HANCOCK PROSPECTING PTY LTD

Alpha Coal Project Environmental Impact Statement

F2 Flooding Technical Report

Alpha Coal Project
Flooding Technical Report

September 2010

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from a Universal Transverse Mercator projection of latitudes and longitudes on the Australian Geodetic Datum (AGD) (now superseded).
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	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*.
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.
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
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 meters 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
PB	Parsons Brinckerhoff Australia.
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.
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.
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	In the opposite direction of the flow of a stream or river, i.e. towards the source.
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.

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

The Alpha Coal Project (the Project) comprises the development of thermal coal resources located approximately 170 km west of Emerald, and 60 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 42 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.

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

The key objectives of this investigation were to determine if the mine development would adversely impact on the flood risk of existing infrastructure, and to determine the likely flood risk to mine development and operations.

A detailed surface water study was completed for the Project. The study included an assessment of the hydrology of the Project's catchment area, flood modelling and a geomorphologic impact assessment.

Hydrological and hydraulic models were developed and used to determine flood behaviour for frequent and large design floods. A flood frequency analysis of historical flows was undertaken and the results were compared to calculated design floods to verify model results. The result of the investigations provided flood extents, velocities and water levels within creeks.

The key findings of the flood impact assessment are:

- the majority of flood level impacts are contained within the land owned by HPPL, with some limited impacts evident outside the MLA. The impacts outside the MLA are generally minor (< 150 mm) in nature and do not affect any properties
- the development of the mine and its associated works will not adversely affect the flood risk of the area
- the maximum predicted increase in upstream flood levels is 150 mm. This increase is predicted to occur at the upstream boundary of the proponent's land in the vicinity of the Lagoon Creek and the adjoining floodplain. The increased water levels do not affect any existing dwellings and are therefore considered to be minor in nature.
- predicted increase in flood levels downstream of the proponent's property boundary is 100 mm. 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.
- predicted flood level increases over the majority of floodplain upstream of the MLA area are generally small (< 50 mm).
- the impacts of the Project on floodplain and creek flow velocities are moderate and there is no significant increase in scour risk.

The creek geomorphology is inherently linked to the flood modelling and creek diversion design, and is discussed in detail in the Geomorphology Technical Report. 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 and their impact on existing creeks will be required during the detailed design of the proposed infrastructure as part of the application for a Water License.

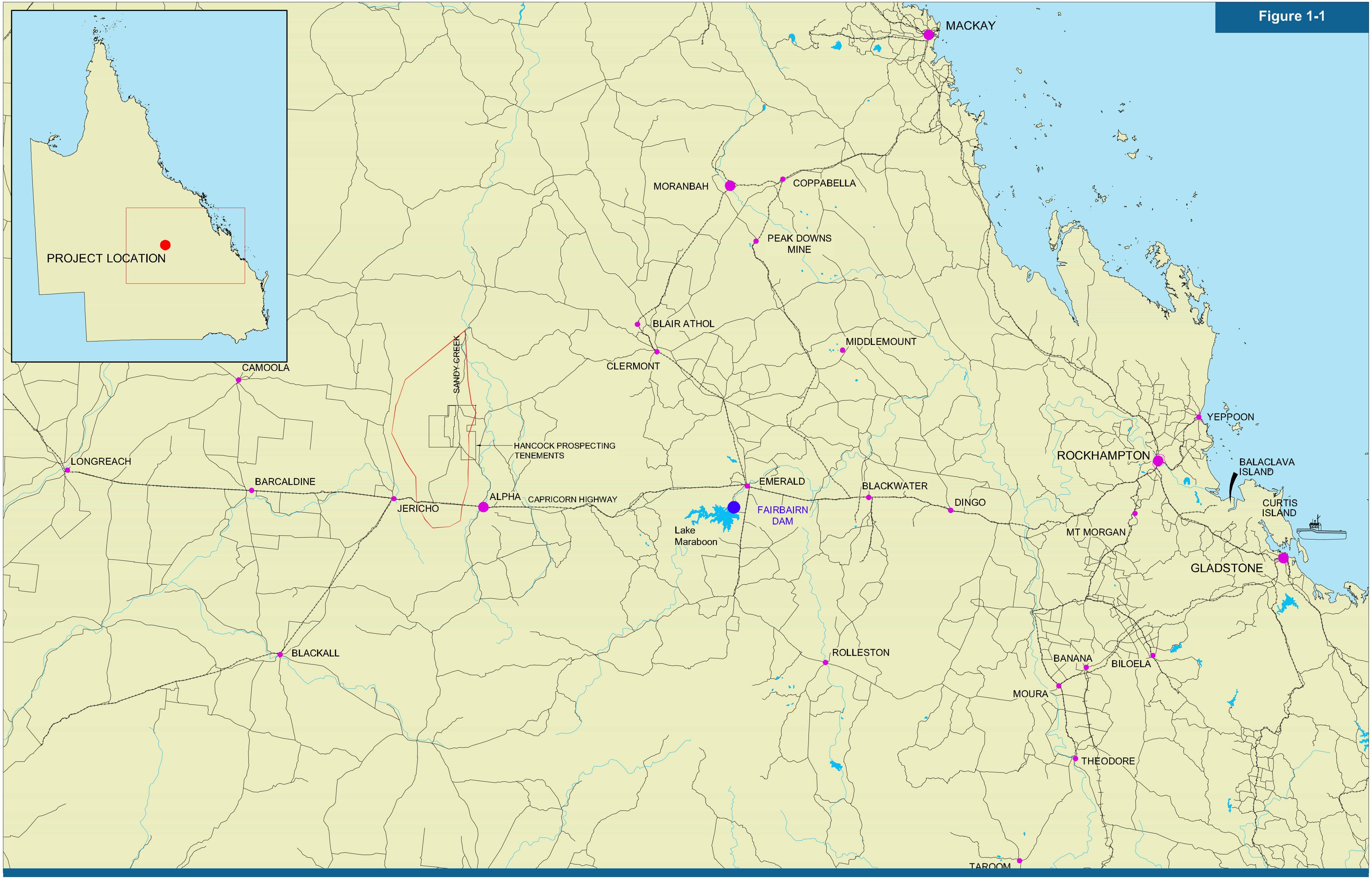
1. Introduction

Hancock Prospecting Pty Ltd (HPPL) has commissioned Parsons Brinckerhoff 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 for any creek and watercourse diversions. This assessment is undertaken in the context of environmental values as defined in such documents as the *Environmental Protection Act 1994* (EP Act) and the Environmental Protection (Water) Policy 2009 (EPP(Water)).

This report is one of several surface water technical reports, including studies on geomorphology, water management and water balance, and water quality assessment that have been undertaken for the Project Environmental Impact Statement (EIS). This technical report is broadly structured as follows:

- background information, including objectives, scope of works, available data and previous studies
- methodology
- hydrological assessment
- hydraulic assessment
- flood Impacts
- mitigation measures
- summary and conclusions.

The Alpha Coal Project is located approximately 60 km north of the town of Alpha in the Galilee Basin, 170 km west of Emerald, and approximately 360 km south-west of Mackay (Refer Figure 1.1).



ALPHA COAL PROJECT
PROJECT LOCATION

PARSONS BRINCKERHOFF

0 10000 20000 40000 60000
Full Size 1:1,000,000 ; Half Reduction 1:2,000,000
SCALE (m)

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. Methodology of assessment

2.1 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 will be introduced.

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

a) Appreciation of current legislation and guidelines.

b) Establish cases to be considered.

c) Undertake a hydrological assessment, covering the mine site and surrounding areas to determine existing rainfall frequency and intensity.

d) Undertake an assessment of the existing catchments to determine the design runoff at key locations around the Project site.

e) Develop hydraulic models of the existing case (refer Section 2.1.2) to determine flows, inundated areas, depths, velocity and stream power for a range of design conditions (Refer Section 2.1.3). This will provide an accurate assessment of the existing flow conditions of the watercourses. Also refer to the geomorphology Technical Report.

f) Develop hydraulic models of the developed case (refer Section 2.1.2) to determine flows, inundated areas, depths, velocity and stream power for a range of design conditions (Refer Section 2.1.3). 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.

g) Comparison of the developed and existing case results (the impact). Where appropriate the design of the proposed diversions will be altered to achieve better correlation with the natural creek systems.

h) Introduction of mitigation measures to ensure equilibrium and long term stability of the proposed works.

i) Conclusion and recommendations for the design development to meet compliance with current legislation and guidelines (Refer Section 2.1.1).

2.1.1 Legislation and guidelines

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

Water Act 2000

The *Water Act 2000* 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 required 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* replacing the *Integrated Planning Act 1997*. The 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 *Sustainable Planning Act 2009* 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), 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 license 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 under the *Water Act 2000*, and a development permit under the *Sustainable Planning Act 2009* formerly *Integrated Planning Act 1997*) 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, Australian Coal Association Research Program (2002).

This Design guideline 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 above Central West Water Management and Use Regional Guideline – Watercourse Diversions document refers to this publication.

2.1.2 Design conditions and criteria

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

Flood immunity Will be up to a 3000 year ARI event. Flood immunity is provided by levees located between the creek diversion and the mine pits and associated works.

Flood inundation Flood inundation extending from proposed watercourse diversions will be contained within the Project's MLA.

Diversions Diversion channels will for this Technical Report, be assessed for three flow events: 2 year ARI, 50 year ARI and 1000 year ARI.

Active Channel An active channel will be provided in the high flow channel. The active channel is sized to a size 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.

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

Roughness Adopted roughness for the existing and developed cases is as set out in Table 6.1.

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.

2.1.3 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 on mine life. This case assumes that the following features are realised:

- the mine is protected by levees to a 3000 year ARI flood immunity
- approximately 14 km of the existing Lagoon Creek active channel is diverted to a 9 km long and 240 m wide high flow diversion channel (refer to Geomorphology technical report)
- 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.

Figure 2.1 illustrates the developed case infrastructure and proposed diversions and levees.

The impact of the project is assessed at 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 is carried out for the diversion design while the 3000 year event is intended solely to understand the stream behaviour for the levees providing flood immunity.

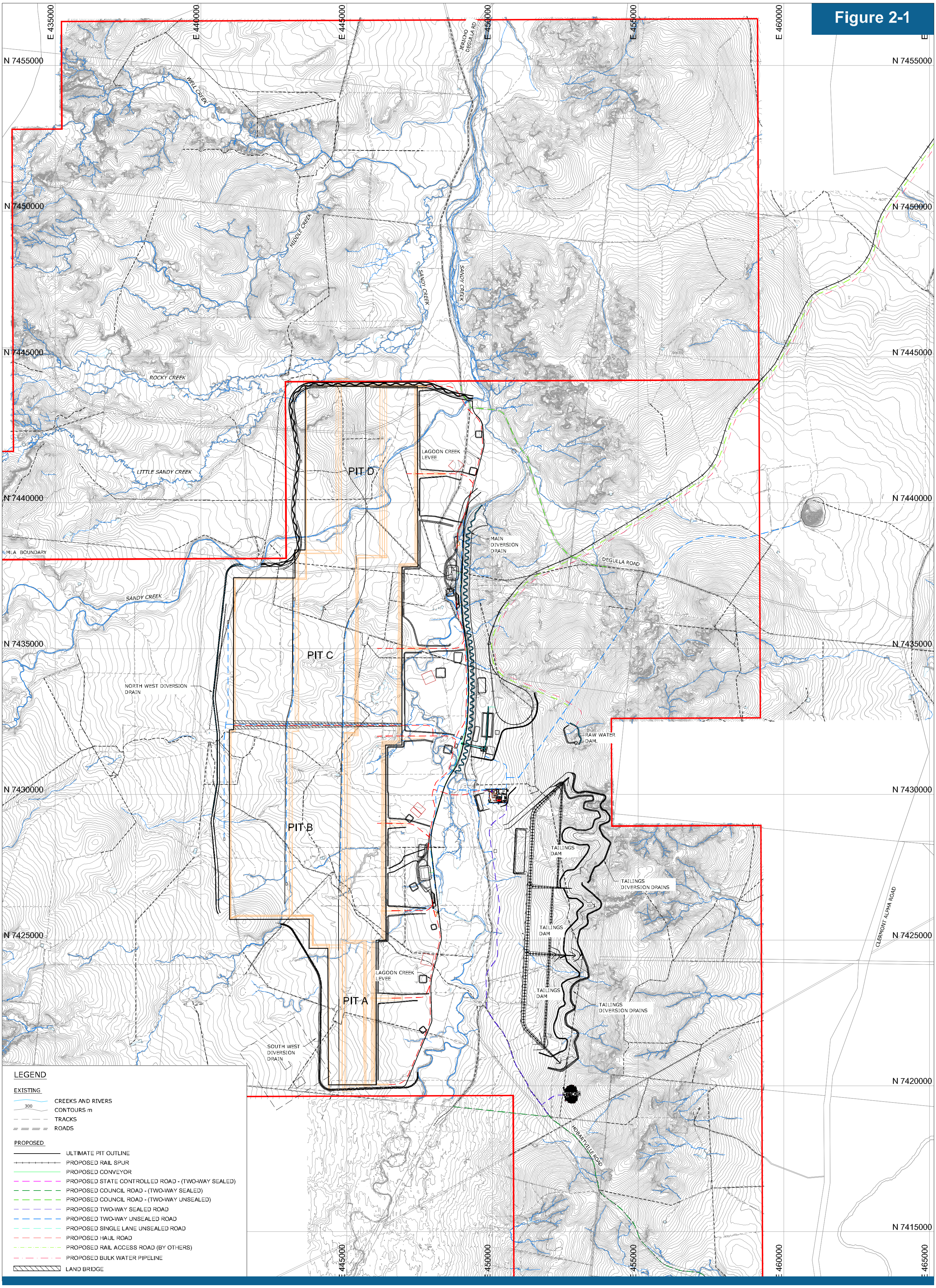
2.2 Data compilation and review

2.2.1 Existing data

The following data was collated and reviewed:

- a previously developed MIKE21 model for the adjacent Kevin's Corner Project (Connell Hatch. 2008) was utilised. Only limited data from this model was used to develop the MIKE21 Model for the Alpha 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 from the additional DTM purchased for the area immediately upstream of the mine
- AR&R 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 2-1



PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

WATER INFRASTRUCTURE AND LEVEES

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 14:25 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1013A_LAYOUT PLAN - Figure 2-1.dwg

- a previously developed RORB model for the adjacent Kevin's Corner Project (Connell Hatch. 2008) was utilised. Only limited data from this model was used to develop the RORB Model for the Alpha Project, due to its proximity to the Alpha MLA tenement
- stream gauging data was 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 1820 m^3/s
- a site visit was undertaken as part of the geomorphic 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 geomorphologic finding are contained in the Geomorphology Technical Report. Photographs were taken of key areas along the creeks within and immediately outside the MLA area. These photographs are provided in the Geomorphology Technical Report of Volume 5, Appendix F.

2.2.2 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 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.

2.2.3 Development of DTM

Development of the Digital Terrain Model (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, inclusive of 7 km Lagoon Creek upstream of the Alpha MLA and 12 km of Sandy Creek, downstream of the MLA was developed, covering the extent of the existing watercourses and proposed diversions, and the potential area of impact. The DTM was developed from the data presented in Section 2.2.2.

2.2.4 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 data used for the flooding assessment is collected by both government and private organisations. The Bureau of Meteorology (BoM) and the Department of Environment and Resource Management (DERM) are the prime custodians of water resources data records in Queensland. The Bureau of Meteorology (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, in terms of location and physiography, to the Project area. Details of these gauging stations are provided in Table 2.1. The location of these gauging stations in proximity to the Project area is shown in Figure A-1 in Appendix A.

Table 2.1 DERM stream gauging stations

Location	Station	Period of record	Catchment Area (km^2)	Distance (km)
Belyando River at Mt. Douglas	120301A	1949 – 1975	35,471	168
Belyando River at Gregory Development Road	120301B	1976 – present	35,411	168
Native Companion Creek at Violet Grove	120305A	1967 – present	4,065	64
Mistake Creek at Charlton	120306A	1968 – 1993	2,583	81
Mistake Creek at Twin Hills	120309A	1976 – present	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 and proximity to the study area. The historical dataset is displayed in Figure 2.2 and monthly stream flow totals are summarised in Figure 2.3.

This hydrological assessment considers rainfall, landuse, 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 catchments.

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

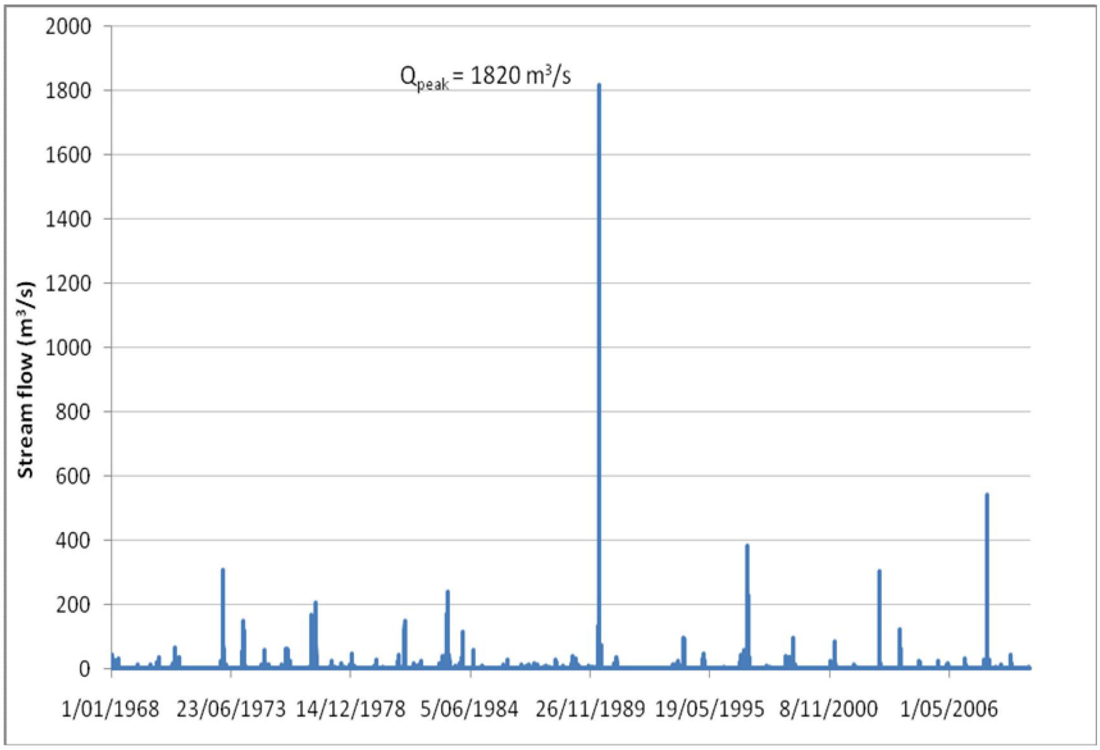


Figure 2.2 Stream flow record at gauging station 120305A

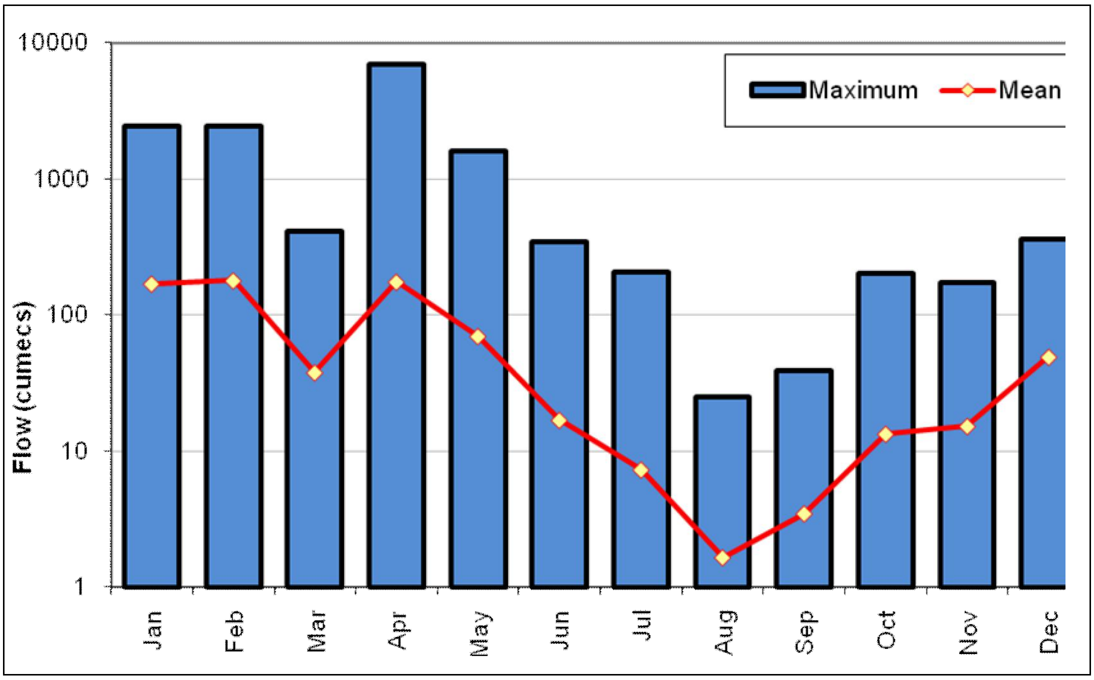


Figure 2.3 Monthly stream flow data at 120305A

2.3 Hydrological modelling

The objective of the hydrological assessment is to appreciate the rainfall runoff characteristics of the catchment and determine catchment runoff for a range of flood events, so these can be used in the hydraulic modelling and design of the Project's infrastructure.

The hydrological assessment comprised the following key tasks:

- extract rainfall from IDF curves for a range of Average Recurrence Interval (ARI) events
- use of temporal patterns for each ARI event
- divided the catchment into sub-catchments 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 is used to estimate hydrographs for the various design ARI events, at given nodes around the site for input into the hydraulic model. Details of the hydrological assessment are contained in Section 5 and Appendix A.

2.4 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
- to replicate the hydraulic and geomorphologic behaviour of the natural creeks in the design of the proposed creek diversions
- to estimate the impacts of the proposed creek diversion on the upstream and downstream environment and landholders.

For the Flooding Technical Report, a hydraulic model was prepared using a 2D Hydrodynamic MIKE21 model developed by DHI Water and Environment (2009). A previously developed model existed for the adjacent Kevin's Corner Project. Part of this model was used to develop the MIKE21 Model for the Alpha Project. The use of a 2D hydraulic modelling package is better suited to the Alpha Project as it more appropriately represents the braided channel systems and locally wide floodplains than a 1D model.

The advantages of using MIKE21 are presented below:

- the model was able to produce design flood levels and inundation mapping along the entire length of the Project area
- the model can easily be extended further upstream or downstream at a later date
- provided a consistent approach to flood modelling of the Lagoon and Sandy Creeks system
- the model was used to assess flooding scenarios associated with joint probabilities of flooding in both the Lagoon Creek and Sandy Creek catchments
- it significantly simplified the process of updating the model results with inflow changes or revisions.

As part of the geomorphic assessment, a HEC-RAS model developed by the US Army Corps of Engineers, Hydrological Engineering Centre (2010), was used to determine flood behaviour up to 50 year ARI events. Details of this assessment are contained in the Geomorphology Technical Report. For completeness, details of the HEC-RAS model and results are included in Appendix C.

The following represents the adopted approach to the MIKE 21 modelling:

a) 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.

b) Prepare grid network for existing and developed case.

c) Input the hydrographs for each inflow node, derived from the hydrological assessment.

d) 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).

e) 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.

f) 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.

g) 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.

h) 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, although some mitigation measures may be incorporated at this stage. Further refinement of the model will be carried out as part of the detailed design processes, with the aim to fully meet the criteria set in the legislation and guidelines (Refer Section 2.1.1) and meet the criteria for Water Licensing.

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

3. 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 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).

The Sandy Creek catchment covers an area of approximately 7,700 square kilometres, while the area of interest is around 337 km^2. Designated watercourses that flow within or adjacent to the Project area include Lagoon Creek, Spring Creek, (upper) Sandy Creek (locally referred to as Greentree Creek), and located to the north of the Project, Little Creek, Rocky Creek, Middle Creek and Well Creek.

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 area's catchment is approximately 2,734 km^2 and covers the watercourses associated with the Alpha Coal Project including Lagoon Creek, Spring Creek, Sandy Creek and Rocky Creek (Refer Figure 1.1). The catchment also includes the proposed project area, including mine pits, overburden areas and associated mining infrastructure. The Alpha Coal Project tenement is traversed by Lagoon Creek which flows south to north, and by Spring Creek and Sandy Creek (also referred to a Greentree Creek) from west to east.

The existing landform is predominantly flat with wide floodplains flanking 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. The nature and flood behaviour of the creeks is discussed in detail in the Geomorphology Technical Report.

4. Project description

The Project from a flooding perspective includes all infrastructure required to divert existing waterways and overland flows around the mine site and infrastructure required to minimise contact of fresh water with the 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, western diversion and southern diversion. All diversions are complemented by an adjacent levee to provide 3000 year ARI flood immunity to the mine. Figure 2.1 provides locations of the various flood management infrastructure, being:

- Lagoon Creek Diversion:
  - 9 km long diversion channel designed with a high flow channel to 50 year ARI and an active channel equivalent to 2 year ARI
  - a levee situated on the west (left) bank of Lagoon Creek through the MLA, will provide flood immunity of up to 3000 year ARI. The mine infrastructure on the east (right) bank of Lagoon Creek is unaffected by flood levels, due to the generally higher elevation of this area.
- Western diversion (Sandy Creek):
  - 26 km long diversion channel, capturing flows from various unnamed creeks and areas of overland flow. This diversion channel is located just inside the perimeter of the MIA (refer Figure 2.1). The diversion is designed with a high flow channel to 50 year ARI and includes a low flow channel sixed to 2 year ARI. This diversion rejoins 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 raise against the levee and locally temporarily inundate the adjacent (upstream) land. No third party properties are affected
  - north west levees may be included to avoid break out of flows from the diversion to adjacent third party properties, and similarly to protect the Alpha infrastructure from adjacent creeks (e.g. Little and Rocky Creek). This may be a concern in the north west corner of the site. These levees will be designed to 3000 year ARI.
- Southern diversion (Spring Creek):
  - 9 km long diversion 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
  - 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 raise against the levee and locally temporarily inundate the adjacent (upstream) land. No third party properties are affected.

The Lagoon Creek diversion will allow unimpeded access to mine coal reserves. The route allows adequate offsets between the diverted creek and proposed mining operations, reducing any impact that the mining operations will have on the water flow in Lagoon Creek. The diversion is anticipated to provide a stable and sustainable creek alignment for Lagoon Creek into the future.

In the mine pit area, additional temporary catch drains running south to north will be provided, to divert clean overland flows from these catchments to the diversion channel at the northern and southern 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.

5. Hydrological assessment

5.1 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 subcatchments. The RORB program was used to obtain the runoff hydrograph and detailed information of the hydrology is included in Appendix A.

5.1.1 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 catchment less than 25 km^2.

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 or 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 2.1. 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.

5.1.2 RORB model parameters

The RORB model network supplied by Hatch was reviewed and was adopted in this study. 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 12 km downstream of the mine site boundary. The Sandy Creek catchment has a total area of 2,734 km^2. The RORB model has been calibrated on the neighbouring catchment gauging station (120305A) as detailed above. It should be noted that the Sandy Creek catchment is ungauged and within the basin 06 gauging stations with periods varying from 25 to 64 years of records. The DERM ratings for Native Companion Creek were adopted for the study to ensure some representation of flow peaks calibration.

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 (Kc) and catchment non-linearity parameter (m).

Non-linearity of the catchment is defined using the parameter m. A value of 1 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. Kc and m are 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 kc = 0.8, however a 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 5.2.

5.1.2.1 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 eastern Queensland the initial loss lies between 0 mm and 140 mm in extreme cases for catchments in Australia. Initial loss of zero is recommended if estimation of maximum possible or probable flood estimations, while a value of about 10 mm for a flood estimated from a large to rare storm and 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 2.5mm/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 design events greater than ARI 1 in 1000yr.

5.1.2.2 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 5.1).

Table 5.1 Estimated Kc 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

In addition to this, 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 the "peakiness" of the resulting flow hydrograph, must be determined for input. The calibrated k_c value of 108 lies within the two other Queensland and RORB methods, 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 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.

Table 5.2 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.

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 *Australia Rainfall and Runoff* (ARR).

5.2 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 given ARFs listed in Appendix A are values specific to the Sandy Creek catchment.

- For Frequent to Large floods up to 1 in 100 AEP, point rainfall estimates were derived using the Intensity-Frequency-Duration (IFD) methods described by Volume 2 of ARR (IEAust 1998) for AEPs up to 100 and for durations up to 72 hours. The given rainfall depths listed in Appendix A are values specific to the Sandy Creek catchment. The parameters used to generate the intensities are shown in Table 5.2.

- For Rare events beyond 1 in 100 AEP to the credible limit of extrapolation 1 in 2000 AEP, rainfall estimates were derived using the regional CRC-FORGE method described in Book VI of ARR (IEAust 1998) for durations up to 120 hours. The given rainfall depths listed in Table 5.3 are values specific to the Sandy Creek catchment.

- Extreme events between 1 in 2000 up to the 3000 AEP rainfall estimates were derived using a log-log extrapolation techniques described in Book VI of ARR (IEAust 1998). The given rainfall depths listed in Table 5.5 are values specific to the Sandy Creek catchment.

5.2.1 Rainfall estimation for frequent and large floods

Design rainfall estimates for the 1 in 2 to the 1 in 100 AEPs for durations of 1 hour up to 72 hours are normally based on an Intensity-Frequent-Duration (IFD) analysis. The IFD data for Emerald, which is the approximate location of the catchment to the Sandy Creek catchment, was adopted. Table 5.3 summarises the design areal rainfall estimates based on point IFD estimates modified by the ARFs.

Table 5.3 IFD Design rainfall (ARFs applied) (mm)

AEP (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 parameters used to generate the intensities are shown in Table 5.4.

Table 5.4 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

5.2.2 Rainfall estimation for rare floods

5.2.2.1 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 AEP) are based on pooled data from a few stations around the focal point, while design rainfall estimates at the AEP 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 AEP 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 5.5 contains the available CRC-FORGE estimates for the 1 in 5 to the 1 in 2000 AEP design point rainfall depths for the durations of 24 hours up to 120 hours with the appropriate Areal Reduction Factors (ARF) applicable to the region.

Table 5.5 CRC-FORGE design rainfall (ARFs applied) (mm)

AEP (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

5.3 Flood frequency analysis (FFA)

Flood frequency analysis 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. Flood frequency analyses are generally based on data extracted from continuous flow records or event based observations for extreme events.

As outlined in AR&R, 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.

Flood frequency analyses 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. Flood frequency analysis 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 5.6.

Table 5.6 Flow records

Gauging Station		Period of record	Number of years N
Belyando River at Gregory Development Road	120301AB	1949 – present	64
Native Companion Creek at Violet Grove	120305A	1967– present	44
Mistake Creek at Charlton	120306A	1968 – 1993	25
Mistake Creek at Twin Hills	120309A	1976 – present	34

The accuracy and reliability of a flood frequency analysis 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 AEP of the 1990 flood.

The following Table 5.7 compares the flood frequency analysis of the LPIII and GEV for the four stations.

Table 5.7 Flood frequency analysis

Gauging Station	1990 Event		1 in 100 AEP Peak Flow Estimate (m^3/s)	
	Peak Flow (m^3/s)	Plotting Position (1 in xx AEP)	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 flood frequency analysis in Table 5.7 and Figure 5.1 suggests that, based on the fitted plotting positions, the 1990 flood at Native Companion was approximately 1 in 200 AEP. Table 5.7 shows that this event is an isolated event. A flow of 1,258 m^3/s was adopted for the 1 in 100 AEP flow at Native Companion Creek. Table 5.8 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.

Table 5.8 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

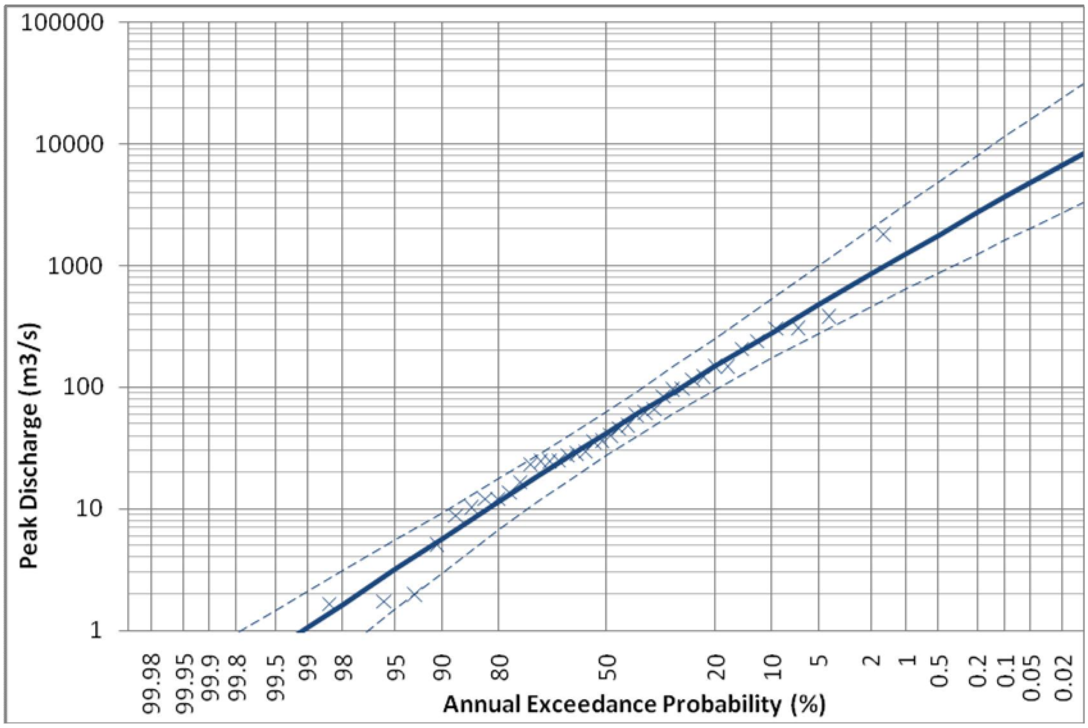


Figure 5.1 LPIII Annual series flood frequency analysis – Native Companion Creek at Violet Grove (120305A)

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 AEP of the 1990 flood is approximately correct, alternative fitting distributions might be investigated in the detailed design to ascertain if the flood frequency analyses can be further refined.

5.3.1 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 ungauging 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, and

A_g is catchment area for the gauged site.

Flood frequencies for 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 following 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) is better than Weeks method at GS 120308A which is located in the same basin of the Project area. Table 5.11 shows that Queensland Rational Method has estimated Q100 of 905 m^3/s (ARI 100 year) which is comparable to estimated value of 880 (2.8% differences).

In addition, Native Companion gauging station GS 120305A is located at EL 343 m AHD with a mean annual rainfall (MAR) of 540 mm and a MAR of 529 mm for Sandy Creek catchment. Table 5.9 summarises the peak flows for value of exponent. The results from the transposition are summarised in Table 5.9. 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 5.9 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.

5.4 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 for the storm events. The results of the design floods produced from the RORB model simulations are shown in Table 5.10. The results of the estimated peak inflows for a range of AEPs 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 5.10. 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 MIKE21 model at the locations of tributary inflows. The peak flows of each of these hydrographs are summarised in Table 5.10. Appendix A contains the full model results.

Table 5.10 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	—

5.5 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 Kc and second on m value to investigate the influence on design peak flows.

The range of kc values selected are based on recommended regional parameters which are adjacent to the adopted region. The results of the analysis are shown in Table 5.11. 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 Kc parameter is as described in Section 5.2.1.1.

Table 5.11 Peak flows using varying Kc 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 Kc value of 58.4 (Weeks method)	1,766	5,697	6,584
RORB* - with suggested Kc value of 115 (Weeks method)	772	2,808	3,284
Yu (1989) AusWide Kc 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 flood frequency analysis. The adopted values are within the range of the calibrated events. The initial losses are as follows: for AEPs >100, IL = 75 and AEPs =100, IL = 70. The result of the analysis is shown in Table 5.12.

Table 5.12 Analysis of RORB parameters for ARI up to 100 year ARI

ARI (years)	Kc	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

5.6 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 Australian Rainfall and Runoff (1989) for deriving intensity–frequency duration 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%
- subcatchments that included hardstand: Average 10%.

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

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

5.6.1 Results

Design flood hydrographs were extracted from the RORB model for a range of ARIs for input to the MIKE21 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 5.13.

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 5.13 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. 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.

A two dimensional (2D) MIKE21 hydrodynamic model was developed for 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.

A separate one dimensional HEC-RAS hydraulic model, mainly for frequent and large flows (up to 50 year ARI) was prepared as part of the geomorphology technical study. The results of this assessment are documented in the Geomorphological Technical Report. For completeness, the details of the HEC-RAS model are included in Appendix C. Additionally, the HEC-RAS model was used to undertake the stream shear stress and stream power assessments for all flood events.

6.1 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 mine pit area.

The existing case model comprised 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 to up to some 2 km in width.

The developed case model expands to include the north western and south western diversions and creeks as follows:

Sandy Creek:	Inflow node at the intersection with the proposed north western diversion drain and the channel section at the confluence with Lagoon Creek to approximately 12 km downstream of the mine MLA.
Lagoon Creek:	Channel section from approximately 7 km upstream of the mine MLA to the confluence with Sandy Creek.
Spring Creek:	Inflow node at the intersection with the proposed south western diversion drain.
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 boundary.
Unnamed creeks:	Various inflow nodes are provided along the 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 inflow nodes at their intersection with the diversion drains.

6.1.1 Model setup

Sandy Creek and tributaries (to the extent of the Sandy and Lagoon Creek floodplain) within the MLA have been represented 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 20 m x 20 m square grid. This grid has been created using the DTM described in Section 2.2.3. A layout of the MIKE21 model key features is shown in Figure B-1 in Appendix B.

6.1.1.1 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 6.1 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 6.1 Adopted and sensitivity roughness coefficients

Land use characteristic	Manning's 'n' values		
	-20%	Base case	20%
Diversion drains	0.029	0.035	0.042
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
Creek area	0.029 – 0.046	0.035 – 0.055	0.042 – 0.066

6.1.1.2 Boundary conditions

The upstream boundary conditions are formed by the inflow nodes described in Section 6.1. Discharge hydrographs were extracted from RORB.

The downstream boundary condition is set by the hydrological reference point located approximately 12 km downstream of the northern MLA boundary. It has a constant tailwater level of 282.65 m AHD (1000 year ARI) and 282.82 m AHD (3000 year ARI). The tailwater level was derived using a HEC-RAS model.

For the purposes of this study, a fixed tailwater boundary condition for assessing the maximum flood level and the velocity is acceptable. Sensitivity analysis was undertaken by changing the tailwater level by +0.30 m and -0.50 m. This analysis showed that, there are negligible impacts on the peak water level and velocity further 700 m upstream of the tailwater boundary.

For detailed design phase in the future, the hydraulic assessment using a MIKEFLOOD model (with MIKE21 and MIKE11 coupling) using a rating curve for the downstream tailwater with variable water levels versus flows would be beneficial.

6.2 Results

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

6.2.1 Existing conditions

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 6.2.

Table 6.2 Peak flood level for 1000 and 3000 year ARI at reporting locations

Reporting location ID	Description	Easting (m)	Northing (m)	Flood level			
				1000 yr ARI (mAHD)	Afflux (mm)	3000 yr ARI (mAHD)	Afflux (mm)
1	8 km D/S of mine site	448712	7452178	289.06	168	289.31	168
2	N-E corner of mine site	449303	7444873	299.33	177	299.57	189
3	Within diversion drain	450900	7441156	302.93	391	303.34	528
4	Wendouree Homestead	449048	7436775	305.90	-554	306.45	-492
5	Upstream of diversion drain	449201	7432075	308.63	168	309.22	741
6	Near MIA	448537	7429980	311.75	1552	312.10	1752
7	Opposite Pit B ramp	448475	7427881	312.68	289	312.99	412
8	Hobartville Homestead	448984	7423198	316.50	186	316.68	217
9	S-E corner of mine site	448340	7419974	319.22	143	319.41	184
10	6.4 km U/S of mine site	445561	7414129	325.30	-1	325.39	-3

The reporting locations listed in Table 6.2 are shown in Figures 6.1 and 6.2.

Figure 6.1 provides an overview of the flood extent for the 1000 and 3000 year ARI events under the existing case.

Figure B4 provides longitudinal sections of the 1000 and 3000 year ARI peak flood levels in Lagoon Creek along section A-A (shown in Figure B.5 and B.6) and it includes the existing creek bed levels.

The figures show that the mining development encroaches within the flood extents of Lagoon Creek and other tributaries.

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 1000 year ARI event, modelling shows that peak velocities within Lagoon Creek are in general less than 2.0 m/s and in the overbank area the velocities are less than 1.0 m/s. The creek velocity downstream of the mine pit area is in the range of 2.0 to 2.5 m/s and is generally higher in comparison to the velocity upstream of this area. The only location where the velocity is higher than 2.0 m/s is at the northern MLA boundary where the creek is constricted and the peak velocity (for the existing case) can be as high as 3.5 m/s. 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 main creek bed and this observation is validated from the site visit undertaken by PB in July 2010,

6.2.2 Developed case

Changes due to the development in flood levels within Sandy and Lagoon Creeks, as a result from the mine development and associated works, are shown in the Table and Figures listed below.

Table 6.2 demonstrates that changes in flood levels are significant but do not change the flood risk of existing infrastructure (roads, houses etc) in the area.

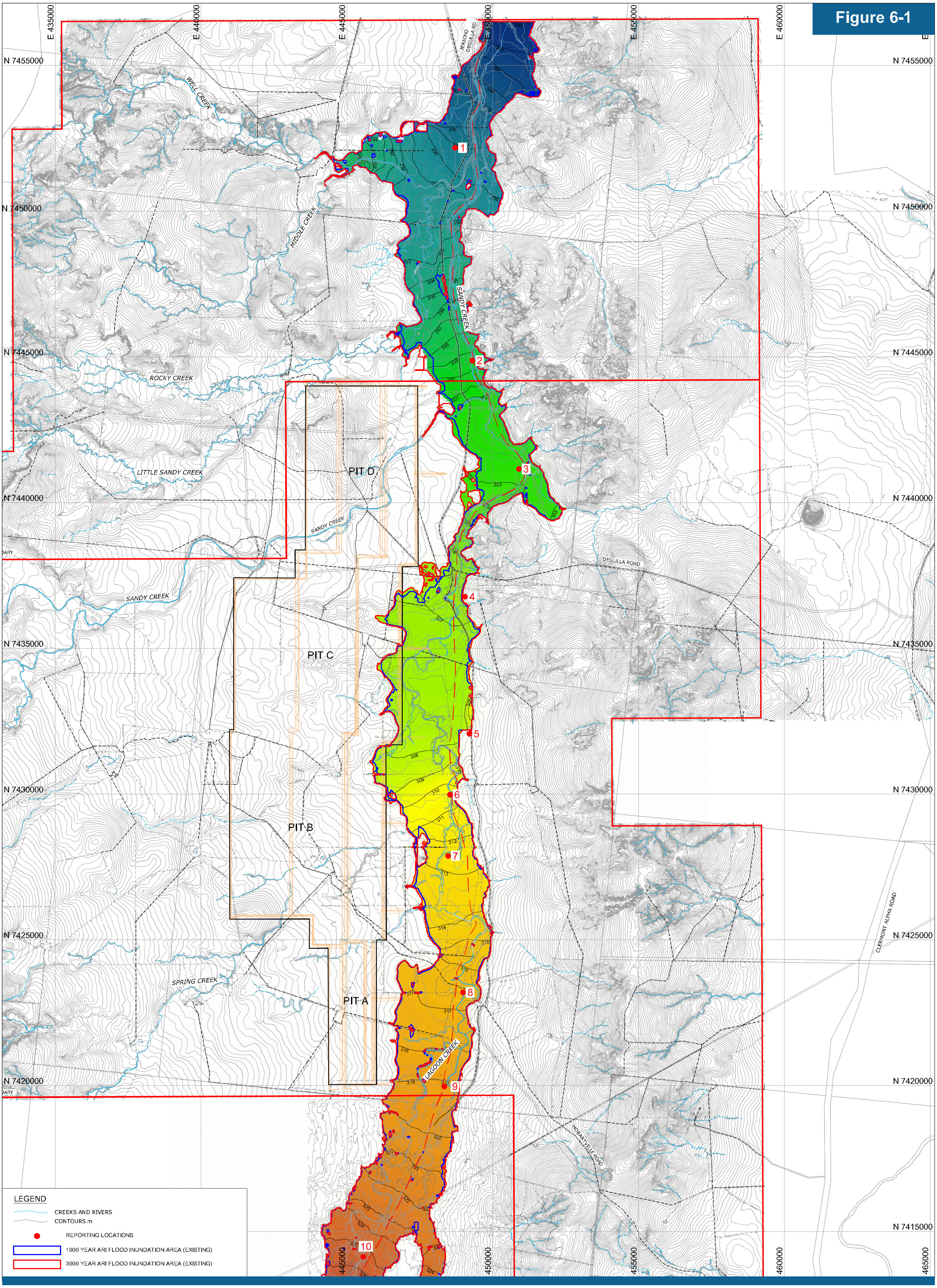
Figure 6.2 provides an overview of the flood extent for the 1000 and 3000 year ARI events under the developed case.

The following figures are shown in appendix B

- Figure B.7 provides a long section of the Lagoon and Sandy Creek with creek diversion, 1000 and 3000 year ARI water levels along cross section A-A as shown in Figures B.8 and B.9.
- Figure B.8 and B.9 provide details of velocities under the developed case for the 1000 year ARI event.
- Figure B.10 provides longitudinal velocity profiles for the 1000 year ARI Existing case and the Developed case along cross section A-A as shown in Figures B.8 and B.9.

These results confirmed that there are some changes in flood levels and velocities for the proposed mine development.

Figure 6-1



PARSONS BRINCKERHOFF

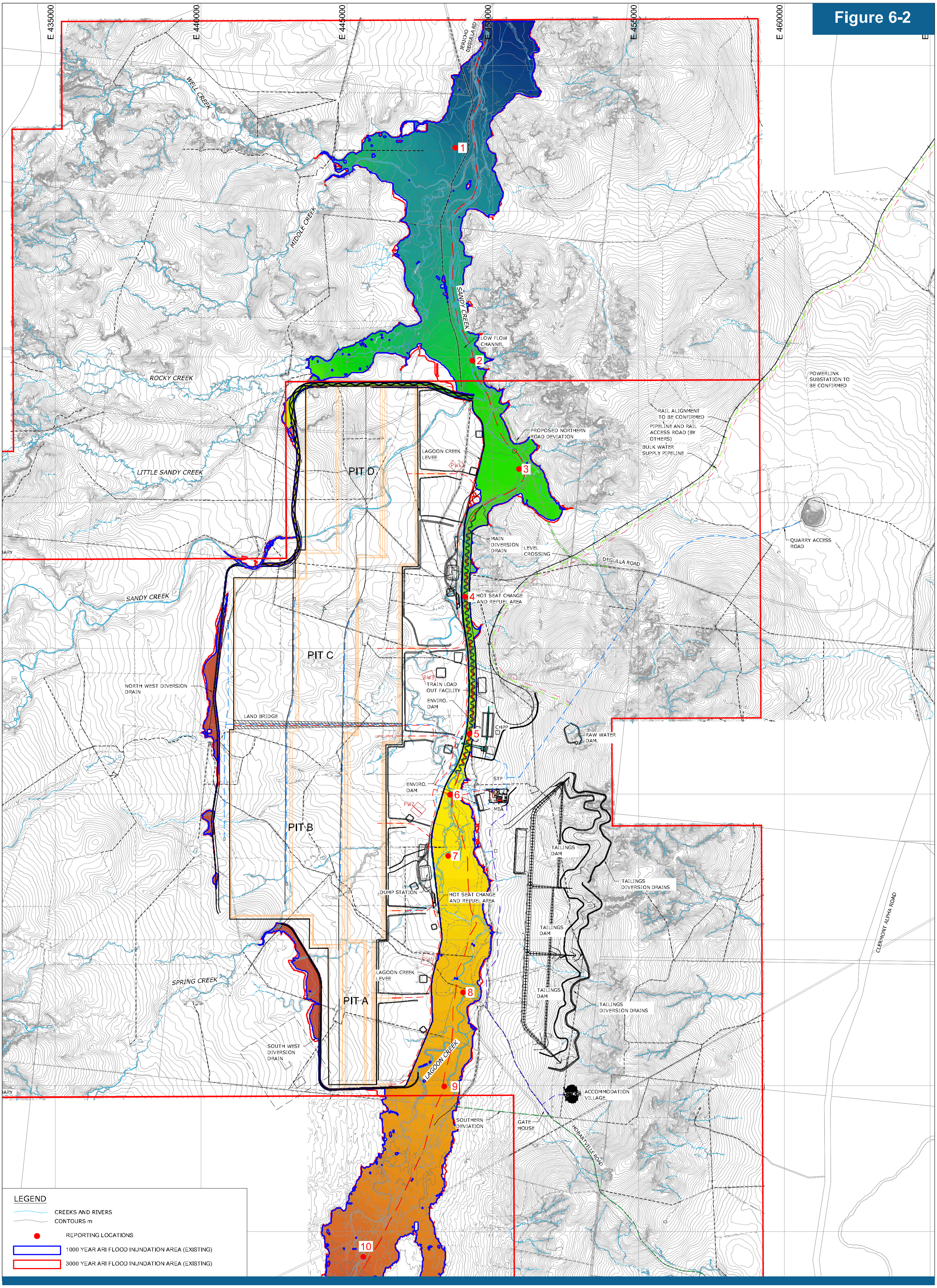
0 1000 2000 3000
SCALE (m)

ALPHA COAL PROJECT

1000 AND 3000 YEAR ARI FLOOD EXTENT
EXISTING CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 14:27 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1012_WM Existing 1000 Yr ARI Flood Extent.dwg



PARSONS BRINCKERHOFF

0 1000 2000 3000
SCALE (m)

ALPHA COAL PROJECT

1000 AND 3000 YEAR ARI FLOOD EXTENT
DEVELOPED CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 14:28 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1013_WM Diversion Drain 1000 Yr ARI Flood Extent.dwg

Flooding within the tributaries from high flows in Lagoon Creek is limited to the lower reaches of each tributary. The increase in the 1000 year ARI peak flood level at Hobartville Homestead is 186 mm. At Wendouree Homestead the reduction in the peak flood level is 554 mm and is due to the reduction in the flows upstream of this site as a result of the mine pit and diversion drain developments. At 8 km downstream of the northern MLA boundary the increase in flood level is 168 mm. Typically within the diversion channel, water levels vary by up to 800 mm from the exiting case, while afflux immediately upstream of the diversion is significant (up to 1,552 mm opposite the MIA). This is likely due to the funnelling effect at the beginning of the diversion channel and may to some extent be resolved by providing a smoother transition between the existing creek bed levels and the diversion (Refer Figure B7 in Appendix B).

For the developed case, the modelling shows that the peak velocity within the Lagoon Creek diversion is approximately 2.0 m/s. At other locations the peak velocities are in general similar or within 0.2 m/s of the existing creek velocities. Immediately downstream of the MLA, the velocity results of the developed case shows small increase of up to 0.3 m/s due to the constriction in this area (narrow creek channel). This increase of peak velocities is also due to the diversion of the western drain flow. Figure B-10 around the diversion drain location, shows the existing creek peak velocity is small (up to 0.4 m/s) due to the wide floodplain (approximately 3 km wide).

The total shear stress is a measure of force exerted on the channel bed and banks by the action of flowing water. The total 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.

A general discussion on the shear stress and stream power for the 1000 year ARI is given below and this evaluation is based upon the HEC-RAS modelling result. Detailed assessment of the shear stress and stream power for the 2 and 50 year ARI events have been discussed in detail in the Geomorphological Technical Report. It is noted that the DERM guideline provides the limiting criteria for the shear stress and stream power for the 2 and 50 year ARI events only, and it does not provide criterion for extreme flood events such as 1000 and 3000 year ARI.

A plot of the total shear stress and stream power for the 1000 year ARI for the existing and developed cases are shown in Figures C-8 and C-9, respectively (Appendix C).

6.3 Sensitivity analyses

Where historical flood data is available the hydraulic model can be calibrated to recorded flood levels. Calibration of hydraulic models is undertaken by varying roughness values within a reasonable range, until calculated water levels match recorded water levels.

No appropriate historical flood levels were available for the Sandy Creek catchment and therefore it has been decided to select roughness values from published values for creeks with similar characteristics. To establish the robustness of the model, roughness values, tailwater level, and flows have been varied to examine the variation in peak water levels and velocities.

The sensitivity analysis has been undertaken for the 1000 year ARI event by varying the roughness values of both the creeks and floodplain by ±20%. The adopted roughness coefficients for the sensitivity analysis are represented in Table 6.3.

Table 6.3 1000 year ARI flood levels with increased Manning's roughness coefficients

ID	Key Location	Easting (m)	Northing (m)	1000 year ARI		
				Normal roughness	+20% roughness	
				Flood level (mAHD)	Flood level (mAHD)	Change (mm)
1	8 km D/S of mine site	448712	7452178	289.06	289.21	155
2	N-E corner of mine site	449303	7444873	299.33	299.50	175
3	Within diversion drain	450900	7441156	302.93	303.13	203
4	Wendouree Homestead	449048	7436775	305.90	306.25	344
5	Upstream of diversion drain	449201	7432075	308.63	309.01	378
6	Near MIA	448537	7429980	311.75	311.96	205
7	Opposite Pit B ramp	448475	7427881	312.68	312.89	208
8	Hobartville Homestead	448984	7423198	316.50	316.64	142
9	S-E corner of mine site	448340	7419974	319.22	319.36	135

The results of the sensitivity analysis demonstrate a consistent variation of flood levels. With the increased catchment hydraulic roughness, the modelling predicts increases in the peak flood levels of 135 mm to 380 mm within the mine site. The outcomes of this analysis need to be considered at the detailed design phase of the diversion drain including the adoption of the freeboard for the levees.

6.4 HEC-RAS model

The 2 and 50 year ARI flood assessment for this study has been undertaken using a one dimensional HEC-RAS model. The description, model development and results for the HEC-RAS hydraulic assessment is presented in Appendix C.

Additionally, the geomorphologic technical report provides a more detailed design philosophy and results for the diversion drain design and the geomorphologic characteristics evaluation of the existing waterways and the impacts due the Project development.

6.5 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 geomorphologic assessment of the existing creeks and channels and then replicated in the diversion design. Examples of mitigation measures appropriate to the Project include but are not limited to:

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 storm event and replicates the channel gradient of the creek.

Diversions tend to be shorter than the original active channel length and therefore need to include a low flow channel that meanders within the high flow channel, to

	an extent that replicates the length and gradient of the original active 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 sometime be appropriate to provide a drop structure to replicate existing cascades or force a reduction in gradient without excessive meandering
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.

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

From the list above it is however evident that there are numerous ways to achieve the channel equilibrium that exists in the existing natural channel. During detailed design the existing natural channels will be further analyses and their characteristics replicated on a reach by reach basis.

7. Summary

A key aspect of this Flooding Technical Report is to investigate and develop a flood management system for the creeks, channel diversions and flood levees, and ensure that the mining of the Alpha Project is feasible and it protects the environment. In particular, this report sets the framework for satisfying the appropriate authorities that the Project's proposals for creek diversion and flood protection will meet the requirements for Water Licensing.

This flooding assessment has analysed the flood behaviour of the existing Sandy creek and its tributaries that are affected by the proposed Alpha Coal Mine development and determined the flood behaviour of the existing creeks and associated floodplains.

The study has also investigated the proposed developed scenario, including diversion of Lagoon Creek, Spring Creek and Sandy Creek at the mine site to provide flood protection for the mine pit and other infrastructures.

Results of the assessment show that there will be minor to some changes to flood water levels and velocities near the mine site. 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 landuse type.

The modelling shows that for both the existing and the developed cases, in general, the total shear stress and the stream power values are lower than those specified in the DERM guideline for the 50 year ARI. The exceptions are at the beginning of the Lagoon Creek diversion drain and at the southern end of the mine levee bund. With a smoother transition of the natural creek bed and bank in these areas, the creek flow can be can be made less turbulent and it is considered that the total shear stress and stream power can be lowered in these areas.

For the 1000 year ARI storm event, the afflux at the MLA boundary to the north is 140 mm and this impact reduces rapidly upstream with no impact at approximately 6 km upstream of the MLA boundary. At the downstream MLA boundary the afflux for the 1000 year ARI event is approximately 177 mm and it reduces marginally to 168 mm at approximately 8 km downstream of this locations.

The modelling shows that there will be negligible increase 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 southern MLA boundary shows high velocities of up to 3.5 m/s.

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 a flood immunity of up to 3000 year ARI plus an additional freeboard on top of this peak flood level.

8. Conclusions and recommendations

This investigation concludes that the mine pit area will not be adversely affected by flooding and the mine development and its associate infrastructure will have minor to some flooding impacts to the surrounding area.

The main results of the flood study show that the proposed development will have negligible impact further 6 km upstream of the south MLA. At 8 km downstream of the north MLA, the increase in the 1000 year ARI peak flood level will be approximately 170 mm. Immediately upstream of the Lagoon Creek diversion, the model predicts an afflux of approximately 1550 mm in a 1000 year ARI and this is due to the constriction of the floodplain due to the diversion drain and the levee bund.

Downstream of the mine site up to 8 km north of the north MLA boundary, there is some increase of approximately 170 mm in the 1000 year ARI peak flood level. The reason for this increase in the flood level is due to the loss of flood storage and the increase in the flows for the developed case.

The proposed Lagoon Creek diversion is unlikely to have a significant impact on the distribution of flow between the creek channel and floodplain upstream or downstream of the Project. There will be some increase in the flows at the northern reach of Lagoon Creek within the mine site due to the diversion of Spring Creek. Due to the mine pit area, the study assumes that there be no contribution to the flow from this area to Lagoon Creek. There will be some increase in the local flows from catchments affected by mine activities as a result of the increase in the land use impervious factor. There is unlikely to be any material impact on the serviceability of existing infrastructure in this area.

Localised peak velocities for the 1000 and 3000 year ARI vary greatly at the main creek channel and at the overbank area. The maximum velocity can be as high as up to 3.4 m/s at the channelised area immediately north of the mine pit area. Generally, the existing 1000 year ARI event peak velocities in the natural channel downstream of the mine site are up to 2.3 m/s.

Developed case peak velocities within the creek for the 1000 and 3000 year ARI flows can be up to 0.2 m/s higher in comparison to the existing case. Within diversion channel the velocity is approximately 2.0 m/s. Evaluations of 2 and 50 year ARI events, and in general the diversion drain design and the stream geomorphology have been assessed as part of the geomorphologic report.

Key recommendations from this study are:

- the levee bunds around the mine pit area should be provided with sufficient freeboard above the 3000 year ARI flood levels
- further detailed modelling be undertaken to optimise the diversion design
- where possible, the flood plain storage in Lagoon Creek should be optimised to minimise the flooding impact upstream and downstream of the Project
- Prior to the mine closure, levees adjacent to Lagoon, Sandy Creek and Spring Creek should be rehabilitated, and where practical, the area should be reclaimed into the natural creek channel

- future modelling should evaluate the impacts of climate change and probable maximum flood (PMF)
- For the detailed design stage, the hydraulic model should incorporate a finer grid mesh in comparison to the 20 m x 20 m grid size used for this study, incorporate the north and south diversion in the 1D component of the MIKE FLOOD model and use a downstream rating curve for tailwater boundary condition using varying water level versus discharge.

9. References

ACARP, 2002. Bowen Basin River Diversions, Design and Rehabilitation Criteria, Australian Coal Association Research Program.

Barnes, H. H. Jr., 1967. "Roughness Characteristics of Natural Channels," U.S. Geological Survey Water-Supply Paper 1849.

BoM, 2003. The Estimation of Probable Maximum Precipitation in Australia: generalised short duration method. Hydro-meteorological advisory service June 2003.

BoM, 2003. Bureau of Meteorology, Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method, November 2003.

Boyd, MJ, Rigby, EH, Van Drie, R and Schymitzek, I, 2007, 'Watershed Bounded Network Model: Details of the Theory used in WBNM', January 2007.

Chow, VT, 1959. Open Channel Hydraulics, McGraw-Hill Book Company, New York, NY.

Connell Hatch (2008), Hydraulic Assessment Report, Alpha Coal Mine for Hancock Prospecting.

DHI Water and Environment (2009), Scientific Documentation, MIKE21 Hydrodynamic Module.

E.M. Laurenson, R.G. Mein, and R. J. Nathan, 2007. RORB Version 6 Runoff Routing Program.

Hargraves, G. 2004. Final Report: Extreme Rainfall Estimation Project, Water Assessment Group, Water Assessment and Planning, Resource Science Centre, Australia, 2004.

Hargraves, G., 2005. Rainfall Application Version 1.0 User Manual – August 2005: Estimation of Rare Design Rainfall Events in Queensland, Australia. Department of Natural Resources and Mines, Australia, 2005.

IEAust. 1998, The Institution of Engineers, Australia, Australian Rainfall and Runoff: A Guide to Flood Estimation, Volume 1, 1997.

IEAust. 1988, The Institution of Engineers, Australia. Australian Rainfall and Runoff: A Guide to Flood Estimation, Volume 2, 1988.

Institution of Engineers Australia, 2001, Australian Rainfall and Runoff (ARR).

Laurenson E.M. and R.G. Mein, 1997. RORB, Runoff Routing Program User Manual, January 1997.

Laurenson et al 2006, *RORB Version 5 Runoff Routing Program User Manual 2006*, Monash University & Sinclair Knight Merz Pty Ltd.

Nandakumar et al (1997), *Estimation of extreme rainfalls Victoria using CRC-FORGE method (for rainfall durations 27 to 72 hours)*, CRC Research Report 97/4, Melbourne, Cooperative Research Centre for catchment Hydrology.

Queensland Government (2008), Natural Resources and Water, Central West Water Management and Use Regional Guideline: Watercourse Diversions – Central Queensland Mining Industry.

Siriwardena, L. and Weinmann, P.E. (1996). *Development and Testing of Methodology to Derive Areal Reduction Factors for Long Duration Rainfall. Working document 96/4.* Cooperative Research Centre for Catchment Hydrology, Monash University, Victoria, Australia.

US Army Corps of Engineers, Hydrological Engineering Centre (2010), HEC-RAS River Analysis System, User's Manual Version 4.1.

US Interagency Advisory Committee on Water Data, Bulletin 17-B (1982).

Appendix A

Hydrological Calculations

Figure A-1

ALPHA COAL PROJECT

Location of hydrological gauging stations

PARSONS BRINCKERHOFF

File: \\AUBNEF\proj\H\Hancock_Coal\2123204C_AlphaKevins_cnr_wtr_suply_P1110_GIS\Projects\Drawings_Figures_Sketches\2136669C_GIS_F017_A1.mxd Author: TK Print Date: 17/08/2010

Figure A-2

ALPHA COAL PROJECT

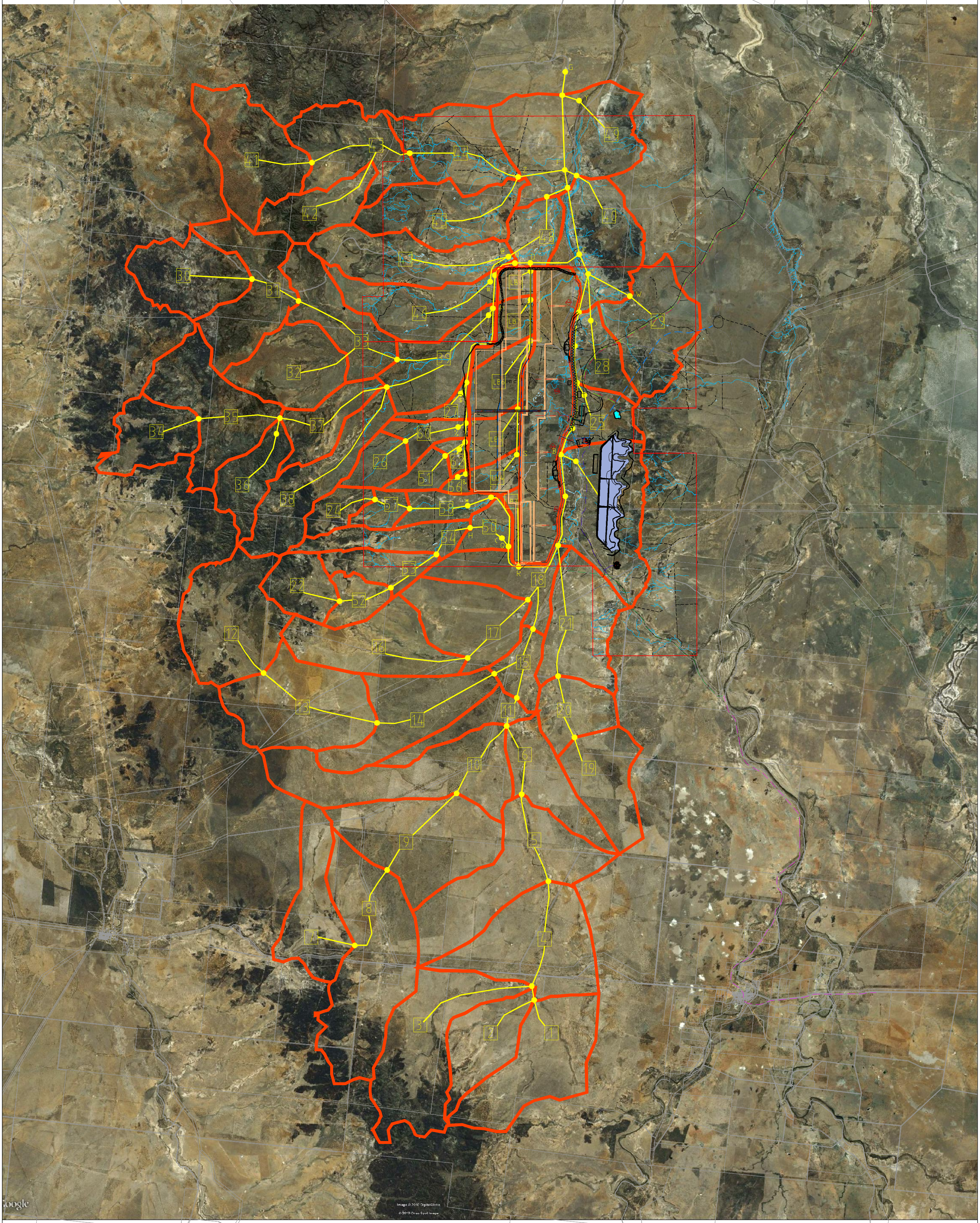
EXISTING SUB CATCHMENT AREA

PARSONS BRINCKERHOFF

0 1000 2000 4000 6000
Full Size 1:100000 ; Half Reduction 1:200000
SCALE (m)

August 20, 2010

Figure A-3



PARSONS BRINCKERHOFF

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

ALPHA COAL PROJECT

DEVELOPED CASE SUB CATCHMENT AREA

August 20, 2010

Plotted By: hamillm   Plot Date: 20/08/10 - 10:19   Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1017_WM Design Catchment Area.dwg

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

Node	Area – existing (km^2)	Area – developed (km^2)
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

Table A.2 Existing RORB model peak flow outputs at reporting locations

Output Node	ARI	Durations (hr) 1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
A	2	0.6	0.4	0.4	0.3	0	0	0	0	0	3.8	20	18.8	0
	5	1.1	0.9	0.9	0.8	0.2	0	0	0.6	39	45.6	99	70.8	45.1
	10	1.3	1.2	1.2	1.2	0.4	1.2	7.8	16.4	91.9	77.2	170.3	106.2	101.4
	20	1.6	1.5	8.7	26.7	45.6	78.1	107.7	105.2	195.6	147.4	234.9	178	208.9
	50	91.9	110.3	122.8	217.2	236.4	329	348.4	358.1	404.5	415.7	413.4	381.7	354.4
	100	162.6	183.6	199	350.2	379.4	497.1	525.4	540.8	605.7	606.1	596.3	563.4	519.7
	1000	501.6	552.2	588.2	1205	1311	1381	1465	1512	1633	1578	1355	1243	1121
	3000	584.5	794.1	892.7	1402	1704	1632	1952	1834	2011	1964	1862	1610	1444
B	2	0.1	0	0	0.1	0	0	0	0	0	0.4	2.3	2.2	0
	5	0.1	0.1	0.1	0.2	0.1	0	0	0.1	5.1	6	13	9.3	5
	10	0.2	0.1	0.1	0.3	0.1	0.2	1.1	2.4	12.1	10.1	22.4	13.9	11
	20	0.2	0.2	1.1	5.3	9	10.3	14.3	14	25.6	18.6	30.8	22.7	23.2
	50	17.3	20.5	22.4	36.4	40.3	43.3	45.5	46.5	51.4	47.8	48.5	40.7	35.7
	100	32.2	35.9	38.4	56.5	62.1	65.3	68.4	69.9	75	67.9	64.7	55.3	49.9
	1000	106.7	118	125.9	146.1	158.1	165.4	170.5	171.1	169.1	134.6	133.6	112.4	108.8
	3000	123.6	167.4	188.7	170	205.2	195.1	225.5	205.3	206.6	166.6	183.1	145.9	139.4
C	2	1.6	1.1	1.1	0.7	0	0	0	0	0	4.3	20.4	19.2	0
	5	2.3	2	2	1.7	0.5	0.1	0	0.9	39.3	45.9	99.7	71.3	46.4
	10	2.8	2.5	2.6	2.4	0.9	1.6	7.6	16.3	92.6	77.8	171.4	107	104.5
	20	3.5	3.3	18.6	41.3	63.5	70	97.7	92.1	197	148.7	236.5	179.5	216.3
	50	189.2	219	232.2	242.8	239.2	320.7	335.7	342.8	408	421.9	419.5	391.1	366.4
	100	329.2	355.1	364.8	360.4	350.2	492.5	517.1	529.9	611.8	616.4	610.6	583.1	560
	1000	920.3	923.6	901.5	1157	1247	1405	1493	1544	1682	1671	1439	1387	1195
	3000	1054	1269	1294	1363	1655	1661	1990	1875	2071	2081	1975	1774	1537

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
D	2	0	0	0	0	0	0	0	0	0	0.2	1.1	1	0
	5	0.1	0.1	0	0.1	0	0	0	0.1	2.6	3	6.6	4.7	2.5
	10	0.1	0.1	0.1	0.1	0	0.1	0.6	1.2	6.1	5.1	11.3	7	5.6
	20	0.1	0.1	0.6	2.7	4.5	5.2	7.2	7.1	12.9	9.4	15.5	11.4	11.7
	50	9	10.7	11.7	18.4	20.4	21.9	23	23.5	25.9	23.9	24.4	20.3	17.8
	100	16.8	18.8	20.1	28.6	31.4	33	34.6	35.3	37.7	33.8	32.3	27.5	25
	1000	50.8	56.2	59.9	69.7	75.5	79	81.6	82	81.4	65.1	64.9	54.8	52.9
	3000	58.8	79.7	89.8	81.1	98	93.2	108	98.4	99.5	81.1	89	71.1	67.8
E	2	0.5	0.3	0.3	0.3	0	0	0	0	0	3.9	20.6	19.4	0
	5	0.8	0.6	0.6	0.8	0.2	0	0	0.5	39.5	46.1	99.9	71.5	46.8
	10	1	0.8	0.8	1.1	0.4	0.9	5.8	12.2	92.9	78	171.9	107.3	105.5
	20	1.2	1.1	6.9	22	37.5	65	88.7	85.3	197.6	149.3	237.2	180.1	218.8
	50	87.6	105.3	116.7	164	179.7	306.1	318.8	324.8	409.3	424.1	422	394.7	373.6
	100	158.2	178.6	193.6	261.4	284.6	475.2	496.6	507.7	614.1	620.1	615.9	591.4	563.2
	1000	450.5	501.3	539.6	1092	1173	1416	1506	1558	1702	1705	1474	1412	1227
	3000	519.3	702.4	795.6	1293	1571	1674	2007	1892	2097	2124	2028	1824	1579
F	2	1.6	1.1	1.2	0.7	0	0	0	0	0	4.2	13.1	15	0
	5	2.4	2	2.1	1.8	0.5	0.1	0	0.9	32.9	38.6	58.6	46.2	21.8
	10	2.9	2.6	2.7	2.5	1	1.6	7	15.7	78.9	54	92.2	61.7	45.5
	20	3.6	3.4	19	40.8	61.1	62.2	95.6	70.6	124.2	71.7	119.7	82.9	76
	50	189.4	216.1	224.9	226.8	217.1	201.4	201.8	164.1	167.6	138.7	148.4	108.3	95.6
	100	328.3	347.2	349.2	333.6	312.3	288.5	262.5	244.6	199.8	218.2	175.6	146.8	116
	1000	891.8	865.8	829.1	739.7	627.4	588.7	521.9	519.8	350.6	515.2	345.3	385.3	246.9
	3000	1020	1184	1183	847.1	790.8	676.8	660.1	598.8	409.9	593.9	435.4	450.8	297.7
G	2	1.8	1.2	1.3	0.8	0	0	0	0	0	5.4	20.7	21.4	0
	5	2.7	2.3	2.4	2.1	0.6	0.1	0	1.1	47.3	55	99.7	72	46.8
	10	3.3	3	3.1	2.9	1.1	1.9	10	21.7	106.3	83.1	171.4	107	105.8

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	20	4.1	3.9	23.1	54.2	84.9	88.5	127.4	100.7	197.1	149	236.6	179.6	219.7
	50	243.8	288.2	309.3	323.4	318.6	308	319.1	308.7	408.4	423.9	422	395.9	378.6
	100	430.9	471.9	486.8	480	466.4	454.8	474.4	484.7	613	620.1	617.7	595.8	582.7
	1000	1203	1201	1169	1089	1115	1420	1511	1564	1714	1737	1647	1607	1392
	3000	1378	1649	1678	1253	1498	1678	2014	1900	2112	2167	2271	2015	1765
H	2	0.4	0.3	0.3	0.2	0	0	0	0	0	1.4	5.5	5.6	0
	5	0.7	0.6	0.7	0.6	0.2	0	0	0.3	13.5	14.5	24.4	19.9	10
	10	0.9	0.8	0.8	0.8	0.3	0.5	2.7	5.9	30.8	21.9	41.2	27.4	21.3
	20	1.1	1.1	6.2	14.6	23.5	24.7	35.7	27.9	52.1	33.2	54.1	39.5	37.6
	50	65.2	77.6	84.4	89.5	88.2	84.6	85.8	74	82.8	60.5	71.4	56.4	50.3
	100	115.2	128.1	134.2	133.6	128.7	121.4	118.1	104.1	108.1	90.8	87.4	70.1	63.6
	1000	317.7	323.4	316.3	293.5	266.9	248.8	234.8	214.5	198.7	203.5	154.4	155.3	133
	3000	364.7	444.8	454.3	337.1	338.5	287.9	303.2	248.7	238.2	235.9	203.6	184.3	160.7
I	2	0.5	0.3	0.3	0.2	0	0	0	0	0	1.8	9.5	8.9	0
	5	0.8	0.7	0.7	0.6	0.2	0	0	0.4	19.9	23.2	50.4	36	22.8
	10	0.9	0.8	0.9	0.8	0.3	0.7	4.4	9.1	46.9	39.3	86.5	53.8	50.9
	20	1.2	1.1	6.4	16.6	28.4	40	55.4	54.2	99.3	73.4	119.4	89.2	102.8
	50	65.9	77.6	84.7	130.3	142.7	167.6	177	181.6	202.8	201.3	194.8	174.1	160.6
	100	115.6	127.8	135.3	207.3	225.8	253.1	266.6	273.8	300.8	292.5	266.9	246.3	220.5
	1000	313.8	338.3	360.1	583	632.7	664.6	697.7	715.4	738.1	716.4	557.7	501.2	450.5
	3000	360.4	486.5	546.8	678.2	821.9	784.5	927.6	865.2	905.8	880.6	765.3	659.9	588.3
J	2	0.8	0.5	0.5	0.3	0	0	0	0	0	3.1	20.3	19.1	0
	5	1.3	1.1	1.1	1	0.3	0	0	0.5	36.2	40.7	97.4	69.6	46
	10	1.5	1.4	1.4	1.3	0.5	0.9	5.7	11.8	88.9	72.1	167.6	104.7	103.9
	20	1.9	1.8	10.6	25.3	43.2	53	73	71.2	192.7	144.7	231.3	175.7	216.6
	50	112.6	136.2	152.2	179.4	198.6	240.4	251.2	257	399.5	415.5	414	390	374.8
	100	200.1	227.6	247.3	280	307.7	375.4	392.4	401.8	600	608.1	608.7	589.3	573

Output Node	ARI	Durations (hr) 1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	1000	575.4	630.8	663.9	839.2	907.6	1390	1480	1534	1685	1725	1646	1612	1415
	3000	662.5	879.1	969.7	992.5	1212	1643	1973	1863	2077	2153	2292	2051	1847
K	2	0.2	0.1	0.1	0.2	0	0	0	0	0	4.4	25.8	24.2	0
	5	0.4	0.3	0.3	0.8	0.2	0	0	0.6	47.8	55.2	122	87.3	58.5
	10	0.5	0.4	0.4	1.2	0.4	1.2	8.2	17.1	113.5	94.7	209.9	131.2	132.8
	20	0.7	0.6	3.9	27.9	47.8	84.3	115.8	112.5	241.6	183.5	289.8	220.9	277.2
	50	64.6	76.2	82.9	228.3	248.6	372.8	392.1	401.8	502.3	526.9	531.6	506.5	489.3
	100	121.8	135.4	144.2	367.6	398.6	571	601.1	617.4	755.9	772.2	794.7	774.7	747.7
	1000	504.6	552.7	583.3	1296	1403	1762	1880	1950	2165	2247	2126	2060	1805
	3000	591.8	806.8	901.9	1521	1853	2083	2508	2371	2671	2810	2942	2648	2305
L	2	0.8	0.5	0.5	0.4	0	0	0	0	0	5	27.7	26.1	0
	5	1.5	1.2	1.3	1.4	0.4	0.1	0	0.9	51.8	60.5	131.2	93.8	63.3
	10	1.8	1.6	1.6	1.9	0.7	1.6	10.4	21.7	121.9	102.5	225.8	141.3	143.9
	20	2.2	2.1	12.4	40.2	68.7	101.8	140.3	136.8	259.7	198	311.8	238.2	301.1
	50	142.3	171.3	189.7	304.5	333.7	434.9	460.2	473	540.9	570.7	586.6	561.1	541.6
	100	256.4	289.2	313.4	483.3	526.7	658.8	697.1	718	815.4	836.7	885.5	862.8	836.6
	1000	787.3	870.3	929.1	1563	1698	1887	2018	2098	2359	2498	2518	2436	2127
	3000	914.1	1240	1397	1825	2220	2231	2693	2552	2915	3130	3494	3144	2738
M	2	0.9	0.6	0.7	0.4	0	0	0	0	0	5	27.7	26	0
	5	1.6	1.4	1.4	1.4	0.4	0.1	0	0.8	51.8	60.5	131.3	93.8	63.3
	10	2	1.8	1.8	2	0.7	1.5	10	20.9	122	102.5	225.8	141.3	144
	20	2.5	2.3	13.8	39.8	68	99.8	137.4	133.6	259.8	198.1	311.9	238.3	301.4
	50	154.8	186.6	207.2	295.1	324	431.9	456	468.1	541.1	571	586.6	561.3	542.3
	100	277.3	313	340.3	467.2	509.8	656.1	693.2	713.2	815.8	837.1	885.4	863.5	840.6
	1000	811.3	899.8	964.5	1548	1680	1887	2018	2098	2361	2502	2533	2469	2134
	3000	938.4	1271	1436	1810	2202	2230	2693	2552	2917	3136	3520	3191	2765

Output Node	ARI	Durations (hr) 1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
N	2	0.3	0.2	0.2	0.3	0	0	0	0	0	4.9	27.6	25.9	0
	5	0.6	0.5	0.4	1.1	0.3	0	0	0.7	51.6	60.1	130.7	93.4	63.1
	10	0.7	0.6	0.6	1.5	0.5	1.4	9	18.9	121.5	102.1	224.9	140.7	143.5
	20	0.9	0.8	5.3	33.5	57.3	93.4	128.2	124.3	258.8	197.3	310.6	237.3	300.2
	50	85.3	100.7	109.6	259.8	284.2	415.8	436.8	447.3	539.2	568.9	583.4	558.4	539.8
	100	160.3	178	189.9	414.1	450.6	636.6	669.9	687.6	812.8	834.1	880.1	858.4	836.5
	1000	643.1	707.8	751	1478	1598	1881	2012	2091	2353	2489	2512	2457	2122
	3000	750.1	1020	1144	1734	2108	2223	2685	2544	2908	3119	3495	3177	2740
O	2	1.8	1.2	1.3	0.8	0	0	0	0	0	4	10.4	11.9	0
	5	2.6	2.2	2.3	1.9	0.6	0.1	0	1	31.6	33.5	45.2	35.1	15.6
	10	3.2	2.8	2.9	2.6	1	1.6	6.7	14.4	73.2	43.8	74.1	46.1	31.9
	20	3.9	3.7	19.9	40.3	57	55.7	90.6	63.7	102.3	55.9	95.5	60.6	60.6
	50	191.7	209.6	208.8	200.4	183	166.3	156.2	137.5	127.4	112.7	114.3	78.3	75.3
	100	325.1	330.6	322.8	288.4	252.6	237.8	190.5	210.2	148.8	190.6	134.5	118	90.9
	1000	843.5	781.7	718.1	626.5	533.8	466.4	446.2	388	292.3	402.5	253.7	291	163.6
	3000	962	1065	1019	714.5	669.7	534.5	559.5	445.9	339.2	461.3	318	339.1	194.6
P	2	0.1	0.1	0.1	0.1	0	0	0	0	0	0.7	3.6	3.4	0
	5	0.3	0.2	0.2	0.3	0.1	0	0	0.2	8	9.3	20	14.3	7.8
	10	0.3	0.3	0.3	0.4	0.2	0.3	1.8	3.7	18.7	15.5	34.2	21.2	16.8
	20	0.4	0.4	2.3	8.1	13.9	16	22.1	21.6	39.1	27.5	47.1	33.9	35.3
	50	32.3	38.5	42.4	56.2	62.3	66.7	69.6	70.6	76.4	65.4	70.2	55.8	52
	100	59.1	66.5	71.4	87.4	95.8	100.4	104.1	105.3	108.9	90.2	90.3	73.3	70
	1000	171	190.2	204.4	224.4	240.8	249.2	248.4	241.7	226	196.1	183.2	156.7	141.2
	3000	196.9	265.9	300.7	260.9	312.2	293.3	326.2	287.8	275	233	247.6	190.2	180.4
Q	2	0.7	0.4	0.5	0.3	0	0	0	0	0	2	8.7	8.6	0
	5	1.1	1	1	0.9	0.3	0	0	0.5	19.6	23.1	41.8	32	17.1
	10	1.4	1.3	1.3	1.2	0.5	0.8	4.3	9.1	44.7	36.5	69.4	46	36.9

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	20	1.7	1.6	9.5	21.7	34.7	37.8	52.2	46.6	85.7	62.9	94.2	71.6	71.9
	50	98	115.2	125.4	136.2	140.9	142.3	145	138.7	161.9	154.7	151.3	130.3	111.4
	100	171.7	189.5	200	206.9	210.4	208.3	211.3	203.5	234.3	217.9	202.6	177.9	157.5
	1000	456.2	480	489.1	494	490.2	489.4	502.7	500.2	542.6	427.2	382.5	335.6	309.4
	3000	523.9	665	710.6	572	631.4	576.7	657.7	601.1	659.2	525.7	520.4	429.6	391.6
R	2	0.9	0.6	0.7	0.4	0	0	0	0	0	2.6	9.8	10.5	0
	5	1.5	1.2	1.3	1.1	0.3	0	0	0.6	22.6	26.7	43.2	34.3	16.9
	10	1.8	1.6	1.6	1.5	0.6	1	4.9	10.6	52.4	39.2	70.7	46.7	35.7
	20	2.2	2.1	11.8	26.5	41	43	62.7	48.8	90.1	54.9	92.9	64.8	59.7
	50	120.9	140.5	149.8	157.3	154.8	149.1	150.9	128.3	132.9	101.5	117.1	86.4	77.5
	100	210.4	228.5	235.8	233.6	226.3	212.5	205.6	178.2	164.4	159.8	139.7	113.3	95.2
	1000	579.3	586.2	575.1	537.6	484.4	452.3	379	395	280.7	368.6	259.9	285.5	214.8
	3000	664	806.6	827.3	617.6	612.5	522.1	483.2	457.2	334.1	426.6	329.4	335.3	259.3
S	2	0.2	0.2	0.2	0.1	0	0	0	0	0	0.7	2.7	2.8	0
	5	0.4	0.4	0.4	0.3	0.1	0	0	0.2	6.8	8	12.8	10.2	5
	10	0.5	0.5	0.5	0.5	0.2	0.3	1.5	3.2	15.8	11.7	20.9	13.8	10.5
	20	0.7	0.6	3.6	8	12.3	12.8	19	14.6	26.8	16.2	27.3	19	17.3
	50	36.7	42.5	45.1	47.1	46.1	44.2	44.7	37.7	38.9	30.2	34.3	25.2	22.4
	100	63.8	69	70.9	69.9	67.3	62.9	60.4	52	47.7	47.2	40.9	33.4	27.4
	1000	160.9	163	160	150	135.4	126.3	106.4	110.3	78.8	102.7	72.5	79.6	60.3
	3000	184.4	224.3	230.3	172.3	171.2	145.9	135.7	127.6	93.8	118.9	92	93.5	72.8

Table A.3 Design case RORB model peak flow outputs at reporting locations

Output Node	ARI	Durations (hr)											
		1	**1.5**	**2**	**3**	**4.5**	**6**	**9**	**12**	**18**	**24**	**36**	**48**	**72**
A	2	0.7	0.5	0.5	0.4	0	0	0	0	0	4.7	24.6	23.1	0
	5	1.3	1.1	1.1	1.3	0.4	0.1	0	0.9	47.8	55.8	121.2	86.7	54.6
	10	1.5	1.4	1.4	1.8	0.7	1.6	10.3	21.5	112.6	94.5	208.4	130.1	122.5
	20	1.9	1.8	10.3	38.8	66.4	96.1	132.8	130.3	239.4	179.8	287.6	217.4	252
	50	119.6	143.6	159.3	303.1	332	402.9	426.4	438.1	493.8	503.5	500.2	458.5	417.7
	100	216.8	244.7	264.9	482.4	525.6	608.6	642.9	661.4	738	732.8	714.5	670.2	593.6
	1000	733.6	807.5	858.1	1479	1608	1693	1792	1846	1973	1879	1600	1445	1306
	3000	855.9	1164	1307	1721	2090	2001	2386	2237	2428	2335	2188	1878	1681
B	2	1	0.9	0.7	0.6	0	0	0	0	0	4.5	23.5	22.1	0
	5	1.5	1.5	1.3	1.4	0.3	0.3	0	0.6	45.3	52.9	114.8	82.1	52.5
	10	1.8	1.9	1.7	1.9	0.6	1.1	7.4	15.7	106.6	89.5	197.4	123.2	117.8
	20	2.2	2.5	12.3	27	41.2	84.6	115.6	111.6	226.8	170.6	272.3	206.1	242.5
	50	122	141.2	149.6	187.3	201.6	378.8	398.3	407.6	468.4	480.6	476	439	403.5
	100	211.9	228.6	234.9	308.3	331.3	576	607.2	623.6	701.2	700.9	684.9	646.6	598.7
	1000	575.1	578.7	566	1380	1491	1616	1713	1768	1904	1843	1561	1440	1280
	3000	658.9	795.4	813.6	1617	1964	1909	2281	2144	2342	2289	2137	1876	1650
C	2	1.1	1.1	1.1	0.9	0.3	0.1	0	0	0	4.3	23	21.6	0
	5	1.7	1.7	1.7	1.6	1	0.8	0.2	1.6	44.1	51.5	111.8	79.9	51.4
	10	2	2.1	2.2	2.1	1.5	1.4	5	10.5	103.9	87.2	192.3	120	115.5
	20	2.5	2.6	6.6	14.3	24.2	65.9	88.9	84.5	220.9	166.3	265.1	200.9	238.4
	50	48.3	55.6	59	119.5	128.9	330.6	341	345.7	456.5	469.3	464.7	430.1	398.1
	100	82.2	88.7	93.4	197.2	211.8	519.2	539.2	548.9	683.6	684.8	670.3	635.4	587.1
	1000	261.6	288.6	307.5	1163	1241	1578	1674	1729	1867	1822	1539	1434	1275
	3000	304.3	413.3	464.9	1387	1685	1864	2230	2097	2295	2264	2116	1868	1646

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
D	2	0.1	0.1	0.1	0.3	0.1	0	0	0	0	4	22.7	21.4	0
	5	0.3	0.3	0.2	0.6	0.3	0.3	0.1	0.6	43.4	49.7	110.3	78.9	50.9
	10	0.4	0.3	0.3	0.8	0.5	0.6	3.8	7.7	102.5	85.9	189.8	118.5	114.4
	20	0.5	0.4	1.2	10.6	17.6	50.5	67.6	63.6	218	164.2	261.9	198.4	235.7
	50	17.8	20.6	22.1	87.3	94.2	275.3	279.9	281.8	450.8	463.8	459.3	425.3	395.3
	100	33.8	37.2	39	143.3	154.1	444.4	456.2	461.4	675.1	676.8	662.8	629.6	581.8
	1000	160.7	174.9	183.1	932.3	986	1560	1654	1709	1847	1809	1529	1428	1272
	3000	189.9	260.1	289.2	1129	1373	1842	2204	2074	2274	2250	2102	1860	1641
E	2	1.4	1.1	1.1	1.2	0.3	0.1	0	0	0	6.2	29.2	27.5	0
	5	2.3	2.1	2.1	2.7	1.5	1	0.3	2.6	54.4	63.3	137.6	98.3	64.5
	10	2.8	2.7	2.7	3.5	2.3	2.5	10.3	17.4	127.9	107.4	236.4	147.8	145.5
	20	3.5	3.4	13.8	33.4	54.5	86.9	118.4	114.1	272.2	205.7	326.5	247.9	301.8
	50	130.6	157.9	176.6	229.6	252.3	406.3	422.8	431	563.9	584.8	583.4	546.7	519.3
	100	230.4	262.2	285.6	363.7	396.9	632.6	660.6	675.1	846.2	854.8	852.9	820.4	785
	1000	632.6	698.6	743	1420	1526	1990	2116	2190	2391	2405	2078	2019	1758
	3000	728.4	974.8	1094	1685	2051	2351	2821	2659	2947	2997	2863	2604	2278
F	2	0.9	0.6	0.6	1	0.1	0	0	0	0	7.3	31.8	29.9	0
	5	1.7	1.4	1.4	2.8	1.1	0.8	0.2	2.5	57.9	67.2	146.2	104.5	70.1
	10	2.1	1.8	1.8	3.7	1.9	2.9	14	25.1	136	114.2	251.3	157.2	158.7
	20	2.6	2.4	13.5	52.2	86.4	106.6	146.4	142.8	289.4	219.6	346.9	264.3	331.9
	50	168.6	201.6	222.1	354.5	392	457.5	482.4	495.4	601	629.3	632	602.4	587.7
	100	307.1	345	372	552.3	606.3	699.6	737.4	758.2	903.9	922	942.9	924.1	899.8
	1000	996.1	1102	1177	1650	1788	2147	2289	2374	2626	2728	2587	2486	2185
	3000	1155	1564	1763	1935	2357	2537	3053	2885	3240	3411	3577	3180	2777
G	2	0.3	0.2	0.2	0.3	0	0	0	0	0	6.4	31.2	29.2	0
	5	0.5	0.4	0.4	1	0.3	0.4	0.1	1.4	55.7	63.3	143.5	102.4	69

Output Node	ARI	Durations (hr)												
		1	**1.5**	**2**	**3**	**4.5**	**6**	**9**	**12**	**18**	**24**	**36**	**48**	**72**
	10	0.7	0.5	0.5	1.4	0.5	2	11	20.4	132.2	109.2	246.5	154.3	156
	20	0.8	0.7	4.6	29.8	50	96.2	130.5	126	283.9	215.1	340.2	259.4	325.4
	50	68.2	80.9	88.5	243.2	263.7	420.2	441.4	452.1	589.8	618.6	623.5	594.2	574.8
	100	127	141.5	151.6	393.1	424.8	644.3	677.6	695.4	887.4	906.1	931.2	908.5	879.1
	1000	513.8	563.2	595.1	1483	1603	2098	2239	2323	2580	2677	2533	2463	2139
	3000	602.6	822.1	919.5	1742	2119	2480	2987	2824	3184	3348	3502	3171	2739
H	2	0.4	0.3	0.3	0.2	0	0	0	0	0	1.2	4.7	4.8	0
	5	0.7	0.6	0.6	0.5	0.2	0	0	0.3	10.9	13	22.1	17.5	9.2
	10	0.9	0.8	0.8	0.7	0.3	0.5	2.4	5.1	25.3	20.2	37.2	24.8	19.7
	20	1.1	1	5.8	12.7	19.6	20.9	30.2	25.3	47.3	32.6	49.7	37.3	37
	50	58.2	67.3	71.5	76	77	76.6	79.9	71.9	82.4	68.6	71.4	58.7	52.5
	100	101.2	109.1	112.7	114.1	114.4	111.9	114.7	103.5	113.6	92.5	90.7	75.3	68.8
	1000	261	266.9	266.8	264.3	257.5	247.3	248.6	221.8	229.7	194.9	165.1	155.7	134.1
	3000	299.3	368.4	386.4	305.6	329.5	288.7	322	261.8	276.9	228.7	220.6	186	163.8
I	2	0.3	0.2	0.2	0.1	0	0	0	0	0	0.7	2.5	2.7	0
	5	0.5	0.4	0.4	0.3	0.1	0	0	0.2	6.4	7.7	12.2	9.6	4.8
	10	0.6	0.5	0.5	0.5	0.2	0.3	1.4	3.1	15.4	11.3	19.7	13.3	10.2
	20	0.7	0.7	3.7	7.9	11.9	12.2	18.6	13.9	26.2	17.4	26	19.6	17.9
	50	36.8	42	43.8	44.6	43.4	41.2	43	36.2	42.8	34.2	36.1	29.6	24.9
	100	63.7	67.5	68.2	66	63.1	58.6	59.1	51.2	58.2	45.4	44.9	37.4	32.2
	1000	155.9	154.3	149.8	137.2	125.1	116.4	117.8	101.9	111.9	96.2	77	75.3	63.1
	3000	178.4	211.6	214.7	157.6	158.7	134.6	152.6	120.5	134.3	111.2	102.5	88.6	76.7
J	2	0.4	0.4	0.3	0.3	0.1	0	0	0	0	0.9	1.2	1.1	0
	5	0.6	0.6	0.6	0.5	0.3	0.2	0.1	0.5	3.1	2.4	3.4	2.6	1.3
	10	0.7	0.8	0.8	0.7	0.5	0.4	1.2	1.3	5.5	3	5.3	3.3	2.1
	20	0.9	0.9	2.2	3.8	4.7	4.5	7	4.7	7.2	3.8	6.7	4.3	4.2

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	50	15.4	16.4	16.1	14.6	13	12	10.5	10.3	8.8	8	7.9	5.4	5.1
	100	25.6	25.1	24	21.2	17.7	16.6	14.5	14.7	10.2	14.1	9.3	8.4	6.2
	1000	55.6	51.3	46.8	41	35.1	30.1	28.7	25.2	18.8	25.5	15.9	18.4	10.5
	3000	63.3	69.7	66.3	46.8	44	34.5	35.9	28.9	21.7	29.1	19.9	21.3	12.3
K	2	0.8	0.8	0.8	0.6	0.2	0	0	0	0	2.2	3.1	3.3	0
	5	1.3	1.3	1.4	1.2	0.7	0.5	0.2	1.1	8	7.5	12.2	9.3	5.2
	10	1.6	1.6	1.7	1.5	1.1	1	2.8	3.6	15.3	10.7	18.9	12.5	9.4
	20	1.9	2	4.9	9.1	12.2	12.6	18.7	13.6	24.7	14.7	24.6	17.1	15.3
	50	36.8	41.3	42.8	43.4	42.2	40	40.7	34	35	27.6	30.6	22.5	19.8
	100	62.2	65.3	65.7	63.8	61	56.5	54.3	46.8	42.5	42.3	36.4	30	24.2
	1000	141.4	139.4	136.1	127.2	116.1	107.9	92.1	94.3	67.3	87.8	62.1	68.4	52.1
	3000	161.6	191.3	195.4	146.2	146.8	124.7	117.3	109.1	80.1	101.6	78.7	80.3	62.8
L	2	0.9	0.9	0.9	0.7	0.2	0	0	0	0	2.8	5.7	5.1	0
	5	1.4	1.5	1.5	1.3	0.9	0.6	0.2	1.3	10.4	9.9	21.8	14.6	9.7
	10	1.7	1.8	1.8	1.7	1.2	1.2	3.9	5.3	20.1	16.1	34.3	21.2	16.9
	20	2.1	2.2	5.5	10.6	15.7	18.5	24.2	22.9	39.2	25.7	45.5	30.6	33.1
	50	40.5	47	51.7	59.3	65.5	68.7	67.7	65.3	67.2	47.8	60.8	43.9	44.2
	100	69	76.1	82.8	91	99.2	101.2	98	92.4	88.3	74.5	74.2	54.8	55.4
	1000	171.1	189.9	203.5	221.1	222.4	215.5	199.4	182.1	154.1	170.5	131.7	135.9	111.1
	3000	197	265.2	298.8	256.5	285.1	251	256.9	213.8	185.5	199.7	175.5	161.9	134.4
M	2	0.8	0.7	0.7	0.5	0.1	0	0	0	0	3	11.7	11	0
	5	1.4	1.3	1.4	1.3	0.7	0.4	0.1	1.2	24.1	28	60.7	43.4	26.7
	10	1.7	1.7	1.7	1.7	1.1	1.2	5.6	11.1	56.5	47.3	104.2	64.9	58.7
	20	2.1	2.1	8.2	23.6	40.1	48.3	66.7	65.4	119.7	88.6	143.6	107.7	115
	50	84.3	101.3	112.6	169	186.9	202	213.4	219.1	244.7	244.3	232.7	205.6	175.7
	100	151	170.9	185.3	263.6	289.5	305.1	321.6	330.5	363.3	355.5	319.6	290.3	251.3

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	1000	466.2	515.5	550	711.8	772.6	811.5	852	873.5	897	795.5	661.5	577.8	539.3
	3000	540.8	733.4	825.1	828.1	1004	958.4	1132	1056	1100	978.6	908.1	759.2	698.4
N	2	0.1	0.1	0.1	0.4	0.1	0	0	0	0	2.5	11.5	10.8	0
	5	0.3	0.3	0.2	1	0.5	0.3	0.1	0.9	23.6	27.3	59.4	42.4	25.6
	10	0.4	0.3	0.3	1.4	0.8	1	5.4	10.9	55.2	46.2	101.8	63.4	56.7
	20	0.5	0.5	2.2	20.5	34.3	47.2	65.2	63.8	116.9	86.6	140.4	105.1	112.7
	50	41.6	48.5	52.1	153.9	168.8	197.2	208.3	213.9	239	238.1	228.7	202.7	173.2
	100	79.9	88	92.7	244	266.1	297.8	313.9	322.6	354.8	345.5	313.7	284	245.9
	1000	351.5	385	406.1	695.6	755.1	793.5	833.2	854	878.2	775.6	653	570.3	528.5
	3000	412.1	561.6	627.6	809.3	980.9	936.6	1107	1032	1075	956	896.7	748.8	686.4
O	2	1.2	1.2	1.1	1	0.3	0.1	0	0	0	5	13.6	12.1	0
	5	2	2	2	2.2	1.4	0.9	0.3	2.2	24.8	27.9	60.7	43.3	28.3
	10	2.4	2.5	2.5	2.8	2	2	7.9	12	56.4	47.3	104	64.9	62.9
	20	3	3.1	8.6	24.5	40	48.3	66.6	65.3	119.7	89.7	143.4	108.6	125.3
	50	86.2	102.6	113.1	163.3	180.6	201.6	213.4	219.5	246.7	256.9	246.9	224.3	195.7
	100	155	174.3	187.6	255.7	280.6	304.5	321.8	331.5	369.7	375.4	357.2	327.2	282.2
	1000	477.7	529.4	566.9	721.6	785	826.7	876.8	906.9	975.3	889.8	733.1	652.6	603.8
	3000	552.3	747.4	843.8	839.5	1020	976.5	1168	1100	1198	1099	1003	845.5	771.6
P	2	0.8	0.8	0.8	0.6	0.2	0	0	0	0	3	5.7	5.6	0
	5	1.3	1.4	1.5	1.4	0.9	0.6	0.2	1.5	12.3	11.2	21.4	16	9.9
	10	1.6	1.7	1.8	1.8	1.3	1.3	4.1	5.8	23.7	17.1	34	22.2	17.4
	20	2	2.2	5.9	12.4	18.7	20.9	27.4	23.1	41.2	25.7	44.5	31.5	31.5
	50	46.8	56.2	62.2	69.4	71.4	70.3	69	61.6	65.1	48.2	57.6	43.7	41.5
	100	81.4	92.1	99.1	104.7	104.7	100.9	96	87.1	83.4	75.5	69.7	54.3	51.6
	1000	206.4	223.7	230	226	212.4	199.4	182.1	162.6	142.2	160.3	122.7	127.7	105.3
	3000	237.4	310.5	333.5	260.6	270.1	231.2	234.2	189.7	170.6	186.4	161.6	151.4	127

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
Q	2	0.4	0.3	0.3	0.2	0	0	0	0	0	1.1	4.7	4.5	0
	5	0.7	0.6	0.6	0.5	0.2	0	0	0.3	10.6	12.5	26.5	19	10.1
	10	0.9	0.8	0.8	0.7	0.3	0.5	2.3	4.9	25	21	45.4	28.1	22.1
	20	1.1	1	5.5	11.8	18.5	21.3	29.4	28.7	52	38.4	62.5	45.3	46.4
	50	54.8	62.6	66.4	74.9	82.9	88.8	93	95	104.1	95.5	95.6	76.4	69.9
	100	94.7	101.1	105	116.4	127.6	133.7	139.8	142.4	151.4	133.3	125.1	102.2	95.9
	1000	232.7	252.3	271	297.1	320	333.8	329.4	325.9	319.9	259.7	242.9	210.9	191.2
	3000	266.7	352.6	398.5	345.4	416.1	393.2	433.5	388.5	389	308.3	329.2	253.8	242.4
R	2	0.3	0.3	0.3	0.2	0.1	0	0	0	0	1.1	4.9	4.6	0
	5	0.6	0.5	0.6	0.5	0.3	0.2	0.1	0.5	10.7	12.4	26.8	19.2	10.5
	10	0.7	0.7	0.7	0.7	0.4	0.5	2.4	4.9	25.1	20.9	45.9	28.5	22.9
	20	0.9	0.9	4.2	10.9	18.6	21.5	29.6	28.9	52.6	37.8	63.2	45.9	47.4
	50	46.7	56.2	62.6	75.4	83.5	89.5	93.8	95.7	104.5	95.1	97.5	78.4	71
	100	83.7	94.9	103.1	117.1	128.5	134.8	140.7	143.3	151.8	133.2	127.2	104.4	95.8
	1000	229.6	255.3	274.4	301.2	324.3	337.5	337.6	331.8	327.3	263.8	246	212.4	194.7
	3000	264.4	356.8	403.5	350.3	420.7	397.7	444.5	395.9	398.7	313.7	334	260.7	246.5
S	2	0.8	0.9	0.8	0.6	0.2	0	0	0	0	2.4	3.2	3.2	0
	5	1.3	1.3	1.4	1.2	0.8	0.5	0.2	1.2	7.7	6.4	9.4	6.9	3.9
	10	1.6	1.6	1.7	1.5	1.1	1	2.9	3.4	14	8.4	14.3	9.1	6.3
	20	1.9	2	4.9	8.9	11.4	11.5	17.4	12.2	19.5	10.8	18.1	11.8	11.7
	50	35.7	39.1	39.2	37.8	34.8	31.7	30	26	24.4	21.8	21.7	15.3	14.5
	100	59.4	60.9	59.7	54.1	48.1	45.1	36.9	39.7	28.5	35.5	25.5	22.5	17.4
	1000	139.3	130.4	122.8	108.4	92.5	80.7	77.7	70.3	51.5	73	47.3	53.5	30.5
	3000	158.9	178	174.5	123.7	115.9	92.4	97.8	80.7	59.9	83.8	59.3	62.4	36.7
T	2	0.8	0.8	0.8	0.7	0.2	0	0	0	0	3.1	5.5	5.4	0
	5	1.3	1.4	1.4	1.3	0.9	0.6	0.2	1.4	11.2	10.2	18.8	13.6	8.5

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	10	1.6	1.7	1.8	1.7	1.3	1.3	4	5.5	20.6	14.9	28.4	18.6	13.9
	20	2	2.1	5.5	11.6	17	18.8	24.6	19.5	33.5	20.2	36.4	24.5	22.7
	50	42.7	51.3	56.6	61.5	61.4	59.5	57.2	49.4	46.4	40.7	45	32	29.1
	100	74.2	83.8	89.3	91.8	89.1	84	76.5	66.8	55.4	63.6	53.3	44.7	35.3
	1000	191.8	203.5	204.7	195.3	175.1	163.8	125.7	141.7	89.9	132.7	91.9	99.9	76.2
	3000	220.4	281.4	295.4	224.4	220.8	188.9	159.6	163.9	107.1	153.6	116.4	117.3	91.5
U	2	1.5	1.5	1.5	1.2	0.4	0.1	0	0	0	5.2	9.3	9	0
	5	2.1	2.3	2.4	2.2	1.4	1	0.3	2.3	17.9	16.5	31.3	22.5	14.4
	10	2.6	2.8	2.9	2.8	2.1	2	6.5	9	33.1	24.7	47.8	31.2	23.7
	20	3.3	3.5	9	18.5	26.9	30.3	39.1	33	56.4	34.3	61.7	41.6	40.6
	50	68.8	81.5	89.5	98.3	100.8	99	97.2	85.4	81.3	67.6	76.6	54.5	52
	100	118.7	132.5	141.2	147.7	147.5	141.9	133.4	118.6	98	106.1	91	75.4	63.4
	1000	309.5	329.2	335.6	328.6	303.5	282.4	228.2	239.9	158.8	227.7	158	169	135.9
	3000	355.5	456.2	486.2	378.4	384	326.2	289.8	278.2	189.3	264.3	204	199.4	163.4
V	2	1.5	1.5	1.5	1.2	0.4	0.1	0	0	0	5.7	11.8	10.4	0
	5	2.3	2.4	2.5	2.3	1.5	1.1	0.3	2.5	20.3	18.4	37.4	26.6	17.5
	10	2.8	2.9	3.1	3	2.2	2.2	7.7	10.3	38.5	28.6	57.8	37.6	29
	20	3.4	3.6	9.6	20.2	30.5	35.5	44.9	40.3	68.4	40.8	75	50.3	52
	50	74.2	89.3	99.6	113.2	120.4	120.6	116.6	105.5	100.2	82.7	93.3	66.4	66.6
	100	128.9	146.5	158.9	172.4	177.7	173.3	161.8	148.2	121	128.6	111.2	91.4	81.2
	1000	347	381.8	401.4	404.6	377.9	353.1	288.7	288.6	194.6	283.8	201.8	219.8	174.1
	3000	399.3	532.1	585	466.6	479.7	408.6	367	335.5	232.7	330	261.6	259.6	209.2
W	2	1.9	1.3	1.4	0.8	0	0	0	0	0	4.2	10.7	12.2	0
	5	2.8	2.3	2.4	2	0.6	0.1	0	1	32.9	34.4	45.8	36.1	15.7
	10	3.3	3	3.1	2.8	1.1	1.7	7	14.9	75.8	44.8	76.2	46.9	32
	20	4.1	3.9	20.9	42.2	59.2	57.7	94.1	65.8	104.9	57	97.8	61.3	61.8

Output Node	ARI	1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
		Durations (hr)												
	50	200.8	218.3	216.8	206.7	187.9	171.2	159	142.4	130	115.6	117	79	76.8
	100	340	343.6	334.5	297	257.5	243.1	195.9	215.8	151.6	197.4	137.6	121.2	92.5
	1000	879.4	812.7	743.5	649.9	554.6	480.5	458.5	400.6	299.5	409.3	256.5	295.3	167.5
	3000	1002	1105	1054	742.3	696.8	550.3	574.3	460.1	347.2	468.8	321.2	343.9	196.9
X	2	0.5	0.3	0.3	0.2	0	0	0	0	0	1.4	5.5	5.7	0
	5	0.8	0.7	0.7	0.6	0.2	0	0	0.3	12.7	15	24.9	19.8	10
	10	0.9	0.9	0.9	0.8	0.3	0.5	2.8	5.9	29	22.5	41.4	27.3	21.2
	20	1.2	1.1	6.4	14.5	22.9	24.3	34.5	28	51.8	32.6	54.7	38.5	36.8
	50	65.8	77	83	88.5	88.5	86.1	87.7	75.8	80.1	58.3	70	52.5	48.2
	100	115	126	131.3	132.7	130.1	124.5	121.8	107.4	101.4	93	84.2	66.4	59.7
	1000	308.3	317.8	316.1	303.3	281.3	261.1	233.9	224.4	175.3	209.5	152.7	161	131.4
	3000	353.7	438.6	456.1	349.2	356.9	302.4	299.4	260.3	209.4	243.5	199.6	189.4	158.8
Y	2	1	0.7	0.7	0.4	0	0	0	0	0	2.8	10.2	10.9	0
	5	1.5	1.3	1.4	1.2	0.3	0	0	0.6	23.6	27.9	44.8	35.5	17.4
	10	1.9	1.7	1.7	1.6	0.6	1	5.1	11	55	40.7	73	48.3	36.8
	20	2.3	2.2	12.5	27.9	43	44.8	65.9	51	93.6	56.6	95.8	66.7	60.8
	50	127.4	147.8	157.1	164.3	160.9	154.5	156.3	132.2	136.4	105.5	120.4	88.6	78.8
	100	221.7	240	247	243.8	234.9	220	211.6	182.6	167.8	165.3	143.4	116.9	96.6
	1000	609.2	614.3	601.1	556.9	498.9	466.7	384.8	408.8	285.3	384	269	296	218.4
	3000	698.1	844.6	864.1	639.5	629.9	538.7	490.3	472.9	339.4	444.2	340.8	347.5	263.6
Z	2	0.7	0.5	0.5	0.3	0	0	0	0	0	2.1	9.1	9.1	0
	5	1.2	1	1.1	0.9	0.3	0	0	0.5	20.7	24.3	43.8	33.6	17.9
	10	1.5	1.3	1.4	1.3	0.5	0.8	4.5	9.6	47	38.4	72.7	48.3	38.7
	20	1.8	1.7	10	22.9	36.6	39.8	54.9	48.9	89.9	66.1	98.7	75.2	75.4
	50	103.6	121.7	132.2	143.3	147.8	149.1	152.4	145.6	170.1	161.5	156.5	134.2	115.3
	100	181.4	200	210.6	217.5	220.6	218.3	221.8	213.7	246.1	226.5	207.5	181.3	161

Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	1000	483	506.5	515.2	519.4	515.8	516.3	531.1	526.7	564	428.4	392.1	341.7	316.6
	3000	554.6	701.5	748.2	601.4	664.6	608.7	694.7	632.4	684.2	527.4	534.2	438.3	401.4
~	2	0.4	0.3	0.3	0.2	0	0	0	0	0	1.2	4.7	4.8	0
	5	0.7	0.6	0.6	0.5	0.2	0	0	0.3	10.9	13	22.1	17.5	9.2
	10	0.9	0.8	0.8	0.7	0.3	0.5	2.4	5.1	25.3	20.2	37.2	24.8	19.7
	20	1.1	1	5.8	12.7	19.6	20.9	30.2	25.3	47.3	32.6	49.7	37.3	37
	50	58.2	67.3	71.5	76	77	76.6	79.9	71.9	82.4	68.6	71.4	58.7	52.5
	100	101.2	109.1	112.7	114.1	114.4	111.9	114.7	103.5	113.6	92.5	90.7	75.3	68.8
	1000	261	266.9	266.8	264.3	257.5	247.3	248.6	221.8	229.7	194.9	165.1	155.7	134.1
	3000	299.3	368.4	386.4	305.6	329.5	288.7	322	261.8	276.9	228.7	220.6	186	163.8
!	2	0.4	0.3	0.3	0.2	0	0	0	0	0	2	10.3	9.7	0
	5	0.7	0.6	0.6	0.6	0.2	0	0	0.4	21.7	25.3	54.7	39.2	23.9
	10	0.9	0.8	0.8	0.8	0.3	0.8	4.8	10	51	42.6	94	58.4	52.4
	20	1.1	1	5.9	18.8	32.2	43.5	60.2	58.9	107.7	79	129.5	96.2	105.2
	50	60.4	70.6	76.3	147	161.2	182	192	196.8	218.7	212.6	205.8	180.4	160.6
	100	105.4	115.6	121.3	232.6	253.8	274.9	289	296.5	322.8	307.7	276.5	248.4	215.2
	1000	337.5	370.5	391.6	635.5	688.7	722.3	753.6	769.1	772.9	704.4	574.7	503.3	460.1
	3000	395.2	538.6	601.9	739.2	894.4	852.8	1001	928.4	946	864	786.5	663.7	600.3
@	2	0.3	0.2	0.2	0.1	0	0	0	0	0	1	5.2	5	0
	5	0.6	0.5	0.5	0.5	0.1	0	0	0.2	11.9	13.7	28.4	20.5	10.9
	10	0.7	0.7	0.7	0.6	0.2	0.4	2.6	5.4	27.9	22.4	47.7	29.4	23.7
	20	0.9	0.9	5.1	12.1	20.7	23.8	32.6	31.2	55.2	36.5	64.3	44.1	47.2
	50	54	65.4	73	83.7	91.7	96	95.3	92.2	98.6	74	89.4	66.4	65.1
	100	96	109.1	118.7	129.8	140	142.2	139.2	132.3	133.1	104.4	111.5	85.2	84.1
	1000	256.7	284.5	304.1	326.1	327.3	317.7	299.8	275.6	249.5	249.7	206.7	201.8	166.4
	3000	295.6	397.4	446.3	378.2	420.1	371	388.3	324.8	301.3	292.9	275.2	240.4	207.8

Output Node	ARI	Durations (hr) 1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
#	2	0.2	0.1	0.1	0.1	0	0	0	0	0	0.6	2.6	2.6	0
	5	0.3	0.3	0.3	0.3	0.1	0	0	0.1	6.2	7.3	13.2	10.2	5.4
	10	0.4	0.4	0.4	0.4	0.1	0.2	1.4	2.9	14.3	11.5	21.9	14.4	11.5
	20	0.5	0.5	2.9	6.7	10.9	12	16.4	14.9	26.9	18.2	29.2	21.4	21.7
	50	30.2	35.8	39.3	43.2	45.1	45.5	45.8	42.1	46.4	35.5	40.8	32.2	30
	100	53.1	59.1	63	65.9	67.4	66.4	66.3	60.8	62.3	49.1	51	41.2	38.8
	1000	137.9	147.5	151.8	154.1	150	144.2	140.1	125.7	117.6	113.9	95.4	91.2	76.8
	3000	158.5	204.7	220.9	178.3	192	168.1	181.1	148	141.7	133.5	127.1	108.7	93.8
$	2	0.9	0.9	0.9	0.7	0.2	0	0	0	0	2.2	2.8	2.7	0
	5	1.4	1.4	1.4	1.2	0.8	0.5	0.2	1.2	7.3	5.6	7.9	6	3
	10	1.7	1.7	1.8	1.6	1.1	1	2.8	3	12.9	7.1	12.4	7.8	4.8
	20	2.1	2.1	5.1	8.7	10.9	10.4	16.4	11	16.9	9	15.7	10	9.8
	50	35.8	38.1	37.4	34.1	30.4	28.1	24.8	24.1	20.5	18.8	18.6	12.7	12.1
	100	59.3	58.4	55.9	49.3	41.2	38.9	33.8	34.5	23.9	32.9	21.8	19.8	14.5
	1000	135.2	124.4	113.3	99.6	85.2	72.7	69.1	60.8	45	60.8	37.9	43.8	25.2
	3000	154	168.9	160.6	113.7	106.8	83.1	86.3	69.7	52.1	69.5	47.3	50.9	29.6
%	2	0.6	0.6	0.6	0.4	0.2	0	0	0	0	1.9	2.8	3	0
	5	0.9	0.9	1	0.9	0.6	0.4	0.1	0.9	6.2	5.9	10.4	7.7	4.8
	10	1.1	1.2	1.2	1.1	0.8	0.8	2.3	3	11.7	8.8	16	10.9	8.3
	20	1.4	1.4	3.6	7	9.5	10.2	14.3	10.8	20.5	13.7	21	15.7	15.1
	50	27	31	32.7	34.1	33.7	32.7	34.2	29.5	34.2	25.9	28.4	22.9	20.5
	100	45.9	49.3	50.4	50	48.9	46.9	47.8	42.4	45.9	35	34.9	28.6	26
	1000	110.9	112.3	110.5	105.9	100.7	94.8	96.6	85.2	83.9	74.9	61.8	59.9	51.8
	3000	127	154.5	159.1	122	128.3	110.6	124.8	100.4	100.5	87.7	82.3	71.4	62.8
^	2	0.8	0.8	0.8	0.6	0.2	0	0	0	0	1.9	2.6	2.6	0
	5	1.3	1.3	1.3	1.1	0.7	0.4	0.2	1.1	7	6.2	9.4	7.3	4

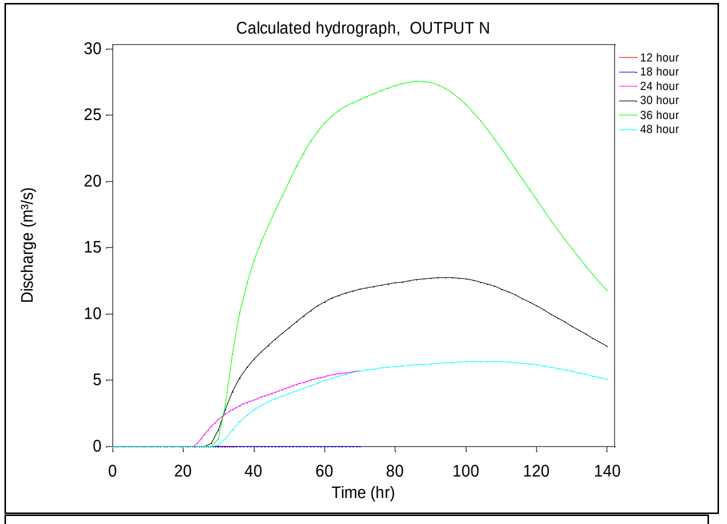
Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	10	1.5	1.6	1.6	1.4	1	0.9	2.5	2.9	13.1	8.8	14.6	9.9	7.4
	20	1.9	2	4.7	8.1	10.4	10.3	16.2	11.4	20.6	12.1	19.2	13.6	12.5
	50	33.8	36.5	36.4	35.4	33.8	31.1	33.2	27.2	29.5	21.5	24.1	18	15.8
	100	56.2	56.8	55.6	51.4	48.2	44.3	44.4	38.3	36	33.7	28.6	23.3	19.2
	1000	127	118.4	111.1	99.8	91.9	85.1	76.8	75.1	56.8	71.4	49.9	55.6	41.4
	3000	144.8	161.5	158.3	114.5	116.5	98.4	97.9	86.9	67.4	82.4	63.2	65.2	50
&	2	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0
	50	0	0	0	0	0	0	0	0	0	0	0	0	0
	100	0	0	0	0	0	0	0	0	0	0	0	0	0
	1000	0	0	0	0	0	0	0	0	0	0	0	0	0
	3000	0	0	0	0	0	0	0	0	0	0	0	0	0
*	2	0.4	0.3	0.3	0.2	0	0	0	0	0	1.2	4.7	4.8	0
	5	0.7	0.6	0.6	0.5	0.2	0	0	0.3	10.9	13	22.1	17.5	9.2
	10	0.9	0.8	0.8	0.7	0.3	0.5	2.4	5.1	25.3	20.2	37.2	24.8	19.7
	20	1.1	1	5.8	12.7	19.6	20.9	30.2	25.3	47.3	32.6	49.7	37.3	37
	50	58.2	67.3	71.5	76	77	76.6	79.9	71.9	82.4	68.6	71.4	58.7	52.5
	100	101.2	109.1	112.7	114.1	114.4	111.9	114.7	103.5	113.6	92.5	90.7	75.3	68.8
	1000	261	266.9	266.8	264.3	257.5	247.3	248.6	221.8	229.7	194.9	165.1	155.7	134.1
	3000	299.3	368.4	386.4	305.6	329.5	288.7	322	261.8	276.9	228.7	220.6	186	163.8
(	2	0.4	0.3	0.3	0.2	0	0	0	0	0	1	3.6	3.7	0
	5	0.7	0.6	0.6	0.5	0.1	0	0	0.3	8.8	10.4	18.3	13.7	7.5
	10	0.9	0.8	0.8	0.7	0.3	0.4	1.8	4.2	20.9	16.6	31.3	20.1	16.3
	20	1.1	1	5.4	10.9	15.8	16.1	25.4	19.9	39.8	29.2	42.9	32	32.8

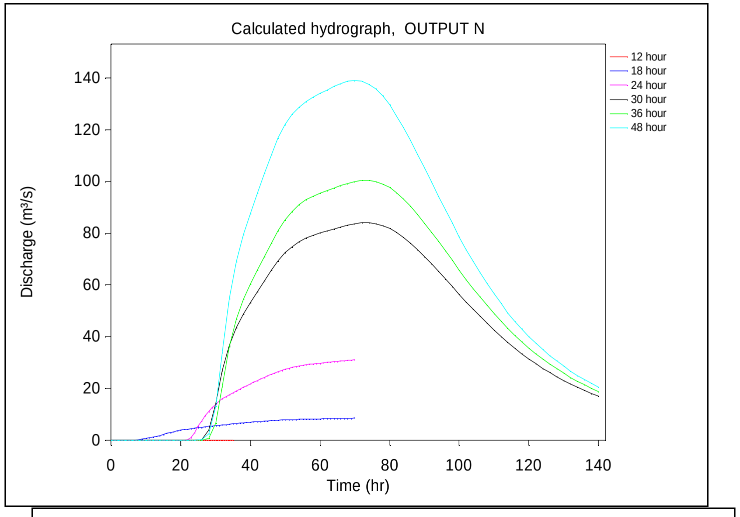
Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	50	51.8	57.1	58.2	58.6	58.7	61.3	66	66.9	77.2	69.3	67.4	55.9	49.6
	100	87.9	90.7	89.8	86.8	88.1	92.3	97.9	100.5	111.5	96.1	88.5	74.7	68.3
	1000	212.6	203.5	198.5	208.7	227.4	238.3	242.5	233.6	235.4	184.3	173.4	149.4	136.3
	3000	242.8	278.8	285.8	242.6	296.1	281.2	316.1	278.5	285.2	219	235.2	180	172.8
)	2	0.3	0.2	0.2	0.1	0	0	0	0	0	0.7	2.7	2.9	0
	5	0.4	0.4	0.4	0.3	0.1	0	0	0.2	6.9	8.1	13.1	10.4	5.1
	10	0.5	0.5	0.5	0.5	0.2	0.3	1.5	3.2	16	11.9	21.4	14.1	10.8
	20	0.7	0.6	3.6	8.1	12.5	13.1	19.1	14.8	27.3	16.6	28.1	19.5	17.9
	50	36.9	42.9	45.6	47.8	47	45.2	45.7	38.7	40.1	30.8	35.3	26	23.3
	100	64.3	69.7	71.8	71	68.6	64.3	62	53.7	49.4	48.3	42.1	34.2	28.5
	1000	162.7	165.3	162.6	153.4	139.2	129.7	110.7	112.9	82	104.6	74.3	81.4	62.6
	3000	186.6	227.7	234.2	176.4	176.2	149.8	141.2	130.8	97.7	121.2	94.2	95.7	75.6
-	2	0.2	0.1	0.2	0.1	0	0	0	0	0	0.7	3.6	3.4	0
	5	0.4	0.3	0.4	0.3	0.1	0	0	0.2	7.9	9.2	19.8	14.2	7.6
	10	0.5	0.4	0.5	0.4	0.2	0.3	1.7	3.6	18.6	15.4	34.1	21.1	16.5
	20	0.6	0.6	3.3	8.1	13.8	15.9	21.9	21.4	38.9	27.7	46.7	34.1	34.8
	50	33.3	38.8	41.7	55.7	61.8	66.2	69.5	70.8	77.1	73.9	70.2	58	51.2
	100	58	63.3	66	86.6	95.1	99.8	104.2	106.3	111.5	105.6	90.6	77.2	69.4
	1000	164.3	181.7	194	223.1	240.6	250.9	257.5	260.8	251.4	208.4	189.6	157.9	148.9
	3000	190.3	257.8	290.5	259.5	312.2	295.9	341.8	312.6	305.7	250.7	259.7	203.3	193.2
=	2	0.7	0.5	0.5	0.3	0	0	0	0	0	3.5	22.4	21.1	0
	5	1.1	1	1	0.9	0.3	0.2	0	0.5	41.1	45.8	108.6	77.6	50.2
	10	1.4	1.3	1.3	1.2	0.5	0.8	4.8	9.9	100.4	81.7	186.6	116.5	113
	20	1.7	1.6	9.5	22.7	38.4	43.1	58.4	52.1	214.5	161.6	257.5	195.1	232.9
	50	100.6	121.6	135.4	152.9	161.2	225.5	227.2	228	443.6	457	452.8	420	391.5
	100	178.7	202.8	219.7	234.9	240.5	371.1	378.2	381	664.5	667.1	654.6	623	577.3

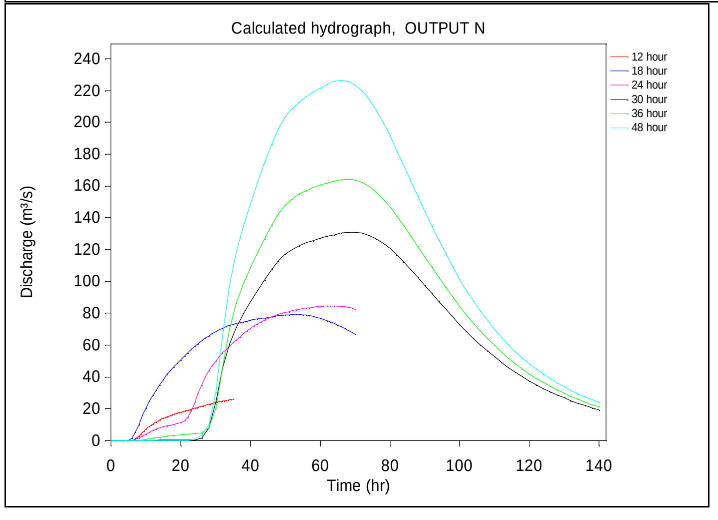
Output Node	ARI	Durations (hr)												
		1	1.5	2	3	4.5	6	9	12	18	24	36	48	72
	1000	516.9	562.1	583.6	738.9	778.5	1537	1631	1686	1824	1798	1520	1435	1343
	3000	594.7	781.6	847.9	903.3	1101	1815	2173	2045	2247	2235	2090	1866	1740

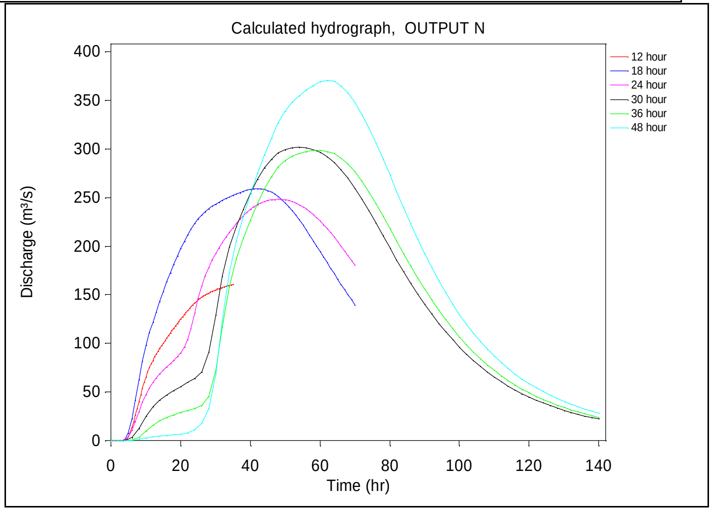
Areal Reduction Factor

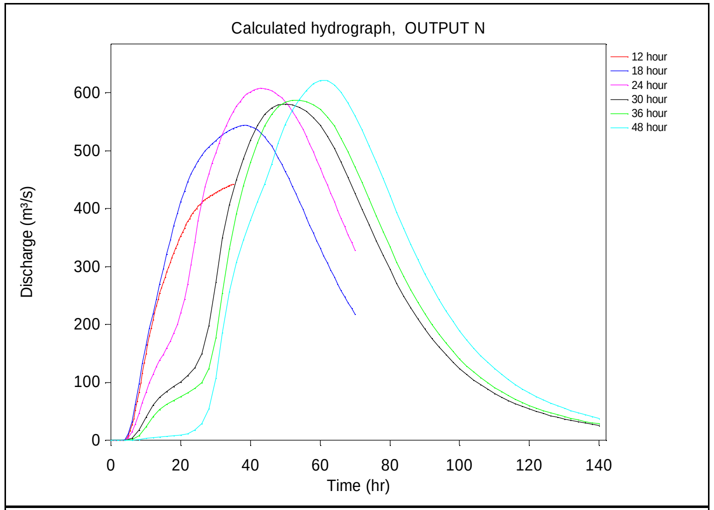
Duration (hours)	Areal Reduction Factor
24	0.83259
48	0.88510
72	0.90826
96	0.92200
120	0.931340

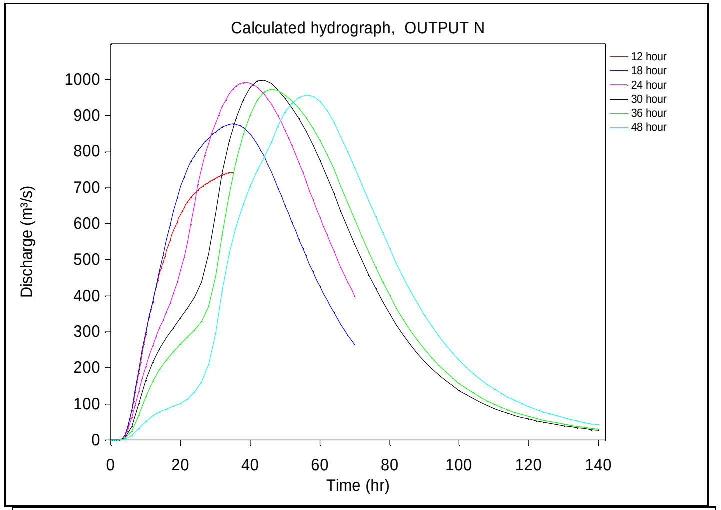

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour

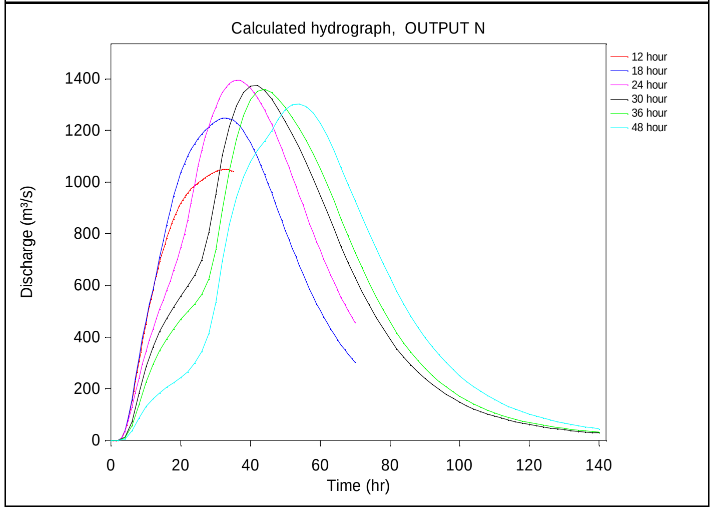

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour

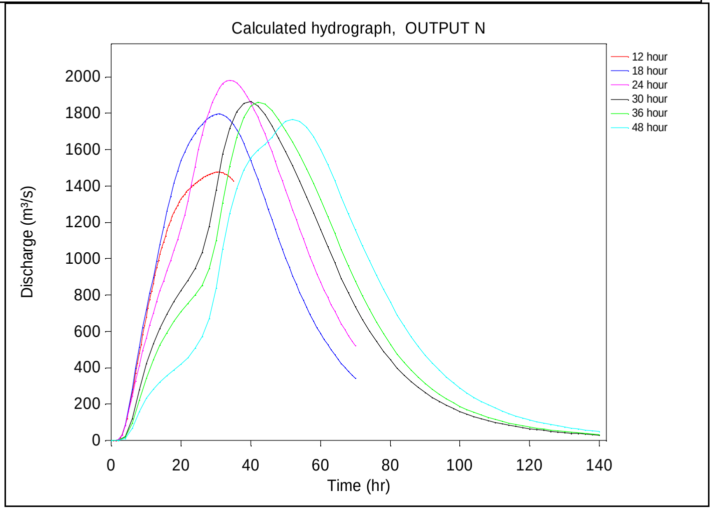

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour

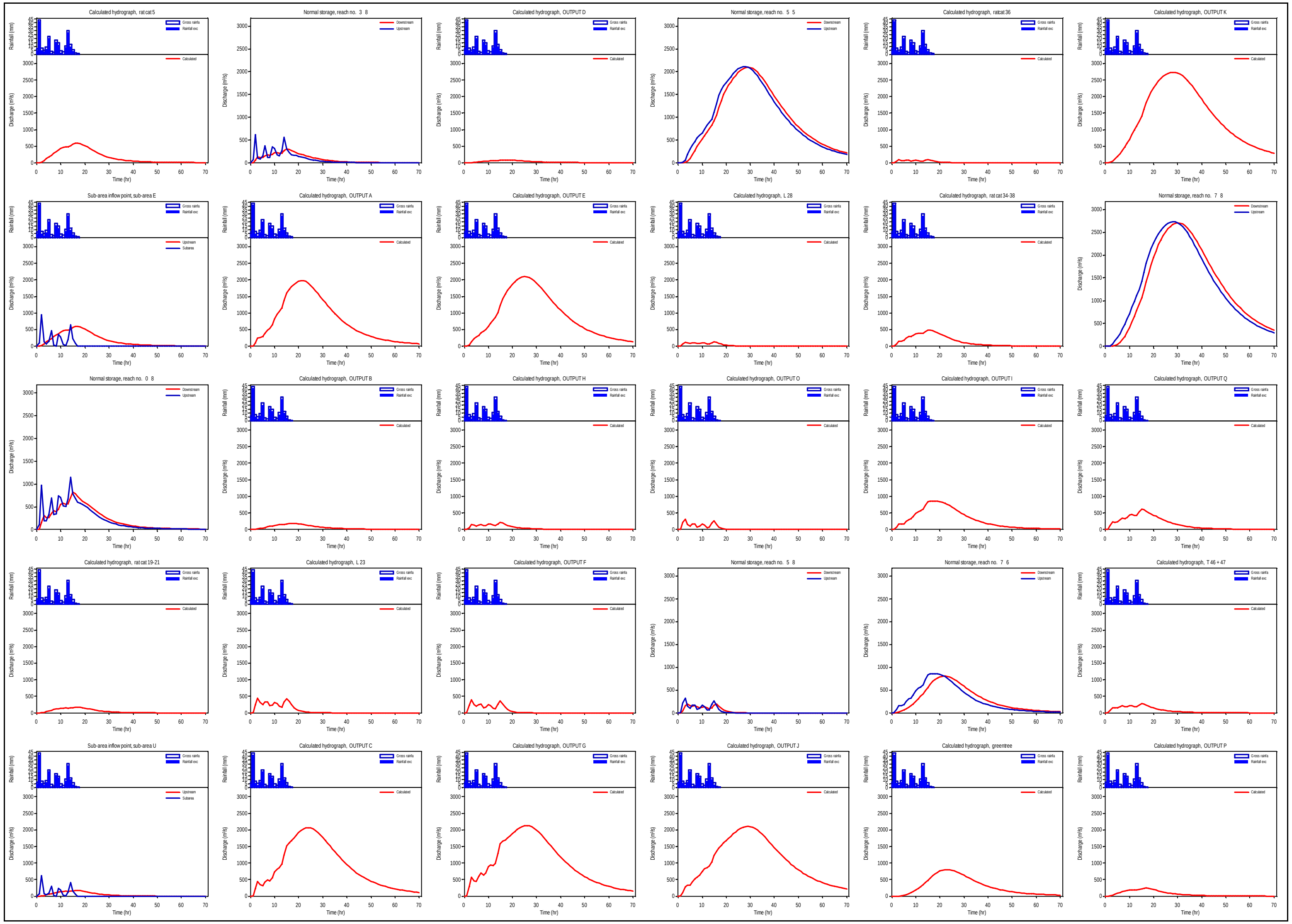

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour

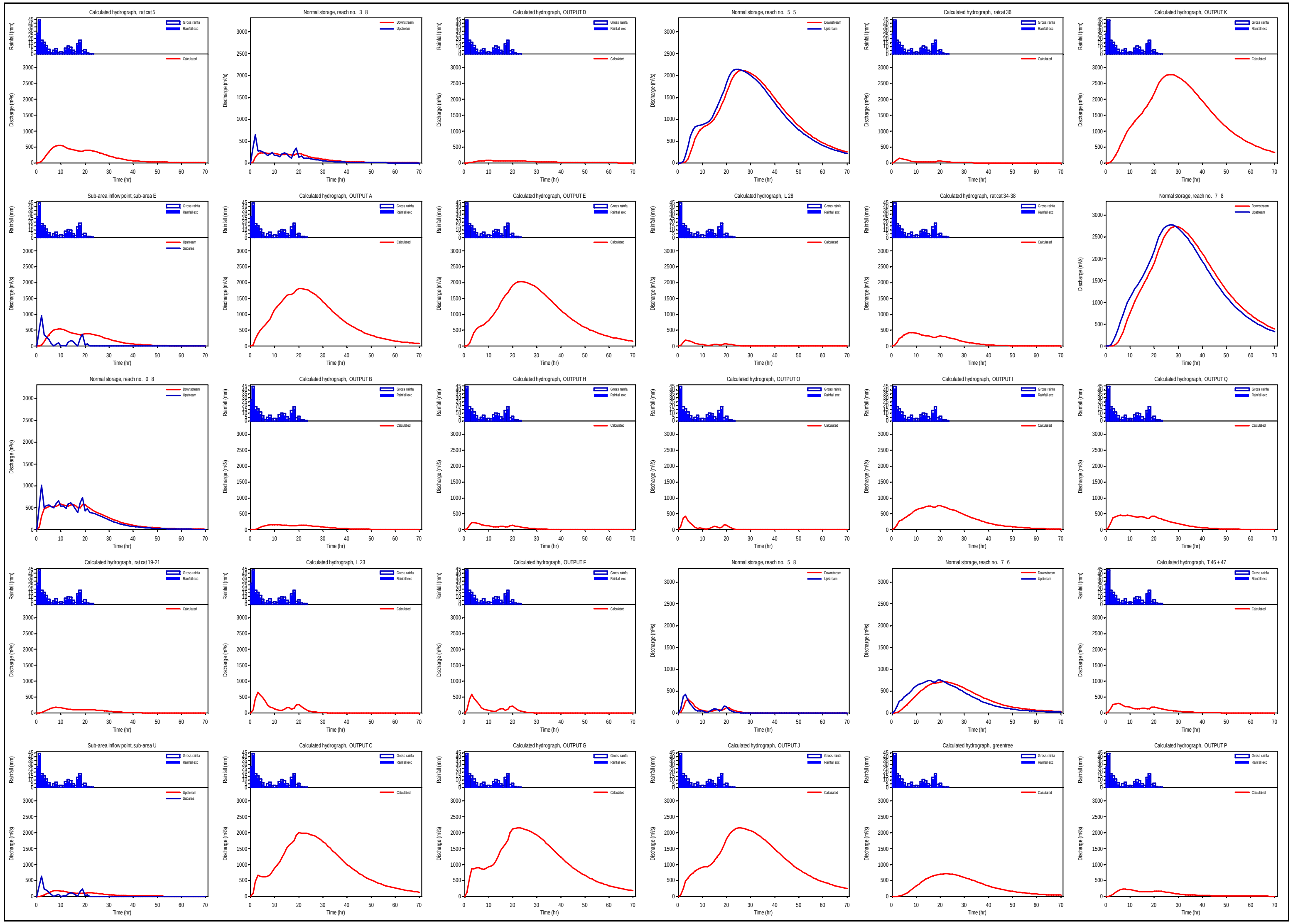

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour

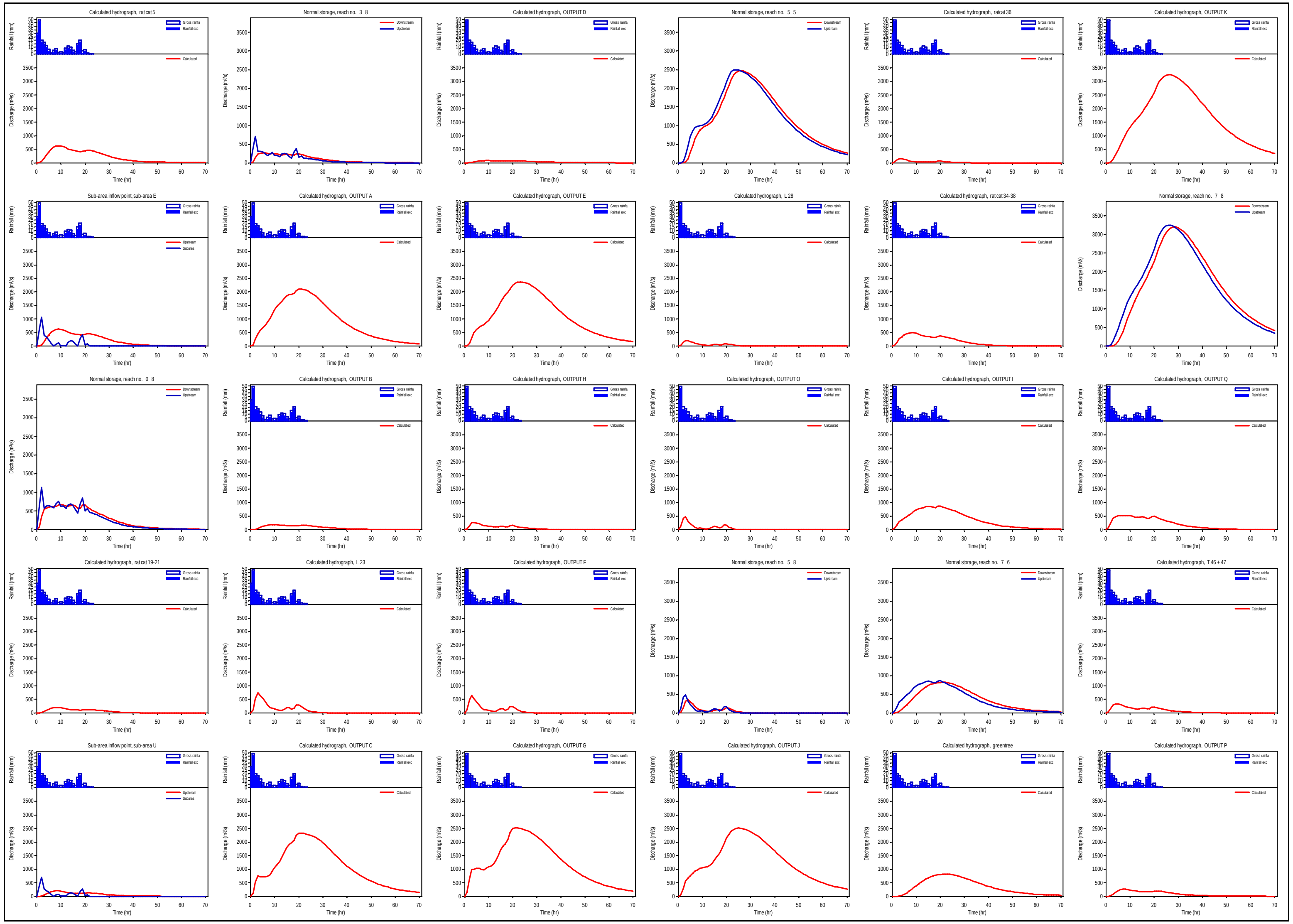

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour

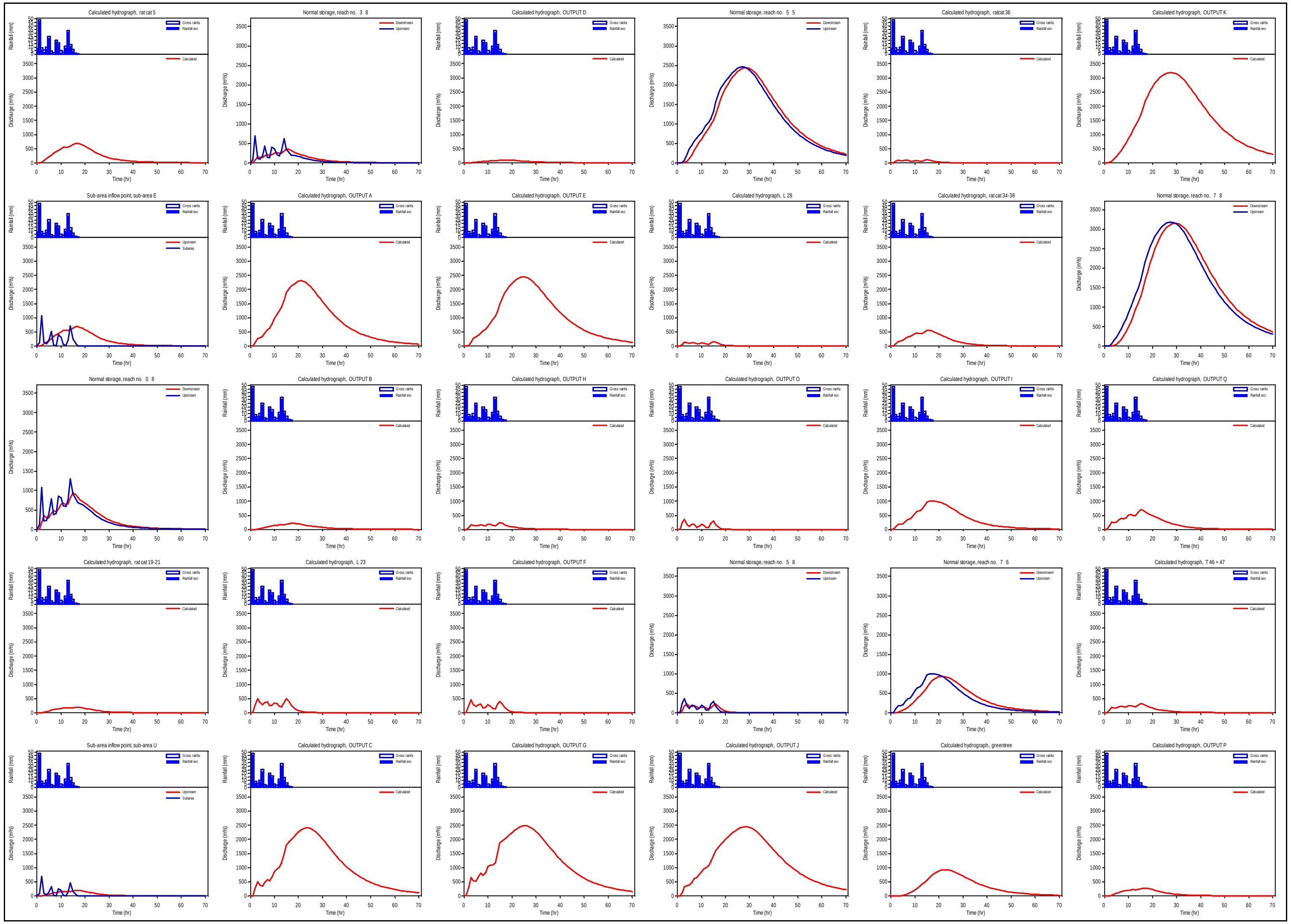

Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour


Calculated hydrograph, OUTPUT N
Discharge (m³/s)
Time (hr)
12 hour
18 hour
24 hour
30 hour
36 hour
48 hour


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, 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


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, 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
Rainfall (mm)
Discharge (m³/s)
Time (hr)

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Normal storage, reach no. 3 8
Calculated hydrograph, OUTPUT D
Normal storage, reach no. 5 5
Calculated hydrograph, rafcat 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, rafcat 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, rafcat 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

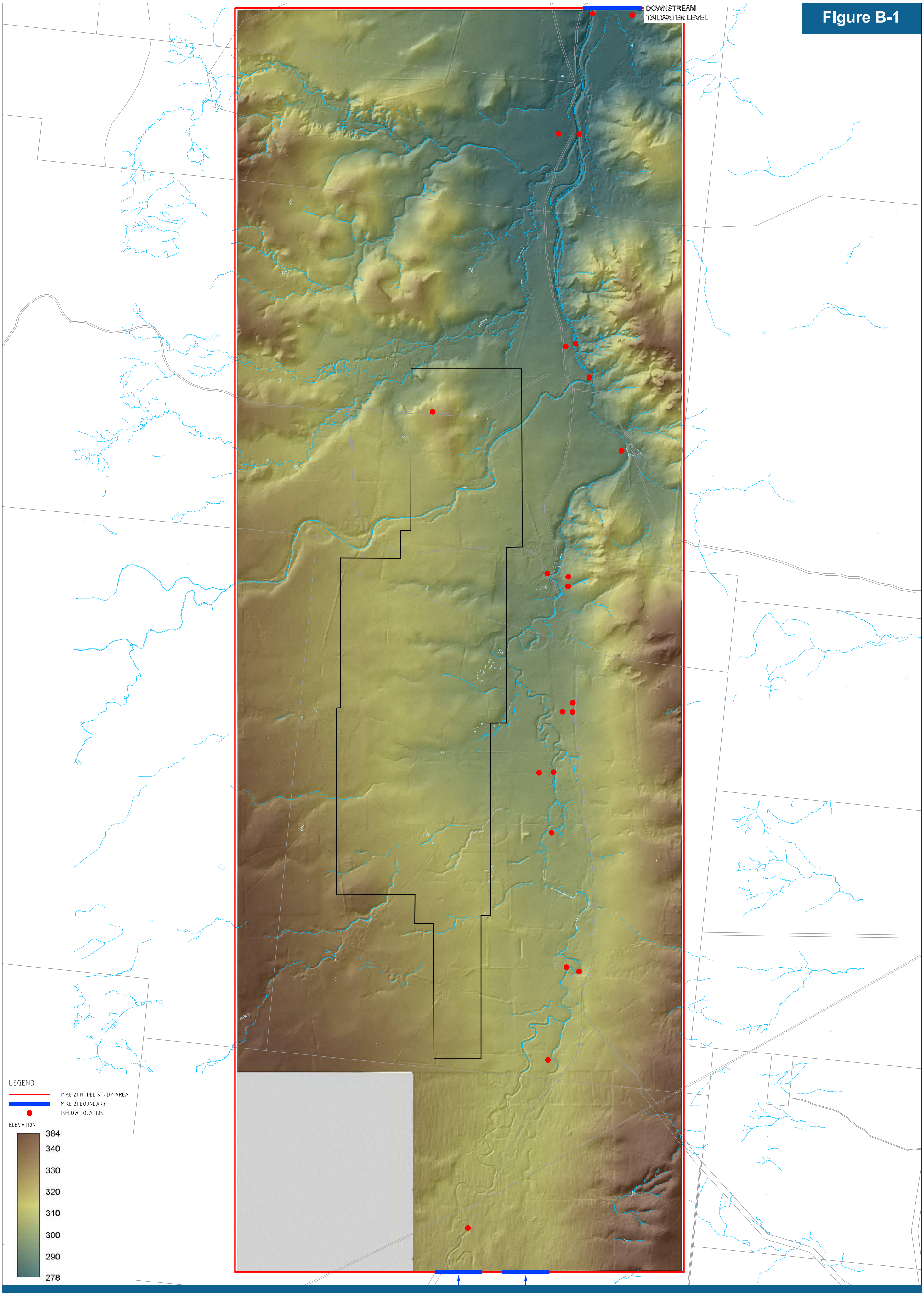
Appendix B

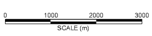
2D Hydraulic Assessment using MIKE21

Appendix B – 2D Hydraulic Assessment using MIKE21

Figure Number	Description
B-1	Mike21 Model layout- Developed case
B-2	Roughness-Photos
B-3	Roughness-Map- Existing case
B-4	Long Section 1000 year and 3000 year ARI -Existing Case
B-5	1000 year ARI Velocity- Existing case Sheet1/2
B-6	1000 year ARI Velocity- Existing case Sheet 2/2
B-7	Long Section 1000 year and 3000 year ARI - Developed case
B-8	1000 year ARI Velocity- Developed case Sheet1/2
B-9	1000 year ARI Velocity- Developed case Sheet 2/2
B-10	Longitudinal velocity profiles for the Existing and Developed Cases for 1000 year ARI
B-11	1000 year ARI flood level profiles for varying tailwater levels
B-12	1000 year ARI velocity profiles for varying tailwater levels

Figure B-1





PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

MIKE 21 MODEL LAYOUT

August 20, 2010

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)

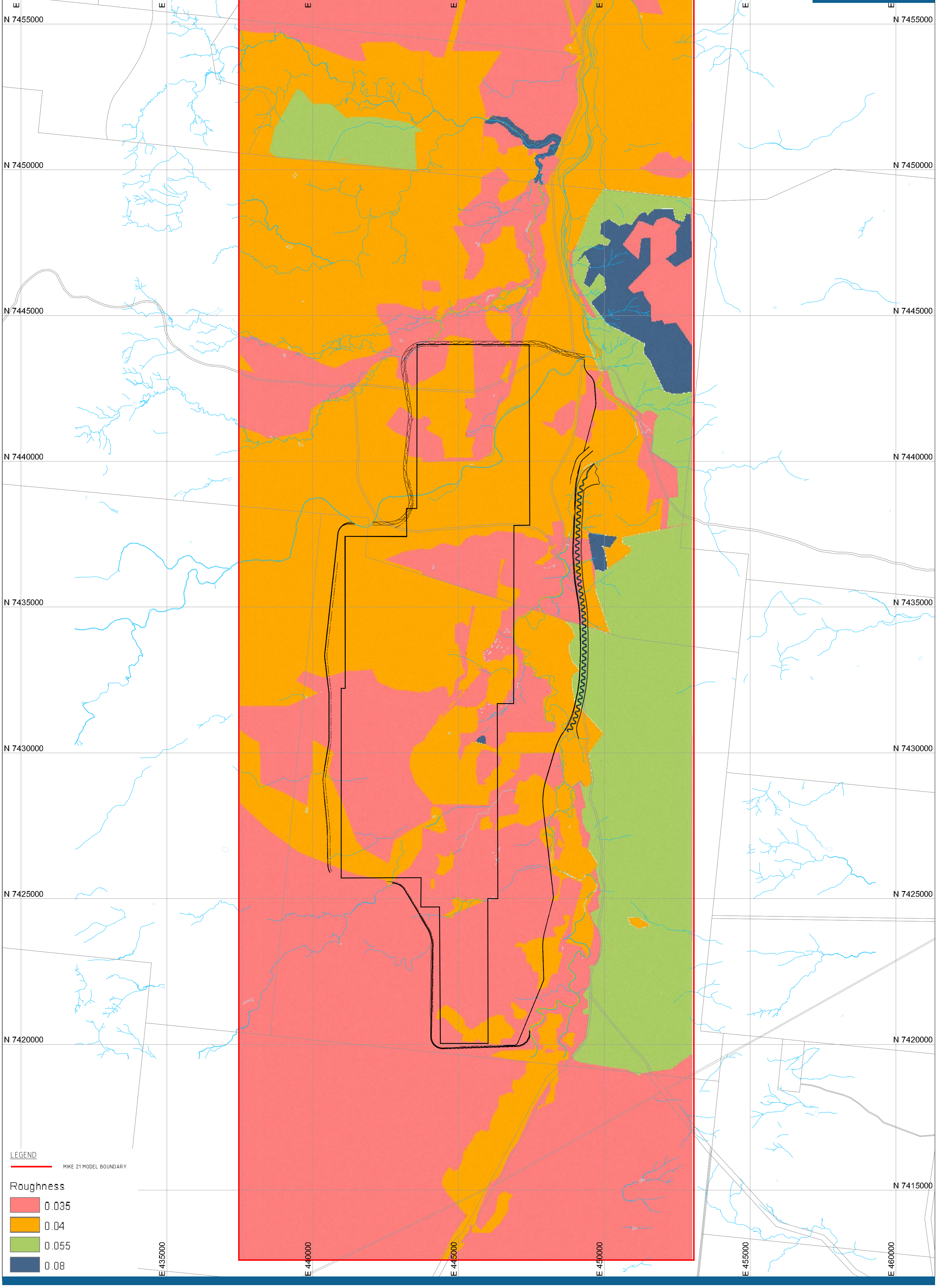
Plate 3: Medium vegetation (roughness = 0.055)
Background trees in Lagoon Creek (23.239 S, 146.498 E)

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)

Figure B-3



PARSONS BRINCKERHOFF

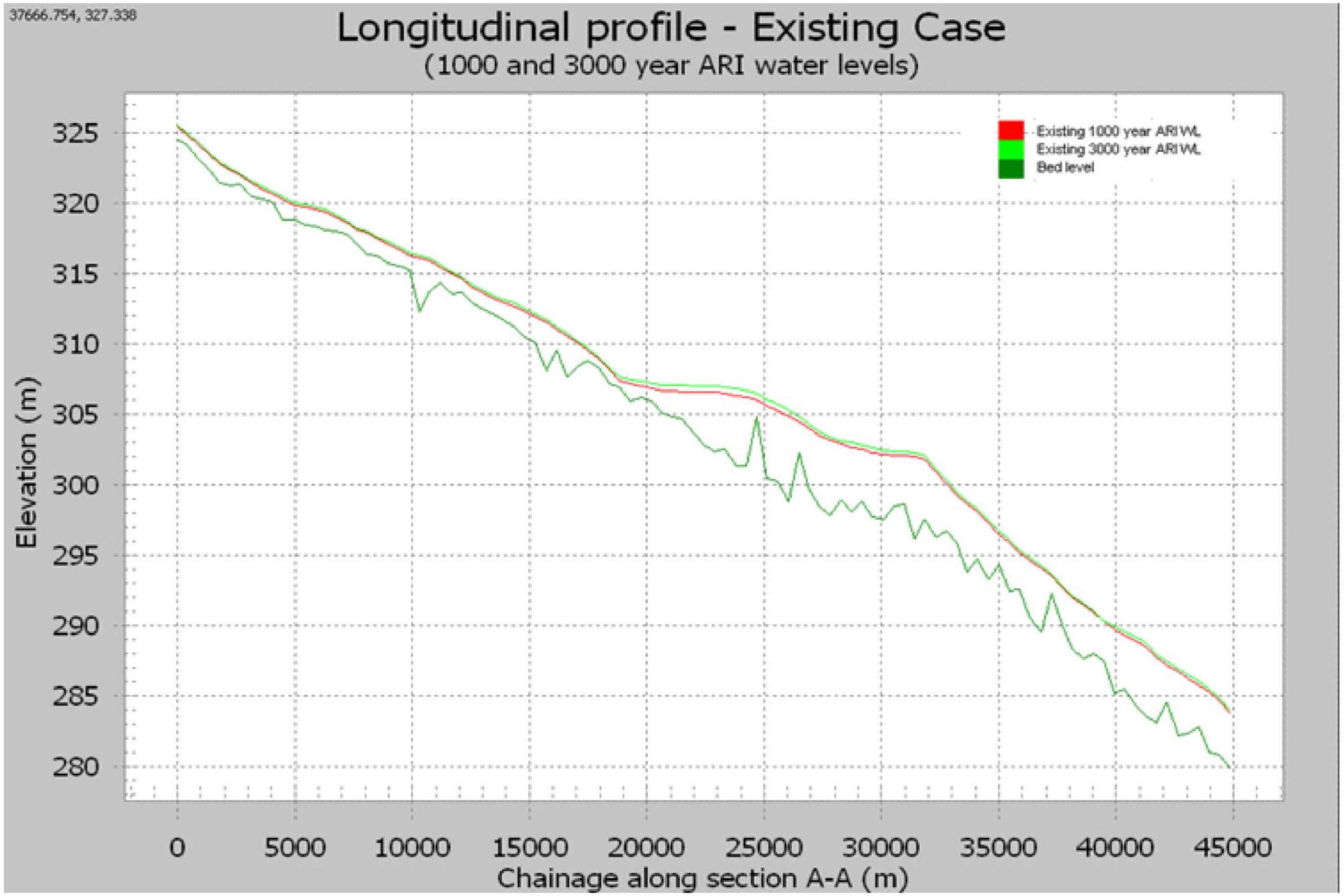
0 1000 2000 3000
SCALE (m)

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

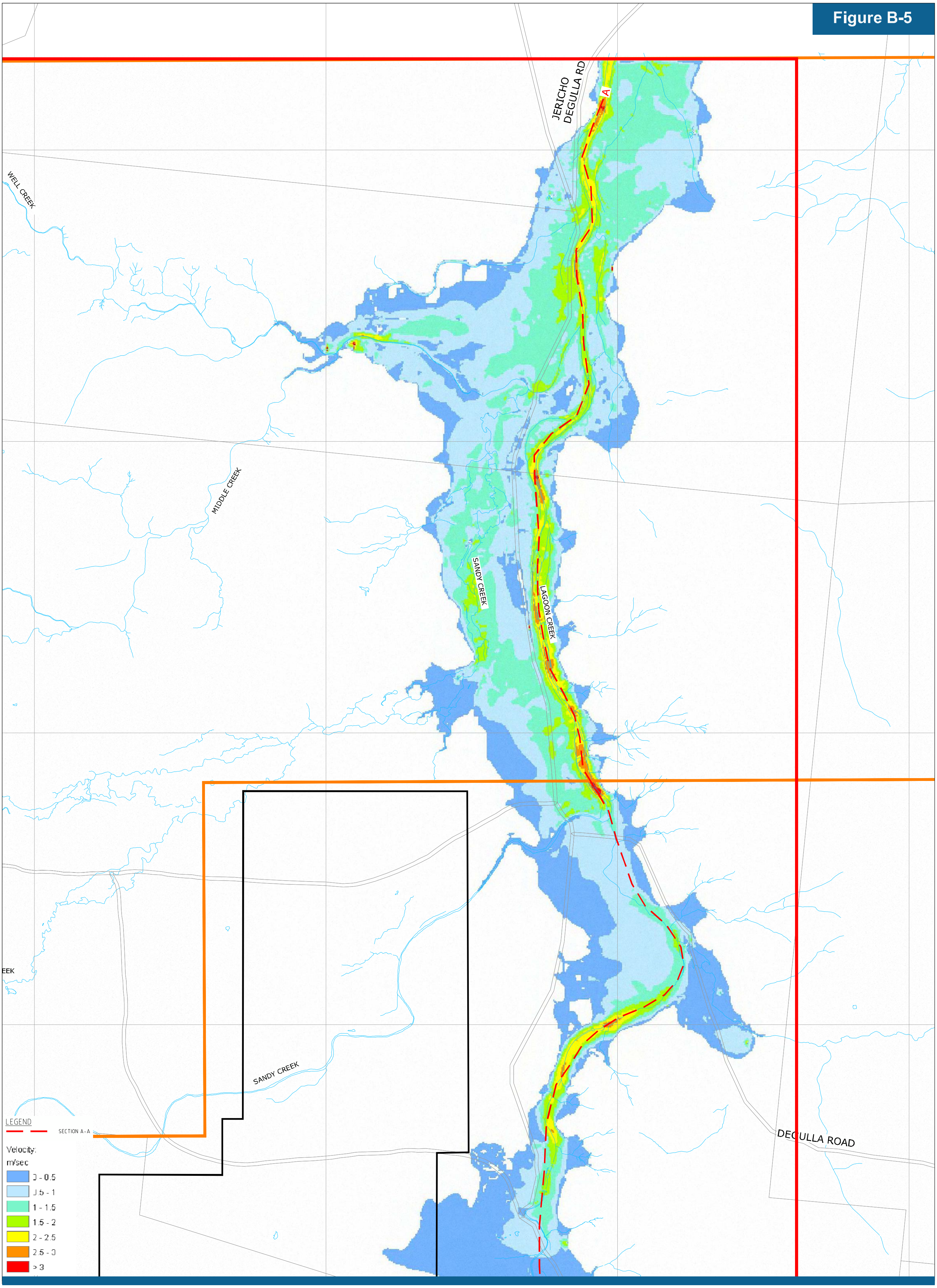


PARSONS BRINCKERHOFF

ALPHA COAL PROJECT
LONG SECTION 1000 AND 3000 YEAR ARI
EXISTING CASE

August 20, 2010

Figure B-5



PARSONS BRINCKERHOFF

0 200 400 800 1200
Full Size 1:20000 ; Half Reduction 1:40000
SCALE (m)

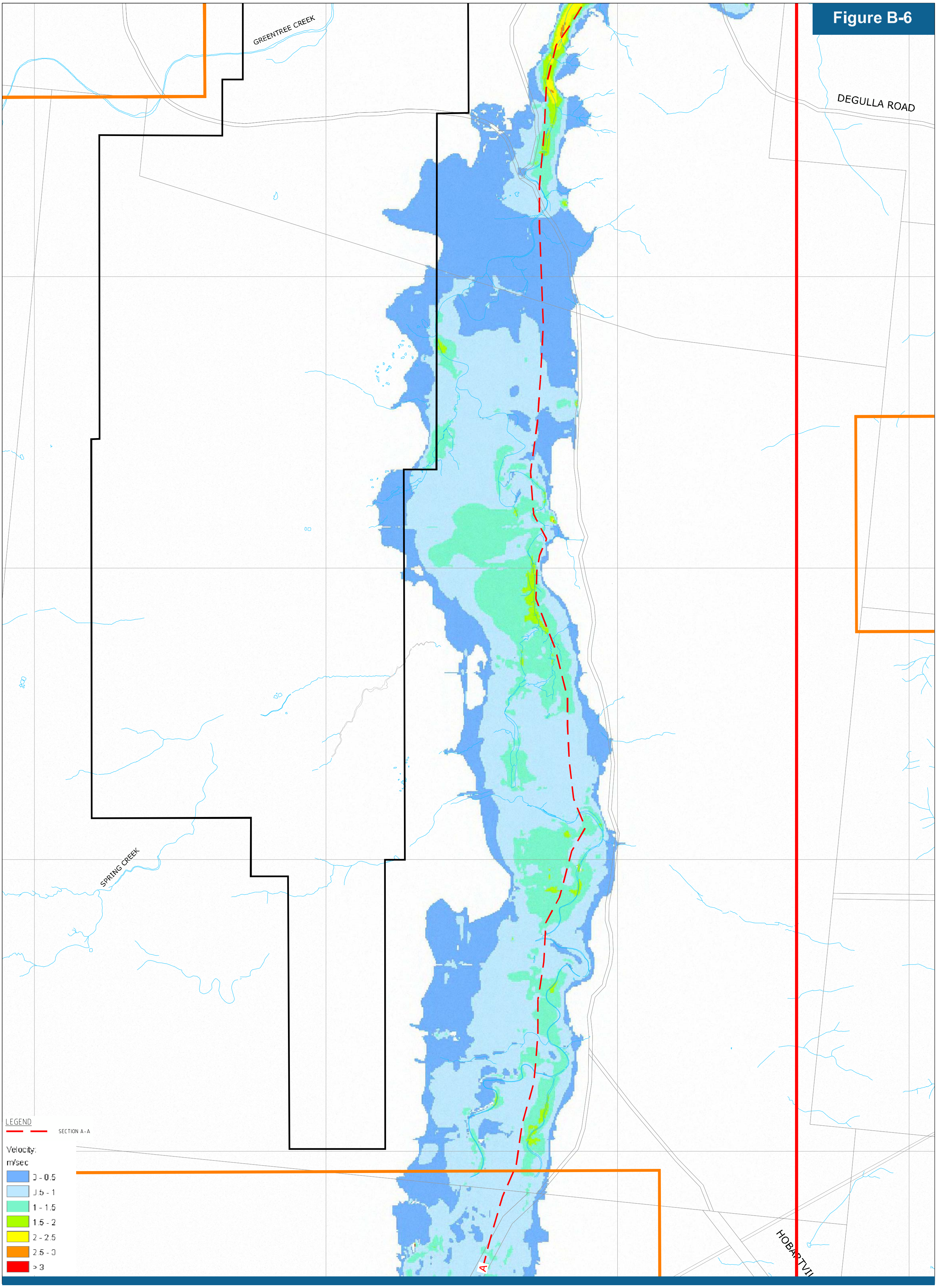
ALPHA COAL PROJECT

1000 YEAR ARI VELOCITY
EXISTING CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 16:25 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1048_1000 Year ARI Exist Velocity 1 of 2.dwg

Figure B-6



PARSONS BRINCKERHOFF

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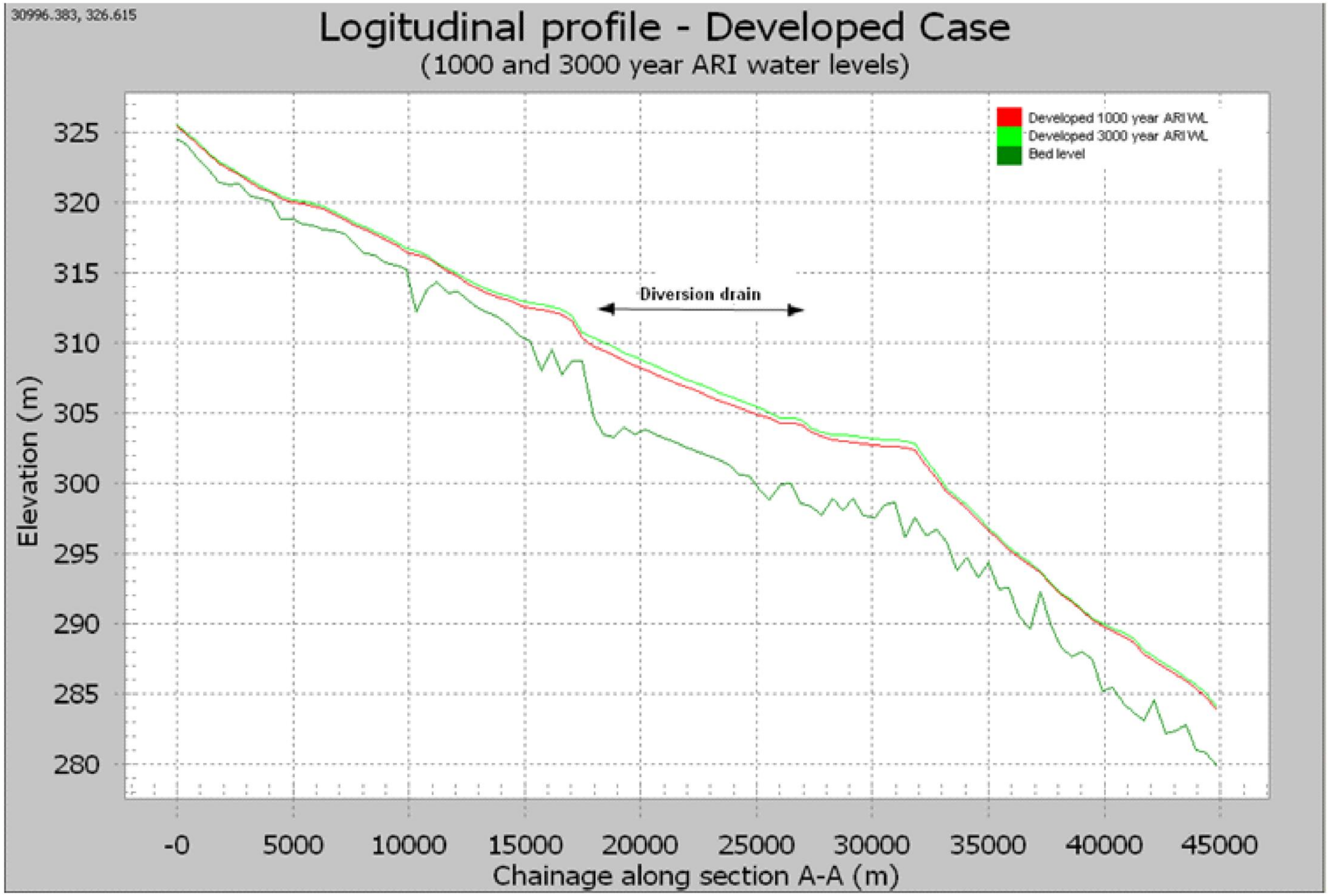
Full Size 1:20000 ; Half Reduction 1:40000
SCALE (m)

ALPHA COAL PROJECT

1000 YEAR ARI VELOCITY
EXISTING CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 16:25 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1049_1000 Year ARI Exist Velocity 2 of 2.dwg



PARSONS BRINCKERHOFF

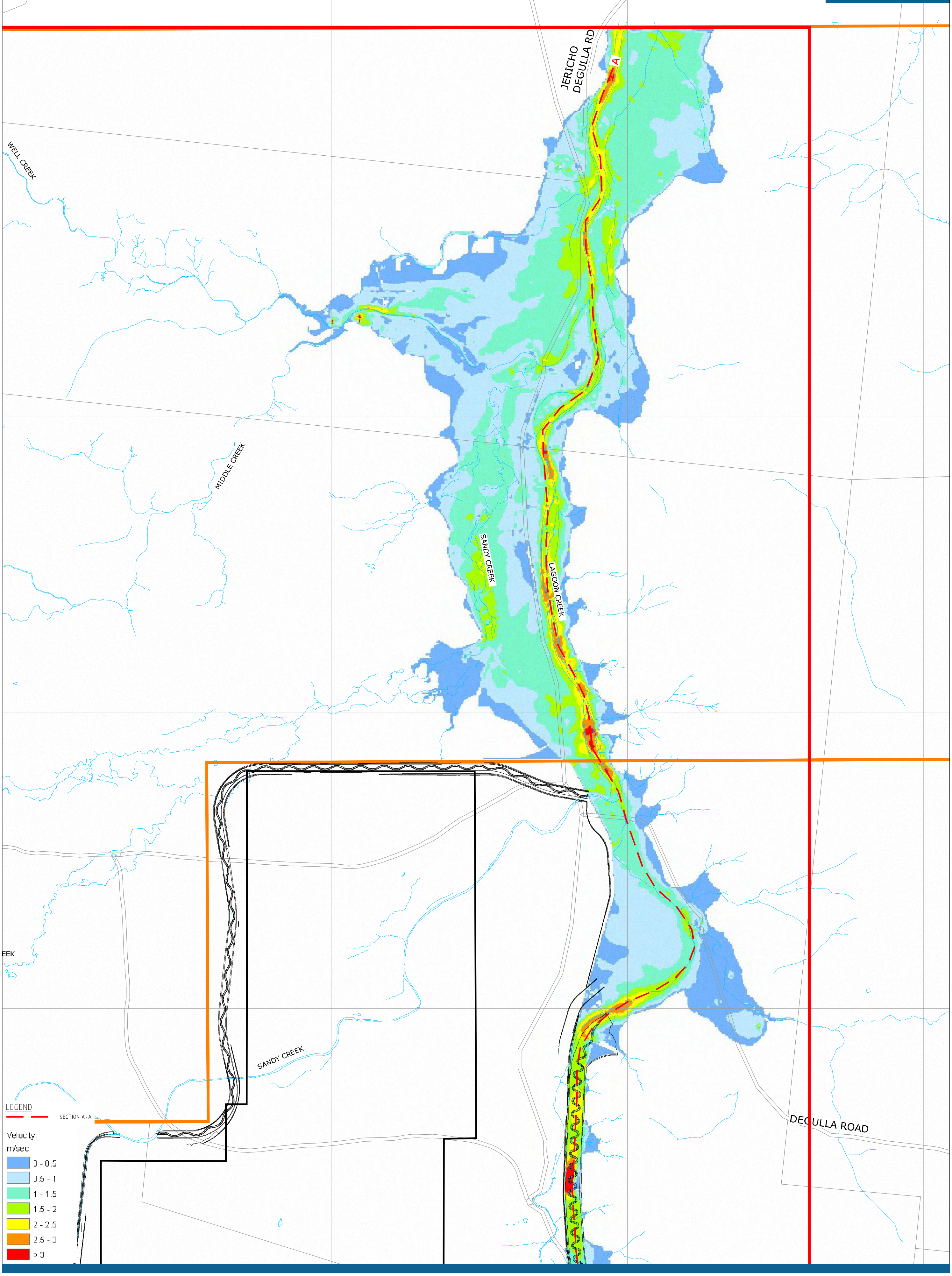
ALPHA COAL PROJECT

LONG SECTION 1000 AND 3000 YEAR ARI

DEVELOPED CASE

August 20, 2010

Figure B-8



PARSONS BRINCKERHOFF

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Full Size 1:20000 ; Half Reduction 1:40000
SCALE (m)

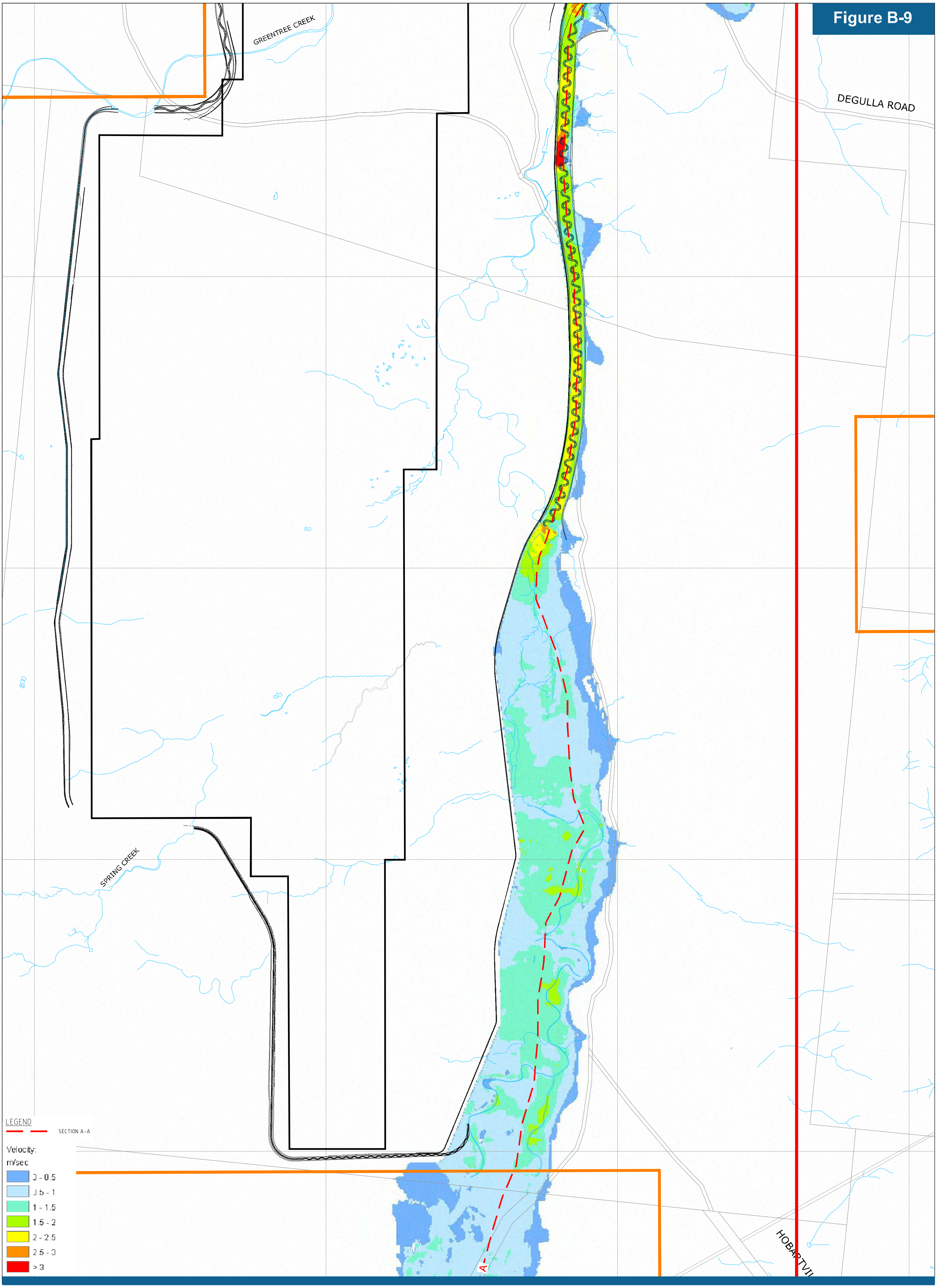
ALPHA COAL PROJECT

1000 YEAR ARI VELOCITY
DEVELOPED CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 16:26 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1035_1000 Year ARI Developed Velocity 1 of 2.dwg

Figure B-9



PARSONS BRINCKERHOFF

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Full Size 1:20000 ; Half Reduction 1:40000
SCALE (m)

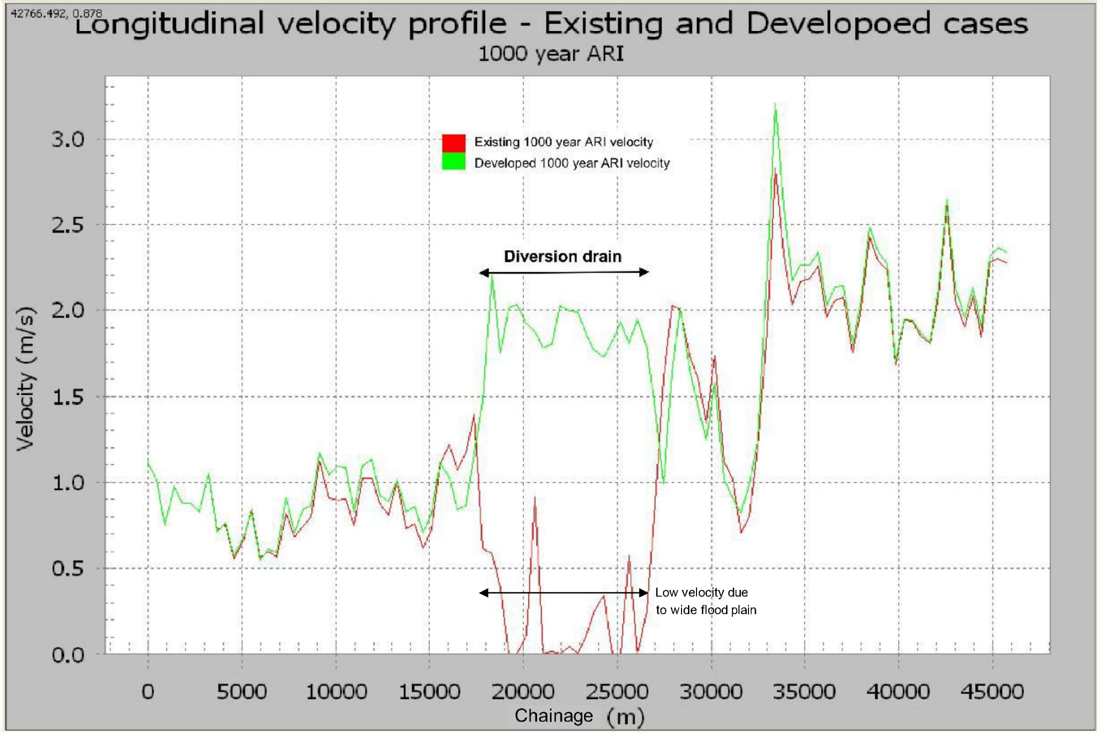
ALPHA COAL PROJECT

1000 YEAR ARI VELOCITY
DEVELOPED CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 16:27 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1036_1000 Year ARI Developed Velocity 2 of 2.dwg

Figure B-10



PARSONS BRINCKERHOFF

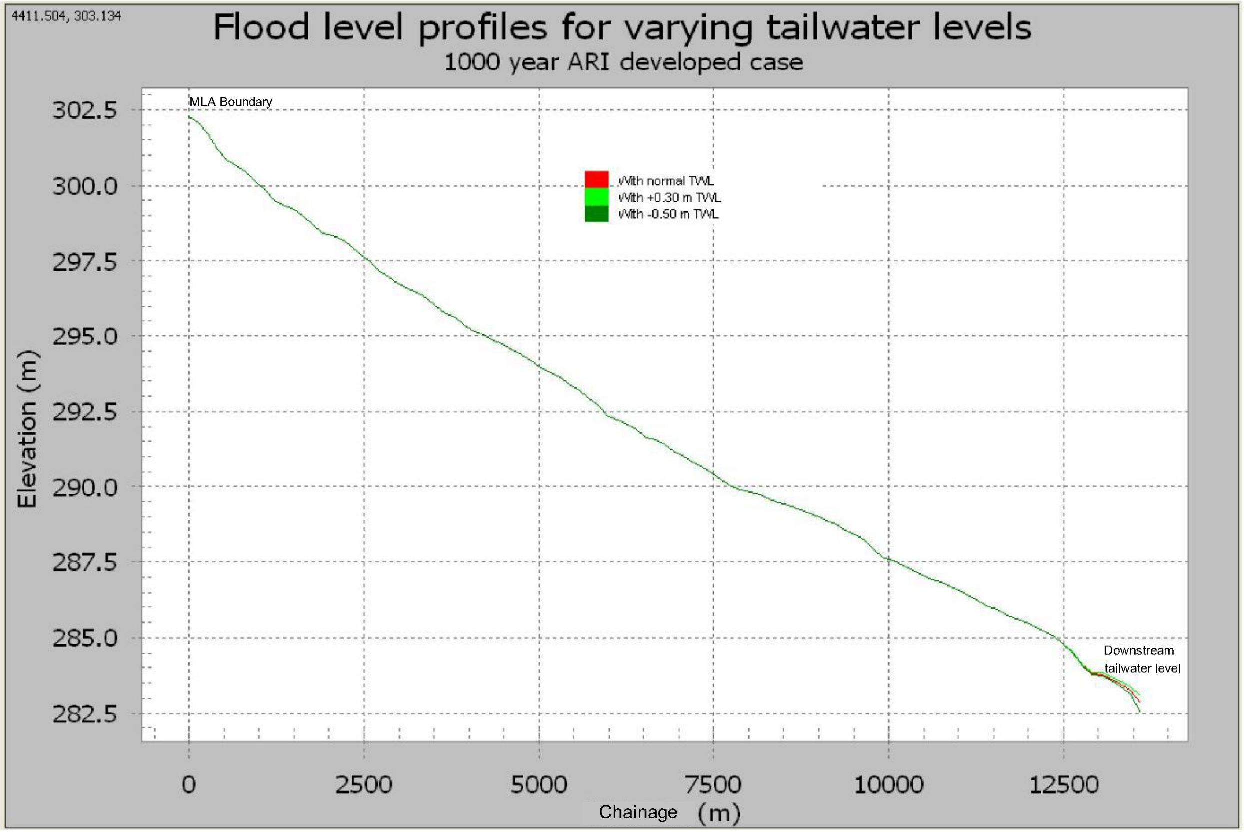
ALPHA COAL PROJECT

LONG VELOCITY PROFILES FOR 1000 YEAR ARI
EXISTING AND DEVELOPED CASE

August 20, 2010

Plotted By: hamillm Plot Date: 15/09/10 - 14:37 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1056_WM Long Section 1000 ARI EXISTING AND DEVELOPED CASES.dwg

Figure B-11



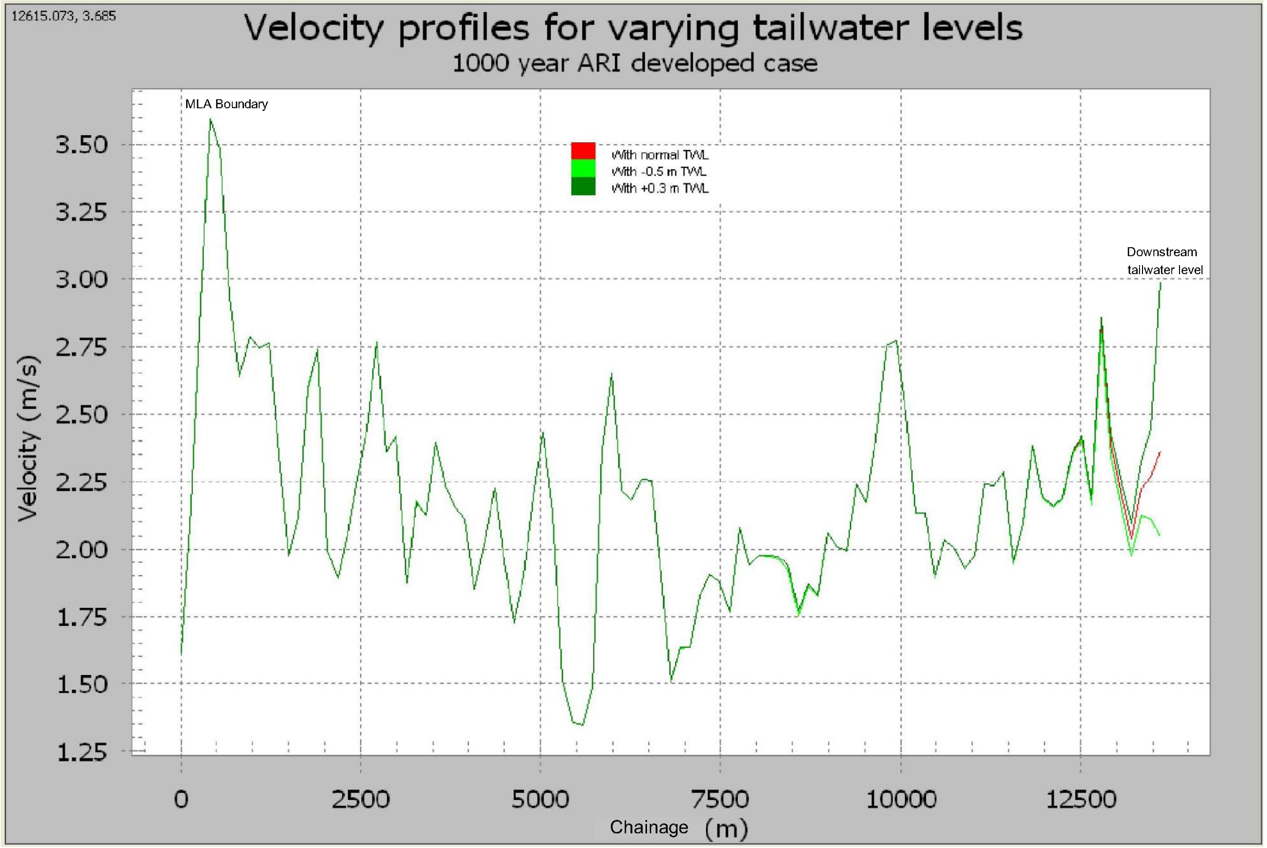
PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

FLOOD LEVEL PROFILES FOR VARYING TAILWATER LEVELS
1000 YEAR ARI DEVELOPED CASE

August 20, 2010

Figure B12



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ALPHA COAL PROJECT

VELOCITY PROFILES FOR VARYING TAILWATER LEVELS
1000 YEAR ARI DEVELOPED CASE

August 20, 2010

Appendix C

1D Hydraulic Assessment using HECRAS

Appendix C – 1D Hydraulic Assessment using HECRAS

HEC-RAS model

A one-dimensional steady state hydraulic model of the proposed Lagoon Creek was developed using the US Army Corps of Engineers' Hydrologic Engineering Centre River Analysis System (HEC-RAS). The HEC-RAS model is designed to perform one-dimensional steady and unsteady flow river hydraulics computations for a full network of natural and constructed channels. The cross-section geometry point elevations have been extracted from the digital terrain model (DTM) of the Alpha Coal Mine. Other inputs include the Manning's roughness coefficient (n), flow data and model boundary conditions.

Full details of the HEC-RAS model setup and results are presented in the geomorphology technical report.

Model development

The 22 km extent of the HEC-RAS model was chosen to establish design flood levels throughout the MLA, and in the vicinity of the proposed creek diversion of the Lagoon Creek floodplain.

The HEC-RAS model covers the full extent of available topographical data spanning from the upstream MLA boundary (South) to 12 km downstream of the MLA (north). Using the full available data extent for the HEC-RAS model ensures that boundary effects do not impact on model results in the immediate vicinity of the mine site.

The HEC-RAS model was predominantly used to model the smaller 2 years and 50 years ARI events for creek diversions and diversion drains. For this assessment the flooding environment for both the existing and the developed cases were investigated.

Results

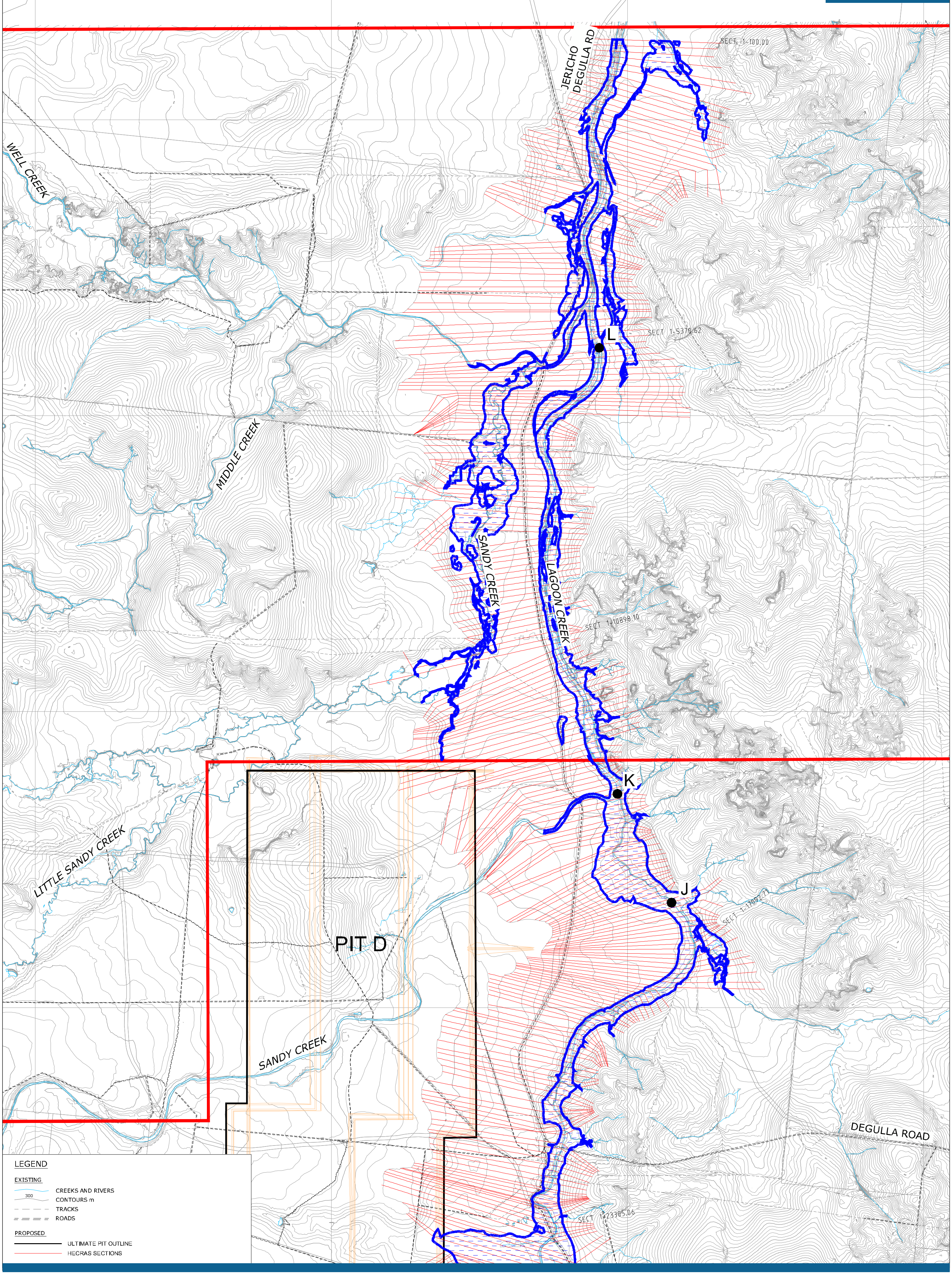
The Figures presented in this Appendix provide details of the results of the HEC-RAS hydraulic assessment. The following Figures are included:

Figure C-1	Existing 50 year ARI flood extent and HECRAS cross sections Sheet 1/2
Figure C-2	Existing 50 year ARI flood extent and HECRAS cross sections Sheet 2/2
Figure C-3	Developed case Existing 50 year ARI flood extent and HECRAS cross sections Sheet 1/2
Figure C-4	Developed case Existing 50 year ARI flood extent and HECRAS cross sections Sheet 2/2
Figure C-5	Typical cross sections at creeks and diversion channels Sheet 1/2
Figure C-6	Typical cross sections at creeks and diversion channels Sheet 1/2

Tabulated results of the HEC-RAS assessment for the 50 year ARI is included.

Interpretation of the results is included in the geomorphology Technical report.

Figure C-1



PARSONS BRINCKERHOFF

0 200 400 800 1200
Full Size 1:20000 | Half Reduction 1:40000
SCALE (m)

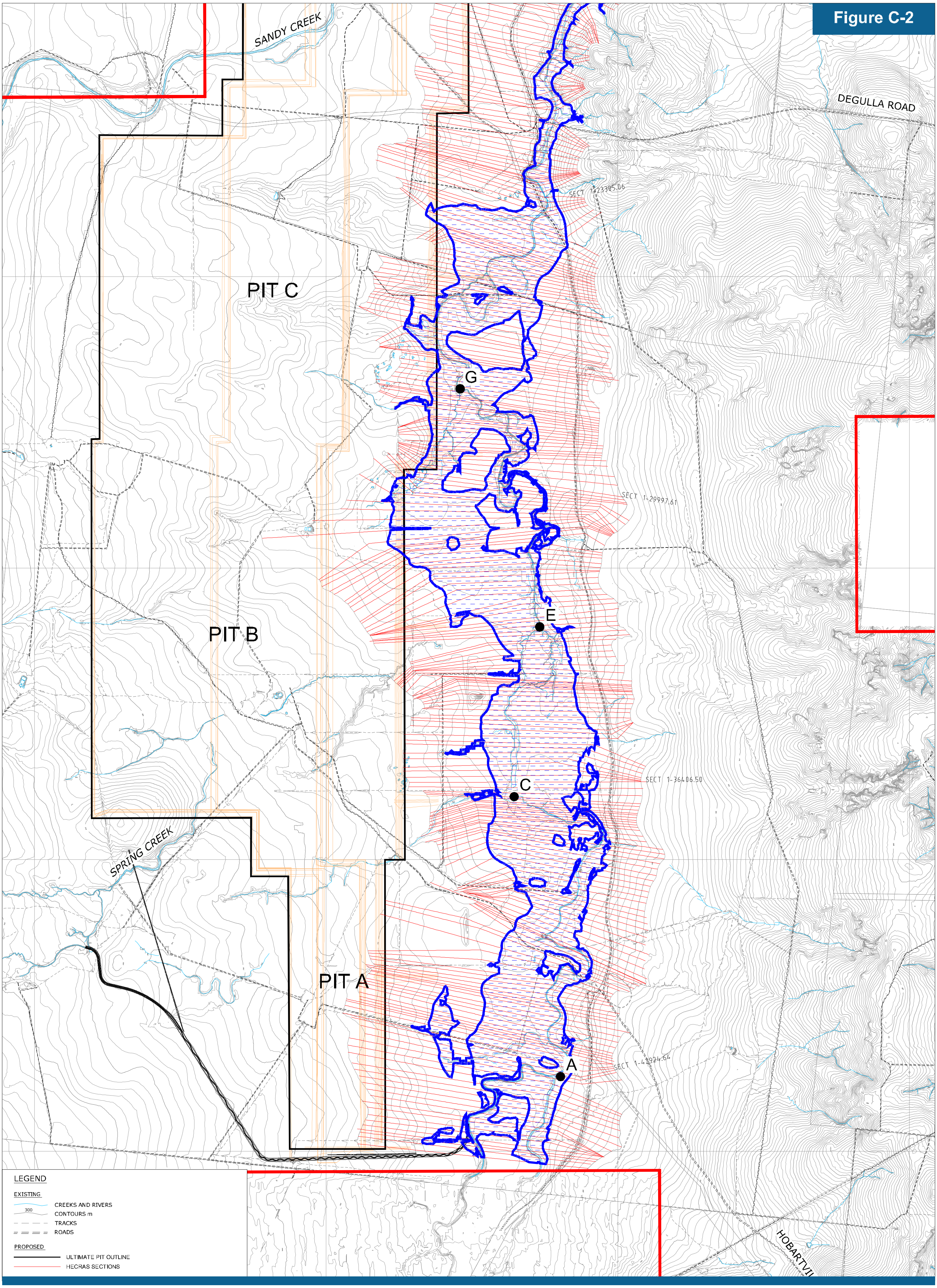
ALPHA COAL PROJECT

EXISTING 50 YEAR ARI FLOOD EVENT
AND HECRAS SECTIONS SHEET 1 OF 2

August 20, 2010

Plotted By: hamillm Plot Date: 20/08/10 - 09:35 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1018_WM Hecras Sections Existing 1 of 2.dwg

Figure C-2



PARSONS BRINCKERHOFF

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Full Size 1:20000 ; Half Reduction 1:40000
SCALE (m)

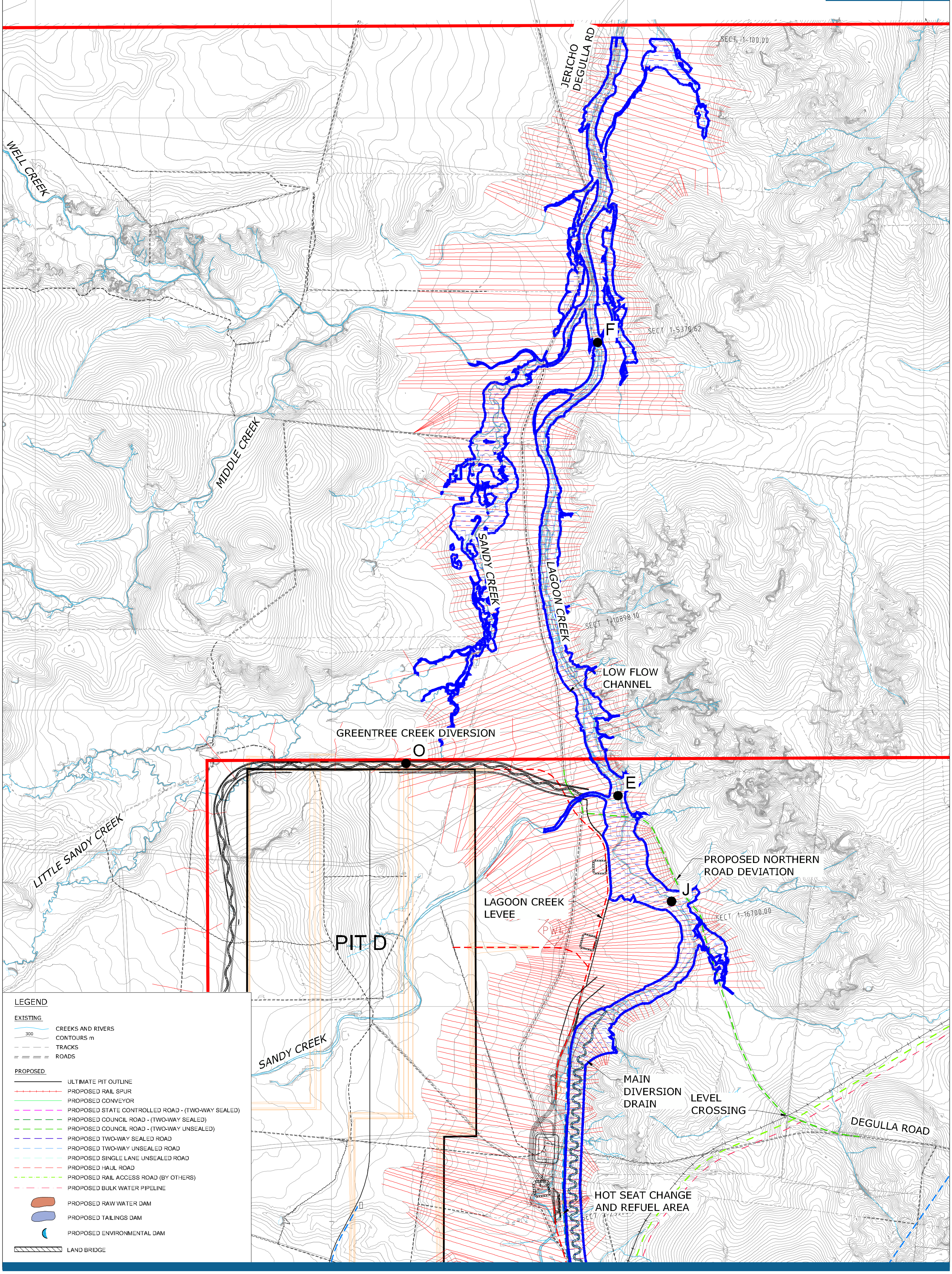
ALPHA COAL PROJECT

EXISTING 50 YEAR ARI FLOOD EVENT
AND HECRAS SECTIONS SHEET 2 OF 2

August 20, 2010

Plotted By: hamillm Plot Date: 20/08/10 - 09:35 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1019_WM Hecras Sections Existing 2 of 2.dwg

Figure C-3



PARSONS BRINCKERHOFF

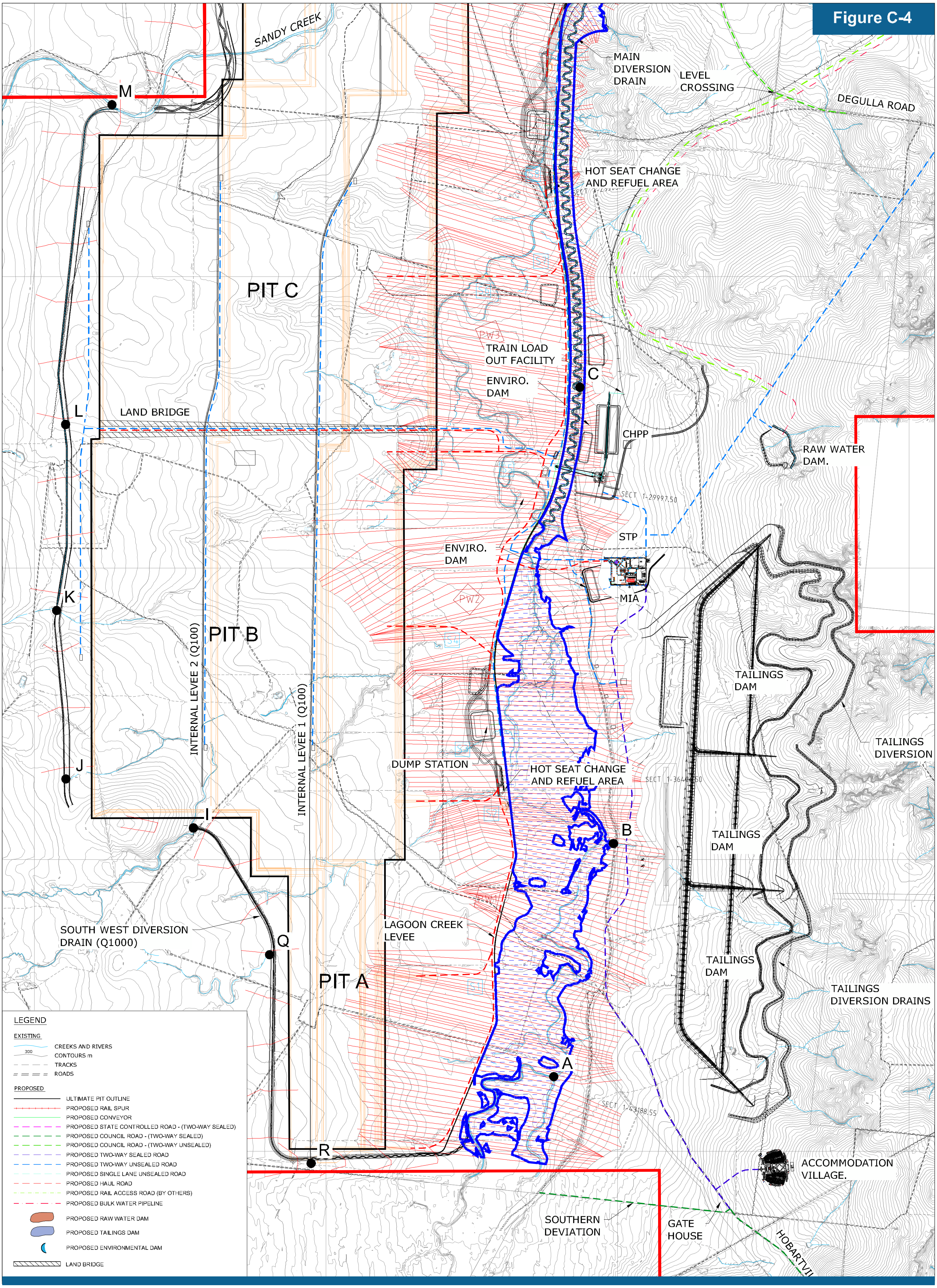
ALPHA COAL PROJECT

DEVELOPED CASE 50 YEAR ARI FLOOD EVENT AND HECRAS SECTIONS SHEET 1 OF 2

August 20, 2010

Plotted By: hamillm Plot Date: 20/08/10 - 09:43 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1020_WM Hecras Sections Design 1 of 2.dwg

Figure C-4



PARSONS BRINCKERHOFF

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SCALE (m)

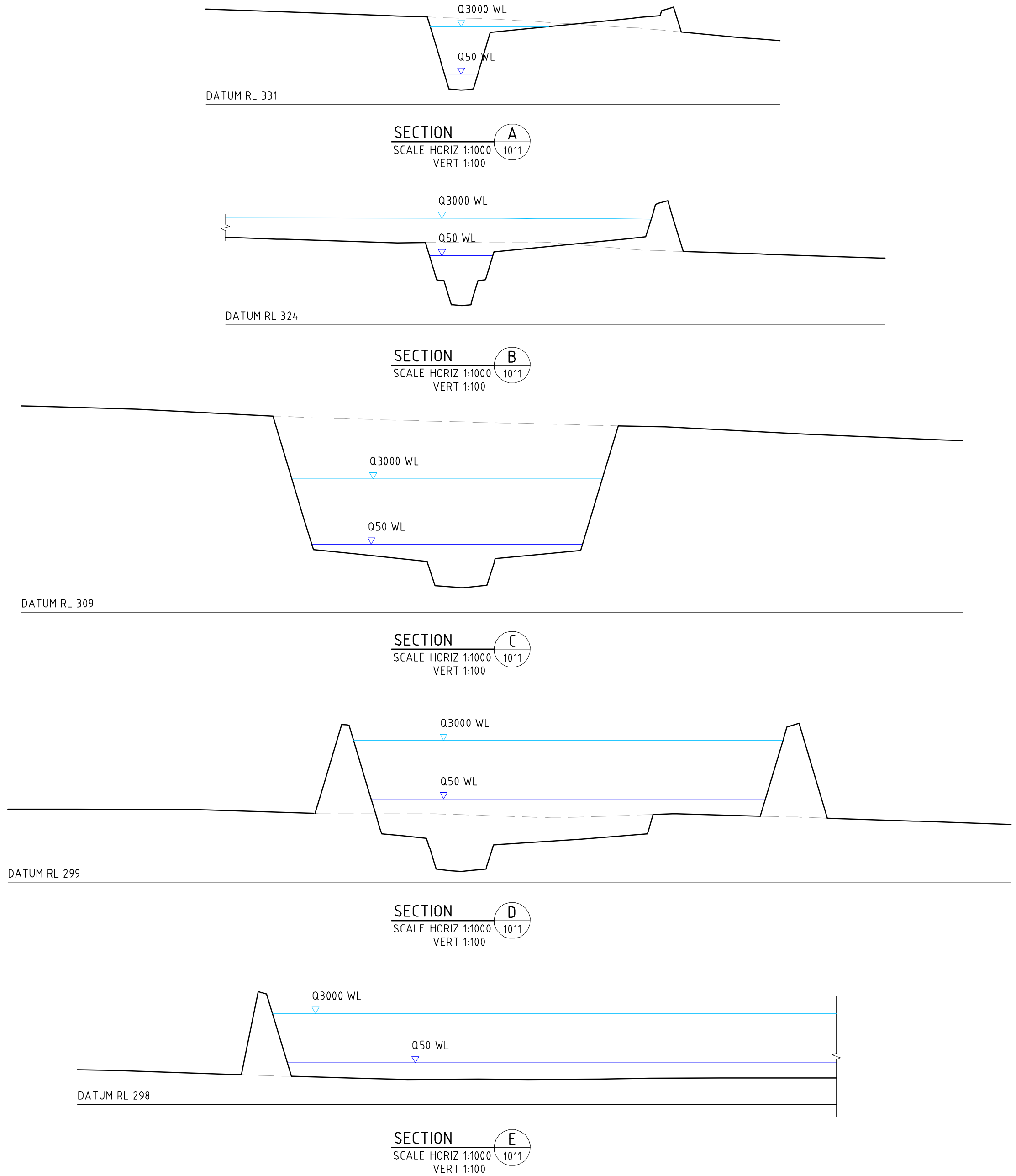
ALPHA COAL PROJECT

DEVELOPED CASE 50 YEAR ARI FLOOD EVENT
AND HECRAS SECTIONS SHEET 2 OF 2

August 20, 2010

Plotted By: hamillm Plot Date: 20/08/10 - 09:43 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1021_WM Hecras Sections Design 2 of 2.dwg

Figure C-5



PARSONS BRINCKERHOFF

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SCALE (m)

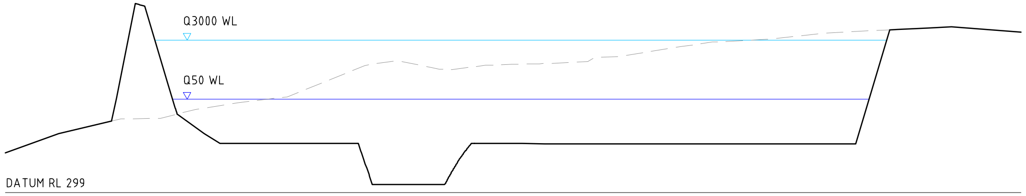
ALPHA COAL PROJECT

TYPICAL CROSS SECTIONS AT DIVERSION DRAINS
SHEET 1 OF 2

August 20, 2010

Plotted By: hamillm Plot Date: 20/08/10 - 11:40 Cad File: \\AUBNEF\proj\H\Hancock_Coal\2123204A_HANCOCK_COAL_FEASIBILITY_STUD\09_CADD\Drawings\Figures\Figure_67500-1014_WM Typical Cross Sections at Diversion Drains 1 of 2.dwg

Figure C-6



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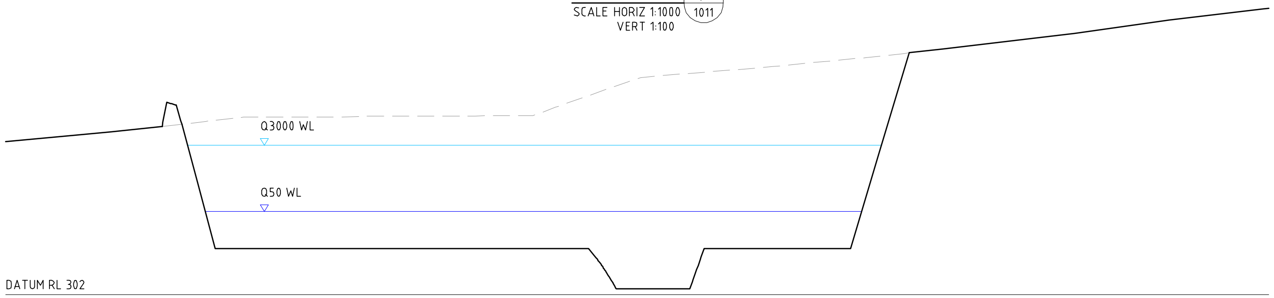

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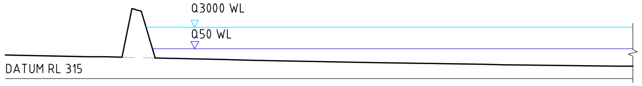

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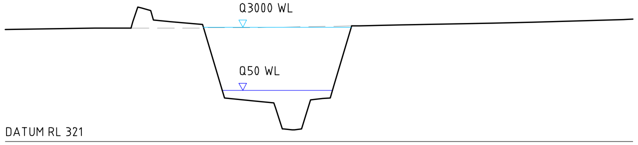

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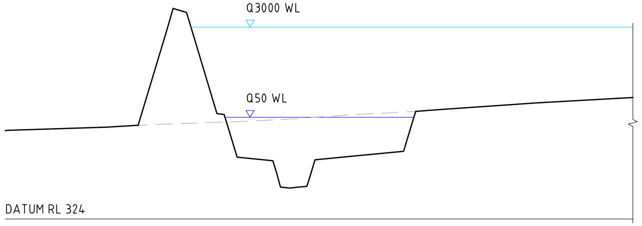

SECTION J
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PARSONS BRINCKERHOFF

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Full Size 1:1000 ; Half Reduction 1:2000
SCALE (m)

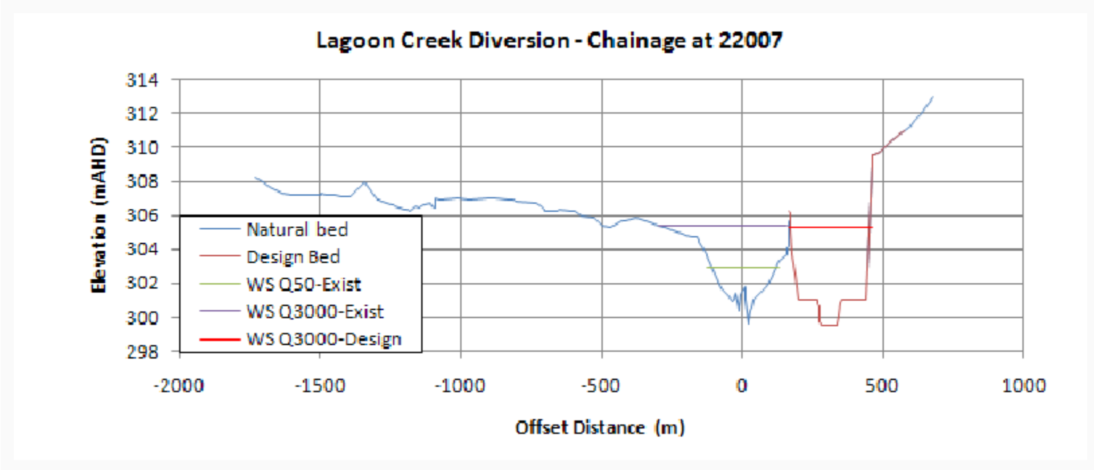
ALPHA COAL PROJECT

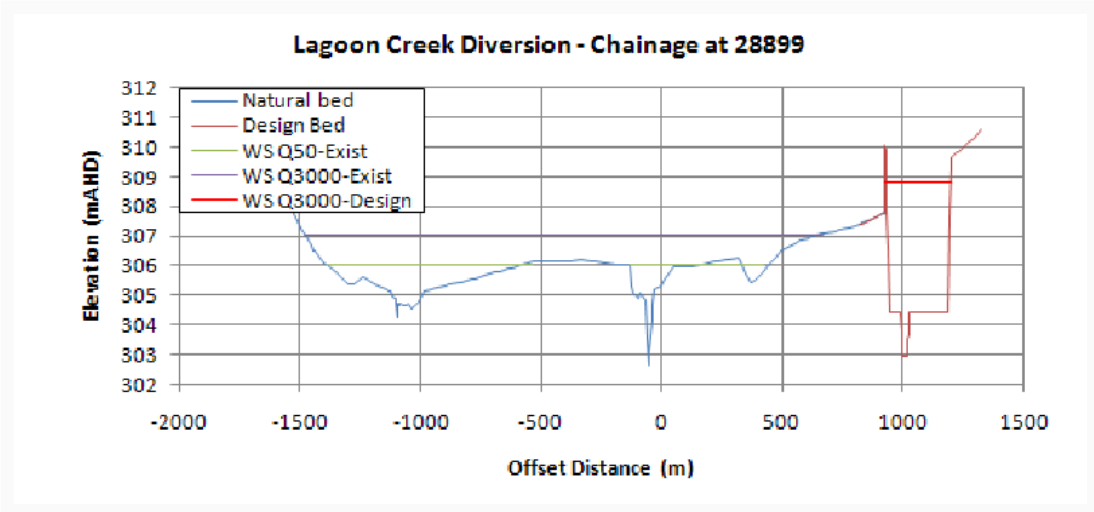
TYPICAL CROSS SECTIONS AT DIVERSION DRAINS

SHEET 2 OF 2

August 20, 2010

Figure C-7



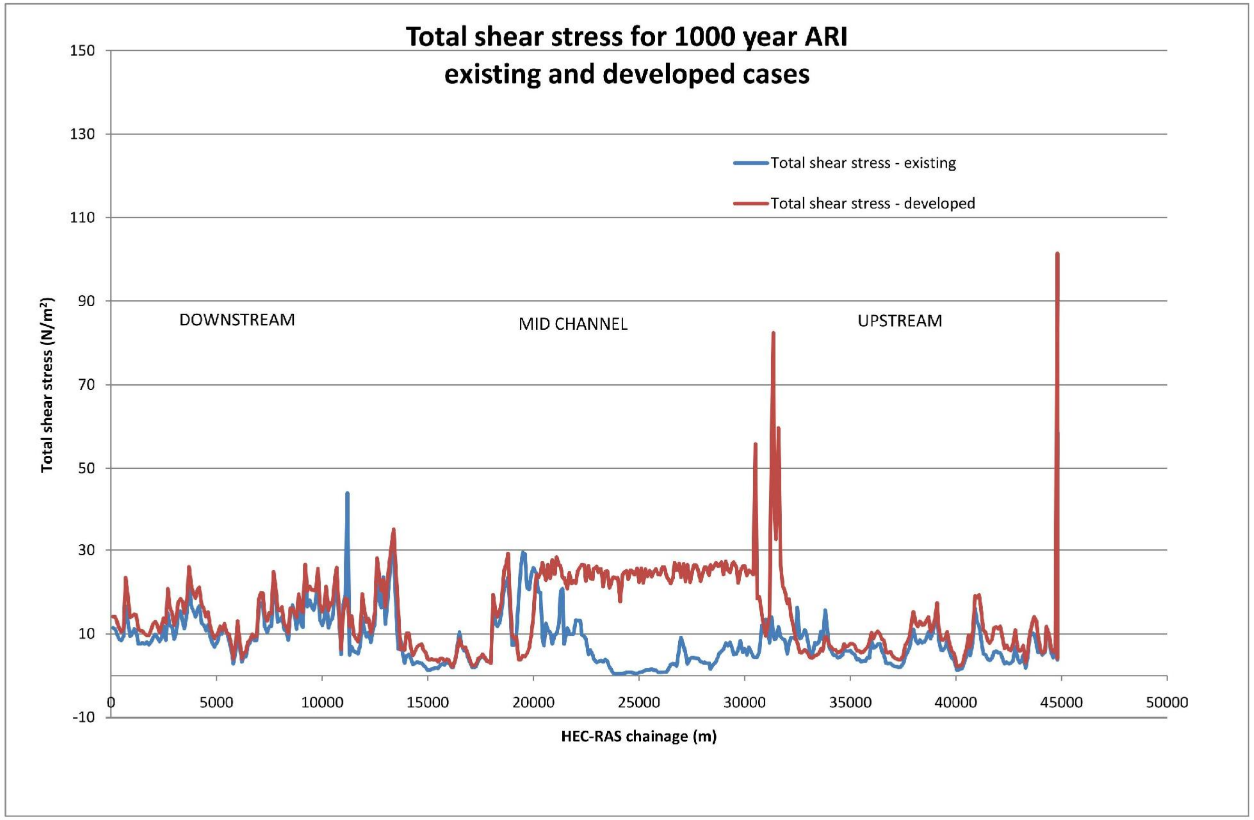


PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

CROSS SECTIONS - LAGOON DIVERSION CHANNEL

August 20, 2010



PARSONS BRINCKERHOFF

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SCALE (m)

0 10 20 40 60
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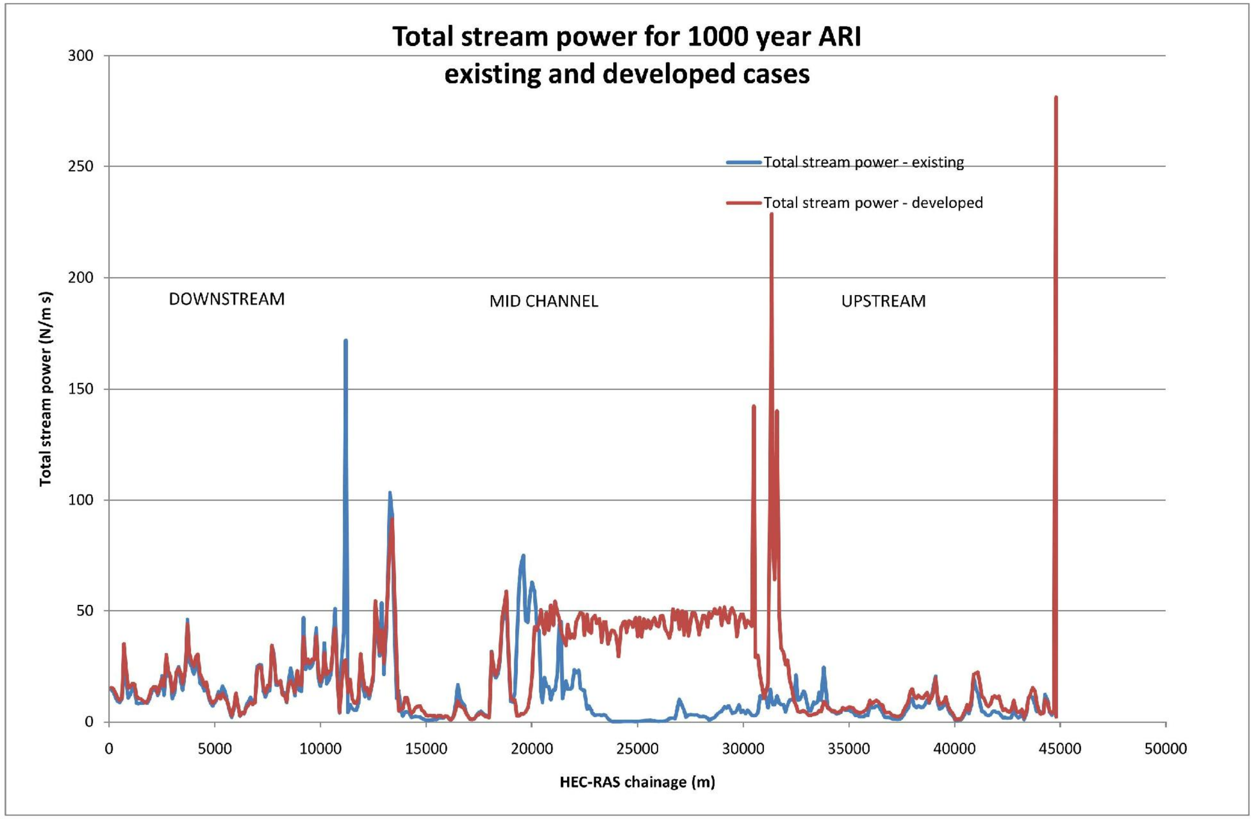
SCALE (m)

ALPHA COAL PROJECT

TOTAL SHEAR STRESS FOR 1000 YEAR ARI
EXISTING AND DEVELOPED CASES

August 20, 2010



PARSONS BRINCKERHOFF

ALPHA COAL PROJECT

TOTAL STREAM POWER 1000 YEAR ARI
EXISTING AND DEVELOPED CASES

August 20, 2010

Appendix D

DERM Guideline: Watercourse Diversions – Central Queensland Mining Industry

Natural Resources and Water
Managing Queensland's natural resources
... for today and tomorrow

CENTRAL WEST WATER MANAGEMENT AND USE REGIONAL GUIDELINE

Title of Guideline: Watercourse Diversions - Central Queensland Mining Industry

Document Details:

Version Number: 4.0

*****Documentation Status:*** *(Please tick one box)*

☐ Draft ☒ Endorsed and Published ☐ Archived

***SIGN OFF BY DELEGATED OFFICER:**

Operationally capable of being implemented				
Endorsed by	**Position**		**Signature**	
	Date			
2. Meets business policy and legislative needs				
Endorsed by	**Position**	Manager, Water Management and Use, Central West Region	**Signature**	[signature]
	Date	14/1/08.		
3. Approved to be implemented				
Approved by	**Position**	Regional Manager, Water Services, Central West Region	**Signature**	[signature]
	Date	14/1/08		
4. Approved to be published on the Internet (Please *Tick the box*)				☑

PUBLISHING REQUIREMENTS: (Please tick one box)

☒ Cleared for External Use ☐ NRW Use Only

(Please tick box) ☐ **Original signed off by officer** ☐ **Filed on .**

AUTHOR:
Chris Vernon, Leader (River & Water Management)

When to use
This guideline is to be used when providing advice and assessing applications submitted by mining companies for authorisations for watercourse diversions. It is also intended as a guide for mining companies and their consultants for use in the planning of diversions and when making applications for authorisations for diversions.

Purpose
The purpose of this guideline is to summarise the design criteria against which applications will be assessed, the information required to accompany applications for watercourse diversion authorisations, the legislative basis of the requirement for authorisations and the application process for a licence to interfere and development permit for the works.

Governing legislation
Watercourse diversions require a water licence to interfere under the provisions of the *Water Act 2000* and a development permit under the *Integrated Planning Act 1997* for the on ground works.

Background
Throughout the Bowen Basin, coal deposits frequently extend beneath creeks and rivers. In many cases the value of the extracted coal exceeds the cost of diverting the watercourse. The viability of the mining project can sometimes rest on the feasibility of diversion of a watercourse to allow uninterrupted access to a coal deposit that might otherwise be uneconomic to mine. Where economic justification exists and the impacts of diversion can be adequately managed, diversion of the watercourse is a viable option.

In the past watercourse diversions were often engineered to suit the immediate short term needs of mining without adequate consideration for end of mine life and longer term physical integrity and environmental issues.

It is now recognized that this approach could result in long term liabilities for individual mines and more sustainable designs are required.

In granting approvals for the diversion of watercourses the Department is attempting to achieve a diversion structure that appears and functions as a natural feature in the landscape largely indistinguishable from the pre-existing natural watercourse.

The design and construction of the diversion should be to a standard that allows relinquishment of the licence to interfere prior to end of mine life. This approach provides for expenditure by the mine at the development stage at a time when revenue is commencing rather than waiting until end of mine life when the revenue stream has ceased.

This guideline provides a generic approach for planning, design and operation of stream diversions for the mining industry in Central West Region.

Economic factors

Economic justification for the necessity of the diversion must be provided. Economic factors will often be a primary issue from the mines perspective. In addition to initial construction costs, operation and maintenance, any end of mine life decommissioning cost should be evaluated.

Transparent analysis of options, including economic evaluations provides NRW with a clearer understanding of the mines position and demonstrates all matters and consequences have been considered.

Economic analysis could be a brief summary explaining the effects on mine production and additional costs associated with leaving the creek where it is, compared to the cost of the diversion works. This should be supported by a direct comparison in dollar terms of the costs of construction of the diversion compared to the loss of profit associated with loss of production through not diverting the watercourse.

Planning

Planning of a watercourse diversion should not be undertaken in isolation and consideration has to be given to all aspects of the mine development plan. Once the requirement to divert has been clearly established planning should proceed along the following lines:

- Determine the preferred location for the diversion taking into consideration topography, geology, location in relation to mine infrastructure and sterilisation of possible reserves;
- Complete hydraulic modelling of the existing natural watercourse to determine the hydraulic needs of the proposed diversion such that it operates in dynamic equilibrium indistinguishable from the existing natural watercourse;
- Develop and evaluate options for the proposed diversion within the constraints of the hydraulic and environmental parameters demonstrated by the existing natural watercourse;
- Determine the preferred option and prepare the conceptual design;
- It is recommended that the conceptual design is submitted to NRW for review and consultation before proceeding with detailed engineering design;
- Prepare the detailed design including construction drawings based on the conceptual design;
- Make application for a licence to interfere with flow and associated development permit for the works based on the conceptual and detailed design;
- Other external issues may be identified from submissions through the public notification process which may result in a requirement for changes to the design;
- Any commitments under an approved EMOS, EMP or Plan of Operations for the mine site that has been used to support the application for an environmental authority issued under the *Environmental Protection Act 1994*, will also need to be considered when planning a diversion.

The foregoing steps will enable detailed consideration of the authorisation applications by NRW. Each step of the planning process is considered in more detail below.

Location of diversion

The following matters need to be considered in relation to the location of the diversion during the planning stage:

- The diversion should be located wholly within the area covered by the mine lease or land under the ownership of the mine owner/operator;
- Location of the diversion in relation to other mine infrastructure and the constraints this may impose on the route of the diversion;
- Topography constraints which may dictate the route of a diversion;
- Geology of the preferred route of the diversion including soils and how this will impact on the design to achieve a state of dynamic equilibrium.

Given the nature of channels to develop meanders over time, any diversion constructed in erodible materials should be located within a corridor of suitable width to accommodate anticipated future movements. Therefore spoil, stockpiles, rehabilitation, etc should be suitably located outside this corridor.

Consideration should be given to a comparison of aerial photography of the watercourse to be diverted to assess the relative stability of the existing natural channel.

Hydrology and geomorphology

A typical stream has natural features that develop through geomorphologic processes. It is possible to mimic these natural stream characteristics (meanders, channel profiles, cross sections, riffles, vegetation, etc) to provide an environment where these conditions can continue to develop at a rate consistent with the natural watercourse. This is referred to as 'dynamic equilibrium'. Similar features should be designed into the diversion channel in order to obtain a similar dynamic equilibrium to that displayed by the natural watercourse.

The engineering design of a stream diversion should be based on the results of hydraulic modelling and should include consideration of the following factors:

- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity;
- The length of the channel should be nearly the equivalent length of the watercourse it replaces or some form of stable energy dissipater must be incorporated;
- The diversion channel must exhibit features similar to the natural existing watercourse such as meanders, terraces, benches, etc;
- Assessment of the stability and erosion characteristics of the diversion design;
- The capacity of the floodplain to deal with out of channel flows;
- Potential hydraulic and geomorphic impacts of the diversion channel on the adjoining natural reaches of the watercourse both upstream and downstream of the diversion.

Hydraulic modelling of the watercourse should be undertaken to determine the peak discharges for the 2, 5, 10, 20, 50 and 100 year Annual Recurrence Interval (ARI) flow events. The peak discharges derived should be used to develop channel geometry design that aims to provide flow velocities, stream power and shear stresses within the parameters outlined in Table 1 below. If these parameters cannot be accommodated within the design, consideration should be given to construction of the diversion and establishment of vegetation before flows are directed into the diversion. In some cases this may require construction of the diversion a year or two before actually needed.

The ACARP project 'Bowen Basin River Diversions – Design and Rehabilitation Criteria, July 2002' established a range of stream powers, velocities and shear stresses that are considered to be the upper range for natural Bowen Basin watercourses. Consideration must be given to these upper limits (Table 1) when undertaking the design of a diversion.

Table 1

Scenario	Stream Power (Watts/metre^2)	Velocity (Metres/second)	Shear Stress (Newtons/metre^2)
2 year ARI (no vegetation)	<35	<1.0	<40
2 year ARI (vegetated)	<60	<1.5	<40
50 year ARI	<220	<2.5	<80

ARI – Annual Recurrence Interval

Design of the diversion

Any application under the *Water Act* 2000 for a Licence to Interfere for a diversion and any associated application for operational works made under the *Integrated Planning Act* 1997 should be accompanied by reports giving full details of the proposed interference. The submitted information should also include a detailed design report for all works involved with the diversion and details of the proposed monitoring and evaluation program for approval prior to implementation.

The design of any diversion would need to be to acceptable engineering standards and in accordance with this guideline on stream diversions for the Central Queensland mining industry. The design should also be in accordance with the principles outlined in the Australian Coal Association Research Program (ACARP) report - "Maintenance of Geomorphic Processes in Bowen Basin River Diversions, Stages 1, 2 & 3".

The detailed design should include construction drawings of a suitable scale and line form to include:

- Schedule of drawings, notes and locality plan;
- Legend and cross sections setout table;
- Existing site plan;
- New works site plan;
- Longitudinal profile;
- Detailed works plans;
- Cross sections of diversion at set distances;
- Details of diversion plugs, energy dissipaters, floodplain drainage paths and other diversion related works.

Energy Dissipation

Where the length of the diversion is less than the watercourse it replaces there is a resultant increase in bed slope. This has the effect of increasing flow velocities, stream power and shear stress. To overcome the impacts due to increased slope some form of energy dissipation to reduce velocities will be required. Given the long term need to ensure a state of dynamic equilibrium in keeping with the characteristics of the natural stream, most energy dissipation structures are not appropriate if they require long term maintenance. If the diversion is only in a temporary position, then structural energy dissipation may be a viable option.

Monitoring and evaluation
The proponent should prepare a monitoring and evaluation program during the development of the diversion design and submit for assessment by NRW at the time of submission of applications for authorisation. Monitoring and evaluation programs may be developed in accordance with the ACARP report, "Monitoring & Evaluation Program for Bowen Basin River Diversions" ACARP Project C9068, ID&A, February 2001.

The monitoring and evaluation must include natural reaches of the existing creek both upstream and downstream of the diversion works

The detailed monitoring program for the diversion should include monitoring of the condition of any associated works such as levees, including the success of protection measures and a strategy for maintenance of both levees and the diversion, if these works are proposed to remain after mine closure. The monitoring and evaluation program will provide a measure of how well the diversion works are performing in comparison to the natural watercourse and will assist in identifying and tracking any maintenance works required.

Instream Structures
Instream structures such as culverts and bed level crossings are often used as controls and/or energy dissipaters. If these are to be removed at some stage of the mining operation or at end of mine life, then the design cannot rely on such controls in the long term. Consideration will need to be given to how these structures will be replaced in the long term or the design amended to remove the need for a control.

The design of instream structures must be undertaken with adequate regard to maintenance of the ecology and biodiversity of the watercourse. Consultation must be undertaken with Queensland Fisheries Service (QFS) to ensure that any instream structures provide for fish movement or a fish movement exemption notice is obtained. Instream structures that form waterway barrier works will require approval through the *Integrated Planning Act 1997*.

Subsidence
If subsidence resulting from underground workings is expected to impact on the diversion channel the design should accommodate any special needs created by the subsidence. Consideration should be given to altering the route of the diversion to avoid areas that may be affected by subsidence.

Vegetation
Most recently submitted diversion designs incorporate vegetation as an integral part of the design. This has come about through recognition of the valuable role that vegetation provides in stabilising the channel banks, terraces and floodplain drainage paths.

As Built Plans
As built construction information will be required under the terms of any waterworks licence. As built plans are to be to the same scale and form as the construction design drawings.

Application for authorisations
Applications for a Licence to Interfere by Diverting Flow and for a Development Permit are to be submitted on the approved forms and must be accompanied by the appropriate fee. Forms and details of current fees may be obtained via the internet or from the nearest NRW office. The following additional information should accompany the applications:

- Economic justification of the need for the diversion;
- Hydrology report and a conceptual design report outlining the rationale for the chosen route and design;
- Detailed design report based on the conceptual design with construction drawings;
- A proposed monitoring and evaluation program against which the performance of the diversion can be assessed.

Licence terms
A licence to interfere for a watercourse diversion will include a term that ties the licence back to the conceptual and detailed design documentation including construction plans and specification. It is therefore important that documentation provided in support of applications reflect what is intended to be constructed.

Development permit terms
A development permit for the works of a watercourse diversion will have terms that include:

- A date by which the works are to be substantially complete;
- The requirement to provide 2 copies of as built plans within 90 business days after completion of the works;
- The requirement that the works are to be constructed in accordance with detailed design documentation including construction plans and specification;
- The requirement to carry out monitoring and evaluation of the works in accordance with an agreed monitoring and evaluation program;
- The requirement to provide a report on the performance of the works at the time of each renewal of the Licence to Interfere. The report is to be prepared by a Registered Professional Engineer Queensland and is to provide a recommendation for any remedial works required.

Timeframes
The timeframe from initial discussions with the Department in relation to an outline proposal to divert a watercourse, through concept development, planning and final design, until issue of a water licence to interfere and a development permit can take from 6 to 12 months depending on the complexity of the proposal. To avoid delay to a mining project, proponents should endeavour to involve NRW officers at the earliest stage of a project.

In those cases where NRW have been fully consulted and all the necessary information in support of applications has accompanied the applications, NRW will endeavour to make a decision on applications within 90 business days of receipt of all the required information. However, there may be issues, which are outside the control of NRW that may result in this timeframe not being met. This may be due to external factors such as submissions by third parties, etc.

Further information

For further information on this guideline please contact the following:

Rockhampton office: Kristy Meacle, Natural Resource Officer
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Email: Kristy.Meacle@nrw.qld.gov.au

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Telephone: (07) 4992 9104
Email: Scott.Stevens@nrw.qld.gov.au