HANCOCK PROSPECTING PTY LTD

Alpha Coal Project Supplementary Environmental Impact Statement

K | Coal Mine – Flooding Technical Report

Alpha Coal Project: Flooding Technical Report

April 2011

HANCOCK COAL PTY LTD

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Glossary

AEP	Annual Exceedance Probability: The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year (see footnote).
AMDT	Adopted Middle Thread Distance: The distance from the mouth of the watercourse or the confluence of the watercourse with the main watercourse measured along the middle of the watercourse.
Afflux	Rise in flood level caused by a hydraulic structure.
AGD84	The coordinate reference system used in Australia prior to the introduction of GDA94.
AMG	Australian Map Grid — Cartesian co-ordinate system derived from a Universal Transverse Mercator projection of latitudes and longitudes on the Australian Geodetic Datum (AGD) (now superseded).
ARF	Areal Reduction Factors
ARR	Australian Rainfall and Runoff.
Attenuation	The reduction of flood peaks due to storage effects.
Australian Height Datum (AHD)	The datum used for determining elevations in Australia which uses a national network of bench marks and tide gauges, and has set mean sea level as zero elevation. Elevations in metres above Australian Height Datum are annotated with the suffix m AHD (see below).
Average Recurrence Interval (ARI)	The average, or expected, value of the periods between exceedances of a given rainfall or a stream flow over a given duration (see footnote).
BoM	Bureau of Meteorology.
Catchment	The area of land which collects and transfers runoff into a waterway.
CL	Continuous loss.
Confluence	Area where two or more waterways come together to form one waterway.
Critical storm duration	The critical storm duration is the duration of rainfall that will result in the highest peak flood levels at a particular location.
DEM	Digital Elevation Model.
DERM	Queensland Department of Environment and Resource Management.
DIP	Queensland Department of Infrastructure and Planning.
Discharge	Instantaneous rate of flow measured in volume per unit time (such as m^3/s).
Downstream (d/s)	In the direction of flow of a stream or river i.e. away from the source.
DTM	Digital Terrain Model.
EIS	Environmental Impact Statement.
EP Act	Queensland *Environment Protection Act 1994*
EPP	Environmental Protection (Water) Policy 2009
Erosion	The process by which soil and rocks are loosened, worn away and removed from parts of the Earth's surface. Includes removal of debris supplied to the streams by slope wash, mass movement, and gullies.
FFA	Flood frequency analysis
Flood plain	That portion of a river valley that is covered during periods of high flood water.

Flow	Quantity of fluid measured over a period of time (such as ML/day).
Frequency	A measure of the number of occurrences per unit of time.
GDA94	Geocentric Datum of Australia. The coordinate reference system currently used in Australia to define co-ordinate systems.
GDR	Great Dividing Range.
GEV	Generalized Extreme Value
Groundwater	Water found underground in porous rock or soil strata.
HPPL	Hancock Prospecting Pty Ltd
Headwaters	Upstream Section of a river before it is joined by main tributaries. Typically smaller in width and flow than the main Section of the river.
HEC-RAS	A computer program that models water flow hydraulics of rivers and channels.
Hydraulic analysis	Refers to the assessment of flood levels, flows and velocities in waterways, creeks and rivers.
Hydrograph	A record of the discharge of a creek, stream or river over time.
Hydrological analysis	Refers to the estimation of flows that enter waterways, creeks and rivers.
Hydrology	The study of the occurrence, distribution, and chemistry of all waters of the earth.
IFD	Intensity Frequency Duration of rainfall
IL	Initial loss
Impervious Surfaces	Artificial structures such as pavements and building roofs, which replace naturally pervious soil.
Left/Right Bank	Defined for a watercourse with the observer facing downstream.
Log Pearson Type III flood frequency curve	A method described in Australian Rainfall and Runoff to relate flood peaks to annual exceedance probability.
m AHD	Metres (above the) Australian Height Datum. Refers to the number of metres above Australia's theoretical reference surface, approximately equivalent to the height above sea level.
MGA	Map Grid of Australia – current Cartesian co-ordinate system for use in Australia derived from a Universal Transverse Mercator projection of latitudes and longitudes on the Geocentric Datum of Australia (GDA).
MIKE FLOOD	A computer program that combines the MIKE11 and MIKE21 programs.
MIKE11	A one dimensional computer program that performs a hydraulic analysis of rivers, channels and water bodies.
MIKE21	A two dimensional computer program that performs a hydraulic analysis of rivers, channels and water bodies.
ML	Megalitre (1,000,000 litres)
MLA	Mining Lease Application
MRRM	Main Roads Rational Method
PB	Parsons Brinckerhoff
Peak discharge	The maximum discharge or flow during a flood.
Photogrammetry	Remote sensing technology used to determine geometric properties about objects from photographic images.

Pluviograph	A rain gauge which automatically records, usually in graph form, the cumulative amount of rainfall with reference to time.
PMF	Probable Maximum Flood
Rainfall Intensity	Depth of rainfall per unit time.
Rational Method	A procedure for determining peak discharge, which corresponds to a critical storm duration and specified catchment characteristics.
Reach	Portion of a stream channel between two specified points.
Recharge	The process involving the infiltration of water from the surface to groundwater.
RORB	A computer program that models urban and rural stormwater drainage by analysing rainfall and runoff in any land use area.
Runoff	The portion of rainfall which becomes surface flow.
SEIS	Supplementary EIS
SP Act	Sustainable Planning Act 2009
SRTM	Shuttle Radar Topographic Mission.
Temporal	Relating to time as distinguished from space.
Topography	Concerned with local detail in general, including relief and vegetative and human-made characteristics.
Tributary	A stream or river that does not reach the sea but joins another major river (parent river), swelling its discharge. Sometimes described in terms of “left bank” or “right bank”, referring to the bank of the parent river that the tributary connects to.
Upstream (u/s)	In the opposite direction of the flow of a stream or river, i.e. towards the source.
Water Act	Water Act 2000
Weir	A small overflow type dam in a stream or river, generally used to raise the water level or divert its flow.

Probabilities, ARI and AEP

For the purpose of this report, the Average Recurrence Interval (ARI) is generally used. It is recognised that other references to flood frequency are commonly used, however the ARI reference appears more widely understood by the public and has therefore been adopted in this report.

See http://www.bom.gov.au/hydro/has/ari_AEP.shtml. The Average Recurrence Interval (ARI) and Annual Exceedance Probability (AEP) are both a measure of the rarity of an event. With ARI expressed in years, the relationship is:

AEP = 1 – exp(-1/ARI)

This results in the following conversions:

ARI (years)	Percent Annual Exceedance Probability (% AEP)	Fraction Annual Exceedance Probability (AEP)
1	63.5	0.632
2	39.3	0.393
5	18.1	0.181
10	9.5	0.095
20	4.9	0.049
50	2	0.02
100	1	0.01
1,000	0.1	0.001
3,000	0.03	0.0003

Executive summary

General

This Flooding Technical Report is a revision of the Technical Report submitted with the Alpha Coal Project Environmental Impact statement (EIS) submission (September 2010) and incorporates responses to the comments from various stakeholders and statutory authorities. This Flooding Technical Report accompanies the Supplementary EIS (SEIS) submission.

The Alpha Coal Project (the Project) comprises the development of thermal coal resources located approximately 170 km west of Emerald, and 50 km north of the town of Alpha in the Galilee Basin. The coal reserves for this Project exist within the mining lease application (MLA) 70426. The coal resources will be developed by open cut mining with related infrastructure. Coal will be mined at a peak rate of around 40 million tonnes per annum (Mtpa) run of mine (ROM) coal. The coal will be crushed, sized and washed, with product coal transported by rail to Abbot Point. The Project covers an area of approximately 33,706 ha and will be developed by Hancock Prospecting Pty Ltd (HPPL).

The Project interacts with three main watercourses; Lagoon, Spring and Sandy Creek. This necessitated undertaking a flooding investigation of the whole catchment as part of the EIS/SEIS. This investigation determined the flood risk of the area, the potential impact of the mine development and any required mitigation works.

Objectives

The objective of this Technical Report is to describe the existing hydrological and hydraulic properties of the Project area and develop appropriate flood protection measures around the proposed mine works, to avoid any future damage to the environment. These measures are designed to cause as little impact as reasonably possible, while maintaining a high degree of protection to the site and the environment.
The stream morphology for the active channels is further determined in the Stream Morphology Technical Report and specifically addresses the detailed design requirements for the creek diversions.

Key deliverables of the flood assessment include:

- extent of existing 3000 year ARI flooding prior to mine implementation
- impact of the mine implementation on flood behaviour in the area
- measures required, to protect the mine against a 3000 year ARI flood event, while avoiding impact on the environment
- sustainable measures to divert fresh water around or away from the mine and back into the natural environment
- where impacts on existing creeks and channels occur, mimic the existing stream morphology as closely as reasonably possible in the developed environment.

Key outcomes of the flood assessment include the following features:

- The existing creek and drainage system traversing the Project area is highly variable. Key stream morphological characteristics range from wide flat floodplains to well defined creeks and gullies, sometimes featuring high velocities. High silt and sand loads are carried through the system with each passing flood event.

- The majority of flood level impacts are contained within the MLA, with some limited impacts evident outside the MLA. The flood level impacts outside the MLA are generally minor (<200 mm), relatively short in duration and do not affect any residences.
- The development of the flood protection levees and diversions around the mine and its associated works will not adversely impact on flood risk upstream of downstream of the MLA.
- The maximum predicted increase in upstream flood levels is 190 mm at the MLA boundary and last up to two and half hours in duration. This increase is predicted to occur at the upstream boundary of the proponent’s land in Lagoon Creek and floodplain. The increased water levels do not affect any existing dwellings or future mining infrastructure and are therefore considered to be minor in nature and acceptable.
- Predicted increase in flood levels downstream of the mine site is 130 mm at the MLA boundary and last up to four and half hours in duration. This increase is due to the loss of flood storage and redistribution of flows. The increased water levels do not affect any existing dwellings and are therefore considered to be minor in nature and acceptable.
- The hydraulic parameters, including velocity, shear stress and stream power of the existing Lagoon, Spring and Sandy Creek creeks are locally raised to levels well over those recommended in the ACARP guidelines. The proposed diversions have ensured that the values have not increased, but are generally within the ACARP guidelines with incidental increases to values similar to the existing values. The velocity, shear stress and stream power values are pertinent to the diversion channel design and are discussed in detail in the Stream Morphology Technical report contained in Volume 2, Appendix J of the SEIS. The Project is not expected to have a significant impact on the morphology of the Lagoon, Spring and Sandy Creeks in the long-term.

Further detailed assessment of the proposed diversions in order to minimise future impact on existing creeks will be undertaken during the detailed design of the proposed infrastructure as part of the application for a Water Licence.

1. Introduction

Hancock Coal Pty Ltd (HCPL) has commissioned Parsons Brinckerhoff (PB) to undertake a flooding technical study for the Alpha Coal Project, focussing on the existing flood behaviour and potential flood impacts due to mine development, and recommend mitigation measures against flooding and for any creek and watercourse diversions. This assessment is undertaken in the context of environmental values as defined in the *Environmental Protection Act 1994* (EP Act) and the Environmental Protection (Water) Policy 2009 (EPP (Water)).

This revision of the Flooding Technical Report is an update to the version submitted with the EIS and responds to comments and feedback received as part of the EIS process, as well as to specific design changes introduced by HCPL.

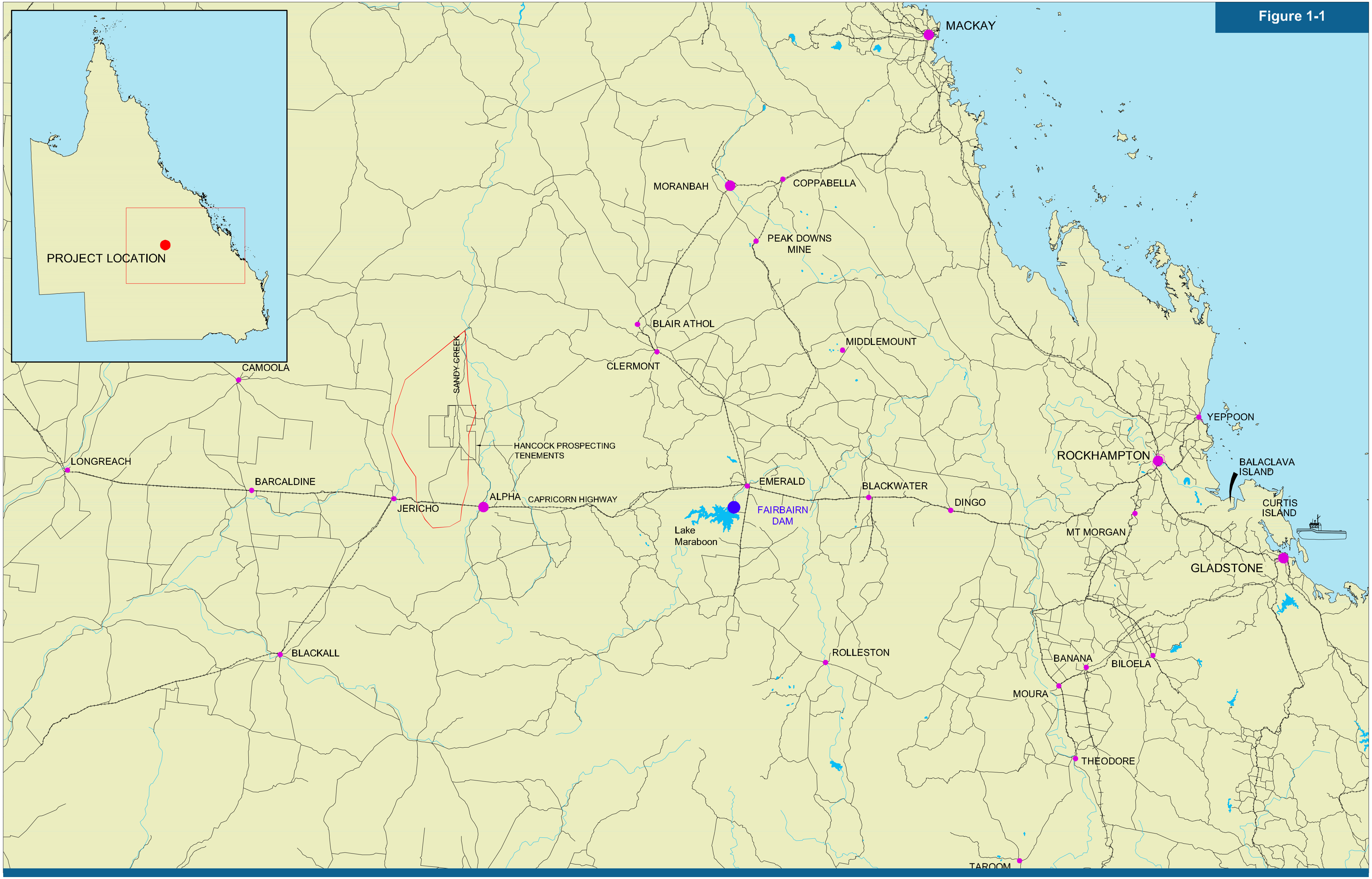
This report is one of several surface water technical reports, including studies on stream morphology, water management, water balance and water quality assessment that were undertaken for the Project EIS. In addition, this report incorporates recommendations made as part of an independent Flood Risk Study (C&R Consulting, December 2010) commissioned by HCPL.

This technical report is broadly structured as follows:

- background information, including objectives, scope of works, available data, previous studies and key changes to the design and approach to flooding
- methodology
- hydrological assessment
- hydraulic assessment
- flood impacts
- mitigation measures
- summary and conclusions.

The Alpha Coal Project is located approximately 50 km north of the town of Alpha in the Galilee Basin, 170 km west of Emerald, and approximately 170 km west of Emerald (Refer Figure 1.1).

Figure 1-1



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Full Size 1:1,000,000 ; Half Reduction 1:2,000,000
SCALE (m)

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ALPHA COAL PROJECT
PROJECT LOCATION

September 3, 2010

Plotted By: hamillm Plot Date: 03/09/10 - 09:57 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1055_PROJECT LOCATION.dwg

2. Background

2.1 Objective

The objective of this Technical Report is to describe the existing hydrological and hydraulic properties of the Project area and develop appropriate flood protection measures around the proposed mine works, to minimise environmental impacts.

2.2 Scope

The scope of this Technical Report is to describe the hydrology and hydraulics of the Project area and areas immediately upstream and downstream for the undeveloped case and the developed case with mine infrastructure in place.

The hydraulic assessment considers all proposed mine infrastructure including levees, creek diversions and diversion drains, and in collaboration with the stream morphological component, optimises the hydraulic design to meet the appropriate guidelines for submission to the planning authorities and gain DIP/DERM approval.

2.3 Available data

The following hydrological and hydraulic data is available:

- climate data (DERM and BOM) (Refer Section 3.2)
- stream gauging data (DERM) (Refer Section 3.2)
- digital terrain models (DTM) for the extent of the hydraulic model (including 7 km upstream and 12 km downstream of the site) (HCPL)
- Alpha Coal Project Mine Plan and 3D landform models (HCPL)
- civil design (PB BFS team)
- 12 D sectional data (PB).

2.4 Previous studies

Kevin's Corner Preliminary Flood Assessment (Connell Hatch, 2008)

Bankable Feasibility Study (BFS) Flood Studies (PB, August 2010)

Flood Risk Analysis (C&R Consulting, November 2010).

2.5 Key SEIS changes

Key changes to the scope and approach to flooding from the EIS (August 2010) include:

- Lagoon Creek flood protection levee is located further from the creek centreline to enhance conveyance and storage capability in the creek

- revised mine layout, with the western extremity of the mine footprint reduced by up to 2 kilometres
- revised alignments of the north western and south western diversions, optimising the topography to enhance conveyance and reduce the size of the diversion channels and levees
- revised hydrology for revised layout of the mine and associated catchments
- revised hydraulic modelling to include the full Project area using MIKE FLOOD, which combines the attributes of the 1D MIKE 11 and 2D MIKE 21 packages to allow a more detailed assessment of the stream morphological parameters essential for creek diversions
- comments regarding the water management and flooding impacts of the mine site were incorporated as appropriate (Refer Volume 2 Section 04).

3. Methodology of assessment

3.1 General

The Flooding Technical Report focuses on the potential impacts that the proposed mine development may have on the existing creeks. Where the impacts are deemed to exceed acceptable standards, appropriate mitigation measures are introduced.

In order to assess the impacts of a proposed development, the following process is adopted and discussed in detail in this section:

- appreciation of current legislation and guidelines (including various meetings with DERM to discuss the adopted approach and seek clarification)
- establish modelling cases to be considered
- undertake a hydrological assessment, covering the mine site and surrounding areas to determine existing rainfall frequency and intensity
- undertake an assessment of the existing catchments to determine the design runoff at key locations around the Project site
- develop hydraulic models of the existing case to determine flows, inundation areas, depths, velocity and stream power for a range of design conditions (Refer Section 3.1.2 and 3.1.3). This will provide an accurate assessment of the existing flow conditions of the watercourses. Refer to the Stream Morphology Technical Report (Volume 2, Appendix J).
- develop hydraulic models of the developed case to determine flows, inundated areas, depths, velocity and stream power for a range of design conditions (Refer Sections 3.1.2 and 3.1.3). This will provide an accurate assessment of the revised flow conditions as a result of mine development, and in particular the performance of the proposed creek diversions
- comparison of the developed and existing case results (the impact). The objective of the SEIS hydraulic modelling is to achieve a hydraulic design of the watercourses, representative of the existing hydraulic performance of the watercourses and that of the proposed design. It is accepted that further refinement may be required during the detailed design phase to fully meet the design guidelines and gain the relevant Authority's approval
- Inclusion of mitigation measures to ensure equilibrium (e.g. no impact) and long term stability of the proposed works
- conclusion and recommendations for the design development to comply with current legislation and guidelines (Refer Section 3.1.1).

3.1.1 Legislation and guidelines

The following legislation and guidelines set out the requirements and issues to be discussed as part of the Project's SEIS.

Water Act 2000

The *Water Act 2000* (Water Act) aims to provide for the sustainable management of water and other resources. The Act sets out the legislation in terms of the management of water as a consequence of a development.

For this Flooding Technical Report, the Act requires the following to be addressed:

- “Potential impacts to the flow and the quality of surface waters from all phases of Project activities, including creek diversions, with particular reference to implications for current and potential downstream uses, including the requirements of any affected riparian area and in-stream biological uses in accordance with the EPP (Water) and the Water Act 2000. The impacts of surface water flow on any existing water infrastructure should also be considered”.

- “The need, or otherwise, for licensing of any creek diversions, under the *Water Act 2000*, should be discussed”.

The governing legislation for watercourse diversions require a water licence to interfere (with an existing watercourse), under the provisions under the *Water Act 2000*.

Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (SP Act) replacing the *Integrated Planning Act 1997*. The SP Act seeks to achieve sustainable planning outcomes through managing the process by which development takes place, managing the effects of development on the environment, and continuing the coordination and integration of local, regional and state planning.

The governing legislation for watercourse diversions, require a development permit under the SP Act for the on ground works.

Central West Water Management and Use - Regional Guideline – Watercourse Diversions

The Queensland Government Department for Environment and Resource Management (DERM), has prepared the Central West Water Management and Use Regional Guideline – Watercourse Diversions – Central Queensland Mining Industry (January 2008).

This guideline sets out the design criteria against which applications for watercourse diversions will be assessed, the information required to accompany applications for diversions, the legislative basis of the requirement for authorisations and the application process for a licence to interfere and development permit for the works.

The governing legislation for watercourse diversions require a water licence to interfere (with an existing watercourse), under the provisions of the Water Act, and a development permit under the SP Act, for the on ground works.

This publication is based on research undertaken by ACARP in the Bowen Basin River Diversions – Design and Rehabilitation Criteria (2002).

ACARP, Bowen Basin River Diversions, Design and Rehabilitation Criteria

The Australian Coal Association Research Program (ACARP), Bowen Basin River Diversions, Design and Rehabilitation Criteria (2002) provides design criteria based on research undertaken in the Bowen Basin and is widely referred to as the reference document for Creek Diversions in Australia. The Central West Water Management and Use Regional Guideline – Watercourse Diversions document refers to this publication.

3.1.2 Design conditions and criteria

The key design criteria for the flood assessment and proposed creek diversions are as follows:

Flood immunity Will be designed to withstand a 3000 year ARI event (1% of mine life). Flood immunity is provided by levees located around the entire mine area west of Lagoon Creek. Levees are located adjacent to Lagoon Creek and the north western and south western diversions, protecting the mine pits from flooding from the creeks and diversions, and protecting the environment from any mining affected runoff.

Flood inundation Flood inundation extending from proposed creek diversions along the northern and southern MLA boundary will be contained within the Project's MLA, by providing an additional levee between the creek diversion and the MLA boundary. This levee will be designed to align with 3000 year ARI water line in Lagoon Creek.

Diversions Diversion channels will be assessed for three flow events: 2 year ARI, 50 year ARI and 3000 year ARI.

Active Channel An active (low flow) channel will be provided in the high flow channel. The active channel is sized similar to the existing "bank full" channel. The bank full flow is assessed as equivalent to a 2 year ARI event. The active channel may, as required to achieve equilibrium, meander within the high flow channel.

High Flow A high flow channel is provided to convey flows of up to a 50 year ARI event. If flows exceed the capacity of this channel, the water will break out onto the flood plain area confined by a levee on the mine pit side and high ground levels on the other side. Where flows from the high flow channel potentially impact on adjacent tenures, a levee will be provided on the MLA boundary.

Vegetation It is assumed that diversions will be vegetated prior to commissioning. The adopted roughness coefficient assumes vegetation.

Roughness Adopted roughness for the existing and developed cases is as set out in Chapter 6. In selected areas roughness has been increased to simulate mitigation measures against velocities above the recommended values. Measures to increase the channel roughness are discussed in the Stream Morphology Technical Report (Volume 2, Appendix J).

Velocities Acceptable velocities will be as per the Central West Water Management and Use Regional Guideline – Watercourse Diversions, Table 1.

Stream Power Stream power is an appropriate measure to determine changes to flow conditions in watercourses. Acceptable stream power values will be as per the Central West Water Management and Use Regional Guideline –

Watercourse Diversions, Table 1. Further details of stream power are provided in the Stream Morphology Technical Report.

3.1.3 Cases considered

This Flooding Technical Report assesses the impacts of the Project based on two development cases:

Existing case: The existing (base) case is where no mine development has taken place and the existing creeks and watercourses are unaffected by mining operations.

Developed case: The developed case for the purpose of this study is the ultimate development of the Project at year 30 of mine life. This case assumes that the following features are realised:

- The mine is protected by levees to provide 3000 year ARI flood immunity.
- Lagoon Creek is defined by a levee along its left (west) bank and natural high ground along its right (east) bank.
- Approximately 14 km of the existing Lagoon Creek active channel is diverted to a 9.6 km long active diversion channel (refer to Stream Morphology Technical Report). The active channel remains within the existing flood plain of Lagoon Creek; the flood plain being narrowed by a levee in that location.
- The south western Spring Creek and local overland flows are diverted to enter Lagoon Creek immediately upstream of the mining activities.
- The western and north western Sandy Creek and local overland flows are diverted to enter Sandy Creek at the northern perimeter of the mine site.
- Both western diversions comprise a high flow channel and, as appropriate, a low flow channel. The diversions are defined by a levee running parallel to the diversions on the eastern side, protecting the mine from flooding. In the event of flows in excess of bank full (high flow channel), water will temporarily inundate the area to the west of the levee and diversion channels.
- The diversions traversing the northern and southern MLA boundaries, and sections leading up to these areas, are further defined by an additional levee between the diversion channel and the MLA boundary, to ensure that flood waters do not break out onto adjacent properties.

Figure 3.1 illustrates the developed case infrastructure and proposed diversions and levees and indicates the above levees and diversions.

The impact of the Project is assessed as the difference in flows, water levels, velocity and stream power between the developed case and the existing case.

Mitigation measures are developed to minimise the impacts of the Project on the natural creeks upstream and downstream of the site.

Each of the above cases will be assessed against two flood events: the 1000 year ARI event and the 3000 year ARI flood event. The 1000 year event assessment is carried out for the diversion design while the 3000 year event assessment is intended solely to understand the stream behaviour for the levees providing flood immunity. The 2 year and 50 years ARI flow conditions are further discussed in the Stream Morphology Technical Report (Volume 2, Appendix J).

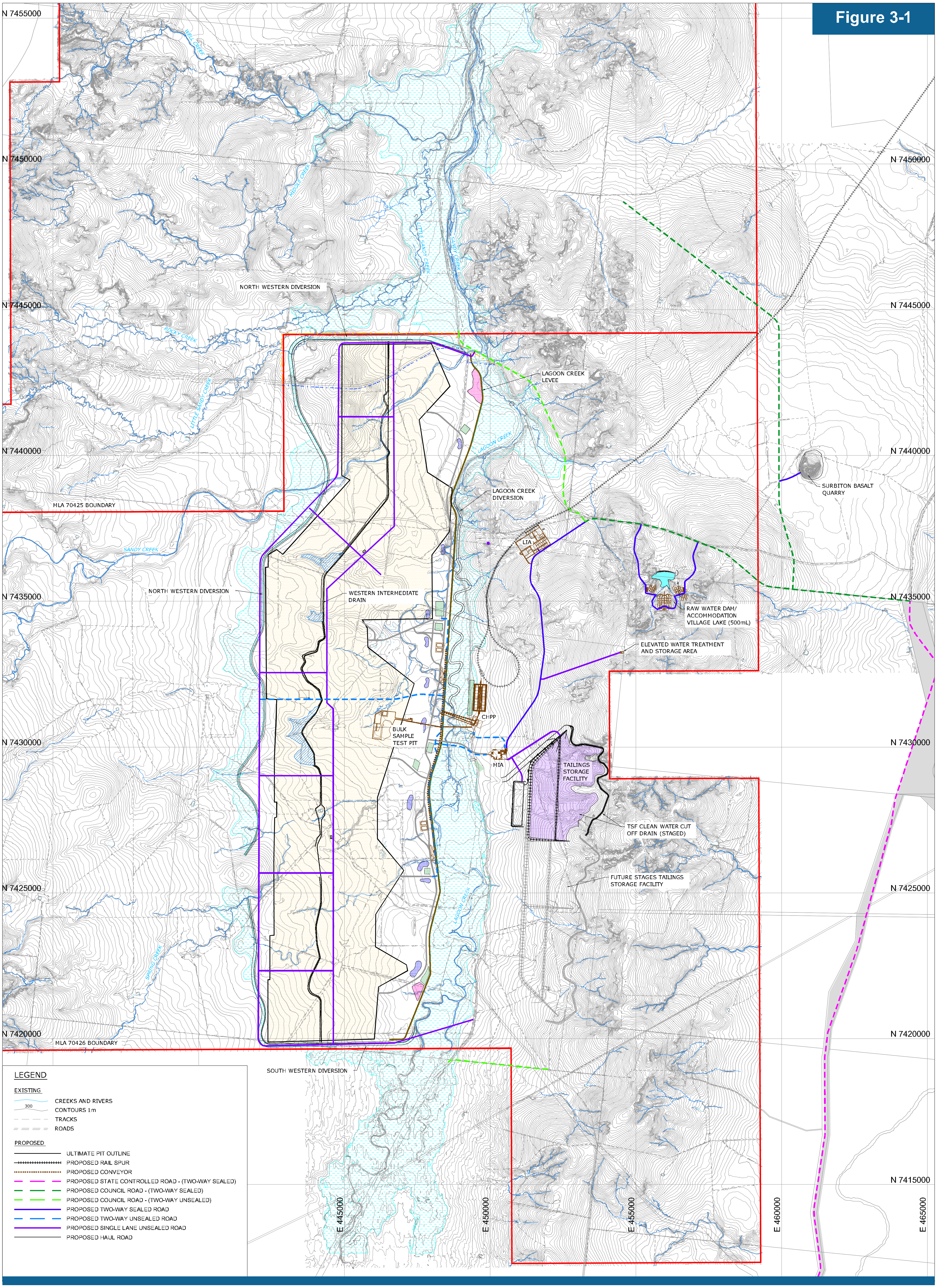
3.2 Data compilation and review

3.2.1 Existing data

The following data was collated and reviewed:

- The previously developed MIKE21 model for the adjacent Kevin's Corner Project (Connell Hatch. 2008). Only limited data from this model was used to develop the MIKE21 Model for the Project, due to its proximity to, and impact on the Alpha MLA tenement.
- Existing topographical data, for the adjacent Kevin's Corner Project was used where appropriate. This included the Digital Terrain Model (DTM) for the entire Project area, except for the additional DTM purchased for the area immediately upstream of the mine.
- ARR rainfall temporal patterns for the Project area were reviewed and used for the calibration of the developed hydrological models. There is no suitable pluviograph record for this catchment or nearby catchments that could be used for this assessment.

Figure 3-1



ALPHA COAL PROJECT

WATER INFRASTRUCTURE AND LEVEES

PARSONS BRINCKERHOFF

0 1 2 3 4 5
Kilometres

April 7, 2011

Plotted By: duffyt Plot Date: 07/04/11 - 15:24 Cad File: \\Aubne1\PROJ\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1013A_Water Infrastructure & Levees - Figure 3-1.dwg

- The previously developed RORB model for the adjacent Kevin's Corner Project (Connell Hatch. 2008). Only limited data from this model was used to develop the RORB Model for the Project, due to its proximity to the Alpha MLA.
- Stream gauging data collected from various sources for model calibration.
- Anecdotal evidence (Connell Hatch. 2008) providing flood levels and recollections of flood behaviour were reviewed and used for verification of model results. Anecdotal evidence suggests that during the 1990 flood event, the flood levels at the "Wendouree" property reached 305 m AHD. For this flood event, the stream gauging data in the nearby catchment at Native Companion Creek gauging station 120305A shows that the maximum discharge was 1,820 m^3/s.
- A site visit was undertaken as part of the stream morphology assessment on 26, 27 and 28 July 2010. All creeks subject to diversion were inspected and their existing condition and flood behaviour assessed. Details of the stream morphologic findings are contained in the Stream Morphology Technical Report (Volume 2, Appendix J of the SEIS). Photographs were taken of key areas along the creeks within and immediately outside the MLA area are also contained in this report.

3.2.2 Additional studies

During the EIS and SEIS process, the following studies and assessments were carried out providing additional information for the Flooding Technical Report:

- Flood Risk Assessment, C&R Consulting, October 2010. This study questioned some of the input parameters and in particular the validity of gauging and rainfall data for the assessment. It also queried the appropriateness of roughness coefficients adopted for various saturation conditions. The assessed 90^{th} percentile chance of exceedance of the nominated flood event, produced flows within the 20% upper boundary of the EIS flood assessment, which is contained within the levee's freeboard allowances for the Project.
- January 2011 Flood Frequency assessment, PB, March 2011. This assessment determined:
  - That the January 2011 flood event at gauge GS120305A in Native Companion Creek (close to Alpha town) was equivalent to an 82 year ARI event
  - That 168 km downstream of the Project site (north of the Project site) at gauge GS120301B in the Belyando River at Mt. Douglas, the flood frequency had reduced to a 4.5 year ARI event at its peak
  - Rainfall in the Alpha Coal Project area was limited with rainfall occurring intermittently. During the period 23/12/10 to 28/12/10 it rained over six days with a total rainfall of 81.1 mm. The peak daily rainfall for the period 1 November 2010 to 23 February 2011 was 35.3 mm and the total rainfall for the period was 442.6 mm. Rainfall over the January 2011 period is estimated to be between a two year and five year ARI event.

3.2.3 Topographical and aerial photography data

Topographic data was used to define catchment boundaries and develop the hydraulic models used. The following data was used for this study:

- Shuttle Radar Topographic Mission (SRTM) data covering the catchment area for the purposes of delineating the catchments.
- A digital terrain model (DTM) was developed using information sourced from AAMGlobal. The topographic data included 1 m contour data derived from photogrammetric aerial survey supplied by AAMGlobal through HPPL dated 2008.
- Additional photogrammetric aerial survey data sourced from AAMGlobal in July 2010, covering the area immediately south of the MLA area. The additional survey data was used in the hydraulic modelling to evaluate the extent of the flooding impact upstream of the mine site. A quoted vertical accuracy of ±0.15 m and a horizontal accuracy of ±0.50 m applies to the topographic data supplied by AAMGlobal.
- Aerial photography was sourced from AAMGlobal.

3.2.4 Development of DTM

Development of the DTM is a critical part of this study, as the quality of the DTM can greatly influence the results of the hydraulic modelling. A 2D model of the Project area, including Lagoon and Sandy Creek, extending 7 km upstream and 12 km downstream of the Project was developed. The extent of the site was adopted to ensure that all existing watercourses and proposed diversions would be adequately captured and that any areas of potential impact would be included.

3.2.5 Historical flood records

Historical data used for the flooding assessment include daily rainfall (pluviograph data was not available) and stream gauge data. This information was used to validate and provide confidence in the models used.

Historical rainfall data is collected by both government and private organisations. The Bureau of Meteorology (BoM) and DERM are the prime custodians of water resources data records in Queensland. The BoM maintains much of the rainfall and pluviograph network and DERM owns and operates the network of stream gauges.

There are no gauging stations operating within the Sandy Creek catchment. However, five stream gauging stations located within the Belyando River basin were representative of the Project area, in terms of location and physiography. Details of these gauging stations are provided in Table 3.1. The location of these gauging stations in proximity to the Project area is shown in Figure A-1 in Appendix A.

Table 3.1 DERM stream gauging stations

Location	Station	Period of record	Length of record (Yrs)	Catchment Area (km^2)	Distance (km)
Belyando River at Mt. Douglas	120301A	1949 – 1975	26	35,471	168
Belyando River at Gregory Development Road	120301B	1976 – present	35	35,411	168
Native Companion Creek at Violet Grove	120305A	1967 – present	44	4,065	64
Mistake Creek at Charlton	120306A	1968 – 1993	25	2,583	81
Mistake Creek at Twin Hills	120309A	1976 – present	35	8,048	125

For the purposes of calibration of the hydrological model, the DERM stream gauge record at Native Companion Creek (120305A) was adopted, because of comparable catchment area, characteristics, proximity to the study area and longevity of the data records. The historical dataset is displayed in Figure 3.2 and monthly stream flow totals are summarised in Figure 3.3.

This hydrological assessment considers rainfall, land use, topography, antecedent conditions and catchment development to determine catchment runoff.

For the purpose of this assessment, the RORB Runoff Routing software as developed by the University of Monash, has been used. This software package was chosen for its ability to accurately predict response to rainfall over time, for large and complex, and in particular, rural catchments.

A hydrological model of the Sandy Creek catchment with the tributaries of Lagoon Creek, Spring Creek, Sandy Creek (upstream section), Little Sandy Creek, Rocky Creek, Middle Creek and Well Creek, as well as numerous unnamed creeks was developed using the RORB software.

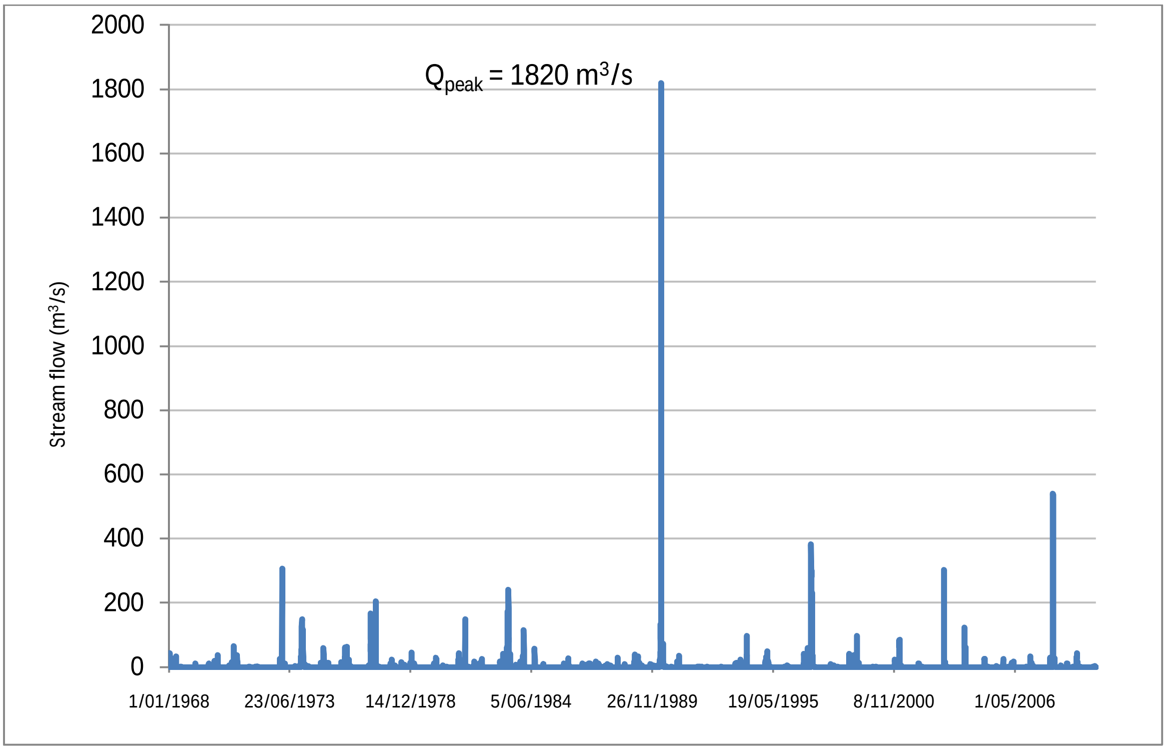


Figure 3-2 Stream flow record at gauging station 120305A

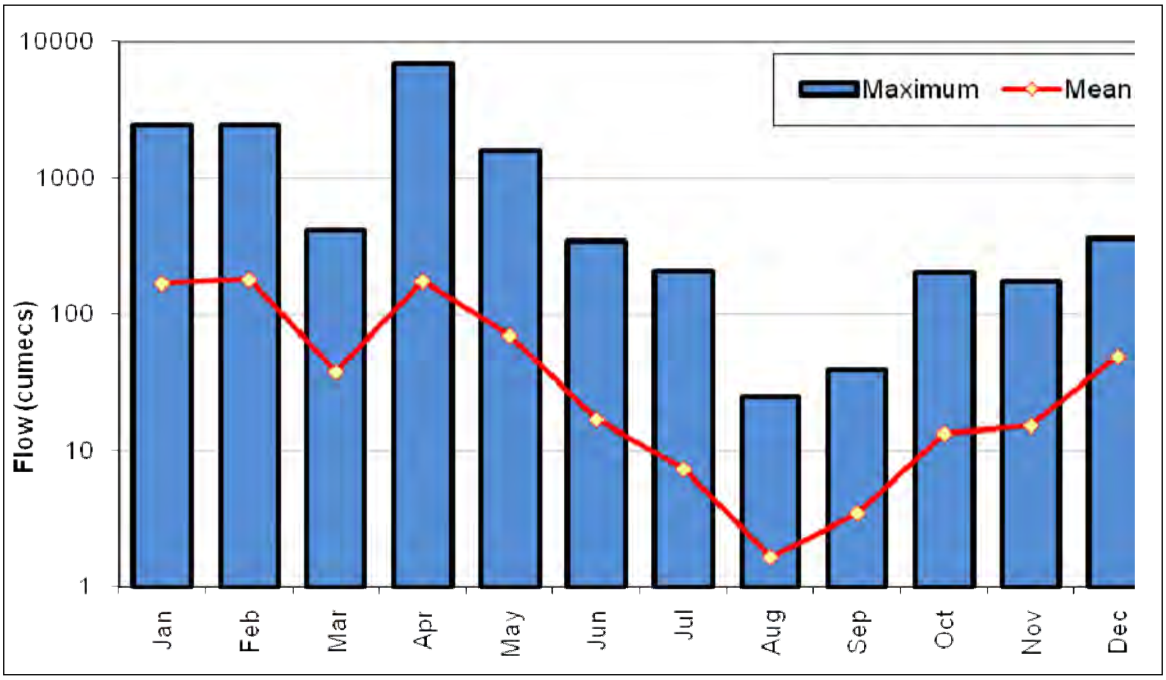


Figure 3-3 Monthly stream flow data at 120305A

3.3 Hydrological modelling

The objective of the hydrological assessment is to determine catchment runoff for a range of flood events, taking into account catchment characteristics. These are used in the hydraulic modelling for design of the Project's infrastructure.

The hydrological assessment comprised the following key tasks:

- extract rainfall depths from Intensity-Frequency-Duration (IFD) curves for a range of Average Recurrence Interval (ARI) events
- use of temporal patterns for each ARI event
- divide the catchment into sub-catchments (using Catchment-Sim) for greater definition of catchment parameters within the hydrological model
- consider initial and continuing losses for each catchment and adjust rainfall input accordingly
- estimate runoff from sub-catchments based on pervious/impervious areas
- route subcatchment runoff through the channel system to catchment outlet locations (i.e. input node for hydraulic models).

The hydrological model estimates hydrographs for the various ARI design events, at given nodes around the site for input into the hydraulic model. Details of the hydrological assessment are contained in Section 6.

3.4 Hydraulic modelling

The objective of the hydraulic assessment is:

- to determine the flood behaviour of existing water courses that may be affected by the Project (Base Case)
- to replicate the hydraulic and stream morphologic behaviour of the natural creeks in the design of the developed catchment scenario, including levees, creek diversions and diversion drains
- to estimate the impacts of the proposed creek diversion on the upstream and downstream environment and landholders
- to determine the flood water surface levels to which the mine infrastructure will be designed to provide appropriate flood immunity and protect the environment.

For the Flooding Technical Report, a hydraulic model was prepared using MIKE FLOOD. MIKE FLOOD incorporates a 1D MIKE 11 model and a 2D Hydrodynamic MIKE21 model developed by DHI Water and Environment (2009). The use of a 2D hydraulic modelling package is better suited to the Project as it more appropriately represents the braided channel systems and locally wide floodplains than a 1D model. The MIKE11 component however better represents the smaller flows experienced in the active channel of the creeks and facilitates the design of the creek diversions. The stream morphology uses MIKE 11 to determine existing flow conditions and develop appropriate diversion design. The combination of the two capabilities is ideally suited to models of this magnitude, allowing dynamic modelling of the entire system while providing details for wide ranging flow conditions.

As part of the Stream Morphology assessment, MIKE11 was used to determine flood behaviour up to the 50 year ARI events. Details of this assessment are contained in the Stream Morphology Technical Report contained in Volume 2, Appendix J of the SEIS.

The following represents the adopted approach to the MIKE FLOOD modelling:

- Establish a DTM covering the full extent of the hydraulic model, including the potential upstream and downstream channel reach that might be impacted by the Project.
- Prepare grid network for existing and developed case.
- Input the hydrographs for each inflow node, derived from the hydrological assessment.
- Run the model for the existing case for the 1000 year ARI event to assess the flood characteristics of the existing creek system (water level, depth, velocity, stream power).
- Run the model for the existing case for the 3000 year ARI event to assess the flood extent and hydraulic properties (water level, depth, velocity, stream power) of the existing creek system.
- Run the model for the developed case for the 1000 year ARI event to assess the performance of the proposed creek diversion system, and upstream and downstream channel reaches. Compare the channel performance against the existing case. For the developed case the dynamic model will route the various catchment floods through the system, based on their proximity, size, roughness and rainfall characteristics. Hence not all flows will occur simultaneously.
- Run the model for the developed case for the 3000 year ARI event to assess the performance of the levees to provide appropriate flood immunity to the mine pits and compare the channel performance against the existing case.
- Revise the developed case model runs as necessary to more accurately replicate the existing case flow conditions by introducing mitigation measures.

Modelling was carried out to primarily highlight potential impacts of and identify appropriate mitigation measures for the major flood events (1000 and 3000 year ARI). Further refinement of the Lagoon, Spring and Sandy Creek hydraulics may be carried out as part of the detailed design phase, with the aim to fully meet relevant legislation and guidelines (refer Section 3.1.1) and meet the criteria for Water Licensing.

For the purpose of this SEIS Technical Report, further mitigation measures will be presented with an explanation of how these measures may influence the impacts determined in the modelling process and how the design aims to achieve approval.

4. Existing environment

The Project area is located within the Sandy Creek catchment, forming the south westerly portion of the Belyando River system. The Sandy Creek catchment is bounded by the Great Dividing Range (GDR) to the west and a north-south trending line of low hills to the east, and extends to the south of the Capricorn Highway and northward to around Wendouree (Refer Figure A.1).

For the purpose of this flood study, the hydrological reference point is located on Sandy Creek, some 12 km downstream of the northern MLA boundary. The study catchment area is approximately 2,734 km^2 and covers the watercourses associated with the Project including Lagoon, Spring, Sandy and Rocky Creek (refer Figures A-2 and A-3 in Appendix A). The catchment also includes the Project area, including mine pits, overburden areas and associated mining infrastructure. The Project tenement is traversed by Lagoon Creek which flows south to north, and by Spring Creek and Sandy Creek from west to east.

The existing landform is predominantly flat with wide floodplains flanking generally well-defined creeks and some smaller tributaries. The floodplains are vegetated with tall native grass, bushes, sparse trees and dense vegetation around the creeks and water courses. All creeks in the Project area are ephemeral upland freshwater creeks.

Sediment transport is common in Spring and Sandy Creeks, as well as the unnamed creeks draining from the west. Typically silt is carried through the system with every storm event picked up in the upper catchments and deposited as flows diminish and velocities no longer keep the silt suspended. It is therefore to be expected that this phenomenon will continue in the future and it should not be discouraged in any way, as this would unsettle the natural equilibrium in the channel system.

The nature and flood behaviour of the creeks is discussed in detail in the Stream Morphology Technical Report.

5. Project description

The Project from a flooding perspective, includes all infrastructure necessary to divert existing waterways and overland flow around the mine site, with the aim of minimising contact of fresh water with mining affected land. This assessment therefore focuses on watercourse diversions and flood protection levees.

Three creek diversions will be constructed as part of the mine development, namely, Lagoon Creek diversion, north western diversion and south western diversion. All diversions are complemented by an adjacent levee to provide 3000 year ARI flood immunity to the mine.

The philosophy of this approach is that it is more economical and risk-averse to provide long term flood immunity for the mine from the onset, rather than moving the western diversions and levees, as mining progresses.

The diversion channels are designed with an active channel generally equivalent to the 2 year ARI event. Where flows are of a minor nature the active channel may be enlarged to take flows up to 50 years ARI. Generally however the 50 year ARI flows are contained in a high flow channel, with the active channel meandering within it. Both the Spring and Sandy Creek diversions include a high flow and active channel.

Figure 3.1 provides locations of the various flood management infrastructure, being:

- **Lagoon Creek Diversion:**
  - the Lagoon Creek diversion comprises the diversion of the active channel only, to another location within the natural flood plain. The 9.6 km long diversion channel is designed to connect the existing upstream and downstream natural active channels, while providing a degree of meandering to replicate the existing natural channel. The excavated channel is a combination of the active (2 year ARI flows) and high flow (50 year ARI flows) channel but, similar to the existing active channel does not feature a separately distinguishable low flow section set into the high flow channel
  - a levee situated on the west (left) bank of Lagoon Creek through the MLA, will provide flood immunity of up to 3000 year ARI for mining operations. The EIS assumed that the levee would be set further into Lagoon Creek, however following discussions with DERM and stakeholders, the levee was moved further west to provide better conveyance and storage within Lagoon Creek. The topography on Lagoon Creek's right (east) bank rises rapidly and therefore mine infrastructure on the east bank is unaffected by the floods
  - the Lagoon Creek diversion is positioned to minimise sterilisation of coal, even though coal deposits remain sterilised under the existing constricted channel section of Lagoon Creek (located at the downstream end of the active channel diversion). The adopted levee and active channel route allows adequate offsets between the diverted creek and proposed mining operations, reducing any impact that the mining operations will have on the conveyance capacity of Lagoon Creek. The diversion is anticipated to provide a stable and sustainable creek alignment for Lagoon Creek into the future.

- **North Western Diversion (Sandy Creek):**
  - the north western diversion totals 25.5 km in length, of which Sandy Creek comprises 11 km. The remaining length of the channel captures overland flows and discharge from unnamed creeks. The most northern section of this diversion channel is located just inside the perimeter of the MLA (refer Figure 3.1) and includes an additional levee on its left bank, to avoid flood waters from this diversion affecting the adjacent property. The diversion is designed with a high flow channel to 50 year ARI and includes a low flow channel sized to 2 year ARI. This diversion rejoins the original Sandy Creek some 100 m before the confluence with Lagoon Creek
  - a flood levee is located adjacent to, and on the mine side of the diversion channel, and provides flood immunity to the mine to 3000 year ARI. In the event of floods exceeding 50 year ARI, flood water will breakout of the high flow channel and rise against the levee, temporarily inundating adjacent (upstream) low lying areas. No third party properties will be affected
  - additional levees may be included between the diversion and the MLA boundary to avoid breakout of flows from the diversion to adjacent third party properties, and similarly to protect the Project infrastructure from adjacent creeks (e.g. Little and Rocky Creek).
- **South Western Diversion (Spring Creek):**
  - the south western diversion totals 11.2 km in length, of which Spring Creek comprises 10 km, running parallel to the south-west MLA boundary. The diversion is designed with a high flow channel to 50 year ARI and an active channel to 2 year ARI. This diversion channel joins Lagoon Creek some 150 m inside the upstream boundary of the MLA boundary. As with the north western diversion, an additional levee is provided between the diversion channel and the MLA boundary to avoid breakout of flood waters onto the adjacent tenement
  - a flood levee is located adjacent to, and on the mine side of the diversion channel and provides flood immunity to the mine to 3000 year ARI. In the event of floods exceeding 50 year ARI, flood water will rise against the levee and locally breakout, temporarily inundating adjacent low lying areas. No third party properties will be affected.
- **Mine internal drainage:**
  - within the area surrounded by levees, additional temporary catch drains and levees running south to north will be provided, to divert clean overland flows from these catchments to the diversion channel at the northern perimeter of the site. These catch drains will include a levee on the downstream side, ensuring that the down-slope pits are protected against flooding to 100 years ARI. 3000 year ARI immunity is not considered necessary at this location as this immunity is already provided at the western diversions and the catchments associated within the mine site are more manageable. To avoid backflow from the north western diversion, flap valves and appropriately raised levees will be provided at the interface between the two structures. Temporary storage in case of higher water levels in the receiving diversion will be provided as appropriate.

6. Hydrological assessment

6.1 Hydrological modelling

Hydrological modelling is the process of determining runoff generated from rainfall on a catchment. To take into account the factors that contribute to catchment runoff, the runoff routing hydrological model RORB has been used for this Project. This software generates inflow hydrographs which are used in the hydraulic models.

Factors affecting the runoff volume and peak flow include:

- size and slope of the catchment and adjoining channels
- catchment land use, soil conditions and level of development
- condition of the catchment (dry or saturated) when the rainfall starts
- intensity and temporal pattern of rainfall
- ability of the catchment and other features, to store runoff.

Simplistic methods exist to estimate the amount of runoff from a small catchment (i.e. peak flow methods like the Rational Method). However, with large and complex catchments, the use of modelling software such as RORB is required to accurately predict the response to rainfall over time and the interaction between sub-catchments. The RORB program was used to obtain the runoff hydrograph and detailed information of the hydrology is included in Appendix A.

6.1.1 Runoff – Routing model

The main reason for developing the RORB model was to obtain the runoff hydrograph characteristic or shape, which is not easily obtainable by applying the Rational Method. In addition, rational method is only limited to catchments less than 25 km2.

The conceptual runoff routing model RORB (Laurenson et al 2006) was utilised to model runoff behaviour of the Sandy Creek catchment. RORB is a computer based, hydrologic modelling program that enables the simulation of catchment storage and runoff response by a network of conceptual storages representing the stream network and reservoirs. RORB is an interactive runoff and streamflow routing program that calculates catchment losses and stream-flow hydrographs resulting from rainfall events. It has been widely used in Australia and is recommended by ARR for flood estimation, spillway and detention basin design, and flood routing. RORB is similar to other commercially available programs such as URBS and RAFTS, which are also based on Laurenson method, and is the industry benchmark for catchments of this nature.

The RORB model represents the catchment response by a network of conceptual storages. The net rainfall (after deducting losses) is routed through the network resulting in a surface runoff hydrograph at the catchment outlet. Each node in RORB represents a sub-catchment, with individual parameters reflecting catchment data as listed in Table 6.1. The nodes are connected by links with an associated lag time, reflecting the length and/or grade of a channel between inflow locations. The model provides more flexibility to simulate catchment behaviour than in the analytical mode.

6.1.2 RORB model parameters

The RORB model network supplied by Connell Hatch (2008) was reviewed and was adopted in this study, with some minor amendments of sub-catchments to suit the Project configuration . The RORB model of the Sandy Creek catchment comprises 49 sub-catchments, the layout of which is shown in Appendix A. The model was extended to include 7 km upstream and 12 km downstream of the Project boundary. The Sandy Creek catchment has a total area of 2,734 km^2. The RORB model has been calibrated on the neighbouring Native Companion Creek catchment gauging station (120305A).

Two sets of calibration parameters were derived for each event to give the best fit to the observed data:

- loss parameters; initial loss (IL), continuing loss (CL)
- model parameters; catchment lag parameter (k_c) and catchment non-linearity parameter (m).

Non-linearity of the catchment is defined using the parameter 'm'. A value of one implies a linear catchment where the resulting flow (hydrograph) is proportional to the rainfall, and additional flows can be summed to be representative of a total hydrograph of all the inputs. k_c is dependent on the value of m to obtain optimum fit of a hydrograph. In this study, no pluviograph and or hydrograph are available to fit peaks or the lag time. The default value is k_c = 0.8, however the 'm'-value was adjusted to match peak flows as there are no local catchment conditions that would suggest that the catchments have a more or less linear response to rainfall. The calibrated model parameters are summarised in Table 6.1.

Table 6.1 RORB model input parameters

Event (years ARI)	k_c	m	Initial loss, IL (mm)	Continuous loss, CL (mm/hr)
2 *	108	0.80	65	2.5
5	108	0.90	70	2.5
10	108	0.90	70	2.5
20	108	0.90	60	2.5
50	108	0.90	30	2.5
100	108	0.90	15	2.5
1000	108	0.83	0	2.5
3000	108	0.83	0	1.9

* Due to large disparity between catchment size and flow, calibration of this event was difficult to achieve and hence m and IL values are incongruent to other event values. However the calibration was deemed acceptable for this event because it is a small event and a 20% sensitivity margin is assumed to account for issues of this nature.

HCPL commissioned a Flood Risk Assessment study (C&R Consulting, Nov. 2010). The issues raised in the report have been taken into consideration in the sensitivity analysis and the resulting increased flows incorporated within the 20% upper bound assessment of the flood flows for all events (refer Section 6.7).

6.1.2.1 Rainfall losses

Loss attributed to catchment antecedent conditions and soil infiltration during an event can significantly change the magnitude of the resulting flood. Site specific loss values are best determined following an assessment of historical data, and forms part of calibrating the hydrological model. RORB uses two rainfall loss parameters and two runoff routing parameters to calculate stormwater flows. The initial loss (IL) and continuing loss (CL) affect how much rainfall is lost to soil infiltration and therefore how much is converted into surface runoff. It is an accepted rule-of-thumb that storm events of larger ARI have lower initial losses. *Australian Rainfall and Runoff* (ARR) Book II Section 3, recommends that for catchments in central Queensland the initial loss lies between 0 mm and 140 mm in extreme cases for catchments in Australia. An initial loss of zero is recommended for estimation of maximum possible or probable flood estimations, while a value of about 10 mm is recommended for a flood estimated from a large to rare storm event. Values of continuing losses can vary greatly in Australian catchments, and values of 0 to 3 mm/hr are used for average design conditions. For the 100 year ARI, the continuing loss rate was 2.5 mm/hr. The continuing loss value of 2.5 mm/hr was adopted in the RORB model. A continuing loss rate of 1.9 mm/hr was adopted for design events greater than ARI 1 in 1000 yr.

6.1.2.2 Routing K_c parameters

Weeks (1986) investigated k_c values for 86 catchments across Queensland. Most of the available data are for coastal streams but values are included for some catchments west of the Great Dividing Range and near Mt Isa. No regional trends were evident. The derived relationship is $k_c = 0.88A^{0.53}$. The Weeks method is a relationship available in RORB for the Queensland Region. This relationship may not be representative for the Project area as it overestimates peak flows. To refine k_c values adopted for design flood estimation, alternate k_c estimates were calibrated using $k_c = 0.80A^{0.62}$. A number of regional k_c relationships exist for Queensland (ARR workshop for Catchment Modelling, 2005), that are based on characteristics such as catchment area and geometry (Table 6.2).

Table 6.2 Estimated k_c Values using Queensland regional relationships

Relationship	k_c value
$k_c = 0.69A^{0.63}$	101
$k_c = 0.35A^{0.71}$	96
$k_c = 0.80A^{0.62}$	108
$k_c = 0.88A^{0.53}$	58
RORB method default equation	115

Parameter k_c, is the principal parameter of the RORB model, which is a function of reach delay, and hence has a significant impact on how pronounced the resulting flow hydrograph, will be. The calibrated k_c value of 108 lies within the Queensland and RORB relationships (refer Table 6.2), suggesting this is an acceptable result. The flows used in the hydraulic modelling have been based on the calibrated k_c value of 108 and comparisons made to the other k_c values using equations developed for Queensland catchments.

It is noted that the 'm' values for both the 1000 year and 3000 year ARI events is limited to 0.83. This value is adopted due to the prevailing shape of Lagoon Creek and its floodplain, with localised widening of the floodplain. Only for the most extreme events, such as the Probable Maximum Flood (PMF), would 'm' be taken as 1.0, generating a linear relationship between reach storage S, and reach inflow Q.

Losses used in this study have been selected to be consistent with published values for the soils within the catchment area. The losses used provide a close match to the Native Companion Creek catchment peak flows. Lower loss rates have been adopted for the rare and extreme events in accordance with the recommended values in ARR.

6.2 Estimation of design rainfall

Estimation of the design flood hydrographs, using the runoff-routing modelling technique, involved the application of the design event rainfall data as input into the Sandy Creek RORB model. Rainfall-based design flood estimation assumes that the probability of the design flood event is the same as the associated design rainfall event from which it is estimated. Summarised below are the methods used to derive the design rainfall estimates for the Sandy Creek catchment:

- Areal Reduction Factors (ARFs) to convert point rainfall to areal estimates were based on the methodology outlined by Siriwadena and Weinmann (1996). The ARFs for Queensland were applied to the rainfall estimates derived from the IFD and CRC-FORGE methodologies. Book VI of ARR (IEAust 1998) Section 3.2.2 discusses this in more detail. The ARFs adopted for this study were derived using the CRC-FORGE methodology for the Sandy Creek catchment. The ARFs listed in Appendix A are values specific to the Sandy Creek catchment.

- For frequent to large floods up to 1 in 100 ARI, point rainfall estimates were derived using the IFD methods described by Volume 2 of ARR for ARIs up to 100 and for durations up to 72 hours.

- For rare events beyond 1 in 100 ARI to the credible limit of extrapolation 1 in 2000 ARI, rainfall estimates were derived using the regional CRC-FORGE method described in Book VI of ARR for durations up to 120 hours.

- Extreme events between 1 in 2000 up to the 3000 ARI rainfall estimates were derived using a log-log extrapolation techniques described in Book VI of ARR (IEAust 1998).

6.2.1 Rainfall estimation for frequent and large floods

Design rainfall estimates for the 1 in 2 to the 1 in 100 ARI for durations of 1 hour up to 72 hours are normally based on an IFD analysis. The IFD data for Emerald, which is the closest location of the catchment to the Sandy Creek catchment, was adopted. Table 6.3 summarises the design areal rainfall estimates based on point IFD estimates modified by the ARFs.

Table 6.3 IFD Design rainfall (ARFs applied) (mm)

ARI (1 in …)	Durations (hours)							
	6	9	12	18	24	36	48	72
2	51.0	56.6	61.9	71.2	79.5	89.2	97.0	106.3
5	66.8	74.3	81.3	93.9	105.2	118.7	129.5	142.7
10	76.4	85.0	93.1	107.8	121.0	136.9	149.6	165.3
20	89.0	99.1	108.6	125.9	141.5	160.5	175.7	194.7
50	105.8	118.0	129.3	150.3	169.2	192.4	211.0	234.4
100	118.9	132.6	145.4	169.3	190.8	217.3	238.6	265.6

Rainfall intensities were calculated using the maps provided in Volume 2 of ARR (IEAust. 1998) for the standard durations considered as part of flood risk assessment. The IFD parameters used to generate the intensities are shown in Table 6.4.

Table 6.4 Sandy Creek catchment IFD parameters

Variable	Symbol	Value
Rainfall intensity (mm/hr) (2 year ARI; 1 hour storm duration)	${}^{2}I_{1}$	39.00
Rainfall intensity (mm/hr) (2 year ARI; 12 hour storm duration)	${}^{2}I_{12}$	5.83
Rainfall intensity (mm/hr) (2 year ARI; 72 hour storm duration)	${}^{2}I_{72}$	1.58
Rainfall intensity (mm/hr) (50 year ARI; 1 hour storm duration)	${}^{50}I_{1}$	78.00
Rainfall intensity (mm/hr) (50 year ARI; 12 hour storm duration)	${}^{50}I_{12}$	11.90
Rainfall intensity (mm/hr) (50 year ARI; 72 hour storm duration)	${}^{50}I_{72}$	3.40
Average coefficient of skewness	G	0.08
Geographical factor (2 year ARI)	F2	4.05
Geographical factor (50 year ARI)	F50	16.30

6.2.2 Rainfall estimation for rare floods

6.2.2.1 CRC-FORGE Methodology

CRC-FORGE is a method of regional rainfall frequency analysis that derives rainfall depth estimates of large to rare flood events. The method uses the concept of an expanding region focused at the site of interest. The CRC-FORGE method for Queensland was developed by Hargraves (2004 & 2005) and was based upon earlier work by Nandakumar et al. (1997) and Siriwadena and Weinmann (1996). Design rainfall estimates for frequent events (e.g. 1 in 50 and 1 in 100 ARI) are based on pooled data from a few stations around the focal point, while design rainfall estimates at the ARI limit of extrapolation are based on pooled rainfall data from up to several hundred stations. Before data from different sites can be pooled, maximum annual rainfalls from each site need to be standardised by dividing by an index variable. The index variable may be the mean annual maximum for the site, or rainfall of any specified ARI that is reasonable and accurately determined from a short record.

The CRC-FORGE software (Hargraves 2005) was used to derive rainfall estimates for frequent to rare flood events for storm durations from 15 minutes to 120 hours. Table 6.5 contains the available CRC-FORGE estimates for the 1 in 5 to the 1 in 2000 ARI design point rainfall depths for the durations of 24 hours up to 120 hours with the appropriate ARF applicable to the region.

Table 6.5 CRC-FORGE design rainfall (ARFs applied) (mm)

ARI (1 in …)	Durations (hours)						
	6	12	18	24	48	72	120
5	64.6	76.5	87.3	95.6	133.6	152.2	164.3
10	73.9	87.3	100.0	109.8	153.5	175.0	188.7
20	86.1	101.6	116.7	128.4	179.5	204.6	220.7
50	102.3	120.6	139.0	153.3	214.3	244.2	263.5
100	115.9	136.7	157.5	173.8	240.7	274.0	295.4
200	130.2	153.5	176.9	195.1	267.6	303.4	326.7
500	150.2	177.1	204.1	225.1	303.0	342.4	367.7
1000	166.0	195.7	225.5	248.9	329.9	372.0	398.7
2000	183.1	215.8	248.8	274.3	356.9	401.6	429.6

6.3 Flood frequency analysis

Flood frequency analysis (FFA) is a statistical method of analysis that produces a relationship between flood magnitude and probability of exceedance of the event. The shape of the flood frequency curve reflects the interaction of hydrologic factors for a catchment and the flood response at a specific site. FFAs are generally based on data extracted from continuous flow records or event based observations for extreme events.

As outlined in ARR, the shape of the fitted frequency in the annual series can be unduly biased by the very small floods, resulting in a poor fit towards the large events. This problem can be overcome in a partial series analysis when the selected base value is sufficiently high enough to exclude the influence of small events that are not really floods.

Each analysis fits a Log Pearson Type III or a Generalized Extreme Value (GEV) distribution to the plotting position calculated for each event.

FFA of the annual and partial series were carried out on the gauging station GS120305a Native Companion Creek, GS120306a Mistake Creek at Charlton and GS120309a Mistake Creek at Twin Hills, using the flow records extracted from the DERM Watershed web site. FFA for GS 120301ab Gregory Development Road on Belyando River was also carried out using flow records. Details of the records available for the analyses are shown in Table 3.1.

The accuracy and reliability of a FFA is related to the number of records available. Given that the Belyando River gauging station has nearly 64 years of record, it is anticipated that the flood frequency analysis at this location will produce more reliable estimates than at Native Companion and Mistake Creek at Twin Hills.

Native Companion Creek (120305A) gauging station, located 64 km south-east of the hydrological reference point of the Project, provides the “best fit” for FFA calibration with the catchment being in close proximity to the Project (adjacent) and the catchment area and conditions being similar.

In all four cases, the Log Pearson Type III and GEV distributions did not give a particularly good fit to the data in the annual series. A comparison of the two types of analyses at each location is given in Appendix A. The calculated plotting position is a function of the number of records, K, and the calculated plotting positions for floods at Native Companion and Mistake Creek are similar in both the LPIII and GEV analysis. However, this is not the case at Belyando River where the number of records used in each analysis differs significantly. As a result, the calculated plotting positions for the same floods at Belyando River are quite different for the LPIII and GEV.

In the annual series analyses, the fitted frequency of the 1990 event is much higher than the calculated plotting positions at all three locations and seems to give an unrealistically high estimate of the ARI of the 1990 flood.

The following Table 6.6 compares the FFA of the LPIII and GEV for the four stations.

Table 6.6 Flood frequency analysis

Gauging Station	1990 Event		1 in 100 ARI Peak Flow Estimate (m^3/s)	
	Peak Flow (m^3/s)	Plotting Position (Year ARI)	LPIII Fit	GEV Fit
120305A	1,820	200	1,258	1,187
120301AB	801	4	4,335	3,243
120306A	200	2	744	863
120309A	328	5	609	583

The FFA in Table 6.6 and Figure 6.1 suggests that, based on the fitted plotting positions, the 1990 flood at Native Companion was approximately 1 in 200 ARI. Figure 6.1 shows that the 1990 event is an isolated event. A flow of 1,258 m^3/s was adopted for the 1 in 100 ARI flow at Native Companion Creek. Table 6.7 shows comparison of unit discharges for different gauging stations. The unit discharge for the gauged site near the study area is higher in comparison to the other sites located within the same basin.

The December 2010/January 2011 flood event was assessed for comparison and stream gauging data for GS 120305A on 28 December 2010 recorded a peak flow of 1360 m^3/s. The recorded peak flow value was added to the annual peak series in order to update the FFA. The recorded peak flow on the 28 December 2010 event was found to have a return period of 1 in 82 years (0.0118 AEP).

Table 6.7 Unit Peak discharge for ARI 100 year event

Gauging station	Gauging station No	Catchment area km^2	100 year ARI peak flow (m^3/s)	Unit discharge ($m^3/s/km^2$)
Native Companion Creek at Violet Grove	120305A	4,065	1,258	0.31
Mistake Creek at Twin Hills	120309A	8,048	609	0.08
Mistake Creek at Charlton	120306A	2,583	744	0.29
Belyando River at Mt. Douglas	120301AB	35,411	4,335	0.12
Study area	Sandy Creek	2,734	880	0.32

It should be recognised that the Log Pearson III and GEV fits of the flow records at Native Companion, Belyando River and Mistake Creek are not considered ideal. While the different analyses give confidence that the ARI of the 1990 flood is approximately correct, alternative fitting distributions might be investigated in the detailed design to ascertain if the FFA can be further refined.

The December 2010 flood event having a discharge of 1360 m^3/s equivalent to an 82 year ARI (AEP of 1.18 %) also appears to be a good fit with this assessment.

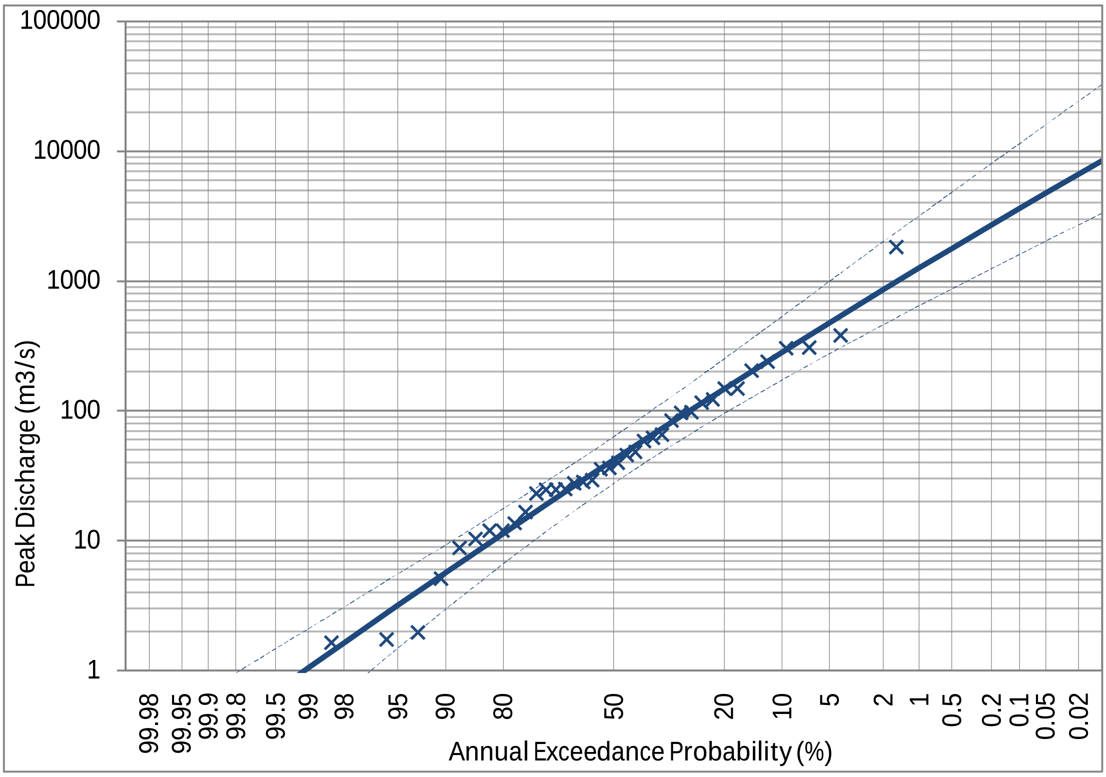


Figure 6-1 LPIII Annual series flood frequency analysis – Native Companion Creek at Violet Grove (120305A)

6.4 Catchment–Area ratio method

The catchment–area ratio method is based on the assumption that the streamflow for a site of interest can be estimated by multiplying the ratio of the drainage area for the site of interest and the catchment area for a nearby flow gauging station by the flow for the nearby flow gauging station.

Thus the catchment–area ratio method is given by:

$$Q_u = (A_u \div A_g)a \times Q_g. \qquad (1)$$

Where:

- Q_u is peak flow for the selected flood frequency for the ungauged site
- Q_g is peak flow for the selected flood frequency for the gauged site
- A is exponent for catchment area

- A_u is catchment area for the ungauged site
- A_g is catchment area for the gauged site.

Flood frequencies for an ungauged site near gauged sites on the same basin can be estimated using a ratio of catchment area for the ungauged site to catchment area for the gauged site as shown in the above equation (the drainage-area ratio (A_u/ A_g) should be approximately between 0.5 and 1.5 (USGS, 2002). Therefore for this study, the assumption is made that the exponent of (A_u/A_g) is 1. The two catchments are located within the same basin and located immediately adjacent to each other and are comparable in size (ratio of 1.48 which is less than 1.5), topography, soils and climatic conditions. In addition, Eq 6.4.1 in Australian Rainfall & Runoff Revision Projects Report - PROJECT 5: Regional Flood Methods 2009 (P5/S1/003) provided a list of equations developed by Weeks to estimate flooding based on catchment area and rainfall intensity in Queensland. These equations indicate the range of “a” values are between 0.752 and 0.645. Testing was conducted by ARR and presented in Table 6.4.2 of the same Project (Australian Rainfall & Runoff Revision Projects Report - PROJECT 5). It found that Queensland Main Roads Rational Method (MRRM) provides better results than the Weeks method at GS 120308A which is located in the same basin of the Project area. Section 6.5 discusses the RORB sensitivity analysis and comparison between the two methods in more detail.

In addition, Native Companion gauging station GS 120305A is located at elevation 343 m AHD with a mean annual rainfall (MAR) of 540 mm and a MAR of 529 mm for Sandy Creek catchment. Table 6.8 summarises the peak flows for varying values of exponent. The results were linearly interpolated based on their drainage areas to estimate the flows contributing at Sandy Creek at the hydrological reference location. These flows were used to calibrate the hydrological model using design rainfall events.

Table 6.8 Peak flow with varying exponent ‘a’ for different ARIs

GS 120305A		Sandy Creek with varying exponent ‘a’ (m^3/s)			
ARI	**Peak Flows**	**0.7**	**0.85**	**0.9**	**1**
2	42	32	30	29	28
5	148	112	106	104	100
10	282	214	201	197	190
20	478	362	341	334	321
50	857	649	612	600	576
100	1258	953	898	880	846

It should be noted that the best way to determine the exponent, ‘a’, is by using regional regression method taking into account all peak flow data and basin and climatic characteristics that were similar to those of the ungauged site. Generalised least-squares can be used to develop the predictive equation which takes into account the correlation between sites, as well as the differences in record lengths and variability of peak flows for gauged sites.

6.5 Estimation of critical storm duration

A range of design event durations was run through the RORB model to determine the critical duration event for the Sandy Creek catchment. The critical storm duration was determined by examining a range of design flood events with storm durations of 1 to 48 hours. The results of the design floods produced from the RORB model simulations are shown in Table 6.9. The results of the estimated peak inflows for a range of ARIs for the various storm durations are summarised in Appendix A. Plots of the design storm event outflow hydrographs are also included in Appendix A.

The RORB model conservatively overestimates flood flows as is evident from Table 6.10. For higher frequency events, the relative difference tends to be larger. This overestimate of peak discharge means that the flood impacts predicted for the Project are likely to be overestimated.

The 3000 year ARI design flood hydrographs were extracted from the RORB model for a range of ARIs and storm durations for input into the MIKEFLOOD model at the locations of tributary inflows. The peak flows of each of these hydrographs are summarised in Table 6.10. Appendix A contains the full model results.

Table 6.9 Peak flows for various ARI events

Event (years ARI)	Interpolated flow (m^3/s)	Calibrated peak discharge (m^3/s)	% difference between results
2	28	28	0%
5	100	131	31%
10	190	225	18%
20	321	311	-3%
50	576	583	1%
100	846	880	4%
1000	N/A	2,512	—
3000	N/A	3,496	—

6.6 RORB sensitivity analysis

For an ungauged system the results from a routing analysis could be in error by a factor of up to two (2) (E.M Laurenson et al 2007). A sensitivity analysis was carried out first on the catchment storage parameter k_c and second on 'm' value to investigate the influence on design peak flows.

The range of k_c values selected are based on recommended regional parameters which are adjacent to the adopted region. The results of the analysis are shown in Table 6.10. The difference between the other regional parameters and the adopted parameter was found to be acceptable for ungauged catchments. The creeks are fully vegetated and two metres of fine to coarse sands were observed in the stream bed of Lagoon Creek and Sandy Creek. Therefore the adopted k_c parameter is as described in Section 6.1.2.2.

Table 6.10 Peak flows using varying k_c value

Method of calculation	Flow (m^3/s) ARI (years) 100	1000	3000
Queensland Rational Method (Bransby Williams)	905	1,262	1,402
RORB* - with suggested QLD k_c value of 58.4 (Weeks	1,766	5,697	6,584

method)			
RORB[*] - with suggested k_c value of 115 (Weeks method)	772	2,808	3,284
Yu (1989) AusWide k_c value of 54.5	1,908	5,974	6,898
Annual and Partial series Flow event estimation – ARR method, Site 120305A Native Companion Creek	1,258	3,620	6,330

The parameter 'm' with a value 0.8 was assessed. Table 3.6 of Section 3.5 of Book II, ARR (IEAust. 1998) suggests that an initial loss up to 140 mm could be adopted for frequent to large events. For events in this range, an initial loss has been selected to match the flows estimated by the Sandy Creek FFA. The adopted values are within the range of the calibrated events. The result of the analysis is shown in Table 6.11.

Table 6.11 Analysis of RORB parameters for ARI up to 100 year ARI

ARI (years)	k_c	m	IL (mm)	CL (mm/hr)	Flows (m^3/s)
2	108	0.8	75	2.5	27.6
5	108	0.8	75	2.5	100
10	108	0.8	75	2.5	164
20	108	0.8	75	2.5	298
50	108	0.8	75	2.5	586
100	108	0.8	70	2.5	998

6.7 Creeks and tributaries properties

Runoff coefficients and the percentage of impervious areas, were derived in accordance with the Department of Main Roads method for rural catchments (Pilgrim, 1997) and rainfall intensity data was derived for the Project area according to the method outlined in ARR for deriving IFD relationships.

The adopted impervious fraction in areas of the catchment is as follows:

- areas unchanged by mine operations: remained 2%
- spoil piles and mine disturbed areas: 5%
- sub-catchments that included hardstand: Average 10%.

For sub-catchments with multiple land use types, an area-weighted fraction impervious was calculated.

The breakdown and location of each sub-catchment is included in Figures A-2 and A-3 contained in Appendix A.

6.7.1 Results

Design flood hydrographs were extracted from the RORB model for a range of ARIs for input to the MIKEFLOOD model at the locations of tributary inflows.

The peak design flows for the downstream hydrograph at the hydrological reference point located approximately 12 km downstream of the northern MLA boundary are summarised in Table 6.12.

These values provide a comparison of peak flows in Sandy Creek, between the existing and design cases, based on the changes in the routing of flows through the system.

Table 6.12 Design case model results for the hydrological reference point

Event (Years ARI)	Flows m^3/s		% Change
	Existing case	Design case	
2	28	31	10.7%
5	131	144	9.9%
10	225	247	9.8%
20	311	340	9.3%
50	583	624	7.0%
100	880	931	5.8%
1000	2,512	2,533	0.8%
3000	3,495	3,502	0.2%

6.8 Upper Bound estimation

There are considerable uncertainties with many of the hydrologic parameters used in catchment hydrology. The most uncertain are the parameters used and assumptions made for defining the initial and continuous losses. Section 6.5 describes the selection of the equations for the estimation of k_c parameters used in this report. Because of the high degree of uncertainty of loss-values and model parameters (i.e. catchment lag parameters (k_c) and catchment non-linearity ('m') for runoff routing modelling, an upper bound of risk assessment was performed to better understand the degree to which catchment parameters have an effect on the model results. An increase of the peak flow for each design flow event by 20% is used to provide an upper bound of uncertainty and a reasonable and practical flow level of risk against which the construction of diversions, levees and flood mitigation measures is referenced. The results are presented in Table 6.13.

Table 6.13 Analysis of RORB parameters for 1000 and 3000 year ARI

ARI	k_c	m	IL	CL	Flows
(years)			(mm)	(mm/hr)	(m^3/s)
1000	108	0.8	0	0	4186
3000	108	0.77	0	0	5497

Under normal flow conditions, estimates of model parameters (catchment lag parameter (k_c) and non-linearity parameters ('m') can be fairly accurate when experience and references are used. However, in the case of catchments unsupported by flow records where high porosity is evident, typical parameters do not apply. For example, a large flood wave will generate a large amount of turbulence and carry with it large quantities of debris. Furthermore, scouring of sediment from the catchment and in the stream reach will entrain a high concentration of sediment. All of these factors contribute to an increase in overall continuous loss (CL) parameters, particularly in the middle of Lagoon Creek.

7. Hydraulic modelling

Hydraulics is a topic of science and engineering that involves understanding how flow is conveyed along creeks and rivers, passed through culverts, under bridges, over weirs and stored in floodplains.

The MIKE FLOOD hydraulic modelling suite, comprising the two dimensional (2D) MIKE21 hydrodynamic model and the one dimensional (1D) MIKE11 was developed for the Project. MIKE21 was developed to assess the rare (1000 year ARI) and extreme (3000 year ARI) flows for the Project. Details of the hydraulic modelling are given below and the associated results including model layouts and flood maps are included in Appendix B.

The MIKE11 hydraulic model was used to undertake the stream shear stress and stream power assessments for the flood events, but more importantly to assess the frequent and large flows (up to 50 year ARI) as part of the stream morphology technical study. The results of this assessment are documented in the Stream Morphology Technical Report.

7.1 MIKE FLOOD model

The MIKE flood model covers the entire Project area as well as the upstream and downstream extents defined in Section 3.2.3. MIKE FLOOD has been used for the full range of flood events for both the existing and developed scenarios as appropriate

7.2 MIKE21 model

The MIKE21 model covers the Sandy Creek catchment and includes Lagoon Creek, Spring Creek, Sandy Creek and Little Creek near the mine site. The model extends 7 km upstream and 12 km downstream of the MLA area.

The existing case model comprises Lagoon Creek and the downstream section of Sandy Creek, with inflow nodes to represent inflows for tributaries. The model includes the full extent of the “bank full” channel as well as the flood plain area, which locally extends up to two kilometres in width.

7.2.1 Model features

The developed case model expands to include the north western and south western diversions and creeks as follows (Refer Figure 3-1):

Lagoon Creek: Channel section from approximately 7 km upstream of the Alpha MLA southern boundary, to the confluence with Sandy Creek (at the Alpha MLA northern boundary).

Sandy Creek: Inflow node at the intersection with the proposed north western diversion drain (1), and the channel section at the confluence with Lagoon Creek (2) to approximately 12 km downstream of the Alpha northern MLA boundary.

Spring Creek: Inflow node at the intersection with the proposed south western diversion drain to the intersection with Lagoon Creek, close to the Alpha MLA southern boundary.

Little Sandy Creek: Inflow node, not associated with any proposed diversions, located at the north-west corner of the mine area adjacent to the north west diversion channel, and from there flowing naturally to the confluence with Sandy Creek some 2 km downstream of the Alpha MLA northern boundary. This creek predominantly traverses the Kevin's Corner Mine tenement.

Unnamed creeks: Various inflow nodes are provided along the north western and south western diversion drains and on the east side of Lagoon Creek to represent contributing catchments and overland flow.

Internal drainage: Mine site internal drainage of fresh water is represented as an inflow node at its intersection with the North Western diversion drain.

7.2.2 Model setup

Sandy Creek and tributaries (to the extent of the Sandy and Lagoon Creek floodplain) within the MLA have been represented in MIKE21. The model has been dynamically developed to allow for flow transfer between the main creek and the floodplain.

The MIKE21 model requires the definition of the channel geometry, roughness values and boundary conditions. Geometry of the model is defined by using a 15 m x 15 m square grid. The grid adopted in the SEIS was reduced from a 20 m to a 15 m square grid, to better represent the active channel and diversion channels within the model. This grid has been created using the DTM described in Section 4.2.3. A layout of the MIKE21 model key features is shown in Figure B-1 in Appendix B.

7.2.2.1 Roughness

Manning's roughness coefficients have been assigned to land uses for the model extent, including creek channel and floodplain areas. Roughness values can be determined as part of calibrating the model, when there are suitable recorded flood levels.

The roughness values used in the hydraulic analysis were based on published values for similar conditions (Chow, 1959; Barnes, 1967), aerial photograph and site interpretation and engineering judgement. Site photographs taken during the site inspection were used to confirm adopted roughness coefficients. Adopted roughness coefficients are listed in Table 7.1 and corresponding photographs are shown in Figure B-2 in Appendix B. Figure B-3 provides a map of the adopted existing case (base case) roughness values. Sensitivity analysis was undertaken to see the flooding impact with ±20% change in the roughness values over the whole of the hydraulic model.

Table 7.1 Adopted and sensitivity roughness coefficients

Land use characteristic	Manning's 'n' values		
	-20%	Mean	20%
Diversion drains	0.032	0.040	0.048
Open space	0.029	0.035	0.042
Light vegetation	0.033	0.040	0.048
Medium vegetation	0.046	0.055	0.066
Dense vegetation	0.067	0.080	0.096
Rock induced roughness	0.048	0.060	0.072
Creek area	0.029 – 0.046	0.035 – 0.055	0.042 – 0.066

7.2.2.2 Boundary conditions

The upstream boundary conditions are formed by the inflow nodes described in Section 7.2.4. Discharge hydrographs were extracted from RORB.

The downstream dynamic boundary condition is set by the hydrological reference point located approximately 12 km downstream of the northern MLA boundary.

7.3 Results

Using the approach detailed in the previous sections, the flood impacts for the Sandy Creek catchment and its tributaries have been assessed. This section summarises the outcomes of the flooding investigations of the Sandy Creek catchment and its tributaries in the Project area.

7.3.1 Existing conditions

The existing hydraulic conditions against which the Project is assessed, are those of the Sandy Creek catchment and its tributaries, before the Project is developed (e.g. 'no Project' case). To establish what the hydraulics of the existing creek system looks like, it is modelled as the 'base case' and the output from this model, provides the key parameters against which any developed case (with Project) is measured/compared. If there are differences in these parameters, they are described as 'impact' and these impacts can be both positive and negative, and can in both cases be acceptable as well as unacceptable. The following sections set out the parameters of the existing Sandy Creek catchment and its tributaries.

Peak flood levels

Flood levels and extents have been calculated for a range of events. A summary of the peak water levels at different reporting locations along Lagoon Creek for the 1000 and 3000 year ARI events are shown in Table 7.2. Note that the existing conditions apply to Lagoon and Sandy Creeks only.

Table 7.2 Peak flood levels for 1000 and 3000 year ARI at reporting locations

Reporting location ID	Description	Creek	Flood level (m AHD)	
			1000 yr ARI	3000 yr ARI
1	5 km U/S of mine site	Lagoon Creek	324.92	325.02
2	1 km U/S of mine site	Lagoon Creek	321.30	321.49
3	U/S MLA Boundary	Lagoon Creek	320.90	321.06
4	Hobartville Homestead	Lagoon Creek	317.74	317.93
5	Opposite Pit 2 ramp	Lagoon Creek	313.71	313.90
6	Opposite MIA	Lagoon Creek	311.46	311.60
7	Chainage Km 1 of active channel diversion	Lagoon Creek	309.02	309.36
8	Chainage Km 5 of active channel diversion	Lagoon Creek	308.68	309.08
9	Chainage Km 9 of active channel diversion	Lagoon Creek	308.04	308.47
10	Wendouree Homestead	Lagoon Creek	308.48	308.88
11	500 m U/S of NW Creek	Lagoon Creek	303.63	303.86

	diversion			
12	D/S MLA Boundary	Sandy Creek	300.51	300.69
13	1 km D/S of mine site	Sandy Creek	298.88	299.04
14	4 km D/S of mine site	Sandy Creek	294.49	294.56
15	8 km D/S of mine site	Sandy Creek	290.60	290.79

The reporting locations listed in Table 7.2 are shown in Figures 7.1 and 7.2.

Figures 7.1 and 7.2 provides an overview of the existing case flood extent for the 1000 and 3000 year ARI events, projected over the proposed mining development. The Figures illustrate that the mine development encroaches within the base case flood extents of Lagoon Creek and its tributaries.

Figures B-4 (Appendix B) provides a longitudinal sections of the 1000 and 3000 year ARI peak flood levels in Lagoon Creek for the base case. The longitudinal sections are taken through the 1000 year ARI flood extent (i.e. they do not follow the active creek alignment) and follow the same chainage as presented in Table 7.2.

Figure B-6 (Appendix B) provides a water level contour map of the 3000 year ARI peak flood levels in Lagoon Creek for the base case.

Peak velocities

Peak velocities have been extracted from the model runs for the 1000 and 3000 year ARI events, thus providing an assessment of velocities that could be expected in rare to extreme events. Peak velocities for the Sandy Creek flood model are shown in Figures B.5 and B.6.

For the 3000 year ARI event, base case modelling shows that peak velocities are in general less than 2.0 m/s (average 0.83 m/s) within Lagoon Creek and less than 1.0 m/s in the overbank areas. Velocities downstream of the MLA boundary are generally in the range of 2.0 to 2.5 m/s and are higher than the creek section traversing the mine. It is noted that these velocities are in excess of the stipulated maxima in the guidelines. However, since these are existing velocities within a natural system, they are deemed to represent equilibrium in the channel, and therefore not warrant being reduced in line with the guidelines.

In one area within the MLA, the existing velocity is higher than 2.0 m/s. This is within a naturally constricted section of the creek, some 4.5 km upstream of the northern MLA boundary and under the developed case, some 300 m upstream of the end of the active channel diversion. Estimated (base case) velocities are as high as 2.67 m/s. During the detailed design phase of the Project, further investigation will be undertaken to verify whether the natural channel is appropriate for the velocities and associated sheer stress and if deemed necessary appropriate bank and bed protection will be provided to ensure stability of the channel at all times. In general, higher velocities tend to occur in the middle of the creek and lower values apply in the overbank area. The higher velocity can lead to localised bank erosion and scouring of the creek bed. This observation was validated during the site visit undertaken by PB in July 2010.

7.3.2 Developed case

Changes in flood levels within Sandy and Lagoon Creeks due to the proposed mine development are shown in Table 7.3 and Figures 7-1 to 7-4.

Figures 7.3 and 7.4 provide an overview of the flood extent for the 1000 and 3000 year ARI events under the developed case, projected over the proposed mining development.

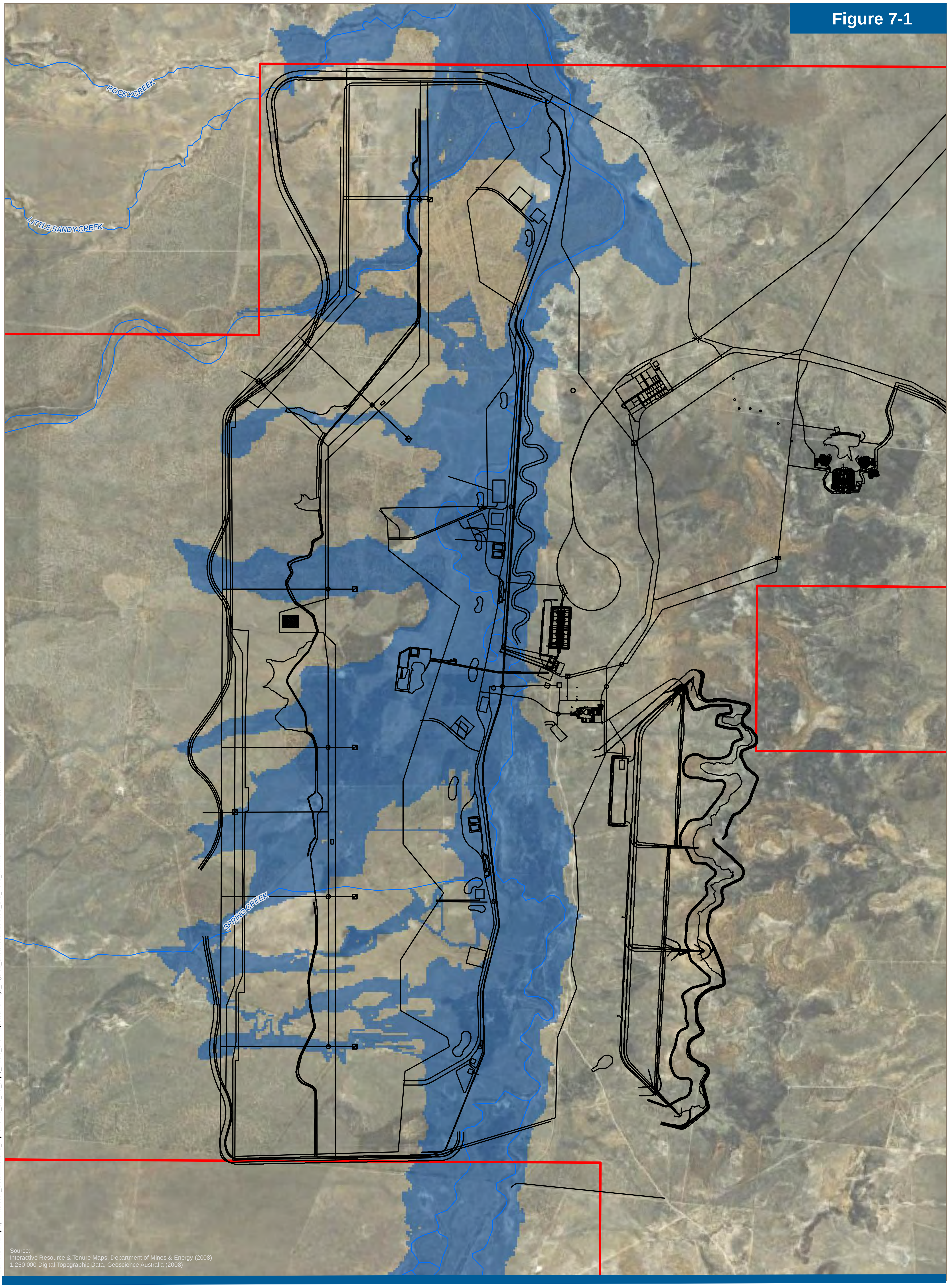
The following figures for the developed case are provided in Appendix B:

- Figure B.5 - longitudinal section for Lagoon and Sandy Creek showing the 1000 and 3000 year ARI events water levels. The longitudinal sections are taken through the 1000 year ARI flood extent (i.e. they do not follow the active creek alignment) and follow the same chainage as presented in Table 7.3
- Figure B-7 (Appendix B) provides a water level contour map of the 3000 year ARI peak flood levels in Lagoon Creek for the developed case.
- Figure B-8 provides an afflux map for the 300 year ARI case

Table 7.3 Peak flood levels for 1000 and 3000 year ARI at reporting locations (developed case)

Reporting location ID	Description	Creek	Flood level (m AHD)	
			1000 yr ARI	3000 yr ARI
1	5 km U/S of mine site	Lagoon Creek	324.99	324.99
2	1 km U/S of mine site	Lagoon Creek	321.52	321.59
3	U/S MLA Boundary	Lagoon Creek	321.19	321.25
4	Hobartville Homestead	Lagoon Creek	317.95	318.00
5	Opposite Pit 2 ramp	Lagoon Creek	314.34	314.43
6	Opposite MIA	Lagoon Creek	313.39	313.49
7	Chainage km 1 of active channel diversion	Lagoon Creek	310.73	310.84
8	Chainage km 5 of active channel diversion	Lagoon Creek	309.62	309.76
9	Chainage km 9 of active channel diversion	Lagoon Creek	307.63	307.78
10	Wendouree Homestead	Lagoon Creek	308.92	309.04
11	500 m U/S of NW Creek diversion	Lagoon Creek	304.26	304.48
12	D/S MLA Boundary	Sandy Creek	300.70	300.83
13	1 km D/S of mine site	Sandy Creek	299.01	299.12
14	4 km D/S of mine site	Sandy Creek	294.55	294.59
15	8 km D/S of mine site	Sandy Creek	290.62	290.79

Figure 7-1



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PB PARSONS BRINCKERHOFF

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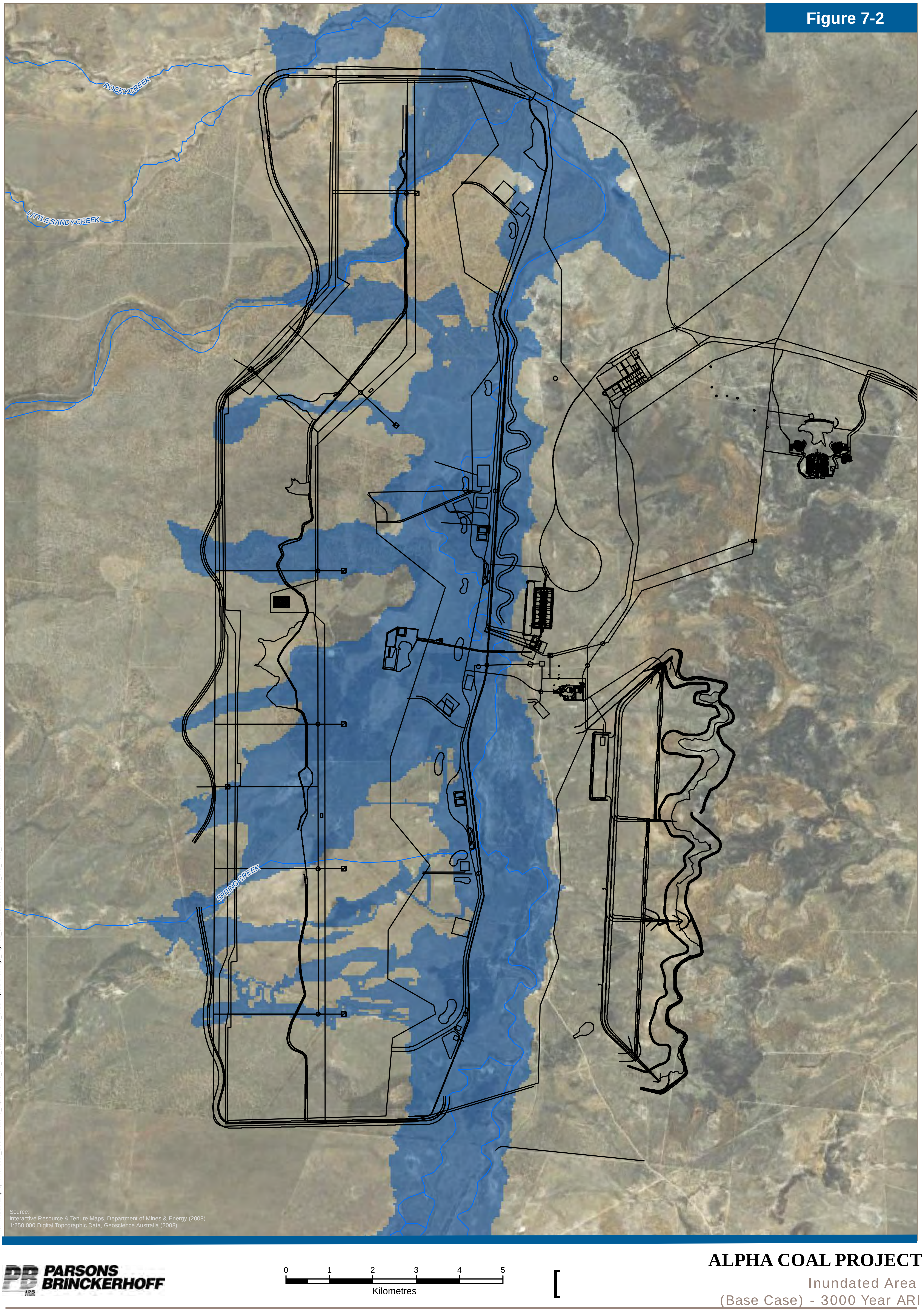
Kilometres

ALPHA COAL PROJECT

Inundated Area (Base Case) - 1000 Year ARI

Figure 7-2



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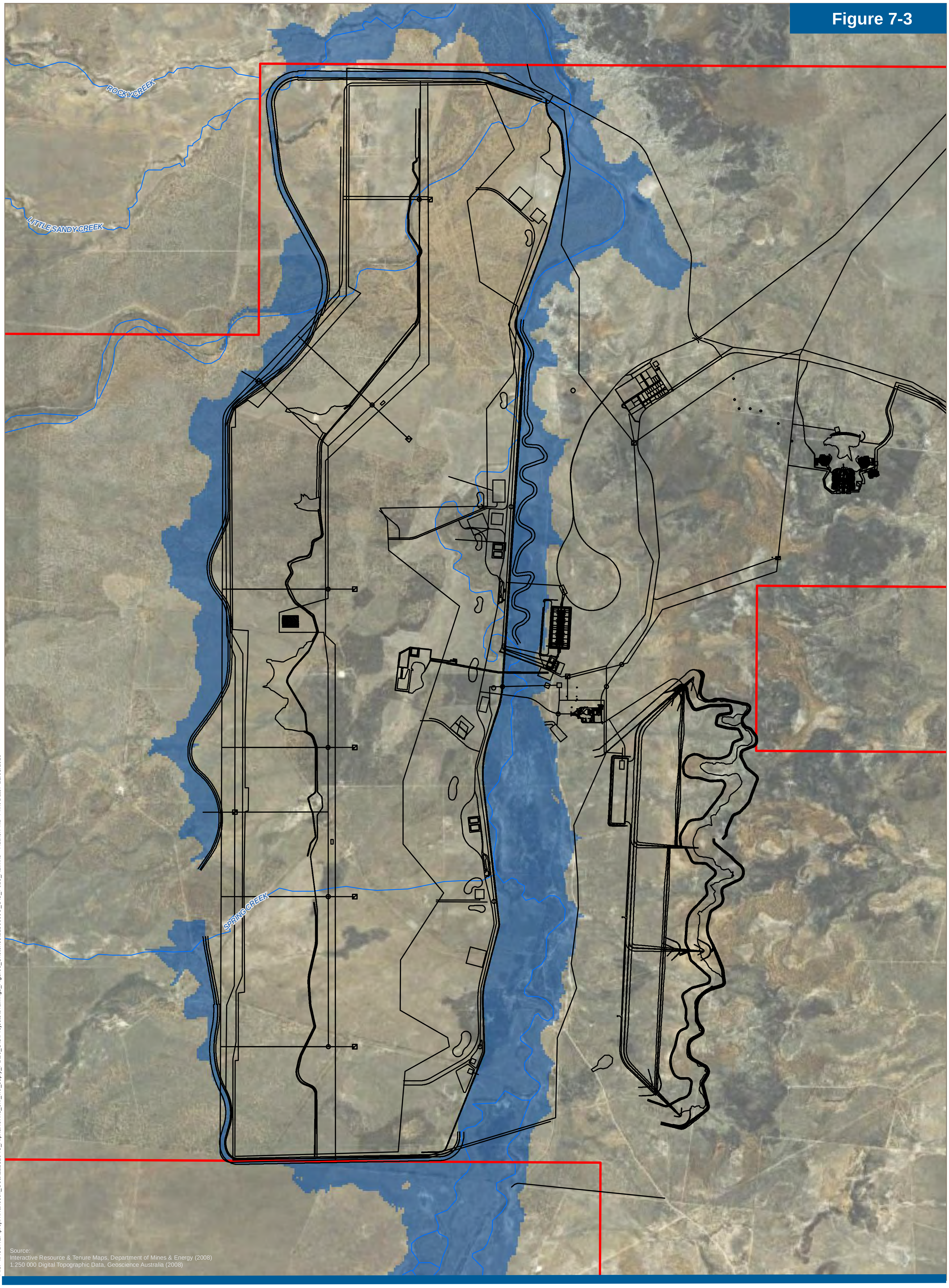
PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

Inundated Area (Base Case) - 3000 Year ARI

Figure 7-3



Source:
Interactive Resource & Tenure Maps, Department of Mines & Energy (2008)
1:250 000 Digital Topographic Data, Geoscience Australia (2008)

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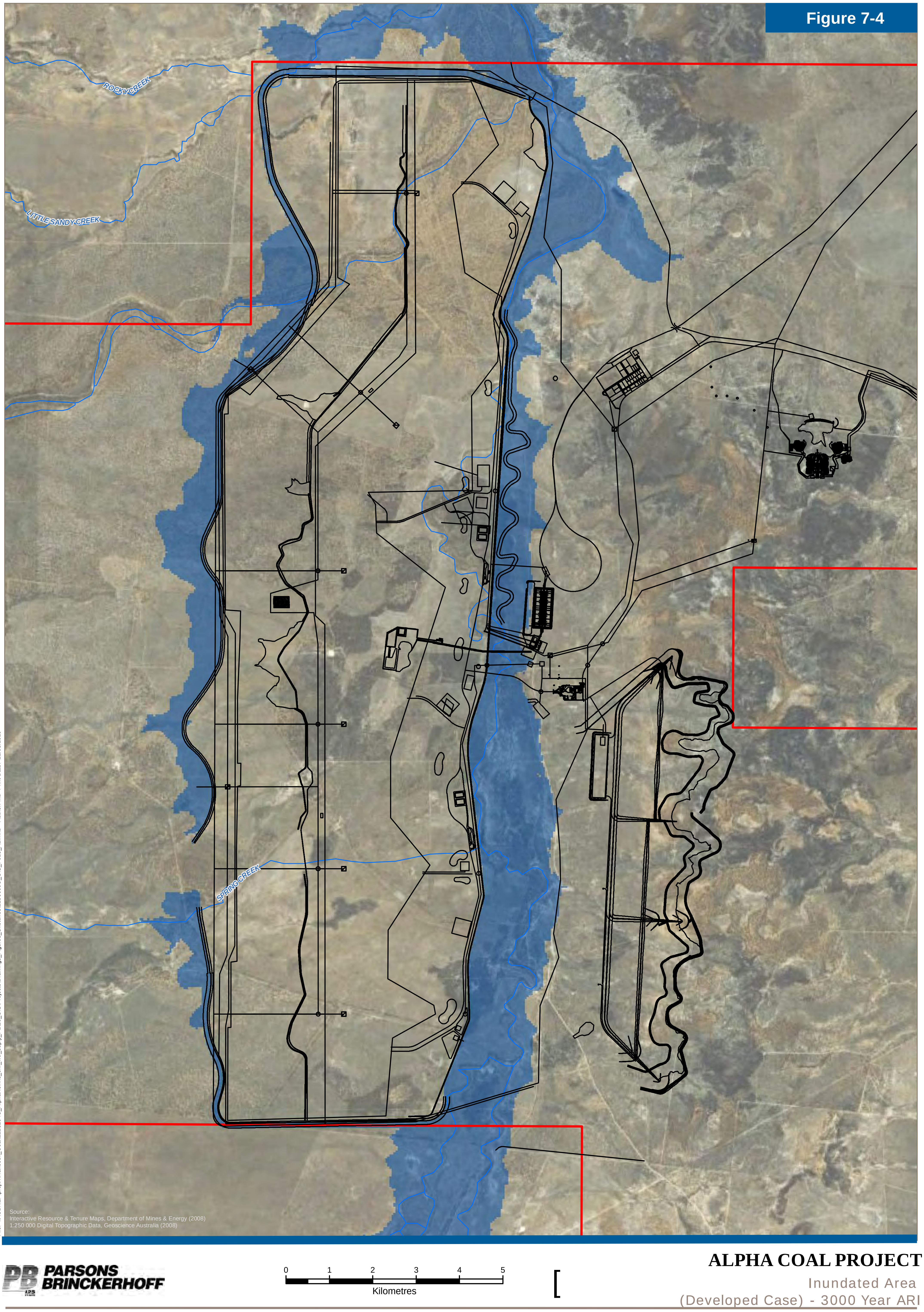
PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

Inundated Area (Developed Case) - 1000 Year ARI

Figure 7-4



Source:
Interactive Resource & Tenure Maps, Department of Mines & Energy (2008)
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PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

Inundated Area
(Developed Case) - 3000 Year ARI

7.3.3 Impact

The hydraulic impact as a result of the mine infrastructure is discussed in this Section. The afflux as a result of the levees and diversion within the Project is set out in Table 7.4.

Table 7.4 Maximum afflux for 1000 and 3000 year ARI at reporting locations

Reporting location ID	Description	Creek	Flood level (m AHD)	
			1000 yr ARI	3000 yr ARI
1	5 km U/S of mine site	Lagoon Creek	0.08	-0.03
2	1 km U/S of mine site	Lagoon Creek	0.22	0.10
3	U/S MLA Boundary	Lagoon Creek	0.29	0.19
4	Hobartville Homestead	Lagoon Creek	0.21	0.07
5	Opposite Pit 2 ramp	Lagoon Creek	0.62	0.53
6	Opposite MIA	Lagoon Creek	1.93	1.89
7	Chainage km 1 of active channel diversion	Lagoon Creek	1.71	1.48
8	Chainage km 5 of active channel diversion	Lagoon Creek	0.94	0.68
9	Chainage km 9 of active channel diversion	Lagoon Creek	-0.40	-0.68
10	Wendouree Homestead	Lagoon Creek	0.44	0.15
11	500 m U/S of NW Creek diversion	Lagoon Creek	0.63	0.62
12	D/S MLA Boundary	Sandy Creek	0.19	0.13
13	1 km D/S of mine site	Sandy Creek	0.14	0.08
14	4 km D/S of mine site	Sandy Creek	0.06	0.03
15	8 km D/S of mine site	Sandy Creek	0.02	0.00

Key findings of the modelled results are summarised as follows:

- Inundation of the lower reaches of the diversion channels as a result of high flows in Lagoon Creek is limited to the lower reaches of each tributary and is generally shallow and of short duration.
- For the 3000 year ARI flood event the expected afflux due to the Project is likely to extend to 4 km upstream of the MLA boundary.
- The 3000 year ARI peak afflux at the upstream MLA boundary is 190 mm. The residence time of this elevated peak is approximately 2.5 hours (note: residence time is the period that the developed case water levels are elevated above that of the base case peak).
- The 3000 year ARI peak afflux at the downstream MLA boundary is 130 mm. The residence time of this elevated peak is approximately 4.25 hours.
- For the 3000 year ARI flood event the expected afflux due to the Project is likely to extend to 6 km downstream of the MLA boundary.

- The 3000 year ARI peak afflux at 1 km downstream of the northern MLA boundary is 80 mm.
- Within the Lagoon Creek diversion channel, water levels vary by up to +1,480 mm and -680 mm from the existing case. Afflux immediately upstream of the diversion is only moderately higher (up to 1,890 mm opposite the MIA), which suggests that the afflux is predominantly attributable to the naturally narrow section at the downstream end of the diverted active channel, together with the adopted levee alignments. (Refer Figure B7 in Appendix B).
- Velocities for the 1000 and 3000 year ARI events are of limited interest to the design of the levees and diversions. Instead the stream morphology focuses in the stream velocities of the 2 year and 50 year ARI events, which tend to be more pronounced and destructive. (Refer Stream Morphology Technical report (Volume 2, Appendix J of the SEIS). This notwithstanding, the 3000 year ARI developed case, shows peak velocity within the Lagoon Creek diversion channel of approximately 2.0 m/s. 3000 year ARI peak velocities for all diversion channels are in general similar to, or within 0.2 m/s of the existing velocities and are deemed acceptable.
- Shear stress is a measure of force exerted on the channel bed and banks by flowing water. Shear stress is of no significant interest for flood events in excess of 100 year ARI. Shear stress and its implications for the diversions is further discussed in the Stream Morphology Technical report (Volume 2, Appendix J of the SEIS)
- Stream power is a measure of the potential of the channel to be eroded. If the stream power values are high, it indicates that there is a potential for erosion; a lower value indicates the potential for sediment deposition in the creek. Stream power is of no significant interest for flood events in excess of 100 year ARI. Stream Power and its implications for the diversions is further discussed in the Stream Morphology Technical report (Volume 2, Appendix J of the SEIS)

7.4 Sensitivity analysis

For the purposes of the hydraulic modelling, sensitivity analysis was carried out on the hydrology, and the resulting upper bound flow (refer Section 6.7) was adopted for each of the modelled ARI events.

The hydraulic assessment has fully incorporated the sensitivity analysis, which demonstrates consistent increases in the peak flood levels and velocities throughout the mine site. The current hydraulic assessment has taken full account of these increases.

7.5 Mitigation measures

Mitigation measures are design features introduced into a diversion channel, to create a channel that more closely represents the flow conditions of the natural channel.

Such design features are typically derived from the stream morphologic assessment of the existing creeks and channels and then replicated in the diversion design. Examples of mitigation measures appropriate to the Project include:

Meandering	The active channel of the creeks found in the Project area tend to meander within the flood plain. The active channel is sized to approximately a 2 year ARI flood event and replicates the channel gradient of the creek where possible. However, with the creek length either shortening or lengthening, the extent and location of meanders have been selectively applied to replicate the natural channel to the largest extent possible. The Lagoon Creek active channel diversion is shorter than the original active channel length and is located within the existing flood plain. The channel is bound by the upstream and downstream active channel bed levels and the channel depth is controlled by the level of the existing flood plain at that location. The objective has been to not impact on the levels of the flood plain, but only to carve the new active channel into it. Any excavated material will be removed out of the flood plain (developed case). The NW and SW diversions tend to be longer than the original channel. Meandering will therefore be selectively applied in areas where velocities are expected to be higher than average for that channel. Meandering should be adjusted to meet the natural channel's stream power. Care should be taken not to flatten that channel more than necessary, as this may cause siltation.
Vegetation	Vegetation in the diversion channel encourages stability of the channel and also increases the roughness of the channel, thus reducing velocity and stream power.
Rock	Rip-rap or dumped rock will increase the overall roughness of the channel and reduce velocity and stream power. Typically rock (or in gabion boxes) may be placed at the toe of the high flow channel batter and levee or where the velocity is high, but can similarly be placed as for river training works such as spurs and groynes.
Drop structures	Although hard engineered structures are not preferred in diversion design, it may sometimes be appropriate to provide a drop structure to replicate existing cascades or force a reduction in gradient without excessive meandering. No drop structures are however envisaged at this time.
Pools	Pools may be introduced to replicate existing lagoons and billabongs that provide storage.
Storage area	Providing storage areas within the creek tributaries where it intersects the western and southern levee bunds and providing purpose built spillway structures. These structures may be used to ameliorate the peak discharge contributions from the tributaries into Lagoon Creek and Spring Creek and will assist in lowering the peak flood levels and velocities. Prior discussions and approval from authorities will be required to progress further this design concept.

While no specific mitigation measures are incorporated into the diversion channel at this stage, it has been assumed that these measures will be included in the detailed design phase of the Project, and that all diversions and levee bunds will be constructed and progressively vegetated in advance of the flow through the diversions.

8. Summary

The key objective of this Flooding Technical Report was to investigate and develop a flood management strategy to protect the mine from flooding and consequently protect the environment from any impacts resulting from mining activities and infrastructure. In particular, this report sets the framework for satisfying the appropriate authorities that the Project's proposals for creek diversions and flood protection will meet the requirements for Water Licensing.

This flood assessment has analysed the flood behaviour of the existing Sandy Creek and its tributaries that are affected by the proposed Project development and has determined the flood behaviour of the existing creeks and associated floodplains.

The study has also investigated the proposed developed scenario, including diversion of the active channel of part of Lagoon Creek and the diversions of Spring Creek and (upper) Sandy Creek, to provide flood protection for the mine pits and other infrastructure.

Based on the hydraulic modelling of the existing and developed scenarios for the Project, the impacts of the flood protection levees and creek diversions is assessed. The mine pit will be protected from flooding from Lagoon Creek as well as other creeks to the west, north and south of the pit area. This is achieved by providing levees with flood immunity for the 3000 year ARI event.

Within the area protected by the levees, internal drainage is provided to capture and divert clean water away from the progressing mining activities, and discharge this water into the north western diversion.

Results of the assessment show that there will be minor changes to flood water levels and velocities for up to 4 km upstream and 6 km downstream of the site, with the duration of the impact being limited in duration. These changes are largely attributed to the redistribution of flows from the various watercourses, constrictions of the waterway area due to the levee bunds and diversions, and the changes in the land use type.

For the 3000 year ARI flood event, the afflux at the MLA boundary to the north is 190 mm and this impact reduces rapidly upstream with no impact at approximately 4 km upstream of the MLA boundary. At the downstream MLA boundary the afflux for the 3000 year ARI event is approximately 130 mm reducing to no impact 6km downstream of the MLA boundary.

The modelling shows that there will be negligible increases in the creek overbank velocity and minor increases of up to 0.2 m/s within the main creek. It is noted that some sections of Lagoon Creek within the constricted area near the northern MLA boundary show high velocities of up to 2.7 m/s for the modelled base case. This value exceeds the Queensland Government (2008), Natural Resources and Water, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry stipulated maximum velocities. This notwithstanding, the existing high velocities represent natural equilibrium in the natural channel and it is therefore reasonable to assume that these velocities can also be sustained for the diversion. During the detailed design phase of the Project and prior to application of a Water Licence for the creek diversions, this particular scenario will need to be further investigated, supported with geotechnical and geomorphologic investigation to ensure that the channel is and remains stable.

9. Recommendations

This Flooding Technical Report confirms that the proposed levees and creek diversions for Lagoon, Spring and Sandy Creeks and various unnamed catchments, adequately provides the Project with a 3000 year flood immunity without causing significant impact to the upstream and downstream environment.

Impact to flood levels are limited to 4 km upstream of the mine, and to 6 km downstream of the mine, with affluxes at the upstream and downstream MLA boundaries being limited to 190 mm and 130 mm respectively and for a duration of no more than 2 ½ hours upstream and 4 ½ hrs downstream. 3000 year ARI peak flood affluxes within the MLA are expected to rise as high as 1.9 m just upstream of the active creek diversion. While this has no significant impact to others, it may be appropriate to widen the naturally occurring channel within the lower section of the diverted active channel.

The base case modelling shows that the Lagoon Creek channel is subject to high velocities, well in excess of those recommended in the Queensland Government (2008), Natural Resources and Water, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry. Further investigation is recommended as part of the detailed design phase to determine whether the channel is adversely impacted by the proposed diversion work and whether there may be an option to widen the channel to mitigate both afflux and naturally occurring velocities.

The proposed diversions will have a moderate effect on the distribution of flows, with the braided Spring Creek outflows now concentrated by outflow from the south western diversion at the upstream MLA boundary and Sandy Creek and various unnamed tributaries, having a collective outflow point from the north western diversion at the northern MLA boundary. The dynamic routing of the flood events means that the two diversions pass the flows through the system slightly quicker than previously, consequently not further contributing to afflux and velocities, but slightly extending the period of flow in Lagoon and Sandy Creeks.

Lagoon Creek velocities vary greatly throughout the length of the mine site, due to highly variable channel and floodplain widths. Typically existing 1000 and 3000 year ARI velocities are less than 1 m/s, however there is a natural constriction in the channel where low flow velocities rise to 2.8 m/s. The developed case is confined by the same constricted area and hence velocities for the developed case will be similar to the existing scenario and therefore not comply with the Queensland Government (2008), Natural Resources and Water, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry. It is however considered that the natural case represents equilibrium and would preside over the prescribed maximum velocities.

Developed case peak velocities within the creek for the 3000 year ARI flows can be up to 0.2 m/s higher in comparison to the existing case. Within the north western and south western diversion channels the velocity is approximately 2.0 m/s. Evaluations of the 2 and 50 year ARI events and in general the diversion drain design has been assessed as part of the Stream Morphology Technical Report (Volume 2, Appendix J of the SEIS).

The EIS and SEIS have been subject to dialogue, comments and feedback from DERM and other consultees. In March 2011 the surface water investigations and proposals were presented to DERM in Rockhampton and several key issues were further clarified.

Key issues that have been recognised and actions that have resulted from this consultation include:

- Flood modelling if the existing (undeveloped) Project area has demonstrated that the existing Lagoon and Sandy Creek systems experience excessive velocities, shear stress and stream power values, which exceed the Queensland Government (2008), Natural Resources and Water, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry. In spite of these high values, the existing channel appears stable. The creek diversion design will ensure that no worsening of these values will occur.

- Lagoon Creek levee has been moved further west to improved conveyance of and storage in the creek flood plain area. This has resulted in some sterilisation of coal deposits, in particular at the northern constriction in Lagoon Creek

- The north western and south western diversions located adjacent to the northern and southern MLA boundary are fully located within the Project's MLA. The diversions include levees to pit side as well as on the boundary side to ensure that the diversion does not impact on the adjacent properties. The 240 m offset of the pit from the MLA boundary, is sufficient to ensure that the diversions and levees, as well as any inspection roads and easements, will fit into the corridor

- The Lagoon Creek diversion is limited to the diversion of the active channel, and sits within the existing flood plain and connects the bed levels of the existing channel upstream and downstream of the diverted channel section. The active channel does therefore not include the typical engineered low flow (2 years ARI) and High flow (50 years ARI) channel profiles, but is a combination of the two, set within the constraints of the existing flood plain. The active channel is designed to meander in similar fashion to the existing active channel, but does not replicate the existing channel in length, as this would result in an unnatural alignment

- The north western and south western diversions include the typical engineered low flow (2 years ARI) and High flow (50 years ARI) channel profiles. The low flow channel will meander within the width of the high flow channel, with more intensive meanders in areas with increased gradient and velocity.

- The existing creek system features active bed migration, with ongoing erosion and sediment deposition during every flood event. This is considered part of the natural process and equilibrium, and will also be a feature of the diversions.

While most of the comments regarding flooding have been incorporated into this Technical Report, there are some gaps that require further investigation and refinement. Therefore, key recommendations from this study are:

- The hydrological assessment has included an additional 20 % flow in consideration of uncertainties in the modelling. Normally this capacity is included in the assessment of freeboard height. Therefore freeboard considerations should be limited to a minimal freeboard to cater for construction level error, settlement and erosion only. It is proposed that a freeboard of 200 mm be adopted over and above the 3000 year ARI flood level and added to the mine side top of bank, sloping to zero freeboard at the channel side top of bank.

- Current design has included increased roughness at selected points along the channels to reduce velocities. The detailed design is to ensure that the required roughness is replicated in the design through appropriate vegetation and selective inclusion of rock.

- Prior to the mine closure, levees located adjacent to spoil dump areas adjacent to Lagoon, Sandy and Spring Creek should be rehabilitated, and where practical, the area should be reclaimed to allow unhindered drainage off the spoil dump areas, straight into the creek or diversion channels.
- During detailed design the constricted area in Lagoon Creek needs further investigation to assess whether the channel will remain stable under developed condition.

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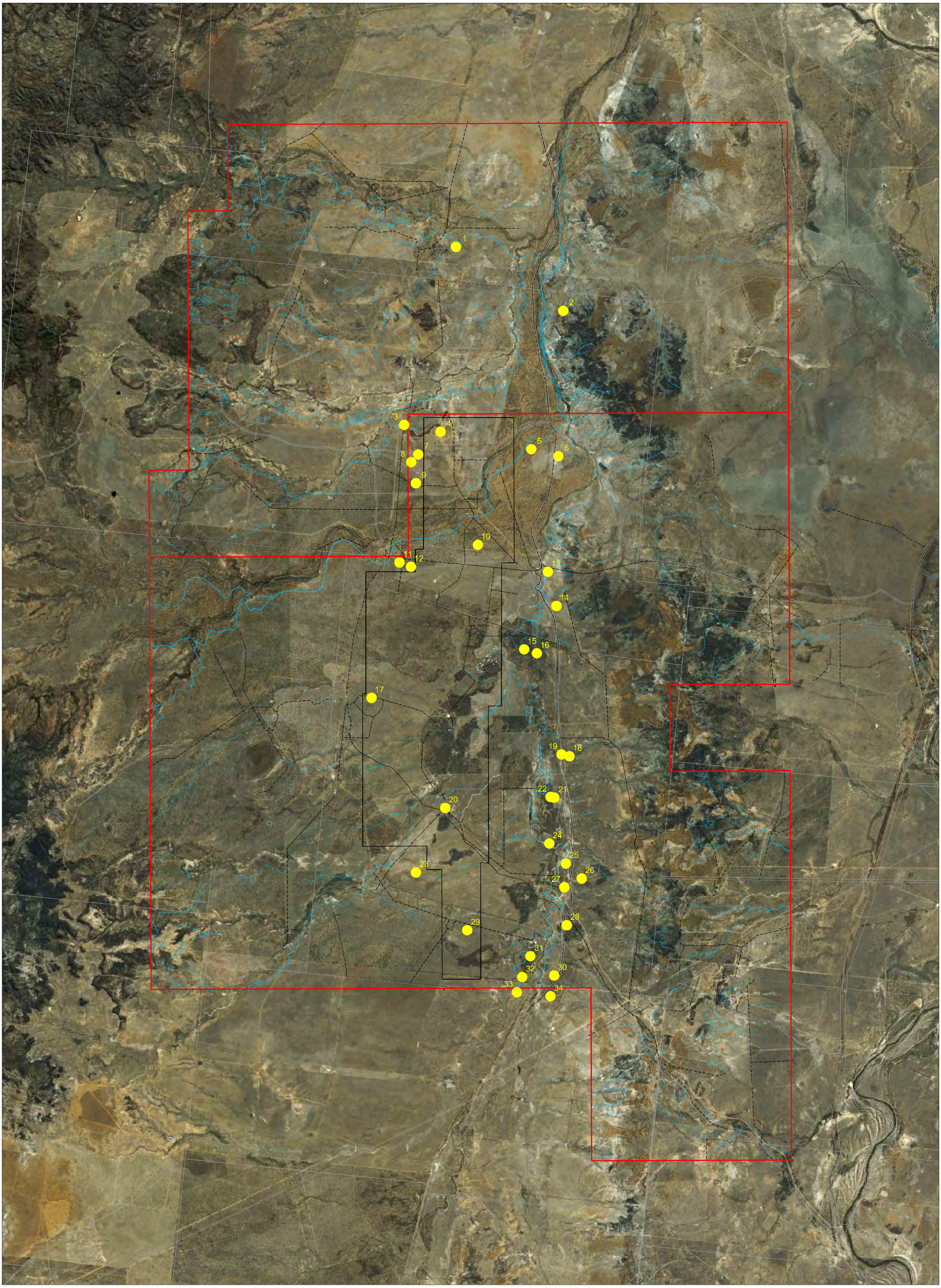
Appendix A

Hydrological Calculations



ALPHA COAL PROJECT

PARSONS BRINCKERHOFF

0 500 1000 2000 3000
Full Size 1:50000 ; Half Reduction 1:100000
SCALE (m)

N

HANCOCK COAL PTY LTD

FIGURE 67500-1045

SITE VISIT
PHOTOGRAPH LOCATIONS

August 13, 2010

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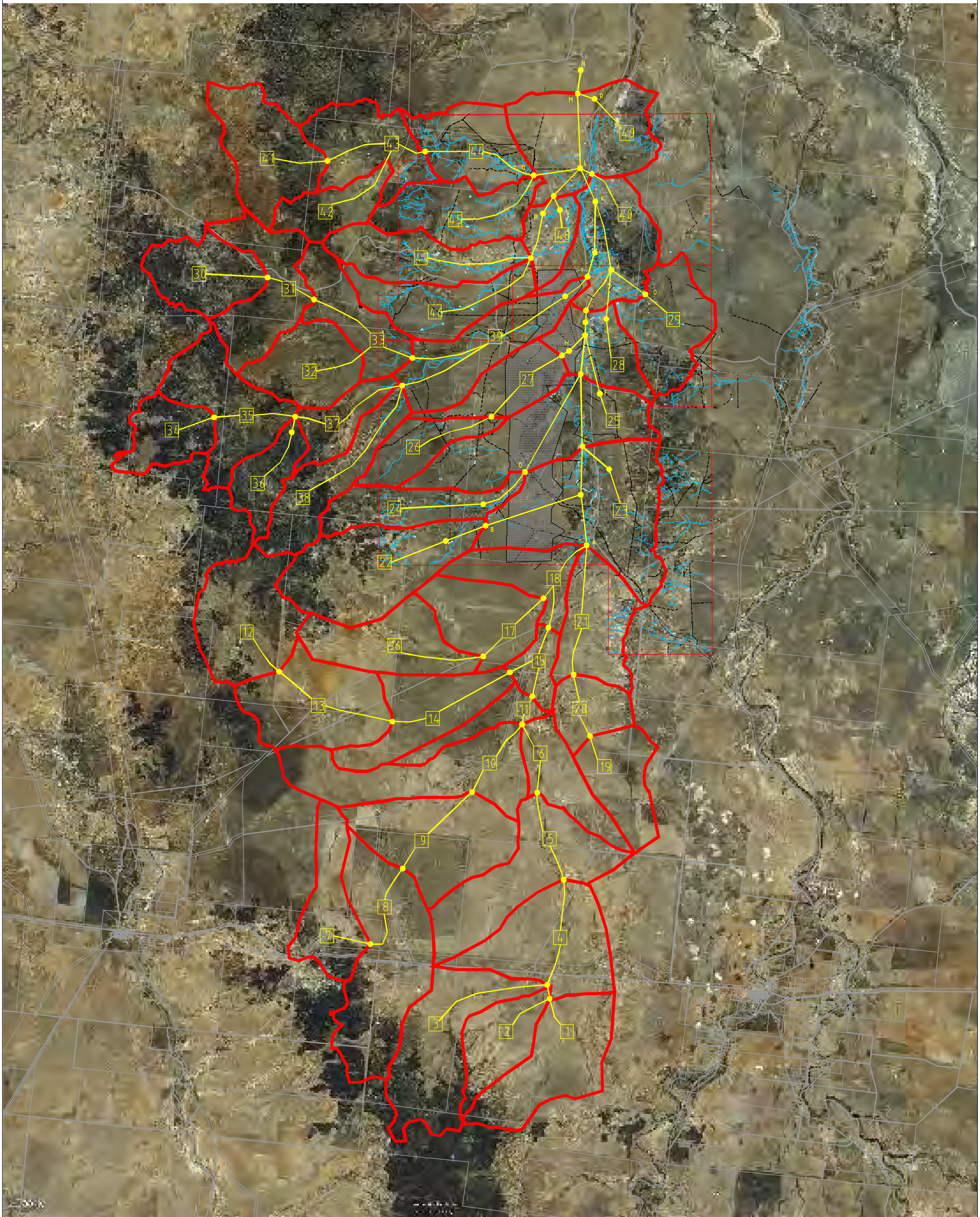
Figure A-2



ALPHA COAL PROJEC

EXISTING SUB CATCHMENT AREA

PARSONS BRINCKERHOFF

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Full Size 1:100000 ; Half Reduction1:200000
SCALE (m)

April 7, 20:

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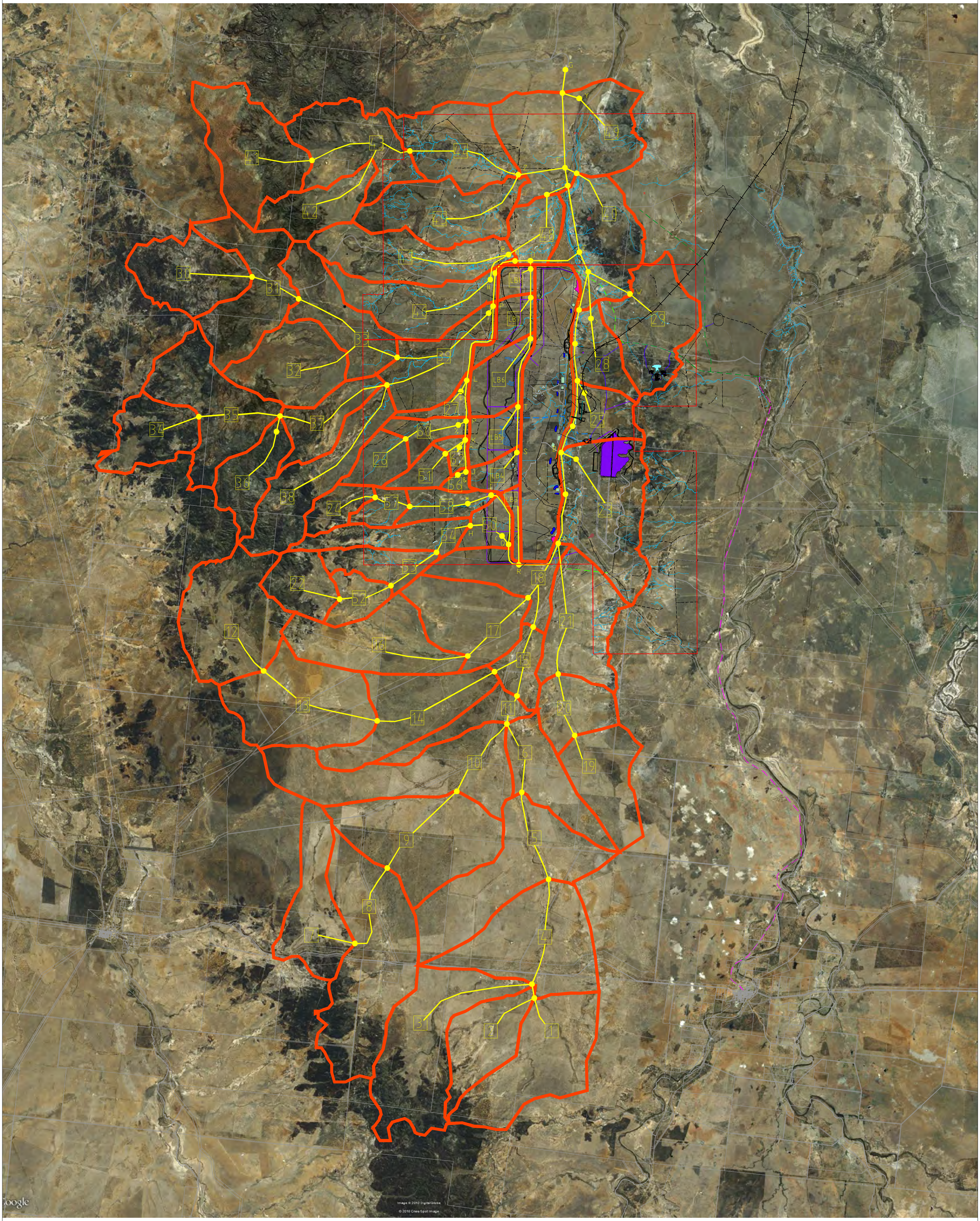
Figure A-3



ALPHA COAL PROJECT

DEVELOPED CASE SUB CATCHMENT AREA

PARSONS BRINCKERHOFF

Full Size 1:100000 ; Half Reduction 1:200000 SCALE (m)

April 7, 2011

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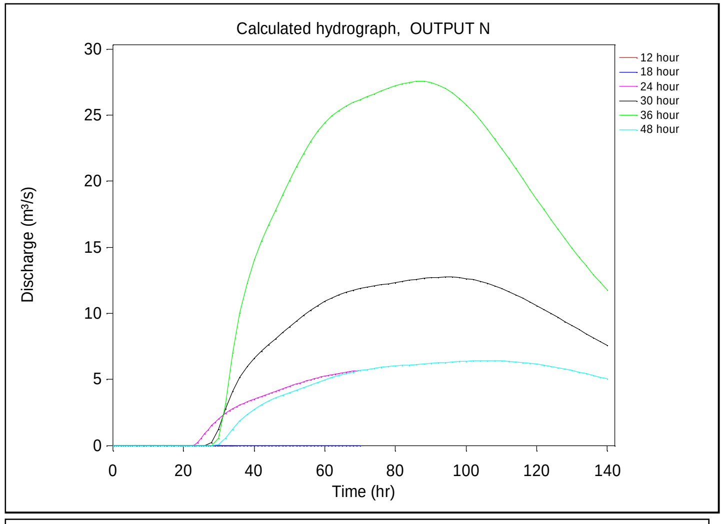
Table A.1 Existing and developed sub-catchment areas

Node	Area – existing (km^2)	Area – developed (km^2)
1	70.17	70.17
2	38.672	38.672
3	81.648	81.648
4	76.456	76.456
5	82.95	82.95
6	38.303	38.303
7	48.03	48.03
8	104.226	104.226
9	80.763	80.763
10	80.652	80.652
11	19.901	19.901
12	72.846	72.846
13	74.407	74.407
14	56.706	56.706
15	17.463	17.463
16	57.169	57.169
17	52.033	52.033
18	37.804	34.391
19	42.732	42.732
20	28.89	28.89
21	53.611	53.611
22	89.713	25.114
23	116.148	74.163
24	44.122	14.335
25	88.966	23.589
26	32.299	16.821
27	36.785	8.002
28	38.986	25.197
29	55.161	55.161
30	47.173	47.173
31	57.437	57.437
32	48.27	48.27
33	44.42	44.42
34	34.671	34.671
35	63.004	63.004
1	70.17	70.17
36	29.663	29.663
37	27.967	27.967
38	52.227	52.227
39	63.682	43.253
40	64.925	56.892
41	63.41	63.41
42	30.714	30.698
43	53.835	53.835
44	50.429	50.429
45	54.324	54.324
46	51.636	47.348
47	54.855	54.855
48	23.91	20.771
49	84.732	84.732
50	N/A	13.528
51	N/A	10.997
52	N/A	15.76
53	N/A	21.713
54	N/A	27.126
56	N/A	3.383
57	N/A	10.805
58	N/A	16.395
60	N/A	13.89
62	N/A	6.018
LB3	N/A	5.236
LB4	N/A	10.829
LB5	N/A	16.097
LB6	N/A	22.647
LB7	N/A	14.623
LB8	N/A	7.559

Areal Reduction Factor

Duration (hours)	Areal Reduction Factor
24	0.83259
48	0.88510
72	0.90826
96	0.92200
120	0.931340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Discharge (m³/s)
Time (hr)
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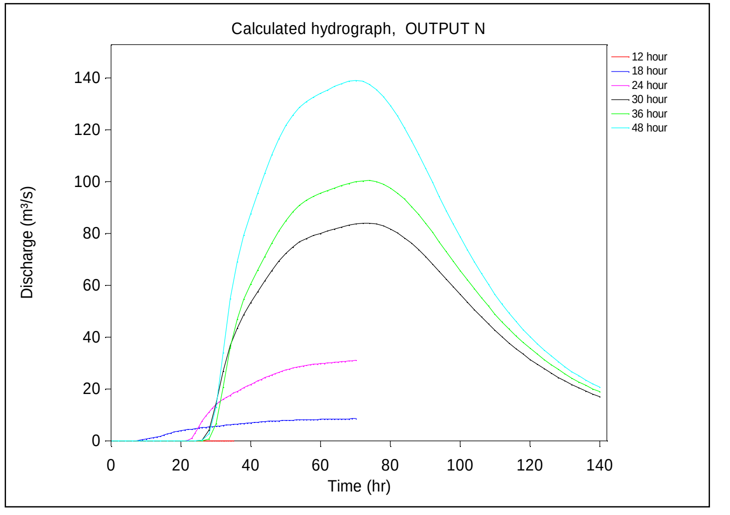
18 hour
24 hour
30 hour
36 hour
48 hour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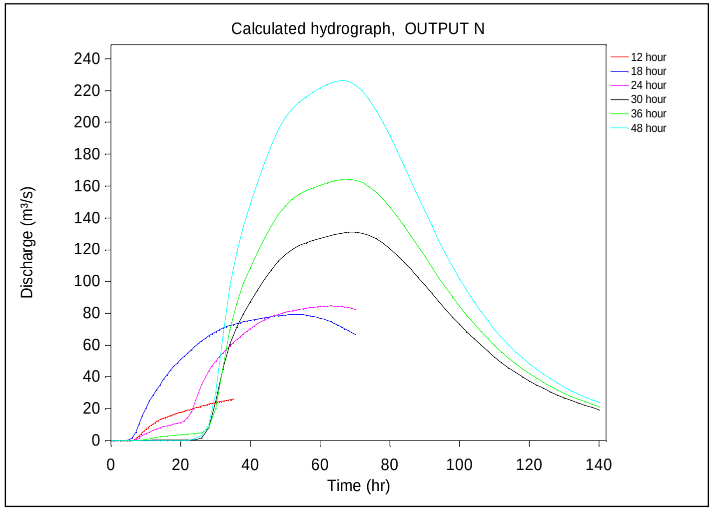
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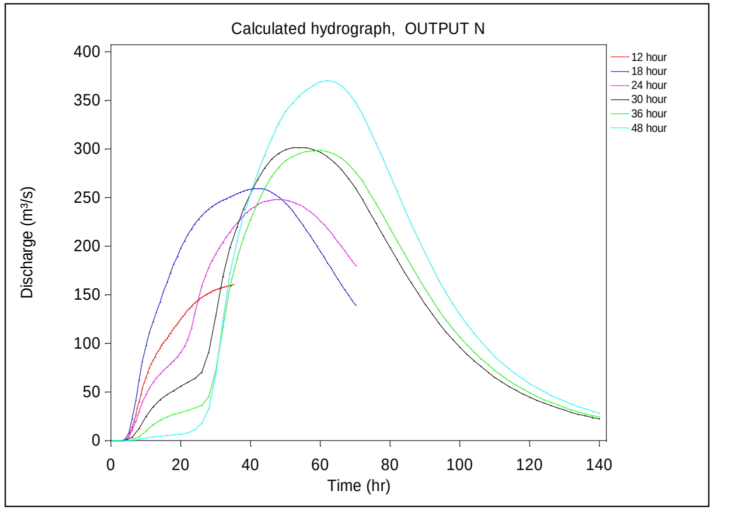
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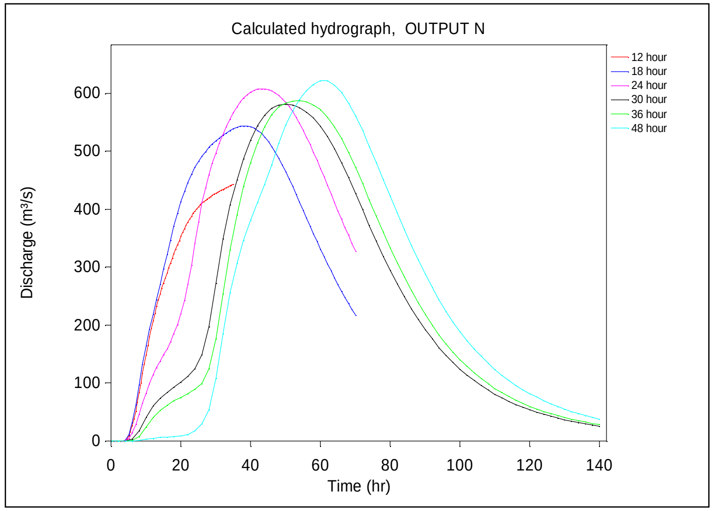
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Discharge (m³/s)
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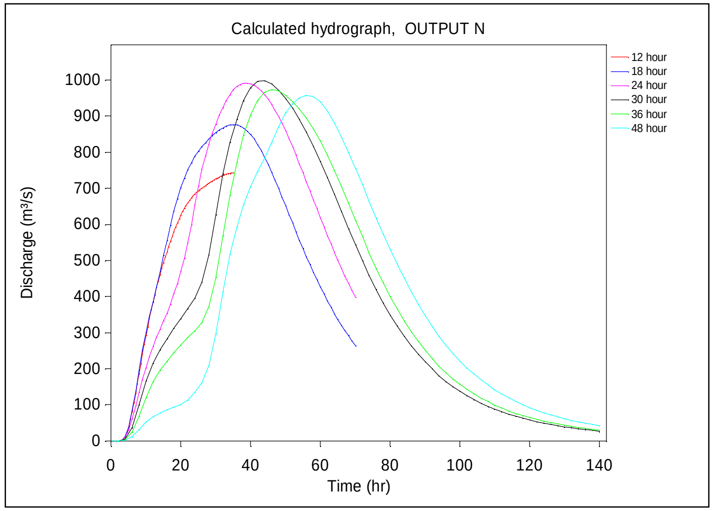
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Discharge (m³/s)
Time (hr)
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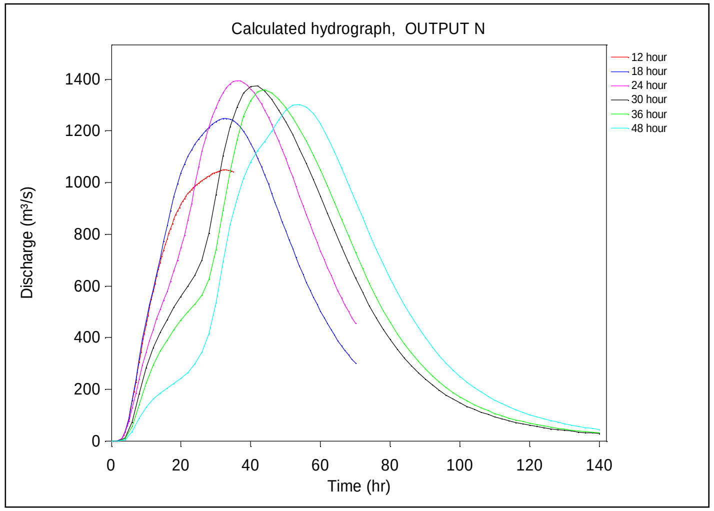
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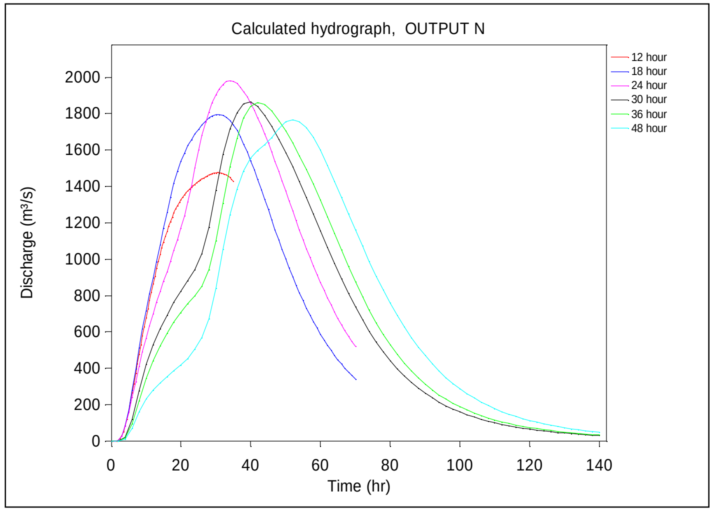
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Discharge (m³/s)
Time (hr)
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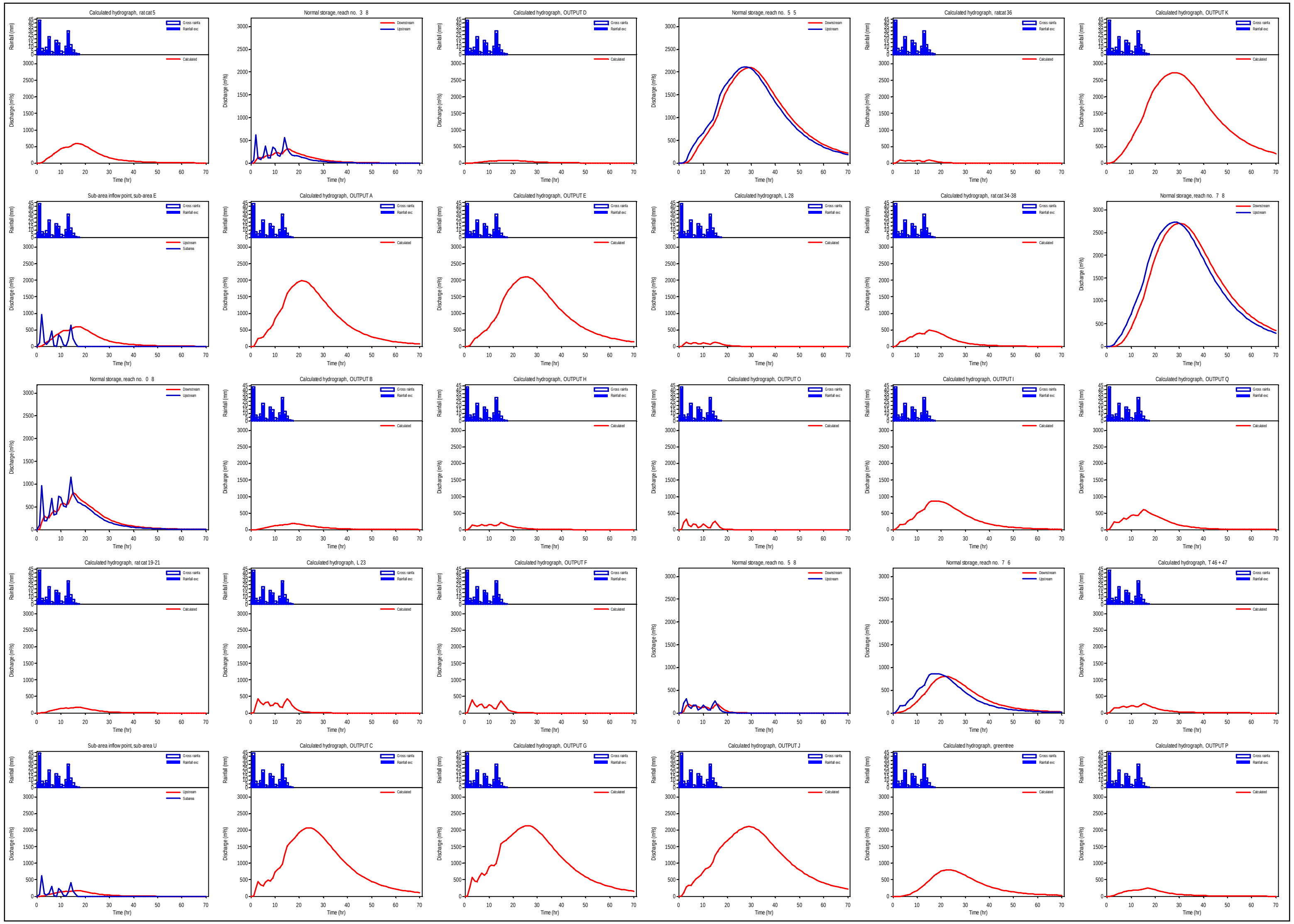

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Calculated hydrograph, OUTPUT D
Normal storage, reach no. 5 5
Calculated hydrograph, ratcat 36
Calculated hydrograph, OUTPUT K
Sub-area inflow point, sub-area E
Calculated hydrograph, OUTPUT A
Calculated hydrograph, OUTPUT E
Calculated hydrograph, L 28
Calculated hydrograph, ratcat 34-38
Normal storage, reach no. 7 8
Normal storage, reach no. 0 8
Calculated hydrograph, OUTPUT B
Calculated hydrograph, OUTPUT H
Calculated hydrograph, OUTPUT O
Calculated hydrograph, OUTPUT I
Calculated hydrograph, OUTPUT Q
Calculated hydrograph, ratcat 19-21
Calculated hydrograph, L 23
Calculated hydrograph, OUTPUT F
Normal storage, reach no. 5 8
Normal storage, reach no. 7 6
Calculated hydrograph, T 46 + 47
Sub-area inflow point, sub-area U
Calculated hydrograph, OUTPUT C
Calculated hydrograph, OUTPUT G
Calculated hydrograph, OUTPUT J
Calculated hydrograph, greentree
Calculated hydrograph, OUTPUT P
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Time (hr)
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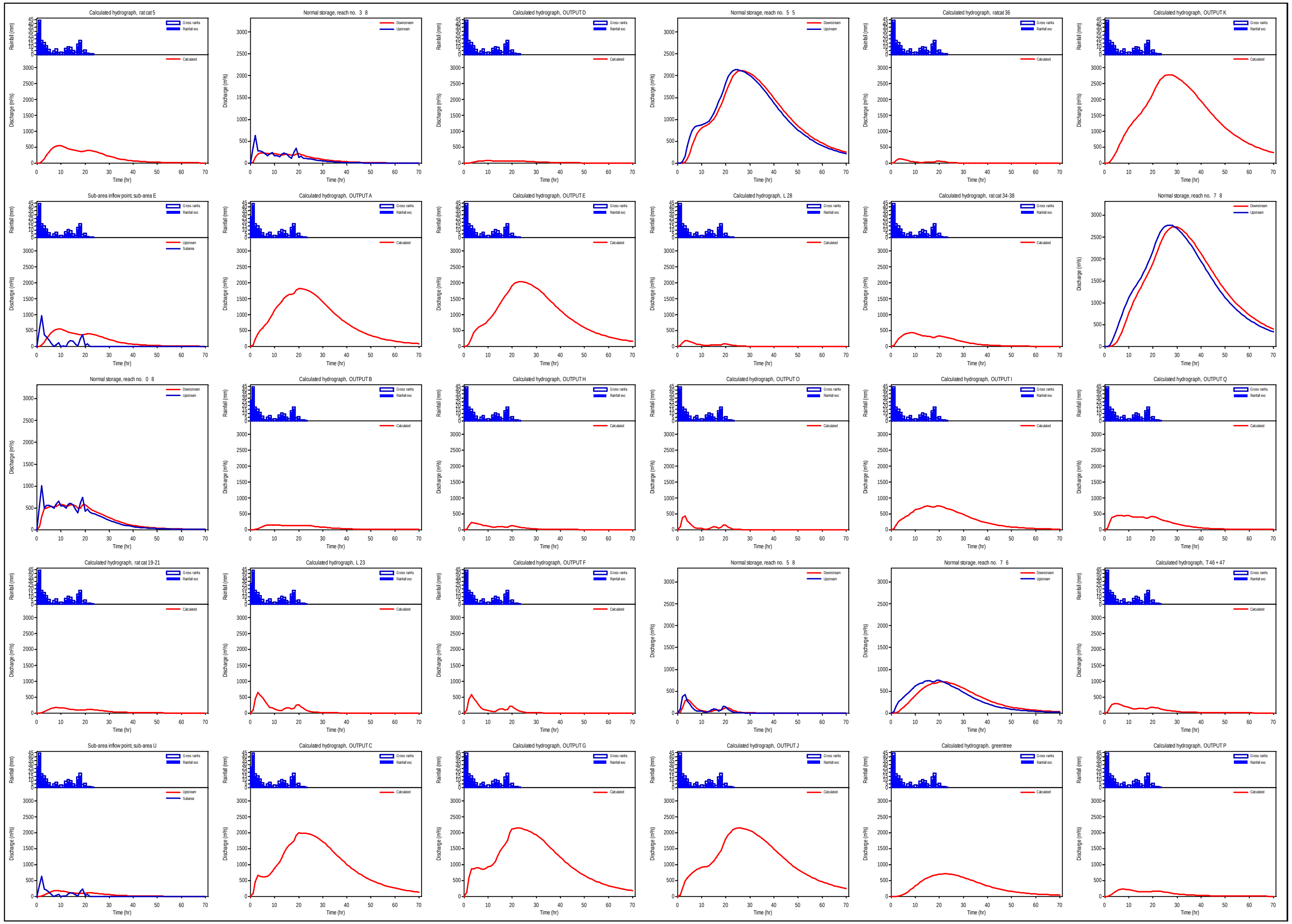
Calculated
Downstream
Upstream
Subarea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Calculated hydrograph, OUTPUT I
Calculated hydrograph, OUTPUT Q
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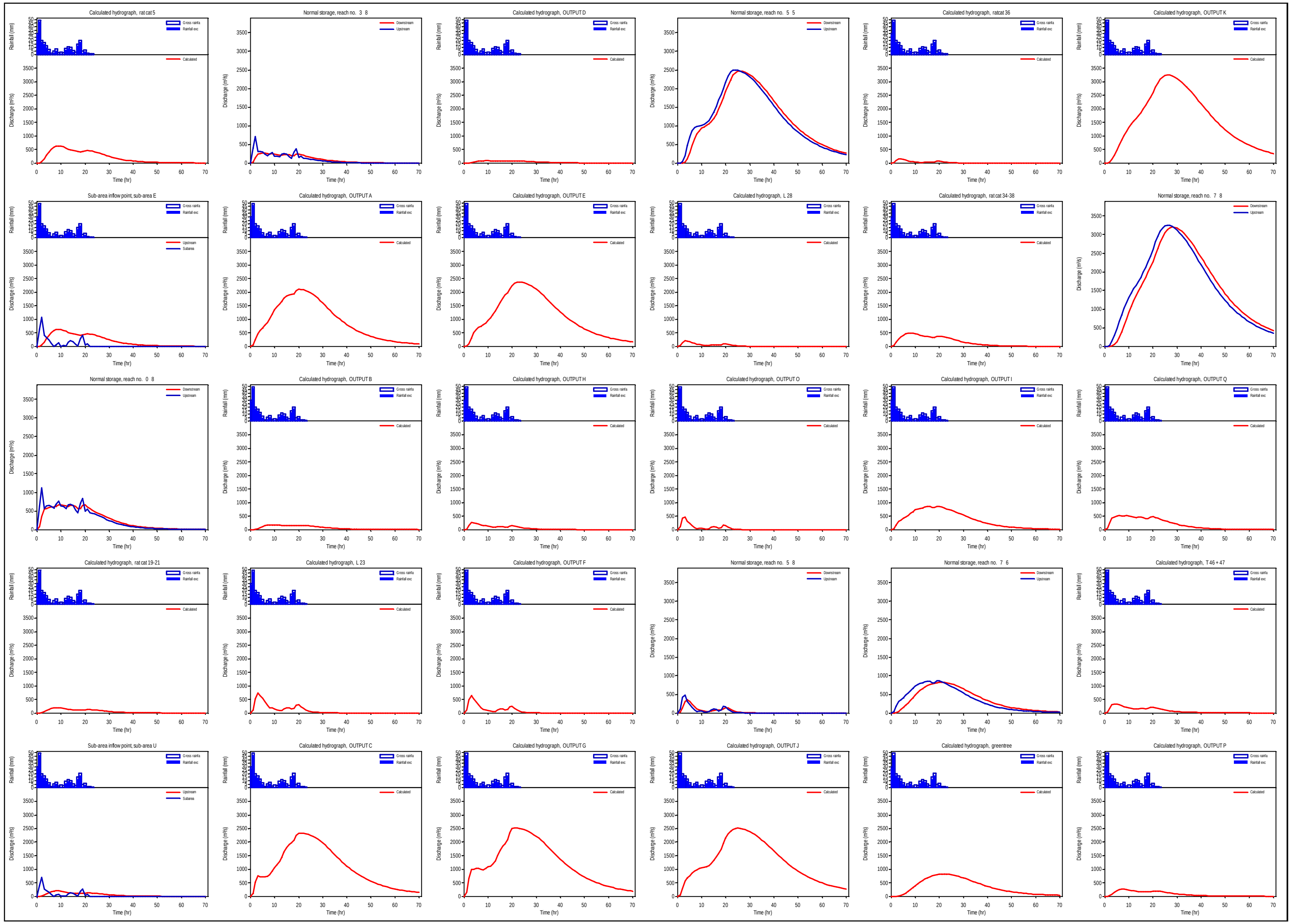
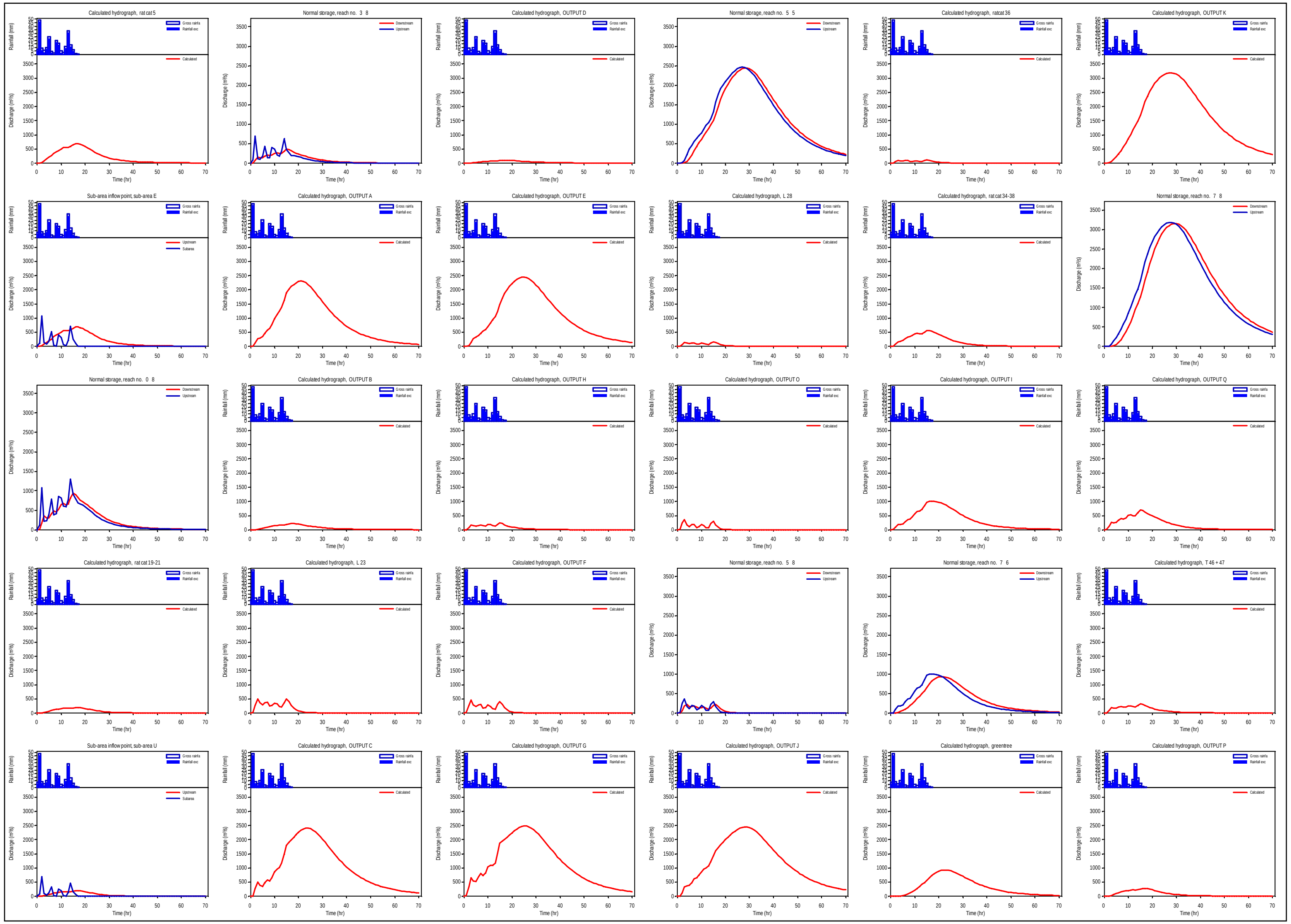
Calculated hydrograph, L 23
Calculated hydrograph, OUTPUT F
Normal storage, reach no. 5 8
Normal storage, reach no. 7 6
Calculated hydrograph, T46 + 47
Sub-area inflow point, sub-area U
Calculated hydrograph, OUTPUT C
Calculated hydrograph, OUTPUT G
Calculated hydrograph, OUTPUT J
Calculated hydrograph, greentree
Calculated hydrograph, OUTPUT P
Rainfall (mm)
Discharge (m³/s)
Time (hr)
Gross rainfa
Rainfall exc
Calculated
Downstream
Upstream
Subarea


Calculated hydrograph, ratcat 5
Normal storage, reach no. 3 8
Calculated hydrograph, OUTPUT D
Normal storage, reach no. 5 5
Calculated hydrograph, ratcat 36
Calculated hydrograph, OUTPUT K
Sub-area inflow point, sub-area E
Calculated hydrograph, OUTPUT A
Calculated hydrograph, OUTPUT E
Calculated hydrograph, L 28
Calculated hydrograph, ratcat 34-38
Normal storage, reach no. 7 8
Normal storage, reach no. 0 8
Calculated hydrograph, OUTPUT B
Calculated hydrograph, OUTPUT H
Calculated hydrograph, OUTPUT O
Calculated hydrograph, OUTPUT I
Calculated hydrograph, OUTPUT Q
Calculated hydrograph, ratcat 19-21
Calculated hydrograph, L 23
Calculated hydrograph, OUTPUT F
Normal storage, reach no. 5 8
Normal storage, reach no. 7 6
Calculated hydrograph, T46 + 47
Sub-area inflow point, sub-area U
Calculated hydrograph, OUTPUT C
Calculated hydrograph, OUTPUT G
Calculated hydrograph, OUTPUT J
Calculated hydrograph, greentree
Calculated hydrograph, OUTPUT P
Time (hr)
Discharge (m³/s)
Rainfall (mm)


Calculated hydrograph, ratcat 5
Normal storage, reach no. 3 8
Calculated hydrograph, OUTPUT D
Normal storage, reach no. 5 5
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Calculated hydrograph, OUTPUT K
Sub-area inflow point, sub-area E
Calculated hydrograph, OUTPUT A
Calculated hydrograph, OUTPUT E
Calculated hydrograph, L 28
Calculated hydrograph, ratcat 34-38
Normal storage, reach no. 7 8
Normal storage, reach no. 0 8
Calculated hydrograph, OUTPUT B
Calculated hydrograph, OUTPUT H
Calculated hydrograph, OUTPUT O
Calculated hydrograph, OUTPUT I
Calculated hydrograph, OUTPUT Q
Calculated hydrograph, ratcat 19-21
Calculated hydrograph, L 23
Calculated hydrograph, OUTPUT F
Normal storage, reach no. 5 8
Normal storage, reach no. 7 6
Calculated hydrograph, T 46 + 47
Sub-area inflow point, sub-area U
Calculated hydrograph, OUTPUT C
Calculated hydrograph, OUTPUT G
Calculated hydrograph, OUTPUT J
Calculated hydrograph, greentree
Calculated hydrograph, OUTPUT P
Time (hr)
Discharge (m³/s)
Rainfall (mm)

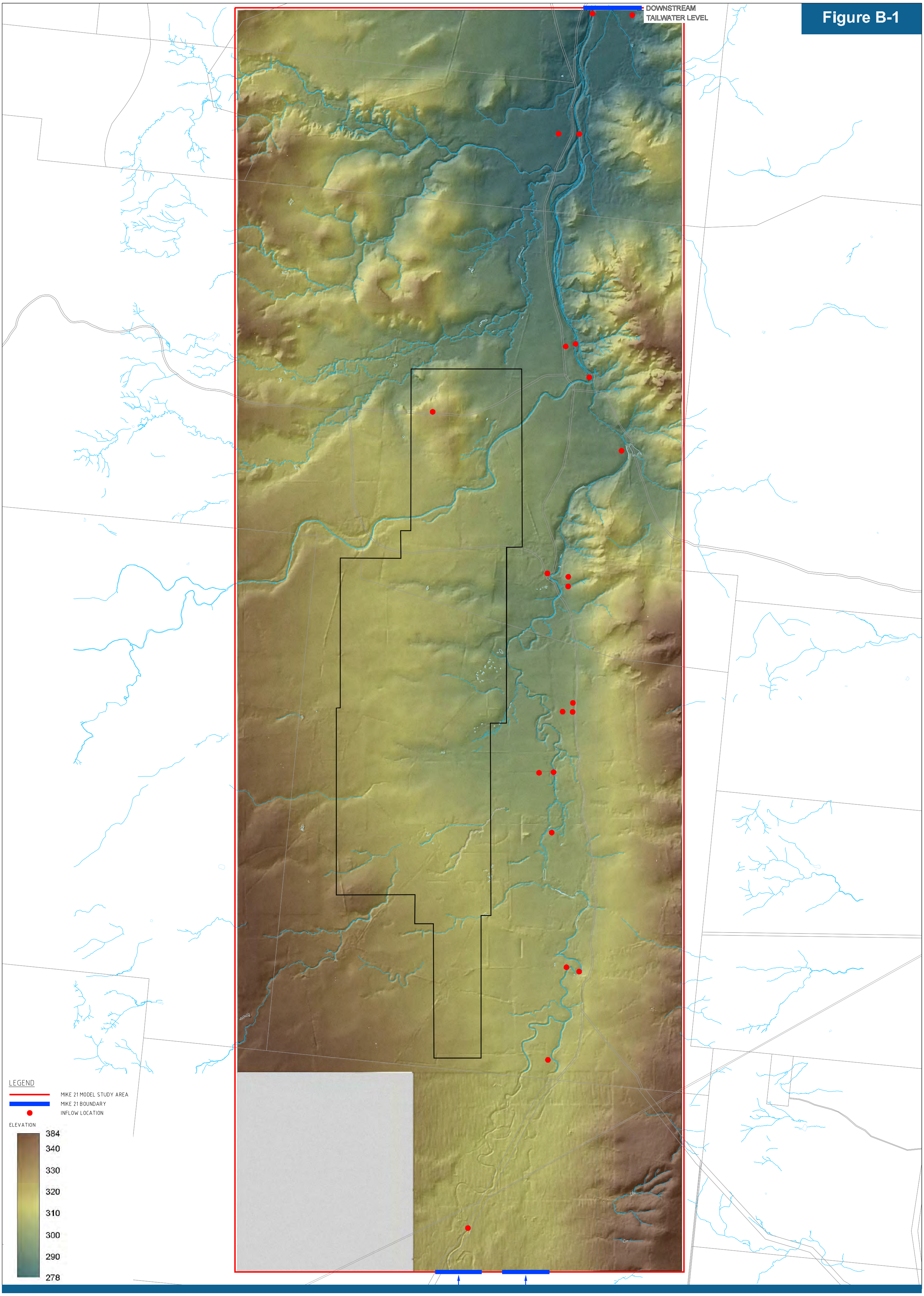
Appendix B

Hydraulic Assessment

Appendix B –Hydraulic Assessment

Figure Number	Description
B-1	MIKE21 Model layout- Developed case
B-2	Roughness-Photos
B-3	Roughness-Map- Existing case
B-4	Base case - 1000 year and 3000 year ARI - Longitudinal Section
B-5	Developed case –1000 and 3000 year ARI - Longitudinal section
B-6	Base case – 3000 year ARI water level contour map
B-7	Developed case – 3000 year ARI water level contour map
B-8	300 Year ARI afflux map

Figure B-1



PARSONS BRINCKERHOFF

SCALE (m) 0 1000 2000 3000

ALPHA COAL PROJECT

MIKE 21 MODEL LAYOUT

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 14:33 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1031_Mike21 Model Layout_Developed.dwg

Figure B-2

Plate 1: Open space (roughness = 0.035)
View at western creek diversion
(23.220 S, 146.420 E)

Plate 2: Light vegetation (roughness = 0.04)
Lagoon Creek – Looking downstream
(23.236 S, 146.499 E)

Plate 3: Medium vegetation (roughness = 0.055)
Background trees in Lagoon Creek (23.239 S, 146.498 E)

Plate 4: Dense vegetation (roughness = 0.08)
Background trees in Lagoon Creek (23.060 S, 146.503 E)

Plate 5: Creek area (roughness = 0.035 - 0.055)
Sandy Creek – Looking downstream
(23.119 S, 146.503 E)

Plate 6: Creek area (roughness = 0.035 - 0.055)
Lagoon Creek – Looking downstream
(23.324 S, 146.495 E)

PARSONS BRINCKERHOFF

ALPHA COAL PROJECT
ROUGHNESS PHOTOS

August 20, 2010

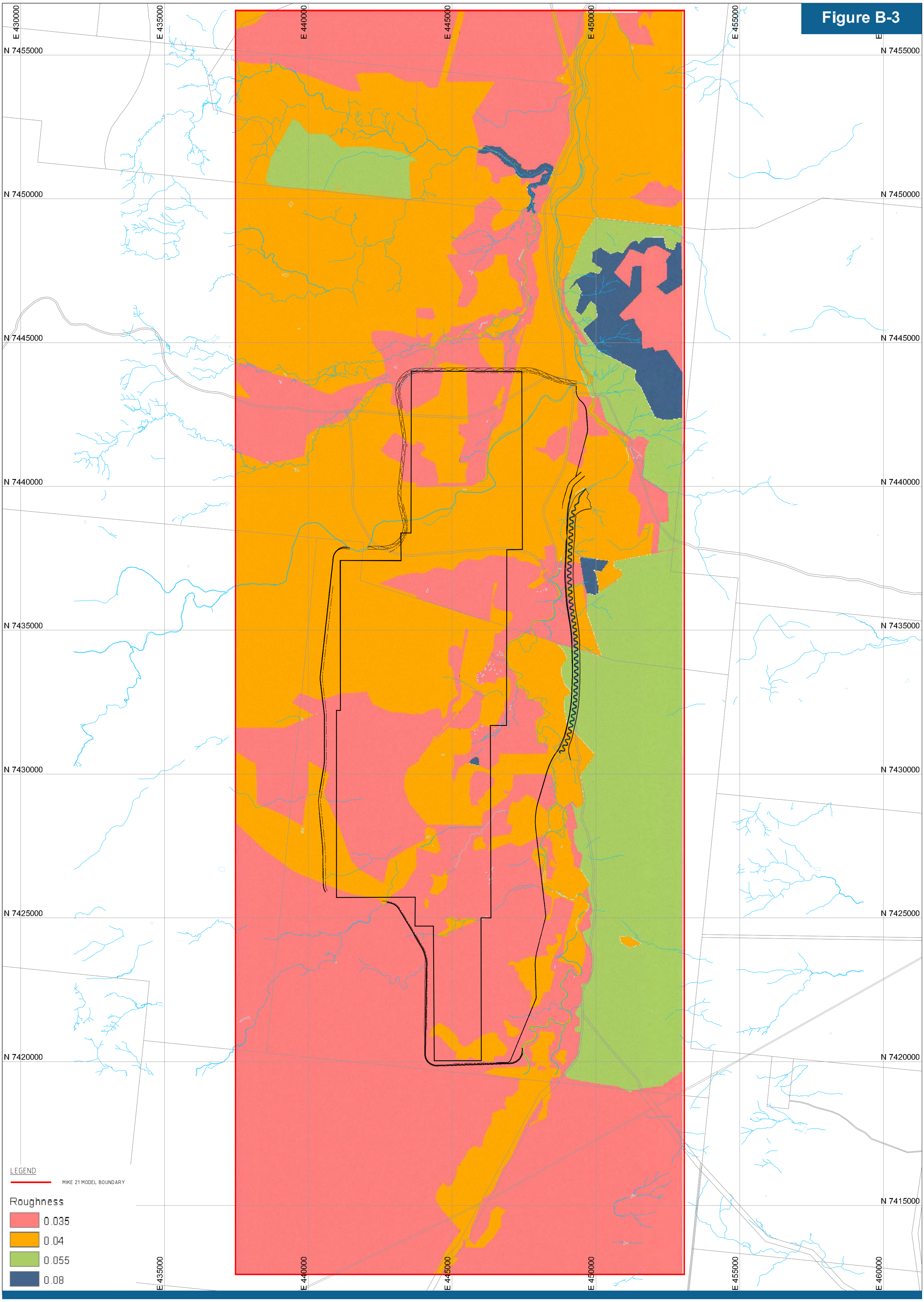


Figure B-3

PARSONS BRINCKERHOFF

SCALE (m) 0 1000 2000 3000

ALPHA COAL PROJECT

ROUGHNESS MAP
EXISTING CASE

August 20, 2010

Plotted By: hamillm Plot Date: 20/08/10 - 11:09 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1032_Roughness Map_Existing.dwg

Figure B-4
Longitudinal section of the 1000 and 3000 year ARI peak flood levels for the existing case.

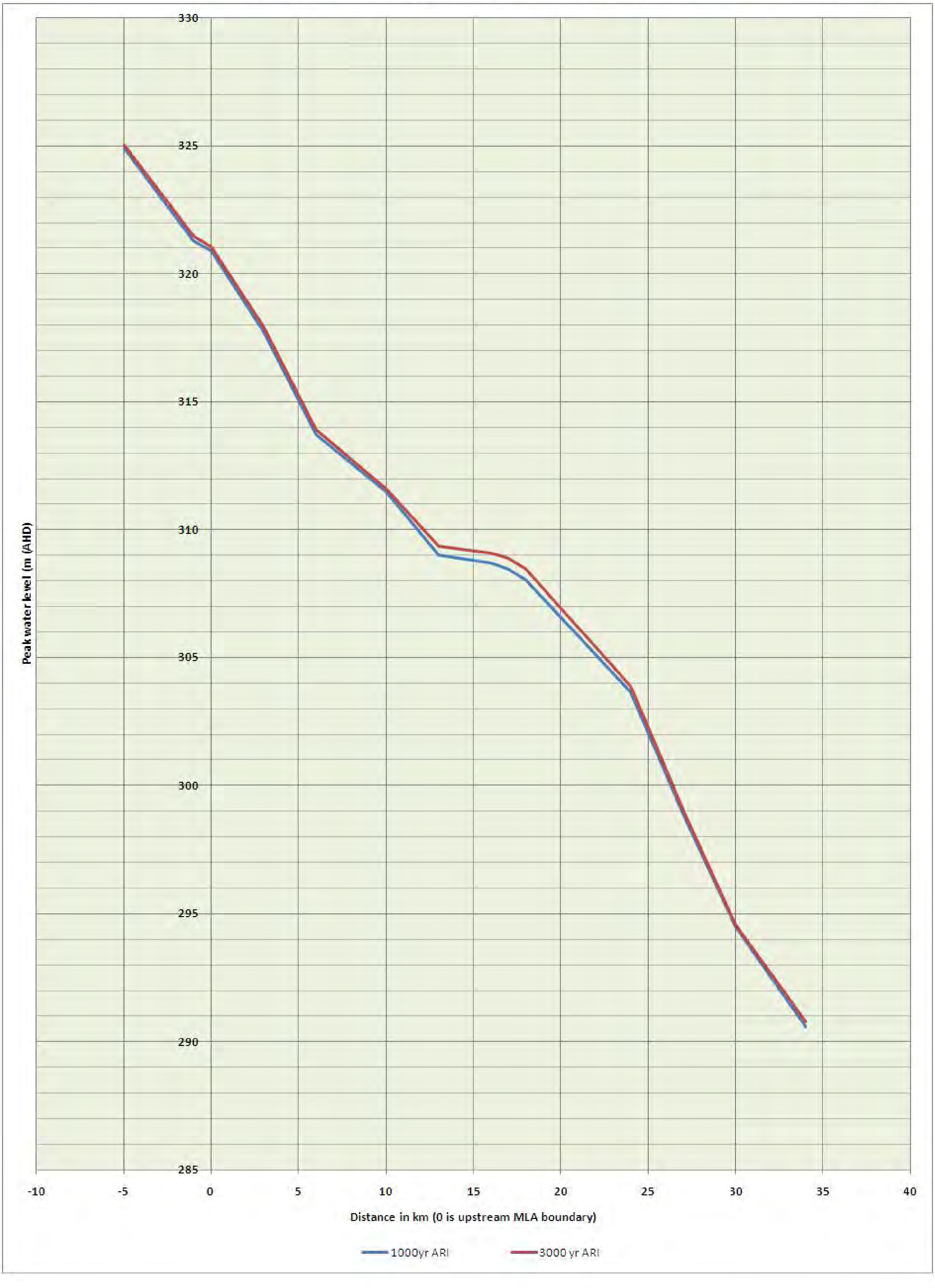
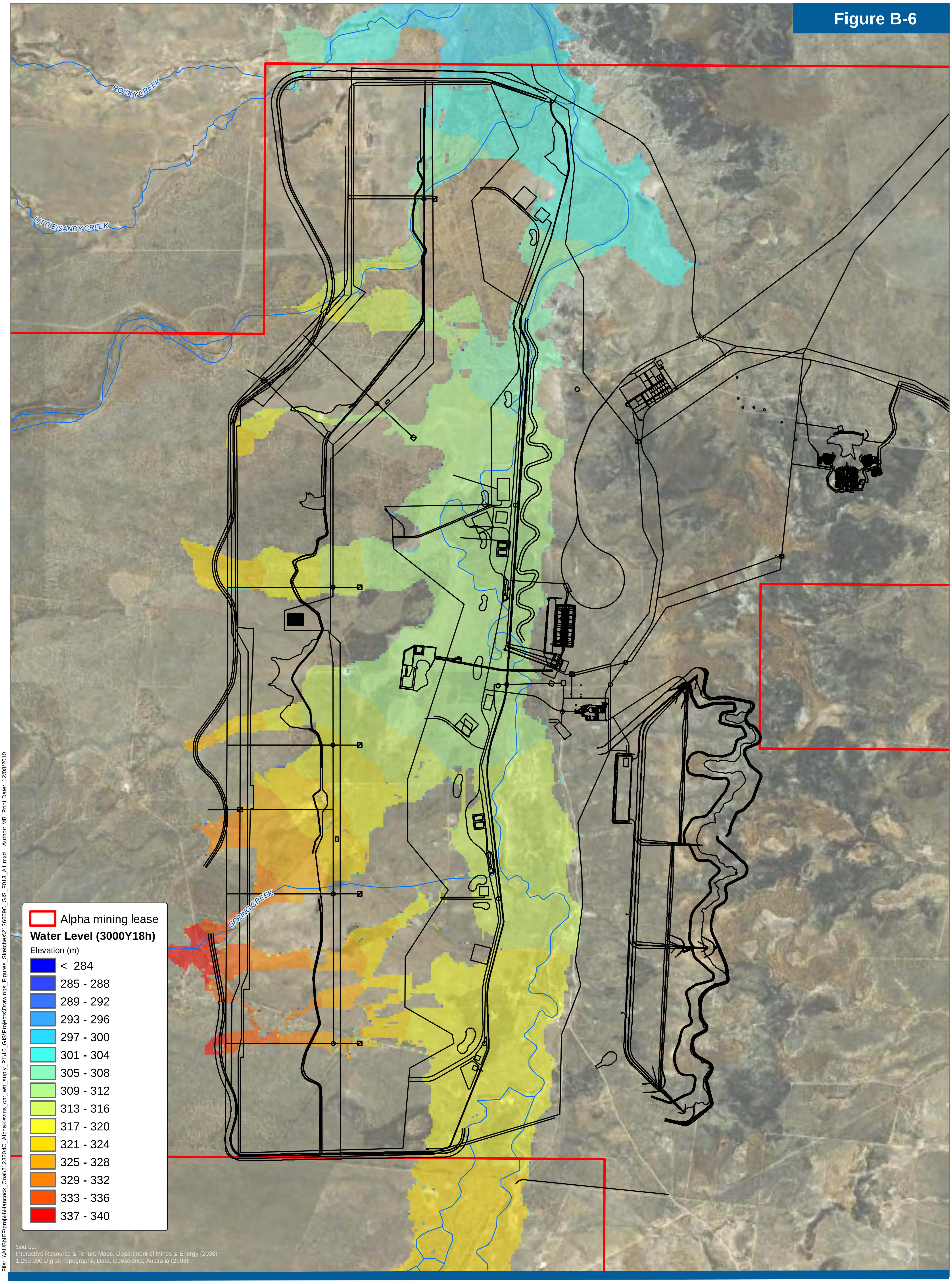


Figure B-5
Longitudinal section of the 1000 and 3000 year ARI peak flood levels for the developed case.

Figure B-6

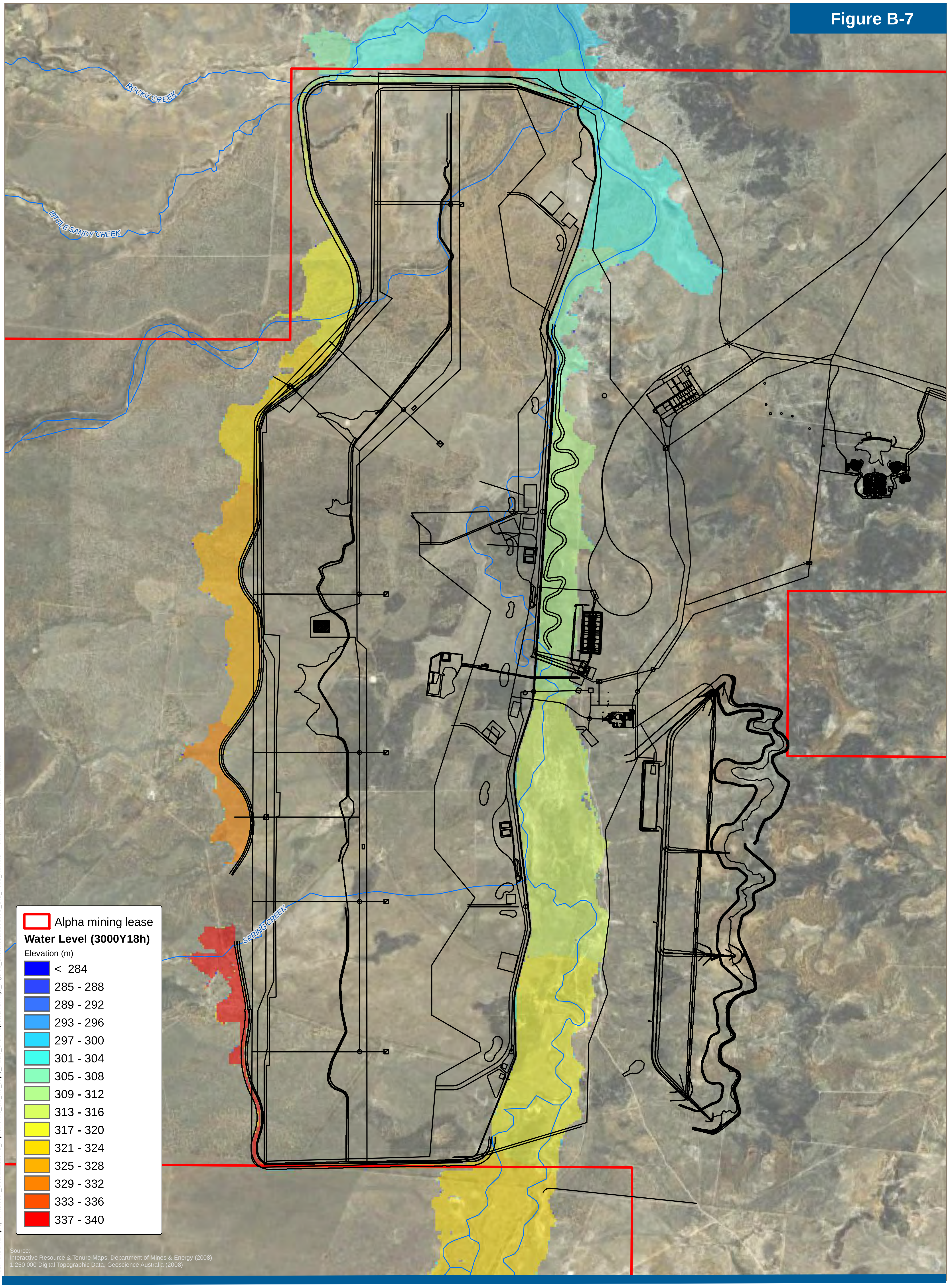


PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

Water Level Map
(Base Case) - 3000 Year ARI

Figure B-7



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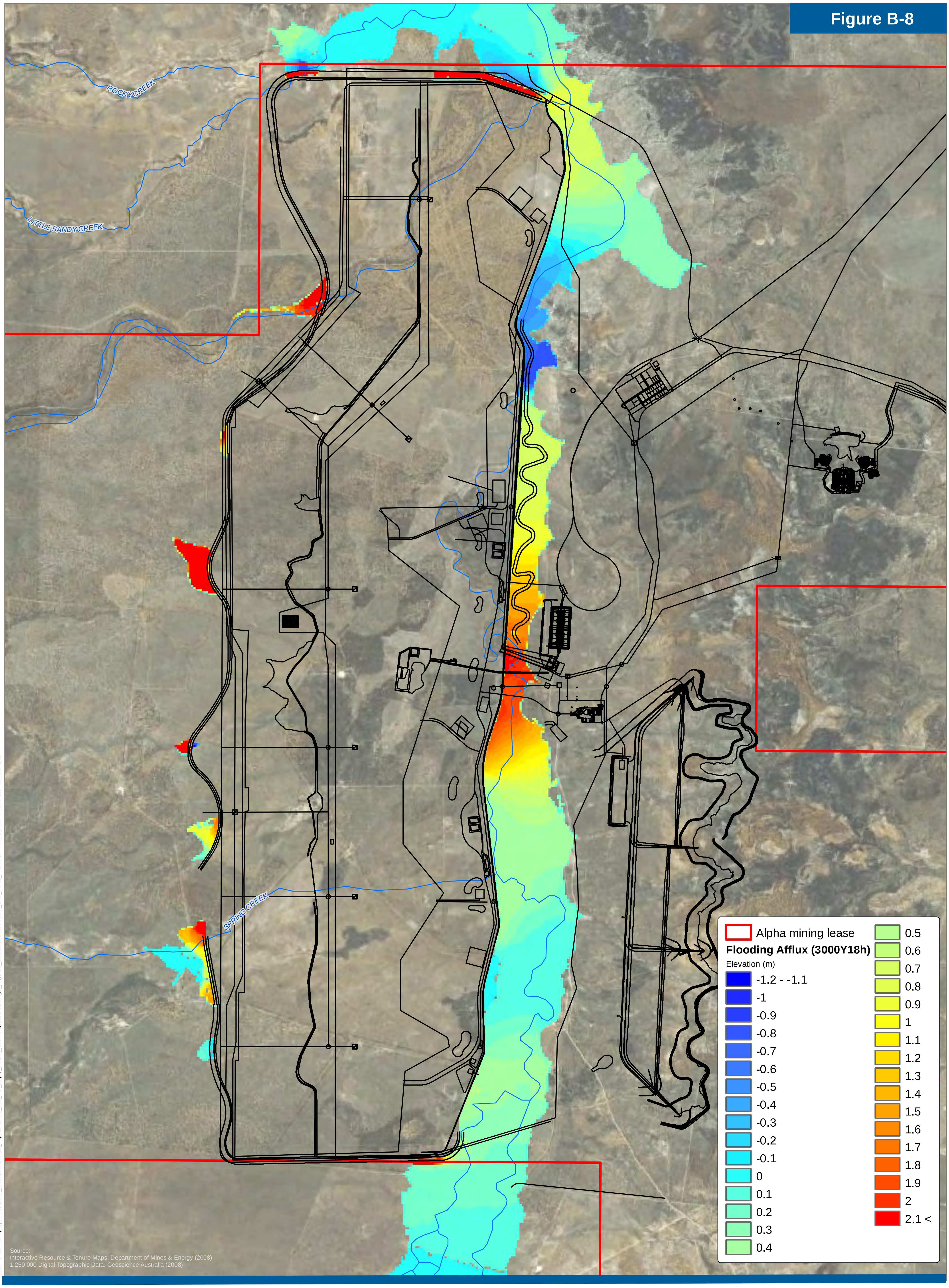
PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

Water Level Map (Developed Case) - 3000 Year ARI

Figure B-8



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PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

Afflux - 3000 Year ARI

Appendix C

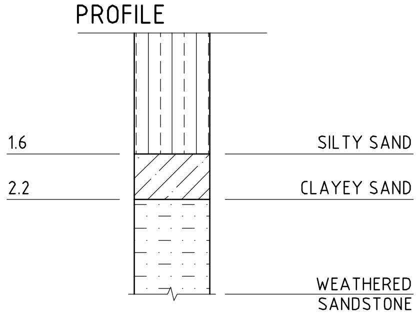
Creek Diversion Cross Sections

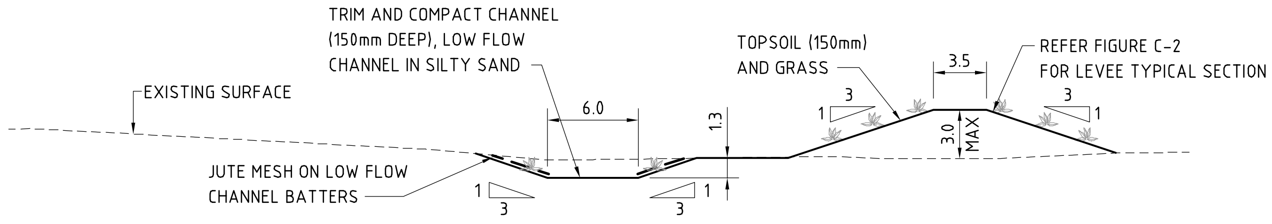
Appendix C – Creek diversion cross sections

Figure Number	Drawing No:	Description
C-1	HC-PBA-67560-DRG-1255	North western diversion / Sandy Creek
C-2	HC-PBA-67560-DRG-1256	South western diversion / Sandy Creek – Typical levee section

Figure C-1

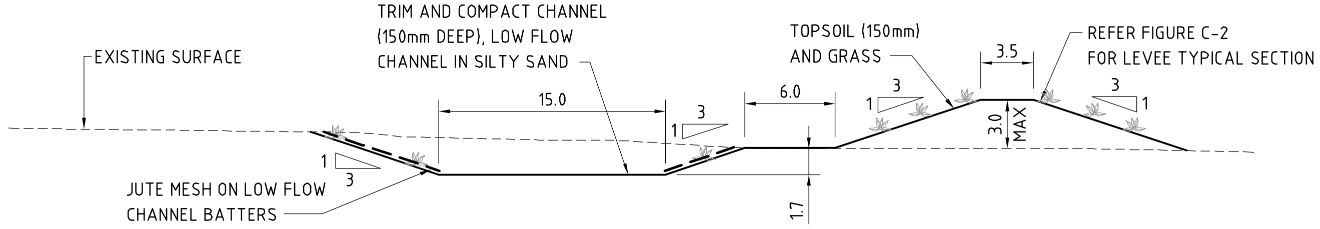
INFERRED GEOTECHNICAL PROFILE





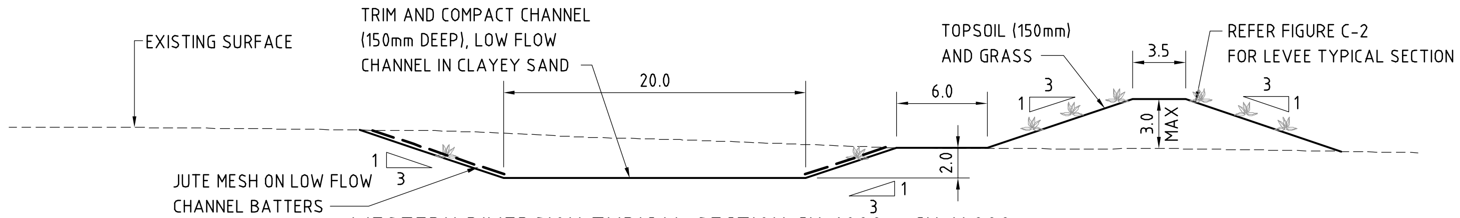
WESTERN DIVERSION TYPICAL SECTION CH 0.0 – CH 2500

SCALE 1:250



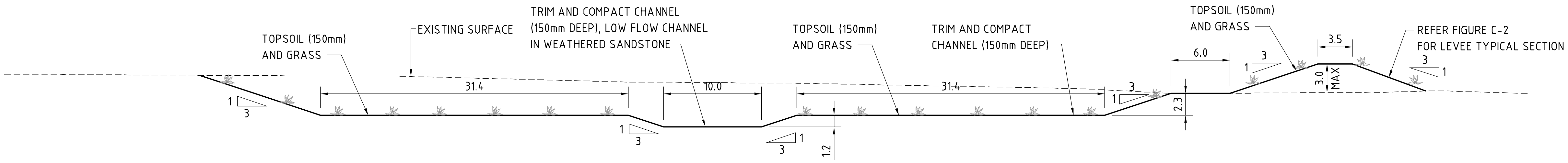
WESTERN DIVERSION TYPICAL SECTION CH 2500 – CH 6000

SCALE 1:250



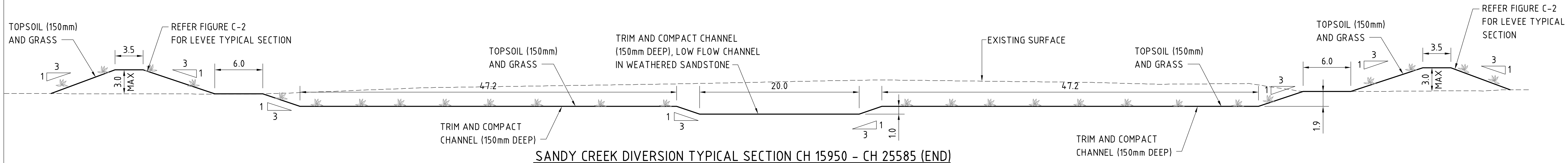
WESTERN DIVERSION TYPICAL SECTION CH 6000 – CH 14000

SCALE 1:250



SANDY CREEK DIVERSION TYPICAL SECTION CH 14000 – CH 15950

SCALE 1:250



SANDY CREEK DIVERSION TYPICAL SECTION CH 15950 – CH 25585 (END)

SCALE 1:250

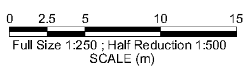
NOTES

1. AFTER STRIPPING OF TOPSOIL, THE EXPOSED SURFACES ARE TO BE RIPPED AND RE-COMPACTED WITH THE FIRST LAYER OF FILL PLACED THEREON TO NOT LESS THAN 98% MDD (STANDARD COMPACTION) AT ±2% OF OMC TO A MINIMUM DEPTH OF 0.6m FROM THE ORIGINAL SURFACE LEVEL.
2. A GEOTECHNICAL ASSESSMENT FOR APPROVED FOUNDATION SURFACE, AND SUITABILITY OF MATERIALS IN THE DAM EMBANKMENT SHOULD BE CARRIED OUT BY A COMPETENT PERSON. THIS SHOULD BE COMPLETED PRIOR TO PROCEEDING WITH CONSTRUCTION OF THE EMBANKMENT WALLS.
3. THE EMBANKMENT MATERIAL SHALL BE COMPACTED TO 98% STANDARD MAXIMUM DRY DENSITY (MDD) AT THEIR OPTIMUM MOISTURE CONTENT (OMC) OR JUST ABOVE IT (I.E. WITHIN RANGE OF -1% OMC AND +3%).
4. MEDIUM TO HIGH PLASTICITY SANDY CLAY SOILS ENCOUNTERED IN THE AREA ARE CONSIDERED SUITABLE ZONE 1A MATERIALS PROVIDED THEY MEET SOIL PARAMETERS :

MATERIAL PROPERTY	RECOMMENDED LIMITS
% PASSING 0.075mm	> 30%
LIQUID LIMIT	30% TO 70%
PLASTIC INDEX	> 15%
EMERSON NUMBER	> 4

5. EXISTING SURFACE LEVELS ARE DETERMINED FROM AERIAL SURVEY. CONTROL LINE LEVEL MAY BE ADJUSTED ACCORDINGLY TO ALLOW FOR ANY DISCREPANCY BETWEEN AERIAL AND ACTUAL LEVELS.

PARSONS BRINCKERHOFF



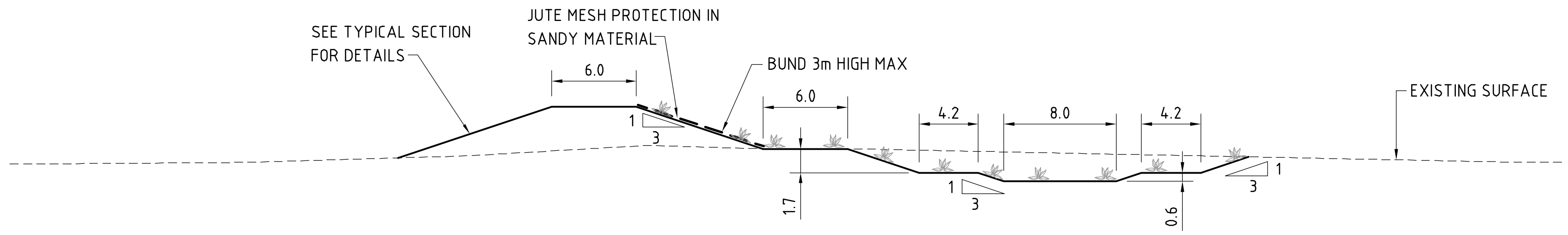
ALPHA COAL PROJECT

WESTERN, SANDY CREEK & SPRING CREEK DIVERSIONS

TYPICAL CROSS SECTIONS

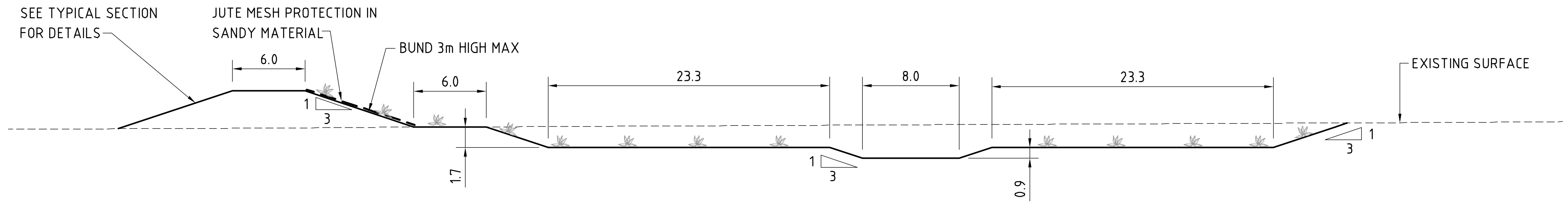
April 7, 2011

Figure C-2



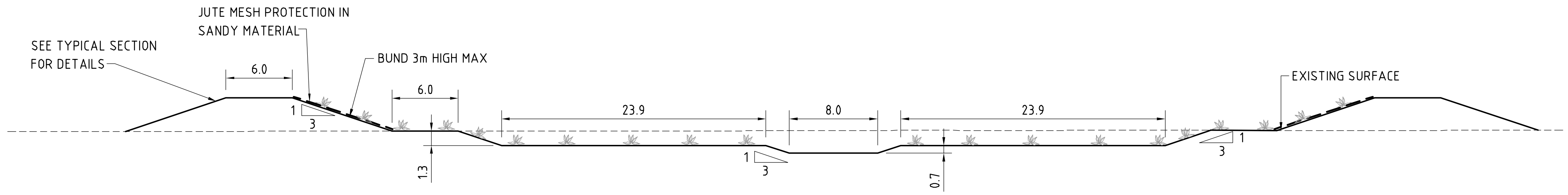
SPRING CREEK DIVERSION TYPICAL SECTION CH 0.0 – CH 2000

SCALE 1:250



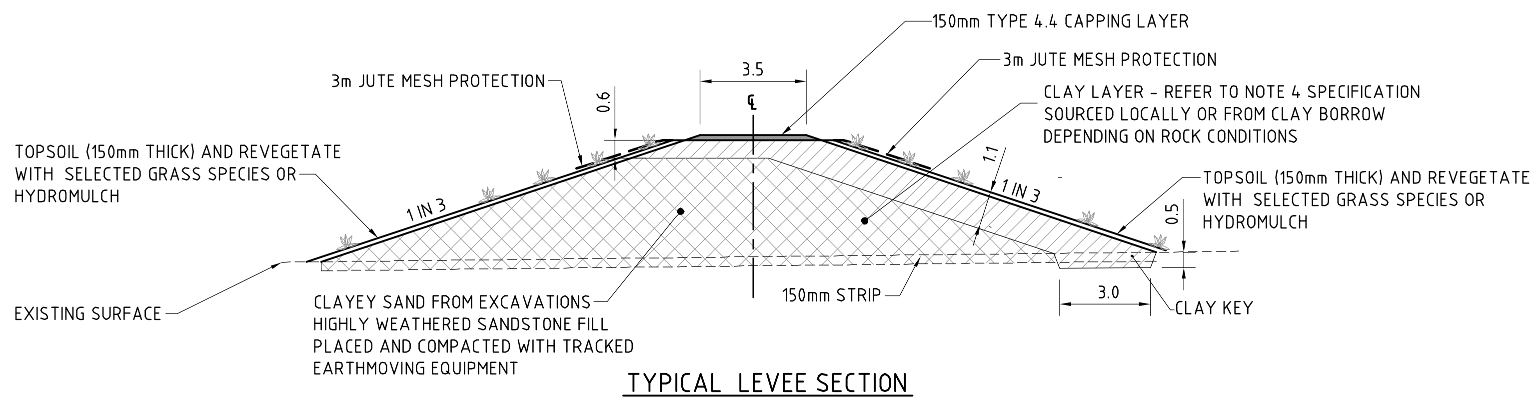
SPRING CREEK DIVERSION TYPICAL SECTION CH 2000 – CH 5600

SCALE 1:250



SPRING CREEK DIVERSION TYPICAL SECTION CH 5600 – CH 11200 (END)

SCALE 1:250



TYPICAL LEVEE SECTION

SCALE 1:250

NOTES

1. AFTER STRIPPING OF TOPSOIL, THE EXPOSED SURFACES ARE TO BE RIPPED AND RE-COMPACTED WITH THE FIRST LAYER OF FILL PLACED THEREON TO NOT LESS THAN 98% MDD (STANDARD COMPACTION) AT ±2% OF OMC TO A MINIMUM DEPTH OF 0.6m FROM THE ORIGINAL SURFACE LEVEL.
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3. THE EMBANKMENT MATERIAL SHALL BE COMPACTED TO 98% STANDARD MAXIMUM DRY DENSITY (MDD) AT THEIR OPTIMUM MOISTURE CONTENT (OMC) OR JUST ABOVE IT (I.E. WITHIN RANGE OF -1% OMC AND +3%).
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PLASTIC INDEX	> 15%
EMERSON NUMBER	> 4

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PARSONS BRINCKERHOFF

0 2.5 5 10 15
Full Size 1:250 ; Half Reduction 1:500
SCALE (m)

ALPHA COAL PROJECT

SPRING CREEK DIVERSION

TYPICAL CROSS SECTIONS

April 7, 2011

Plotted By: duffyt Plot Date: 07/04/11 - 13:41 Cad File: \\Aubnef\PROJ\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_C-2_Spring_Ck_Diversion_Xsections.dwg