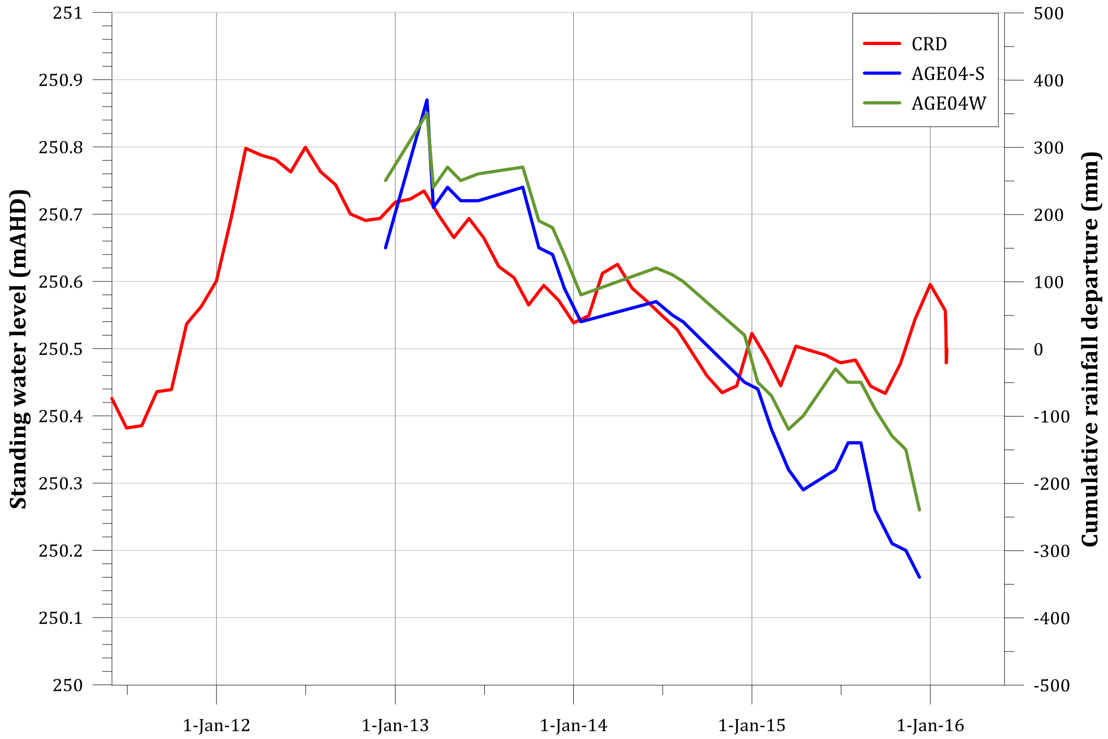


Figure 5-17 Groundwater levels – AGE04-S and AGE04W

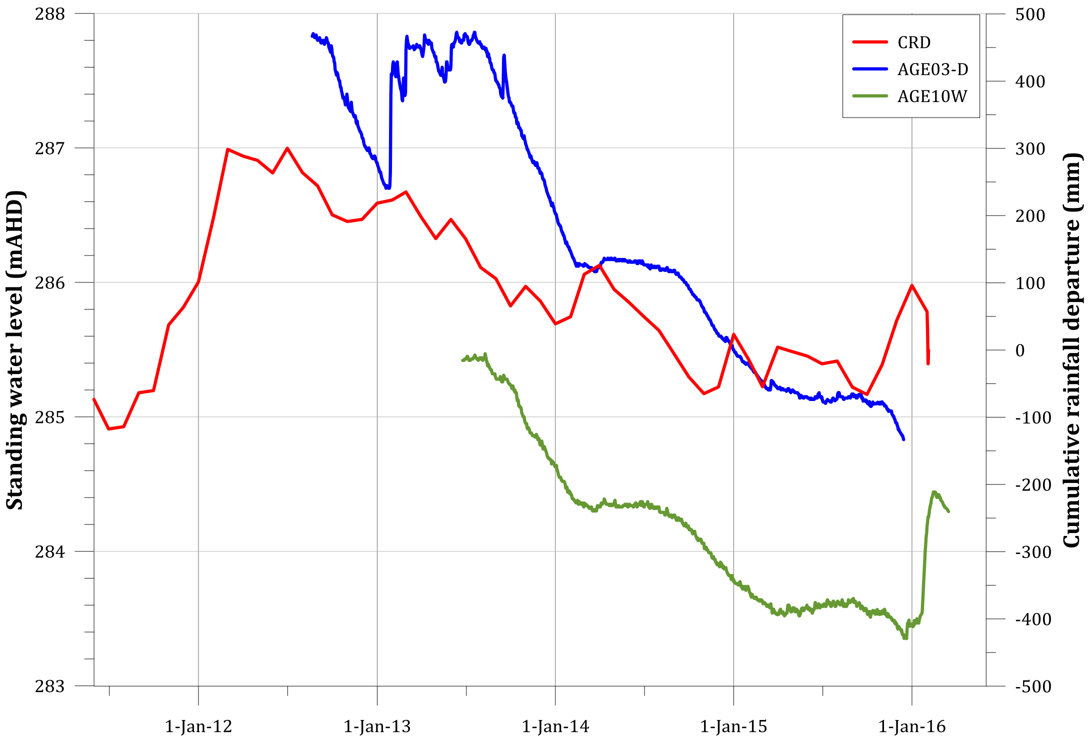


Figure 5-18 Groundwater levels – AGE03-D and AGE10W

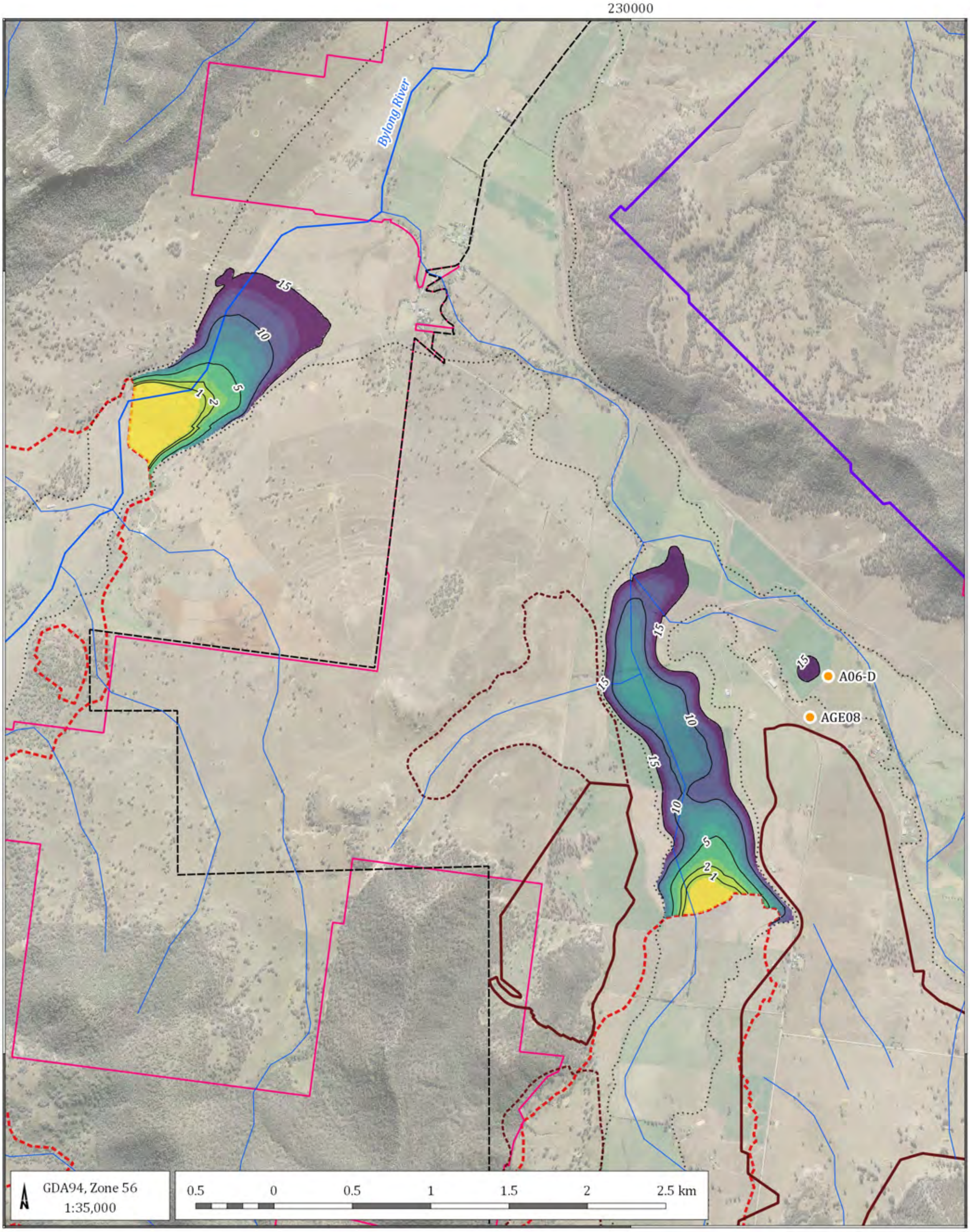
The hydrographs show similar water levels and trends over time within the alluvium and the weathered zone indicating a relatively direct hydraulic connectivity between these units. The exception is AGE10W which records similar fluctuations to the alluvium, but at a level of about 1 m below the alluvial water level. This bore is approximately 1 km away from the alluvial bore.

The results of the field investigations and monitoring indicate that the weathered zone is in hydraulic continuity with the alluvium and will yield groundwater seepage to the open cut mining area where the weathered zone extends into the water table. The water flux is likely to be locally variable due to the broad range in hydraulic conductivity.

Section 6.3 describes updates to the numerical model, with hydrographs showing modelled water levels included with Appendix C. Examination of simulated groundwater levels within monitoring bores installed within the weathered zone show a response in groundwater levels to climatic events and confirm the unit is well connected to the surficial alluvium within the groundwater model.

5.3.2 Coal seam connectivity with alluvium

DPI Water interpreted from maps presented within the RTS document that a hydraulic connection between the Quaternary alluvial aquifer and the Coggan Coal seam aquifer was likely to exist. It is agreed that the available data does indicate in some areas there is a direct or direct hydraulic connection between the alluvium and the coal seams proposed to be mined. Figure 5-19 shows where the Coggan Coal seam either subcrops below the alluvium, or outcrops close to the land surface. The areas where the coal seam subcrops directly beneath the alluvium, or is separated by a thin layer of weathered Permian sediments will be areas where the connectivity is enhanced. Figure 5-19 shows this occurs primarily in the area of the Lee Creek alluvium between the Eastern and Western open cut mining areas. Towards the south of this area the coal seams outcrop above the water table and therefore do not have any direct connection with the alluvial aquifer.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Project Boundary
- Kepco owned land
- Quaternary alluvium
- Coggan Seam subcrop
- Monitoring bore
- Thickness contour (m)
- Major drainage
- Minor drainage

Thickness of saturated material above Coggan coal seam and below alluvium (m)

- 0.5
- 2
- 5
- 10
- 12
- 15

Bylong Coal Project (G1606G)

Coggan coal seam subcrop below water table and recharge area

DATE 15/07/2016

FIGURE No: **5-19**

Figure 5-20 shows groundwater levels measured in alluvial monitoring bore A06-D and coal seam monitoring bore AGE08, which is about 15 m below the base of the alluvium. The groundwater levels fluctuate similarly indicating connectivity between these units.

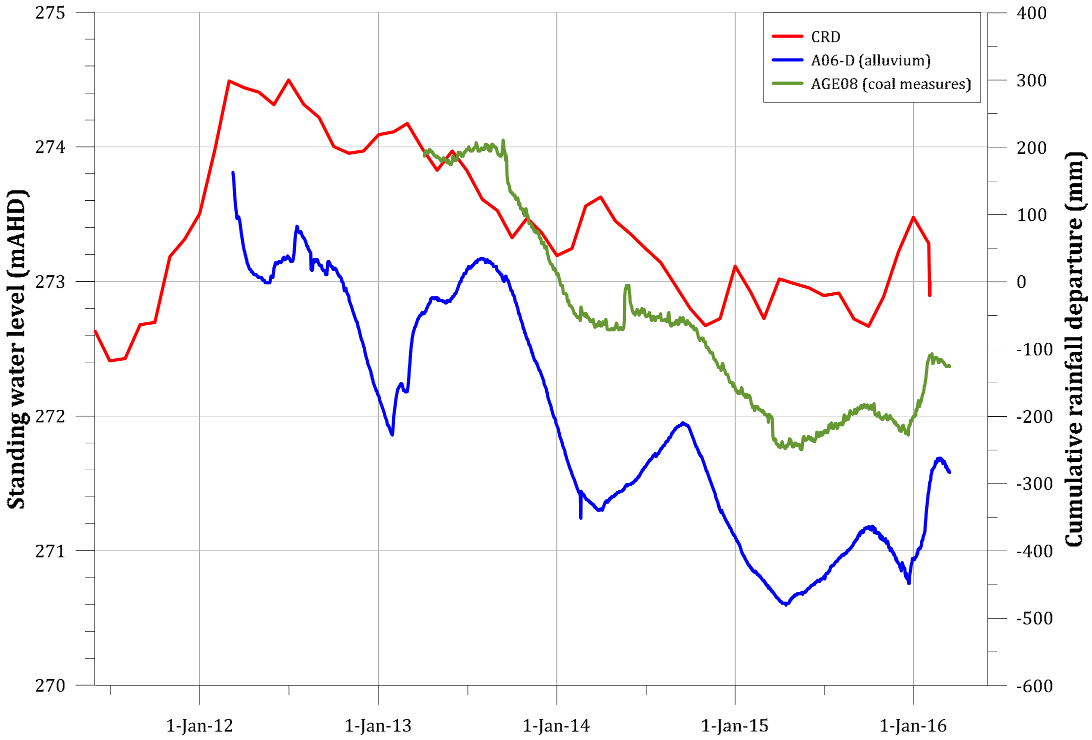


Figure 5-20 Groundwater levels – A06-D and AGE08

6 Numerical modelling

6.1 Background and history

Hansen Bailey commissioned AGE to commence developing the initial numerical modelling for the Bylong Coal Project in mid-2012, with the modelling presented in a report in late 2013. This report (AGE 2013) described the development of this early version of the model which formed part of a submission to the Gateway Panel. The numerical model was set up using MODFLOW SURFACT. MODFLOW SURFACT has two options to represent the recharge processes. These allow representing movement of water within the unsaturated vadose zone, or without these processes as a pseudo soil model. The vadose zone model approach uses the van Genuchten equations and required values are parameters alpha and beta that determine the shape of the relative permeability versus negative pressure head curve. These values are derived for soils but are not commonly available for rock profiles. Whilst these values were not available, a default set of values were used, that promoted rapid numerical convergence and allowed large complex regional models to be developed and calibrated.

In 2014 and 2015 a new version of the numerical model was developed for the Bylong Coal Project EIS. The purpose of the modelling was to address the Secretary's Environmental Assessment Requirements (SEARs) and the recommendations from the Gateway Panel. Whilst this modelling was being undertaken, third party peer reviewers of groundwater studies on other major mining projects began to question the use of the vadose zone approach for regional models. Their concern centred around the lack of data for the α, β and Rs in rock profiles.

To proactively address this concern, for the Project attempts were made to assess the sensitivity of the numerical modelling predictions to both the vadose zone and pseudo soil approaches. The EIS document (AGE 2015) describes the attempts to utilise the pseudo soil option within the MODFLOW SURFACT model developed for the EIS, and the eventual development of a new model in MODFLOW USG allowing the use of the pseudo soil function, known as upstream weighting in MODFLOW USG. The EIS document (AGE 2015) described the sensitivity of the modelling predictions to the vadose zone and pseudo soil approaches, but maintained the use of the vadose zone approach as the base case. The sensitivity analysis outlined in the EIS concluded that increased seepage rate to the proposed mining areas, but reduced the drawdown within the alluvial aquifer system are predicted when adopting the upstream weighting option (equivalent of pseudo soil in MODFLOW USG).

During this time, AGE corresponded with the author of MODFLOW SURFACT and MODFLOW USG, Dr Sorab Panday regarding use of the vadose zone and pseudo soil approaches for regional groundwater flow models. Based on this correspondence and further experience testing the influence of the vadose zone and pseudo soil approaches, whilst previous modelling was considered meaningful, it was decided to conduct further modelling with the upstream weighting approach using MODFLOW USG for the Project.

The numerical groundwater model for the Project was updated in response to submissions in early 2016, and utilised the MODFLOW USG model developed during the EIS along with the upstream weighting option. Modelling for the RTS is described by AGE (2016). The most current numerical modelling undertaken to incorporate the results of the pump testing program described in this document also adopted the MODFLOW USG model with the upstream weighting option as the 'basecase' to predict mining impacts.

The numerical modelling has undertaken an evolutionary path since it was commenced over four years ago in response to new data, requests from stakeholders and peer review experts. It is not considered this invalidates any previous work, rather that it shows that groundwater models have some inherent uncertainty, but this can be addressed by considering the potential range of outcomes and gradually refining models over time. The sections below describe the further improvements made to the numerical model with:

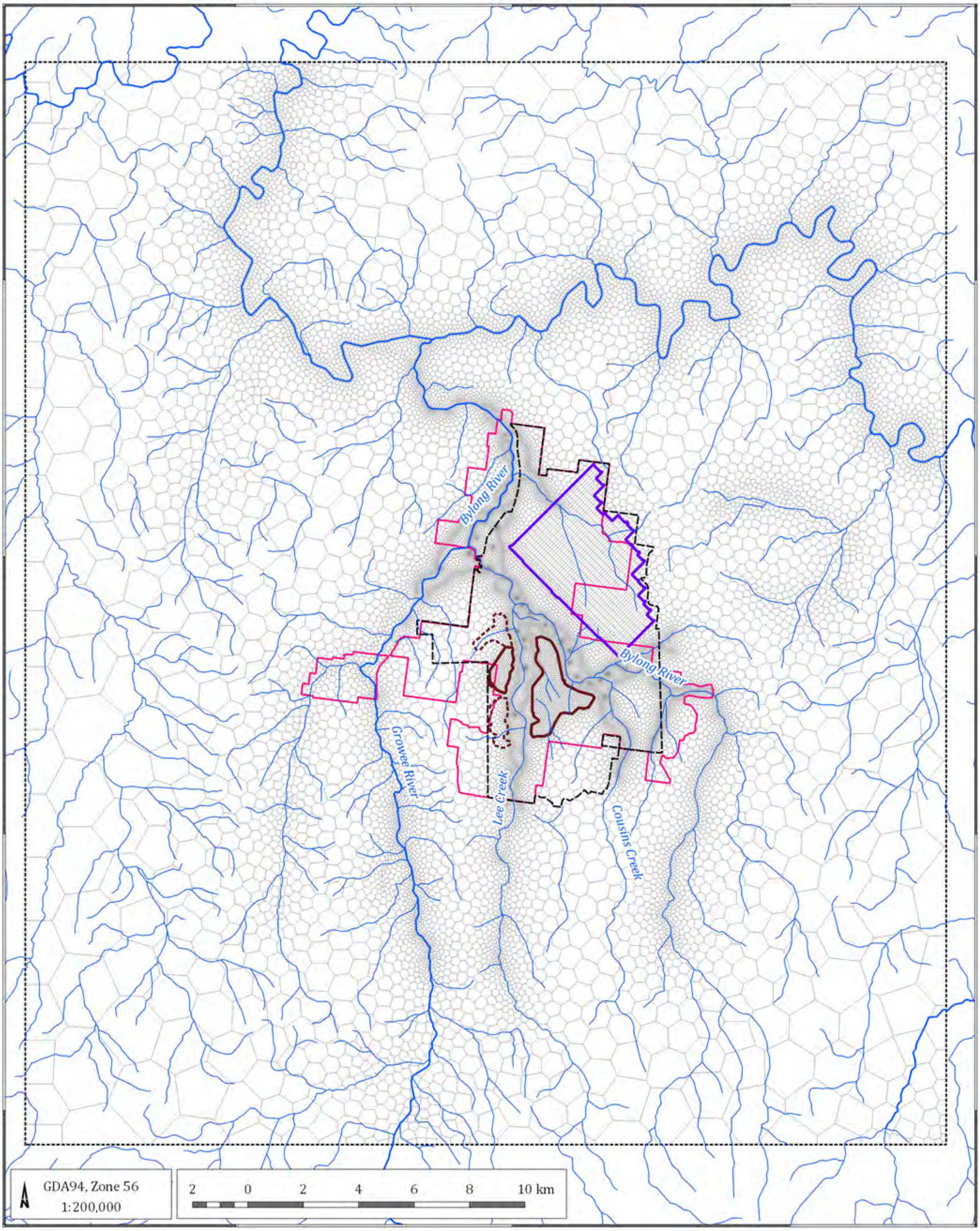
- Section 6.2 outlining the model updates;
- Section 6.3 presenting the updated calibration utilising pump test results; and
- Section 6.4 provides predictions of mining impacts using the updated and recalibrated model.

6.2 Model updates

As discussed, a series of updates were made to the numerical model to address queries raised by stakeholders, and to incorporate new data obtained from the pump testing program and monitoring data of recent rainfall recharge events. The sections below describe the refinements made to the model. The MODFLOW USG model with the upstream weighting option was used for the modelling. The reader should refer to the EIS and RTS reports for a detailed description of the setup of the MODFLOW USG model. The sections below outline the latest changes and refinements to the numerical model.

6.2.1 Mesh refinement

The model cells were refined around the key features including the Goulburn River and the alluvial aquifer to better represent these key features. The model mesh was also refined around the sites of the pumping bores to allow the cone of depression around each pumping bore to be more accurately replicated. Figure 6-1 shows the refined mesh for comparison with Figure 27 of the RTS report.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Model extent
- Project Boundary
- Model mesh
- Major drainage
- Minor drainage

Bylong Coal Project (G1606G)

Refined MODFLOW USG model mesh

DATE: 15/07/2016

FIGURE No: **6-1**

6.2.2 Aquifer thickness

The thickness of the alluvial aquifer was also reviewed and updated to ensure it represented the saturated thickness of the alluvium identified during the pumping test program. The updated thickness of the alluvial aquifer was adjusted in the MODFLOW USG model based on the data shown in Section 5.1.2 and Figure 5-5.

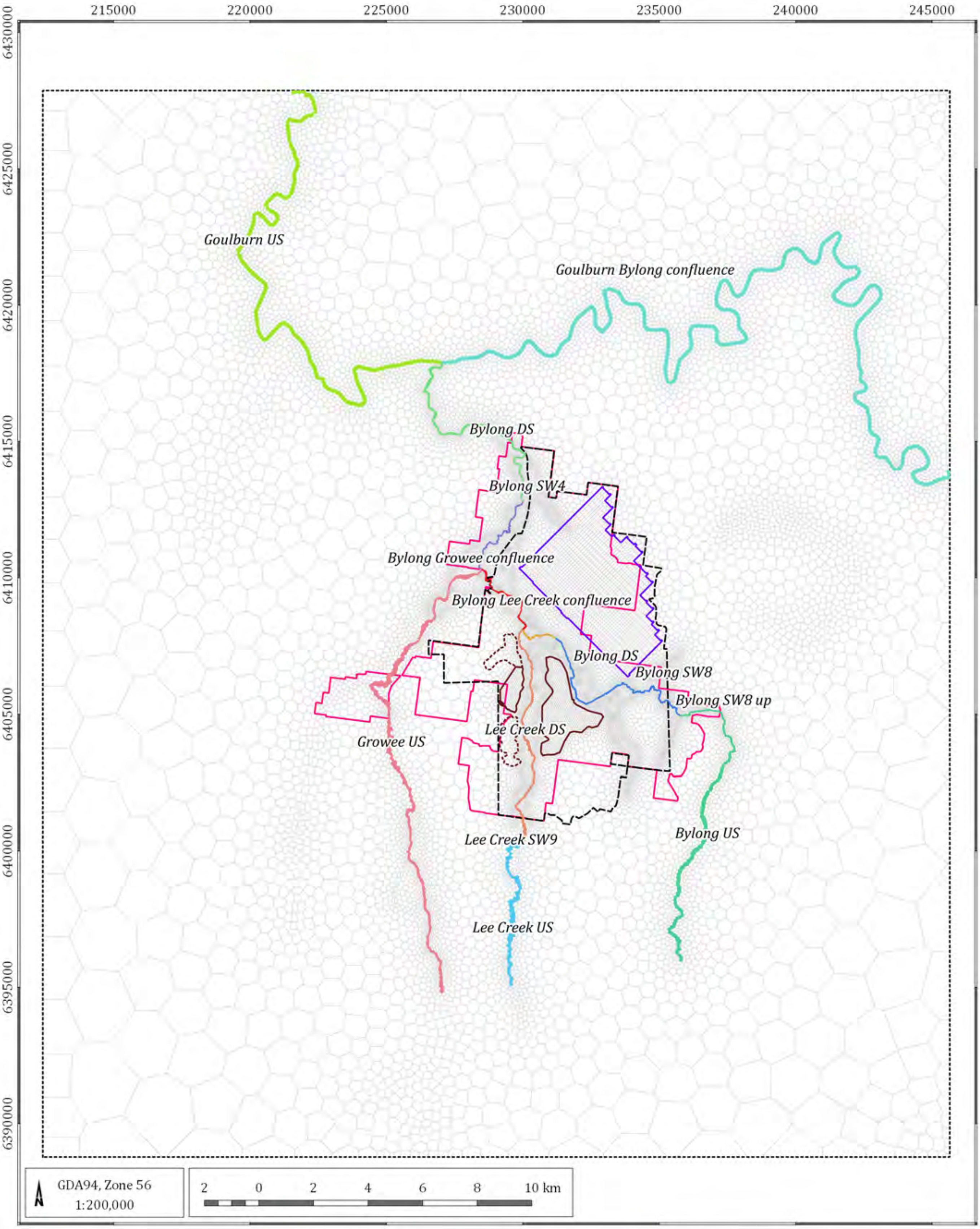
6.2.3 Stream flow package

The model was also updated to incorporate requests from KA to utilise the MODFLOW stream package (STR) in the model to simulate recharge to the groundwater system through the stream systems that are highly connected to the alluvial aquifer. The streams were divided into reaches and the simulated stream flow from the AWBM rainfall runoff model used as input data to create the package for the baseline calibration period.

Figure 6-2 shows the stream flow segments within the model, with Table 6-1 summarising the set-up of each stream segment within the numerical model.

Table 6-1 Summary of stream flow package set-up

Segment	Location	Width (m)	Depth (m)	Bed thickness (m)	Slope	Manning's Coefficient	Vertical hydraulic conductivity (m/day)
1	Lee Creek US	3	1	1.5	0.005	0.03	0.46
2	Lee Creek - SW9	3	1	1.5	0.005	0.03	0.06
3	Lee Creek DS	3	1	1.5	0.005	0.03	0.46
4	Growee US	3	1	1.5	0.005	0.03	0.30
5	Bylong US	5	2	2	0.004	0.03	0.51
6	Bylong SW8 up	5	2	2	0.004	0.03	0.01
7	Bylong DS	5	2	2	0.004	0.03	0.51
8	Bylong SW8	5	2	2	0.004	0.03	0.01
9	Bylong DS	5	2	2	0.004	0.03	0.51
10	Bylong Lee Creek	5	2	2	0.004	0.03	0.51
11	Bylong Growee	5	2	2	0.004	0.03	0.51
12	Bylong SW4	5	2	2	0.004	0.03	0.05
13	Bylong DS	5	2	2	0.004	0.03	0.51
14	Goulburn US	15	5	3	0.002	0.03	0.04
15	Goulburn Bylong	15	5	3	0.002	0.03	0.41



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Project Boundary
- Model extent
- Model mesh

Stream flow segments

- 1 - Lee Creek US
- 2 - Lee Creek SW9
- 3 - Lee Creek DS
- 4 - Growee US
- 5 - Bylong US
- 6 - Bylong SW8 up
- 7 - Bylong DS
- 8 - Bylong SW8
- 9 - Bylong DS
- 10 - Bylong Lee Creek confluence
- 11 - Bylong Growee confluence
- 12 - Bylong SW4
- 13 - Bylong DS
- 14 - Goulburn US
- 15 - Goulburn Bylong confluence

Bylong Coal Project (1606G)

Stream flow segments

DATE 15/07/2016

FIGURE No: **6-2**

6.3 Calibration

The revised MODFLOW USG model from the RTS was recalibrated with the objective of:

- increasing the hydraulic conductivity of the alluvial aquifer to reflect the results of the pumping testing program;
- ensuring the model does not uniformly over-predict groundwater levels, particularly within the alluvial aquifer as noted by DPI Water in its submission;
- accounting for changes in recharge rates induced by adding the stream recharge and changing the hydraulic conductivity of the alluvial aquifer; and
- representing the recharge event that occurred in December 2015 / January 2016 that resulted in some recovery in groundwater levels.

Sections below outline the results of the calibration process.

6.3.1 Hydraulic properties

Table 6-2 below presents the hydraulic properties in previous models developed for the EIS and RTS and the updated hydraulic properties in the recalibrated model.

Table 6-2 Calibrated aquifer parameters

Unit	Horizontal hydraulic conductivity (m/day)			Vertical hydraulic conductivity (m/day)				Specific yield (%)			Specific storage (m^{-1})		
	EIS	RTS	RTS2	EIS	RTS	RTS2	Kh/Kv	EIS	RTS	RTS2	EIS	RTS	RTS2
Alluvium upper (L1)	2.7	4.2	60	1.06	1.65	23.52	3	10	3	3	5E-3	1E-3	1E-3
Alluvium lower (L2)	4.72	10.1	100	1.66	3.55	35.1	3	9	6	6	1E-3	5E-3	5E-3
Colluvium (L3)	4.6E-1	4.6E-1	4.6E-1	8.62E-4	4.6E-2	1.9E-2	10	8	2	2	2E-5	1E-3	1E-3
Weathered Permian (L3)	2.41E-1	2.41E-1	2.41E-1	1.21E-1	1.21E-1	1.21E-1	2	10	10	10	2E-4	2E-4	2E-4
Tertiary basalts (L5)	1.10	1.10	1.10	1.92E-2	1.92E-2	1.92E-2	57	5	5	5	1.5E-5	1.5E-5	1.5E-5
Wallerawang Subgroup (L4)	1.5E-3	1.5E-3	2E-3	1.5E-4	1.5E-4	1.5E-4	10	2	2	2.2	1.6E-5	1.6E-5	1.6E-5
Charbon Subgroup (L5)	3.64E-4	3.64E-4	3.64E-4	4.32E-7	4.32E-7	4.32E-7	84	3	3	3	2.3E-6	2.3E-6	2.3E-6
Ulan Coal Seam (L6)	1E-5 - 0.05	1E-5 - 0.05	8.6E-6 - 0.05	1E-6 - 0.03	1E-6 - 0.03	4.3E-6 - 0.03	2	2	2	1.6	2.3E-5	2.3E-5	2.3E-5
Interburden (L7)	1.5E-3	1.5E-3	2E-3	1.5E-4	1.5E-4	1.5E-4	10	1	1	1	7.6E-5	7.6E-5	7.6E-5
Coggan Coal Seam (L8)	1E-5 - 0.13	1E-5 - 0.13	8.6E-6 - 0.13	1E-6 - 0.03	1E-6 - 0.03	9.9E-7 - 0.015	9	2	2	2	2E-4	2E-5	2E-5
Marrangaroo Fm (L9)	1.63E-3	1.63E-3	2E-3	3.15E-6	3.15E-6	3.2E-5	52	1	1	1	1.3E-5	1.3E-5	1.3E-5
Shoalhaven Group (L10)	1.87E-4	1.87E-4	1.87E-4	1.87E-5	1.87E-5	1.87E-5	10	1	1	1	7.1E-6	7.1E-6	7.1E-6
Triassic intrusions (L11)	1.49E-3	1.49E-3	1.49E-3	7.47E-4	1.49E-3	1.49E-3	2	1	1	1	1.6E-5	1.6E-5	1.6E-5

Table 6-2 shows the key changes to the hydraulic properties including increasing the horizontal and vertical hydraulic conductivity within the alluvial aquifer layers, and reducing the contrast between the horizontal and vertical hydraulic conductivity in selected bedrock layers. Figure 6-3 below illustrates the horizontal hydraulic conductivity values adopted for the EIS, RTS and RTS2 graphically. It shows the most significant change to the model has been the increase in horizontal hydraulic conductivity within the alluvial layers in the RTS2 version of the model.

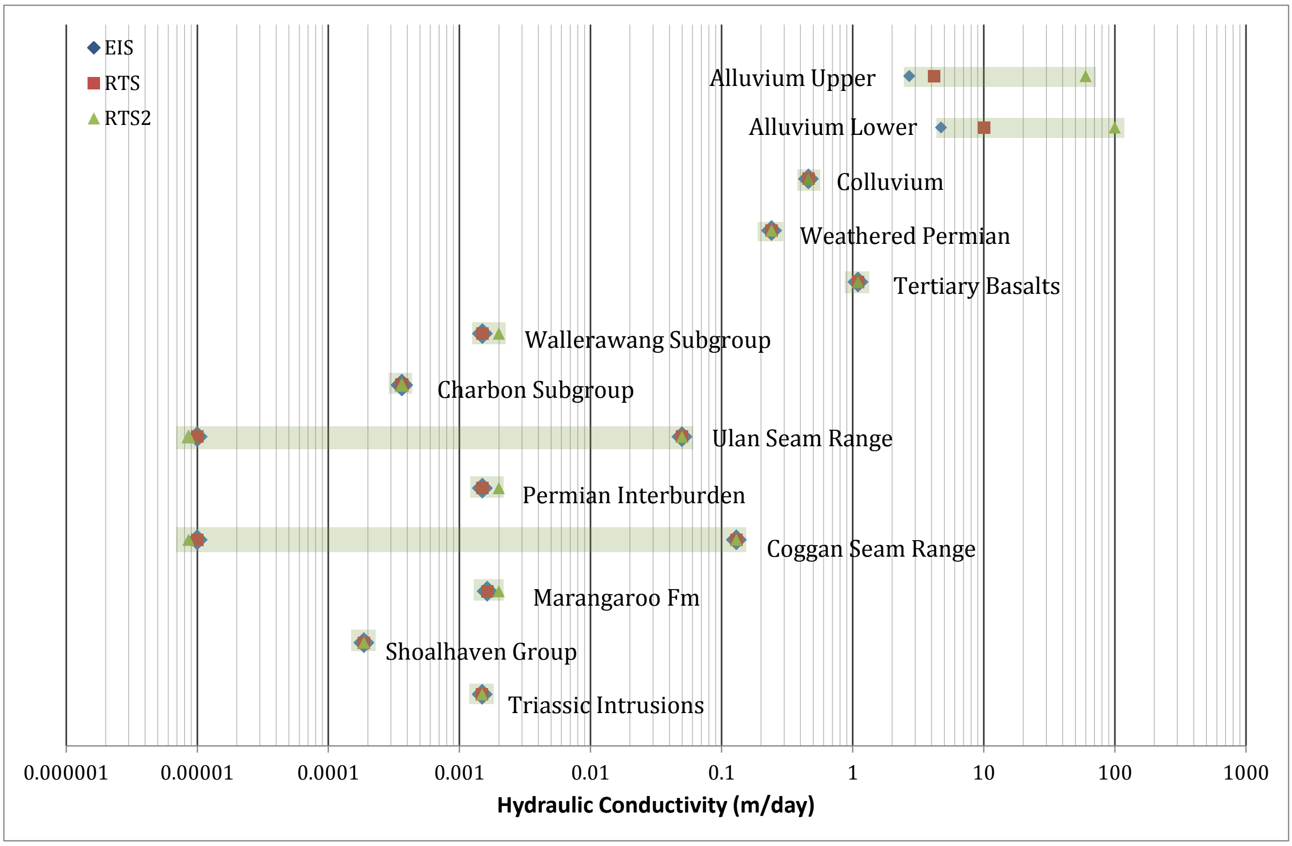


Figure 6-3 Horizontal hydraulic conductivity in numerical models

The large range in the hydraulic conductivity within the coal seams shown in the above figure is due to the function that represents these layers as becoming less permeable with depth below the surface. The model reduced the hydraulic conductivity of the coal seams exponentially with depth to represent the effects of mechanical loading from overburden and sealing of cleats. Table 6-3 shows the relationship between coal seam depth and hydraulic conductivity in the groundwater model.

Table 6-3 Horizontal hydraulic conductivity of coal seam layers

Coal seam depth below land surface (m)	Horizontal hydraulic conductivity (m/day)	
	Ulan seam plys and interburden (Layer 6)	Coggan seam (Layer 8)
10	0.049	0.13
25	0.029	0.077
50	0.017	0.045
100	0.0055	0.015
200	0.0006	0.002

Comments from DPI Water suggested that the hydraulic conductivity of the coal seam aquifer was too low and the numerical model should be set-up in a manner that allows the connectivity between the coal seams and the alluvial aquifer. Table 6-3 shows that the hydraulic conductivity of the coal seams is relatively high where they are shallow and subcrop under the alluvium. The RTS2 model also pinches out the overlying non-coal layers where they do not occur and this directly connects the alluvial aquifer cells with the coal along the subcrop where appropriate in the numerical model.

6.3.2 Rainfall recharge

Increasing the hydraulic conductivity within the numerical model necessitated an increase in the recharge rate to maintain groundwater levels within the alluvial aquifer consistent with what had been measured in the field. The rainfall recharge rate estimated using the soil moisture balance (Section 5.1.3) was adjusted manually to achieve the best match between measured and simulated groundwater levels. The match was achieved by increasing the recharge rate on the alluvium to 2.5 times the rate estimated with the soil moisture balance. The total rainfall over the calibration period from January 2012 to June 2016 was 2,596 mm, with the model calibrating best with 439 mm of rainfall recharge, which is equivalent to 17% of the total rainfall over the baseline period. A factor of 0.1 times the rates within the soil moisture balance was used for rainfall recharge over the remainder of the model where alluvium was not present at bedrock outcrops. In the areas of bedrock outcrop this was equivalent to 17.56 mm of rainfall recharge, which is equivalent to 0.7% of the total rainfall over the baseline period. The total recharge to the model area averaged 20.62 ML/day as outlined below.

6.3.3 Water budget

Table 6-4 below summarises the average water fluxes simulated by the updated numerical model, with Figure 6-4 showing the transient water budgets for the baseline calibration period graphically.

Table 6-4 Water balance - averages for calibration period (ML/day)

Parameter	EIS		RTS		RTS2	
	Input	Output	Input	Output	Input	Output
Rainfall recharge	14.9		11.5	-	20.62	-
Streams	-	-	-	-	2.95	11.3
Rivers	34.7	43.3	58	3.1	0	3.98
Evapotranspiration		21.5	-	64.9	0	11.28
General head		0.1	0.0	0.0	0	0
Wells		6.2	0.0	6.5	0	6.05
Storage	36.4	15.2	18	13	31.08	22.22
Totals	**86**	**86.3**	**87.5**	**87.5**	**54.65**	**54.65**

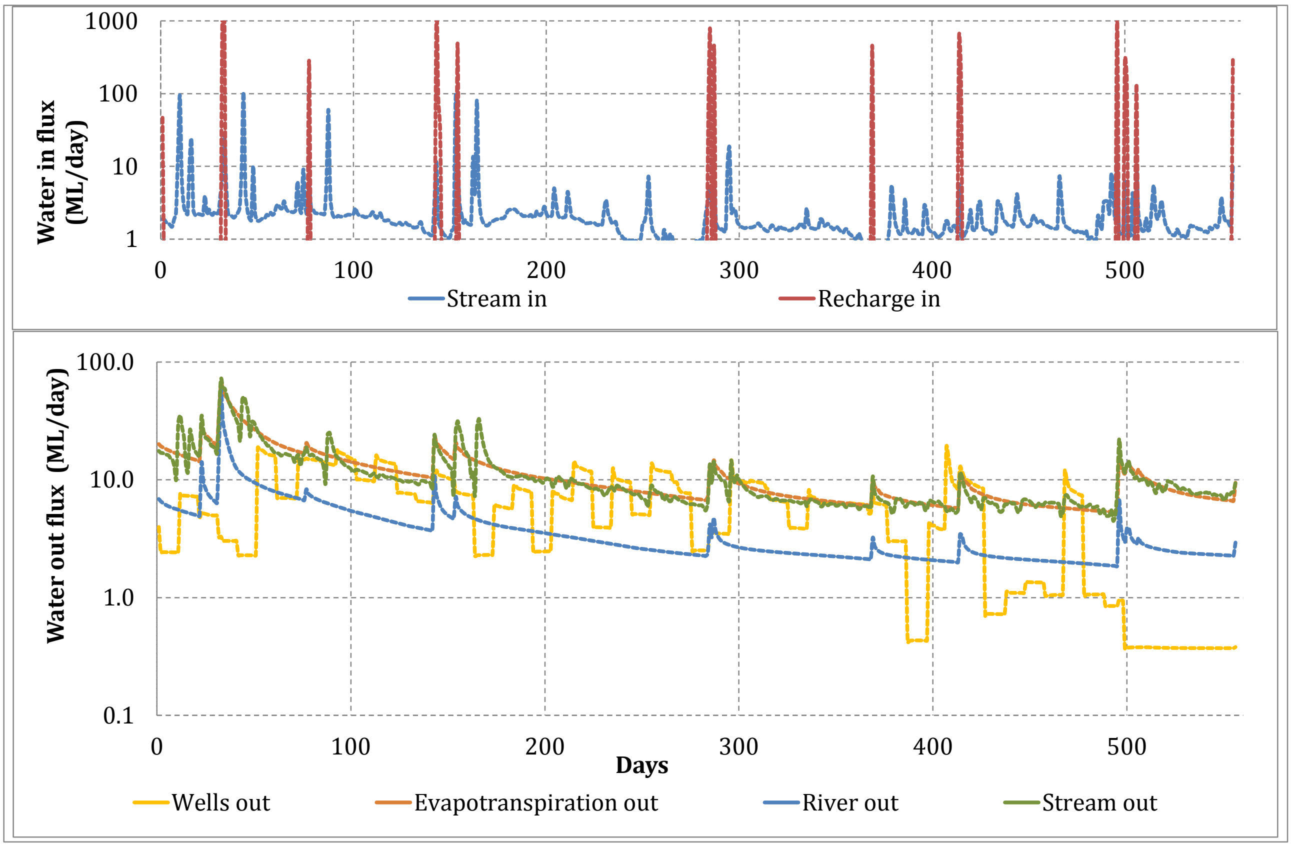


Figure 6-4 Calibration period transient water balance

Table 6-4 shows whilst the diffuse rainfall recharge rate was increased within the groundwater model, the total volume of water moving through the model was reduced. This was due to the more refined cells along the Goulburn River representing the bed elevation more accurately. This reduced the 'short circuiting' movement of water between adjacent river cells along the Goulburn River.

The net increase in rainfall recharge during the baseline calibration was a necessary increase required to maintain groundwater levels due to the increased hydraulic conductivity that promotes drainage of the aquifer. The increased recharge was also required to improve the ability of the model to replicate the rainfall recharge events that have occurred generally annually during the summer months over the baseline monitoring period.

6.3.4 Simulated groundwater levels

Figure 6-5 compares the observed groundwater levels with the levels simulated by the recalibrated model. Appendix C contains the hydrographs for each bore showing the match between the measured and model simulated groundwater levels.

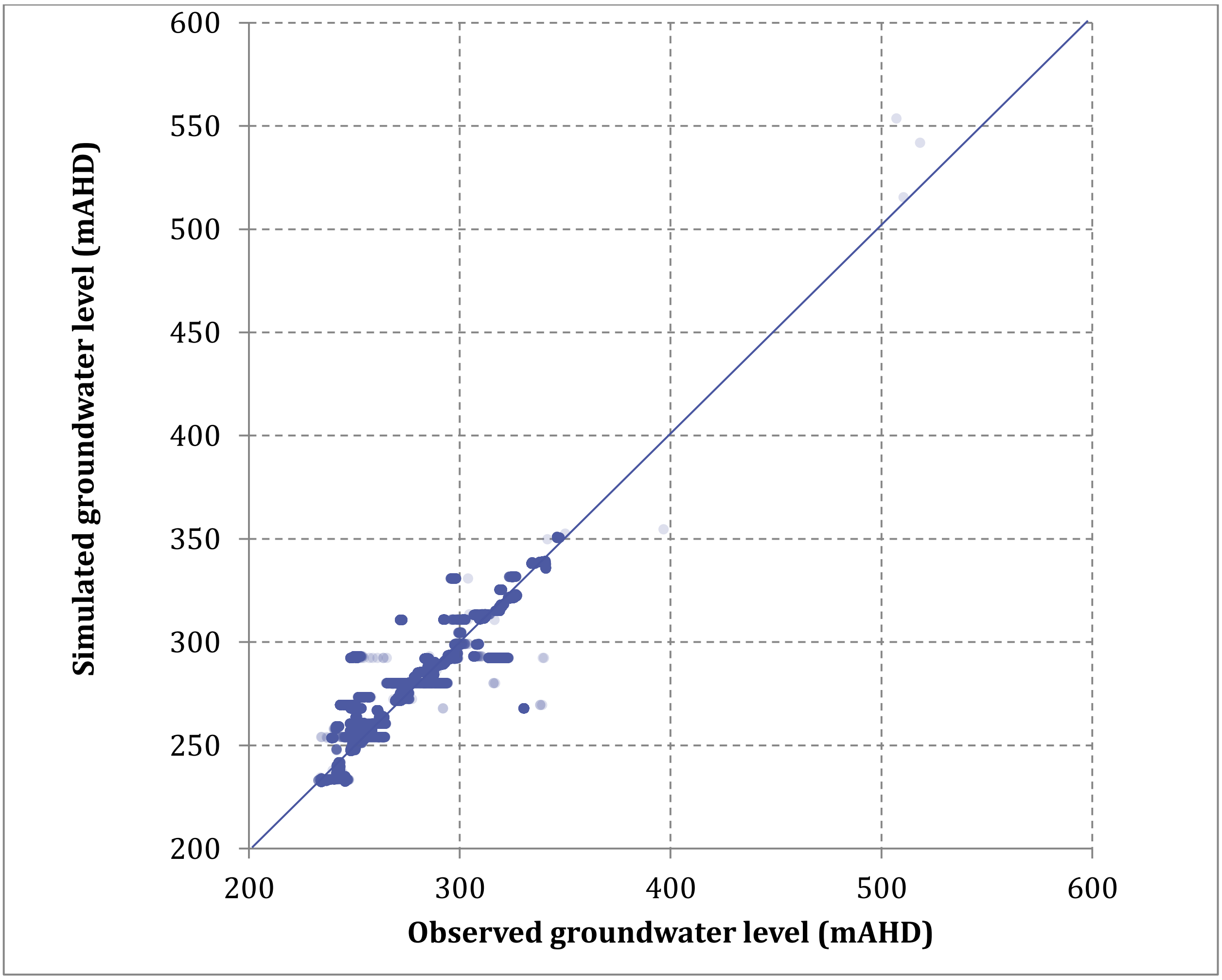
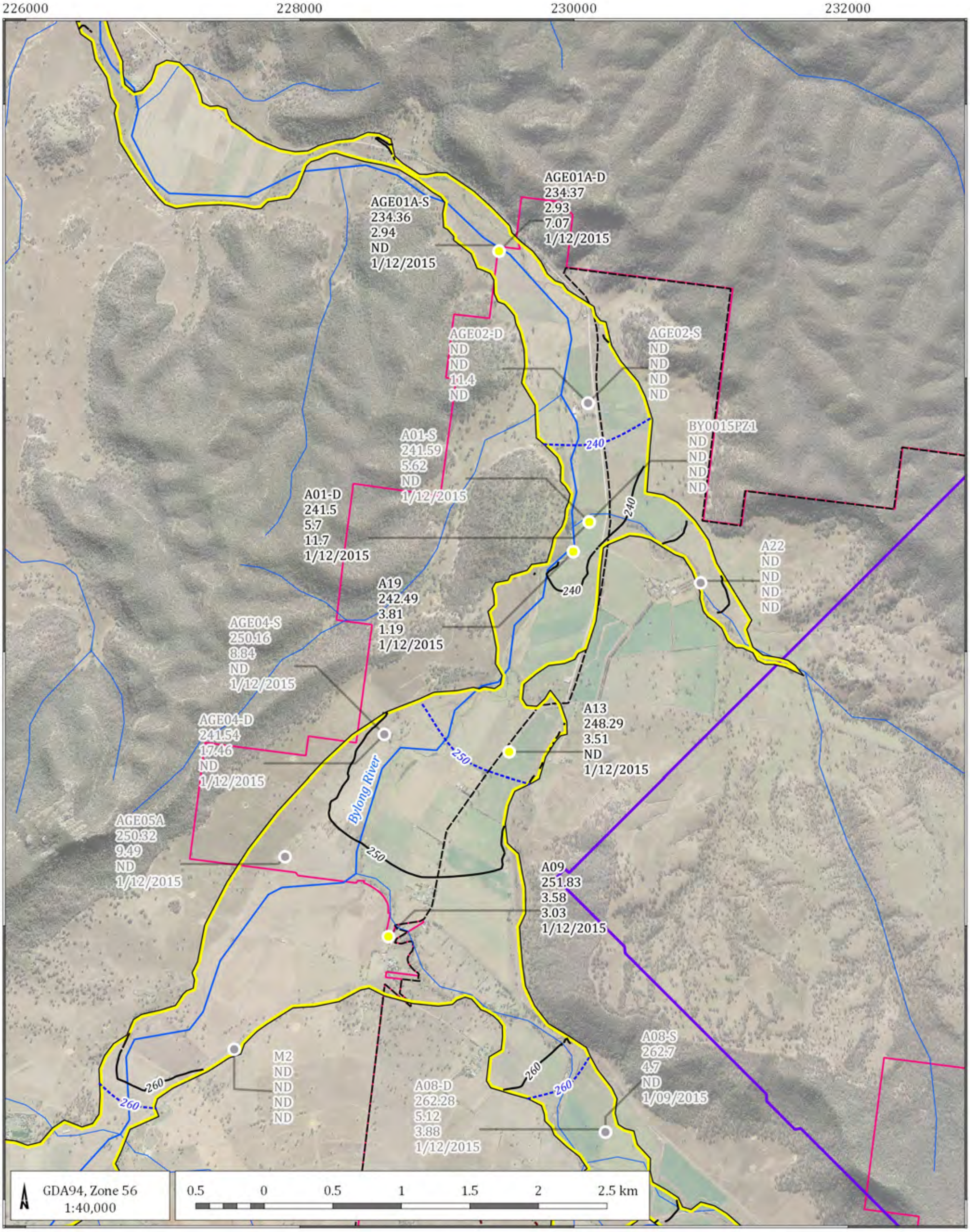


Figure 6-5 Observed and simulated groundwater levels

The hydrographs show that whilst the refined groundwater model does not replicate perfectly the measured groundwater levels within each bore, it does represent the starting levels and trends better than previous versions of the model developed for the EIS and RTS. The observed declining trend in groundwater levels over the baseline monitoring period that occurs due to below average rainfall is generally replicated by the model. Further the refined model does not systematically over predict the groundwater levels as has been identified in the previous versions of the model noted by DPI Water.

Figure 6-6 to Figure 6-9 display the measured and simulated groundwater levels within the alluvium and the coal seams at December 2015. As discussed, previous versions of the model systematically over predicted groundwater levels in the majority of the model layers. The figures show the changes made to the model described above improved the ability of the model to match groundwater levels measured within the alluvium and within the Coggan coal seam.



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Underground Extraction Area
- Kepco owned land
- Quaternary alluvium
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

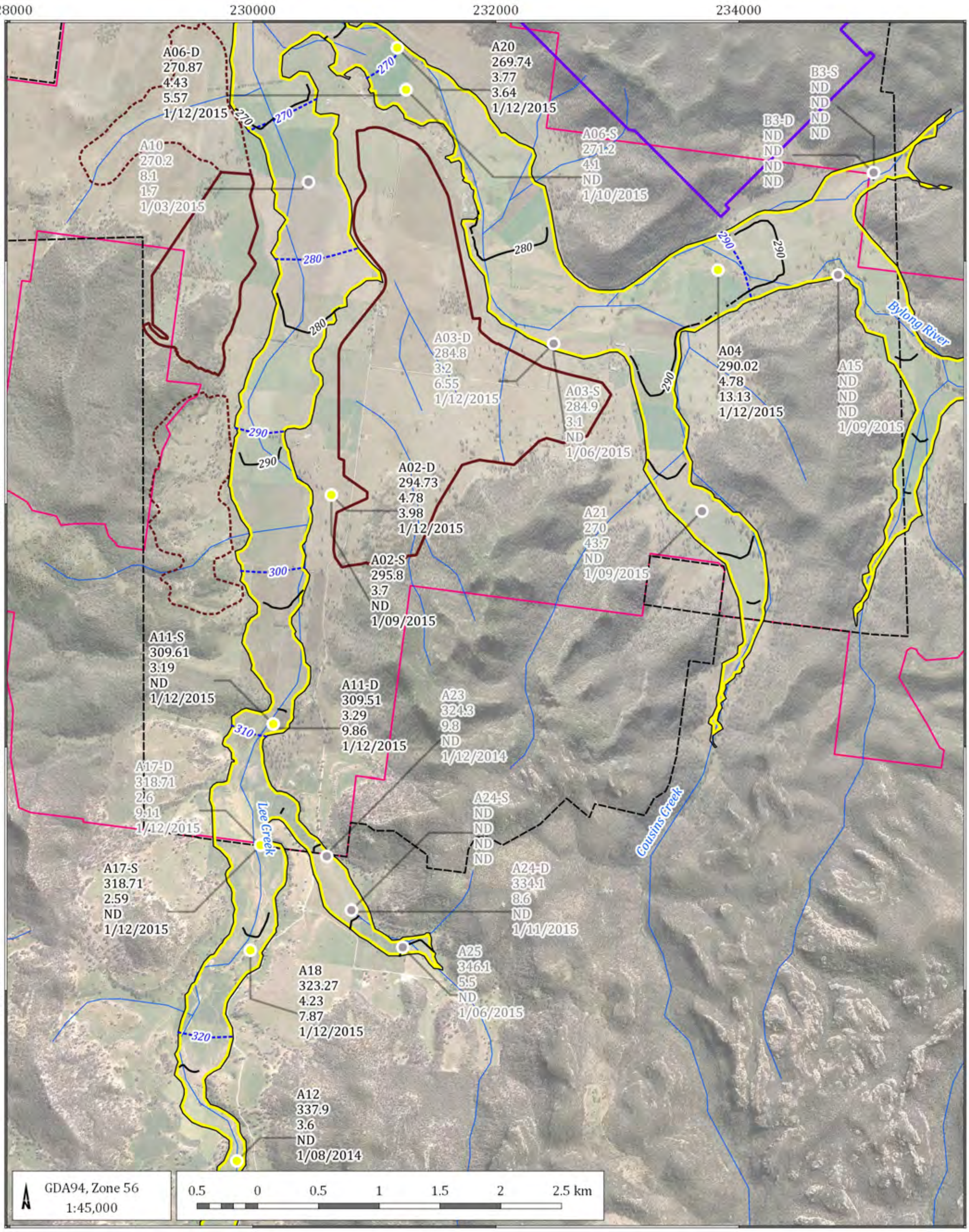
ND = no data

Bylong Coal Project (G1606G)

Simulated and observed groundwater levels north - alluvium (layer 2) - December 2015

DATE 15/07/2016

FIGURE No: **6-6**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Groundwater level contour (mRL)
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Quaternary alluvium
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Saturated thickness
5. Date of measurement

ND = no data

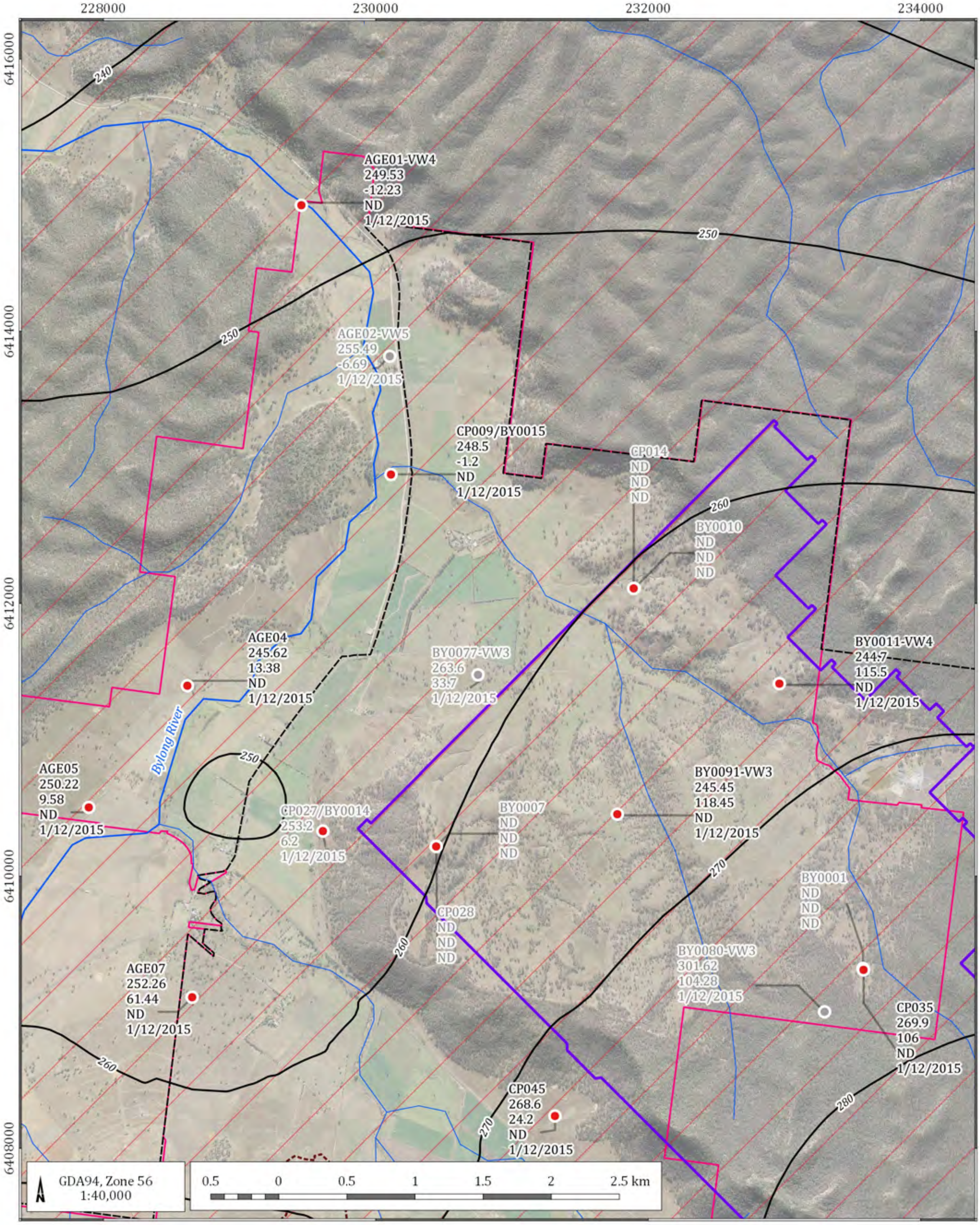
Bylong Coal Project (G1606G)

Simulated and observed groundwater levels south - alluvium (layer 2) - December 2015

AGE GROUNDWATER & ENVIRONMENTAL

DATE 15/07/2016

FIGURE No: **6-7**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Coggan coal seam sub-crop
- Simulated groundwater level contour (mRL)
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

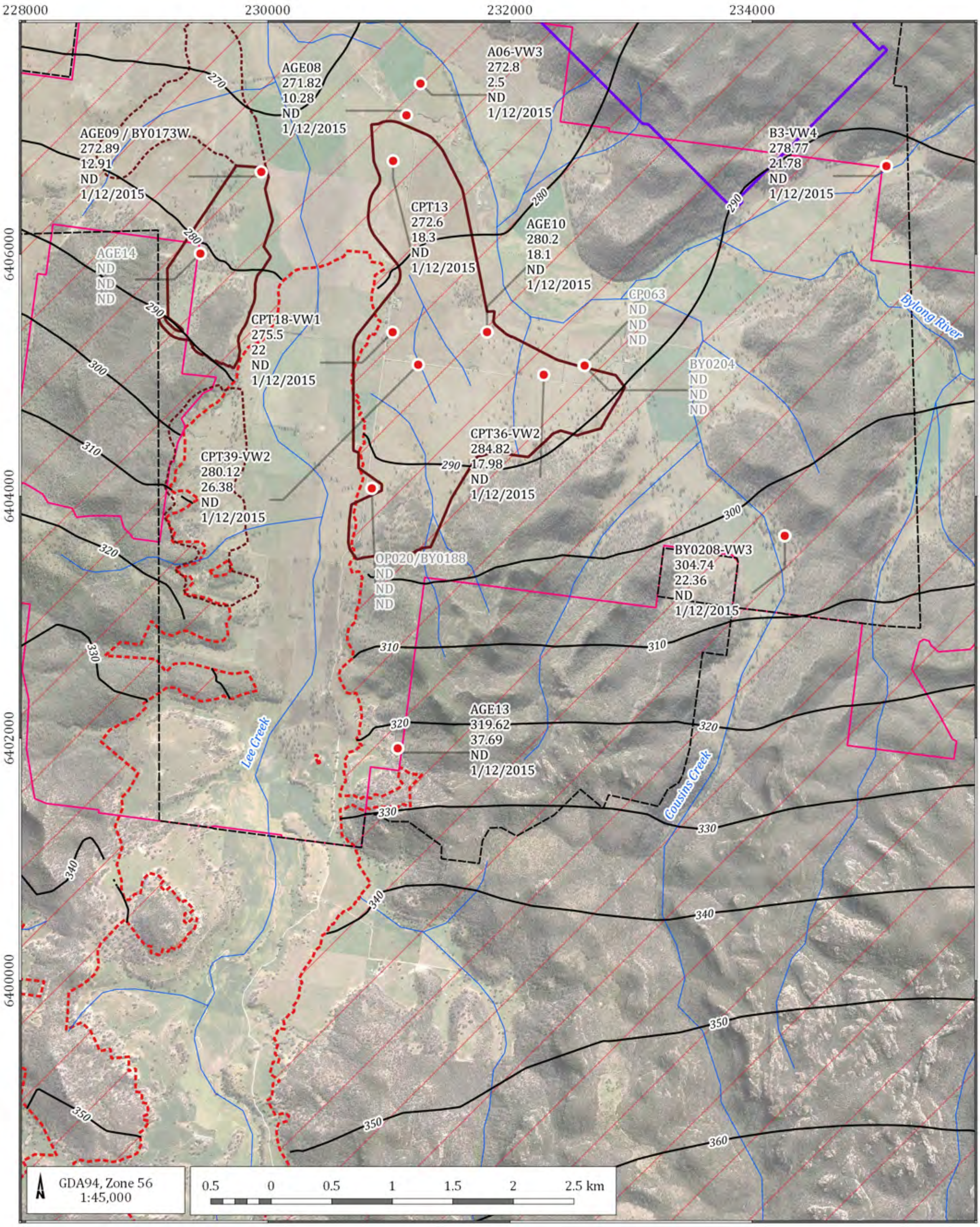
ND = no data

Bylong Coal Project (G1606G)

Simulated and observed groundwater levels north (layer 8) - Coggan Coal Seam - December 2015

DATE 15/07/2016

FIGURE No: **6-8**



LEGEND

- Monitoring locations used for water table contours
- Monitoring locations not used for water table contours
- Simulated groundwater level contour (mRL)
- Coggan coal seam sub-crop
- Project Boundary
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Major drainage
- Minor drainage

Bore Label:

1. Bore ID
2. Standing water level (mRL)
3. Depth to water
4. Date of measurement

ND = no data

Bylong Coal Project (G1606G)

Simulated and observed groundwater levels south - Coggan Coal Seam (layer 8) - December 2015

DATE 15/07/2016

FIGURE No: **6-9**

There are significantly fewer monitoring locations for measuring groundwater levels in the overlying Permian and Triassic non coal sediments, and therefore groundwater level maps are not presented for these layers. Instead Figure 6-10 shows graphically the match between simulated and measured groundwater levels in the Triassic and Permian overburden layers for each VWP sensor. This figure demonstrates the challenge in closely matching pressure data from VWP sensors. Whilst the match is not perfect, the model does generally replicate the trend of lower groundwater pressures occurring at lower elevations under the plateau area where underground mining is proposed. This indicates downward movement of groundwater from the surface through the profile in both the data and the model.

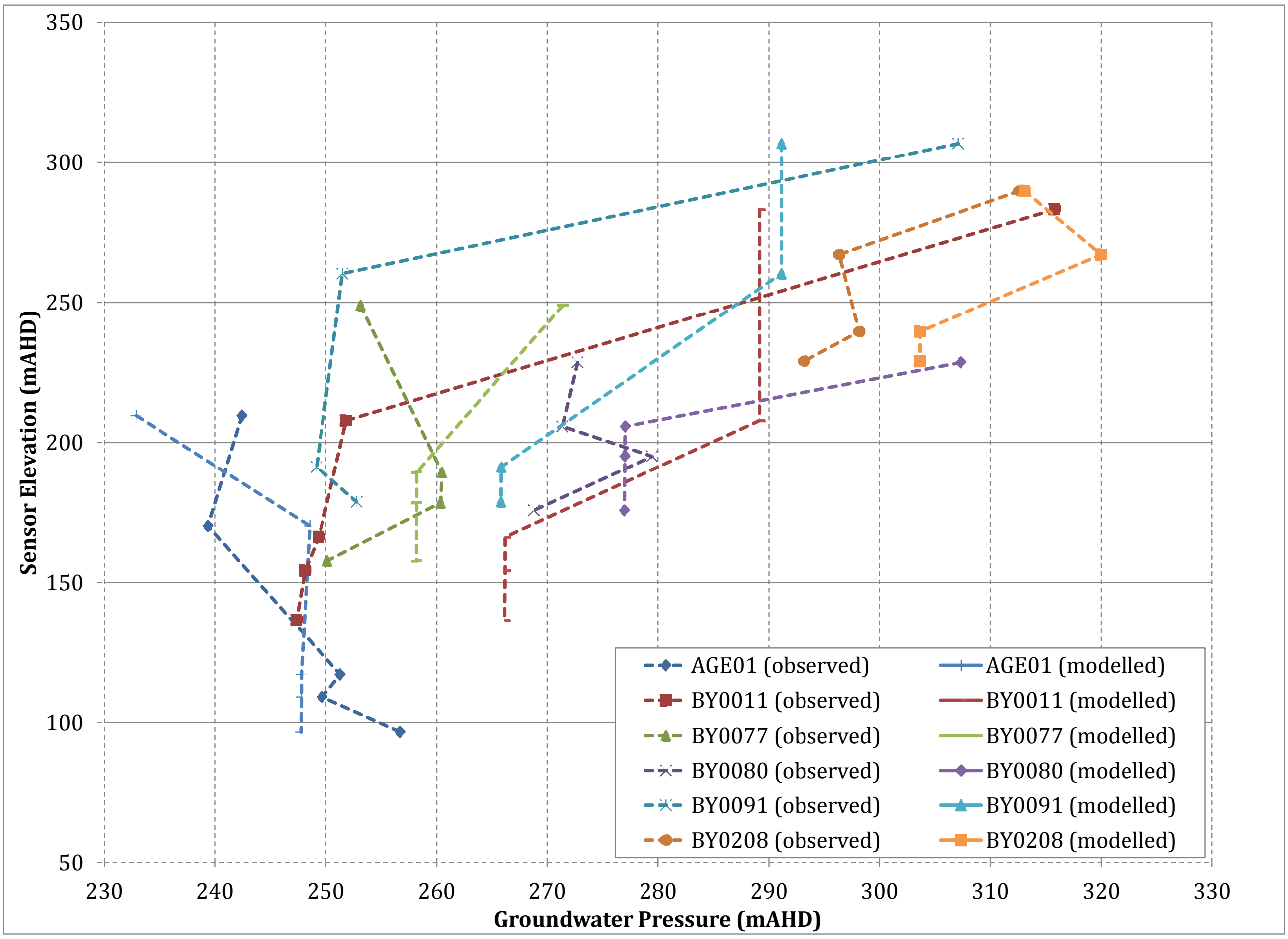


Figure 6-10 Simulated and observed pressures at VWPs

6.4 Predictions

The recalibrated and amended USG model was used to predict the impact of the open cut and underground mining on the groundwater regime. The sections below describe the changes made to the setup of the predictive model, the simulation results and uncertainty.

6.4.1 Borefield layout

As discussed in the EIS and RTS, there is potentially a need to supplement surface water collected in storages by pumping from a borefield installed within the alluvial aquifer to ensure adequate water available for the Project. The volume of 'make up water' required from the borefield depends on the volumes of groundwater that can be recovered and used from the open cut and underground mining areas and climatic conditions that control water held in surface storages.

Previous versions of the numerical model included a borefield to provide additional water in the event of a water deficit. The borefield comprised bores spaced evenly throughout the alluvial aquifer, and located at sufficient distances from constraints such as other private bores, government bores, water courses and property boundaries. Since this time, the pumping test program has provided additional information on the yield of bores installed within the alluvial aquifer and the zone of drawdown generated around each bore whilst pumping. The sites for the pumping bores were therefore revised giving consideration to the new data.

The locations of the pumping bores were adjusted manually to maximise the yield from the borefield, whilst minimising the drawdown impacts at the private bores. Unlike previous versions of the model presented within the EIS and RTS, the sites of the pumping bores were also constrained so as to be offset from potential GDEs. The pumping bores were located according to the rules of the Hunter Unregulated and Alluvial Water Sources Water Sharing Plan as follows:

- 400 m from access license bores on private property;
- 200 m from basic landholder rights bores;
- 50 m from a boundary with an adjacent landholder;
- 400 m from departmental monitoring bores; and
- 200 m from groundwater dependent ecosystems.

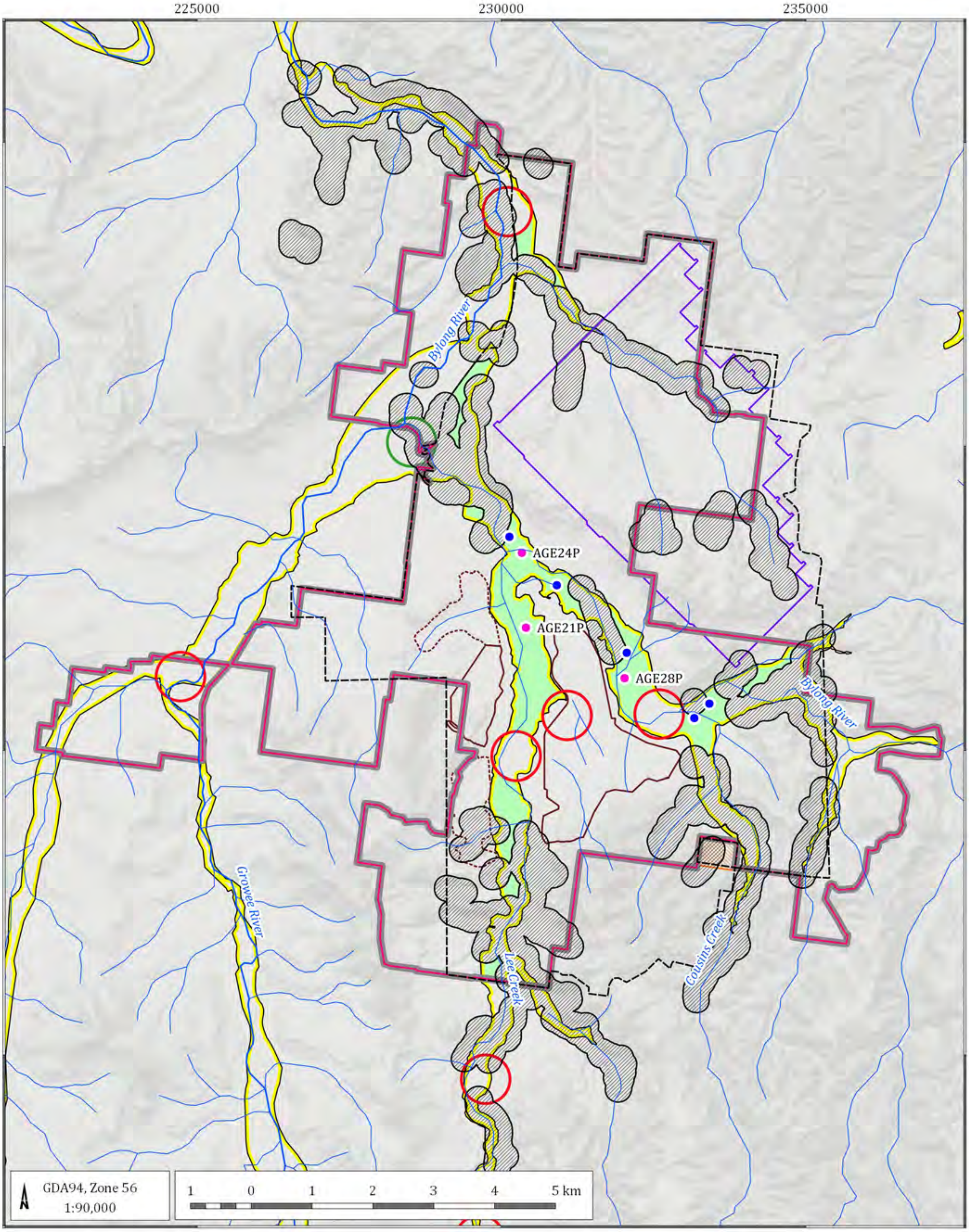
Three (AGE21P, AGE24P and AGE28P) of the existing four pumping bores installed to test the alluvial aquifer were included within the borefield proposed to supply the make up water. Bore AGE32P was excluded from the borefield as it is located within 200 m of an area of potential GDE. An additional five pumping bores were added, with the proposed borefield comprising a total of eight bores. Figure 6-11 shows the locations of each bore within the proposed borefield, and the buffer zones around the sensitive features where bores could not be located. Table 6-5 provides the coordinates for each of the proposed bore sites.

Table 6-5 Optimised borefield sites

Bore ID	Status	Easting	Northing	Ground elevation (mAHD)
AGE21P	Existing	230403	6407018	275.6
AGE24P	Existing	230335.7	6408249.8	267.3
AGE28P	Existing	232022.9	6406186.7	284.0
AGE34P	Proposed	230130	6408513	259.8
AGE35P	Proposed	230910	6407716	267.2
AGE36P	Proposed	232059	6406605	271.3
AGE37P	Proposed	233416	6405768	282.0
AGE38P	Proposed	233168	6405531	280.3

Note: *Coordinate system - GDA94 Z56*

The construction of the proposed bores will mirror the existing trial bores, comprising 219mm steel casing and stainless steel wire wound screens.



LEGEND

- Suitable bore location
- Unsuitable bore location
- GDE 200m buffer
- Project Boundary
- Goverment bore 400m buffer
- Entitlement bore 400m buffer
- Private property 50m buffer
- Kepco boundary 50m buffer
- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Kepco owned land
- Quaternary alluvium
- Installed pumping bore
- Proposed pumping bore
- Major drainage
- Minor drainage

Bylong Coal Project (G1606G)

Optimised borefield layout

DATE 15/07/2016

FIGURE No: **6-11**

6.4.2 Rainfall Recharge

As described in the RTS (AGE 2016), groundwater recharge was calculated for the predictive model by using rainfall records from 2000 to 2013 that encompassed a period of drought, followed by a number of years where the drought was broken by above average rainfall. This period included part of the 'Millennium drought' that occurred between 1995 and 2007, and was followed by a number of years of above average rainfall. Figure 6-12 shows the Southern Oscillation Index and the El Niño and La Niña climate cycles that occurred over this period that represent below average and above average rainfall and therefore variability groundwater recharge.

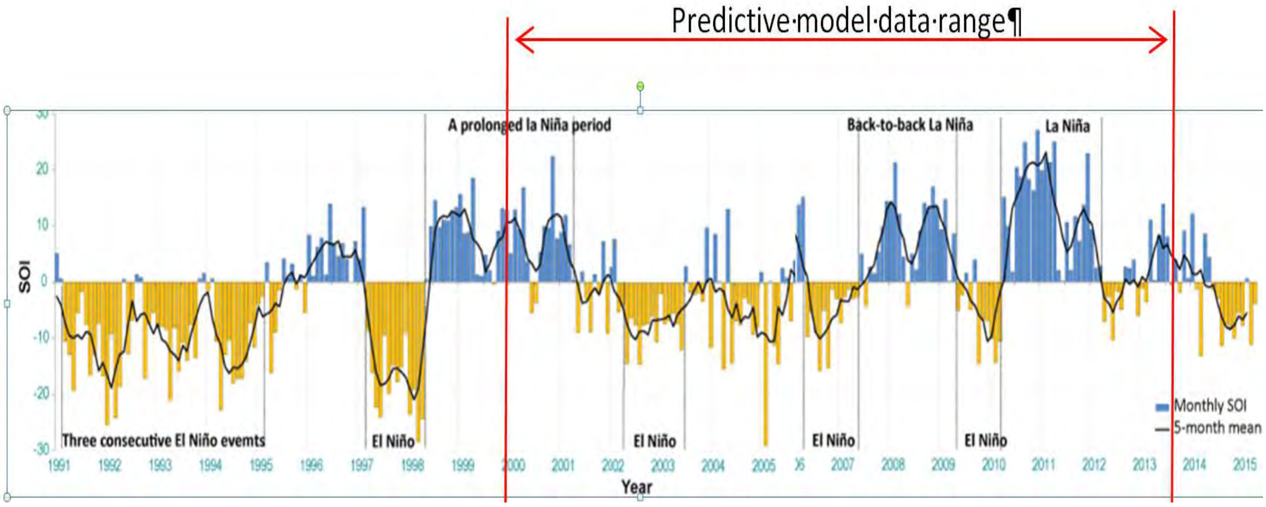


Figure 6-12 Southern oscillation index between 1991 and mid-2015[2]

Daily rainfall records from 2000 to 2013 generated by SILO for within the Project Boundary were used to estimate recharge rates using the soil moisture spreadsheet described in Section 5.1.3. This allowed the model to represent a drought from 2001 to 2007 followed by years of generally above average rainfall from 2008 to 2013. This cycle of recharge was then repeated for the proposed 23 years of mining for the Project.

The total rainfall over the period January 2000 to September 2013 was 8,452 mm. This is equivalent to an average of about 620mm per year and similar to the long term average recorded at Wollar (062032) of 593mm. The recharge over the period 2000 to 2013 is estimated at 898 mm, which is equivalent to 10% of annual rainfall reaching the water table. Figure 6-13 shows the rainfall and recharge rates used in the predictive model graphically.

[2] http://www.bom.gov.au/climate/about/australian-climate-influences.shtml?bookmark=enso

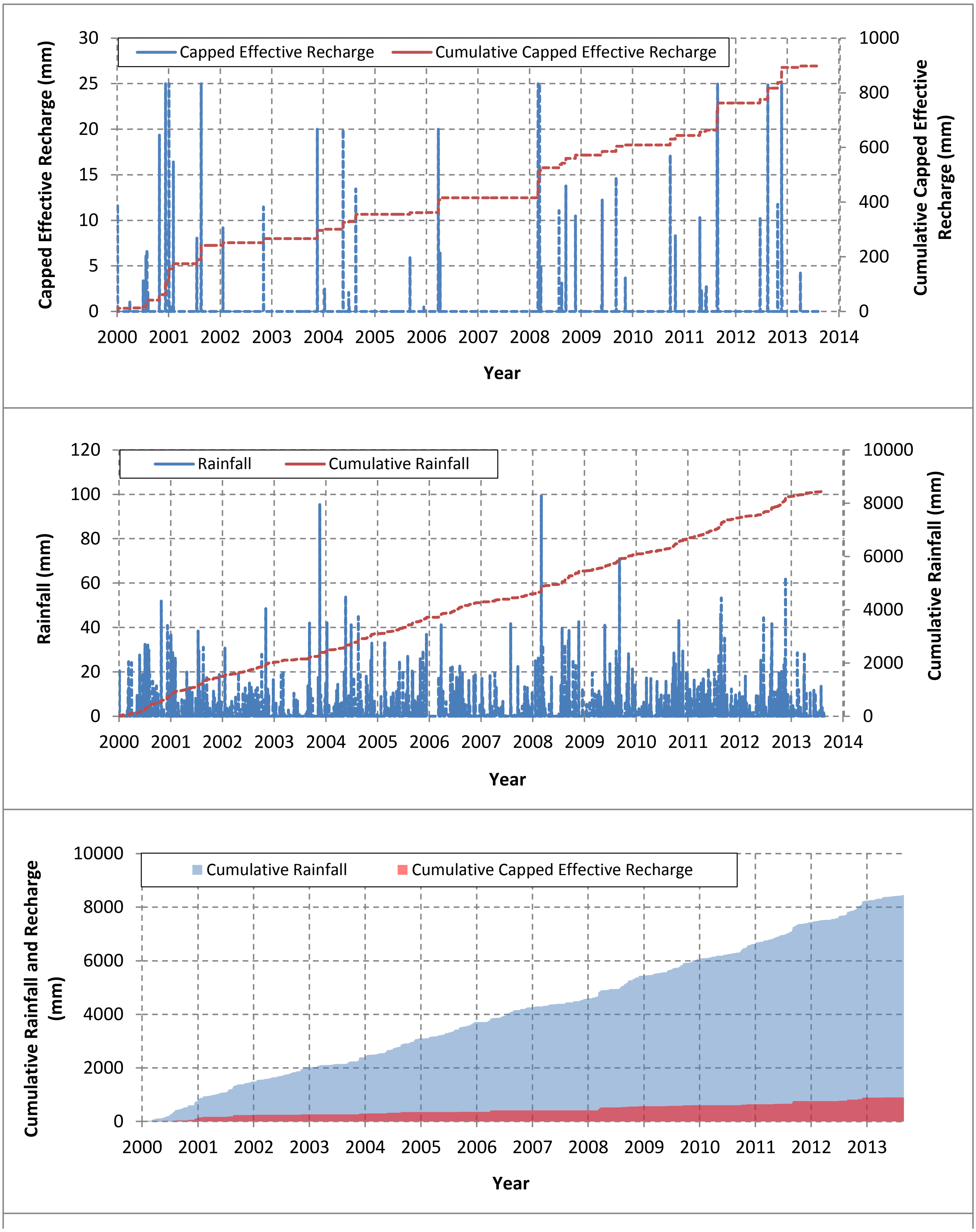


Figure 6-13 Recharge rates for predictive model (one cycle of data)

6.4.3 Subsidence induced fracturing

The model represented the fractured zone above the longwall panels by increasing the vertical hydraulic conductivity of the overlying layers. The EIS and RTS models represented the fracturing above the longwall mine by running the model in short time "slices" of three months. The mining was subdivided into 100 stress periods, each three months in length. At the beginning of each stress period changes in aquifer parameters resulting from the effects of the subsidence of material into the mined panel and the formation of a goaf above the panel were applied.

The updated model utilised the Time Variant Materials (TVM) package developed by HydroAlgorithmics Pty Ltd for MODFLOW USG. This package removed the need for time slices with changes to the hydraulic properties made during a single predictive model run.

6.4.4 Predictions and uncertainty

The sections below present predictions for mine inflow and drawdown from the updated groundwater model. The uncertainty in the model predictions is also presented.

The uncertainty analysis was conducted using a non-linear methodology described by Watermark Numerical Computing (2015). This is a more rigorous method than the linear uncertainty conducted for the RTS document. This is because the linear method assumes the range of impacts can be determined by projecting the predictions linearly either side of the base case according to a standard deviation. In some cases this can lead to unrealistic predictions at the lower bounds resulting in negative mine inflow or drawdown. The non-linear uncertainty analysis represents skewness better and prevents this issue. The linear method was undertaken for the RTS as it is suitable as a 'first pass' screening method that can indicate the range of uncertainty and the potential for non-linear processes.

The range in the parameters explored within the linear uncertainty analysis was based upon the expected upper and lower bounds from field testing data where available, and previous experience / judgement where data is sparse. Table 6-6 summaries the bounds on the non-linear uncertainty analysis, with Figure 6-14 showing the parameter ranges graphically.

Table 6-6 Non-linear uncertainty analysis parameter ranges

Parameter	Parameter number	Description	RTS			RTS2		
			Lower bound	Mean	Upper bound	Lower bound	Mean	Upper bound
Horizontal hydraulic conductivity (m/day)	hc01	Upper Alluvium parameters	0.152	4.2	17.7	10	60	120
	hc02	Lower Alluvium parameters	0.152	10.1	35.4	30	100	250
	hc03	Colluvium parameters	0.046	0.46	4.6	0.046	0.46	4.6
	hc04	Weathered parameters	0.024	0.24	2.4	0.01	0.24	1
Vertical hydraulic conductivity (m/day)	vhc01	Upper Alluvium parameters	0.001	0.392	0.7	0.0784	0.392	0.784
	vhc02	Lower Alluvium parameters	0.001	0.351	0.5	0.0702	0.351	0.702
	vhc03	Colluvium parameters	0.001	0.1	0.5	0.02	0.1	0.5
	vhc04	Weathered parameters	0.001	0.5	0.5	0.1	0.5	0.75
	vhc06	Interburden (layer 4) parameters	0.001	0.1	0.5	0.02	0.1	0.2
Specific yield	sy01	Upper Alluvium parameters	0.01	0.03	0.1	0.01	0.03	0.25
	sy02	Lower Alluvium parameters	0.01	0.06	0.15	0.01	0.06	0.25
	sy03	Colluvium parameters	0.002	0.02	0.2	0.01	0.02	0.1
	sy04	Weathered parameters	0.01	0.1	0.1	0.01	0.1	0.2
Specific storage (m^{-1})	ss01	Upper Alluvium parameters	0.001	0.001	0.0125	0.0002	0.001	0.005
	ss02	Lower Alluvium parameters	0.005	0.005	0.01875	0.001	0.005	0.025
	ss03	Colluvium parameters	0.0001	0.001	0.01	0.0005	0.001	0.002
	ss04	Weathered parameters	0.00002	0.0002	0.002	0.0001	0.0002	0.0004
Rainfall recharge (proportion of recharge rate estimated from soil moisture spreadsheet)	rch01	% of rainfall on alluvium	1	14	18	1	14	18
	rch02	% of rainfall on colluvium	0.5	2.79	10	0.5	2.79	10
	rch04	% of rainfall on regolith	0.001	0.1	1	0.001	0.1	1

Parameter	Parameter number	Description	RTS			RTS2		
			Lower bound	Mean	Upper bound	Lower bound	Mean	Upper bound
	rch01tr	% of rainfall on alluvium	30	100	150	30	100	150
	rch02tr	% of rainfall on colluvium	0.5	5	10	0.5	5	10
	rch04tr	% of rainfall on regolith	0.001	1	1	0.001	1	1
Irrigation return (proportion of volume of water pumped by irrigators)	irrig	% of rainfall from irrigation	0.01	0.05	0.1	0.01	0.05	0.1

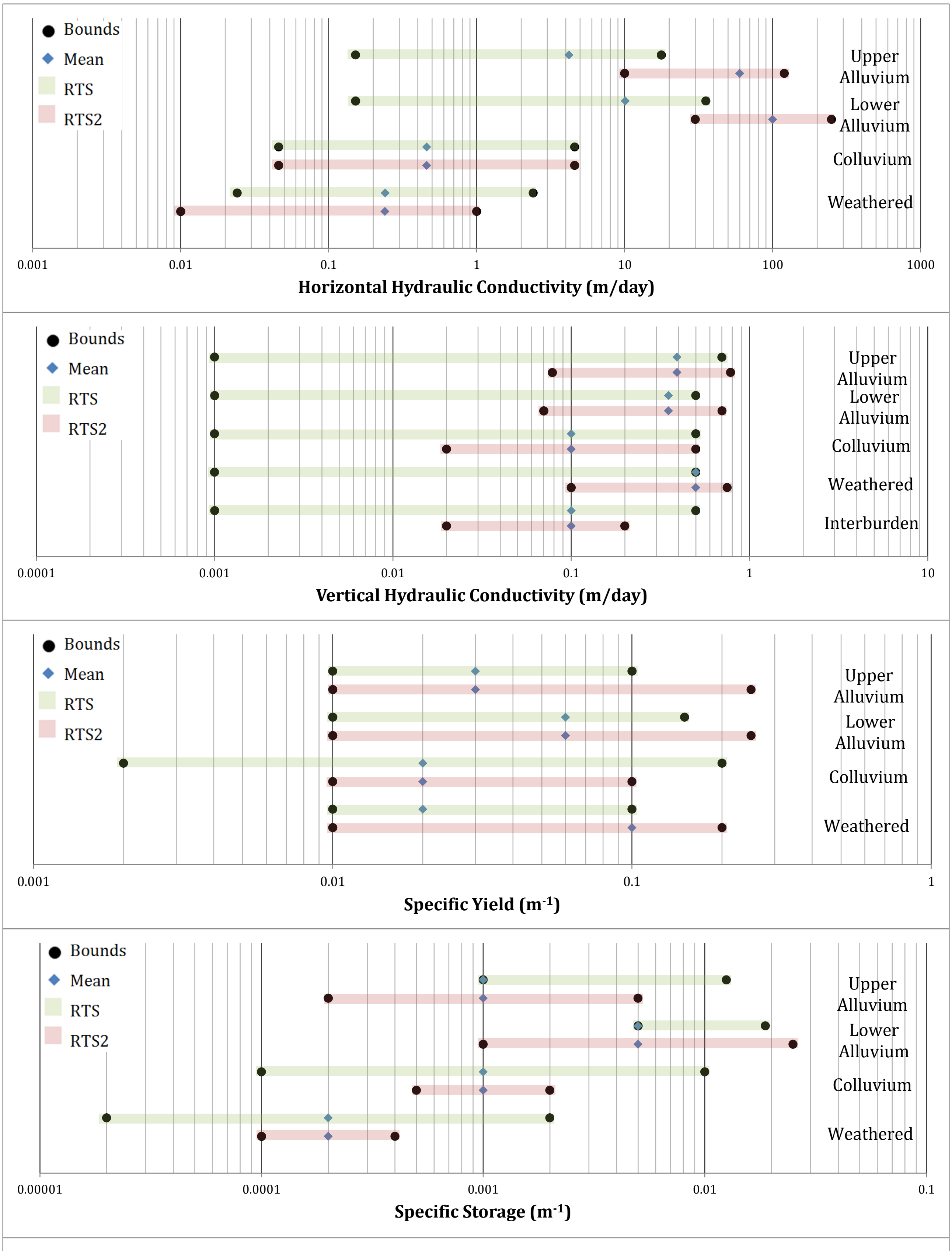


Figure 6-14 Non-linear uncertainty analysis parameter ranges

6.4.5 Water levels and drawdown

The updated numerical model was used to simulate the drawdown within the alluvial aquifer and the Coggan Coal seam during mining. Figure 6-15 and Figure 6-16 display the maximum drawdown predicted within the Quaternary alluvium (layer 2) and the Coggan coal seam (layer 8) respectively during the mine life. The figures also show the maximum drawdown within the mine life predicted by previous versions of the model presented within the EIS and RTS. A version of the RTS2 with the vadose zone van Genuchten option is also provided to assess the influence of this option on model predictions.

When comparing these models, it is important to note that the models are not the same. They each have differing underlying model code, parameters, stresses and layering. As described previously, the model has evolved from the EIS to the RTS2 with the key changes including:

- increasing the thickness, hydraulic conductivity, storage and recharge within the alluvial aquifer;
- moving from average rainfall recharge conditions in the EIS to representing a varying climate with El Niño drought periods and La Niña periods when rainfall is typically above average in the RTS; and
- moving from representing the unsaturated zone processes in the EIS to adopting the upstream weighting function for the base case within the RTS and RTS2.

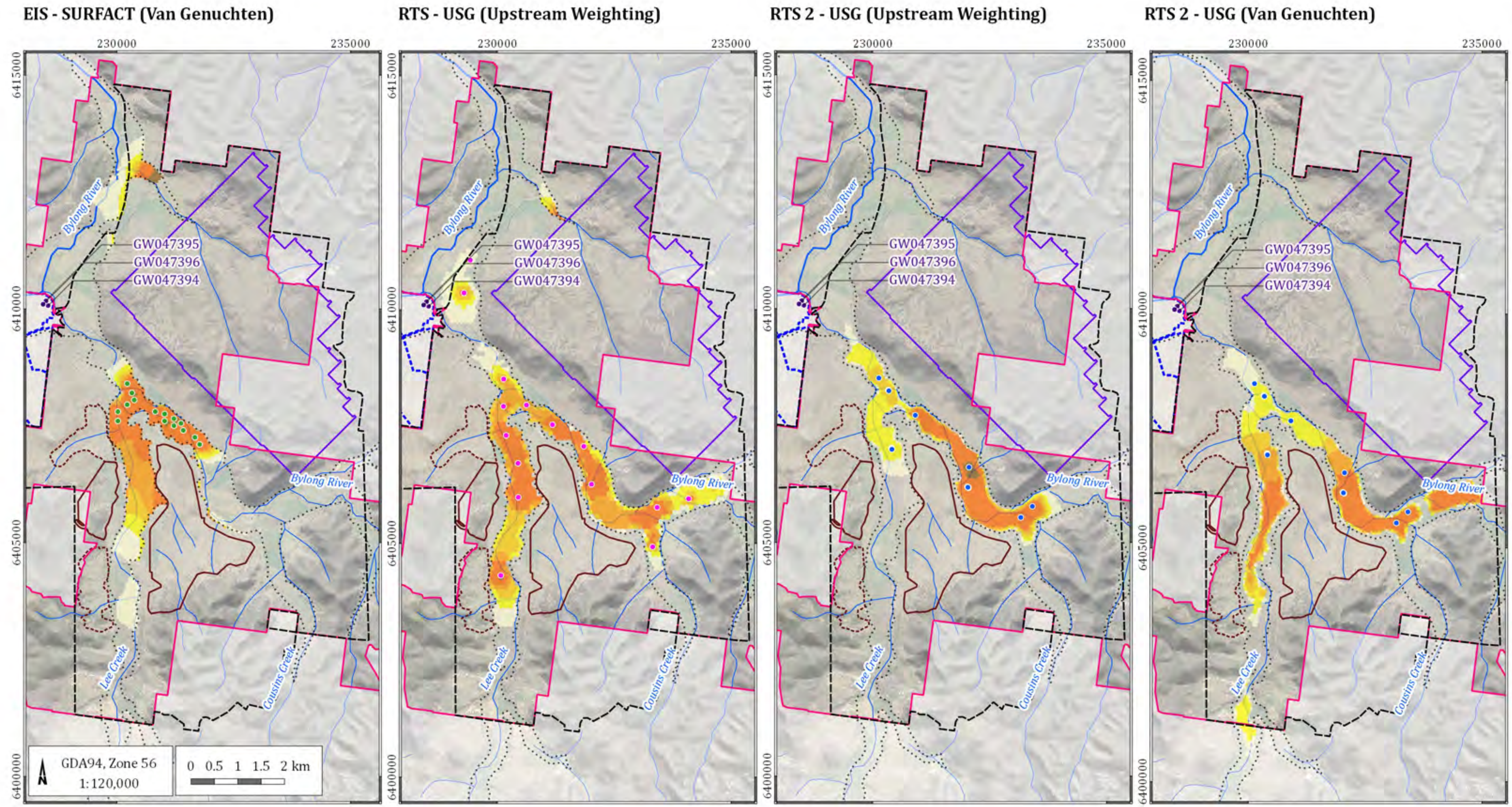
For these reasons, the predictions are not expected to be the same, but represent the gradual evolution of the numerical model based on feedback from stakeholders and as more data has become available to improve the predictive capacity. Despite these changes, the predicted impacts are generally comparable and provide a range of outcomes for consideration of environmental impacts.

Figure 6-17 and Figure 6-18 show the drawdown within the alluvium and Coggan coal seam, and the 0.1th and 99.9th percentile drawdown from the uncertainty analysis. These percentiles are effectively the lower and upper bounds of impacts for the current version of the model based on the parameter ranges selected for the uncertainty analysis.

Figure 6-15 shows how the sites selected for the pumping bores within the borefield have evolved and the maximum drawdown from the EIS, RTS and the RTS2. The figures show how the drawdown within the alluvium occurs mainly clustered around the pumping bores in each scenario. This is not unexpected given abstraction is directly from the borefield, as opposed to the mining areas that are not directly connected with the alluvium, and therefore only influence the alluvium through lower permeability bedrock.

Figure 6-15 shows the magnitude of drawdown within the alluvium is generally less with the current RTS2 version of the model (both upstream weighting and van Genuchten) than previous versions due to the improved capacity of the alluvial aquifer to supply water. The figure also shows the closest private licensed water bores on the “Eagle Hill” property are outside the zone of influence in all model scenarios, including the 99th percentile from the uncertainty analysis (Figure 6-17).

Figure 6-16 shows the maximum drawdown predicted within the Coggan coal seam for the various scenarios. The drawdown is of a similar extent at the regional scale in the EIS, RTS and RTS2. Figure 6-18 shows the drawdown becomes less extensive within the Coggan coal seam at the 1st percentile and more extensive at the 99th percentile upper bound. The drawdown within the coal seam is of no direct environmental consequence, as the coal seams dips to the east becoming deeper and more remote from surface water features. There are also no users of water abstracting directly from the coal seam aquifer within the predicted zone of depressurisation.



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Quaternary alluvium
- Major drainage
- Minor drainage
- KEPCO owned land
- Project Boundary
- Eagle Hill property
- EIS proposed bores
- RTS proposed bores
- RTS 2 existing and proposed bores
- Private bores on Jarvet PTY LTD property

Drawdown (m)

1-2	4-5
2-3	5-10
3-4	10-15

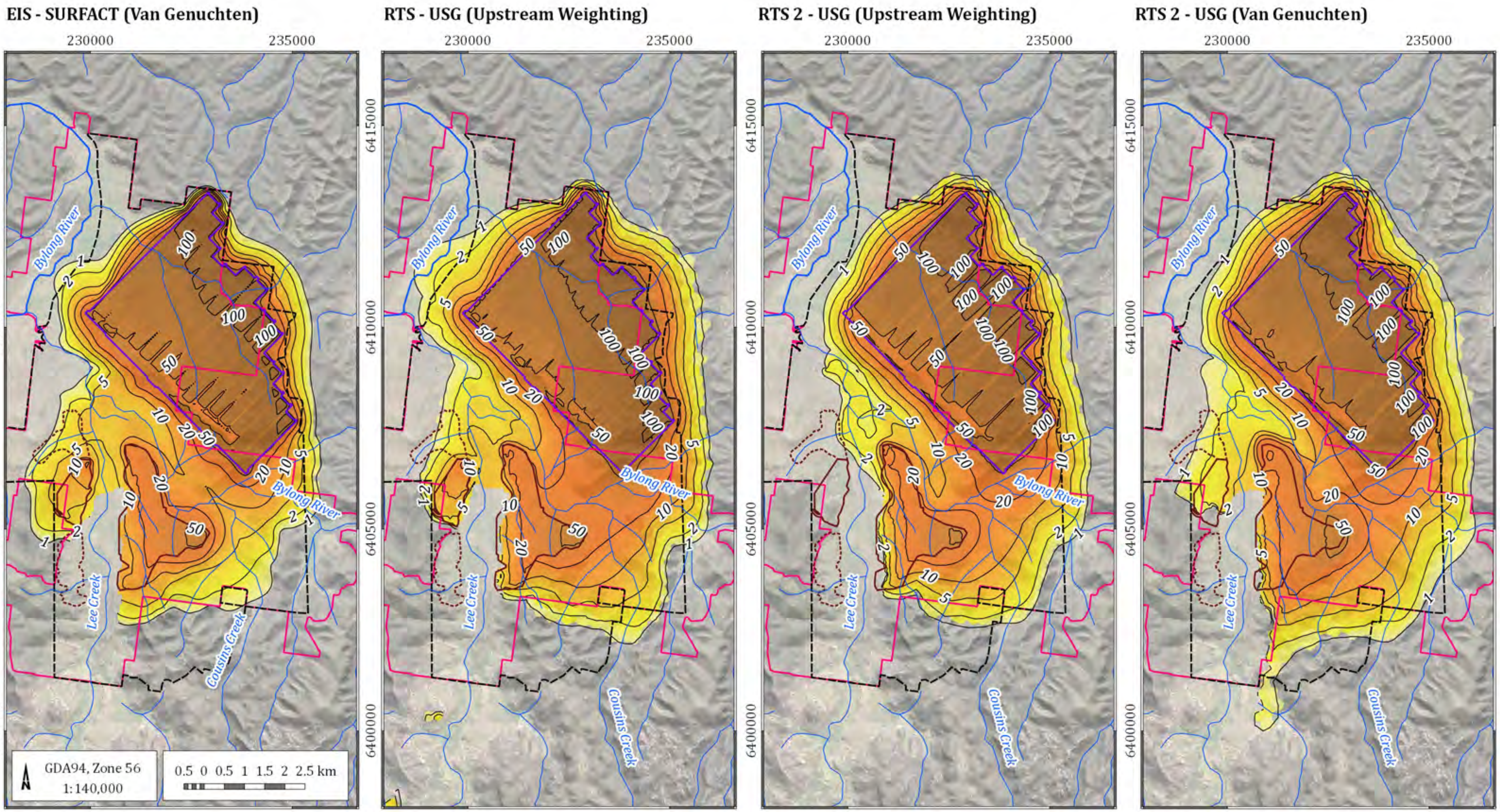
Bylong Coal Project (G1606G)

Predicted maximum drawdown within alluvium (layer 2)

Note these models have differing parameters and stresses

DATE 27/07/2016

FIGURE No: **6-15**



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- KEPCO owned land
- Project Boundary
- Drawdown contour (m)
- Major drainage
- Minor drainage

Drawdown (m)

1	20
2	50
5	100
10	200

Bylong Coal Project (G1606G)

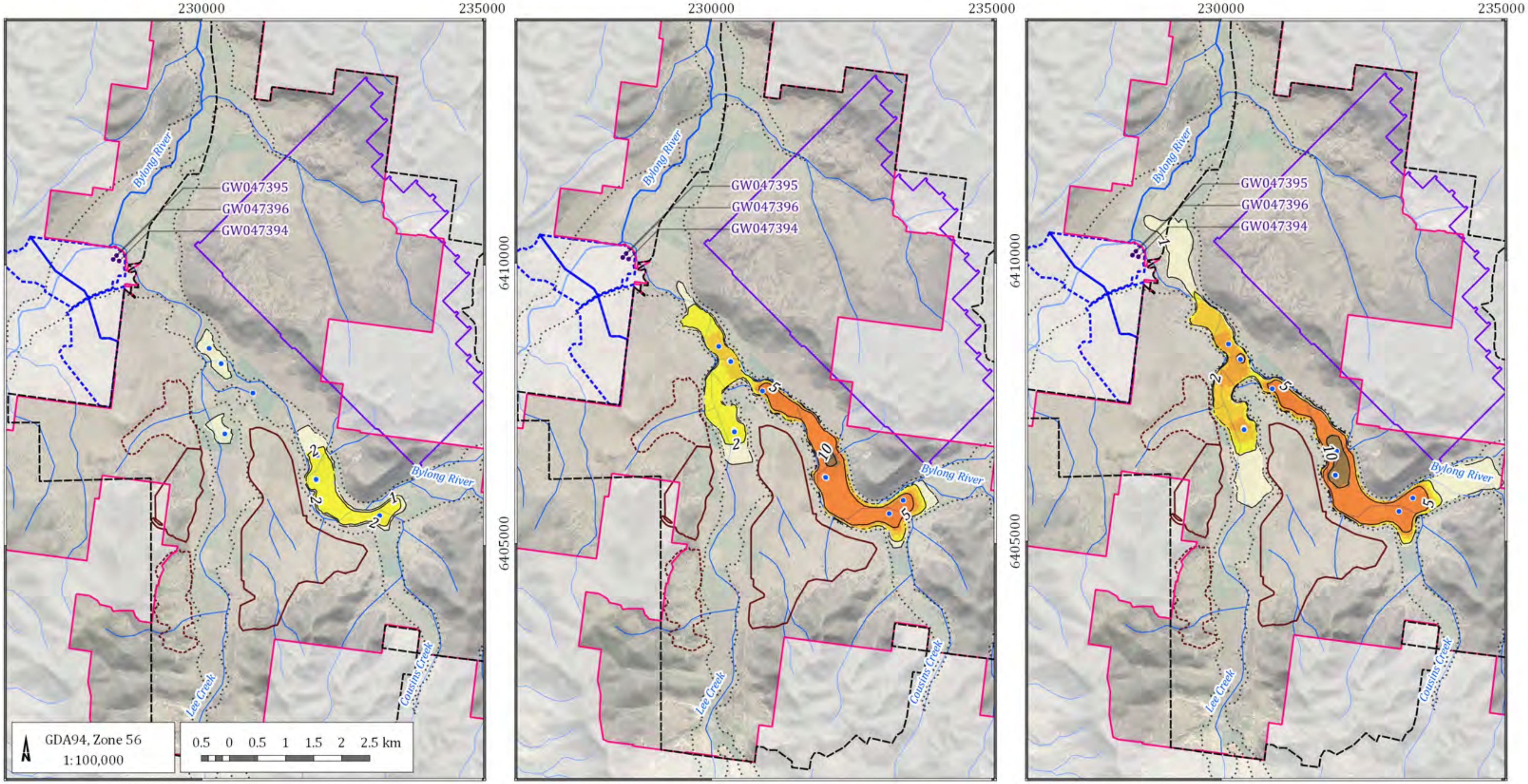
Predicted maximum drawdown within Coggan coal seam (layer 8)

Note these models have differing parameters and stresses

DATE
15/07/2016

FIGURE No:
6-16

RTS 2 - 1st Percentile | RTS 2 - Mean | RTS 2 - 99th Percentile



LEGEND

- Open Cut Mining Area
- Overburden Emplacement Area
- Underground Extraction Area
- Quaternary alluvium
- Major drainage
- Minor drainage
- KEPCO owned land
- Project Boundary
- Eagle Hill property
- RTS 2 proposed bores
- Private bores on Jarvet PTY LTD property

Drawdown (m)

- 1-2
- 2-3
- 3-4
- 4-5
- 5-10
- 10-15
- Drawdown contour (m)

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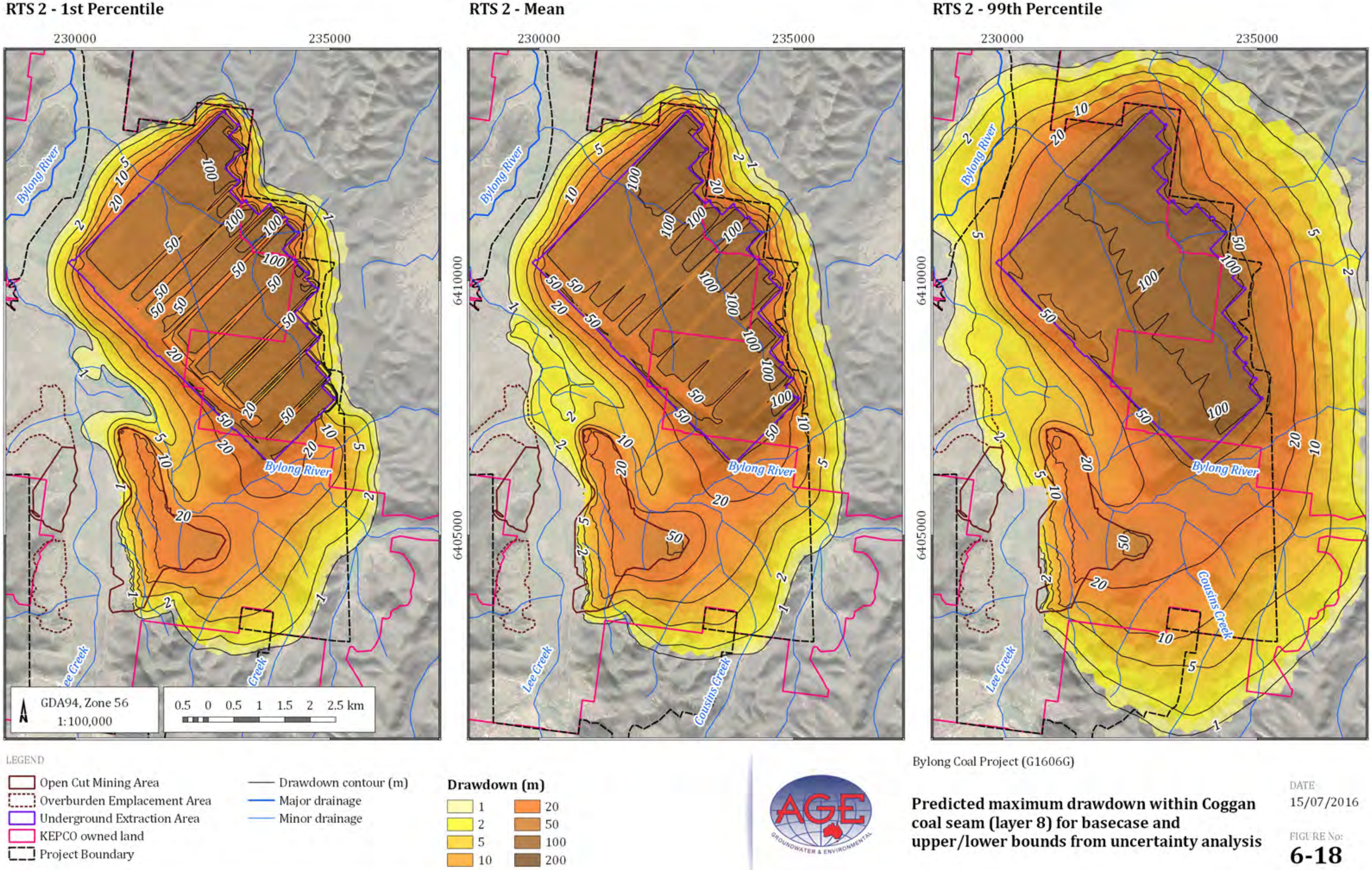
Bylong Coal Project (G1606G)

Predicted maximum drawdown within alluvium (layer 2) for basecase and upper/lower bounds from uncertainty analysis

DATE 27/07/2016

FIGURE No: **6-17**



Bylong Coal Project (G1606G)

Predicted maximum drawdown within Coggan coal seam (layer 8) for basecase and upper/lower bounds from uncertainty analysis

DATE 15/07/2016

FIGURE No: **6-18**

6.4.6 Mine inflow

The updated numerical model was used to estimate the volume of groundwater intercepted by the open cut and underground mining areas. The recalibrated model was considered the basecase, and used as the basis of the uncertainty analysis to provide 1st percentile and 99th percentile bounds to the predictions.

Two additional scenarios were run to test the sensitivity of key model assumptions. Firstly, a run was undertaken using the basecase USG model where the drain cells remained active for the entire mine life to prevent any recovery of groundwater within the open cut or underground mining areas during the mine life. The second sensitivity was also run using the basecase USG model, but with the van Genuchten option for the unsaturated zone active. The results from the original EIS model that utilised MODFLOW SURFACT and the van Genuchten option are also presented.

Table 6-7 outlines the differences between each of the model runs. Figure 6-19 presents the volume of water predicted to be intercepted by the proposed mining on a logarithmic scale. Table 6-8 tabulates the data on an annual basis.

Table 6-7 Basecase and uncertainty / sensitivity analysis for mine inflows

Model	Version of MODFLOW	Unsaturated zone	Calibration	Drain setting	Notes
RTS2	USG	upstream weighting	Recalibrated using pumping tests	turn off after each longwall panel	Used for basecase and uncertainty analysis (1st and 99th percentile)
RTS2	USG	van Genuchten	Recalibrated using pumping tests	turn off after each longwall panel	
RTS2	USG	upstream weighting	Recalibrated using pumping tests	remain active for life of mine	
EIS	SURFACT	van Genuchten	EIS Calibration	turn off after each longwall panel	

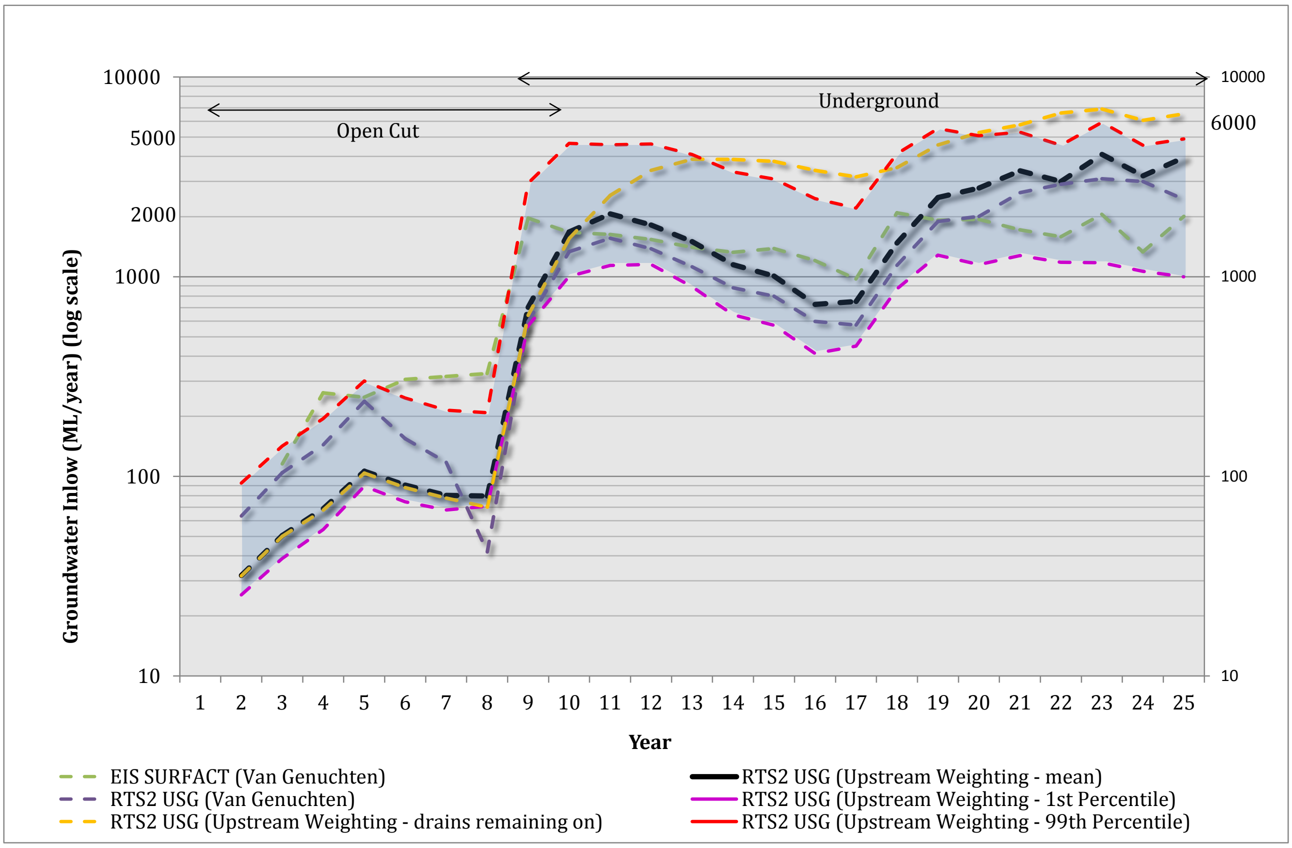


Figure 6-19 Predicted seepage to open cut and underground mining areas (semi log scale)

Table 6-8 Predicted seepage to mining areas

Year	RTS2 MODFLOW USG					EIS SURFACT
	upstream Weighting - basecase	upstream Weighting - 1st %ile	upstream weighting - 99th%ile	upstream weighting - drains remaining on	van Genuchten	van Genuchten
1	0	0	0	0	0	0
2	32	25	93	32	63	0
3	51	39	142	50	104	116
4	69	54	195	68	144	262
5	106	89	300	104	238	249
6	90	75	247	88	155	306
7	80	68	215	78	118	316
8	80	71	208	70	42	327
9	702	567	2937	641	596	1,968
10	1,675	1,004	4,659	1,553	1,334	1,667

Year	RTS2 MODFLOW USG					EIS SURFACT
	upstream Weighting - basecase	upstream Weighting - 1st %ile	upstream weighting - 99th%ile	upstream weighting - drains remaining on	van Genuchten	van Genuchten
11	2,065	1,139	4,577	2,555	1,560	1,629
12	1,812	1,152	4,618	3,402	1,382	1,538
13	1,498	892	4,090	3,868	1,123	1,405
14	1,148	645	3,347	3,867	880	1,324
15	1,006	571	3,084	3,780	799	1,385
16	725	413	2,459	3,408	597	1,207
17	751	450	2,206	3,157	573	975
18	1,471	870	4,129	3,516	1,141	2,093
19	2,492	1,283	5,514	4,570	1,892	1,921
20	2,776	1,150	5,078	5,262	2,005	1,940
21	3,387	1,277	5,298	5,755	2,637	1,720
22	2,999	1,181	4,550	6,602	2,907	1,584
23	4,099	1,176	5,923	6,917	3,099	2,053
24	3,202	1,063	4,551	6,069	2,997	1,331
25	3,952	1,000	4,892	6,542	2,438	2,005
TOTAL	**36,267**	**16,253**	**73,313**	**71,952**	**28,824**	**29,323**
AVERAGE	**1,451**	**650**	**2,933**	**2,878**	**1,153**	**1,173**

The recalibrated version of the numerical model predicts lesser groundwater inflow to the open cut mine, but increased volumes to the underground mining area when compared with the EIS. The changes are a function of approach to the unsaturated zone, changes in alluvial and bedrock parameters, differing recharge stresses and layering.

The 1st and 99th percentile indicate the uncertainty in the total inflow and also demonstrate the non-linear nature of the inflow with the basecase being skewed towards the lower end of the inflow range during the open cut mining, but moving close to the upper bound towards the end of the mine life.

6.4.7 Water take and licensing

The proposed mining will directly intercept groundwater in the open cut and underground mining areas. Some of this water will be lost to evaporation, or bound with spoils and coal, and therefore will not require pumping from the mining areas. For the purposes of water licensing, it has been assumed all the water predicted to be intercepted by the model drain cells is from the Permian or Triassic strata. Therefore, this water should be accounted for with water access licenses under the North Coast Porous and Fractured Rock Water Sharing Plan.

KEPCO has previously applied for a Water Access License under the *Water Act 1912* for the Project to extract groundwater from the Permian strata. It is understood that DPI Water will grant licenses applied for under the *Water Act 1912* within two years prior to the commencement of the North Coast Porous and Fractured Rock Water Sharing Plan which commenced on 1 July 2016. A water access license allowing extraction of up to 4,100ML/year will account for the peak annual water take in the base case.

The Aquifer Interference Policy also requires the assessment of the volume of groundwater indirectly influenced by the mining activities. This includes the volume of water pumped from the alluvial aquifers for make-up water and the reduction in Permian flow to the alluvial groundwater system. This water needs to be accounted for with water access licences from the Hunter Unregulated and Alluvial Water Sources Water Sharing Plan. Figure 6-20 presents the volume of water directly intercepted from the alluvial groundwater by pumping from bores and indirectly due to reduced flow of Permian groundwater to the alluvium due to depressurisation induced by mining.

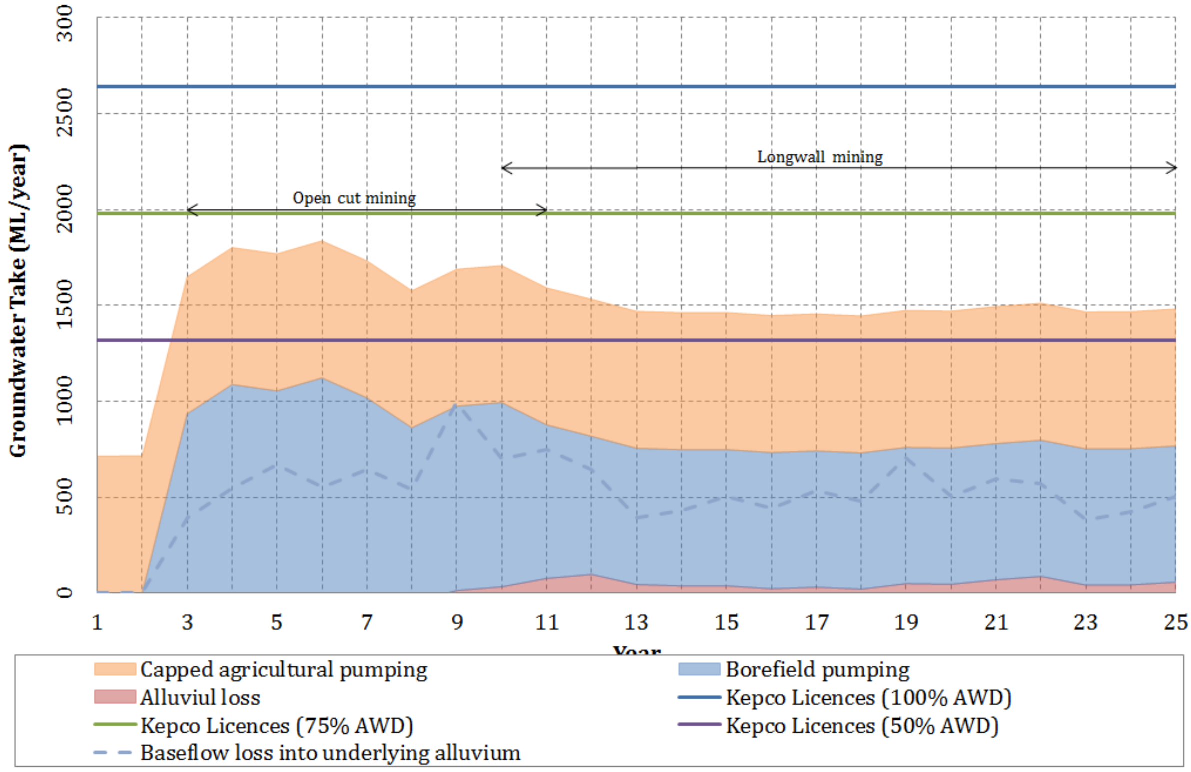


Figure 6-20 Water take from alluvium (mining interception + borefield + agriculture)

In the model, the pumping from the alluvial aquifer induces a flow of water from the surface water systems due to the lower head in the underlying aquifer. The induced flow from the surface water system is presented separately in Figure 6-21. As the change in surface water is part of the alluvial water budget, the surface water must enter the alluvium to flow to the borefield and therefore is accounted for in the well extraction and is excluded from the water licensing figure to avoid double accounting. Table 6-9 summarises the water budgets from the updated numerical model and the volumes of water required to account for water taken under the Hunter Unregulated and Alluvial Water Sources WSP and the North Coast Porous and Fractured Rock WSP. Table 6-9 demonstrates that KEPCO holds sufficient licenses to account for the water take from the alluvium. KEPCO will seek a variation to the *Water Act 1912* licence application to allow for the change to the base case modelling for extraction from the Permian strata.

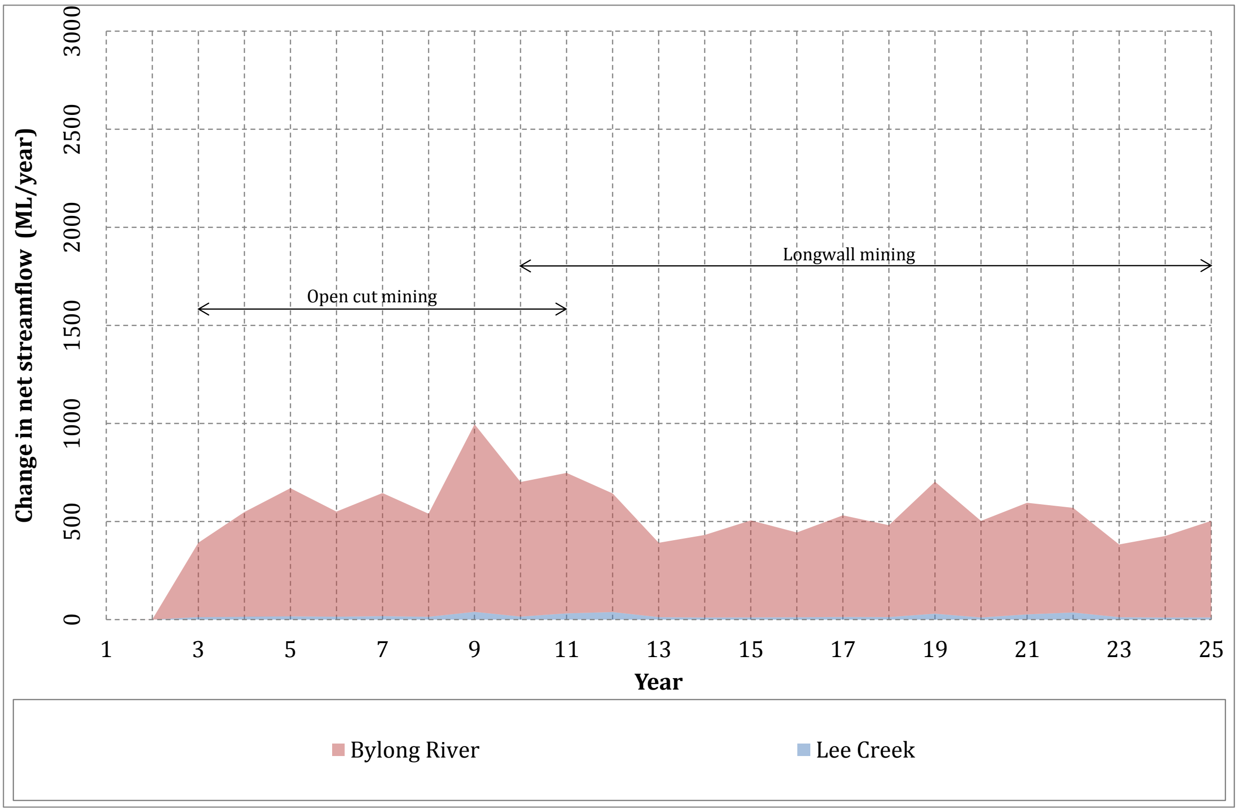


Figure 6-21 Water interception from stream flow

Table 6-9 Model water budgets and water licensing for the project

Year	Numerical model water budget item (ML/year)					Water licensing (ML/year)					
						Hunter Unregulated WSP			North Coast WSP		
	(a) Permian to alluvium flow change	(b) borefield pumping	(c) agricultural pumping (capped)	(d) stream flow change	(e) mine inflow	Surface water take (=d)	Ground water take (=a+b+c-d)	Total water take (=f+g)	Ground water take (=e)	Surface water take (=0)	Total water take (=e+0)
1	0	0	714	0	0	0	714	714	0	0	0
2	2	0	714	0	32	0	716	716	32	0	32
3	-65	1,000	714	390	51	390	1,259	1,649	51	0	51
4	-62	1,150	714	548	69	548	1,254	1,802	69	0	69
5	-46	1,100	714	670	106	670	1,098	1,768	106	0	106
6	-68	1,189	714	548	90	548	1,287	1,835	90	0	90
7	-56	1,071	714	639	80	639	1,090	1,729	80	0	80
8	-47	901	714	535	80	535	1,033	1,568	80	0	80
9	76	960	714	994	702	994	756	1,750	702	0	702
10	32	960	714	700	1675	700	1,006	1,706	1,675	0	1,675
11	74	800	714	746	2065	746	842	1,588	2,065	0	2,065
12	94	720	714	640	1812	640	888	1,528	1,812	0	1,812
13	43	710	714	390	1498	390	1,077	1,467	1,498	0	1,498
14	36	710	714	429	1148	429	1032	1,460	1,148	0	1,148
15	36	710	714	503	1006	503	957	1,460	1,006	0	1,006
16	21	710	714	441	725	441	1,004	1,445	725	0	725
17	29	710	714	528	751	528	925	1,453	751	0	751
18	18	710	714	477	1471	477	965	1,442	1,471	0	1,471

Year	Numerical model water budget item (ML/year)					Water licensing (ML/year)					
						Hunter Unregulated WSP			North Coast WSP		
	(a) Permian to alluvium flow change	(b) borefield pumping	(c) agricultural pumping (capped)	(d) stream flow change	(e) mine inflow	Surface water take (=d)	Ground water take (=a+b+c-d)	Total water take (=f+g)	Ground water take (=e)	Surface water take (=0)	Total water take (=e+0)
19	46	710	714	700	2,492	700	770	1,470	2,492	0	2,492
20	43	710	714	500	2,776	500	967	1,467	2,776	0	2,776
21	65	710	714	590	3,387	590	899	1,489	3,387	0	3,387
22	85	710	714	564	2,999	564	944	1,509	2,999	0	2,999
23	37	710	714	380	4,099	380	1,082	1,461	4,099	0	4,099
24	45	710	714	423	3,202	423	1,046	1,469	3,202	0	3,202
25	45	710	714	499	3,952	499	970	1,469	3,952	0	3,952

6.4.8 Borefield yield

The uncertainty analysis comprised 140 separate model runs with parameters varying randomly between the ranges outlined within Section 6.4.4. The yield from the proposed borefield was extracted for each model run to determine the potential to meet the estimated demand for makeup water. The data from the 140 model runs was used to calculate the proportion of the 140 model runs that failed to meet the upper makeup water demand presented within the RTS. Figure 6-22 shows the estimated makeup water demand presented within the EIS and RTS as well as the percentage of model runs that fell below the make up water demand.

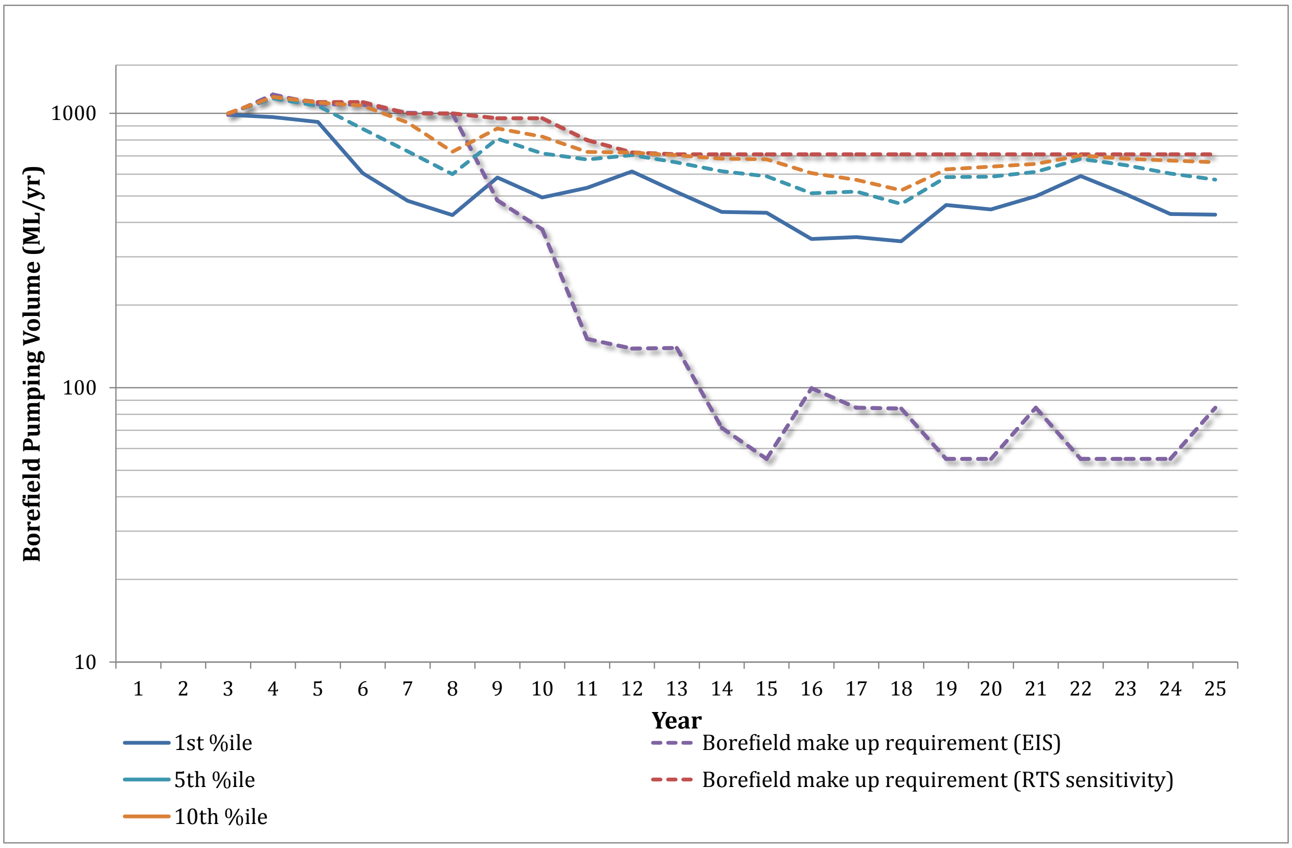


Figure 6-22 Uncertainty in borefield yield

Figure 6-22 indicates the borefield in the majority of the model runs was capable of supplying the make up water estimated within the RTS as a sensitivity. The figure shows the 1st and 5th percentiles for borefield pumping fall slightly below the RTS sensitivity make up water demand, with the 10th percentile falling below the demand intermittently.

Figure 6-22 indicates when the model is recalibrated to account for the higher hydraulic conductivity and storage determined from the pumping test program, the potential for the borefield to supply the make up water increases significantly. The basecase model can supply the make up water along with the majority of the models developed for the uncertainty analysis. This was achieved with a reduced borefield of eight bores installed within the alluvials throughout the Project Boundary. In the unlikely scenario that the borefield cannot meet the demand for make up water, there remains sufficient area to augment the borefield with additional bores. It should be noted that the scenarios where the borefield does not supply the entire makeup water demand are the extremes in both the groundwater and surface water models. Therefore, this outcome is improbable. However as noted in the RTS, should climatic conditions limit yield from the borefield, there will be appropriate contingency measures to implement.

As outlined in Section 6.4.6 the updated basecase model predicts reduced inflow to the open cut mine, but periods of increase in inflow during underground mining. WRM (2016) considered how this change in the mine inflow could influence the need to supplement the mine water circuit with additional water from the borefield. WRM (2016) concluded *“the annual bore water requirements will reduce to zero from PY12, as high groundwater inflows to the underground operations are predicted.”* Between Project Years one to 12, the water balance model indicated additional water required from the borefield could increase from 79ML/yr to 304ML/yr for the 1st percentile scenario. This volume of water is expected to be available by augmenting the proposed borefield with an additional one or two bores within the most productive zones of the Bylong River alluvial aquifer. Adequate water access licenses are also available to account for this additional demand from the borefield should it be required.

7 Discussion and conclusions

The additional field work and numerical modelling has indicated a higher hydraulic conductivity and recharge rate to the alluvial groundwater system than that previously assumed within the groundwater modelling presented in the EIS and the RTS. The impact of this is to improve the capacity for a smaller borefield comprising eight bores to supply make up water during periods of surface water deficit. In the unlikely scenario that the borefield fails to supply the makeup water, it can be augmented with additional bore sites within the alluvial aquifer.

The pumping bore locations were selected to be more than 200 m from the vegetation communities that have been identified as potentially GDEs. Whilst the vegetation communities are not listed within the Water Sharing Plan and therefore do not require buffer zones, a conservative approach for the placement of these pumping bores has been was adopted.

The predicted take of water from the alluvial aquifer via the borefield and from the indirect impacts of mining on the alluvial water source remains less than the total volume of entitlements held by KEPCO for all scenarios modelled to date. The Project will therefore not impact upon water security under the Hunter Unregulated and Alluvial Water Sources Water Sharing Plan.

KEPCO has also applied for a water license under the *Water Act 1912* for the predicted water takes from the Permian. KEPCO understands DPI Water has assessed its earlier application under the *Water Act 1912* and will transfer the relevant license to the North Coast Porous and Fractured Rock Water Sharing Plan and will be issued based on the revised numerical modelling estimates of inflow to the mine. A water access license allowing extraction of up to 4,100 ML/year will account for the peak annual water take in the base case. There is no other known licenced usage of water from the North Coast Porous and Fractured Rock Water Sharing Plan in the vicinity of the Project, and therefore this access license is not expected to affect water security within the region.

As groundwater will be extracted directly from the borefield and the mining areas, as well as indirectly via mining depressurisation, measurement of groundwater volumes will be important. The Water Management Plan will outline a program to install flow meters and level loggers on selected agricultural bores operated by KEPCO and the borefield utilised for the Project. KEPCO have also installed water level loggers on selected surrounding agricultural properties and will continue to undertake this upon request. Monitoring of the volume of water pumped into and out of the open cut and underground mines will also be required to estimate the volume of groundwater entering the mining areas.

The closest private bores within the alluvium in proximity to the Project are located on the Eagle Hill property (receiver 60). The modelling has indicated that for all modelling scenarios, impacts will be less than 1 m for these three private bores, with a maximum drawdown of 0.1 m on the Eagle Hill property for the base case Therefore the statement within the EIS that *‘there are no bores on privately held land where the drawdown is predicted by the numerical model to be greater than 0.1 m at any time’* remains unchanged for the updated base case version of the model. The Water Management Plan will outline a program for monitoring water levels within the alluvial aquifer between the private property and the borefield to monitor changes over time and to ensure that the private landholder is not impacted.

8 References

Australasian Groundwater and Environmental Consultants Pty Ltd (2013), "Bylong Coal Project Bylong Coal Project Gateway Groundwater Study", prepared for Hansen Bailey Pty Ltd, Project No. G1606, December 2013.

Australasian Groundwater and Environmental Consultants Pty Ltd (2015), "*Bylong Coal Project Groundwater Impact Assessment*", prepared for Hansen Bailey Pty Ltd, Project No. G1606, June 2015.

Australasian Groundwater and Environmental Consultants Pty Ltd (2016), "*Bylong Coal Project Response to Submissions on Groundwater*", prepared for Hansen Bailey Pty Ltd, Project No. G1606E, March 2016.

Doherty, John. (2015) "*Watermark Numerical Computing, Calibration and Uncertainty Analysis for Complex Environmental Models".*

WRM (2016) Memorandum - Bylong Coal Project – Water Balance Modelling for Revised Groundwater Inflows (Base Case), 14 July 2016

Appendix A Borehole logs and construction details

Australasian Groundwater & Environmental Consultants Pty Ltd

4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

AGE21P

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **19.03.2016**
LOGGED BY: **T.Walters (AGE)**

DRILLING COMPANY: **Gricks Drilling**
DRILLER: **S. Gricks**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Gardner Denver 1500W**

EASTING: **230402.8 mE**
NORTHING: **6407017.53 mN**
DATUM: **MGA94 (z56)**
RL: **275.42 mAHD**
EOH: **18 mBGL**

COMMENTS: **Pumping bore.**

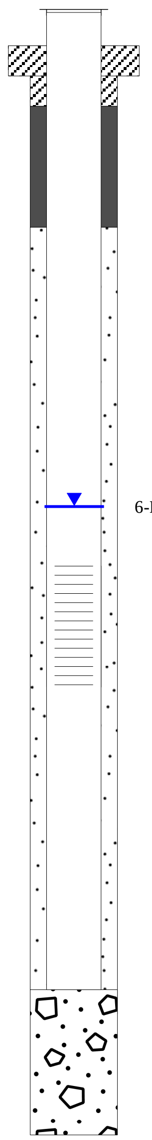
Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Soil, black with clayey matrix. Black to very dark brown, 14mm bolus, very sticky.
Alluvial sand and gravel	Sand, blotched mottled grey with orange, very fine grained sand (SA1) to gravel granules 2 - 4 mm (G1), poorly sorted, subangular clasts.
Alluvial sand and gravel	Sand, blotched mottled dark brown with grey, very fine grained sand (SA1) to gravel granules 2 - 4 mm (G1), poorly sorted, sub angular clasts.
Alluvial sand and gravel	Sand, dark brown, fine sand (SA1) with gravel granules 2 - 4 mm (G1). Granules low proportion randomly distributed, poorly sorted. At 4 - 5 m interval silty soft matrix, and 6 - 7.5 m interval downwards fining.
Alluvial sand and gravel	Gravel, blotched mottled, gravel sized 1 - 20 mm, subrounded to subangular, poorly sorted.
Alluvial sand and gravel	Sandstone. Driller noted hard layer. Interpreted as sandstone, identified grey sandstone with washed out coal fragments.
BOW	Sandstone, grey to black, fine grained (S2), well sorted, hard, with weathered (CW) to dull coal (C5).
Competent rock	Coal, black, mainly dull (C4), hard, with light brown siltstone (F), hard.
Competent rock	Siltstone (F), carbonaceous, black, hard.
Competent rock	Sandstone, light grey, fine grained (S2), well sorted, hard, with carbonaceous (R), laminations.
Competent rock	Sandstone, blotched light grey and orange, fine grained (S2), well sorted, moderate to low strength.
Competent rock	Coal, black, mainly dull (C4), moderately hard.

Graphic Log

R.L. (mAHD): 276, 274, 272, 270, 268, 266, 264, 262, 260, 258, 256, 254, 252

Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description
Protective lockable steel collar
PVC stick up: +0.9 m
Bentonite grout dry weight (10 %): 0 m to 1 m
609.6 mm hole opener: 0 m to 1.9 m (air)
Bentonite seal: 1 m to 3 m
203.2 mm blade: 0 m to 10 m (mud)
203.2 mm rock roller: 10 m to 18 m (mud)
381 mm rock roller: 0 m to 18 m (mud)
219 mm steel blank casing: 0 m to 8.6 m
1.5-3 mm washed, rounded, quartz gravel pack: 3 m to 16 m
Open hole flow rate at 11 m: 2.2 L/s
Bore development: 3.5 hr; EC: 655 µS/cm; pH: 7.94
219 mm steel wire wound screen, slot aperture: 0.6mm mm, slot length: mm, slots / m, 8.6 m to 10.6 m
End of bore: 15.6 m
End of hole: 18 m BGL

Australasian Groundwater & Environmental Consultants Pty Ltd
4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

AGE22M

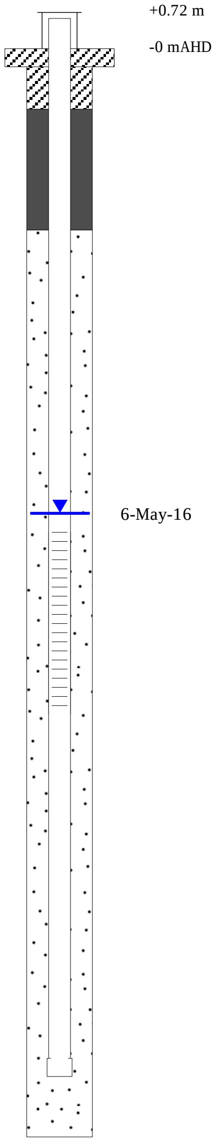
PROJECT No: **G1606F**	DRILLING COMPANY: **Hagstrom Drilling**	EASTING: **230405.74 mE**
PROJECT NAME: **Bylong borefield installation**	DRILLER: **S. Mortimer**	NORTHING: **6407002.82 mN**
DATE DRILLED: **21.03.2016**	DRILLING METHOD: **Mud Rotary**	DATUM: **MGA94 (z56)**
LOGGED BY: **B.McKay (AGE)**	DRILL RIG: **Hydrapower scout**	RL: **275.67 mAHD**
		EOH: **18 mBGL**

COMMENTS: **Alluvial monitoring bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Clay, very dark brown, medium plasticity, subangular lithic clasts up to 5mm throughout. Clay highly cohesive.
Alluvial sand and gravel	Clay, mottled dark brown and orange, medium plasticity, moderately cohesive, subrounded to subangular siliceous clasts to 3mm. Poorly sorted clayey throughout.
	Granular gravel, siliceous subrounded clasts averaging 2mm across. Medium sorting. Clayey throughout (light brown), various colours.
	Fluvial sediments, granular gravel, siliceous, white to dark brown, rounded to subangular, whole sequence fining up.
	Gravel, ~3mm across average, white to clear to orange subrounded to subangular clasts, rounding increasing with depth. Clayey throughout.
	Gravel, granular to pebble sized, subrounded to subangular, poorly sorted. Clear, white, pink and iron staining on siltstone clasts, sideritic nodules. Carbonaceous siltsone fragments throughout. Clast size increasing with depth. Carbonaceous towards base.
	Dull stony coal 5% / carbonaceous siltstone 30% / fine grained sandstone iron stained (65%).
Highly weathered competent rock	Sandstone 80%, light grey, fine grained, carbonaceous siltstone 20%.
	Sandstone, light grey, fine grained, coaly with carbonaceous fragments throughout, iron stained sandstone bands throughout.

Graphic Log | R.L. (mAHD): 276, 274, 272, 270, 268, 266, 264, 262, 260, 258, 256, 254, 252 | Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.72 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 18 m (mud)

152.4 mm blade: 0 m to 18 m (mud)
Bentonite seal: 1 m to 3 m

50 mm PN 18 uPVC blank casing: 0 m to 8 m

2 mm washed, rounded, quartz gravel pack: 3 m to 18 m

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 8 m to 11 m

End of bore: 17 mBGL

End of hole: 18 m BGL

Australasian Groundwater & Environmental Consultants Pty Ltd
4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

AGE23M

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **23.03.2016**
LOGGED BY: **B.McKay (AGE)**

DRILLING COMPANY: **Hagstrom Drilling**
DRILLER: **S. Mortimer**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Hydrapower scout**

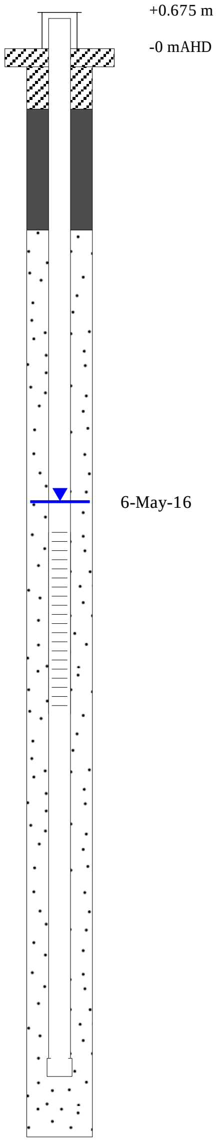
EASTING: **230408.72 mE**
NORTHING: **6406988.01 mN**
DATUM: **MGA94 (z56)**
RL: **275.5 mAHD**
EOH: **18 mBGL**

COMMENTS: **Alluvial monitoring bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Clay, very dark brown, medium plasticity, subangular lithic clasts up to 5mm throughout. Clay highly cohesive.
Alluvial sand and gravel	Clay, mottled dark brown and orange, medium plasticity, moderately cohesive, subrounded to subangular siliceous clasts to 3mm. Poorly sorted, clayey throughout.
Alluvial sand and gravel	Granular gravel, siliceous subrounded clasts averaging 2mm across. Medium sorting. Clayey throughout (light brown), various colours.
Alluvial sand and gravel	Fluvial sediments, granular gravel, siliceous, white to dark brown, rounded to subangular, whole sequence fining up.
Alluvial sand and gravel	Gravel, ~3mm across average, white to clear to orange subrounded to subangular clasts, rounding increasing with depth. Clayey throughout.
Alluvial sand and gravel	Gravel, granular to pebble sized, subrounded to subangular, poorly sorted. Clear, white, pink and iron staining on siltstone clasts, sideritic nodules. Carbonaceous siltsone fragments throughout. Clast size increasing with depth. Carbonaceous towards base.
Alluvial sand and gravel	Dull stony coal 5% / carbonaceous siltstone 30% / fine grained sandstone iron stained (65%)
Highly weathered competent rock	Sandstone 80%, light grey, fine grained, carbonaceous siltstone 20%.
Highly weathered competent rock	Sandstone, light grey, fine grained, coaly with carbonaceous fragments throughout, iron stained sandstone bands throughout.

Graphic Log | R.L. (mAHD): 276, 274, 272, 270, 268, 266, 264, 262, 260, 258, 256, 254, 252 | Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.675 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 18 m (mud)

152.4 mm blade: 0 m to 18 m (mud)
Bentonite seal: 1 m to 3 m

50 mm PN 18 uPVC blank casing: 0 m to 8 m

2 mm washed, rounded, quartz gravel pack: 3 m to 18 m

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 8 m to 11 m

End of bore: 17 mBGL

End of hole: 18 m BGL

Australasian Groundwater & Environmental Consultants Pty Ltd
4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

BOREHOLE LOG

AGE24P

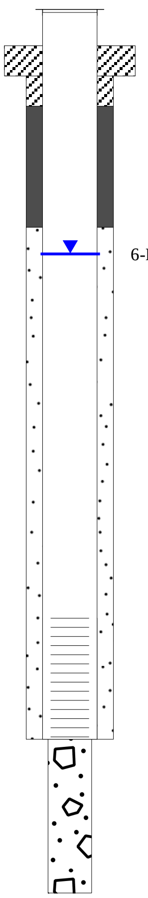
PROJECT No: **G1606F**	DRILLING COMPANY: **Gricks Drilling**	EASTING: **230335.7 mE**
PROJECT NAME: **Bylong borefield installation**	DRILLER: **S. Gricks**	NORTHING: **6408249.8 mN**
DATE DRILLED: **20.03.2016**	DRILLING METHOD: **Mud Rotary**	DATUM: **MGA94 (z56)**
LOGGED BY: **B.McKay (AGE)**	DRILL RIG: **Gardner Denver 1500W**	RL: **267.07 mAHD**
		EOH: **14 mBGL**

COMMENTS: **Alluvial pumping bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
Soil	Fine sandy clay, dark brown, low plasticity.	0–1
Alluvial sand and gravel	Fine sandy clayey gravel; granular up to 55mm silic clasts, subrounded, dark brown. Clay content decreasing with depth.	1–4
Alluvial sand and gravel	Gravel to 55mm across, subangular to subrounded, clayey throughout, medium brown.	4–6
Alluvial sand and gravel	Coarse gravel, clayey throughout, brown, subangular to subrounded siliceous clasts to 1cm, poorly sorted.	6–9
Alluvial sand and gravel	Very coarse gravel to cobble size in part, subrounded to subangular. Orange and brown. Clayey throughout.	9–10
Alluvial sand and gravel	Gravel conglomerate 60% / carbonaceous siltstone and dull stony cindered coal 20% / fine grey sandstone 5% / basalt 15%.	10–11
Alluvial sand and gravel	Basalt black 80% / gravel with fine grained orange and red sandstone. Occasional dull stony coal.	11–13
competent rock	Sandstone, light grey, fine grained, intruded by basalt, occasional coaly fragments and carbonaceous siltstone.	13–14

R.L. (mAHD) scale: 268, 266, 264, 262, 260, 258, 256, 254, 252, 250, 248, 246, 244
Depth (mBGL) scale: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.6 m

Bentonite grout dry weight (10 %): 0 m to 1 m

609.6 mm hole opener: 0 m to 2 m (air)

Bentonite seal: 1 m to 3 m

203.2 mm blade: 0 m to 13 m (mud)

203.2 mm rock roller: 13 m to 14 m (mud)

381 mm rock roller: 0 m to 12.2 m (mud)

219 mm steel blank casing: 0 m to 9.46 m

1.5-3 mm washed, rounded, quartz gravel pack: 3 m to 11.46 m

Open hole flow rate at 11.46 m: 6.29 L/s

219 mm steel wire wound screen, slot aperture: 0.6mm mm, slot length: mm, slots / m, 9.46 m to 11.46 m

End of bore: 11.46 mBGL

Bit refusal on boulder.

Bore development: 1.4 hr; EC: 1669 µS/cm; pH: 7.78

End of hole: 14 m BGL

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BOREHOLE LOG

AGE25M

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **01.04.2016**
LOGGED BY: **B.McKay (AGE)**

DRILLING COMPANY: **Hagstrom Drilling**
DRILLER: **S. Mortimer**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Hydrapower scout**

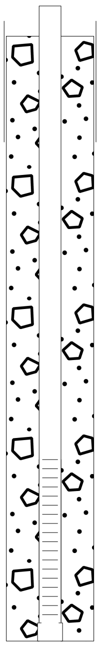
EASTING: **230333.2 mE**
NORTHING: **6408259.1 mN**
DATUM: **MGA94 (z56)**
RL: **267.21 mAHD**
EOH: **10 mBGL**

COMMENTS: **PVC used to prevent collapsing hole. Failed hole, bit refusal at 10m.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
Soil	Sandy clay, very dark brown, medium plasticity.	0 – 1
Alluvial sand and gravel	Granular 80% to pebble 18%, subangular to subrounded gravel. Highly weathered coaly fragments 2%. Clayey in part.	1 – 2
Alluvial sand and gravel	Granular gravel, subangular to subrounded, occasional pebbles 15%, rare carbonaceous fragments decreasing in number with depth.	2 – 6
Alluvial sand and gravel	Pebbly gravel, subangular to subrounded, predominantly highly siliceous clasts with occasional highly weathered sandstone/siltstone clasts and rare coaly fragments.	6 – 8
Alluvial sand and gravel	Pebbly granular gravel, basalt throughout, subrounded to subangular. Bit refusal at 10m.	8 – 10

R.L. (mAHD): 268, 266, 264, 262, 260, 258, 256, 254, 252, 250, 248, 246, 244
Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



+TBA m
-0 mAHD

Bore Description

Protective lockable steel collar

PVC stick up: + m

609.6 mm hole opener: 0 m to 2 m (air)

203.2 mm blade: 0 m to 6 m (mud)

203.2 mm rock roller: 6 m to 10 m (mud)

50 mm PN 18 uPVC blank casing: 0 m to 7 m

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 7 m to 10 m

Hole collapse: 0 m to 10 m

Bit refusal at 10m, required total depth not achieved. Surface casing left in ground.

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BOREHOLE LOG

AGE26M

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **01.04.2016**
LOGGED BY: **B.McKay (AGE)**

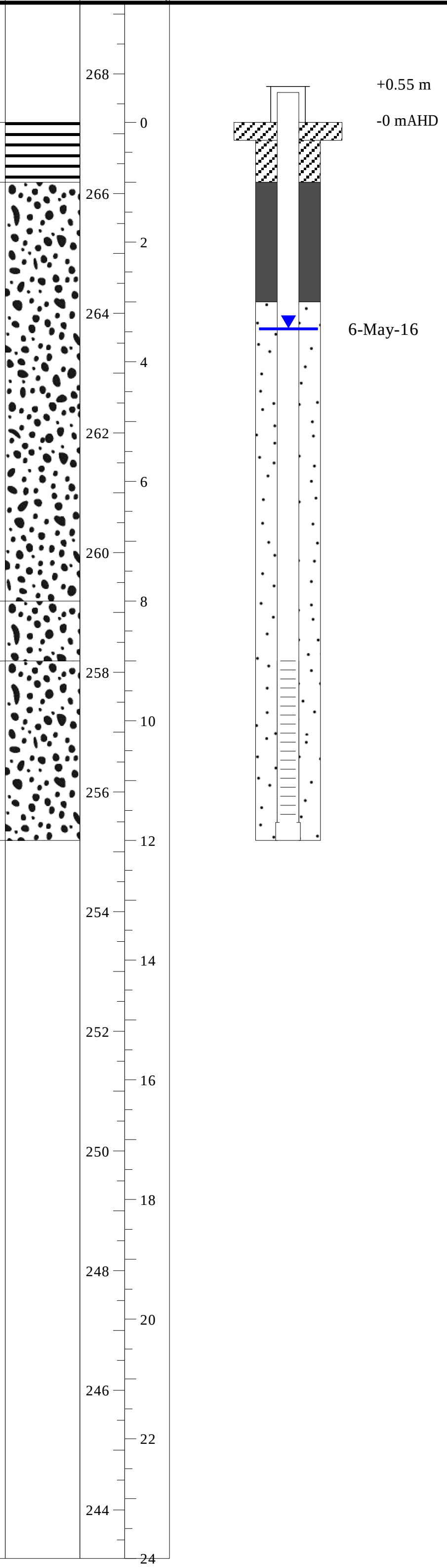
DRILLING COMPANY: **Hagstrom Drilling**
DRILLER: **S. Mortimer**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Hydrapower scout**

EASTING: **230338.9 mE**
NORTHING: **6408244.7 mN**
DATUM: **MGA94 (z56)**
RL: **267.19 mAHD**
EOH: **12 mBGL**

COMMENTS: **Alluvial monitoring bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Clay dark brown, medium plasticity.
Alluvial sand and gravel	Granular pebbly gravel, clayey throughout, very poorly sorted., subangular, weathered siltstone/sandstone siliceous clasts to 1cm. Occasional clast to 4cm.
	Granular to pebbly gravel 95%, basalt 5%, very poorly sorted subangular to sub rounded, very hard drilling on blade.
	Granular gravel, pebbly in part 60%, basalt 40%, poorly sorted, subangular to subrounded, clast size and basalt abundance increasing with depth.

Graphic Log | R.L. (mAHD) | Depth (mBGL) | Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.55 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 12 m (mud)

Bentonite seal: 1 m to 3 m

152.4 mm blade: 0 m to 12 m (mud)

50 mm PN 18 uPVC blank casing: 0 m to 9 m

2 mm washed, rounded, quartz gravel pack: 3 m to 12 m

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 9 m to 12 m

End of bore: 12 mBGL

End of hole: 12 m BGL

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BOREHOLE LOG

AGE27M

PROJECT No: **G1606F**	DRILLING COMPANY: **Hagstrom Drilling**	EASTING: **230343.2 mE**
PROJECT NAME: **Bylong borefield installation**	DRILLER: **S. Mortimer**	NORTHING: **6408240.9 mN**
DATE DRILLED: **01.04.2016**	DRILLING METHOD: **Mud Rotary**	DATUM: **MGA94 (z56)**
LOGGED BY: **B.McKay (AGE)**	DRILL RIG: **Hydrapower scout**	RL: **267.34 mAHD**
		EOH: **12 mBGL**

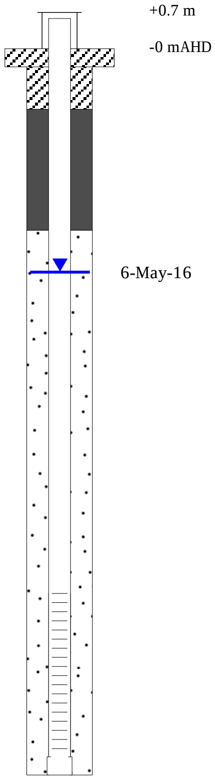
COMMENTS: **Alluvial monitoring bore.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
Soil	Sandy clay, dark brown, low plasticity.	0 – 1
Alluvial sand and gravel	Sandy clay, dark brown, granular gravel towards base.	1 – 2
Alluvial sand and gravel	Granular gravel, clayey throughout, subangular to subrounded, rare coal/carbonaceous fragments, darker clay fraction towards base.	2 – 8
Alluvial sand and gravel	Granular gravel, clayey throughout, subangular to subrounded clasts. Rare basalt fragments 5% near top. Basalt increasing with depth to 30% modal composition.	8 – 10
Alluvial sand and gravel	Granular gravel, basalt throughout 40%. Weathered sandstone subangular. Potential weathered bedrock. Basalt fraction increasing with depth.	10 – 12

R.L. (mAHD): 268, 266, 264, 262, 260, 258, 256, 254, 252, 250, 248, 246, 244

Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.7 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 12 m (mud)

Bentonite seal: 1 m to 3 m

152.4 mm blade: 0 m to 12 m (mud)

50 mm PN 18 uPVC blank casing: 0 m to 9 m

2 mm washed, rounded, quartz gravel pack: 3 m to 12 m

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 9 m to 12 m

End of bore: 12 mBGL

End of hole: 12 m BGL

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BOREHOLE LOG

AGE28P

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **04.04.2016**
LOGGED BY: **B.McKay (AGE)**

DRILLING COMPANY: **Gricks Drilling**
DRILLER: **S. Gricks**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Gardner Denver 1500W**

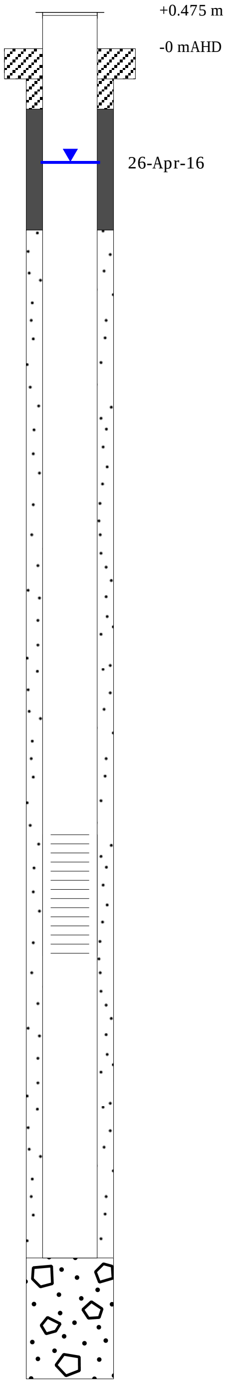
EASTING: **232022.9 mE**
NORTHING: **6406186.7 mN**
DATUM: **MGA94 (z56)**
RL: **283.91 mAHD**
EOH: **22 mBGL**

COMMENTS: **Alluvial pumping bore southern Tarwyn Park.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
Soil	Sandy clay, dark brown, fine to coarse grained, low plasticity.	0–1
Alluvial sand and gravel	Sandy clay, gravelly at base. Dark brown subangular to subrounded clasts from 2 to 10mm, low plasticity.	1–2
Alluvial sand and gravel	Gravel, granular to pebbly, extremely clayey throughout, brown, subangular to subrounded, very poorly sorted.	2–4
Alluvial sand and gravel	Gravelly clay, granular to clay fraction, with coal fragments throughout, subangular to subrounded clasts, rare pebbly clasts, poorly sorted. Larger weathered sandstone clasts, sub rounded, starting from 10m, medium plasticity.	4–12
Alluvial sand and gravel	Clayey gravel, pebbly. Rare coaly fragments. Subrounded to subangular, poorly sorted.	12–13
Alluvial sand and gravel	Clayey gravel, granular to pebbly in part. Basalt and coal 1%. Clasts subangular to subrounded.	13–14
Alluvial sand and gravel	Clayey gravel, granular to pebbly in part, subangular to subrounded. Basalt throughout sample modal 40%. Base of alluvium.	14–15
Alluvial sand and gravel	Coal, dull, and granular gravel throughout sample.	15–15.3
Weathered competent rock	Coal, dull stony/sooty/minor bright. Silcrete/quartzite. Weathered rock.	15.3–16
Weathered competent rock	Coal dull, pyritic, highly weathered; with tuffaceous claystone band.	16–17
Weathered competent rock	Coal dull to stony / carbonaceous mudstone / siltstone with minor silcrete/quartzite.	17–18
Weathered competent rock	Sandstone grey, weathered, with dull minor bright coal lenses throughout.	18–19
Weathered competent rock	Sandstone grey, fine grained, weathered.	19–20
Weathered competent rock	Sandstone dark grey, very fine grained, weathered, with siltstone laminae and coaly/carbonaceous wisps throughout.	20–22

R.L. (mAHD)	Depth (mBGL)
284	0
282	2
280	4
278	6
276	8
274	10
272	12
270	14
268	16
266	18
264	20
262	22
260	24

Bore Construction



Bore Description

- Protective lockable steel collar
- PVC stick up: +0.475 m
- Bentonite grout dry weight (10 %): 0 m to 1 m
- 609.6 mm hole opener: 0 m to 2 m (air)
- Bentonite seal: 1 m to 3 m
- 203.2 mm blade: 0 m to 13 m (mud)
- 203.2 mm rock roller: 13 m to 20 m (mud)
- 381 mm rock roller: 0 m to 20 m (mud)
- 219 mm steel blank casing: 0 m to 13 m
- 1.5-3 mm washed, rounded, quartz gravel pack: 3 m to 20 m
- Bore development: 1.1 hr; EC: 407 µS/cm; pH: 7.72
- Open hole flow rate at 15 m: 5.633 L/s
- 219 mm steel wire wound screen, slot aperture: 0.6mm mm, slot length: mm, slots / m, 13 m to 15 m
- End of bore: 20 mBGL
- End of hole: 22 m BGL

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BOREHOLE LOG page:1 of 1

AGE29M

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **04.04.2016**
LOGGED BY: **B.McKay (AGE)**

DRILLING COMPANY: **Hagstrom Drilling**
DRILLER: **S. Mortimer**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Hydrapower scout**

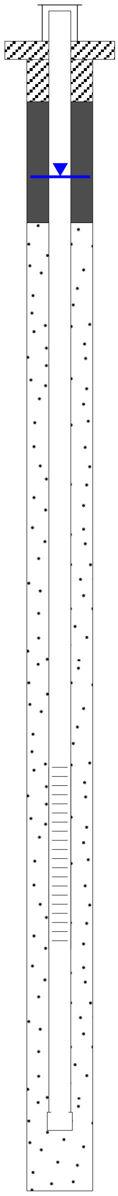
EASTING: **232047.4 mE**
NORTHING: **6406165.6 mN**
DATUM: **MGA94 (z56)**
RL: **284.19 mAHD**
EOH: **19 mBGL**

COMMENTS: **Alluvial monitoring bore southern Tarwyn Park.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Sandy clay, brown, fine sand, low plasticity.
Alluvial sand and gravel	Granular gravel, brown, rare pebbly clasts, extremely clay rich. Clasts subrounded to subangular siliceous clasts.
Alluvial sand and gravel	Granular gravelly clay, brown, subrounded to subangular clasts throughout. Rare coal fragments, poorly sorted, low to medium plasticity.
Alluvial sand and gravel	Granular gravelly clay brown, pebbly in part, subangular to subrounded, siliceous clasts present, poorly sorted, medium plasticity. Rare coaly/carbonaceous fragments.
Alluvial sand and gravel	Granular to pebbly gravelly clay, brown, subangular to subrounded siltstone and silceous clasts, low to medium plasticity. Rare coal and basalt fragments. Basalt black/green angular towards base of unit.
Alluvial sand and gravel	Granular to pebbly gravel, brown. Clay and basalt 20% throughout. Rare weathered coal, dull to minor bright.
competent rock	Coal, dull to bright banded, highly weathered. Coal with pyrite staining and minor silcrete/quartzite, and tuffaceous claystone band ~16.5m.
competent rock	Sandstone, light grey, very fine grained trending to siltstone, highly weathered. Dull coal bands throughout.

Graphic Log | Depth (mBGL) | R.L. (mAHD)

Bore Construction



Bore Description

- Protective lockable steel collar
- PVC stick up: +0.675 m
- Bentonite grout dry weight (10 %): 0 m to 1 m
- 149.2 mm rock roller: 0 m to 15 m (mud)
- Bentonite seal: 1 m to 3 m
- 152.4 mm blade: 15 m to 19 m (mud)
- 50 mm PN 18 uPVC blank casing: 0 m to 12 m
- 2 mm washed, rounded, quartz gravel pack: 3 m to 19 m
- Sampled 05.05.2016 paramaters - SWL 1.565mBGL, pH 6.37, 390uS/cm, 18.2C and 260ppm TDS.
- 50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 12 m to 15 m
- End of bore: 18 mBGL
- End of hole: 19 m BGL

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BOREHOLE LOG

AGE30M

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **04.04.2016**
LOGGED BY: **B.McKay (AGE)**

DRILLING COMPANY: **Hagstrom Drilling**
DRILLER: **S. Mortimer**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Hydrapower scout**

EASTING: **232035.4 mE**
NORTHING: **6406175.6 mN**
DATUM: **MGA94 (z56)**
RL: **284.03 mAHD**
EOH: **19 mBGL**

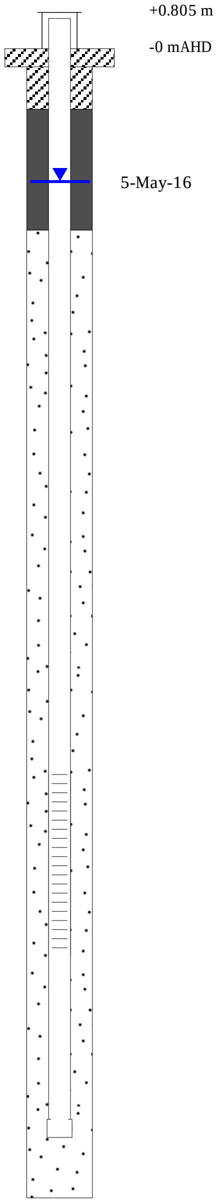
COMMENTS: **Alluvial monitoring bore southern Tarwyn Park.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Sandy clay, brown, fine sand, low plasticity.
Alluvial sand and gravel	Granular gravel, brown, rare pebbly clasts, extremely clay rich. Clasts subrounded to subangular siliceous clasts.
Alluvial sand and gravel	Granular gravelly clay, brown, subrounded to subangular clasts throughout. Rare coal fragments, poorly sorted, low to medium plasticity.
Alluvial sand and gravel	Granular gravelly clay brown, pebbly in part, subangular to subrounded, siliceous clasts present, poorly sorted, medium plasticity. Rare coaly/carbonaceous fragments.
Alluvial sand and gravel	Granular to pebbly gravelly clay, brown, subangular to subrounded siltstone and silceous clasts, low to medium plasticity. Rare coal and basalt fragments. Basalt black/green angular towards base of unit.
Alluvial sand and gravel	Granular to pebbly gravel, brown. Clay and basalt 20% throughout. Rare weathered coal, dull to minor bright.
competent rock	Coal, dull to bright banded, highly weathered. Coal with pyrite staining and minor silcrete/quartzite, and tuffaceous claystone band ~16.5m.
competent rock	Sandstone, light grey, very fine grained trending to siltstone, highly weathered. Dull coal bands throughout.

Graphic Log

Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24
R.L. (mAHD): 285, 283, 281, 279, 277, 275, 273, 271, 269, 267, 265, 263, 261

Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.805 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 15 m (mud)

Bentonite seal: 1 m to 3 m

152.4 mm blade: 15 m to 19 m (mud)

50 mm PN 18 uPVC blank casing: 0 m to 12 m

2 mm washed, rounded, quartz gravel pack: 3 m to 19 m

Sampled 05.05.2016 paramaters - SWL 1.392mBGL, pH 6.45, 394uS/cm, 18.1C and 262ppm TDS.

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 12 m to 15 m

End of bore: 18 mBGL

Hole collapse: m to m

End of hole: 19 m BGL

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BOREHOLE LOG page:1 of 1

AGE31M

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **14.04.2016**
LOGGED BY: **T.Walters (AGE)**

DRILLING COMPANY: **Hagstrom Drilling**
DRILLER: **S. Mortimer**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Hydrapower scout**

EASTING: **231762.56 mE**
NORTHING: **6406941.95 mN**
DATUM: **MGA94 (z56)**
RL: **279.03 mAHD**
EOH: **19 mBGL**

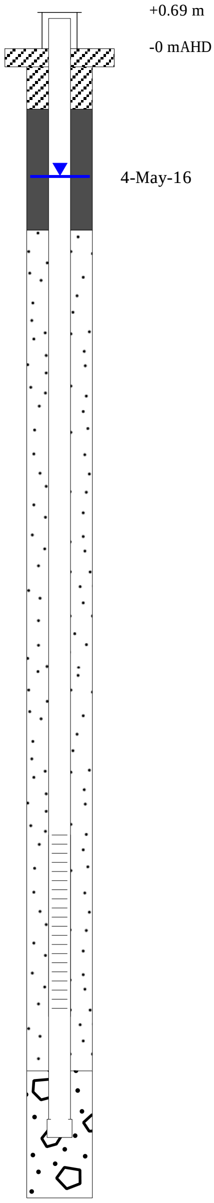
COMMENTS: **Alluvial monitoring bore on Tarwyn Park.**

Stratigraphic Cloumn	Soil or Rock Field Material Description
Soil	Soil (O), dark brown to black with silt.
Alluvial sand and gravel	Gravel, light brown with grey speckling, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.
	Gravel, light grey, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.
	Gravel, light brown to orange, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.
	Gravel, light brown, orange and black, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Noted increased abundance of black chips, interpreted bedload clasts.
	Gravel, light brown, orange and black, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Less coarse chips 13m, coarser 14m interval. Driller deduced clay at 15.5m prior to competent rock.
BOW	
competent rock	Sandstone, light grey, very fine grained (SA1), low strength, with black to brown, very hard carbonaceous siltstone. competent rock.
	Sandstone, light grey, very fine grained (SA1), moderate strength, with low strength black siltstone.
	Siltstone, black, carbonaceous, low strength, with light grey, very fine grained (SA1), moderate strength sandstone.

Graphic Log | Depth (mBGL) | R.L. (mAHD)

R.L. (mAHD): 280, 278, 276, 274, 272, 270, 268, 266, 264, 262, 260, 258, 256
Depth (mBGL): 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

Bore Construction



Bore Description

Protective lockable steel collar

PVC stick up: +0.69 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 19 m (mud)

Bentonite seal: 1 m to 3 m

152.4 mm blade: 0 m to 19 m (mud)

50 mm PN 18 uPVC blank casing: 0 m to 13 m

2 mm washed, rounded, quartz gravel pack: 3 m to 16.9 m

Sampled 04.05.2016 paramaters - SWL 1.422mBGL, pH 6.45, 454uS/cm, 17.1C and 306ppm TDS.

50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 13 m to 16 m

Hole collapse: 16.9 m to 19 m

End of bore: 18 mBGL

End of hole: 19 m BGL

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BOREHOLE LOG

AGE32P

PROJECT No: **G1606F**
PROJECT NAME: **Bylong borefield installation**
DATE DRILLED: **16.04.2016**
LOGGED BY: **T.Walters (AGE)**

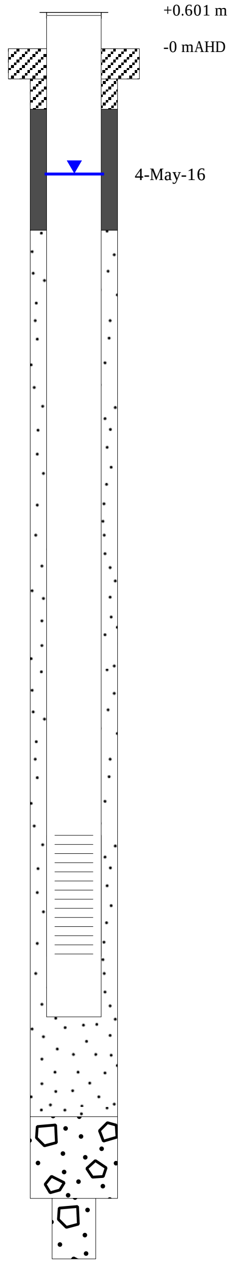
DRILLING COMPANY: **Gricks Drilling**
DRILLER: **S. Gricks**
DRILLING METHOD: **Mud Rotary**
DRILL RIG: **Gardner Denver 1500W**

EASTING: **231768.38 mE**
NORTHING: **6406929.72 mN**
DATUM: **MGA94 (z56)**
RL: **279.08 mAHD**
EOH: **20 mBGL**

COMMENTS: **Alluvial pumping bore on Tarwyn Park.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL) / R.L. (mAHD)	Bore Description
		280	Protective lockable steel collar
			PVC stick up: +0.601 m
Soil	Soil (O), dark brown to black with silt.	0–2 / 278	Bentonite grout dry weight (10 %): 0 m to 1 m
Alluvial sand and gravel	Gravel, light brown with grey speckling, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Fining downwards to 7m, driller noted harder at this point. Alluvium.	2–8 / 276, 274, 272	609.6 mm hole opener: 0 m to 1.9 m (air) Bentonite seal: 1 m to 3 m 203.2 mm blade: 0 m to 6 m (mud) 203.2 mm rock roller: 6 m to 19.5 m (mud) 381 mm rock roller: 0 m to 19.5 m (mud) 219 mm steel blank casing: 0 m to 13 m 1.5-3 mm washed, rounded, quartz gravel pack: 3 m to 17.7 m
	Gravel, light brown to orange, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.	270	
	Gravel, light brown, orange and black, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Noted increased abundance of blacker chips, interpreted bedload clasts.	10 / 268	
	Gravel, light brown, orange and black, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Less coarse chips 13m, coarser 14m interval. Driller deduced clay at 15.5m prior to competent rock.	12–16 / 266, 264	Open hole flow rate at 15 m: 8.3 L/s Bore development: 4 hr; EC: 460 µS/cm; pH: 7.11 219 mm steel wire wound screen, slot aperture: 0.6mm mm, slot length: mm, slots / m, 13 m to 15 m
BOW / competent rock	Sandstone, light grey, very fine grained (SA1), low strength, with black to brown, very hard carbonaceous siltstone. competent rock.	16	End of bore: 16 mBGL
competent rock	Sandstone, light grey, very fine grained (SA1), moderate strength, with low strength black siltstone.	262	
competent rock	Siltstone, black, carbonaceous, low strength, with light grey, very fine grained (SA1), moderate strength sandstone.	18	Hole collapse: 17.7 m to 20 m
	Sandstone, light grey, very fined grained (SA1), with hard carbonaceous fines.	260 / 20	End of hole: 20 m BGL
		258, 22, 256, 24	

Bore Construction



Australasian Groundwater & Environmental Consultants Pty Ltd
4 Hudson St, Hamilton, NSW 2303
Level 2, 15 Mallon Street, Bowen Hills, Queensland 4006

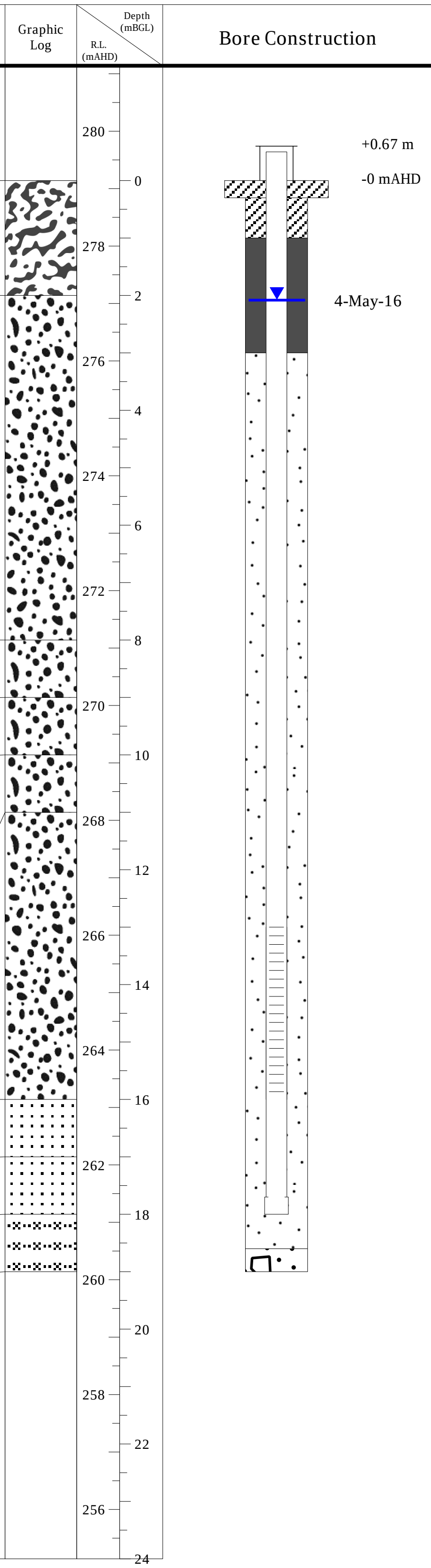
BOREHOLE LOG

AGE33M

PROJECT No: **G1606F**	DRILLING COMPANY: **Hagstrom Drilling**	EASTING: **231774.97 mE**
PROJECT NAME: **Bylong borefield installation**	DRILLER: **S. Mortimer**	NORTHING: **6406915.71 mN**
DATE DRILLED: **16.04.2016**	DRILLING METHOD: **Mud Rotary**	DATUM: **MGA94 (z56)**
LOGGED BY: **T.Walters (AGE)**	DRILL RIG: **Hydrapower scout**	RL: **279.14 mAHD**
		EOH: **19 mBGL**

COMMENTS: **Alluvial monitoring bore on Tarwyn Park.**

Stratigraphic Cloumn	Soil or Rock Field Material Description	Depth (mBGL)
Soil	Soil (O), dark brown to black with silt.	0 – 2
Alluvial sand and gravel	Gravel, light brown with grey speckling, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.	2 – 8
Alluvial sand and gravel	Gravel, light grey, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.	8 – 9
Alluvial sand and gravel	Gravel, light brown to orange, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted.	9 – 10
Alluvial sand and gravel	Gravel, light brown, orange and black, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Noted increased abundance of blacker chips, interpreted bedload clasts.	10 – 11
Alluvial sand and gravel / BOW	Gravel, light brown, orange and black, fine sand 0.125mm (SA2) to gravel pebbles 5mm (G2), subangular grains, poorly sorted. Less coarse chips 13m, coarser 14m interval. Driller deduced clay at 15.5m prior to competent rock.	11 – 16
competent rock	Sandstone, light grey, very fine grained (SA1), low strength, with black to brown, very hard carbonaceous siltstone. competent rock.	16 – 17
competent rock	Sandstone, light grey, very fine grained (SA1), moderate strength, with low strength black siltstone.	17 – 18
competent rock	Siltstone, black, carbonaceous, low strength, with light grey, very fine grained (SA1), moderate strength sandstone.	18 – 19



Bore Description

Protective lockable steel collar

PVC stick up: +0.67 m

Bentonite grout dry weight (10 %): 0 m to 1 m

149.2 mm rock roller: 0 m to 19 m (mud)

152.4 mm blade: 0 m to 19 m (mud)
Bentonite seal: 1 m to 3 m

50 mm PN 18 uPVC blank casing: 0 m to 13 m

2 mm washed, rounded, quartz gravel pack: 3 m to 18.6 m

Sampled 04.05.2016 paramaters - SWL 1.412mBGL, pH 6.23, 439uS/cm, 16.4C and 296ppm TDS.
50 mm PN 18 uPVC machine slotted casing, slot aperture: 0.5 mm, slot length: 50 mm, 672 slots / m, 13 m to 16 m

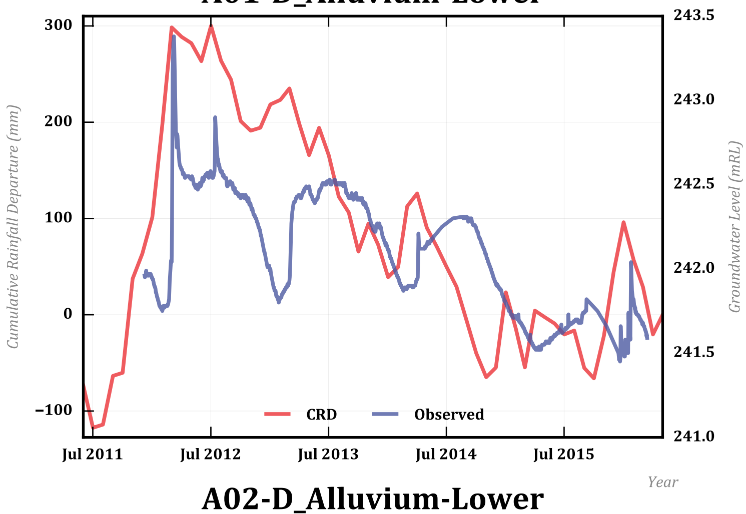
End of bore: 18 mBGL

Hole collapse: 18.6 m to 19 m

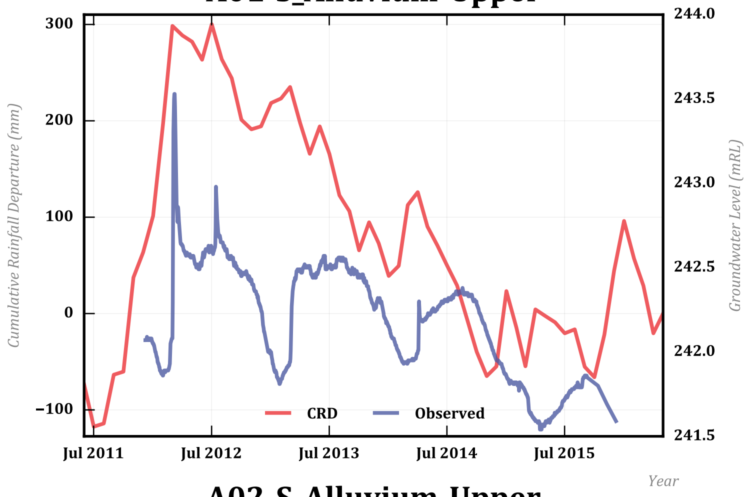
End of hole: 19 m BGL

Appendix B Groundwater level monitoring data

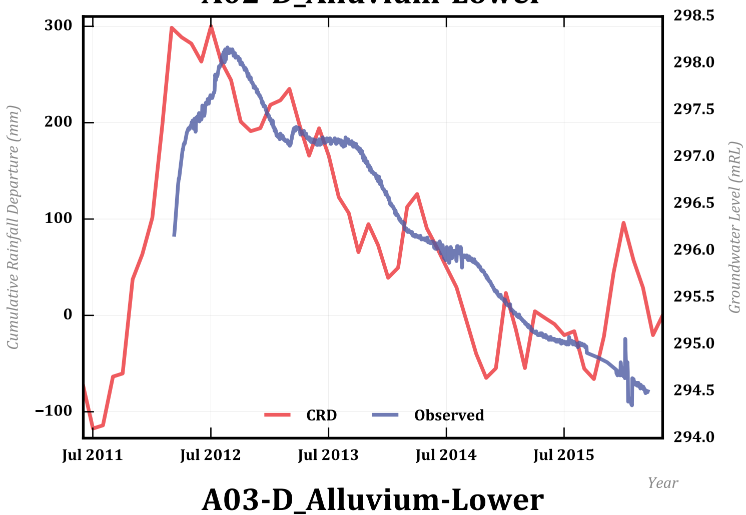
A01-D_Alluvium-Lower



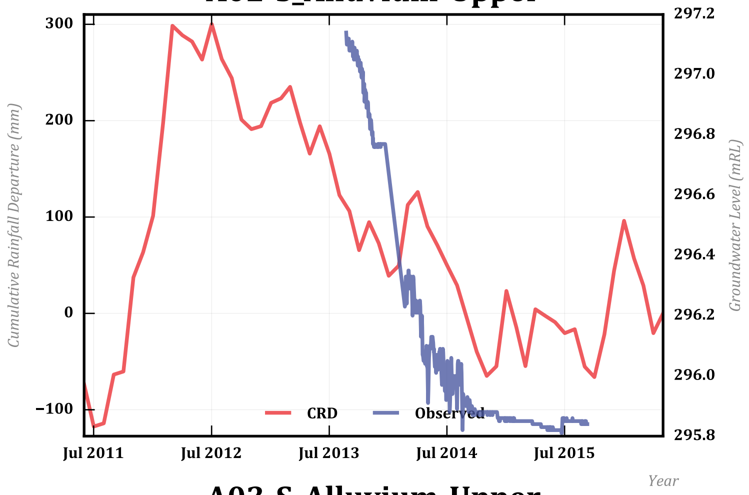
A01-S_Alluvium-Upper



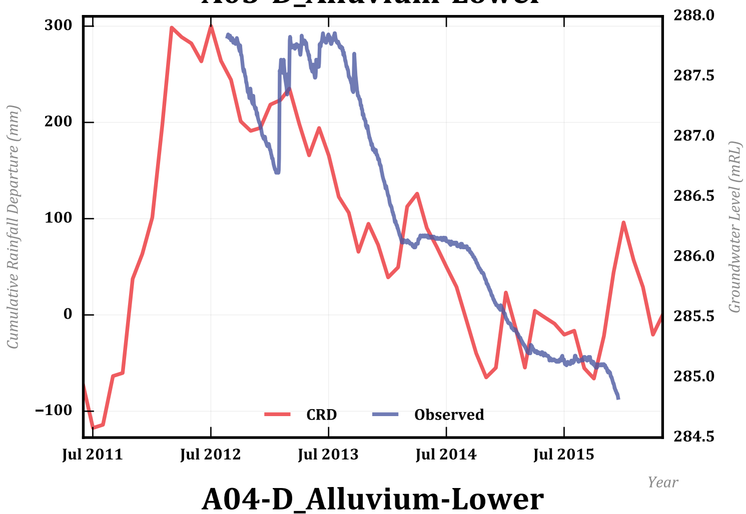
A02-D_Alluvium-Lower



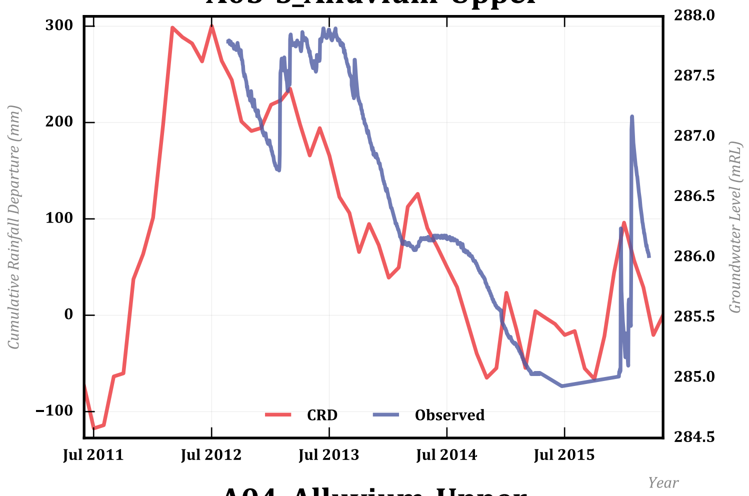
A02-S_Alluvium-Upper



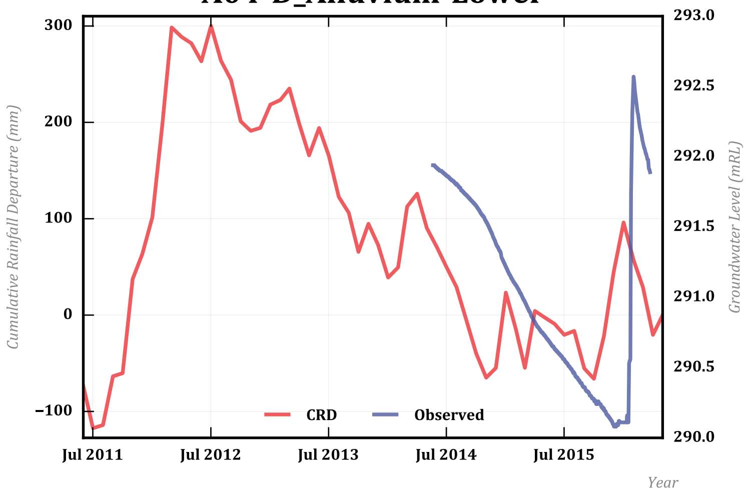
A03-D_Alluvium-Lower



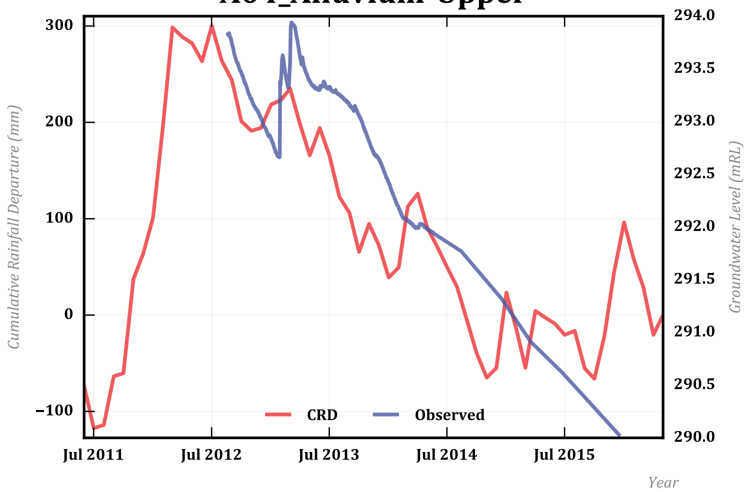
A03-S_Alluvium-Upper

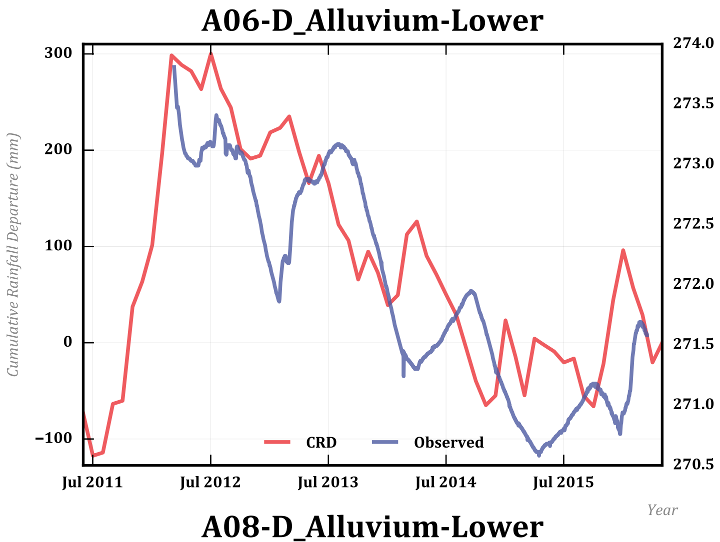


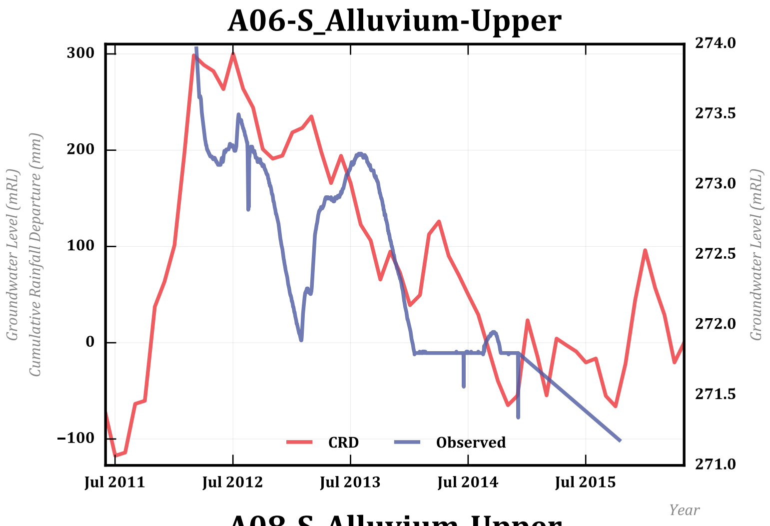
A04-D_Alluvium-Lower

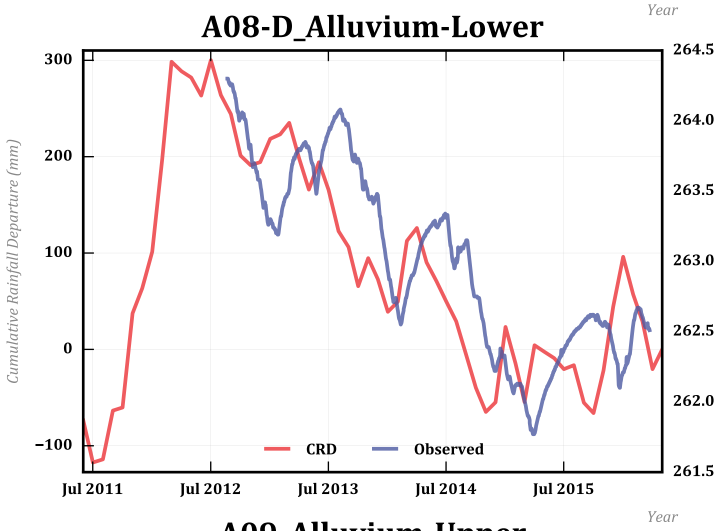


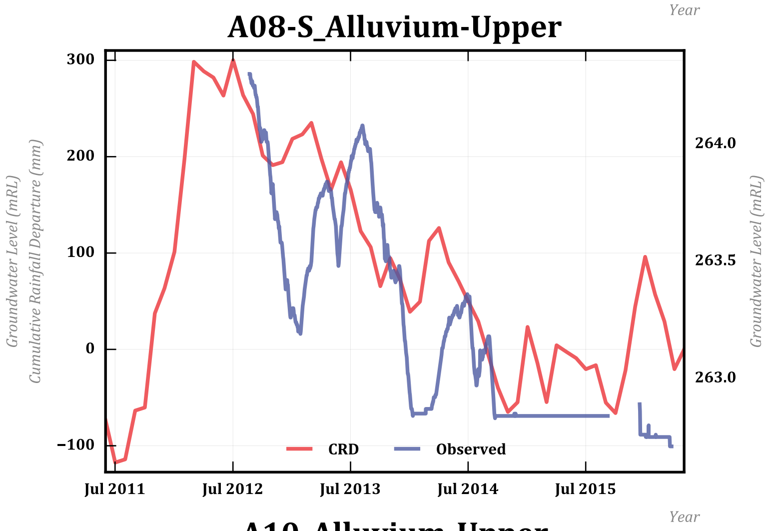
A04_Alluvium-Upper

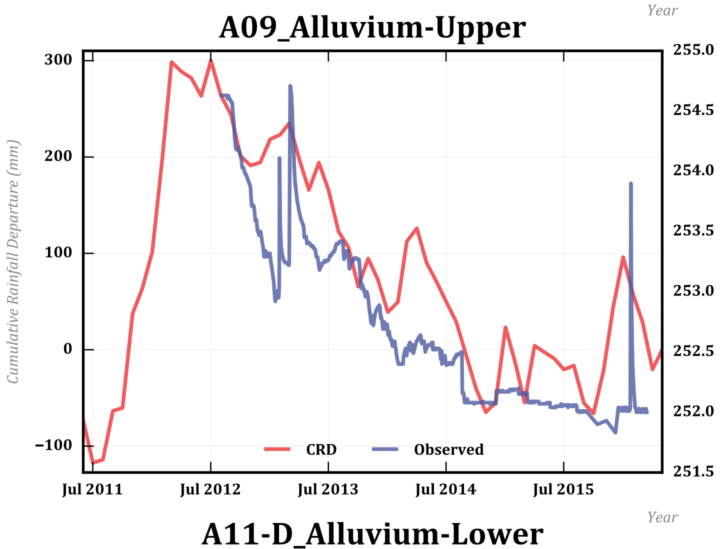


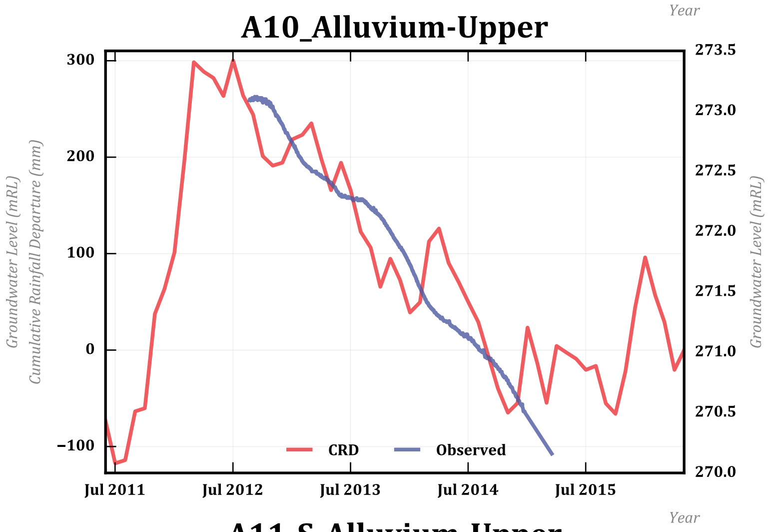

A06-D_Alluvium-Lower
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
274.0
273.5
273.0
272.5
272.0
271.5
271.0
270.5
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

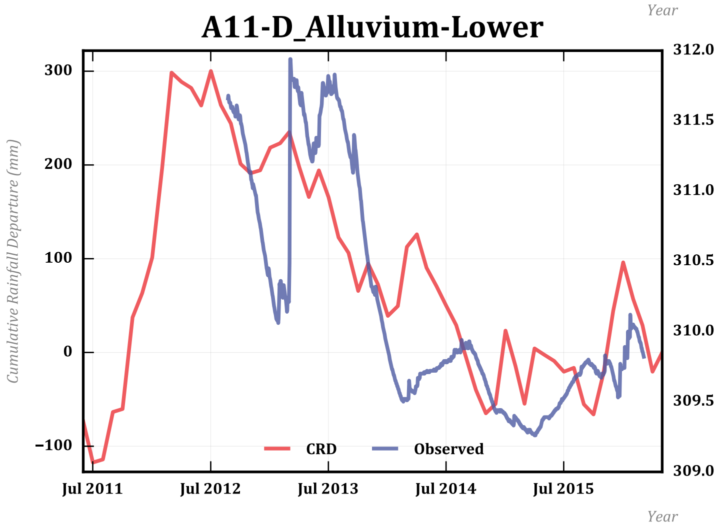

A06-S_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
274.0
273.5
273.0
272.5
272.0
271.5
271.0
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

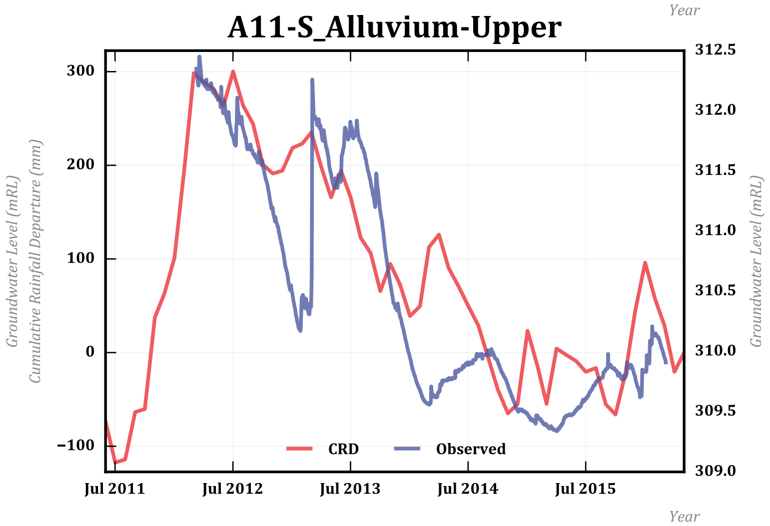

A08-D_Alluvium-Lower
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
264.5
264.0
263.5
263.0
262.5
262.0
261.5
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

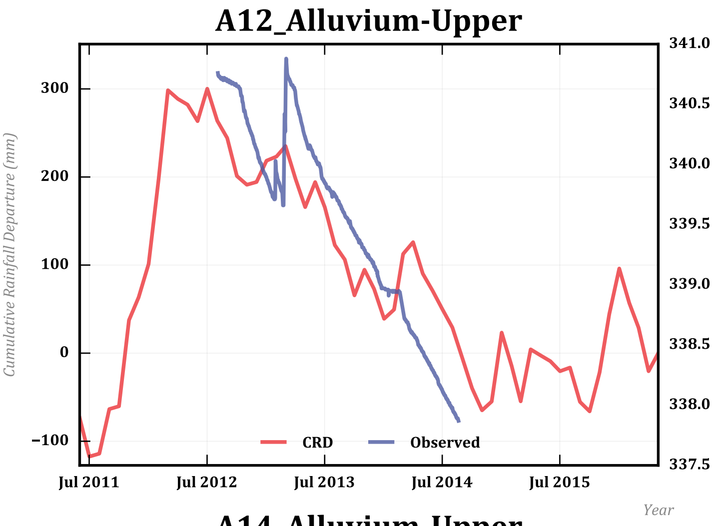

A08-S_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
264.0
263.5
263.0
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

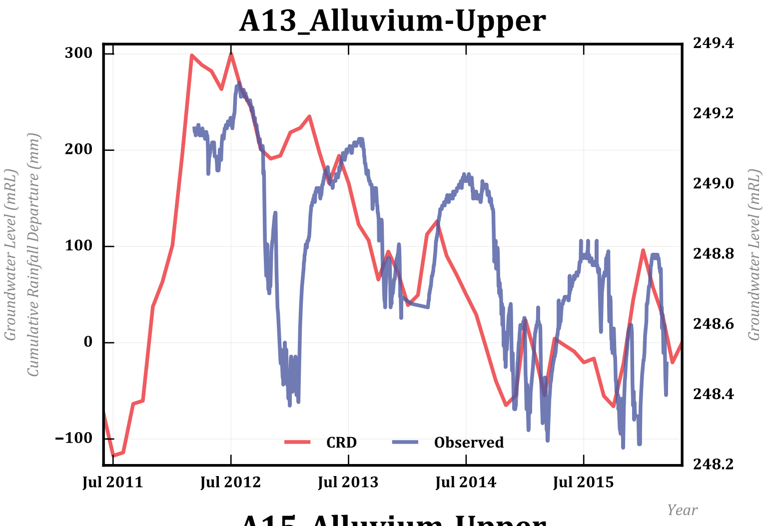

A09_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
255.0
254.5
254.0
253.5
253.0
252.5
252.0
251.5
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

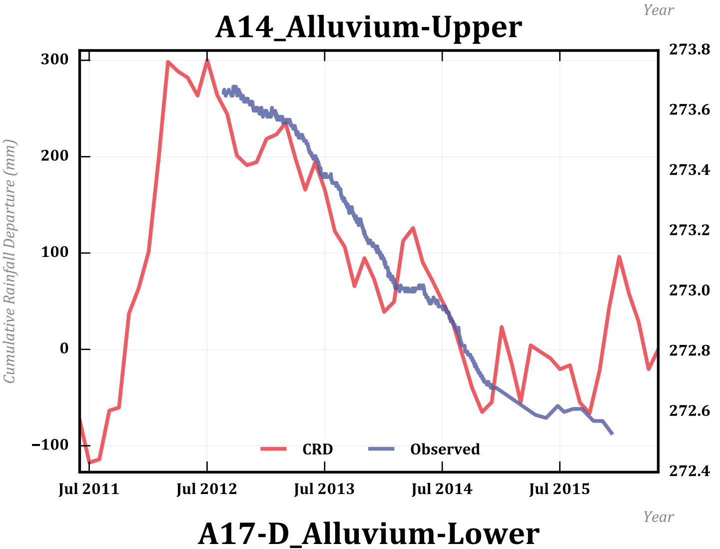

A10_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
273.5
273.0
272.5
272.0
271.5
271.0
270.5
270.0
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

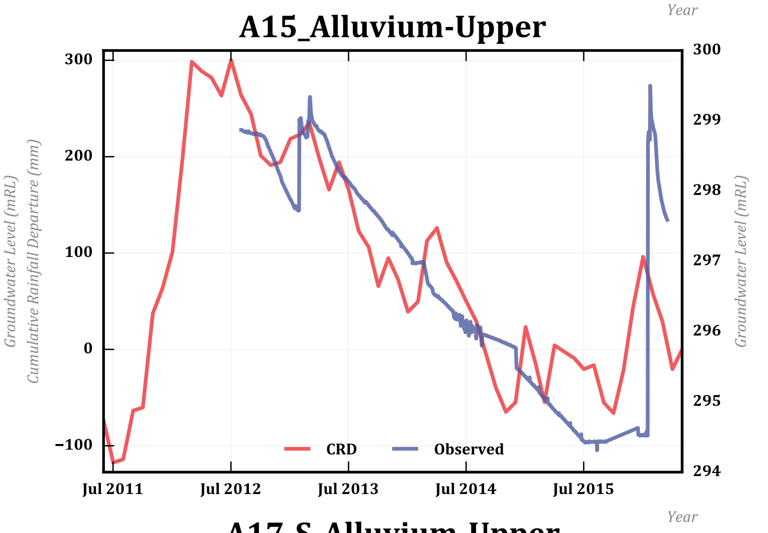

A11-D_Alluvium-Lower
Cumulative Rainfall Departure (mm)
Year
300
200
100
0
−100
312.0
311.5
311.0
310.5
310.0
309.5
309.0
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

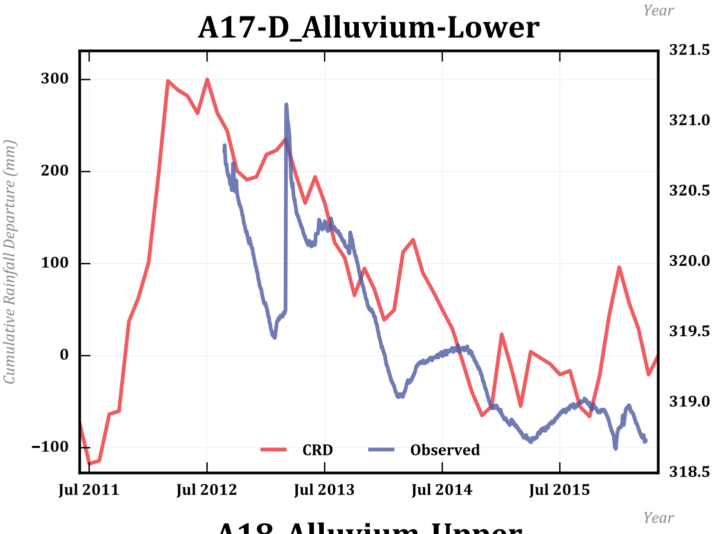

A11-S_Alluvium-Upper
Groundwater Level (mRL)
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
300
200
100
0
−100
312.5
312.0
311.5
311.0
310.5
310.0
309.5
309.0
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
CRD
Observed

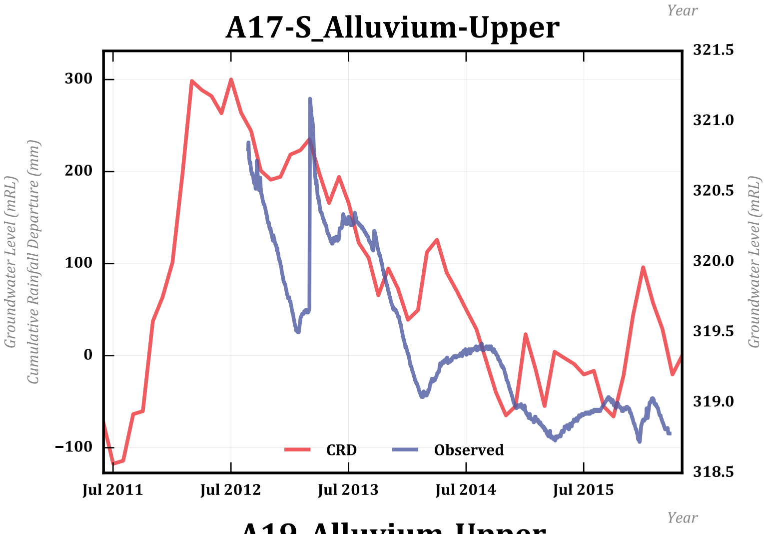

A12_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
341.0
340.5
340.0
339.5
339.0
338.5
338.0
337.5
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed

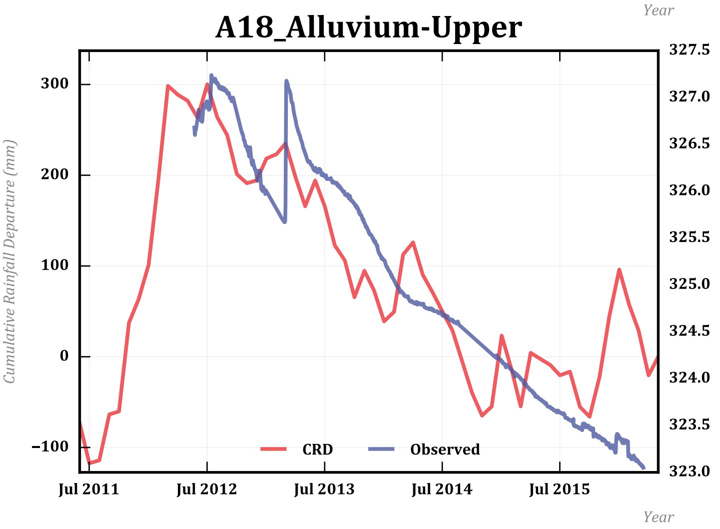

A13_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
249.4
249.2
249.0
248.8
248.6
248.4
248.2
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed

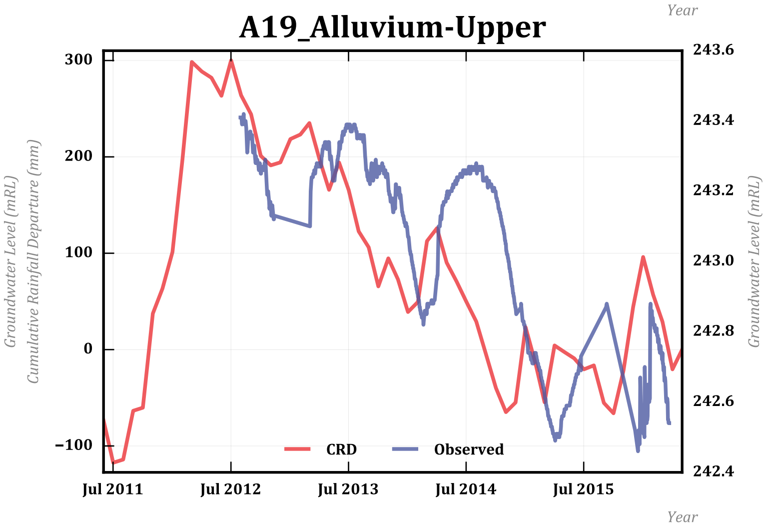

A14_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
273.8
273.6
273.4
273.2
273.0
272.8
272.6
272.4
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed


A15_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
300
299
298
297
296
295
294
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed

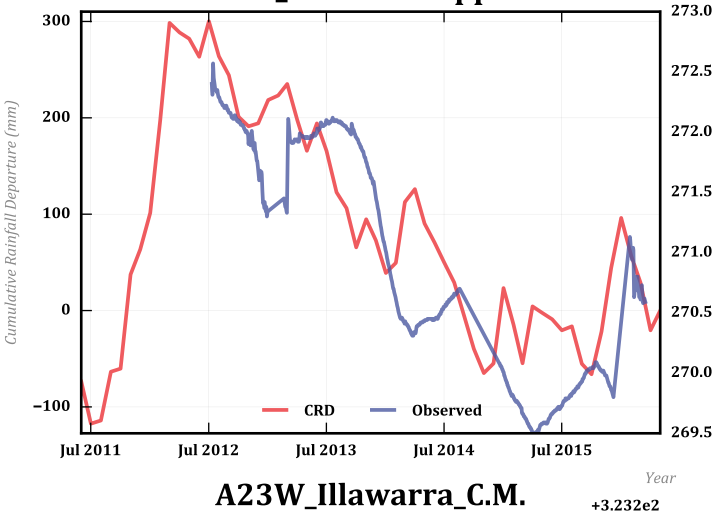

A17-D_Alluvium-Lower
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
321.5
321.0
320.5
320.0
319.5
319.0
318.5
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed


A17-S_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
321.5
321.0
320.5
320.0
319.5
319.0
318.5
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed

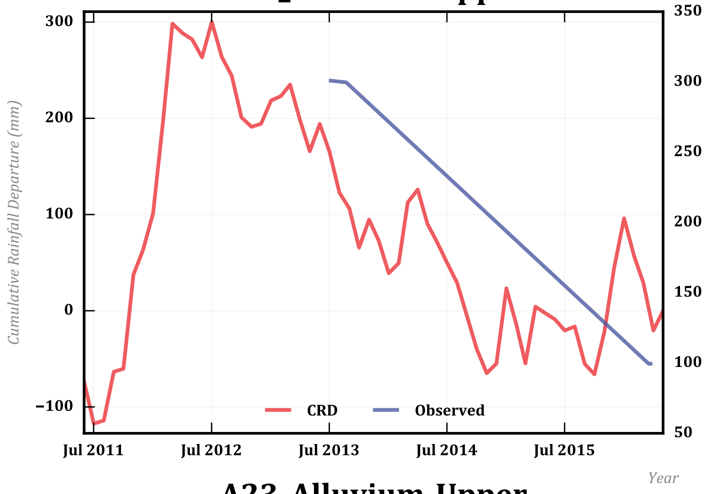

A18_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
327.5
327.0
326.5
326.0
325.5
325.0
324.5
324.0
323.5
323.0
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed


A19_Alluvium-Upper
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
300
200
100
0
−100
243.6
243.4
243.2
243.0
242.8
242.6
242.4
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year
CRD
Observed

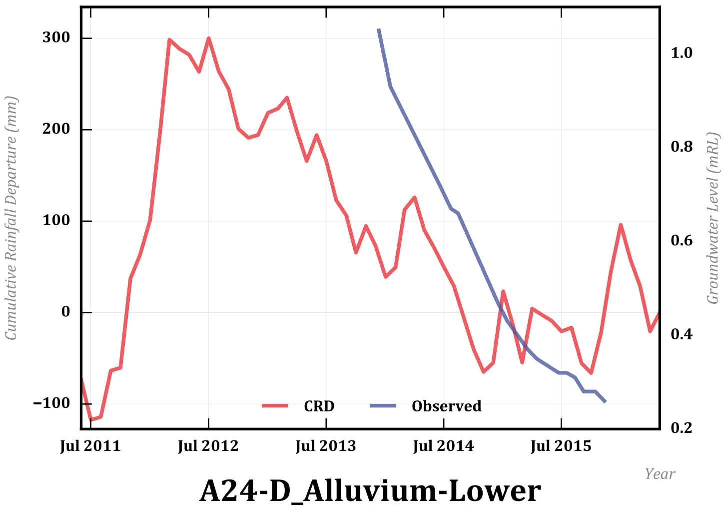
A20_Alluvium-Upper



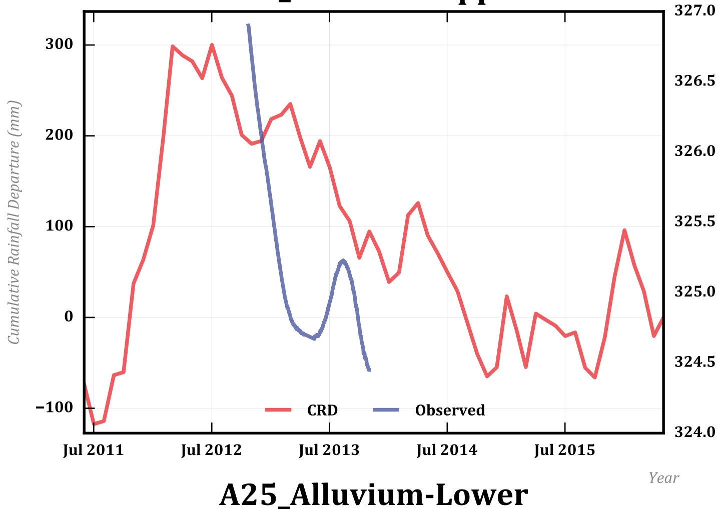
A21_Alluvium-Upper



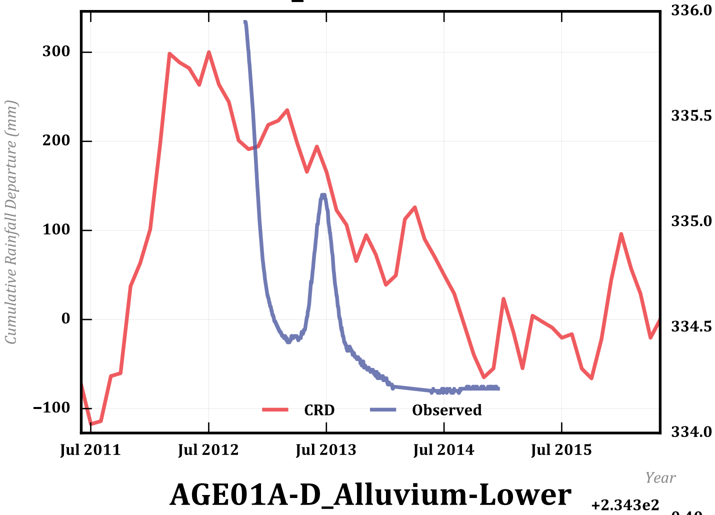
A23W_Illawarra_C.M.



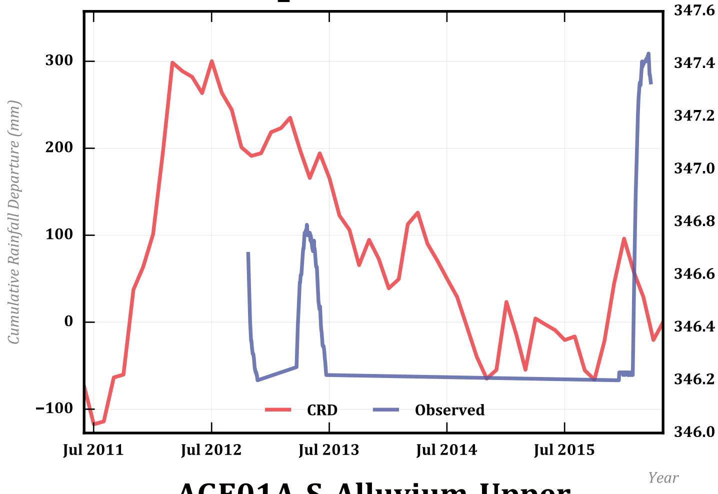
A23_Alluvium-Upper



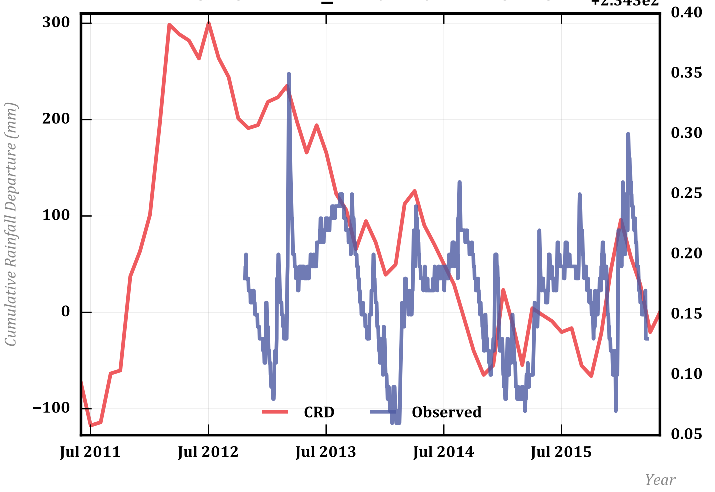
A24-D_Alluvium-Lower



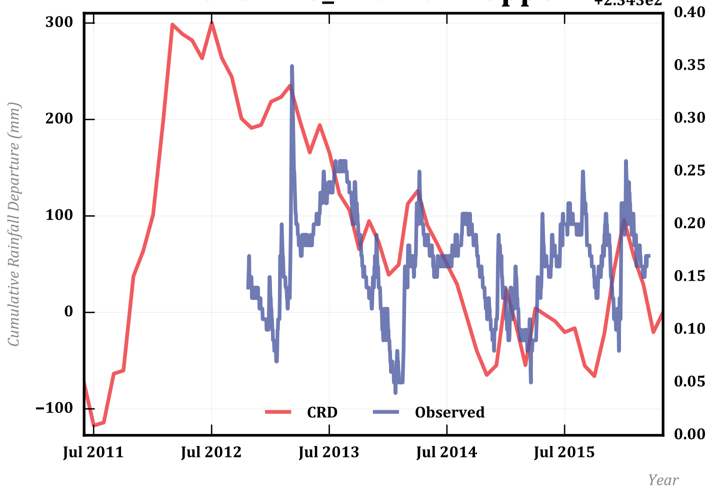
A25_Alluvium-Lower

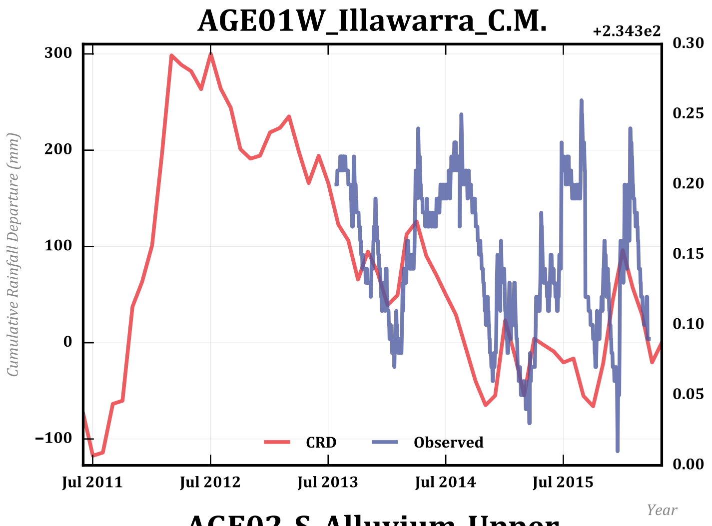


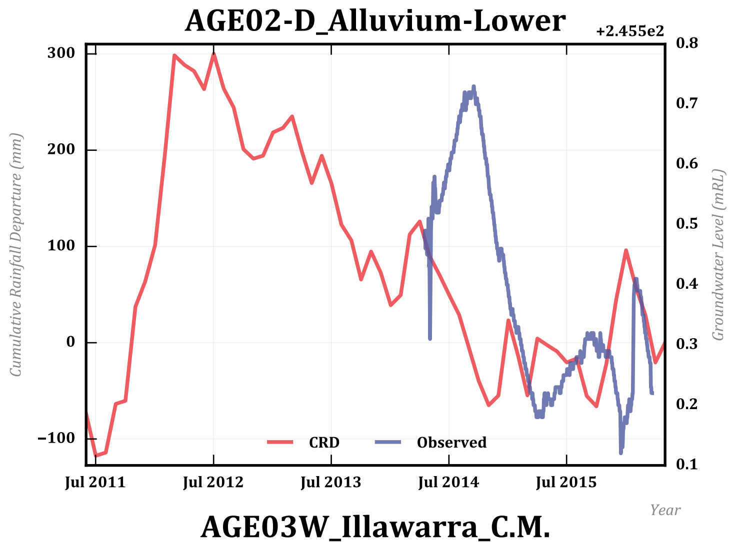
AGE01A-D_Alluvium-Lower

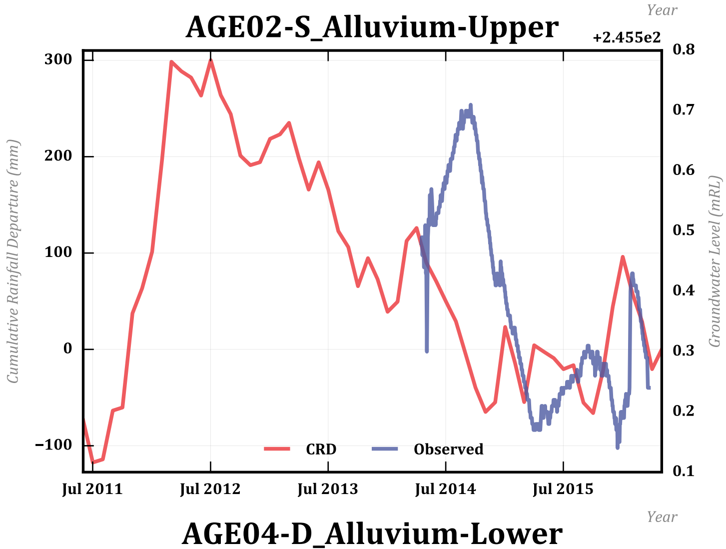


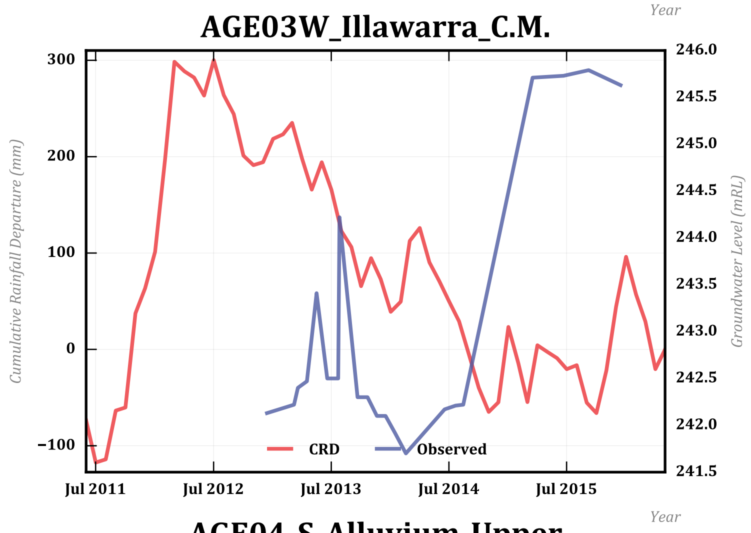
AGE01A-S_Alluvium-Upper

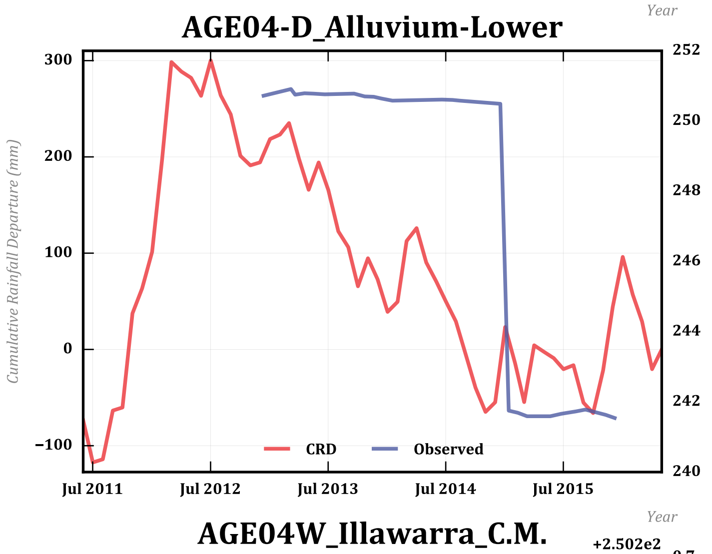


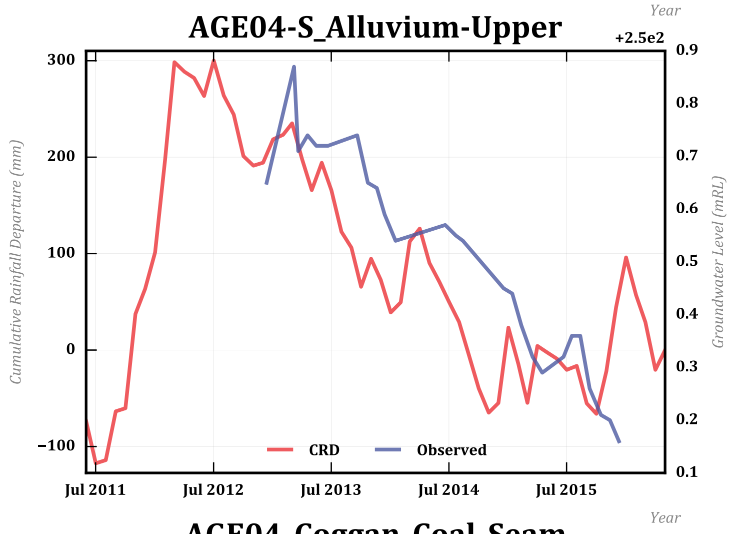

AGE01W_Illawarra_C.M.
+2.343e2
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed

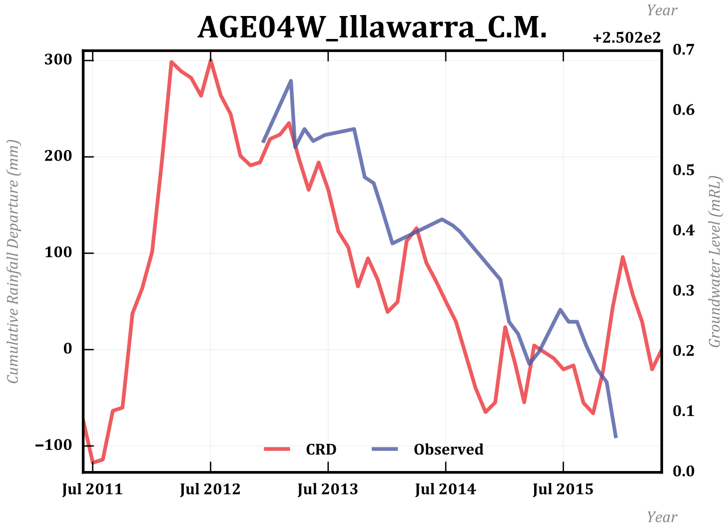

AGE02-D_Alluvium-Lower
+2.455e2
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed

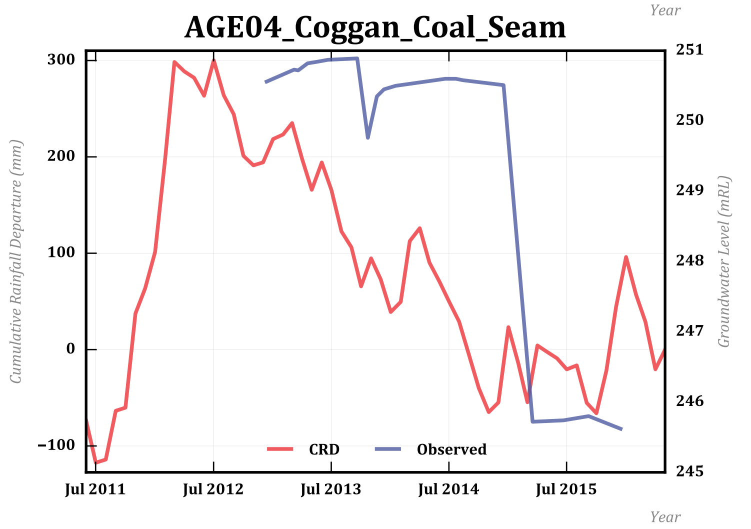

AGE02-S_Alluvium-Upper
+2.455e2
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed

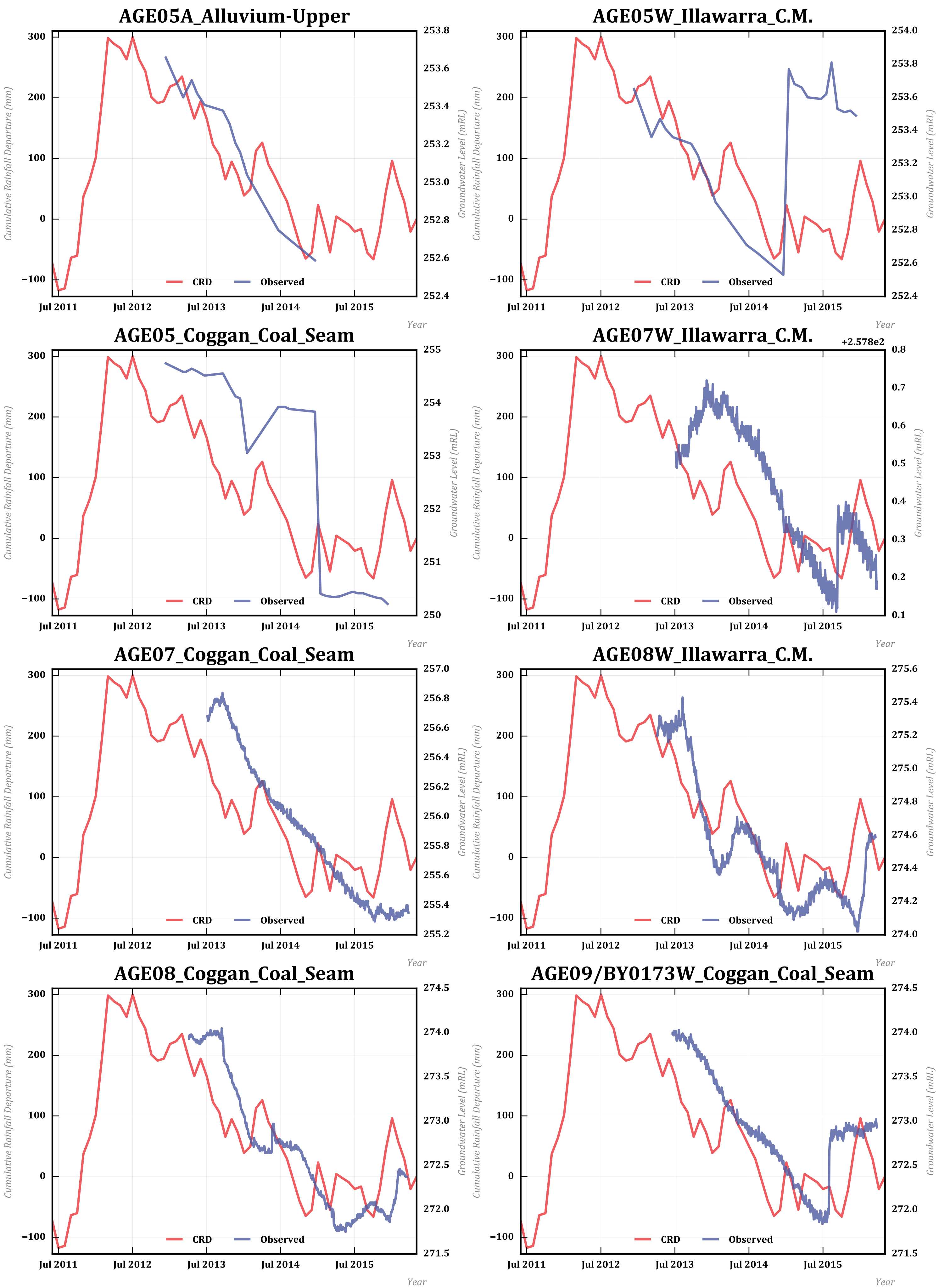

AGE03W_Illawarra_C.M.
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed


AGE04-D_Alluvium-Lower
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed

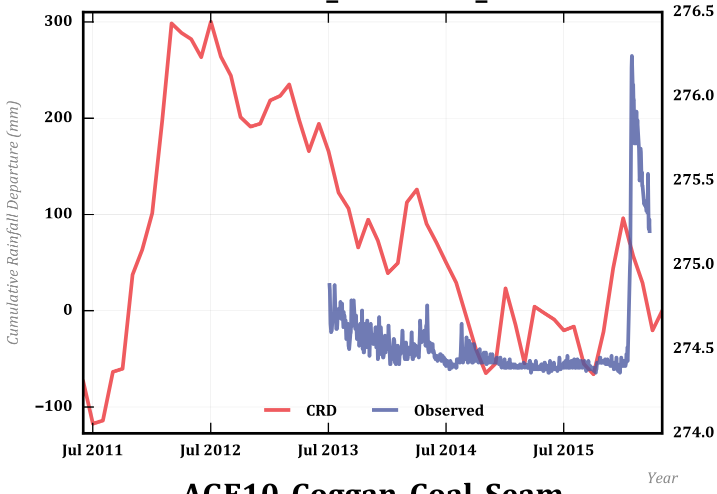

AGE04-S_Alluvium-Upper
+2.5e2
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed


AGE04W_Illawarra_C.M.
+2.502e2
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed

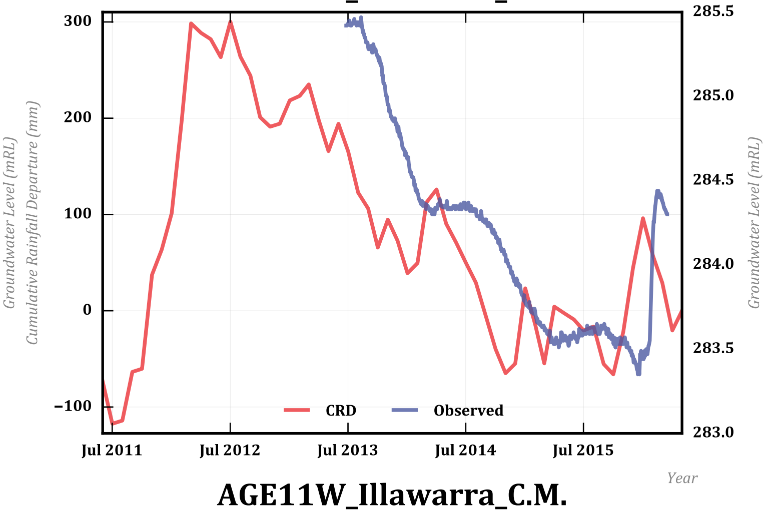

AGE04_Coggan_Coal_Seam
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed


AGE05A_Alluvium-Upper
AGE05W_Illawarra_C.M.
AGE05_Coggan_Coal_Seam
AGE07W_Illawarra_C.M.
+2.578e2
AGE07_Coggan_Coal_Seam
AGE08W_Illawarra_C.M.
AGE08_Coggan_Coal_Seam
AGE09/BY0173W_Coggan_Coal_Seam
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015

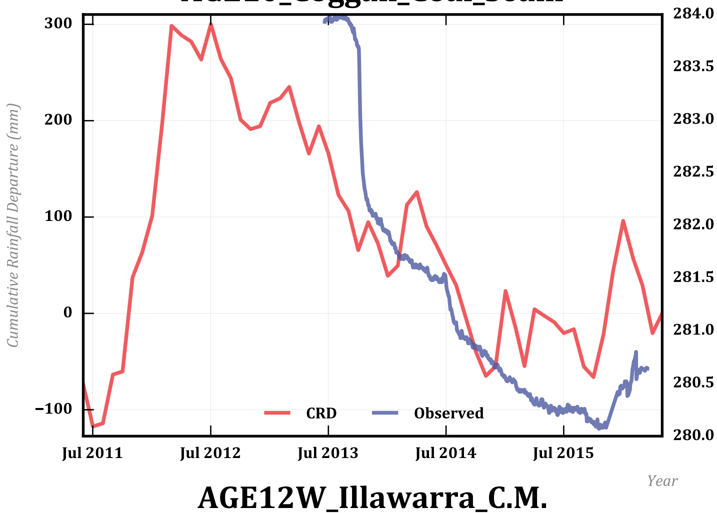
AGE09W_Illawarra_C.M.



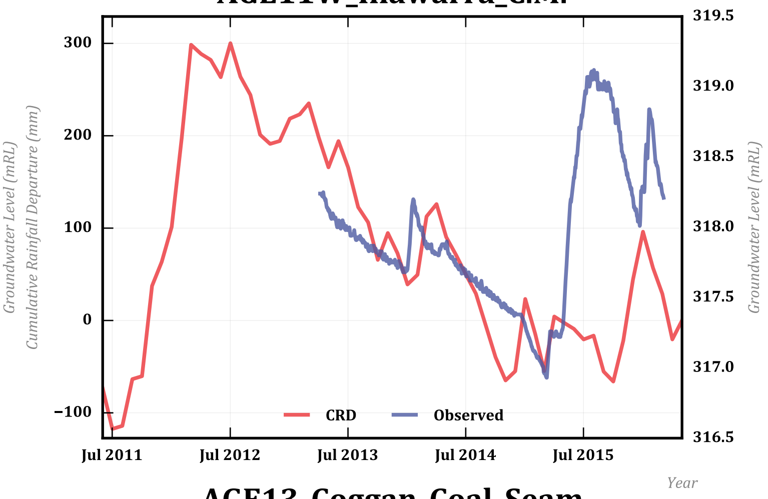
AGE10W_Illawarra_C.M.



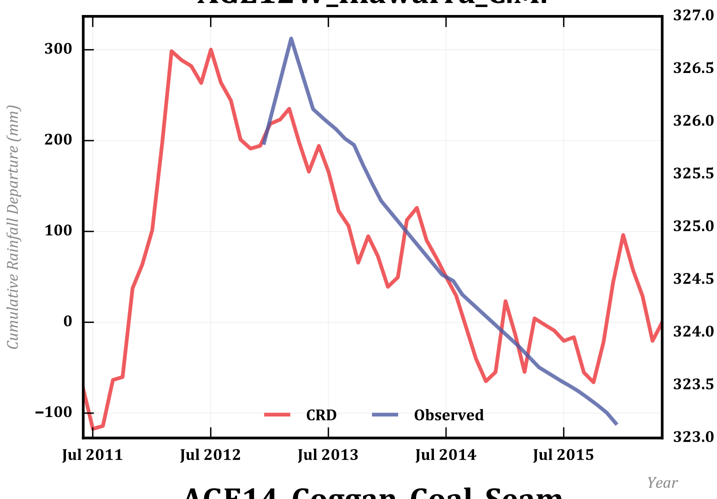
AGE10_Coggan_Coal_Seam



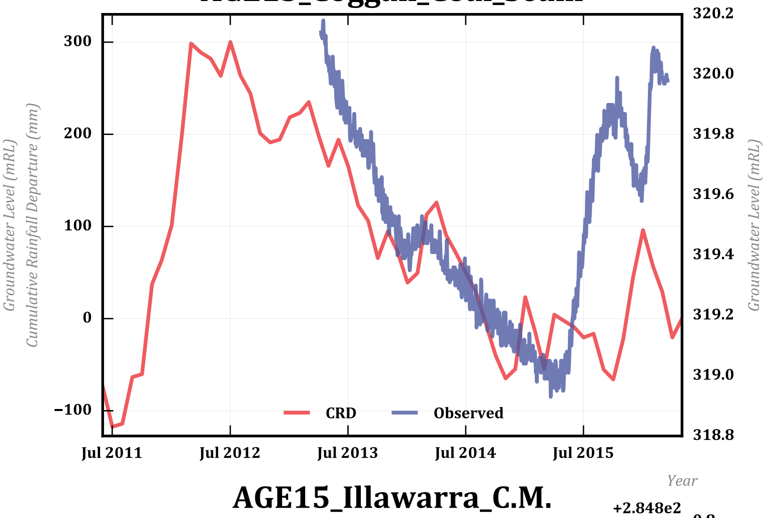
AGE11W_Illawarra_C.M.



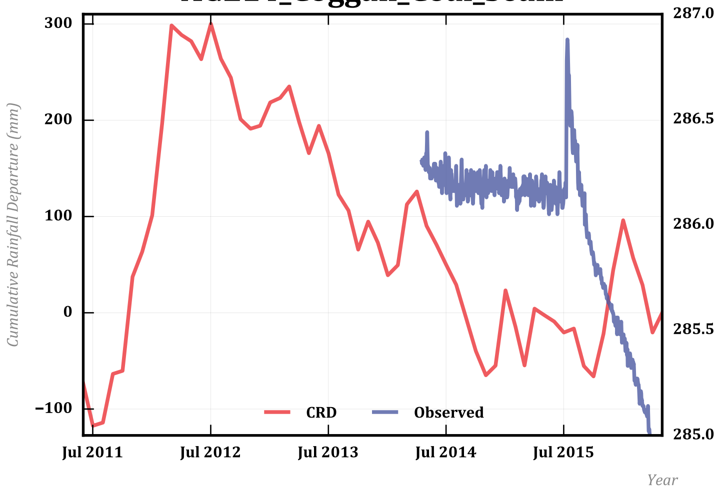
AGE12W_Illawarra_C.M.



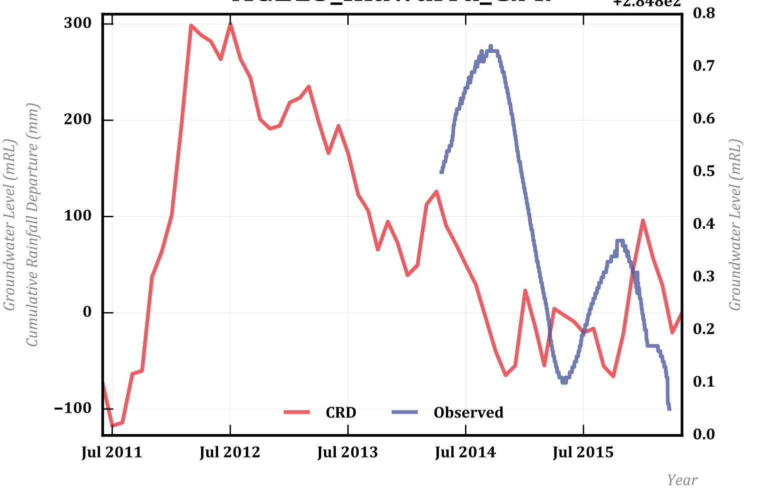
AGE13_Coggan_Coal_Seam



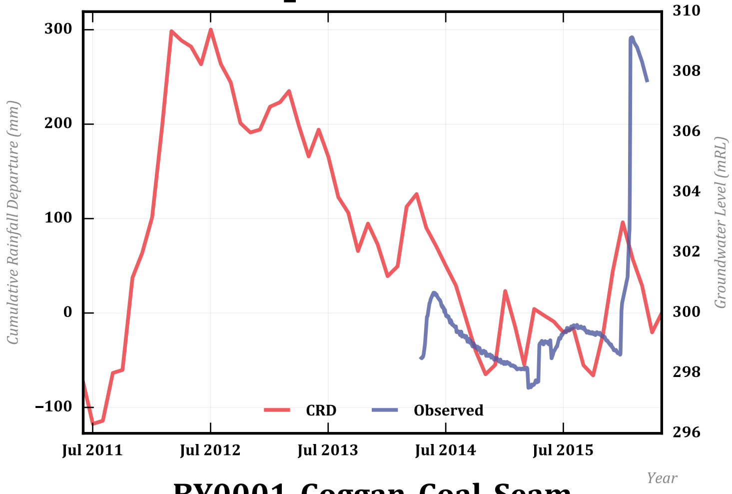
AGE14_Coggan_Coal_Seam



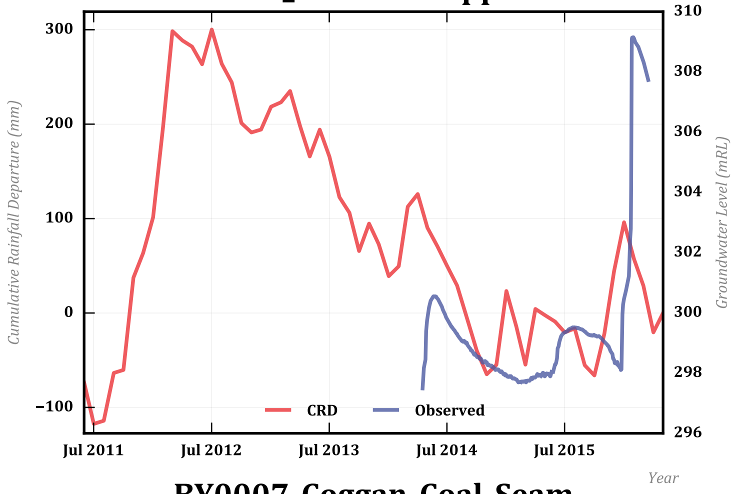
AGE15_Illawarra_C.M.



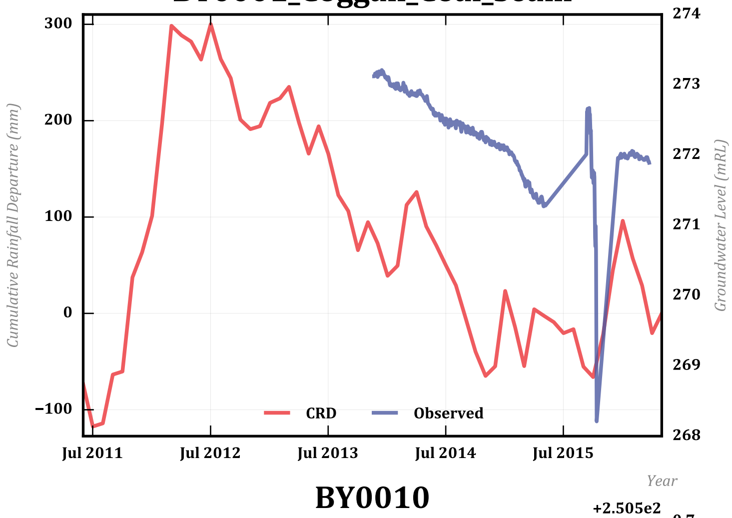
B3-D_Alluvium-Lower



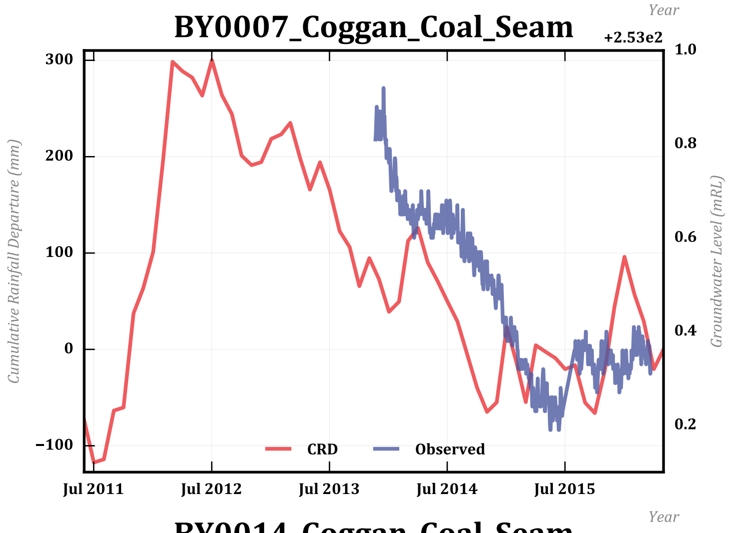
B3-S_Alluvium-Upper



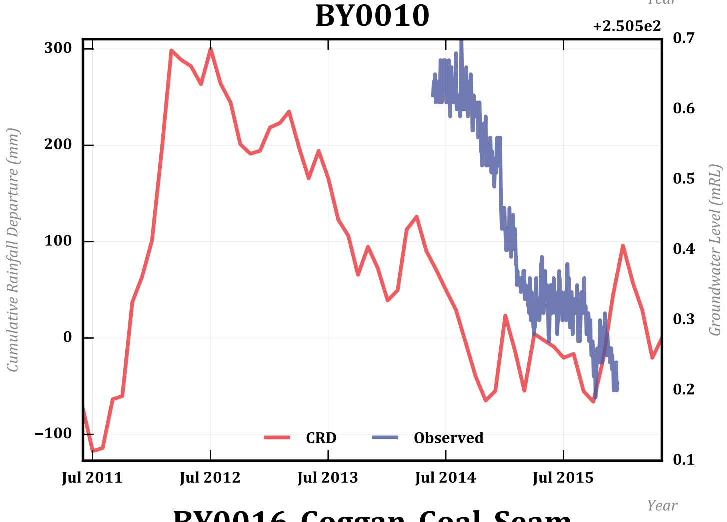
BY0001_Coggan_Coal_Seam



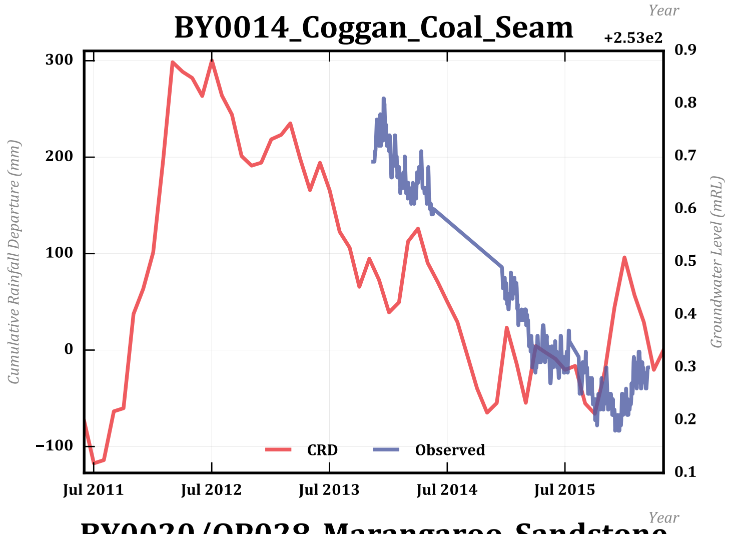
BY0007_Coggan_Coal_Seam



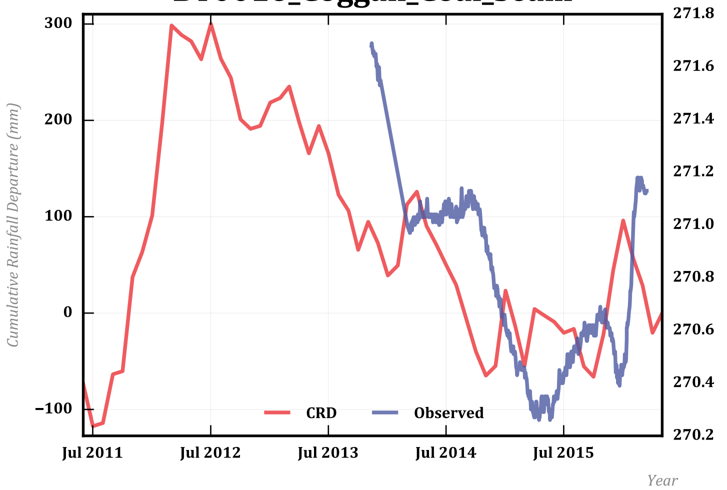
BY0010



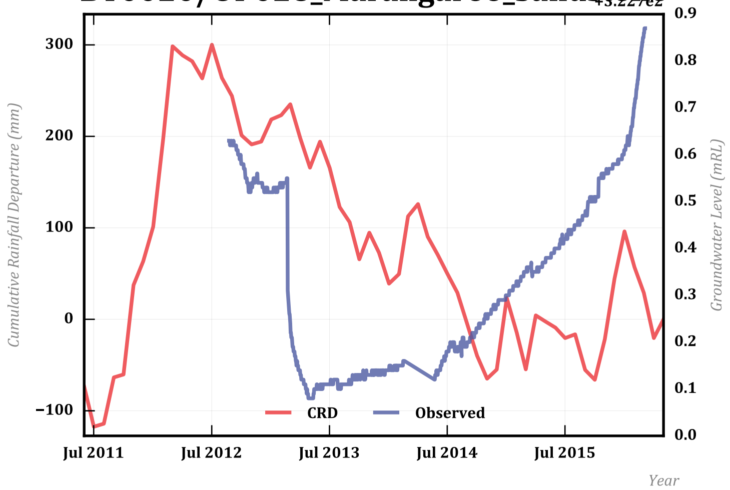
BY0014_Coggan_Coal_Seam



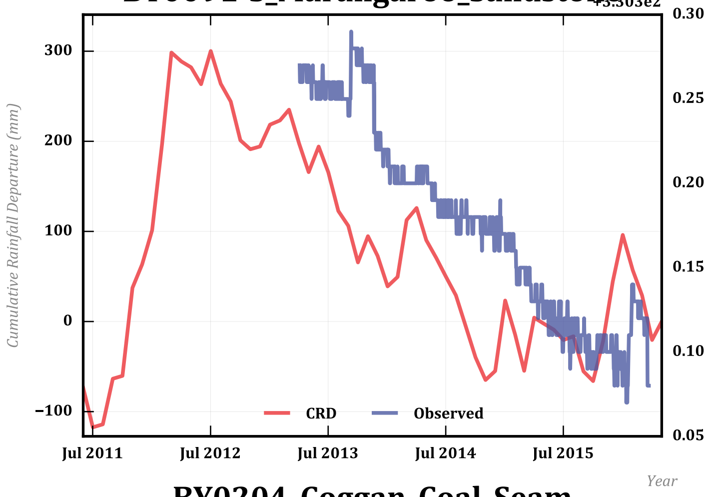
BY0016_Coggan_Coal_Seam



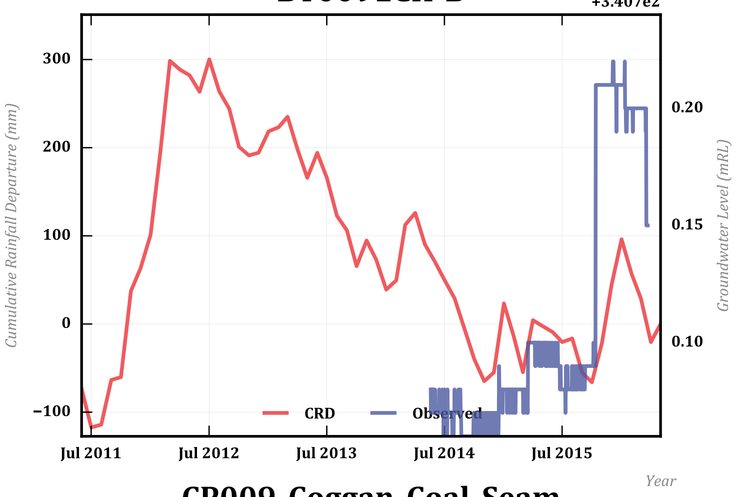
BY0020/OP028_Marangaroo_Sandstone



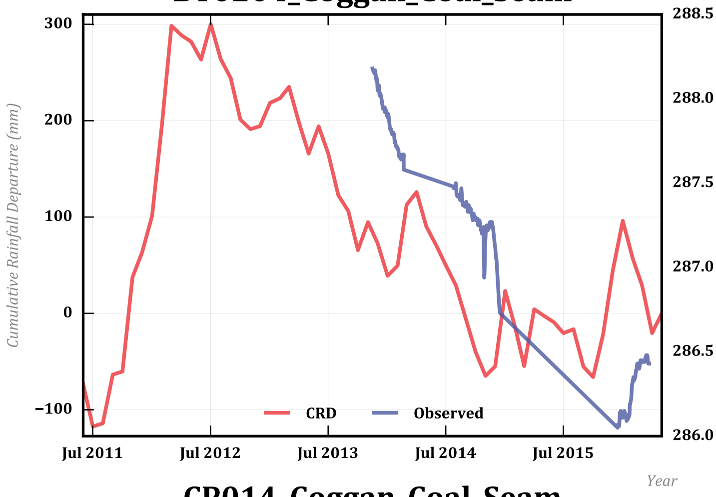
BY0091-S_Marangaroo_Sandstone



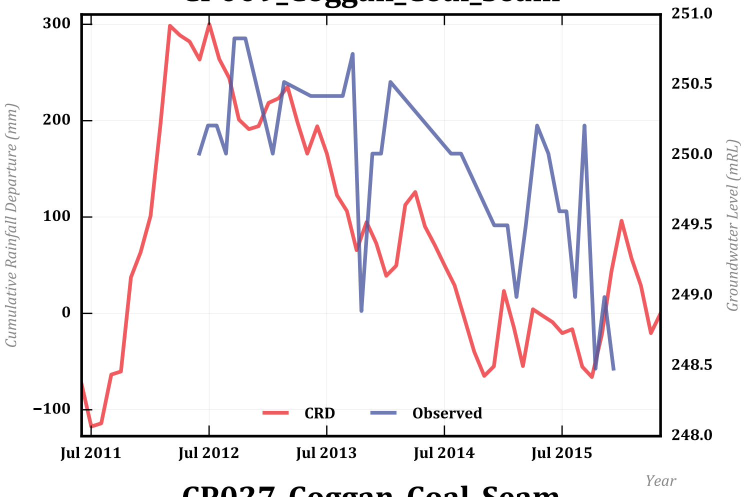
BY0091CH-B



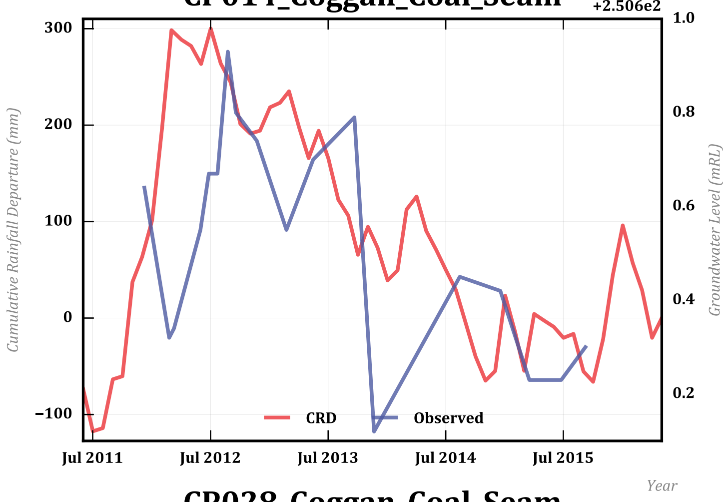
BY0204_Coggan_Coal_Seam



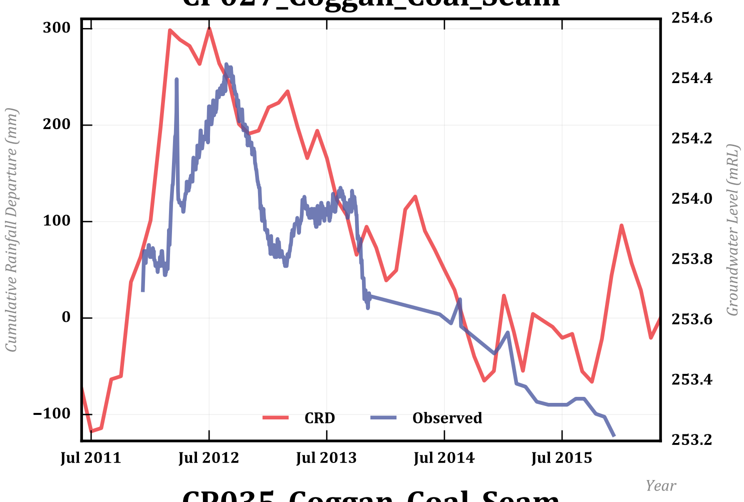
CP009_Coggan_Coal_Seam



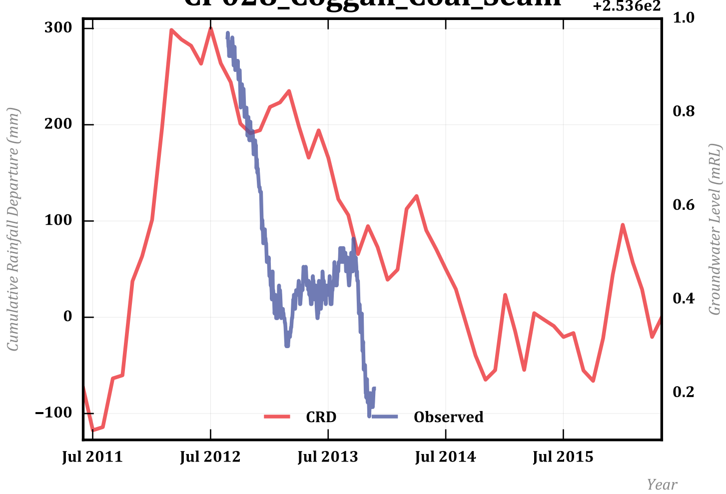
CP014_Coggan_Coal_Seam



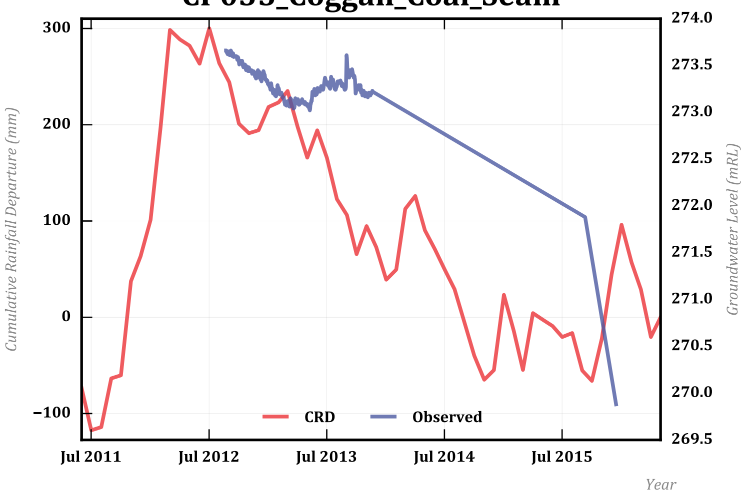
CP027_Coggan_Coal_Seam

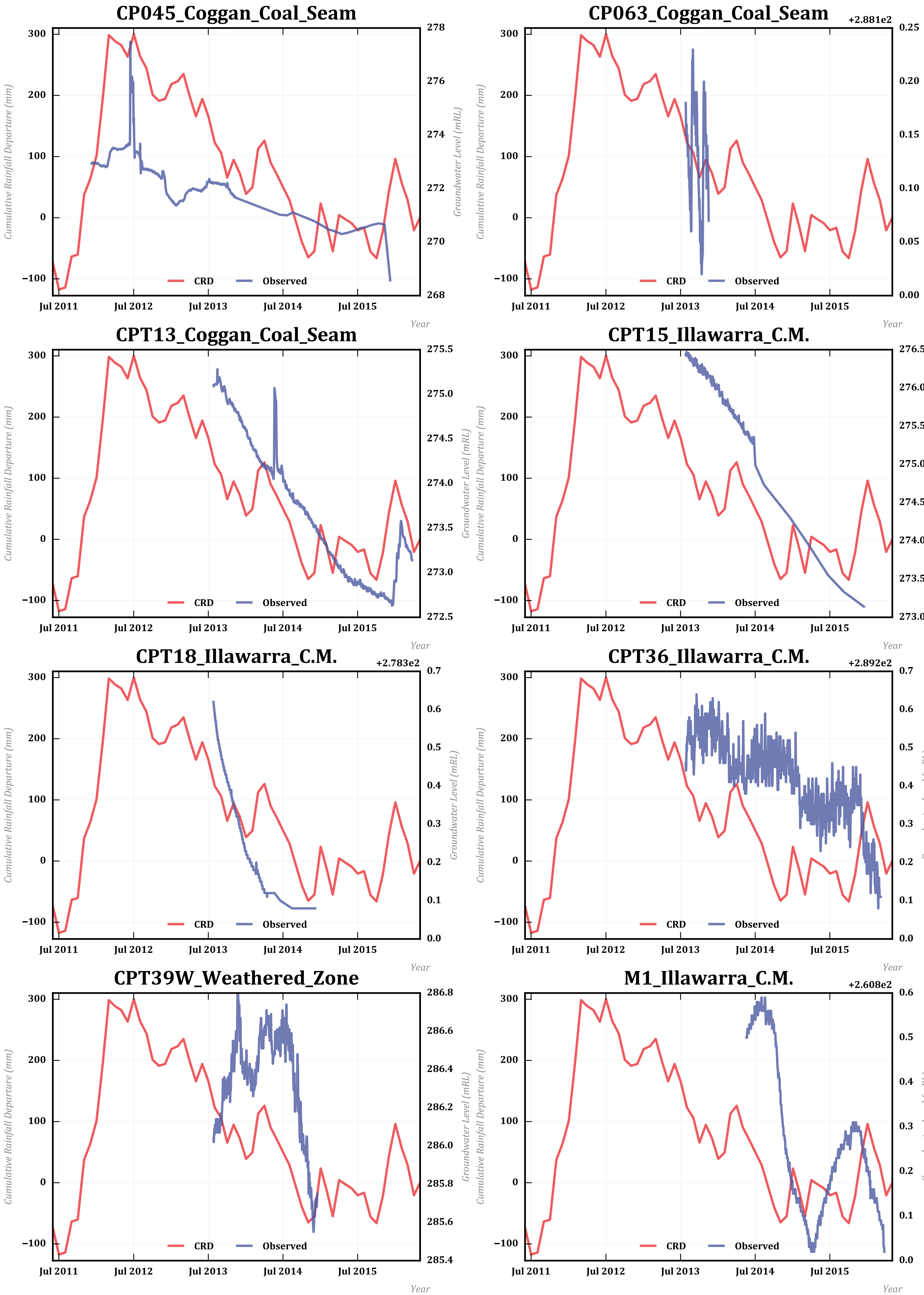


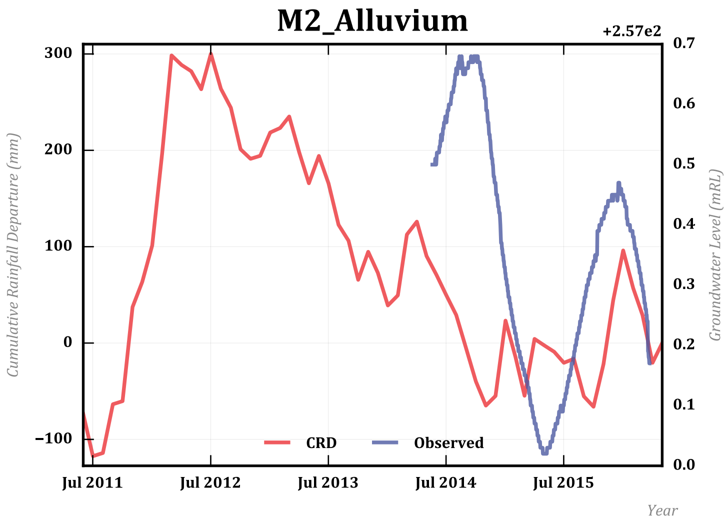
CP028_Coggan_Coal_Seam



CP035_Coggan_Coal_Seam

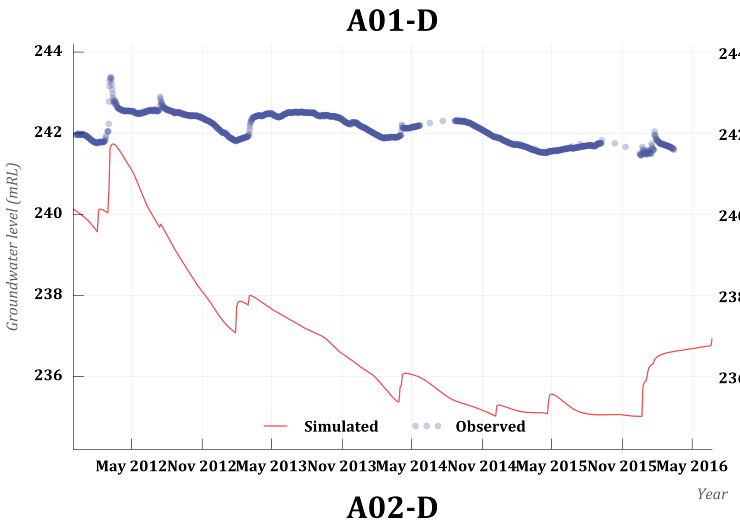


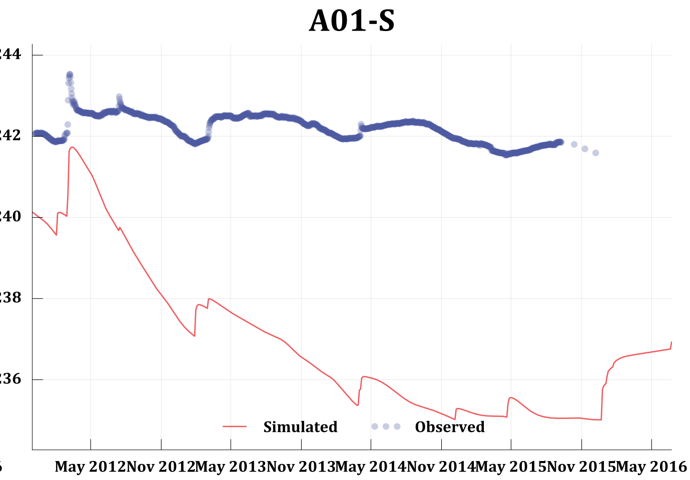

CP045_Coggan_Coal_Seam
CP063_Coggan_Coal_Seam
+2.881e2
CPT13_Coggan_Coal_Seam
CPT15_Illawarra_C.M.
CPT18_Illawarra_C.M.
+2.783e2
CPT36_Illawarra_C.M.
+2.892e2
CPT39W_Weathered_Zone
M1_Illawarra_C.M.
+2.608e2
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
Year
CRD
Observed
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015

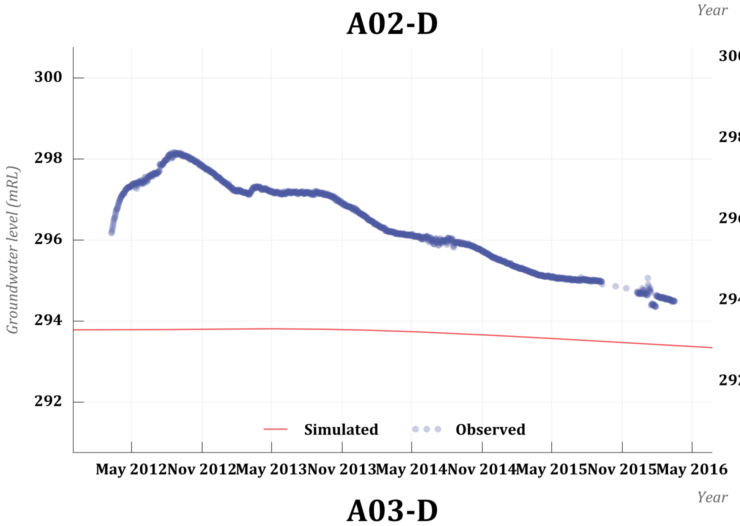


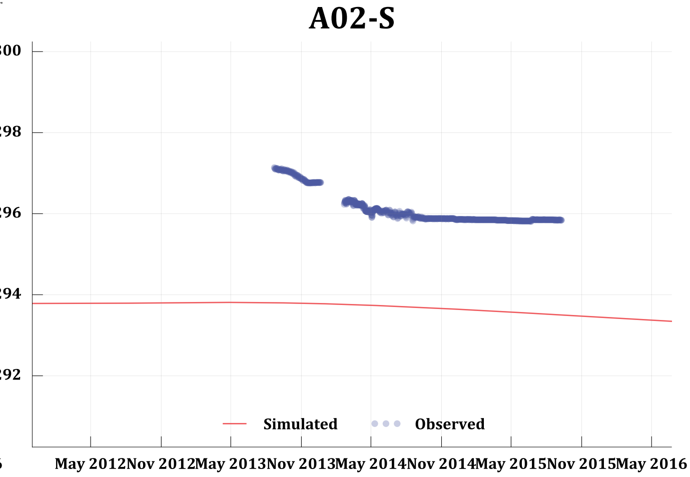
M2_Alluvium
+2.57e2
300
200
100
0
−100
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Cumulative Rainfall Departure (mm)
Groundwater Level (mRL)
CRD
Observed
Jul 2011
Jul 2012
Jul 2013
Jul 2014
Jul 2015
Year

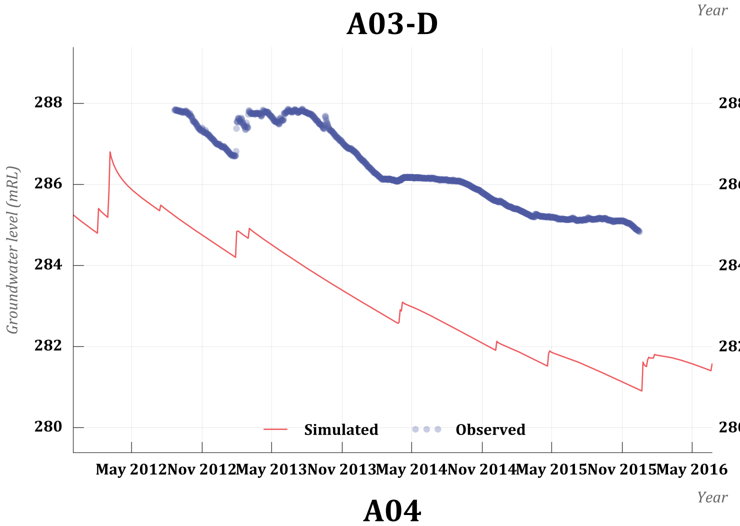
Appendix C **Transient calibration hydrographs**

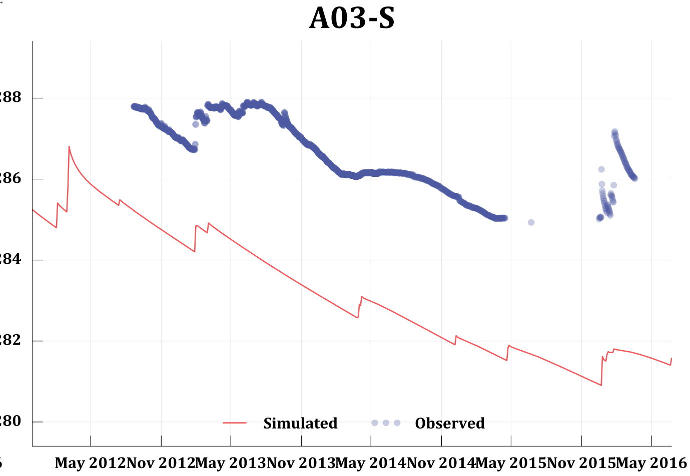

A01-D
244
242
240
238
236
Groundwater level (mRL)
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016
Year

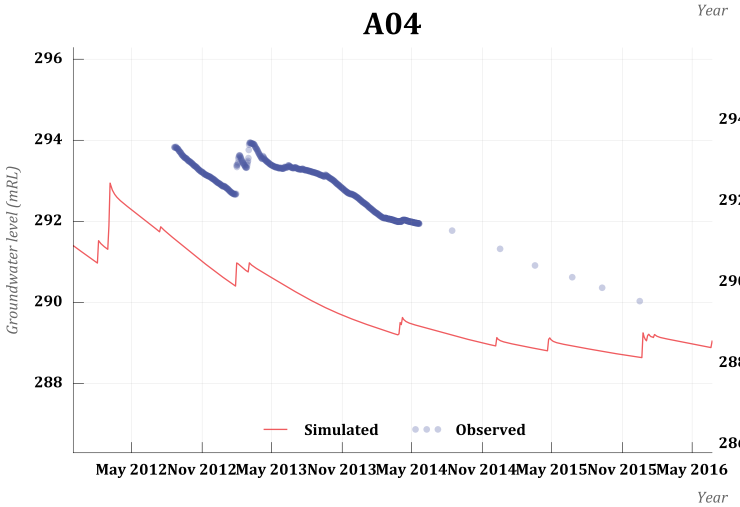

A01-S
244
242
240
238
236
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016

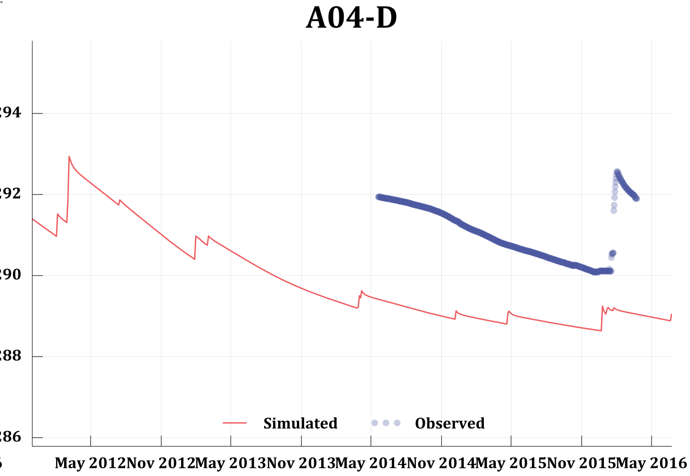

A02-D
300
298
296
294
292
Groundwater level (mRL)
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016
Year


A02-S
300
298
296
294
292
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016

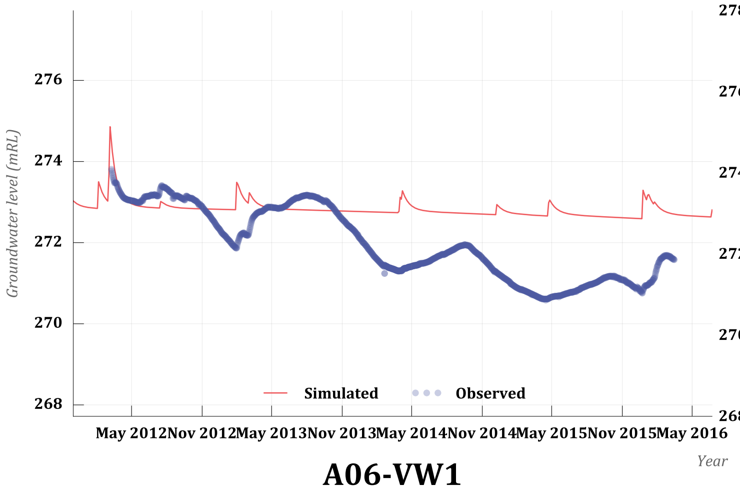

A03-D
288
286
284
282
280
Groundwater level (mRL)
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016
Year


A03-S
288
286
284
282
280
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016

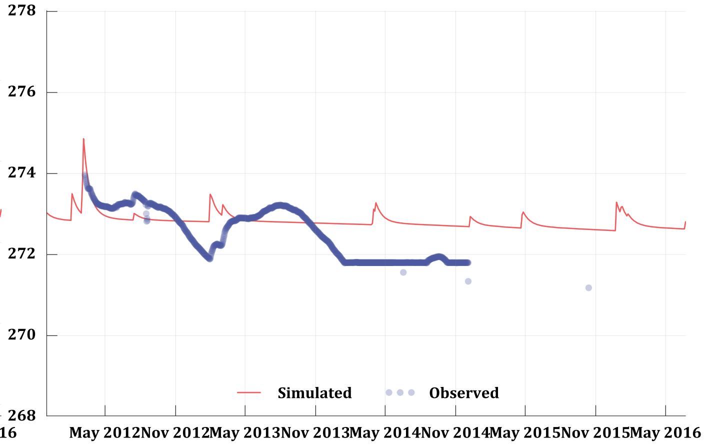

A04
296
294
292
290
288
Groundwater level (mRL)
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016
Year


A04-D
294
292
290
288
286
Simulated
Observed
May 2012 Nov 2012 May 2013 Nov 2013 May 2014 Nov 2014 May 2015 Nov 2015 May 2016

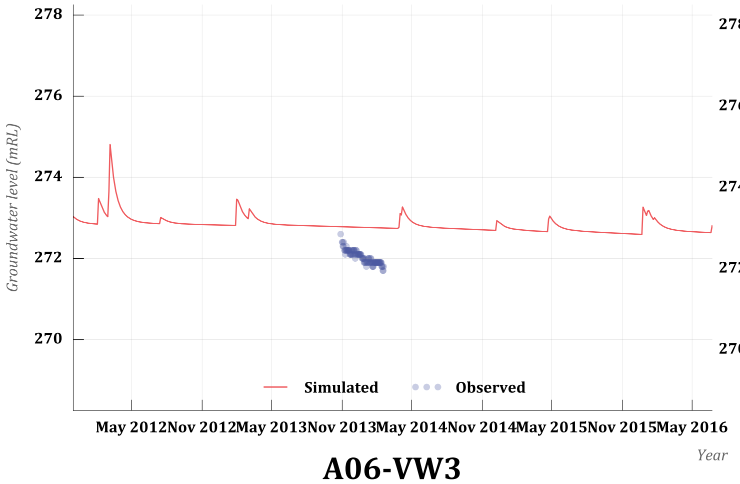
A06-D



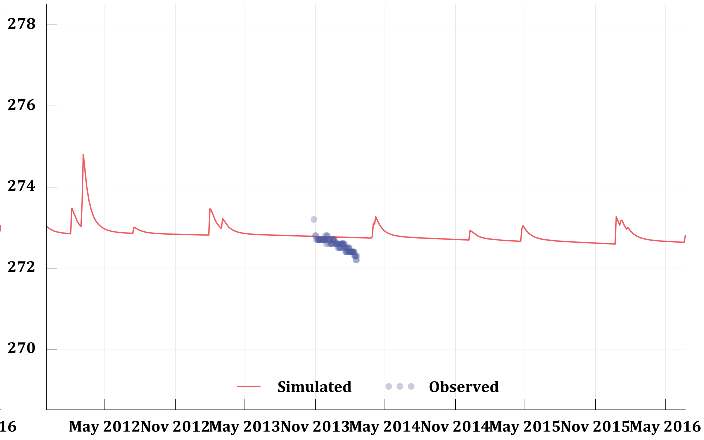
A06-S



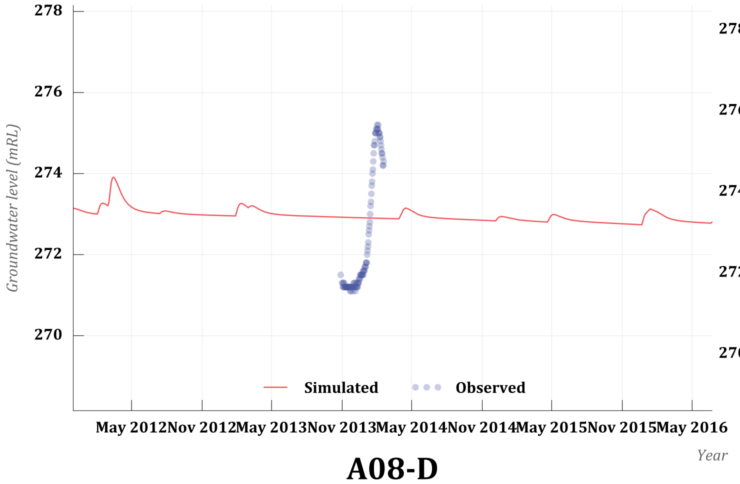
A06-VW1



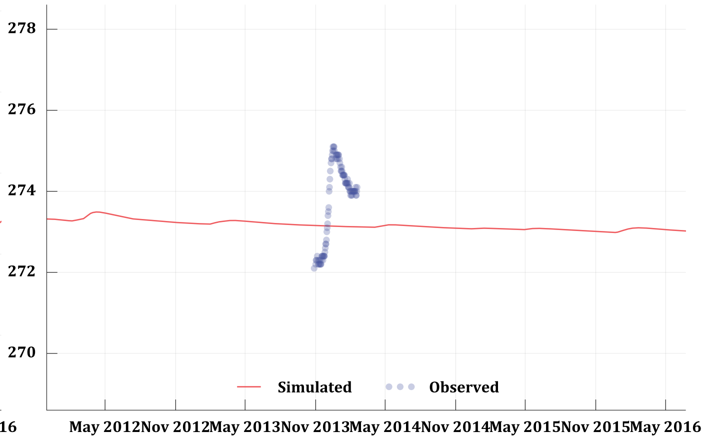
A06-VW2



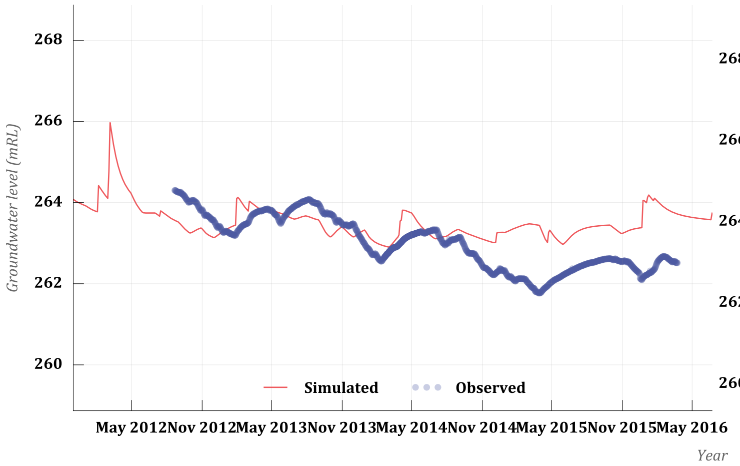
A06-VW3



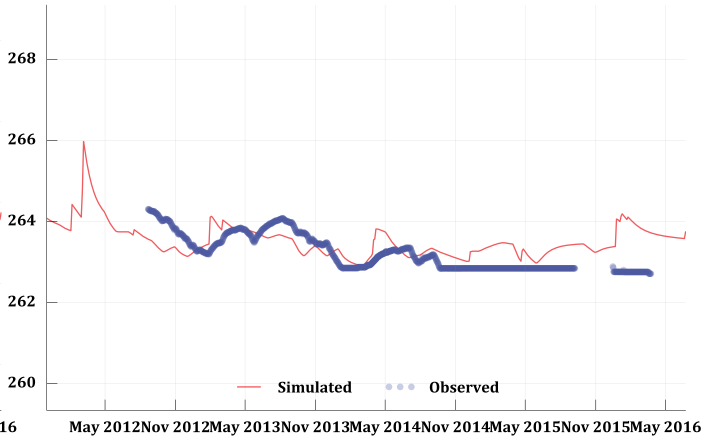
A06-VW4

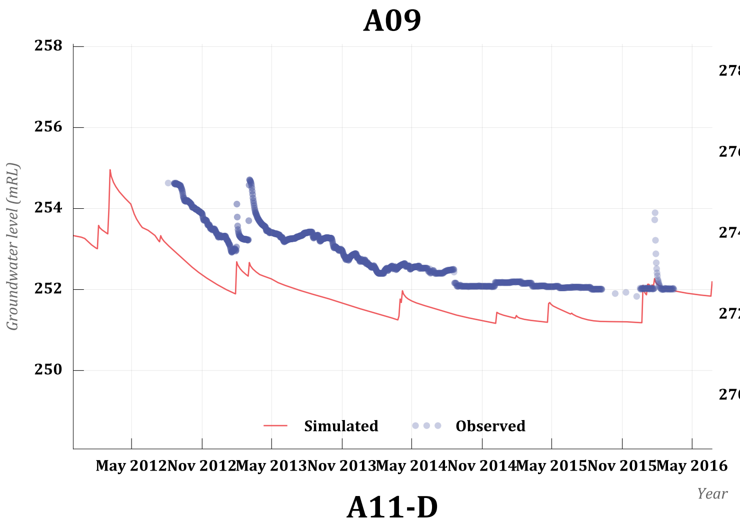


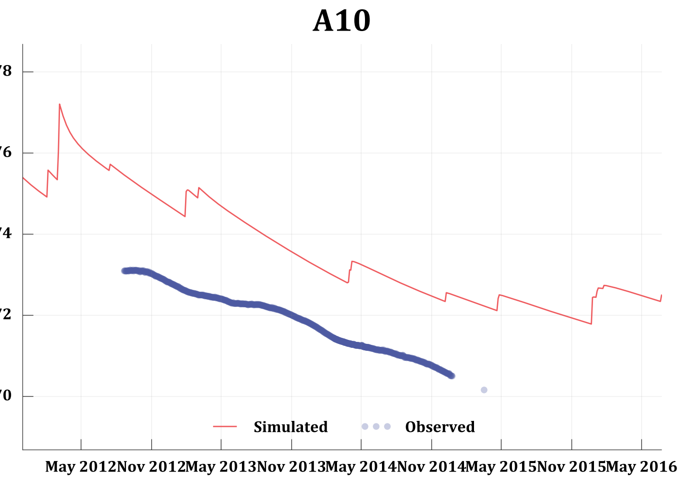
A08-D

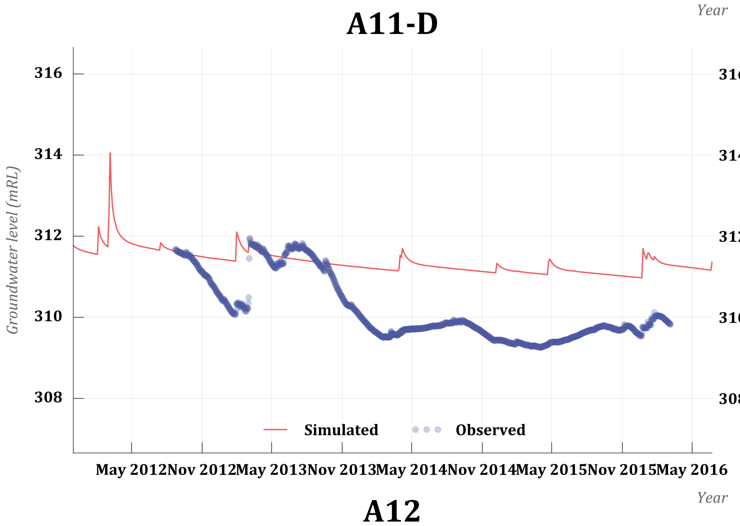


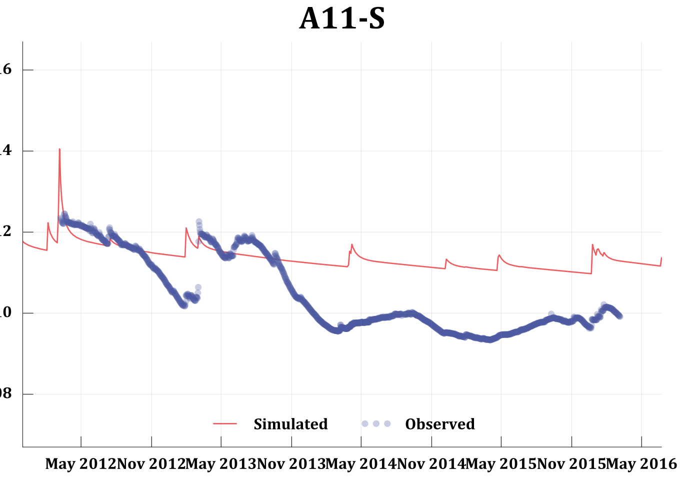
A08-S

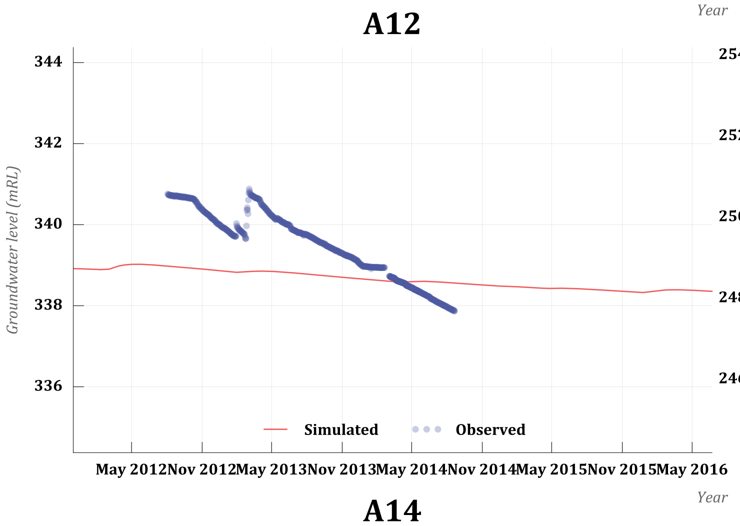


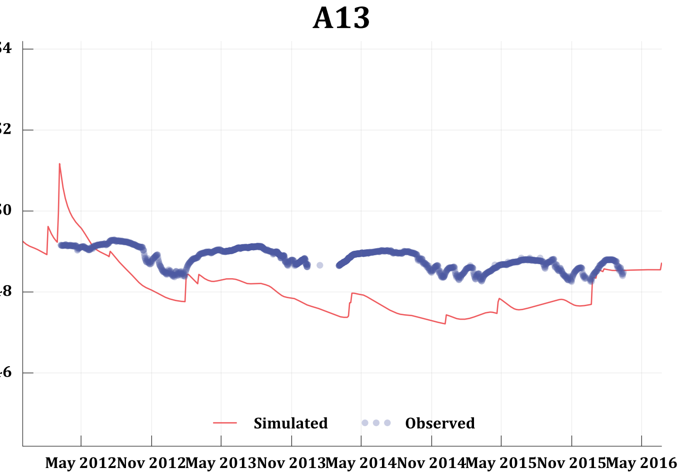

A09
258
256
254
252
250
Groundwater level (mRL)
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016
Year

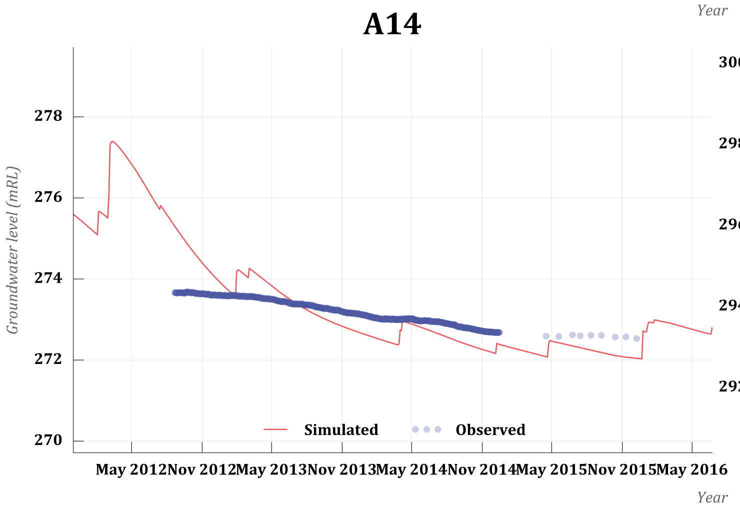

A10
278
276
274
272
270
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016

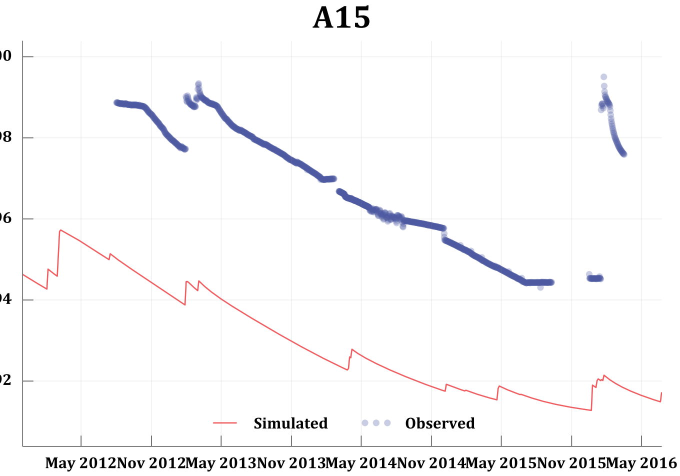

A11-D
316
314
312
310
308
Groundwater level (mRL)
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016
Year


A11-S
316
314
312
310
308
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016

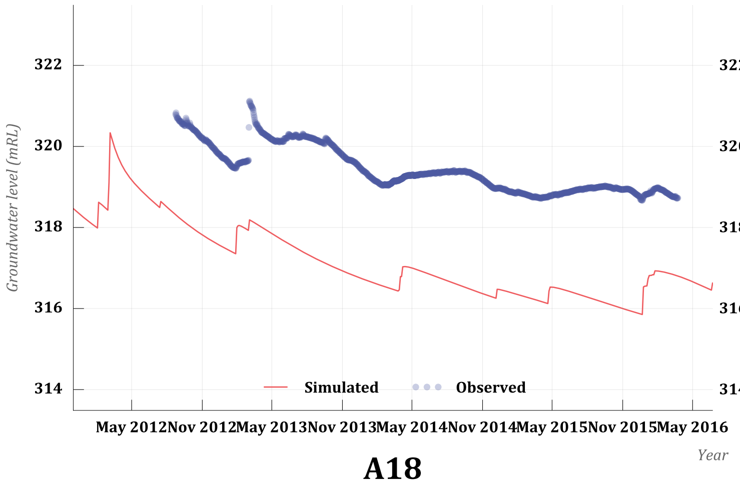

A12
344
342
340
338
336
Groundwater level (mRL)
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016
Year


A13
254
252
250
248
246
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016

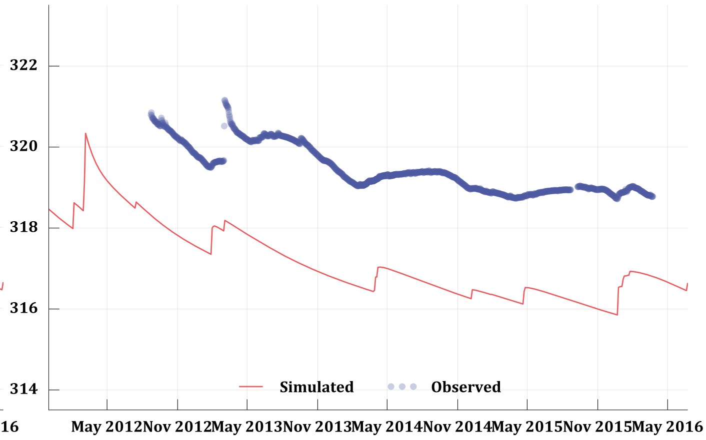

A14
278
276
274
272
270
Groundwater level (mRL)
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016
Year


A15
300
298
296
294
292
Simulated
Observed
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015
May 2016

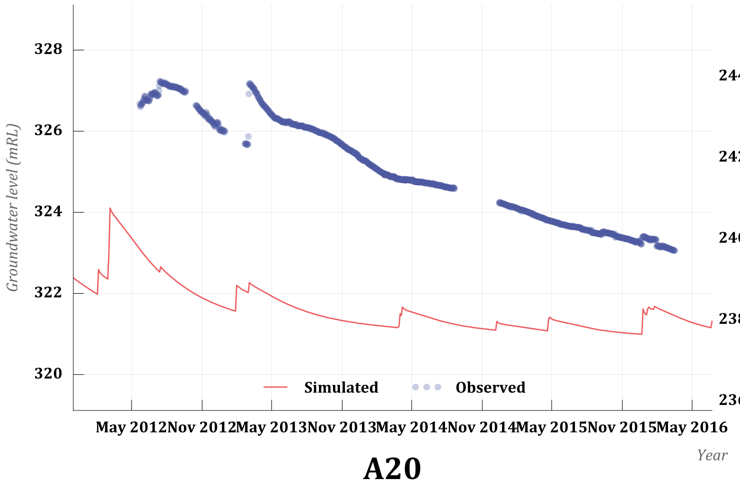
A17-D



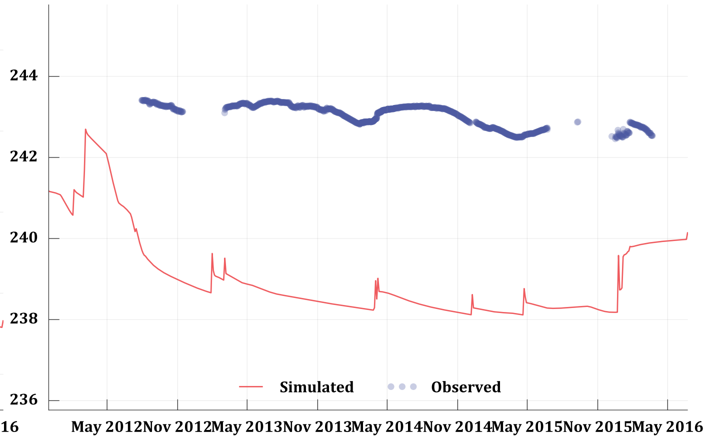
A17-S



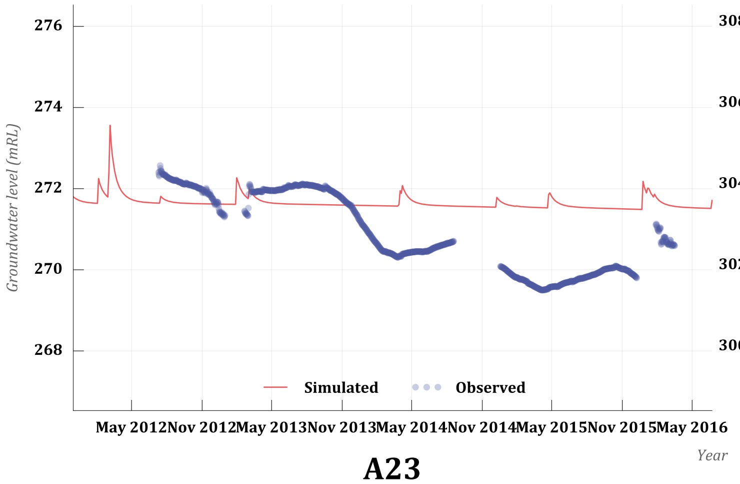
A18



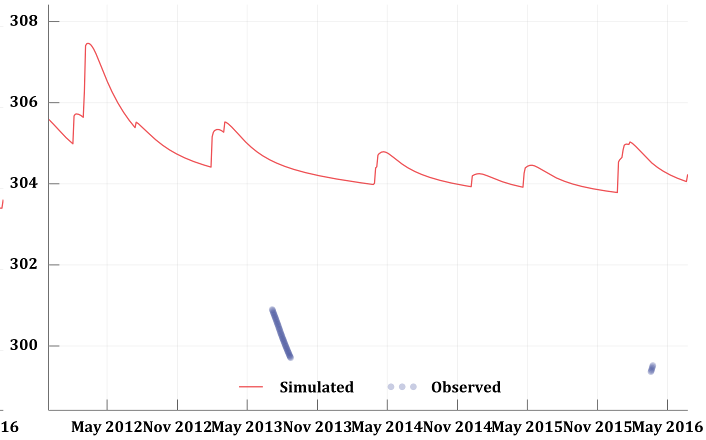
A19



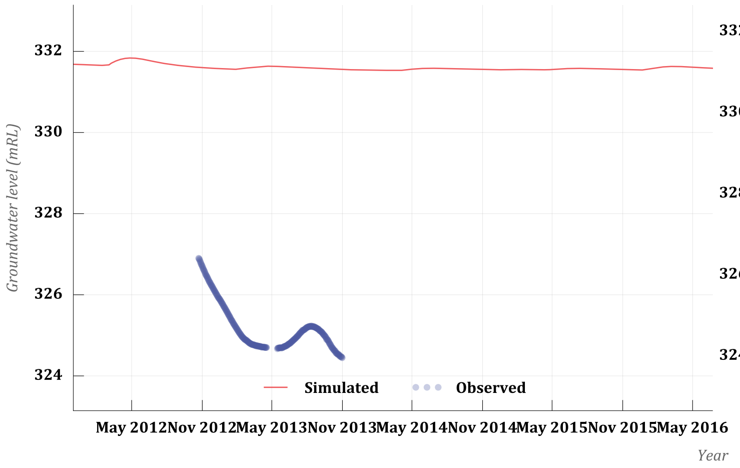
A20



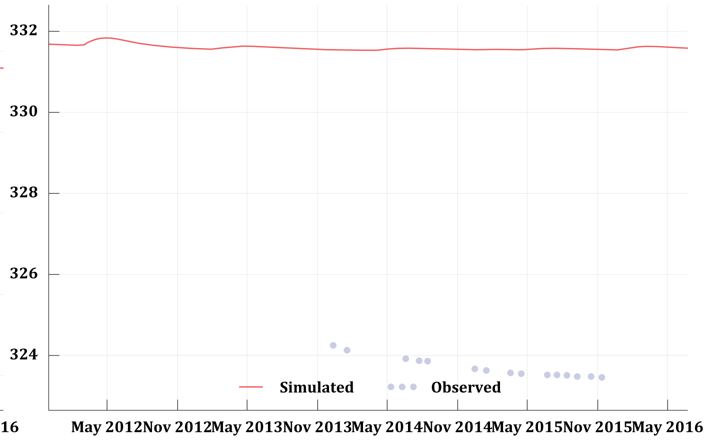
A21



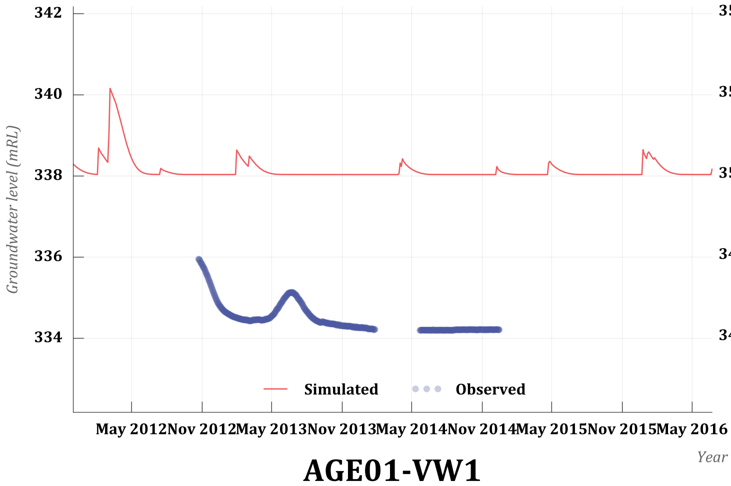
A23



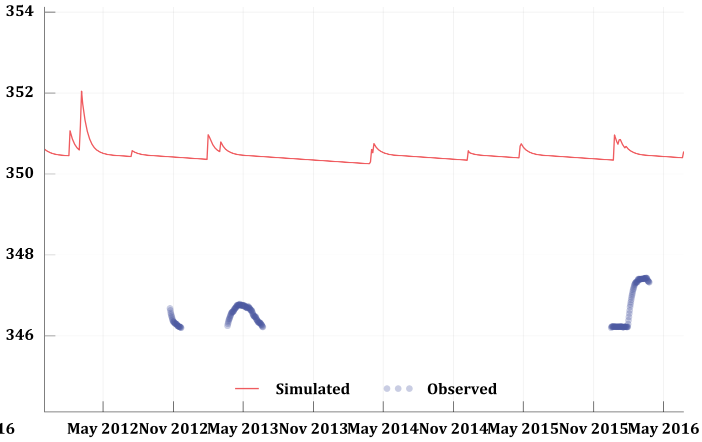
A23W



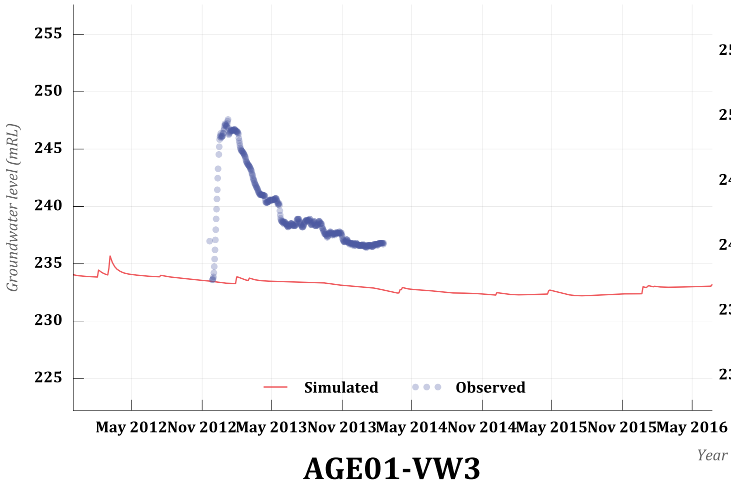
A24-D



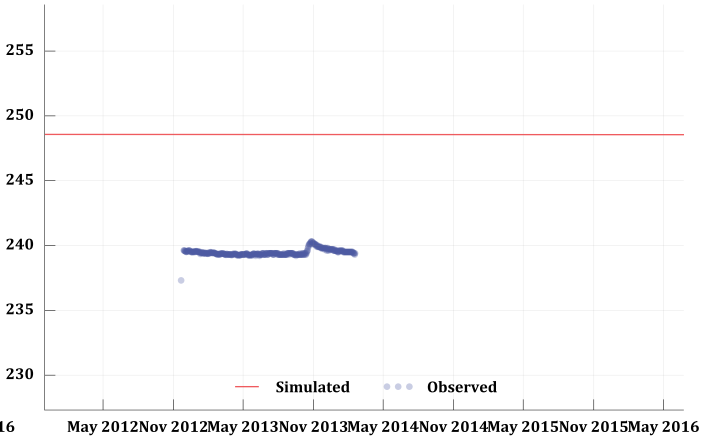
A25



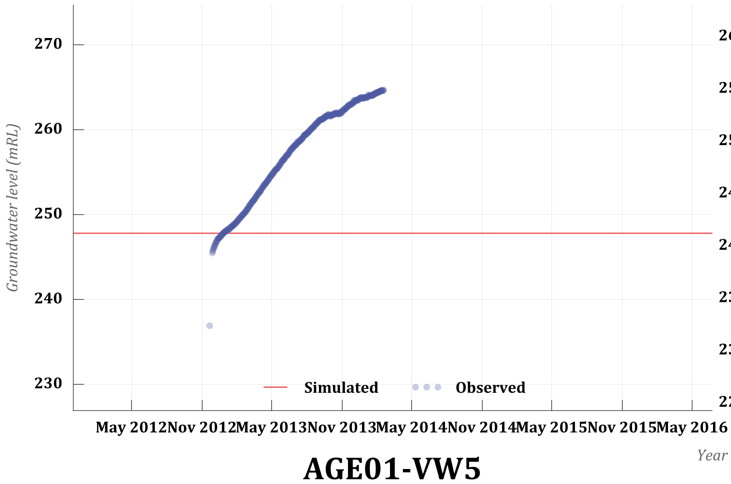
AGE01-VW1



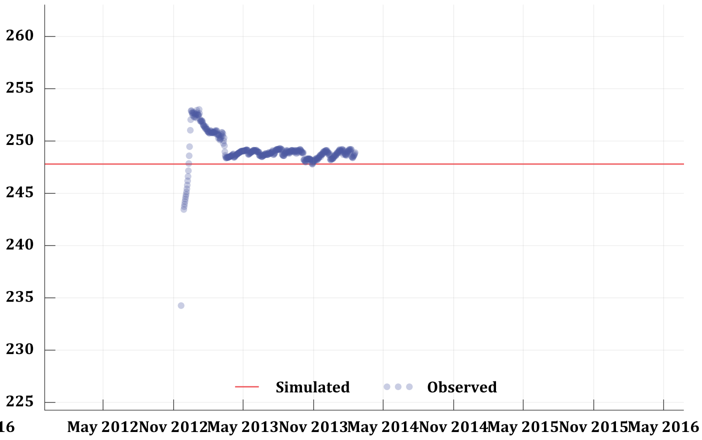
AGE01-VW2



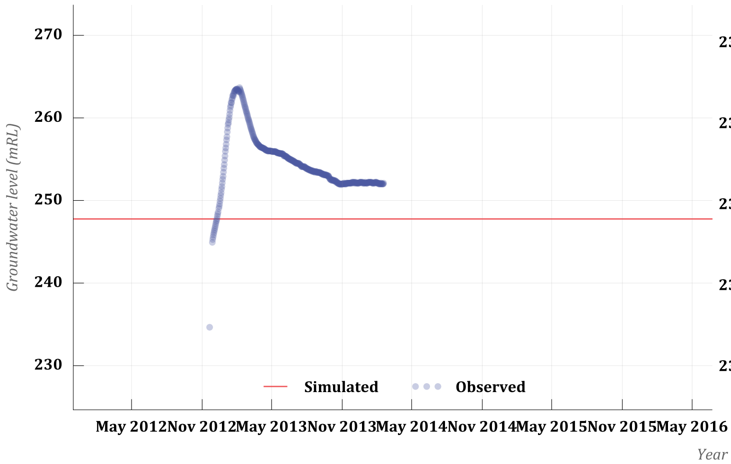
AGE01-VW3



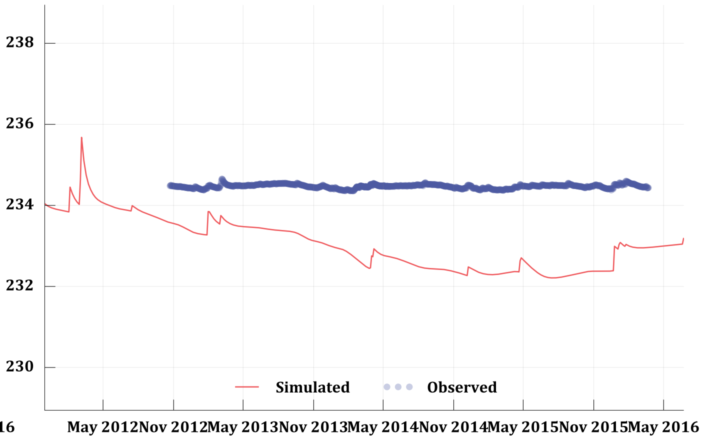
AGE01-VW4



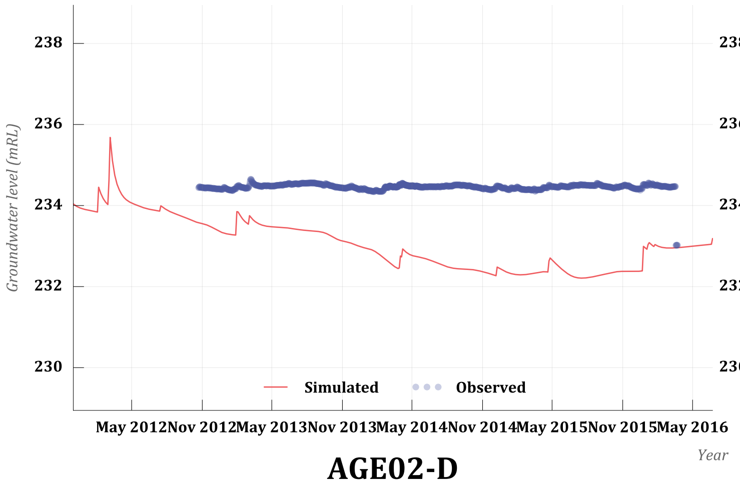
AGE01-VW5



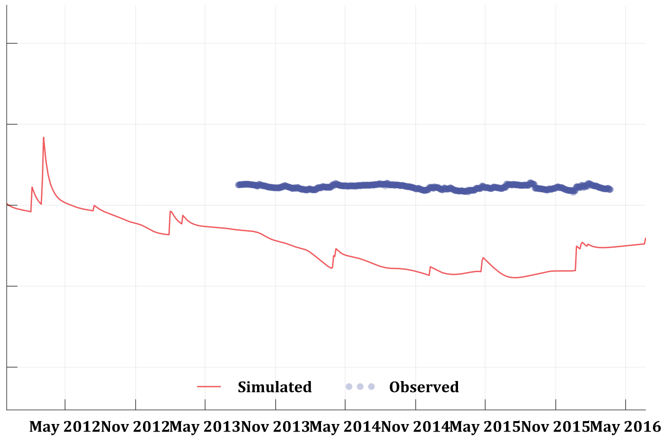
AGE01A-D



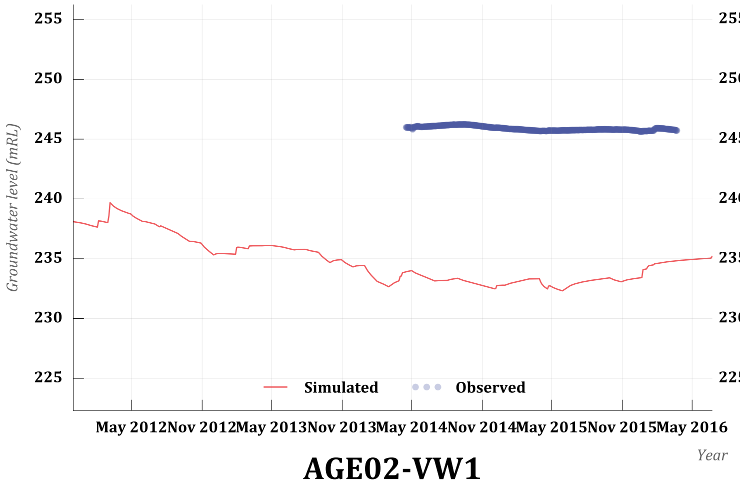
AGE01A-S



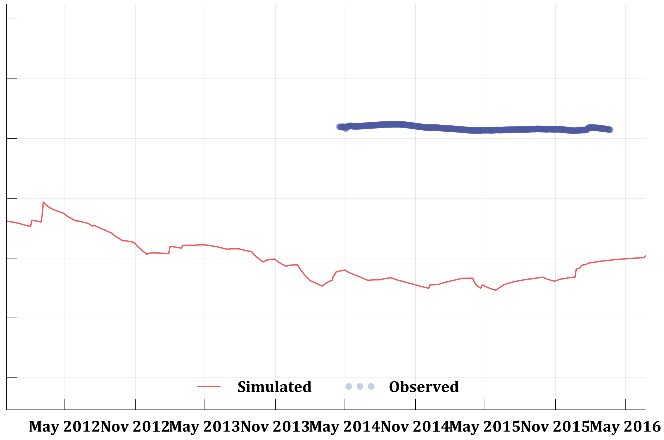
AGE01W



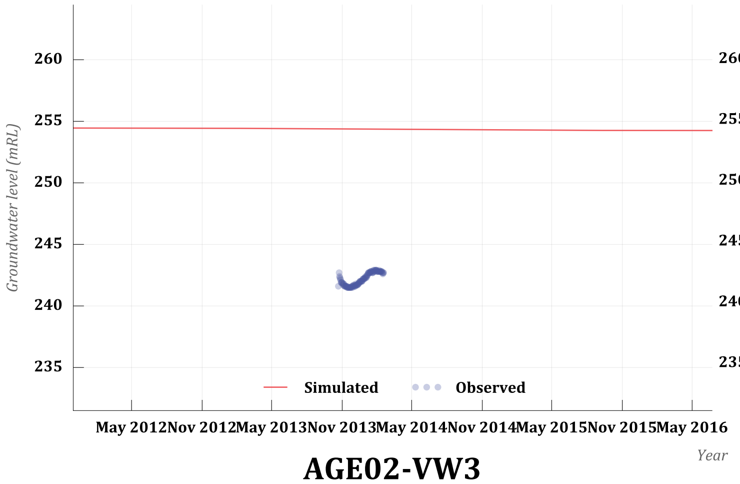
AGE02-D



AGE02-S



AGE02-VW1



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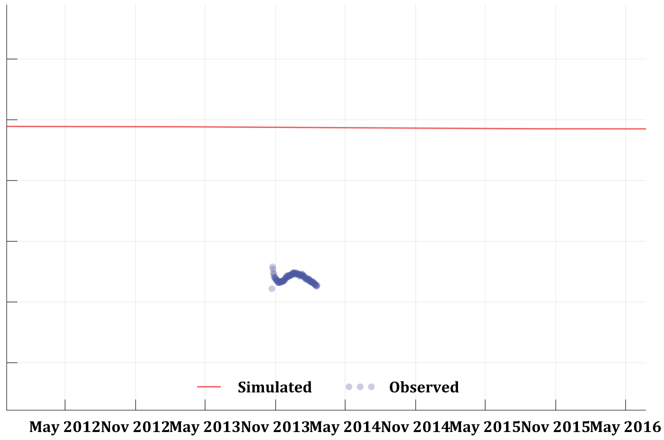
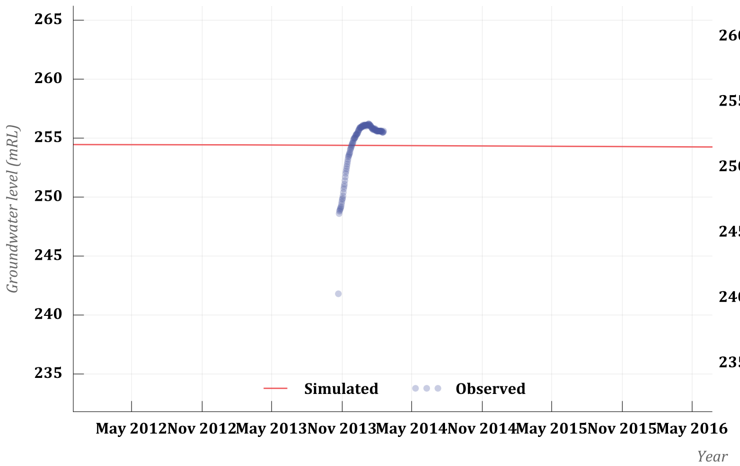
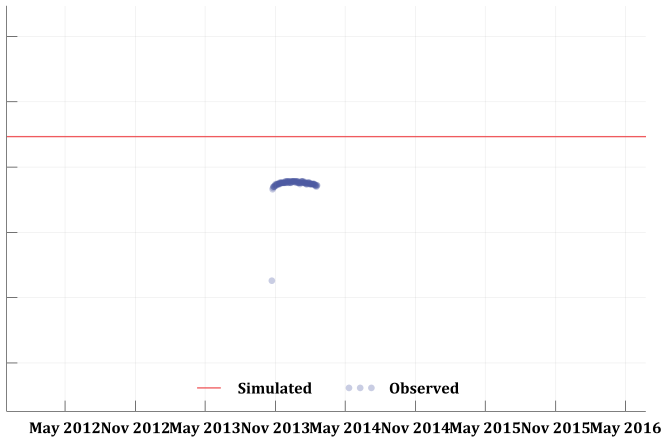


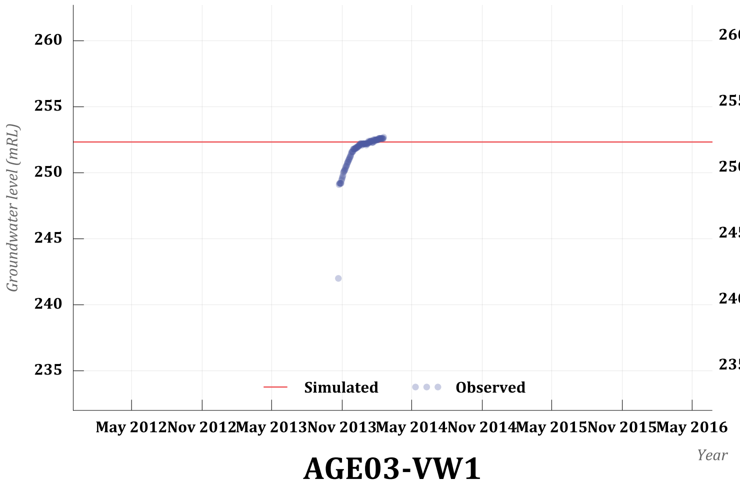
AGE02-VW3



AGE02-VW4



AGE02-VW5



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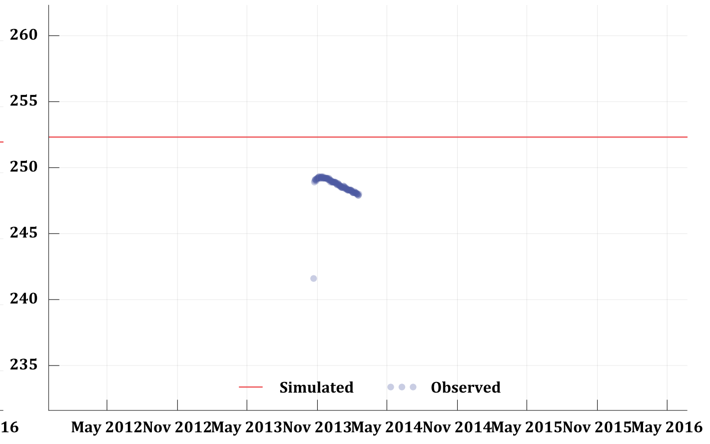
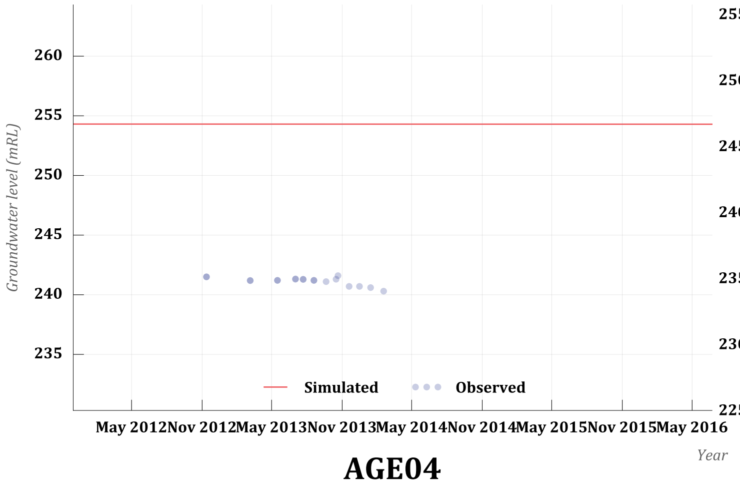
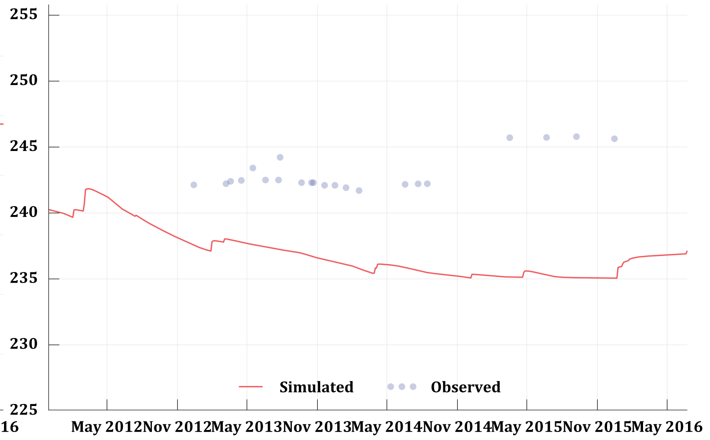


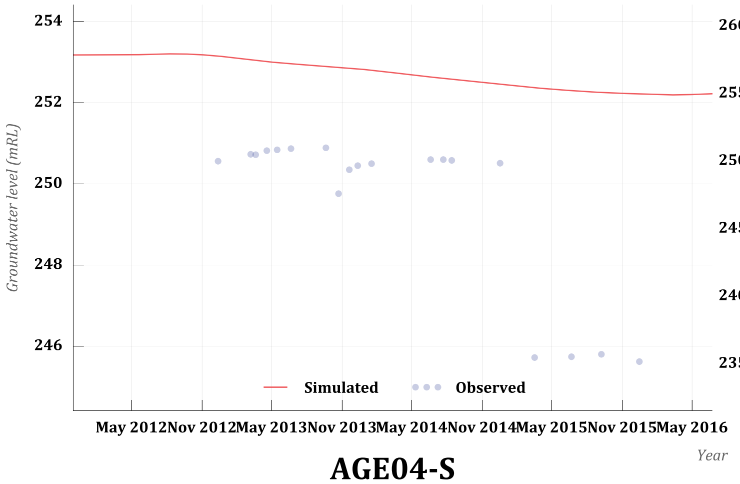
AGE03-VW1



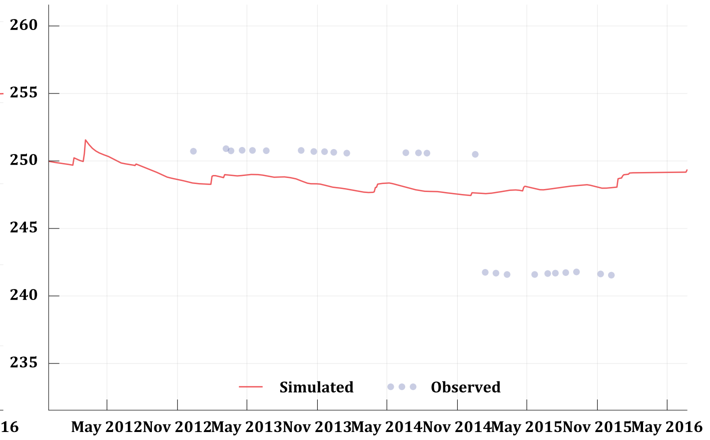
AGE03W



AGE04



AGE04-D



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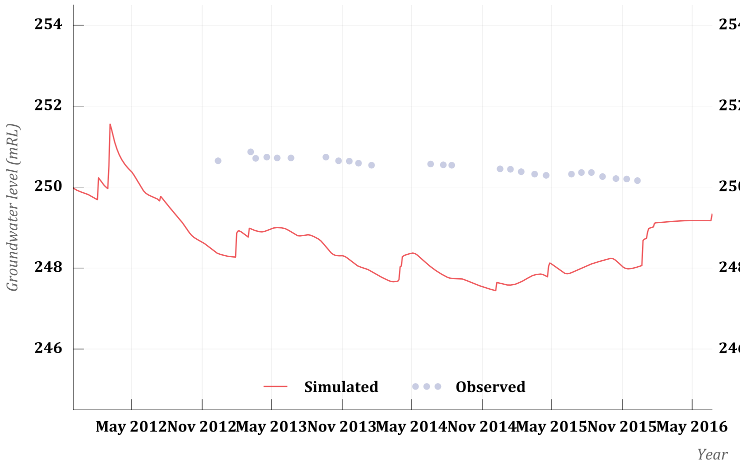

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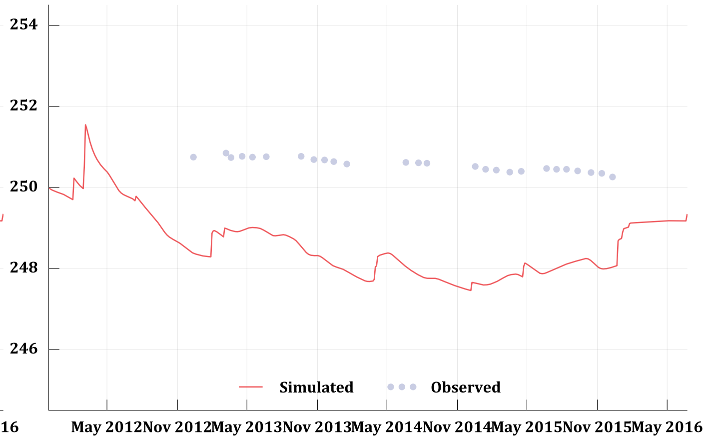

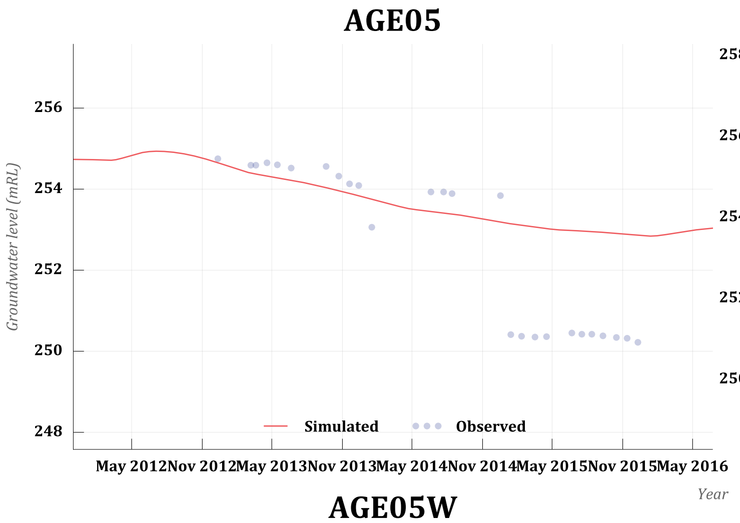
AGE05
Groundwater level (mRL)
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252
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248
Simulated
Observed
May 2012
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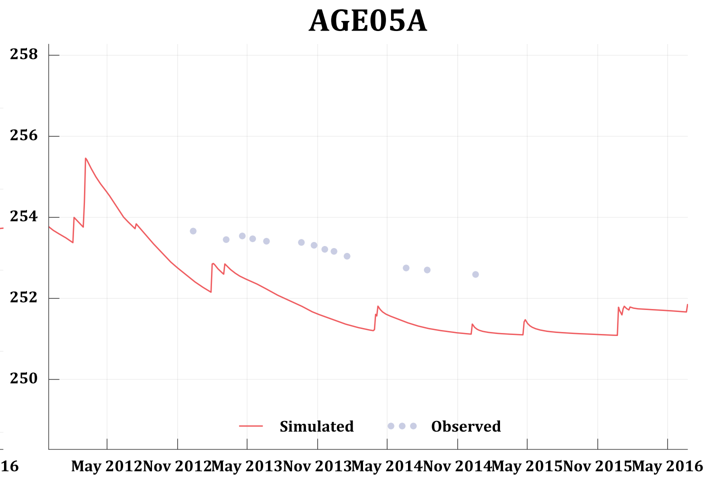
Nov 2015
May 2016
Year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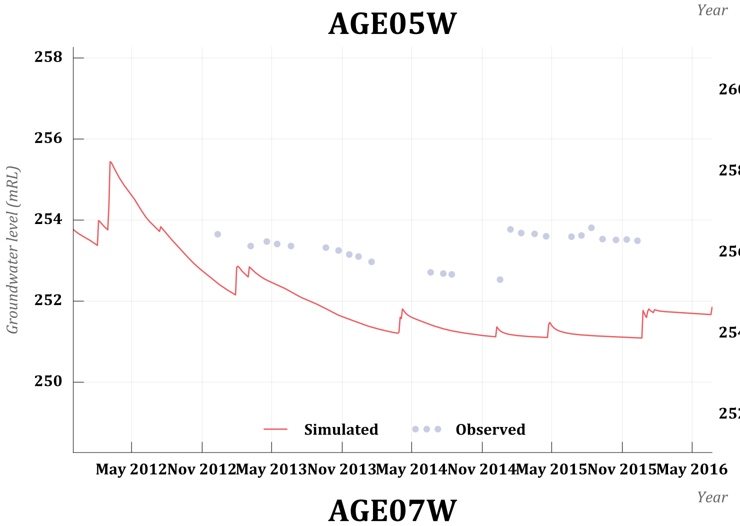
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Groundwater level (mRL)
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Observed
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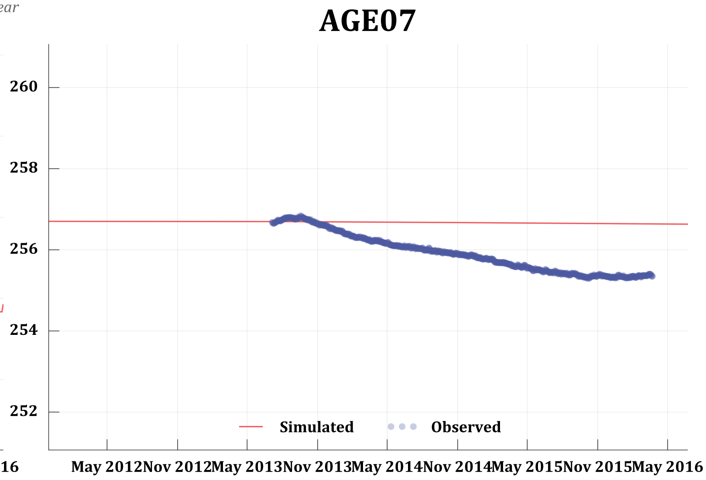
May 2016
Year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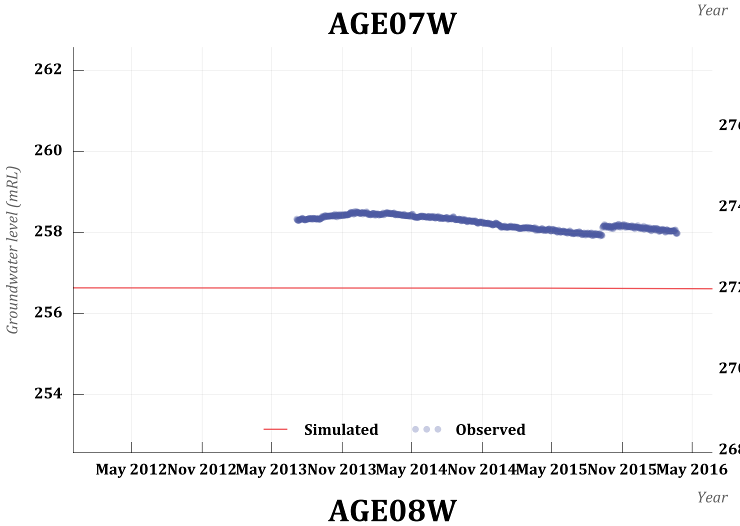
AGE07W
Groundwater level (mRL)
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Observed
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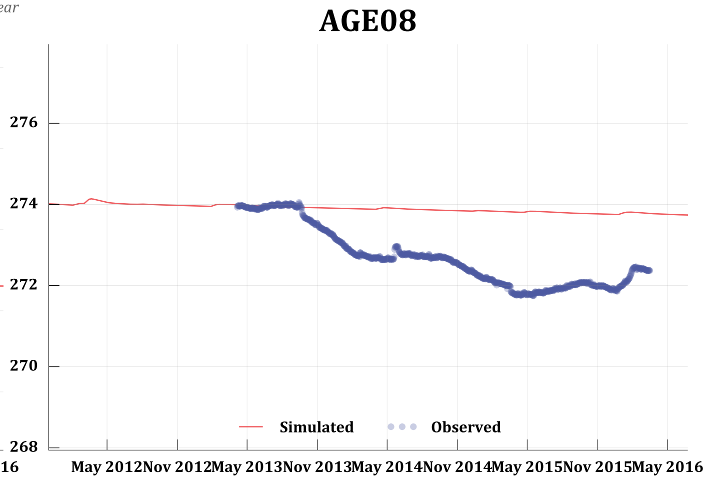
Year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Simulated
Observed
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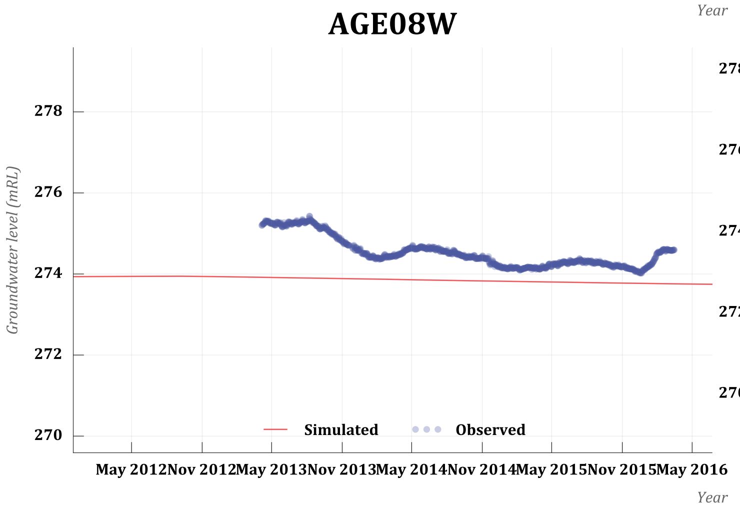
AGE08W
Groundwater level (mRL)
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Simulated
Observed
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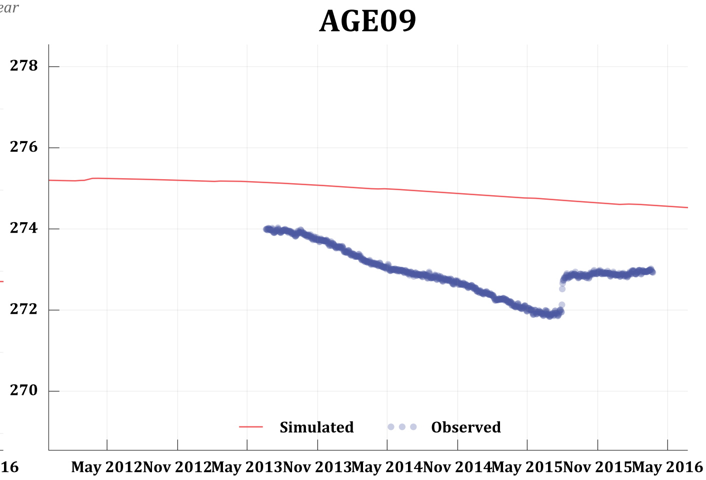
Year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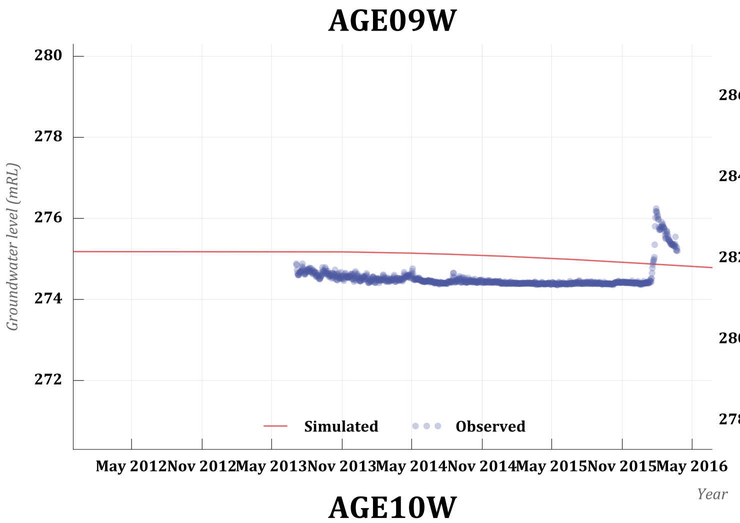
AGE09W
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Groundwater level (mRL)
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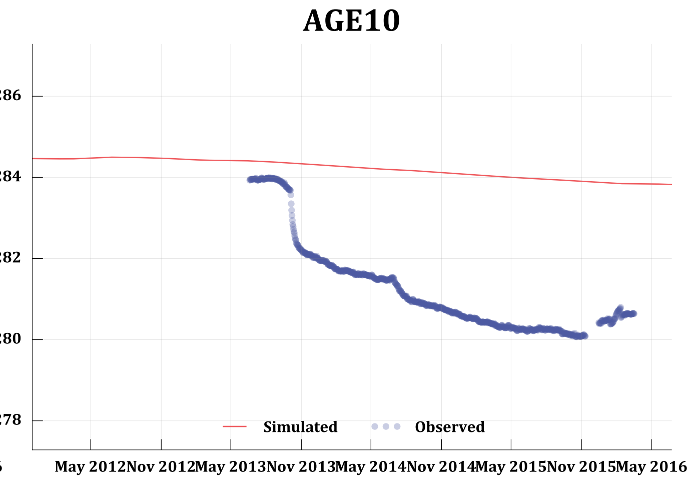
Year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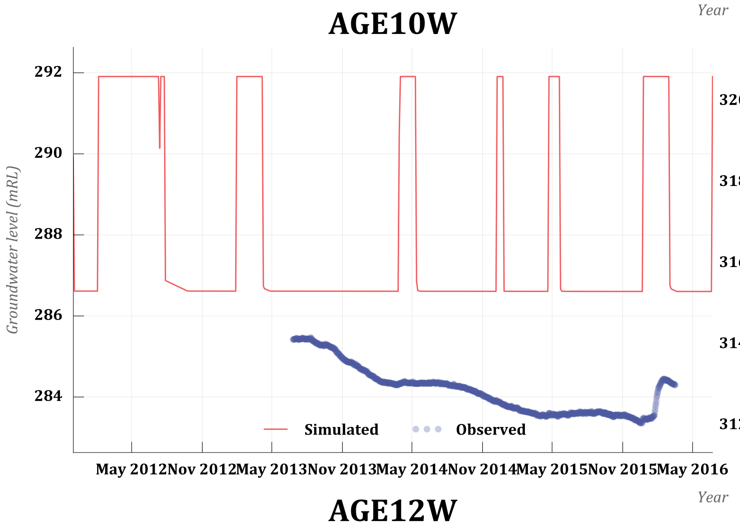
AGE10W
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288
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Groundwater level (mRL)
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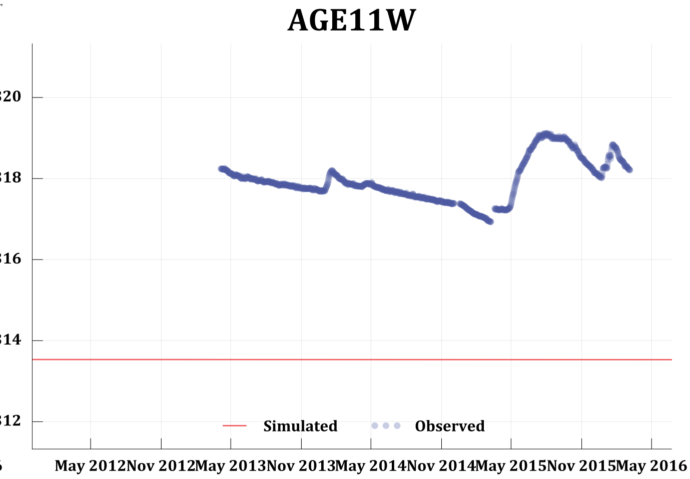
Year


AGE11W
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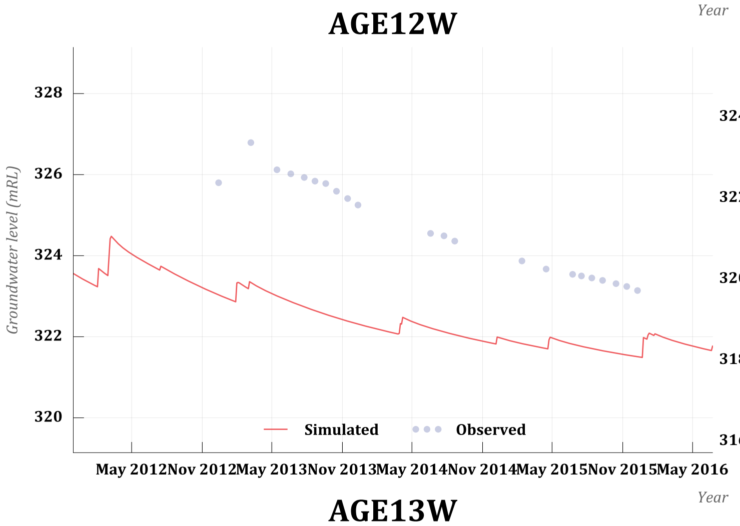
AGE12W
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Groundwater level (mRL)
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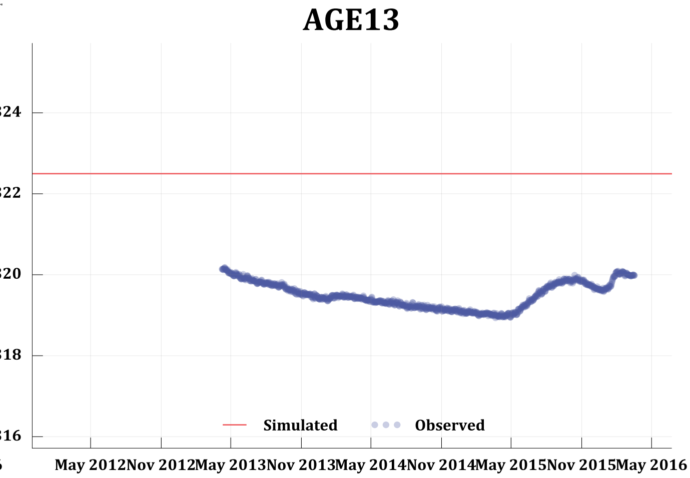
Year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AGE13W
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346
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Groundwater level (mRL)
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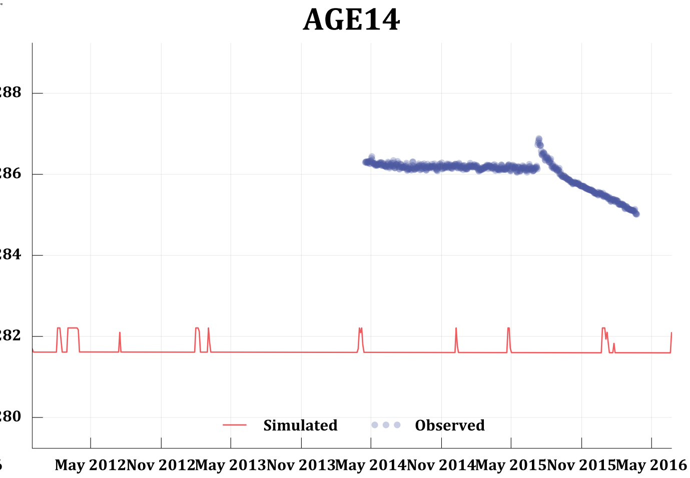
Year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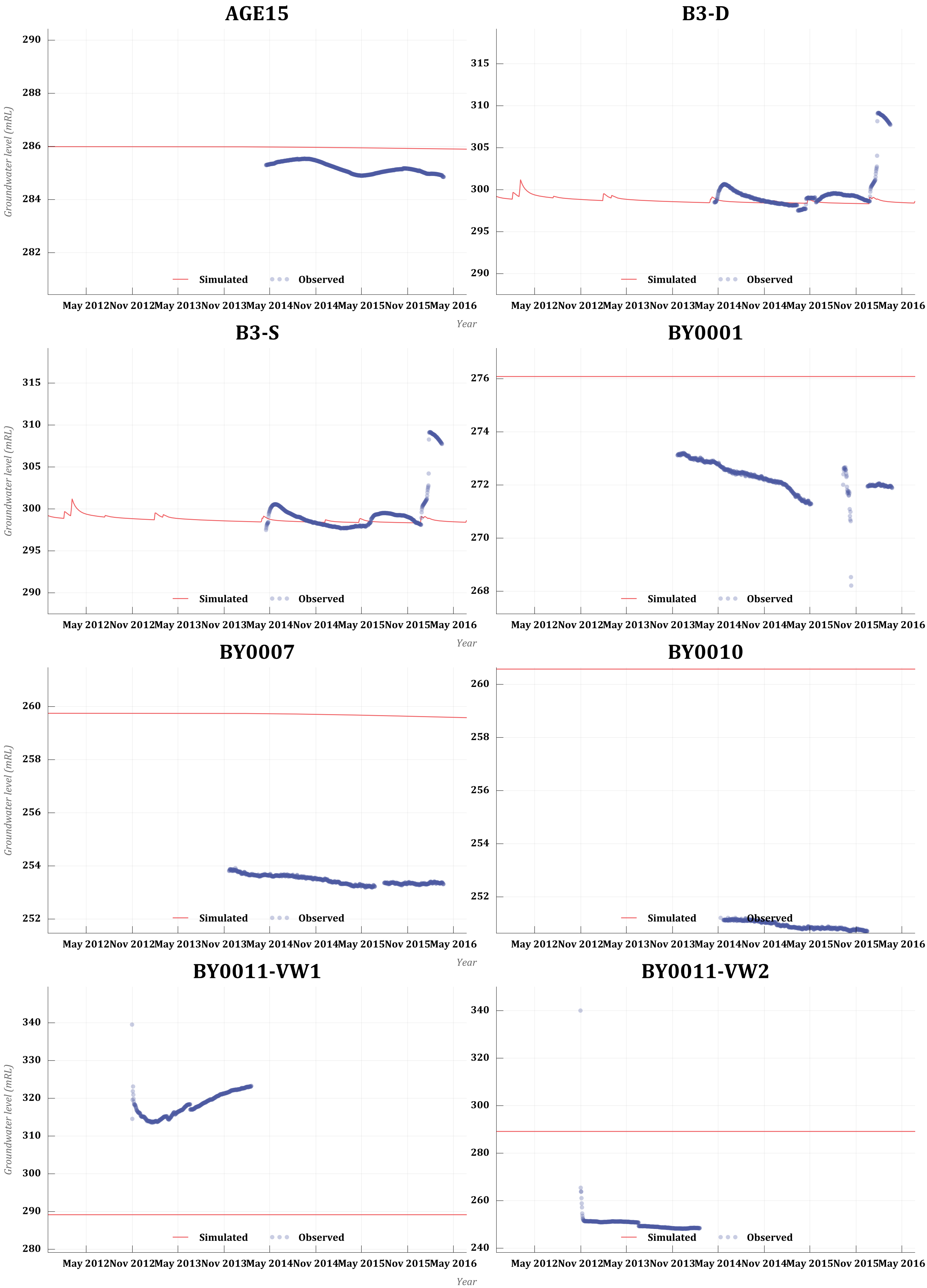
AGE15
B3-D
B3-S
BY0001
BY0007
BY0010
BY0011-VW1
BY0011-VW2
Groundwater level (mRL)
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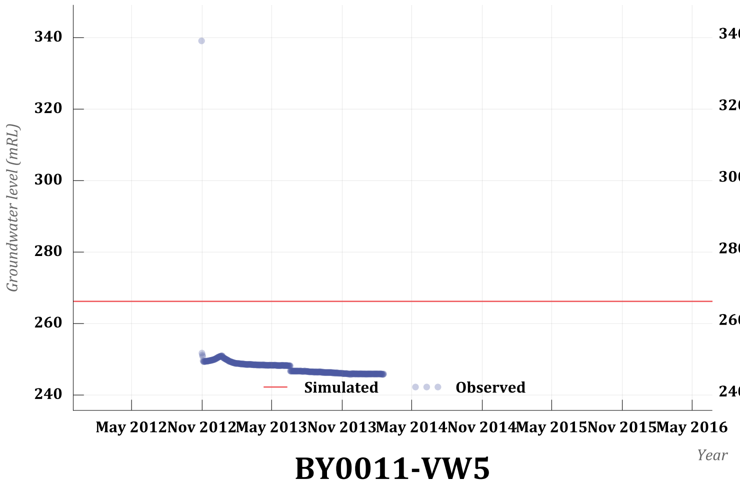
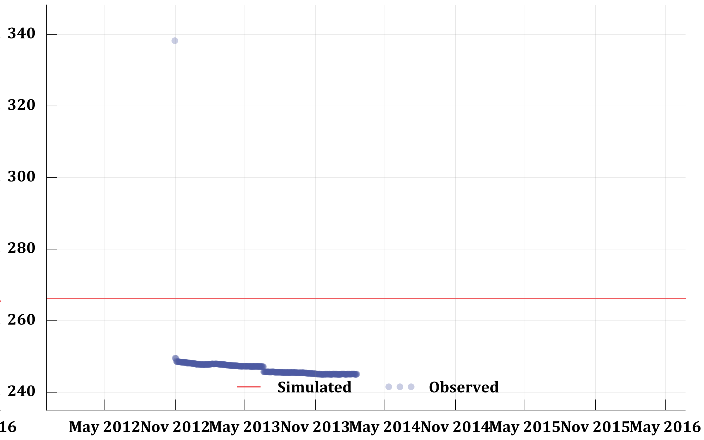
May 2016
Year

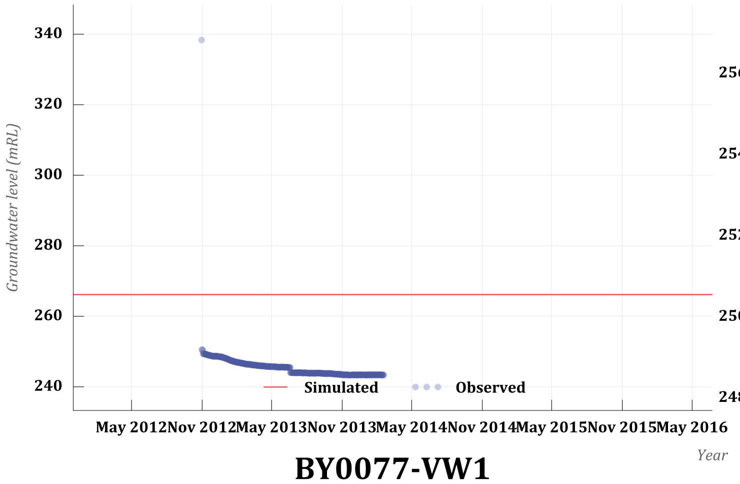
BY0011-VW3



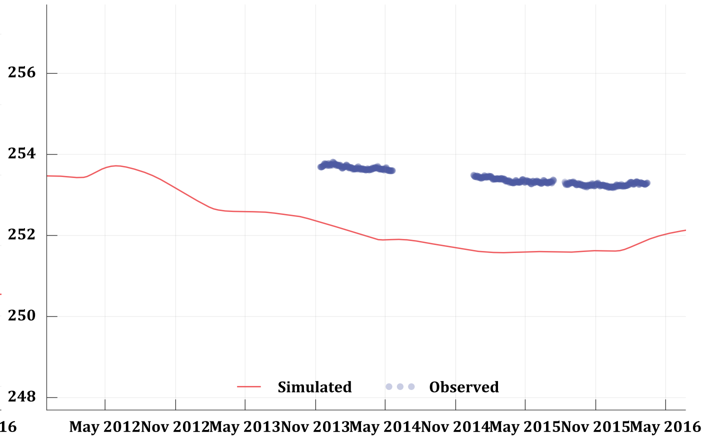
BY0011-VW4



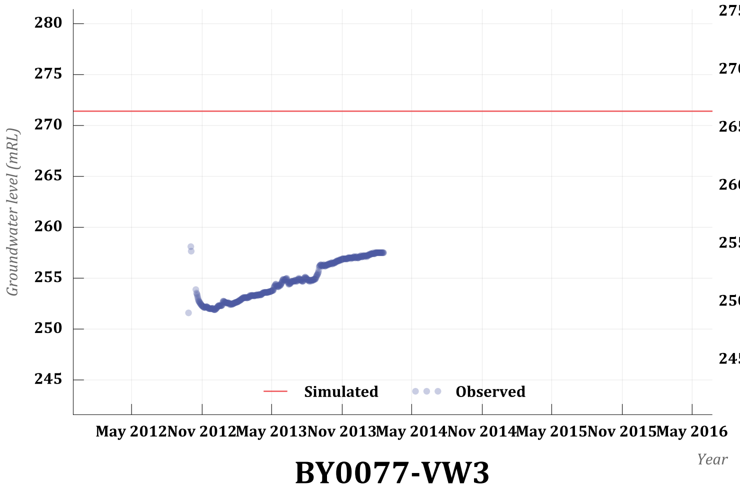
BY0011-VW5



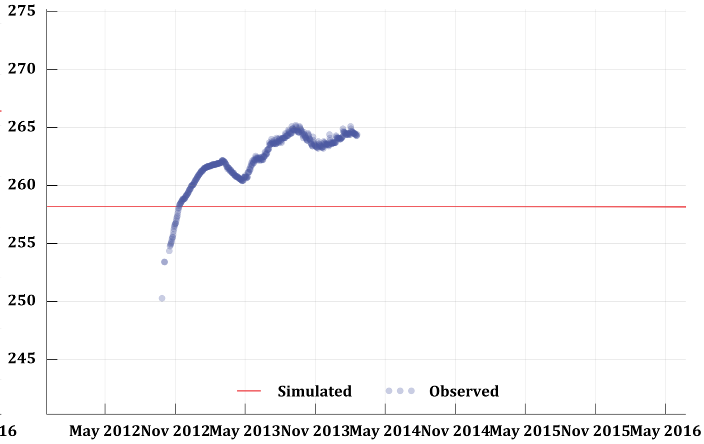
BY0014



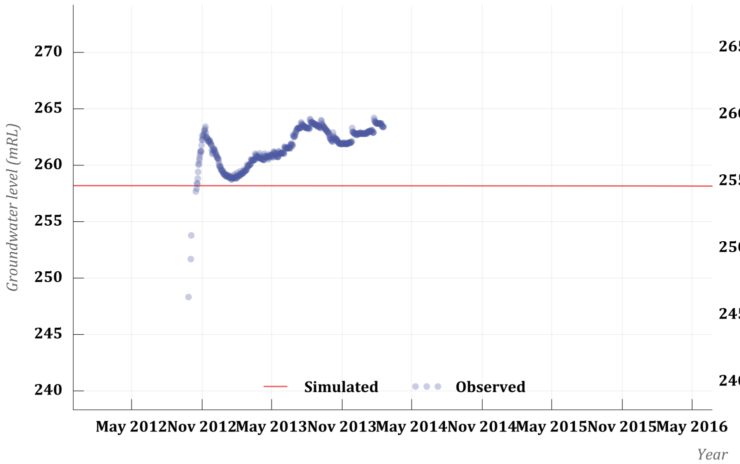
BY0077-VW1



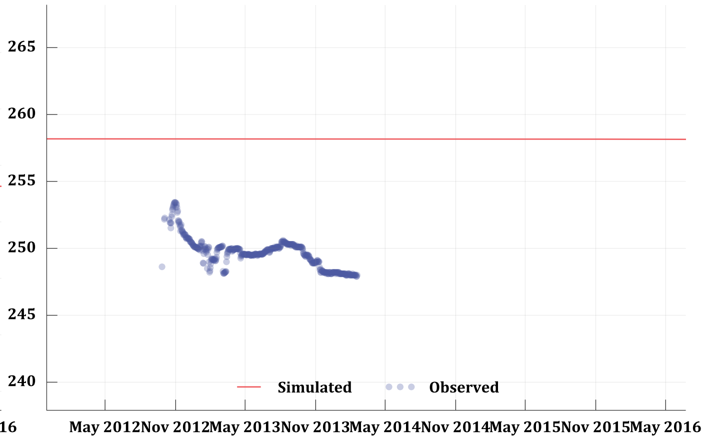
BY0077-VW2



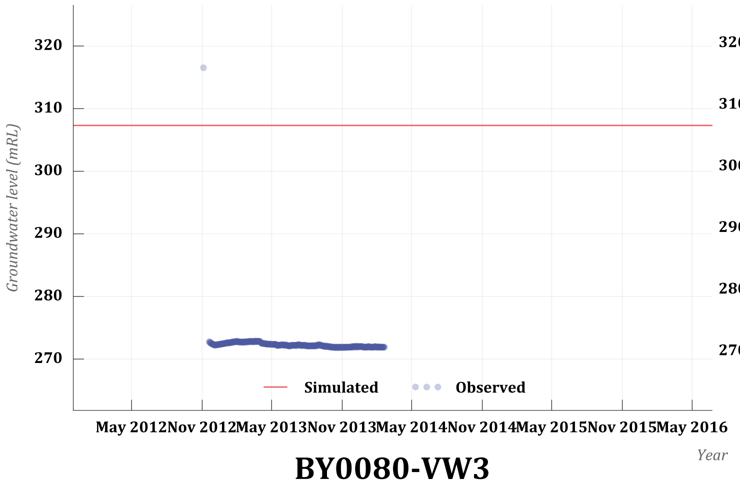
BY0077-VW3



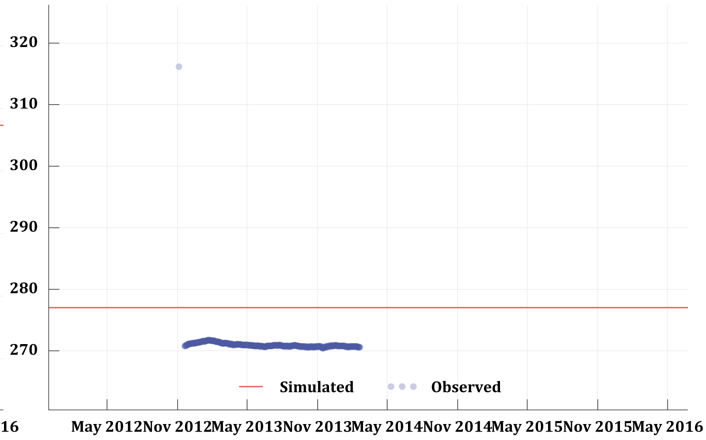
BY0077-VW4



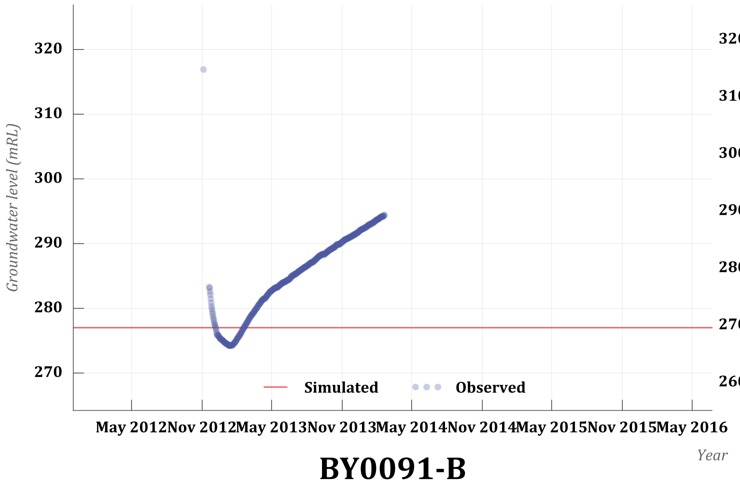
BY0080-VW1



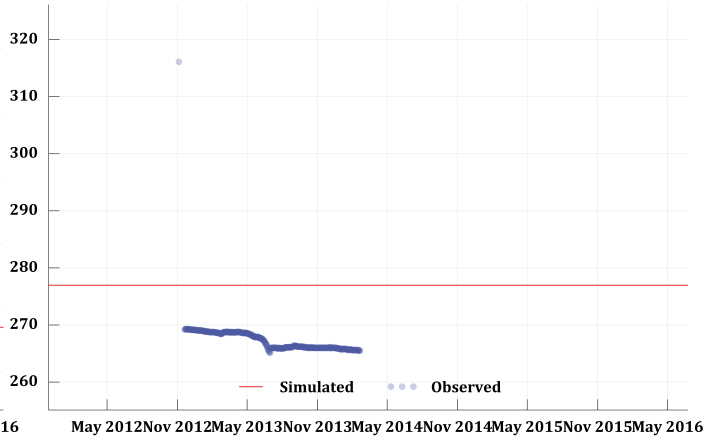
BY0080-VW2



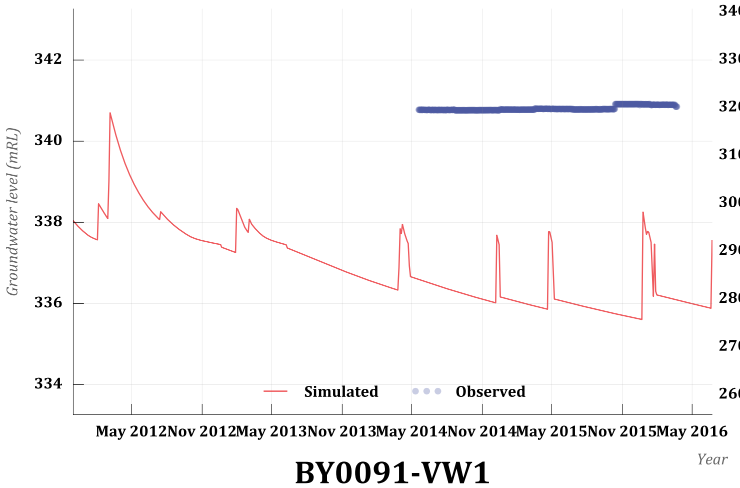
BY0080-VW3



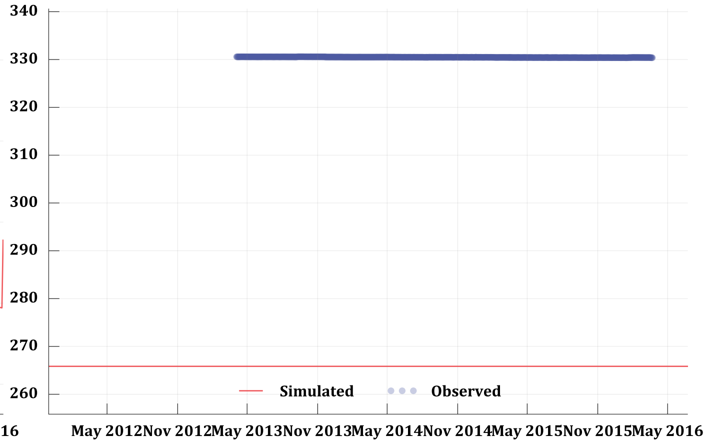
BY0080-VW4



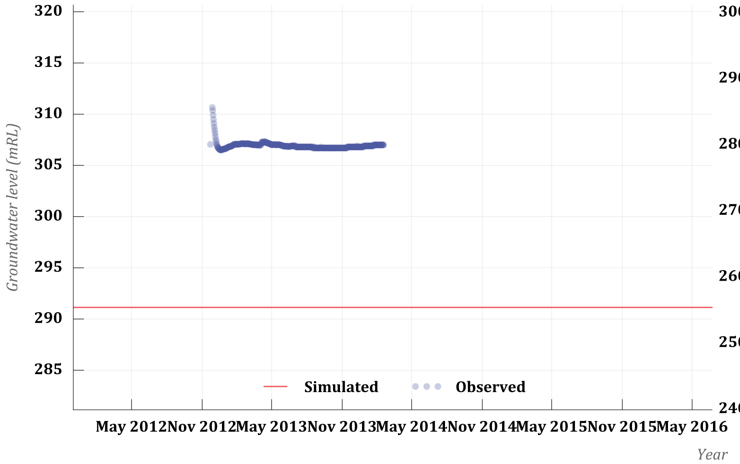
BY0091-B



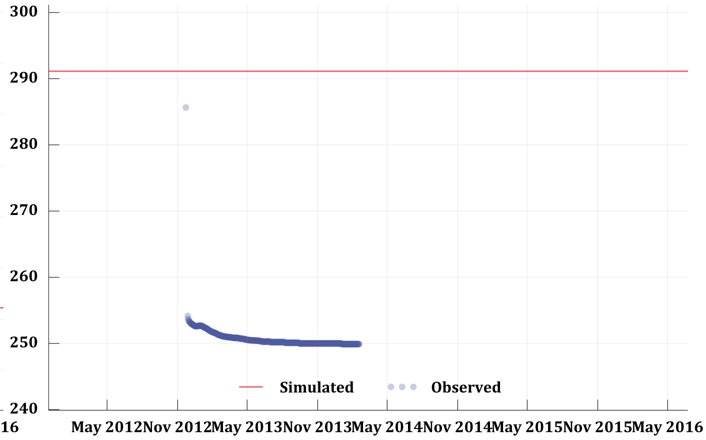
BY0091-S



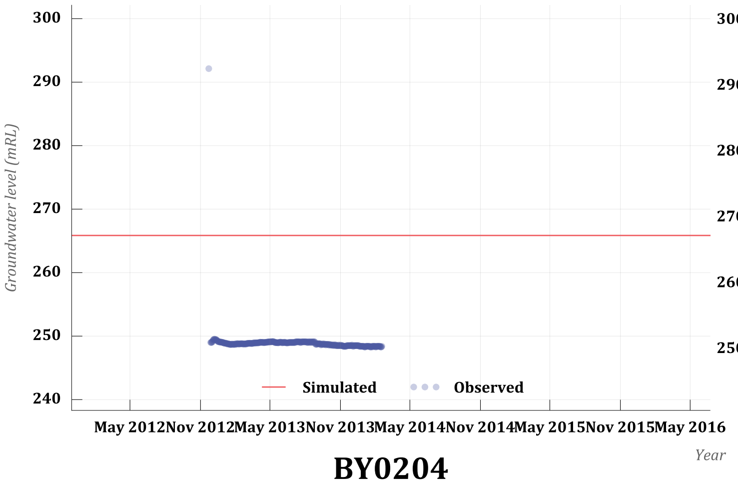
BY0091-VW1



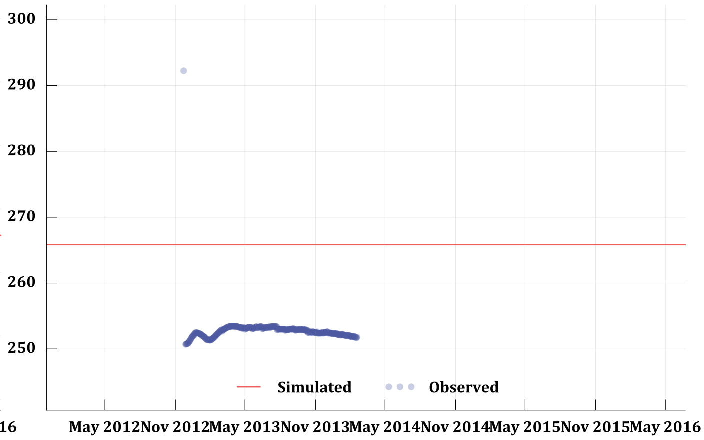
BY0091-VW2



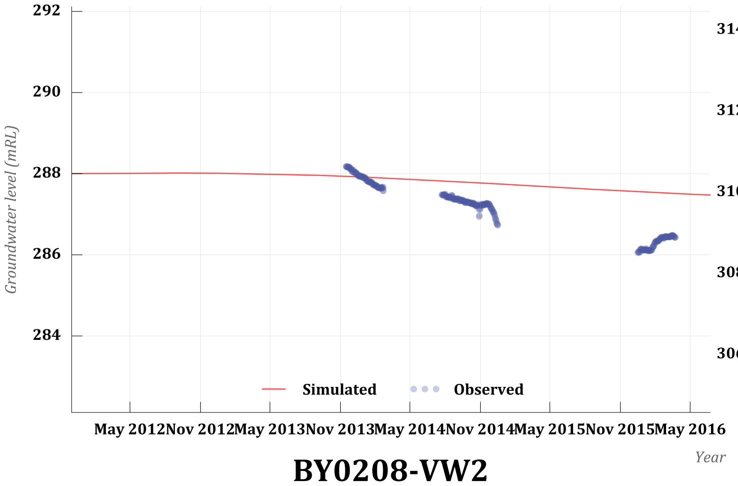
BY0091-VW3



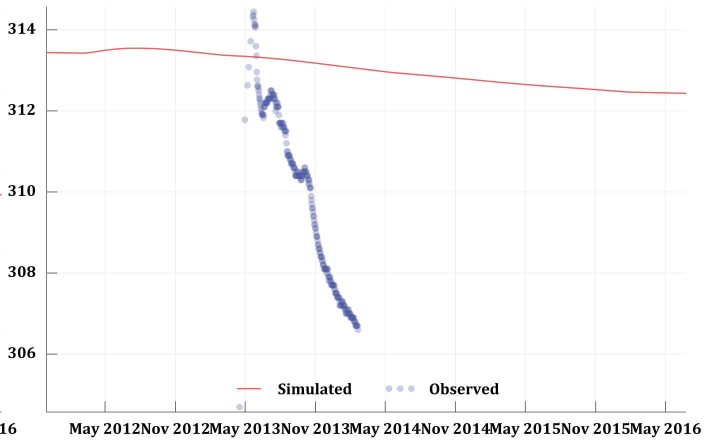
BY0091-VW4



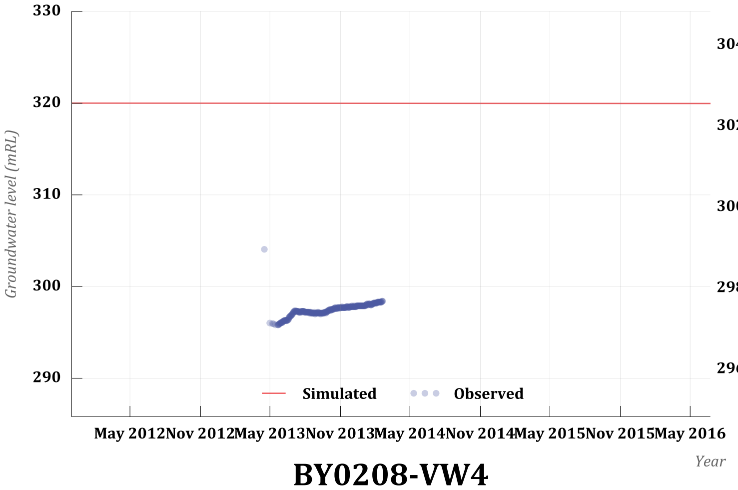
BY0204



BY0208-VW1



BY0208-VW2



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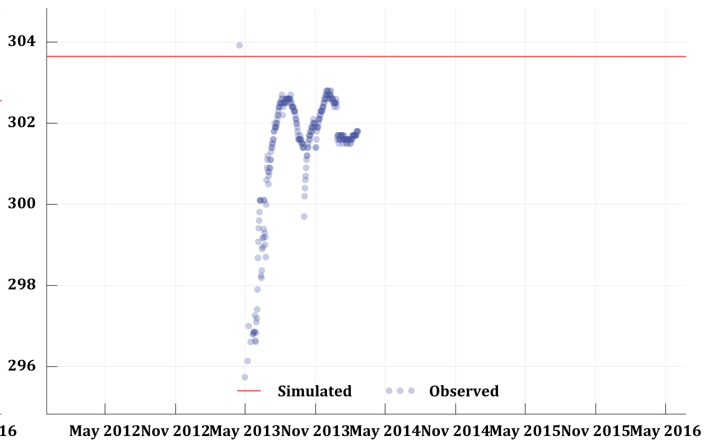

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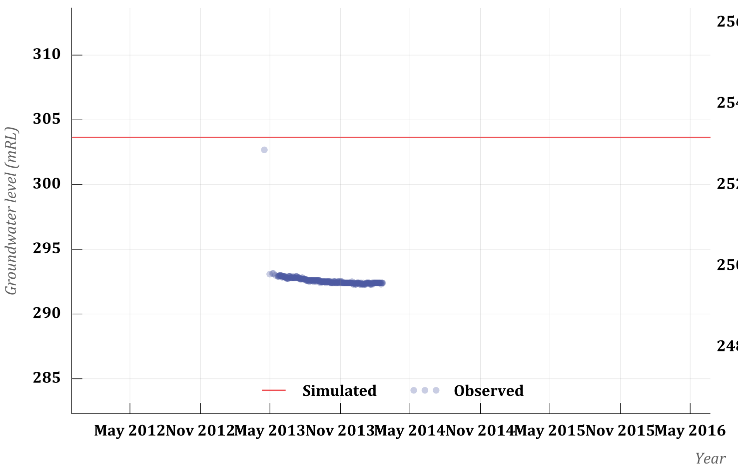

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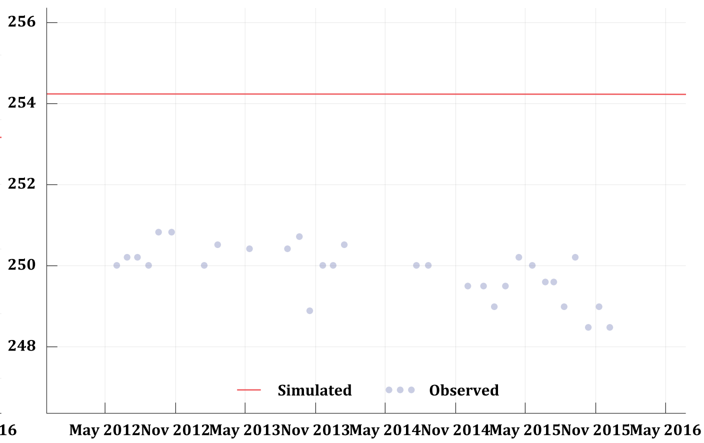

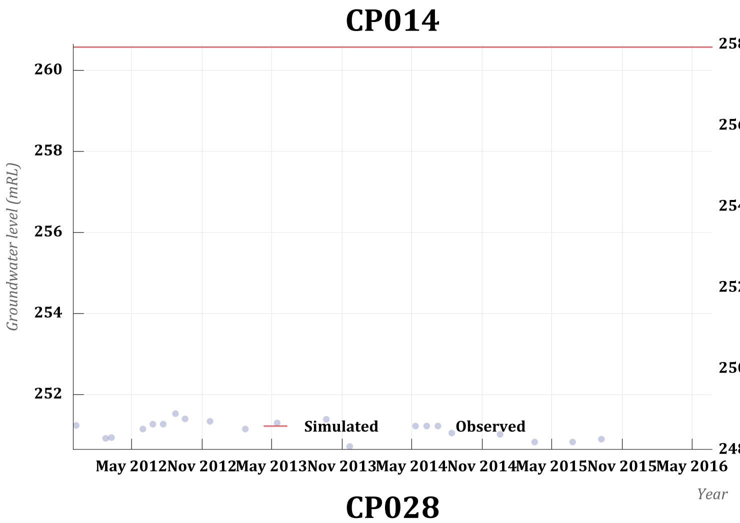
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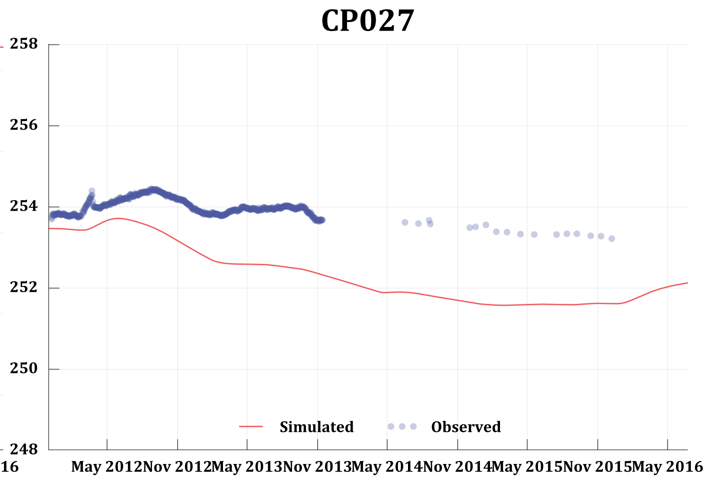
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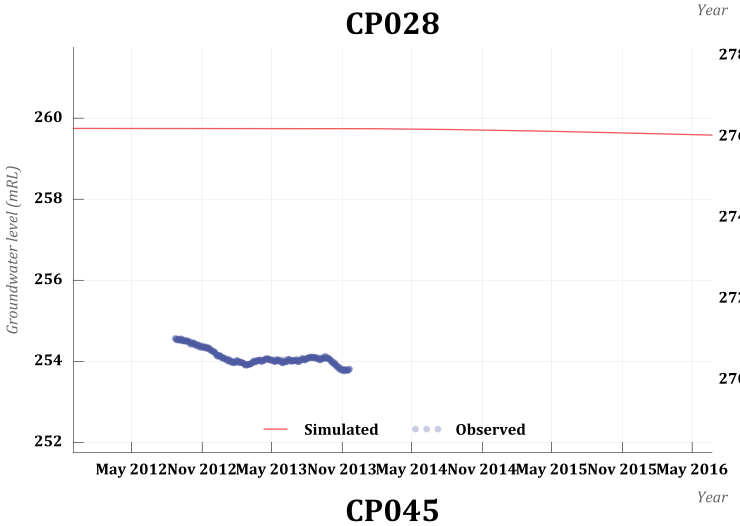
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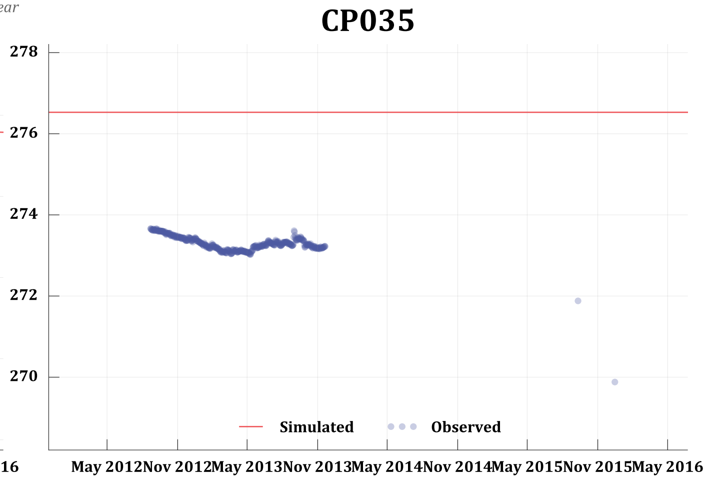
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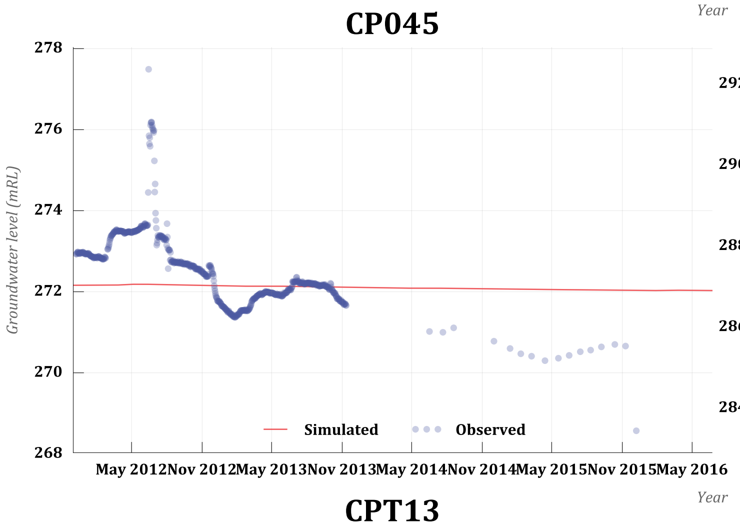
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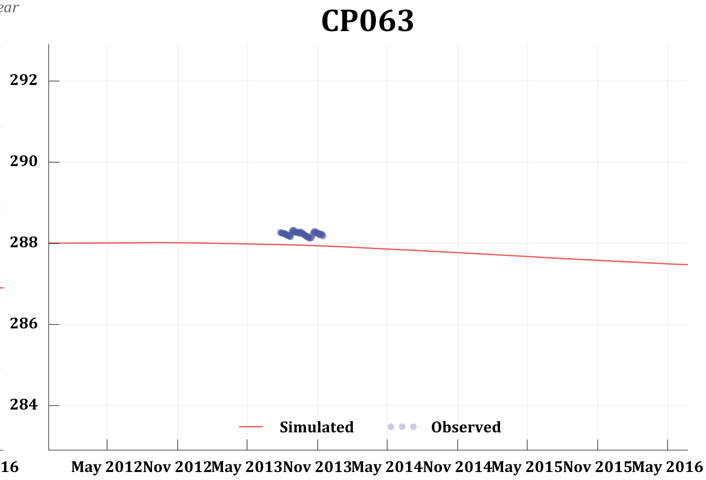
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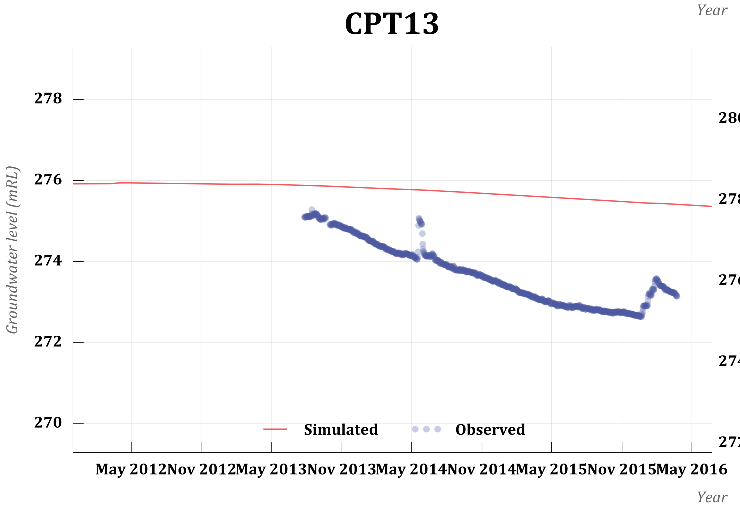
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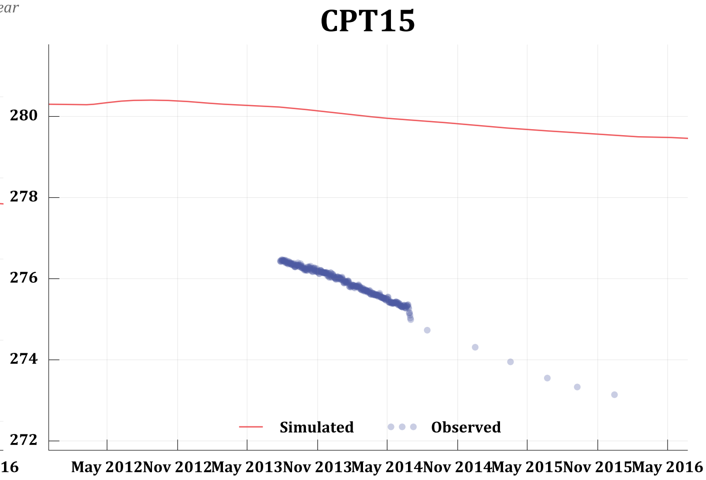
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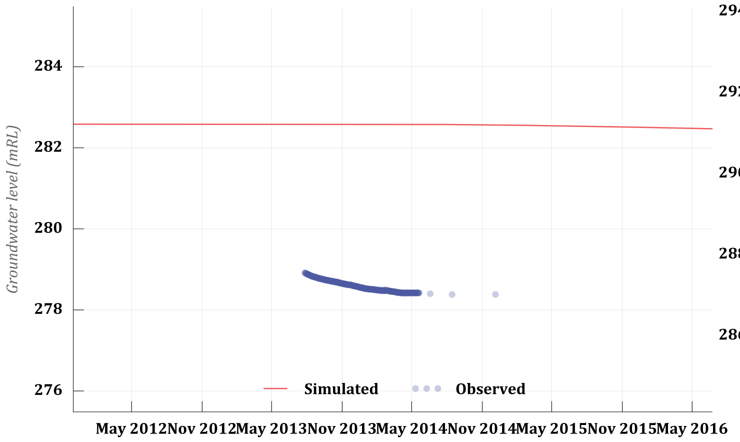

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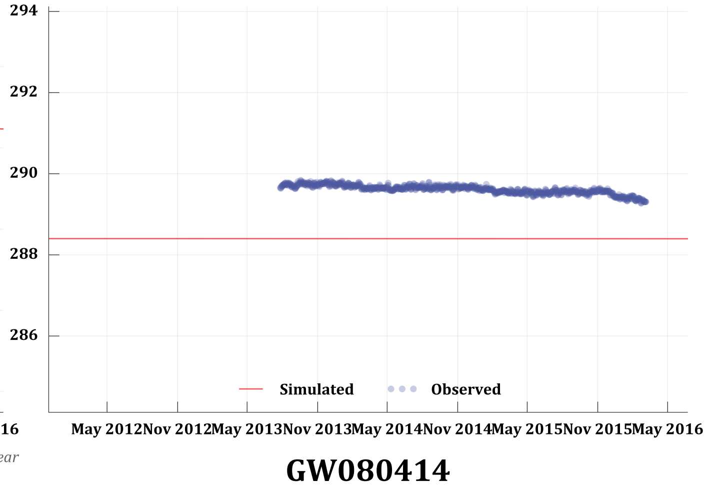

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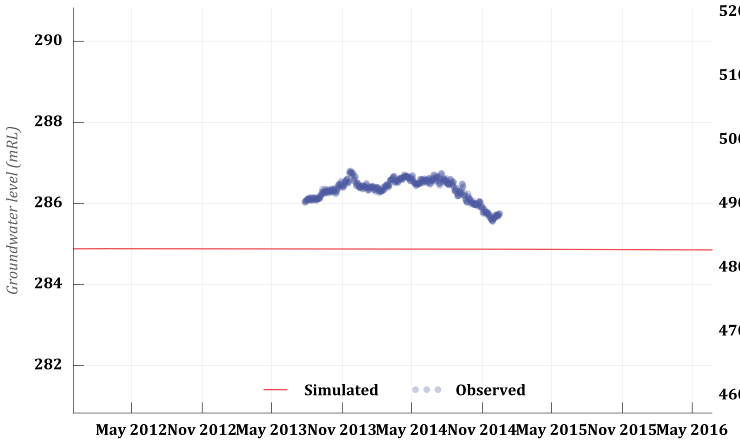

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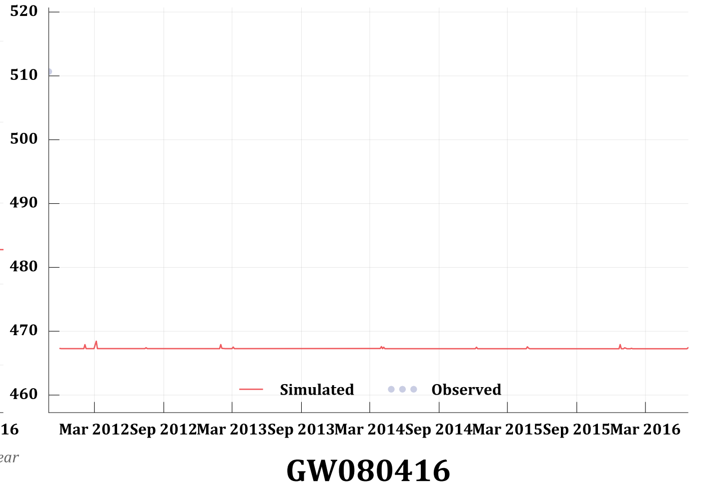

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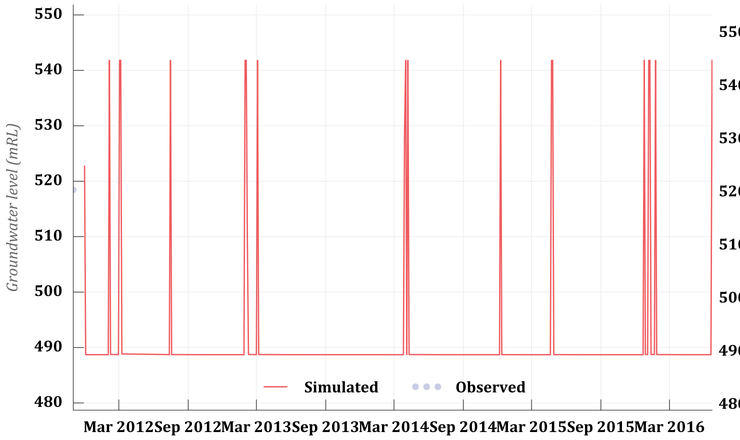

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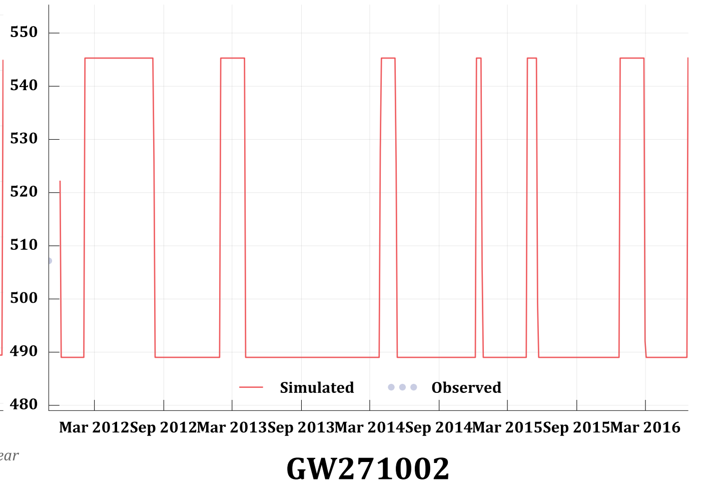

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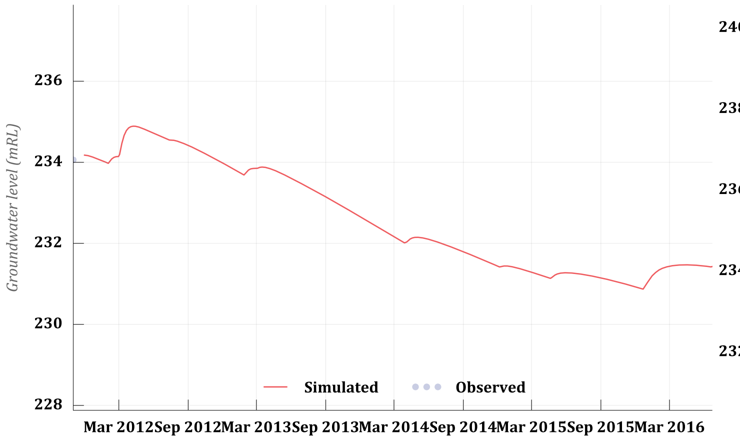

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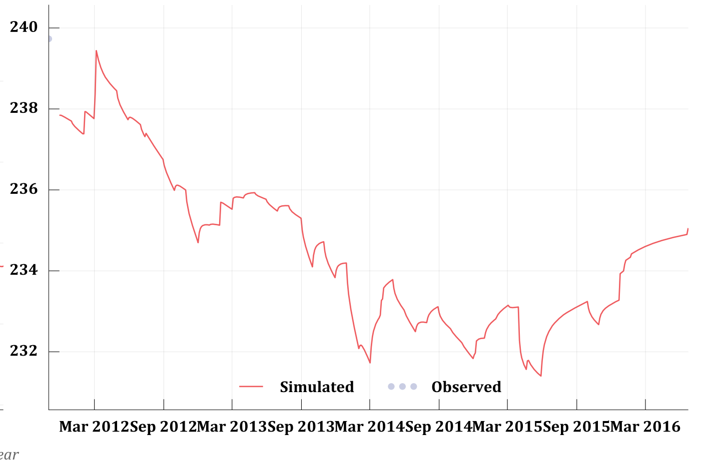

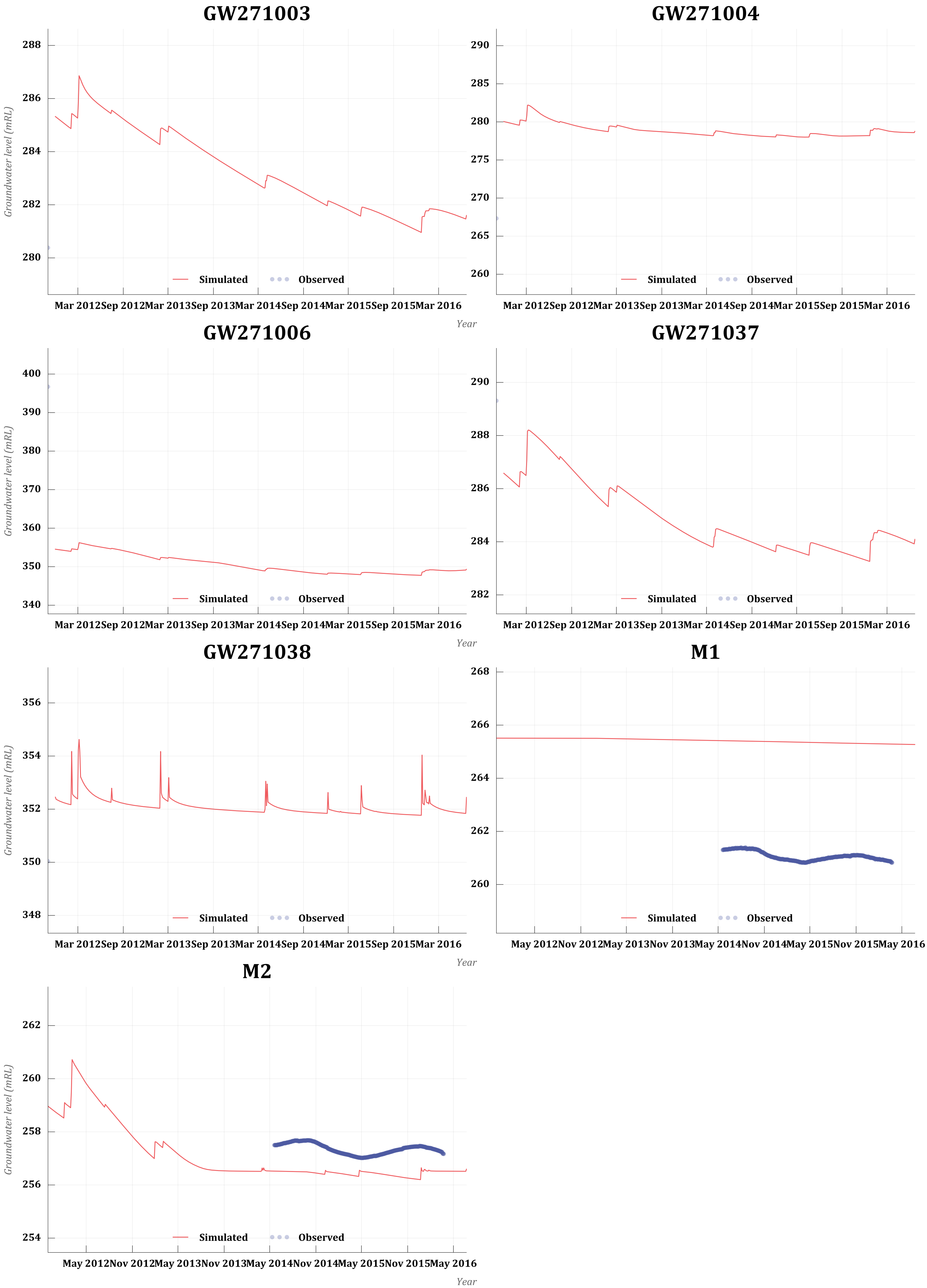

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Year
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Mar 2012
Sep 2012
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350
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Sep 2015
Mar 2016
Year
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M2
Groundwater level (mRL)
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Simulated
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May 2016
Year

APPENDIX B

BYLONG COAL PROJECT – WATER BALANCE MODELLING FOR REVISED GROUNDWATER INFLOWS

wrm water + environment

Memorandum

Date	17 August 2016	Pages	8
Attention	Nathan Cooper		
Company	Hansen Bailey Pty Ltd		
Job No.	0887-03-D2		
Subject	Bylong Coal Project – Water Balance Modelling for Revised Groundwater Inflows (Base Case)		

Dear Nathan,

Overview

We understand that AGE have revised the Bylong Coal Project EIS groundwater model to address comments from DP&E Peer Reviewer and DPI-Water, and incorporate monitoring data obtained from the alluvial aquifer. The groundwater inflows to the Bylong Project have been revised from the remodelling.

As requested, we have updated the OPSIM water balance model of the Bylong Coal Project (WRM, 2015) with the revised RTS 2 Upstream Weighting (Mean) groundwater inflows. This model run with revised groundwater inflows is referred as the Base Case. This report provides the adopted groundwater inflows and the water balance results of the Base Case.

Adopted revised groundwater inflows

Revised groundwater inflows to the open cut and underground mining areas over the life of the Project were adopted based on estimates provided by AGE (email dated 12/07/2016). The adopted groundwater inflow rates for water balance modelling are the average for each representative phase, as shown in Table 1 and Table 2. While there is variation in annual inflows within each phase (particularly for the PY11+ phase), the total volumes over each phase are consistent. All other parameters are assumed to be unchanged from the previous assessment (WRM, 2015).

For comparison, we have included the previously adopted groundwater inflows in Table 1 and Table 2. A summary of the change in groundwater inflows is as follows:

- Groundwater inflows for the open cut have decreased significantly, by up to 220 ML/a (depending on the mine phase).
- Groundwater inflows to the underground have increased significantly, by up to 430 ML/a (depending on the mine phase).
- Overall, the combined revised Base Case groundwater inflows to the Bylong Project are higher than those previously adopted.

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PO Box 10703, Brisbane Adelaide St Qld 4000

Tel 07 3225 0200
wrmwater.com.au

ABN 96 107 404 544

Table 1 - Adopted groundwater inflows - open cut

Project Year	Total groundwater intercepted (ML/a)	Representative mine phase (ML/a)	Avg. groundwater intercepted for each representative mine phase (ML/a)	Previously adopted groundwater inflows (ML/a)
PY2	23	PY3	32	128 (PY3 to PY4)
PY3	28			
PY4	44			
PY5	68	PY5	66	165
PY6	64			
PY7	62	PY7	59	217
PY8	56			
PY9	49	PY9	25	245
PY10	0			
PY11	0	PY11+	0	47

Table 2 - Adopted groundwater inflows - underground

Project Year	Total groundwater intercepted (ML/a)	Representative mine phase (ML/a)	Avg. groundwater intercepted for each representative mine phase (ML/a)	Previously adopted groundwater inflows (ML/a)
PY3	0	PY3	0	1
PY4	0			
PY5	0	PY5	0	9
PY6	0			
PY7	0	PY7	3	13
PY8	6			
PY9	604	PY9	889	1,148
PY10	1,173			
PY11	1,446	Post open-cut mining	1,558	1,125
PY12	1,268			
PY13	1,049			
PY14	804			
PY15	704			
PY16	508			
PY17	526			
PY18	1,030			
PY19	1,744			
PY20	1,943			
PY21	2,371			
PY22	2,099			
PY23	2,869			
PY24	2,241			
PY25	2,766			

Water balance model results

Interpretation of results

In interpreting the results of the water balance assessment, it should be noted that the results provide a statistical analysis of the water management system's performance over the 23 years of mine life, based on 102 realisations with different climatic sequences.

The model results are presented as a probability of exceedance. For example, the 10th percentile represents 10% probability of exceedance and the 90th percentile results represent 90% probability of exceedance. There is an 80% chance that the result will lie between the 10th and 90th percentile traces.

Whether a percentile trace corresponds to wet or dry conditions depends upon the parameter being considered. For site water storage, where the risk is that available storage capacity will be exceeded, the lower percentiles correspond to wet conditions. For example, there is only a small chance that the 1 percentile storage volume will be exceeded, which would correspond to wet conditions. For off-site site water supply volumes, where the risk is that insufficient water will be available, there is only a small chance that more than the 1 percentile water supply volume would be required. This would correspond to dry climatic conditions.

It is important to note that a percentile trace shows the likelihood of a particular value on each day, and does not represent continuous results from a single model realisation. For example, the 50th percentile trace does not represent the model time series for median climatic conditions.

A single realisation can also be selected from the 102 modelled realisations in order to show the water management system's actual performance (not a statistical representation) for a particular climate sequence. This approach has been used for calculation of the overall water balance.

Borefield water supply requirements

Figure 1 shows the total annual modelled demand for water from groundwater bores over the Project period. A summary of bore water requirements for different periods of operation is shown in Table 4. The results indicate that the annual bore water requirements are generally highest during the period of open cut only operations (PY3 to PY6). The bore water requirements significantly reduce once underground operations commence due to the increase in groundwater inflows to the mine workings and reduction in site water demands.

During the period of open cut only operations and combined mining operations, the annual bore water requirements are generally higher than those requirements reported in the previous EIS assessment (WRM, 2015). This is due to the reduced groundwater inflows to the open cut pits.

The revised groundwater inflows to the underground only operations are considerably higher than the previous EIS assessment (WRM, 2015). As a result the annual bore water requirements are lower for the Base Case compared to the previous EIS assessment (WRM, 2015). The annual bore water requirements will reduce to zero from PY12, as high groundwater inflows to the underground operations are predicted.

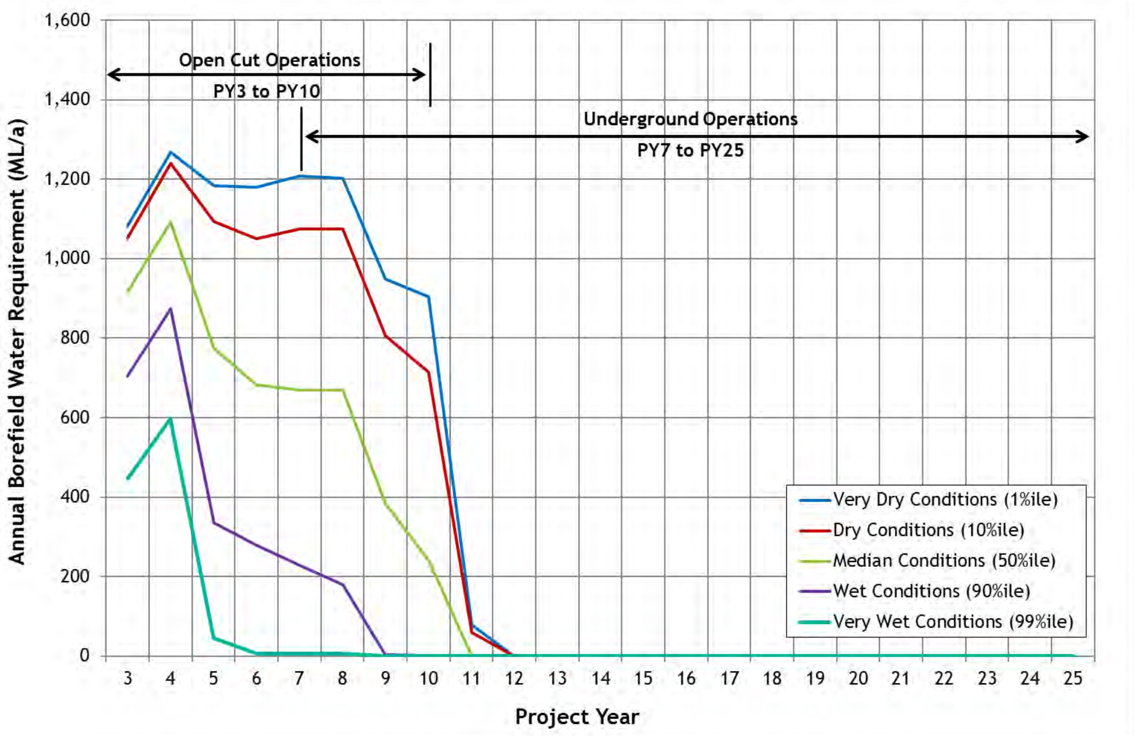


Figure 1 - Annual borefield water requirements

Table 4 - Summary of bore water requirements

Operational period	Bore Water Supply		
	1% chance of requiring more than	10% chance of requiring more than	50% chance of requiring more than
Open cut only operations (PY3 to PY6)	1,082 to 1,268 ML/a	1,050 to 1,239 ML/a	683 to 1,091 ML/a
Combined mining operations (PY7 to PY10)	904 to 1,208 ML/a	715 to 1,074 ML/a	241 to 670 ML/a
Underground only operations (PY11 to PY25)	0 to 79 ML/a	0 to 60 ML/a	0 ML/a

Mining pit inundation characteristics

The water management system is configured to pump excess water to the mining areas when the capacity of the water management system is exceeded. The stored water is available for re-use as required.

Figure 2 shows the percentile plots of stored inventory in the combined mining pits over the Project life. The results indicate the following:

- prior to the commencement of underground mining, there is a low risk of significant volumes of water accumulating in the open cut mining areas. Once underground operations commence, groundwater inflows increase significantly. This results in the potential for water accumulating within the mining voids if wet climatic conditions occur.

- during open cut only operations (PY3 to PY6), there is a:
  - 1% chance of storing more than 860 ML in the open cut mining areas;
  - 10% chance of storing more than 350 ML in the open cut mining areas; and
  - 50% chance that the mining area will not be required to store significant volumes of water.
- during combined and underground only operations (PY7 to PY25), there is a:
  - 1% chance of storing more than 6,940 ML in the Eastern open cut mining area;
  - 10% chance of storing more than 6,420 ML in the Eastern open cut mining area; and
  - 50% chance of storing up to 5,540 ML in the Eastern open cut mining area.

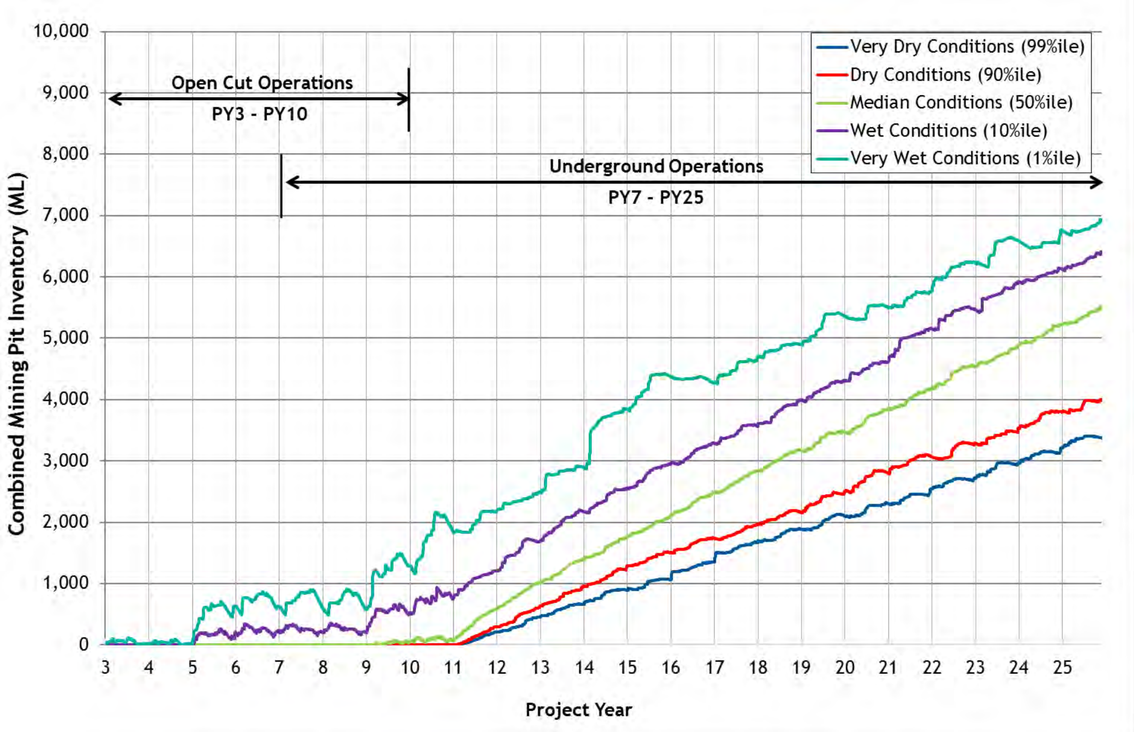


Figure 2 - Combined open cut mining area stored inventory

The model results show that during open cut only operations, the accumulation of water with the open cut mining operations is manageable. However once underground operations commence, the additional groundwater inflows and reduction in site water demands increase the risk of water accumulation. This water will need to be managed within the water management system, most likely within one or both of the Eastern Open Cut voids.

Once open cut operations cease around PY 10, the capacity of the Eastern Void will be around 18,800 ML, providing capacity to store any excess water if climatic conditions are very wet. In addition, it is proposed that the Eastern Void will be used to store rejects. The total bulk volume of rejects during underground operations is estimated to be around 11,700 ML. This would indicate approximately 7,000 ML of remaining capacity available within the Eastern Void to store excess mine water captured through surface runoff and groundwater inflows.

Under all climatic conditions, the revised water balance modelling indicates that a significant volume of excess mine water would be required to be stored in the Eastern Void. At the completion of mining, there is a 1% chance (very wet conditions) of storing up to 6,940 ML in the Eastern open cut mining area. This is close to the estimated capacity available within the Eastern Void to store excess mine water.

Note that our assessment has not considered the feasibility or geotechnical risk of storing up to 7 GL of water within the Eastern Void. These issues would generally be investigated in the post-approvals stage of the Project.

Uncontrolled offsite releases

The results of the site water balance modelling show that the site water management system can be operated to ensure with at least a 99% probability that no uncontrolled release of saline water over the Project life.

The only uncontrolled offsite releases will be from sediment dams during periods of rainfall above the relevant design criteria.

Overall water balance

Water balance results for one of the 102 modelled realisations is presented in Table 3, averaged over each phase of modelled mine life. The water balance results provided are those for the single realisation with inflows for median climatic conditions (as well as groundwater inflows) over the life of the Project. The results for this single realisation (Realisation 72) show inflows, outflows and overall water balance for each of the mine phases for a representative climate sequence. It should be recognised that the following items are subject to climatic variability:

- rainfall runoff;
- evaporation;
- bore water requirements; and
- site releases/spills.

The results in Table 3 show that, over the life of the Project:

- bore water supply is required in all phases, with the greatest amount required in PY3;
- the largest demand from the water management system is due to dust suppression;
- total mine water demand (including CHPP make-up, dust suppression, accommodation camp, OC/UG MIA usage, underground operations) supplied from the water management system ranges between approximately 1,317 ML/a and 1,942 ML/a, with the highest demand in PY 9+;
- no overflows from the mine water system occurred for this simulation; and
- the combined spill volume from the sediment dams is highest in PY 11+ (152 ML/a), and ranges between 0 ML/a and 51 ML/a for the remaining phases.

Note that the results presented in Table 3 are for a single realisation and will include wet and dry periods distributed throughout the mine life. Rainfall yield for each phase is affected by the variation in climatic conditions within the adopted climate sequence. For example, the high runoff yield indicated for PY 7 likely reflects a wet period during this part of the selected realisation.

The average annual water balance for Realisation 72 for PY3 to PY7 is generally similar to the previous EIS assessment (WRM, 2015). The change in storage volumes for PY9 is 130 ML/a lower, due to the lower groundwater inflows to the underground operations at PY9. The change in storage volumes for PY11+ is 316 ML/a higher, due to the significantly higher groundwater inflows to the underground operations for the post open-cut periods.

Table 3 - Average annual water balance - for “median” Realisation 72 (1960 to 1982)

	PY 3	PY 5	PY 7	PY 9	PY11+
Water Inputs (ML/a)					
Rainfall/runoff yield	218	733	959	541	787
Groundwater inflows	32	66	62	912	1,558
Raw (bore) water intake	1,023	573	708	335	1
GROSS WATER INPUTS	**1,273**	**1,372**	**1,728**	**1,788**	**2,345**
Water Outputs (ML/a)					
Evaporation from storages	46	48	66	67	440
Dam overflows (offsite)					
Mine water system	0	0	0	0	0
Sedimentation system	0	0	51	0	152
Total	0	0	51	0	152
CHPP demand (loss)	249	266	269	395	366
Dust suppression	1,041	1,041	1,041	1,041	500
WAF	22	22	0	0	0
OC MIA Dam usage	5	7	7	1	0
UG MIA Dam usage	0	0	5	5	7
Underground operations Usage	0	0	50	500	500
GROSS WATER OUTPUTS	**1,363**	**1,384**	**1,488**	**2,009**	**1,965**
Water Balance (ML/a)					
Change in storage volumes	-90	-12	240	-221	380

Memorandum

For and on behalf of

WRM Water & Environment Pty Ltd

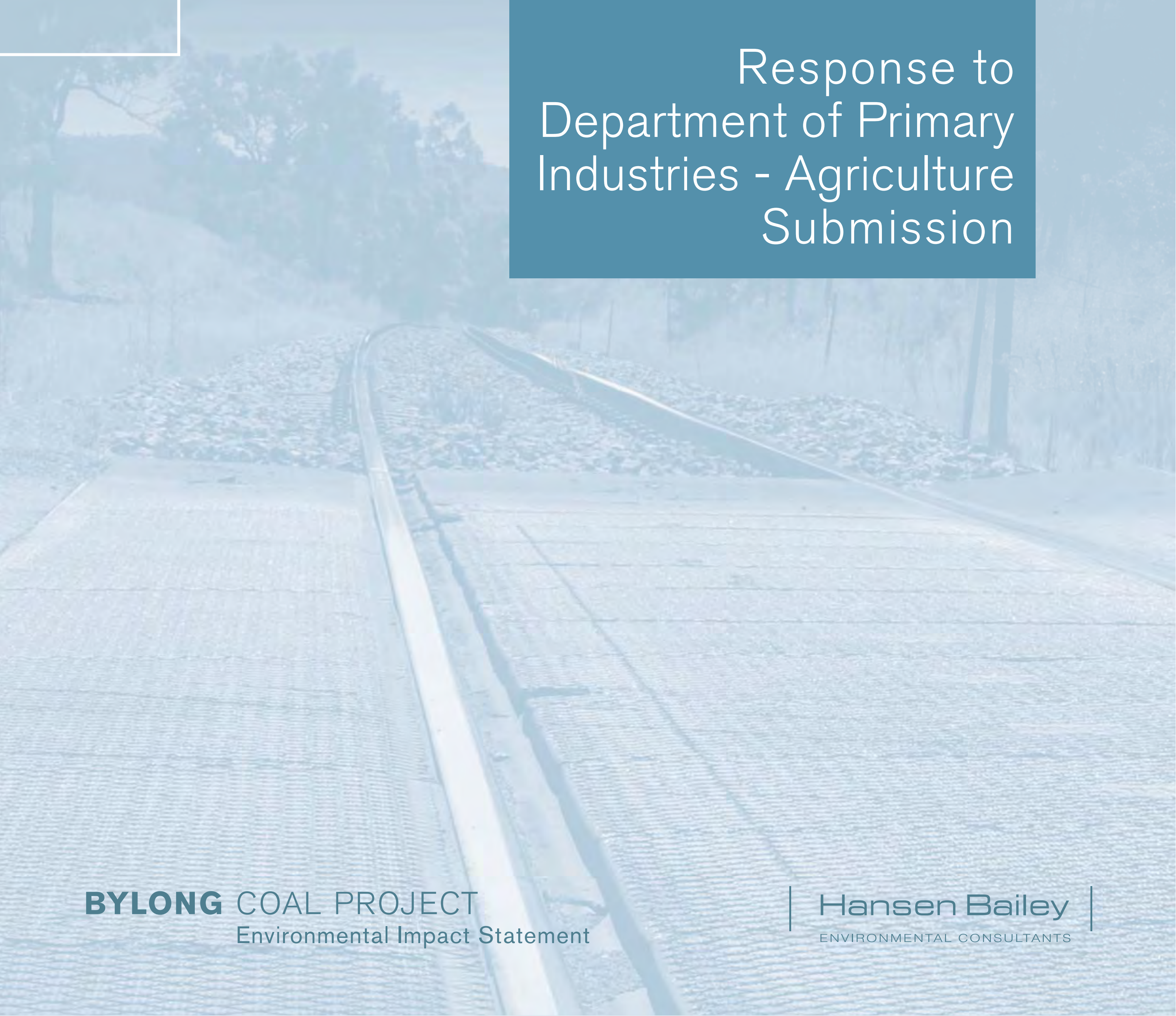
Matthew Briody
Senior Engineer

References:

WRM, 2015 *'Bylong Coal Project – Surface Water and Flooding Impact Assessment'* Report prepared for Hansen Bailey Pty Ltd by WRM Water & Environment Pty Ltd, Report No. 0887-01-P3, 18 June 2016.

K

Response to Department of Primary Industries - Agriculture Submission



17 August 2016

Team Leader
Planning Assessment
22-33 Bridge Street
SYDNEY NSW 2000

Attention: Mr Stephen O'Donoghue

Dear Steve,

Bylong Coal Project EIS
Response to NSW Department of Primary Industries – Agriculture Submission, Dated 12 May 2016

1. INTRODUCTION

The '*Bylong Coal Project Environmental Impact Statement*' (EIS) which supported Development Application (SSD) 14_6367 for the Bylong Coal Project (the Project) was placed on public exhibition between 23 September and 6 November 2015.

Hansen Bailey prepared the document '*Bylong Coal Project Response to Submissions*' (RTS) dated 23 March 2016 to address comments received from agencies and other stakeholders during the exhibition of the EIS. The RTS included responses to the NSW Department of Primary Industries – Agriculture (DPI–Agriculture) submission dated 11 November 2015 in relation to agriculture and soil matters. During the period of preparing the RTS, a meeting was held with DPI–Agriculture in Singleton on 1 March 2016 to clarify issues raised in its submission.

DPI-Agriculture has provided a further letter dated 12 May 2016 to the Department of Planning and Environment (DP&E) over various matters addressed in previous correspondence. This letter has been prepared to respond to DPI–Agriculture comments within DPI's letter of the 12 May 2016. It should be noted that a separate response will be provided to the comments made by DPI–Water, which are also included in DPI's letter of 12 May 2016.

Two meetings have been held with DPI-Agriculture (on 27 May 2016 and the 17 June 2016) to discuss the submission dated 12 May 2016. These meetings are further discussed within this letter.

During the meeting held on 17 June 2016, DPI-Agriculture requested that a draft response to their issues be provided to ensure that the final response addresses all of DPI-Agriculture's concerns. A draft response to the submission dated 12 May 2016 was provided to DPI-Agriculture and DP&E on 5 July 2016. DPI-Agriculture subsequently provided letter dated 20 July 2016 (see **Appendix A**) which provides further clarifications on their concerns which have been addressed within this response.

2. RESPONSE TO DPI–AGRICULTURE SUBMISSION

2.1 BSAL IMPACTS

Issue 1 – Updated BSAL Impacts

Additional soil investigations have identified more BSAL than originally described in the EIS. However the areas within the Project Disturbance Footprint (PDF) are unclear. To clarify the areas outstanding in the response to submission DPI Agriculture request the Proponent provide maps as outlined in table 1 and populate table 2 to show area details of BSAL within the Project.

Table 1: Maps to be supplied and their required information

Map 1	***Map 2***
- Project Boundary *- Project Disturbance Boundary* *- Subsidence areas* *- Offset areas* *- Revised BSAL*	*- Project Boundary* *- Project Disturbance Boundary* *- Subsidence areas* *- Offset areas* *- Areas of continued agricultural production during the project* *- Retained BSAL in Offset areas and access to these* *- Rehabilitated BSAL*

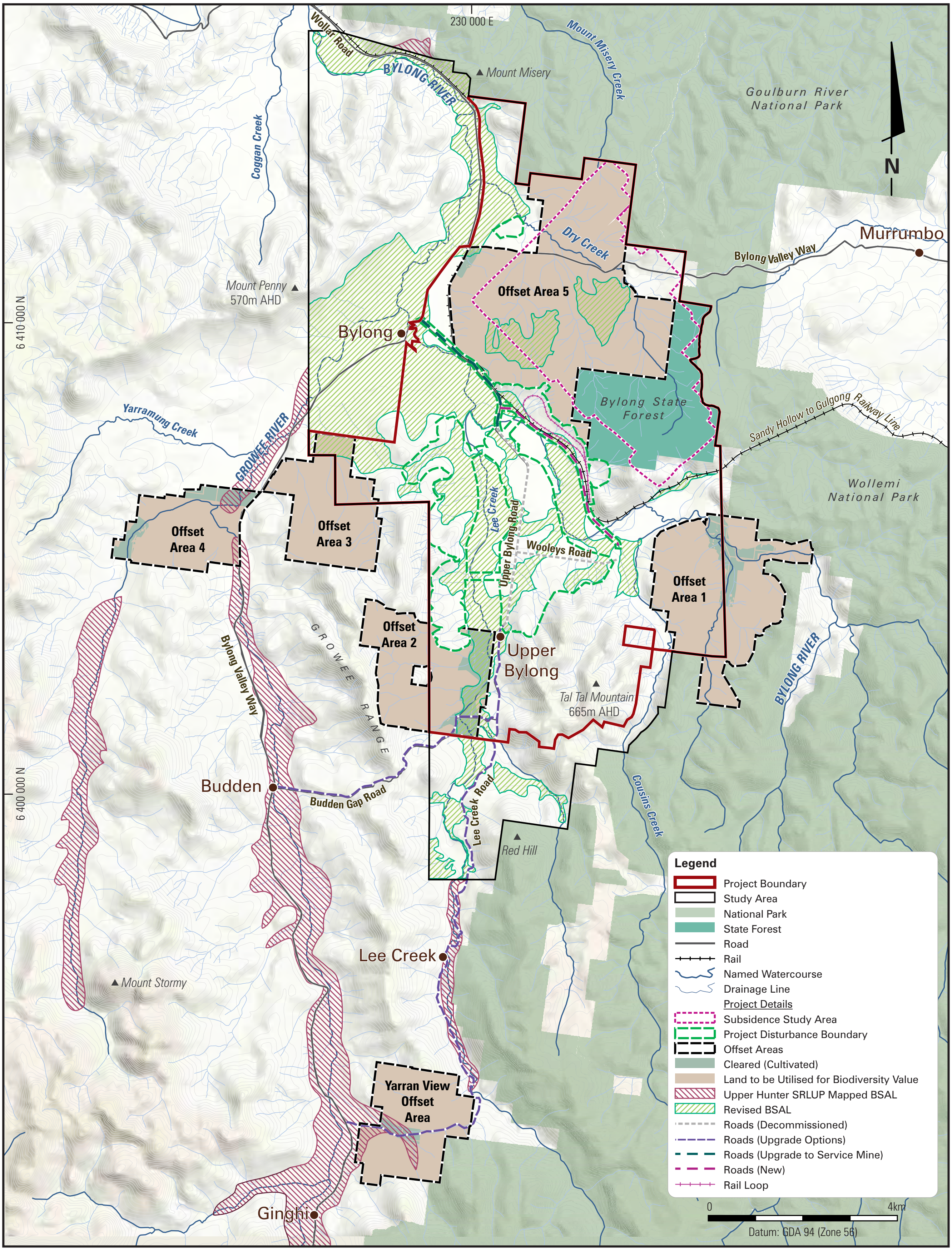
Table 2: BSAL areas to be confirmed

Table reproduced below (see Table 1) including requested areas.

DPI Agriculture requests a meeting with KEPCO and their associated representatives for the EIS to clarify the issues outstanding and provide a more efficient review of the Project.

Response

Figure 1 to **Figure 3** illustrate the information requested in DPI–Agriculture's Table 1. It is noted that **Figure 3** has been included in a separate figure to the requested DPI-Agriculture Map 2 for clarity. **Figure 4** to **Figure 9** provides further detail to the future land use and associated management for each of the Biodiversity Offset Areas as requested during a meeting with DPI-Agriculture on 17 June 2016. **Table 1** provides the information requested in DPI–Agriculture's Table 3. **Table 2** provides a breakdown of the Land and Soil Capability (LSC) of the verified Biophysical Strategic Agricultural Land (BSAL) which is to be impacted by the Project.



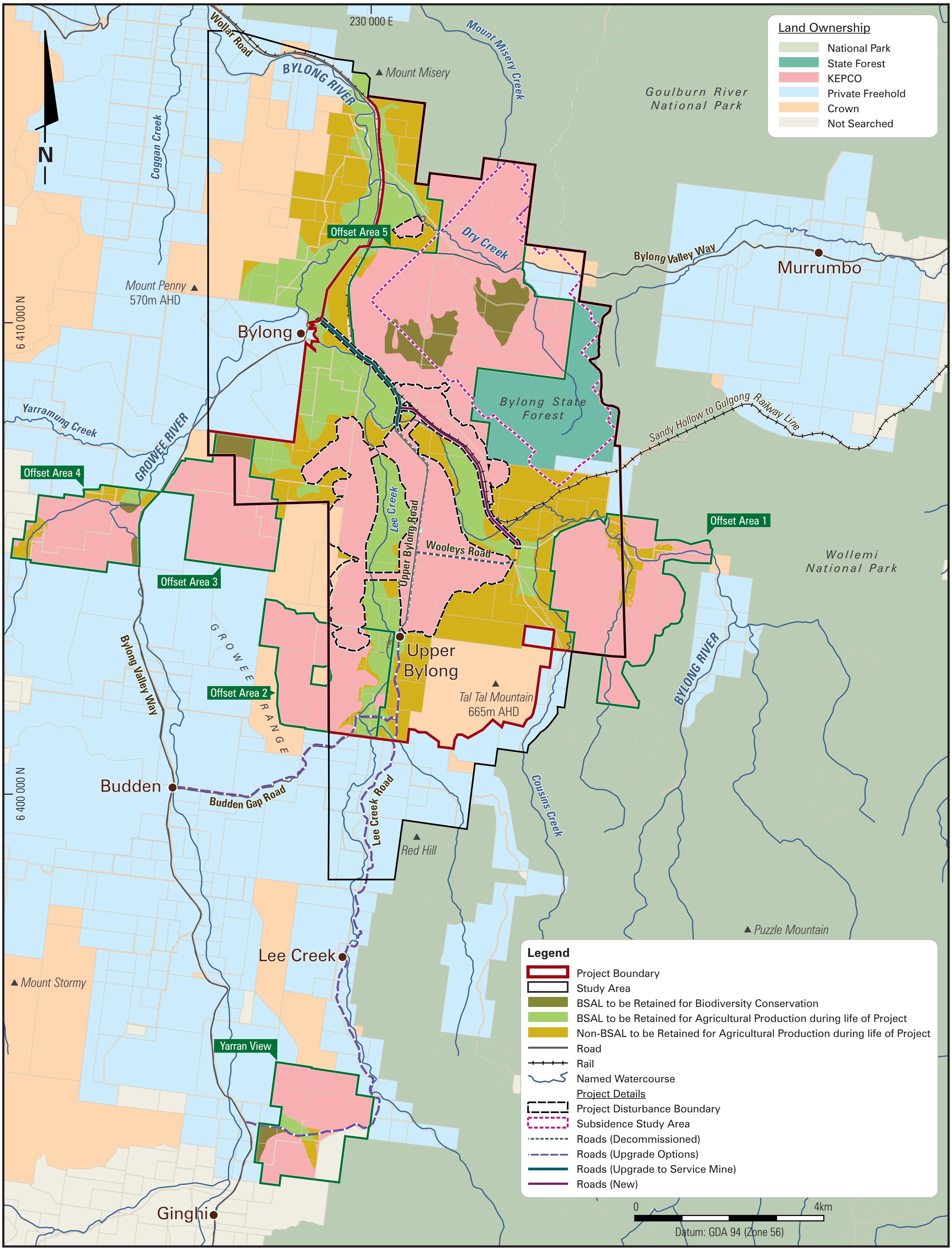
HB BYLONG RTS Post Works 1538 F2 Areas of Continued Agricultural Production 04 07 2016

BYLONG COAL PROJECT

KEPCO BYLONG AUSTRALIA | Hansen Bailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

DPI-Agriculture Map 1

FIGURE 1

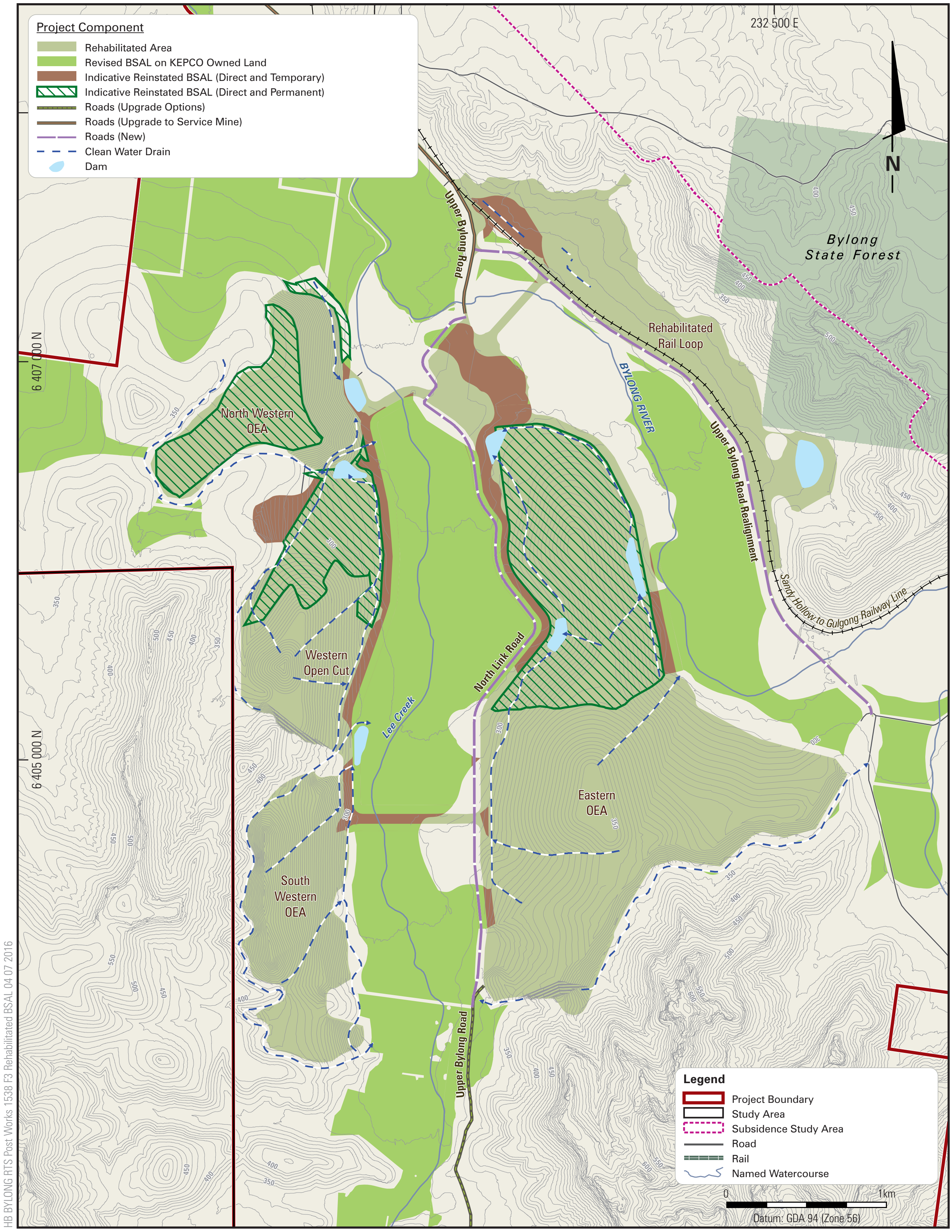


HB BYLONG RTS Post Works 1538 F2 Areas of Continued Agricultural Production 04 07 2016

BYLONG COAL PROJECT

DPI-Agriculture Map 2

FIGURE 2

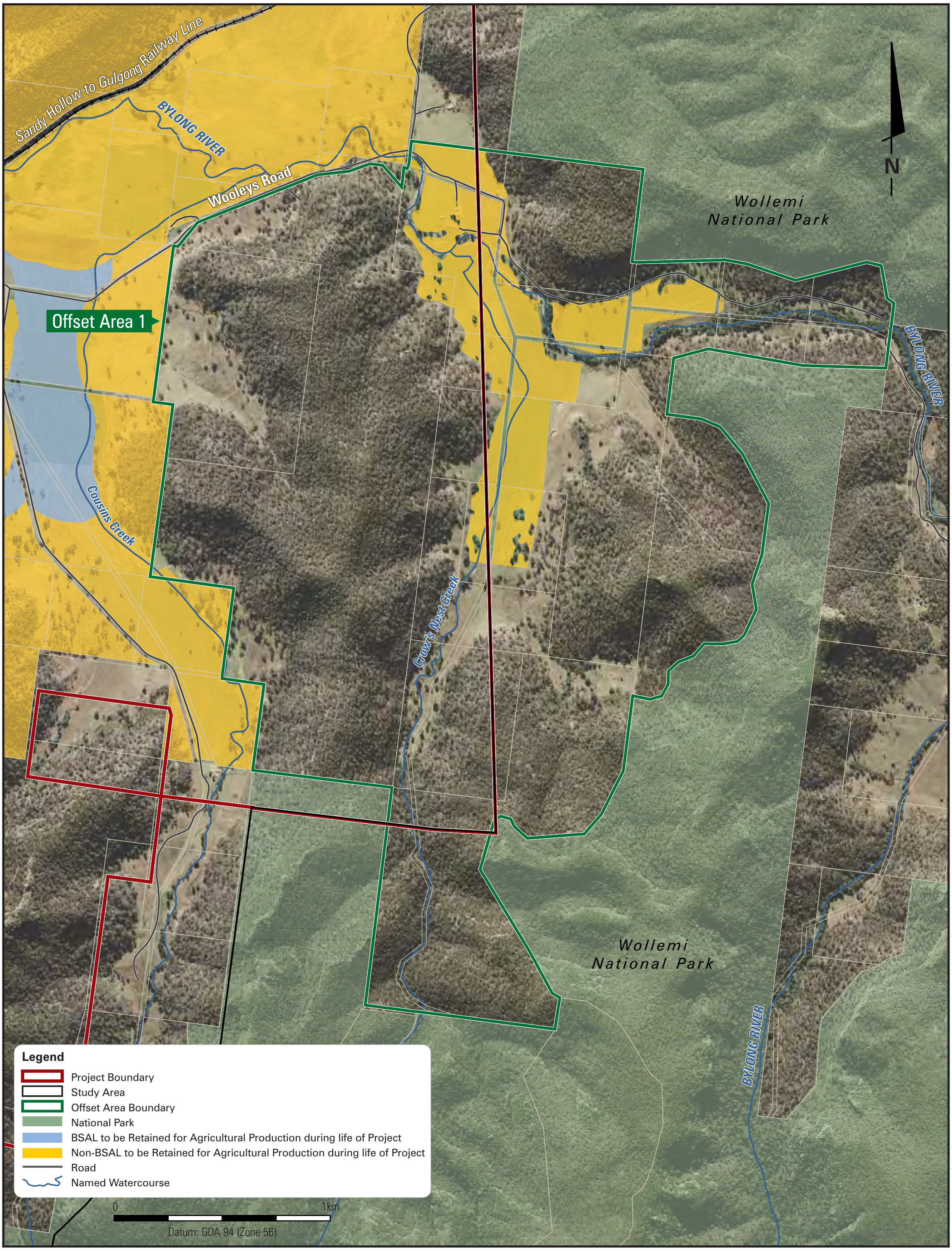


BYLONG COAL PROJECT

KEPCO KOREA ELECTRIC POWER CORPORATION BYLONG AUSTRALIA | HansenBailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

DPI-Agriculture Map 3

FIGURE 3



HB BYLONG RTS Post Works 1538 F4 Ongoing Land Use in Offset Area 1 04 07 2016

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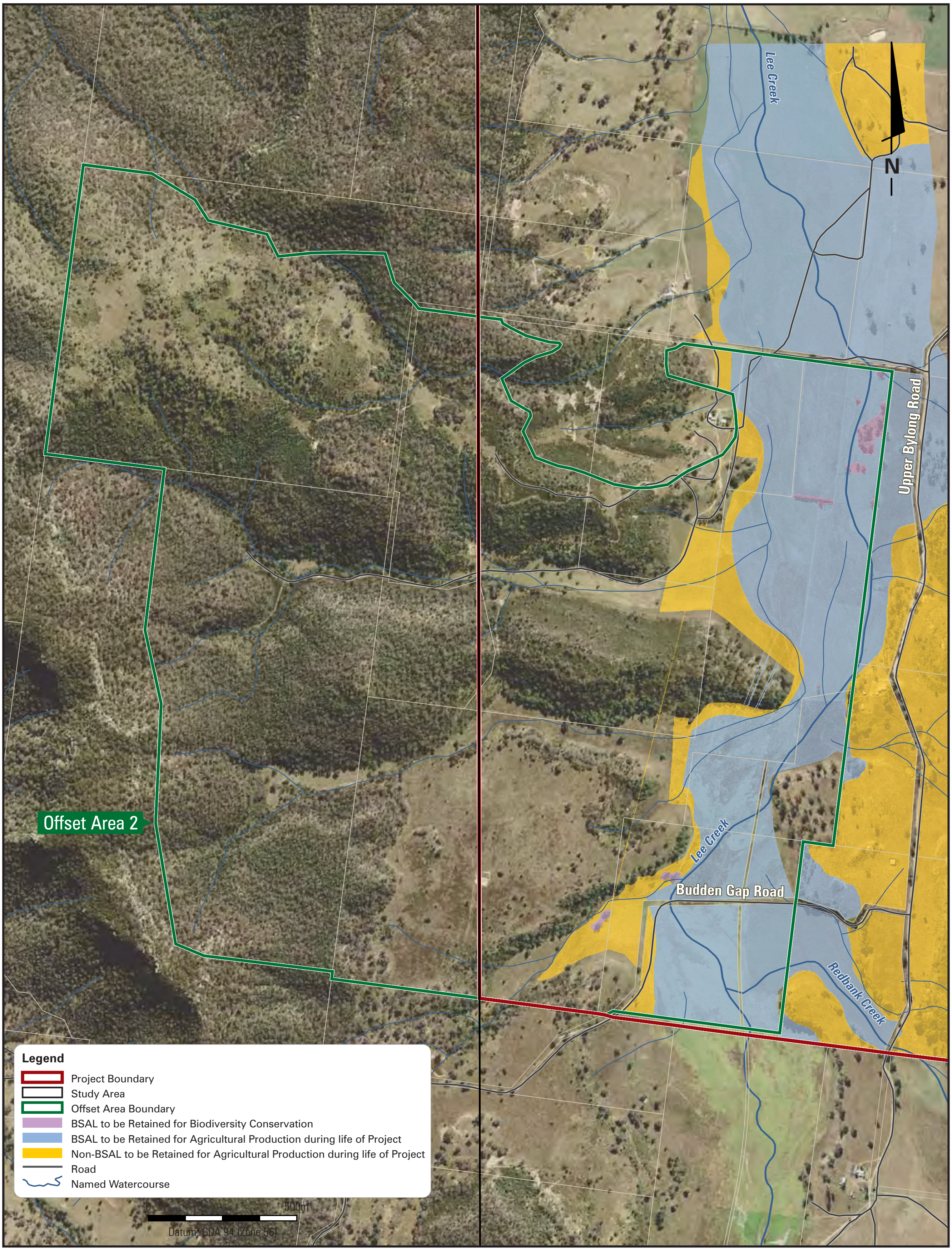
KEPCO BYLONG AUSTRALIA | Hansen Bailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

Ongoing Land Use in Offset Area 1

FIGURE 4



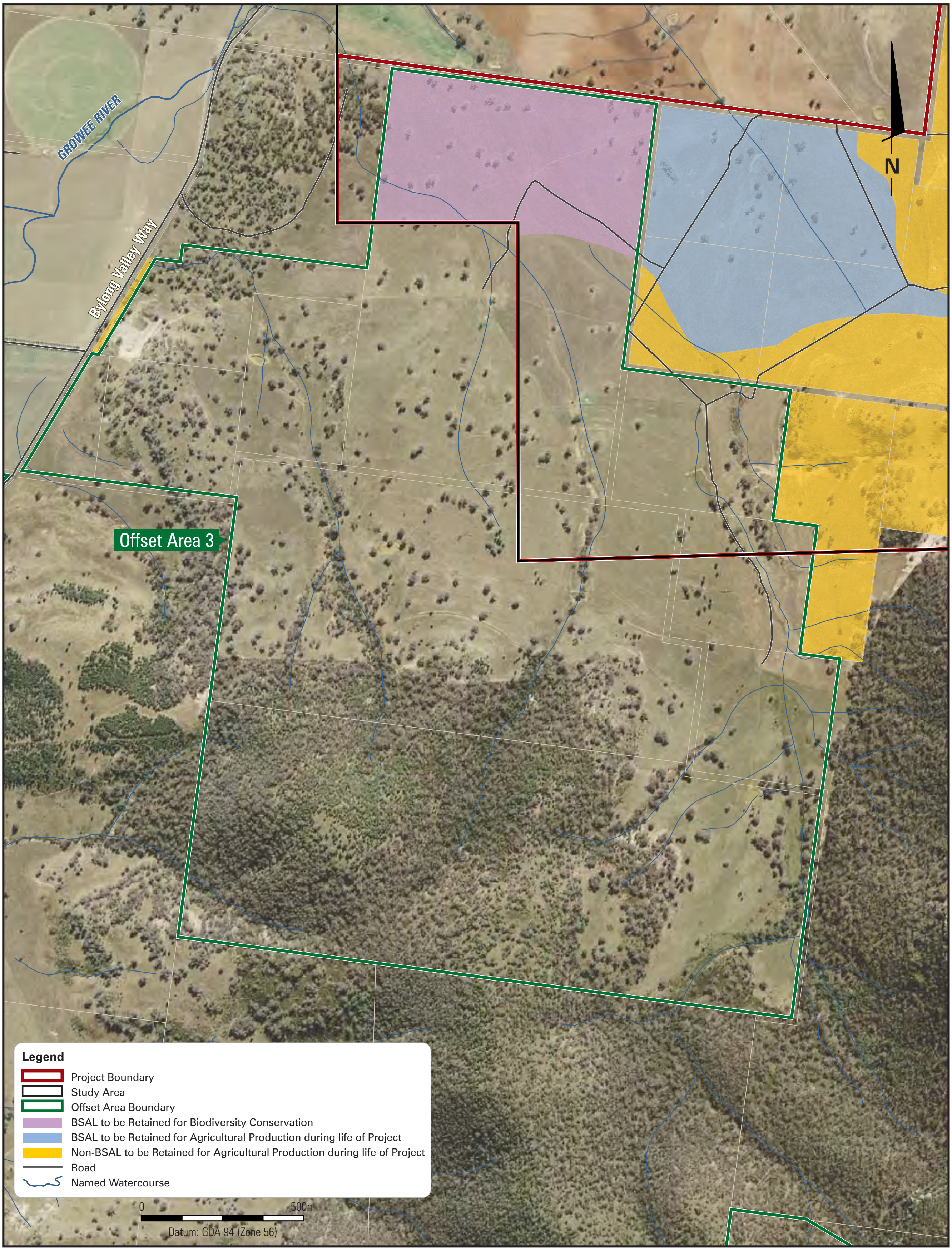
HB BYLONG RTS Post Works 1538 F5 Ongoing Land Use in Offset Area 2 04 07 2016

BYLONG COAL PROJECT

KEPCO Korea Electric Power Corporation BYLONG AUSTRALIA | Hansen Bailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

Ongoing Land Use in Offset Area 2

FIGURE 5



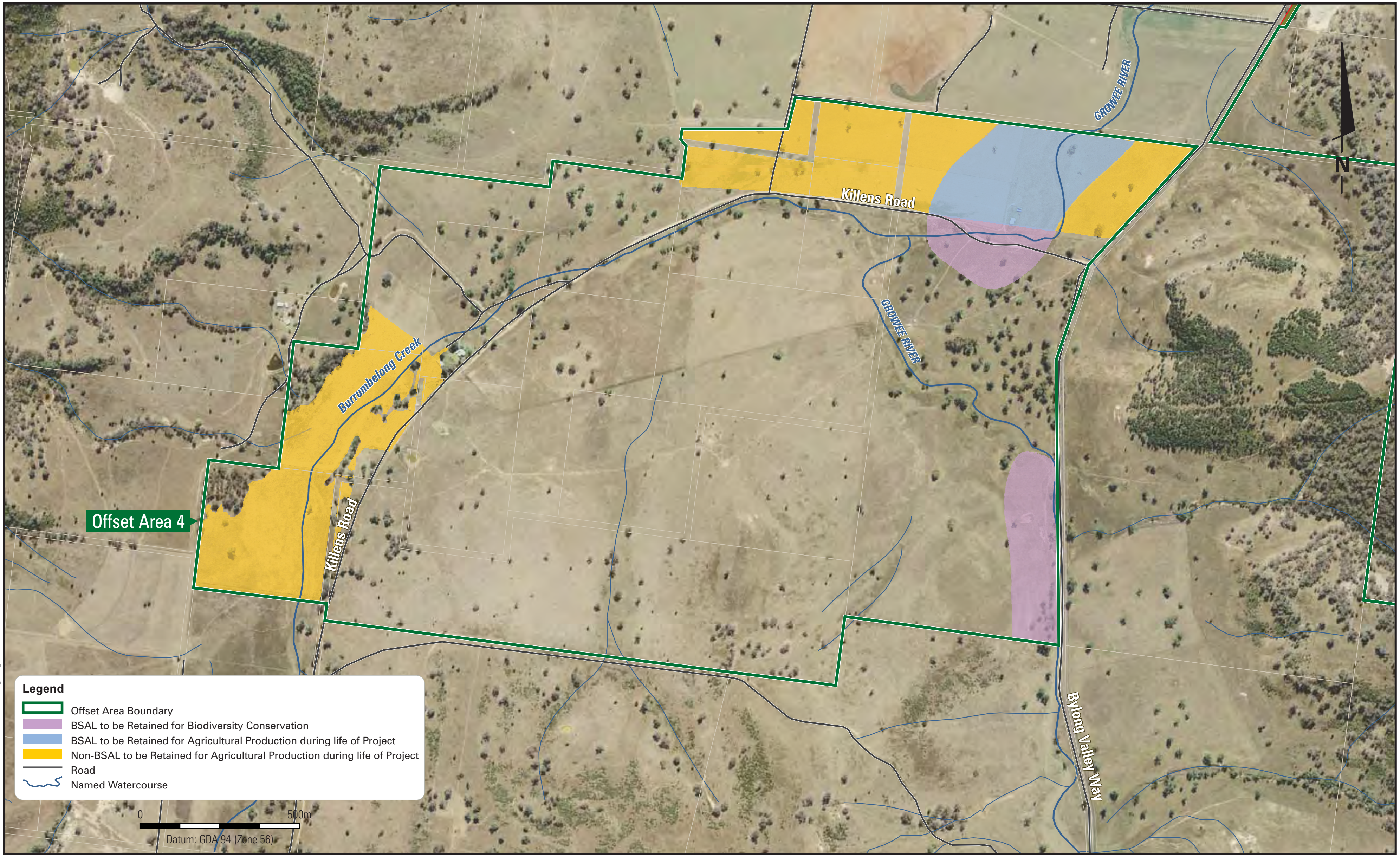
HB BYLONG RTS Post Works 1538 F8 Ongoing Land Use in Offset Area 3 04 07 2016

BYLONG COAL PROJECT

KEPCO KOREA ELECTRIC POWER CORPORATION BYLONG AUSTRALIA | Hansen Bailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

Ongoing Land Use in Offset Area 3

FIGURE 6

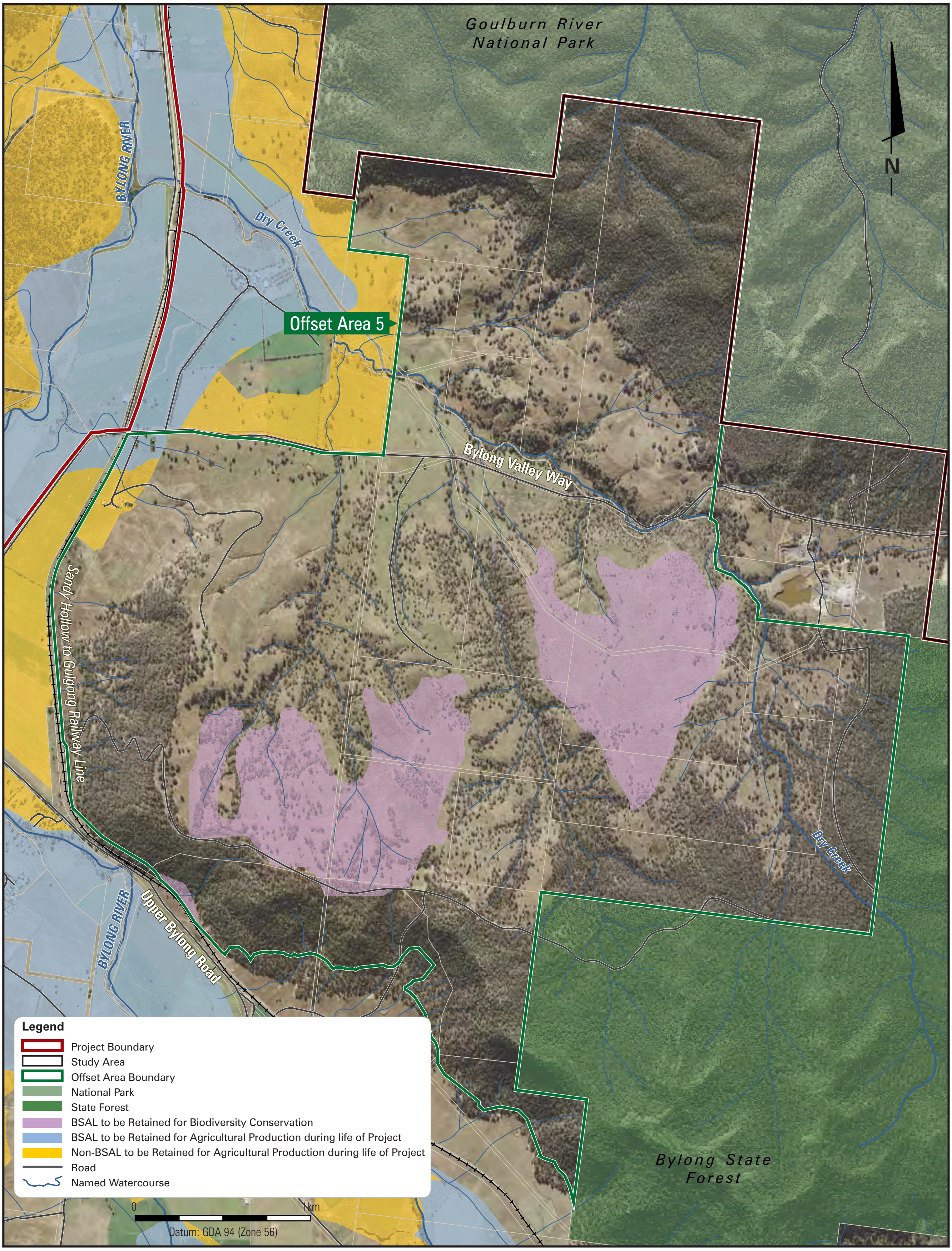


HB BYLONG RTS Post Works 1538 F8 Ongoing Land Use in Offset Area 4 01 07 2016

BYLONG COAL PROJECT

Ongoing Land Use in Offset Area 4

FIGURE 7



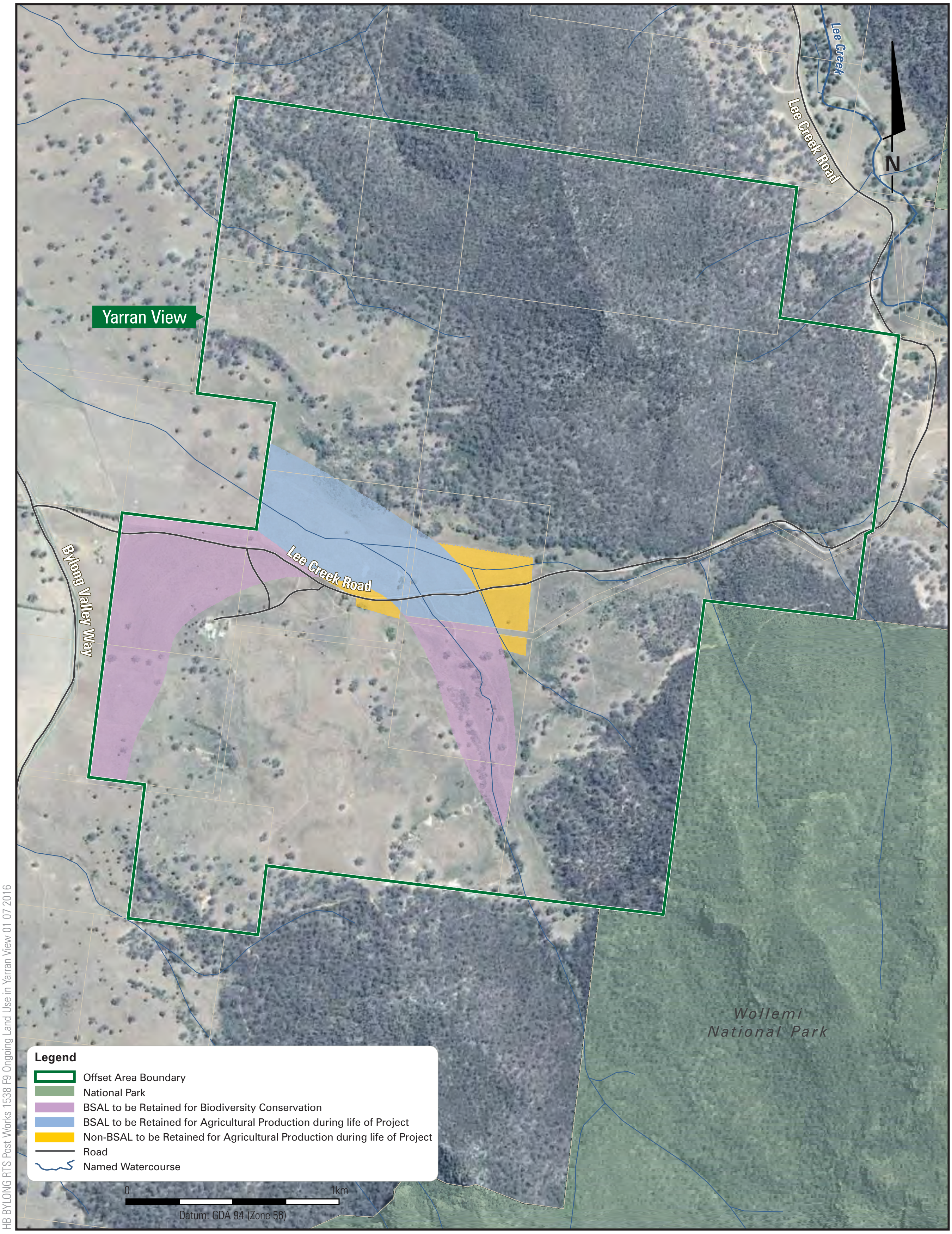
HB BYLONG RTS Post Works 1538 F8 Ongoing Land Use in Offset Area 5 04 07 2016

BYLONG COAL PROJECT

KEPCO BYLONG AUSTRALIA | Hansen Bailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

Ongoing Land Use in Offset Area 5

FIGURE 8



BYLONG COAL PROJECT

KEPCO BYLONG AUSTRALIA | Hansen Bailey ENVIRONMENTAL CONSULTANTS | WorleyParsons resources & energy

Ongoing Land Use in Offset Area Yarran View

FIGURE 9

Table 1
DPI-Agriculture's BSAL Areas to be Confirmed

Item		Area (ha)
BSAL in Study Area		3,031.1
BSAL in Project Boundary		1,711
BSAL in Project Disturbance Footprint	Project Disturbance Boundary	423.1
	Subsidence Study Area	171.8*
	Total BSAL in Project Disturbance Footprint	***594.9***
KEPCO Land**	BSAL to be available for Agricultural Production (includes BSAL on cultivated land within BOS both within and outside Study Area)	1,384
	Non-BSAL to be available for Agricultural Production (includes non-BSAL on cultivated land within BOS both within and outside Study Area)	1,720
	Total KEPCO land to be available for Agricultural Production (within and outside Study Area)	***3,104***
	BSAL (within the Project Boundary and the portions of BOS in Project Boundary) to be available for Agricultural Production	978.2
	BSAL (within the Project Boundary and the portions of BOS in Project Boundary) Containing CEEC and Other Biodiversity Attributes (excluding land within Offset Area 5 affected due to subsidence)	116.1
	BSAL (within the Project Boundary and portion of Offset Area 5 affected due to subsidence) Containing CEEC and Other Biodiversity Attributes	171.8*
	Non-BSAL (within Project Boundary) to be available for Agricultural Production during life of Project	1,319
	Total KEPCO land (within Project Boundary) to be available for Agricultural Production	***2,180***
BSAL Impacted	Indirect and Temporary (i.e. impacted due to subsidence)	171.8*
	Direct and Temporary	103.6
	Direct and Permanent	319.5 (63% Class 4 and above)
	Total BSAL in Project Disturbance Footprint	***594.9***
Biodiversity Offset Areas	BSAL to be available for Agriculture	119.6
	BSAL Containing CEEC and Other Biodiversity Attributes	287.8
	Total BSAL within BOS	***407.4***
Total BSAL Rehabilitated (Direct and Temporary & Direct and Permanent)		423.1

**BSAL not to be removed.*
*** There are minor discrepancies between BSAL on KEPCO Land and other defined areas due to the exclusion of various cadastral elements between lots.*

Table 2
LSC Class BSAL within Project Disturbance Footprint

LSC Class of BSAL areas in Project Disturbance Footprint	Indirect and Temporary (ha)	Direct and Temporary (ha)	Direct and Permanent (ha)	Totals (ha)	% of total BSAL to be Directly and Permanently Impacted
Class 3	171.75	35.72	118.68	326.15	37.14
Class 4	0	4.99	50.81	55.80	15.90
Class 5	0	57.28	132.7	189.98	41.53
Class 6	0	5.56	17.33	22.89	5.42
Totals	171.75	103.55	319.52	594.82	100

As illustrated in **Table 2** above, it must be stressed that 63% of the BSAL to be directly and permanently disturbed is Class 4 to Class 6 and would therefore not suitable for cultivation.

As suggested in DPI-Agriculture's submission, a phone conference was held with DPI-Agriculture, WorleyParsons, Hansen Bailey and SLR on 26 May 2016 to discuss DPI-Agriculture's comments and clarify the methodology required to enable the relevant work to proceed.

KEPCO and its representatives met with DPI–Agriculture on 17 June 2016 to present the work undertaken in response to its submission and discuss the proposed responses to each issue raised. The feedback received from both meetings with DPI-Agriculture and its subsequent letter dated 20 July 2016 has been included within this letter response.

To clarify DPI-Agriculture's query in letter dated 20 July 2016, the areas of land within the Biodiversity Offset Areas for the Project that contain cleared or cultivated land are not proposed to be contained within the biodiversity conservation mechanism. Accordingly these areas of land will be available for agriculture or other land uses during the life of the Project and beyond.

Issue 2 – BSAL within Subsidence Study Area

> *As a result of an extra 154 ha of BSAL being identified – with 319.52 now being confirmed within the direct and permanent loss area, the proponent should clarify whether their earlier commitment to reinstating more than 227 ha of BSAL will accommodate this recently identified additional BSAL.*

Response

The commitment made in the EIS to re-instate 227 ha of BSAL within post mining rehabilitation was based on the identification of 206.3 ha of BSAL within the direct and permanent disturbance footprint.

In response to DPI–Agriculture's submission on the EIS, an additional 191 soil samples from 49 sites within the proposed disturbance footprint were tested and assessed against the BSAL criteria. The testing and subsequent re-mapping of BSAL resulted in the identification of an additional 113.2 ha of BSAL within the direct and permanent impact domain and a further 40.9 ha of BSAL within the direct and temporary impact domain. The revised total area of BSAL within the direct and permanent impact domain is 319.5 ha.

KEPCO is committed to re-instating all BSAL to be directly and permanently impacted. Similarly KEPCO is committed to re-instating the BSAL to be directly and permanently impacted by the Project. This will result in the creation of 423.1 ha of BSAL rehabilitation which satisfies the BSAL criteria as illustrated in **Table 1**.

The proposed location of the rehabilitated BSAL remains generally consistent with the 227 ha proposed in the EIS, with the remaining 92.5 ha to be located within the rehabilitated Eastern Open Cut Mining Area post mining. The direct and temporary impacted BSAL will be re-instated within the same areas as they were impacted. **Figure 3** illustrates the proposed location of the rehabilitated BSAL.

As explained within Section 7.1.4 of the EIS, the consequences of the subsidence related impacts will be remediated. The monitoring of subsidence related impacts and the associated remediation of these impacts will be described within the Extraction Plans. The associated remediation measures will be consistent with the intentions of the BOS for the Project. Accordingly, the indirect and temporary impacts predicted for the BSAL within the Subsidence Study Area will be rehabilitated according to the proposed biodiversity conservation land use for these areas.

Issue 3 – Repair of BSAL Impacts

> *Further detail on BSAL reinstatement required. Simple replacement of soil is insufficient to meet the pre disturbed condition.*

Response

As mentioned above, a phone conference was held between DPI-Agriculture, Hansen Bailey, WorleyParsons and SLR representatives on 26 May 2016 to discuss DPI-Agriculture's submission on the RTS, with specific attention on this issue. It was confirmed during the phone conference that this comment was in relation to the impacts to BSAL within the "direct and temporary" impact domain. SLR and Hansen Bailey advised that the proposed BSAL rehabilitation within the "direct and temporary" impact domain would be subject to the same rigorous methodology as detailed in the EIS for BSAL rehabilitation in the "direct and permanent" impact domain. This methodology is further described within EIS Appendix W Sections 6 to 10, and RTS Section 4.4.6 BSAL Rehabilitation. Furthermore, the criteria for confirming the successful rehabilitation of BSAL will be applied to all BSAL rehabilitation to be undertaken for the Project.

Issue 4 – BSAL Loss to Mining

> *Available information does not identify location of BSAL to provide adequate comment. DPI Agriculture requests maps as requested in table 1.*

Response

Figure 1, **Figure 2** and **Figure 3** provide the information requested in DPI–Agriculture's Table 1.

Issue 5 – Adjoining BSAL

> *Location and detail of buffers applied not supplied.*

Response

Drawing files illustrating these buffers were provided to DPI–Agriculture on 15 June 2016.

Section 4.4.2.5 of the RTS states "*that since the Gateway Application process, the Project Disturbance Boundary was modified and included an additional standoff from the proposed disturbance. This buffer was included within the EIS in response to the Gateway Panel's recommendations."*

The offset between the Project Disturbance Boundary from the indicative locations of the open cut mining areas, overburden emplacement areas and associated infrastructure is the buffer referred to by DPI-Agriculture. The buffer applied to the disturbance areas is demonstrated in the Project Layout Figure (Figure 18 of the EIS). It is noted that the assessments and appropriate mitigation measures for the EIS have considered the impacts from the disturbance within the Project Disturbance Boundary.

Issue 5 – Loss of Farming Land

> *Acknowledge that some BSAL will still be impacted by the land use change. There is a need to consider how the 109 ha of BSAL deemed of less ecological value due to clearing or previous agricultural use will be able to be accessed for agriculture in this situation.*

Response

Noted.

As illustrated in **Figure 1** to **Figure 9**, areas of cleared and cultivated lands within the offset properties which are to be available for agricultural use are located adjacent to existing farm tracks, access roads or public roads. Approximately 119.6 ha of this cleared and cultivated land within the offset areas is verified BSAL or SRLUP mapped BSAL.

Access arrangements to these areas of BSAL will be maintained for the purpose of supporting the potential ongoing agricultural use of this KEPCO owned land. KEPCO will detail within its Farm Management Plan the logistics for managing the areas of land within the offset properties which provide limited value to biodiversity conservation which will be available for agricultural or other land uses.

2.2 CRITICAL INDUSTRY CLUSTER IMPACTS

Issue 1 – Equine CIC

> *There are no current operating horse studs in the Project Area because KEPCO has bought the land. Prior to this it was a successful enterprise. This demonstrates that the land is suitable for the equine industry and the rehabilitation objectives should reflect this.*

Response

Whilst the Bylong Valley has historically been used for thoroughbred breeding and other horse enterprises, the available information provides that this industry experienced the vast majority of its decline within the Valley prior to KEPCO land purchases. This is discussed at length in Section 5.20.3.1 of the RTS.

There has been a history of various agricultural pursuits within the Project Boundary including grazing enterprises, areas of historical cropping and horse breeding businesses. The businesses operating immediately prior to KEPCO purchasing the land within the surrounding locality included cattle grazing, some fodder cropping, improved pastures, irrigated cropping and equine related activities (Australian stock horse and pleasure and performance horses).

KEPCO purchased a single property in 2012 which was being utilised for thoroughbred horse breeding. The operations on this property were subsequently relocated to Denman, closer to the centre of the mapped Equine CIC. Further, it must be stressed that this property is not proposed to be directly disturbed by mining activities and remains available for agricultural pursuits, including thoroughbred horse breeding.

Part of the area within the Project Boundary has since been mapped by the NSW Government as Equine CIC, which indicates that at the time of mapping there was valuable horse related industries operating in the area. Horse studs in NSW vary greatly in the biophysical features of the land upon which they are located. There are no set requirements for natural features, landforms or soil types, which dictate whether an area is suited to establishing an equine enterprise. However, typically the landscapes which provide better quality grazing have been traditionally chosen to develop equine businesses upon.

The aim of the rehabilitation within the Project Boundary is to establish a range of soil profiles and land capabilities, including the creation of BSAL, and LSC classes 3, 4, 5, 6 and 7. The target outcomes for these land capabilities reflect the use of this land to various agricultural enterprises, in particular cropping and grazing. These target outcomes are congruent with the potential for the rehabilitated land to be used as an equine grazing business, and therefore the use of the land for such an endeavour will not be limited by the physical landform, soil profile or pasture established on site.

Issue 2 – Losses of Equine CIC

> *A permanent change in landuse to Biodiversity Offsets should be considered and assessed as a permanent loss of equine CIC, unless the biodiversity offsets are implemented in a way that does not have a negative impact on CIC values.*

Response

Section 4.4.3.1 of the RTS explains that the lucerne hay sales from within the Study Area could feed approximately 2.7% of the Upper Hunter thoroughbred horse population (assuming all lucerne produced is sold within the Equine CIC). This is not a significant quantum relative to the total annual hay production from the Upper Hunter, of 57,851 tonnes, which represents only 3% of the NSW total annual yield (DPI, 2013). As such, the Project will not impact on the Upper Hunter Equine CIC.

It is acknowledged that the land that is used for biodiversity offsets will not be available for future equine use, either for horse husbandry or growing of forage/fodder for use by equine enterprises within the Upper Hunter Equine CIC.

The inclusion of land mapped as Equine CIC within the Biodiversity Offset Strategy for the Project will change the land use from general agricultural grazing activities to a biodiversity conservation land use.

It must be noted however that the land in question contains CEEC and other biodiversity attributes and would not be able to be extensively modified for the purposes of equine related activities. As such, it cannot be asserted that setting this land aside for further ecological enhancement and a higher level of biodiversity protection will have any impact on the Equine CIC.

In summary, given that this land is currently not utilised for equine related purposes and unlikely to in the future due to the significance of its ecological values, it is determined that there will be:

- No impact on the viability of the Equine CIC as a whole;
- No product or service provided to the Equine CIC to which the Equine CIC can value add to; and
- No impact on the reputation or market ability of the industries of the Upper Hunter Equine CIC.

Issue 3 – Water Impacts

> *The Company has indicated that it will seek to mitigate the impacts of reduced water availability to agriculture by carrying out its own irrigated agriculture. However, given that this is not a core activity of the project, and the proponent has also indicated that during periods of low water availability irrigated agricultural activities will be scaled back, the proponent should provide an indication of the likely agricultural impacts of these activities ceasing, alternatively commit within its statement of commitments to a minimum level of irrigated agriculture.*

Response

It should be noted that under normal operational and rainfall conditions, no required reduction to the agricultural water supply on KEPCO owned properties not to be utilised for the Project has been identified. Water modelling for the EIS and RTS has identified that only in the extreme and unlikely scenario that a period of extreme dry coincides with the highest project demand phase (Project Year 3) would a reduction in agricultural water on KEPCO owned properties be required.

As discussed in Section 5.9.14 of the RTS, KEPCO has purchased various landholdings within the Bylong River valley that have contained associated water licenses. The most recent allocation announcements for the Hunter catchment have allowed license holders to extract 100% of their license entitlement. KEPCO will operate within the constraints of its license entitlements and any annual reductions in allocations, including any future changes to account for climate change.

KEPCO will prepare and implement a Water Management Plan (WMP) for the Project. The WMP will detail a program to monitor water yields and availability from the borefield, particularly if there are extended periods of drought. The WMP will detail trigger levels to monitor against and if reached, the Project will implement a contingency plan to ensure the supply of water to the Project. The contingency plan may include the expansion of the borefield (subject to approval), temporarily reducing KEPCO's agricultural activities (and temporarily transferring associated water entitlements to the Project) and in a worst case scenario, progressively adjusting mining-related activities (such as coal processing) to match the available water supplies.

KEPCO undertakes to retain its non-mine agricultural land in productive agriculture. In this regard, KEPCO has employed a full time Farm Manager to operate its non-mine agricultural land in productive agriculture throughout the life of the Project. As noted within Section 7.16.6 of the EIS, a Farm Management Plan will be prepared and implemented by the Farm Manager. The Farm Management Plan will provide direction in relation to the productive management of all areas of non-mine agricultural land owned by KEPCO.

KEPCO also undertakes to make available for agricultural use any water shares it holds not required for operation of the Project (including a risk buffer). However, it is not reasonable for KEPCO to make a binding undertaking to keep a certain area under irrigated agriculture due to the time frame of the Project (25 years) and the potential for changes in agricultural economics and technology during this period.

The best agricultural use for the water not required for the mine operation may be for an agricultural enterprise not currently operating within the area that can source water from the Bylong Water Source but may become established in the future. This could include enterprises such as a horticultural project or a controlled environment agricultural project.

A key aspect of the establishment of Water Sharing Plans was that water would be used for its highest level of economic return. KEPCO giving an undertaking to keep a certain area of land under its management under current agricultural practices would be counter to the aim of the Water Sharing Plans.

Issue 4 – Biodiversity Offsets Impacts

> *The ability of the cleared/cultivated land to be continued to be used for agriculture is noted. It is recognised that some BSAL land that has high biodiversity value will be removed from agriculture. As noted in our response to 4.4.2.6 consideration of the practicality of access and suitability of these sites to undertake an agricultural activity requires attention.*
>
> *Some of the lightly timbered/vegetated BSAL in the Offset area can be used for high quality grazing. DPI Agriculture recommends that consideration be given to excising the BSAL within the Offset that is used for this agricultural production, including the necessary additional shelter zones of more heavily timbered areas for animal welfare.*

Response

Figure 2 to **Figure 9** shows BSAL areas within the Biodiversity Offset Areas and areas which will continue to be available for agricultural production. **Figure 2** illustrates the areas of BSAL within the offset properties which will be utilised for biodiversity conservation purposes (i.e. 287.8 ha). The ongoing agricultural use of BSAL areas within the Biodiversity Offset areas would conflict with the desired biodiversity outcomes for the Project's offset strategy.

As stated in Appendix J (Ecological Impact Assessment) of the EIS, the Biodiversity Offset Areas will be managed overtime, to reinstate landscapes of Box Gum Woodland Critically Endangered Ecological Community (CEEC).

Part of this process which will be described within the Biodiversity Offsets Management Plan will initially involve grazing to control weeds within these areas. Over time, this grazing shall be progressively reduced as weed control becomes less of a management issue within these re-establishing landscapes.

Eventually grazing shall be removed from these offset lands in perpetuity. These restricted grazing activities on land within the biodiversity offset areas as specified under the Biodiversity Offsets Management Plan will also be consistently considered within KEPCO's Farm Management Plan.

The BSAL within Offset Areas 3 and 4 to be retained for biodiversity conservation purposes comprises native grassland vegetation communities with scattered box trees. There are also pockets of White Box and Yellow Box Woodland vegetation communities within these Offset Areas. The objective of retaining these areas of native grassland (including areas of BSAL) is to promote the natural regeneration of the critically endangered communities which occurred prior to clearing for agricultural land use.

The BSAL to be retained for biodiversity conservation within Offset Area 5 is predominantly covered with Yellow Box Woodland and Derived Native Grassland vegetation which conforms to the White Box Yellow Box Blakely's Red Gum Grassy Woodland and Derided Native Grassland (Box Gum Woodland) community. Box Gum Woodland is listed as a CEEC under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The objective of retaining the BSAL within Offset Area 5 for biodiversity conservation purposes is to improve the condition of the Box Gum Woodland and to promote the natural regeneration of surrounding native grassland areas to woodland. It should be noted that the areas of Box Gum Woodland occurring on the BSAL would not legally (without relevant approvals) be able to be cleared for agricultural practices due to their Commonwealth listing under the EPBC Act.

The areas of land within the offset properties which are to be available for agricultural production will be managed under KEPCO's Farm Management Plan.

Issue 5 – Biodiversity Offsets

> *DPI Agriculture welcomes the opportunity to input into the rehabilitation strategy and actively assist in dealing with BSAL and other agricultural land reestablishment outcomes.*

Response

Noted. KEPCO also supports DPI-Agriculture's desire to be involved in the establishment of trials on the rehabilitation as committed to within the EIS.

Issue 6 – Anthroposols

> *As part of the rehabilitation process, production parameters and the resilience of soil over time should form part of the basis to long term monitoring. This includes water holding capacity, bulk density, chemical and organic components to be monitored for. We acknowledge that other measurements may need to be considered as part of the process.*

Response

The aim of the rehabilitation strategy is to create soil profiles and landforms that satisfy specific land and soil capability (LSC) classes and in designated areas, soil profiles and landforms which satisfy BSAL criteria. Appendix W of the EIS provides further detail in relation to the process proposed in relation to the reinstatement of BSAL.

It is acknowledged that the specific BSAL criteria as detailed in the Interim Protocol for Site Verification of BSAL (2013) will form the criteria for achieving BSAL post mining, and these measurements will be taken over time to identify progress and highlight improvements that may be required. Furthermore, the criteria listed in the LSC Guideline (2012) will be used to create and evaluate the successful establishment of specific land and soil capability classes.

Other criteria such as those suggested by DPI-Agriculture in its submission, whilst not necessarily required for the identification of BSAL pre or post mining, may be used as a monitoring/management tool for assessing general rehabilitation progress. This could include resilience, function of soil processes, requirement for external inputs such as fertilisers to assist vegetation establishment, etc. However, these criteria will not be included in the closure criteria for verifying BSAL or LSC classes. It is noted that the 'inherent fertility' criteria relies on the identification of the Australian Soil Classification (ASC) of the insitu soil profile, and Anthroposols have been omitted from this list. Therefore, to satisfy the BSAL 'inherent fertility' criteria, KEPCO proposes to undertake the following:

- As per Section 7.14.4 of the EIS, KEPCO will maintain an inventory of the salvaged soil resources to ensure adequate topsoil and subsoil materials are available for planned rehabilitation activities. This inventory will record details such as the ASC, including specific layer details, of the original insitu soil profile. These salvaged soil materials will then be tracked to its final location in the rehabilitated landscape. This will provide an accurate map of the type of material used to build the final rehabilitated soil profile. The inference being that soils originally satisfying the 'inherent fertility' criteria are suitable to be used in constructing a BSAL soil profile on the rehabilitated landscape which is required to satisfy the 'inherent fertility' criteria.
- In addition, the use of a pseudo 'inherent fertility' measurement could be used to improve the confidence level that a rehabilitated BSAL soil profile satisfies the intent of the 'inherent fertility' criteria. The use of cation exchange capacity (CEC) is proposed for this purpose. The CEC was also included in the suite of analytes tested on all samples taken for analysis during the EIS and therefore there is background measurements for those soil profiles originally satisfying the 'inherent fertility' criteria for BSAL.

The proposed material tracking and pseudo measurements will be prepared in consultation with DPI–Agriculture as part of finalising the thresholds for the 'inherent fertility' criteria for Anthroposol BSAL within the Rehabilitation Management Plan for the Project.

Any further considerations or methodologies for the measuring the fertility of reinstated BSAL soils will be undertaken in close consultation with DPI-Agriculture for inclusion within the Rehabilitation Management Plan for the Project.

Issue 7 – Rehabilitation Trials – 1

> *Consultation with DPI Agriculture should commence as early as possible – on approval of the project and prior to construction phase.*

Response

Noted. KEPCO will continue to liaise with DPI-Agriculture with regard to the rehabilitation trial designs and monitoring methods to ensure the rehabilitation objectives in relation to re-establishing the post mining agricultural land use is undertaking in a robust and meaningful manner.

Issue 8 – Rehabilitation Trials – 2

> *DPI Agriculture believe a way forward is to ensure a consultative approach is made to developing a rehabilitation plan with sound monitoring processes that address these suggested methods.*
>
> *Consultation with DPI Agriculture should commence as early as possible – on approval of the project and prior to construction phase.*

Response

Noted. Response as per Issue 7.

Issue 9 – Rehabilitation Trials – 3

> *Detail on "as required" is requested*

Response

As explained within Appendix W of the EIS, Landform Function Analysis (LFA) is proposed to be utilised as a tool to monitor land stability and function in the period prior to it being available for the intended post mining land use. Once the LFA has demonstrated the stability of the landform, the use of the landform for intended post mining landuse will be implemented and monitored against the relevant criteria.

The proposed timing of a shift from LFA monitoring to detailed pasture monitoring will vary between areas of the rehabilitation, purely due to the systematic process of rehabilitating areas as they are practically available.

The term 'as required' refers to this timing, in that the intended post mining landuse will be implemented (for example pasture) and monitoring will be undertaken in areas designated for pasture. This will be undertaken at a time when the rehabilitation is deemed resilient and capable of handling the introduction of pasture and grazing regimes. Specific timing on the monitoring process will only be determined following assessment of the LFA and early pasture establishment monitoring results.

Specific closure criteria for the intended post mining landuse will be detailed within the Rehabilitation Management Plan for the Project.

Issue 10 – Trigger Action Response Plans

> *DPI considers that soil pH methodology and sodicity targets be part of the target tool kit and identified in the rehabilitation management plan.*
>
> *Detail on "as required" is requested.*

Response

The Rehabilitation Management Plan will be prepared following development consent approval in consultation with DPI–Agriculture, DP&E and approved by DRE prior to the commencement of construction of the Project.

The term *'as required'* was used in the RTS to reflect the requirement of the plan in accordance with conditions which may form part of a development consent for the Project.

Issue 11 – Soil Reinstatement Volume Calculations

> *Due to the new identified BSAL revised harvestable soil volumes is required. This is essential to ensure adequate supply for rehabilitation.*

Response

The EIS soil stripping assessment and soil balance (EIS Appendix V, Section 8.2) was undertaken based on one representative soil profile per soil map unit. Throughout the RTS process, a review of all soil profiles within the Project Disturbance Footprint were assessed against the BSAL criteria. Furthermore, archived samples from a total of 49 soil profiles were sent to the laboratory for analytical testing to provide a revised BSAL status of each point. This process allowed for an updated verified BSAL map to be produced, which was based on a higher intensity of survey and sample points within the Project Disturbance Footprint.

The increase in BSAL from 206.3 ha to 319.5 ha, was an increase of 113.2 ha, in the Direct and Permanent Impact domain. In the Direct and Temporary impact domain the mapped BSAL increased from 62.7 ha to 103.6 ha, an increase of 40.9 ha.

Therefore, the revised BSAL calculations required consideration of the rehabilitation of these areas of BSAL upon the post mining landform. Additionally a revised soil balance was required to ensure there was an adequate supply of suitable material to fulfil the revised rehabilitation outcomes.

The results of the additional soil sample testing in early 2016 were used to revise and recalculate the soil stripping plan. The additional samples have allowed for a higher intensity assessment of stripping depths within the Project Disturbance Area. A total of 75 laboratory tested soil profiles located within the Project Disturbance Area were assessed to provide the revised soil stripping plan (see **Figure 10** and **Figure 11**).

The criteria used to assess the soil profiles and the suitability of topsoil and subsoil layers for re-use in rehabilitation was based on the BSAL criteria and the LSC criteria. It must be noted that whilst an insitu soil profile may not have satisfied the BSAL criteria, the use of the topsoil and subsoil layers may be suitable in the creation of a BSAL soil profile (along with material from other profiles) provided the limiting factors to BSAL insitu are not transferrable to the rehabilitation.

The revised soil stripping depth mapping is considered a conservative estimate for the following reasons:

1. The EIS soil survey program used a hydraulic ram soil core push tube to extract the soil core and make the assessment, including taking samples from this material for laboratory analysis. The core tube was able to extract up to a maximum of 1.0 m to 1.1 m of soil material, therefore limiting the recommended subsoil stripping depth to 1 m. It is expected that within some soil types the useable subsoil may continue to greater depths than 1 m.

   Therefore, an assessment by an appropriately qualified soils specialist will be undertaken during stripping activities to identify the valuable subsoil beyond 1 m depth to be stripped and salvaged for use in rehabilitation activities.

2. Layers labelled as B/C horizon on the EIS Soil Survey field sheets were excluded from the recommended stripping depths. This material may be suitable to be included in a rehabilitated soil profile, especially at the soil/overburden interface. This material can also be assessed during stripping for rock content and other physical parameters that may dictate if the material is suitable for salvage and re-use in rehabilitation.

The results of the calculations made using all of the available soil profile data is shown in **Table 3**. The results show a minimum total of 6.5 Million cubic metres (MCM) of soil material is available for stripping, salvage and re-use in rehabilitation. There is a total of 2.3 MCM considered topsoil, and 4.2 MCM considered subsoil.

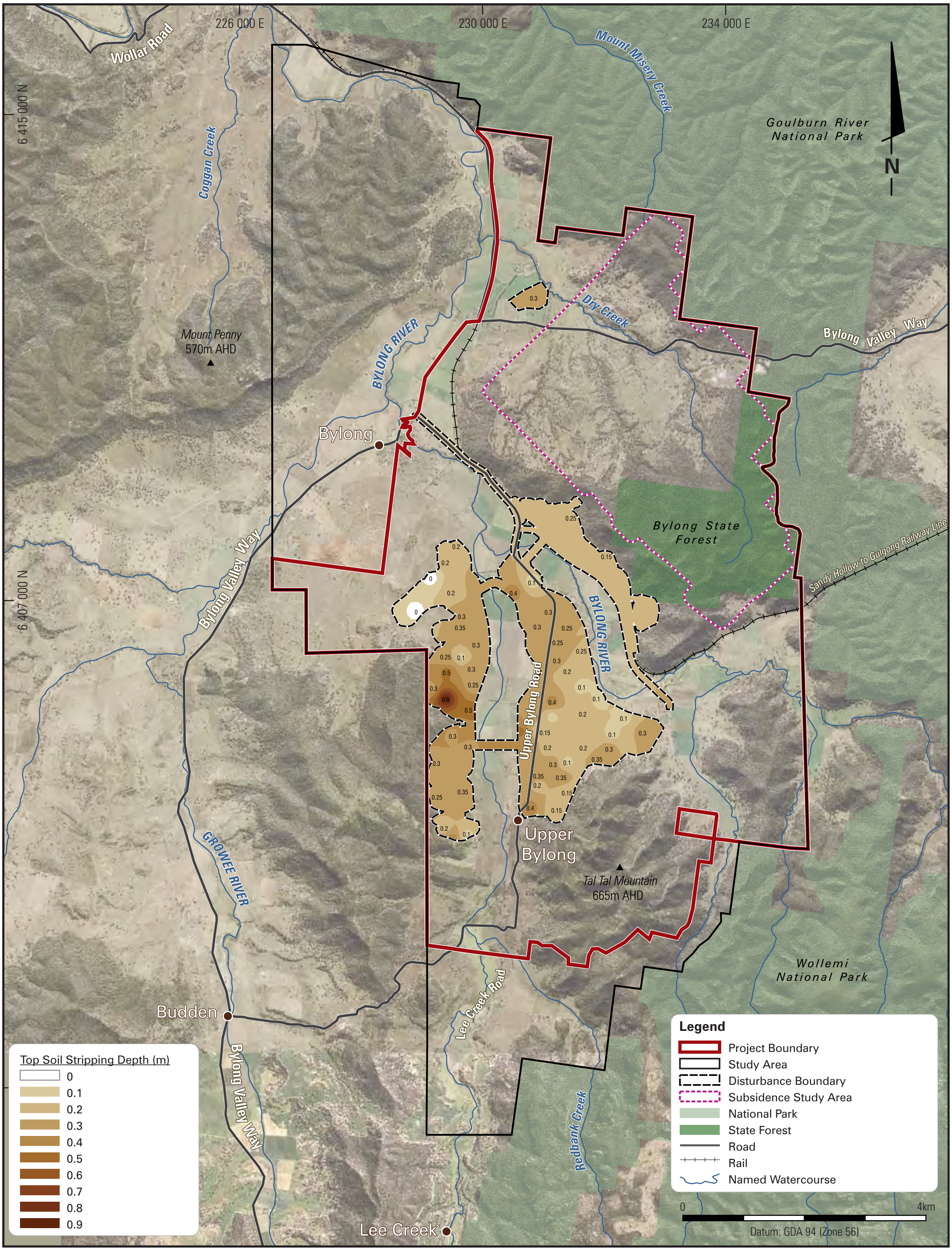
As stated in the EIS (Appendix V Section 8.3.2), the land within the Direct and Temporary impact domain will be returned to the pre mining BSAL/LSC status, replacing material that was stripped, in its original location. Therefore, the soil balance essentially allows for equal amounts of soil that is salvaged, to be replaced in the rehabilitation process.

The results of the soil balance calculations for the Direct and Permanent impact domain is provided in **Table 4**.

The total volume of soil required to reinstate the soil profiles and target land and soil capability classes is 5.4 MCM (1.49 MCM topsoil and 3.91 MCM subsoil). This demonstrates that there is a surplus of both topsoil and subsoil in the calculated soil balance. In total, there is 6.5 MCM of soil resource available and 5.4 MCM of soil resource required to achieve the target BSAL and LSC outcomes. Therefore, allowing for a 10% handling loss of the resource there is still a surplus of 0.45 MCM or 450,000 m^3.

Table 3
Revised Available Soil Volume (2016)

		EIS Soil Volumes			Revised Soil Volumes (2016)		
Domain	**Area (ha)**	**Topsoil (Primary media) (MCM)**	**Subsoil (Secondary media) (MCM)**	**Total (MCM)**	**Topsoil (Primary media) (MCM)**	**Subsoil (Secondary media) (MCM)**	**Total (MCM)**
Direct and Permanent (Ex Rail Loop)	831.2	1.65	3.86	5.51	2.13	3.85	5.98
Direct and Permanent (Rail Loop only)	88.3				0.18	0.35	0.52
Total	**919.5**	**1.65**	**3.86**	**5.51**	**2.30**	**4.20**	**6.50**
Direct and Temporary	240.9	0.59	1.32	1.91	0.84	.35	2.19



HB BYLONG RTS Post Works 1538 F10 Topsoil Stripping Depths 04 07 2016

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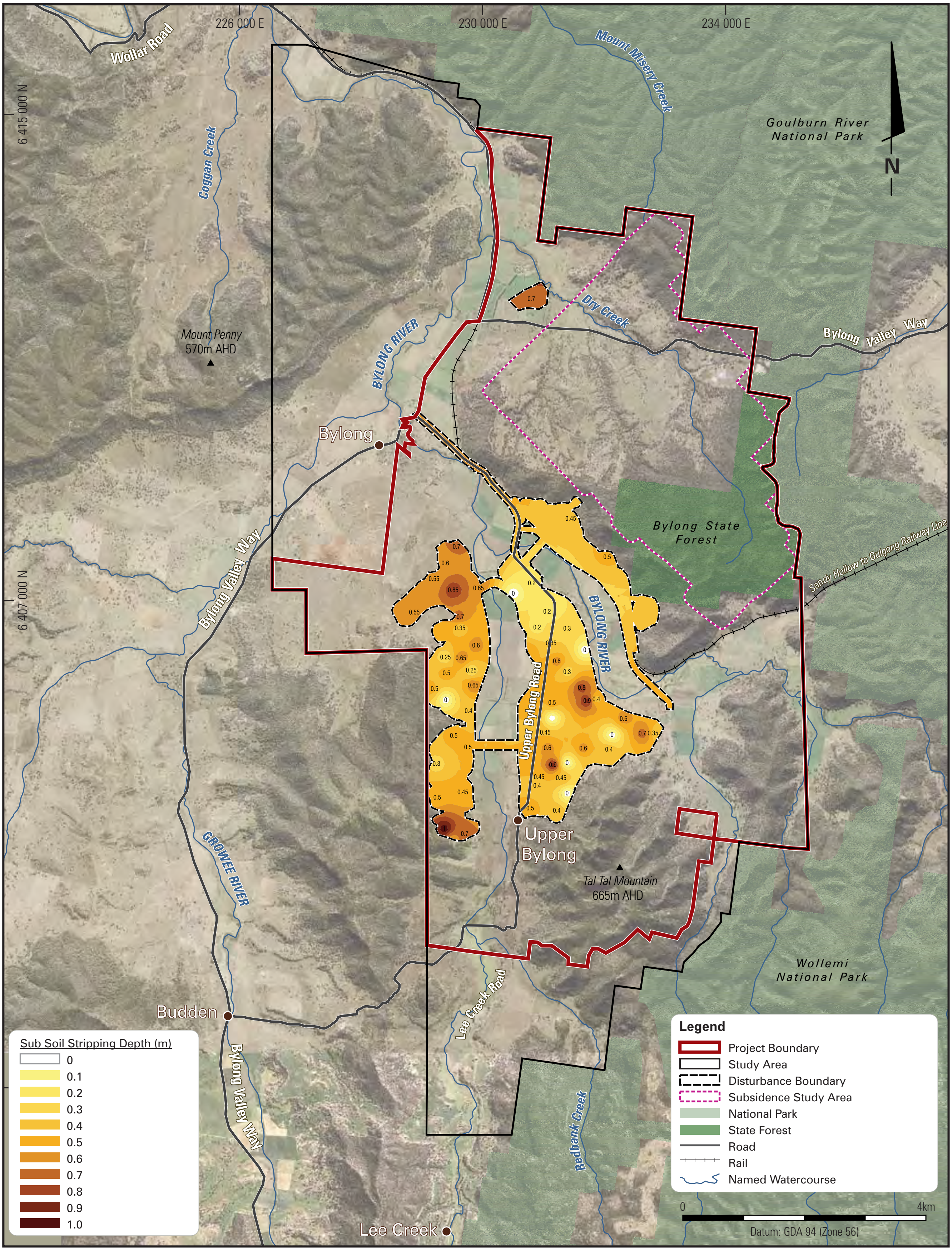
Recommended Top Soil Stripping Depths

FIGURE 10



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Recommended Sub Soil Stripping Depths

FIGURE 11

Table 4
Revised Soil Volume Requirements (2016)

BSAL Status and Land Capability Class	EIS Soil Volume Requirements				2016 Revised Soil Volume Requirements			
	Area (ha)	Topsoil (Primary media) (MCM)	Subsoil (Secondary media) (MCM)	Total (MCM)	Area (ha)	Topsoil (Primary media) (MCM)	Subsoil (Secondary media) (MCM)	Total (MCM)
BSAL/Class 3	227.0	0.57	1.36	1.93	319.5	0.80	1.92	2.72
Class 4	264.8	0.53	1.06	1.59	172.3	0.34	0.69	1.03
Class 5	232.3	0.23	0.93	1.16	232.3	0.23	0.93	1.16
Class 6	11.0	0.01	0.02	0.03	11.0	0.01	0.02	0.03
Class 7	22.6	0.02	0.00	0.02	22.6	0.02	0.00	0.02
Rail Loop*	88.3	0.00	0.00	0.00	88.3	0.09	0.35	0.44
Internal Roads	73.5	0.00	0.00	0.00	73.5	0.00	0.00	0.00
Total	**919.5**	**1.36**	**3.37**	**4.73**	**919.5**	**1.49**	**3.91**	**5.40**

Issue 12 – Losses of Scenic and Landscape Values

Accepted, however, a plan should be put in place to revegetate any important screening for areas of high visual sensitivity lost to drought or bushfire.

Response

It is understood this comment relates to protecting the private freehold property Tinka Tong from losses of scenic and landscape values. Tinka Tong was acquired by KEPCO in June 2016 and is therefore no longer a private freehold property. Visual management measures for all other private freehold and public viewing locations are consistent with the commitments within the EIS and RTS.

2.3 SOCIO-ECONOMIC ASPECTS

Issue 1 – Agricultural Support Services

The proponent has not made any estimate of the significance of this figure to the Hunter equine industry (i.e. as a percentage of the industry). However, the region accounts for a "very large proportion of the national economic value of thoroughbreds" (The Upper Hunter Region Equine Profile, June 2013, NSW DPI). Demand for Australian thoroughbreds plus horse stud and breeding services was worth $728M to the Australian economy in 2008-09 (ABS, Value of Sport Australia 2013, Table 8.6). As such it appears that the estimated loss of gross annual production would be likely to be less than the 5% threshold recommended by NSW DPI as a significant threshold (NSW DPI AIS technical notes, April 2013, Section 4.3, p9).

Response

The AIS (Appendix X of the EIS) identifies that there is no thoroughbred enterprises currently operating in the Project Area.

However, a representative land use scenario (not actual land use) for the mapped CIC was developed to determine its potential value to the Hunter Equine Industry (*Section 5.3.4: Equine CIC within Agricultural Assessment Area pp 57-58)*. This assumed the two best practice equine land-uses for the land would include:

- Lucerne production to be sold to the industry; and
- Broodmare farming.

Based on these land uses, it was predicted that if the 2,040 ha of mapped Equine CIC suitable for Lucerne production and/or broodmare operation was used for these enterprises, the hypothetical annual Gross Value of Production would be $7,860,620.

This would be additional to the current value of the Upper Hunter Equine CIC (that is, not removed from current production). The demand for Australian thoroughbreds plus horse stud and breeding was worth $728 Million to the Australian economy in 2008-09 (ABS, Value of Sport Australia 2013, Table 8.6).

Buchan 2011 (*Report 1 of 3; Upper Hunter Regional Economy and Industry Report,* Upper Hunter Economic Diversification Report) stated the Upper Hunter thoroughbred industry had an annual income $93 Million in 2006, derived from stud services, mare sales, other horse sales, agistment, sales preparation and racehorse spelling. This was an increase of 37% on the value of $68 Million in 2000.

The NSW Department of Primary Industries in its *Upper Hunter Region Equine Profile* (June 2013, Factsheet No.6) stated that the export value of exported Hunter sired or bred yearling (foals - sic) was estimated over $100 Million in 2011. This was from the total mapped 254,900 ha of Upper Hunter Equine CIC, not all of which is used or used solely for equine pursuits and does not take into account the value of the Hunter thoroughbred industry consumed domestically. The ABS (2013) estimates that the value of equine exports represent 19.6% demand for thoroughbred horses Horse Stud and breeding services. Based on the same ratio the Hunter equine breeding industry is estimated to have a value of demand of approximately $500 Million.

The value of the potential equine land use is calculated at $7.86 Million in Section 5.3.4 of the AIS (Appendix X of the EIS) which is additional to current production and assumes that all the mapped Equine CIC within the Project Area is turned over to equine activities or hay production for equine activities. Based on this generous assumption this extra production would represent 1.6% of the current total value of demand. This is well below the 5% threshold recommended by NSW DPI as a significant threshold (NSW DPI AIS technical notes, April 2013, Section 4.3 p9).

This demonstrates that the Project will not have a significant impact on the Hunter Equine industry, including the equine industry's value to the Upper Hunter, regional, State and National economies.

Issue 2 – Processing and Value Adding Industries

> *See above*

Response

See response to Issue 1.

As described above, the value add of the potential outputs from the mapped Equine CIC within the Project area is well below the threshold recommended by NSW DPI (NSW DPI AIS technical notes, April 2013, Section 4.3 p9) as a significant threshold.

This demonstrates that the Project will not have a significant impact on the Hunter Equine CIC, including to the equine industry's value add to the Upper Hunter, regional, State and National economies.

Issue 3 – Agricultural Enterprises

> *The rehabilitation plan for the rail loop area in Section 4.7.2. of the RTS indicates the area will be "topsoiled, seeded and revegetated with native grasses" which seems appropriate. The RTS does not state how this area would be managed after mine closure (would it be suitable for grazing?) and by whom.*

Response

The soil profile will be suited to class 5 LSC and therefore potential grazing (light to moderate only) may be feasible.

Issue 4 – Agricultural Infrastructure – Increased Traffic on Bylong Valley Way

> *"MSC has been consulted" but concerns about road maintenance have not been addressed.*

Response

The Project is located within the Mid-Western Regional Council (MWRC) Local Government Area (LGA) and is remote from regional town centres. KEPCO is seeking that its employees to reside within a one hour commute of the Project (defined as the Local Area). The Local Area comprises the towns of Mudgee, Wollar, Ulan, Rylstone and Kandos within the MWRC LGA; and Sandy Hollow and Denman within the Muswellbrook Shire Council (MSC) LGA.

The EIS has considered that a large proportion of the Project workforce would reside within the MWRC LGA and predominantly within the township of Mudgee. The EIS assessed a small proportion of traffic to utilise Bylong Valley Way to the east and into the MSC LGA, with the majority of movements for the Project to occur within the MWRC LGA. KEPCO is committed to a number of upgrade works on existing roads and intersections and to build new roads and intersections as required.

The Project will also impact a small section of Bylong Valley Way as a result of subsidence effects which will require the appropriate remediation. All of these required road works will be within the MWRC LGA. As the relevant roads authority for the primary roads to be utilised by the Project, KEPCO is in ongoing discussions with MWRC to settle on the relevant road maintenance contribution for the Project.

KEPCO is aware that MSC is the appropriate roads authority for the 40 km section of Bylong Valley Way from the Kerrabee Range (approximately 16 km to the east of the Project Boundary) to the Golden Highway. Accordingly, KEPCO is continuing its discussions with the MSC in relation to providing a road maintenance contribution which is proportionate to the Project's demand on this small section of the regional road network to be utilised for the Project.

3. CONCLUSION

We trust this response addresses the issues raised in the DPI–Agriculture submission. Should you have any queries in relation to this letter, please contact us on 6575 2000.

Yours faithfully

HANSEN BAILEY

James Bailey
Director

Nathan Cooper
Senior Environmental Scientist

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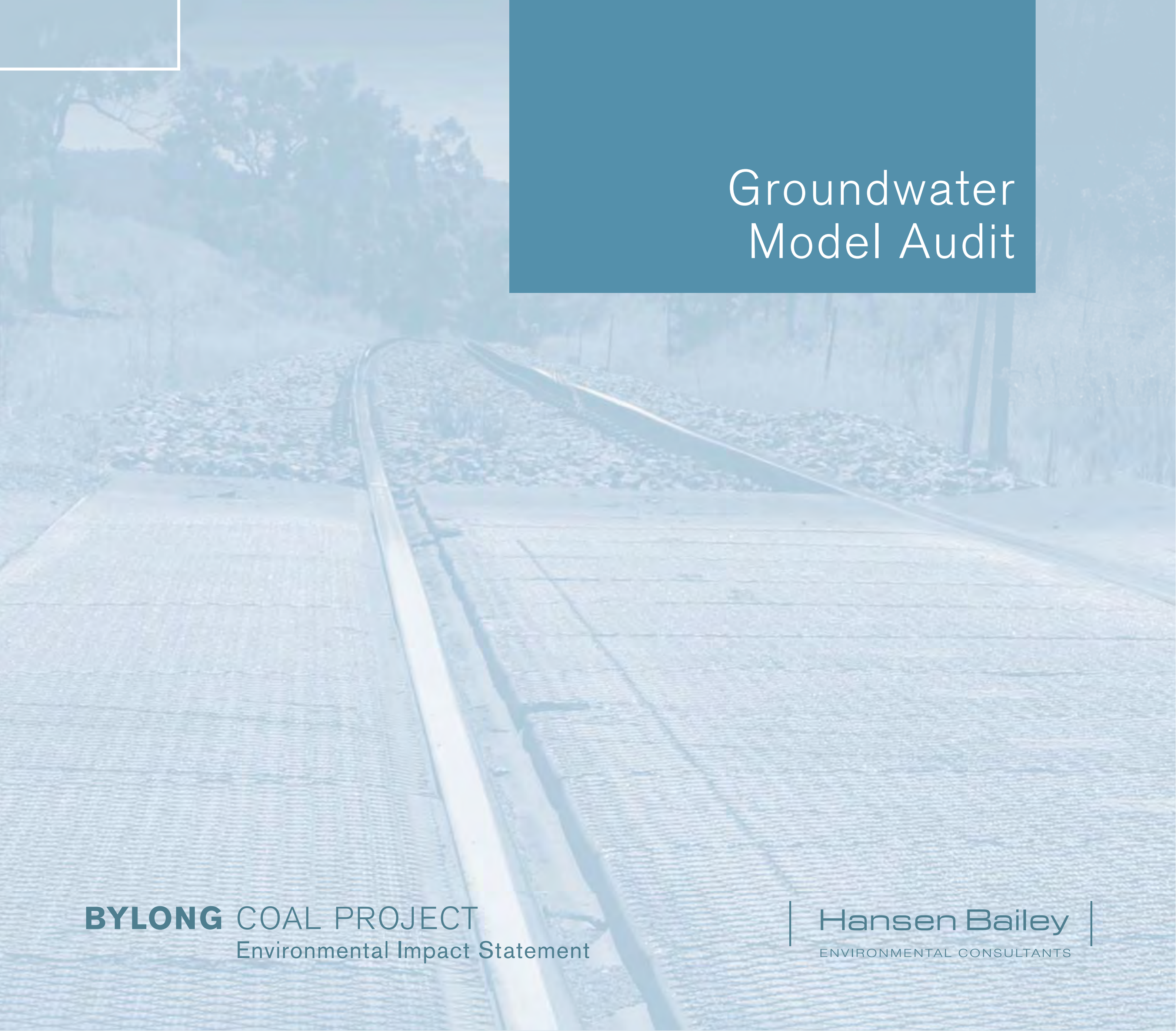
Groundwater Model Audit



BYLONG COAL PROJECT
Environmental Impact Statement

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

BYLONG COAL PROJECT

Groundwater Model Audit

FOR

Hansen Bailey

BY

NPM Technical Pty Ltd

trading as

HydroSimulations

Project number: BYL001

Report: HC2016/33

Date: August 2016

DOCUMENT REGISTER

Revision	Date	Description	Authors	Reviewer	Comments
A	20 July 2016	First Draft	Dr Noel Merrick, Dr Damian Merrick, Will Minchin, Tingting Liu	Dr N Merrick	Initial draft for comment
B	2 August	Second Draft	Dr Noel Merrick, Dr Damian Merrick, Tingting Liu, Will Minchin	W Minchin	Incorporates comments by Hansen Bailey, AGE, WorleyParsons
C	8 August	Final Draft	Dr Damian Merrick, Will Minchin, Tingting Liu	W Minchin	Incorporates further comments by Hansen Bailey, AGE, WorleyParsons & KEPCO
D	15 August	Final	Will Minchin	Dr N Merrick	Final comments to address Worley Parsons comments

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TABLE OF CONTENTS

LIST OF TABLES

FIGURES

GLOSSARY

AGE:	Australasian Groundwater and Environmental Consultants
ATO:	Automatic Time Stepping (in MODFLOW-SURFACT)
ATS:	Adaptive Time Stepping (in MODFLOW-USG)
BCF:	MODFLOW Block- Centred Flow Package
CONSTANTCV:	Constant Vertical Conductance option
DD:	Drawdown (abbrev.)
DISU:	MODFLOW Discretisation File (in MODFLOW-USG)
DRN:	MODFLOW Drain Package
EIS:	Environmental Impact Statement
HA:	HydroAlgorithmics
HS:	HydroSimulations
LCGs:	Lateral Connection Groups
LST:	MODFLOW Listing File (output file from MODFLOW-USG)
LPF:	MODFLOW Layer-Property Flow Package
MS:	MODFLOW-SURFACT
NOVFC:	No Variable Flow Control option (in MODFLOW-USG)
PCG5:	Preconditioned Conjugate-Gradient Package (in MODFLOW-SURFACT)
OC:	Output Control
RTS:	Response to Submissions (phase of EIS)
TMP:	Time-Varying Material Properties (SURFACT)
TVM:	Time-Variant Materials (USG)
USG:	Unstructured Grid (as in MODFLOW-USG)
VCONT:	Vertical Conductance (leakance)
xMD:	one of the numerical solvers available for use with MODFLOW-USG

1 INTRODUCTION

KEPCO Bylong Australia Pty Limited (KEPCO) owns the Bylong Coal Project (the Project) which is located within the Mid-Western Regional Council (MWRC) Local Government Area (LGA) approximately 55 km to the north-east of Mudgee. KEPCO submitted an Application for State Significant Development (SSD) Development Consent under Division 4.1 of Part 4 of the ***Environmental Planning and Assessment Act 1979*** (EP&A Act) on 23 July 2015 to facilitate the development of the Project. This Application was supported by the Bylong Coal Project Environmental Impact Statement (EIS) (Hansen Bailey, 2015).

The Project has been subject to various levels of groundwater modelling through the approvals process. HydroSimulations [HS] has completed Peer Reviews of the modelling and groundwater impact assessments prepared by Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) for inclusion within the EIS.

Hansen Bailey on behalf of their client WorleyParsons Services Pty Ltd (WorleyParsons) engaged HS to conduct a Model Audit of the groundwater models completed for the Project. An audit was requested by Dr F. Kalf of Kalf & Associates Pty Ltd [KA] who is acting on behalf of the Department of Planning and Environment (DP&E) as the Peer Reviewer.

The adopted methodology of the Model Audit has been endorsed by Dr Kalf in his notifications dated 13 June and 16 June 2016. Some minor changes to the agreed methodology proved necessary during the conduct of the audit.

The main concern expressed by Dr Kalf is a discrepancy in predicted drawdown between different versions of the groundwater model, in particular between MODFLOW-SURFACT (MS) and MODFLOW-USG (USG) versions, as they differ in mathematical fundamentals. There is an expectation that the MS and USG versions should give the same predictions for the same model parameterisation and model stresses.

This report details the methodology and findings of the HS's Model Audit. It also provides appropriate recommendations for future groundwater modelling which is undertaken for complex mining related applications.

2 SUMMARY OF MODELS

Three groundwater models relevant to this report have been developed by AGE for the Project:

A. EIS MODFLOW SURFACT (Base Case 1);
B. EIS MODFLOW USG (Base Case 2); and
C. RTS Linear Uncertainty Model MODFLOW USG (RTS Model).

It was noted within the methodology endorsed by KA that model B did not need to be considered within the model audit as model C is sufficient as the representative USG model. Model versions A and C differ in the representation of the unsaturated zone and in structured versus unstructured discretisation of the model mesh, but also in model parameterisation, river/drainage algorithm, landholder pumping bore rates, supply borefield extent and supply borefield rates.

The agreed methodology also includes extensive testing of software performance on two synthetic models, one for longwall mining and the other for open cut mining. The details of these models are given in **Appendix A**.

3 METHODOLOGY

The Model Audit consisted of conventional audit tasks performed by HS, supplemented by verification tasks shared by HydroAlgorithmics [HA] and AGE.

3.1.1 AGREED TASKS

The agreed tasks or steps, and model outputs, are listed below:

1. Audit of model files for models A and C [by HS].
2. Verification of MS and USG on synthetic models for longwall mining and open cut mining [by HS]. Separate tests were run for each model having the same representation of the unsaturated zone (both Richards Equation and pseudo-soil separately) and differing representations (one Richards Equation, the other pseudo-soil).
3. Modified model C to model C^ for any important features found at Step 2 [by AGE]; e.g. (a) lateral connections where alluvium is pinched out; (b) alignment of vertical conductance algorithms.
4. Converted model A to model A^ so that it has the same parameterisation and stresses as model C^, except for the representation of the unsaturated zone [by AGE]; model A uses van Genuchten properties while model C uses pseudo-soil.
5. Removed model stresses to give 'null' versions of each model in which all mining is deactivated and all borefield/landholder pumping is deactivated: A^_Null and C^_Null. Compared the model outputs of model A^_Null with those of model C^_Null [by AGE].
6. Compared the model outputs of model A^ with those of model C^ [by AGE].
7. Attempted to get model A^ running with pseudo-soil by experimentation with solver settings [by HS]; call this model A^^.
8. As Step 7 was successful, compared the model outputs of model A^^ with those of model C^ [by AGE]; both models have the same unsaturated zone representation [pseudo-soil].
9. Although this step was not required (as Step 7 was successful), model C^ was converted to model C^^ by use of the same van Genuchten properties as in model A^. Model C^^ outputs were then compared with the outputs of model A^ [by AGE].
10. Reporting and project management.

Dr Kalf also requested that careful journal entries be kept for:

- Solution algorithm;
- Solution settings:
  - Closure criteria;
  - ATO/ATS time settings;
  - Newton parameters for vadose representations;
  - Richards Equation parameters for vadose representations;
- Computer processor;
- Simulation run time;
- Applied stresses;
- TMP/TVM time varying properties; and
- Other relevant inputs.

3.1.2 AGREED DIAGNOSTIC OUTPUTS

For Task 5, the critical outputs were identified to be:

1. Water balance tables for the entire model extent.
2. Head (h) h(x,y) maps, especially in alluvium.
3. Baseflow graphs (especially for Lee Creek and Bylong River).

For Task 6, the critical outputs would be:

4. Drawdown (DD) magnitude at locations where the reviewer has observed a substantial difference.
5. DD(x,y) maps, especially in the alluvium.
6. Rate of drawdown and recovery (dDD/dt) at sentinel sites of interest. (This is likely to differ between MS and USG alternatives).
7. Differential baseflow graphs between NULL (i.e. no mining) and stressed runs (mining).

3.1.3 RESPONSIBILITIES OF HS

HS was nominated to do Tasks 1, 2, 7 and 10, with checks to be made of the model results reported by AGE to HS on the other tasks:

1. Audit of model files for models A and C.

2. Verification of MS and USG on synthetic models for longwall mining and open cut mining.

7. Attempt to get model A^ running with pseudo-soil by experimentation with solver settings; call this model A^^.

10. Reporting and project management

The findings for Tasks 1, 2 and 7 are reported in Sections 4, 5 and 6 respectively.

3.1.4 RESPONSIBILITIES OF AGE

AGE was nominated to do Tasks 3, 4, 5, 6, 8 and 9:

3. Modify model C to model C^ for any important features found during Task 2.

4. Convert model A to model A^ so that it has the same parameterisation and stresses as model C^.

5. Develop 'Null' models (without stresses). Compare the model outputs of model A^_Null with those of model C^_Null

6. Compare the model outputs of model A^ with those of model C^

8. Compare the model outputs of model A^^ with those of model C^

9. Convert model C^ to model C^^ by use of the same van Genuchten properties as in model A^, then compare the model outputs of model A^ with those of model C^^

The findings for Tasks 5, 6, 8 and 9 are reported in Section 7. Tasks 3 and 4 are not reported on specifically, but are referred to in Sections 4.1 and 4.2.

4 TASK 1

4.1 AUDIT OF MS MODEL A^

In accordance with Task 4, AGE modified the EIS MS model A to model A^ and the audit was conducted on this version of the model.

MS model files were supplied for:

- Steady-state: input and output files.
- Transient calibration: input files only.
- Prediction: input and output files for one representative stress period.

All predictive MS model runs have been set up as a series of batched time-slice simulations to cater for time-varying properties for longwall fracture zones and open cut spoil emplacement. As this procedure is proprietary to AGE and HS prefers to employ the TMP facility in MS, HS was limited in its investigation of predictive simulations.

As no time-varying properties were required for the calibration stage, HS was able to check the full transient calibration model of 412 stress periods. As AGE does not rely on a graphic user interface (GUI) and HS prefers to make use of the Groundwater Vistas (GV) GUI for model setup and visualisation, the provided MS input files were imported into GV and each GV menu was then examined step by step. One problem with the import was that the vertical transmissive property was written in the BCF file as VCONT (leakance), the original property in the earliest MODFLOW release, rather than Kz (vertical hydraulic conductivity). While this is acceptable practice, HS regards VCONT as less physically intuitive than Kz, and the practice complicates comparison with USG software that no longer supports the use of VCONT and insists on the specification of Kz.

The MS model A^ has 1.2 million cells varying in size from 50 m to 500 m, with 400 rows, 292 columns and 10 layers. A walk-through of each row and each column showed fairly smooth geometry with no significant cell dislocations.

All layers are type 43, which is appropriate. The provided steady-state OUT file records the use of "Real Soil Functions" for each layer with the MS option IREALSL = 1, in other words vadose properties for the application of Richards Equation (van Genuchten solution requiring ***alpha, beta, residual saturation***). The vadose parameter values are:

- Alpha = 0.02 [m^{-1}].
- Beta = 7 (Layers 1-2); 5 (Layers 3-10) [unitless].
- Residual saturation (Sr) = 0.01 (Layers 1-3), 0.002 (Layers 4-10) [m^3/m^3].

In some sensitivity analyses in the EIS, AGE used the MS option IREALSL = 2, requiring the specification of the three VG parameters (above) plus the Brooks-Corey exponent (***n***) (which was defined with a value of 2).

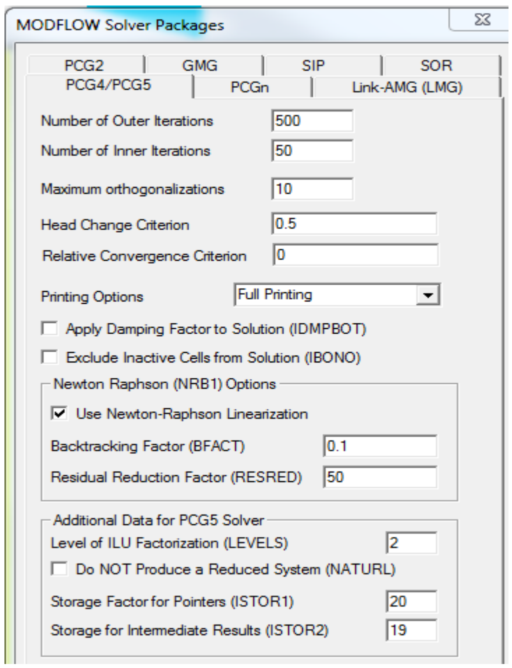
The Layer 1 groundwater heads are controlled by a large number of river (RIV) cells that occupy 12% of the layer cells, as illustrated in **Figure 4-1**. There are instances of strong hydraulic conductivity contrasts within a layer, such as the horizontal hydraulic conductivity (Kx) in Layer 3 shown in **Figure 4-2**. There is also evidence of a dendritic signature surviving down to Layer 6 (**Figure 4-3**) and the coal seam Layer 8.

The storage property is defined as the storage coefficient (S) rather than the specific storage (Ss). Again, comparison with USG is made difficult as USG defaults to the use of Ss. While other layers have a sensible distribution for S, Layer 3 has some anomalies that are shown in **Figure 4-4**.

The VCONT values are high in Layers 1-2 (from 0.01 to 4.5 d^{-1}) and quite low in deeper layers (generally 10^{-6} to 10^{-8} d^{-1}).

The MS Model A^ uses the PCG5 solver with the settings listed in **Table 4-1** (verified in the Bylong_tr.pg5 file).

Table 4-1 Solver Settings for MS Model A^ during Transient Calibration



Overall, no significant issues of concern were detected in Model A^. Note that HS was not able to check the application of time-varying properties.

4.2 AUDIT OF MS MODEL C

AGE supplied the RTS USG model C to HS and the audit was conducted on this version of the model.

USG-Beta model files were supplied for:

- Transient calibration: input files only, plus LST file.
- Prediction: input and output files for two representative stress periods (SP):
  - SP 39 (end of open cut mining);
  - SP 100 (end of longwall mining).
- Unstructured grid, constructed with AlgoMesh[1].

In accordance with Task 3, AGE also provided geometry files for model C^ in which lateral connection groups (LCGs) were implemented in AlgoMesh. For both Model C and Model C^, the CONSTANTCV vertical conductance option was exercised, in compliance with Task 3 for alignment with MS runs. The option NOVFC was not exercised. The absence of this option may result in a more physically-accurate simulation of vertical flow from perched aquifers, but to HS' understanding, may produce different results from the MS model where such flow occurs. It is expected that CONSTANTCV without NOVFC provides the closest matched to MS code.

[1] AlgoMesh software was developed by Dr Damian Merrick of HydroAlgorithmics

Predictive USG model runs have been set up as a series of batched time-slice simulations to cater for time-varying properties for longwall fracture zones and open cut spoil emplacement. As this procedure is proprietary to AGE and HS prefers to employ the TVM[2] facility in USG, HS was limited in its investigation of the predictive simulations.

As no time-varying properties were required for the calibration stage, HS was able to check the full transient calibration model of 507 stress periods. Each stress period of three days' duration consisted of three time steps of specified lengths of 1, 1.5 and then 0.5 days. A check of the mass balance in the provided transient calibration LST file revealed a cumulative discrepancy of 0.00% and time step discrepancies no worse than 0.01%, but typically 0.00%.

To address the inability of HS to properly assess the implementation of time-varying properties within the prediction modelling, AGE made available a TVM file for a new model that has been constructed and calibrated by AGE since the RTS model. While this model, called Model D, is not subject to audit, the TVM file allowed HS to gain some appreciation of the temporal changes applied to properties, relying on the reasonable assumption that a similar approach would have been adopted in the time-slice simulations. HS has run diagnostic software on the TVM file to show that it has sensible physical values. However, without easy discrimination between open cut and longwall DRN cells, the expected alignment of DRN and TVM cells is not obvious (**Table 4-2**).

It was not clear from **Table 4-2** whether any TVM changes are applied to spoil emplacement, anticipated to be up to about SP39, as there are only two early SPs (20 and 28) where TVM changes are made but only for far fewer cells. AGE have indicated that open cut areas were simulated with 'spoil' properties changed, via TVM, two years after mining commences (based on the mine plan) and after Drains were inactivated.

Longwall panels are expected from about SP33 (roadways a little earlier than this) up to SP100. There is an increasing number of TVM cells with time during longwall mining. While the TVM file includes unnecessary redundant changes for cells that have already been given fracture properties, no harm is done to the simulation.

Table 4-2 DRN and TVM Cell Counts for USG Model D during Transient Calibration

SP	#DRN_Cells	#TVM_Cells	SP	#DRN_Cells	#TVM_Cells	SP	#DRN_Cells	#TVM_Cells
1	0	0	35	1115	110	69	89	1883
2	0	0	36	431	860	70	105	1945
3	0	0	37	51	587	71	93	2026
4	0	0	38	59	230	72	105	2082
5	8	0	39	72	289	73	119	2134
6	28	0	40	82	330	74	129	2170
7	48	0	41	47	442	75	90	2274
8	78	0	42	58	489	76	103	2327
9	107	0	43	71	550	77	116	2376
10	134	0	44	84	617	78	129	2425
11	161	0	45	52	708	79	92	2515
12	200	0	46	65	768	80	105	2567
13	270	0	47	76	818	81	117	2611

[2] TVM (Time Varying Materials) software was developed by Dr Damian Merrick of HydroAlgorithmics

SP	#DRN_Cells	#TVM_Cells	SP	#DRN_Cells	#TVM_Cells	SP	#DRN_Cells	#TVM_Cells
14	336	0	48	86	869	82	127	2652
15	394	0	49	54	978	83	92	2740
16	441	0	50	65	1023	84	104	2789
17	510	0	51	71	1055	85	114	2829
18	671	0	52	81	1102	86	128	2899
19	858	0	53	49	1172	87	140	2954
20	860	200	54	59	1214	88	100	3044
21	1035	0	55	69	1259	89	114	3114
22	1204	0	56	83	1317	90	126	3172
23	1404	0	57	64	1392	91	134	3210
24	1564	0	58	73	1422	92	146	3266
25	1654	0	59	84	1465	93	154	3303
26	1749	0	60	64	1536	94	166	3363
27	1834	0	61	74	1568	95	92	3484
28	1054	860	62	84	1607	96	128	3655
29	1185	0	63	67	1659	97	146	3745
30	1087	199	64	74	1688	98	158	3804
31	1163	0	65	81	1713	99	166	3844
32	1034	150	66	88	1740	100	179	3907
33	1065	45	67	68	1792			
34	1094	86	68	76	1822			

All layers are type 4, which is appropriate. The provided transient LST file records the use of the "Upstream" layer type, which is the equivalent of the "pseudo-soil" option in MS models, rather than the vadose properties associated with Richards Equation.

USG Model C uses the Newton-Raphson non-linear solution method with Delta-Bar-Delta under-relaxation and the χMD linear solver. Solver settings are listed in **Table 4-3**.

Table 4-3 MODFLOW-USG Solver Settings for USG Model C

SETTING	DESCRIPTION	VALUE
HCLOSE	Outer iteration head change closure criterion	0.01 (transient calibration model) 0.05 (prediction model)
HICLOSE	Inner iteration head change tolerance	0.001
MXITER	Maximum # outer iterations	500
ITER1	Maximum # inner iterations	10
THETA	Reduction factor for under-relaxation term	0.7
AKAPPA	Increment for under-relaxation term	0.07
GAMMA	Memory factor	0.1
AMOMENTUM	Momentum term	0.0
NUMTRACK	Maximum # backtracks	200
BTOL	Allowed residual change per outer iteration	1.1

SETTING	DESCRIPTION	VALUE
BREDUC	Reduction in step size used for residual reduction	0.2
RESLIM	Limit to which residual is reduced with backtracking	1.0
IACL	Linear acceleration method	2 - BiCGStab
NORDER	Matrix ordering scheme	0 – Original ordering
LEVEL	Level of fill for ILU* preconditioner	7
RRCTOL	Residual tolerance criterion for convergence	0.0 – Ignore residual in favour of HICLOSE head tolerance
IDROPTOL	Drop tolerance flag	1 – Perform drop tolerance
EPSRN	Drop tolerance value	0.001

*ILU = 'Incomplete Lower Upper' preconditioning option for some numerical solvers used in MODFLOW

The two-dimensional Voronoi mesh used in the model comprises 15,502 cells, with approximate cell sizes ranging from 13 m to 3.2 km, with approximate cell size calculated as the square root of cell area. Longwalls are represented by precise rectangular cells of 200 m x 50 m, and open cut areas are meshed with 75 m square cells. Cells in the alluvium are 100 m and approximately hexagonal.

305 concave cells were identified in the mesh, many of which lie along the borders of the rectangular-gridded longwall region. These may affect the numerical accuracy of the control-volume finite-difference (CVFD) flow solution locally to those cells, as the CVFD formulation assumes that all cells are convex. In particular, the distances reported in the DISU file for flow paths from cell centre to cell boundary may be incorrect for concave cells generated by AlgoMesh. This may result in a reduced time for water to flow into or out of each concave cell than what is physically accurate. In practical terms, given the localised nature of these errors in contrast to the scale of the model, HS considers it unlikely that the concave cells would cause a significant deviation in model results. Nevertheless, HS has advised AGE about these concave cells, and it is understood that AGE has rectified the problem in the mesh for subsequent versions of the USG model.

The 3D model discretisation appears to have cell thicknesses of between 3 m and 120 m with varying numbers of cells per layer. AGE has advised HS that cells less than 1 m in thickness have been pinched out. Pinching out cells avoids the use of minimum-thickness "dummy" cells typical of MS models, potentially improving numerical stability and decreasing model run times, and is a typical USG modelling practice.

Time step sizes were controlled by the automatic time-stepping procedure (ATS) within USG-Beta. In the provided representative stress periods of the prediction model, the time step size started at 5 days and increased to a maximum of 25.375 days. A mass balance check on the LST files for these stress periods indicates a cumulative discrepancy per stress period of at most 0.01%, and time step discrepancies of no worse than 0.03%.

Note that HS was not able to fully check the application of time-varying properties or directly assess the equivalence of parameterisation due to different forms of data input (Kz instead of VCONT and Ss instead of storage coefficient). However, the various approaches are all valid.

Figure 4-5 shows a trial conversion from Ss (in the USG model) to S, for comparison with the S-field adopted in the MS model. The agreement with **Figure 4-4** is good.

Figure 4-6 shows one Kx field in the USG model for comparison with that adopted in the MS model. The agreement with **Figure 4-3** is good, allowing for different cell sizes.

5 TASK 2

5.1 CONCEPTUAL MODELS

Separate synthetic models have been set up for longwall (LW) mining and open cut (OC) mining. Conceptual models are illustrated in **Figure 5-1** and **Figure 5-2** respectively. Mining is simulated as occurring for a period of nine years in both models.

The LW synthetic model had already been developed by HS for a separate verification of MS software and USG/AlgoMesh software, using the pseudo-soil (or equivalent upstream weighting) option in both. That investigation was focused on comparing structured [MS] and unstructured [USG] mesh designs with different spatial resolution. In this investigation, the effect of the mesh design has been removed from consideration by applying the same structured grid to both MS and USG versions of the synthetic model.

To handle temporal changes in the fracture zone properties, the Time-Varying Material Property (TMP) and TVM facilities are used respectively for MS and USG.

MS and USG versions of the model have been run for two alternative representations of variable saturation (vadose properties and pseudo-soil) as indicated in **Table 5-1**.

Table 5-1 Software and Unsaturated Zone Simulation Options

CODE	SOFTWARE_UNSAT	LW	OC	COMMENT
1	MS_Vadose	YES	YES	8 scenarios for vadose properties
2	MS_Pseudo	YES*	YES	*also reported in Merrick & Merrick (2015)
3	USG_Vadose	YES	YES	8 scenarios for vadose properties
4	USG_Pseudo	YES	YES	5 vertical conductance (VC) options

Where vadose properties are used, eight scenarios have been examined (**Table 5-2**). Perturbations of a base model A1 are examined in Runs A2-A4. Run B1 uses the properties employed by AGE in the base case EIS model (model A) (except that the Brooks-Corey option was not exercised). Runs A1, A4 and B2 are similar to the three sensitivity analyses examined by AGE in the EIS model. Runs C1 and C2 assess reasonable estimates for "clay" and "sand" end points.

Table 5-2 Scenarios for Vadose Properties

RUN	Alpha (m^{-1})	Beta	Sr	n (B-C)	Comment	Variation
A1	1.0	2.0	0.01	2	HS_Base (~AGE_Sc1)	
A2	3.0	2.0	0.01	2	Base_alpha	Alpha x 3
A3	1.0	4.0	0.01	2	Base_beta	Beta x 2
A4	1.0	2.0	0.05	2	Base_Sr (~AGE_Sc2)	Sr x 5
B1	0.02	7.0	0.01	2	AGE_Base (no use of ***n***)	
B2	10	2.0	0.05	2	AGE_Sc3	
C1	0.3	1.5	0.05	5	Clay_Endpoint	
C2	10	5.0	0.05	2	Sand_Endpoint	

For USG simulations, five VC options have been examined (**Table 5-3**). Option A is taken as the base case for synthetic model simulations. The head (h), thickness (B) and layer base (BOT) references in the vertical conductance and head difference terms are defined in **Table 5-3**.

Table 5-3 MODFLOW-USG Vertical Conductance Options

CODE	OPTION	VERTICAL CONDUCTANCE TERM	HEAD DIFFERENCE TERM	COMMENT
A	CONSTANTCV NOVFC	B1, B2	h1 - h2	As LPF in MODFLOW-NWT
B	nil	h1, b1	h1 - BOT1	Default in USG
C	CONSTANTCV	B1, B2	h1 - BOT1	As BCF in MS
D	NOVFC	h1, b1, B2	h1 - h2	
E	NOCVCORRECTION	h1, b1, B2	h1 - BOT1	

All synthetic model simulations have been run on a laptop with an i5-6200U processor (2.3GHz, turbo to 2.8GHz, 2 cores / 4 threads), and 8GB RAM. Run journals are included in **Appendix D**.

5.2 SYNTHETIC LONGWALL MODEL

For the simulation options in **Table 5-1**, the following combinations have been examined for the LW synthetic model:

- 1 with 3 (8 vadose scenarios) MS_Vadose and USG_Vadose
- 2 with 4 (base scenario) MS_Pseudo and USG_Pseudo
- 3 with 4 (base scenario) USG_Vadose and USG_Pseudo
- 4 (5 VC options) USG_Pseudo

5.2.1 MS_VADOSE AND USG_VADOSE

Details of the results are in **Appendix B1** with the following exhibits for each scenario[3]:

- Mine inflow [kL/day] graph at each time step.
- Annual average mine inflow [ML/day] bar graph.
- Baseflow impact ("river flux") [kL/day] for 50 years.
- Baseflow impact ("river flux") [kL/day] for 10 years.
- Hydrographs for each layer at Bore P1 for 10 years.
- Hydrographs for each layer at Bore P1 for 50 years.
- Comparative whole-of-model water balance.

A comparison of mine inflow and baseflow results (averaged over the nine years of mining represented in the synthetic model) is presented in **Table 5-4**.

Results are tabulated for comparison in the following sections. Results that are notably similar between compared models are highlighted green, while those showing significant or unexpected variance are highlighted red.

[3] Similar outputs are provided for subsequent comparisons.

Table 5-4 Comparative Flows for Vadose Options for the Longwall Synthetic Model

OPTION	MINE INFLOW [ML/YEAR]			BASEFLOW [ML/YEAR]		
	MS	USG	%DIFFERENCE	MS	USG	%DIFFERENCE
A1	279.3	218.0	-28.1	7,832.3	11,781.3	+33.5
A2	285.9	293.3	+2.5	7,718.5	11,781.3	+34.5
A3	288.4	235.5	-22.4	7,677.0	11,781.3	+34.8
A4	271.7	204.8	-32.6	7,832.3	11,781.3	+33.5
B1	179.1	15.7	-1,041	11,777	11,781.3	0.0
B2	278.4	227.7	-22.3	7,669.9	11,781.3	+34.9
C1	197.9	74.9	-164	8,020.8	11,781.3	+31.9
C2	276.5	227.5	-21.5	7,432.6	11,781.3	+36.9

Note: Positive %Difference means USG flow > MS flow

The highlights of this analysis are:

- USG baseflow is invariant of vadose properties.
- MS baseflow is stable for most runs except B1 (as per AGE Base EIS model – this is because this model was run without the Brooks-Corey exponent (IREALSL = 1), and this parameter seems to increase model stability (e.g. IREALSL = 2)).
- USG mine inflow varies substantially.
- MS mine inflow varies substantially.
- USG generally has less mine inflow except A2 (high alpha).
- USG always has higher baseflow (by about 30%).
- MS gives an erroneous increase in baseflow (during mining) for scenarios A1, A2, A3, A4, B1, B2, and C1.
- During mining, hydrographs at P1 agree very well for scenarios A1, A3 (high beta), A4 (high Sr), B1 (low alpha, high beta), B2 (high alpha, high Sr), C1 (clay), and C2 (sand). Only A2 (high alpha) has substantial differences (typically 20-50 m).
- After mining, recovery of water levels is more rapid with USG for scenarios A2 (high alpha), B1 (low alpha, high beta), and C1 (clay). For other scenarios, the water levels continue to match well between MS and USG.
- Runtime was faster with MS (average 10 minutes) than USG (average 21 minutes).
- MS had no difficulty converging; USG had difficulty for runs A3, B1, B2 and C2.

5.2.2 MS_PSEUDO AND USG_PSEUDO

Details of the results are in **Appendix B2**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-5**.

Table 5-5 Longwall Synthetic Model: Comparative Flows for Pseudo-Soil Simulations

OPTION	MINE INFLOW [ML/YEAR]			BASEFLOW [ML/YEAR]		
	MS	USG	%DIFFERENCE	MS	USG	%DIFFERENCE
VC1	350.9	316.7	+10.8	10,702.4	10,702.1	+0.00

Note: Positive %Difference means MS flow > USG flow

The highlights of this analysis are:

- MS gives higher mine inflow (by about 10%).
- Both MS and USG give essentially the same baseflow.
- During mining, hydrographs at P1 agree perfectly.
- During recovery, hydrographs at P1 agree perfectly.
- The MS simulation ran 2 times faster than USG (XMD) and 4 times faster than USG (PCGU).

5.2.3 USG_VADOSE AND USG_PSEUDO

Details of the results are in **Appendix B3**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-6**.

Table 5-6 Longwall Synthetic Model: Comparative Flows for USG Unsaturated Options

	MINE INFLOW [ML/YEAR]			BASEFLOW [ML/YEAR]		
OPTIONS	PSEUDO	VADOSE	%DIFFERENCE	PSEUDO	VADOSE	%DIFFERENCE
VC1/A1	316.7	218.0	+31.2	10,702.1	11,781.3	-10.1

Note: Positive %Difference means Pseudo-Soil flow > Vadose flow

The highlights of this analysis are:

- Pseudo-soil gives higher mine inflow (by about 30%).
- Vadose gives higher baseflow (by about 10%).
- During mining, hydrographs agree very well at bores P2, P3, P4, P5, P6 and P7. At P1, more rapid drawdown by pseudo-soil causes a temporary head differential of between 30-50 m maximum in layers 5-6.
- After mining, the recovery of water levels is more rapid with pseudo-soil at all bores.
- The vadose simulation ran 3.5 times faster than pseudo-soil.

5.2.4 USG_PSEUDO

Details of the results are in **Appendix B4**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-7**.

Table 5-7 Longwall Synthetic Model: Comparative Flows for Vertical Conductance Options

OPTION	MINE INFLOW [ML/YEAR]		BASEFLOW [ML/YEAR]	
	USG	%DIFFERENCE	USG	%DIFFERENCE
VC1	316.7	Base	10,702.1	Base
VC2	316.7	0.0	10,702.1	0.0
VC3	316.7	0.0	10,702.1	0.0
VC4	316.7	0.0	10,702.1	0.0
VC5	316.7	0.0	10,702.1	0.0

Note: %Difference is calculated from the VC1 values

The highlights of this analysis are:

- No difference in mine inflow was observed.
- No difference in baseflow was observed.
- No difference was observed in hydrographs at P1.
- Runtime was least for VC3 (3 minutes).
- VC4 and VC5 would not converge with the XMD solver but converged slowly (10 minutes) with PCGU.

5.3 SYNTHETIC OPEN CUT MODEL

For the simulation options in **Table 5-1**, the following combinations have been examined for the OC synthetic model:

- 1 with 3 (8 vadose scenarios) MS_Vadose and USG_Vadose
- 2 with 4 (base scenario) MS_Pseudo and USG_Pseudo
- 3 with 4 (base scenario) USG_Vadose and USG_Pseudo
- 4 (5 VC options) USG_Pseudo
- E with D (two scenarios) USG_Pinchout and USG_Pseudo

5.3.1 MS_VADOSE AND USG_VADOSE

Details of the results are in **Appendix C1**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-8**.

Table 5-8 Open Cut Synthetic Model: Comparative Flows for Vadose Options

OPTION	MINE INFLOW [ML/YEAR]			BASEFLOW [ML/YEAR]		
	MS	USG	%DIFFERENCE	MS	USG	%DIFFERENCE
A1	3,913.2	5,806.1	+32.6	7,883.4	10,832.0	+27.2
A2	3,709.6	5,853.5	+36.6	7,676.8	10,421.0	+26.3
A3	3,705.8	5,857.2	+36.7	7,588.9	10,493.0	+27.7
A4	3,873.5	5,715.3	+32.2	7,874.9	10,815.1	+27.2
B1	6,400.8	6,533.6	+2.0	8,305.1	7,956.9	-4.4
B2	3,588.1	5,774.6	+37.9	7,577.3	10,035.3	+24.5
C1	4,061.6	4,906.7	+17.2	8,243.1	10,640.0	+22.5
C2	No solution	5,770.0		No solution	9,725.2	

Note: Positive %Difference means USG flow > MS flow

The highlights of this analysis are:

- USG baseflow is stable except B1 (AGE Base EIS model).
- MS baseflow is stable for most runs except B1 and C1 (clay).
- USG mine inflow is stable for most runs except B1 and C1 (clay).
- MS mine inflow is stable for most runs except B1.
- USG always has higher mine inflow (by about 30%) except B1 (AGE Base EIS model).

- USG always has higher baseflow (by about 25%) except B1 (AGE Base EIS model).
- Baseflow dynamics match well only for B1 (AGE Base EIS model)
- During mining, hydrographs at P1 agree very well for all scenarios other than A1, where 30-60 m head difference is observed in layers 2-3.
- After mining, there is no significant difference in rate of recovery of water levels between MS and USG.
- Runtime was faster with MS (average 2.3 minutes) than USG (average 11 minutes).
- USG had no difficulty converging except for C2, where PCGU had to substitute for XMD.
- MS failed to converge for B1 and C2.

5.3.2 MS_PSEUDO AND USG_PSEUDO

Details of the results are in **Appendix C2**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-9**.

Table 5-9 Open Cut Synthetic Model: Comparative Flows for Pseudo-Soil Simulations

OPTION	MINE INFLOW [ML/YEAR]			BASEFLOW [ML/YEAR]		
	MS	USG	%DIFFERENCE	MS	USG	%DIFFERENCE
VC1	5,656.8	5,656.5	0.0	9,913.7	9,915.0	+0.01

Note: Positive %Difference means MS flow < USG flow

The highlights of this analysis are:

- Both MS and USG give essentially the same mine inflow.
- Both MS and USG give essentially the same baseflow.
- During mining, hydrographs at P1 agree perfectly.
- During recovery, the MS water levels recover slightly faster in layer 6.
- The MS simulation ran 4 times faster than USG (XMD) and 2.5 times faster than USG (PCGU).

5.3.3 USG_VADOSE AND USG_PSEUDO

Details of the results are in **Appendix C3**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-10**.

Table 5-10 Open Cut Synthetic Model Comparative Flows for USG Unsaturated Options

	MINE INFLOW [ML/YEAR]			BASEFLOW [ML/YEAR]		
OPTIONS	PSEUDO	VADOSE	%DIFFERENCE	PSEUDO	VADOSE	%DIFFERENCE
VC1/A1	5,656.5	5,806.1	-2.6	9,915.0	10,832.0	-9.2

Note: Negative %Difference means Pseudo-Soil flow < Vadose flow

The highlights of this analysis are:

- Pseudo-soil gives marginally less mine inflow (by about 3%).
- Vadose gives higher baseflow (by about 10%).

- During mining, hydrographs at P1 agree well except in layers 2-3 where maximum head differentials of 20-60 m occur.
- After mining, recovery of water levels is equally rapid at P1 for the two unsaturated options.
- The vadose simulation ran 20% faster than pseudo-soil.

5.3.4 USG_PSEUDO

Details of the results are in **Appendix C4**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-11**.

Table 5-11 Open Cut Synthetic Model: Comparative Flows for Vertical Conductance Options

	MINE INFLOW [ML/YEAR]		BASEFLOW [ML/YEAR]	
OPTION	USG	%DIFFERENCE	USG	%DIFFERENCE
VC1	5,656.5	Base	9,915.0	Base
VC2	5,458.6	+3.5	9,919.5	-0.05
VC3	5,656.5	0.0	9,915.0	0.0
VC4	5,458.6	+3.5	9,919.5	-0.05
VC5	5,458.6	+3.5	9,919.5	-0.05

Note: %Difference is calculated from the VC1 values

The highlights of this analysis are:

- Some difference in mine inflow was observed (by about 3%). VC1 (CONSTANTCV NOVFC) and VC3 (CONSTANTCV) agreed perfectly. VC2, VC4 and VC5 agreed perfectly.
- No significant difference in baseflow was observed.
- During mining, slight differences in hydrographs were observed at bores P2-P7 between the two VC groups. Larger difference was observed in hydrographs at P1 for layers 2-3 (maximum between 15-60 m).
- VC1 and VC3 gave earlier recovery of deep water levels.
- Runtime was least for VC2 using XMD (6 minutes) and for VC1 using PCGU (5 minutes), the latter running 1.7 times faster than the XMD equivalent for VC1.
- Runtime was longest for VC3 (13 minutes).
- All runs converged without undue difficulty.

5.3.5 USG_PINCHOUT AND USG_PSEUDO

Details of the results are in **Appendix C5**. A comparison of mine inflow and baseflow results (averaged over the nine years of mining) is presented in **Table 5-13**.

Two alternative scenarios were created using pinched-out (removed) model cells to combine the layer 1 and layer 2 regolith area together: Scenario 2 and Scenario 3.

Scenario 2 used the Groundwater Vistas (GV) MODFLOW-USG "Pinch Out Layers" option to remove all cells in layer 2 outside of the alluvium, implemented as Hydro-Stratigraphic Unit (HSU) zone 7 in layer 2; see **Table 5-12**. All cells outside the alluvium in layer 1 had their bottom elevation adjusted to 350 m, such that they represented the entire 50 m thickness of the regolith. The standard lateral flow regime applies in Scenario 2, wherein lateral flow connections are only present between cells in the same layer.

Hence, the 50 m regolith cells in layer 1 of Scenario 2 are laterally connected to the alluvium cells, but not to the regolith cells of layer 2 underlying the alluvium cells.

Scenario 3 utilised 6 layers in GV instead of pinching out cells, with the base VC1 model's layer 2 completely removed. Layer 1 was split into two sub-layers in the alluvial region – with sub-layer 1 being alluvium and sub-layer 2 being regolith – using GV's nested grid feature. The rest of layer 1, outside the alluvium, represented the full 50 m thickness of the regolith. The nested grid sub-layering ensures that lateral flow connections are applied in Scenario 3 between the 50 m regolith cells and both the alluvium cells and the regolith cells underlying the alluvium cells. Layers 2-6 in Scenario 3's GV model are identical to the base VC1 model's layers 3-7. The hydrographs presented use the same layer numbering scheme as VC1 in the hydrographs (where layer 2 is the second sub-layer in layer 1, and layers 3-7 are identical between the models).

Table 5-12 Groundwater Vistas MODFLOW-USG Options for Scenario 2 & Pinch-out Region

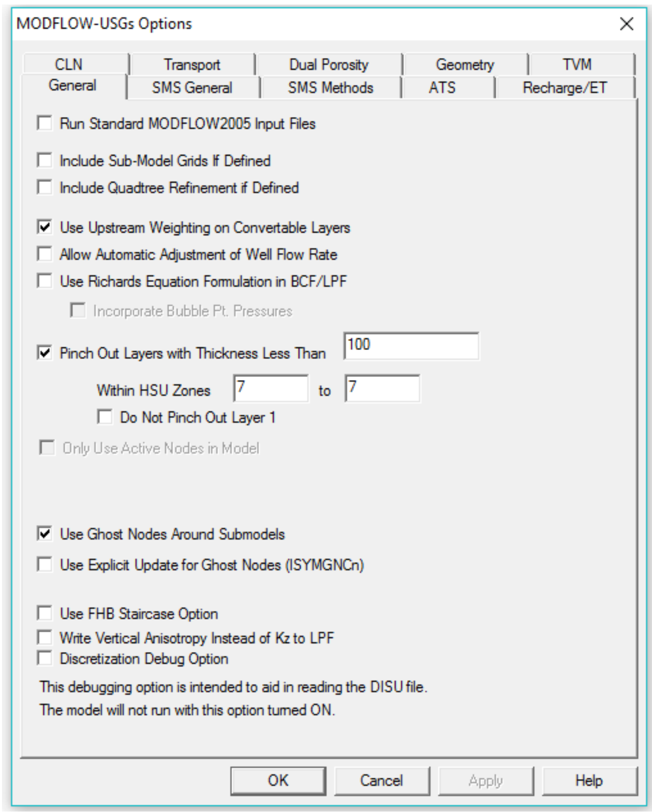


Table 5-13 Open Cut Synthetic Model: Comparative Flows for Vertical Conductance Options

OPTION	MINE INFLOW [ML/YEAR]		BASEFLOW [ML/YEAR]	
	USG	%DIFFERENCE	USG	%DIFFERENCE
VC1	5,656.5	Base	9,915.0	Base
Scenario 2	5,671.4	-0.26	9,891.1	+0.24
Scenario 3	5,666.2	-0.17	9,902.8	+0.12

Note: %Difference is calculated from the VC1 values

The highlights of this analysis are:

- No significant difference in mine inflow was observed. Scenario 2 and Scenario 3 both exhibited about 0.2% more mine inflow than VC1.
- No significant difference in baseflow was observed. Scenario 2 and Scenario 3 both exhibited about 0.2% less baseflow than VC1.
- No difference was observed in hydrographs at P1, except for layer 2, which was pinched out in Scenario 2 – but the head of layer 1 matches the head of VC1's layer 2.
- Scenario 2 did not converge using XMD, but did converge using PCGU.
- Scenario 3 converged using XMD, and its runtime (4 minutes) was faster than Scenario 2's runtime (7 minutes).

6 TASK 7

6.1 MS PSEUDO-SOIL MODEL

The pseudo-soil option of MS is the option recommended by HydroGeoLogic, Mackie Environmental Research and Dr Kalf. AGE could not get the MS pseudo-soil model to converge, which was consistent with HS' experience of other similar MS pseudo-soils models. However, after a period without success, HS managed to get the synthetic model to converge (Steady State and Transient calibrations).

HS and HA's early attempts to get the Bylong model to run with Pseudo Soils consisted of the following:

- Some changes to the number of inner and outer iterations (both reducing and increasing these).
- Long transient and short transient runs.
- PCG4, rather than PCG5 (using Kalf-suggested PCG4 settings plus HS- modified PCG4 settings).
- Different initial heads (AGE supplied, Layer 1 top, plus recycled from other attempts).
- Removing EVT, which is known to be a highly non-linear boundary condition.
- Modifying host Kx and Leakance values for Layers 1-3, mainly Layer 3.
- Activating dampening (which is supposed to be a numerical aid for situations with irregular geometries).
- Both tightening and loosening backtracking controls in the non-linear solver.
- Various levels of ILU preconditioning, with and without the reduced (red-black) system.
- Tightening the closure criterion (HCLOSE).
- Deactivating the Newton solver and using CG instead of Orthomin.
- With and without EVT (Interestingly the vadose model converged more easily with EVT than without - but this didn't seem to help with pseudo-soils).

HS' opinion is that irregular layer geometries, including lots of very thin cells (0.5 m) were resulting in steep hydraulic gradients and variable saturation in adjacent cells. The Richards/vadose configuration of models A and A^ allowed convergence, even in this situation, while the pseudo-soils model (A^^) did not.

Finally, after discussion with HydroGeoLogic, HS/HA altered the Residual reduction control (RESRED) =1.0 to force residual reduction (or equivalence) every iteration. This resulted in:

- Convergence of the Steady State (SS) A^^ model in 176 outer iterations and a run time of about 90 minutes, with an excellent (low) mass balance error.
- Convergence of the Transient (TR) calibration A^^ model in 1 hour 17 minutes for 412 x 2-day stress periods starting from the pseudo-soil SS heads, and HCLOSE of 0.1 m. Mass balance was good for all time steps (worst error -0.38%).

7 TASKS 5-6 AND 8-9

7.1 TASK 5 BY AGE

AGE has provided the results of A^_Null and C^_Null models, in which all mining is deactivated and all borefield/landholder pumping is deactivated. This exercise compares a vadose MS simulation with a pseudo-soil USG simulation without anthropogenic stresses.

Comparative heads are presented in **Figure 7-1** to **Figure 7-6** (supplied by AGE) for layers 1-3 at the end of SP40 (end of OC) and at the end of SP100 (end of LW).

HS has carried out a brief analysis of the supplied head distributions to reveal the spatial head differentials on the water table (in Layer 2) at the end of the simulation period, as shown in **Figure 7-7**.

HS notes that one model (A^, using MS) has a fully extensive Layer 2, while the unstructured model (C^, using USG) has a Layer 2 extent limited to the physical boundaries of the alluvium and basalt areas.

Figure 7-7 shows that modelled water levels are very similar, typically within less than a metre, through the alluvium (green areas on **Figure 7-7**). There are, however, significant differences in the modelled heads in the basalt areas, which are more likely to exist as a perched aquifer and possibly switching between saturated and unsaturated through time (whereas the alluvium is likely to be saturated more consistently). The differences observed between the two sets of modelled heads are up to about 50 m (orange-red areas on **Figure 7-7**), with the MS model simulating heads below those of the USG model.

HS has not determined whether either model is simulating Layer 2 as saturated, or whether a perched water table exists. Comparison of the model result with observed data from bore BY0091-B (in the basalt) is inconclusive, as this bore is dry, and both sets of modelled water levels fall below the base of that bore.

AGE also provided a time-series plot of simulated baseflows for the Bylong River and Lee Creek, as shown in **Figure 7-8**, while the whole-of-model water balance for the two null runs is shown in **Table 7-1**.

Table 7-1 Simulated Water Balance during the Prediction Period for A^_Null and C^_Null

Component	A^_Null Groundwater Inflow (Recharge) (ML/day)	C^_Null Groundwater Inflow (Recharge) (ML/day)	A^_Null Groundwater Outflow (Discharge) (ML/day)	C^_Null Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	15.5	14.4	-	-
Evapotranspiration	-	-	14.4	74.1
Rivers/Creeks	35.1	62.3	37.1	3.6
Production Bores	-	-	-	-
Mines	-	-	-	-
Boundary Flow	0.1	0.0	0.0	0.0
TOTAL	**50.7**	**76.7**	**51.5**	**77.7**
Storage (ML/day)	**0.8 LOSS**	**1.0 LOSS**		
Discrepancy (%)	**0.00**	**0.00**		

Water balance is the average across 25-year predictive period

The pseudo-soil simulation reports much less baseflow (**Figure 7-8**), generally by 70% of an order of magnitude at Bylong River and by 1-2 orders of magnitude at Lee Creek. This is consistent with the water balance (**Table 7-1**), which shows very different magnitudes for evapotranspiration and river leakage and baseflow. For MS, the ET is 28% of the total outflow whereas for USG it is 95%. Conversely, the baseflow is 72% of the total outflow for MS whereas for USG it is only 5%.

7.2 TASK 6 BY AGE

AGE has provided the results of A^ and C^ models, with the same mining stresses and borefield/landholder pumping activated. This exercise compares a vadose MS simulation with a pseudo-soil USG simulation with anthropogenic stresses.

Comparative maximum drawdowns during mining are presented in **Figure 7-9** to **Figure 7-11** (supplied by AGE) for layers 1-3.

HS has carried out a brief analysis of the comparison of the A^ vs C^ model results, as provided by AGE. This has been restricted to a comparison of spatial heads.

A comparison of the predicted groundwater drawdown (water table) from the mining-affected scenario of models A^ and C^ is presented as **Figure 7-12**.

Figure 7-12 shows that the drawdown predicted by the two models is relatively similar across much of the alluvium (yellow), but A^ (MS_vadose) drawdown is typically greater than C^ (USG_pseudo) drawdown in those yellow areas as well as the pink areas in the alluvium.

However, above the longwall area the drawdown predicted by C^ is considerably greater than that predicted by A^ (dark blue areas on **Figure 7-12**), with the exception of the cells immediately overlying the pillars (pink/purple stripes). The key is that the pseudo-soil or upstream weighting setting (as in C^) switches horizontal transmissivity to zero when a cell becomes fully unsaturated, while the vadose zone representation of A^ maintains some horizontal connection (while vertical connection is maintained in both cases)[4].

The key point about this is the pseudo-soil (or upstream weighting) configuration results in greater drawdown immediately above longwalls, but does not allow that drawdown cone to expand laterally, as is allowed in the vadose/Richards equation configuration.

AGE also provided a time-series plot of simulated baseflow impacts for Bylong River and Lee Creek, shown in **Figure 7-13**[5]. The baseflow impacts reported by MS are much greater than reported by USG, by more than one order of magnitude.

The whole-of-model water balances for the MS null run and the MS stress run are compared in **Table 7-2**. The yield of the production bores and the groundwater take by the mine are balanced by losses from storage and reductions in ET (by 13%) and baseflow (by 14%).

[4] AGE modellers commented that they felt there was "some effect caused by residual storage as well". This effect is hard to identify, but AGE's analysis suggests more water gets released from storage using Pseudo-soil. But this could also be because recharge (or flux from saturated units from above) bypasses dry cells, and ends up in the highest saturated cell (impeded only by vertical conductance)).
[5] Comparison is also made between the RtS USG model and a vadose version of it (assessed at Task 9).

Table 7-2 Simulated Water Balance during the Prediction Period for A^ and A^_Null Runs

Component	A^_Null Groundwater Inflow (Recharge) (ML/day)	A^ Groundwater Inflow (Recharge) (ML/day)	A^_Null Groundwater Outflow (Discharge) (ML/day)	A^ Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	15.5	15.7	-	-
Evapotranspiration	-	-	14.4	12.6
Rivers/Creeks	35.1	35.1	37.1	32.2
Production Bores	-	-	-	7.2
Mines	-	-	-	3.3
Boundary Flow	0.1	0.1	0.0	0.0
TOTAL	**50.7**	**50.9**	**51.5**	**55.3**
Storage (ML/day)	**0.8 LOSS**	**4.4 LOSS**		
Discrepancy (%)	**0.00**	**-0.04**		

Water balance is the average across 25-year predictive period

The whole-of-model water balances for the MS and USG stress runs are compared in **Table 7-3**. Mine inflow for USG is almost double that for MS. Very different magnitudes for evapotranspiration and river leakage/baseflow are apparent.

Table 7-3 Simulated Water Balance during the Prediction Period for A^ and C^

Component	A^ Groundwater Inflow (Recharge) (ML/day)	C^ Groundwater Inflow (Recharge) (ML/day)	A^ Groundwater Outflow (Discharge) (ML/day)	C^ Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	15.7	14.6	-	-
Evapotranspiration	-	-	12.6	69.2
Rivers/Creeks	35.1	62.3	32.2	2.9
Production Bores	-	-	7.2	5.6
Mines	-	-	3.3	6.2
Boundary Flow	0.1	0.0	0.0	0.0
TOTAL	**50.9**	**76.9**	**55.3**	**83.9**
Storage (ML/day)	**4.4 LOSS**	**7.0 LOSS**		
Discrepancy (%)	**-0.04**	**0.00**		

Water balance is the average across 25-year predictive period

7.3 TASK 8 BY AGE

Using the solver settings that HS found to be successful for transient calibration, AGE was unable to get the transient A^^ model (i.e. MS with pseudo-soil settings) to converge beyond stress period (SP) 34 – i.e. it failed to converge in SP35 of that run. AGE chose higher values for outer and inner iterations and re-ran the model for SP35. However, these changes were also unsuccessful.

AGE also ran the A^^ model without mining, i.e. a 'Null' run as per the Australian Groundwater Modelling Guidelines (Barnett ***et al.,*** 2012). It reached SP95 after almost 4 days of computer time. The fact that this run fails, without the significant stress of mining, emphasises the difficulty in (reliably) running complex regional models using the MS 'pseudo-soils' option.

This supports the previous experience of both AGE and HS.

7.4 TASK 9 BY AGE

AGE has provided the results of A^ and C^^ models, with the same mining stresses and borefield/landholder pumping activated. This exercise compares MS and USG simulations (with anthropogenic stresses) when both are using the same vadose properties.

Comparative maximum drawdowns during mining are presented in **Figure 7-14** to **Figure 7-16** (supplied by AGE) for layers 1-3.

Highlights of this analysis are:

- The Layer 1 drawdowns match very well visually.
- The Layer 2 drawdowns agree well in the alluvium, but in the basalt area the USG drawdown is greater (roughly doubled).
- The Layer 3 drawdown is noticeably greater for USG in the underground mining area, but beneath the alluvium the differences are marginal.

The baseflow impacts for this comparison are included on **Figure 7-13**, where it is seen that conversion of USG from pseudo-soil to vadose properties results in an approximate doubling of the baseflow impact. However, it is still about one order of magnitude less than that reported by MS for the same vadose properties.

Representative hydrographs are compared for models A^, C^ and C^^ in **Figure 7-17** and **Figure 7-18** at site CP035 (in the underground mining area) and at site A06 (in the alluvial corridor). The locations are indicated in the inset frame on **Figure 7-17**. The MS and USG vadose drawdowns agree quite well inside and outside the mining area. However, in the mining area, the pseudo-soil simulation gives greater drawdown that is sustained to the end of mining, compared with gradual recovery using vadose properties. Outside the mining area in the alluvial corridor, the behaviour is opposite: the pseudo-soil drawdown is less (at all depths), by about 20%.

The whole-of-model water balances for three USG runs (null, pseudo-soil and vadose) are compared in **Table 7-4**. The mine inflow is roughly doubled for pseudo-soil. The vadose option gives marginally more ET impact and marginally less baseflow impact.

Table 7-4 Simulated Water Balance during the Prediction Period for all USG Runs

Component	C^_Null Groundwater Inflow (Recharge) (ML/day)	C^ Groundwater Inflow (Recharge) (ML/day)	C^^ Groundwater Inflow (Recharge) (ML/day)	C^_Null Groundwater Outflow (Discharge) (ML/day)	C^ Groundwater Outflow (Discharge) (ML/day)	C^^ Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	14.4	14.6	14.6	-	-	-
Evapotranspiration	-	-	-	74.1	69.2	67.5
Rivers/Creeks	62.3	62.3	62.3	3.6	2.9	3.8
Production Bores	-	-	-	-	5.6	6.0
Mines	-	-	-	-	6.2	3.3
Boundary Flow	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**76.7**	**76.9**	**76.9**	**77.7**	**83.9**	**80.6**
Storage (ML/day)	**1.0 LOSS**	**7.0 LOSS**	**3.7 LOSS**			
Discrepancy (%)	**0.00**					

Water balance is the average across 25-year predictive period

The whole-of-model water balances for the same vadose properties in MS and USG stress runs are compared in **Table 7-5**. The mine inflows are the same. However, different magnitudes for evapotranspiration and river leakage/baseflow are apparent in line with different behaviours under null conditions.

Table 7-5 Simulated Water Balance during the Prediction Period for A^ and C^^

Component	A^ Groundwater Inflow (Recharge) (ML/day)	C^^ Groundwater Inflow (Recharge) (ML/day)	A^ Groundwater Outflow (Discharge) (ML/day)	C^^ Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	15.7	14.6	-	-
Evapotranspiration	-	-	12.6	67.5
Rivers/Creeks	35.1	62.3	32.2	3.8
Production Bores	-	-	7.2	6.0
Mines	-	-	3.3	3.3
Boundary Flow	0.1	0.0	0.0	0.0
TOTAL	**50.9**	**76.9**	**55.3**	**80.6**
Storage (ML/day)	**4.4 LOSS**	**3.7 LOSS**		
Discrepancy (%)	**-0.04**	**0.00**		

Water balance is the average across 25-year predictive period

8 CONCLUSION

8.1 PURPOSE

This project has consisted of a number of audit and verification functions. Primarily, the purpose has been to establish whether models developed with MODFLOW-SURFACT [MS] and MODFLOW-USG [USG] give the same or similar results and whether one software platform should be used in preference to the other.

The two software platforms solve the same groundwater flow equation, with the same choices of boundary conditions to achieve a characteristic solution for a specific groundwater system. However, there are differences in the underlying mathematical solutions and in a number of options, and potentially in the scale of discretisation.

The approach has been to explore the similarities and differences between the MS and USG applications to synthetic models, to see if generic principles can be elucidated, and to the Bylong model in particular, to see if the predicted environmental impacts are consistent.

Both longwall mining and open cut mining synthetic models have been developed. The focus has been on comparison of MS and USG for different representations of unsaturated conditions, termed here as "vadose" (invoking van Genuchten and Brooks-Corey parameters in the Richards Equation) and "pseudo-soil". For USG models, the effects of vertical conductance [VC] options have been explored. Discretisation scale has been held the same for the synthetic models.

For the Bylong model, the focus has been on the differences in predicted impacts between a vadose MS implementation and a pseudo-soil USG version, all other properties and stresses being similar. Discretisation scale is not the same for the Bylong model variants.

It should be noted that there are many opportunities for the introduction of uncertainty in groundwater models that are outside the scope of this project. We now have a good understanding of the uncertainties introduced by the various software options and particularly on the differential magnitudes of predicted effects, but this is only one aspect. However, the findings are not as clear-cut as we had hoped. The consequence is that, based on these findings, groundwater modellers cannot favour one software approach over the other.

8.2 AUDIT PHASE FINDINGS

An audit of the model files for the MS EIS model and the USG RTS model was the first of nine steps to be undertaken in this project. In the event, the EIS MS model A was converted to model A^, so that both MS and USG models had essentially the same parameterisation and stresses.

8.2.1 MS MODEL A^

As all predictive MS model runs have been set up as a series of batched time-slice simulations to cater for time-varying properties for longwall fracture zones and open cut spoil emplacement, using software that is proprietary to AGE, HS was limited in its investigation of predictive simulations.

HS was able to check the full transient calibration model of 412 stress periods and a walk-through of each row and each column showed fairly smooth geometry with no significant cell dislocations, i.e. the layering appears appropriate.

HS notes that the vertical transmissive property is set up as leakance (VCONT) rather than vertical hydraulic conductivity (Kz) which is required for USG models. Although HS could not completely check the conversion from one to another, the procedure appears to have been followed correctly.

The storage property in MS is defined as storage coefficient (S) rather than specific storage (Ss). Again, comparison with USG is made difficult as USG defaults to use of Ss. Although HS could not completely check the conversion from one to another, the procedure appears to have been followed correctly.

The adopted vadose values are:

- Alpha = 0.02 [m^{-1}]
- Beta = 7 (Layers 1-2); 5 (Layers 3-10)
- Residual saturation = 0.01 (Layers 1-3); 0.002 (Layers 4-10).

HS regards the adopted alpha value as being very low (beyond the values suggested as realistic in literature) and the beta value relatively high, and this combination has allowed the MS model to converge more readily than with more realistic values. **Figure 8-1** demonstrates that MS will use a fully saturated hydraulic conductivity (for the AGE values) even down to 20 m below the mid-elevation of a model cell. Hence, the expectation of proper handling of unsaturated conditions is illusory. A similar solution could have been achieved by defining layer types to be "confined"[6].

Overall, no significant issues of concern were detected in the setup for Model A^. Note that HS was not able to check the application of time-varying properties.

8.2.2 USG MODEL C

AGE also provided geometry files for model C^ in which lateral connection groups (LCGs) were implemented in AlgoMesh. For both Model C and Model C^, the CONSTANTCV vertical conductance option was exercised. The option NOVFC was not exercised. The absence of this option may result in more physically-accurate simulation of vertical flow from perched aquifers, but to HS' understanding may produce different results from the MS model where such flow occurs. It is expected that CONSTANTCV without NOVFC provides the closest match to MS code.

Predictive USG model runs have been set up as a series of batched time-slice simulations to cater for time-varying properties for longwall fracture zones and open cut spoil emplacement. As this procedure is proprietary to AGE, HS was limited in its investigation of predictive simulations. Fortunately, as no time-varying properties were required for the calibration stage, HS was able to check the full transient calibration model of 507 stress periods.

AGE made available a TVM file for a new model that they have constructed and calibrated since the RTS model. This TVM file allowed HS to gain some appreciation of the temporal changes to properties, relying on the reasonable assumption that a similar approach would have been adopted in the time-slice simulations. HS has run diagnostic software on the TVM file to show that it has physically sensible values - it was not clear to HS whether any TVM changes are applied to spoil emplacement, however AGE's stated approach is appropriate.

About 300 concave cells were identified in the Voronoi mesh, many of which lie along the borders of the rectangular-gridded longwall region. These may affect the numerical accuracy of the flow solution locally to those cells. In practical terms, given the localised nature of these errors in contrast to the scale of the model, HS considers it unlikely that the concave cells would cause a significant deviation in model results.

Overall, no significant issues of concern were detected in the setup for Model C. Note that HS was not able to fully check the application of time-varying properties or directly assess the equivalence of parameterisation due to different forms of data input (Kz instead of VCONT and Ss instead of storage coefficient).

[6] AGE modellers commented that because of the variable thickness in the alluvium layers (0.5 m to 15 m, there is a significant difference in the effective permeability at the fringes of the alluvium compared to in the centre in the vadose and pseudo-soil models.

8.3 SYNTHETIC MODEL FINDINGS

The outputs of the synthetic model simulations have been examined in terms of mine inflow, baseflow impact, hydrographs and whole-of-model water balance.

A general observation is that the groundwater levels, in the form of hydrographs, generally match well between contrasting scenarios. In some (but not all) runs, pseudo-soil was observed to give more rapid drawdown and more rapid recovery.

Water balance components have been examined closely. The results are shown in **Table 8-1** for the base case, **Table 8-2** for varying vadose properties, and in **Table 8-3** for different VC options. To assist interpretation, the findings are colour-coded. It is clear that no universal pattern is evident.

For base properties (**Table 8-1**), MS can give either more or less mine inflow when the vadose option is used, depending on the method of mining and probably on the specific properties of the groundwater system being investigated. MS consistently gives less baseflow impact than USG for the vadose option. When the pseudo-soil option is used, mine inflow and baseflow impacts are generally in agreement (within 10%).

Table 8-1 Synthetic Model Flow Comparison for Base Properties

SOFTWARE & UNSAT. METHOD	LONGWALL		OPEN CUT	
	MINE INFLOW	BASEFLOW	MINE INFLOW	BASEFLOW
Both Vadose	MS > USG ~30%	MS < USG ~30%	MS < USG ~30%	MS < USG ~30%
Both Pseudo-Soil	MS > USG ~10%	MS = USG	MS = USG	MS = USG
USG Vadose & Pseudo-Soil	Vadose < Pseudo ~30%	Vadose > Pseudo ~10%	Vadose > Pseudo ~3%	Vadose > Pseudo ~10%

When examining a range of vadose properties (**Table 8-2**), a similar pattern emerges.

Table 8-2 Synthetic Model Flow Comparison for Vadose Properties

VADOSE CASES	LONGWALL		OPEN CUT	
	MINE INFLOW	BASEFLOW	MINE INFLOW	BASEFLOW
Most Cases	MS > USG 20-30% [5 of 8 cases]	MS < USG ~30% [7 of 8 cases]	MS < USG ~30% [6 of 7 cases]	MS < USG ~25% [6 of 7 cases]
Exceptions	MS < USG [1 case; high alpha] MS >> USG 160-1000% [2 of 8 cases]	MS = USG [1 case; very low alpha]	MS = USG [1 case; very low alpha]	MS = USG [1 case; very low alpha]

In most cases MS gives consistently less impact on flows (by 25-30%) (**Table 8-2**), but wildly varying and excessive mine inflows were observed for the longwall model.

HS suspect that differences between the two software packages (i.e. MS vadose versus USG vadose) arise, at least in part, from MS relying on the cell top elevation as the reference point for calculations of relative saturation whereas USG-Beta uses the mid-point (cell centre) elevation as its reference point. HS has not tested this or confirmed it. Other differences may also arise between model runs due to the options in MS to specify just alpha, beta and Sr OR to add the Brooks-Corey exponent (***n***) to that set, whereas in USG there is no option (alpha, beta, Sr <u>and</u> ***n*** are required).

It was found that variations in vadose properties (primarily alpha, beta) affected model stability, especially with MODFLOW-USG. USG failed to converge with high alpha (~10) and with combinations of low alpha with high beta (e.g. alpha 1-2 and beta > 4). HS is not clear on the reason for this, but MS simulations with these settings converged.

Variations in the VC options (**Table 8-3**) gave the clearest pattern. Although very little effect was found, this should not be regarded as a global principle as the degree of desaturation in a model is likely to reveal differences in behaviour.

Table 8-3 Synthetic Model Flow Comparison for Vertical Conductance Options

VC OPTIONS	LONGWALL		OPEN CUT	
	MINE INFLOW	BASEFLOW	MINE INFLOW	BASEFLOW
Most Cases	USG = USG_Base [all 4 cases]	USG = USG_Base [all 4 cases]	USG < USG_Base ~3% [3 of 4 cases]	USG = USG_Base [all 4 cases]
Exceptions	-	-	USG = USG_Base [1 of 4 cases]	-

Use of layer pinch-outs, i.e. more realistically representing real-world geology in the model layering, shows no significant difference (Section 5.3.5). Inspection of the results shows that there was <1% difference in the flow effects.

8.4 BYLONG MODEL FINDINGS

Task 7 of this project saw HS attempting to run AGE's MS pseudo-soil model to completion. As discussed, both AGE and HS have previously had trouble with getting regional, mining-project pseudo soils models to converge or solve successfully. After a significant time, and with some advice from HydroGeoLogic, HS/HA succeeded in getting a steady state pseudo-soil model and a transient calibration pseudo-soil model to run to completion.

Following this, Task 8 was conducted by AGE, which took the solver parameters used to complete Task 7 and applied these to the predictive pseudo-soils models. This model failed to converge part way through the simulation, and despite other tweaks to model configuration, it would not converge. Likewise, even the relevant 'Null' model failed to converge. The finding is that the MS with pseudo-soil combination does not reliably converge (i.e. run to completion) for regional mining projection models.

Comparison of vadose MS simulation with a pseudo-soil USG simulation, without the complication of anthropogenic stresses, showed significant differences in the position of the water table and consequently of the significance of discharge processes. MS vadose tended to simulate water table at a lower elevation, at least across interfluves, compared to USG pseudo-soil, resulting in lower ET but higher baseflow in the MS simulation. The balance between ET and baseflow in the USG pseudo model appears too heavily skewed toward ET (95%) compared to baseflow (5%).

Likewise, once mining-stresses were introduced, the MS vadose simulation produced a wider, but slightly shallower cone of depression compared to the USG pseudo model. The pseudo model produced what appear to be very (overly) conservative drawdown estimates immediately above the mine footprint, but much lower drawdown is predicted outside this area. HS view the cone of depression produced by the MS vadose model as being more realistic.

The findings of Task 9 showed that USG vadose simulations produced similar results to the MS vadose model, and confirmed the previous finding that pseudo-soil models produce a conservative estimate of drawdown immediately above longwall mines, but lesser drawdown is predicted away from mining. These differences in how head and drawdown are simulated have a knock-on effect in that MS vadose predicts more conservative baseflow capture than does USG vadose, and the baseflow capture estimates of both vadose models are significantly higher than a pseudo-soil model.

8.5 OVERARCHING FINDINGS

A primary purpose of this study has been to establish whether models developed with MODFLOW-SURFACT and MODFLOW-USG give the same or similar results and whether one software platform should be used in preference to the other. Our finding is that the results are not always similar, and the size and the direction of the discrepancy between model results has no pattern that can be anticipated reliably. Overall, it has not been possible to state that either of the two software packages (SURFACT and USG) is more suitable than the other, or that vadose (using Richards equation) versus pseudo-soils (or upstream weighting) simulations are more suitable than the other. In different situations and with different conceptual models, the various combinations appear to perform more stably, and produce more 'realistic' or more conservative results than the other. There are differences in the predicted effects of the various software choices – simulated heads were typically more similar than mine inflow or baseflow.

It was hoped that thorough investigation of synthetic models would elucidate general principles for application to more complex models. Some patterns are evident, but exceptions have been noted. Based on the synthetic models, USG typically predicts greater effects on baseflow than MS with vadose methods (similar results with pseudo-soils) while mine inflow predictions are somewhat variable, especially with MS.

Therefore, modelling assessments need to consider and acknowledge this source of uncertainty, additional to the other inherent sources of uncertainty associated with estimation or simulation of subsurface conditions and groundwater behaviour. The choice of model code, given the lack of a definitive finding on suitability here, therefore remains with the modeller and the other perceived benefits of the software (e.g. cost, familiarity, boundary condition types, functionality).

For practical reasons, the use of vadose zone methods remains appealing, given the relative instability of pseudo-soil methods (noting that the results of testing in this study suggest that such methods appear more stable in USG than with MS). There is a need however, when using vadose methods, that the settings address the important physical phenomena in a reasonable way, such as setting alpha, beta within the expected limits and then conducting sensitivity analysis to assess the significance of these parameters on predictions. There are limited data available on consolidated lithologies, however Brooks and Corey (1964) and van Genuchten (1980) do describe results for two sandstones which should be applicable to the typical setting of (black) coal mining operations.

Overall, in the model audit phase of the study, no significant issues of concern were detected in the setup of the SURFACT EIS model or the USG RTS model. The model results show that SURFACT (vadose) gives more baseflow impact (due to a wide, yet gentler, drawdown cone) and USG (pseudo) gives more mine inflow and a more intense drawdown effect localised over the mine footprint.

8.6 LIMITATIONS

Some limitations in this study that may have a bearing on the findings are:

- Inability to interrogate the source code for HydroGeoLogic's proprietary code MS. This means that mathematics behind SURFACT cannot be compared directly to the mathematics underpinning USG.
- The thickness of the alluvium in the synthetic model is potentially too thick to show any variation in the effect of the different vertical conductance (VC) options, and potentially any variation in the effective horizontal permeability.
- Incomplete testing of the range of alpha, beta (and Sr) combinations for vadose simulations. Only a small sample of the possible combinations was tested, so findings regarding the predicted heads, baseflow, as well as conclusions regarding model stability, need to be considered in light of this.

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FIGURES

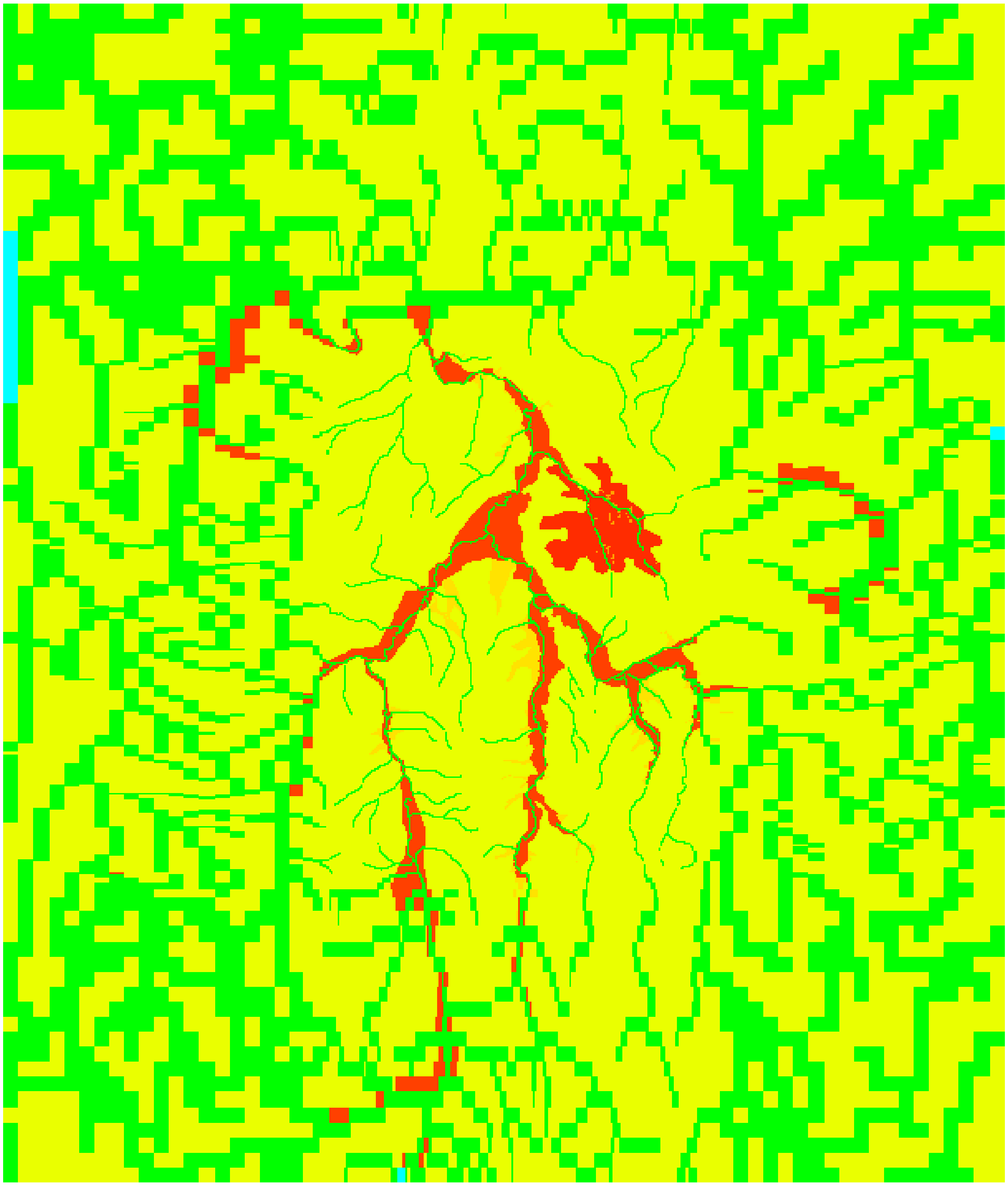


Figure 4-1 MS Model A^ Layer 1 Distribution of RIV Cells

[Green = RIV (rivers); Blue = GHB cells; Red = Alluvium; Yellow = Regolith]

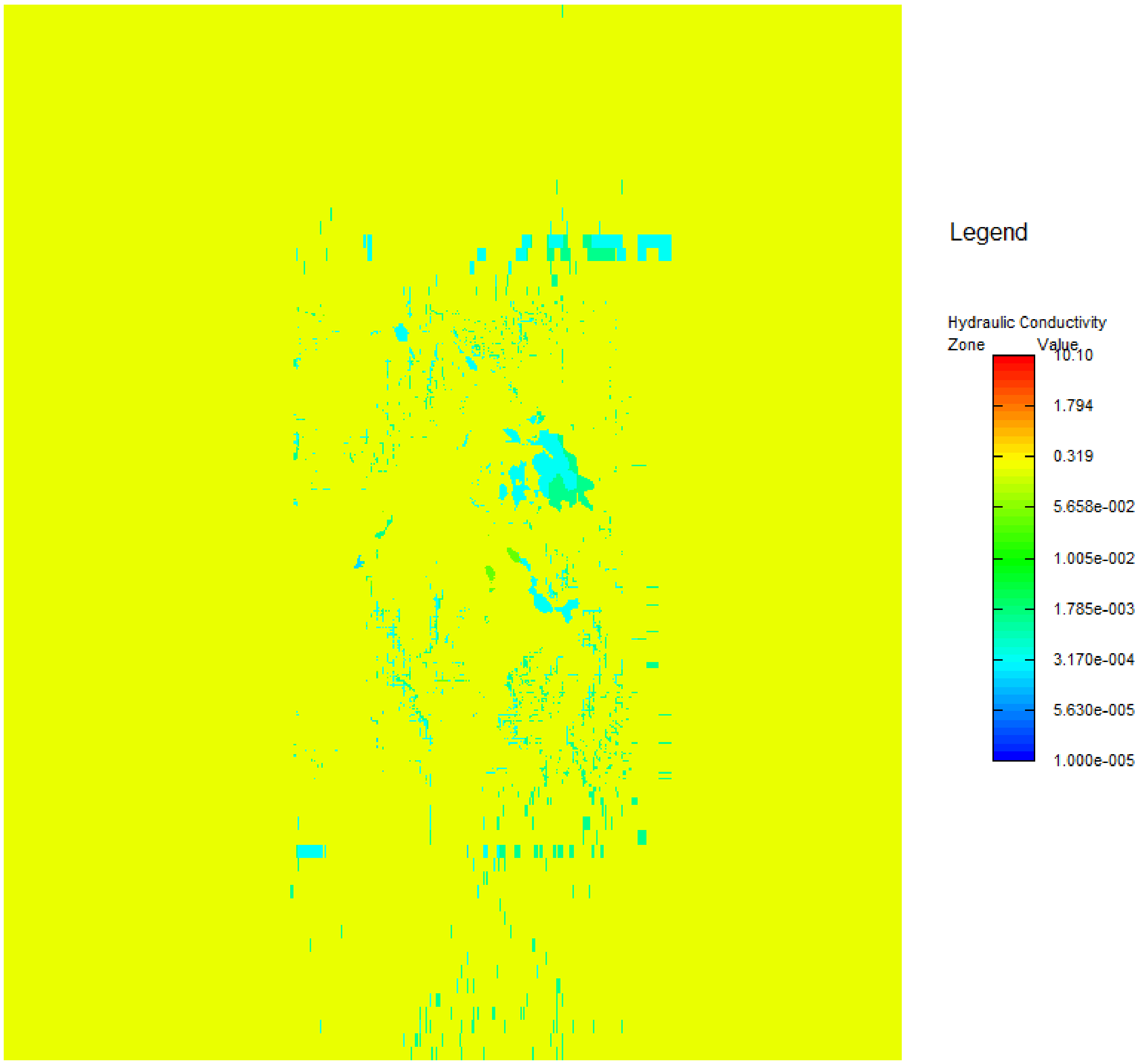


Figure 4-2 MS Model A^ Layer 3 Distribution of Kx (m/day)

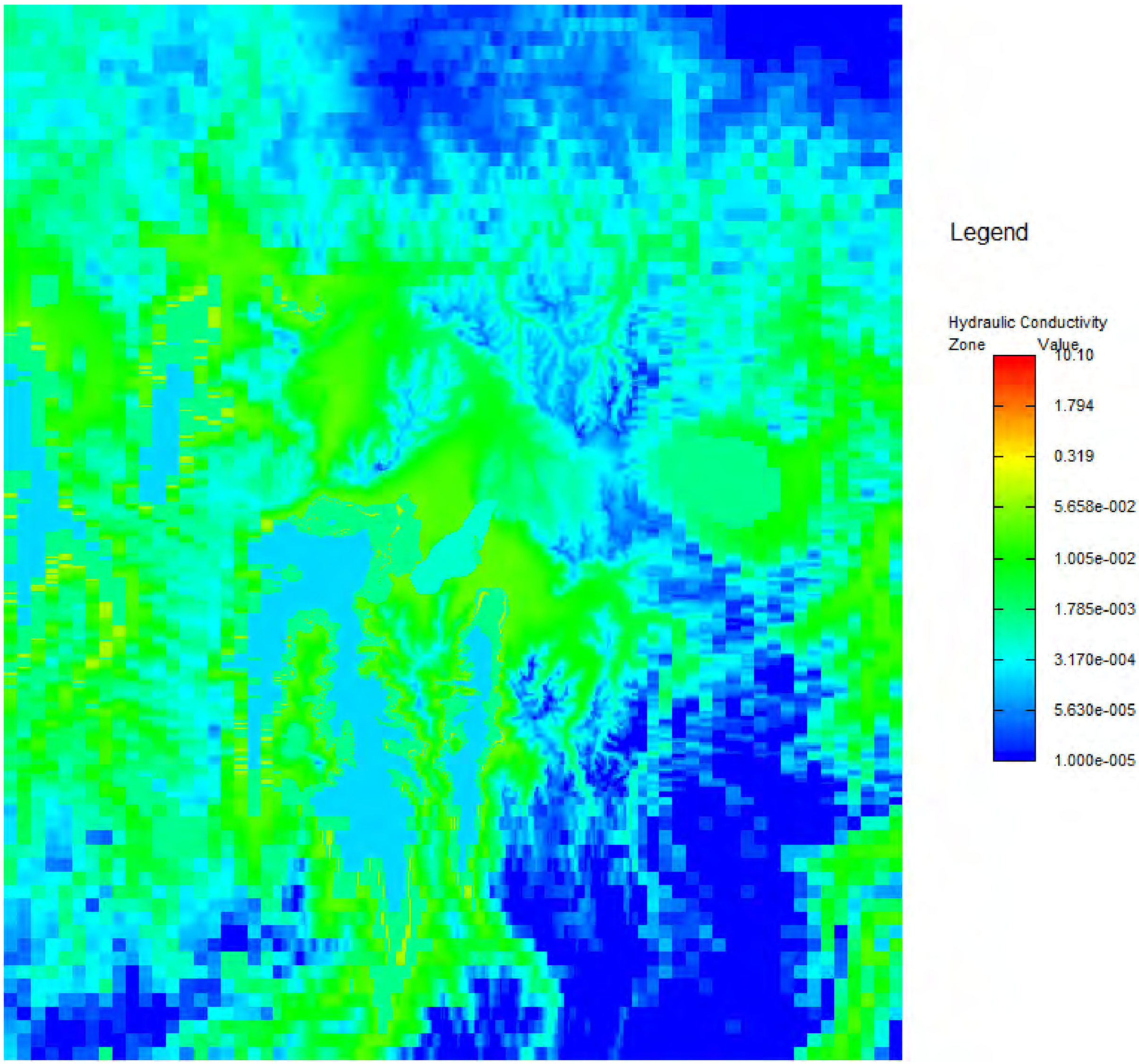


Figure 4-3 MS Model A^ Layer 6 Distribution of Kx (m/day)

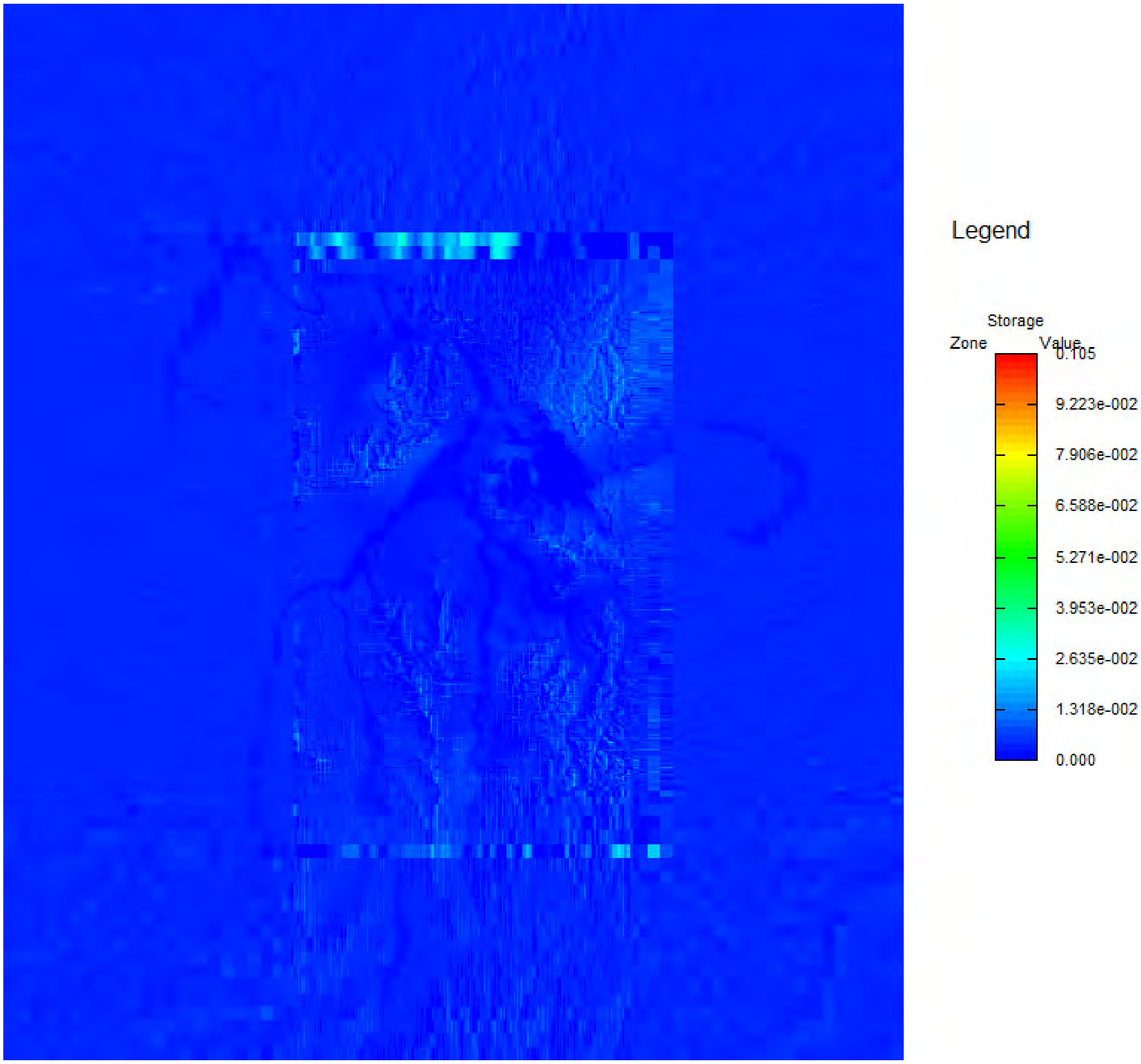


Figure 4-4 MS Model A^ Layer 3 Distribution of S

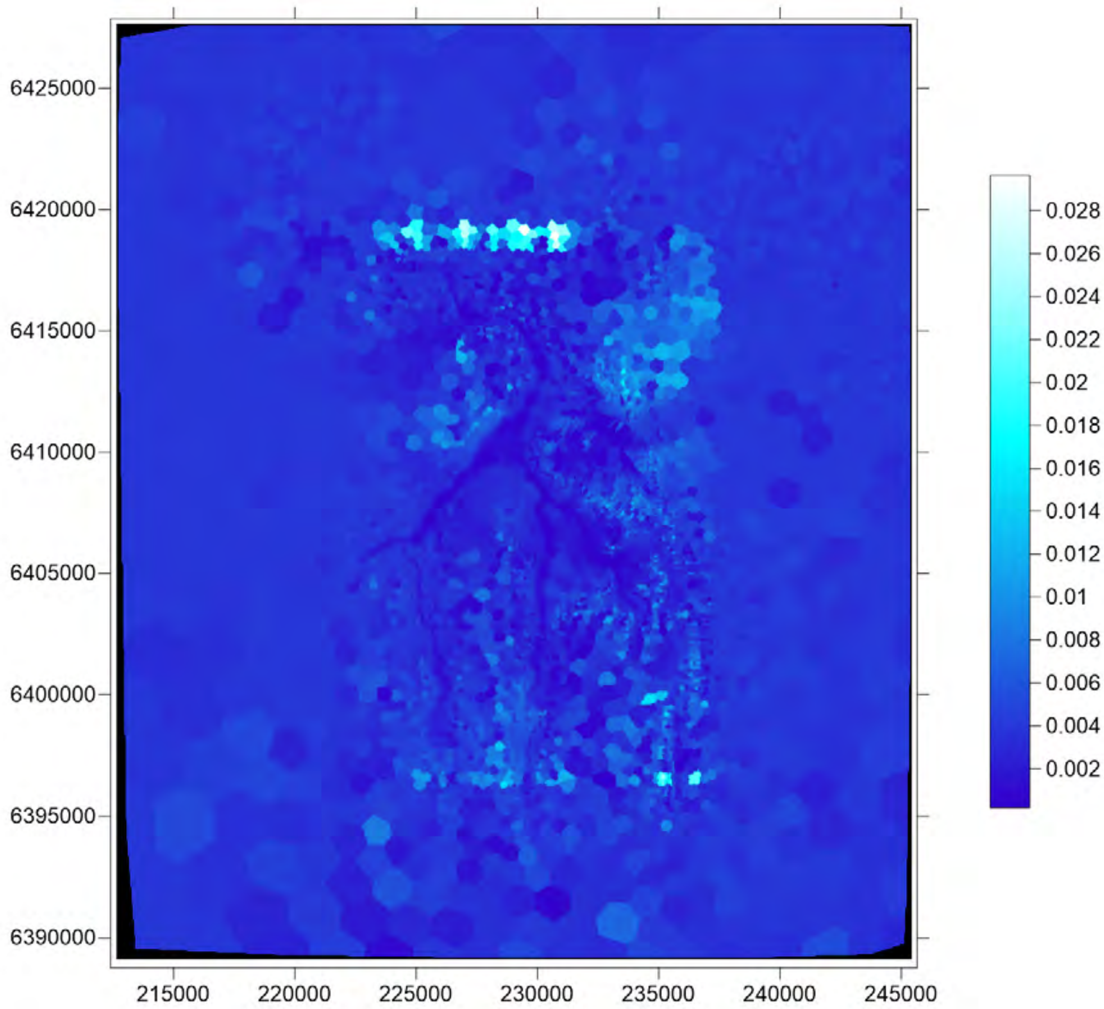


Figure 4-5 USG Model C Layer 3 Distribution of S (Converted from Ss)

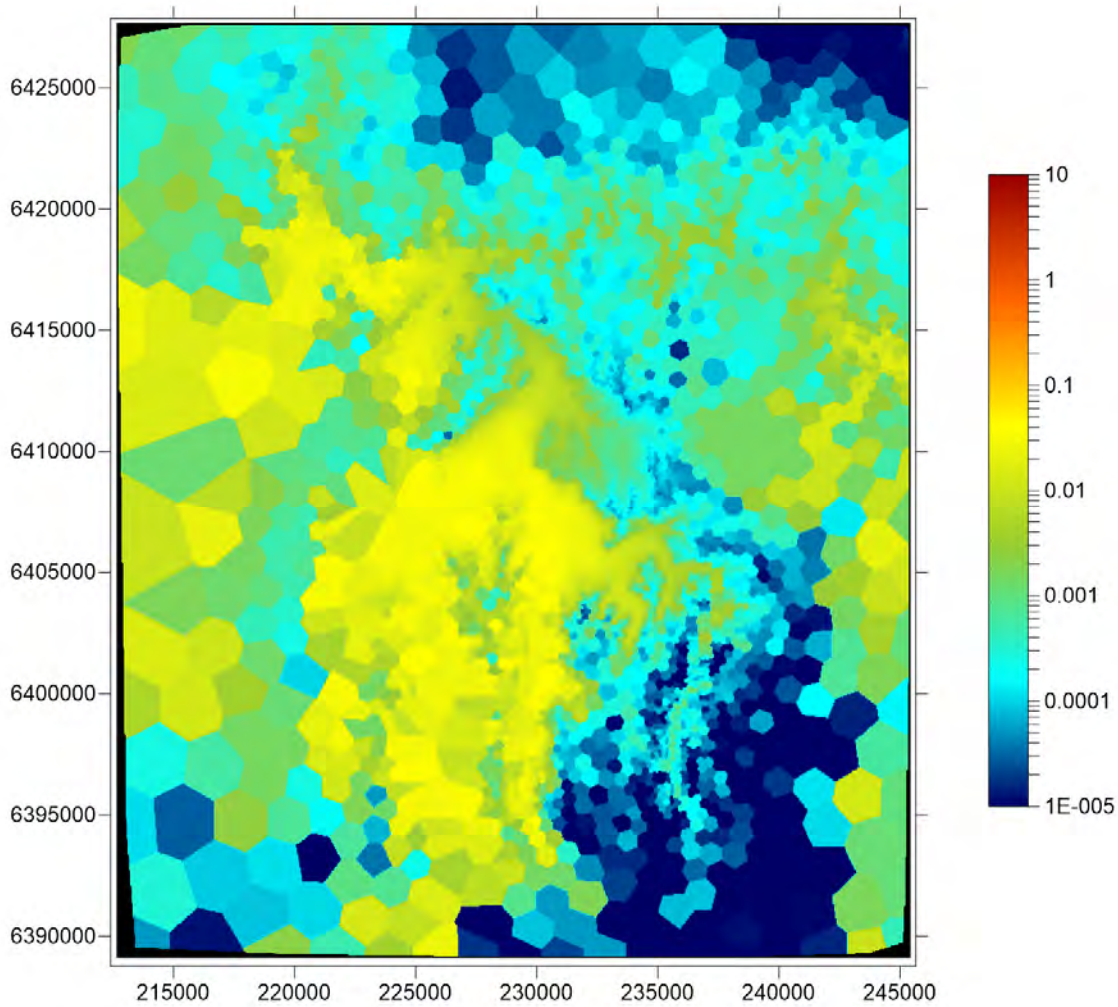


Figure 4-6 USG Model C Layer 6 Distribution of Kx (m/day)

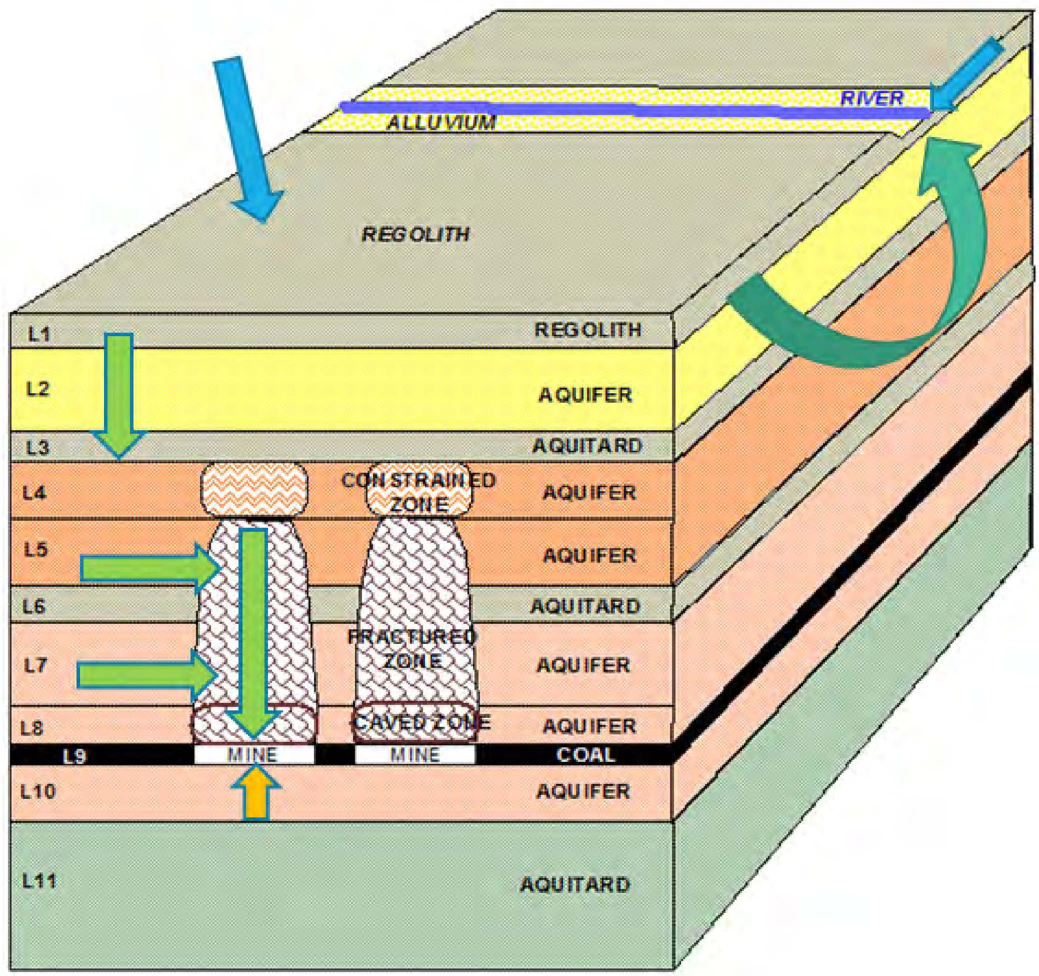


Figure 5-1 Synthetic Model for Longwall Mining

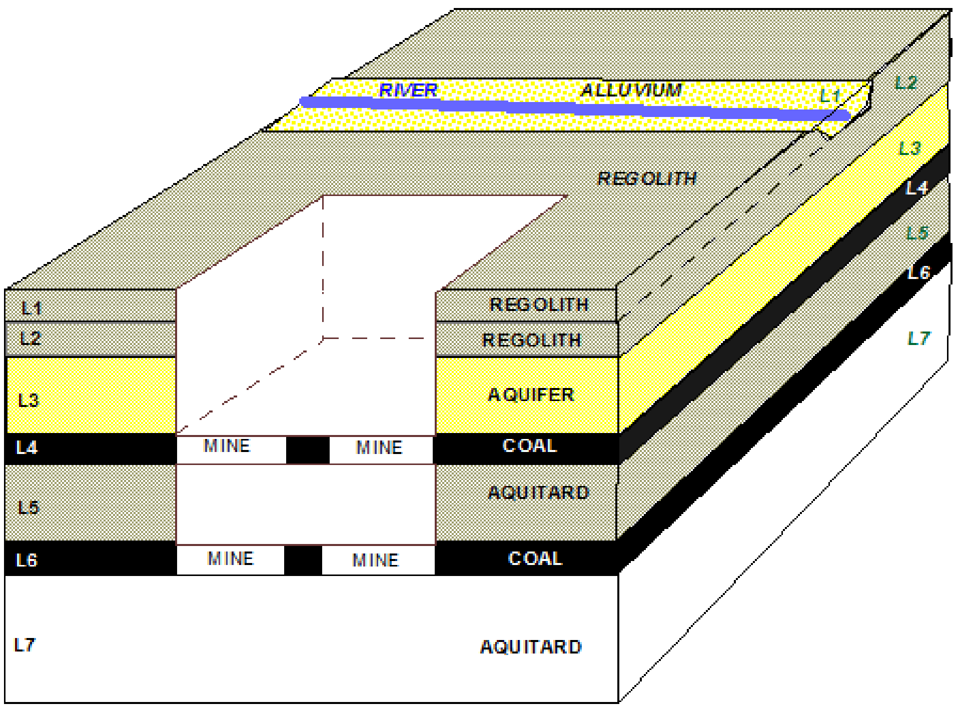


Figure 5-2 Synthetic Model for Open Cut Mining

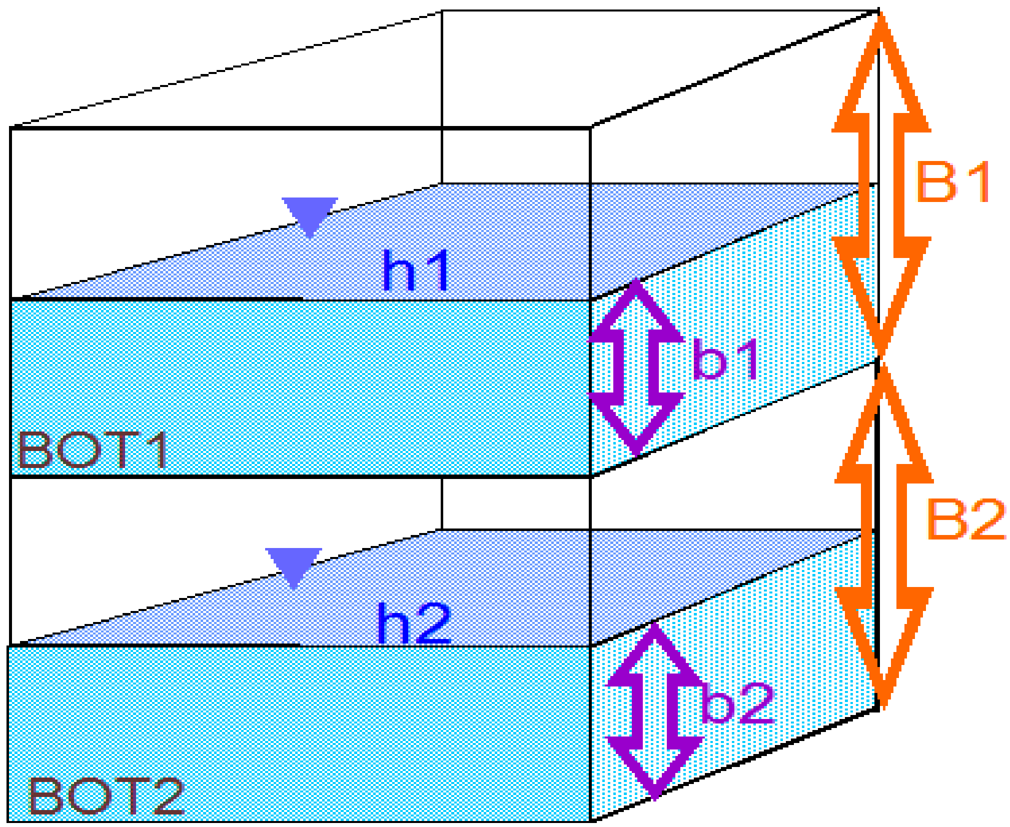


Figure 5-3 Head (h), Thickness (B) and Layer Base (BOT) references in Definitions of Vertical Conductance in MODFLOW-USG

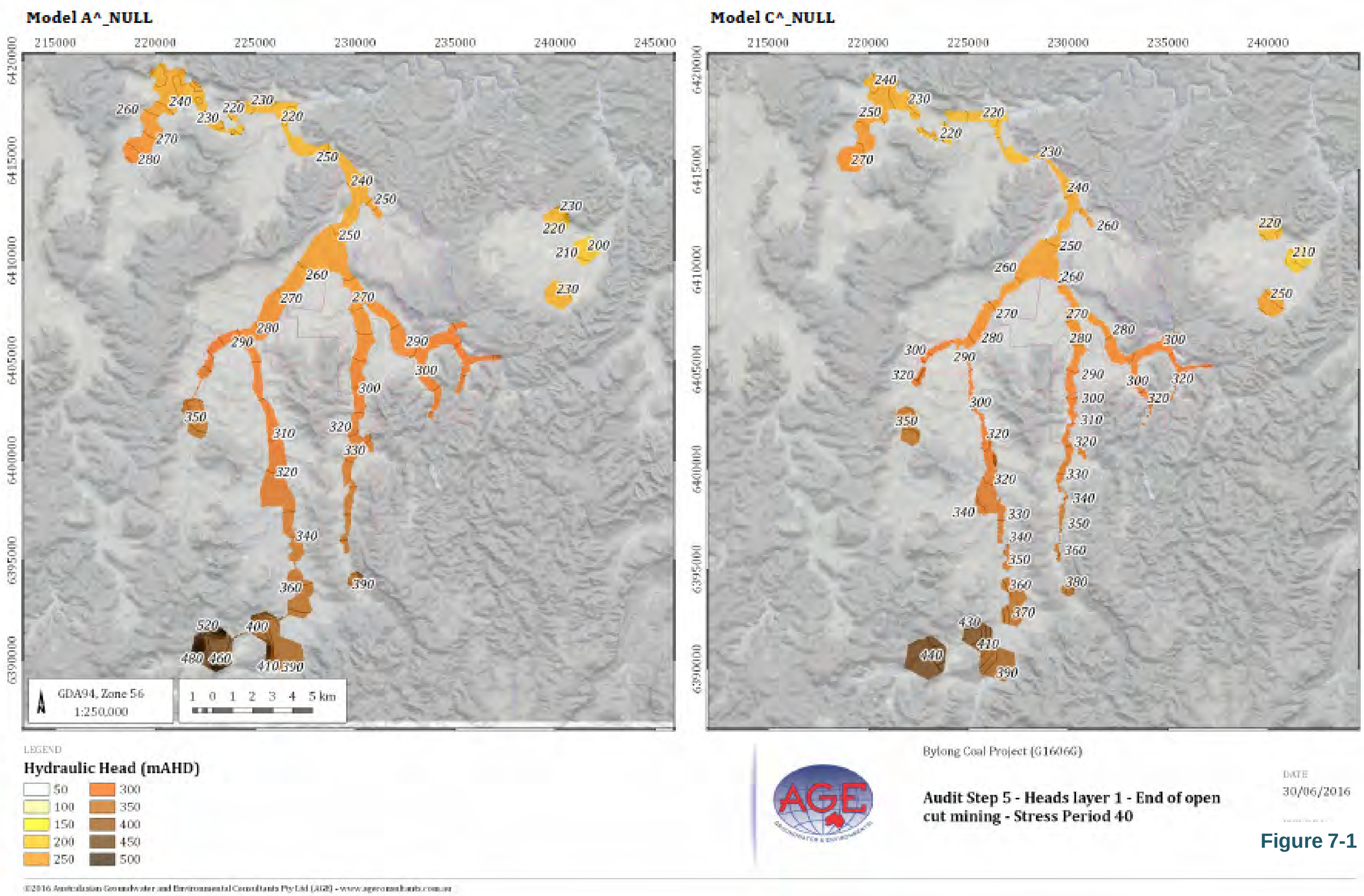
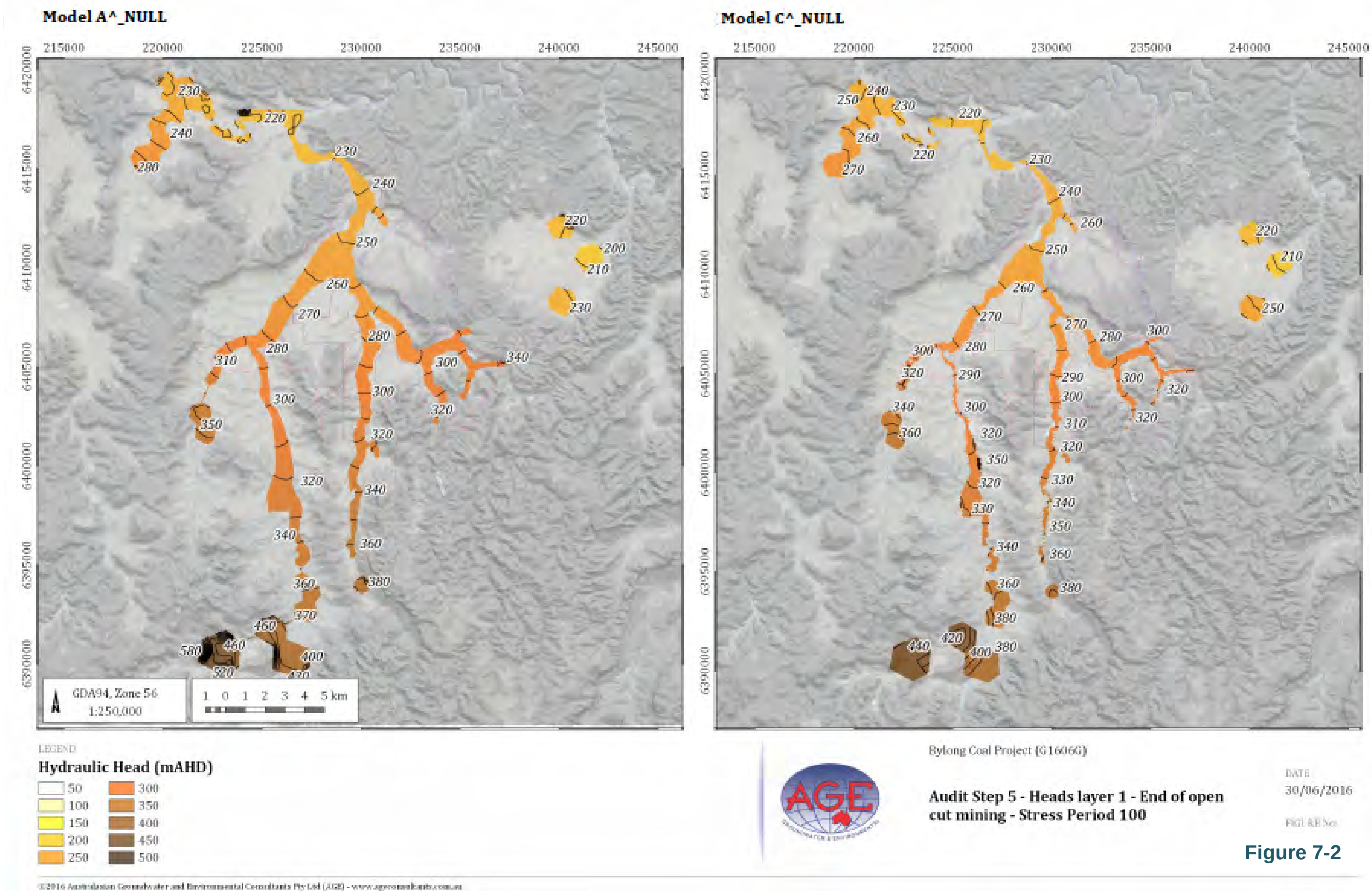
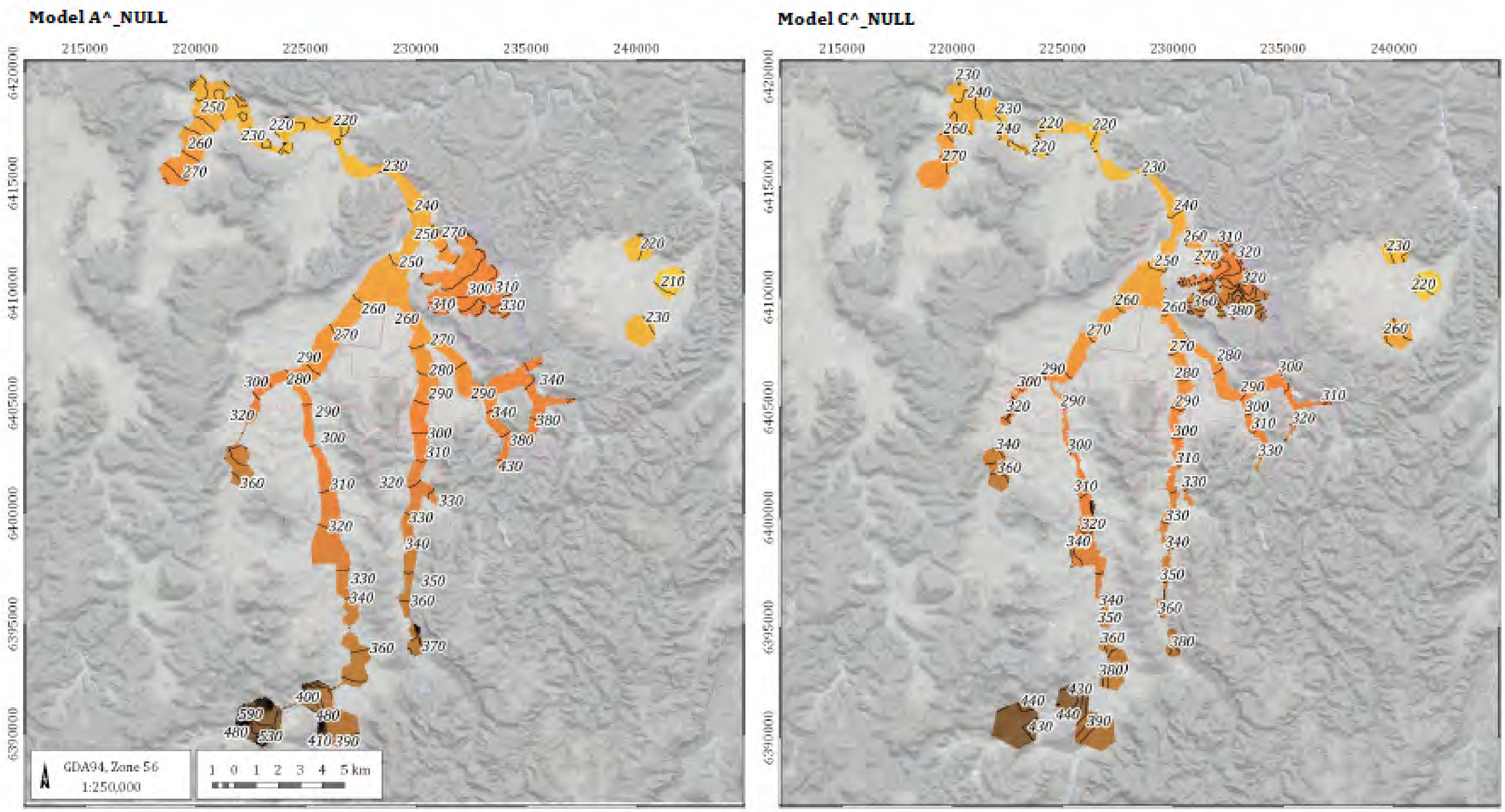

Model A^_NULL
Model C^_NULL
GDA94, Zone 56
1:250,000
1 0 1 2 3 4 5 km
LEGEND
Hydraulic Head (mAHD)
50
100
150
200
250
300
350
400
450
500
Bylong Coal Project (G1606G)
Audit Step 5 - Heads layer 1 - End of open cut mining - Stress Period 40
DATE
30/06/2016
AGE

Figure 7-1


Model A^_NULL
Model C^_NULL
215000
220000
225000
230000
235000
240000
245000
6420000
6415000
6410000
6405000
6400000
6395000
6390000
GDA94, Zone 56
1:250,000
1 0 1 2 3 4 5 km
LEGEND
Hydraulic Head (mAHD)
50
100
150
200
250
300
350
400
450
500
Bylong Coal Project (G1606G)
Audit Step 5 - Heads layer 1 - End of open cut mining - Stress Period 100
DATE
30/06/2016
FIGURE No:
Figure 7-2



LEGEND

Hydraulic Head (mAHD)

	50		300
	100		350
	150		400
	200		450
	250		500

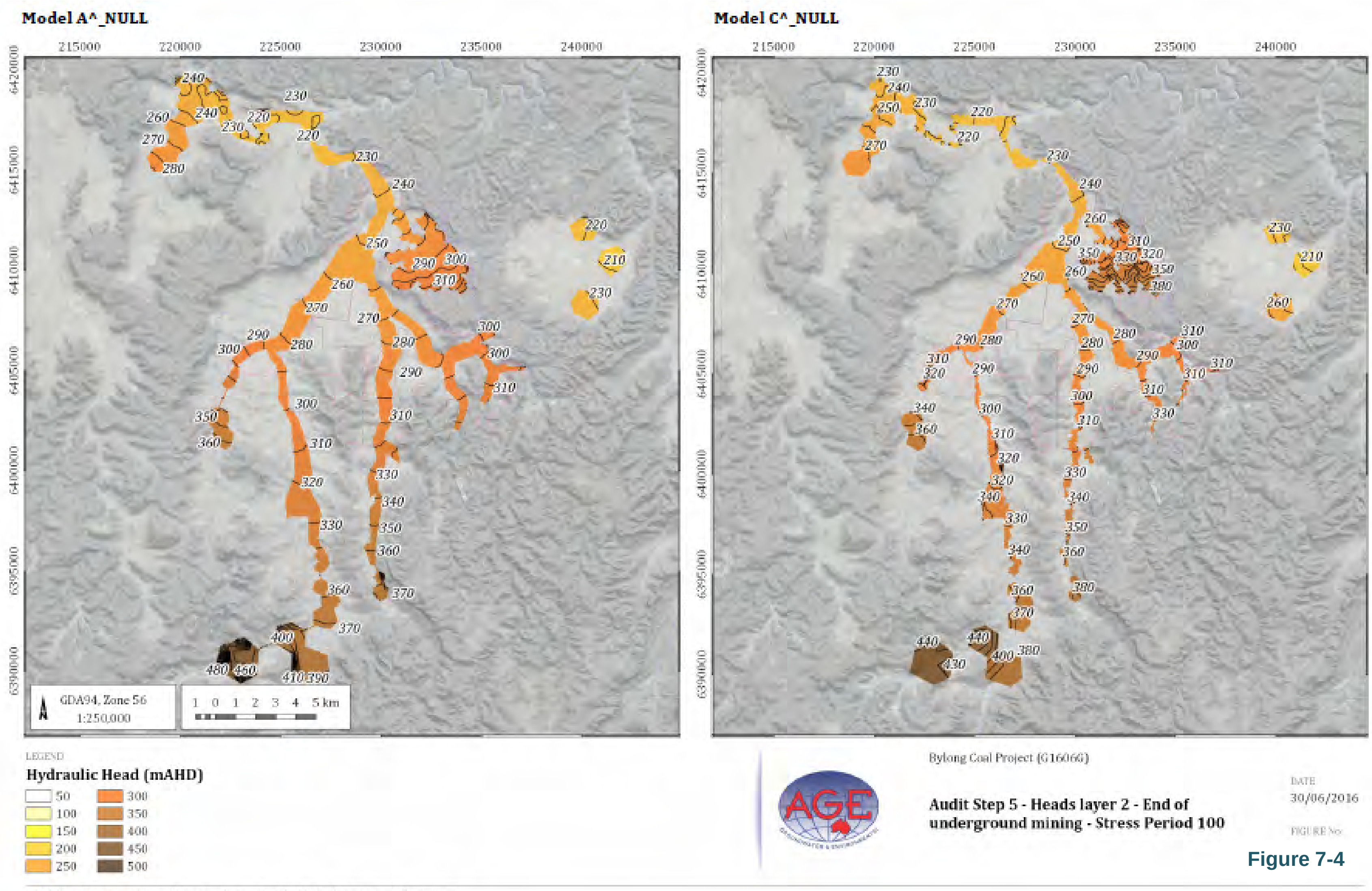
Bylong Coal Project (G1606G)

Audit Step 5 - Heads layer 2 - End of open cut mining - Stress Period 40

DATE 30/06/2016

FIGURE No:

Figure 7-3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Model C^_NULL
215000
220000
225000
230000
235000
240000
6420000
6415000
6410000
6405000
6400000
6395000
6390000
GDA94, Zone 56
1:250,000
1 0 1 2 3 4 5 km
LEGEND
Hydraulic Head (mAHD)
50
100
150
200
250
300
350
400
450
500
Bylong Coal Project (G1606G)
Audit Step 5 - Heads layer 2 - End of underground mining - Stress Period 100
DATE
30/06/2016
FIGURE No:
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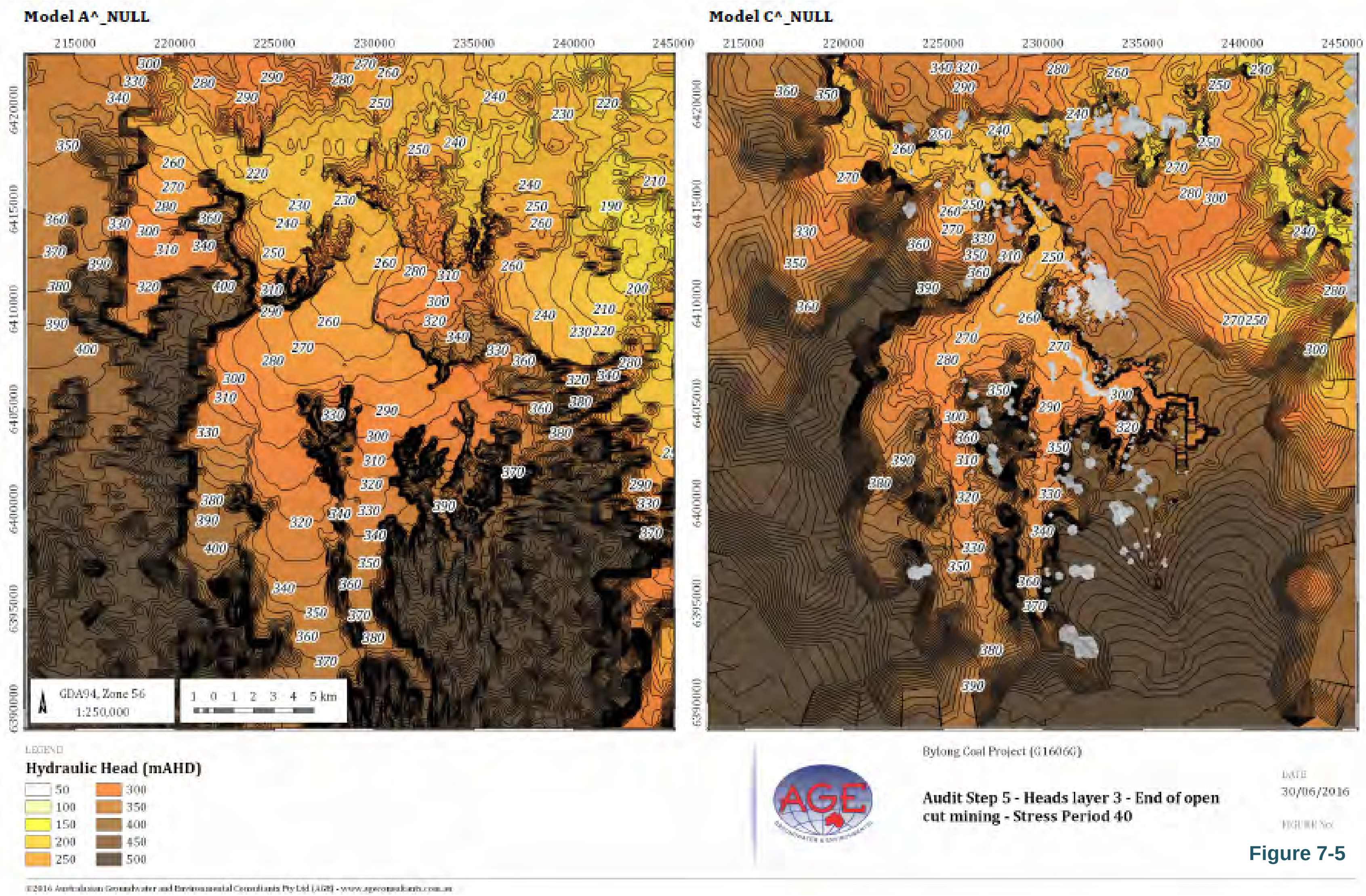
Figure 7-4


Model A^_NULL
Model C^_NULL
GDA94, Zone 56
1:250,000
1 0 1 2 3 4 5 km
LEGEND
Hydraulic Head (mAHD)
50
100
150
200
250
300
350
400
450
500
Bylong Coal Project (G1606G)
Audit Step 5 - Heads layer 3 - End of open cut mining - Stress Period 40
DATE
30/06/2016
FIGURE No:
Figure 7-5


Model A^_NULL
Model C^_NULL
GDA94, Zone 56
1:250,000
1 0 1 2 3 4 5 km
LEGEND
Hydraulic Head (mAHD)
50
100
150
200
250
300
350
400
450
500
Bylong Coal Project (G1606G)
Audit Step 5 - Heads layer 3 - End of underground mining - Stress Period 100
DATE
30/06/2016
FIGURE No:
Figure 7-6

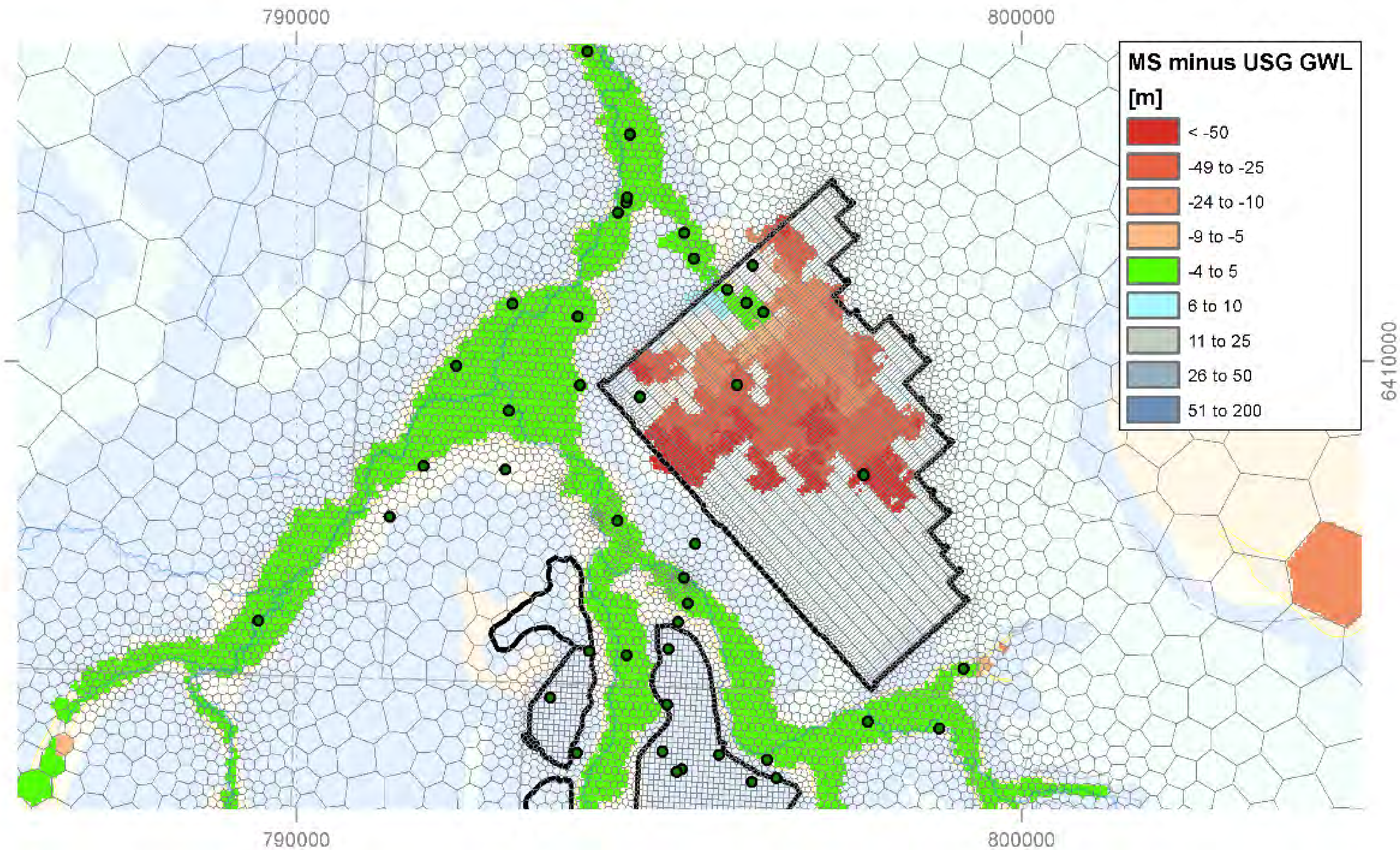


Figure 7-7 Head differentials between MS and USG for Layer 2 for Null Conditions (at the End of the Mining Period)

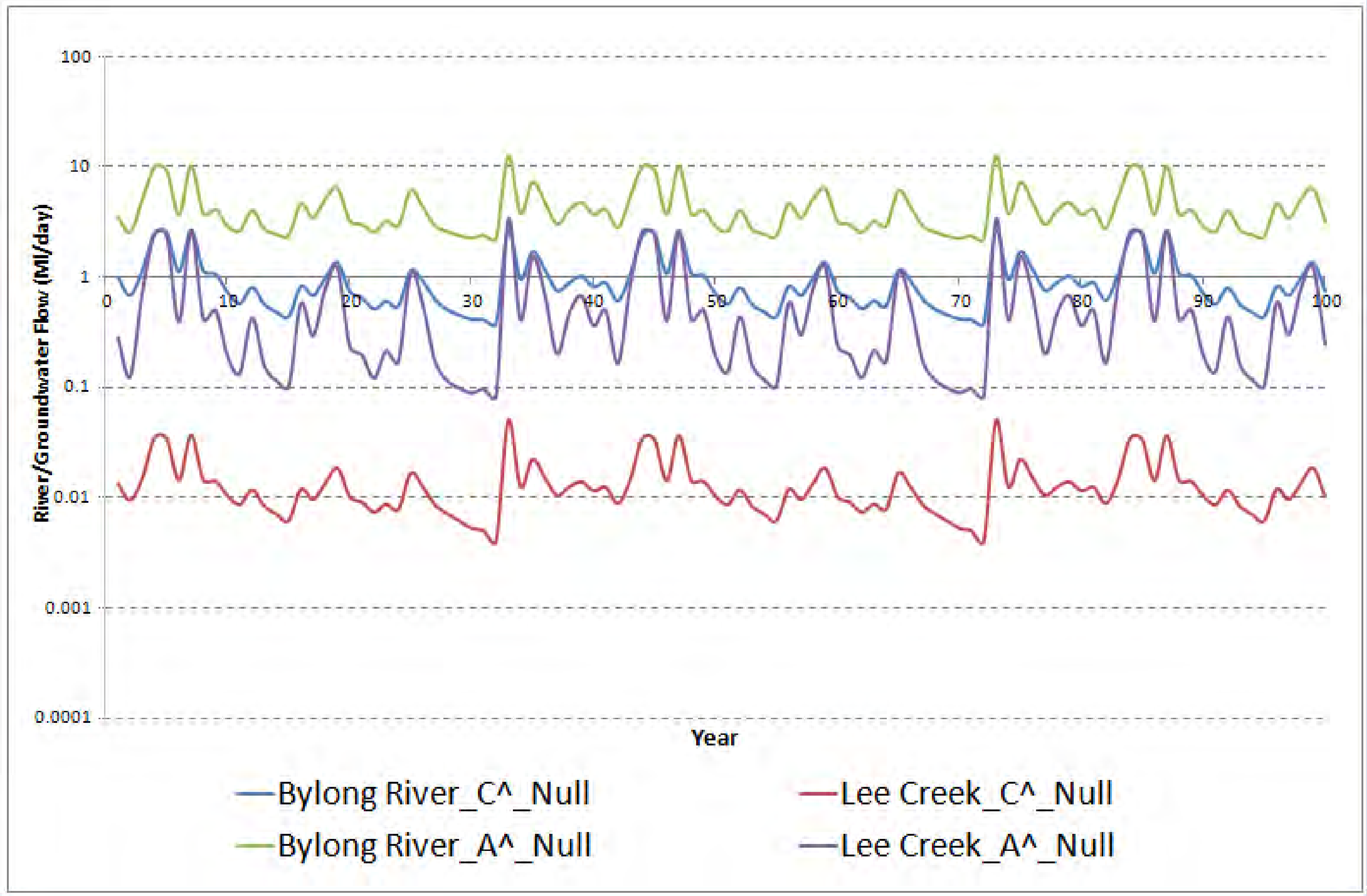
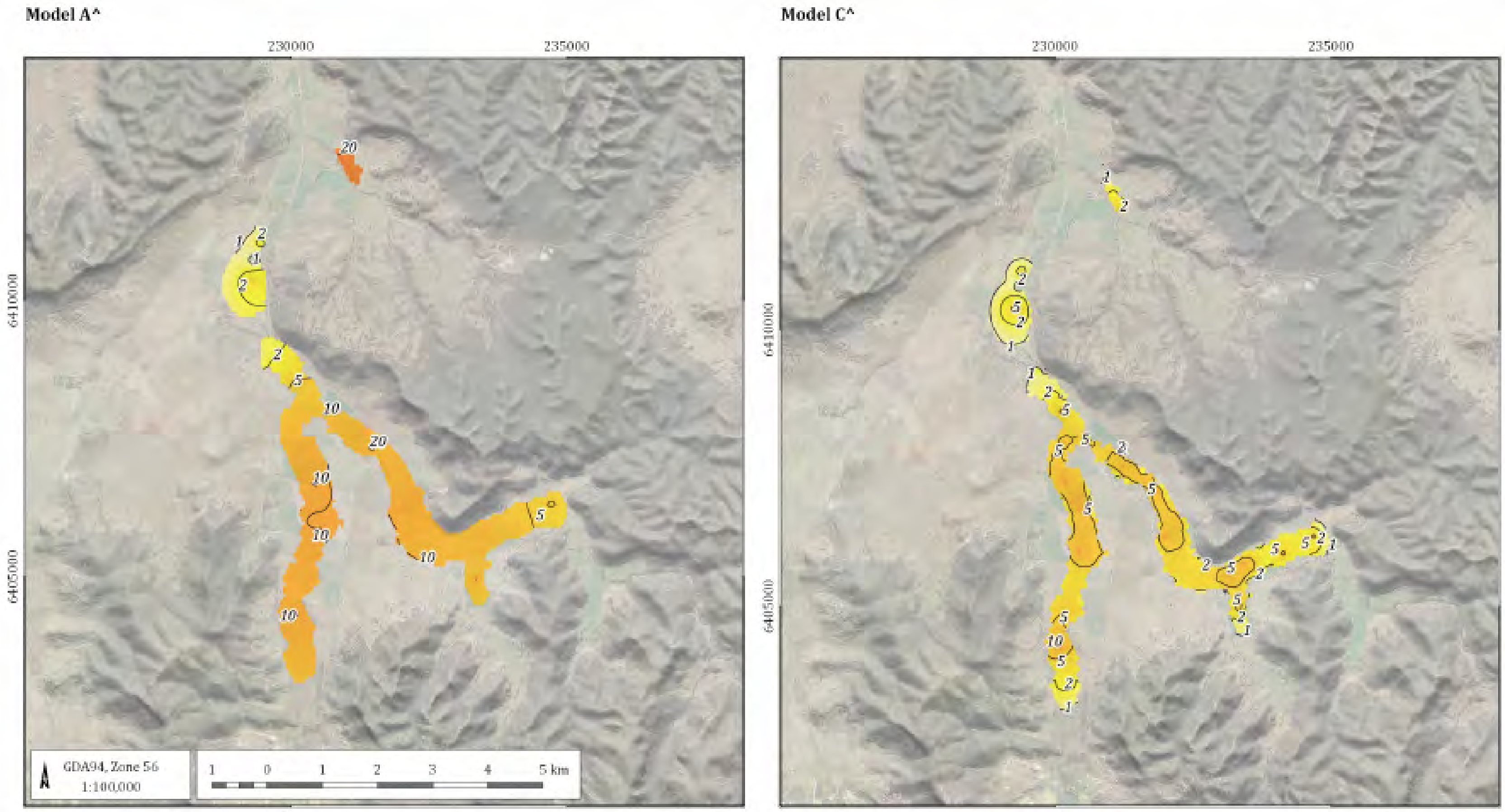


Figure 7-8 Simulated Baseflow for Null Conditions



LEGEND

Drawdown (m)

0	20
1	50
2	100
5	200
10	500

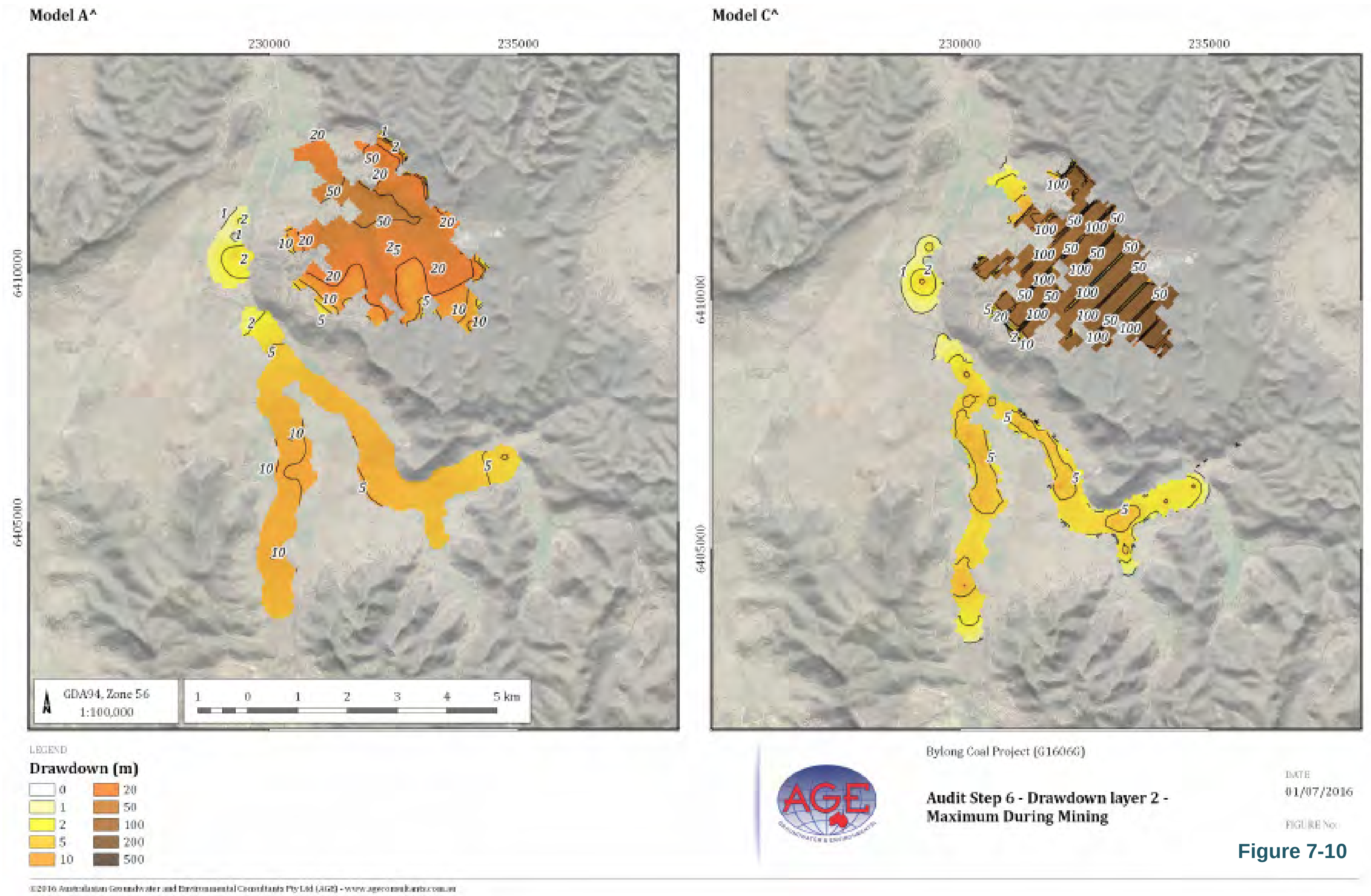
Bylong Coal Project (G1606G)

Audit Step 6 - Drawdown layer 1 - Maximum During Mining

DATE 30/06/2016

FIGURE No:

Figure 7-9



Model A^
Model C^
230000
235000
6410000
6405000
GDA94, Zone 56
1:100,000
1 0 1 2 3 4 5 km
LEGEND
Drawdown (m)
0
1
2
5
10
20
50
100
200
500
Bylong Coal Project (G1606G)
Audit Step 6 - Drawdown layer 2 - Maximum During Mining
DATE
01/07/2016
FIGURE No:
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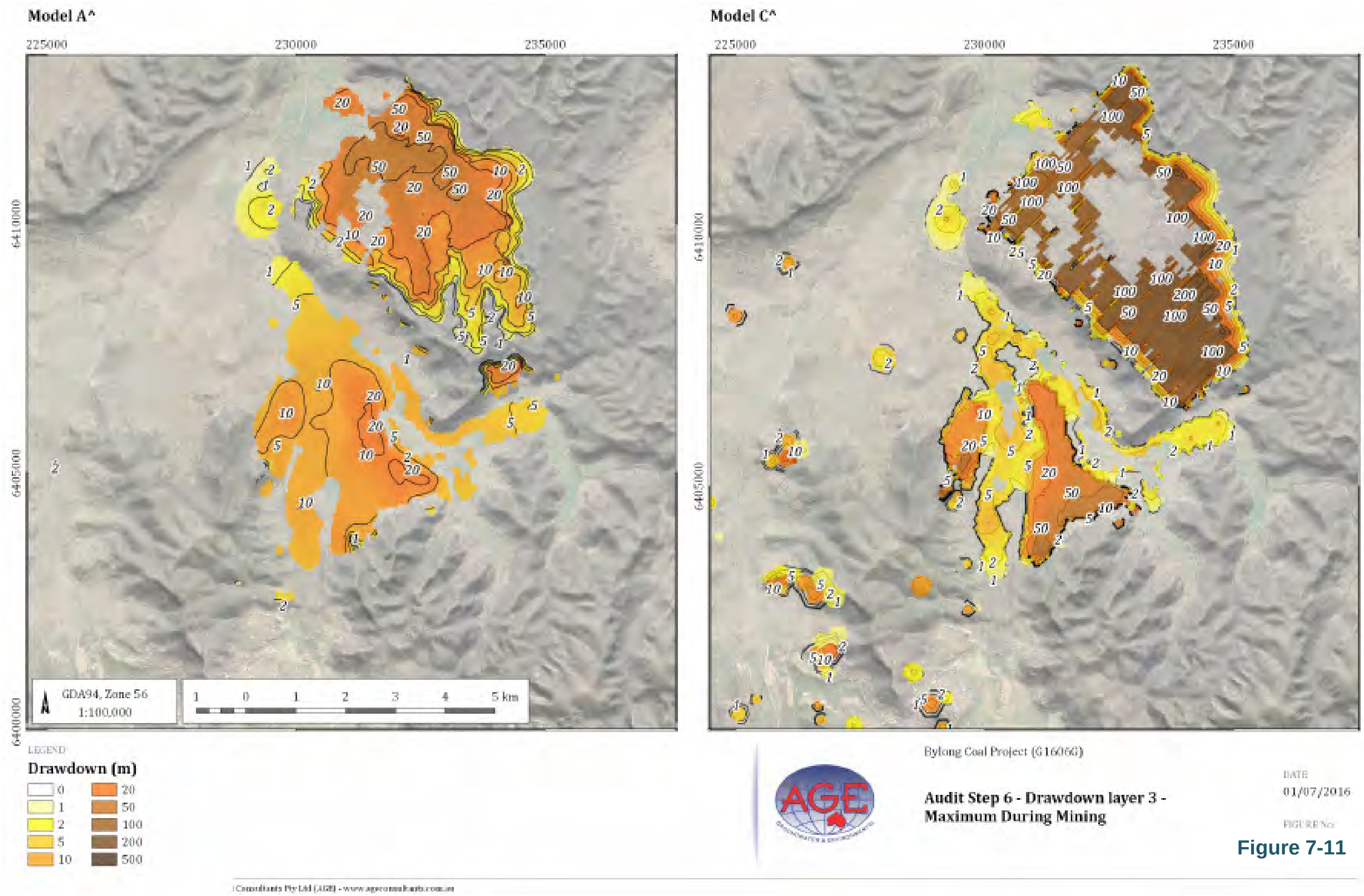
Figure 7-10



Model A^
Model C^
225000
230000
235000
6410000
6405000
6400000
GDA94, Zone 56
1:100,000
1 0 1 2 3 4 5 km
LEGEND
Drawdown (m)
0
1
2
5
10
20
50
100
200
500
Bylong Coal Project (G1606G)
Audit Step 6 - Drawdown layer 3 - Maximum During Mining
DATE
01/07/2016
FIGURE No:

Figure 7-11

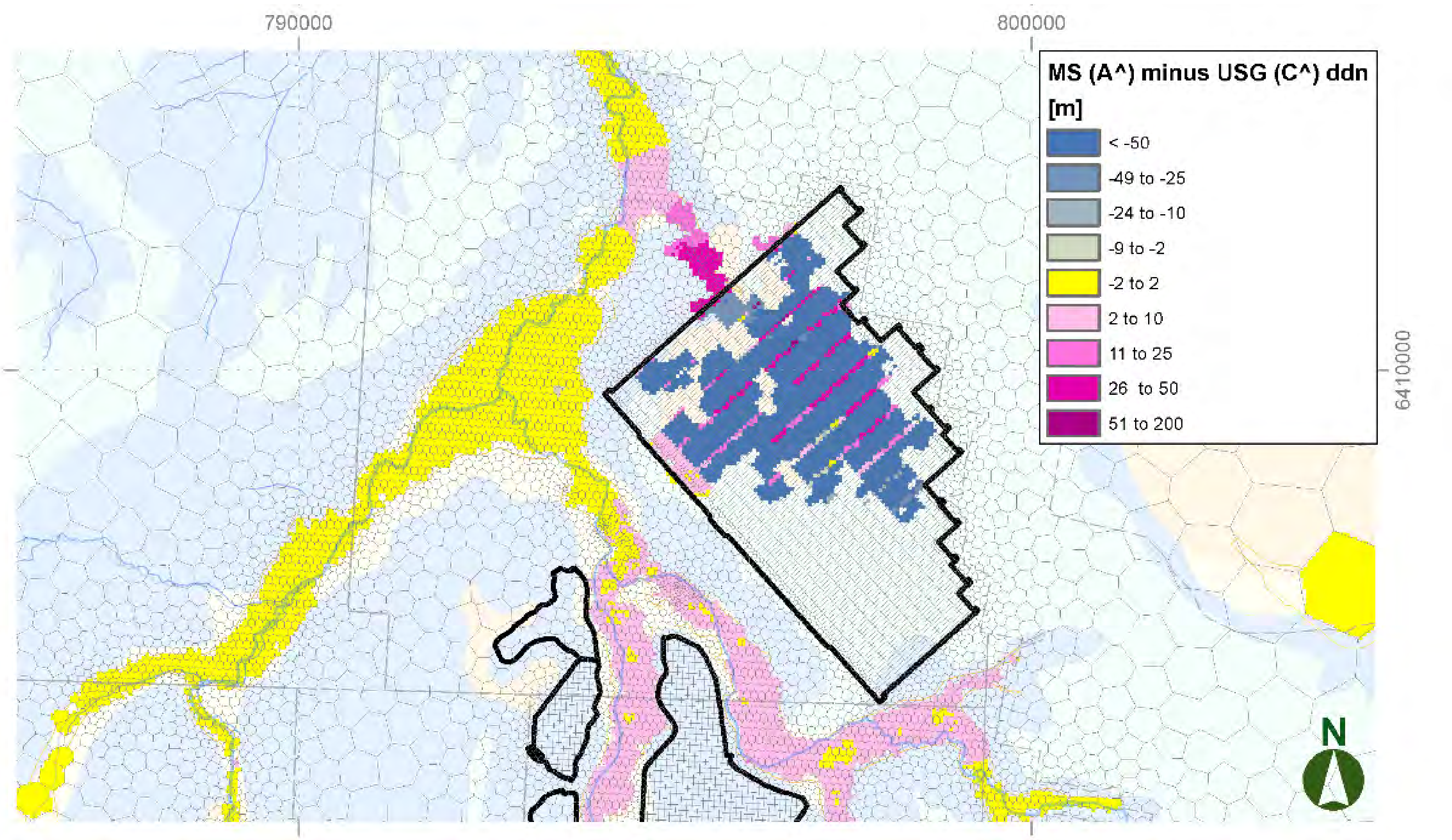


Figure 7-12 Drawdown Differentials between MS and USG for Layer 2 for Mining Conditions

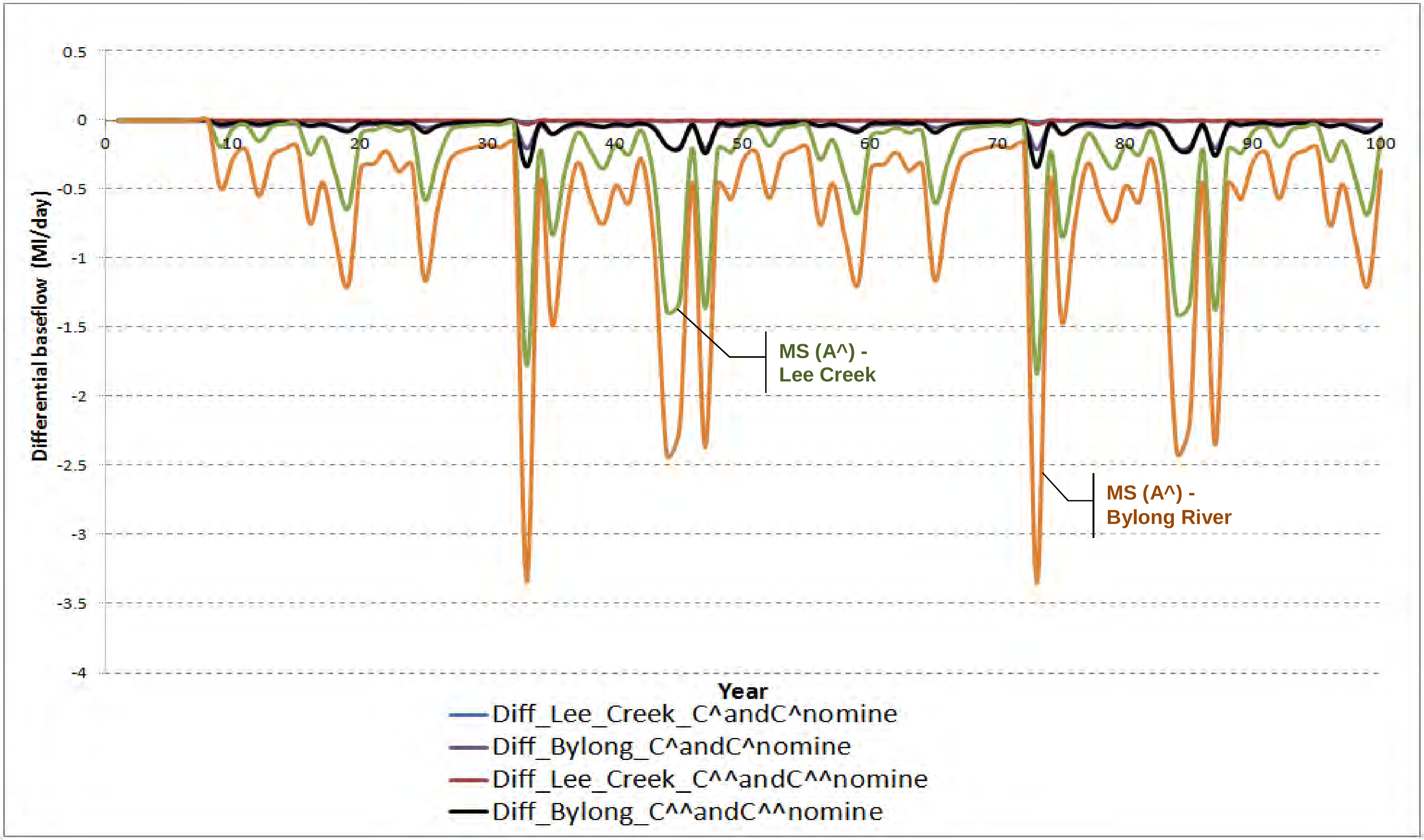


Figure 7-13 Simulated Baseflow Impacts for Mining Conditions

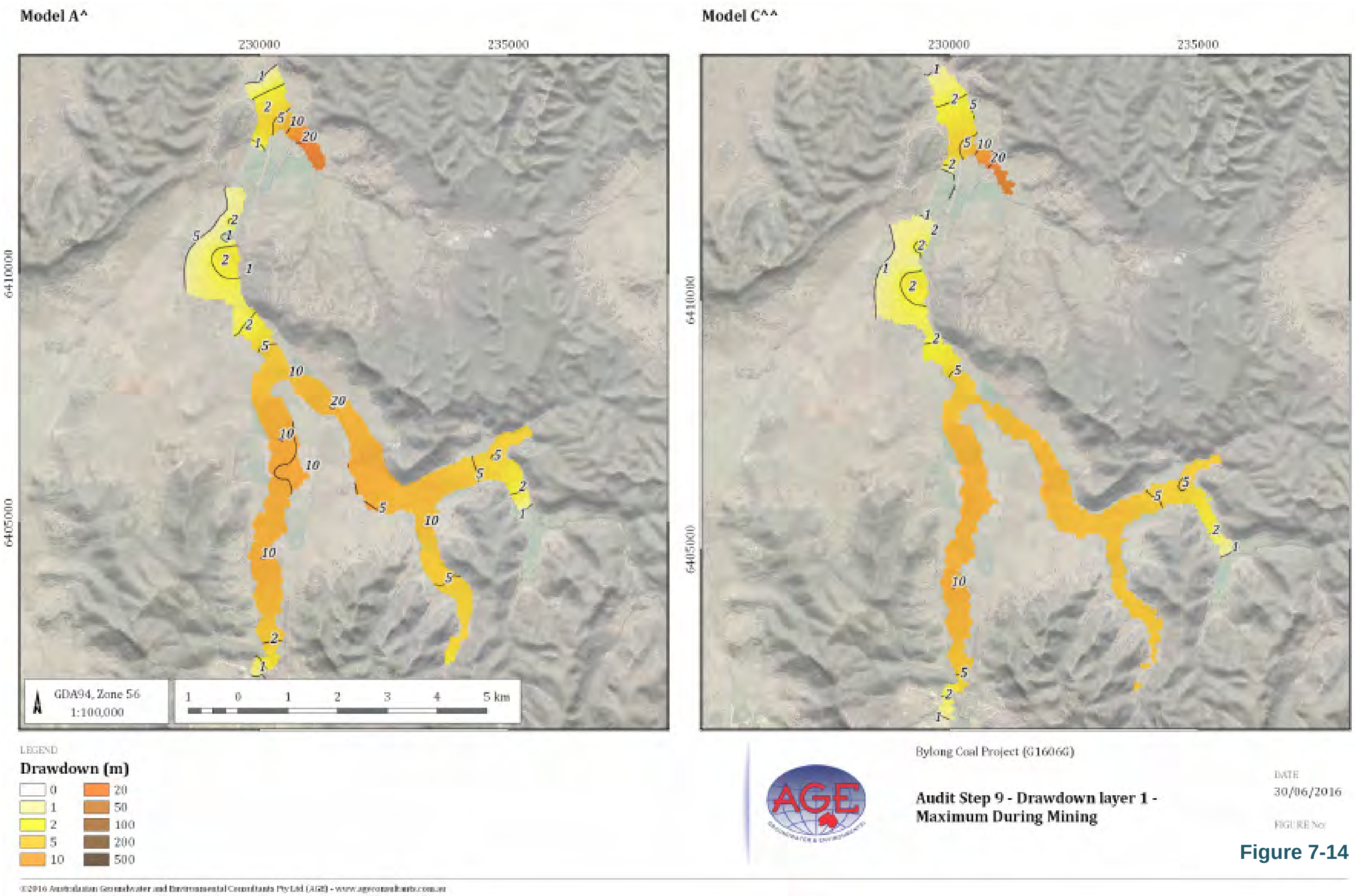

Model A^
Model C^^
230000
235000
6410000
6405000
GDA94, Zone 56
1:100,000
1 0 1 2 3 4 5 km
LEGEND
Drawdown (m)
0
1
2
5
10
20
50
100
200
500
Bylong Coal Project (G1606G)
AGE
Audit Step 9 - Drawdown layer 1 - Maximum During Mining
DATE
30/06/2016
FIGURE No:

Figure 7-14

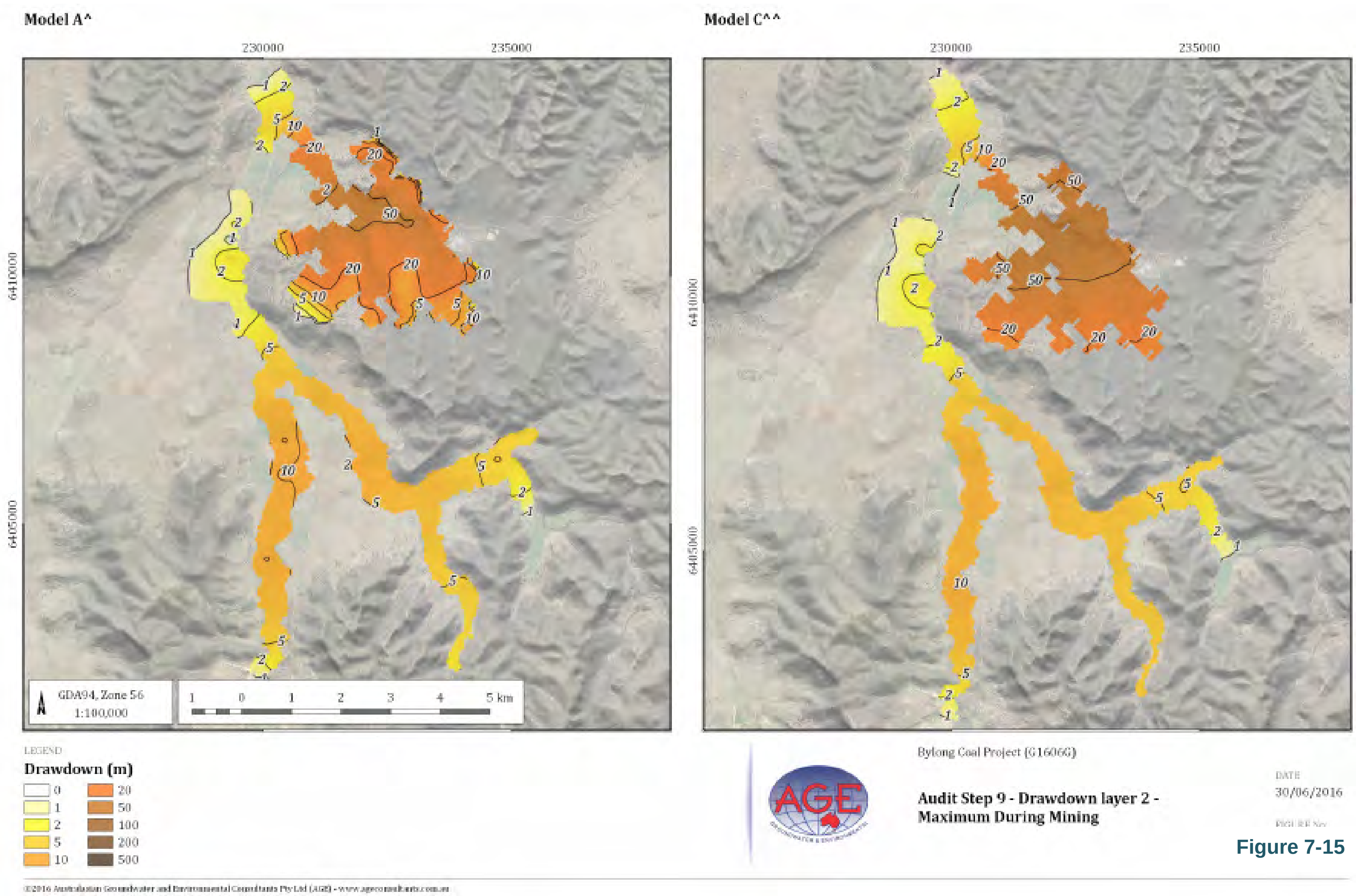

Model A^
Model C^^
230000
235000
6410000
6405000
GDA94, Zone 56
1:100,000
1 0 1 2 3 4 5 km
LEGEND
Drawdown (m)
0
1
2
5
10
20
50
100
200
500
Bylong Coal Project (G1606G)
Audit Step 9 - Drawdown layer 2 - Maximum During Mining
DATE
30/06/2016
AGE
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Figure 7-15

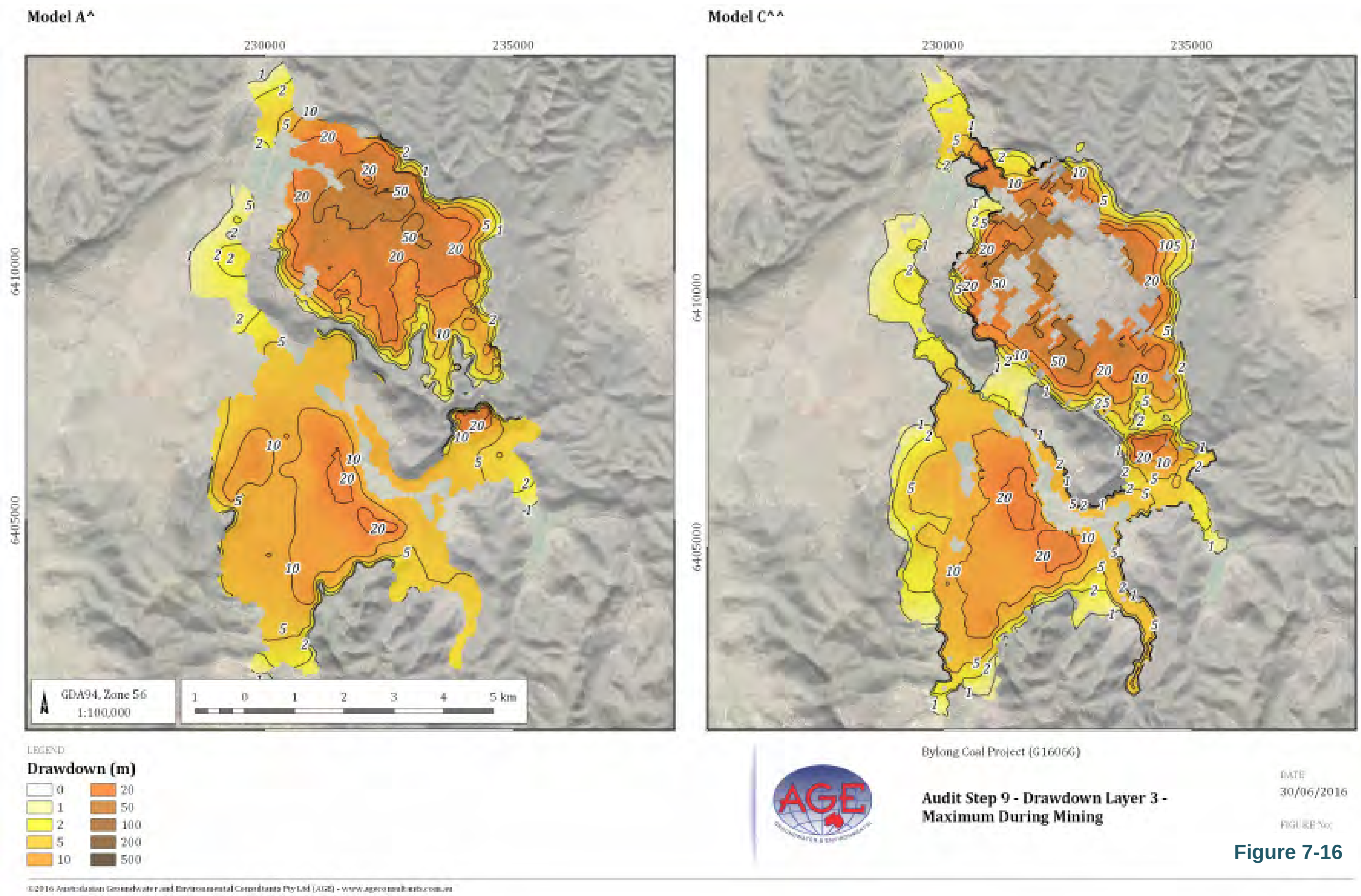
Model A^
Model C^^
230000
235000
6410000
6405000
GDA94, Zone 56
1:100,000
1 0 1 2 3 4 5 km
LEGEND
Drawdown (m)
0
1
2
5
10
20
50
100
200
500
Bylong Coal Project (G1606G)
Audit Step 9 - Drawdown Layer 3 - Maximum During Mining
DATE
30/06/2016
FIGURE No:
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Figure 7-16

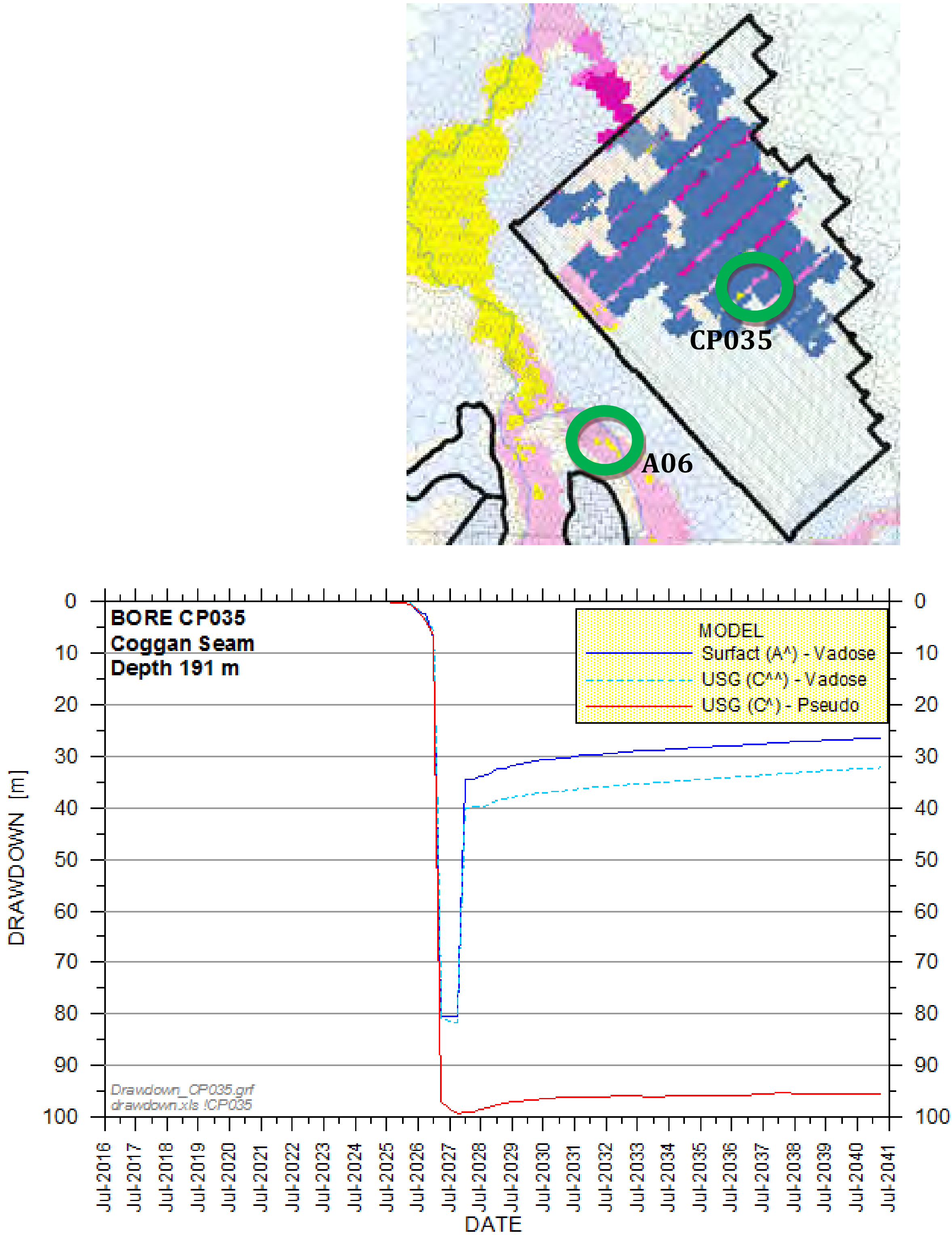
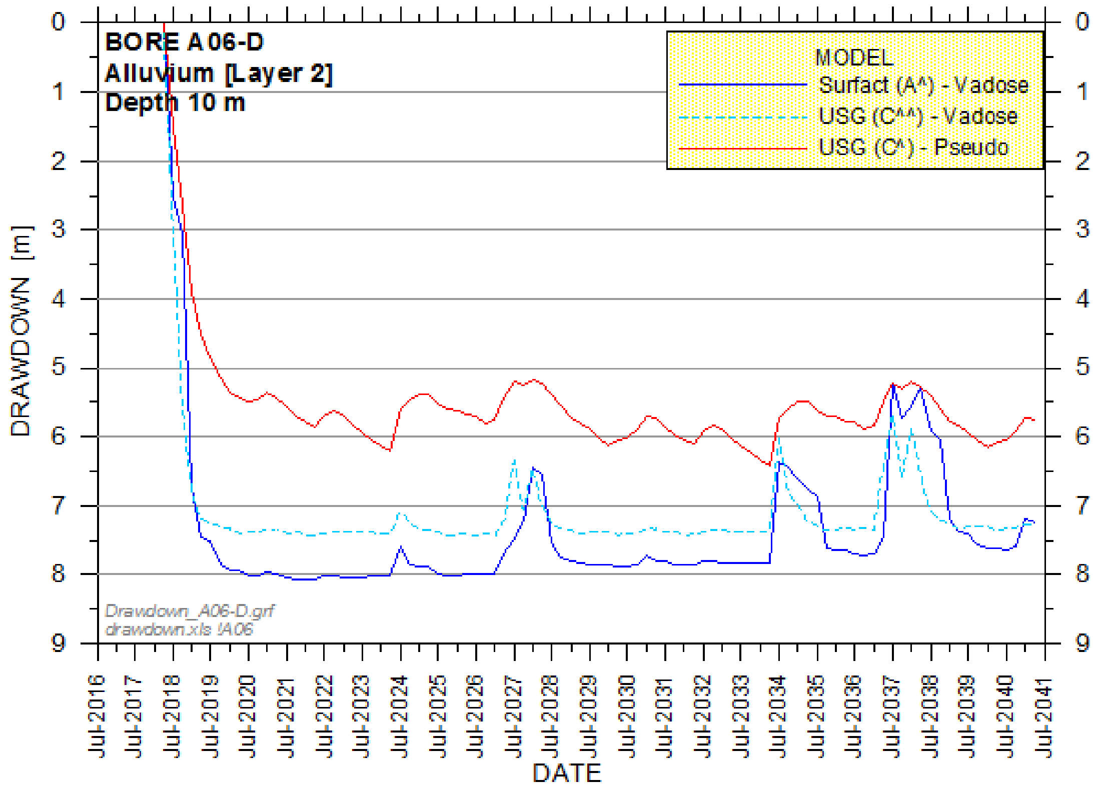


Figure 7-17 Comparative Hydrographs at Site CP035 in the Coggan Seam in the Underground Mining Area



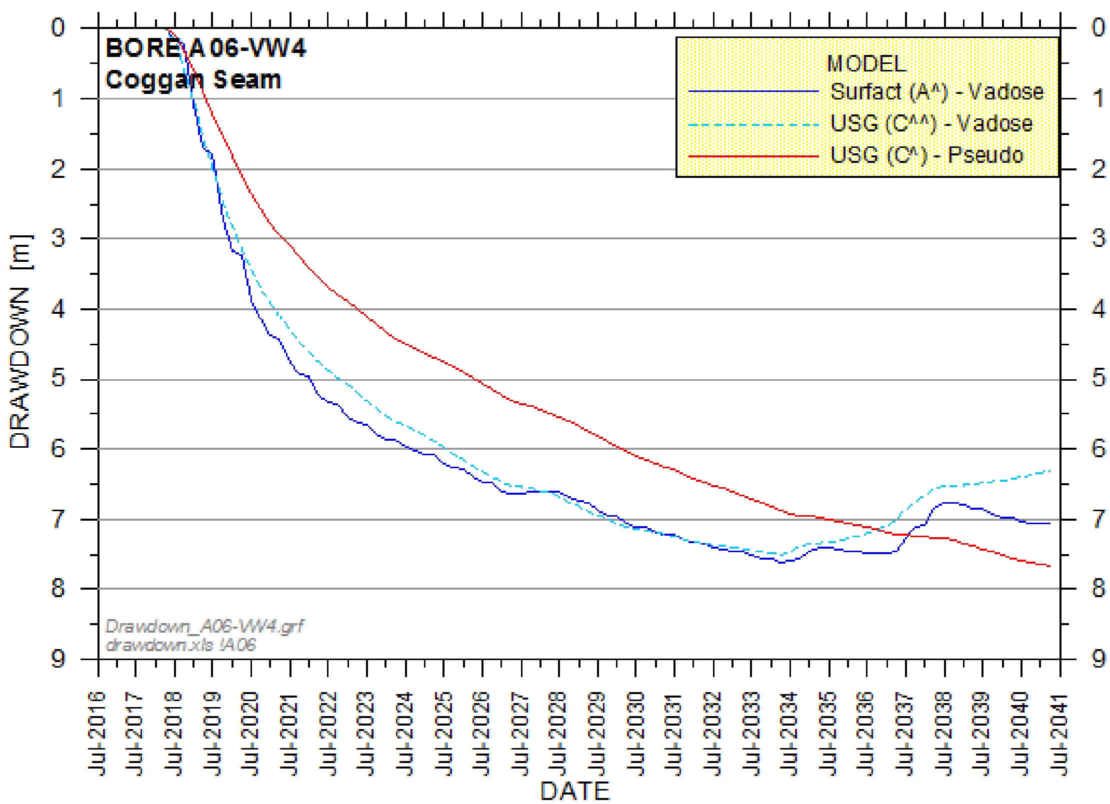


Figure 7-18 Comparative Hydrographs at Site A06 in Alluvium and the Coggan Seam beneath the Alluvial Corridor

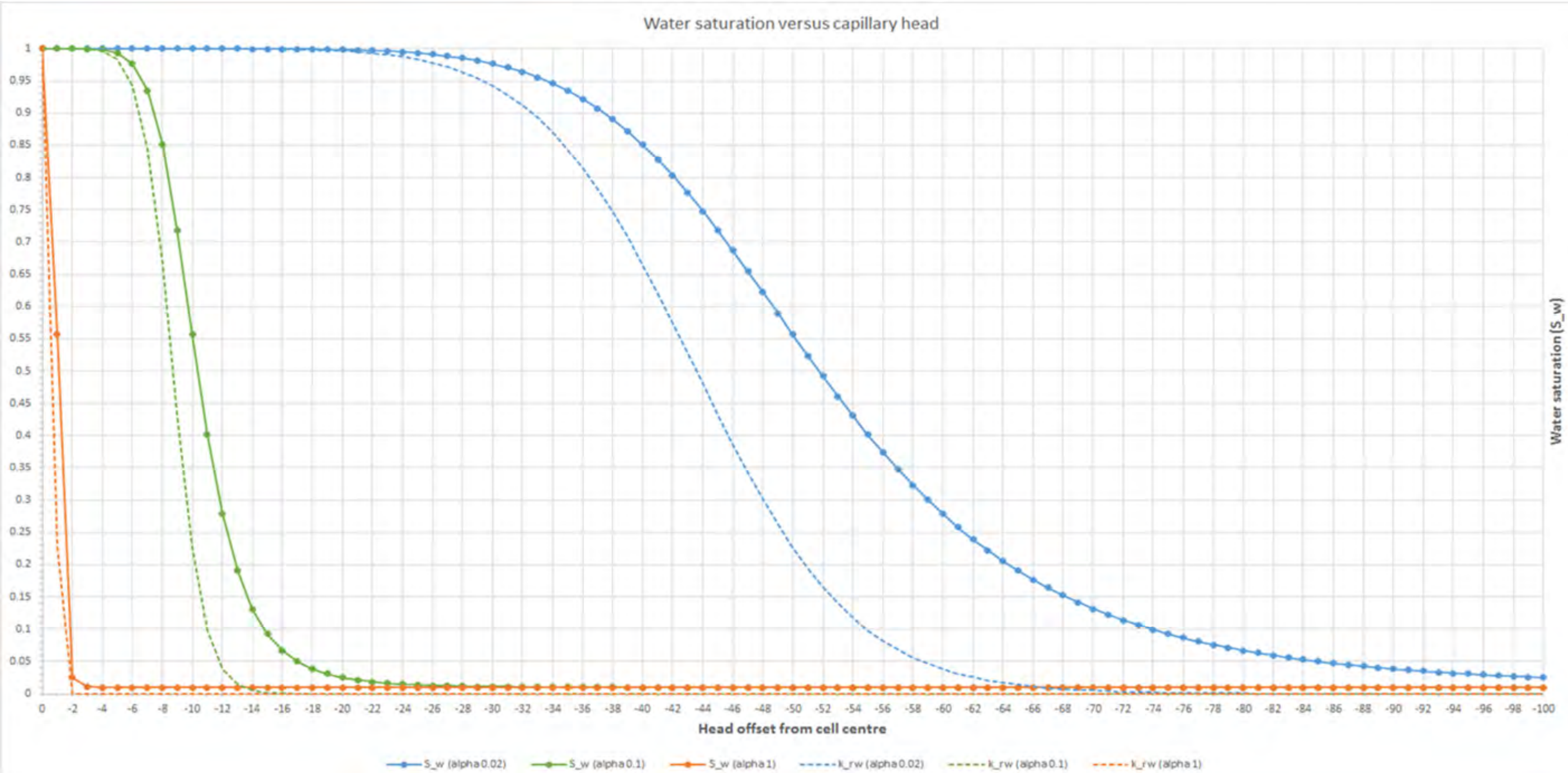


Figure 7-19 Water Saturation Curves for Various Vadose Properties

The blue lines represent the water saturation (solid w/ markers) and relative permeabilities (dashed) using AGE's vadose parameters for a range of heads. The head values are measured as offsets from the cell elevation midpoint (node) - head above cell midpoint is always S_w = 1 (full saturation). The green and orange lines are two alternative values of alpha (0.1 and 1.0 resp.) to illustrate the effect of changing alpha.

APPENDICES

APPENDIX A

SYNTHETIC MODELS

1. LONGWALL MINING SYNTHETIC MODEL

The conceptual model for the assessment of longwall mining impacts is presented in Figure 5-1. The LW model extent is approximately 40 km east-west by 40 km north-south (**Figure A-1**). At ground surface, the model has a uniform regolith interrupted by a corridor of alluvium that hosts a linear river. At depth, the stratigraphic section of 11 layers alternates between consolidated aquifer and aquitard layers, with a coal seam in layer 9. All layers are horizontal and have laterally uniform transmissive and storage properties, although they vary from layer to layer (Table A-1). The initial water table has a change in elevation of 10 m from west to east and the river stage drops 5 m from north to south. The river occupies the central 50 m portion of the alluvial corridor of 450 m width.

The coal seam lies 450 m below ground and is 3 m thick. It is to be mined by two longwall panels which are each 200 m wide and 2,000 m long. A coal pillar of 50 m width separates the two longwall panels.

The temporal scheme is:

- 10 stress periods (SP);
- pre-mining stress period duration of 1 year for SP1;
- mining stress period durations of 1 year each for SP2 to SP9;
- post-mining recovery stress period duration of 50 years for SP10;
- mining progression rate of 500 m/year; and
- fracturing to occur concurrently with excavation using a log-linear increase in permeability and specific yield.

To handle temporal changes in fractured zone properties, the Time-Varying Material Property (TMP) and Time-Variant Materials (TVM) facilities are used respectively for MS and USG.

The fractured zone (for connective vertical fracturing) is taken to be 200 m above the roof of the mined coal seam and spreads across layers 5 to 7 with a caved zone in layer 8 immediately above the seam (layer 9) (Figure 5-1). The fracturing height is taken to be the 95th percentile of the A-height of the Ditton geology model as defined by Ditton and Merrick (2014)[1]:

$$A = 1.52\, W'^{0.4}\, H^{0.535}\, T^{0.464}\, t'^{-0.4} \; +/- \; (0.10 - 0.15)\, W'$$

where:

W is longwall panel width (200 m);
W' is the effective panel width = min (W, 1.4H) (= 200 m);
H is the cover depth (from ground surface to the roof of the coal seam) (450 m);
T is the mining height (3 m); and
t' is the effective thickness of the bridging beam above the fractured zone (20 m)

Enhanced vertical hydraulic conductivity (Kz) is applied progressively above where longwall panels have been mined to create the fractured zone (layers 5-7) and the caved zone (layers 8-9). Enhanced horizontal hydraulic conductivity (Kx) is applied to the same layers but also in the constrained zone (layer 4) to create the fractured zone and the relaxed zone (layer 10) below the mined coal seam (Figure 5-1). Specific yield (Sy) is also increased but only in the created caved zone (layers 8-9) within and immediately above where longwall panels have been mined out (Figure 5-1).

The USG model uses the CONSTANTCV option for the Layer Property Flow (LPF) package to match as closely as possible to vertical conductances calculated by MS in the Block-Centred Flow (BCF) package.

A structured grid is imposed with a maximum cell size of 200 m and a minimum cell size of 50 m (**Figure A-2**). The total number of model cells is 440,000 for a 39.45 km x 39.45 km model extent..

[1] Ditton, S. and Merrick, N., 2014. ***A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields***. Australian Earth Sciences Convention (AESC) 2014. Newcastle, NSW

Table A-1. Geometry, Property and Boundary Condition Specifications for the Longwall Mining Synthetic Model

Head (mASL)	Top_Elevation (mASL)	Thickness (m)	Bottom_Depth (m)	Kx (m/d)	Kz (m/d)	Ss (m^{-1})	Sy (-)	Lithology Zone	Layer	Hydrostratigraphy Unit	Frac_Kx (m/d)	Frac_Kz (m/d)	Frac_Sy (-)	Alluvium (m/d) (m^{-1}) (-)	Us_River (mASL)	Ds_River (mASL)	Head (mASL)
395	400	50	50	5	0.5	1E-05	0.1	1	1	Regolith	5	0.5	0.1	Kx,Kz = 10, 1 Ss,Sy = 1E-5, 0.2	380	375	385
395	350	100	150	0.1	0.01	1E-05	0.1	2	2	Aquifer	0.1	0.01	0.1	[Zone 12]	375 RBOT	370 RBOT	385
No Flow	250	25	175	1E-05	1E-06	1E-05	0.005	3	3	Aquitard	1E-05	1E-06	0.005				No Flow
No Flow	225	75	250	1E-04	1E-05	1E-05	0.05	4	4	Aquifer	1E-03	1E-05	0.05	Constrained Zone			No Flow
No Flow	150	75	325	1E-04	1E-05	1E-05	0.05	5	5	Aquifer	1E-03	1E-04	0.05	Fractured Zone			No Flow
No Flow	75	25	350	1E-05	1E-06	1E-06	0.005	6	6	Aquitard	1E-04	1E-03	0.005	Fractured Zone			No Flow
No Flow	50	75	425	1E-04	1E-05	1E-06	0.02	7	7	Aquifer	1E-03	1E-02	0.02	Fractured Zone			No Flow
No Flow	-25	25	450	1E-04	1E-05	1E-06	0.02	8	8	Aquifer	1E-03	10	0.1	Caved Zone			No Flow
No Flow	-50	3	453	1E-02	1E-03	1E-06	0.01	9	9	Coal	10	10	0.1	Caved Zone			No Flow
No Flow	-53	25	478	1E-04	1E-05	1E-06	0.02	10	10	Aquifer	3E-04	3E-05	0.02	Relaxed Zone			No Flow
No Flow	-78 -178	100	578	1E-05	1E-06	1E-06	0.005	11	11	Aquitard	1E-05	1E-06	0.005				No Flow

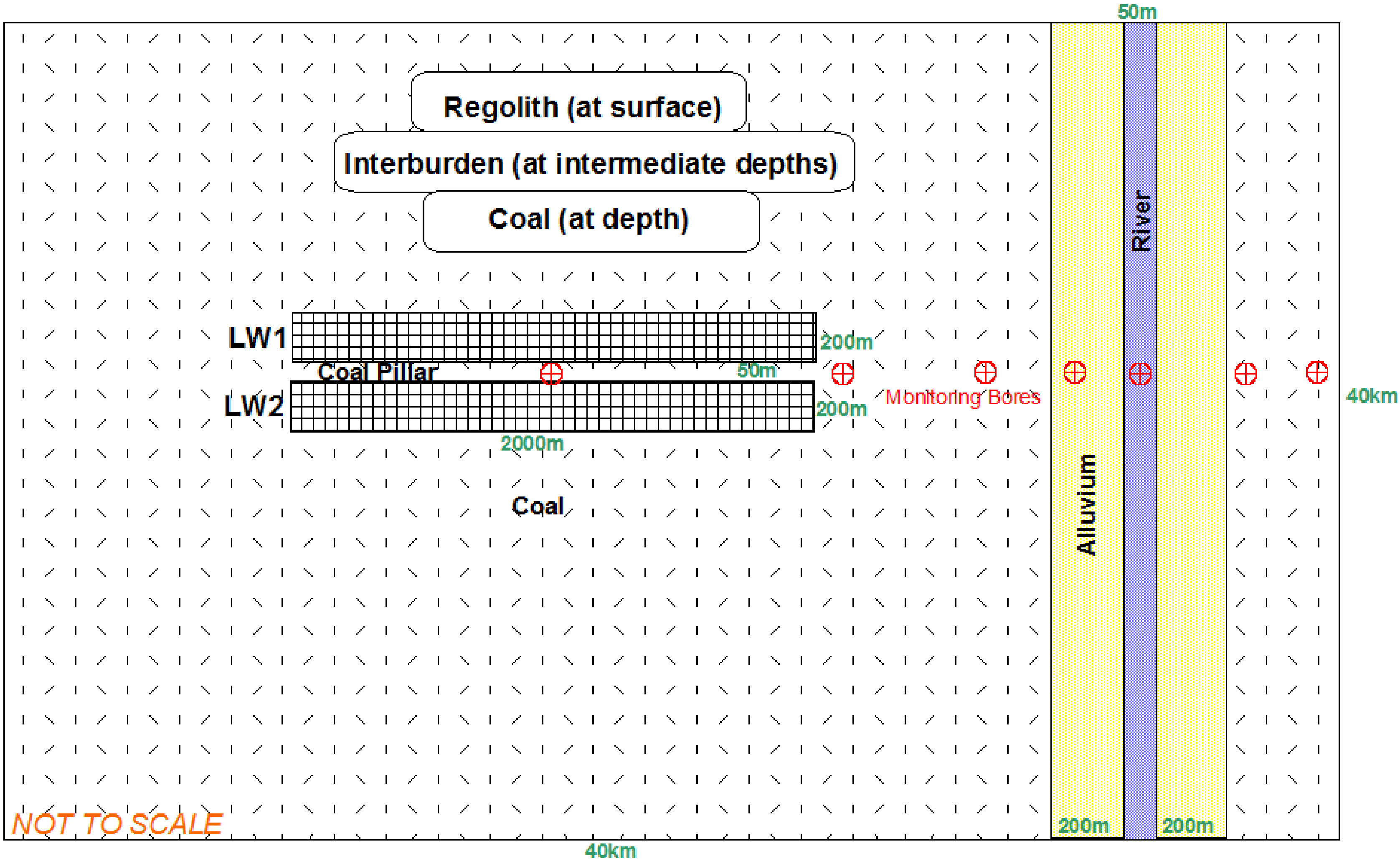


Figure A-1 Plan view of synthetic model design

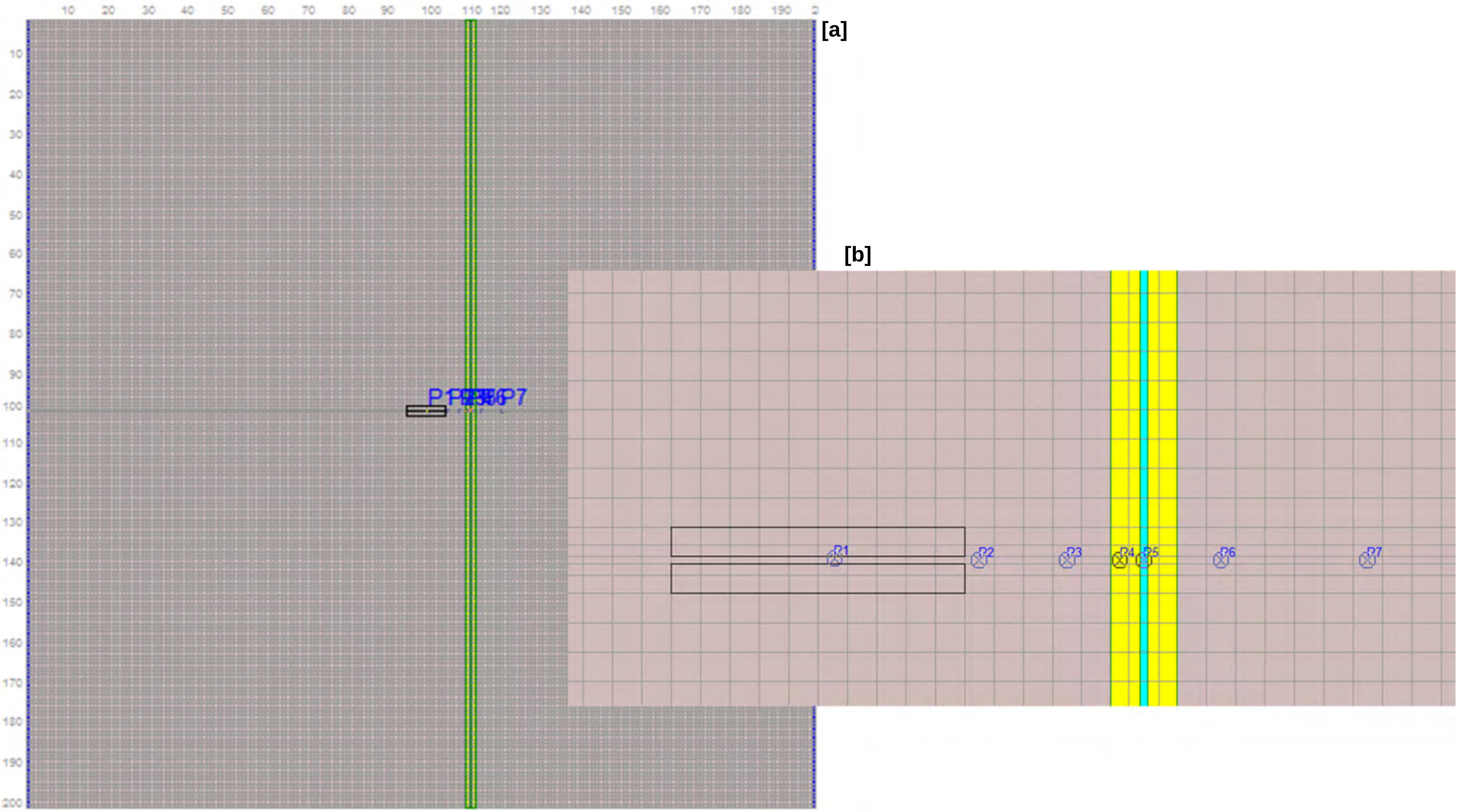


Figure A-2 MODFLOW-SURFACT grid: [a] Full grid; [b] Zoomed grid showing river cells (aqua), alluvium cells (yellow), longwall outlines and monitoring locations P1 to P7

2. OPEN CUT MINING SYNTHETIC MODEL

The conceptual model for the assessment of open cut mining impacts is presented in **Figure 5-2**.

The OC model extent is approximately 40 km east-west by 40 km north-south. At ground surface, the model has a uniform regolith interrupted by a corridor of alluvium that hosts a linear river. At depth, the stratigraphic section of 7 layers alternates between consolidated aquifer and aquitard layers, with coal seams in layers 4 and 6. All layers are horizontal and have laterally uniform transmissive and storage properties, although they vary from layer to layer (**Table A-2**). The initial water table has a change in elevation of 10 m from west to east and the river stage drops 5 m from north to south. The river occupies the central 50 m portion of the alluvial corridor of 450 m width.

The coal seams lie at depths of 100 m and 170 m below ground and are each 20 m thick. They are to be mined in two parallel strips which are each 200 m wide and 2,000 m long. An earth barrier of 50 m width separates the two pits.

The temporal scheme is:

- 10 stress periods (SP);
- pre-mining stress period duration of 1 year for SP1;
- mining stress period durations of 1 year each for SP2 to SP9;
- post-mining recovery stress period duration of 50 years for SP10;
- mining progression rate of 500 m/year; and
- spoil emplacement during SP10 only (with no final void).

To handle temporal changes in SP10 for spoil properties, the Time-Varying Material Property (TMP) and Time-Variant Materials (TVM) facilities are used respectively for MS and USG.

The spoil properties are:

- Kx = 1 m/day;
- Kz = 1 m/day;
- Ss unchanged;
- Sy = 0.1; and
- rain recharge unchanged.

A difference in model layer numbering between MS (left-side tags on **Figure 5-2**) and USG (right-side tags on **Figure 5-2**) is designed to allow investigation of the effects of layer pinch-out by running the model with and without lateral connections between layer 1 [L1] and layer 2 [L2] where alluvium lies adjacent to regolith.

The USG model uses the CONSTANTCV option for the Layer Property Flow (LPF) package to match as closely as possible to the vertical conductance (VC) calculated by MS in the Block-Centred Flow (BCF) package. Different VC options are to be tested.

A structured grid is imposed with a maximum cell size of 200 m and a minimum cell size of 50 m. The total number of model cells is 440,000 for a 39.45 km x 39.45 km model extent.

Table A-2. Geometry, Property and Boundary Condition Specifications for the Open Cut Mining Synthetic Model

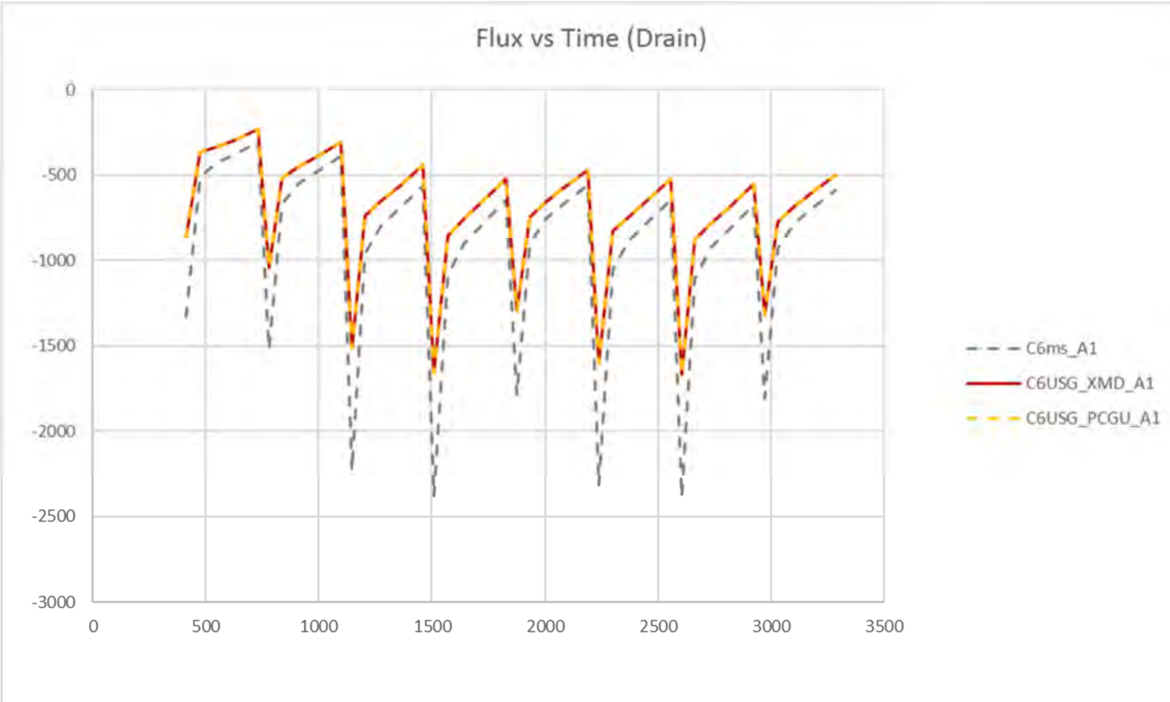
Head	Top_Elevation	Thickness	Bottom_Depth	Kx	Kz	Ss	Sy	MS	USG	Hydrostratigraphy	Alluvium	Us_River	Ds_River	Head
(mASL)	(mASL)	(m)	(m)	(m/d)	(m/d)	(m^{-1})	(-)	Layer	Layer	Unit	(m/d)(m^{-1})(-)	(mASL)	(mASL)	(mASL)
395	400	35	35	5	0.5	1E-05	0.1	1	2	Regolith	Kx,Kz = 10, 1 Ss,Sy = 1E-5, 0.2 [Layer 1, Zone 12]	380	375	385
395	365	15	50	5	0.5	1E-05	0.1	2	2	Regolith	Regolith	375 RBOT	370 RBOT	385
No Flow	350	50	100	0.1	0.01	1E-05	0.1	3	3	Aquifer	Aquifer			No Flow
No Flow	300	20	120	1E-02	1E-03	1E-06	0.01	4	4	Coal	Coal			No Flow
No Flow	280	50	170	1E-05	1E-06	1E-05	0.005	5	5	Aquitard	Aquitard			No Flow
No Flow	230	20	190	1E-02	1E-03	1E-06	0.01	6	6	Coal	Coal			No Flow
No Flow	210	100	290	1E-05	1E-06	1E-05	0.005	7	7	Aquitard	Aquitard			No Flow
	110							[=Zone #]						

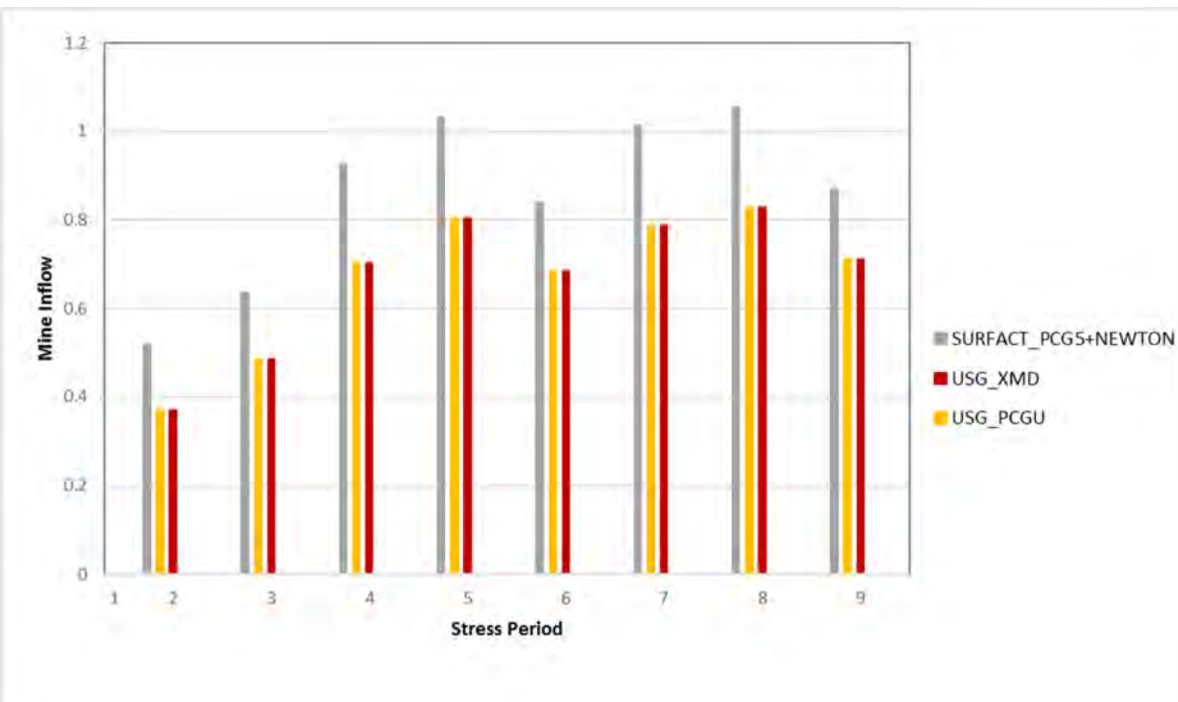
APPENDIX B1

LONGWALL: MS_VADOSE AND USG_VADOSE

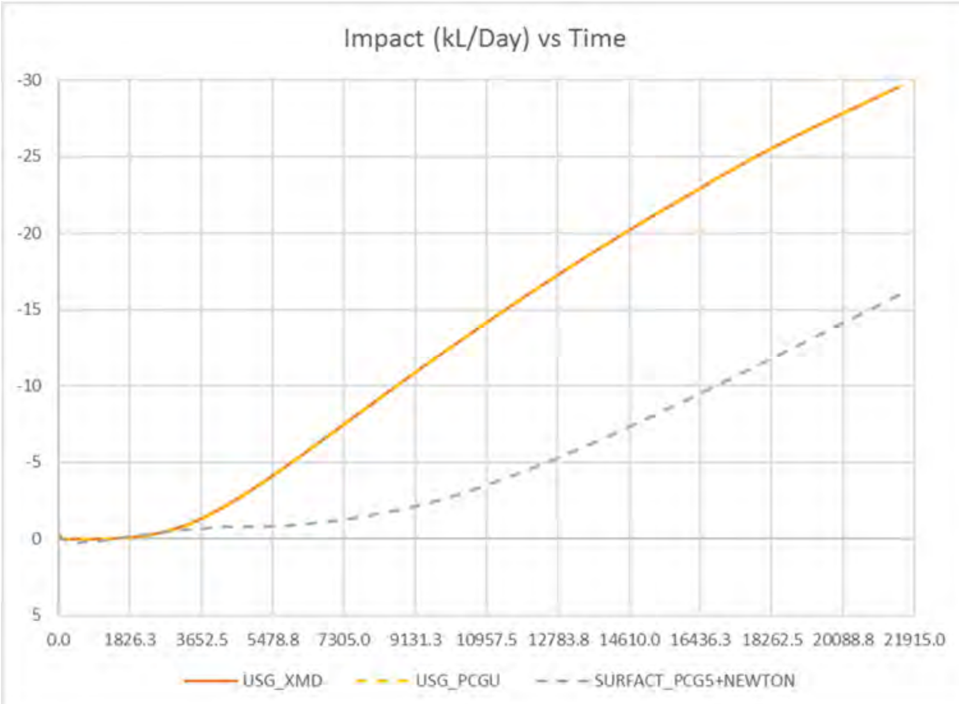
RUN A1 MS vs USG

Mine inflow

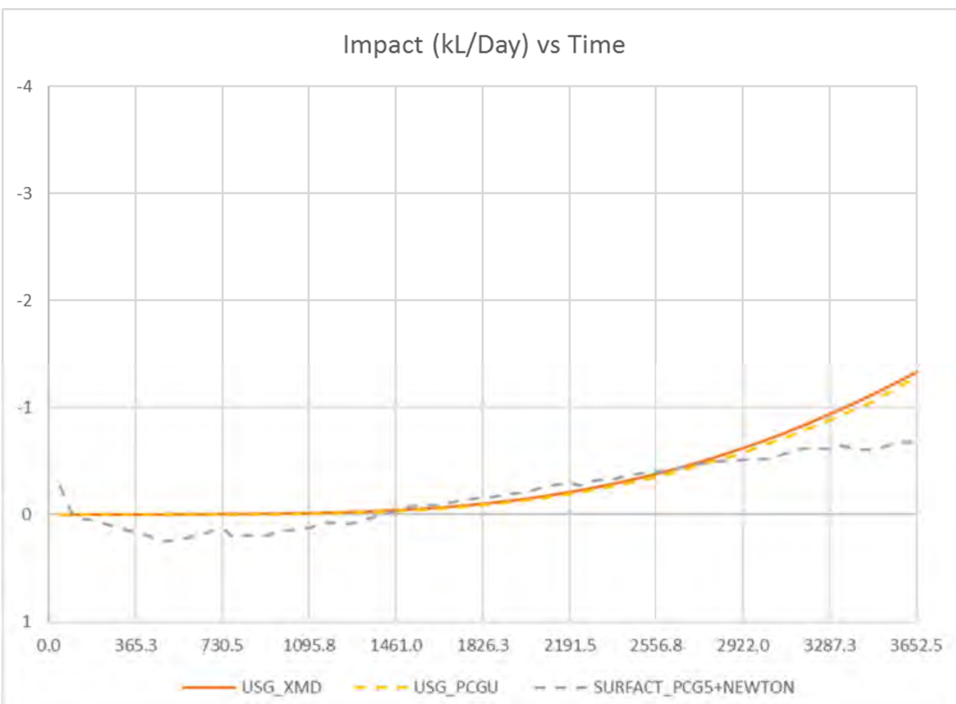




River flux

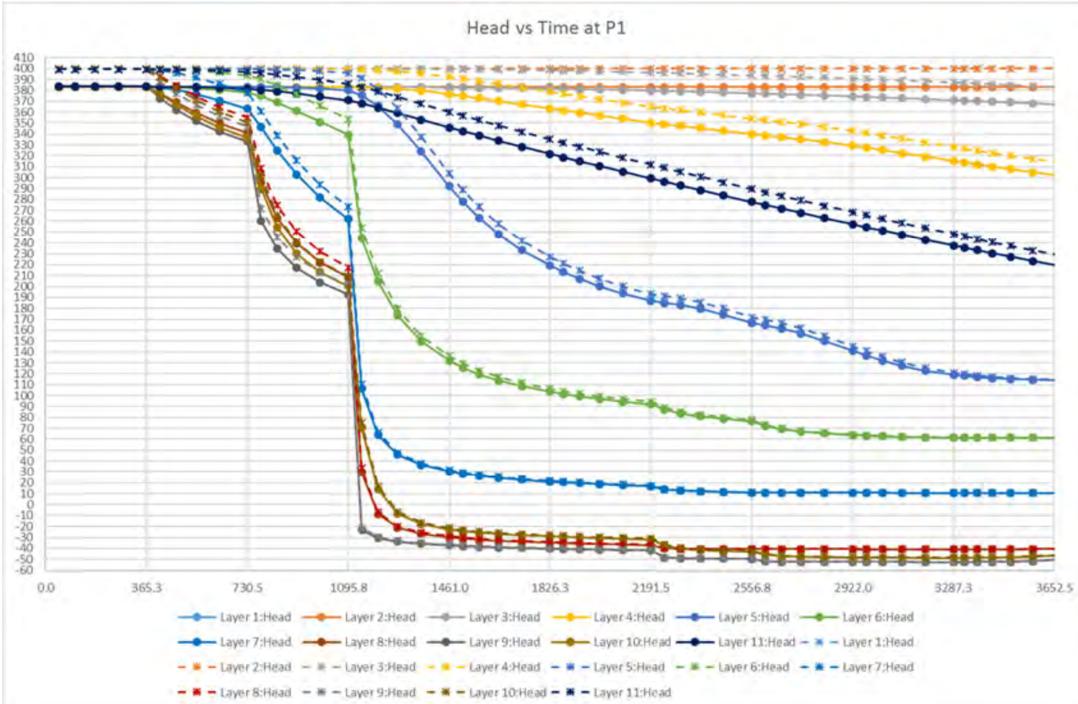


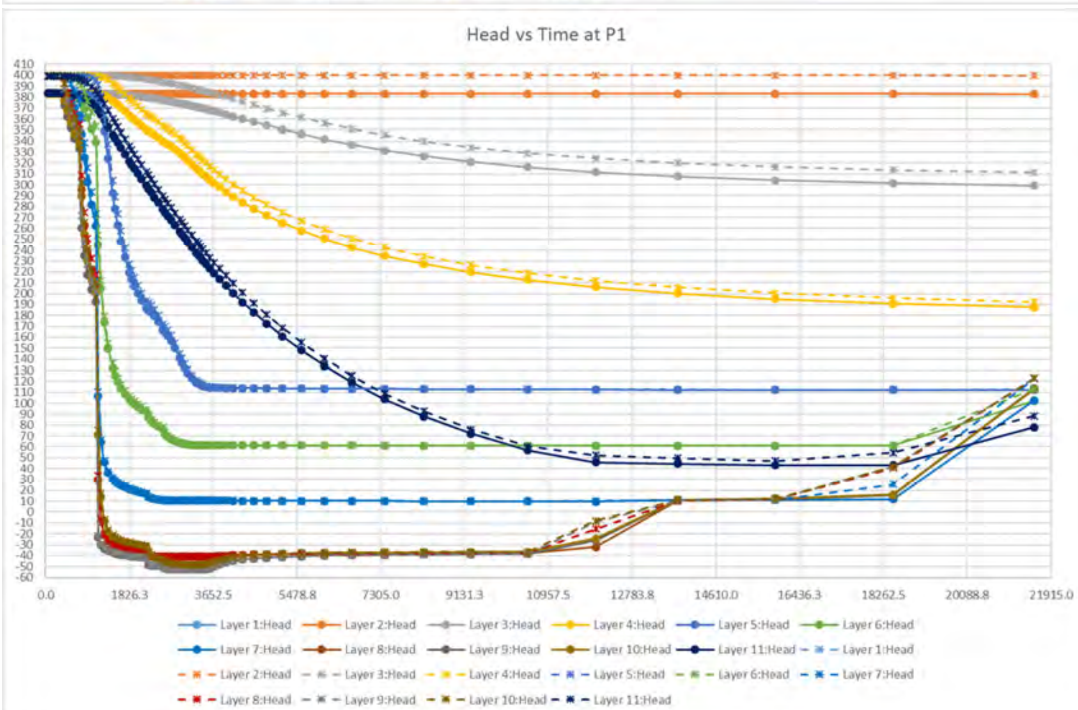
Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
0.0 1826.3 3652.5 5478.8 7305.0 9131.3 10957.5 12783.8 14610.0 16436.3 18262.5 20088.8 21915.0
USG_XMD
USG_PCGU
SURFACT_PCG5+NEWTON



Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
0.0 365.3 730.5 1095.8 1461.0 1826.3 2191.5 2556.8 2922.0 3287.3 3652.5
USG_XMD
USG_PCGU
SURFACT_PCG5+NEWTON

Hydrographs





Water balance

MS_A1

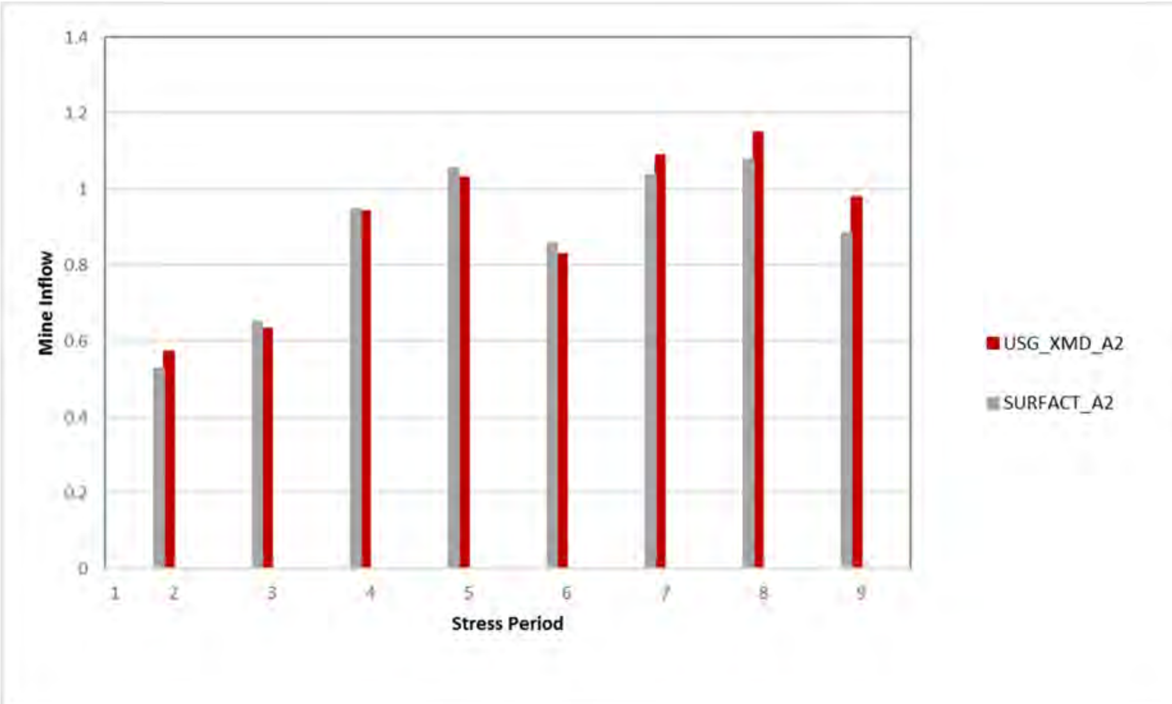
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3												
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			3094610	343.8456	0.941	0.772							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15761.16	43.152	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			555410.2	61.71224	0.169								
CONSTAN	HEAD	=		68272664	7585.852	20.769								
WELLS	=			0	0	0.000								
DRAINS	=			2513331	279.259	0.765								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		70490352	7832.261	21.444								
TOTAL	OUT	=		1.42E+08	15759.08	43.146	42.977							
IN	-	OUT	=	18692.81	2.076979	0.006	0.767							
PERCENT	DISCREPA	=	0.01											

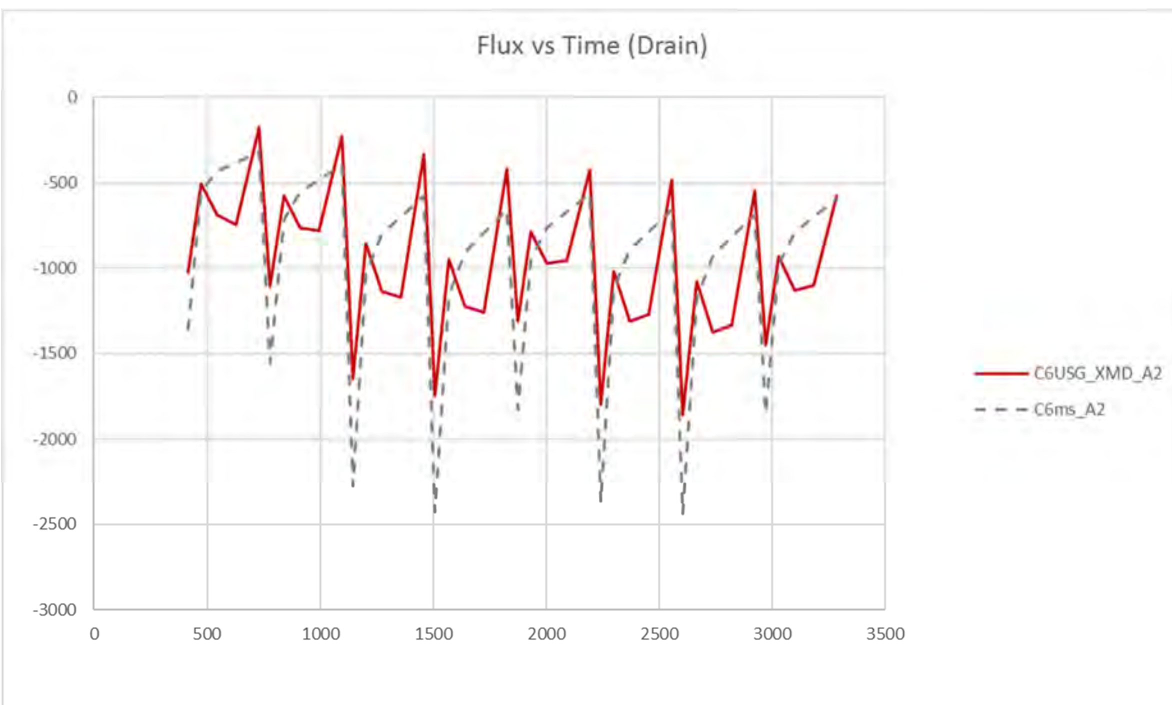
USG_A1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)	DIFF(C6usg_XMD&C6usg_PCGU)					
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2166910	240.7677	0.659	0.597							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%	0.000%					
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15658.09	42.870	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			202984.7	22.55386	0.062								
CONSTAN	HEAD	=		32723199	3635.911	9.955		-108.637%	0.000%					
WELLS	=			0	0	0.000								
DRAINS	=			1962306	218.034	0.597		-28.081%	0.000%					
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.256		33.520%	0.000%					
TOTAL	OUT	=		1.41E+08	15657.82	42.869	42.807	-0.647%	0.000%					
IN	-	OUT	=	2382.32	0.264702	0.001	0.597							
PERCENT	DISCREPA	=	0											

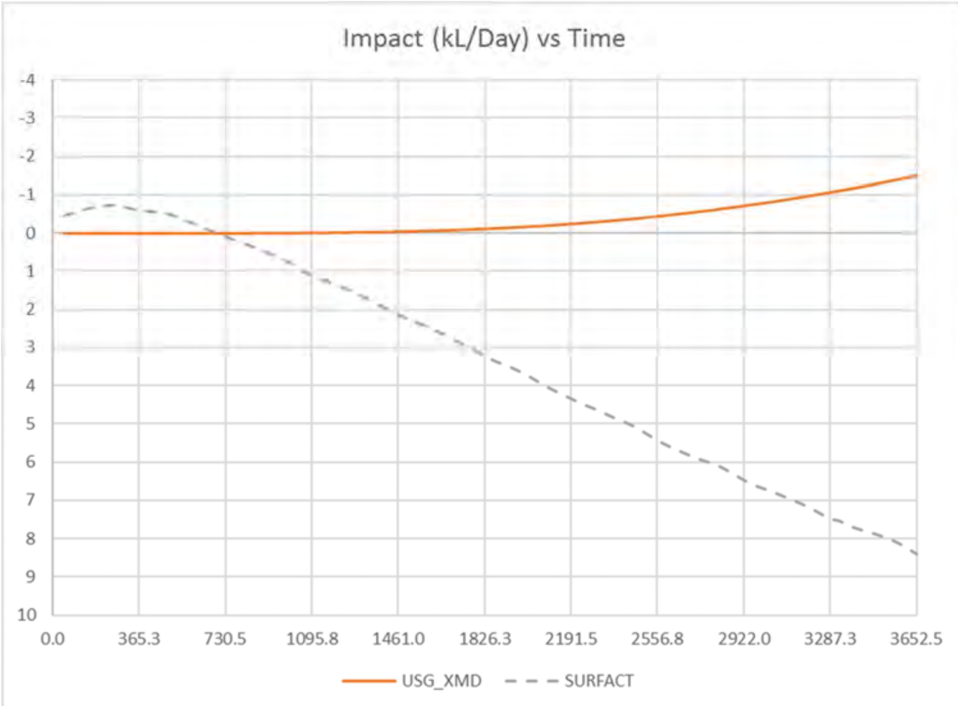
RUN A2 MS vs USG

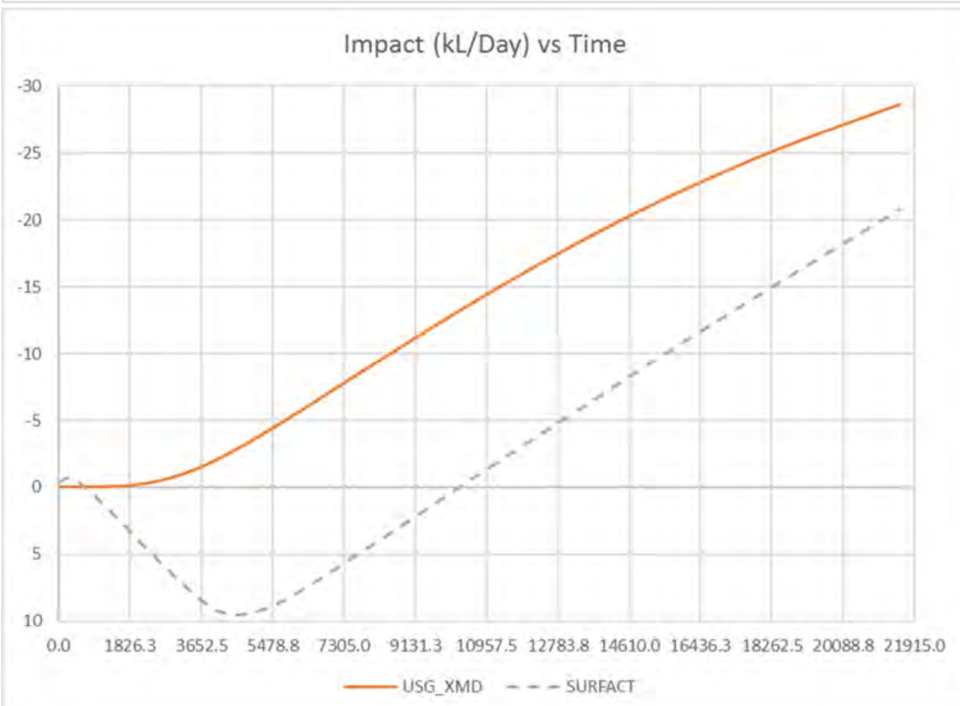
Mine inflow



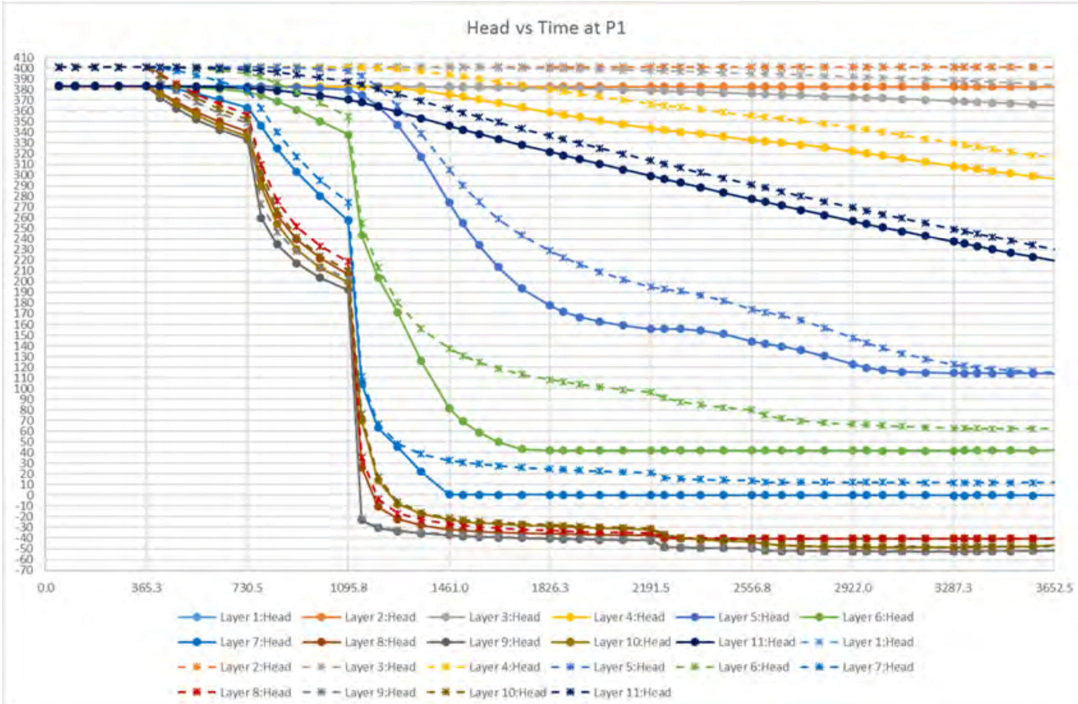


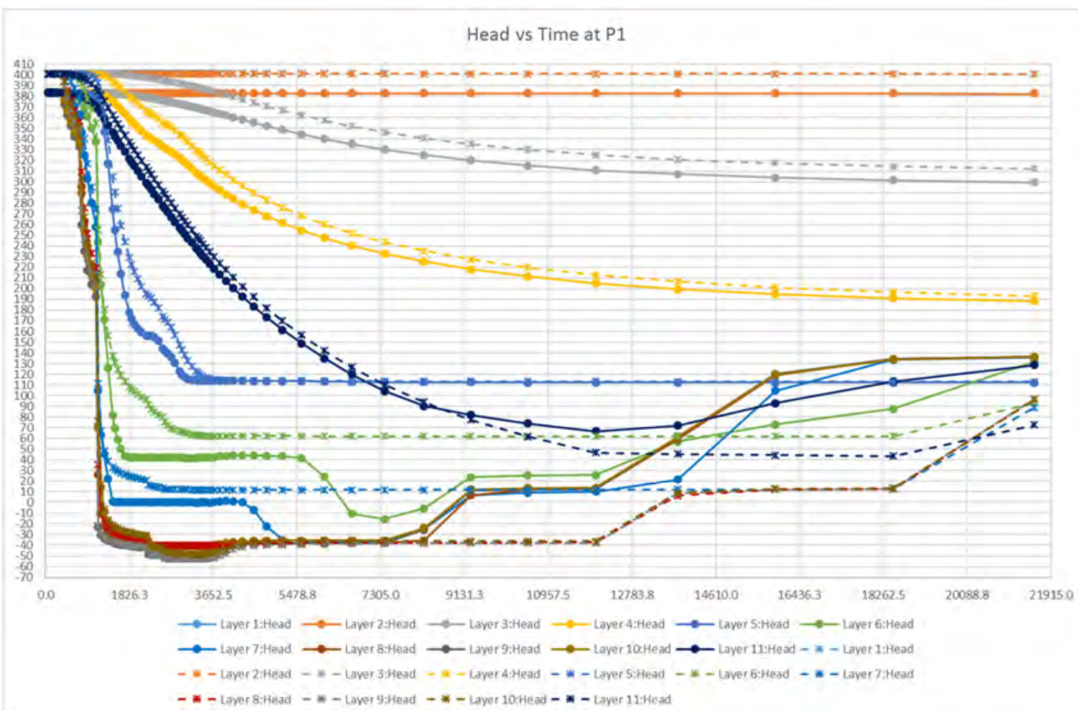
River flux


Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD
SURFACT


Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
10
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD
SURFACT

Hydrographs





MS_A2

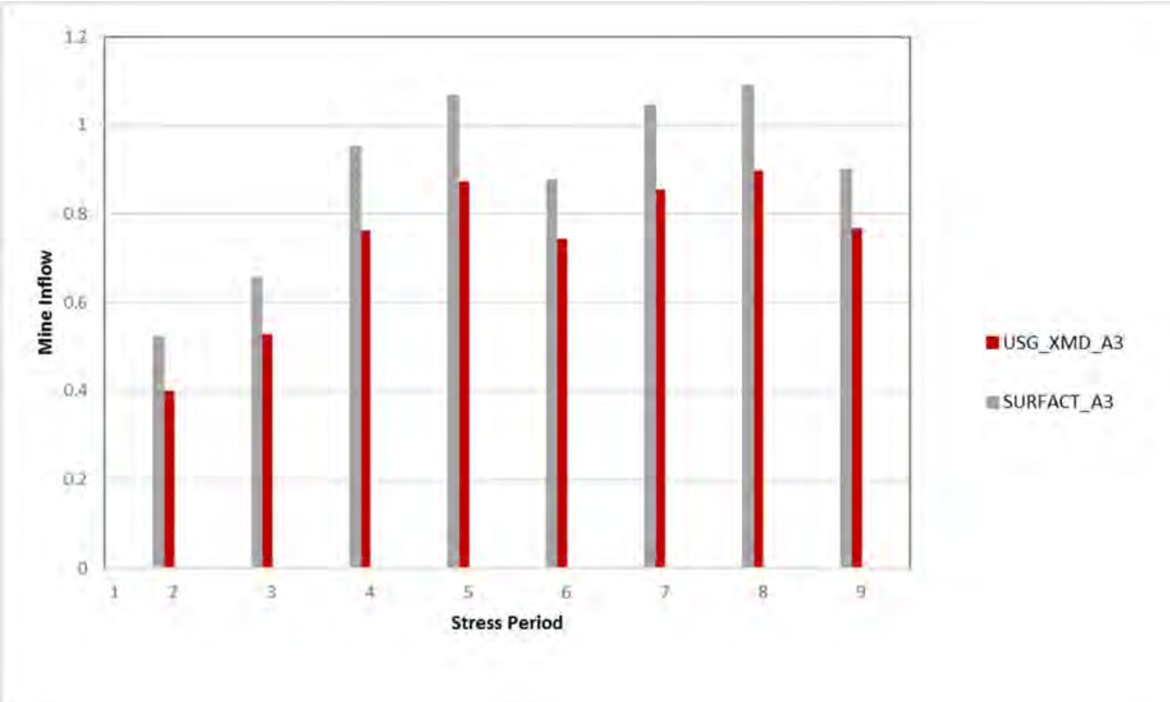
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3												
-----------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2980826	331.2029	0.907	0.694							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15748.52	43.117	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			697955.5	77.55061	0.212								
CONSTAN	HEAD	=		69209112	7689.901	21.054								
WELLS	=			0	0	0.000								
DRAINS	=			2573487	285.943	0.783								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		69466248	7718.472	21.132								
TOTAL	OUT	=		1.42E+08	15771.87	43.181	42.969							
IN	-	OUT	=	-210137	-23.3486	-0.064	0.758							
PERCENT	DISCREPA	=	-0.15											

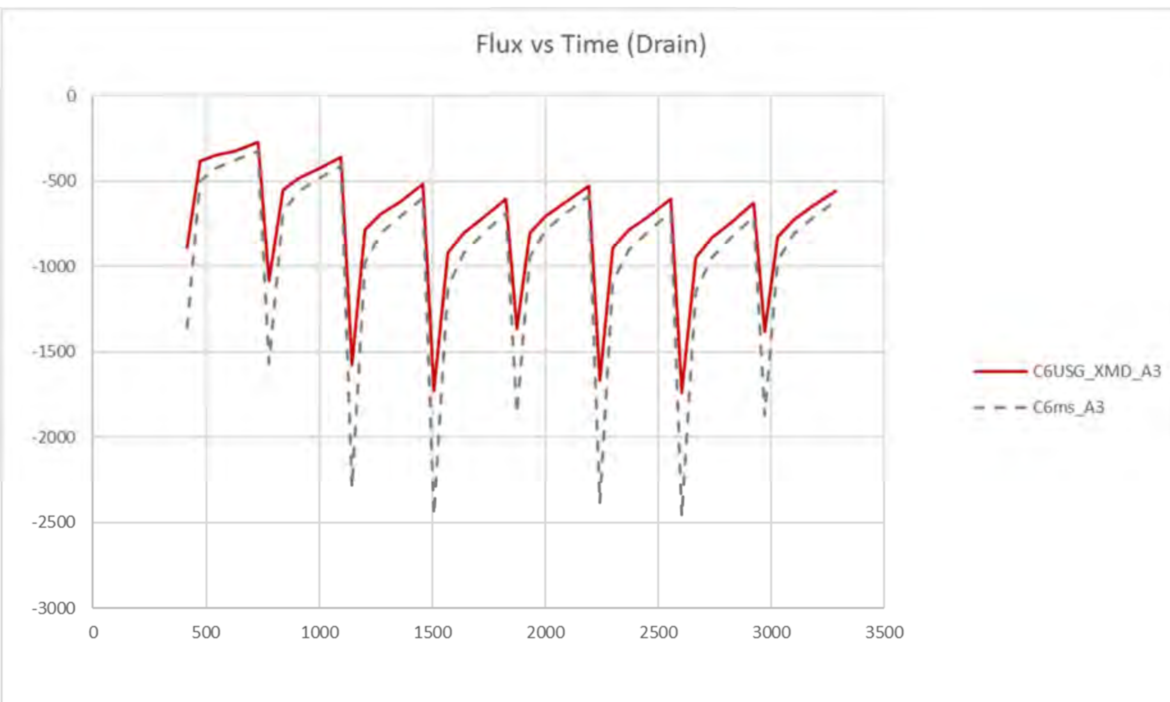
USG_A2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
-----------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2753708	305.9675	0.838	0.803							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15723.28	43.048	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			112543.3	12.50481	0.034								
CONSTAN	HEAD	=		32723184	3635.909	9.955		-111.499%						
WELLS	=			0	0	0.000								
DRAINS	=			2639366	293.2629	0.803		2.496%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.31	32.255		34.485%						
TOTAL	OUT	=		1.42E+08	15722.99	43.047	43.013	-0.311%						
IN	-	OUT	=	2694.021	0.299336	0.001	0.803							
PERCENT	DISCREPA	=	0											

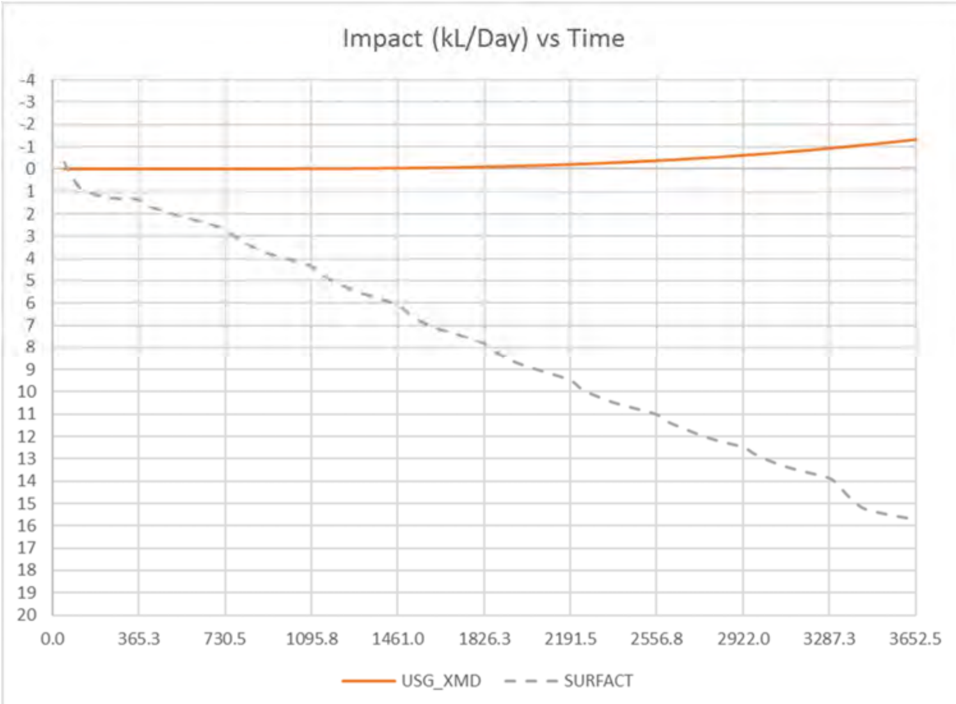
RUN A3 MS vs USG

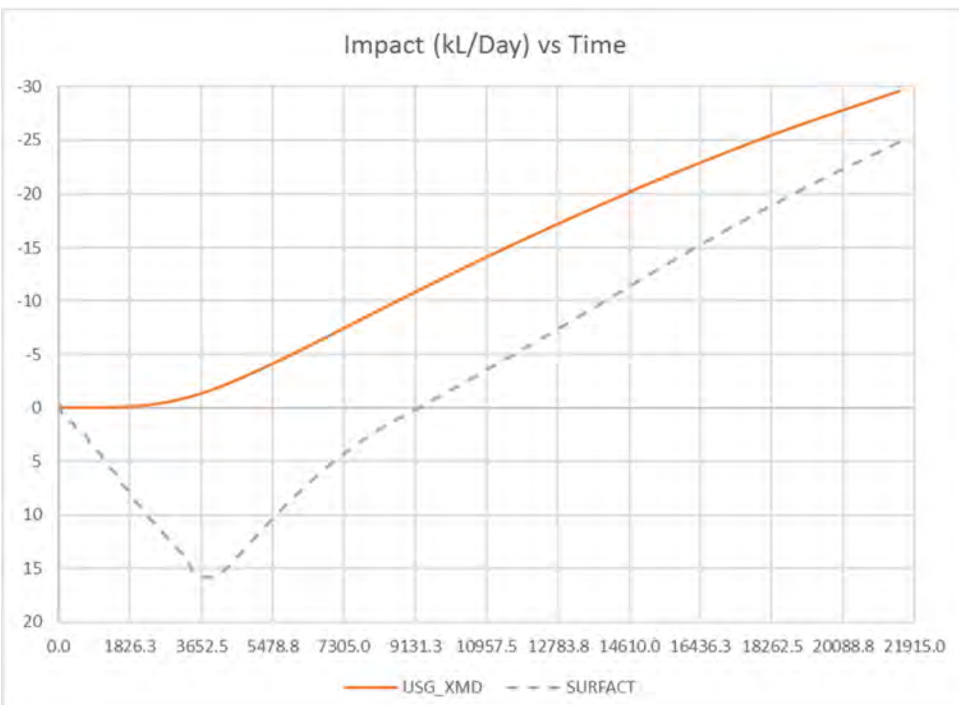
MINE INFLOW



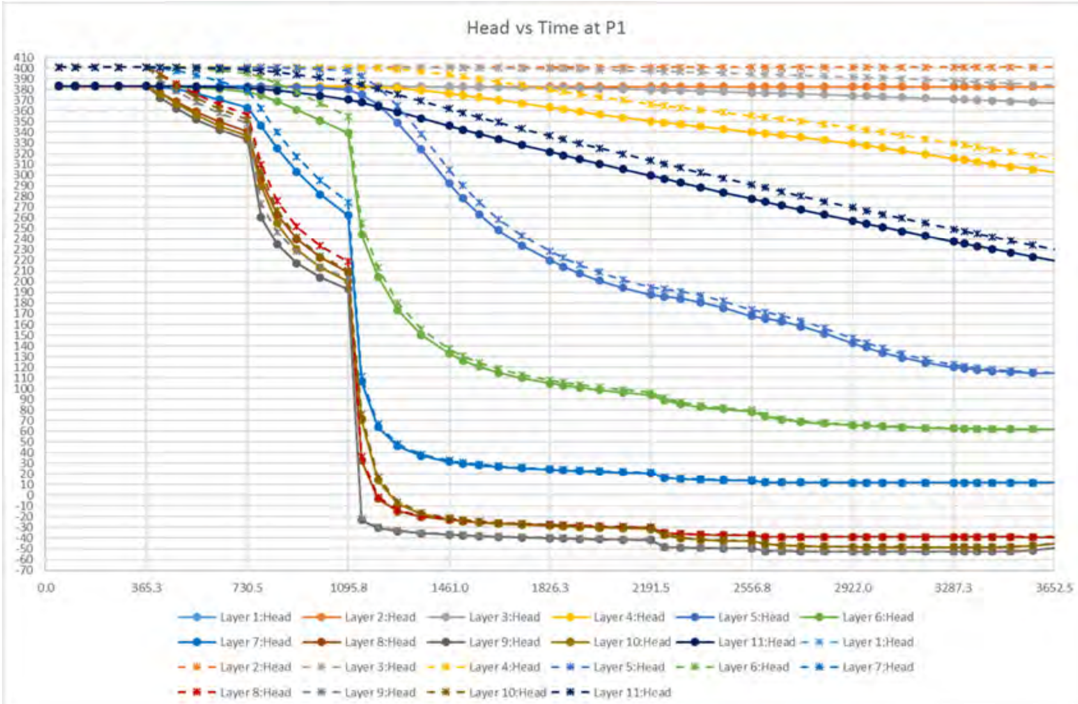


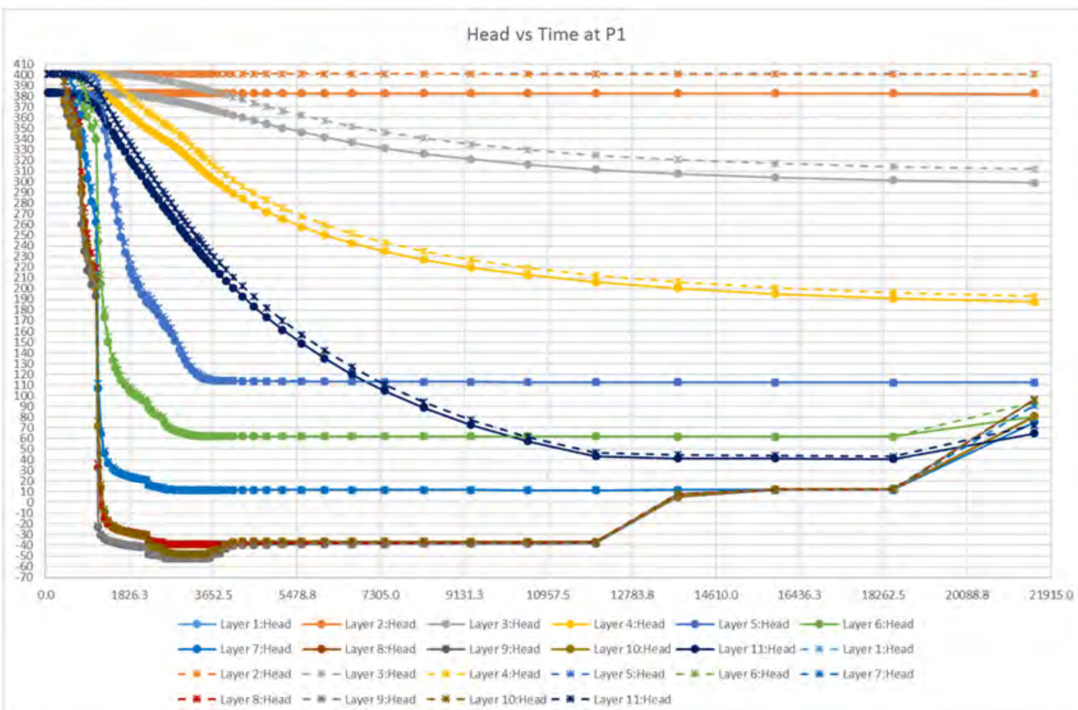
River flux


Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD
SURFACT


Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
10
15
20
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD
SURFACT

Hydrographs





MS_A3

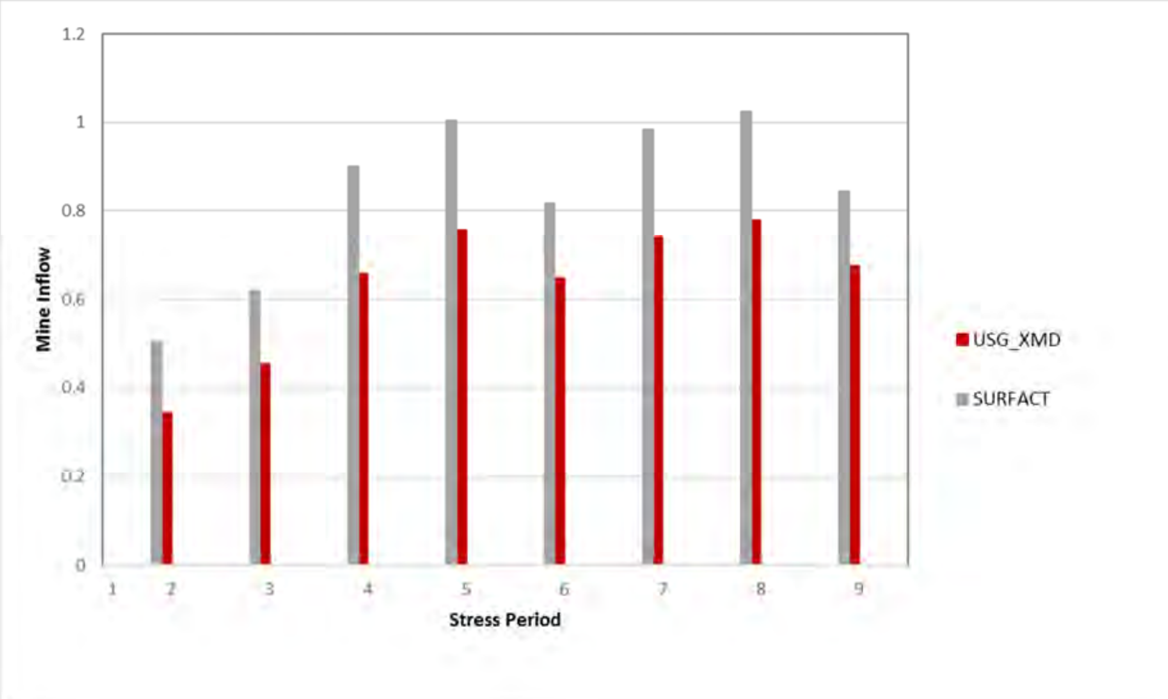
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3												
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			3201816	355.7573	0.974	0.791							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15773.07	43.184	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			602036.7	66.89297	0.183								
CONSTAN	HEAD	=		69870744	7763.416	21.255								
WELLS	=			0	0	0.000								
DRAINS	=			2595251	288.3613	0.789								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		69092848	7676.983	21.018								
TOTAL	OUT	=		1.42E+08	15795.65	43.246	43.063							
IN	-	OUT	=	-203224	-22.5804	-0.062	0.853							
PERCENT	DISCREPA	=	-0.14											

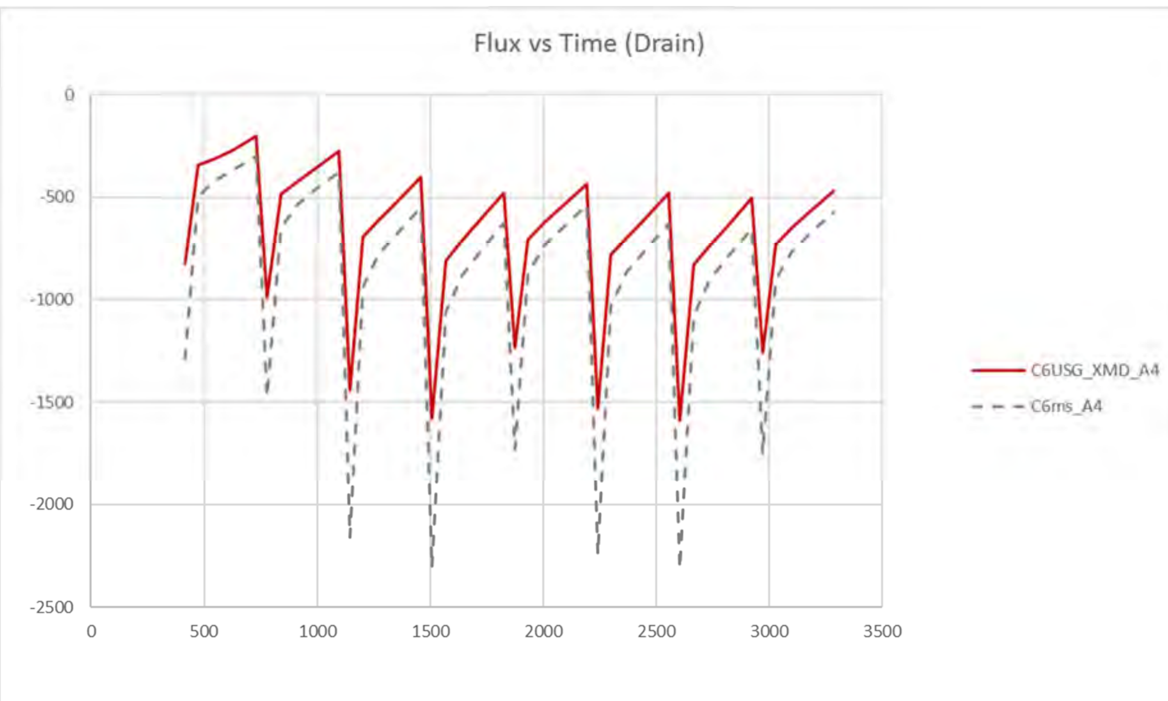
USG_A3

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2214331	246.0368	0.674	0.645							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15663.35	42.884	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			92920.84	10.32454	0.028								
CONSTAN	HEAD	=		32723199	3635.911	9.955		-113.521%						
WELLS	=			0	0	0.000								
DRAINS	=			2119682	235.5202	0.645		-22.436%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.256		34.838%						
TOTAL	OUT	=		1.41E+08	15663.08	42.883	42.855	-0.846%						
IN	-	OUT	=	2488.241	0.276471	0.001	0.645							
PERCENT	DISCREPA	=	0											

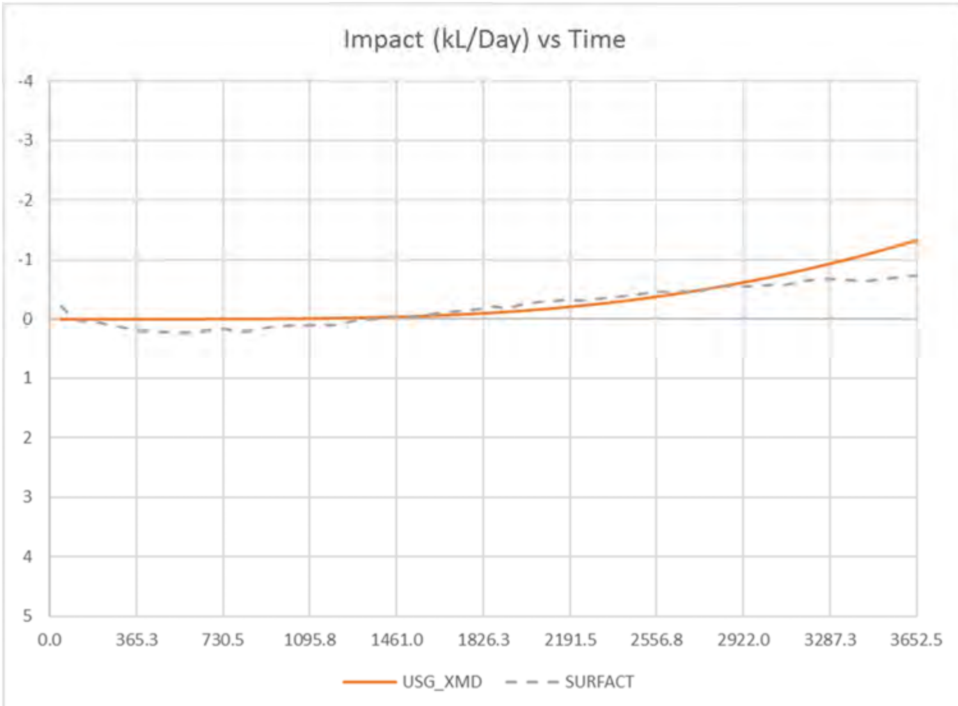
RUN A4 MS vs USG

Mine Inflow

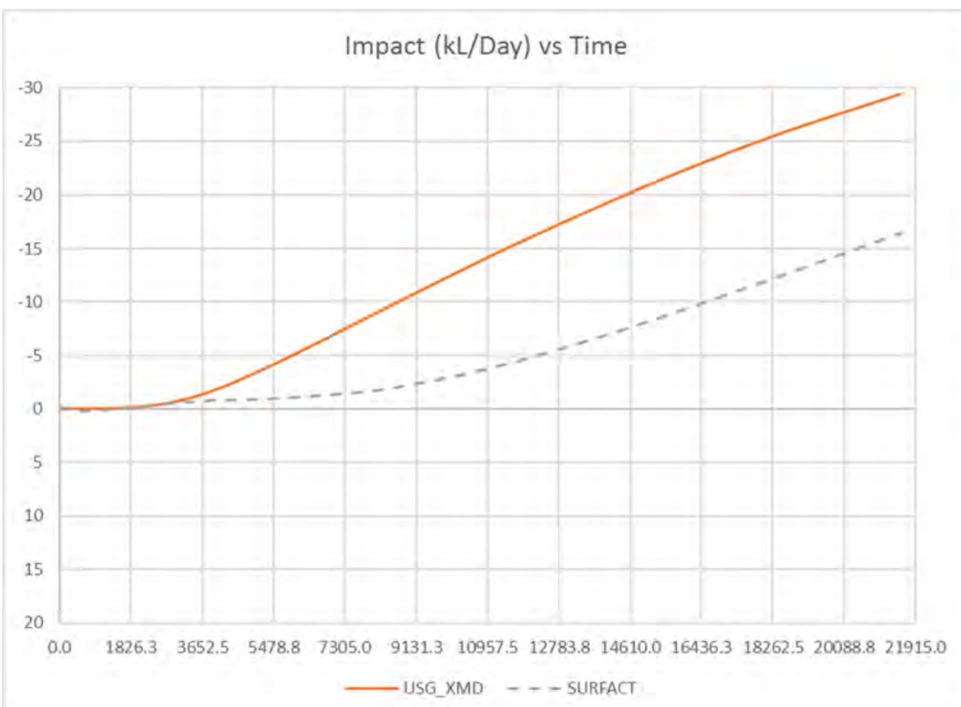




River flux

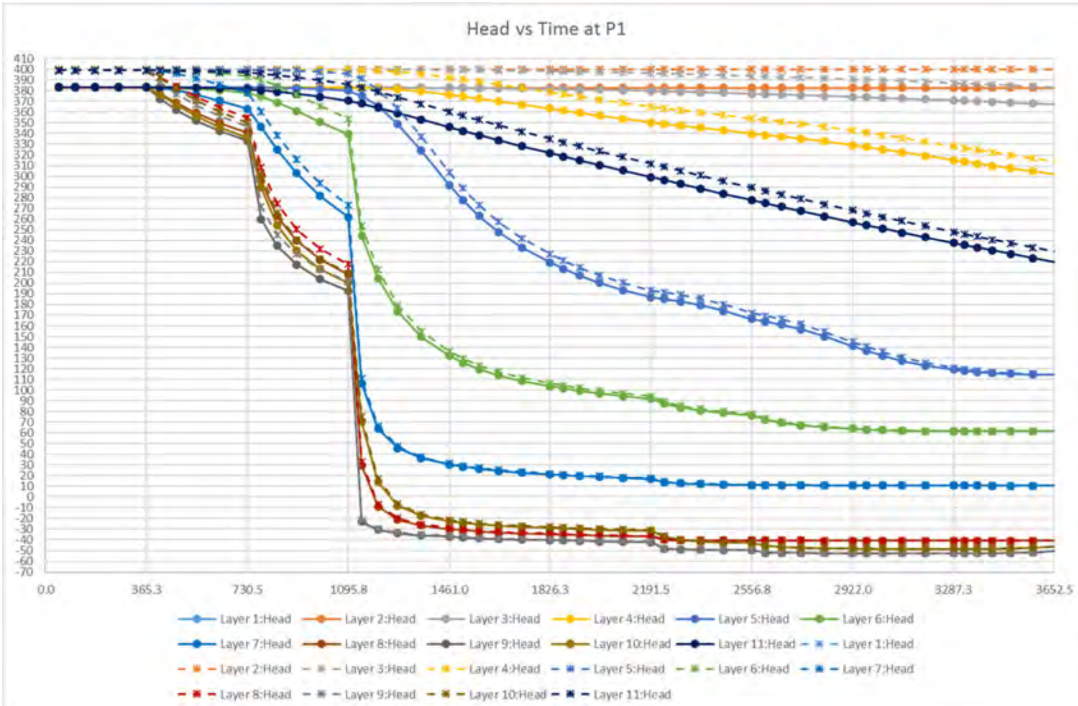


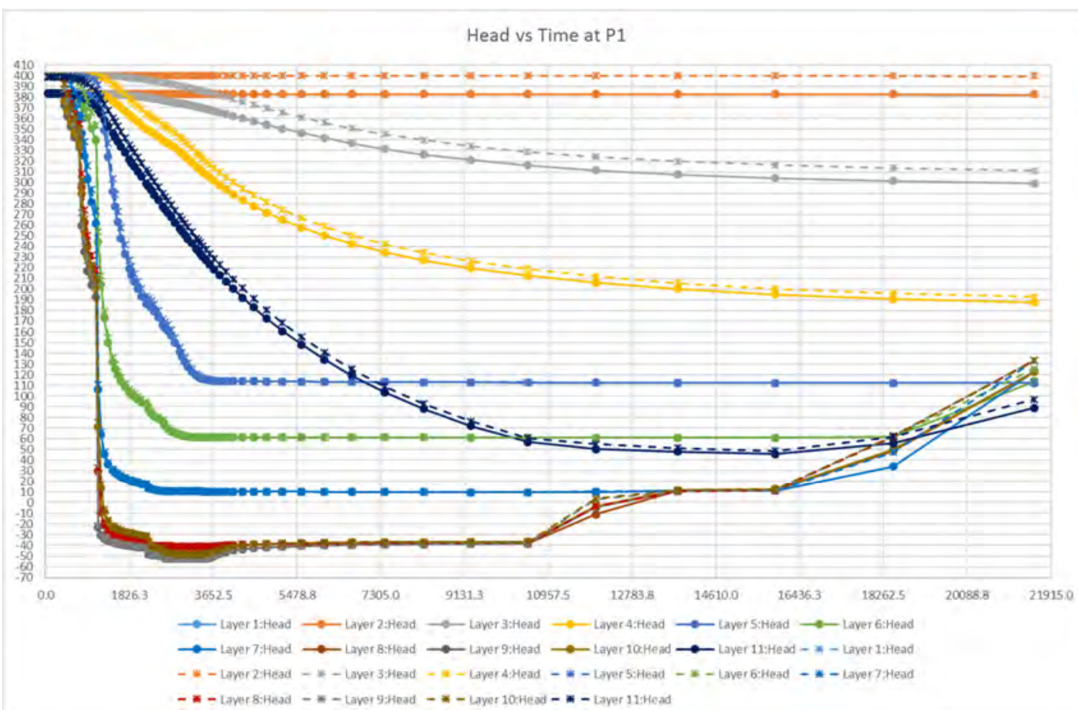
Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
2
3
4
5
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD
SURFACT



Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
10
15
20
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD
SURFACT

Hydrographs





MS_A4

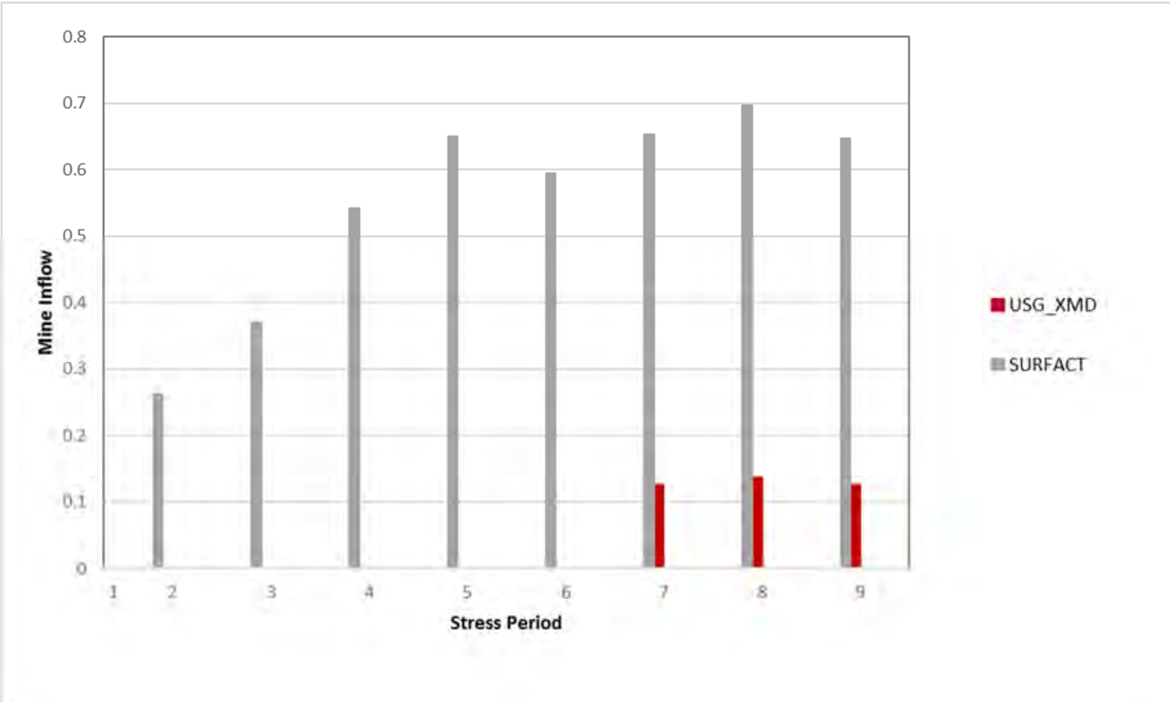
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3												
-----------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			3005284	333.9204	0.914	0.752							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15751.24	43.125	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			533846.3	59.31626	0.162								
CONSTAN	HEAD	=		68272176	7585.797	20.769								
WELLS	=			0	0	0.000								
DRAINS	=			2445049	271.6721	0.744								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		70490280	7832.253	21.444								
TOTAL	OUT	=		1.42E+08	15749.04	43.119	42.956							
IN	-	OUT	=	19772.69	2.196965	0.006	0.746							
PERCENT	DISCREPA	=	0.01											

USG_A4

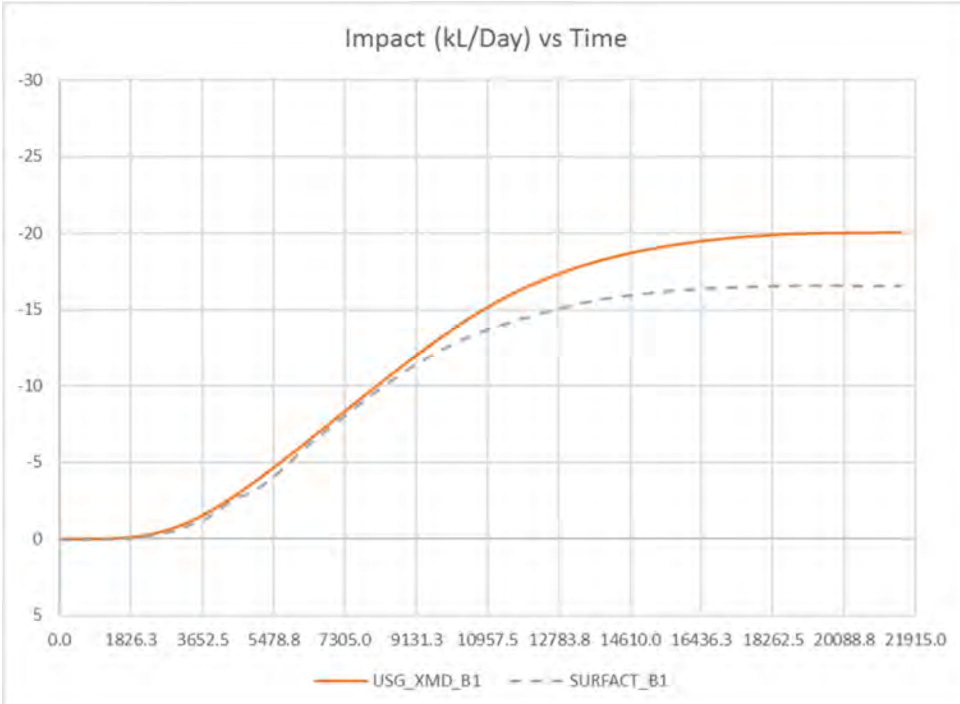
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
-----------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2099227	233.2474	0.639	0.561							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15650.56	42.849	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			254266.5	28.25183	0.077								
CONSTAN	HEAD	=		32723199	3635.911	9.955		-108.635%						
WELLS	=			0	0	0.000								
DRAINS	=			1843423	204.8247	0.561		-32.636%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.256		33.520%						
TOTAL	OUT	=		1.41E+08	15650.31	42.848	42.771	-0.631%						
IN	-	OUT	=	2300.541	0.255616	0.001	0.561							
PERCENT	DISCREPA	=	0											

RUN B1 MS vs USG

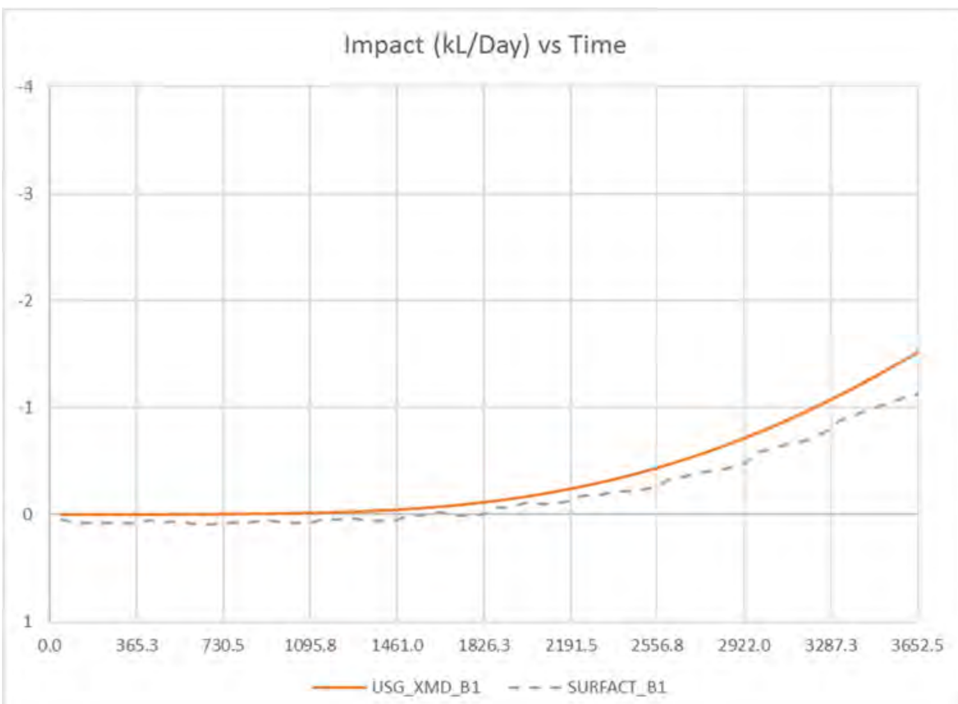
Mine inflow



River flux

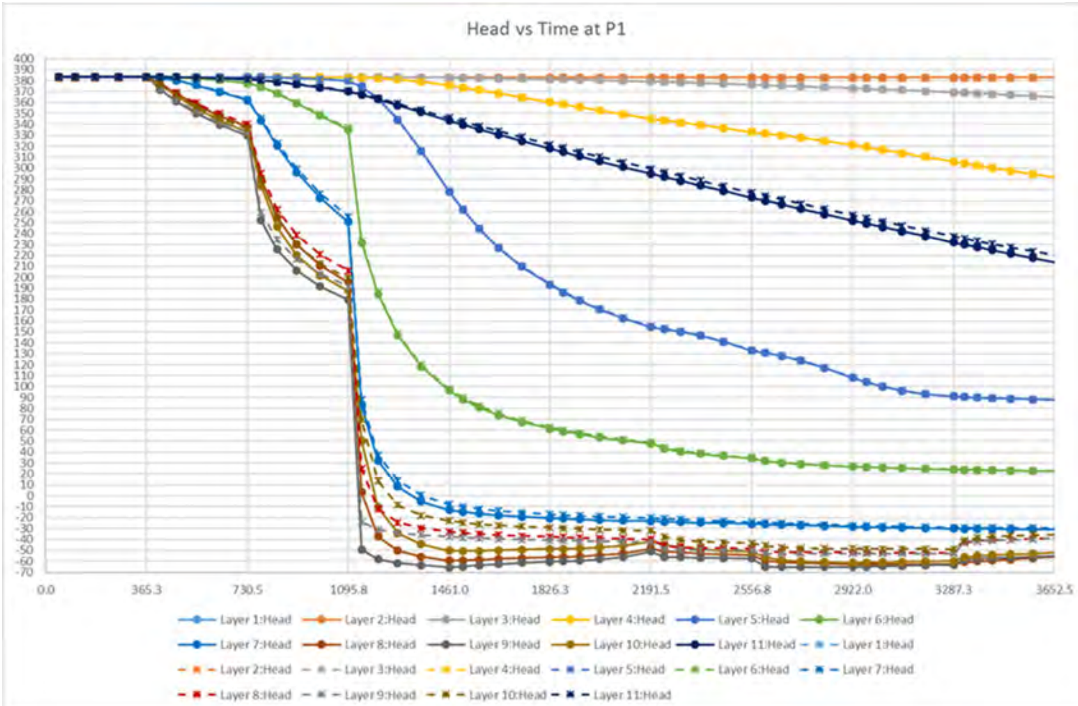


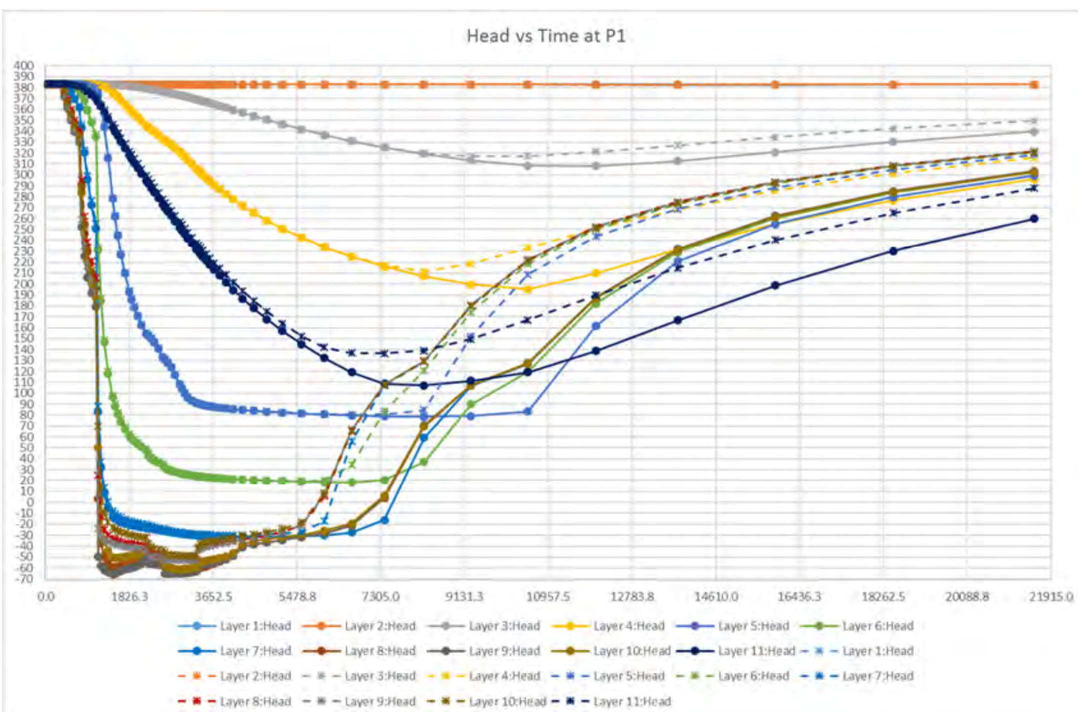
Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD_B1
SURFACT_B1



Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD_B1
SURFACT_B1

Hydrographs





MS_B1

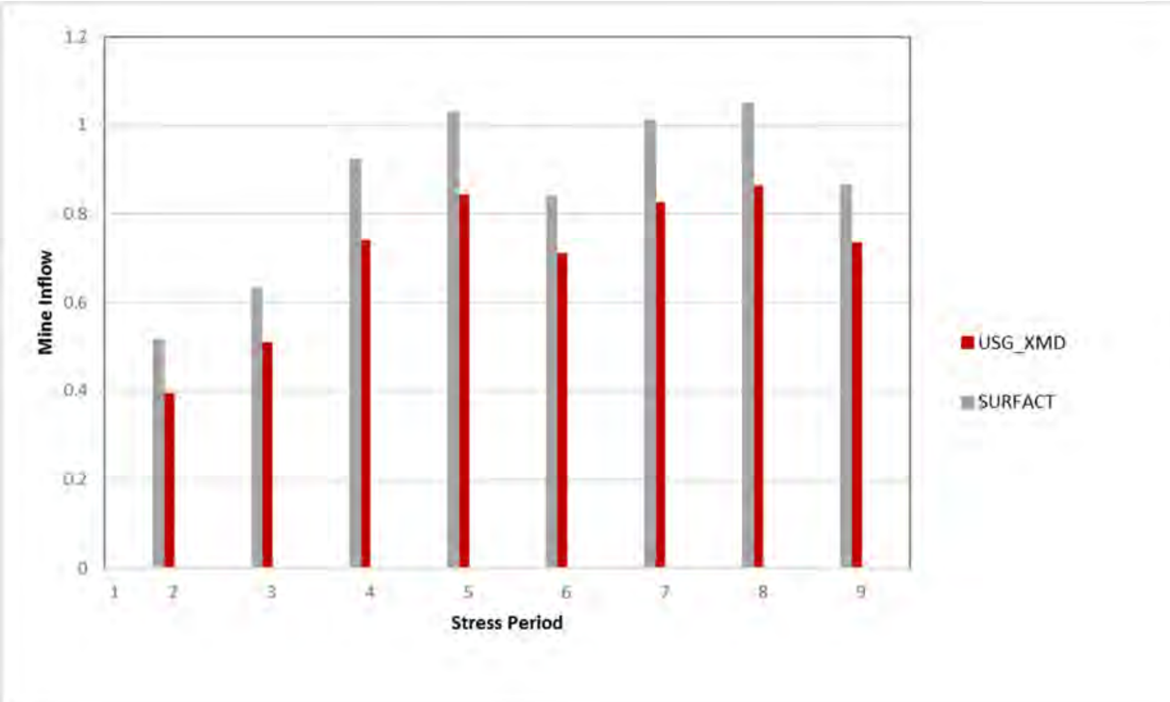
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3												
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			1618524	179.836	0.492	0.490							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.4E+08	15597.15	42.703	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			8335.931	0.926215	0.003								
CONSTAN	HEAD	=		32761232	3640.137	9.966								
WELLS	=			0	0	0.000								
DRAINS	=			1611804	179.0893	0.490								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11777.13	32.244								
TOTAL	OUT	=		1.4E+08	15597.28	42.703	42.701							
IN	-	OUT	=	-1199.31	-0.13326	0.000	0.490							
PERCENT	DISCREPA	=	0											

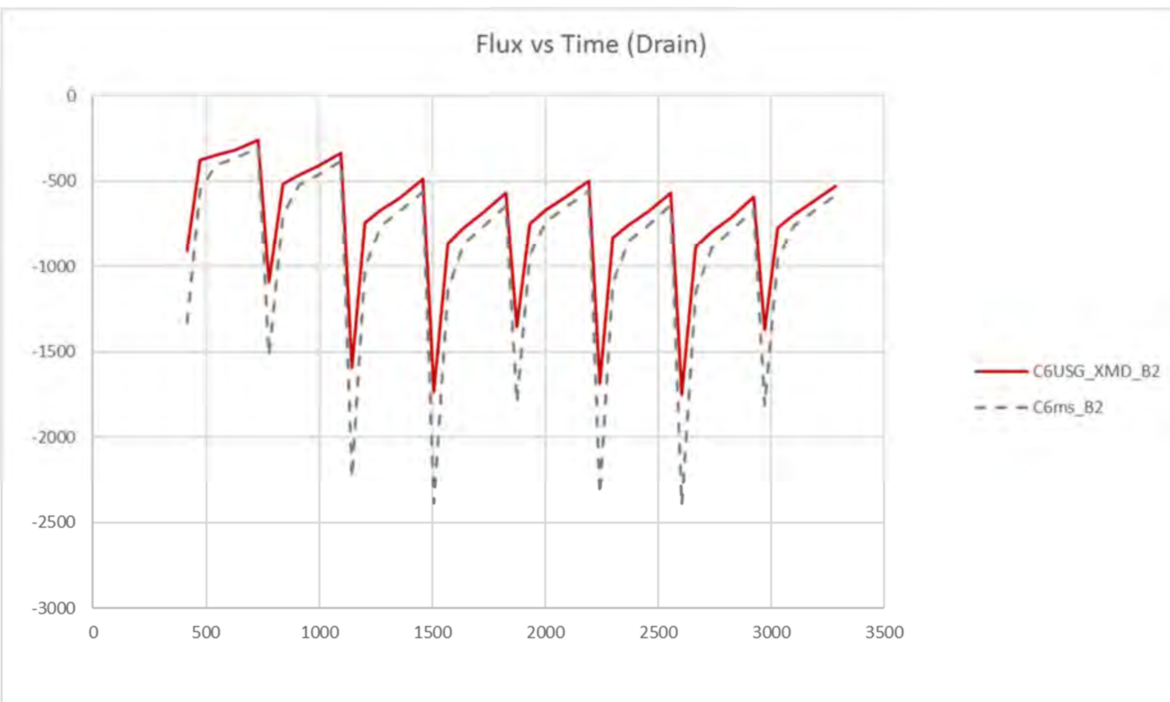
USG_B1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			1773568	197.0631	0.540	0.043							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15614.38	42.750	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			1632542	181.3935	0.497								
CONSTAN	HEAD	=		32723186	3635.91	9.955		-0.116%						
WELLS	=			0	0	0.000								
DRAINS	=			141226.4	15.69182	0.043		-1041.291%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.31	32.255		0.035%						
TOTAL	OUT	=		1.41E+08	15614.31	42.750	42.253	0.109%						
IN	-	OUT	=	678.1246	0.075347	0.000	0.043							
PERCENT	DISCREPA	=	0											

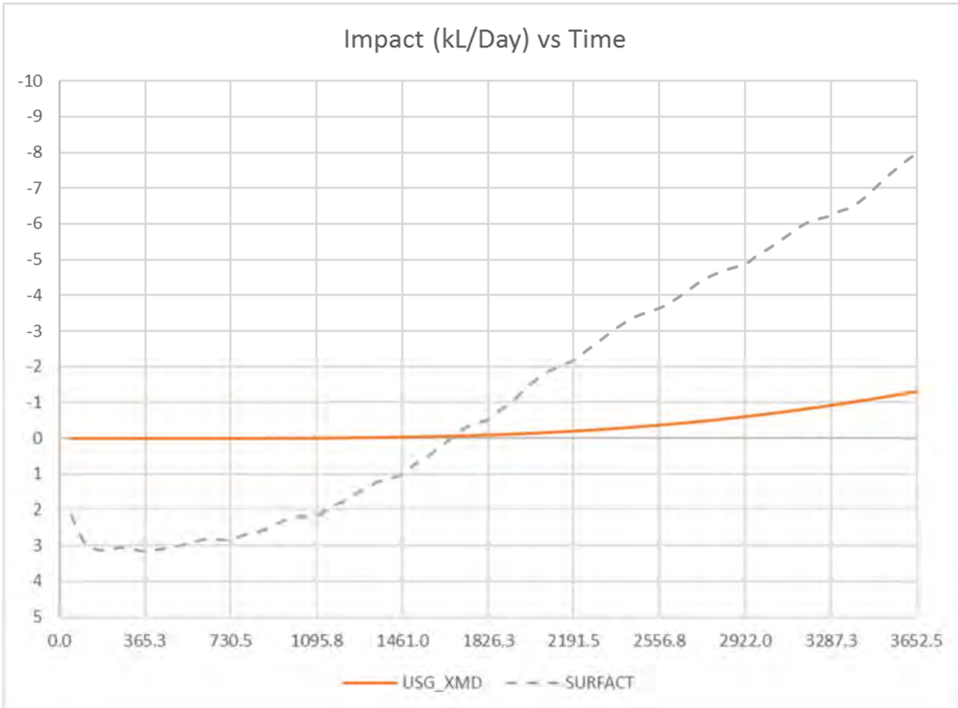
RUN B2 MS vs USG

Mine inflow

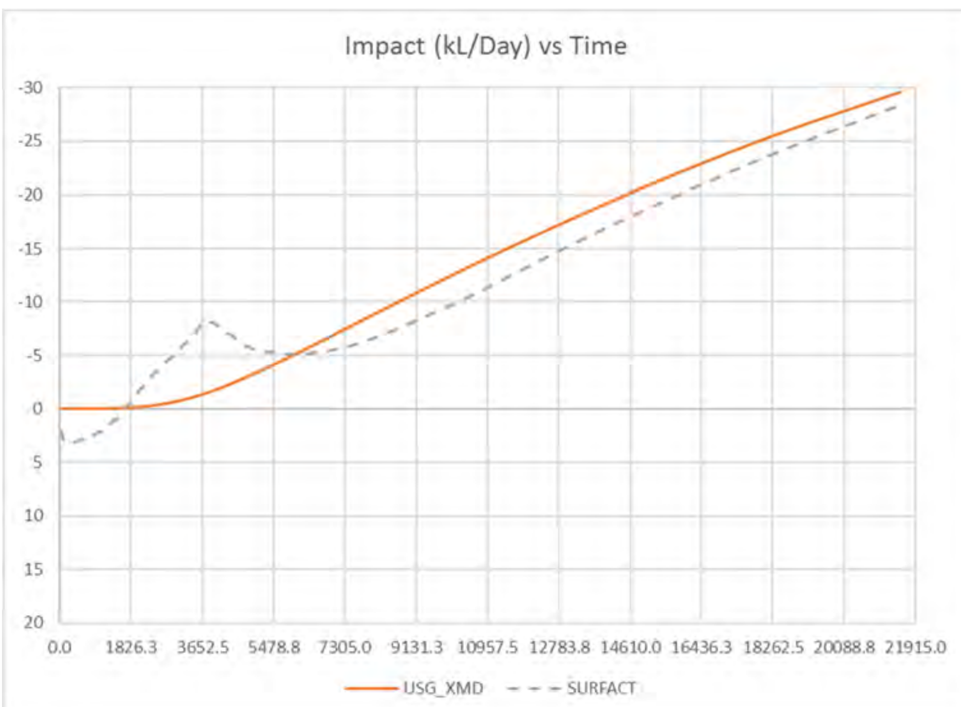




River flux

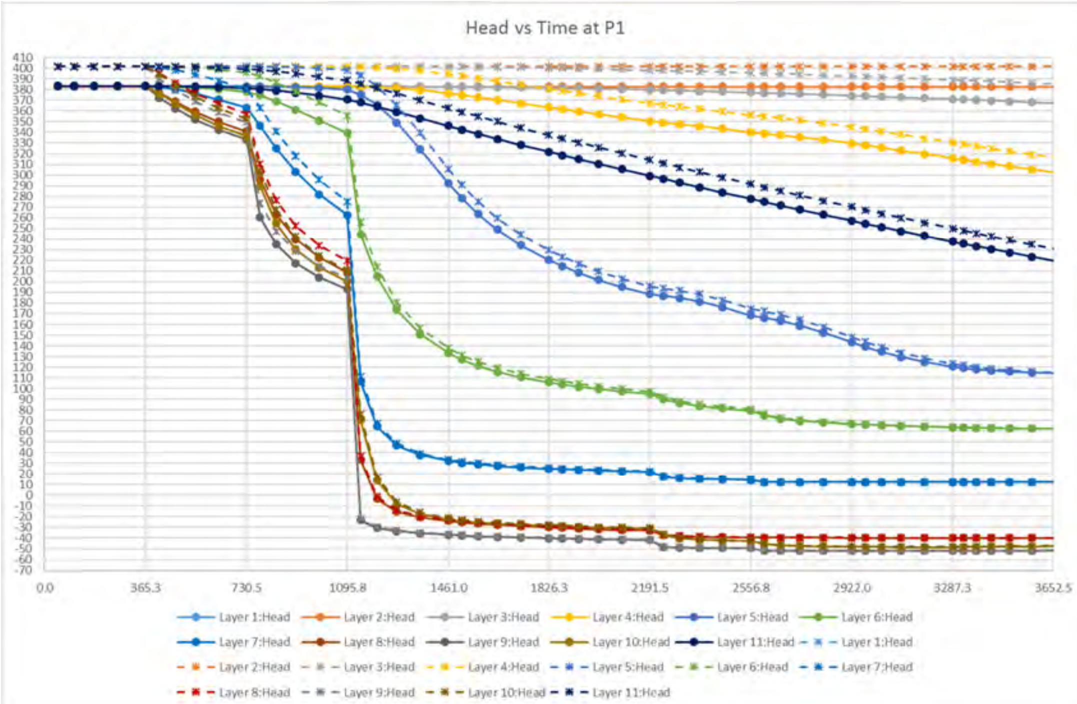


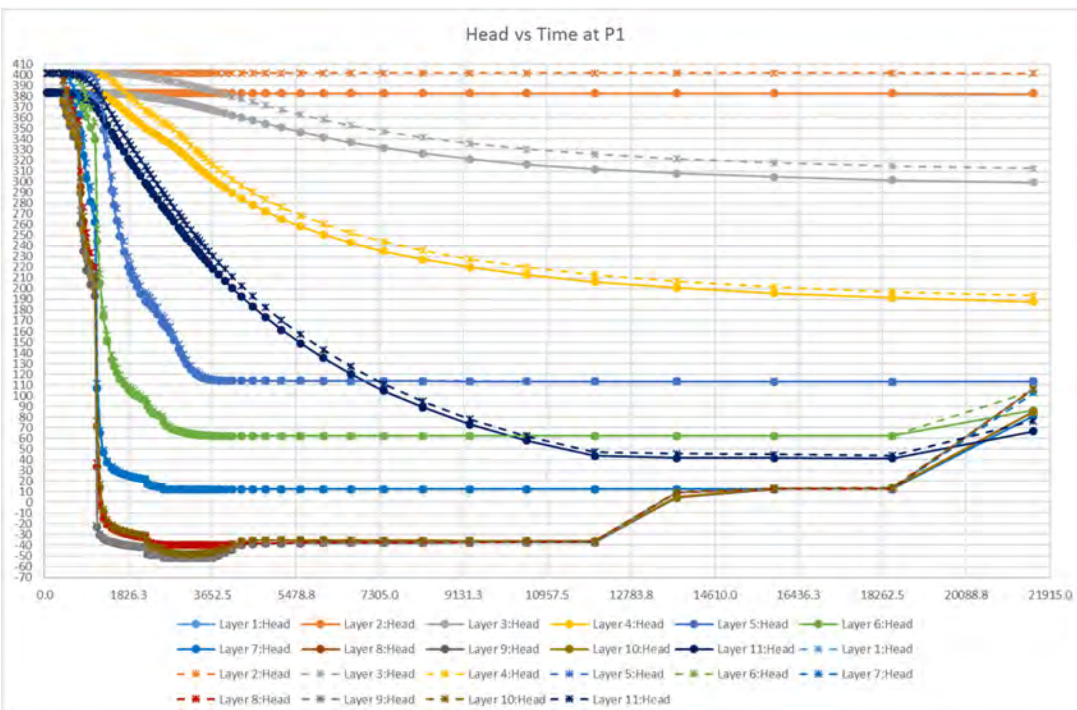
Impact (kL/Day) vs Time
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD
SURFACT



Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
10
15
20
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD
SURFACT

Hydrographs





MS_B2

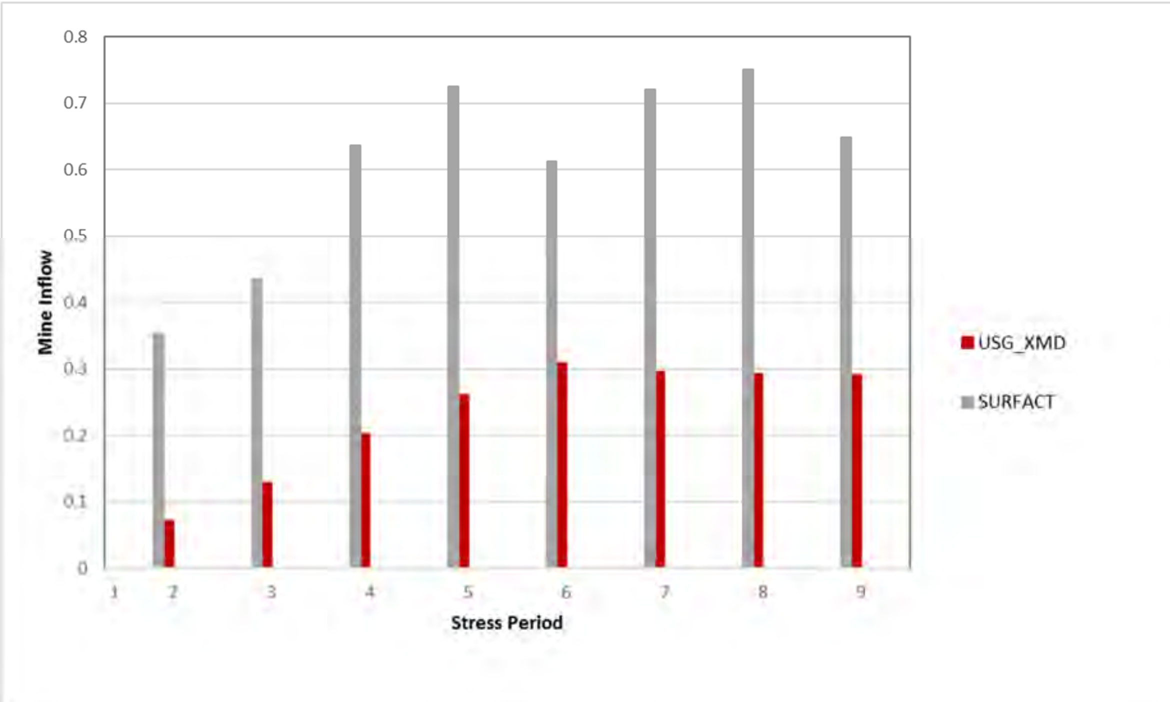
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3												
-----------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			3404065	378.2295	1.036	0.869							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15795.55	43.246	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			546195.3	60.68836	0.166								
CONSTAN	HEAD	=		69884544	7764.949	21.259								
WELLS	=			0	0	0.000								
DRAINS	=			2505643	278.4048	0.762								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		69028752	7669.861	20.999								
TOTAL	OUT	=		1.42E+08	15773.9	43.187	43.020							
IN	-	OUT	=	194770.8	21.64119	0.059	0.810							
PERCENT	DISCREPA	=	0.14											

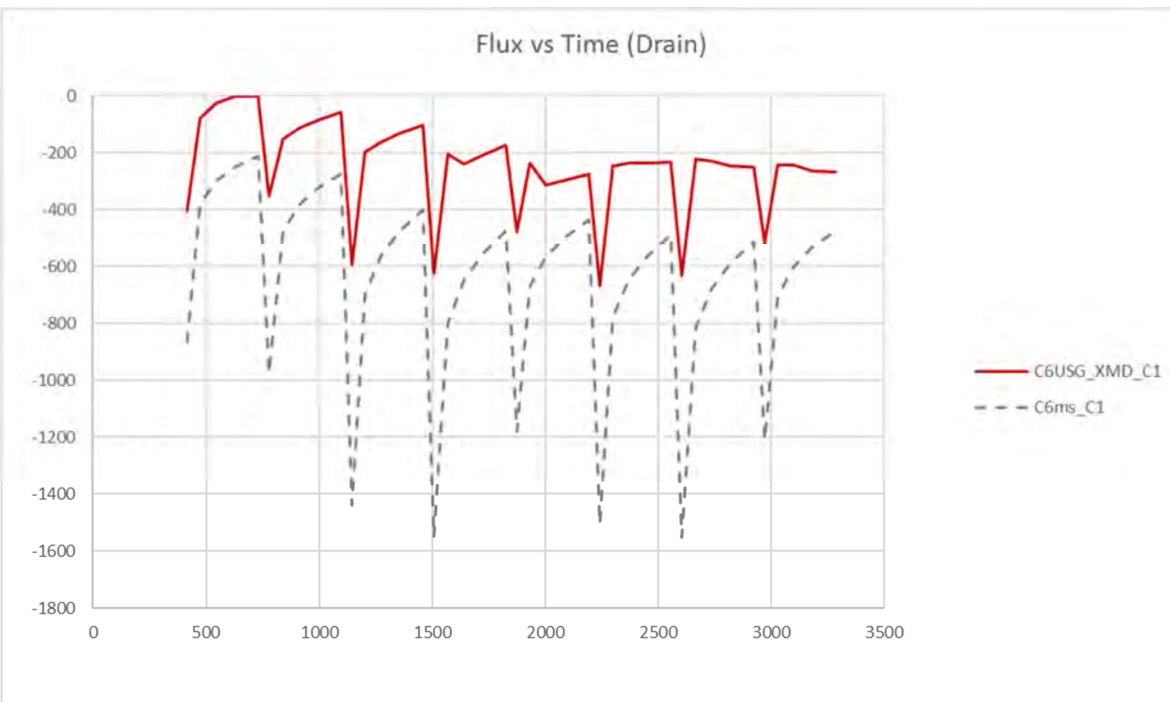
USG_B2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9
--														
CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
-----------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2131297	236.8108	0.648	0.624							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15654.13	42.859	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			80454.39	8.939377	0.024								
CONSTAN	HEAD	=		32723199	3635.911	9.955		-113.563%						
WELLS	=			0	0	0.000								
DRAINS	=			2049012	227.668	0.623		-22.285%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.256		34.898%						
TOTAL	OUT	=		1.41E+08	15653.84	42.858	42.833	-0.767%						
IN	-	OUT	=	2589.229	0.287692	0.001	0.623							
PERCENT	DISCREPA	=	0											

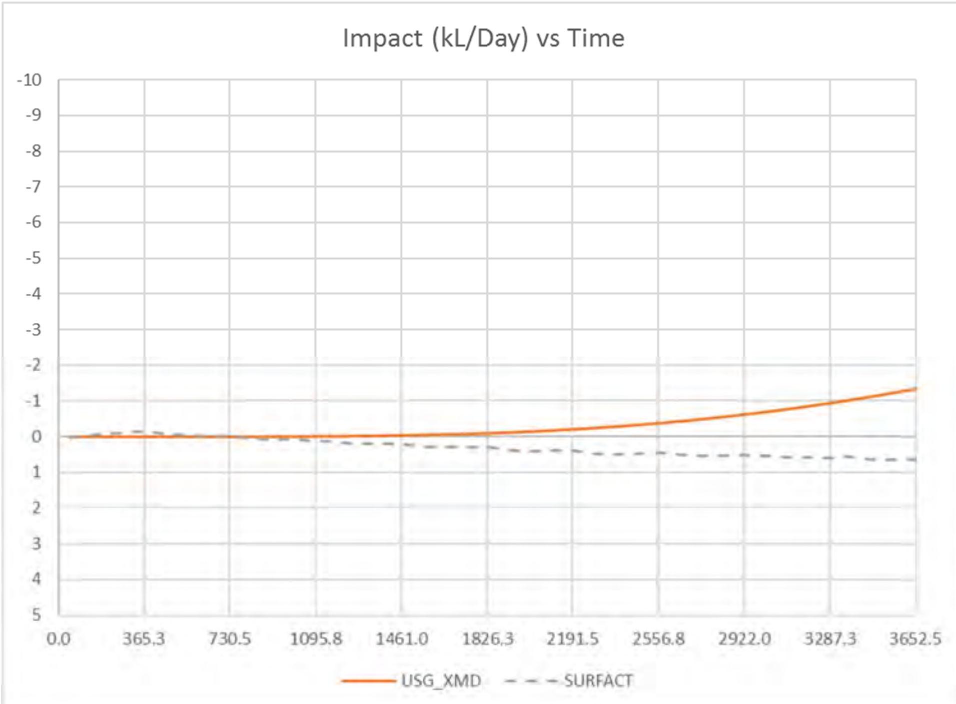
RUN C1 MS vs USG

Mine inflow

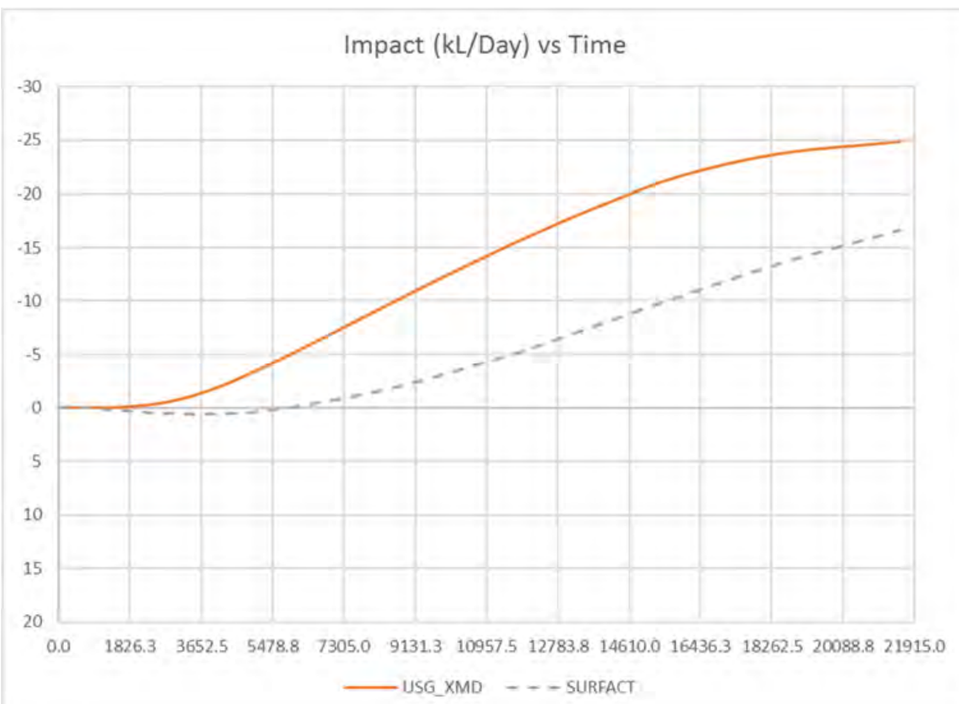




River flux

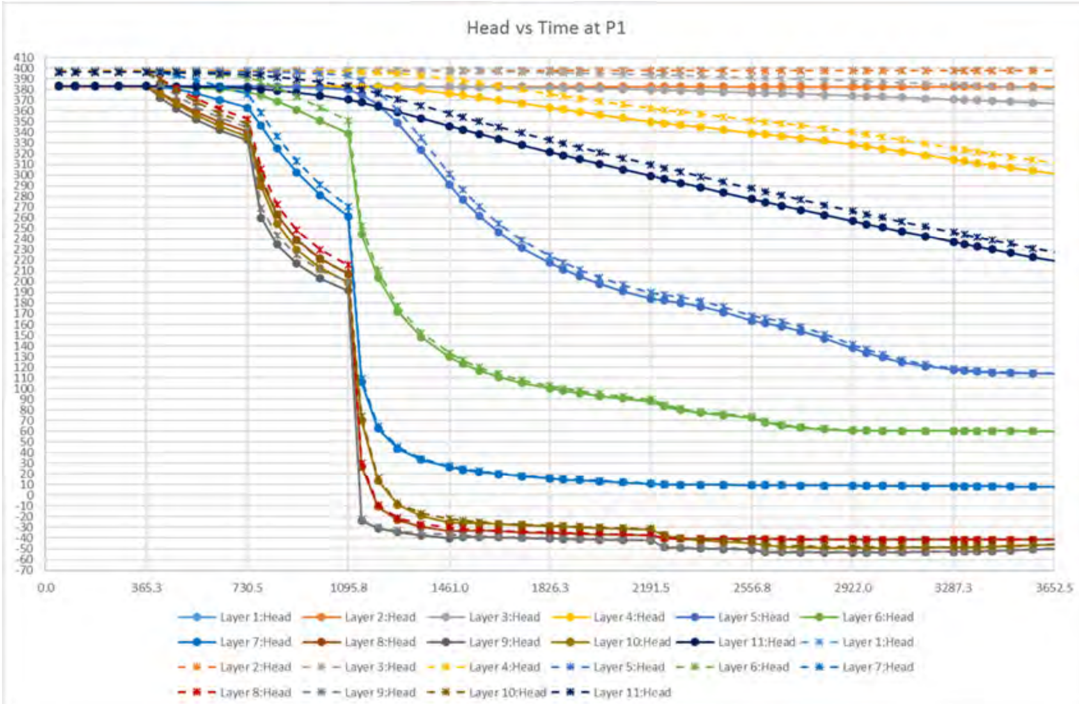


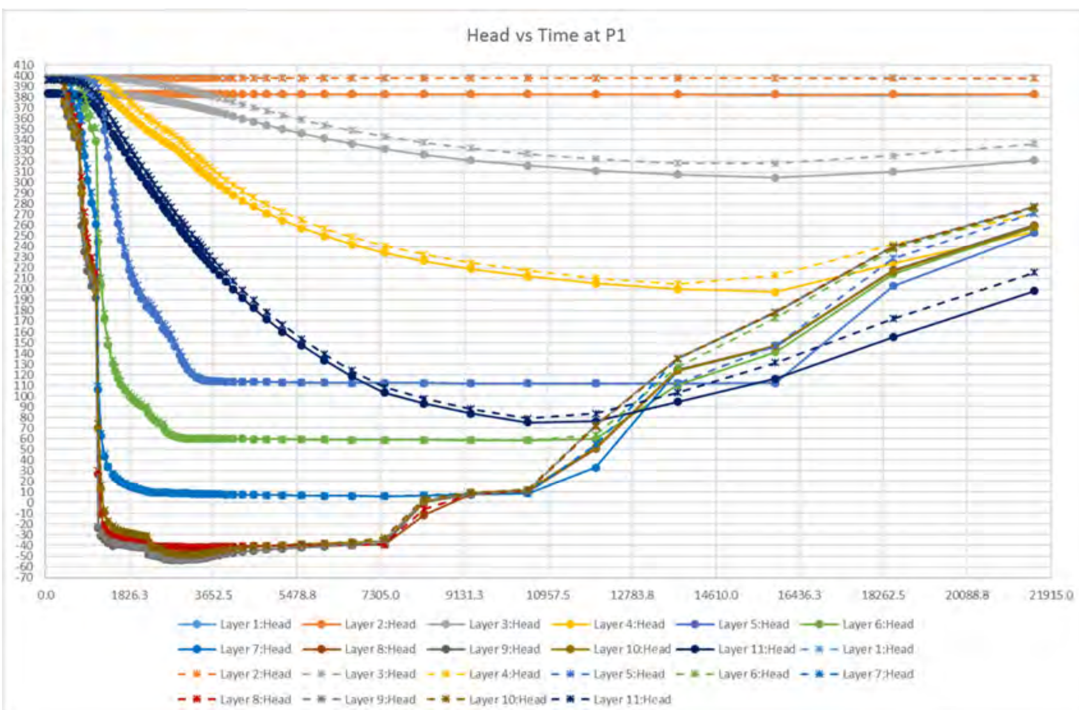
Impact (kL/Day) vs Time
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD
SURFACT



Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
10
15
20
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD
SURFACT

Hydrographs





MS_C1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9

CUMULAT	VOLUMES	L**3												
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2105909	233.9898	0.641	0.536							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15651.31	42.851	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			345443.1	38.38256	0.105								
CONSTAN	HEAD	=		66561796	7395.755	20.248								
WELLS	=			0	0	0.000								
DRAINS	=			1781490	197.9434	0.542								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		72187232	8020.804	21.960								
TOTAL	OUT	=		1.41E+08	15652.88	42.855	42.750							
IN	-	OUT	=	-14212.8	-1.5792	-0.004	0.540							
PERCENT	DISCREPA	=	-0.01											

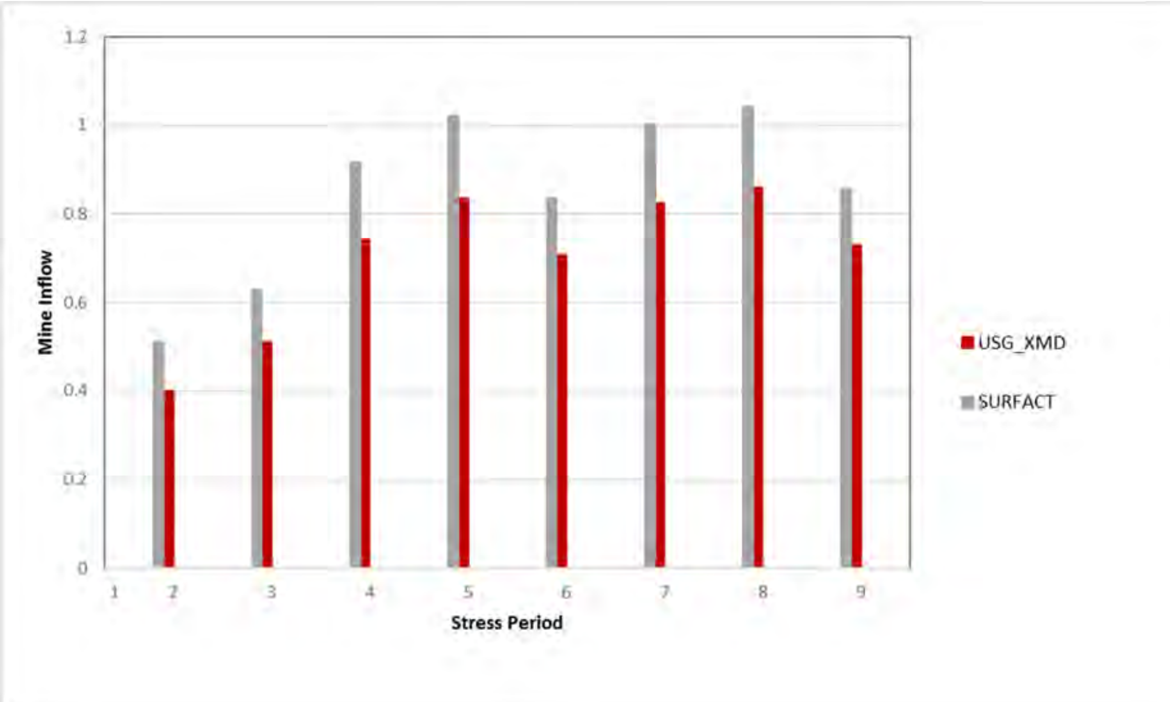
USG_C1

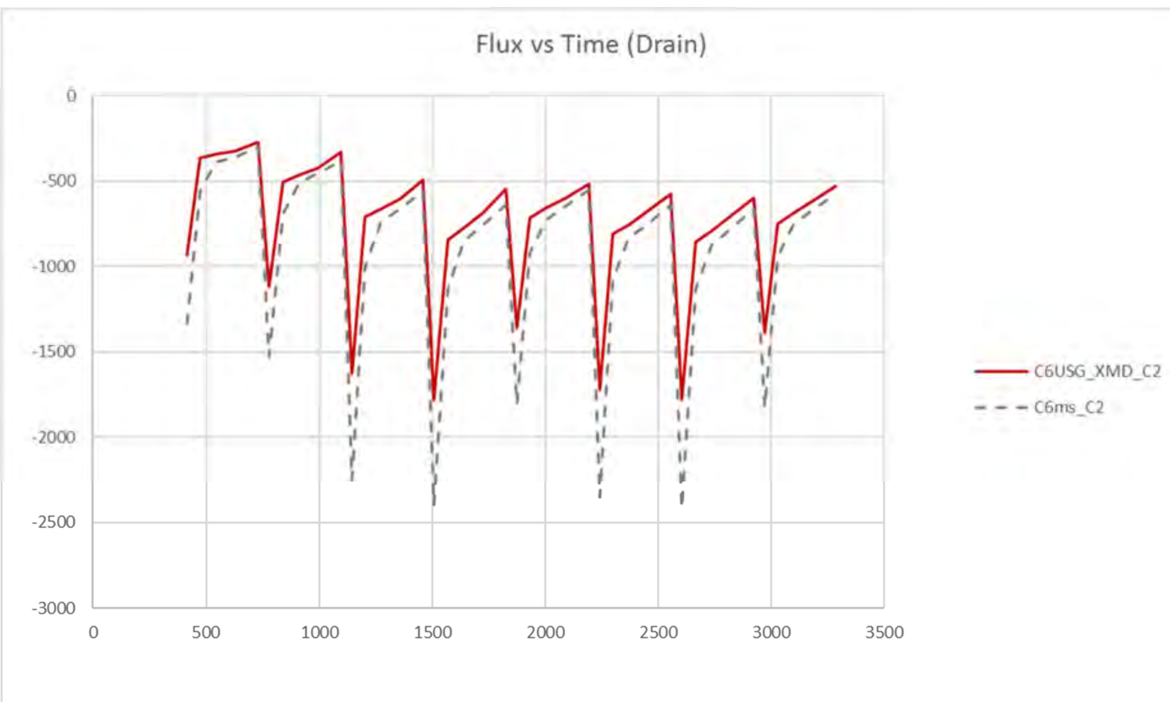
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9

CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			1500943	166.7715	0.457	0.205							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.4E+08	15584.09	42.667	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			825865.4	91.76283	0.251								
CONSTAN	HEAD	=		32723198	3635.911	9.955		-103.409%						
WELLS	=			0	0	0.000								
DRAINS	=			674487	74.943	0.205		-164.125%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.255		31.919%						
TOTAL	OUT	=		1.4E+08	15583.94	42.666	42.415	-0.442%						
IN	-	OUT	=	1362.314	0.151368	0.000	0.205							
PERCENT	DISCREPA	=	0											

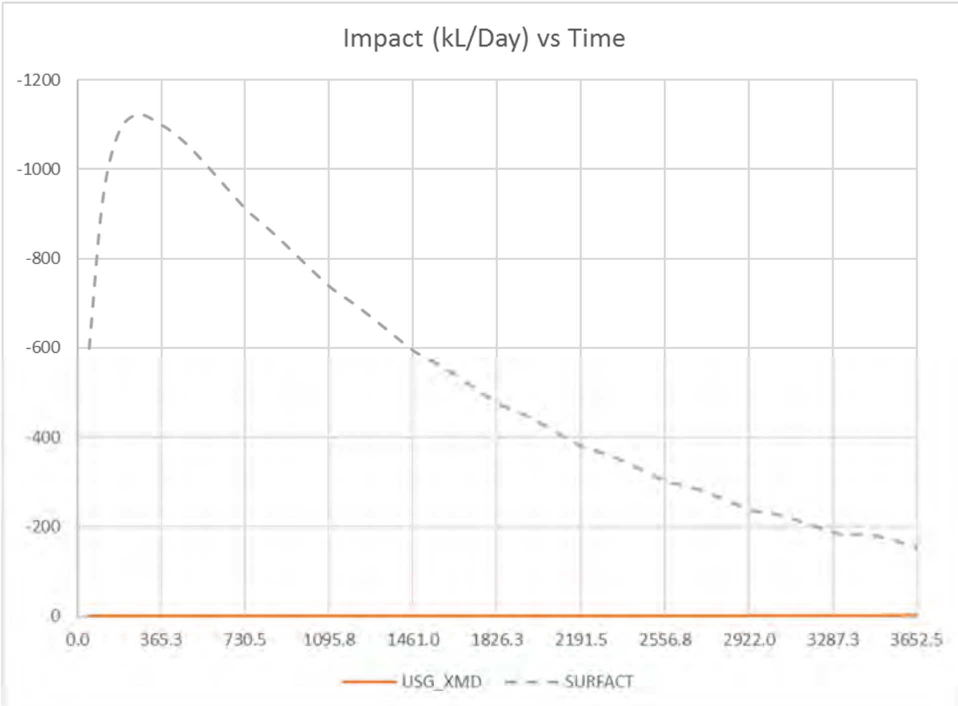
RUN C2 MS vs USG

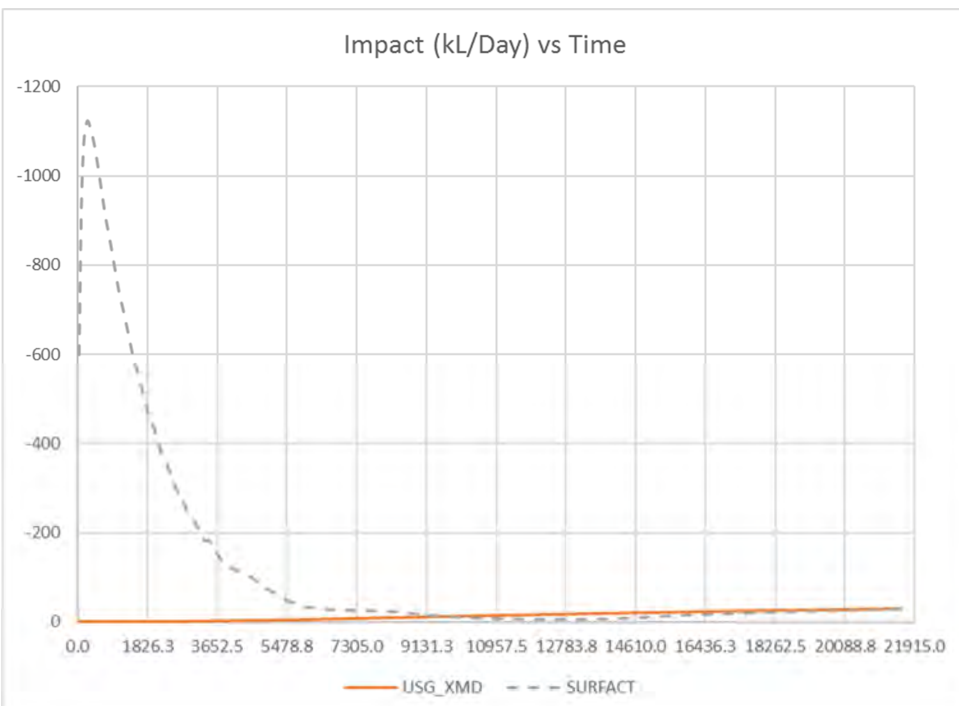
Mine inflow



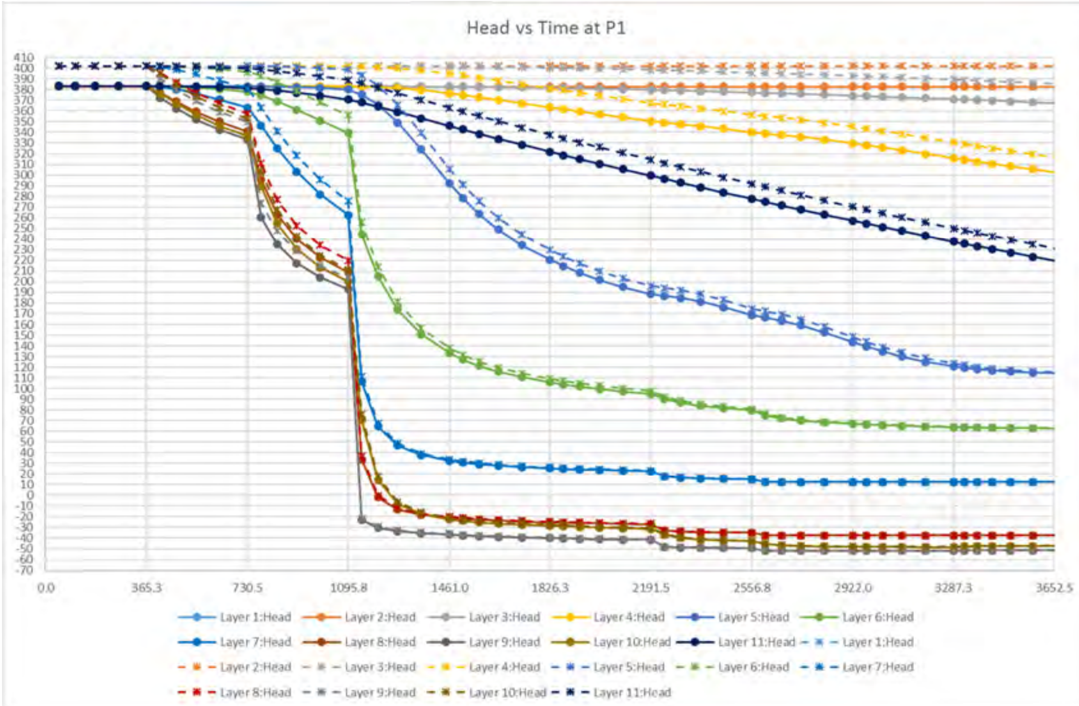


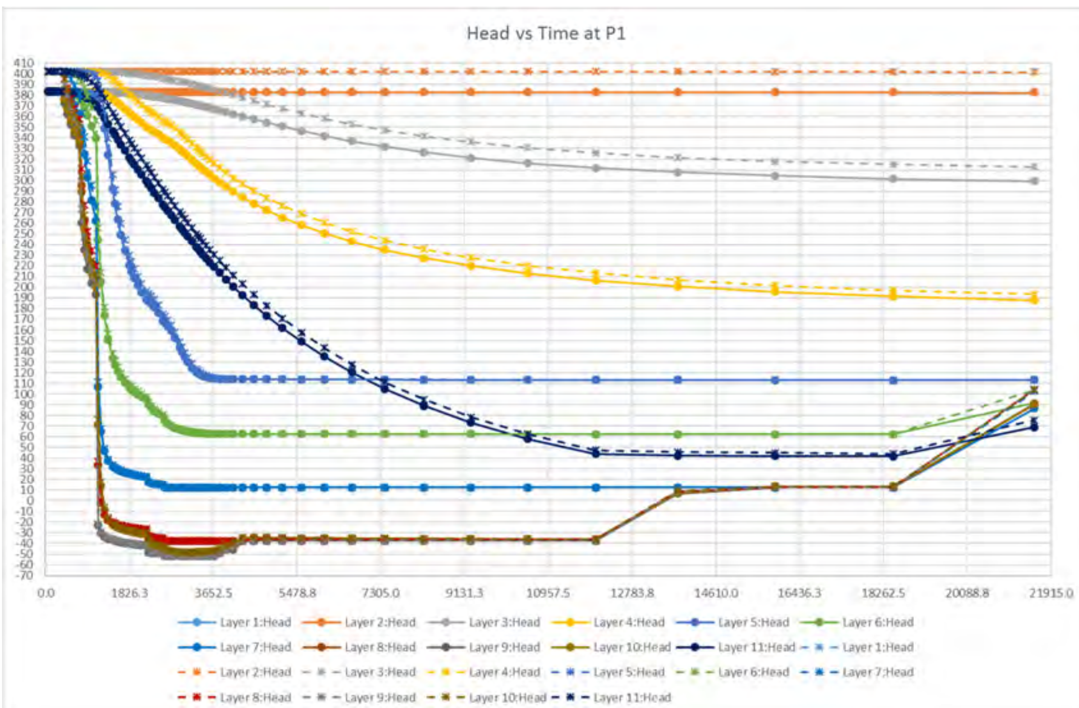
River flux


Impact (kL/Day) vs Time
-1200
-1000
-800
-600
-400
-200
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_XMD
SURFACT


Impact (kL/Day) vs Time
-1200
-1000
-800
-600
-400
-200
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_XMD
SURFACT

Hydrographs





MS_C2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9

CUMULAT	VOLUMES	L**3												
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			3576995	397.4438	1.088	0.316							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210								
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.42E+08	15814.76	43.298	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			2539209	282.1343	0.772								
CONSTAN	HEAD	=		70384448	7820.494	21.411								
WELLS	=			0	0	0.000								
DRAINS	=			2488277	276.4752	0.757								
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		66893304	7432.589	20.349								
TOTAL	OUT	=		1.42E+08	15811.69	43.290	42.518							
IN	-	OUT	=	27596.5	3.066278	0.008	0.307							
PERCENT	DISCREPA	=	0.02											

USG_C2

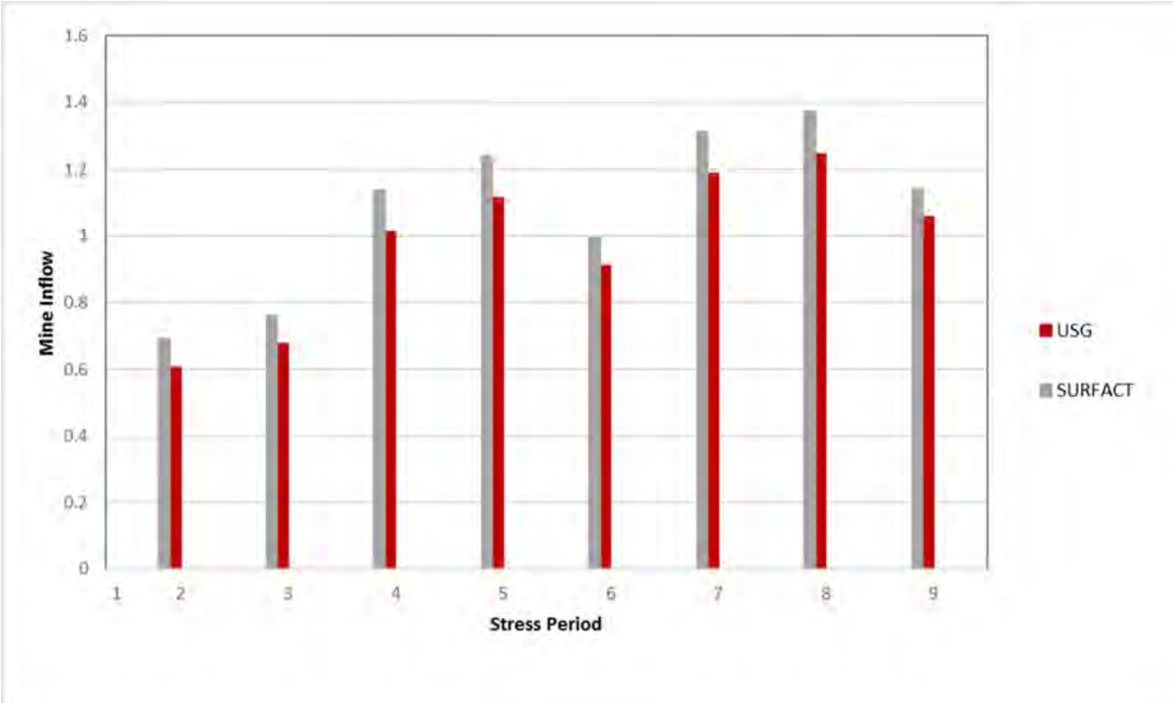
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME	STEP	5	IN	STRESS	PERIOD	9

CUMULAT	VOLUMES	L**3						DIFF(C6usg&C6ms)						
------------------														
				m3/9yrs	ML/a	ML/day								
IN:														
---							LOSS							
STORAGE	=			2107584	234.176	0.641	0.623							
CONSTAN	HEAD	=		0	0	0.000								
WELLS	=			0	0	0.000								
DRAINS	=			0	0	0.000								
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%						
RIVER	LEAKAGE	=		0	0	0.000								
TOTAL	IN	=		1.41E+08	15651.49	42.851	42.210							
OUT:	OUT:													
----	----													
STORAGE	=			59943.88	6.660431	0.018								
CONSTAN	HEAD	=		32723199	3635.911	9.955		-115.090%						
WELLS	=			0	0	0.000								
DRAINS	=			2047479	227.4977	0.623		-21.529%						
RECHARGI	=			0	0	0.000								
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.256		36.912%						
TOTAL	OUT	=		1.41E+08	15651.39	42.851	42.833	-1.024%						
IN	-	OUT	=	918.1989	0.102022	0.000	0.623							
PERCENT	DISCREPA	=	0											

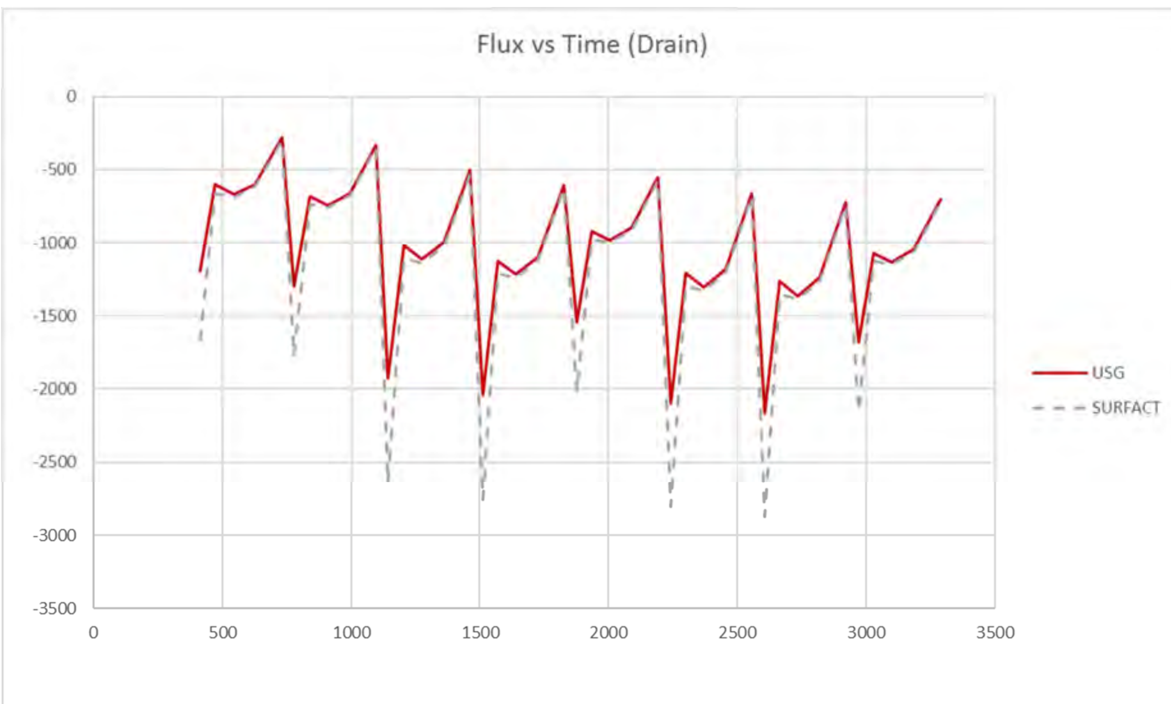
APPENDIX B2

LONGWALL: MS_PSEUDO AND USG_PSEUDO

Mine inflow

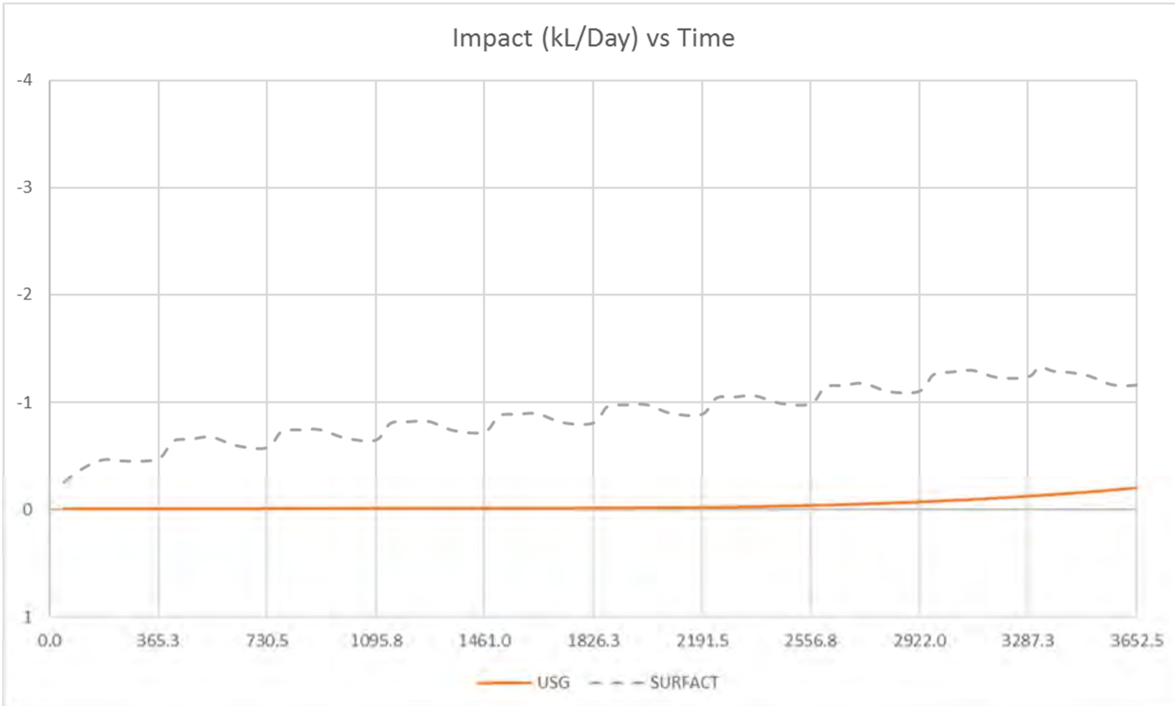


1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Mine Inflow
1
2
3
4
5
6
7
8
9
Stress Period
USG
SURFACT

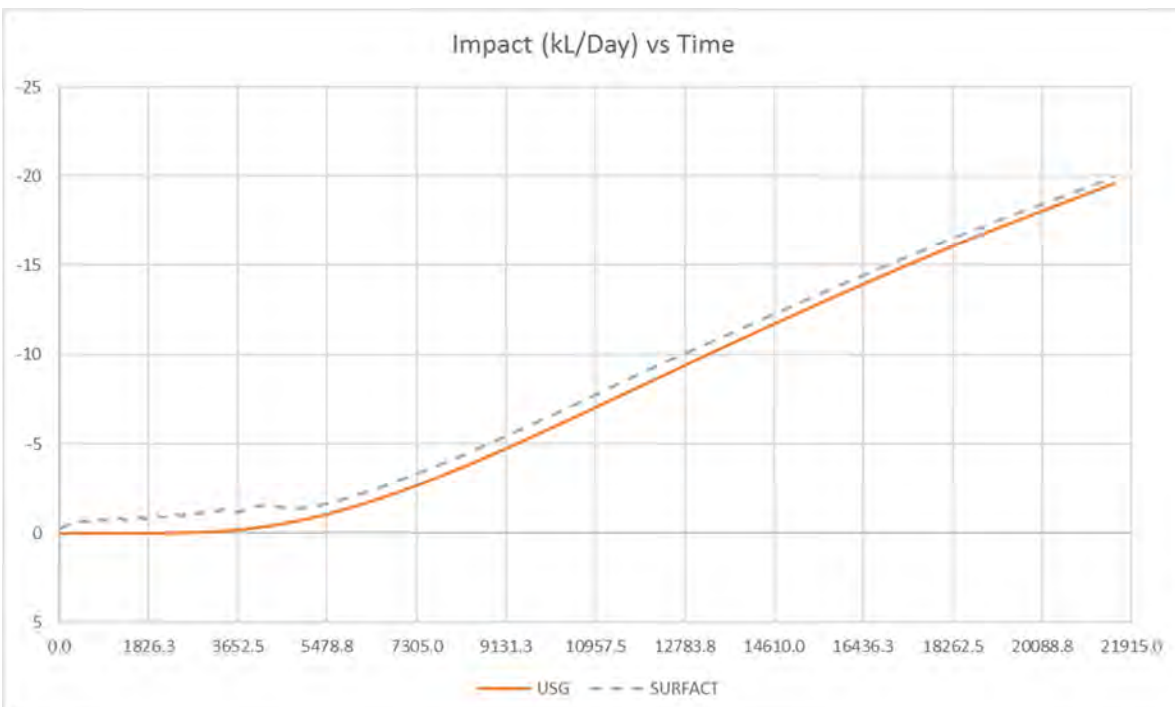


Flux vs Time (Drain)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
0
500
1000
1500
2000
2500
3000
3500
USG
SURFACT

River flux

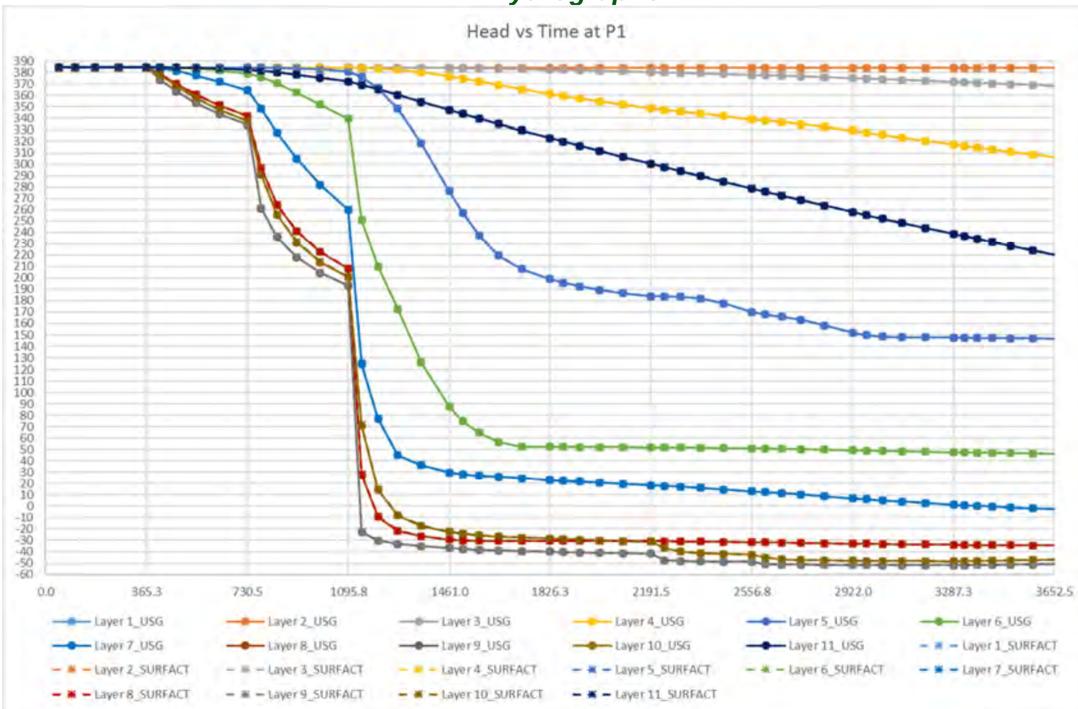


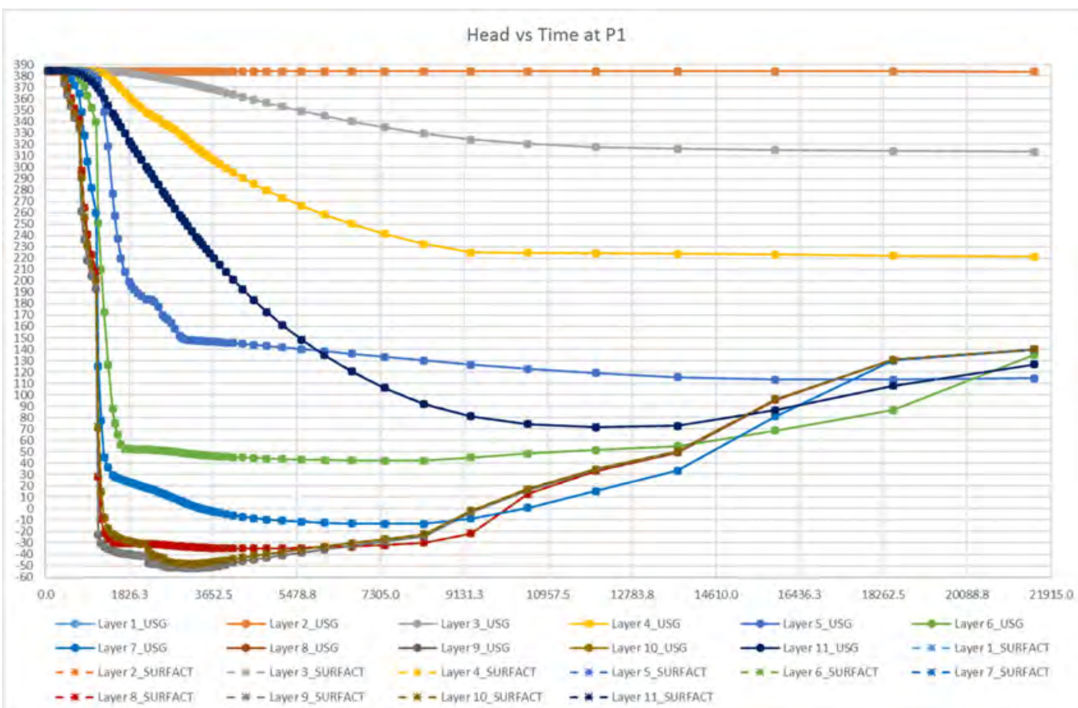
Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-25
-20
-15
-10
-5
0
5
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

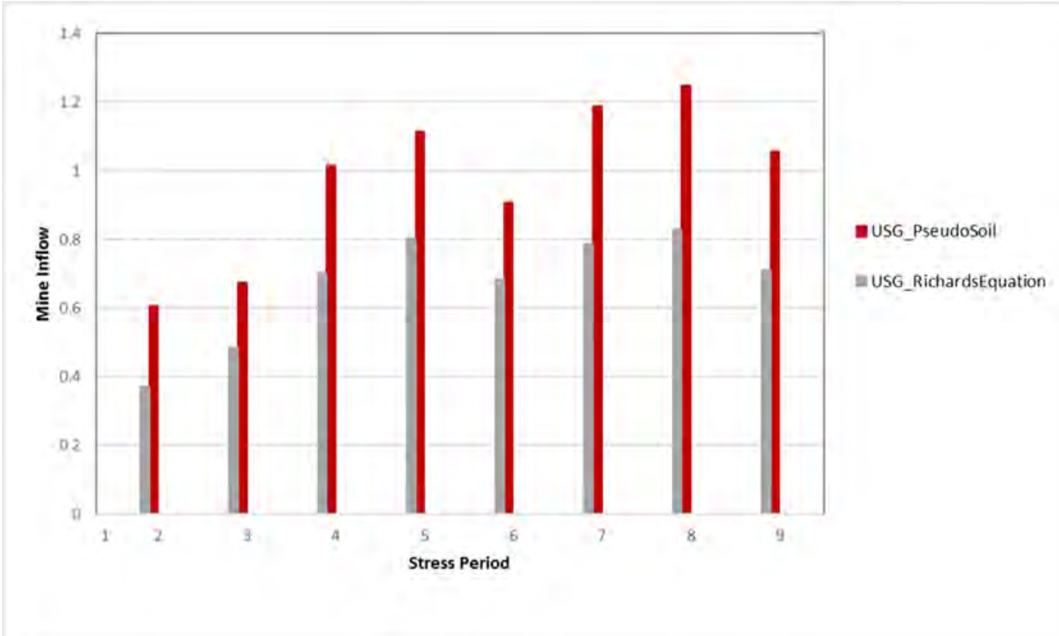
USG | SURFACT

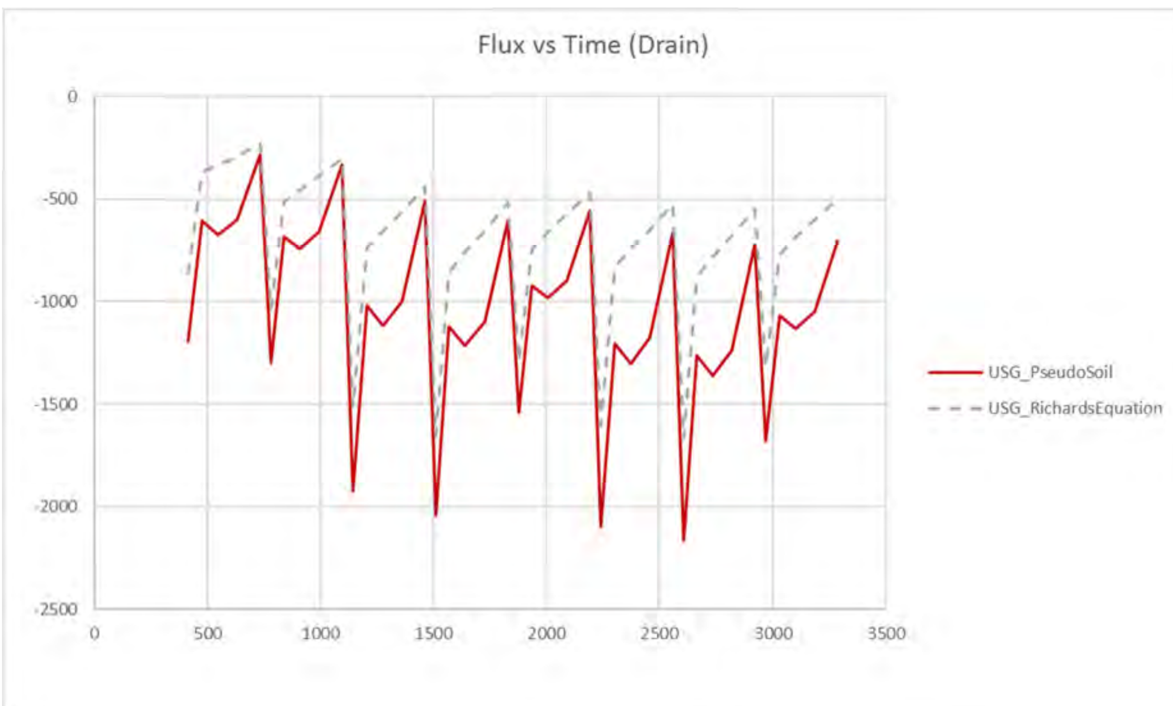
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9	VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--									--							
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)	CUMULAT	VOLUMES	L**3					
------------	-----------------------								------------------							
				m3/9yrs	ML/a	ML/day							m3/9yrs	ML/a	ML/day	
IN:	IN:								IN:							
---	---						LOSS		---							LOSS
STORAGE	=			2881843	320.2048	0.877	0.868		STORAGE	=			3402546	378.0606	1.035	0.970
CONSTAN	HEAD	=		0	0	0.000			CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000			WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000			DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		0	0	0.000			RECHARGI	=			1.39E+08	15417.32	42.210	
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%	RIVER	LEAKAGE	=		0	0	0.000	
TOTAL	IN	=		1.42E+08	15737.52	43.087	42.210		TOTAL	IN	=		1.42E+08	15795.38	43.245	42.210
OUT:	OUT:								OUT:	OUT:						
----	----								----	----						
STORAGE	=			29209.97	3.245552	0.009			STORAGE	=			213476.7	23.71963	0.065	
CONSTAN	HEAD	=		42436786	4715.198	12.910		0.019%	CONSTAN	HEAD	=		42428800	4714.311	12.907	
WELLS	=			0	0	0.000			WELLS	=			0	0	0.000	
DRAINS	=			2850247	316.6941	0.867		-10.801%	DRAINS	=			3158090	350.8989	0.961	
RIVER	LEAKAGE	=		96318489	10702.05	29.301		-0.004%	RECHARGI	=			0	0	0.000	
RECHARGI	=			0	0	0.000			RIVER	LEAKAGE	=		96322000	10702.44	29.302	
TOTAL	OUT	=		1.42E+08	15737.19	43.086	43.077	-0.344%	TOTAL	OUT	=		1.42E+08	15791.37	43.234	43.169
IN	-	OUT	=	2968.295	0.329811	0.001	0.867		IN	-	OUT	=	36018.83	4.002092	0.011	0.959
PERCENT	DISCREPA	=		0					PERCENT	DISCREPA	=	0.03				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9									TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS									SECONDS MINUTES HOURS DAYS YEARS							
--									--							
TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865									TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497							
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000									STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000							
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000									TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000							

APPENDIX B3

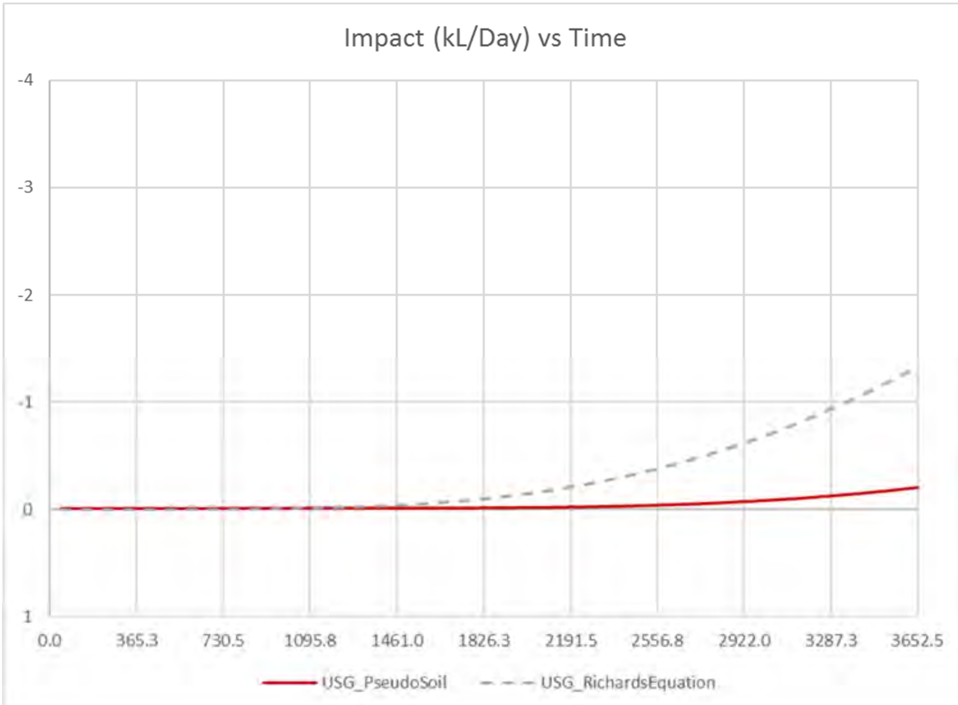
LONGWALL: USG_VADOSE AND USG_PSEUDO

Mine inflow

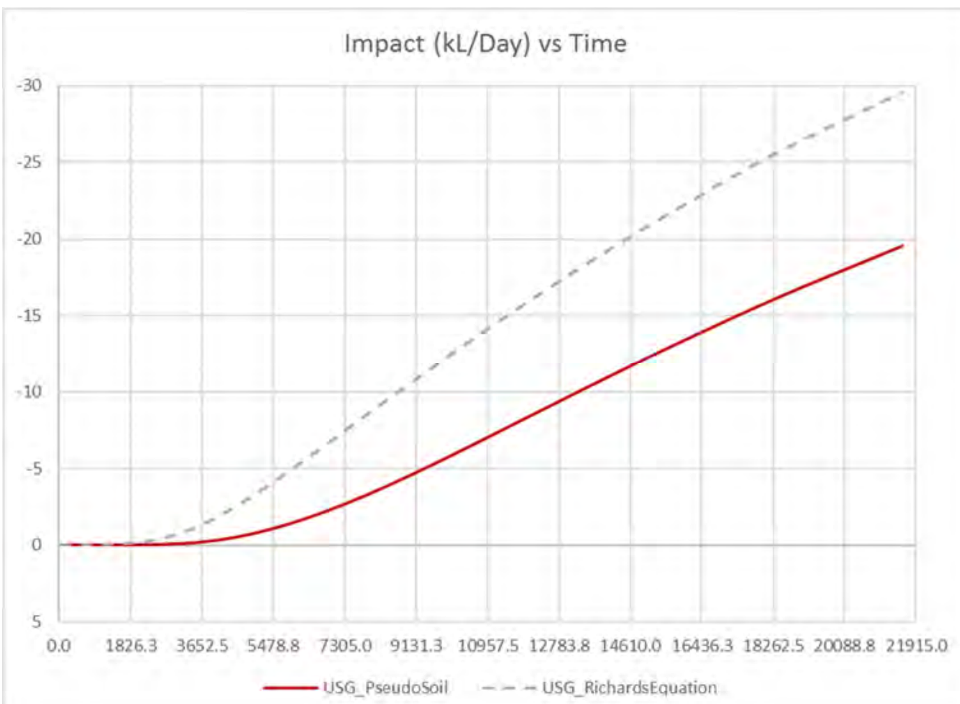

Mine Inflow
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
Stress Period
USG_PseudoSoil
USG_RichardsEquation


Flux vs Time (Drain)
0
-500
-1000
-1500
-2000
-2500
0
500
1000
1500
2000
2500
3000
3500
USG_PseudoSoil
USG_RichardsEquation

River flux

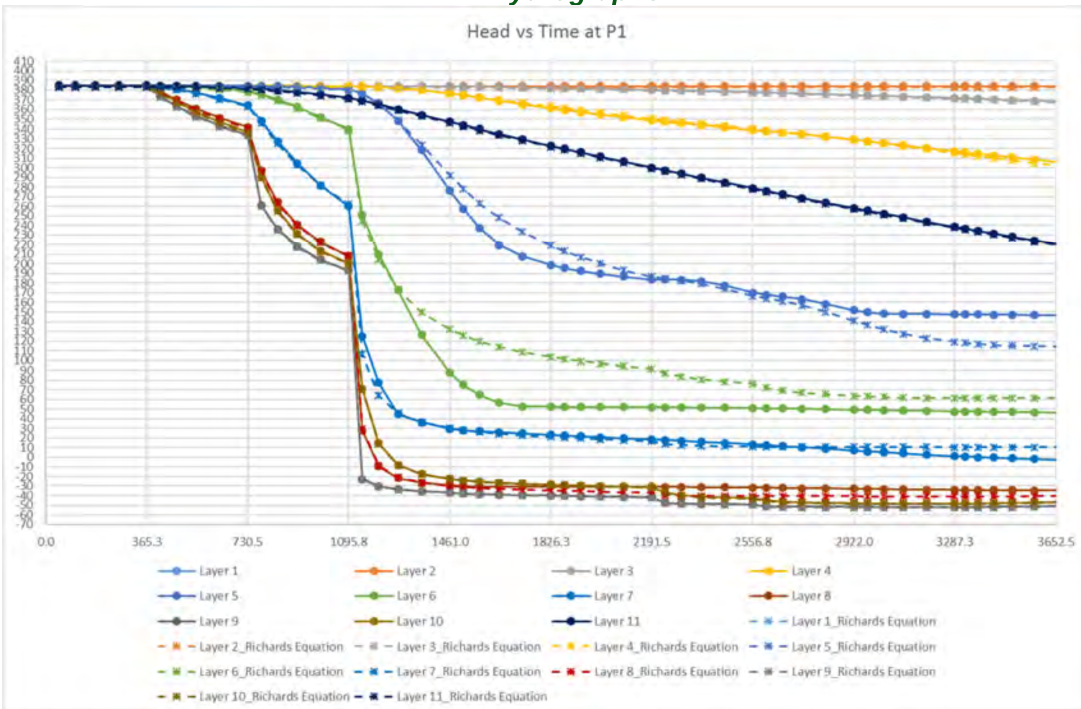


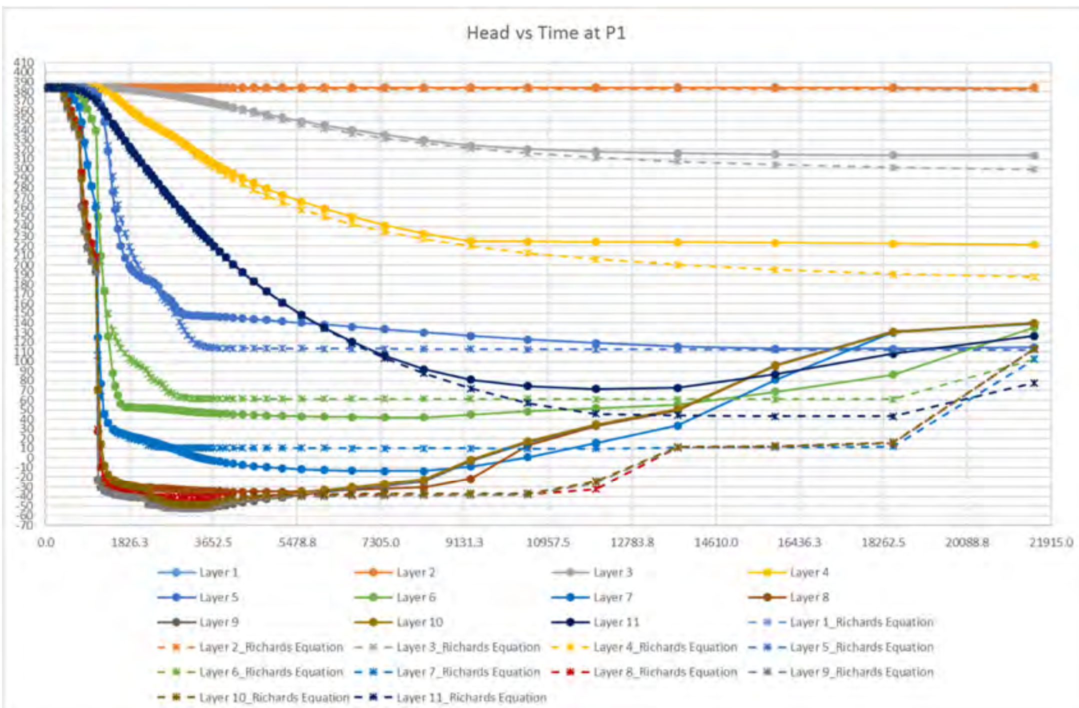
Impact (kL/Day) vs Time
-4
-3
-2
-1
0
1
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_PseudoSoil
USG_RichardsEquation

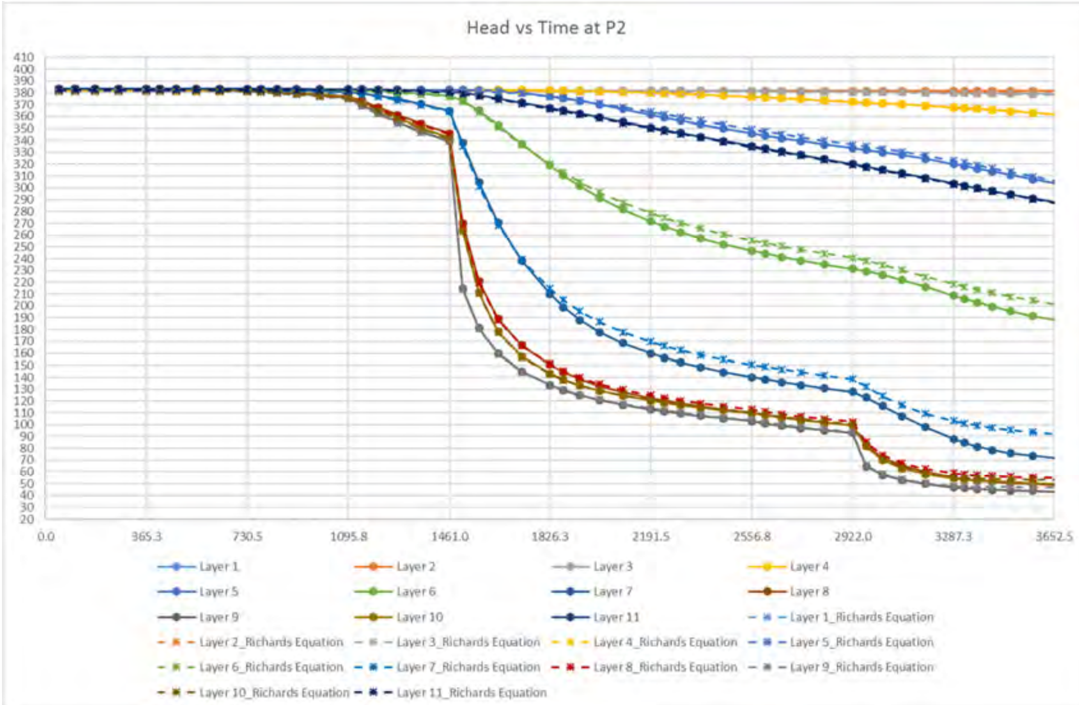


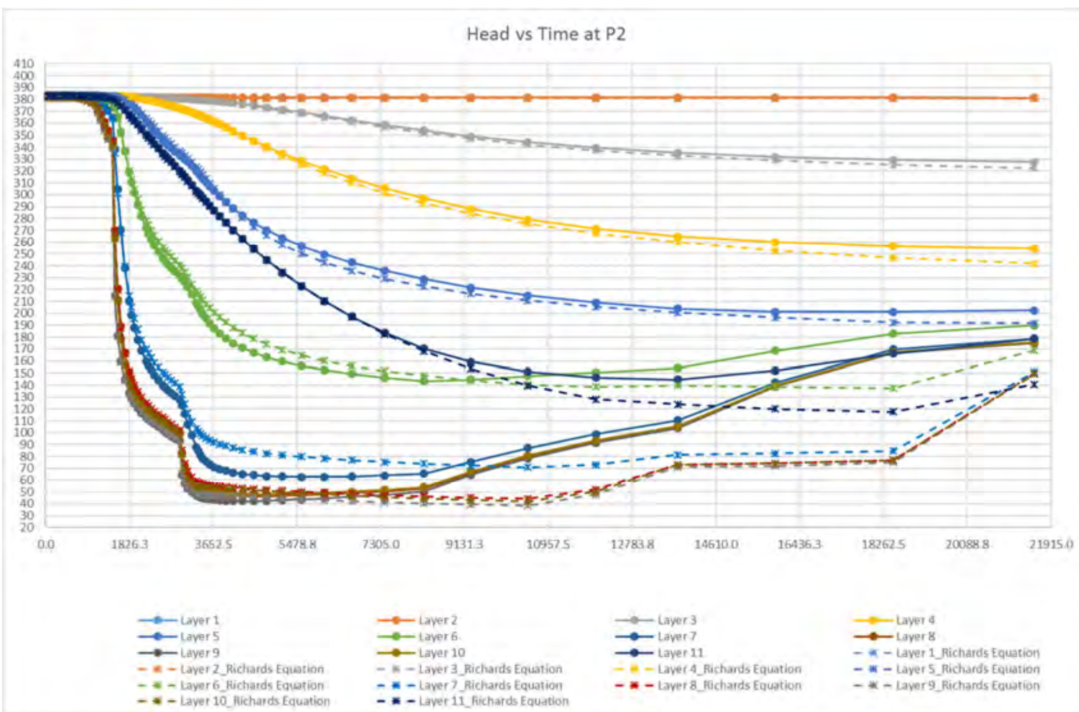
Impact (kL/Day) vs Time
-30
-25
-20
-15
-10
-5
0
5
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_PseudoSoil
USG_RichardsEquation

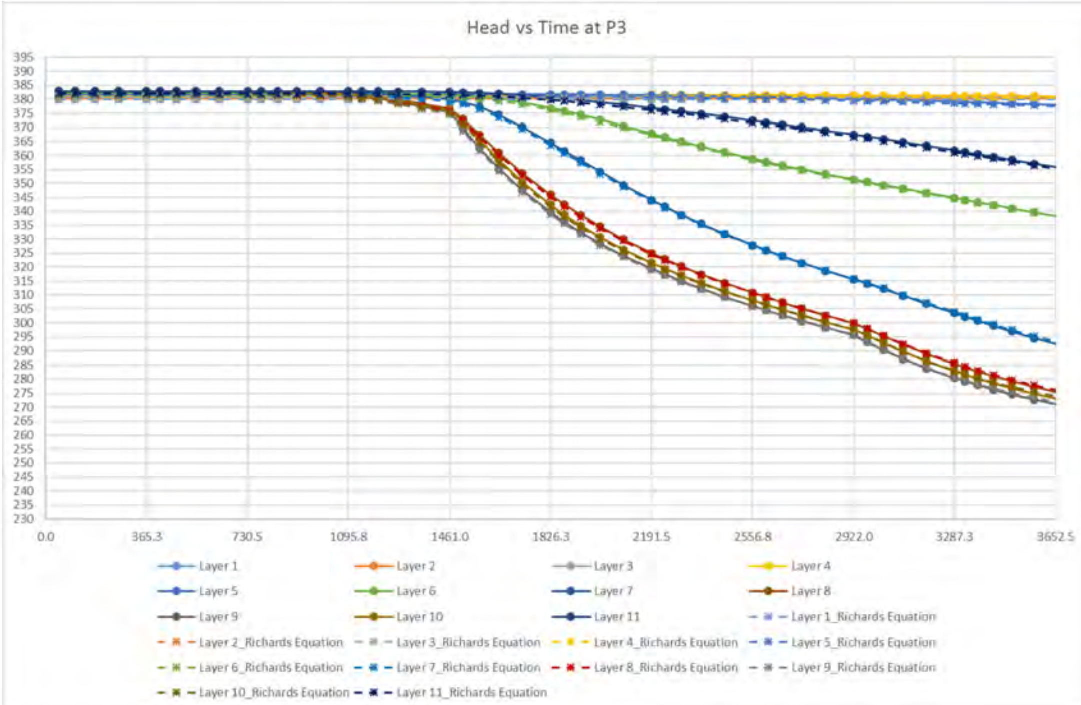
Hydrographs



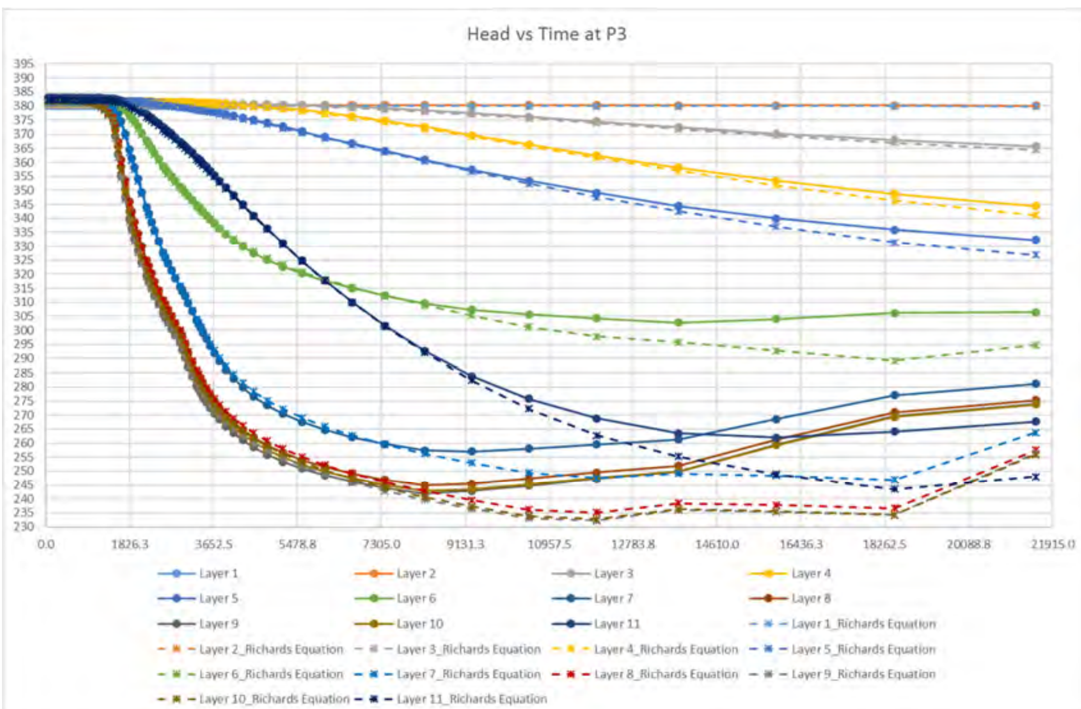



Head vs Time at P2
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation

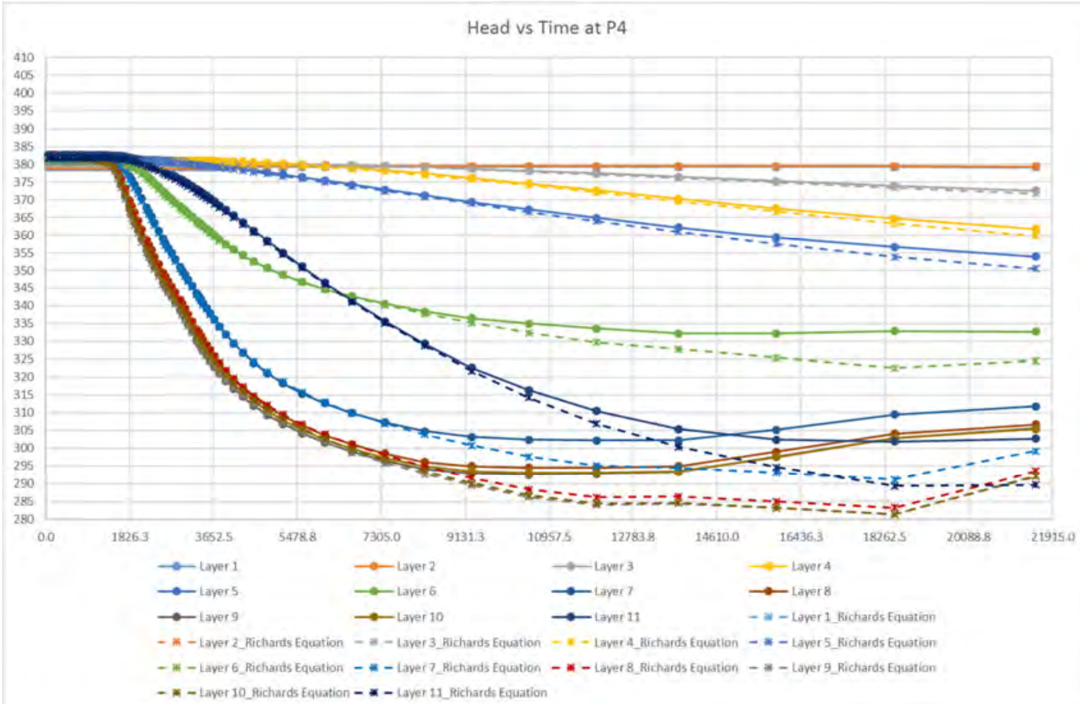

Head vs Time at P2
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation

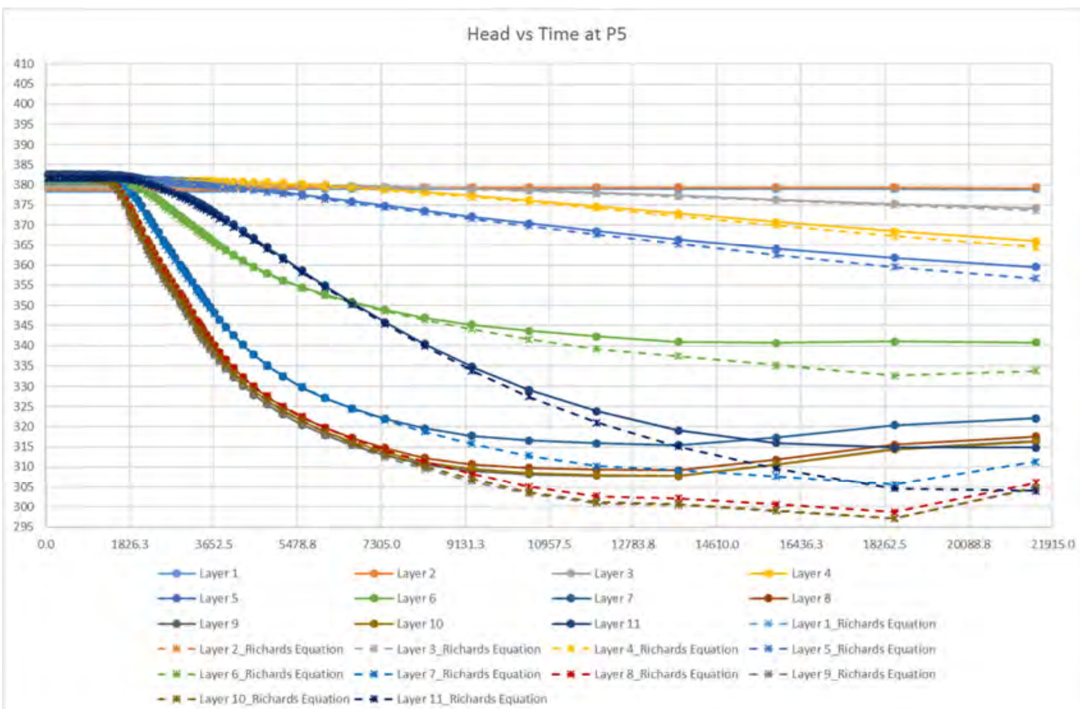


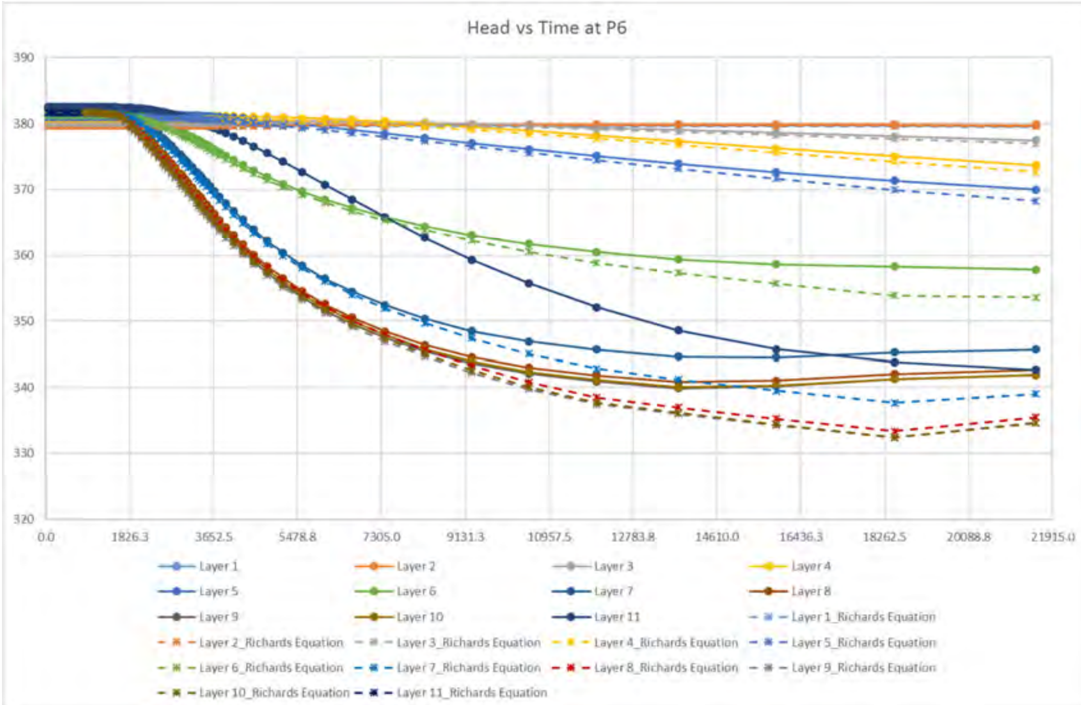
Head vs Time at P3
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
230
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation

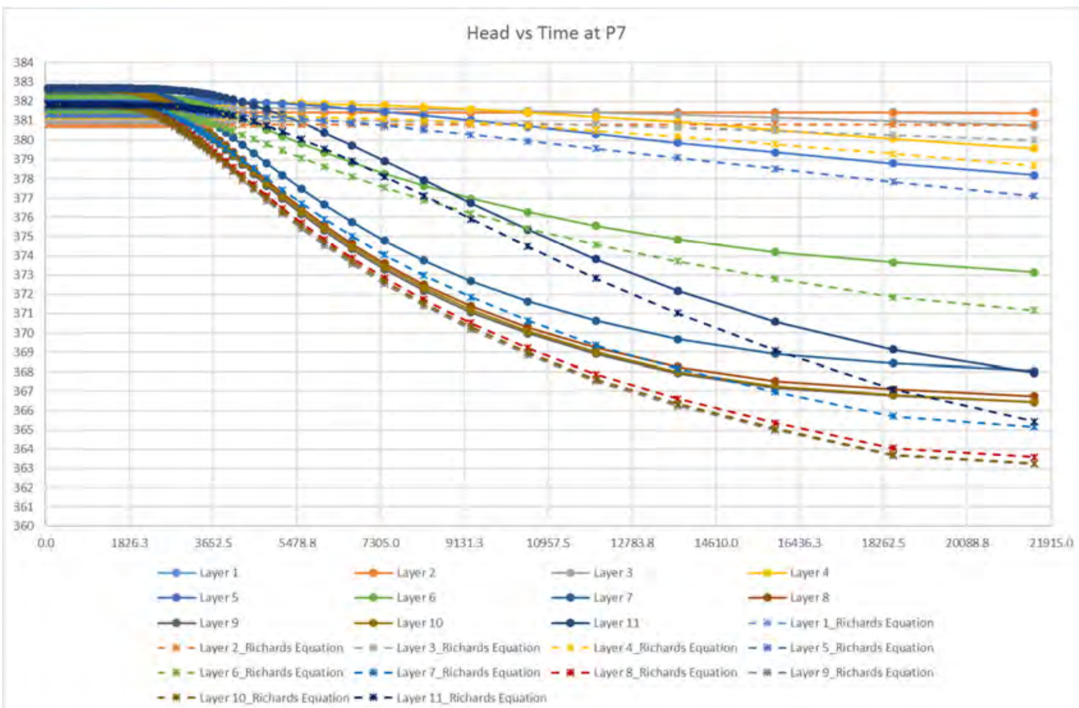


Head vs Time at P3
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
235
230
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation


Head vs Time at P4
410
405
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
295
290
285
280
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation


Head vs Time at P5
410
405
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
295
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation


Head vs Time at P6
390
380
370
360
350
340
330
320
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation


Head vs Time at P7
384
383
382
381
380
379
378
377
376
375
374
373
372
371
370
369
368
367
366
365
364
363
362
361
360
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_Richards Equation
Layer 2_Richards Equation
Layer 3_Richards Equation
Layer 4_Richards Equation
Layer 5_Richards Equation
Layer 6_Richards Equation
Layer 7_Richards Equation
Layer 8_Richards Equation
Layer 9_Richards Equation
Layer 10_Richards Equation
Layer 11_Richards Equation

Water Balance

USG_Pseudo-Soil

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9

CUMULAT	VOLUMES	L**3						DIFF(USG_Pseudo Soil&USG_Richards Equation)
-----------	----------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			2881843	320.2048	0.877	0.868	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.42E+08	15737.52	43.087	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			29209.97	3.245552	0.009		
CONSTAN	HEAD	=		42436786	4715.198	12.910		22.890%
WELLS	=			0	0	0.000		
DRAINS	=			2850247	316.6941	0.867		31.153%
RIVER	LEAKAGE	=		96318489	10702.05	29.301		-10.085%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.42E+08	15737.19	43.086	43.077	0.504%
IN	-	OUT	=	2968.295	0.329811	0.001	0.867	
PERCENT	DISCREPA	=		0				

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000

USG_Vadose

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF

CUMULAT	VOLUMES	L**3					
-----------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			2166910	240.7677	0.659	0.597
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		0	0	0.000	
TOTAL	IN	=		1.41E+08	15658.09	42.870	42.210
OUT:	OUT:						
----	----						
STORAGE	=			202984.7	22.55386	0.062	
CONSTAN	HEAD	=		32723199	3635.911	9.955	
WELLS	=			0	0	0.000	
DRAINS	=			1962306	218.034	0.597	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		1.06E+08	11781.32	32.256	
TOTAL	OUT	=		1.41E+08	15657.82	42.869	42.807
IN	-	OUT	=	2382.32	0.264702	0.001	0.597
PERCENT	DISCREPA	=	0				

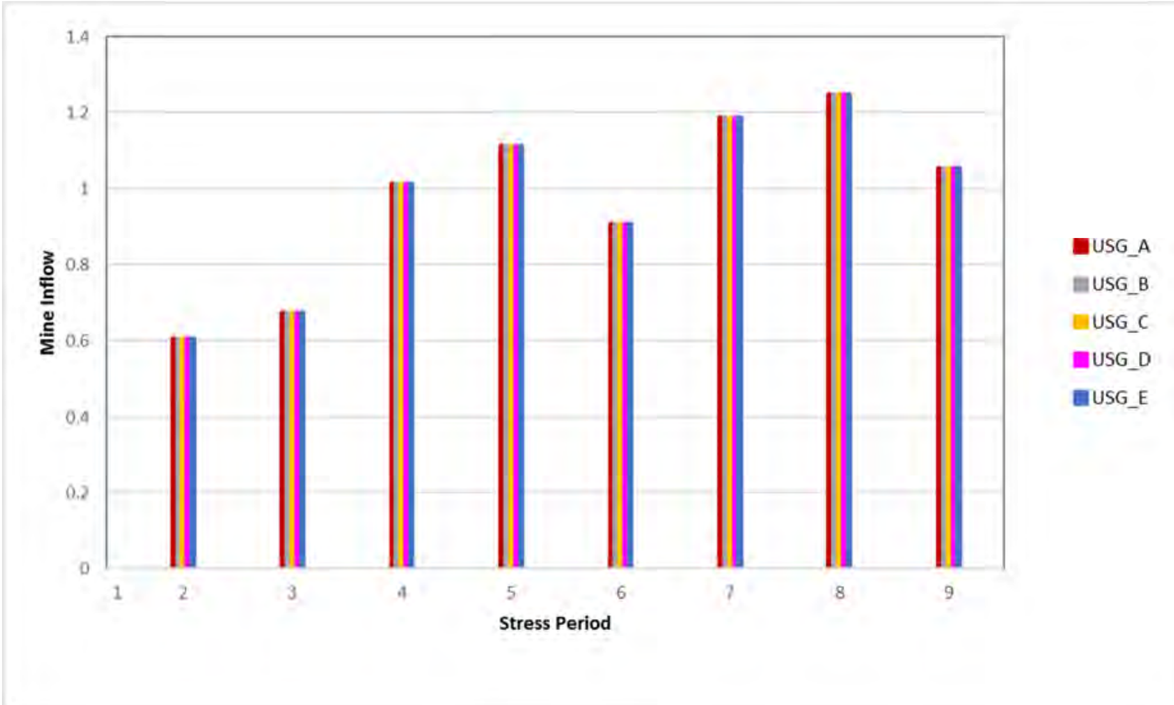
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

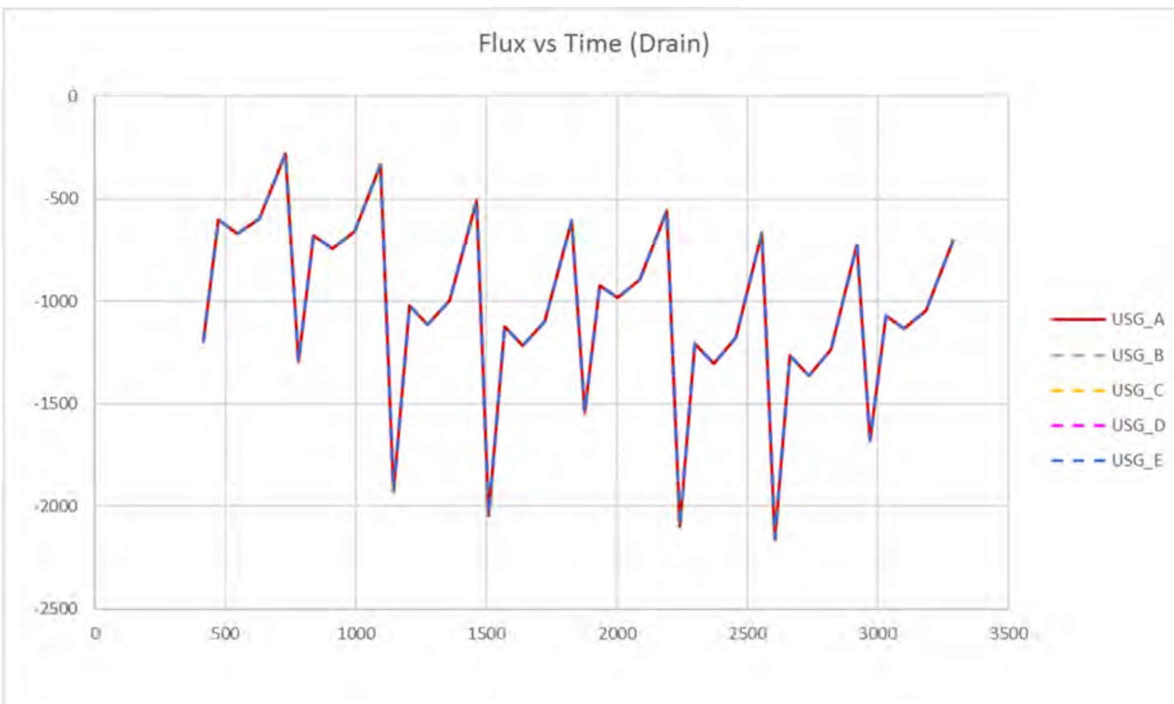
	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	8793517.	146558.6	2442.644	101.7768	0.2786497
STRESS PERIOD TIME	3.1557600E+07	525960.0	8766.000	365.2500	1.000000
TOTAL TIME	2.8401840E+08	4733640.	78894.00	3287.250	9.000000

APPENDIX B4

LONGWALL: USG_PSEUDO

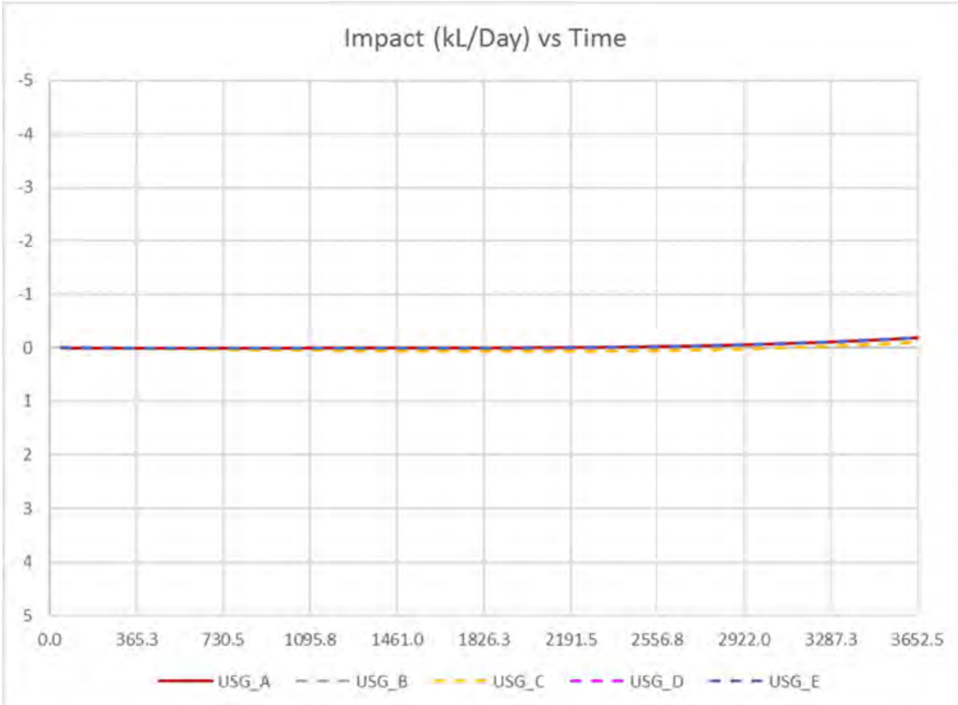
Mine inflow



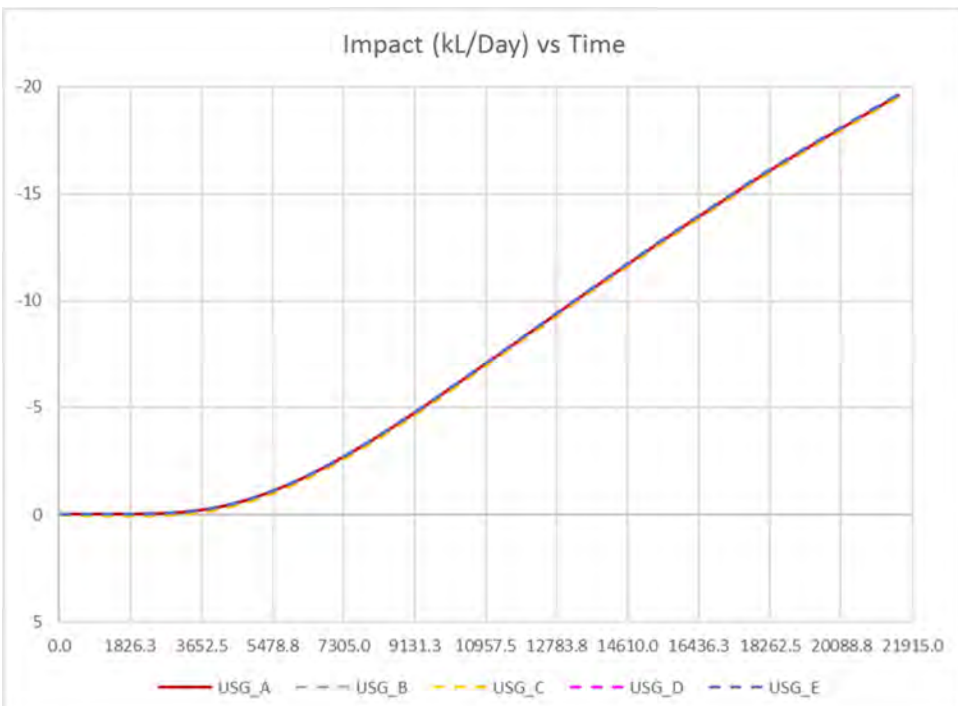


Index: A = VC1 B = VC2 C = VC3 D = VC4 E = VC5

River flux

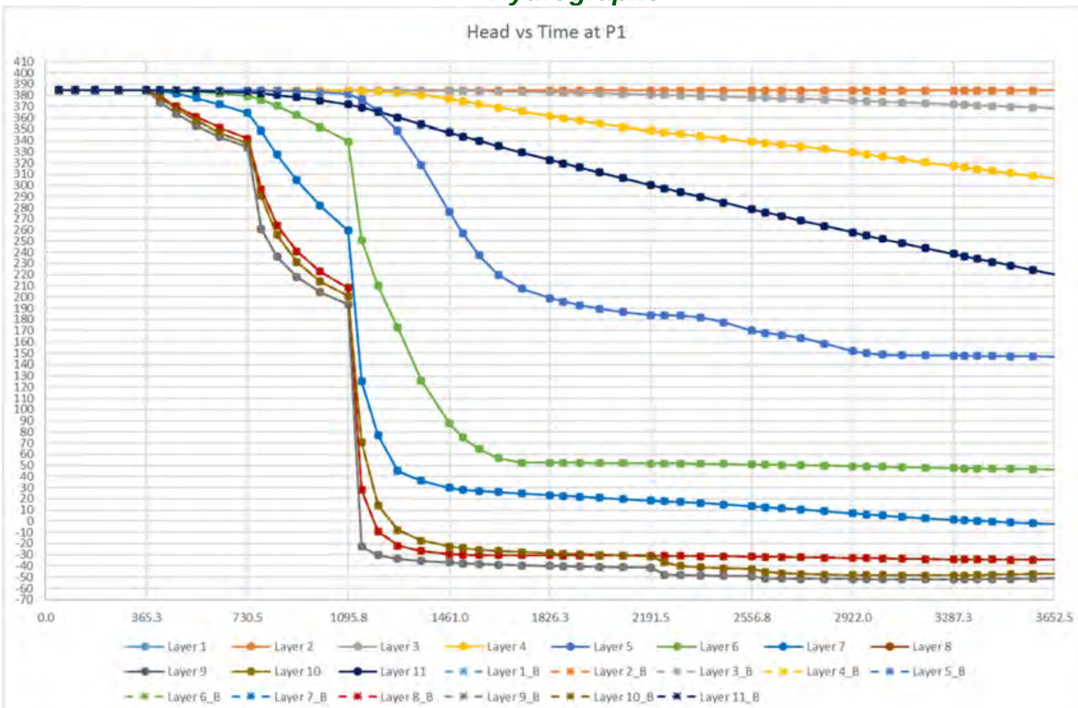


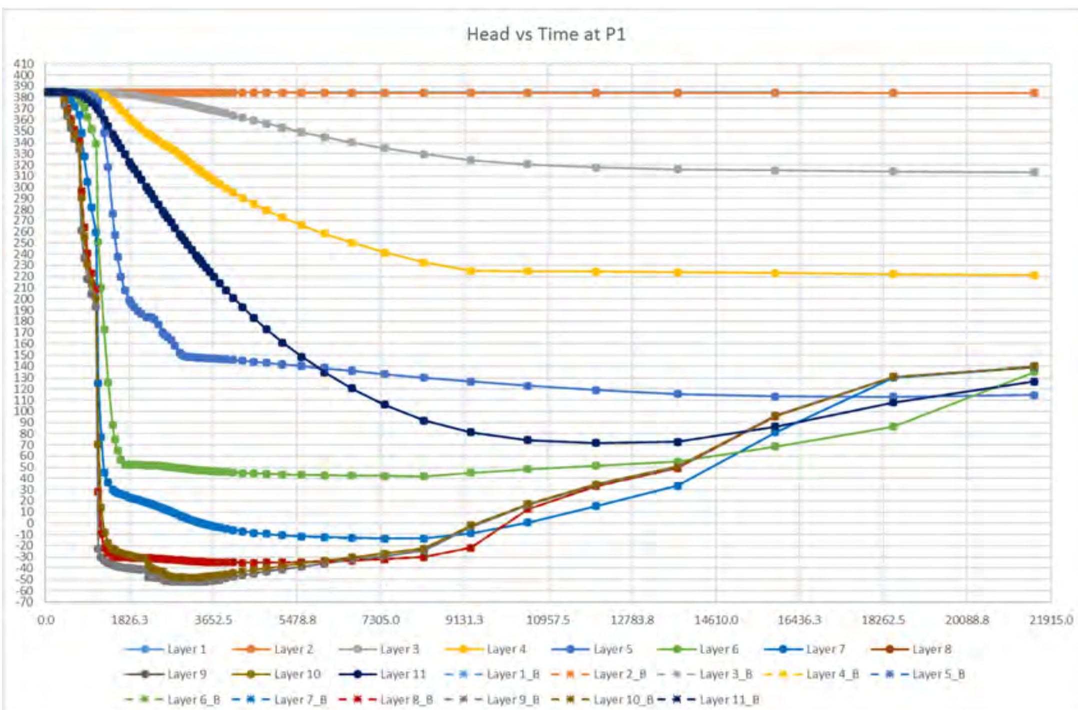
Impact (kL/Day) vs Time
-5
-4
-3
-2
-1
0
1
2
3
4
5
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_A
USG_B
USG_C
USG_D
USG_E

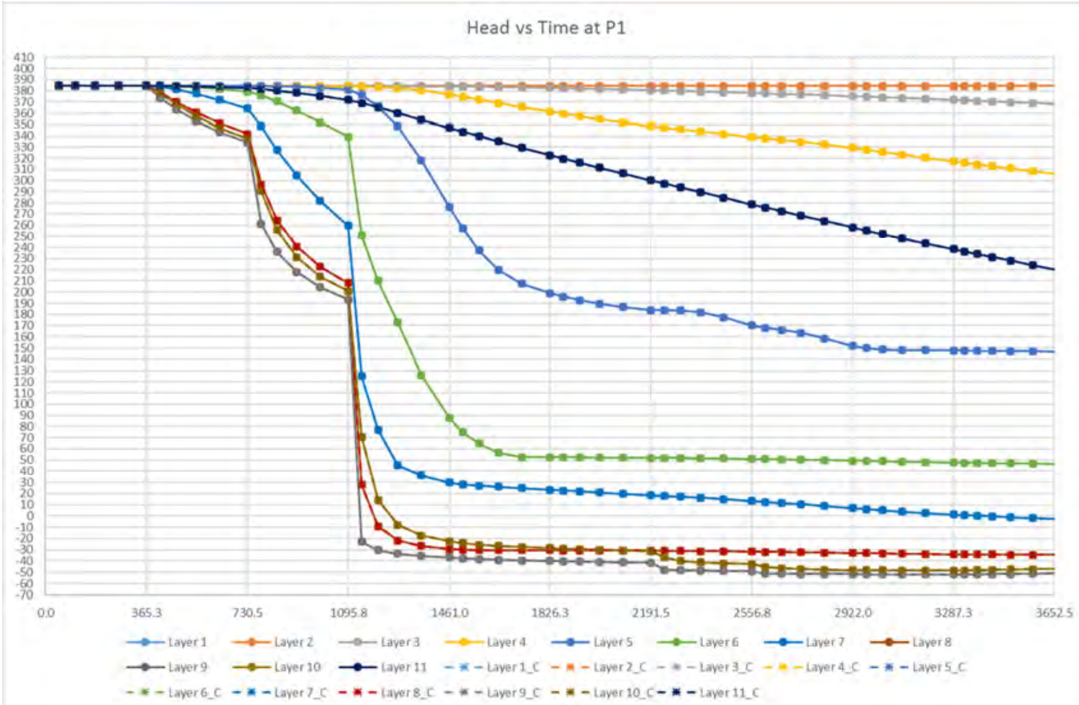


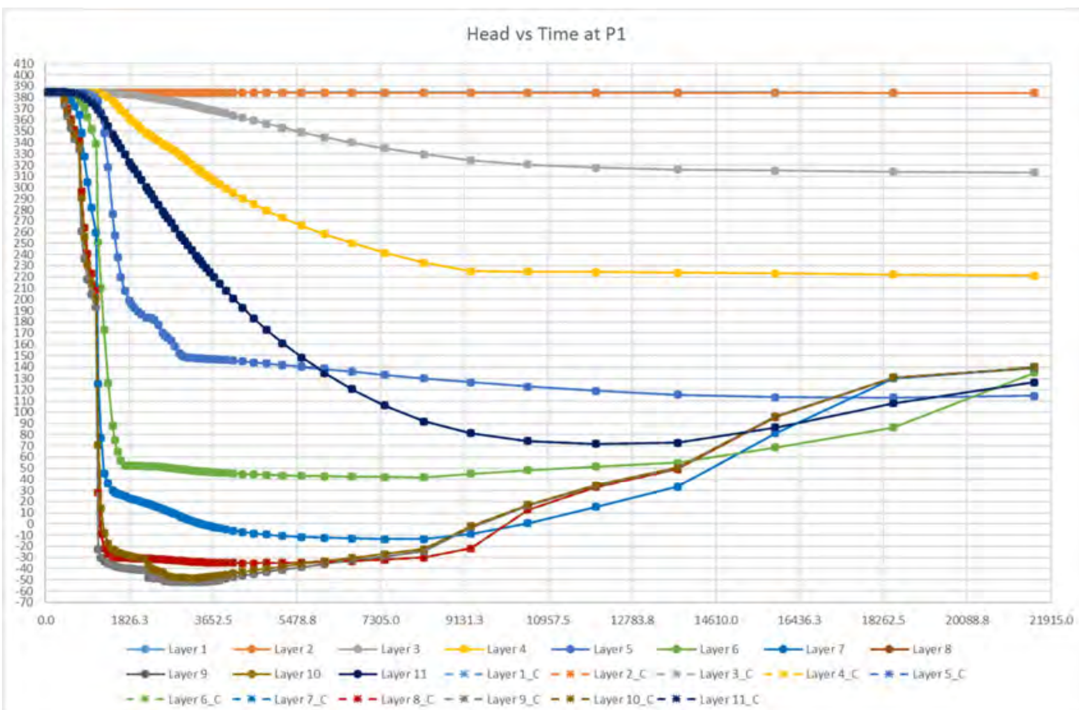
Impact (kL/Day) vs Time
-20
-15
-10
-5
0
5
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_A
USG_B
USG_C
USG_D
USG_E

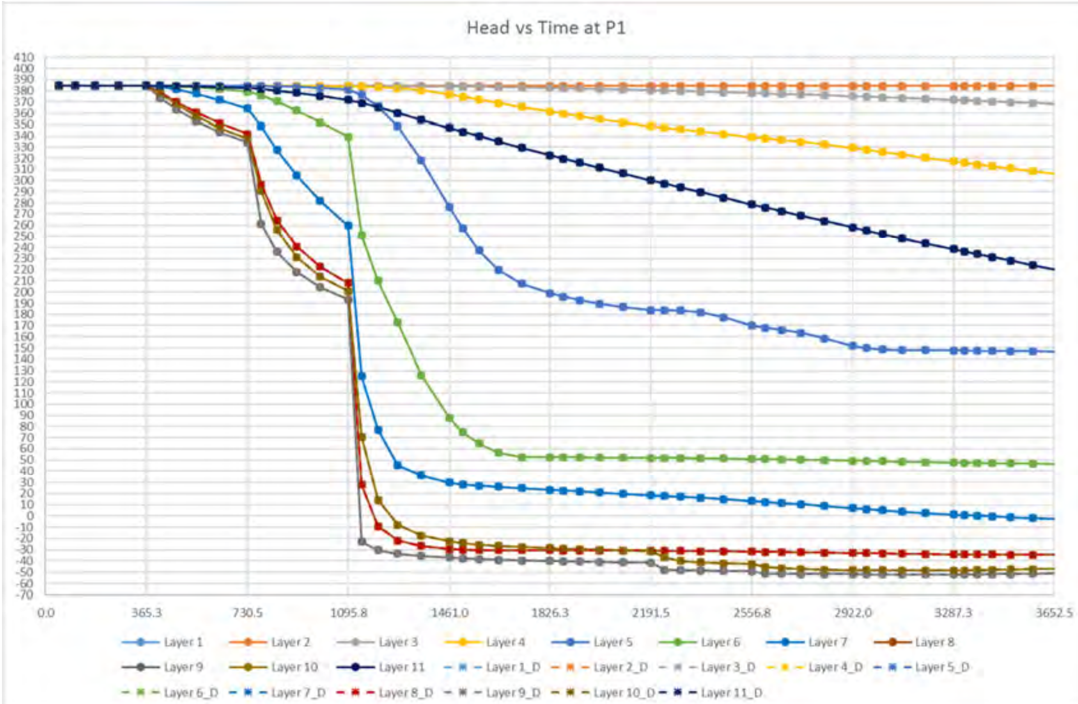
Hydrographs

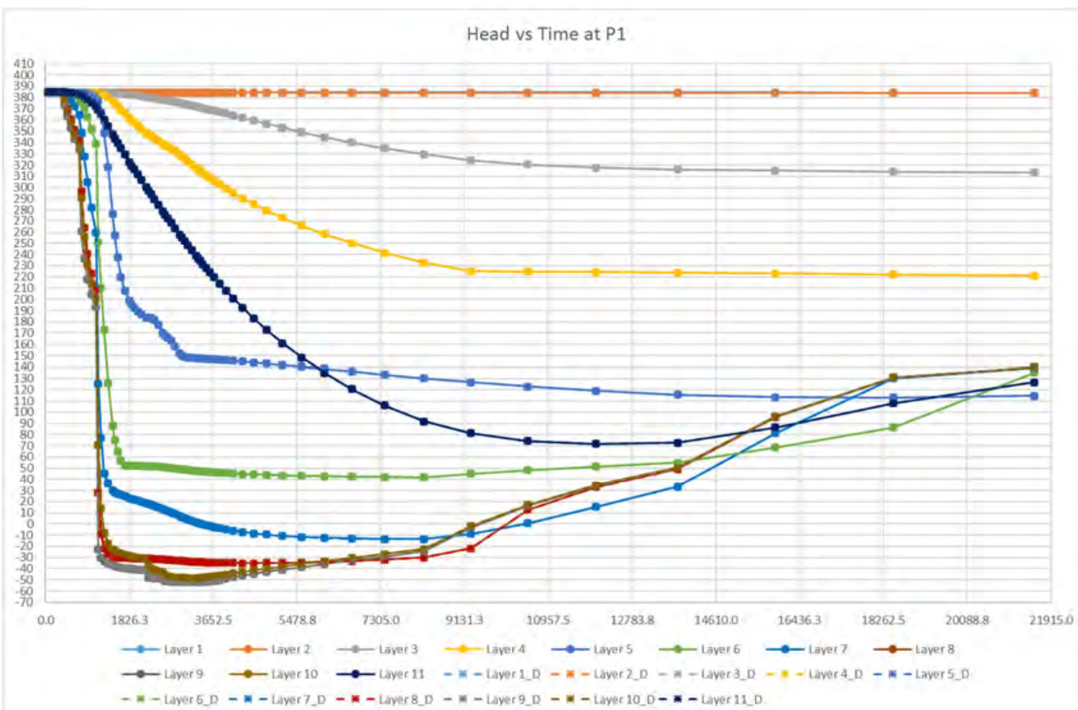


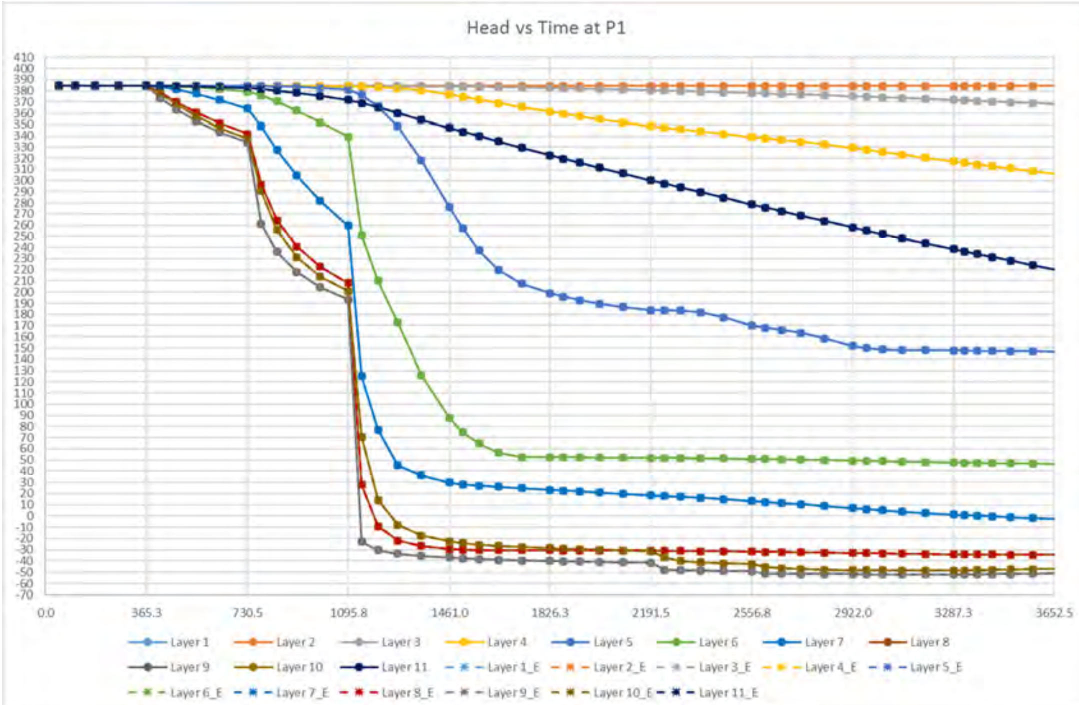


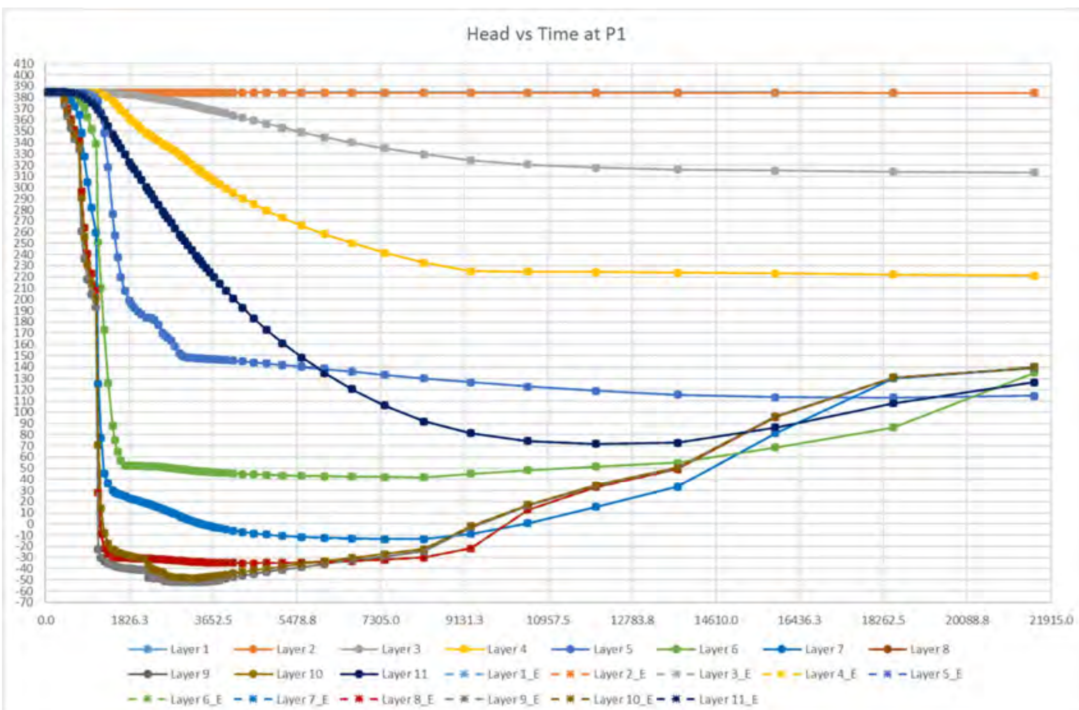

Head vs Time at P1
410 400 390 380 370 360 350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70
0.0 365.3 730.5 1095.8 1461.0 1826.3 2191.5 2556.8 2922.0 3287.3 3652.5
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_C
Layer 2_C
Layer 3_C
Layer 4_C
Layer 5_C
Layer 6_C
Layer 7_C
Layer 8_C
Layer 9_C
Layer 10_C
Layer 11_C


Head vs Time at P1
410 400 390 380 370 360 350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70
0.0 1826.3 3652.5 5478.8 7305.0 9131.3 10957.5 12783.8 14610.0 16436.3 18262.5 20088.8 21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_C
Layer 2_C
Layer 3_C
Layer 4_C
Layer 5_C
Layer 6_C
Layer 7_C
Layer 8_C
Layer 9_C
Layer 10_C
Layer 11_C


Head vs Time at P1
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_D
Layer 2_D
Layer 3_D
Layer 4_D
Layer 5_D
Layer 6_D
Layer 7_D
Layer 8_D
Layer 9_D
Layer 10_D
Layer 11_D


Head vs Time at P1
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_D
Layer 2_D
Layer 3_D
Layer 4_D
Layer 5_D
Layer 6_D
Layer 7_D
Layer 8_D
Layer 9_D
Layer 10_D
Layer 11_D


Head vs Time at P1
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_E
Layer 2_E
Layer 3_E
Layer 4_E
Layer 5_E
Layer 6_E
Layer 7_E
Layer 8_E
Layer 9_E
Layer 10_E
Layer 11_E


Head vs Time at P1
Layer 1
Layer 2
Layer 3
Layer 4
Layer 5
Layer 6
Layer 7
Layer 8
Layer 9
Layer 10
Layer 11
Layer 1_E
Layer 2_E
Layer 3_E
Layer 4_E
Layer 5_E
Layer 6_E
Layer 7_E
Layer 8_E
Layer 9_E
Layer 10_E
Layer 11_E

Water Balance

USG_VC1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9			
--											
CUMULAT	VOLUMES	L**3						DIFF(A&B)	DIFF(A&C)	DIFF(A&D)	DIFF(A&E)
-----------	----------------------										
				m3/9yrs	ML/a	ML/day					
IN:	IN:										
---	---						LOSS				
STORAGE	=			2881843	320.2048	0.877	0.868				
CONSTAN	HEAD	=		0	0	0.000					
WELLS	=			0	0	0.000					
DRAINS	=			0	0	0.000					
RIVER	LEAKAGE	=		0	0	0.000					
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%	0.000%	0.000%	0.000%
TOTAL	IN	=		1.42E+08	15737.52	43.087	42.210				
OUT:	OUT:										
----	----										
STORAGE	=			29209.97	3.245552	0.009					
CONSTAN	HEAD	=		42436786	4715.198	12.910		0.000%	0.000%	-0.001%	-0.001%
WELLS	=			0	0	0.000					
DRAINS	=			2850247	316.6941	0.867		0.002%	0.000%	0.002%	0.002%
RIVER	LEAKAGE	=		96318489	10702.05	29.301		0.000%	0.000%	0.000%	0.000%
RECHARGI	=			0	0	0.000					
TOTAL	OUT	=		1.42E+08	15737.19	43.086	43.077	0.000%	0.000%	0.000%	0.000%
IN	-	OUT	=	2968.295	0.329811	0.001	0.867				
PERCENT	DISCREPA	=		0							
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9											
SECONDS MINUTES HOURS DAYS YEARS											

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865											
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000											
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000											

USG_VC2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	

CUMULAT	VOLUMES	L**3						
-----------------								
				m3/9yrs	ML/a	ML/day		
IN:								
---							LOSS	
STORAGE	=			2881759	320.1954	0.877	0.868	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		
RIVER	LEAKAGE	=		0	0	0.000		
TOTAL	IN	=		1.42E+08	15737.51	43.087	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			29414.12	3.268236	0.009		
CONSTAN	HEAD	=		42436713	4715.19	12.909		
WELLS	=			0	0	0.000		
DRAINS	=			2850201	316.689	0.867		
RECHARGI	=			0	0	0.000		
RIVER	LEAKAGE	=		96318312	10702.03	29.301		
TOTAL	OUT	=		1.42E+08	15737.18	43.086	43.077	
IN	-	OUT	=	2975.515	0.330613	0.001	0.867	
PERCENT	DISCREPA	=	0					
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9								
SECONDS MINUTES HOURS DAYS YEARS								

TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497								
STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000								
TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000								

USG_VC3

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	
--								
CUMULAT	VOLUMES	L**3						
-----------------								
				m3/9yrs	ML/a	ML/day		
IN:								
---							LOSS	
STORAGE	=			2881804	320.2005	0.877	0.868	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RECHARGE	=			1.39E+08	15417.32	42.210		
RIVER	LEAKAGE	=		0	0	0.000		
TOTAL	IN	=		1.42E+08	15737.52	43.087	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			29420.64	3.26896	0.009		
CONSTAN	HEAD	=		42436713	4715.19	12.909		
WELLS	=			0	0	0.000		
DRAINS	=			2850247	316.6941	0.867		
RECHARGE	=			0	0	0.000		
RIVER	LEAKAGE	=		96318312	10702.03	29.301		
TOTAL	OUT	=		1.42E+08	15737.19	43.086	43.077	
IN	-	OUT	=	2968.694	0.329855	0.001	0.867	
PERCENT	DISCREPA	=	0					

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497

STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000

TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000

USG_VC4

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	
--								
CUMULAT	VOLUMES	L**3						
-----------------								
				m3/9yrs	ML/a	ML/day		
IN:								
---							LOSS	
STORAGE	=			2881883	320.2092	0.877	0.868	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RECHARGE	=			1.39E+08	15417.32	42.210		
RIVER	LEAKAGE	=		0	0	0.000		
TOTAL	IN	=		1.42E+08	15737.53	43.087	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			28795.61	3.199512	0.009		
CONSTAN	HEAD	=		42437031	4715.226	12.910		
WELLS	=			0	0	0.000		
DRAINS	=			2850201	316.689	0.867		
RECHARGE	=			0	0	0.000		
RIVER	LEAKAGE	=		96318745	10702.08	29.301		
TOTAL	OUT	=		1.42E+08	15737.2	43.086	43.077	
IN	-	OUT	=	2967.409	0.329712	0.001	0.867	
PERCENT	DISCREPA	=	0					

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497

STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000

TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000

USG_VC5

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	
--								
CUMULAT	VOLUMES	L**3						
-----------------								
				m3/9yrs	ML/a	ML/day		
IN:								
---							LOSS	
STORAGE	=			2881883	320.2092	0.877	0.868	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RECHARGE	=			1.39E+08	15417.32	42.210		
RIVER	LEAKAGE	=		0	0	0.000		
TOTAL	IN	=		1.42E+08	15737.53	43.087	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			28795.61	3.199512	0.009		
CONSTAN	HEAD	=		42437031	4715.226	12.910		
WELLS	=			0	0	0.000		
DRAINS	=			2850201	316.689	0.867		
RECHARGE	=			0	0	0.000		
RIVER	LEAKAGE	=		96318745	10702.08	29.301		
TOTAL	OUT	=		1.42E+08	15737.2	43.086	43.077	
IN	-	OUT	=	2967.409	0.329712	0.001	0.867	
PERCENT	DISCREPA	=	0					

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497

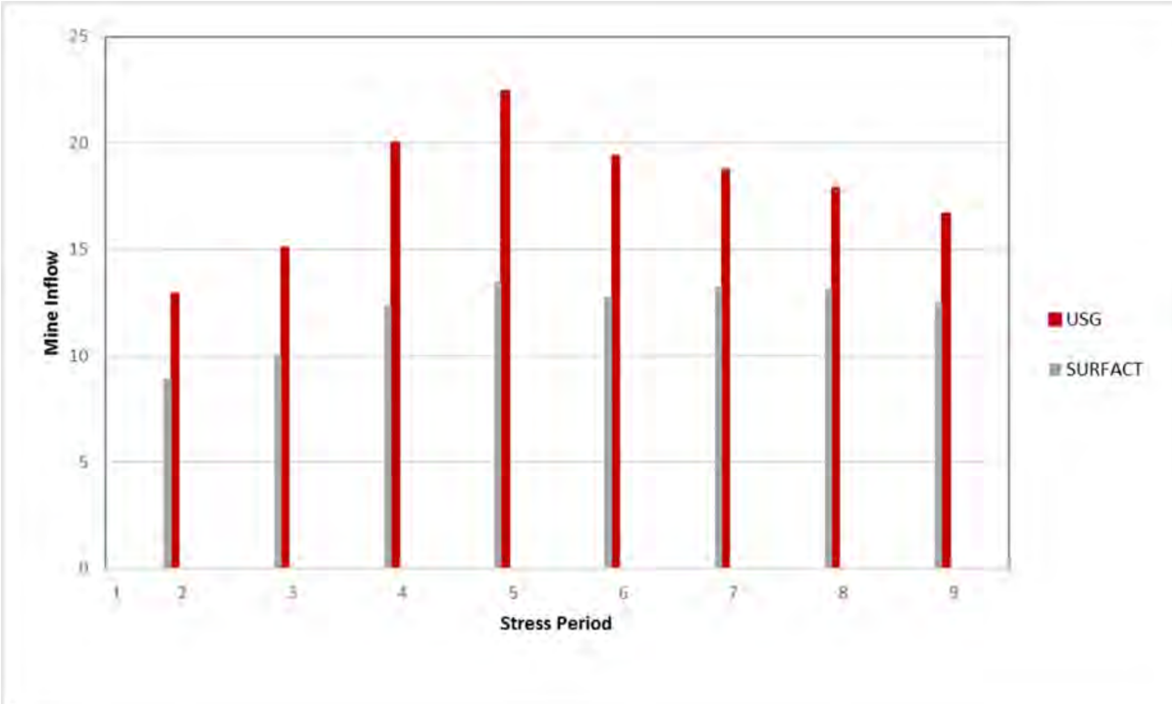
STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000

TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000

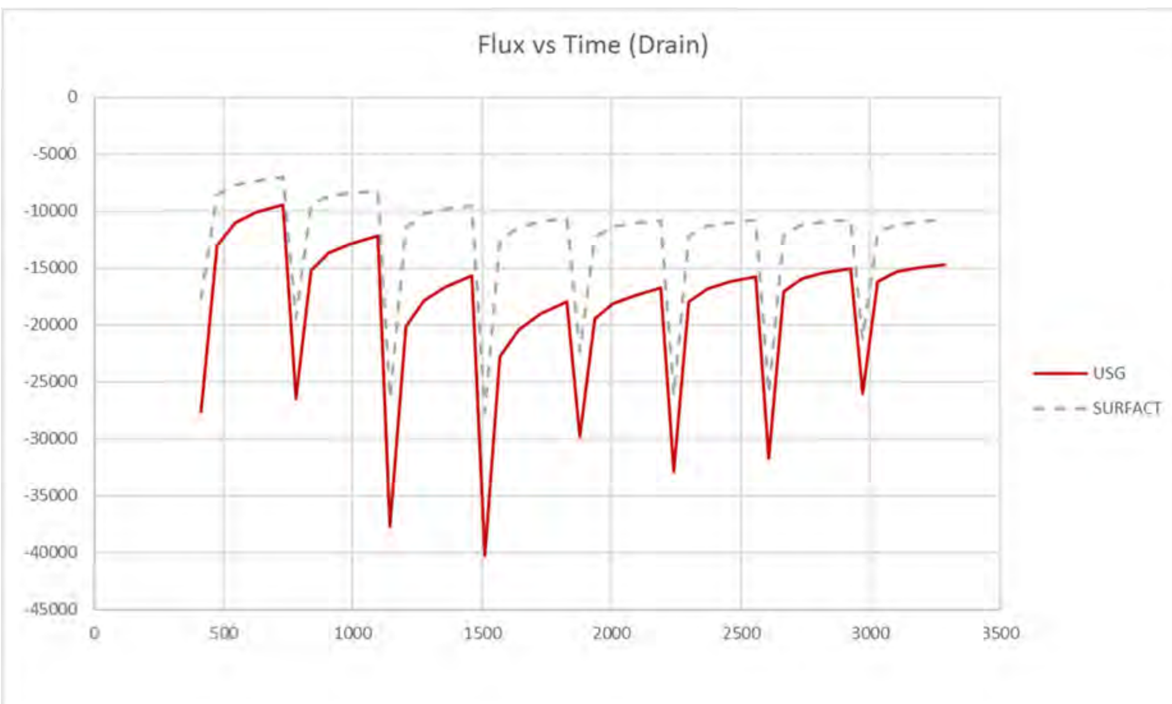
APPENDIX C1

OPEN CUT: MS_VADOSE AND USG_VADOSE

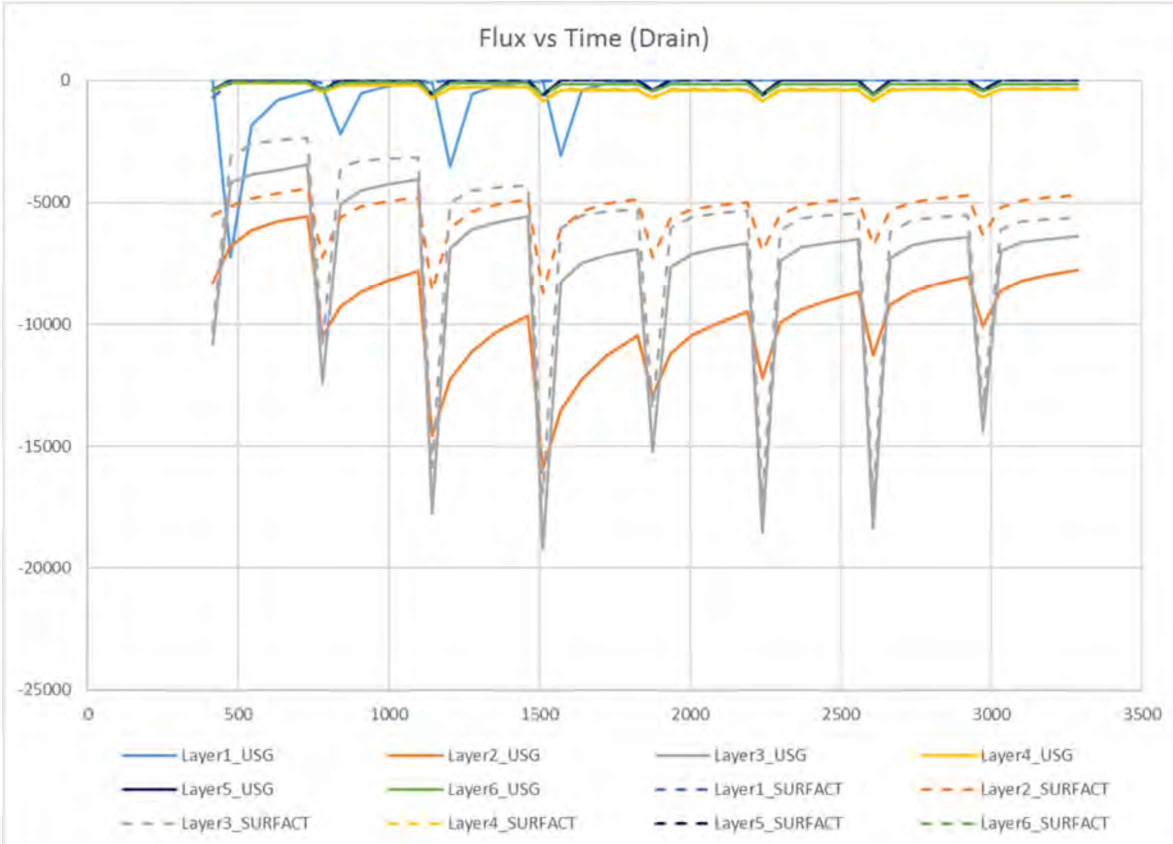
Mine inflow



Mine Inflow
Stress Period
USG
SURFACT

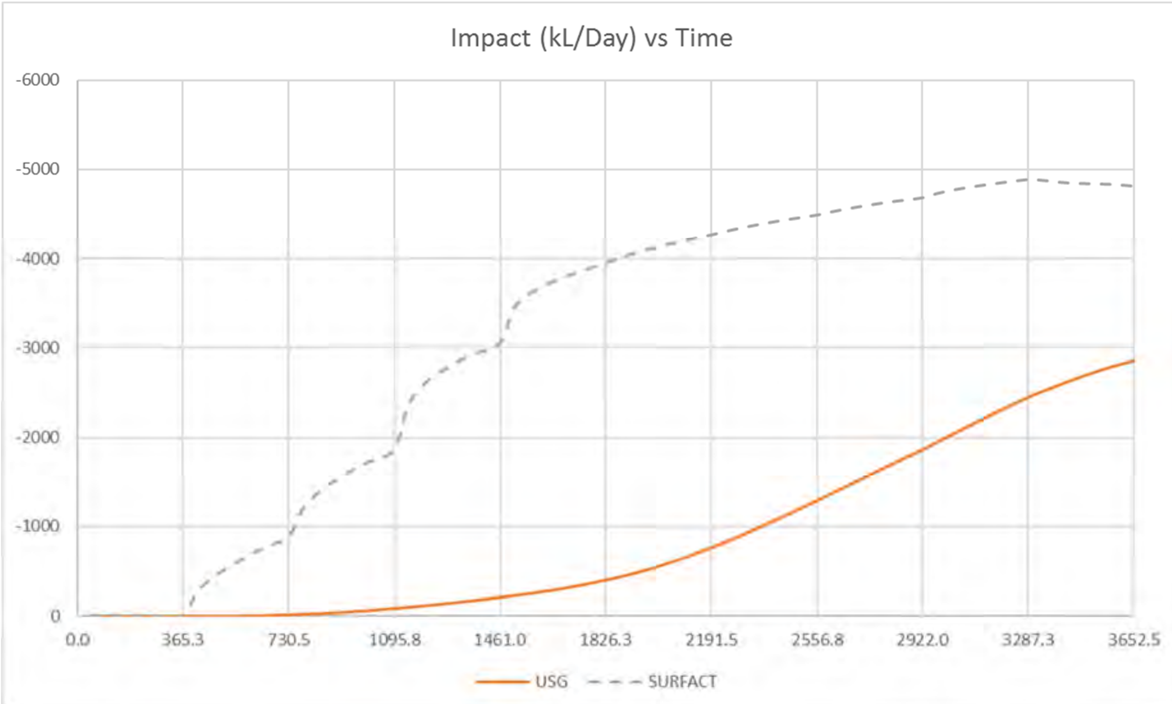


Flux vs Time (Drain)
USG
SURFACT

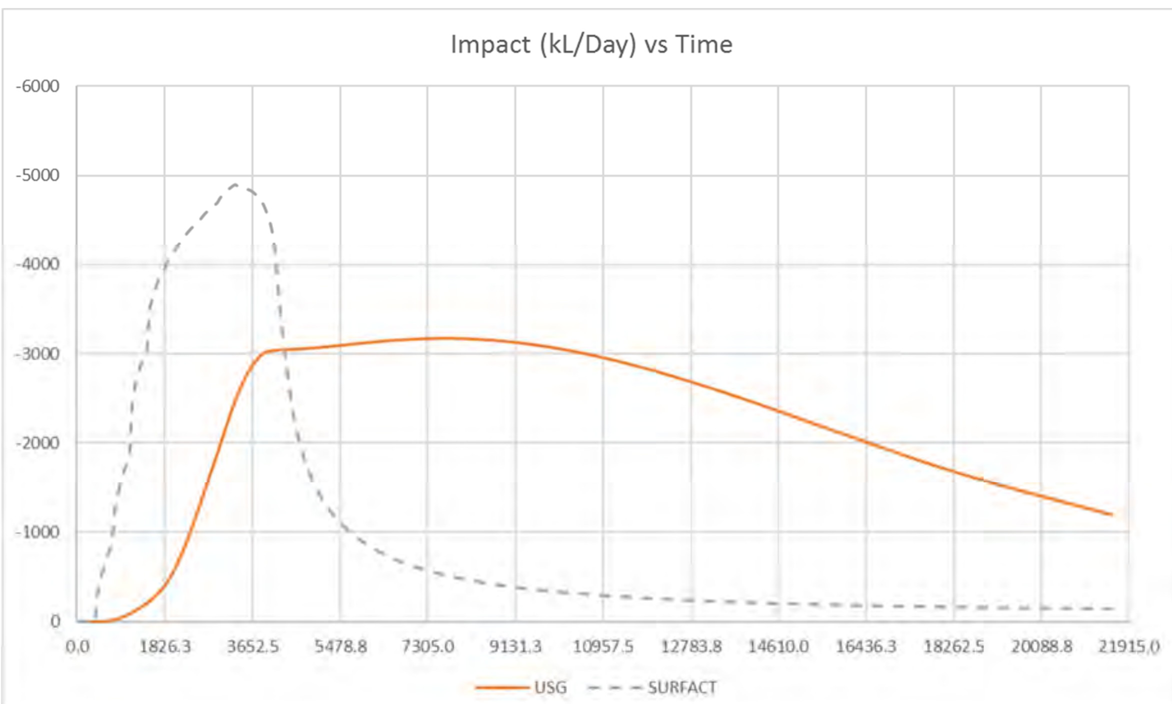


Flux vs Time (Drain)
0
-5000
-10000
-15000
-20000
-25000
0
500
1000
1500
2000
2500
3000
3500
Layer1_USG
Layer2_USG
Layer3_USG
Layer4_USG
Layer5_USG
Layer6_USG
Layer1_SURFACT
Layer2_SURFACT
Layer3_SURFACT
Layer4_SURFACT
Layer5_SURFACT
Layer6_SURFACT

River flux

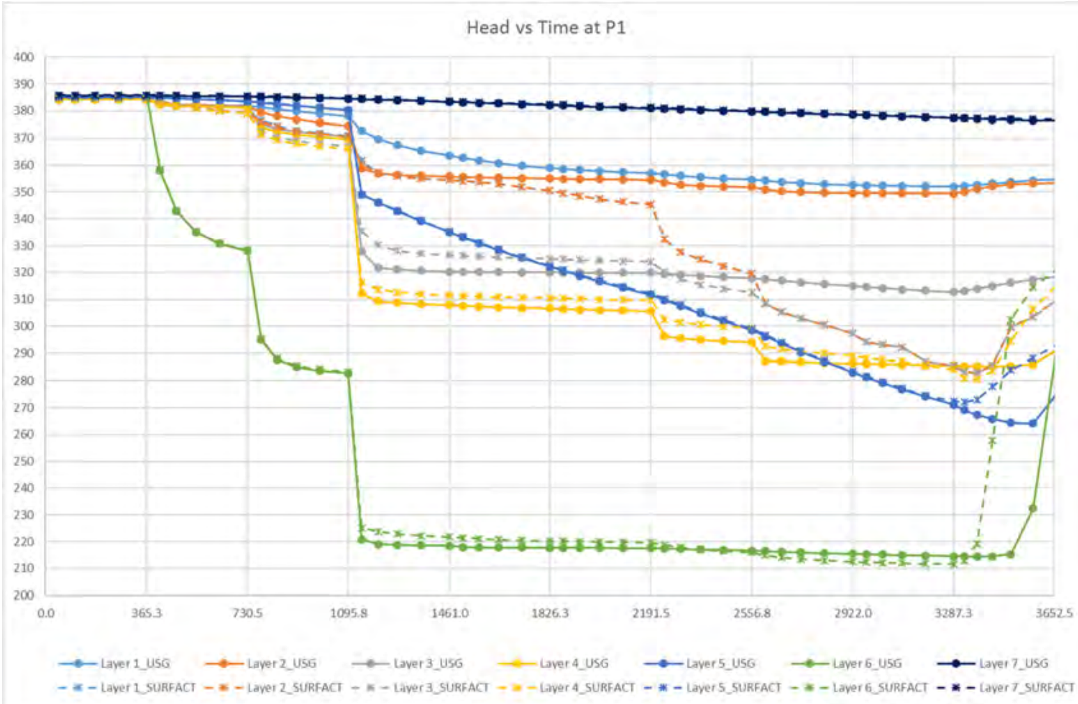


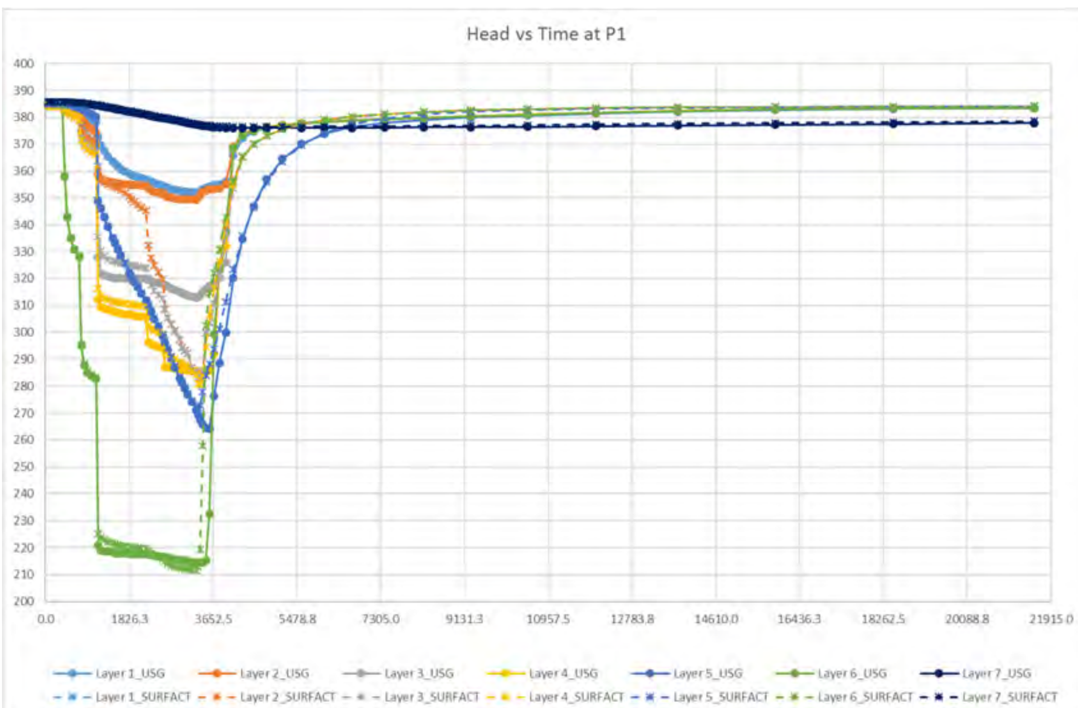
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_A1

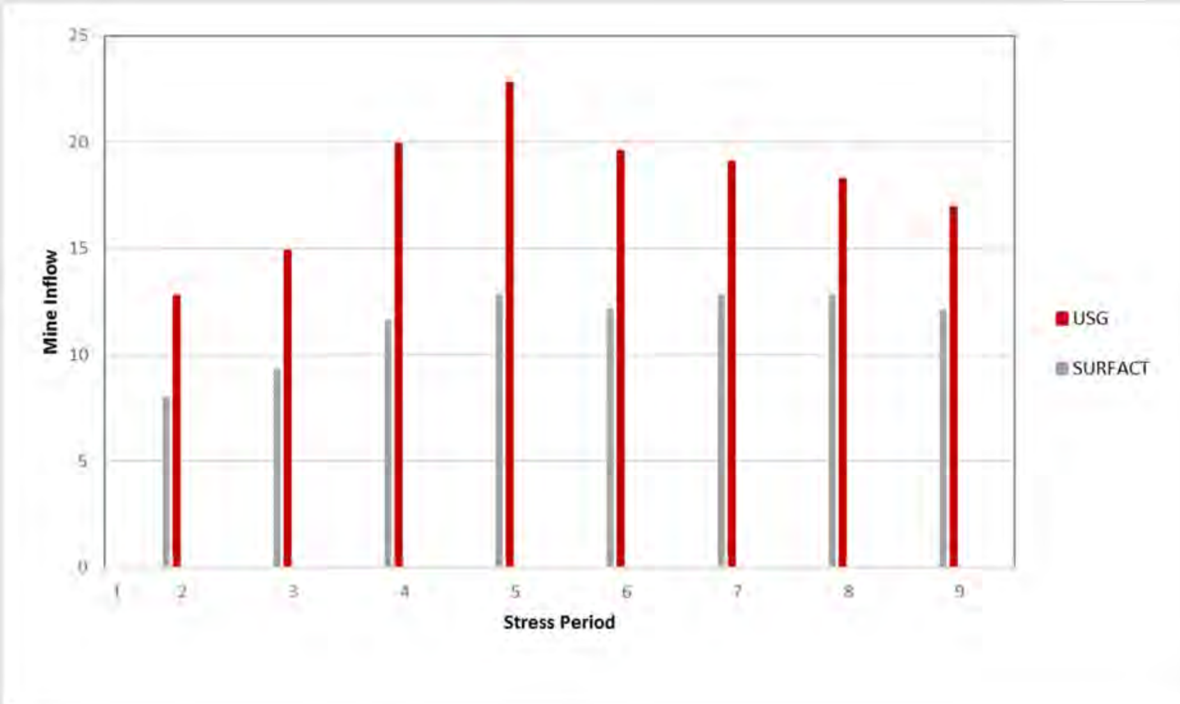
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
-----------	----------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			48745816	5416.202	14.829	14.828	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.88E+08	20833.52	57.039	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			2212.669	0.245852	0.001		
CONSTAN	HEAD	=		37755493	4195.055	11.485		-53.868%
WELLS	=			0	0	0.000		
DRAINS	=			52255193	5806.133	15.896		32.602%
RIVER	LEAKAGE	=		97488314	10832.03	29.656		27.221%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.88E+08	20833.47	57.039	57.038	12.229%
IN	-	OUT	=	460.7561	0.051195	0.000	14.828	
PERCENT	DISCREPA	=		0				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9								
SECONDS MINUTES HOURS DAYS YEARS								
--								
TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865								
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000								
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000								

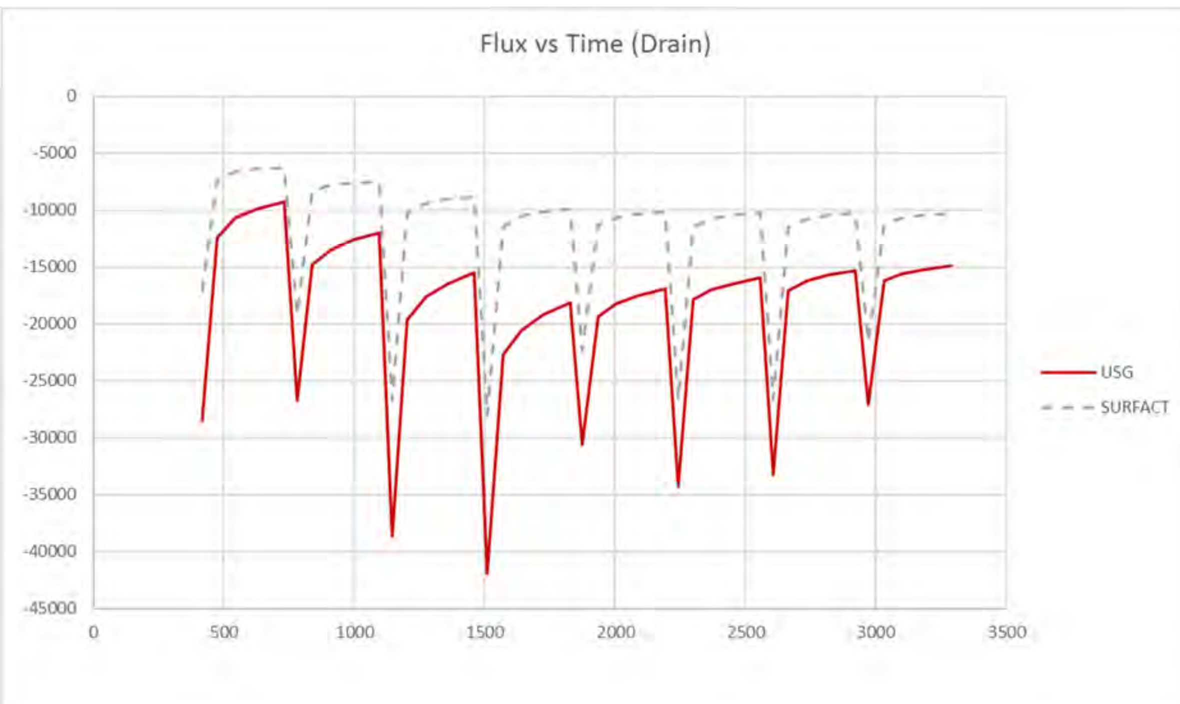
MS_A1

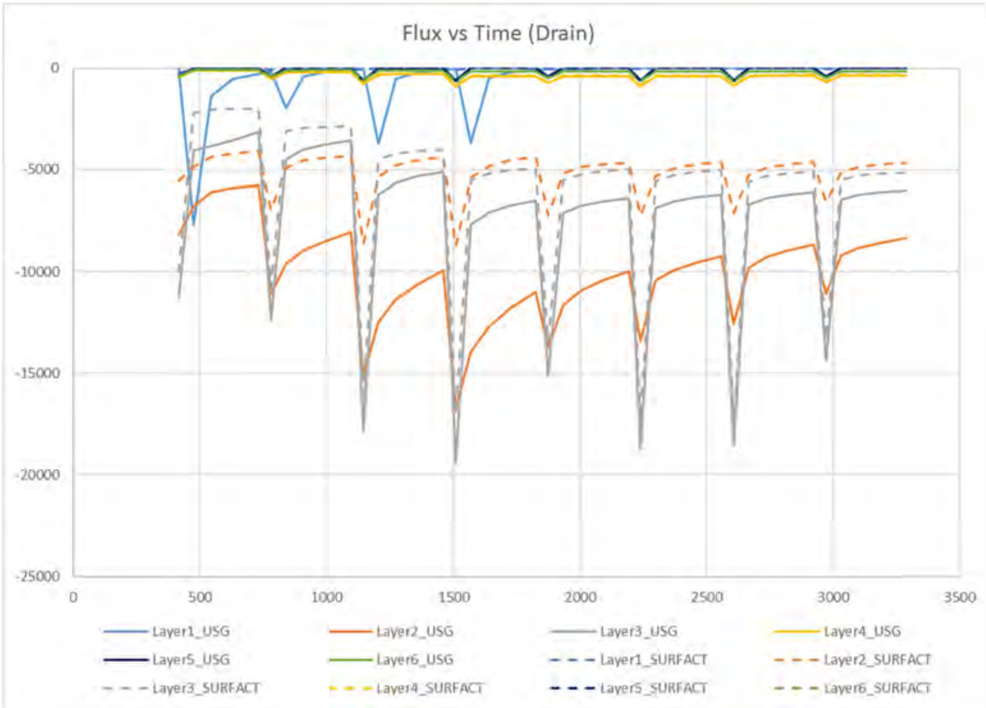
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			25760284	2862.254	7.836	7.743
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		87914.44	9.768271	0.027	
TOTAL	IN	=		1.65E+08	18289.34	50.073	42.237
OUT:	OUT:						
----	----						
STORAGE	=			307510.3	34.16781	0.094	
CONSTAN	HEAD	=		58093656	6454.851	17.672	
WELLS	=			0	0	0.000	
DRAINS	=			35218768	3913.196	10.714	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		70951128	7883.459	21.584	
TOTAL	OUT	=		1.65E+08	18285.67	50.063	49.970
IN	-	OUT	=	36287.8	4.031977	0.011	7.733
PERCENT	DISCREPA	=	0.02				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							
--							
TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497							
STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000							
TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000							

RUN A2 USG VS MS

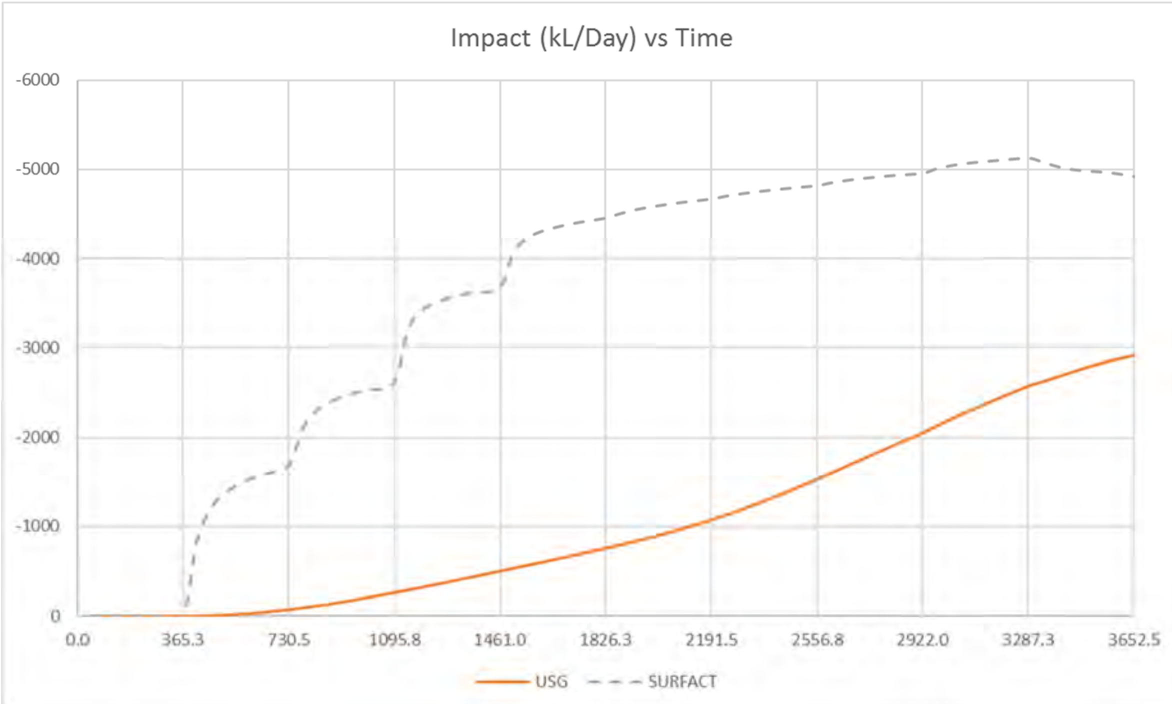
Mine inflow



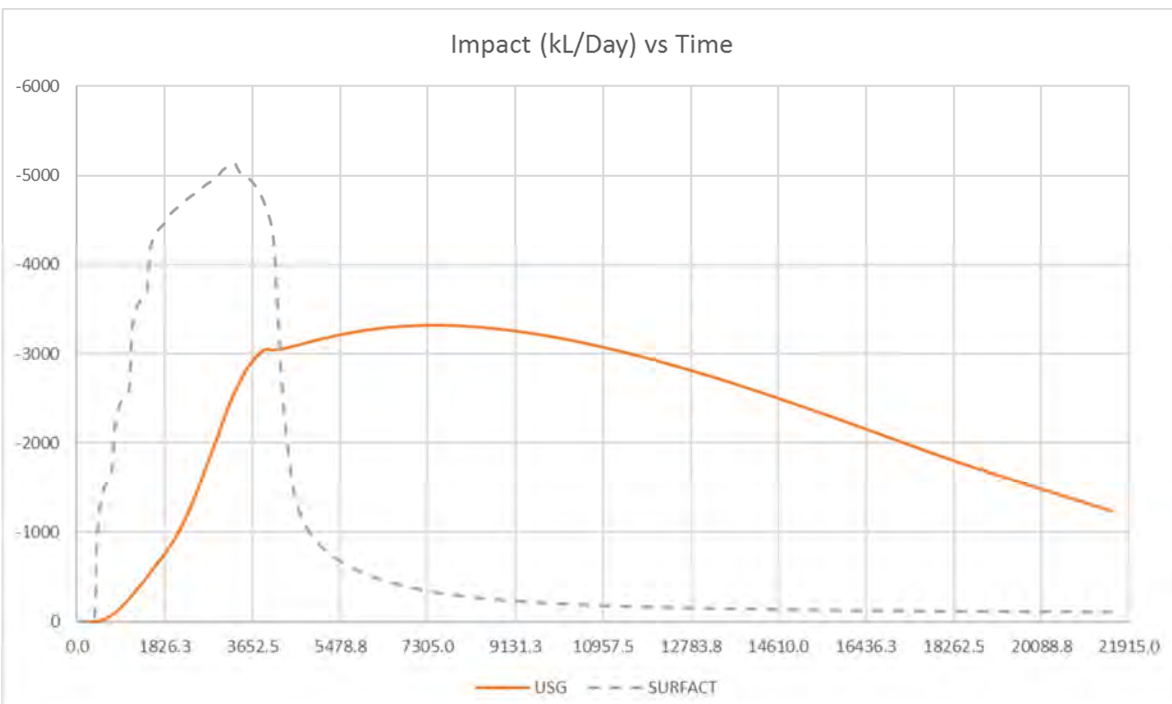



Flux vs Time (Drain)
0
-5000
-10000
-15000
-20000
-25000
0
500
1000
1500
2000
2500
3000
3500
Layer1_USG
Layer2_USG
Layer3_USG
Layer4_USG
Layer5_USG
Layer6_USG
Layer1_SURFACT
Layer2_SURFACT
Layer3_SURFACT
Layer4_SURFACT
Layer5_SURFACT
Layer6_SURFACT

River flux

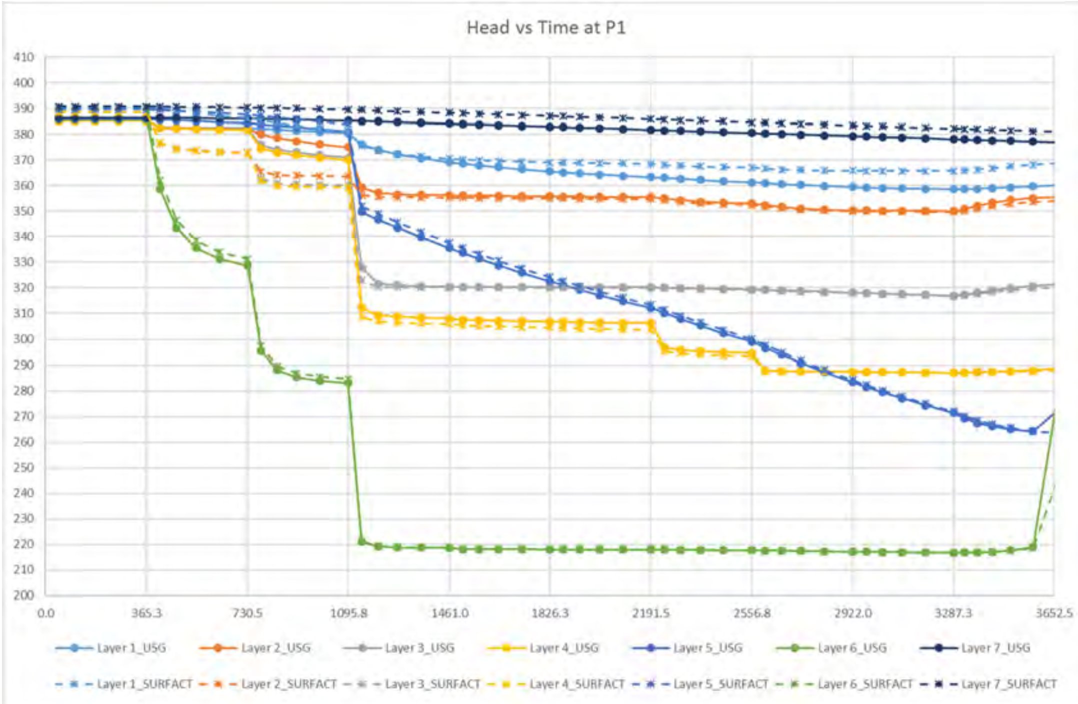


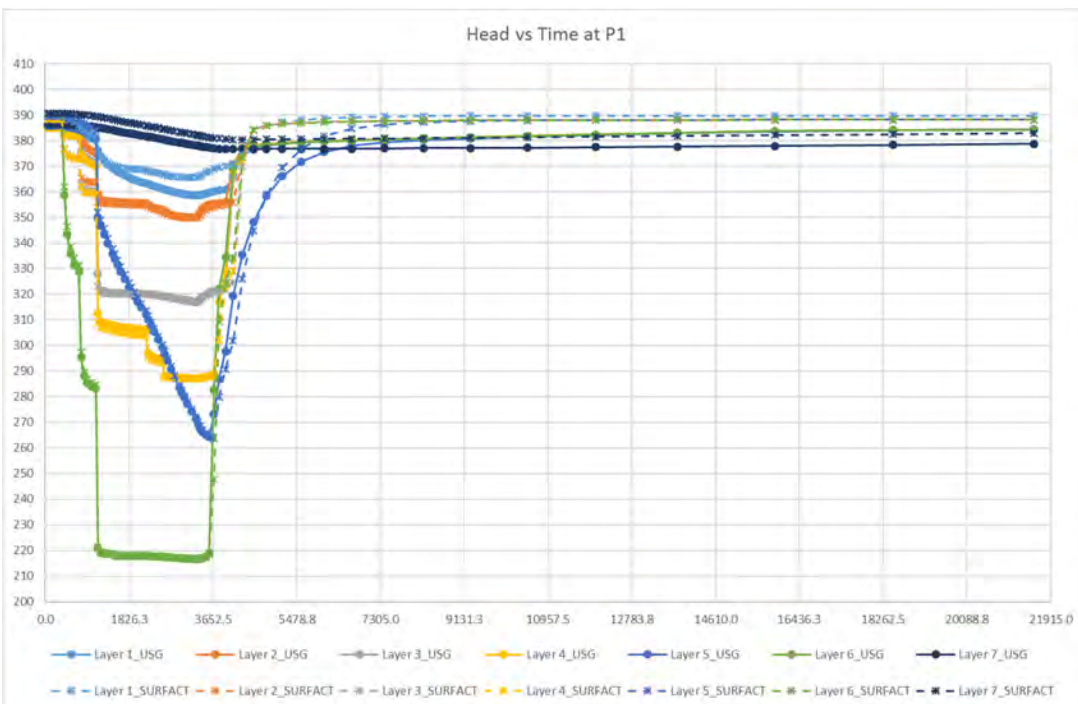
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_A2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
------------	------------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			48450121	5383.347	14.739	14.738	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.87E+08	20800.66	56.949	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			4240.864	0.471207	0.001		
CONSTAN	HEAD	=		40731945	4525.772	12.391		-43.086%
WELLS	=			0	0	0.000		
DRAINS	=			52681077	5853.453	16.026		36.625%
RIVER	LEAKAGE	=		93788822	10420.98	28.531		26.333%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.87E+08	20800.68	56.949	56.948	13.952%
IN	-	OUT	=	-107.064	-0.0119	0.000	14.738	
PERCENT	DISCREPA	=		0				

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000

MS_A2

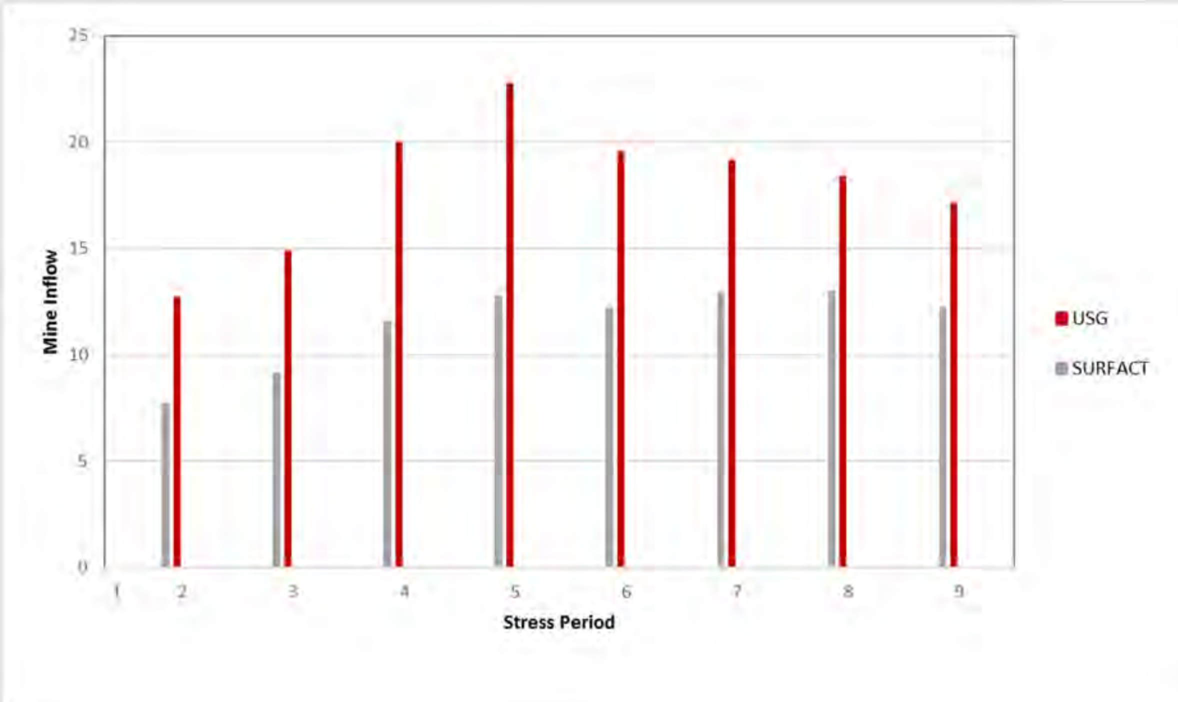
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			22250874	2472.319	6.769	6.669
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		0	0	0.000	
TOTAL	IN	=		1.61E+08	17889.63	48.979	42.210
OUT:	OUT:						
----	----						
STORAGE	=			327576.8	36.39742	0.100	
CONSTAN	HEAD	=		58281868	6475.763	17.730	
WELLS	=			0	0	0.000	
DRAINS	=			33386704	3709.634	10.156	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		69091424	7676.825	21.018	
TOTAL	OUT	=		1.61E+08	17898.62	49.004	48.904
IN	-	OUT	=	-80858.8	-8.98431	-0.025	6.694
PERCENT	DISCREPA	=	-0.05				

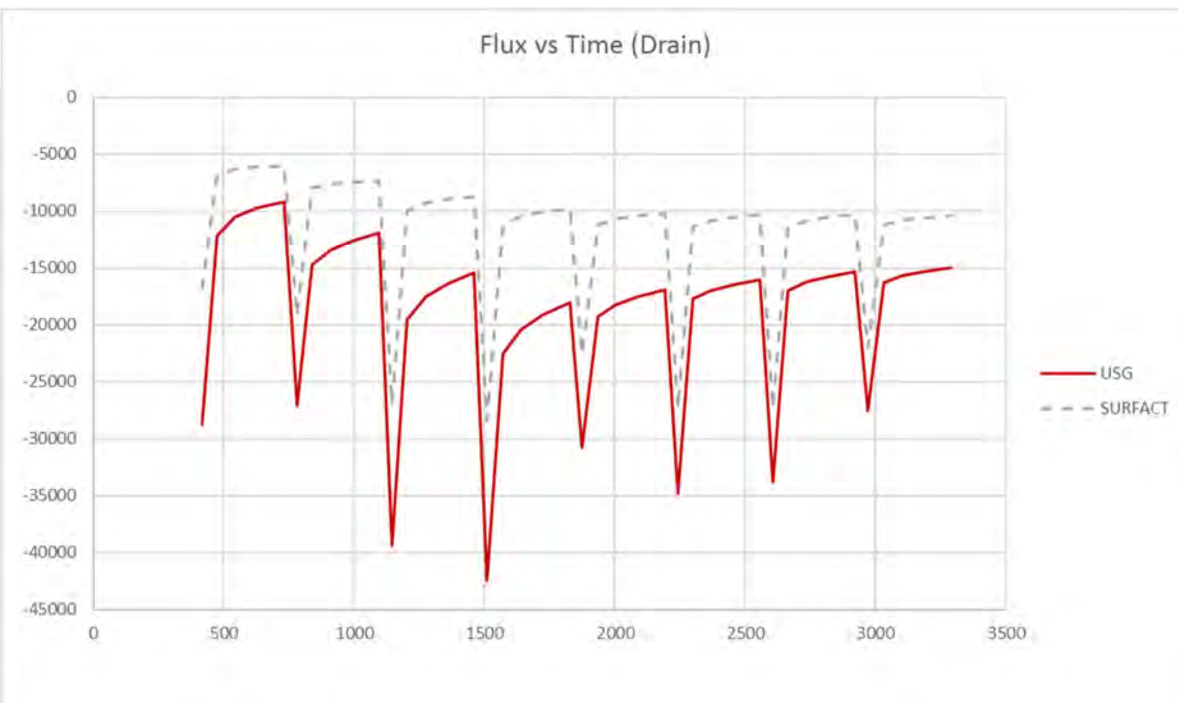
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

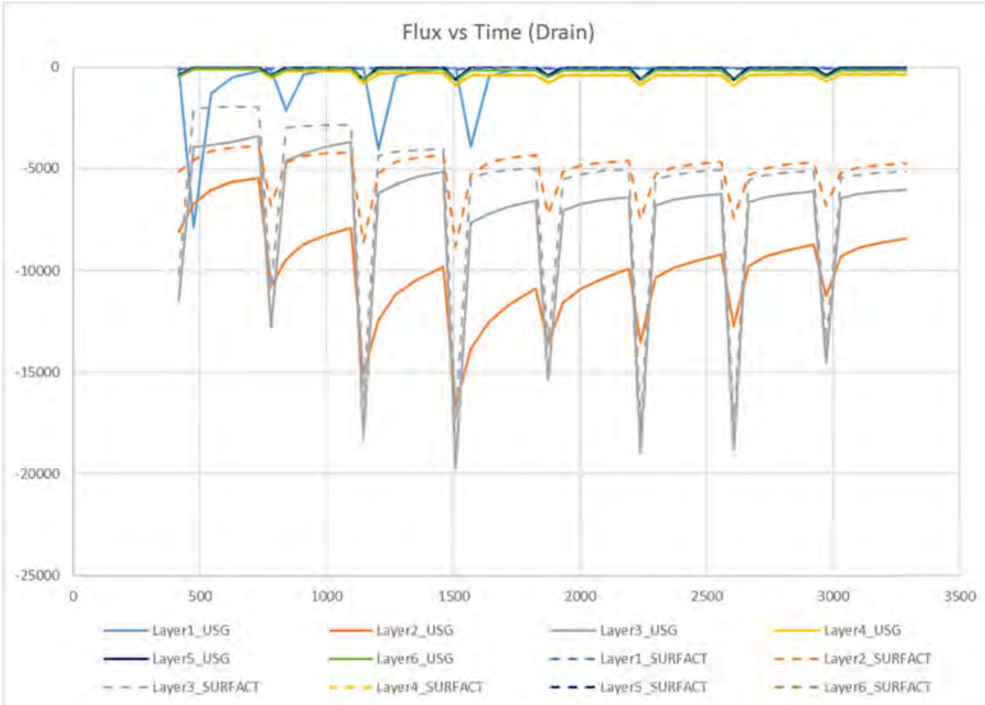
	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	8793517.	146558.6	2442.644	101.7768	0.2786497
STRESS PERIOD TIME	3.1557600E+07	525960.0	8766.000	365.2500	1.000000
TOTAL TIME	2.8401840E+08	4733640.	78894.00	3287.250	9.000000

RUN A3 USG VS MS

Mine inflow

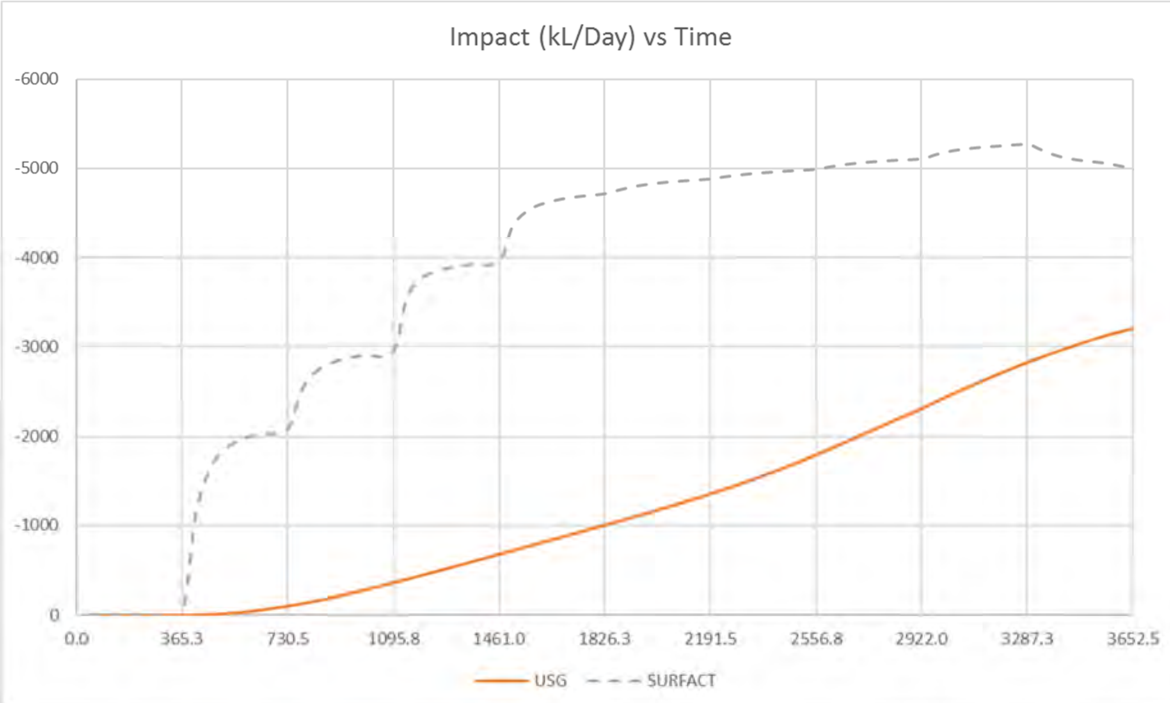




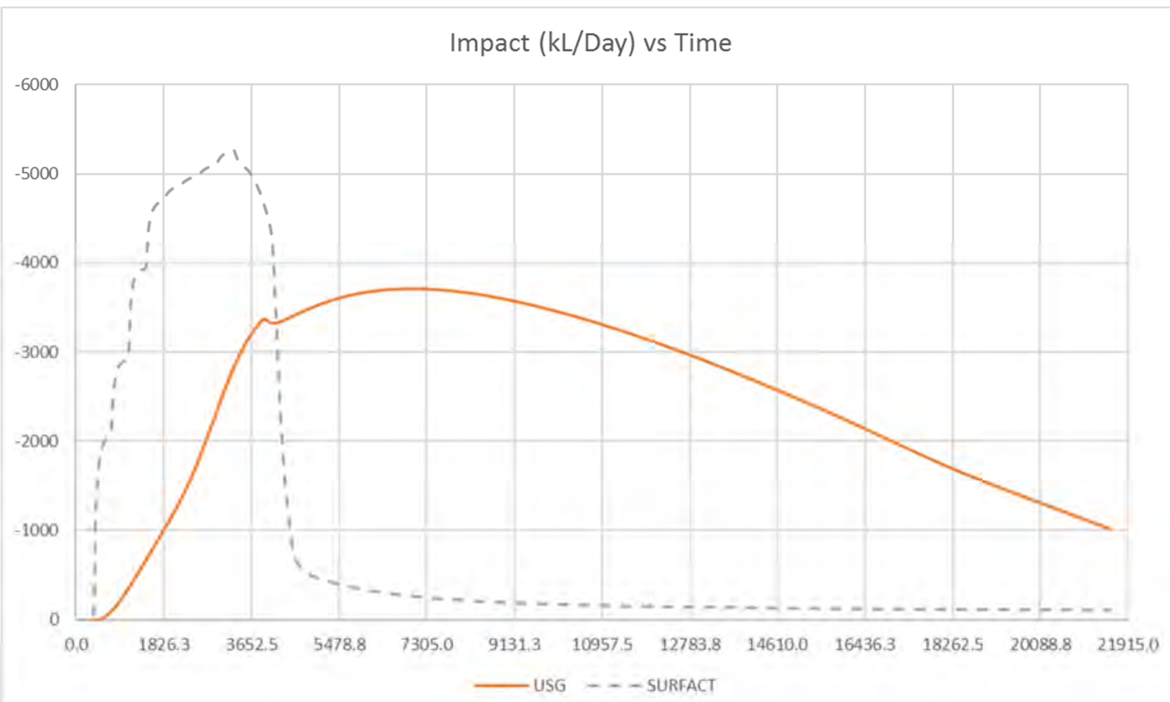


Flux vs Time (Drain)
0
-5000
-10000
-15000
-20000
-25000
0
500
1000
1500
2000
2500
3000
3500
Layer1_USG
Layer2_USG
Layer3_USG
Layer4_USG
Layer5_USG
Layer6_USG
Layer1_SURFACT
Layer2_SURFACT
Layer3_SURFACT
Layer4_SURFACT
Layer5_SURFACT
Layer6_SURFACT

River flux

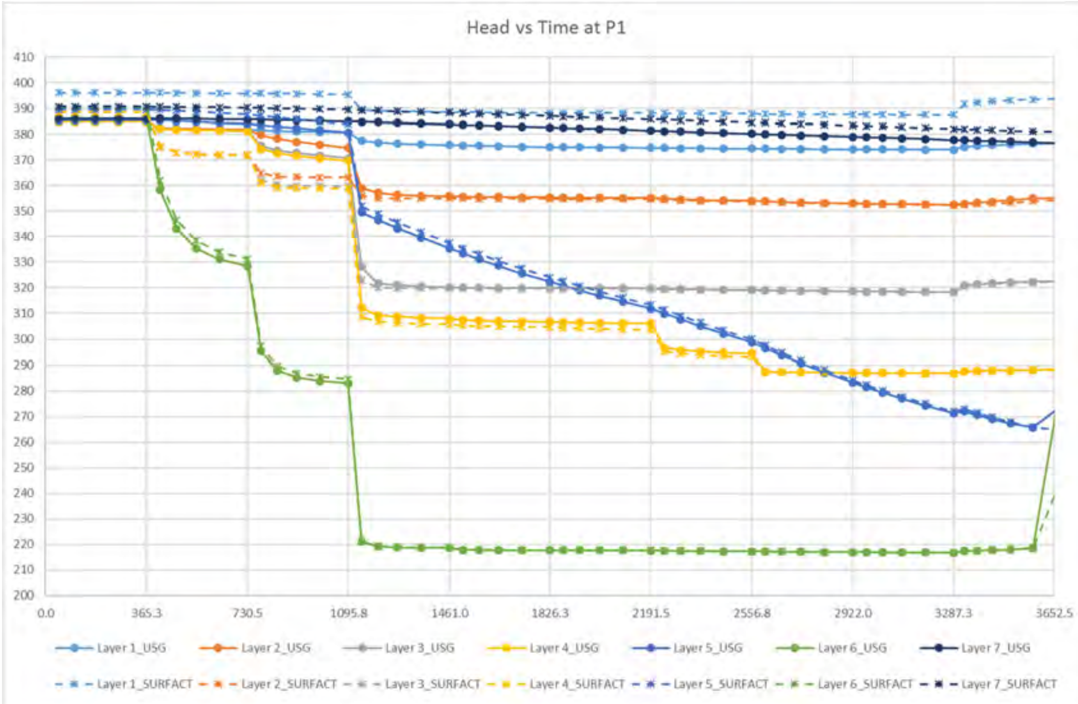


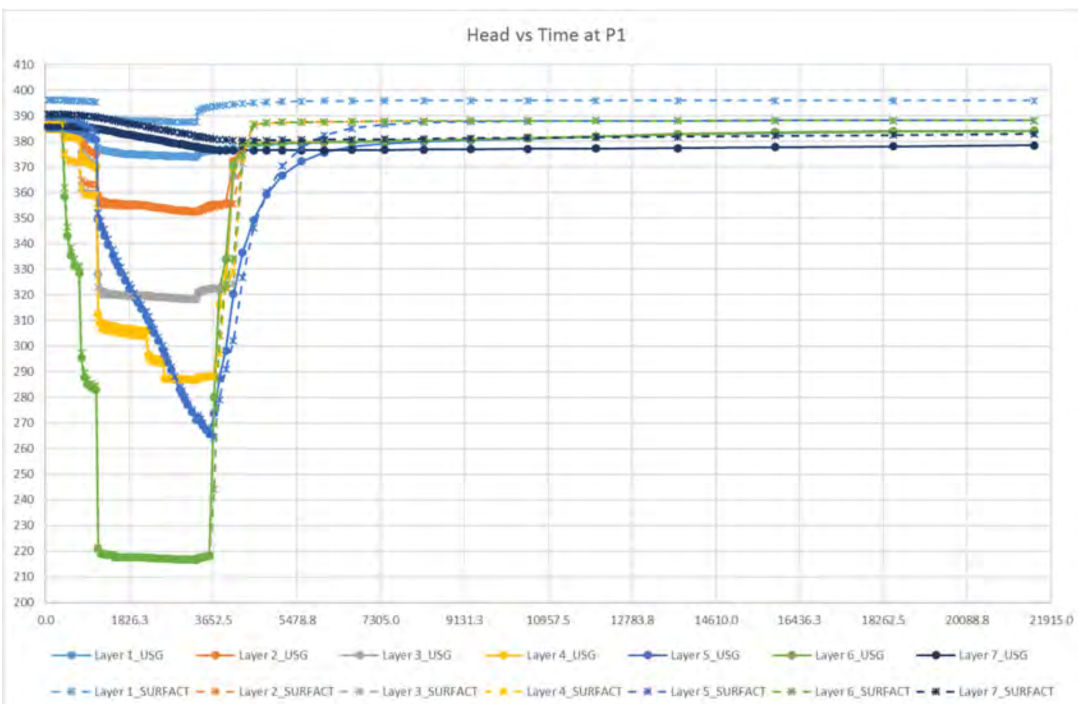
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_A3

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
------------	------------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			47902398	5322.489	14.572	14.572	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.87E+08	20739.81	56.782	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			1924.894	0.213877	0.001		
CONSTAN	HEAD	=		39504242	4389.36	12.017		-47.531%
WELLS	=			0	0	0.000		
DRAINS	=			52714793	5857.199	16.036		36.731%
RIVER	LEAKAGE	=		94437296	10493.03	28.728		27.676%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.87E+08	20739.81	56.782	56.782	14.142%
IN	-	OUT	=	9.25E-02	1.03E-05	0.000	14.572	
PERCENT	DISCREPA	=		0				

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

	SECONDS	MINUTES	HOURS	DAYS	YEARS

TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000

MS_A3

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			21451304	2383.478	6.526	6.426
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		0	0	0.000	
TOTAL	IN	=		1.6E+08	17800.79	48.736	42.210
OUT:	OUT:						
----	----						
STORAGE	=			326957.2	36.32858	0.099	
CONSTAN	HEAD	=		58280820	6475.647	17.729	
WELLS	=			0	0	0.000	
DRAINS	=			33352210	3705.801	10.146	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		68300424	7588.936	20.777	
TOTAL	OUT	=		1.6E+08	17806.71	48.752	48.653
IN	-	OUT	=	-53267.2	-5.91858	-0.016	6.442
PERCENT	DISCREPA	=	-0.03				

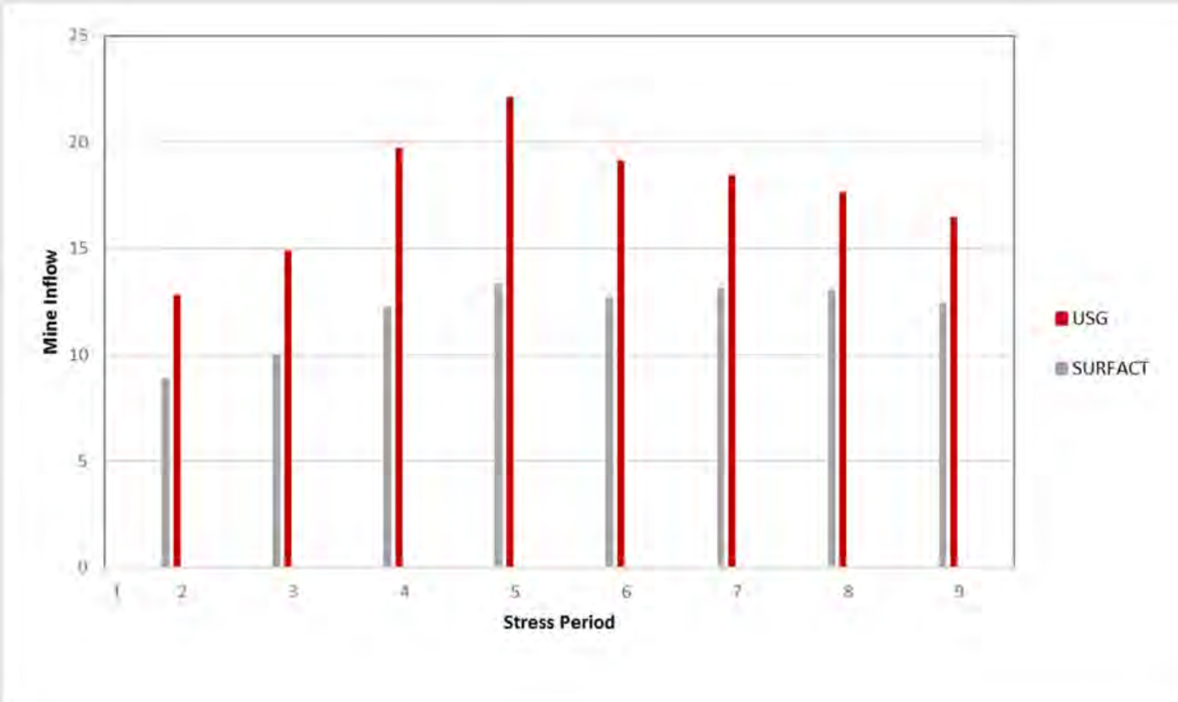
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

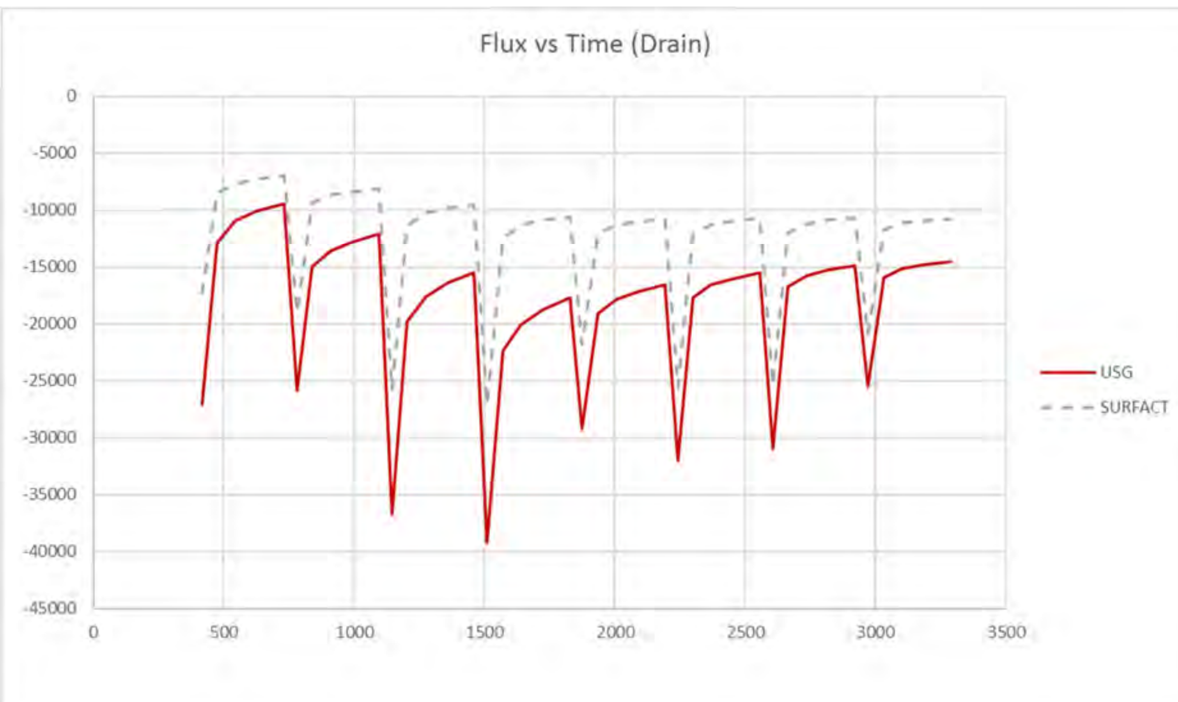
	SECONDS	MINUTES	HOURS	DAYS	YEARS

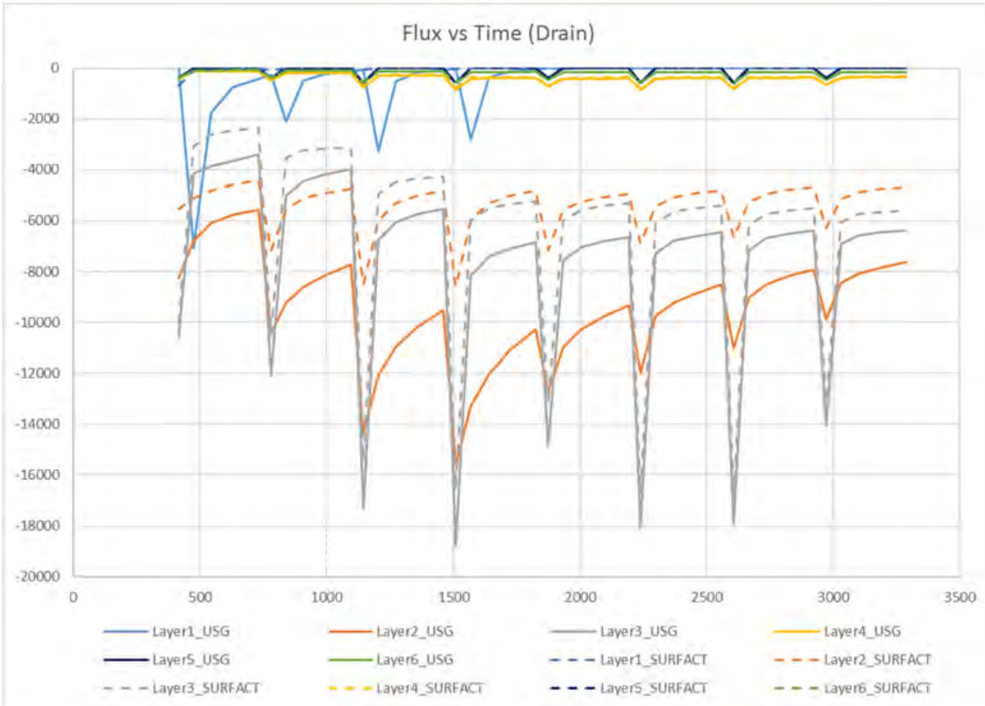
TIME STEP LENGTH	8793517.	146558.6	2442.644	101.7768	0.2786497
STRESS PERIOD TIME	3.1557600E+07	525960.0	8766.000	365.2500	1.000000
TOTAL TIME	2.8401840E+08	4733640.	78894.00	3287.250	9.000000

RUN A4 USG VS MS

Mine inflow

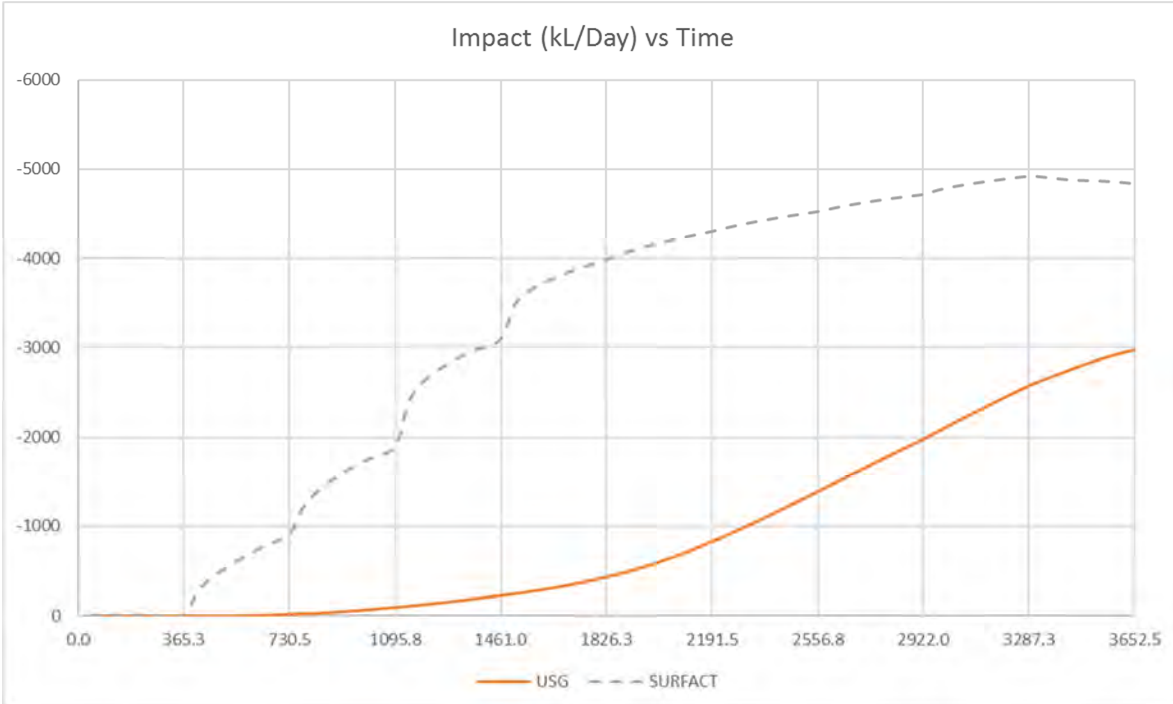




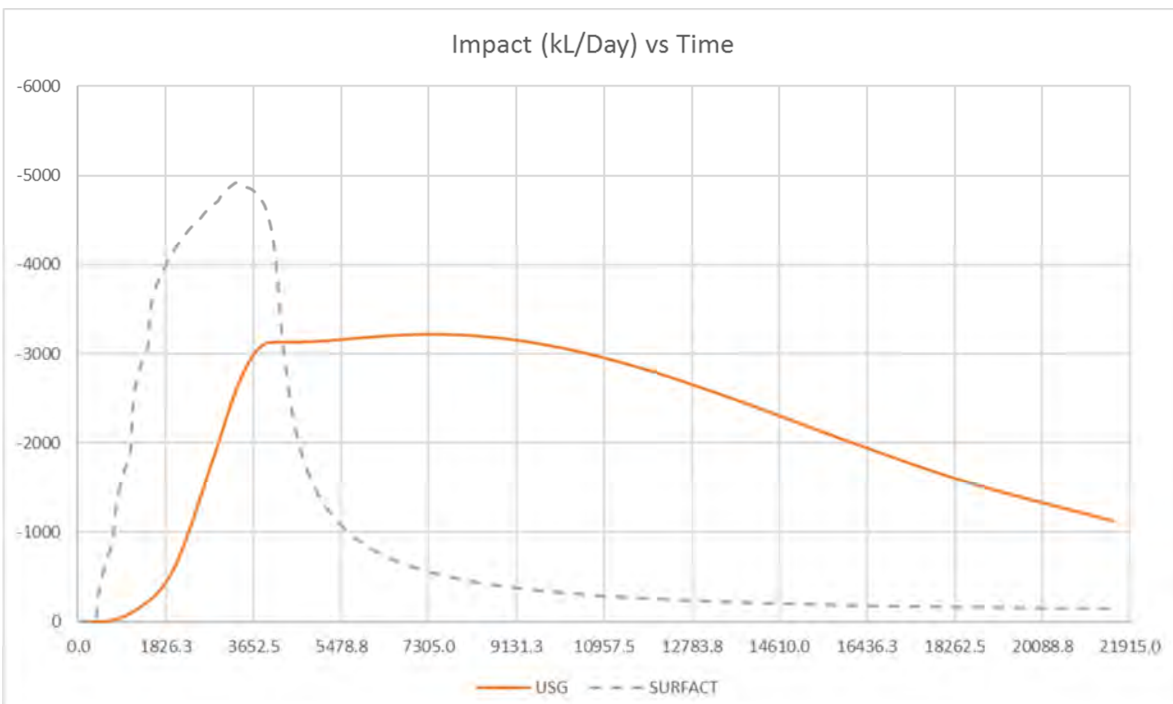


Flux vs Time (Drain)
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
-20000
0
500
1000
1500
2000
2500
3000
3500
Layer1_USG
Layer2_USG
Layer3_USG
Layer4_USG
Layer5_USG
Layer6_USG
Layer1_SURFACT
Layer2_SURFACT
Layer3_SURFACT
Layer4_SURFACT
Layer5_SURFACT
Layer6_SURFACT

River flux

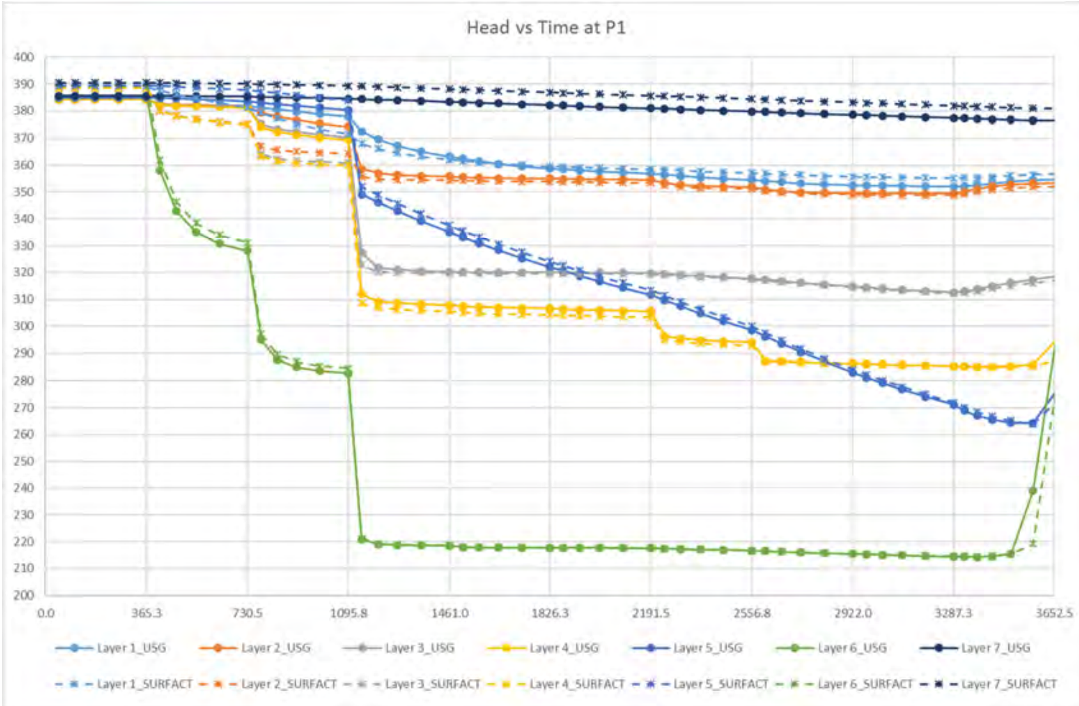


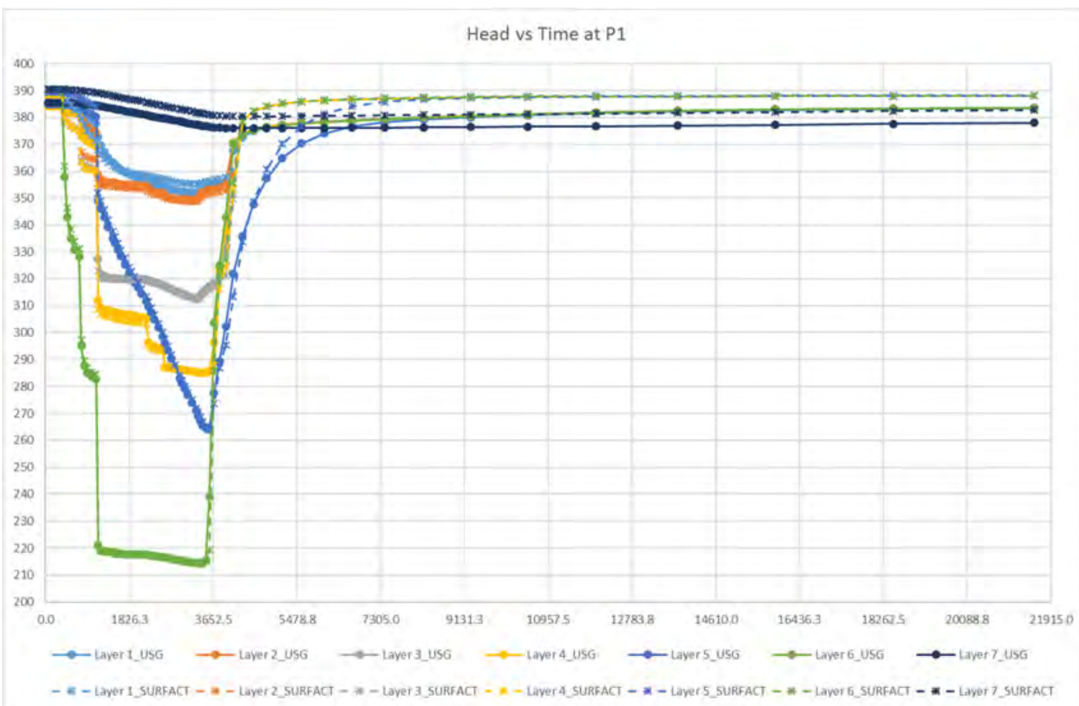
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_A4

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
-----------	------------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			47763212	5307.024	14.530	14.529	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.87E+08	20724.34	56.740	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			2133.591	0.237066	0.001		
CONSTAN	HEAD	=		37743044	4193.672	11.482		-53.919%
WELLS	=			0	0	0.000		
DRAINS	=			51437863	5715.318	15.648		32.227%
RIVER	LEAKAGE	=		97335594	10815.07	29.610		27.186%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.87E+08	20724.29	56.740	56.739	12.007%
IN	-	OUT	=	4.35E+02	0.048279	0.000	14.529	
PERCENT	DISCREPA	=		0				

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

	SECONDS	MINUTES	HOURS	DAYS	YEARS

TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000

MS_A4

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			25310746	2812.305	7.700	7.610
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		90044.09	10.0049	0.027	
TOTAL	IN	=		1.64E+08	18239.63	49.937	42.238
OUT:	OUT:						
----	----						
STORAGE	=			294555.6	32.7284	0.090	
CONSTAN	HEAD	=		58093740	6454.86	17.672	
WELLS	=			0	0	0.000	
DRAINS	=			34861216	3873.468	10.605	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		70873928	7874.881	21.560	
TOTAL	OUT	=		1.64E+08	18235.94	49.927	49.838
IN	-	OUT	=	33190.53	3.687837	0.010	7.600
PERCENT	DISCREPA	=	-0.03				

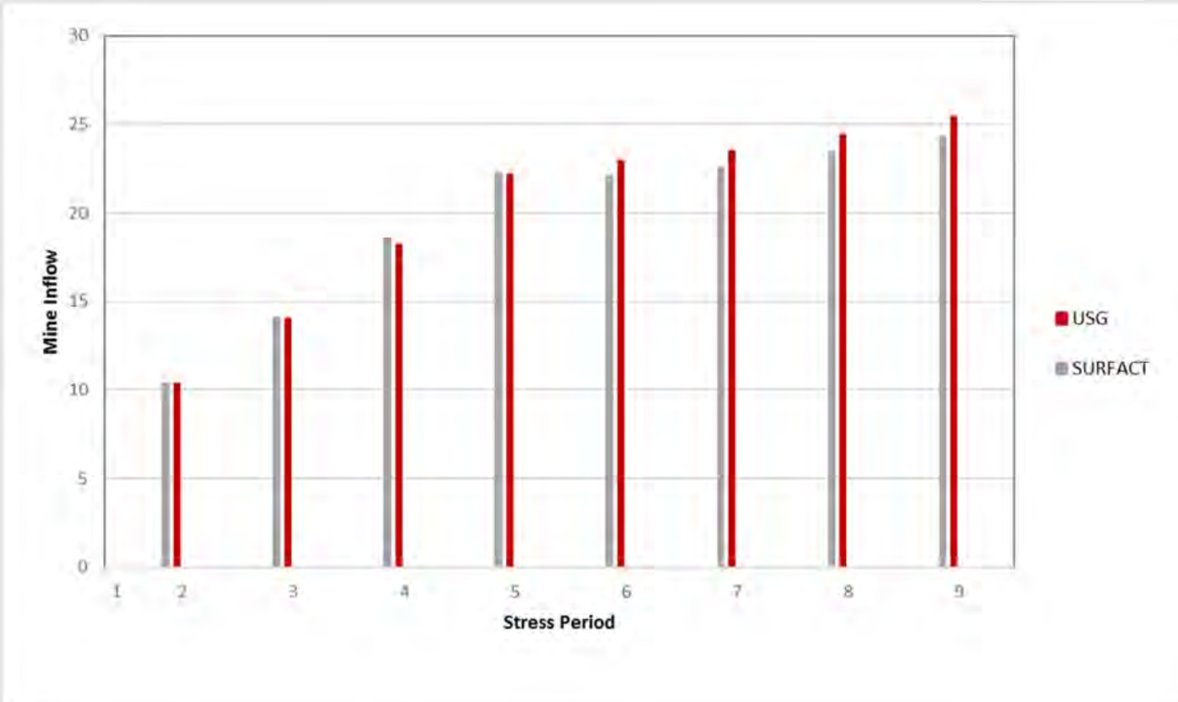
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

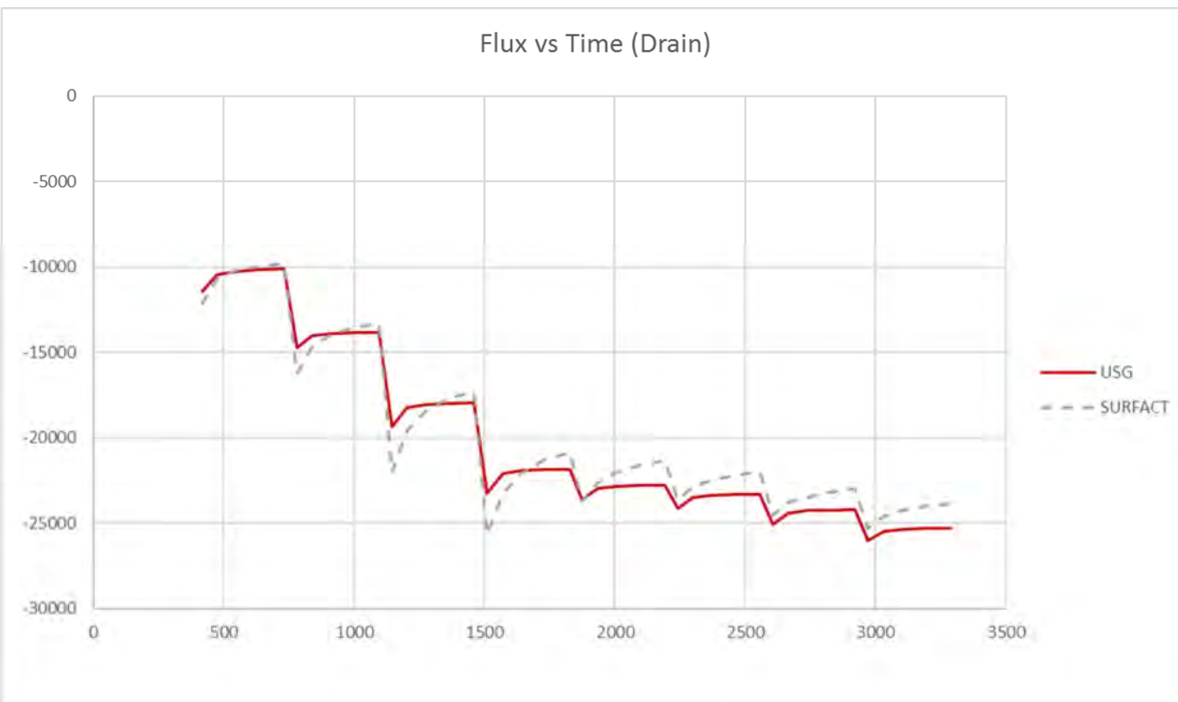
	SECONDS	MINUTES	HOURS	DAYS	YEARS

TIME STEP LENGTH	8793517.	146558.6	2442.644	101.7768	0.2786497
STRESS PERIOD TIME	3.1557600E+07	525960.0	8766.000	365.2500	1.000000
TOTAL TIME	2.8401840E+08	4733640.	78894.00	3287.250	9.000000

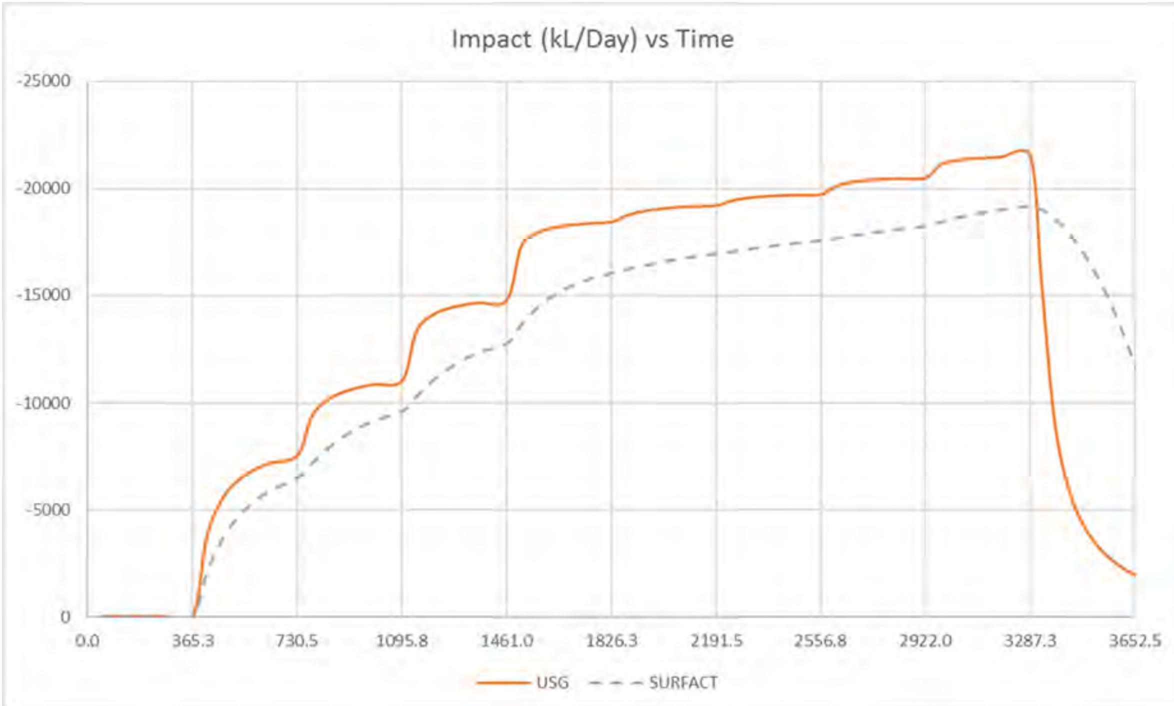
RUN B1 USG VS MS

Mine inflow

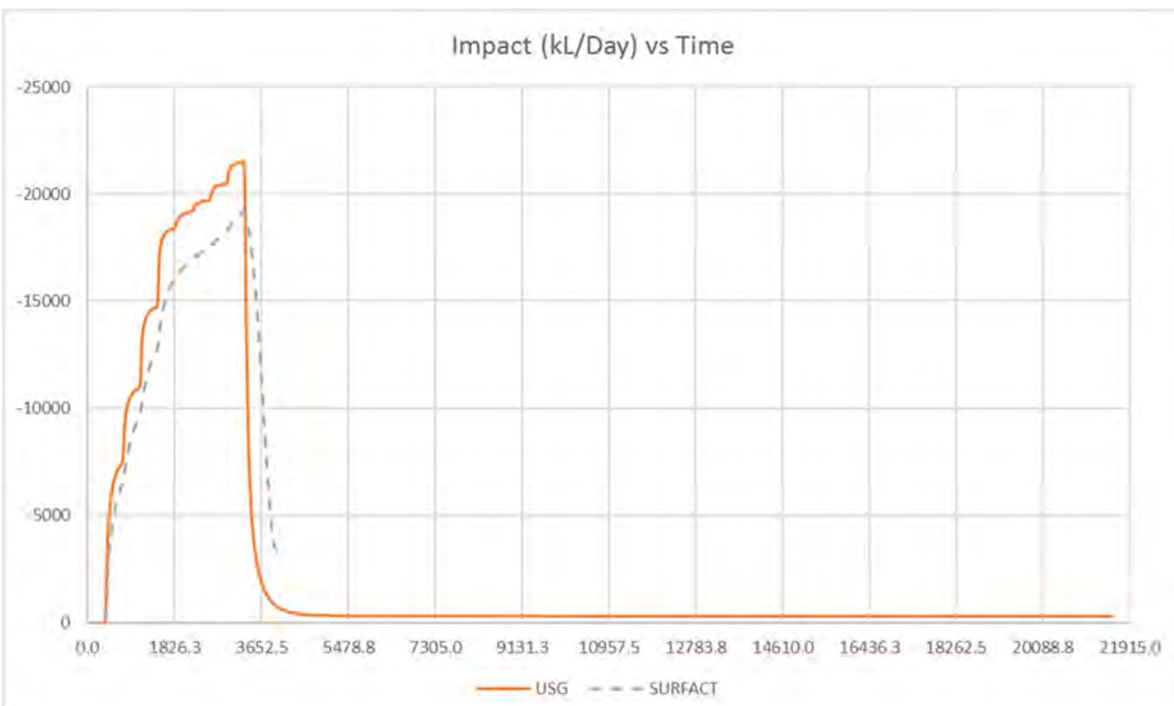




River flux

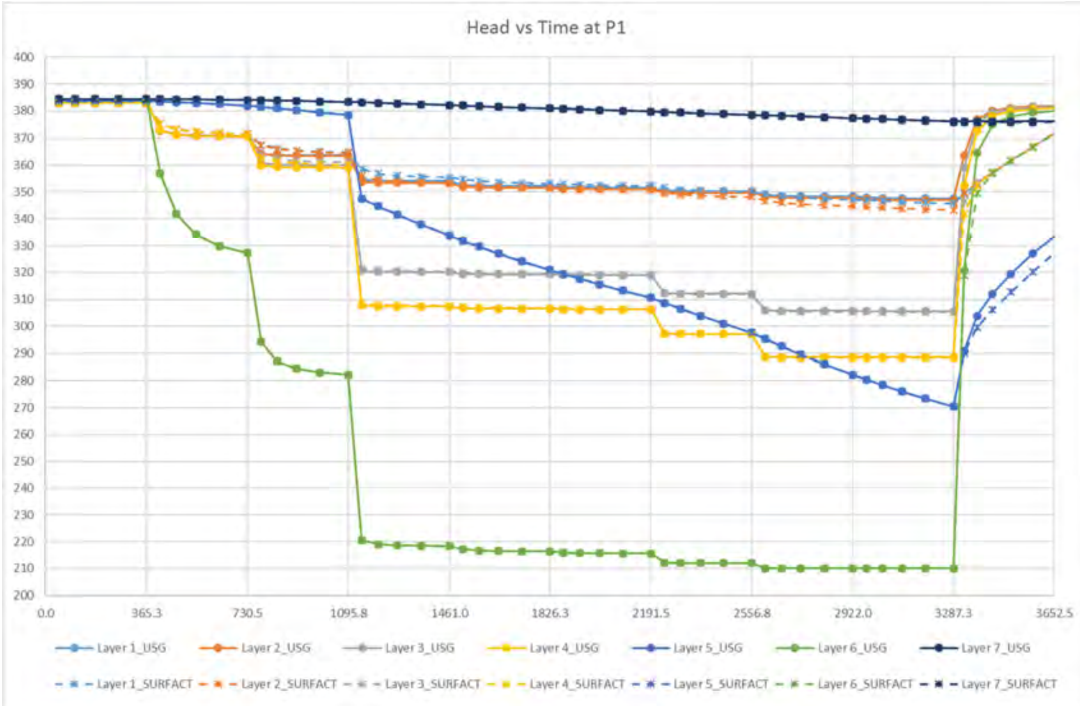


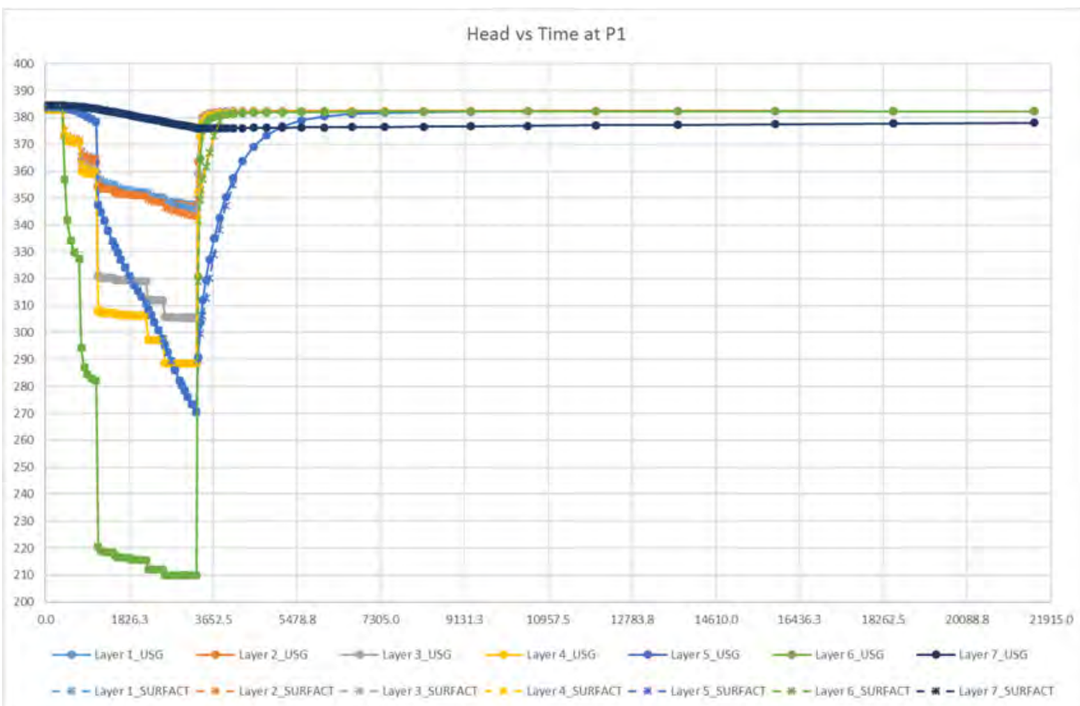
Impact (kL/Day) vs Time
-25000
-20000
-15000
-10000
-5000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-25000
-20000
-15000
-10000
5000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_B1

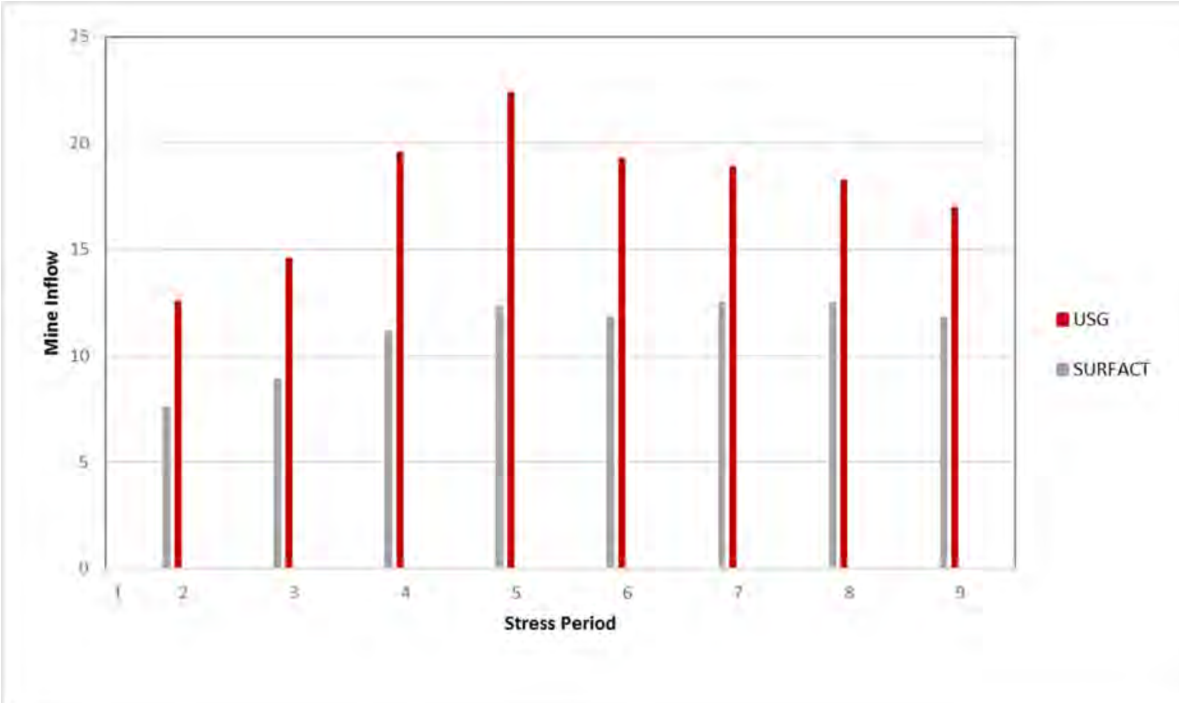
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
------------	------------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			3940571	437.8412	1.199	1.199	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		13739672	1526.63	4.180		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.56E+08	17381.79	47.589	46.390	
OUT:	OUT:							
----	----							
STORAGE	=			23.5657	0.002618	0.000		
CONSTAN	HEAD	=		26020861	2891.207	7.916		-4.428%
WELLS	=			0	0	0.000		
DRAINS	=			58802538	6533.615	17.888		2.033%
RIVER	LEAKAGE	=		71612121	7956.902	21.785		-4.377%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.56E+08	17381.73	47.589	47.589	-1.978%
IN	-	OUT	=	5.57E+02	0.061861	0.000	1.199	
PERCENT	DISCREPA	=		0				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9								
SECONDS MINUTES HOURS DAYS YEARS								
--								
TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865								
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000								
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000								

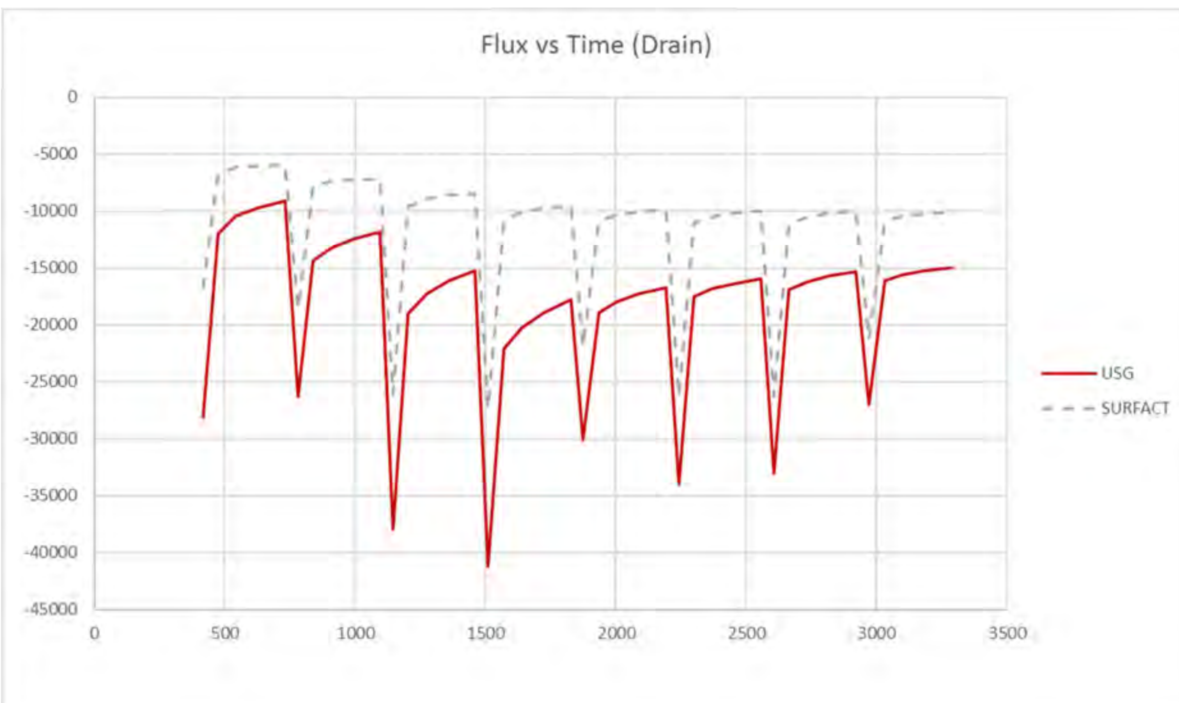
MS_B1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			10564003	1173.778	3.214	3.213
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		10208423	1134.269	3.105	
TOTAL	IN	=		1.6E+08	17725.36	48.529	45.316
OUT:	OUT:						
----	----						
STORAGE	=			3090.731	0.343415	0.001	
CONSTAN	HEAD	=		27173072	3019.23	8.266	
WELLS	=			0	0	0.000	
DRAINS	=			57606796	6400.755	17.524	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		74746312	8305.146	22.738	
TOTAL	OUT	=		1.6E+08	17725.47	48.530	48.529
IN	-	OUT	=	-1004.73	-0.11164	0.000	3.213
PERCENT	DISCREPA	=	-0.03				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							
--							
TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497							
STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000							
TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000							

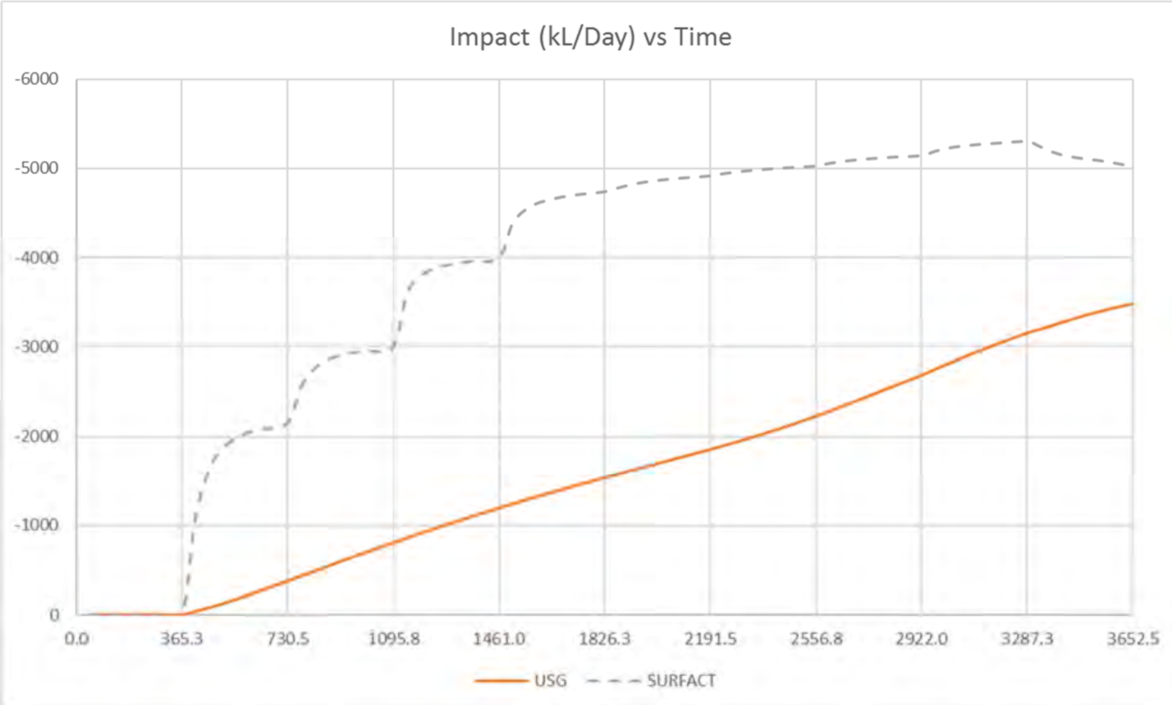
RUN B2 USG VS MS

Mine inflow

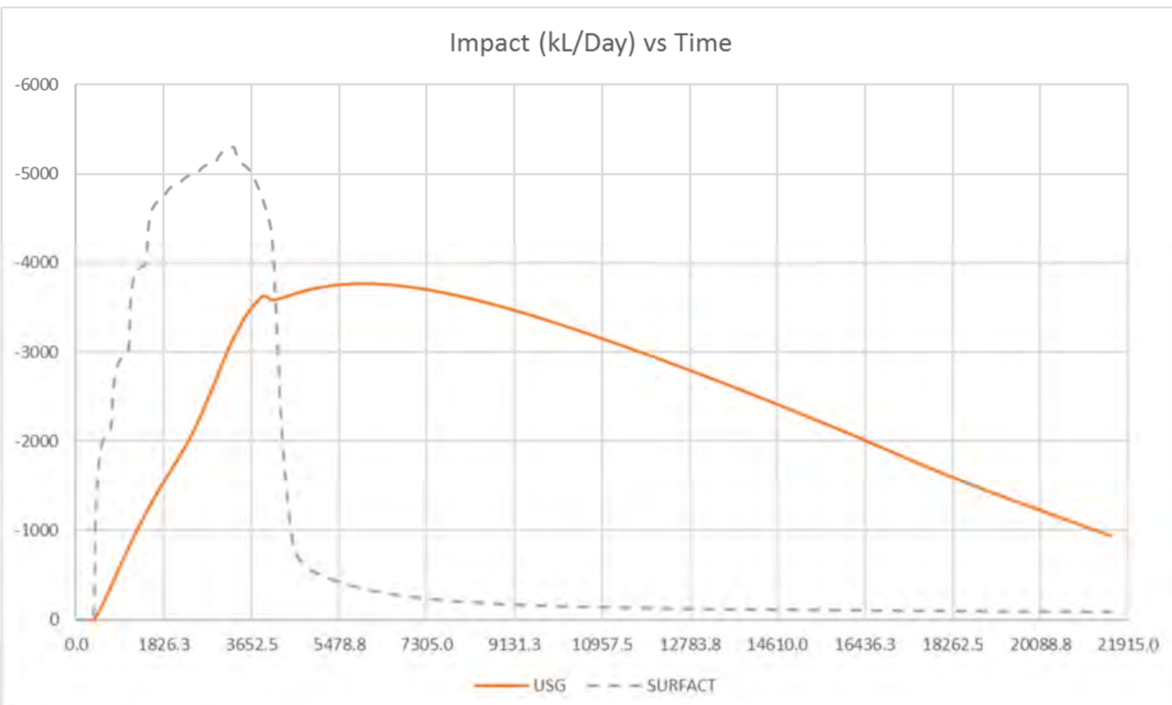




River flux

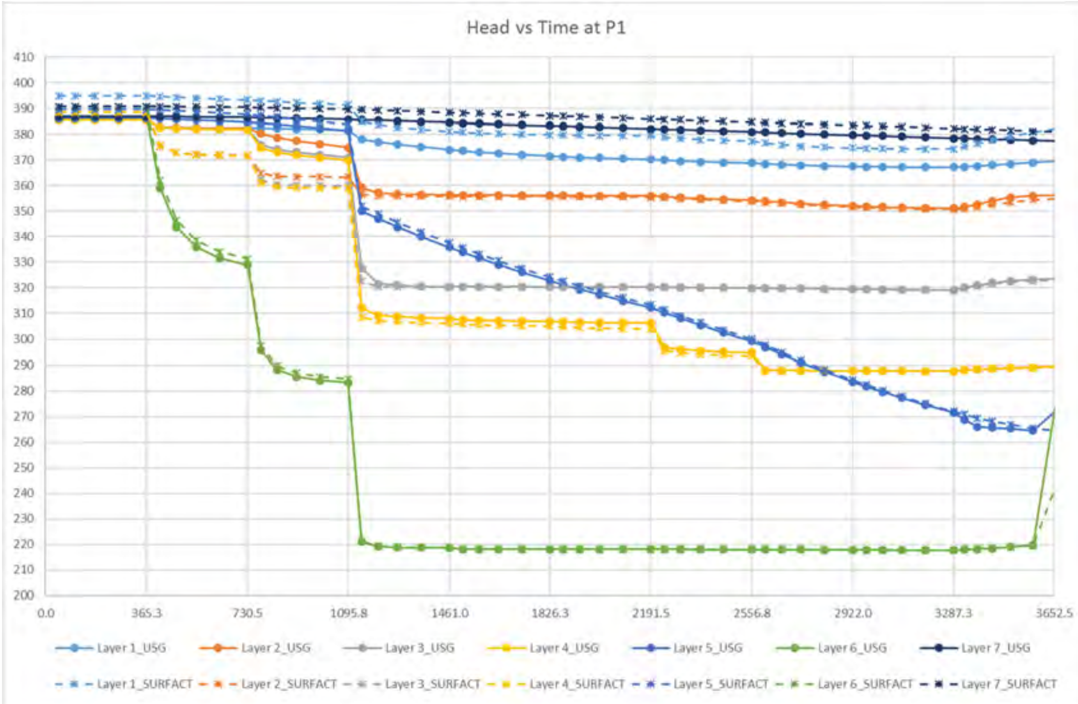


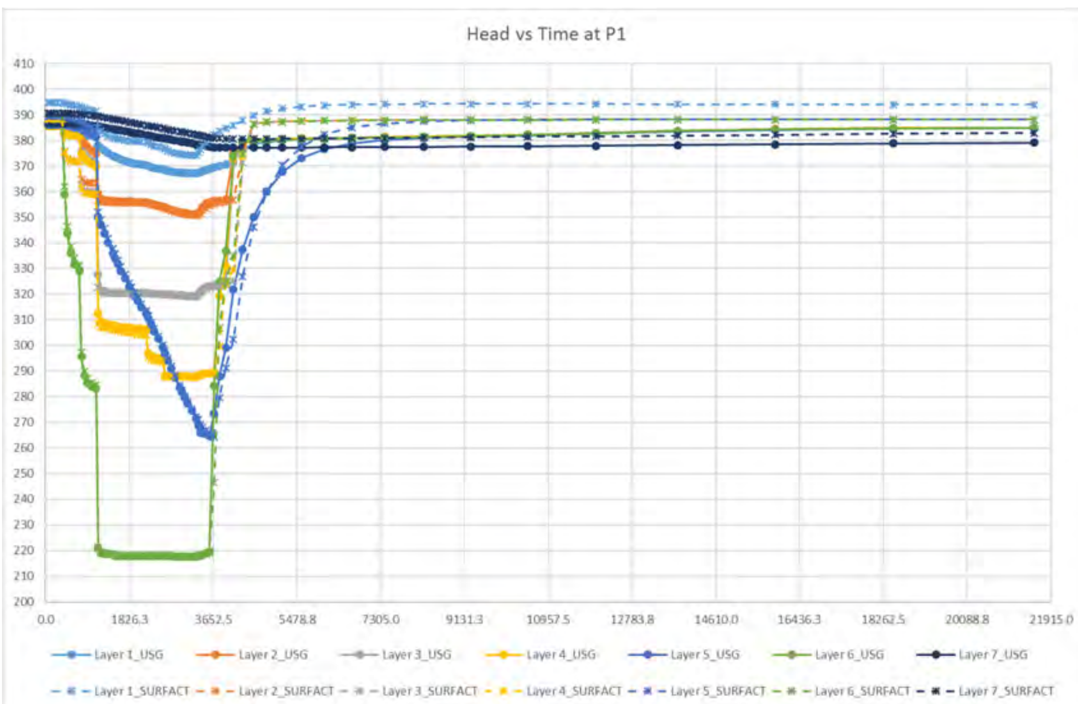
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_B2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9

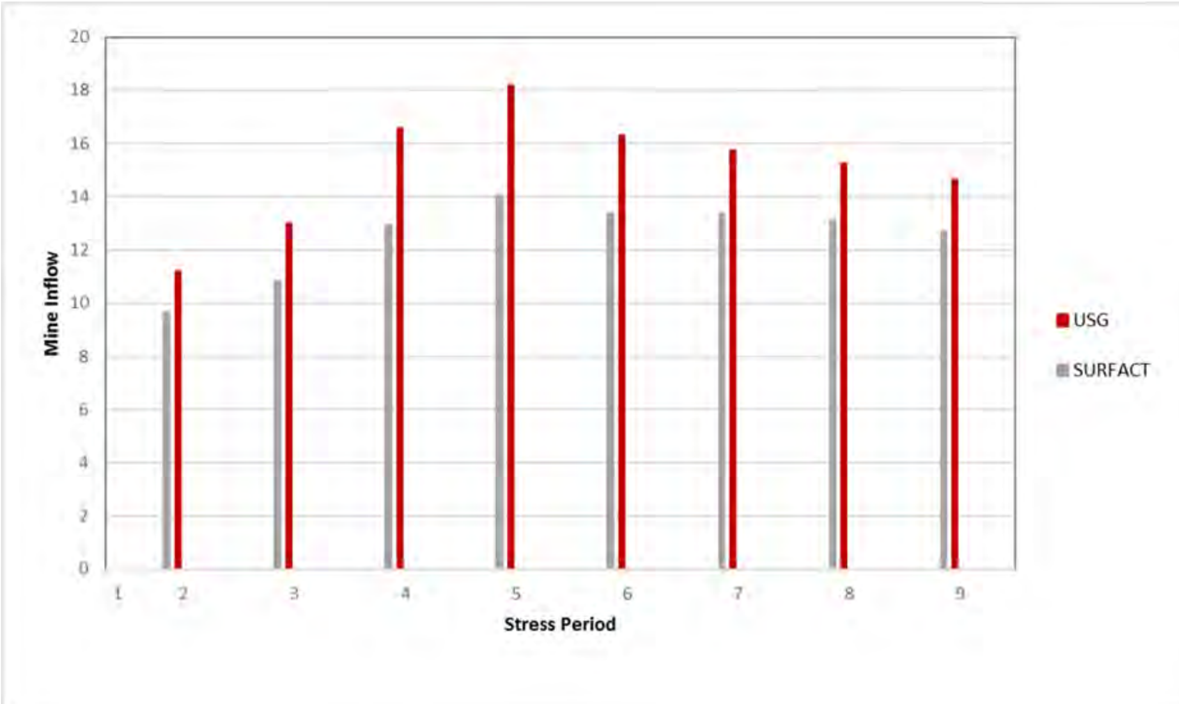
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
-----------	------------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			45884163	5098.24	13.958	13.957	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.85E+08	20515.56	56.169	42.210	
OUT:	OUT:							
----	----							
STORAGE	=			4705.952	0.522884	0.001		
CONSTAN	HEAD	=		42346307	4705.145	12.882		-37.605%
WELLS	=			0	0	0.000		
DRAINS	=			51971247	5774.583	15.810		37.864%
RIVER	LEAKAGE	=		90317754	10035.31	27.475		24.493%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.85E+08	20515.56	56.169	56.167	13.858%
IN	-	OUT	=	6.55E+00	0.000728	0.000	13.957	
PERCENT	DISCREPA	=		0				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9								
SECONDS MINUTES HOURS DAYS YEARS								

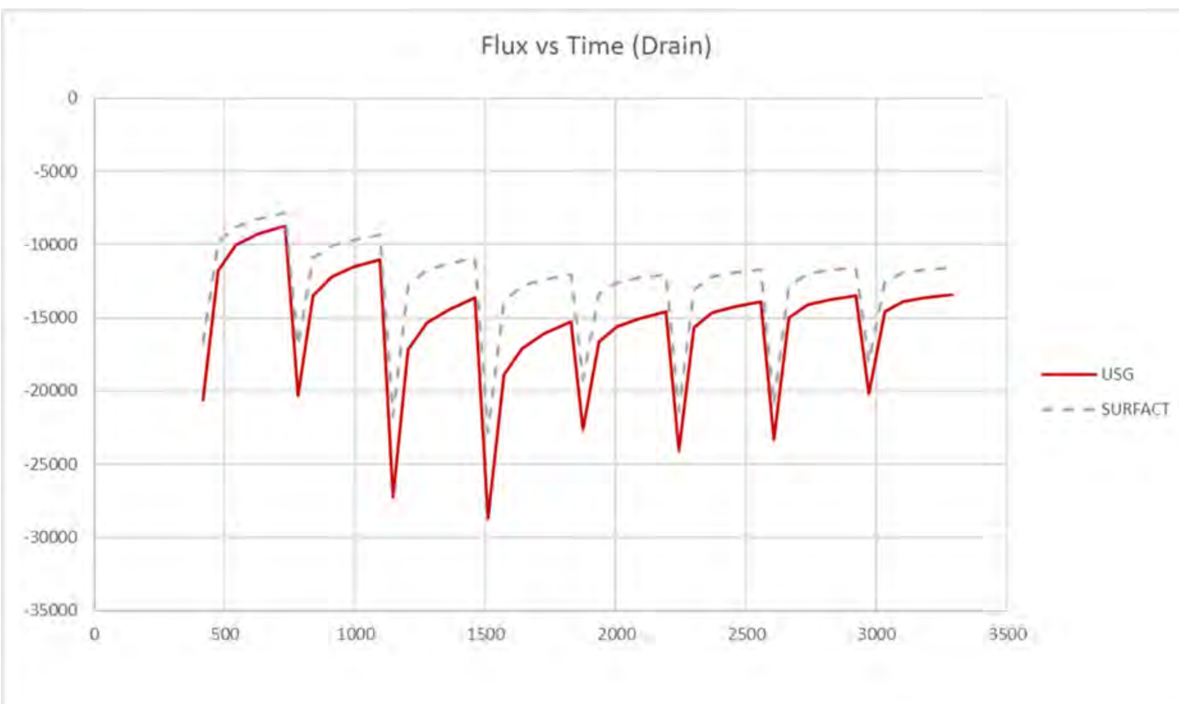
TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865								
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000								
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000								

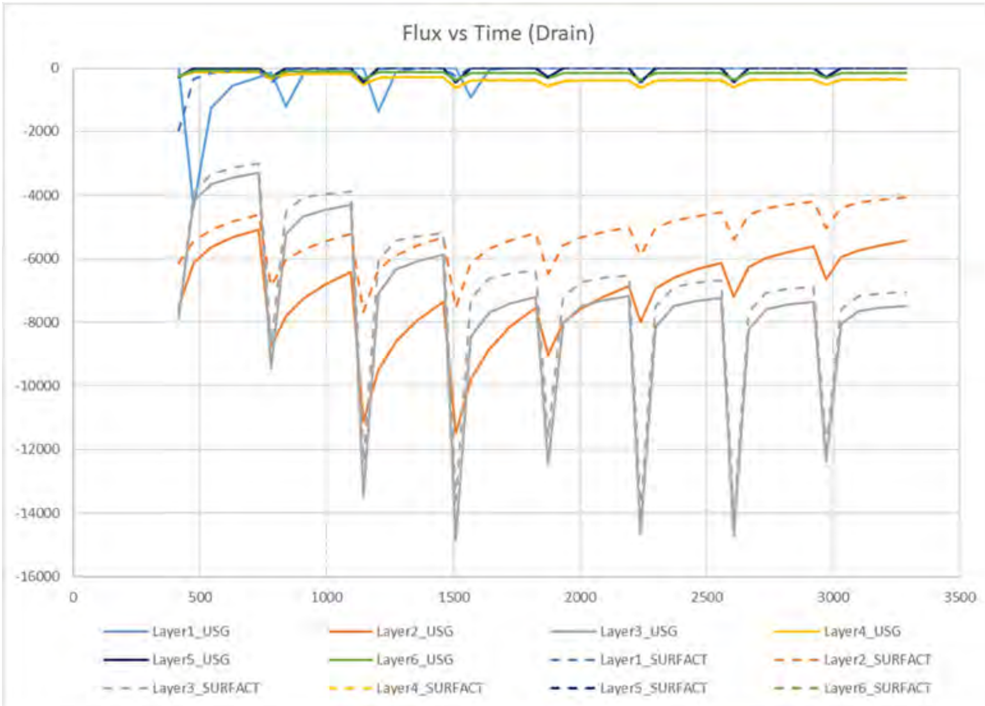
MS_B2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			20310174	2256.686	6.178	6.089
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		0	0	0.000	
TOTAL	IN	=		1.59E+08	17674	48.389	42.210
OUT:	OUT:						
----	----						
STORAGE	=			294117.1	32.67968	0.089	
CONSTAN	HEAD	=		58270440	6474.493	17.726	
WELLS	=			0	0	0.000	
DRAINS	=			32292954	3588.106	9.824	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		68195784	7577.309	20.746	
TOTAL	OUT	=		1.59E+08	17672.59	48.385	48.295
IN	-	OUT	=	12718.88	1.413208	0.004	6.085
PERCENT	DISCREPA	=	0.01				
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							
--							
TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497							
STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000							
TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000							

Mine inflow

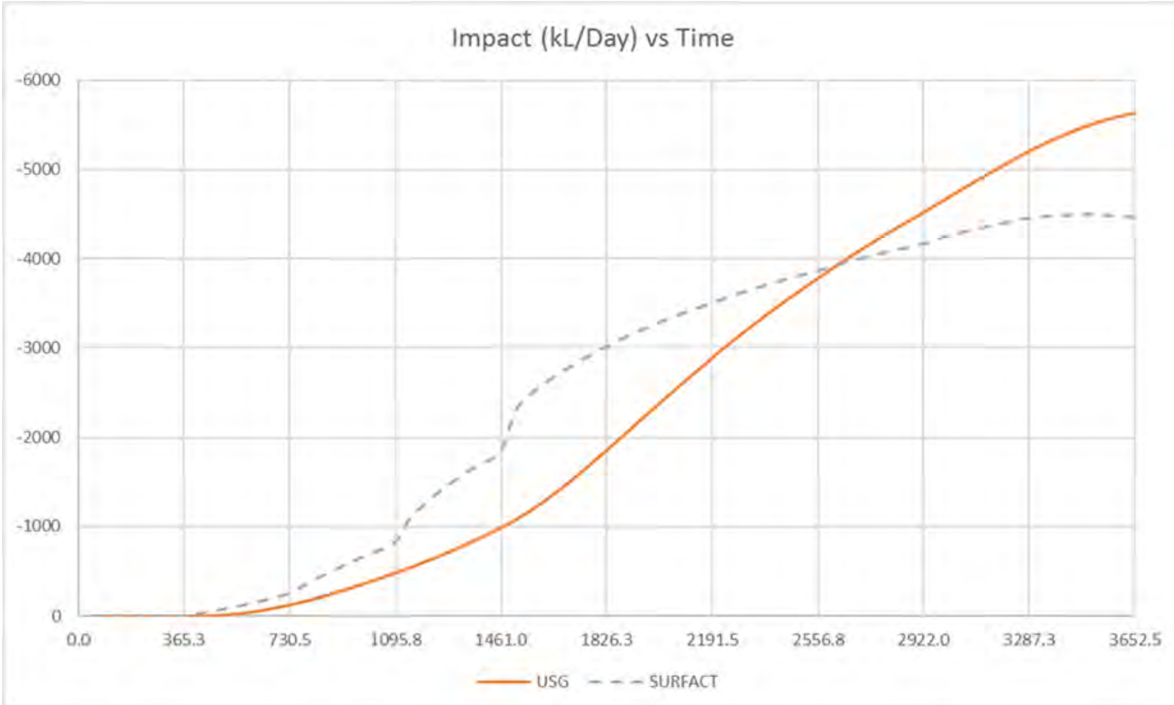

Mine Inflow
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
Stress Period
USG
SURFACT

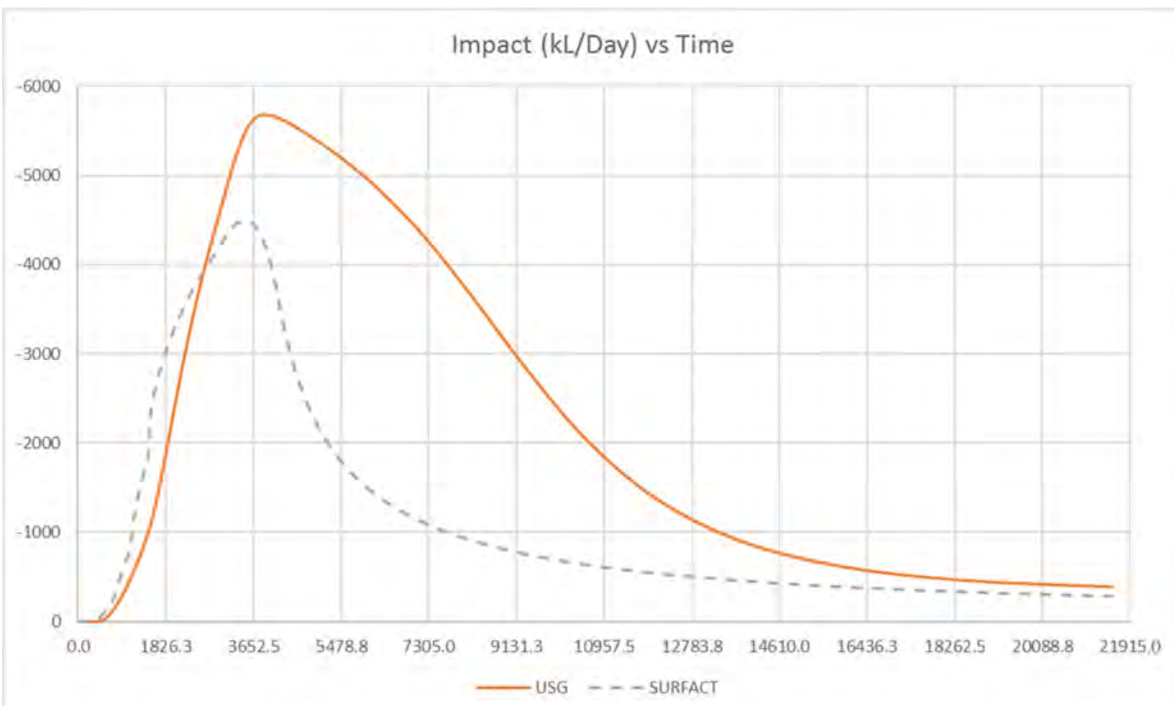

Flux vs Time (Drain)
0
-5000
-10000
-15000
-20000
-25000
-30000
-35000
0
500
1000
1500
2000
2500
3000
3500
USG
SURFACT



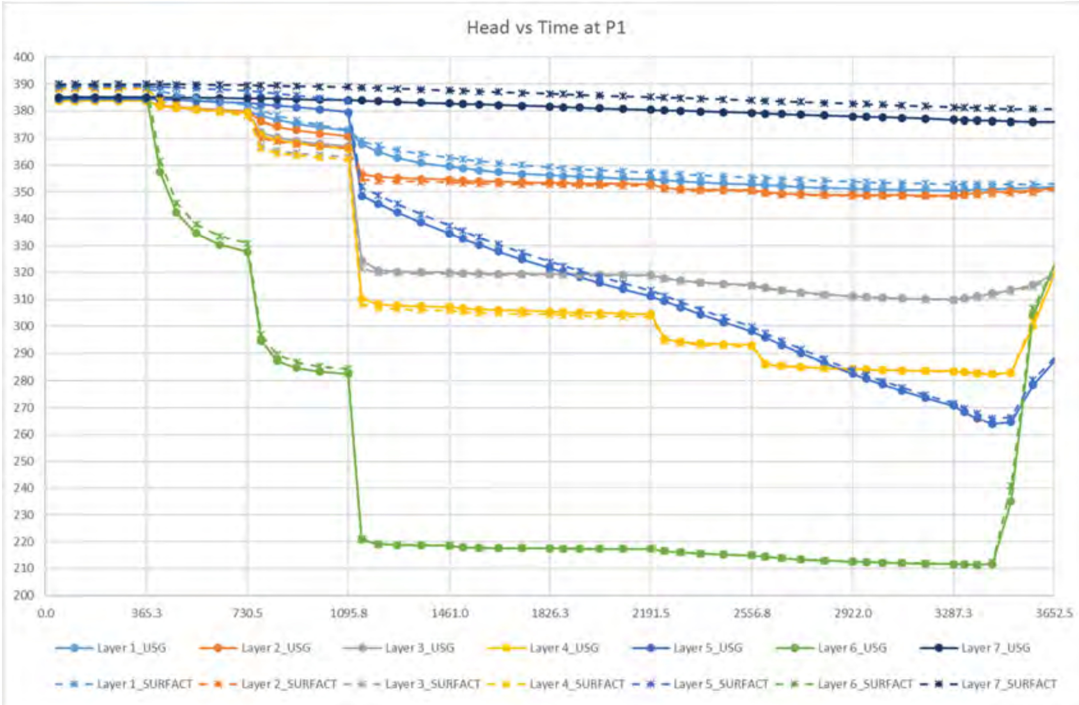
Flux vs Time (Drain)
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
0
500
1000
1500
2000
2500
3000
3500
Layer1_USG
Layer2_USG
Layer3_USG
Layer4_USG
Layer5_USG
Layer6_USG
Layer1_SURFACT
Layer2_SURFACT
Layer3_SURFACT
Layer4_SURFACT
Layer5_SURFACT
Layer6_SURFACT

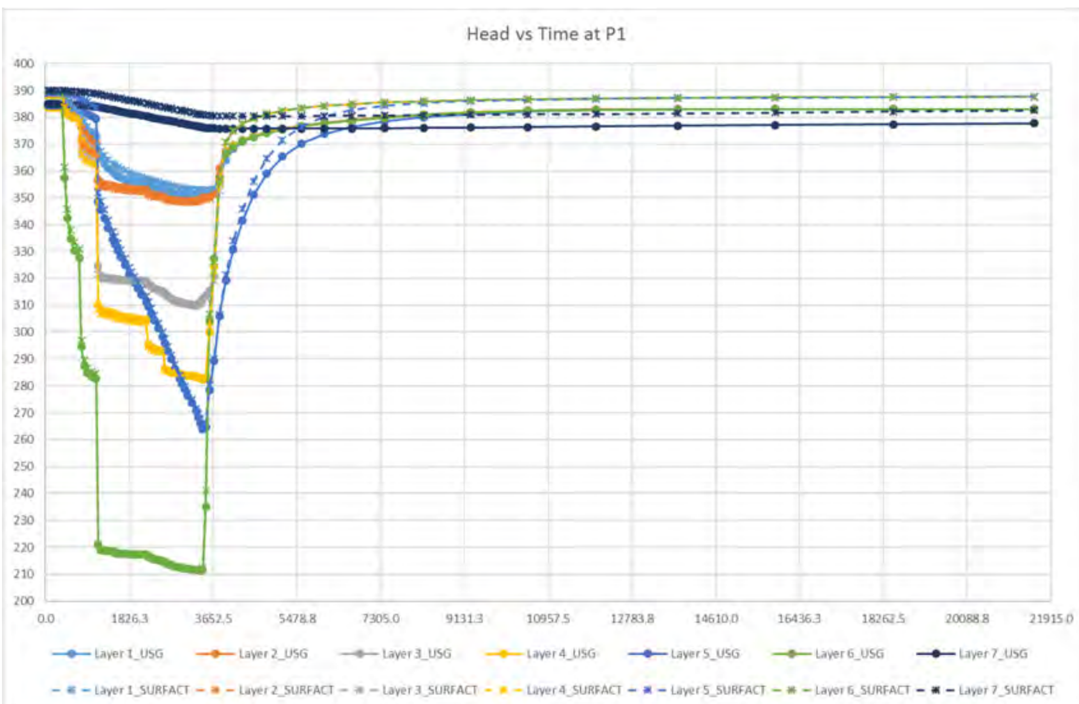
River flux


Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT


Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG_C1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
----------	--------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			36039242	4004.36	10.963	10.963	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		159362.5	17.70695	0.048		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.75E+08	19439.38	53.222	42.259	
OUT:	OUT:							
----	----							
STORAGE	=			830.3702	0.092263	0.000		
CONSTAN	HEAD	=		35032073	3892.453	10.657		-63.643%
WELLS	=			0	0	0.000		
DRAINS	=			44160382	4906.709	13.434		17.223%
RIVER	LEAKAGE	=		95760311	10640.03	29.131		22.527%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.75E+08	19439.29	53.222	53.222	3.810%
IN	-	OUT	=	8.66E+02	0.096192	0.000	10.963	
PERCENT	DISCREPA	=		0				

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

	SECONDS	MINUTES	HOURS	DAYS	YEARS
	------------	------------	------------	------------	------------
TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000

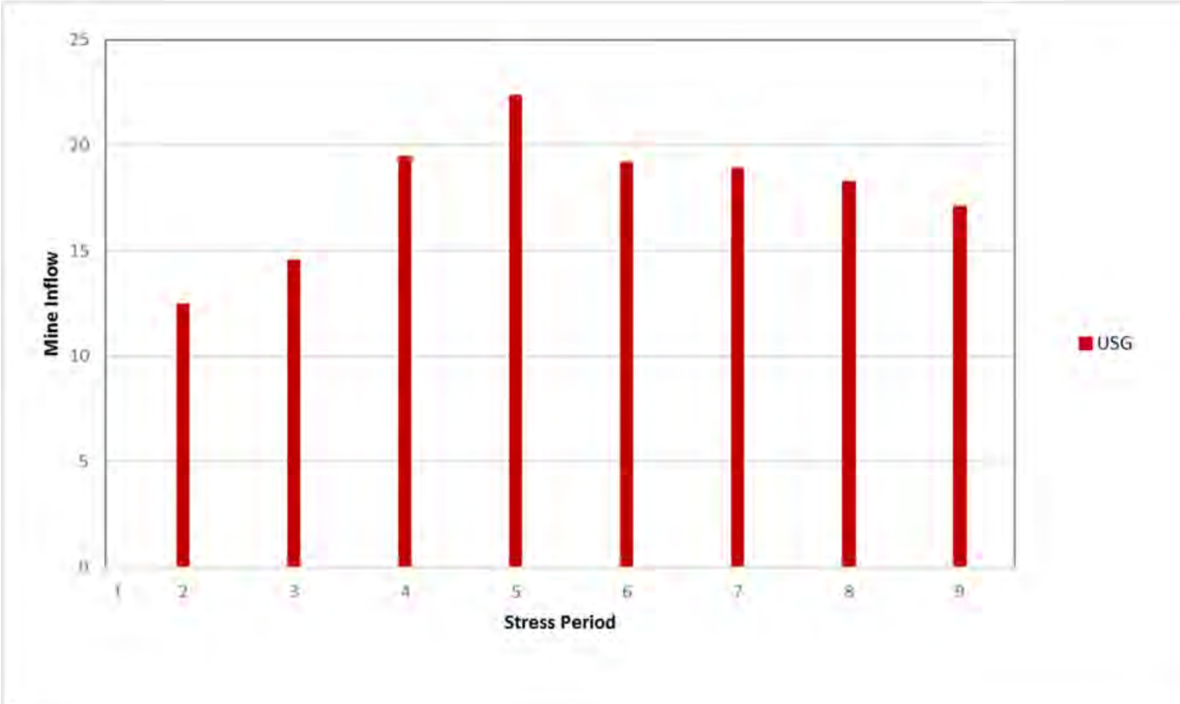
MS_C1

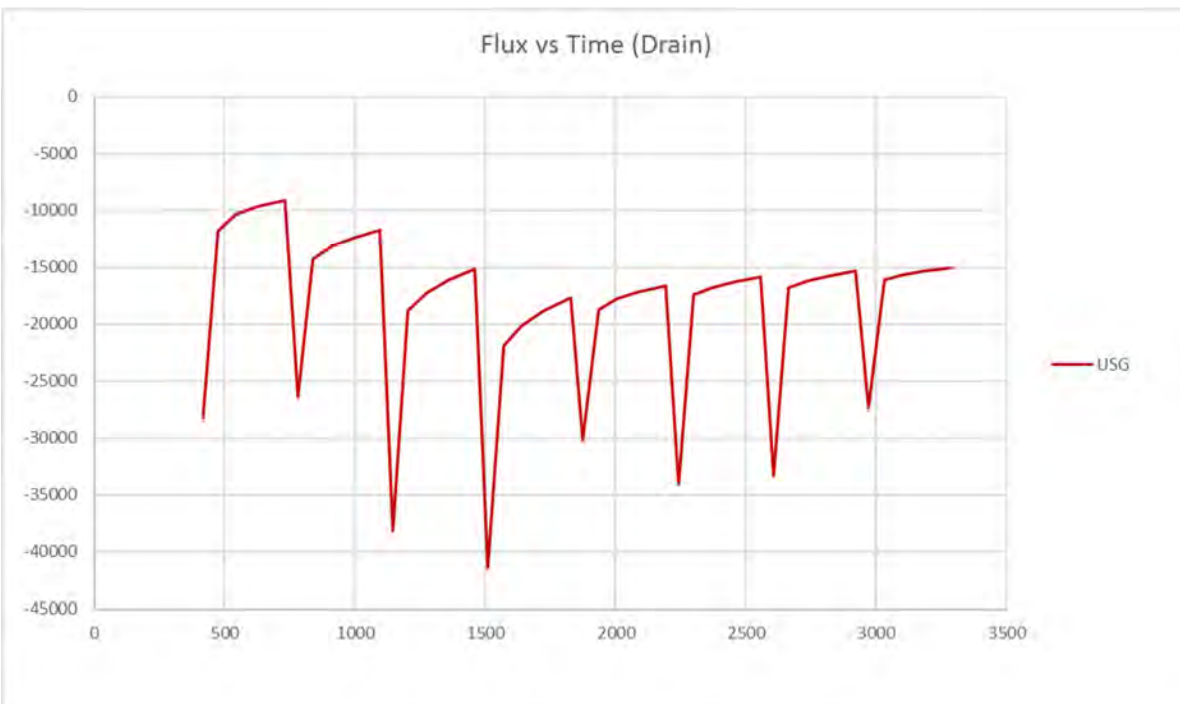
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	
--								
CUMULAT	VOLUMES	L**3						
-----------------								
				m3/9yrs	ML/a	ML/day		
IN:								
---							LOSS	
STORAGE	=			29285000	3253.889	8.909	8.842	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RECHARGI	=			1.39E+08	15417.32	42.210		
RIVER	LEAKAGE	=		227376.2	25.26402	0.069		
TOTAL	IN	=		1.68E+08	18696.47	51.188	42.279	
OUT:	OUT:							
----	----							
STORAGE	=			218010.3	24.22336	0.066		
CONSTAN	HEAD	=		57327376	6369.708	17.439		
WELLS	=			0	0	0.000		
DRAINS	=			36554448	4061.605	11.120		
RECHARGI	=			0	0	0.000		
RIVER	LEAKAGE	=		74188312	8243.146	22.569		
TOTAL	OUT	=		1.68E+08	18698.68	51.194	51.128	
IN	-	OUT	=	-19930.1	-2.21445	-0.006	8.848	
PERCENT	DISCREPA	=	-0.01					

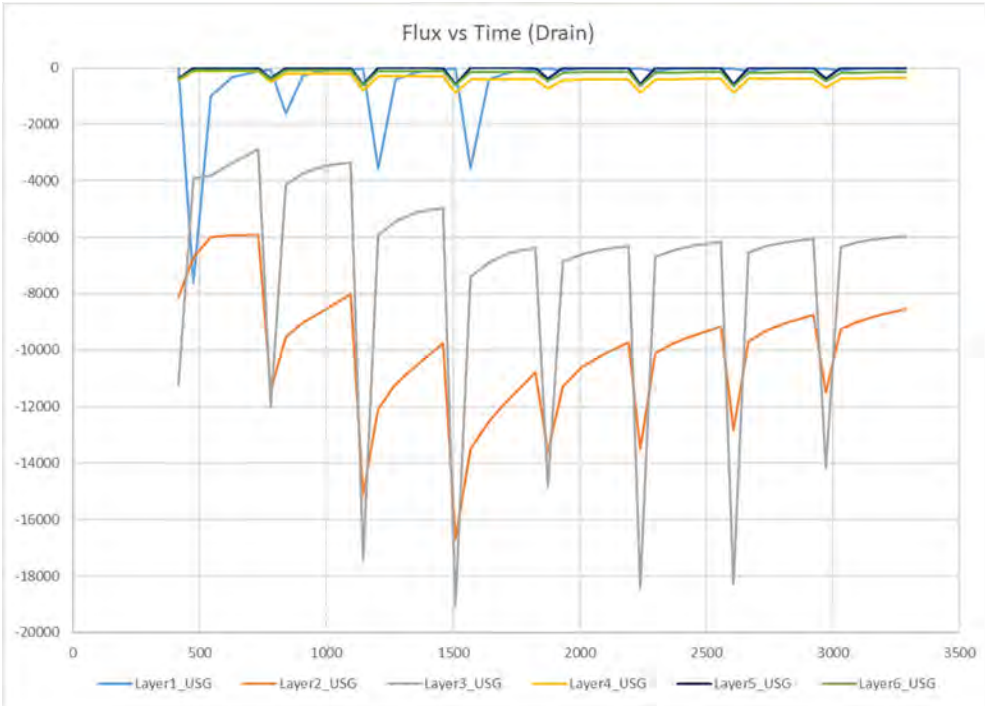
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

	SECONDS	MINUTES	HOURS	DAYS	YEARS
	------------	------------	------------	------------	------------
TIME STEP LENGTH	8793517.	146558.6	2442.644	101.7768	0.2786497
STRESS PERIOD TIME	3.1557600E+07	525960.0	8766.000	365.2500	1.000000
TOTAL TIME	2.8401840E+08	4733640.	78894.00	3287.250	9.000000

RUN C2 USG (MS failed to converge)

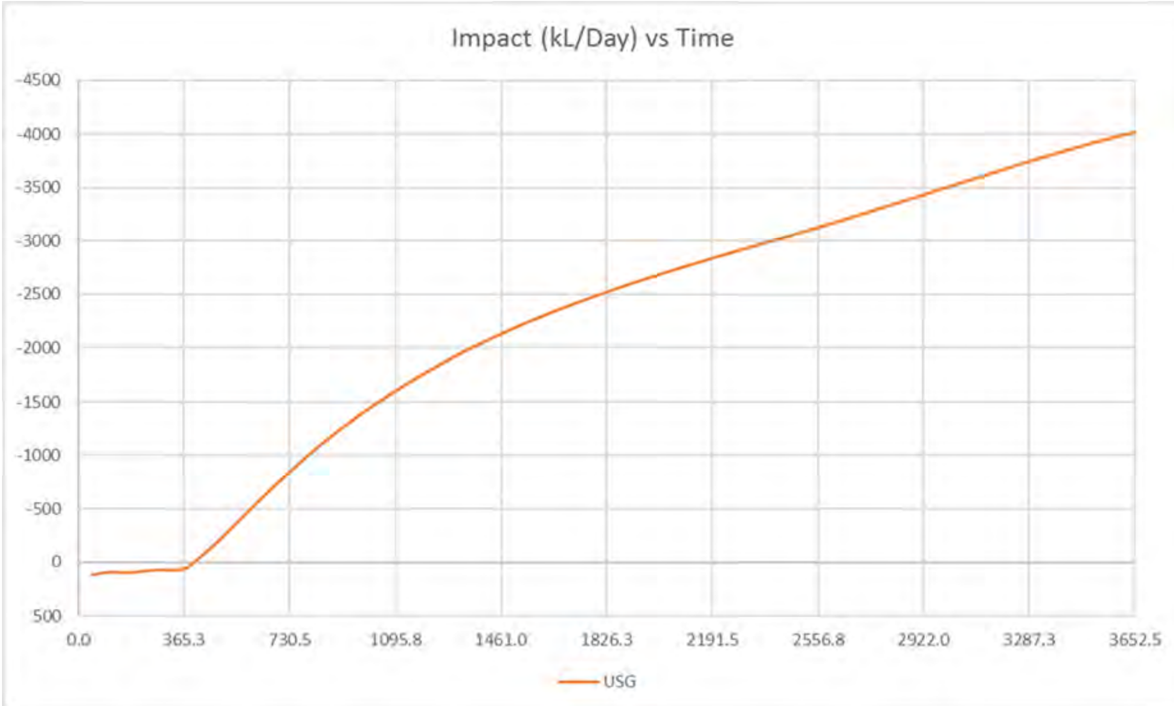


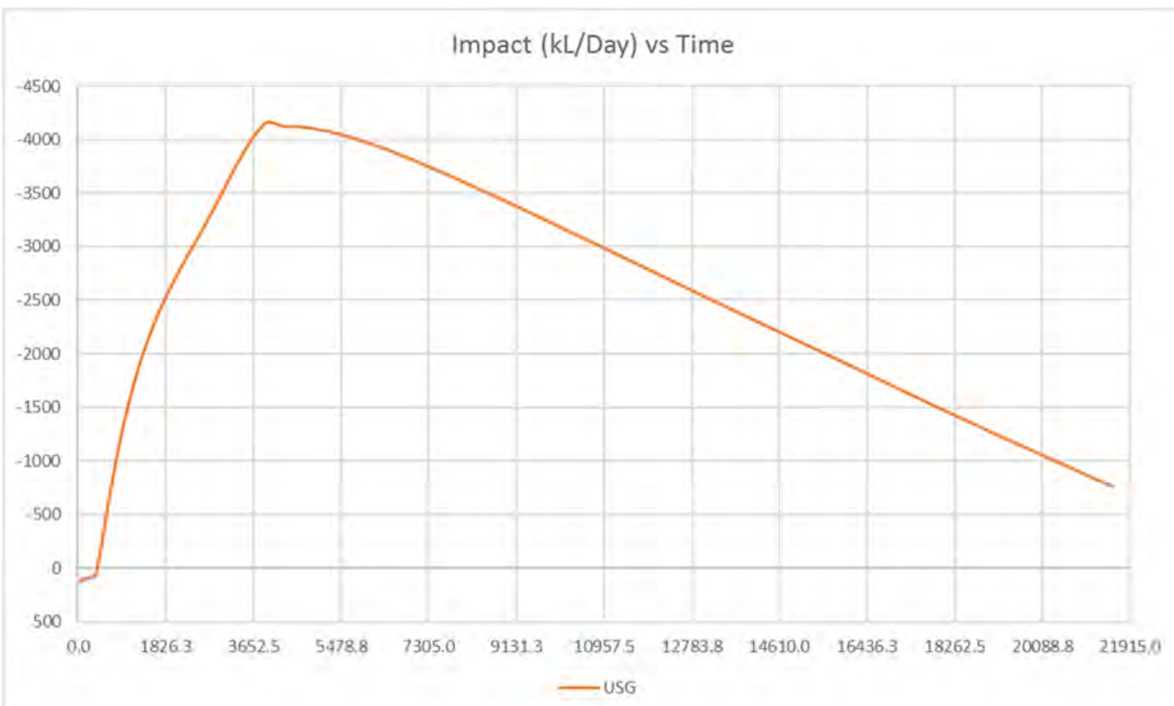




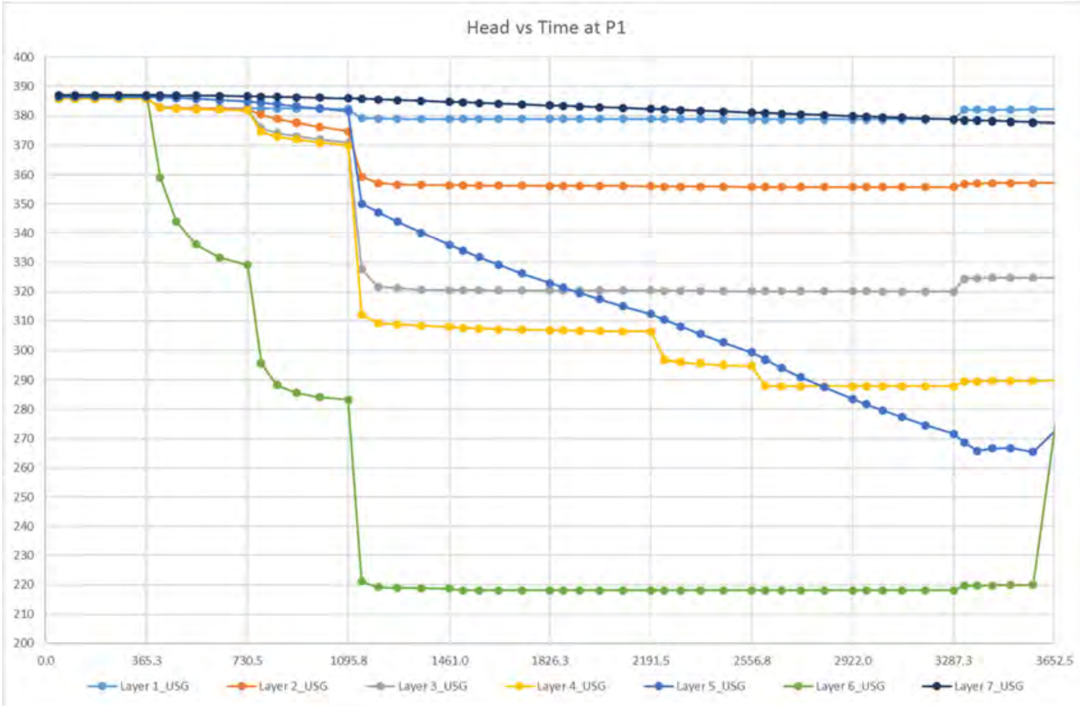
Flux vs Time (Drain)
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
-20000
0
500
1000
1500
2000
2500
3000
3500
Layer1_USG
Layer2_USG
Layer3_USG
Layer4_USG
Layer5_USG
Layer6_USG

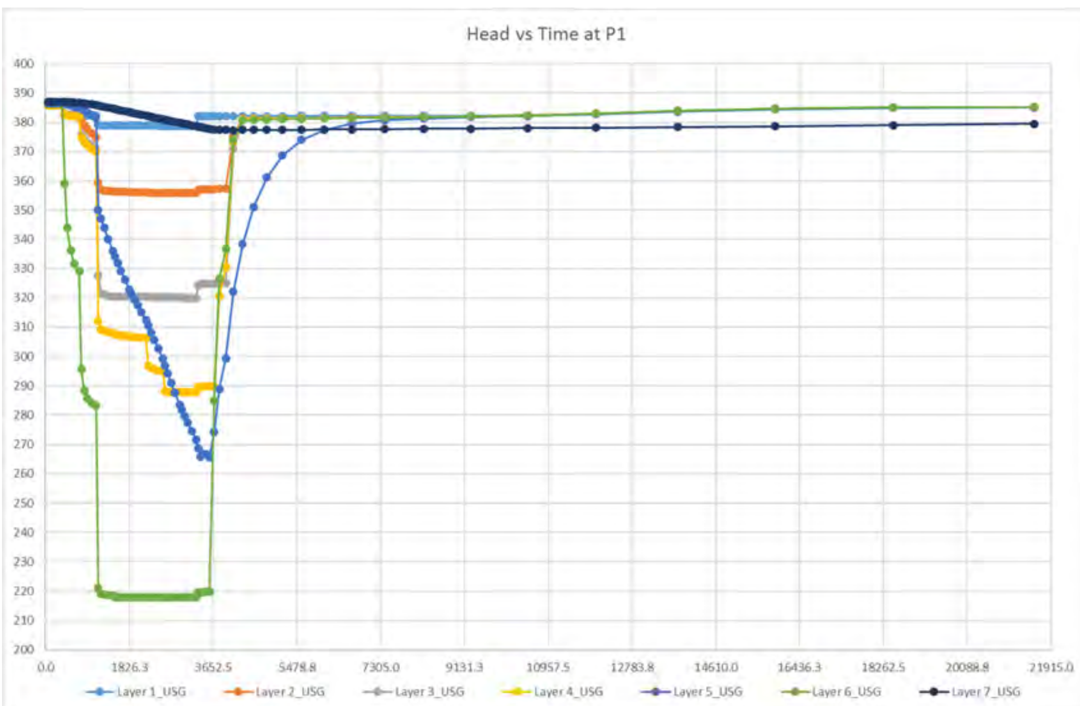
River flux


Impact (kL/Day) vs Time
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG


Impact (kL/Day) vs Time
-4500
-4000
-3500
-3000
-2500
-2000
-1500
-1000
-500
0
500
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG

Hydrographs





Water balance

USG_C2

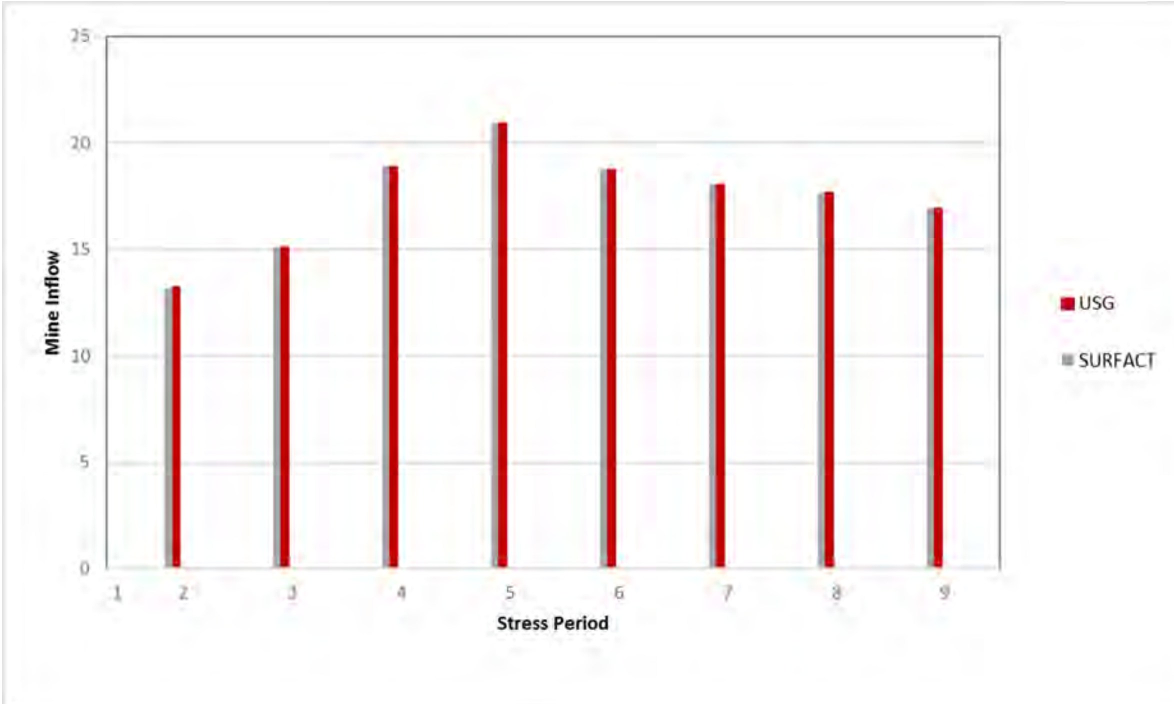
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF TIME STEP 5 IN STRESS PERIOD 9
CUMULAT	VOLUMES	L**3					
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			43579823	4842.203	13.257	13.257
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.82E+08	20259.52	55.468	42.210
OUT:	OUT:						
----	----						
STORAGE	=			1421.176	0.157908	0.000	
CONSTAN	HEAD	=		42876744	4764.083	13.043	
WELLS	=			0	0	0.000	
DRAINS	=			51930189	5770.021	15.797	
RIVER	LEAKAGE	=		87526934	9725.215	26.626	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.82E+08	20259.48	55.467	55.467
IN	-	OUT	=	3.92E+02	0.043596	0.000	13.257
PERCENT	DISCREPA	=		0			

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9					
	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000

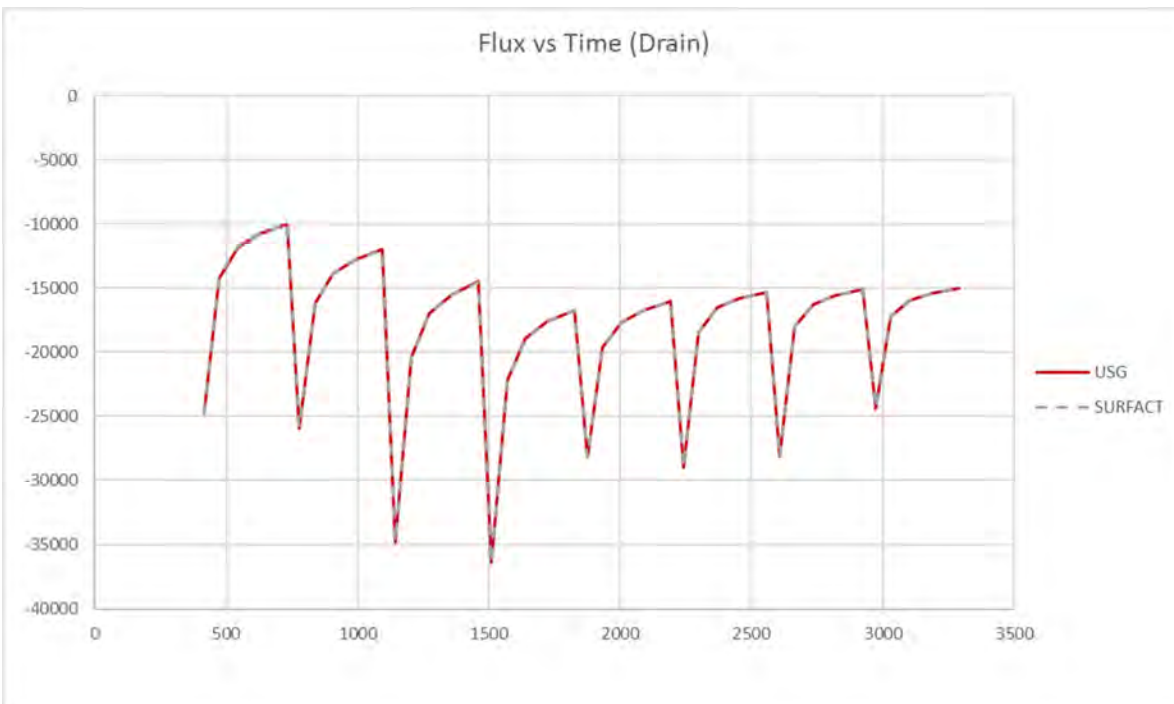
APPENDIX C2

OPEN CUT: MS_PSEUDO AND USG_PSEUDO

Mine inflow

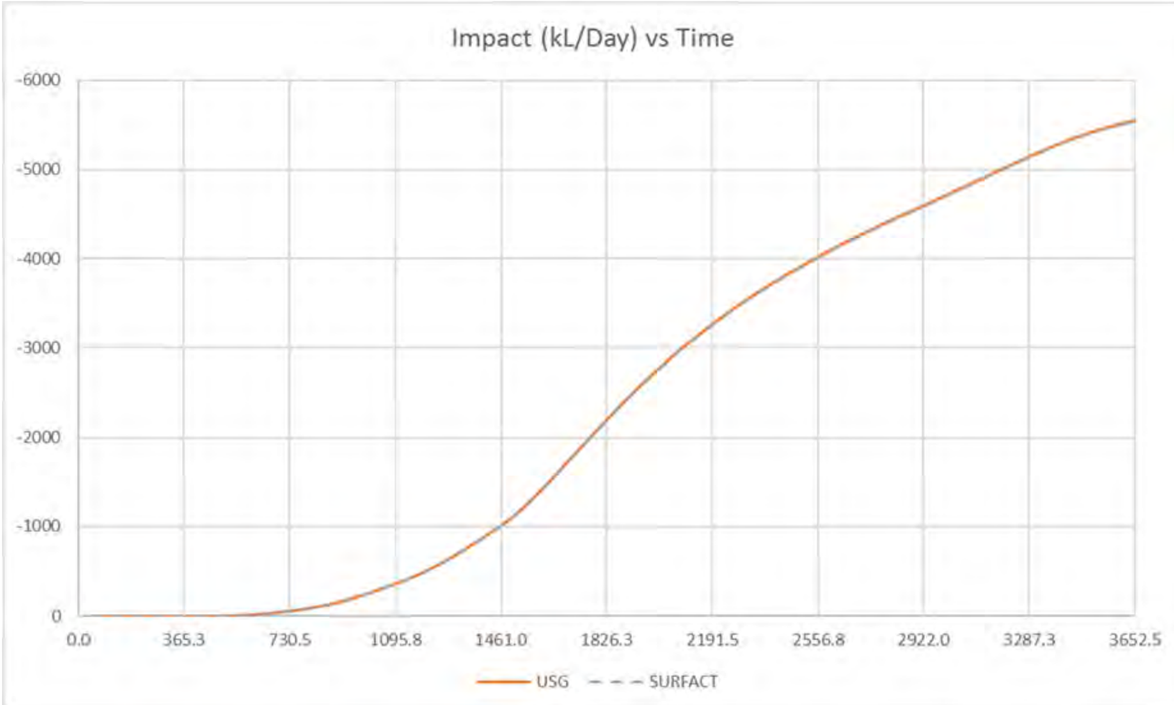


Mine Inflow
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
Stress Period
USG
SURFACT

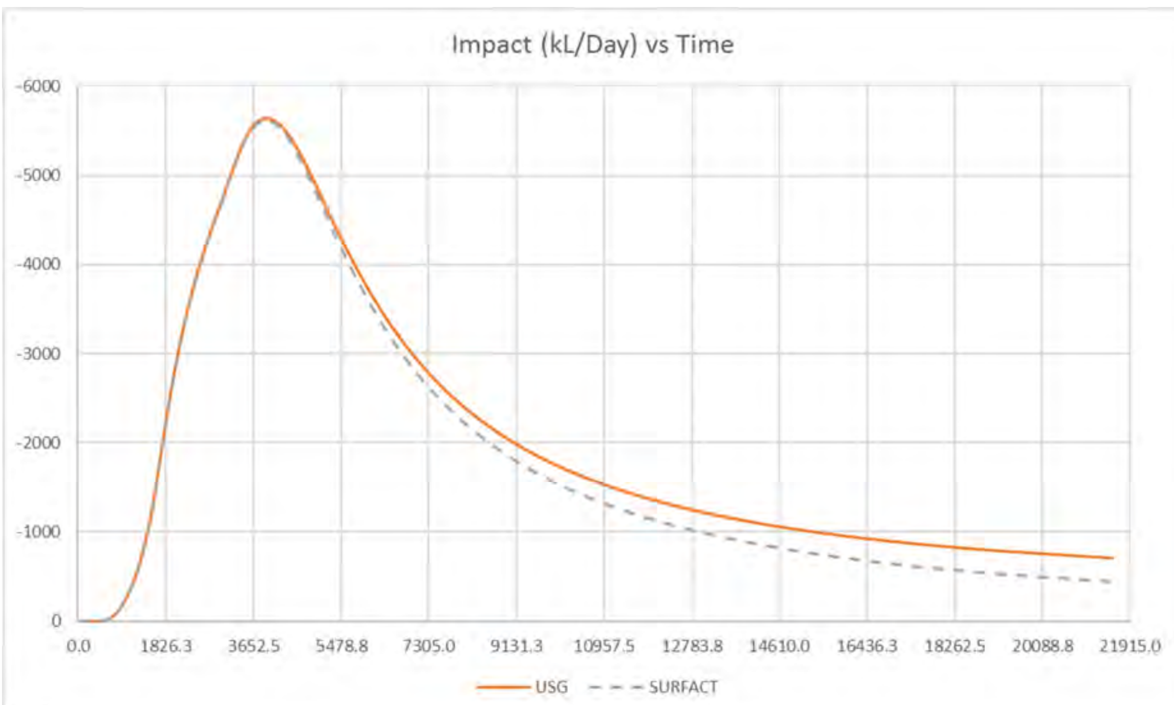


Flux vs Time (Drain)
0
-5000
-10000
-15000
-20000
-25000
-30000
-35000
-40000
0
500
1000
1500
2000
2500
3000
3500
USG
SURFACT

River flux

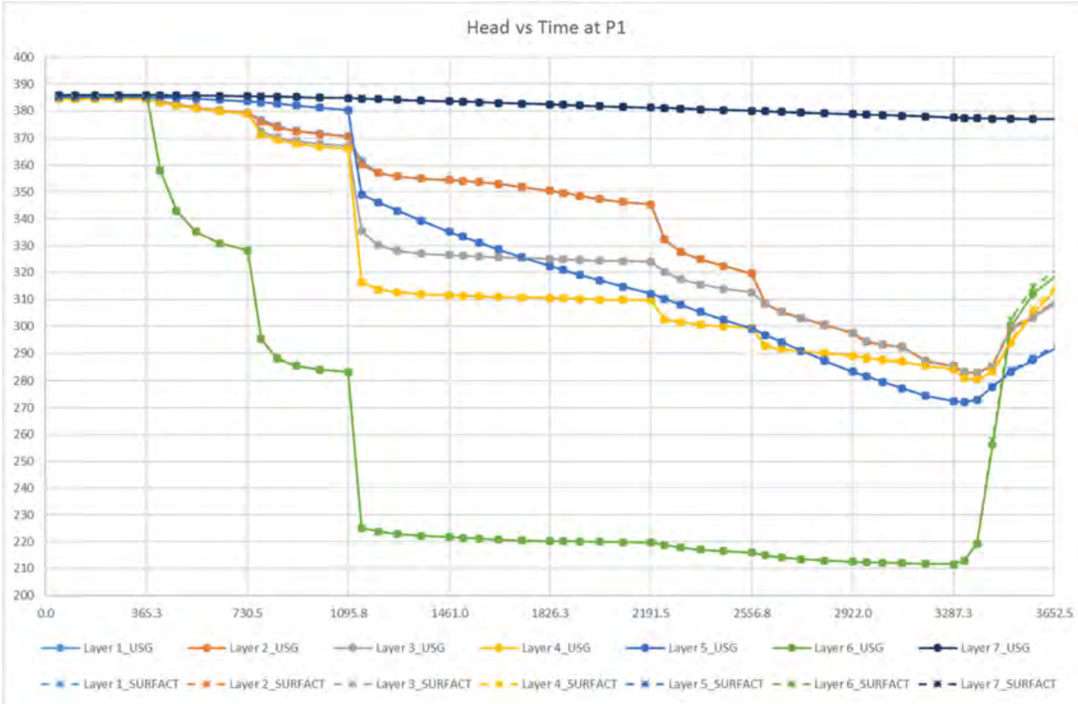


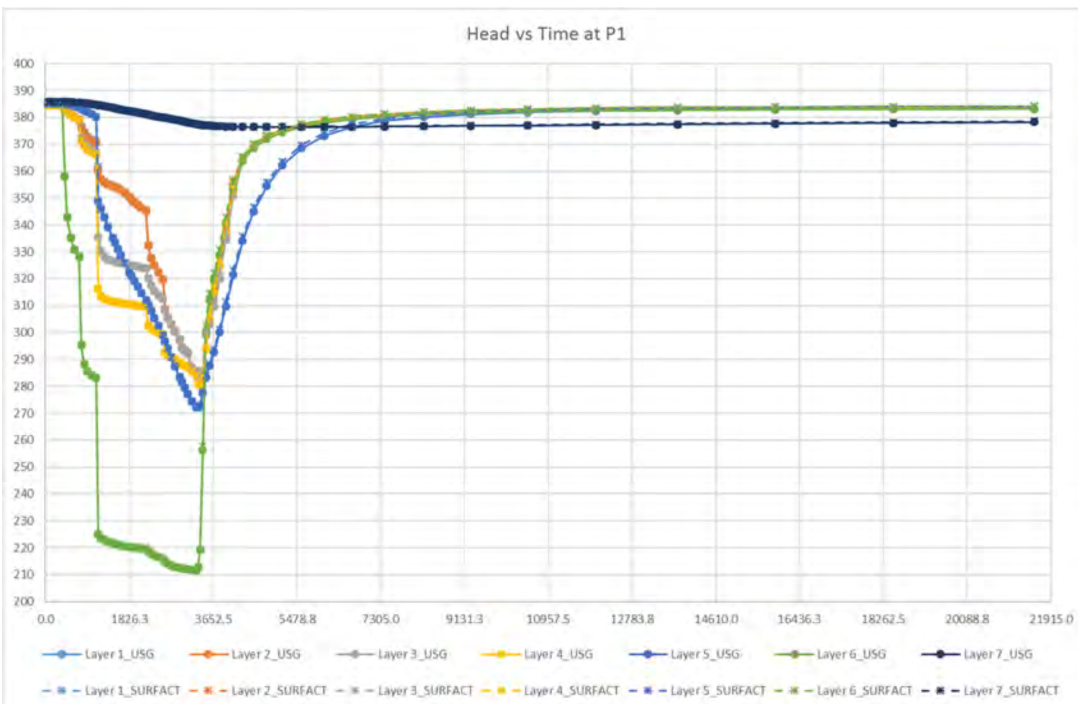
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
SURFACT



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
SURFACT

Hydrographs





Water balance

USG

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9

CUMULAT	VOLUMES	L**3						DIFF(USG&SURFACT)
-----------	----------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			44116399	4901.822	13.420	13.419	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		577328.5	64.14762	0.176		
RECHARGI	=			1.39E+08	15417.32	42.210		0.00%
TOTAL	IN	=		1.83E+08	20383.29	55.806	42.386	
OUT:	OUT:							
----	----							
STORAGE	=			4308.219	0.478691	0.001		
CONSTAN	HEAD	=		43301218	4811.246	13.172		-0.05%
WELLS	=			0	0	0.000		
DRAINS	=			50908860	5656.54	15.487		0.00%
RIVER	LEAKAGE	=		89235194	9915.022	27.146		0.01%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.83E+08	20383.29	55.806	55.805	-0.12%
IN	-	OUT	=	4.1626	0.000463	0.000	13.419	
PERCENT	DISCREPA	=		0				

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9
SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000

MS

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF

CUMULAT	VOLUMES	L**3					
-----------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			44379204	4931.023	13.500	13.437
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		566202.5	62.91139	0.172	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.84E+08	20411.25	55.883	42.383
OUT:	OUT:						
----	----						
STORAGE	=			208502.7	23.16697	0.063	
CONSTAN	HEAD	=		43322228	4813.581	13.179	
WELLS	=			0	0	0.000	
DRAINS	=			50911068	5656.785	15.487	
RIVER	LEAKAGE	=		89223160	9913.684	27.142	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.84E+08	20407.22	55.872	55.808
IN	-	OUT	=	36287.8	4.031977	0.011	13.426
PERCENT	DISCREPA	=	0.02				

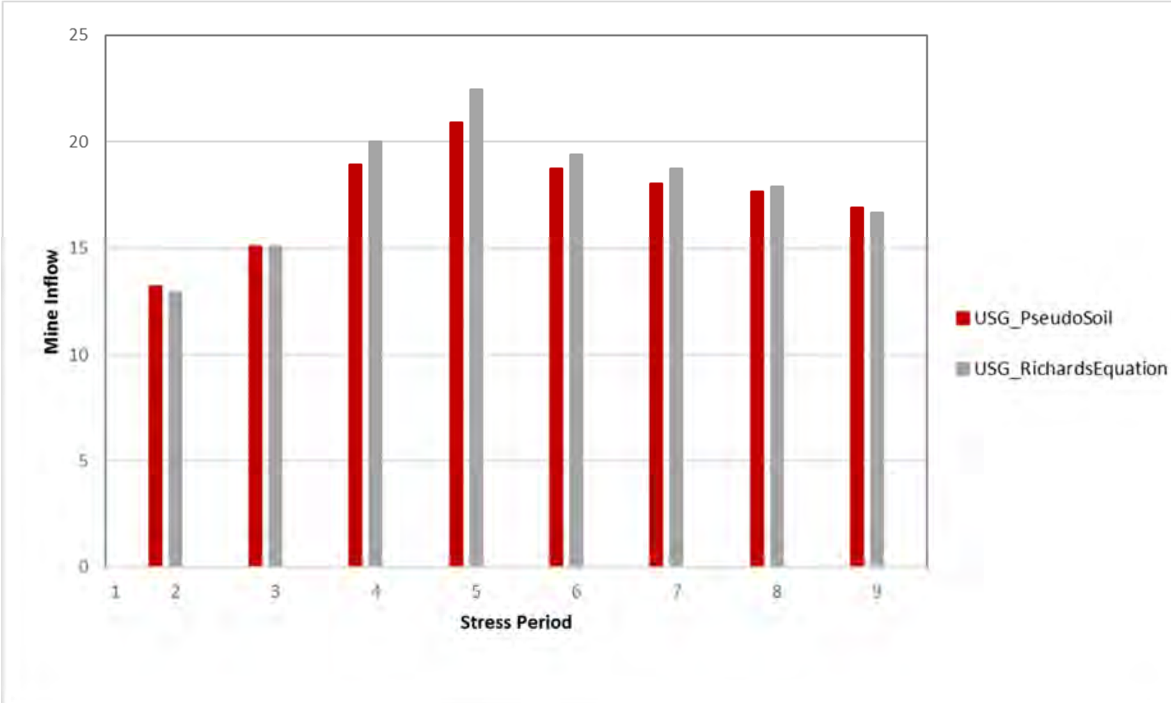
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9
SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8793517. 146558.6 2442.644 101.7768 0.2786497
STRESS PERIOD TIME 3.1557600E+07 525960.0 8766.000 365.2500 1.000000
TOTAL TIME 2.8401840E+08 4733640. 78894.00 3287.250 9.000000

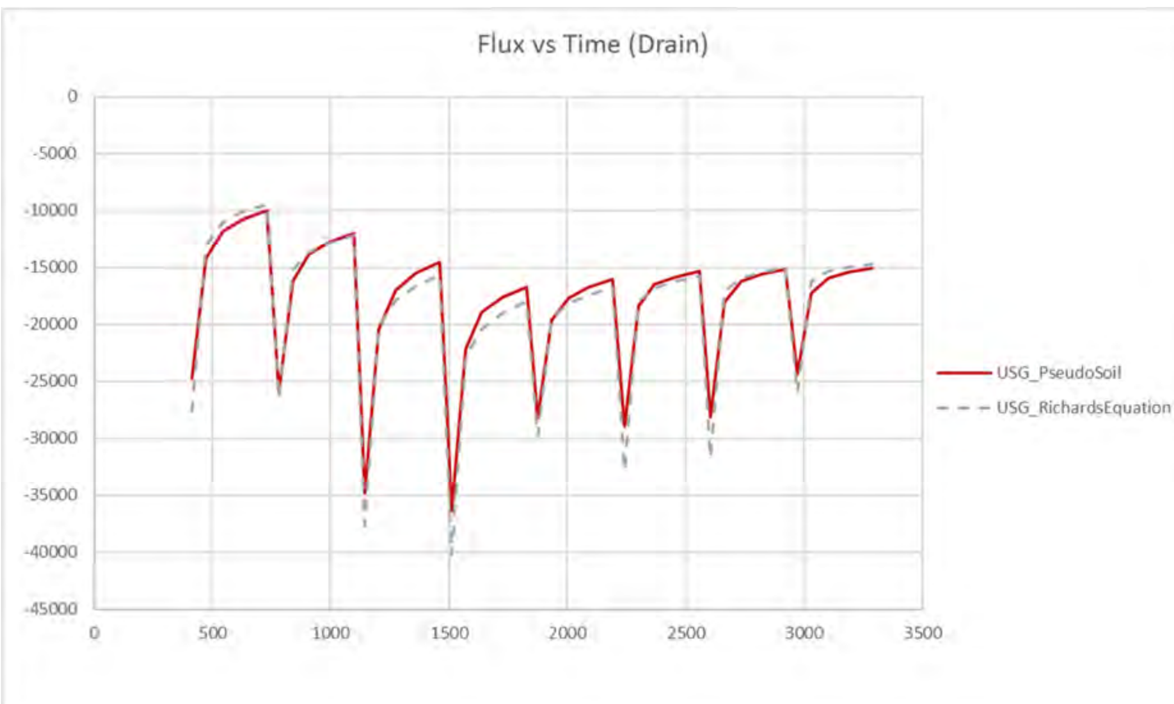
APPENDIX C3

OPEN CUT: USG_VADOSE AND USG_PSEUDO

Mine inflow

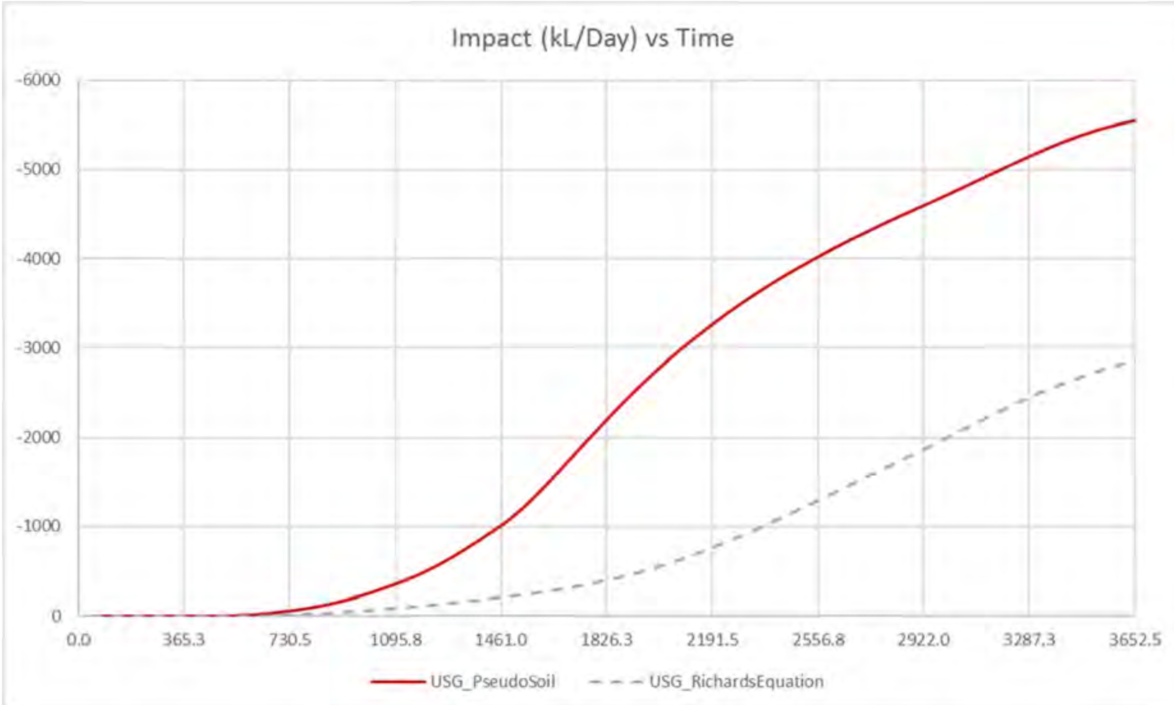


25
20
15
10
5
0
Mine Inflow
1
2
3
4
5
6
7
8
9
Stress Period
USG_PseudoSoil
USG_RichardsEquation

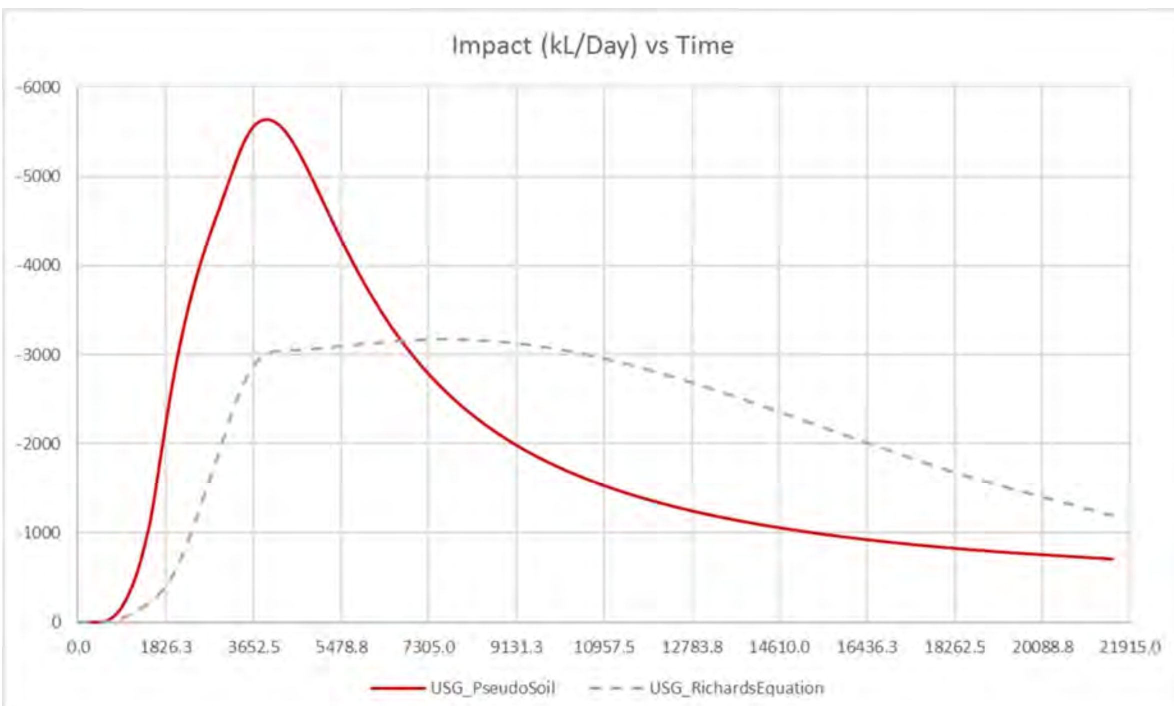


Flux vs Time (Drain)
0
-5000
-10000
-15000
-20000
-25000
-30000
-35000
-40000
-45000
0
500
1000
1500
2000
2500
3000
3500
USG_PseudoSoil
USG_RichardsEquation

River flux

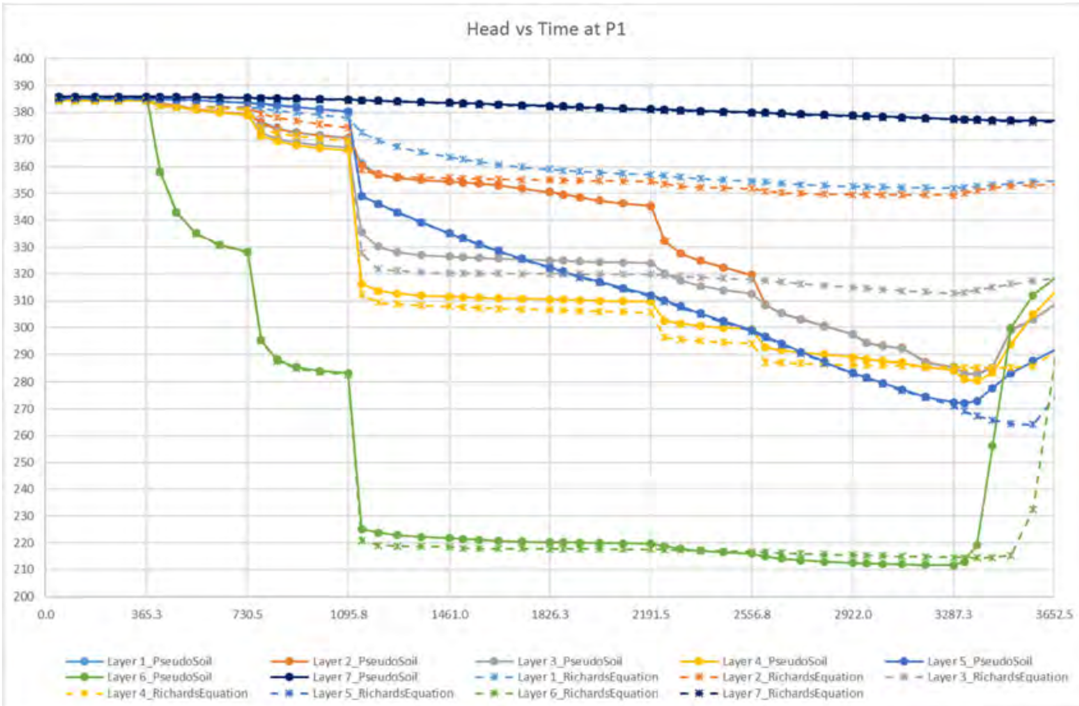


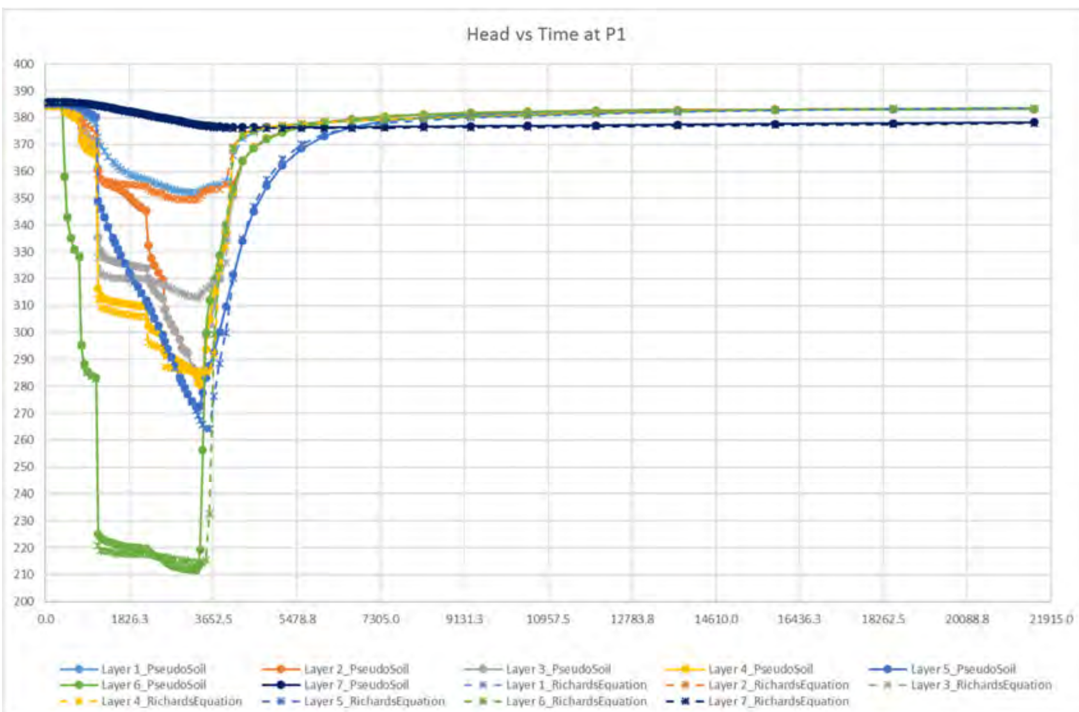
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_PseudoSoil
USG_RichardsEquation



Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_PseudoSoil
USG_RichardsEquation

Hydrographs





Water Balance

USG_Pseudo-Soil

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9
--								
CUMULAT	VOLUMES	L**3						DIFF(USG_PseudoSoil&USG_RichardsEquation)
------------	------------------------							
				m3/9yrs	ML/a	ML/day		
IN:	IN:							
---	---						LOSS	
STORAGE	=			44116399	4901.822	13.420	13.419	
CONSTAN	HEAD	=		0	0	0.000		
WELLS	=			0	0	0.000		
DRAINS	=			0	0	0.000		
RIVER	LEAKAGE	=		577328.5	64.14762	0.176		
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%
TOTAL	IN	=		1.83E+08	20383.29	55.806	42.386	
OUT:	OUT:							
----	----							
STORAGE	=			4308.219	0.478691	0.001		
CONSTAN	HEAD	=		43301218	4811.246	13.172		12.807%
WELLS	=			0	0	0.000		
DRAINS	=			50908860	5656.54	15.487		-2.645%
RIVER	LEAKAGE	=		89235194	9915.022	27.146		-9.249%
RECHARGI	=			0	0	0.000		
TOTAL	OUT	=		1.83E+08	20383.29	55.806	55.805	-2.209%
IN	-	OUT	=	4.1626	0.000463	0.000	13.419	
PERCENT	DISCREPA	=		0				
TIME SUMMARY AT END OF TIME STEP			5 IN STRESS PERIOD			9		
	SECONDS	MINUTES	HOURS	DAYS	YEARS			
	--							
TIME STEP LENGTH	8.79352E+06	1.46559E+05	2442.6	101.78	0.27865			
STRESS PERIOD TIME	3.15576E+07	5.25960E+05	8766.0	365.25	1.0000			
TOTAL TIME	2.84018E+08	4.73364E+06	78894.	3287.2	9.0000			

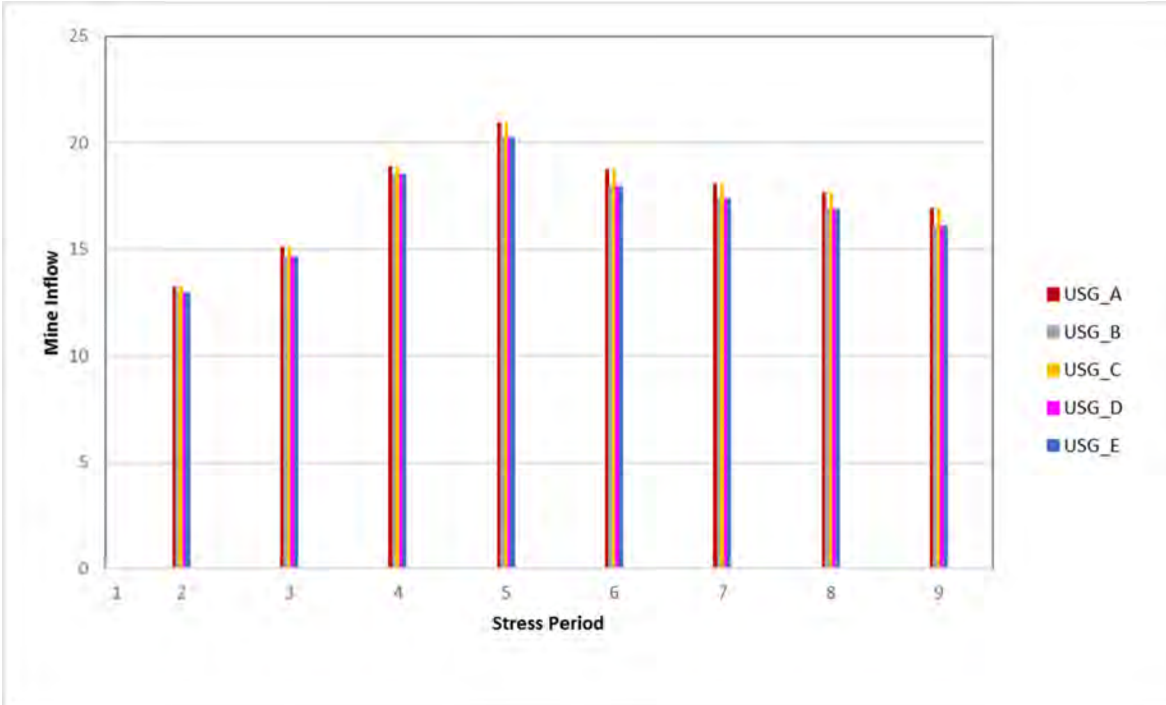
USG_Vadose

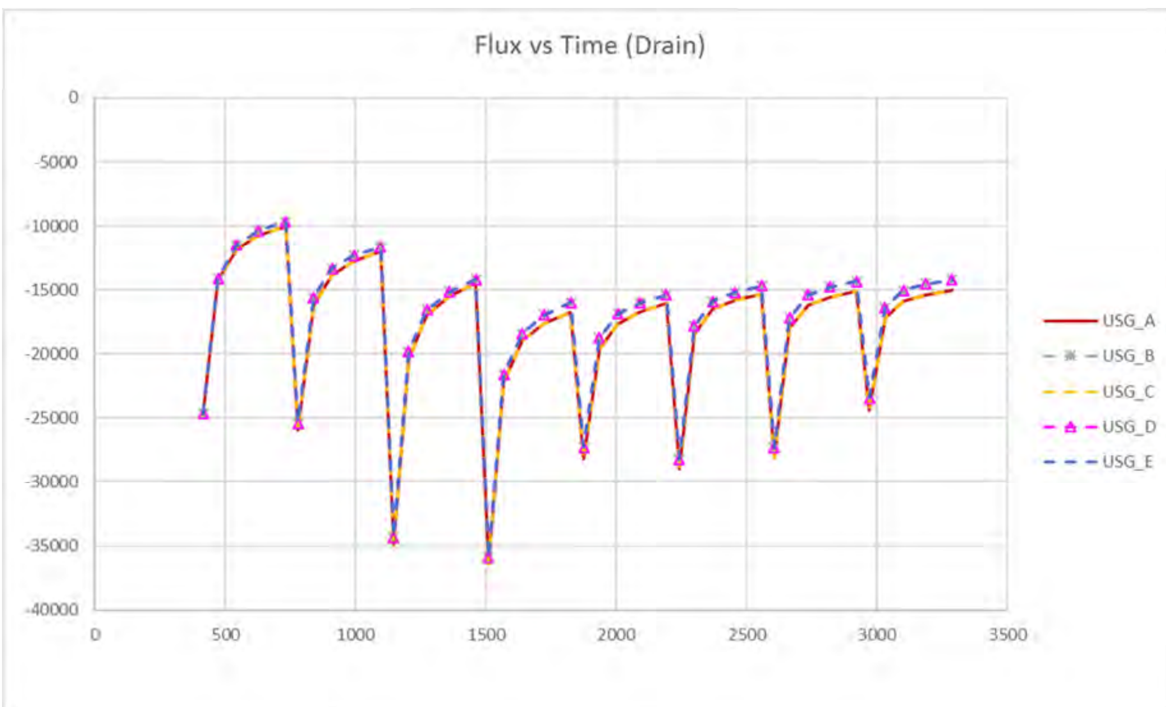
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------------							
				m3/9yrs	ML/a	ML/day	
IN:							
---							LOSS
STORAGE	=			48745816	5416.202	14.829	14.828
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RECHARGI	=			1.39E+08	15417.32	42.210	
RIVER	LEAKAGE	=		0	0	0.000	
TOTAL	IN	=		1.88E+08	20833.52	57.039	42.210
OUT:	OUT:						
----	----						
STORAGE	=			2212.669	0.245852	0.001	
CONSTAN	HEAD	=		37755493	4195.055	11.485	
WELLS	=			0	0	0.000	
DRAINS	=			52255193	5806.133	15.896	
RECHARGI	=			0	0	0.000	
RIVER	LEAKAGE	=		97488314	10832.03	29.656	
TOTAL	OUT	=		1.88E+08	20833.47	57.039	57.038
IN	-	OUT	=	460.7561	0.051195	0.000	14.828
PERCENT	DISCREPA	=	0				
TIME SUMMARY AT END OF TIME STEP			5 IN STRESS PERIOD			9	
	SECONDS	MINUTES	HOURS	DAYS	YEARS		
	--						
TIME STEP LENGTH	8793517.	146558.6	2442.644	101.7768	0.2786497		
STRESS PERIOD TIME	3.1557600E+07	525960.0	8766.000	365.2500	1.000000		
TOTAL TIME	2.8401840E+08	4733640.	78894.00	3287.250	9.000000		

APPENDIX C4

OPEN CUT: USG_VADOSE AND USG_PSEUDO

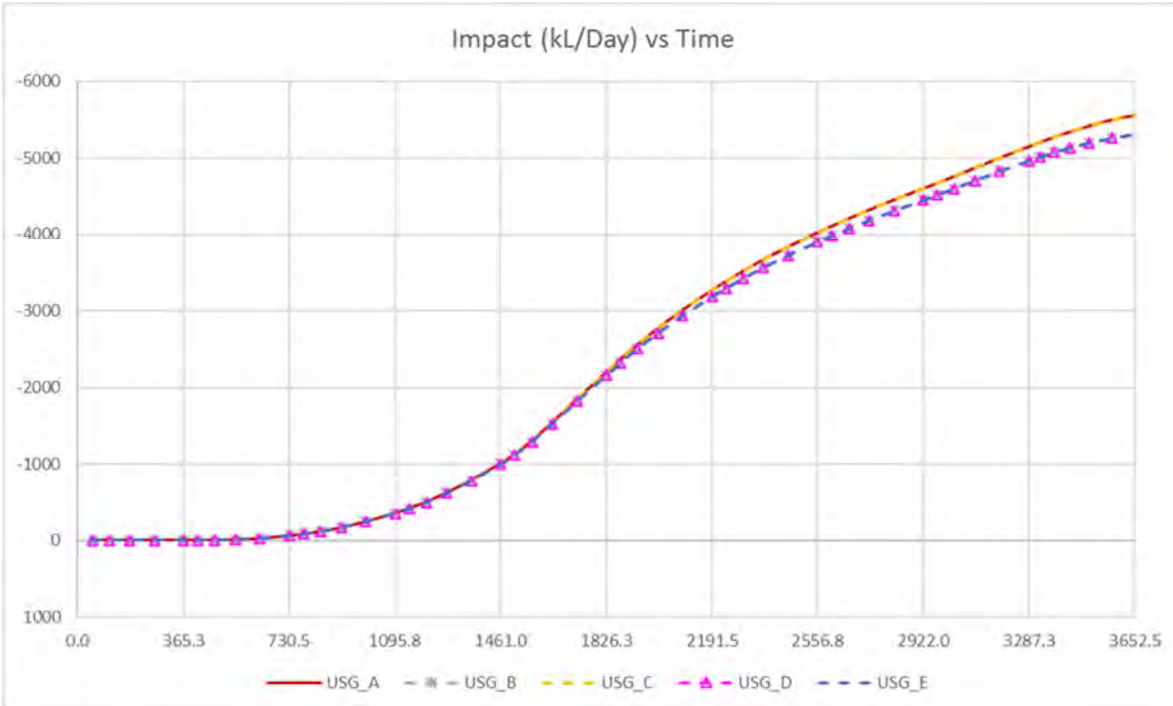
Mine inflow



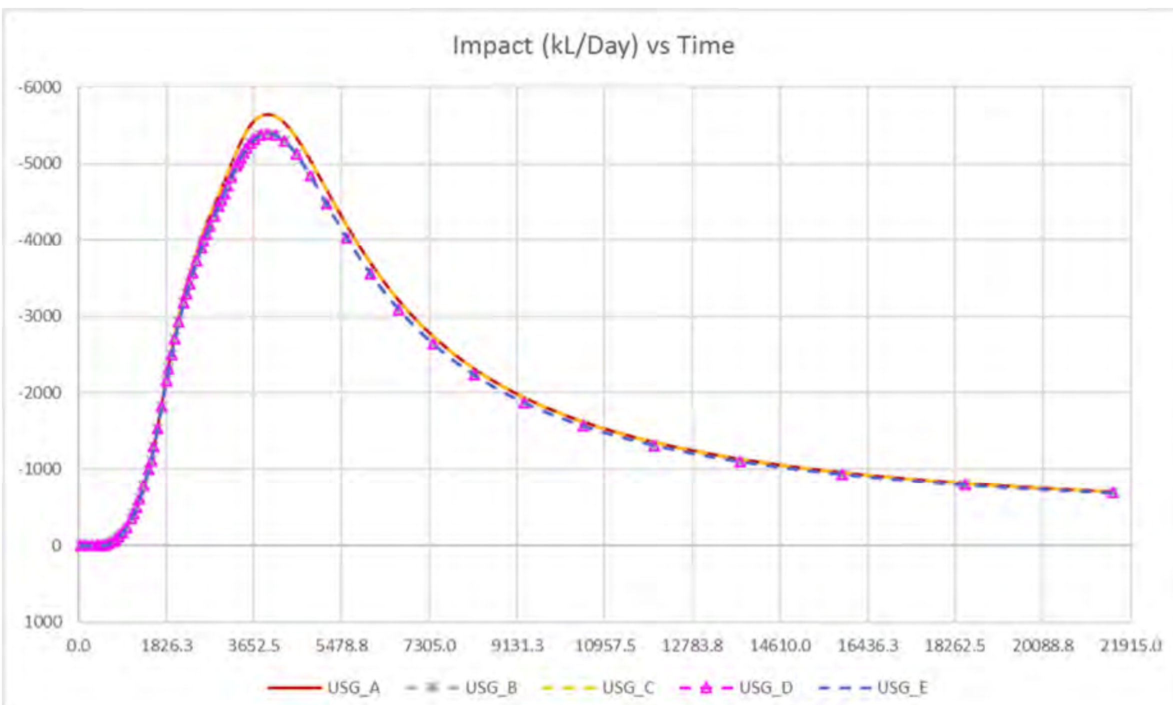


Index: A = VC1 B = VC2 C = VC3 D = VC4 E = VC5

River flux

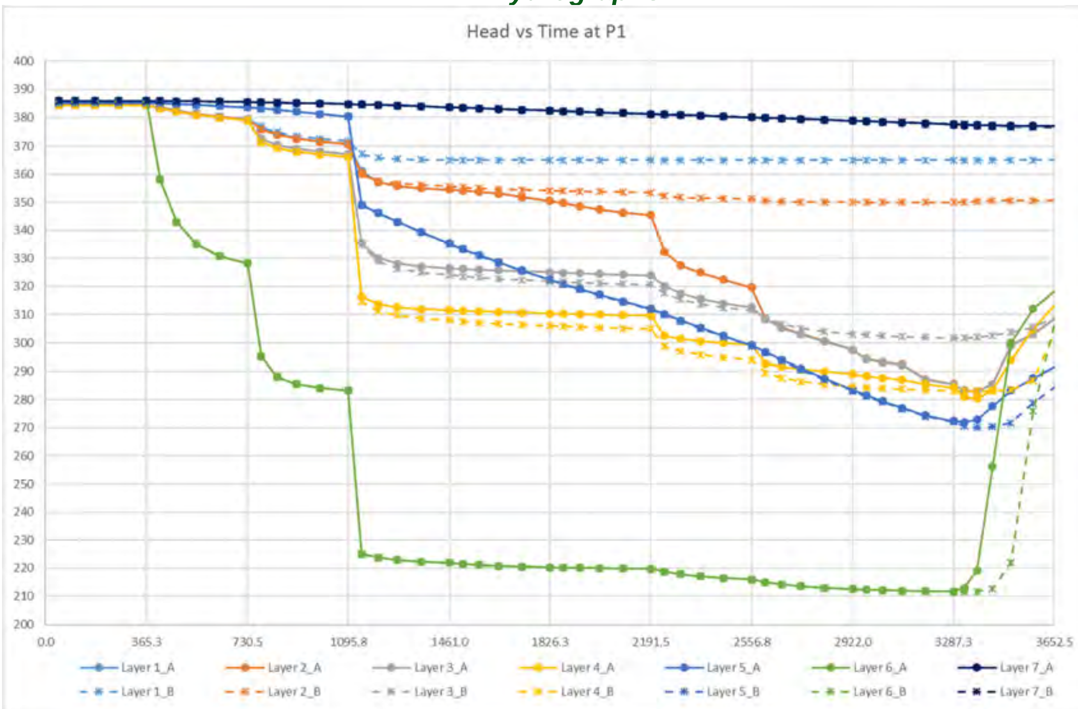


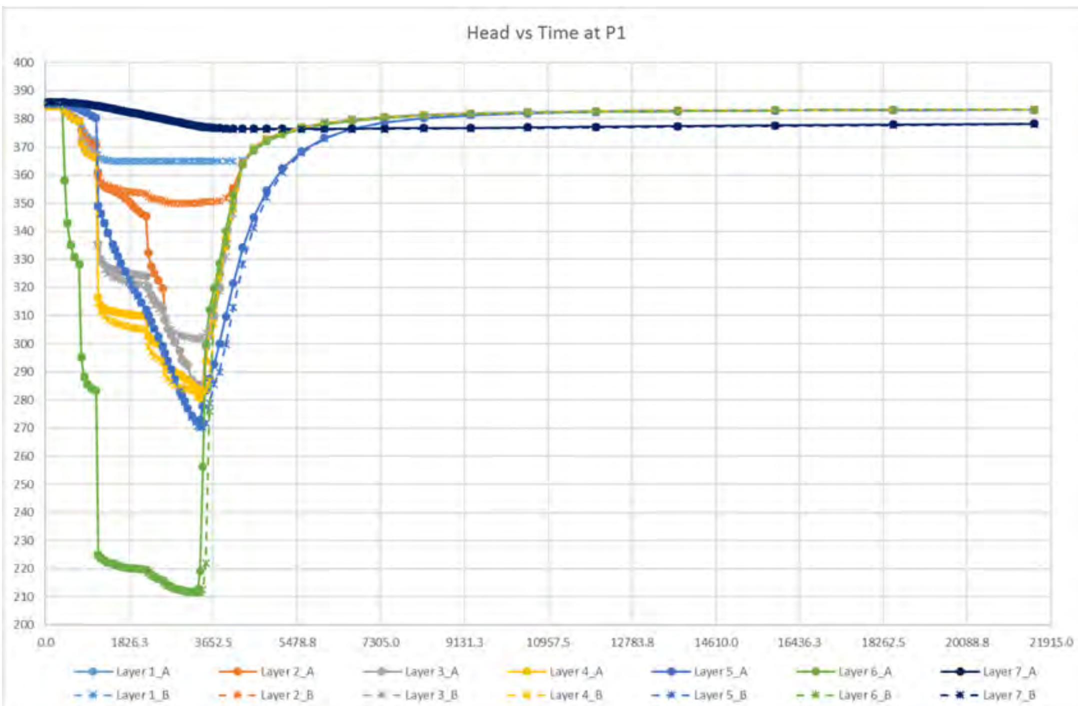
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG_A
USG_B
USG_C
USG_D
USG_E

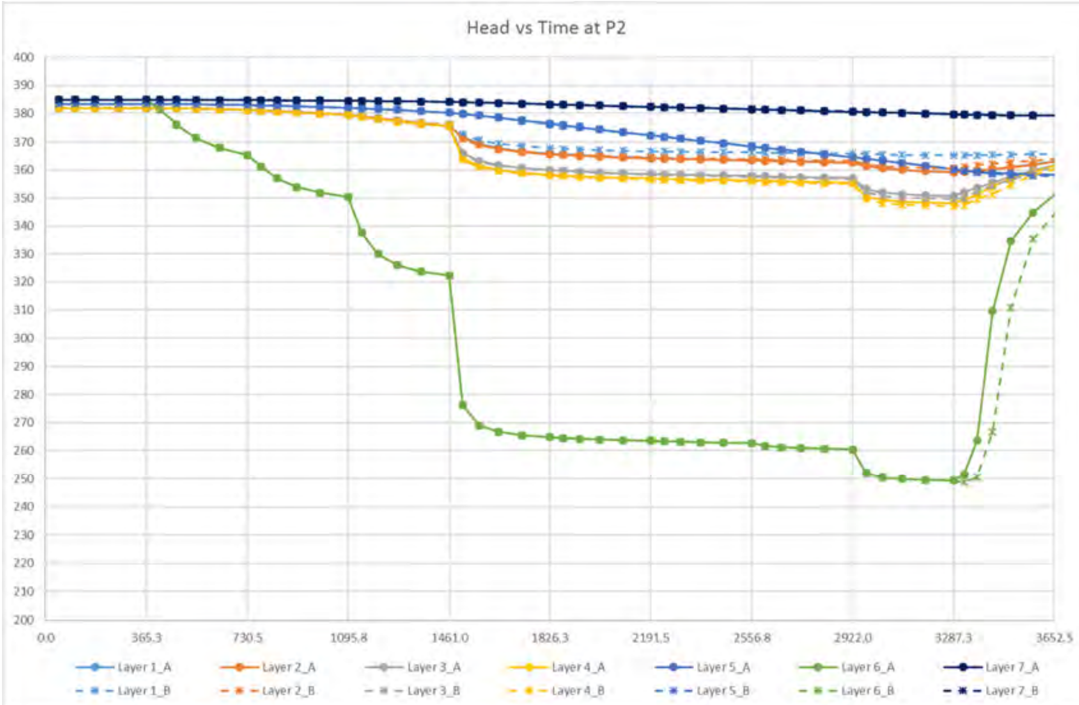


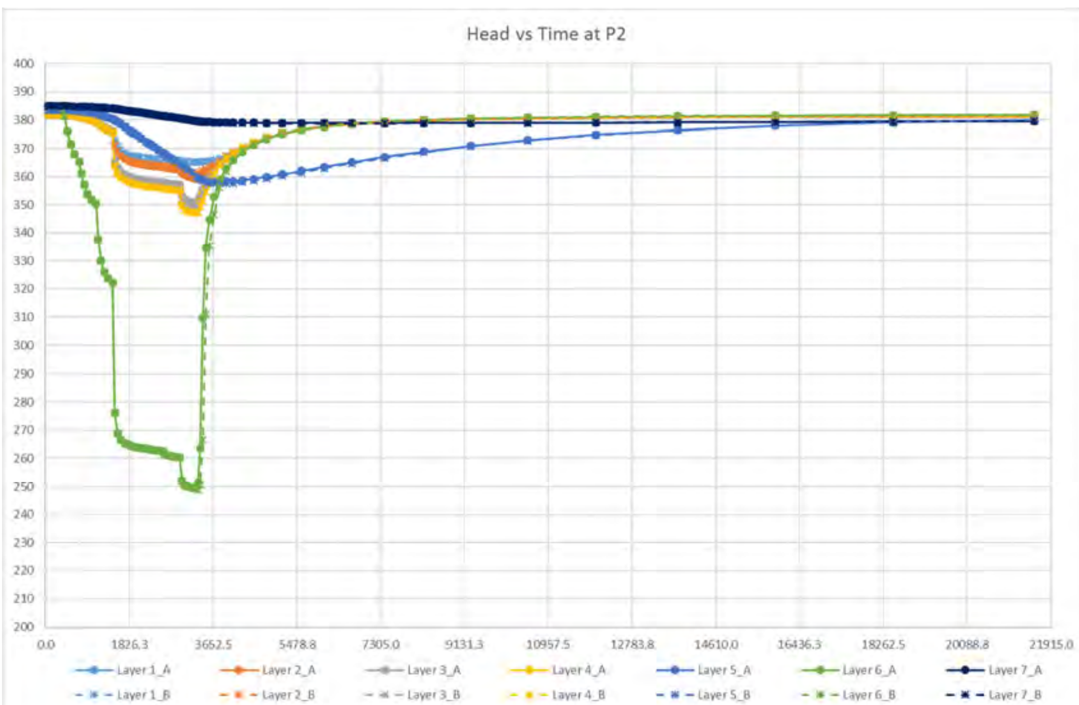
Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG_A
USG_B
USG_C
USG_D
USG_E

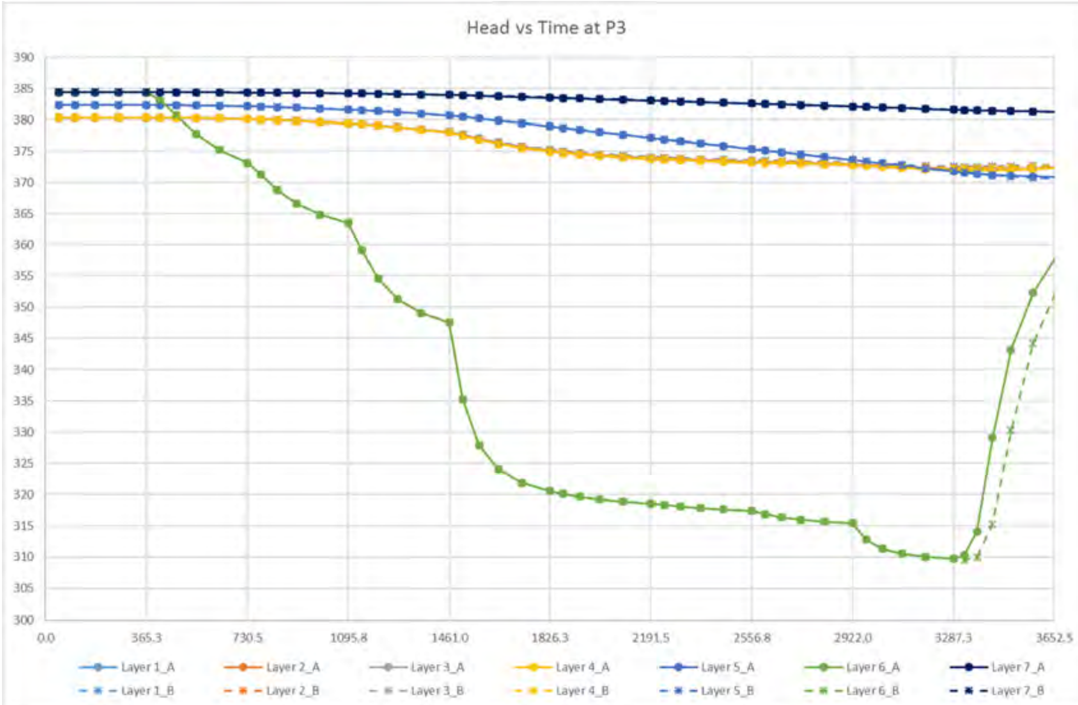
Hydrographs



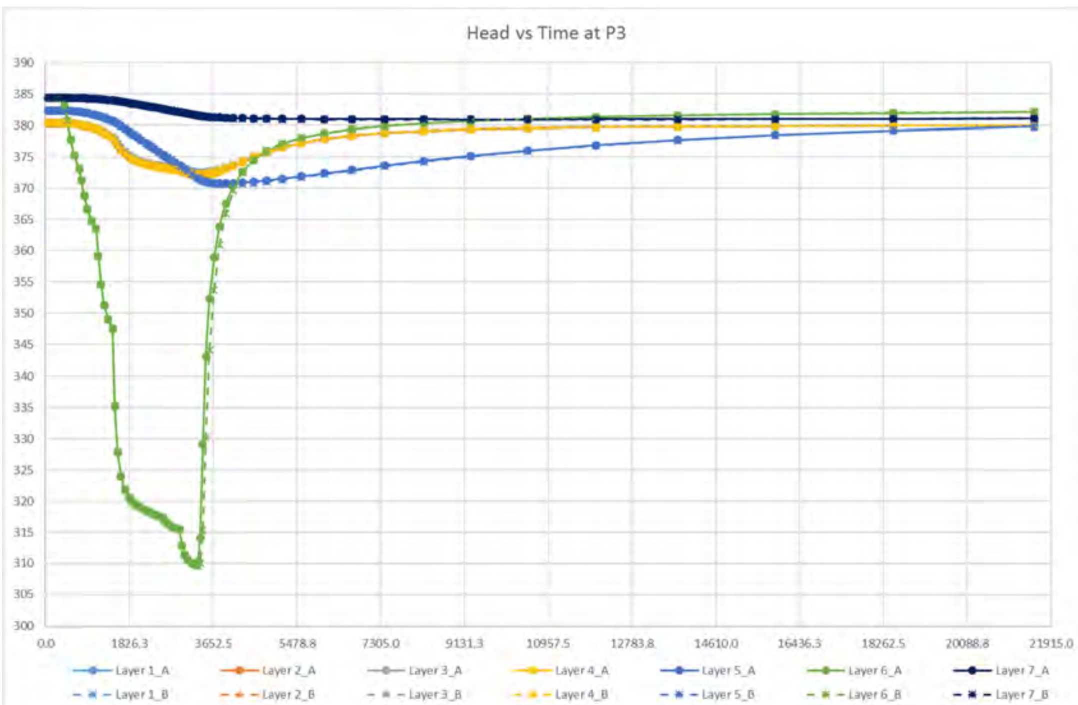



Head vs Time at P2
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

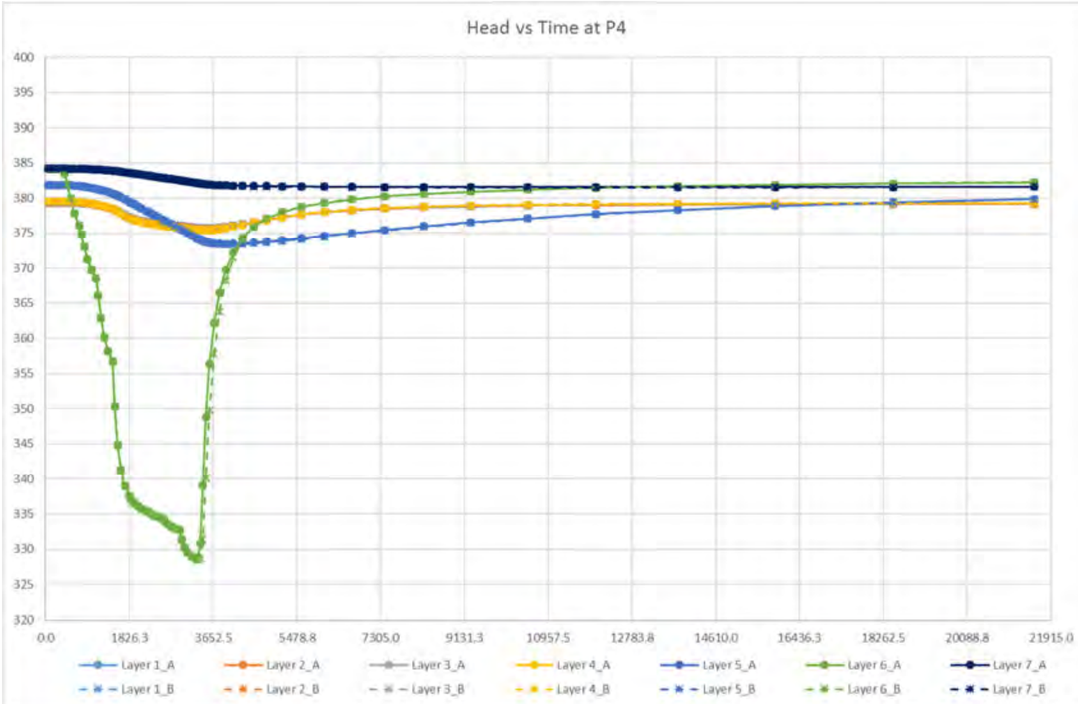

Head vs Time at P2
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

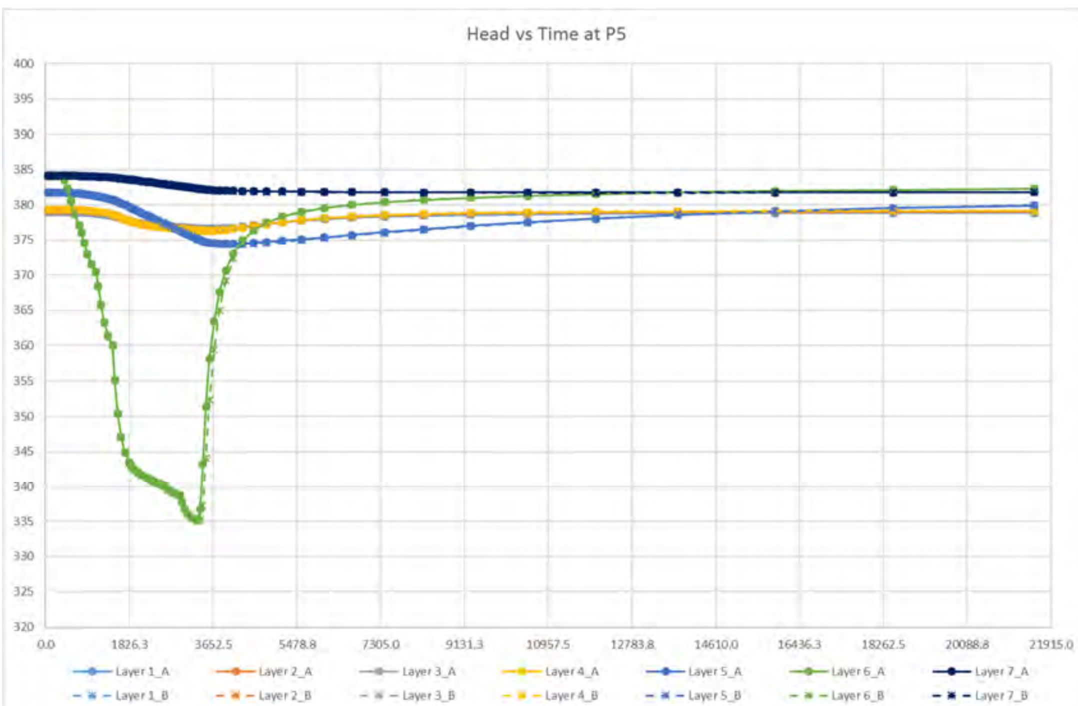


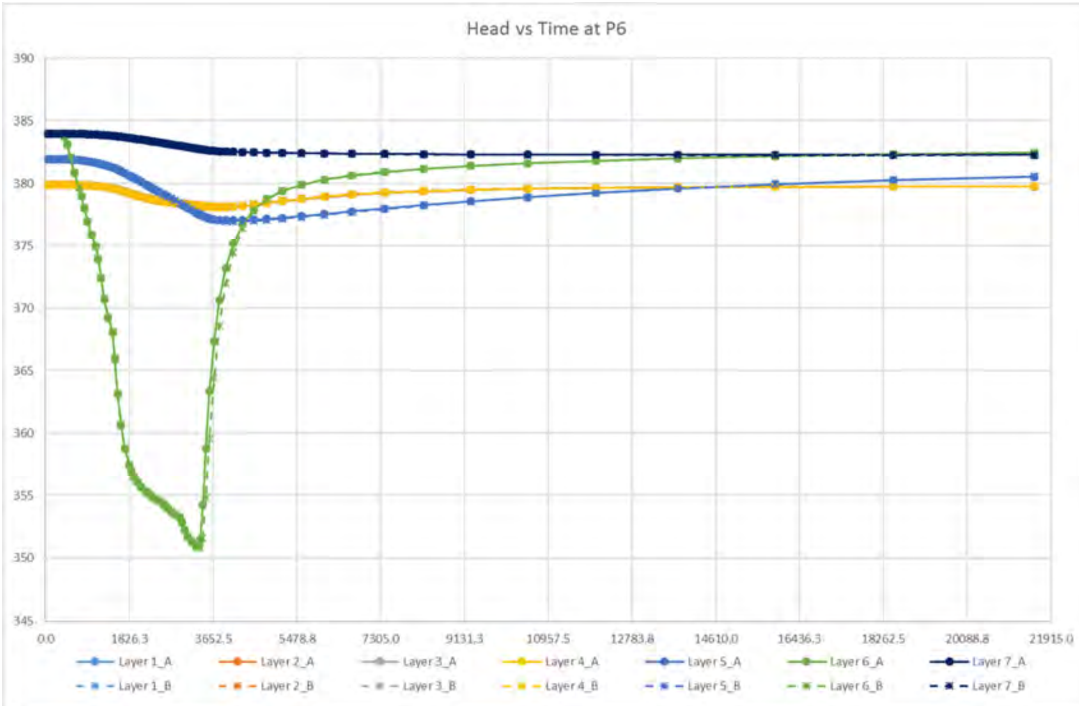
Head vs Time at P3
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

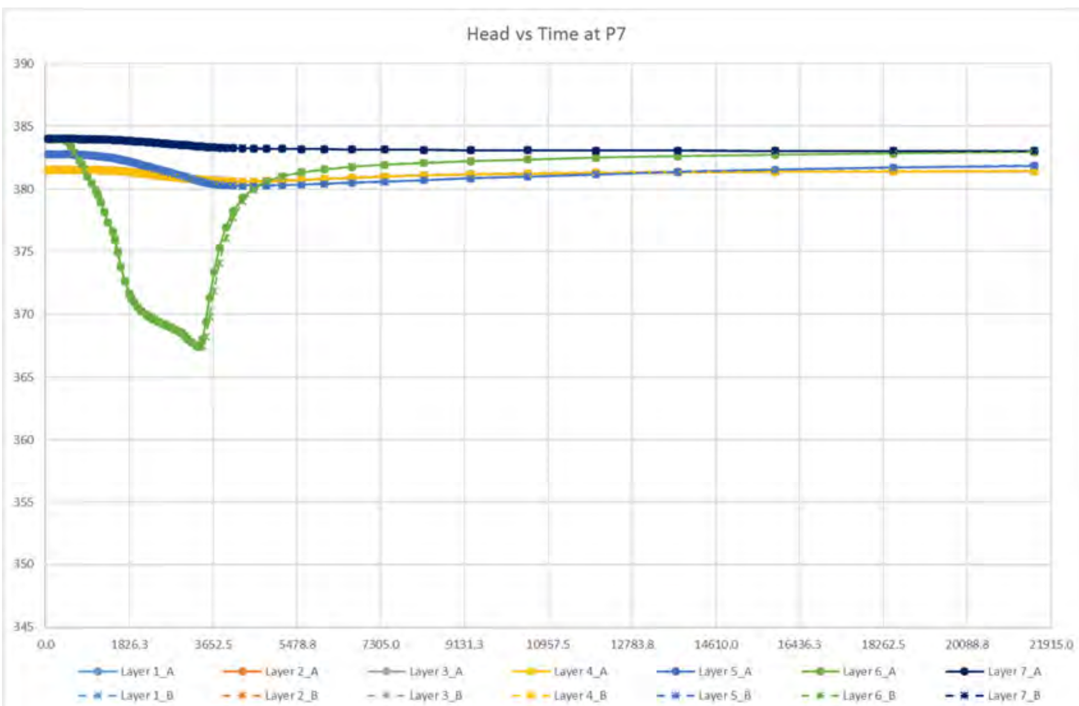


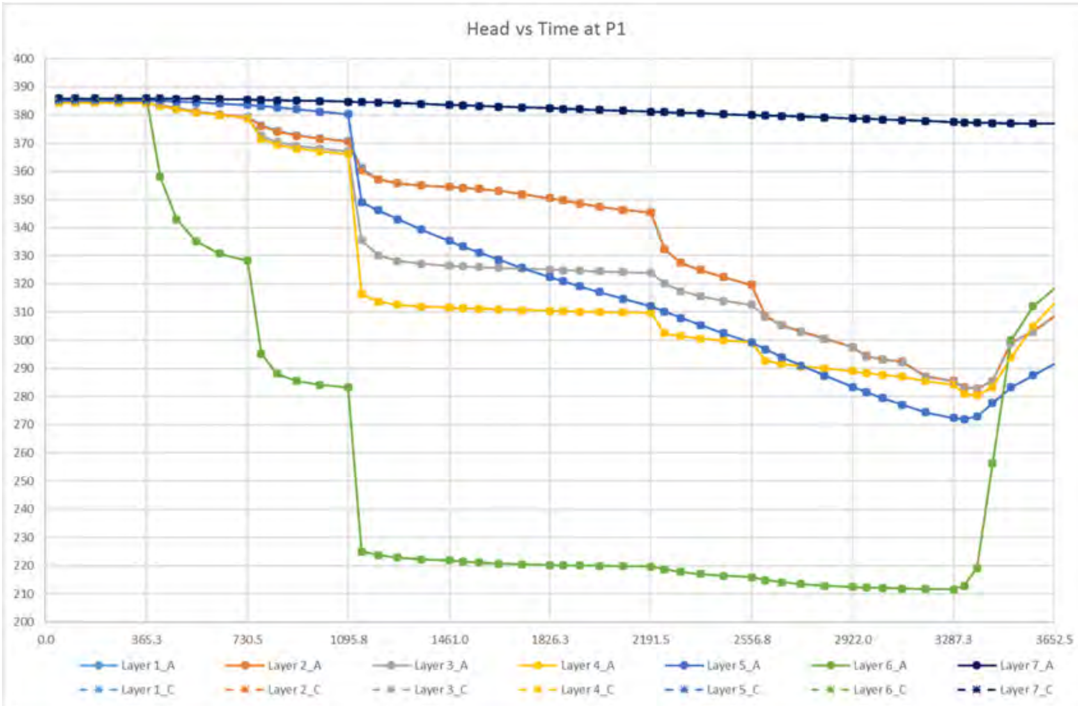
Head vs Time at P3
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
315
310
305
300
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

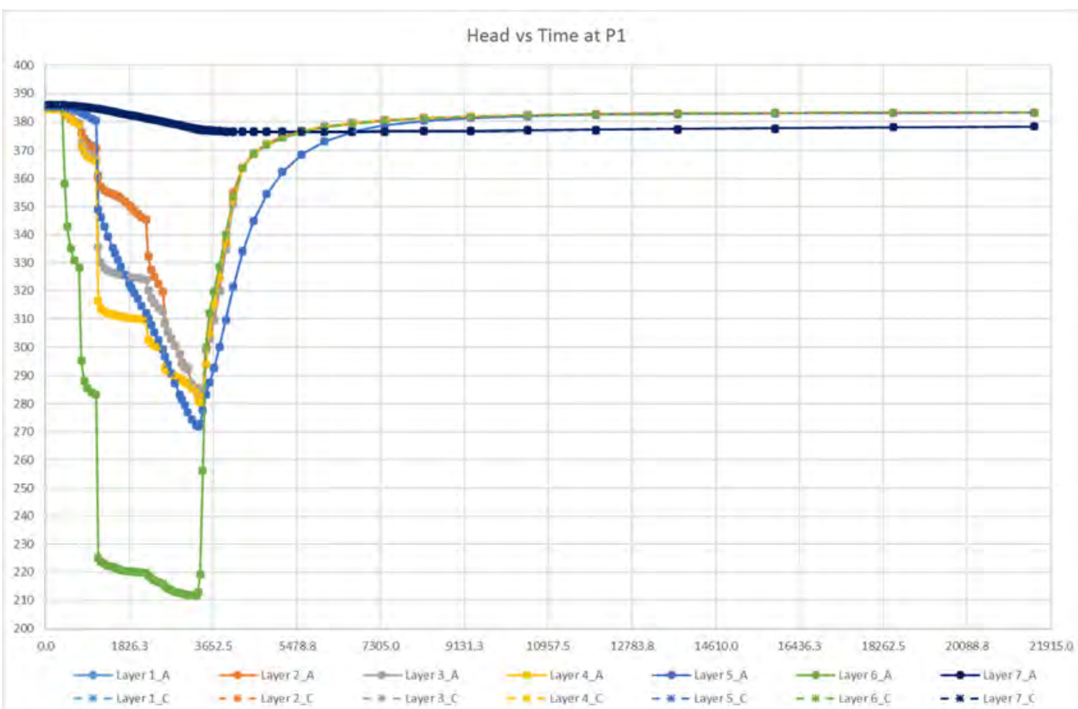

Head vs Time at P4
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B


Head vs Time at P5
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

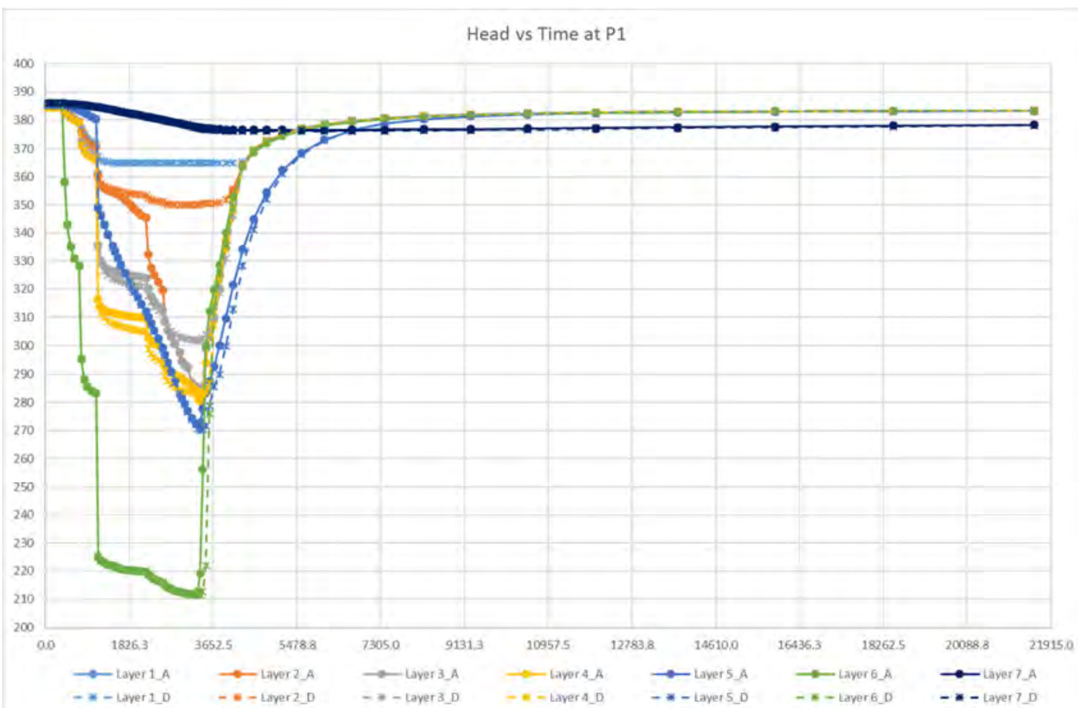

Head vs Time at P6
390
385
380
375
370
365
360
355
350
345
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

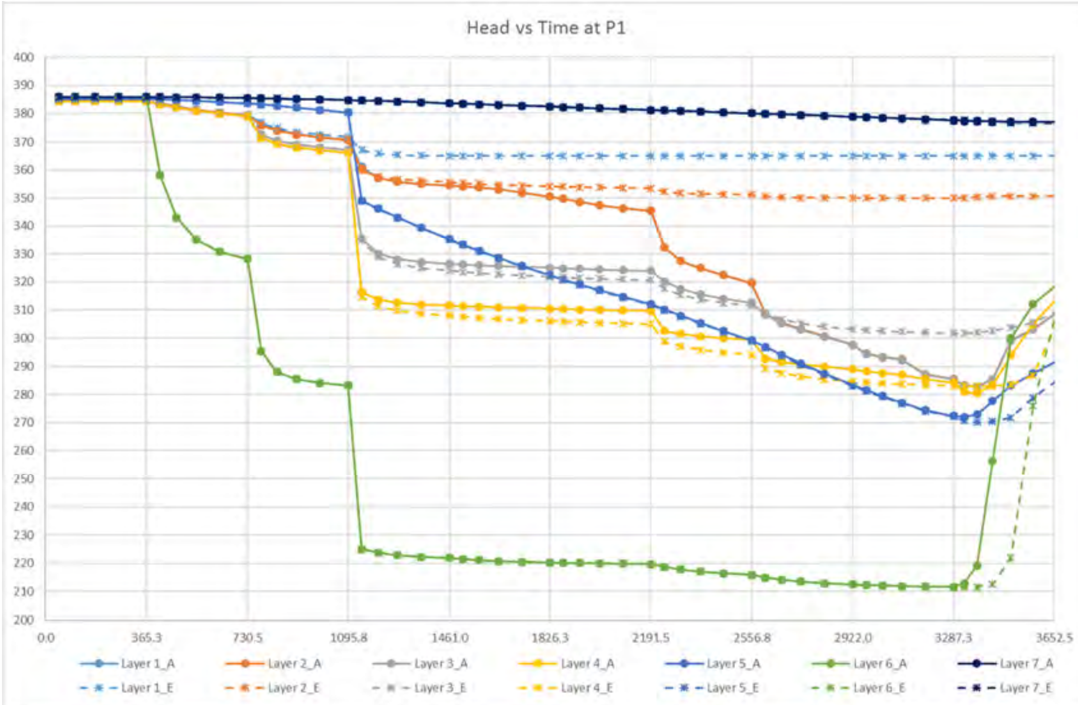

Head vs Time at P7
390
385
380
375
370
365
360
355
350
345
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_B
Layer 2_B
Layer 3_B
Layer 4_B
Layer 5_B
Layer 6_B
Layer 7_B

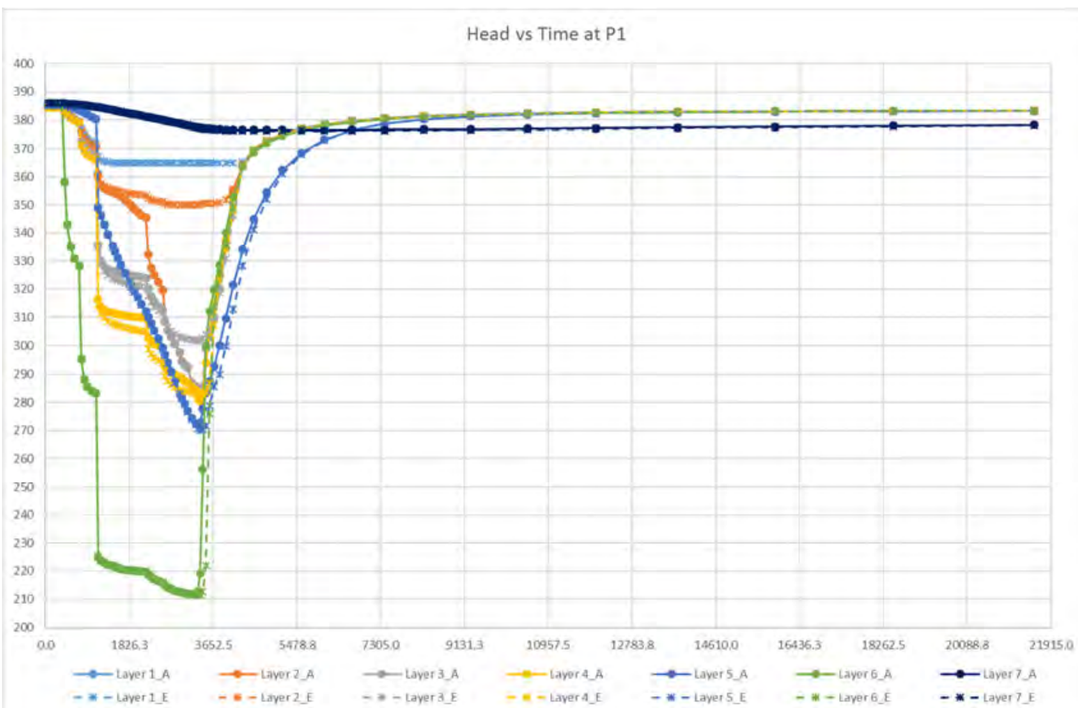

Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_C
Layer 2_C
Layer 3_C
Layer 4_C
Layer 5_C
Layer 6_C
Layer 7_C


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_C
Layer 2_C
Layer 3_C
Layer 4_C
Layer 5_C
Layer 6_C
Layer 7_C


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_D
Layer 2_D
Layer 3_D
Layer 4_D
Layer 5_D
Layer 6_D
Layer 7_D


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_D
Layer 2_D
Layer 3_D
Layer 4_D
Layer 5_D
Layer 6_D
Layer 7_D


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_E
Layer 2_E
Layer 3_E
Layer 4_E
Layer 5_E
Layer 6_E
Layer 7_E


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_A
Layer 2_A
Layer 3_A
Layer 4_A
Layer 5_A
Layer 6_A
Layer 7_A
Layer 1_E
Layer 2_E
Layer 3_E
Layer 4_E
Layer 5_E
Layer 6_E
Layer 7_E

Water Balance

USG_VC1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9			

CUMULAT	VOLUMES	L**3						DIFF(A&B)	DIFF(A&C)	DIFF(A&D)	DIFF(A&E)
------------	-----------------------										
				m3/9yrs	ML/a	ML/day					
IN:	IN:										
---	---						LOSS				
STORAGE	=			44116423	4901.825	13.420	13.419				
CONSTAN	HEAD	=		0	0	0.000					
WELLS	=			0	0	0.000					
DRAINS	=			0	0	0.000					
RIVER	LEAKAGE	=		577328.9	64.14765	0.176					
RECHARGI	=			1.39E+08	15417.32	42.210		0.000%	0.000%	0.000%	0.000%
TOTAL	IN	=		1.83E+08	20383.29	55.806	42.386				
OUT:	OUT:										
----	----										
STORAGE	=			4330.864	0.481207	0.001					
CONSTAN	HEAD	=		43301168	4811.241	13.172		-0.131%	0.000%	-0.131%	-0.131%
WELLS	=			0	0	0.000					
DRAINS	=			50908898	5656.544	15.487		3.500%	0.000%	3.500%	3.500%
RIVER	LEAKAGE	=		89235185	9915.021	27.146		-0.046%	0.000%	-0.046%	-0.046%
RECHARGI	=			0	0	0.000					
TOTAL	OUT	=		1.83E+08	20383.29	55.806	55.805	0.918%	0.000%	0.918%	0.918%
IN	-	OUT	=	26.6007	0.002956	0.000	13.419				
PERCENT	DISCREPA	=		0							

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9
SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000

USG_VC2

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF

CUMULAT	VOLUMES	L**3					
------------	-----------------------						
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			42526164	4725.129	12.937	12.935
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		483150.1	53.68334	0.147	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.82E+08	20196.13	55.294	42.357
OUT:	OUT:						
----	----						
STORAGE	=			4301.406	0.477934	0.001	
CONSTAN	HEAD	=		43357874	4817.542	13.190	
WELLS	=			0	0	0.000	
DRAINS	=			49127117	5458.569	14.945	
RIVER	LEAKAGE	=		89275813	9919.535	27.158	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.82E+08	20196.12	55.294	55.293
IN	-	OUT	=	65.1277	0.007236	0.000	12.935
PERCENT	DISCREPA	=		0			

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9
SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000

USG_VC3

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------	-----------------------						
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			44116423	4901.825	13.420	13.419
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		577328.9	64.14765	0.176	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.83E+08	20383.29	55.806	42.386
OUT:	OUT:						
----	----						
STORAGE	=			4330.864	0.481207	0.001	
CONSTAN	HEAD	=		43301168	4811.241	13.172	
WELLS	=			0	0	0.000	
DRAINS	=			50908898	5656.544	15.487	
RIVER	LEAKAGE	=		89235185	9915.021	27.146	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.83E+08	20383.29	55.806	55.805
IN	-	OUT	=	26.6007	0.002956	0.000	13.419
PERCENT	DISCREPA	=		0			
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865							
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000							
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000							

USG_VC4

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------	-----------------------						
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			42526164	4725.129	12.937	12.935
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		483150.1	53.68334	0.147	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.82E+08	20196.13	55.294	42.357
OUT:	OUT:						
----	----						
STORAGE	=			4301.406	0.477934	0.001	
CONSTAN	HEAD	=		43357874	4817.542	13.190	
WELLS	=			0	0	0.000	
DRAINS	=			49127117	5458.569	14.945	
RIVER	LEAKAGE	=		89275813	9919.535	27.158	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.82E+08	20196.12	55.294	55.293
IN	-	OUT	=	65.1277	0.007236	0.000	12.935
PERCENT	DISCREPA	=		0			
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865							
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000							
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000							

USG_VC5

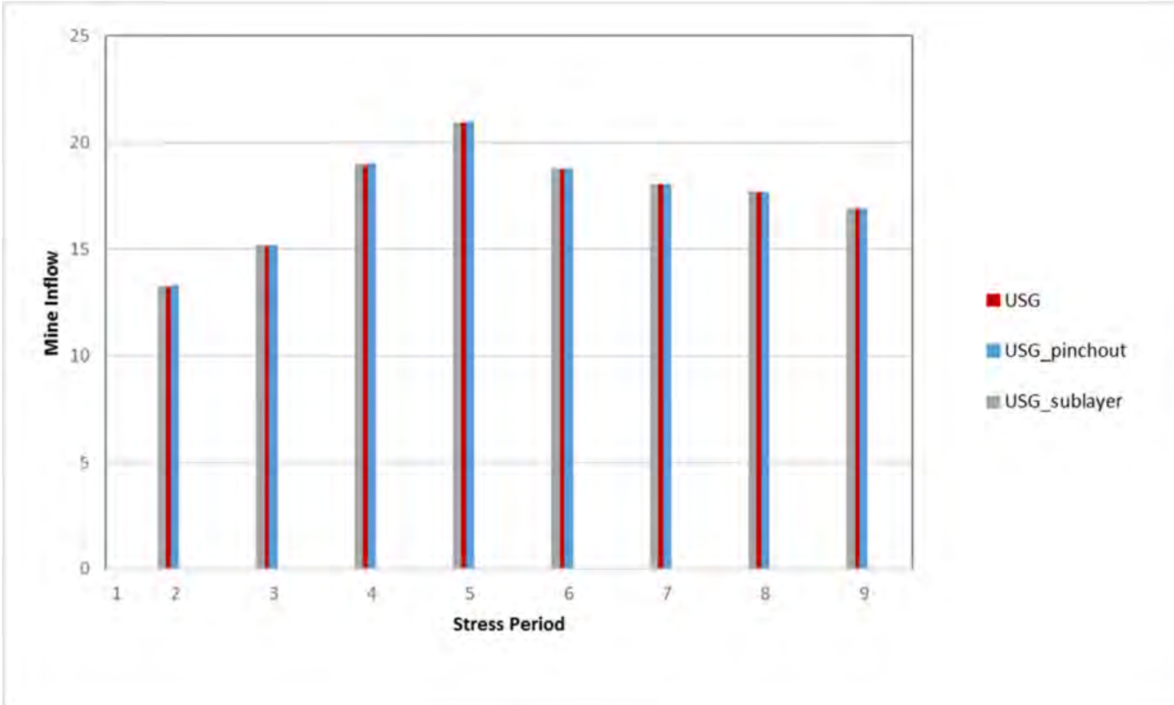
VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
------------	-----------------------						
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			42526164	4725.129	12.937	12.935
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		483150.1	53.68334	0.147	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.82E+08	20196.13	55.294	42.357
OUT:	OUT:						
----	----						
STORAGE	=			4301.406	0.477934	0.001	
CONSTAN	HEAD	=		43357874	4817.542	13.190	
WELLS	=			0	0	0.000	
DRAINS	=			49127117	5458.569	14.945	
RIVER	LEAKAGE	=		89275813	9919.535	27.158	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.82E+08	20196.12	55.294	55.293
IN	-	OUT	=	65.1277	0.007236	0.000	12.935
PERCENT	DISCREPA	=		0			
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							

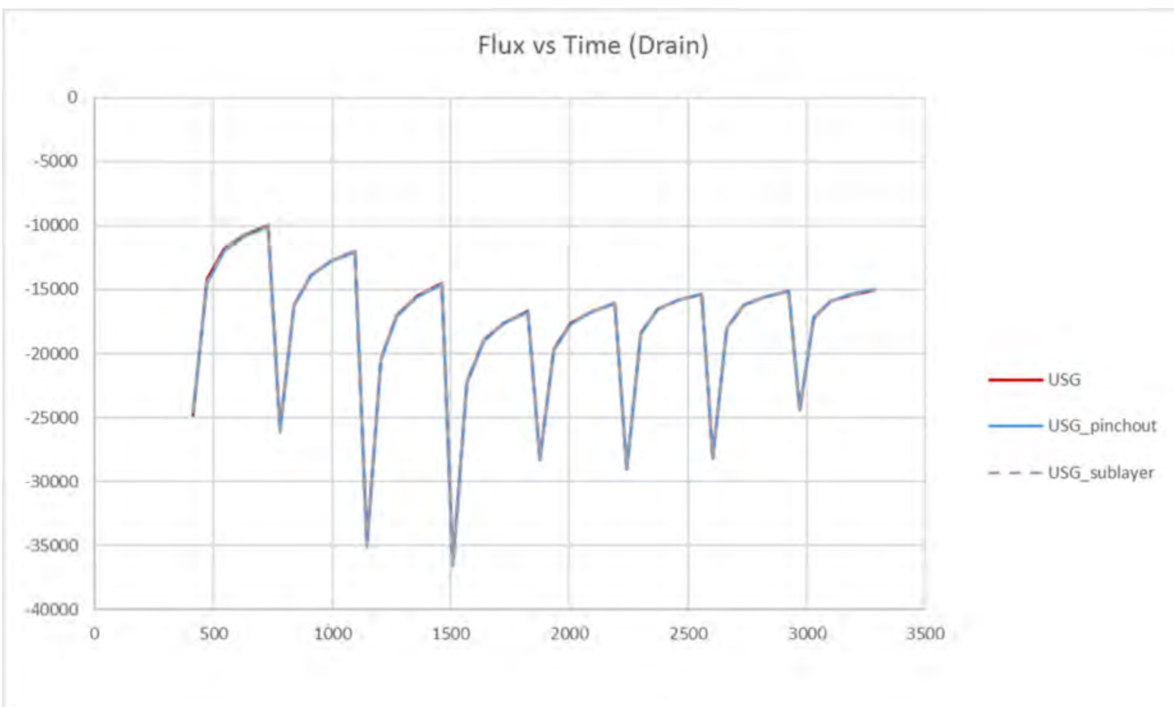
TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865							
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000							
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000							

APPENDIX C5

OPEN CUT: USG_PINCHOUT AND USG_PSEUDO

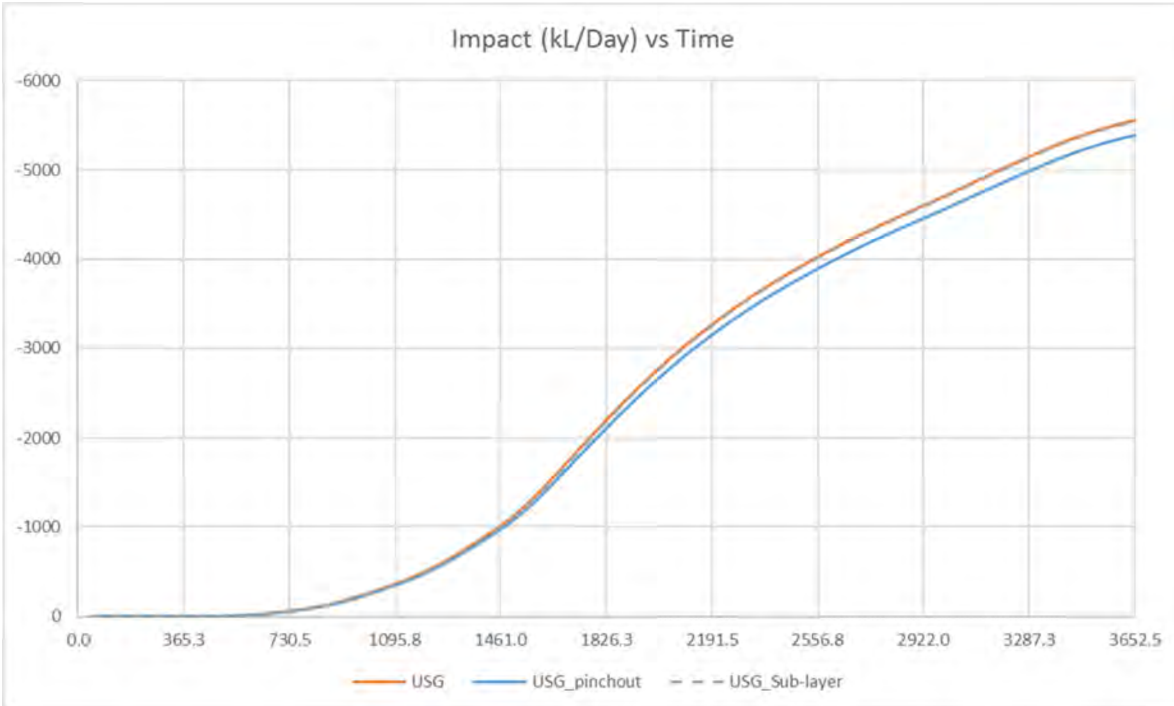
Mine inflow

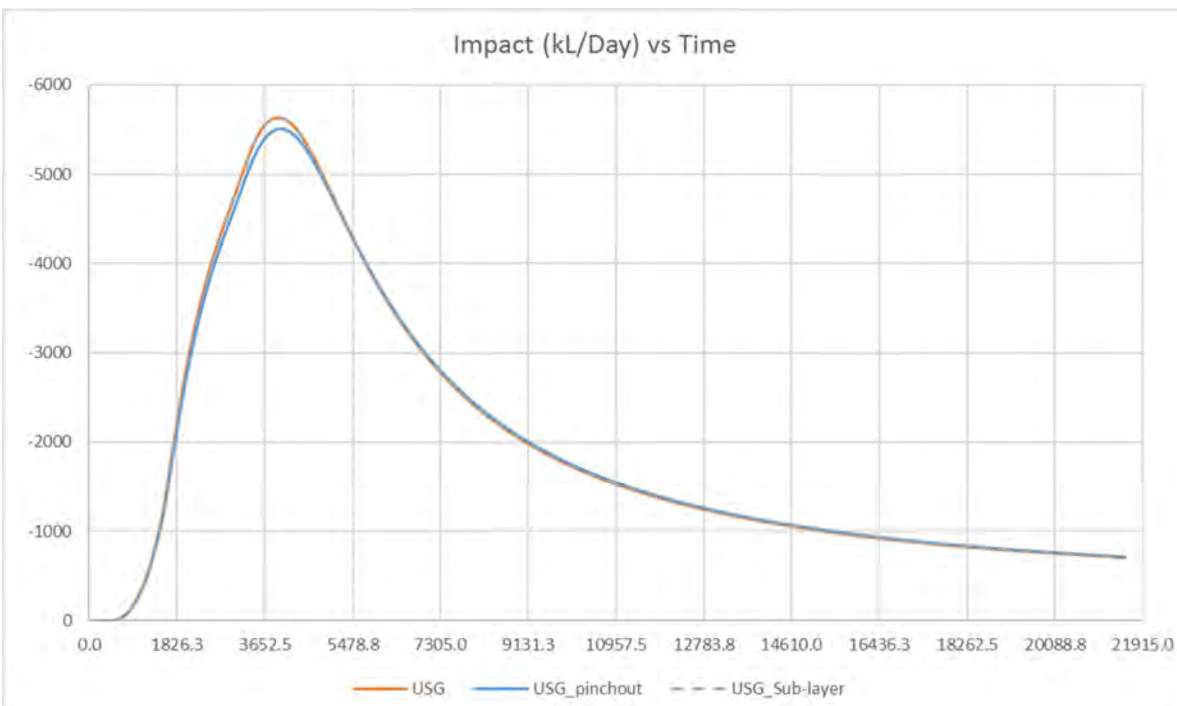




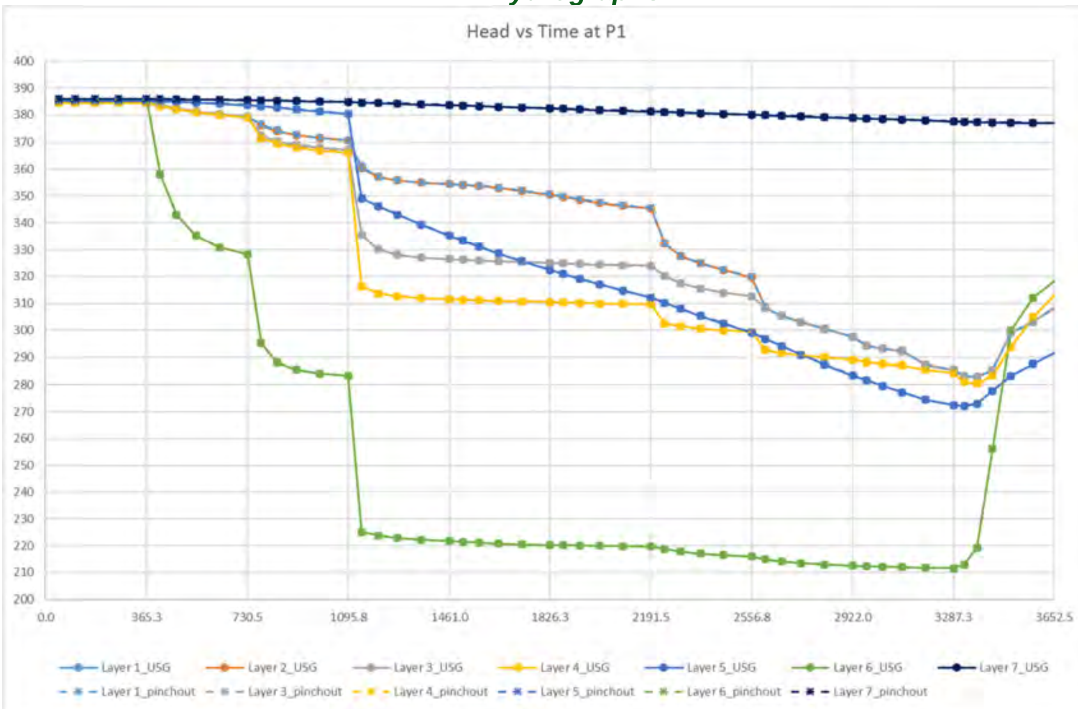
Index: USG = VC1 USG_pinchout = Scenario 2 USG_sublayer = Scenario 3

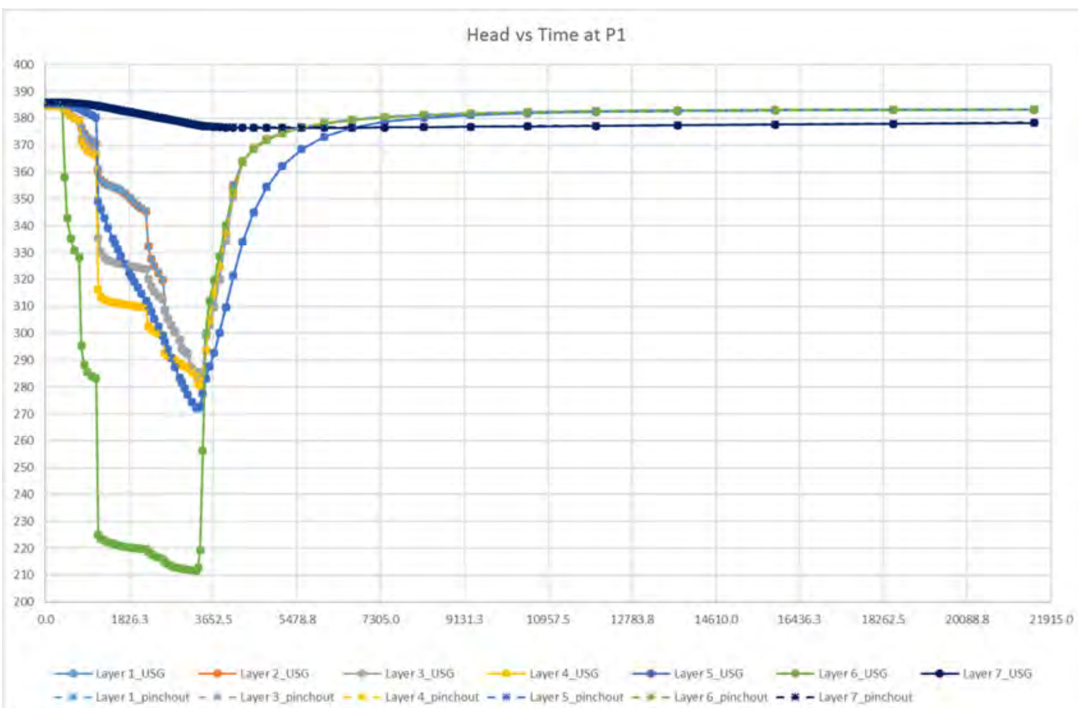
River flux


Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
USG
USG_pinchout
USG_Sub-layer


Impact (kL/Day) vs Time
-6000
-5000
-4000
-3000
-2000
-1000
0
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
USG
USG_pinchout
USG_Sub-layer

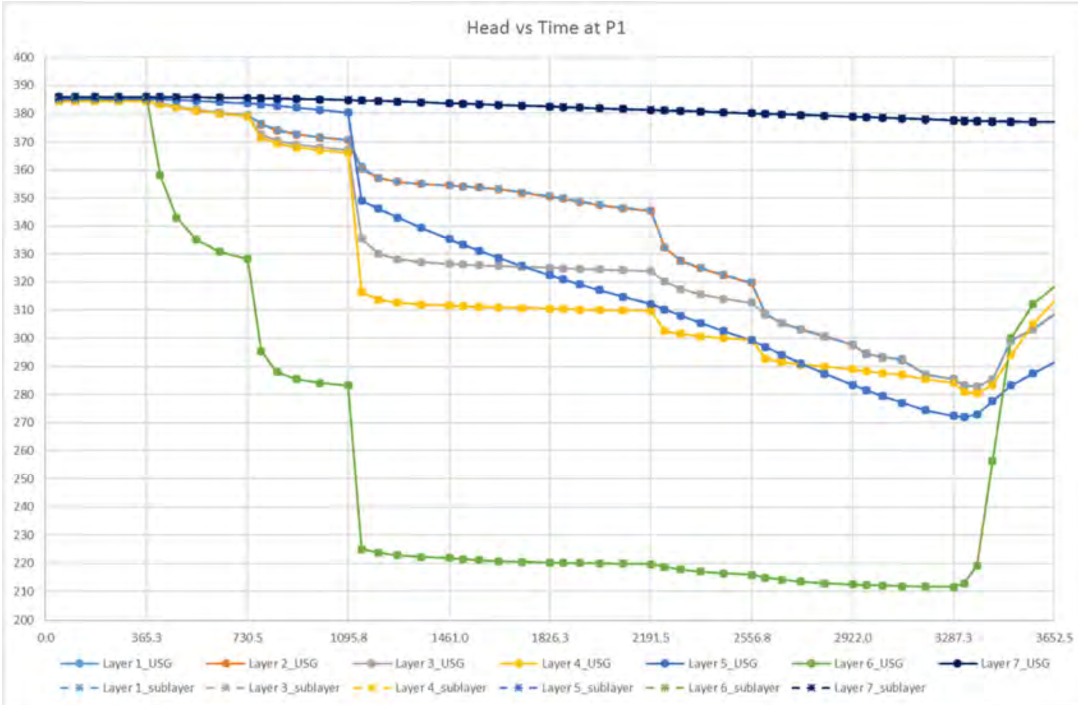
Hydrographs

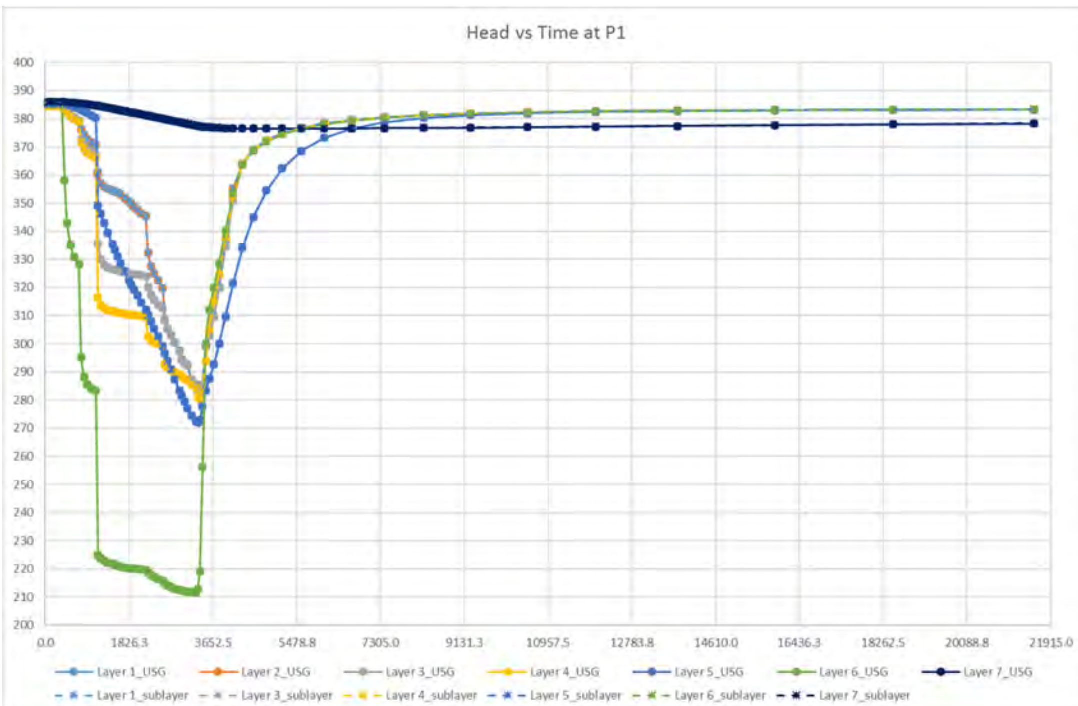




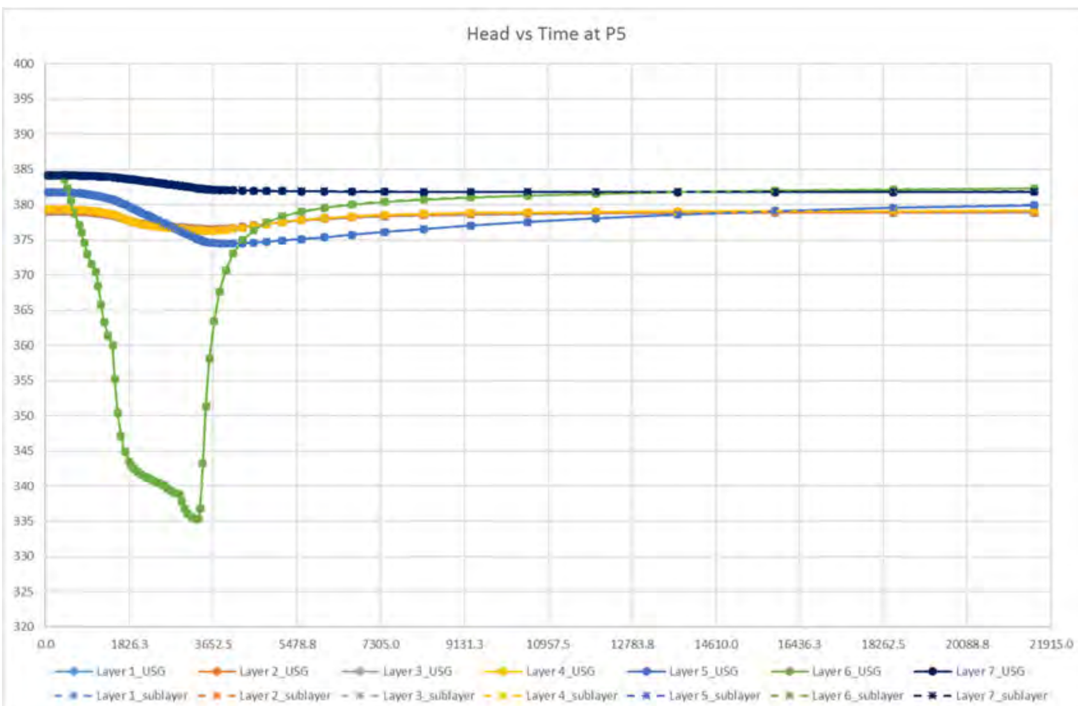

Head vs Time at P5
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_USG
Layer 2_USG
Layer 3_USG
Layer 4_USG
Layer 5_USG
Layer 6_USG
Layer 7_USG
Layer 1_pinchout
Layer 2_pinchout
Layer 3_pinchout
Layer 4_pinchout
Layer 5_pinchout
Layer 6_pinchout
Layer 7_pinchout


Head vs Time at P5
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_USG
Layer 2_USG
Layer 3_USG
Layer 4_USG
Layer 5_USG
Layer 6_USG
Layer 7_USG
Layer 1_pinchout
Layer 2_pinchout
Layer 3_pinchout
Layer 4_pinchout
Layer 5_pinchout
Layer 6_pinchout
Layer 7_pinchout


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_USG
Layer 2_USG
Layer 3_USG
Layer 4_USG
Layer 5_USG
Layer 6_USG
Layer 7_USG
Layer 1_sublayer
Layer 3_sublayer
Layer 4_sublayer
Layer 5_sublayer
Layer 6_sublayer
Layer 7_sublayer


Head vs Time at P1
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_USG
Layer 2_USG
Layer 3_USG
Layer 4_USG
Layer 5_USG
Layer 6_USG
Layer 7_USG
Layer 1_sublayer
Layer 3_sublayer
Layer 4_sublayer
Layer 5_sublayer
Layer 6_sublayer
Layer 7_sublayer


Head vs Time at P5
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
0.0
365.3
730.5
1095.8
1461.0
1826.3
2191.5
2556.8
2922.0
3287.3
3652.5
Layer 1_USG
Layer 2_USG
Layer 3_USG
Layer 4_USG
Layer 5_USG
Layer 6_USG
Layer 7_USG
Layer 1_sublayer
Layer 2_sublayer
Layer 3_sublayer
Layer 4_sublayer
Layer 5_sublayer
Layer 6_sublayer
Layer 7_sublayer


Head vs Time at P5
400
395
390
385
380
375
370
365
360
355
350
345
340
335
330
325
320
0.0
1826.3
3652.5
5478.8
7305.0
9131.3
10957.5
12783.8
14610.0
16436.3
18262.5
20088.8
21915.0
Layer 1_USG
Layer 2_USG
Layer 3_USG
Layer 4_USG
Layer 5_USG
Layer 6_USG
Layer 7_USG
Layer 1_sublayer
Layer 2_sublayer
Layer 3_sublayer
Layer 4_sublayer
Layer 5_sublayer
Layer 6_sublayer
Layer 7_sublayer

Water balance

VC1

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF	TIME STEP 5 IN STRESS PERIOD 9	
--									
CUMULAT	VOLUMES	L**3						DIFF(USG no pinch&pinch)	DIFF(USG no pinch&sublayer)
-----------	----------------------								
				m3/9yrs	ML/a	ML/day			
IN:	IN:								
---	---						LOSS		
STORAGE	=			44116399	4901.822	13.420	13.419		
CONSTAN	HEAD	=		0	0	0.000			
WELLS	=			0	0	0.000			
DRAINS	=			0	0	0.000			
RIVER	LEAKAGE	=		577328.5	64.14762	0.176			
RECHARGI	=			1.39E+08	15417.32	42.210		0.00%	0.00%
TOTAL	IN	=		1.83E+08	20383.29	55.806	42.386		
OUT:	OUT:								
----	----								
STORAGE	=			4308.219	0.478691	0.001			
CONSTAN	HEAD	=		43301218	4811.246	13.172		-0.78%	-0.33%
WELLS	=			0	0	0.000			
DRAINS	=			50908860	5656.54	15.487		-0.26%	-0.17%
RIVER	LEAKAGE	=		89235194	9915.022	27.146		0.24%	0.12%
RECHARGI	=			0	0	0.000			
TOTAL	OUT	=		1.83E+08	20383.29	55.806	55.805	-0.14%	-0.07%
IN	-	OUT	=	4.1626	0.000463	0.000	13.419		
PERCENT	DISCREPA	=		0					
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9									
SECONDS MINUTES HOURS DAYS YEARS									

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865									
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000									
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000									

Scenario 2: USG_pinchout

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
-----------	----------------------						
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			44480252.6196	4942.25	13.531	13.530
CONSTAN	HEAD	=		0.0000	0	0.000	
WELLS	=			0.0000	0	0.000	
DRAINS	=			0.0000	0	0.000	
RIVER	LEAKAGE	=		467693.4053	51.96593	0.142	
RECHARGI	=			138755856.9482	15417.32	42.210	
TOTAL	IN	=		183703802.9731	20411.53	55.884	42.353
OUT:	OUT:						
----	----						
STORAGE	=			4254.8679	0.472763	0.001	
CONSTAN	HEAD	=		43637070.9870	4848.563	13.275	
WELLS	=			0.0000	0	0.000	
DRAINS	=			51042268.0298	5671.363	15.527	
RIVER	LEAKAGE	=		89020184.4286	9891.132	27.080	
RECHARGI	=			0.0000	0	0.000	
TOTAL	OUT	=		183703778.3132	20411.53	55.884	55.882
IN	-	OUT	=	24.6598	0.00274	0.000	13.530
PERCENT	DISCREPA	=		0			
TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9							
SECONDS MINUTES HOURS DAYS YEARS							

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865							
STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000							
TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000							

Scenario 3: USG_sublayer

VOLUMET	BUDGET	FOR	ENTIRE	MODEL	AT	END	OF
--							
CUMULAT	VOLUMES	L**3					
-----------	----------------------						
				m3/9yrs	ML/a	ML/day	
IN:	IN:						
---	---						LOSS
STORAGE	=			44232444	4914.716	13.456	13.454
CONSTAN	HEAD	=		0	0	0.000	
WELLS	=			0	0	0.000	
DRAINS	=			0	0	0.000	
RIVER	LEAKAGE	=		582751.1	64.75013	0.177	
RECHARGI	=			1.39E+08	15417.32	42.210	
TOTAL	IN	=		1.84E+08	20396.78	55.843	42.388
OUT:	OUT:						
----	----						
STORAGE	=			4329.816	0.481091	0.001	
CONSTAN	HEAD	=		43445807	4827.312	13.216	
WELLS	=			0	0	0.000	
DRAINS	=			50995730	5666.192	15.513	
RIVER	LEAKAGE	=		89125180	9902.798	27.112	
RECHARGI	=			0	0	0.000	
TOTAL	OUT	=		1.84E+08	20396.78	55.843	55.842
IN	-	OUT	=	5.2489	0.000583	0.000	13.454
PERCENT	DISCREPA	=		0			

TIME SUMMARY AT END OF TIME STEP 5 IN STRESS PERIOD 9

SECONDS MINUTES HOURS DAYS YEARS

TIME STEP LENGTH 8.79352E+06 1.46559E+05 2442.6 101.78 0.27865

STRESS PERIOD TIME 3.15576E+07 5.25960E+05 8766.0 365.25 1.0000

TOTAL TIME 2.84018E+08 4.73364E+06 78894. 3287.2 9.0000

APPENDIX D

LONGWALL AND OPEN CUT:	**RUN JOURNALS**
AGE MODELS:	**RUN JOURNAL**

LONGWALL MODEL RUNS

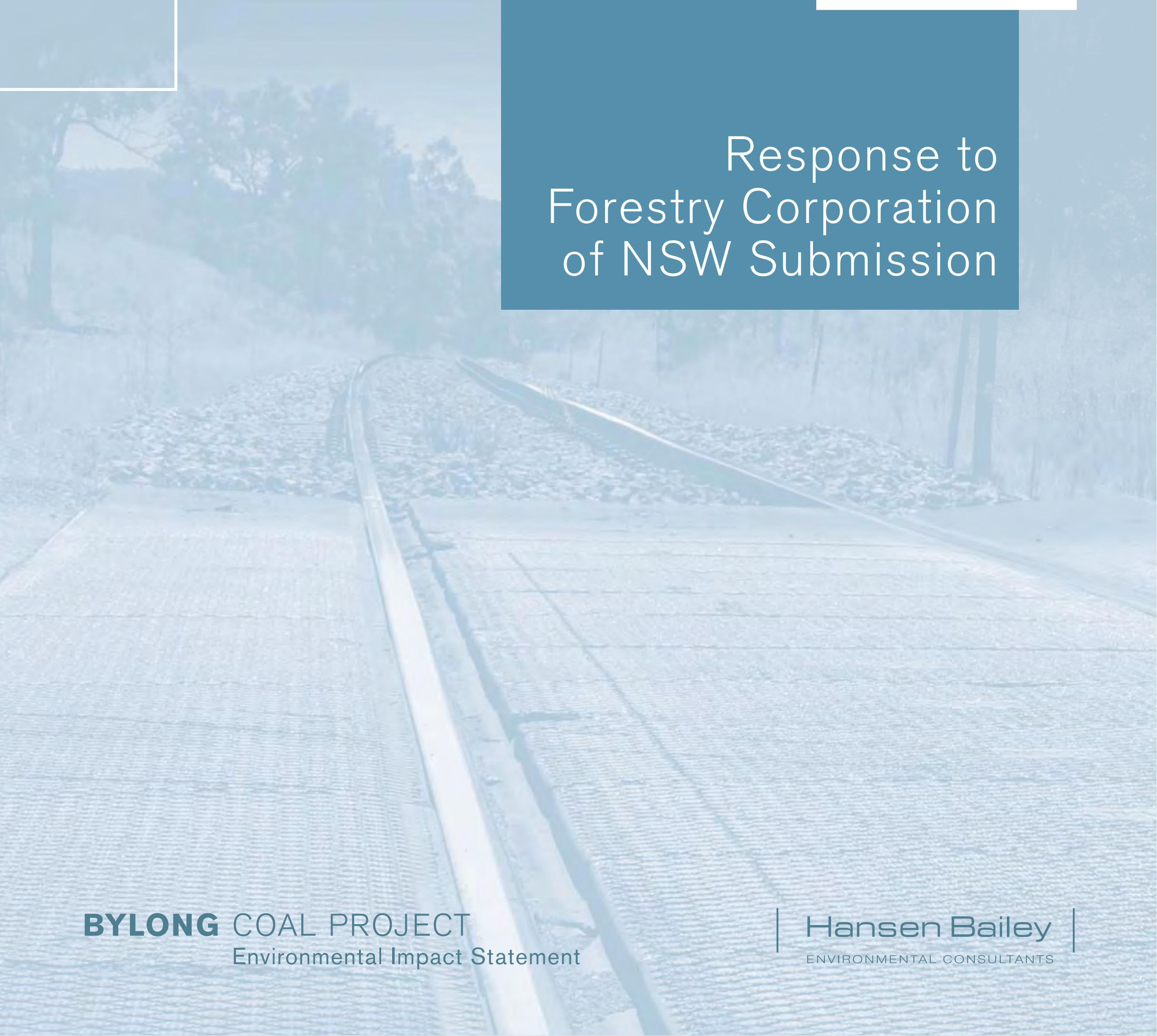
CODE	RUN	SOFTWARE	OPTION	SOLVER	CLOSURE	OUTER	INNER	TIME	NEWTON	NEWTON	NONLINMETH	XMD	XMD	XMD	XMD	PCGU	PCGU	PCGU	PCGU	PCGU	RUNTIME	COMMENT
					[m]	ITERATIONS	ITERATIONS	PACKAGE	BFACT	RESRED		IACL	NORDER	LEVEL	NORTH	RCLOSEPCGU	IPC	ISCL	IORD	CLIN	[mins]	
A	A1	MS_Vadose	Base	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	4.8	h1 above ground
	A2		Alpha x3	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	9.5	h1 above ground
	A3		Beta x2	PCG5	0.001	400	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	10.7	h1 above ground
	A4		Sr x5	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	6.6	h1 above ground
	B1		AGE_Base	PCG5	0.001	200	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	3.2	
	B2		AGE_Sc3	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	12.8	h1 above ground
	C1		Clay	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	2.9	h1 above ground
	C2		Sand	PCG5	0.01	400	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	17.1	h1 above ground
B	VC3	MS_Pseudo	CONSTANTCV NOVFC	PCG5	0.001	100	600	OC	X	X	X	X	X	X	X	X	X	X	X	X	2.6	IAH2015 only. 5 TS for SP1-9; 25 TS for SP10.
C	A1	USG_Vadose	Base	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	17.5	
	A2		Alpha x3	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	11.5	
	A3		Beta x2	XMD	0.1	400	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	24.5	Difficult convergence at SP10
	A4		Sr x5	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	13.2	
	B1		AGE_Base	XMD	0.001	200	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	21.7	Difficult convergence at SP7
	B2		AGE_Sc3	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	36.6	Difficult convergence at SP10
	C1		Clay	XMD	0.001	300	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	11.1	
	C2		Sand	XMD	0.1	400	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	35.0	Difficult convergence at SP3
D	VC1	USG_Pseudo	CONSTANTCV NOVFC	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	5.3	Inner HICLOSE=1E-4
	VC2		nil	XMD	0.02	200	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	6.8	
	VC3		CONSTANTCV	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	6.0	
	VC4		NOVFC	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP4 TS3
			NOVFC	XMD	0.02	200	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP10 TS17
			NOVFC	XMD	0.05	400	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP3 TS5
			NOVFC	PCGU	0.001	200	600	OC	X	X	Delta-Bar-Delta/Picard	X	X	X	X	1	2	2	2	BCGS	17.4	OK.
	VC5		NOCVCORRECTION	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP4 TS3
			NOCVCORRECTION	XMD	0.02	200	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP10 TS17
			NOCVCORRECTION	XMD	0.05	400	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP3 TS5
			NOCVCORRECTION	PCGU	0.001	200	600	OC	X	X	Delta-Bar-Delta/Picard	X	X	X	X	1	2	2	2	BCGS	17.4	OK.

OPEN CUT MODEL RUNS

CODE	RUN	SOFTWARE	OPTION	SOLVER	CLOSURE [m]	OUTER ITERATIONS	INNER ITERATIONS	TIME PACKAGE	NEWTON BFACT	NEWTON RESRED	NONLINMETH	XMD IACL	XMD NORDER	XMD LEVEL	XMD NORTH	PCGU RCLOSEPCGU	PCGU IPC	PCGU ISCL	PCGU IORD	PCGU CLIN	RUNTIME [mins]	COMMENT
A	A1	MS_Vadose	Base	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	2.3	h1 above ground
	A2		Alpha x3	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	1.7	h1 above ground
	A3		Beta x2	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	1.9	h1 above ground
	A4		Sr x5	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	1.4	h1 above ground
	B1		AGE_Base	PCG5	0.01	400	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	Fail	Failed at SP10 TS9
	B2		AGE_Sc3	PCG5	0.001	300	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	4.9	h1 above ground
	C1		Clay	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	1.3	h1 above ground
	C2		Sand	PCG5	0.001	300	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	Fail	Steady-state failed
B	VC3	MS_Pseudo	CONSTANTCV NOVFC	PCG5	0.001	100	600	OC	0.9	1	X	X	X	X	X	X	X	X	X	X	2.7	5 TS for SP1-9; 25 TS for SP10.
C	A1	USG_Vadose	Base	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	6.8	
	A2		Alpha x3	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	9.0	
	A3		Beta x2	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	8.2	
	A4		Sr x5	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	6.3	
	B1		AGE_Base	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	3.6	
	B2		AGE_Sc3	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	17.2	
	C1		Clay	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	10.8	
	C2		Sand	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	
				PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	28.1	
D	VC1	USG_Pseudo	CONSTANTCV NOVFC	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	4.9	Inner HICLOSE=1E-4
			CONSTANTCV NOVFC	PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	8.1	
	VC2		nil	PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	6.3	
	VC3		CONSTANTCV	PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	13.0	
	VC4		NOVFC	PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	12.3	
	VC5		NOCVCORRECTION	PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	8.3	
E	Pinch-out model details																					
	Scenario2	USG_Pseudo	CONSTANTCV NOVFC	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	Fail	Failed at SP6 TS4
			CONSTANTCV NOVFC	PCGU	0.001	100	600	OC	X	X	X	X	X	X	X	1	2	2	2	BCGS	6.9	Inner HICLOSE=1E-4
	Scenario3	USG_Pseudo	CONSTANTCV NOVFC	XMD	0.001	100	600	OC	X	X	Delta-Bar-Delta/Picard	2	0	7	14	X	X	X	X	X	3.7	Inner HICLOSE=1E-4

AGE MODEL RUNS

Code	Software	Solver	Closure (m)	Outer Iterations	Inner Iterations	Newton BFACT	Newton Reserved	Time Package	ATO/OC delt	ATO/OC tmin	ATO/OC tmax	ATO/OC tsmult	ATO/OC tsdiv	Computer processor	Simulation run time Hours	Comment
A^	MS_Vadose	PCG5	0.05	100	50	0.15	1.5	ATO	1	0.3E-9	9	1.5	1.2	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	3	
A^_null	MS_Vadose	PCG5	0.05	100	50	0.15	1.5	ATO	1	0.3E-9	9	1.5	1.2	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	1.5	
A^^	MS_Pseudo	PCG5	0.05	5000	1000	*	*	ATO	0.01	0.3E-9	9	3	1.5	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	120	Failed at SP 35
A^^_null	MS_Pseudo	PCG5	0.05	5000	1000	*	*	ATO	0.01	0.3E-9	9	3	1.5	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	100	Failed at SP 95
C^	USG_Pseudo	SMS	0.05	500	10	*	*	OC	5	0.3E-9	30	1.5	1.2	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	2	
C^_null	USG_Pseudo	SMS	0.05	500	10	*	*	OC	5	0.3E-9	30	1.5	1.2	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	1.2	
C^^	USG_Vadose	SMS	0.05	500	10	*	*	OC	5	0.3E-9	30	1.5	1.2	Intel ® Core™ i7-6700 CPU@ 3.4 GHZ	3	



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Response to Forestry Corporation of NSW Submission

28 June 2016

Team Leader
Planning Assessment
22-33 Bridge Street
SYDNEY NSW 2000

Attention: Mr Stephen O'Donoghue

Dear Steve,

Bylong Coal Project
Response to Forestry Corporation of NSW Submission, Dated 30 May 2016

1. INTRODUCTION

The '*Bylong Coal Project Environmental Impact Statement*' (EIS) which supported Development Application (SSD) 14_6367 for the Bylong Coal Project (the Project) was placed on public exhibition between 23 September and 6 November 2015.

Hansen Bailey prepared the document '*Bylong Coal Project Response to Submissions*' (RTS) dated 23 March 2016 to address comments received from agencies and other stakeholders during the exhibition of the EIS. The RTS included responses to the Forestry Corporation of NSW (FCNSW) submission dated 3 November 2015 which was generally in relation to access and potential impacts due to subsidence.

During the period of preparing the RTS, a meeting was held with FCNSW via a teleconference on 29 February 2016 to clarify issues raised in its submission.

FCNSW has provided a further letter dated 30 May 2016 to the Department of Planning and Environment (DP&E) over various matters addressed in previous correspondence. This letter has been prepared to respond to FCNSW comments in its latest correspondence dated 30 May 2016.

2. RESPONSE TO FCNSW SUBMISSION

FCNSW asks that the proponent explicitly acknowledge that:

Issue 1

FCNSW will be granted an unrestricted 'right of way' for State forest access.

Response

As explained in Section 4.9.1 of the RTS, access to the Bylong State Forest is understood to have typically been via farm tracks on the "Bylong Station" property. This property is now owned by KEPCO.

KEPCO will work with the FCNSW and the relevant parties in the process of establishing an approved "right of way" to the Bylong State Forest. This "right of way" could be via KEPCO owned land or via an alternate access.

Until the appropriate "right of way" easement is established, KEPCO is committed to maintaining access to the Bylong State Forest via the "Bylong Station" property.

As explained to FCNSW during the phone conference on 29 February 2016, access through this property can be arranged through a WorleyParsons' site representative located at the site office. From a safety perspective, KEPCO would seek to be advised through the site representative when visits are to take place.

Issue 2

The use of quantifiable methodologies will be agreed by the parties to determine the compensable losses suffered by FCNSW for:

a – Unrepairable damages to the productivity of FCNSW's estate (i.e. areas of ponding); and

b – Damage and loss of value to existing and future forest products.

Response

As explained in Section 4.9.2 of the RTS, KEPCO will undertake repairs through the current statutory process to any damage caused by subsidence to NSWFC infrastructure as a result of the longwall mining operation below the Bylong State Forest. KEPCO will prepare and implement a monitoring program in consultation with FCNSW to evaluate the impacts of subsidence on aspects that have the potential to affect future harvesting operations or forest productivity. These items can be dealt with in the Extraction Plans that will be developed for the longwall panels in consultation with FCNSW. As indicated in the RTS, the repairs would be undertaken subject to a risk assessment on the safety to persons affecting such repairs. Subject to accessibility, some impacts may be unrepairable.

KEPCO will continue to liaise with FCNSW to agree on the appropriate methodology to be utilised to determine the quantifiable losses suffered by FCNSW in relation to any unrepairable damage to the productivity of the FCNSWs estate. This damage will be determined through the monitoring programs developed in consultation with FCNSW as part of the Extraction Plan process.

Issue 3

> *KEPCO will accept ongoing liability for areas of State forest damaged or disrupted by subsidence where repairs or stabilisation works are not performed on account that KEPCO considers it unsafe to do so.*

Response

KEPCO will undertake repairs to erosion and subsidence cracking caused by subsidence due to its proposed longwall mining operations below the Bylong State Forest. Remediation of erosion and subsidence cracking will be undertaken subject to a risk assessment on the safety to persons affecting such repairs.

As part of the development of Extraction Plans over the area in question, KEPCO will engage with FCNSW representatives to make sure that there is a clear understanding of the expected subsidence impacts and how they will be managed for safety and ultimate rehabilitation. It is noted that active subsidence effects to be experienced on the surface will occur progressively in line with the progress of longwall panel extraction. The active subsidence zone will therefore be able to be closely monitored and managed on the surface. KEPCO will put in place suitable signage to advise members of the public of the potential for subsidence impacts and put in place the appropriate safety requirements in the area.

Remediation activities which are deemed unsafe for workers to undertake will be appropriately identified through an agreed active monitoring program and the potential liabilities will be assessed and presented to FCNSW. KEPCO will ensure that the subsidence related impacts that are not able to be safely remediated will not result in any ongoing material safety, environmental or operational liabilities for FCNSW post-mining.

3. CONCLUSION

We trust this response addresses the issues raised in the FCNSW submission. Should you have any queries in relation to this letter, please contact us on 6575 2000.

Yours faithfully

HANSEN BAILEY

James Bailey
Director

Nathan Cooper
Senior Environmental Scientist