11 Surface Water

Section 11 Surface Water

11.1 Introduction

11.1.1 Overview

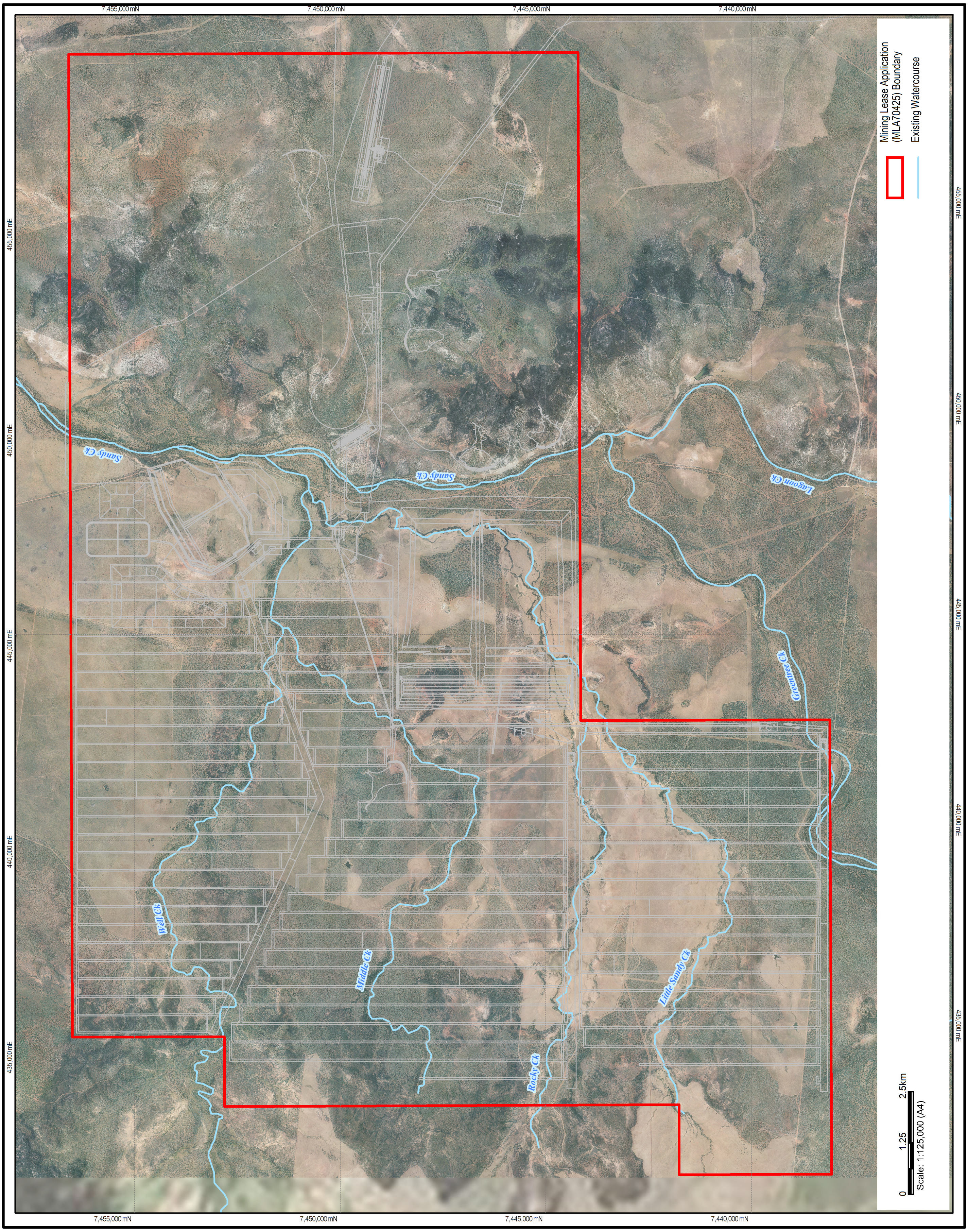
This section of the Environmental Impact Statement (EIS) presents the surface water resource aspects of the proposed Kevin's Corner Coal Project (the Project). The information and assessments describe:

- Relevant legislation for surface water management;
- Assessment methodologies;
- Baseline (existing) surface water environment and associated environmental values;
- Proposed Project surface water assessment;
- Identification of potential impacts and impact assessment;
- Residual risk potential impacts; and
- Proposed mitigation measures.

11.1.2 Surface Water Context of the Project

The Project site is located in the Sandy Creek catchment, which is a tributary of the Belyando River within the greater Burdekin River Basin. The area of the study catchment (to the northern lease boundary of the Project) is approximately 2,740 km^2.

The majority of the mining operations, including the open-cut pits and underground mining operations, would occur to the west of Sandy Creek. Several smaller tributaries, including Little Sandy Creek, Middle Creek, Rocky Creek and Well Creek, are also located on the mine lease boundary, as shown on Figure 11-1. A more detailed discussion of the catchment in relation to the proposed Project is presented in later subsections of this surface water section.



Source: See Copyright Details below and for full disclosure Please Refer to the EIS ***Volume 1 - References***

Datum: GDA94, MGA Zone55

N E S W

HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

EXISTING WATERCOURSES

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-1

File No: 42626660-g-1047.wor

11.1.3 Inter-relationship with other EIS Studies

The assessment of surface water has drawn upon the findings of a broad range of the EIS studies and also informed other studies of potential impacts to ensure that the overall potential environmental impacts of the Project are appropriately managed. To obtain a complete understanding of the significance of surface water values and possible impacts of the Project the following EIS studies of relevance to surface water are referenced:

- Topography and soils (Volume 1, Section 5);
- Land use and tenure (Volume 1, Section 6);
- Aquatic ecology (Volume 1, Section 10);
- Groundwater (Volume 1, Section 12); and
- Waste (Volume 1, Section 16).

11.1.4 Legislative Framework

Key relevant legislative Acts for surface water management include the:

- *Water Act 2000*;
- *Water Supply (Safety and Reliability) Act 2008*;
- *Environmental Protection Act 1994*; and
- *Sustainable Planning Act 2009*.

This legislation and its relevance to surface water values and surface water management for the Project are described below.

11.1.4.1 Water Act 2000

In Queensland, the *Water Act 2000* (Water Act) is the primary statutory document that establishes a system for the planning, allocating and use of non-tidal water. The Water Act is administered by the Department of Environment and Resource Management (DERM).

11.1.4.2 Water Planning Provisions of Water Act

The Water Act prescribes the process for preparing Water Resource Plans (WRPs) and Resource Operation Plans (ROPs) which are specific for catchments within Queensland. Under this process, the WRP identifies a balance between waterway health and community needs. The WRP establishes Environmental Flow Objectives (EFOs) that are of importance for waterway health, and sets Water Allocation Security Objectives which are important to maintain community needs. The ROP provides the operational details on how this balance can be achieved. The WRP and ROP determine conditions for granting water allocation licences, permits and other authorities, as well as rules for water trading and sharing. The Water Act makes the provision for the preparation of land and water management plans in specific areas. DERM has advised there are no such plans in place in the vicinity of the Project.

The Project is located within the Belyando-Suttor subcatchment area covered by the Water Resource (Burdekin Basin) Plan 2007 (refer to Burdekin WRP schedules 1 & 2). The Project site is outside (excluded) from declared Water Management Areas in Part 2 Section 6 of the Burdekin Basin WRP. Part 3 Section 12 (g) of the Burdekin WRP has provisions to make water available in the Belyando-Suttor subcatchment to support growth in irrigated agriculture.

All of the statutory EFO in the Burdekin WRP apply to locations (nodes) that are a long distance downstream of the Project site. The closest WRP node for which some EFO apply is at the junction of the Suttor River and Burdekin River. As the Project location is a long distance upstream of closest the EFO location and the site area is a very small portion of the total catchment to the closest EFO location, the Project will not materially impact on the State's ability to achieve statutory EFO prescribed in the Burdekin WRP.

For surface water aspects of the Project, the main significance of water planning provisions of the Water Act will be the potential impacts on nearby downstream existing water entitlements. The existing downstream entitlements are discussed further in Section 11.4.4.

A second WRP (the Great Artesian Basin WRP 2006) also administered under the Water Act is applicable to the Project location. This Great Artesian Basin WRP is primarily focussed on groundwater and is not discussed further in this section. Further information on the Great Artesian Basin WRP 2006 and its significance to the Project is presented in Volume 1, Section 12 (Groundwater).

11.1.4.3 Protection of Watercourses Provisions of Water Act

The Water Act specifies requirements for works requiring disturbance to the bed and banks of watercourses (e.g. stream diversions). Declared watercourses potentially impacted by the Project are listed in Section 11.4.4

11.1.5 Water Supply (Safety and Reliability) Act 2008

Relevant aspects of the *Water Supply Safety and Reliability Act 2008* include the regulations for licensing and safety management of Referable Dams in Queensland. It should be noted that the provisions of this Act for Referable Dams apply to dams that do not contain hazardous waste (i.e. raw water dams).

11.1.6 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) provides the key legislative framework for environmental management and protection in Queensland.

Chapter 5 of the EP Act establishes a process for obtaining an Environmental Authority (EA) for mining activities. A Level 1 EA (mining activities) is applicable to the Project. In addition, an Environmental Management Plan (EM Plan) is also required under Section 201 of the EP Act.

Under the EP Act, DERM is the regulatory authority with responsibility for granting the EA, as well as compliance, auditing and monitoring of the environmental management of the Project activities.

11.1.6.1 Environmental Management Plan and Environmental Authority Relevance to Surface Water Management

The EP Act regulation of mining activities and associated environmentally relevant activities (ERAs) with the EM Plan and EA conditions provides means to regulate surface water management for the Project.

Dams containing hazardous waste (including tailings storage facilities and mine water dams) that are not Referable Dams (under the *Water Supply Safety and Reliability Act 2008*) are regulated through EA conditions. Surface water discharges from the Project and associated needs for surface water monitoring are also regulated with EA conditions.

Conceptual details and design criteria of the water management systems for the Project are described in the following sections, with this information contributing to proposed conditions of the EM Plan and EA for the Project.

11.1.6.2 Environmental Protection (Water) Policy 2009

The Environmental Protection (Water) Policy 2009 (EPP Water) is subordinate legislation under the EP Act that functions to establish environmental values (EV) associated with water, and ensuring that broad environmental protection measures are defined for protecting these environmental values. The schedules of the EPP Water include prescribed EV for some parts of the Queensland. The Project site is not in area where EVs are currently defined by the EPP Water. Consequently the Project has identified preliminary EVs based on the findings of the EIS studies, and these are described further in Section 11.4.

11.1.7 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* (SP Act) does not directly prescribe requirements for surface water management that are directly relevant for the Project. The relevance of the SP Act for surface water aspects of the Project is that this Act facilitates the approvals process for works and or operations administered under other legislation. An example is that the approval for the Project stream diversions under the Water Act will be administered through the SP Act.

11.2 Methodology

A number of assessment studies were undertaken for the surface water section of the EIS. These include the following technical reports which can be found in Volume 2, Appendix M (Surface Water) and Appendix Q (Waste):

- Geomorphology Assessment (Appendix M1);
- Flood Hydrology Study (Appendix M2);
- Hydraulics Technical Report (Appendix M2);
- Site Water Management System and Water Balance Assessment (Appendix M3); and
- Surface Water Quality Technical Report (Appendix M4).

The methodologies adopted for each of these technical reports are summarised below.

11.2.1 Geomorphology Assessment

A geomorphic assessment was undertaken to:

- Assess the existing geomorphic characteristics of streams in the Project area;
- Guide concept designs for the watercourse diversions which flow through the Project area;
- Evaluate hydraulic parameters that influence geomorphology; and
- Assess the performance of the proposed concept diversion alignments and channel features.

Data used in the assessment were derived from information collected in the field as well as from existing data sets. Spatially referenced data sets of land use, topography, and soils were obtained from several sources. Hydrology and hydraulic modelling to support the geomorphology assessment was referenced from the Hydrology and Hydraulics Technical Reports (Volume 2, Appendixes M2 and M3, respectively).

Field inspection of selected stream reaches and floodplain areas was undertaken to assess stream characteristics. Some stream-channel characterisation was done at selected stream cross-sections. Detailed photographs of the stream conditions at selected locations were taken and are presented in the Geomorphology Technical Report (Volume 2, Appendix M1).

11.2.2 Hydrology Study

A hydrologic investigation of the catchments of Sandy Creek, Rocky Creek, Little Sandy Creek, Well Creek and Middle Creek, which are the defined watercourses traversing the site, was undertaken to estimate design flood flows for watercourses through the proposed Kevin's Corner Project.

The hydrology study considered a wide range of design flood estimates with Annual Exceedance Probabilities (AEPs) ranging up to the Probable Maximum Flood (PMF). These included the 1:10, 1:20, 1:50, 1:100, 1:1,000, 1:2,000 AEP events and the PMF event. A more detailed discussion of the methodologies, substantiating data and results of both the baseline and proposed hydrologic assessment for the proposed mine operation are included in Section 2.1 of the Flood Hydrology Report (Volume 2, Appendix M2).

The key objectives of the hydrology study were to determine whether the Project development would have an adverse impact on the flood hydrology of the surrounding area.

In summary, the process undertaken was as follows:

- Review of relevant legislation and guidelines;
- Hydrological assessment of the catchments at the Project site and surrounding areas to determine rainfall frequency and intensity and design peak flow rates at key locations based on historical rainfall and regional stream gauge data;
- Regional flood frequency analysis transposed to the Project catchments, rainfall based techniques with rainfall runoff routing modelling, and empirical flood estimation methods;
- Comparison of existing case and proposed development case hydrology to assess the potential altered flow conditions as a result of the proposed flood protection measures, creek diversions and planned mine development; and
- Identification of mitigation measures to minimise any potential hydrologic impacts.

Further detailed description of the flood assessment is presented in the Hydrology Study Technical Report (Volume 2, Appendix M2).

The results of the hydrology study were used as inputs into the hydraulic assessment to determine key flood parameters for baseline and impact assessments of the Project.

11.2.3 Hydraulic Technical Report

A study of the hydraulic conditions within the watercourses traversing the Kevin's Corner Project site was undertaken to assess the flooding impacts of the proposed Project. The key objectives of this investigation were to determine if the Project development would adversely impact the flood risk to adjacent properties, and to determine the likely flood risk to the Project development and operations.

The methodology is discussed in detail in Section 2.3 and 2.4 of the Hydraulic Technical Report (Volume 2, Appendix M2). In summary, the process undertaken was as follows:

- Develop hydraulic models of the existing case to estimate flows, inundated areas, depths, velocity and stream power for a range of design flood events;
- Develop hydraulic models of the proposed development case to estimate flows, inundated areas, depths, velocity and stream power for a range of design flood events;
- Compare existing case and proposed development case hydraulic model results to assess the potential altered flow conditions as a result of mine development, and the expected performance of the proposed creek diversions; and
- Identify mitigation measures to ensure equilibrium and long-term stability of the proposed watercourse diversion works.

The results of the hydraulic study were used as inputs into the geomorphic assessment to assess fluvial impacts of the proposed mine works and diversions.

11.2.4 Site Water Management System and Water Balance Assessment

The purpose of the Kevin's Corner Concept Water Management System and Water Balance Technical Report was to establish the concept level planning of the proposed Project mine water management system and undertake a preliminary water balance assessment to characterise the expected performance of the system. The mine water management system (WMS) is the control measure to manage surface water flows from all areas disturbed by the mining activities and associated infrastructure and processing operations.

A conceptual water management strategy was developed in accordance with the following requirements:

- Development of surface water management system concepts at various phases through the Project life;
- Diversion of runoff from undisturbed catchments (clean water) around the Project area (i.e. bypass the WMS);
- Segregation of waters within the Project site based on expected quality;
- Reuse of contaminated water around site, with contaminated water preferentially reused in the mine operations for coal processing;

- Determination of sufficient storage capacity within site dams for mine water containment; and
- Preparation of a preliminary water balance of the Project site to estimate runoff volumes and simulate the balance of runoff (and other mine water generation) with mine water consumption to identify potential overflows and identify potential water deficits / surpluses for the Year 1, 10 and 30 landforms.

The relevant guidelines used to prepare the concept water management strategy are described in detail in Section 2.2 of the Kevin's Corner Concept Water Management System and Water Balance Technical Report (Volume 2, Appendix M3). In summary, these are as follows:

- Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland (Department of Mines and Energy [DME], 1995). These are commonly referred to as the DME Guidelines and require, among other things, that the design of a site water management system for any mining and processing operation should be based on the concept of risk management for the purpose of protection of the environment;
- Code of Environmental Compliance for Environmental Authorities for High Hazard Dams Containing Hazardous Waste (developed by DERM, no date);
- Conditions for Coal Mines in the Fitzroy Basin Approach to Discharge Licensing (developed by DERM, 2009); and
- Model Water Conditions for Coal Mines in the Fitzroy Basin (developed by DERM, 2009).

Adopted design criteria for the mine water management system, and proposed end-of-pipe discharge criteria for releases from the mine water management system are described in Section 11.3.8.4

11.2.5 Surface Water Quality Assessment

A Surface Water Quality Assessment technical report (Volume 2, Appendix M4) was undertaken to assess the potential impacts of the proposed Project on surface water quality in watercourses within and downstream from the Project area. The assessment was undertaken in the context of identifying applicable environmental values in accordance with EPP Water 2009, Australian New Zealand Environment and Conservation Council Guidelines (ANZECC, 2000), and the Queensland Water Quality Guidelines (QWQG) 2009 (DERM, 2009).

The methodology adopted for the surface water quality impact assessment included:

- Identification of relevant Environmental Values applicable to water quality management using classifications outlined in the EPP Water 2009;
- Assessment and preliminary description of the background surface water quality based on available historic water quality datasets from a nearby DERM monitoring station and Project specific water quality sampling;
- Description of the features and activities of the Project relevant to the surface water quality impact assessment and description of potential impacts;
- Identification of mitigation strategies and measures required to manage the potential impacts on surface water quality; and
- Identification of the potential residual impacts, following implementation of mitigation strategies and measures.

11.3 Existing Surface Water Environment

11.3.1 Catchment Context

The Project site (Mining Lease Application [MLA] 70425) is located within the Belyando/Suttor catchment, a sub-catchment of the Burdekin River. Sandy Creek is the main watercourse traversing the site and flows into the Belyando River 19 km to the north of the Project area. The Belyando River flows approximately 200 km to join the Suttor River and eventually flows into the Burdekin River at Lake Dalrymple (Burdekin Falls Dam). Several other watercourses flow into Sandy Creek within the mine lease including Little Sandy Creek, Rocky Creek, Middle Creek and Well Creek. The Belyando/Suttor catchment produces unreliable stream flow, contributing comparatively less to the overall discharge from the Burdekin Basin than the other sub-catchments in the basin (Department of Natural Resource Management [DNRM], 2002).

Sandy Creek has a large catchment (approximately 2,190 km^2 where Sandy Creek enters the Project area at the southern lease boundary, and approximately 2,740 km^2 where Sandy Creek leaves the Project area at the northern lease boundary). The catchments analysed in the EIS studies (as shown on Figure 11-1 and used for the extent of flooding analyses and hydrological assessment for the mine water management system – Technical Reports in Volume 2, Appendix M) extended to the downstream (northern) mine lease boundary.

11.3.1.1 Watercourses

Five key streams within the Project area have been classified as defined watercourses (under Section 5 of the *Water Act 2000*). The defined watercourses are Rocky Creek, Little Sandy Creek, Sandy Creek, Middle Creek and Well Creek and these are presented on Figure 11-1.

The significance of the creeks stated to be defined watercourses under the Water Act, is that the Project development and operation will need to:

- Obtain approvals to divert the watercourses (licensed stream diversion);
- Manage operations and any temporary works in the watercourse areas in accordance with the DERM “Guideline – activities in a watercourse, lake or spring associated with mining operations” within the provisions allowed under that guideline; and
- Obtain Riverine Protection Permits for other works or activities in the watercourse areas that do not fall within the provisions under the DERM guideline.

11.3.1.2 Existing Water Users

Surface water resources around the Project area have limited beneficial uses as they are ephemeral. A search of the State of Queensland Water Entitlements System was undertaken to identify regional surface water license holders. The Burdekin Haughton Water Supply Scheme and the Bowen Broken Water Supply Scheme operate within the wider Burdekin Basin catchment. There is no major water infrastructure in the Belyando/Suttor subcatchment; however, it contains a number of private weirs, pumps and off-stream storages licensed for water harvesting, irrigation and stock water. Licensed irrigators tend to be concentrated in areas with suitable alluvial plains adjacent to the Suttor and Belyando Rivers and their tributaries. No licence holders were identified along Sandy Creek downstream of the Project site.

Details of the search for the surface water licence holders are presented in the Surface Water Quality Technical Report (Volume 2, Appendix M4).

11.3.1.3 Land Use

Historically, the Project area has been predominantly used for pastoral activities relating to primary production, specifically for cattle grazing, fattening and breeding. Grazing activity occurs to the east and west of the Project area on partially cleared land of native and buffel grass pastures. Various forms of agricultural infrastructure is present throughout the study area and includes fence lines, bores and windmills, formed and unformed roads and holding yards.

From the 1970's onwards, the Project area and surrounds underwent extensive mineral and petroleum resource exploration by a number of proponents. Remnants of this exploration are located throughout the study area. Mineral resource exploration has been undertaken on all sides of the Project area with underground and open-cut mines proposed to adjoin the Project area in various stages of planning. However, mining activities at present is limited to the sample pit operation at the Alpha Coal Project.

11.3.2 Climate and Hydrology

11.3.2.1 Climate

A detailed description of the climate at the Project site is presented in Volume 1, Section 3 and is further detailed in Volume 2, Appendix M2. The primary climate influences on hydrology and surface water flows are rainfall and evaporation which are summarised herein.

Climate data was sourced from the from the Bureau of Meteorology SILO Data Drill using 111 years of records (1900 to 2010). The Data Drill is produced by accessing grids of data derived from interpolating the records from individual weather recording stations. The interpolations are calculated using splining and Kriging techniques and the resulting Data Drill consists of fully synthetic data. Analysis of the climate data was based on the full length of data available (1889 to 2010). Figure 11-2 Annual rainfall for Kevin's Corner - SILO data drill (1889 to 2010) shows annual water year totals for the site and Figure 11-3 shows mean monthly rainfall and evaporation.

From Figure 11-2 it can be seen that annual rainfall at Kevin's Corner is highly variable and subject to prolonged periods of above and below average rainfall. The mean monthly rainfall shows a distinct seasonal distribution (refer to Figure 11-3) with monthly rainfall totals greatest in the wet season extending from December through February and peaking in February at 95 mm. Evaporation is always in excess of rainfall and has a similar seasonal distribution peaking in December at 280 mm.

Figure 11-2 Annual rainfall for Kevin's Corner - SILO data drill (1889 to 2010)

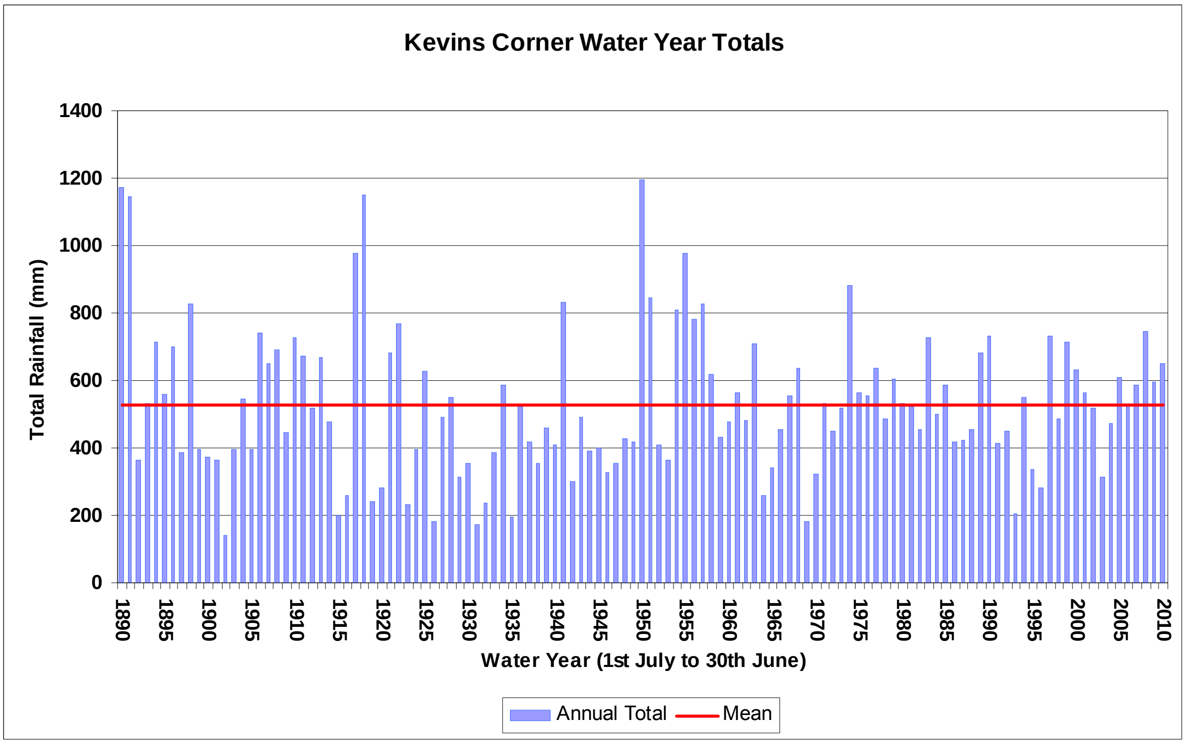
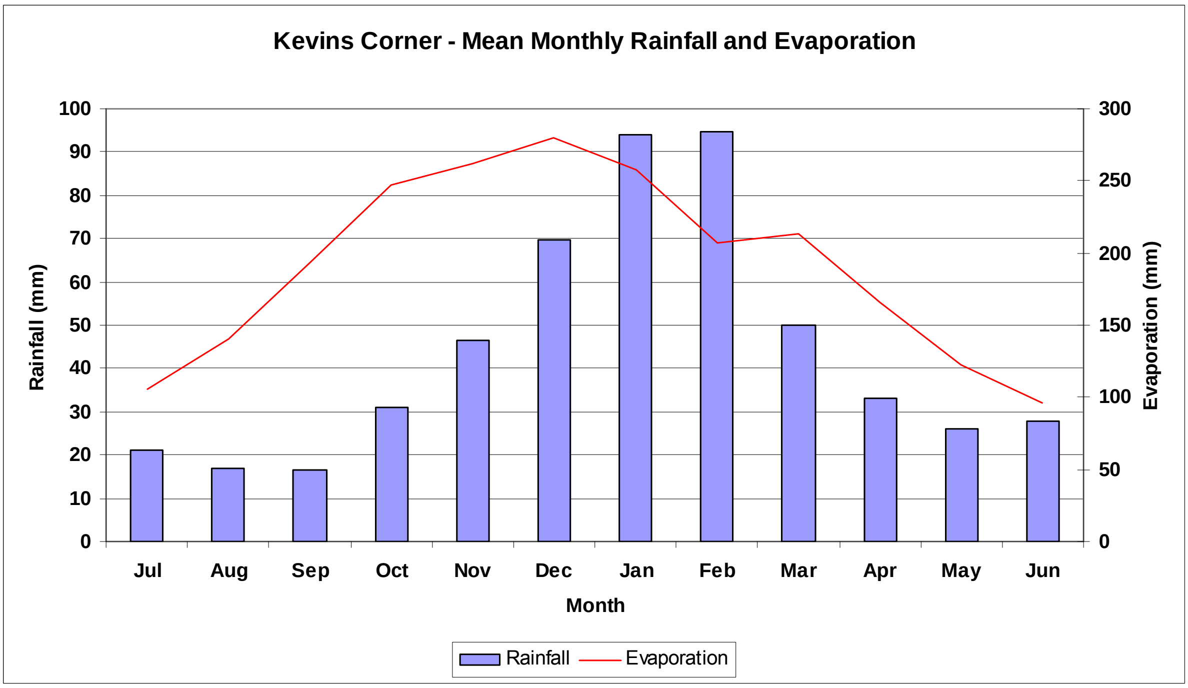


Figure 11-3 Mean monthly rainfall and evaporation for Kevin's Corner (1889 to 2009)



11.3.2.2 Regional Hydrology

The trends evident in climate data for rainfall are reflected in the general characteristics of stream flow hydrology in the local water courses. The Project site is located relatively high in the headwaters of the broader catchment (in the context of the entire Belyando and Burdekin basin area). The catchment areas upstream of the Project site are not sufficient to maintain baseflow and the stream flow hydrology is highly ephemeral. Flow periods are sporadic and limited to direct response to rainfall events and a very short period of baseflow recession after rainfall ceases. The sandy bed conditions in the larger watercourses assist to sustain baseflow but only to a very limited degree.

DERM maintains stream flow data for several locations close to the Project site; however, none are located within the mine lease. Four gauging stations have been identified in the Hydrology Technical Report as suitable reference sites as summarised in Table 11-1. The selection process was based on an assessment of the quality of the gauge data, reporting catchment area and proximity to the site. A more detailed discussion of the selection of these gauges is presented in Volume 2, Appendix M2 – Kevin's Corner Hydrology Technical Report.

River flows in the Project area are characterised by large annual variations due to the seasonal and highly variable nature of rainfall. Stream flows generally occur during December to February when most of the region's rainfall occurs. The prolonged winter dry periods give rise to the ephemeral nature of the key watercourses.

Table 11-1 Stream flow gauging stations for Kevin's Corner baseline assessment

Gauge Number	Location	Period of Record	Catchment Area (km^2)
120306A	Mistake Creek at Charlton	1968 to 1993	2583
120305A	Native Companion Creek at Violet Grove	1967 to present	4065
1303016A	Mimosa Creek at Redcliffe	1957 to present	2473
1303327a	Callide Creek at Goovigen	1971 to present	4457

11.3.3 Flood Hydrology

11.3.3.1 Flood Hydrology Modelling

An assessment of existing flood conditions with the Project site was undertaken with a hydrology study to determine the magnitude of flood flow events for a range of probable design floods. A detailed description of the hydrology study is presented in Volume 2, Appendix M2.

Stream gauge data was not available for the watercourses within and upstream of the Project area. Consequently stream gauge data was sourced from regional stream gauging stations and three different methodologies were used to estimate the design peak flood flows for the Project area watercourses. The methods included:

- Flood Frequency analysis of regional stream gauge data, and transposition of peak flows from the regional catchments to the Project area catchments with non-linear catchment scaling;
- Rainfall runoff routing of design rainfall events for the specific Project area catchments using RORB modelling software, and relevant empirical methods to estimate the key RORB parameters; and

- Empirical peak flood flow estimation methods namely:
  - Australian Coal Association Research Program (ACARP) (2002 project C9068) empirical equations developed for Central Queensland; and
  - Recently developed Queensland QRT-OLS empirical equations for the Australian Rainfall and Runoff Revision Project (National Committee on Water Engineering [NCWE], 2010).

This approach to flood estimation is consistent with recommendations of Australian Rainfall and Runoff - Book VI (Nathan and Weinmann, 1999), which recommends the use of rainfall runoff routing based methods for extreme floods.

Based on the characteristics of climate at and around the Sandy Creek catchment, and the size of the overall catchment, it was identified that small to large floods, nominally up to 1:50 annual exceedance probability (AEP) are likely to be governed by localised extents of spatial distribution of rainfall storms (i.e. not occurring across the entire catchment) and/or influenced by highly variable rainfall loss rates. Conventional rainfall routing methods for estimation of small to large floods could be unrealistic for estimation of small to large floods up to 1:50 AEP because this method typically assumes idealised conditions of a design rainfall event occurring over the entire catchment. It was identified that for this range of floods, preference should be given to flood frequency analysis methods (providing that available data is reliable), as sufficient periods of recorded flood data from the region would inherently include representation of the variability of rainfall depths, spatial extents, and rainfall losses which affect runoff volumes.

For more extreme flood events (nominally 1:100 AEP floods and larger) data suggests that major tropical storms that can cover the entire catchment and produce large rainfall depths could be reasonably expected. For the range of large to extreme flood events (which are needed for design of flood protection), rainfall routing methods for flood estimation are preferred recognising that reasoned, but not excessive, conservatism is important given the significant to extreme consequences that could occur in the event of failure of the Project's flood protection works. The preference for rainfall routing based methods for estimation of the large to extreme floods also recognises the limitations of flood frequency analysis with limited data periods can produce significant uncertainty beyond the credible limit of extrapolation.

11.3.3.2 Flood Hydrology Model Results

The summary results of the flood hydrology estimates of peak design flood flows for the existing watercourses are presented in Table 11-2.

Table 11-2 Summary of baseline peak flood flow estimates

Stream name, location, catchment area	Peak flood flow (m^3/s) for flood events (AEP)						
	1:10	1:20	1:50	1:100	1:1000	1:2000	PMF
	Transposed Regional Flood Frequency			Rainfall Runoff Routing			
Sandy Creek - northern lease boundary (downstream extent of Project area) *Catchment area = 2,737 km^2*	330	590	1,100	3,000 (note 2)	5,900	7,000	29,000
Sandy Creek - southern lease boundary (upstream extent of Project area) *Catchment area = 1,758 km^2*	250	450	850	1,900 (note 2)	3,700	4,400	19,000
Well Creek at Sandy Creek confluence *Catchment area = 455 km^2*	110	200	380	730	1,500	1,700	6,200
Little Sandy Creek at Sandy Ck confluence *Catchment area = 149 km^2*	58	100	190	370	1,000	1,200	4,300
Rocky Creek at Little Sandy Ck confluence *Catchment area = 52.7 km^2*	31	55	100	170	440	580	2,000
Middle Creek at Well Ck confluence *Catchment area = 53.1 km^2*	31	55	100	170	470	590	2,100

Table notes:

(1) All peak flow values rounded to two significant figures.

(2) Refer to discussion regarding significant increase between 1:50 and 1:100 AEP estimates at these locations.

(3) PMF is Probable Maximum Flood derived from Probable Maximum Precipitation PMP rainfall. AEP of PMP rainfall is approximately 1:370,000 for the greater Sandy Creek catchment and approximately 1:10,000,000 for Little Sandy Creek and Middle Creek catchments.

11.3.4 Existing Stream Geomorphic Conditions

11.3.4.1 Landscape scale

The Project is just a few kilometres east of the Great Dividing Range and is thus located near the very top of the hydrologic/geomorphic landscape. Much of the western part of the Project site consists of hills that are the source zone of water and bedload sediment for the east flowing Sandy Creek tributaries – Well Creek, Middle Creek, Little Sandy Creek, and Rocky Creek. At lower elevations the valleys widen and streams enter a transfer zone where sediment is passing through but may be stored for significant periods in the floodplains that occur adjacent to the channel. The drainage features (watercourses) in the Project area are therefore developed in a fluvial landscape comprising dissected hills and escarpments in the west that slope down into lower hills and gentle slopes, that in turn are replaced by floodplains across the wider valley floors. The hill country is mostly underlain by Tertiary age (older than 2 million years) alluvium that was laid down in a former somewhat different fluvial landscape. The present fluvial landscape is of Quaternary age (less than 2 million years) and the older parts of this alluvial material occur on low hills 15 – 20 m above the valley floors, which in turn comprise younger alluvium deposited as floodplains associated with the present stream channels. This material is generally sand and silt and is likely to be >5 m deep.

The older Tertiary alluvium has been deeply weathered and in places forms hard duricrusts that create knick points in the valley floors so that stream beds can drop abruptly 2 m or more in a short distance.

The alluvial materials of both Tertiary and Quaternary age are easily eroded, and when tree cover is removed enhanced surface runoff can occur and cause rapid land degradation. This can in turn deliver increased volumes of sediment to the waterways. All of these processes have been observed in the Kevin's Corner MLA (70425).

Floodplains flank the Sandy Creek tributary channels in their mid and lower reaches, and these are typically a few hundred metres across. Sandy Creek in the lowest part of the landscape receives these tributary stream flows so that here the floodplain is wider, in places over 1 km across.

Sandy Creek is the master valley drainage feature. It is joined from the west by Well Creek, which in turn is fed by Middle Creek and Little Sandy Creek. Rocky Creek is a tributary of Little Sandy Creek.

11.3.4.2 Watercourse Features

Individual water courses are described in the Geomorphology Technical Report (Volume 2, Appendix M1). There is a diversity of channel types including alluvial, bedrock controlled, single and multiple thread channels.

Sandy Creek is the master stream system with a distinctively anabranching channel system and channels 25 – 50 m wide. It carries a significant medium-coarse sand bedload supplied mainly by Greentree Creek, with some contribution from Well Creek. The channel is not obviously aggrading. The 2 – 2.5 km wide floodplain is only active during floods larger than 1:50 AEP events.

Well Creek and Rocky Creek are medium sized, predominantly single thread channels 5 – 25 m across, that carry significant sand bedload, and are aggrading in their upper reaches. Floodplains are only developed consistently along the lower reaches of Well Creek and are active during 1:10 to 1:20 AEP flood events.

Little Sandy Creek and Rocky Creek are small streams with predominantly anastomosing channel systems 5 – 25 m across. They carry some medium sand bedload and show some evidence for current aggradation in their upper reaches.

The aggradation in the upper reaches of these streams is interpreted as resulting from enhanced rates of land degradation arising from grazing land use and tree clearing since the 1960s. This sediment is currently making its way down through the Well Creek and its tributary systems.

The conditions of individual streams in the Project site are described in Section 5 of the Geomorphology Technical Report (Volume 2, Appendix M1), and are summarised below in Table 11-3 to Table 11-7.

Table 11-3 Sandy Creek geomorphic feature summary

Channel characteristic	Description
Landscape setting	Broad asymmetrical valley with low hills distant ~2 km to the west, and adjacent medium hills to east.
Length of channel in MLA 70425	13.2 km
Sinuosity	SI = 1.05, straight
Bed slope	0.17% in upstream 5 km, then 0.11%
Channel planform and type	Ridge and island anabranching, 2 – 5 threads. Some short single thread reaches
Active bed character	Sand sheet with semi braided pattern in low flow channel. Several pools 150 – 500 m long in downstream of Well Creek junction.
Width of bed	Anabranches 25 – 50 m wide, total bed width 70 – 85 m.
Typical flow depth in mean annual flood	1 – 2 m
Sediment type	Medium – coarse sand. Overbank sediment fine sand – silt. Not obviously aggrading.
Sediment sources	Greentree Creek, Well Creek
Channel banks	Low, moderately sloping well grassed with some trees. In-channel benches present.
Bankfull conditions	Anabranch ridges and islands mostly covered by 1:5 to 1:10 AEP flood events. Flow depth 3 – 4 m, mean stream power 10 – 30 W/m^2.
Floodplain	Floodplain merges with Little Sandy Creek floodplain in larger than 1:50 AEP events, up to 2.5 km wide. Channel stream power > 50 – 75 W/m^2.

Table 11-4 Well Creek geomorphic feature summary

Channel characteristic	Description
Landscape setting	Upper reach narrow to moderately narrow valley confined between low hills. Lower reach traverses more open valley floor of Sandy Creek. Catchment tree cover largely intact.
Length of channel in MLA 70425	20.9 km
Reaches	Upper reach: to Middle Creek Junction (15.3 km) Lower reach: from Middle Creek Junction to Sandy Creek junction (5.6 km)
Sinuosity	Upper reach moderately sinuous irregular meandering channel SI = 1.4. Lower reach slightly sinuous SI = 1.1.
Bed slope	Upper reach 0.28% declining downstream to 0.22% Lower reach 0.17%
Channel planform and type	Single thread with occasional ridge anabranching sub-reaches in lower 2 km
Active bed character	Uniform sand sheet with low point bars. Bed aggrading in upper reach and upstream parts of lower reach. Knick points and small waterfalls formed in duricrusts in upper reach.
Width of bed	Upper reach: 10 – 20 m Lower reach 15 – 25 m

Channel characteristic	Description
Typical flow depth in mean annual flood	Upper reach ~1 m. Lower reach ~1.5 m.
Sediment type	Coarse sand with occasional gravel lags. Overbank sediment medium to fine sand. Mud drapes in lower reach.
Sediment sources	Areas of land degradation close to channel and active bend erosion sites mainly in upper reach, and from Middle Creek.
Channel banks	Upper reach mainly low (<2 m) gentle-moderately sloping with grass vegetation down to bed. In places higher banks (>2m) are vertical and being undercut by the stream. Lower reach similar with higher banks and more tree cover. In channel benches in lower reach.
Bankfull conditions	1:10 to 1:20 AEP events, channel 2.5 – 3 m deep. Upper reach mean stream power 75 – 110 W/m^2 Lower reach mean stream power: 40 – 105 W/m^2
Floodplain	Upper reach: Intermittently developed, moderately wide where present – 200 m to 1000 m. Lower reach: well developed and is over 4 km wide where it merges with Sandy Creek floodplain ~ 3.5 km from that stream junction.

Table 11-5 Middle Creek geomorphic feature summary

Channel characteristic	Description
Landscape setting	Narrow valley confined between low hills. Catchment tree cover mostly intact.
Length of channel in MLA 70425	19.5 km, in a single reach
Sinuosity	Upstream SI = 1.4, downstream SI = 1.2
Bed slope	Upper reaches 0.52 – 0.37%, lower 12 km 0.27%
Channel planform and type	Single thread confined, with irregular low sinuosity meanders. Some short ridge anabranching sub-reaches.
Active bed character	Uniform sand sheet with low point bars. Bed aggrading. Knick points common, formed in duricrust materials.
Width of bed	5 – 10 m
Typical flow depth in mean annual flood	0.4 – 0.8 m
Sediment type	Medium to coarse sand in bed. Overbank sediment fine sand.
Sediment sources	Areas of land degradation close to channel and active bend erosion sites.
Channel banks	Mainly low (<2 m) gentle-moderately sloping with grass vegetation down to bed. In places higher banks (>2m) are vertical and being undercut by the stream.
Bankfull conditions	1:5 to 1:10 AEP events, channel 1 – 1.5 m deep. Mean stream power 30 – 40 W/m^2.
Floodplain	Not consistently developed. If present less than 100 m wide.

Table 11-6 Rocky Creek geomorphic feature summary

Channel characteristic	Description
Landscape setting	Upper reach narrow valley in dissected hills. Lower reach 1.5 – 2 km wide valley between low hills. Trees cleared from half of catchment.
Length of channel in MLA 70425	14.5 km
Reaches	Upper reach 3 km confined between hills. Lower reach 11.5 km in wide flat floored valley
Sinuosity	Both reaches SI = 1.3, moderately sinuous.
Bed slope	0.29%
Channel planform and type	Upper reach single thread confined, meander wavelength 300 – 400 m. Lower reach anastomosing with 2 – 3 meandering channels of wavelength 150 – 200 m
Active bed character	Sand sheet arranged into pools and riffles with low point bars. Duricrust knick points upper reach Large woody debris present in lower reach. Upper reach and upstream parts of lower reach actively aggrading.
Width of bed	Upper reach mean width 8 m Lower reach mean width 13 m
Typical flow depth in mean annual flood	0.75 m
Sediment type	Medium to coarse sand with fine sand overbank deposits. Gravel lags below duricrusts knick point. Mud drapes occur in downstream part of lower reach.
Sediment sources	Active land degradation sites along both reaches and active bank erosion on outside of meander bends.
Channel banks	Moderately steep, partly vegetated with grass and some trees
Bankfull conditions	Upper reach: 1:50 AEP event, 2.5 – 3 m deep, mean stream power 30 – 35 W/m^2. Lower reach: 1:20 to 1:50 AEP events declining to 10 – 20 yr Average Recurrence Interval (ARI), 1.5 – 2.5 m deep, mean stream power 20 – 30 W/m^2.
Floodplain	Not present in upper reach. Lower reach: extensive floodplain up to 1 km wide, 1.5 km where it merges with Little Sandy Creek floodplain. Upstream parts only active in larger than 1:50 AEP events, downstream active in larger than 1:10 AEP events.

Table 11-7 Little Sandy Creek geomorphic feature summary

Channel characteristic	Description
Landscape setting	Upper reach narrow valley in dissected hills. Lower reach 1.5 – 2 km wide valley between low hills. Trees cleared from half of catchment. 63%
Length of channel in MLA 70425	34.8 km
Reaches	Upper reach 4.3 km confined between hills. Upper middle reach 11.1 km in wide flat floored valley Lower middle reach 16.4 km in wide flat floored valley Lower reach 3.0 km in wide flat floored valley

Channel characteristic	Description
Sinuosity	Upper reach SI = 1.2, sinuous. Upper middle reach SI = 1.6, meandering. Lower middle reach SI = 1.4, moderately meandering. Lower reach SI = 1.7, meandering.
Bed slope	Upper reach 0.63% Upper middle reach 0.2% Lower middle reach 0.16% Lower reach 0.07%
Channel planform and type	Upper reach single thread confined Upper middle reach single thread, meander wavelength 200 – 300 m. Lower middle reach anastomosing with 2 – 3 meandering channels of wavelength 300 – 400 m. Lower reach single thread meander wavelength 100 – 150 m
Active bed character	Upper reaches have coarse sandy bed with pools and riffles. Lower reaches have finer sand and long pools. Duricrust knick points in upper reach. Large woody debris present in lower reaches. Upper and upper middle reaches actively aggrading.
Width of bed	Upper reach 5 – 10 m Upper middle reach 10 – 15 m Lower middle reach 15 – 20 m Lower reach 10 – 15 m.
Typical flow depth in mean annual flood	Upper reach ~0.5 m Upper middle reach ~0.75 m Lower middle reach ~1.2 m Lower reach ~1.5 m.
Sediment type	Upper and upper middle reaches have medium to coarse sand with fine sand overbank deposits. Finer sands in downstream reaches with mud drapes.
Sediment sources	Active land degradation sites along both upper and upper middle reaches, and active bank erosion on outside of meander bends.
Channel banks	Moderately steep to steep, partly vegetated with grass and some trees. Erosion on outside of bends. In-channel benches and levees occur in lower reach.
Bankfull conditions	Upper reach: larger than 1:50 AEP event, 2.5 – 3 m deep, mean stream power 30 – 35 W/m^2. Upper middle reach: variable from 1:10 to 1:50 AEP events, 1 – 2 m deep, 15 – 35 W/m^2 Lower middle reach: 1:10 to 1:20 AEP events, 2 – 2.5 m deep, mean stream power 12 – 20 W/m^2. Lower reach: 1:5 to 1:10 AEP events, 2.5 – 3 m deep, mean stream power 2 – 7 W/m^2.
Floodplain	Not present in upper reach. Lower reaches: extensive floodplain up to 1 km wide, 2.0 km where it merges with Sandy Creek floodplain. Upstream parts only active in larger than 1:20 AEP events, downstream active in larger than 1:10 AEP events.

11.3.4.3 Significance of Geomorphic Features to Inform Design of the Project Stream Changes

All of the watercourses described above will to some extent be affected by the Kevin's Corner Project such that their geomorphic systems will be partly changed. Potential effects range from complete removal of parts of the Rocky and Little Sandy Creek channels, greatly reduced flow in other parts of Rocky and Little Sandy Creeks, increased flow in downstream reaches of Middle and Well Creeks, and diversion of flow from Little Sandy and Rocky Creeks into Middle Creek. In addition, the floodplain width of Sandy Creek will be reduced in size, and most channels, floodplains and hillsides in the western part of MLA 70425 will be affected by ground surface elevation changes due to underground mining subsidence. The geomorphic assessment has identified characteristics of the existing watercourses and how they may be changing. For sustainable design of the proposed Project stream interventions the following issues need to be considered.

1. The Sandy Creek anabranching channel system requires low channel stream powers and good vegetation cover to maintain stability. The floodplain is a low stream power environment covered during 1:50 to 1:100 AEP floods. Increased flows in this environment could lead to stripping of floodplain sediments. The constriction of the Sandy Creek floodplain will increase flow depths and velocities on the floodplain and in the channels, and stream power will also increase across both environments. These effects will need to be managed through the life of the mine and beyond.
2. Diversion of the small Little Sandy and Rocky Creek flows into Middle Creek Sandy Creek and Well Creek will occur from an anastomosing environment with multiple channels and a wide floodplain. Design will need to ensure all channels and floodplain flows are directed into the diversion. The diversion will reduce a multiple thread channel to a single channel. In MLA 70425 single thread channels tend to also have in-channel benches so these may need to be considered in the diversion design.
3. The Little Sandy/Rocky Creeks diversion will deliver increased flow to Middle Creek. This watercourse is in a confined valley with limited or no floodplain development. Flows will need to be managed to ensure the channel is able to develop a new equilibrium profile with the increased volume and frequency of bankfull discharge events.
4. The increased flow in Middle Creek will also increase flow in Well Creek in the reach between its confluences with Middle and Little Sandy Creeks. In this reach the channel and floodplain environment will experience increased volume and frequency of bankfull discharge events. The channel floodplain environments will therefore function differently.
5. The greatest spatial effect on the watercourses of MLA 70425 will occur in response to the progressive surface subsidence that will work its way west throughout the mine life. Ground subsidence of between 0.5 and 3 m will affect the channels, floodplains, and valley side hillslopes of Well, Middle, Rocky and Little Sandy Creek. The subsidence will create new surface water drainage paths on hillslopes and potentially trigger a phase of enhanced land degradation and sediment input to the streams. Flow paths across floodplains will also change, and some ponding and swamp development may occur. Channel banks may be weakened leading to instability and erosion.
6. It has been demonstrated that the present watercourses of Well Creek, Middle Creek, Little Sandy Creek, and Rocky Creek are beginning to carry more bedload sediment and this is being deposited in the upper channel reaches causing aggradation and channel shallowing. This in turn will increase the frequency of bankfull discharge events. It is expected that this sediment will continue to make its way downstream reaching Sandy Creek within 10 to 20 years. This main stream is already carrying an appreciable sand bedload. Increased sediment loads will also arise from

underground mining subsidence. Therefore, all watercourses and diversions will need to be designed and/or managed for these increased sediment loads throughout the mine life and beyond. Issues such the effects of sand deposition in main channels and tributary junctions, and the potential for reduced channel conveyance capacity may arise.

11.3.5 Existing Flood Conditions Hydraulic Assessment

11.3.5.1 Hydraulic Modelling

A baseline flood hydraulics assessment was performed to estimate key hydraulic parameters and indicators of relevance to existing channel geomorphologic stability and to guide acceptable criteria for design of stream diversions and/or constriction of the floodplain corridor for establishing levee banks to protect the mine from flooding.

Hydraulic modelling was performed using 1-dimensional computer models (HEC-RAS) for floods up to the 1:50 AEP flood and 2-dimensional computer models (TUFLOW) for floods from the 1:100 AEP, up to the Probable Maximum Flood (PMF). The use of two separate modelling programs was precluded by the following:

- 1-Dimensional Flood Modelling (HEC-RAS):
  - The flooding extents for the floods up to the 1:50 AEP are generally contained within each creek system and little interaction with the neighbouring creek systems (i.e. flow is 1-dimensional), thus a 1-dimensional model was considered appropriate.
  - Ease of comparison to the Australian Coal Association Research Program (ACARP) guidelines for designing, maintaining, and managing stream diversions in the Bowen Basin which recommend hydraulic parameters that were derived using 1-dimensional hydraulic modelling for flood events up to the 1:50 AEP event.
- 2-Dimensional Flood Modelling (TUFLOW):
  - The flooding extents for the floods from the 1:100 AEP to the PMF include significant floodplain interaction (i.e. flow is 2-dimensional), thus a 2-dimensional model was considered appropriate.
  - The primary purpose of modelling the more extreme events was to estimate flooding extents at the mine lease boundary and for estimating flood levee heights for protection of the mining operations.

11.3.5.2 Frequent Events (up to 1:50 AEP) Flood Modelling Results

A one-dimensional hydraulic model (HEC-RAS) was developed to assess the existing hydraulic conditions of the Sandy Creek and smaller tributary watercourses. Hydraulic input parameters to the model were developed based on site visits and engineering reference manuals since no stream gauge data was available for model calibration. A detailed description of the model development is presented in Volume 2, Appendix M2.

The purpose of the hydraulic analysis was to quantify key hydraulic parameters for a range of flood events up to the 1:50 AEP flood event and to compare the hydraulic results with the qualitative geomorphologic assessment. These parameters were flow velocity, bed-shear stress, stream power, and sediment transport potential.

Longitudinal profiles of the existing creek flow velocity and stream power for the 1:2 and 1:50 AEP flood events are presented on Figure 11-4 to Figure 11-13 and are summarised in Table 11-8 and Table 11-9. Additional hydraulic profile plots for all parameters and all analysed flow cases are presented in the Hydraulics Technical Report (Volume 2, Appendix M2).

Table 11-8 Summary flood hydraulics parameters for Sandy Creek

Hydraulic Parameter	Flood Event (AEP)	Upstream of Mine	Mine Reach
Velocity (m/s)	1:2 1:50	0.3 – 0.9 0.5 – 2.0	0.5 – 1.0 1.3 – 2.2
Stream Power (W/m2)	1:2 1:50	0.7 – 11 1.0 – 75	1.3 – 18 26 – 115

Table 11-9 Summary flood hydraulics parameters for Little Sandy, Rocky, Middle and Well Creeks

Hydraulic Parameter	Flood Event (AEP)	Existing reach upstream of Diversion	Existing reach downstream of Diversion
Little Sandy Creek			
Velocity (m/s)	1:2 1:50	0.3 – 1.0 0.5 – 2.1	0.1 – 1.1 0.8 – 1.9
Stream Power (W/m2)	1:2 1:50	0.8 – 26 2.1 – 147	0.6 – 24 6.2 – 88
Rocky Creek			
Velocity (m/s)	1:2 1:50	0.3 – 1.5 0.5 – 2.4	0.4 – 1.4 1.0 – 2.6
Stream Power (W/m2)	1:2 1:50	0.5 – 80 2.7 – 218	0.8 – 68 12 – 226
Middle Creek			
Velocity (m/s)	1:2 1:50	0.2 – 1.2 0.8 – 2.1	0.4 -1.4 1.2 – 2.3
Stream Power (W/m2)	1:2 1:50	0.1 – 48 9.9 – 159	1.4 – 55 22 – 154
Well Creek			
Velocity (m/s)	1:2 1:50	0.6 – 1.4 1.4 – 2.9	0.5 – 1.2 0.9 – 2.6
Stream Power (W/m2)	1:2 1:50	3.2 – 61 33 – 311	2.5 – 31 9.7 – 190

Figure 11-4 Velocity results along existing Sandy Creek profile

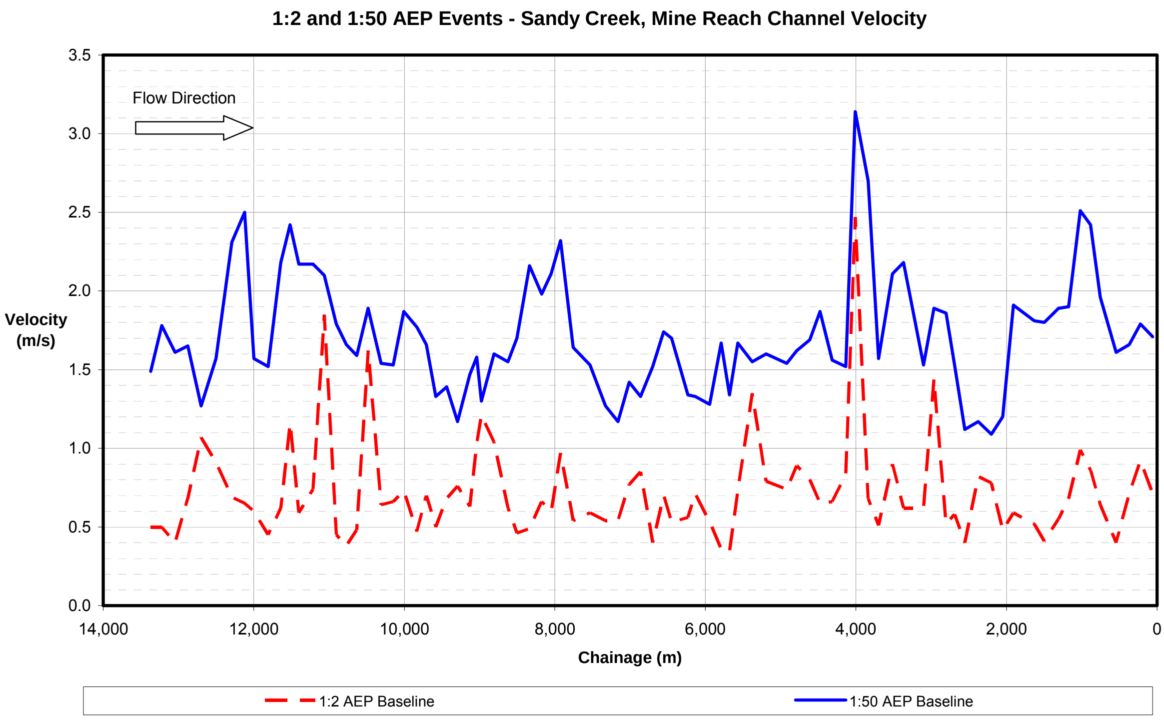


Figure 11-5 Stream power results along existing Sandy Creek profile

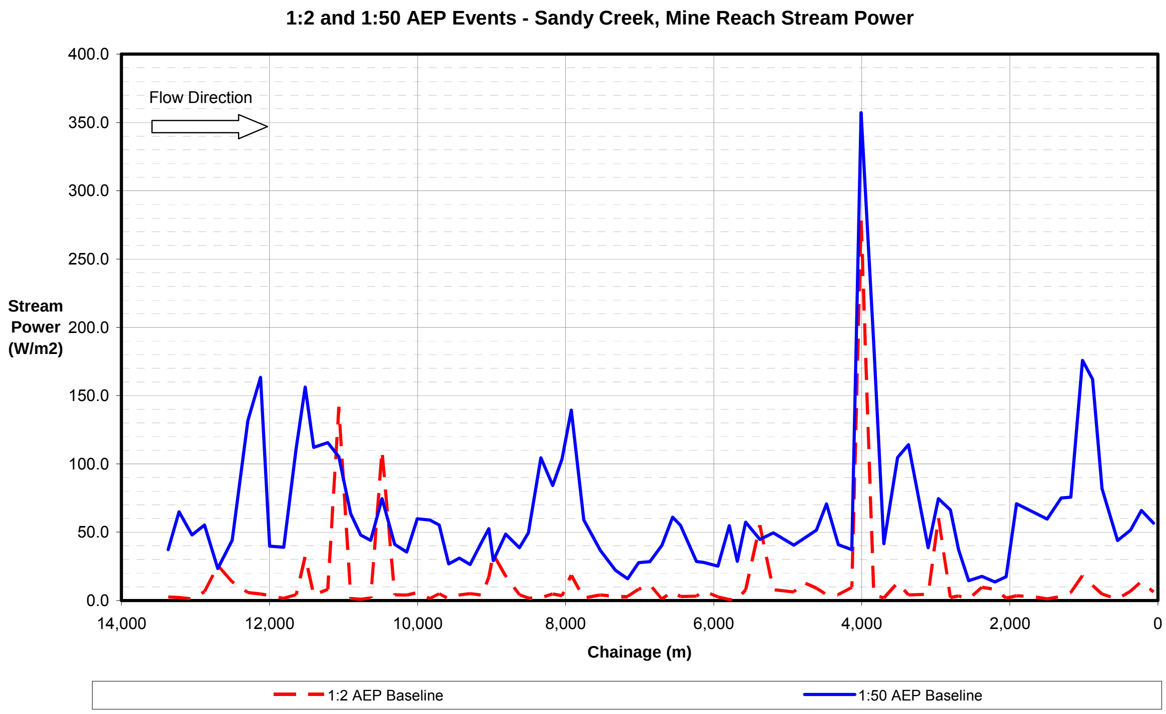


Figure 11-6 Velocity results along existing Little Sandy Creek profile

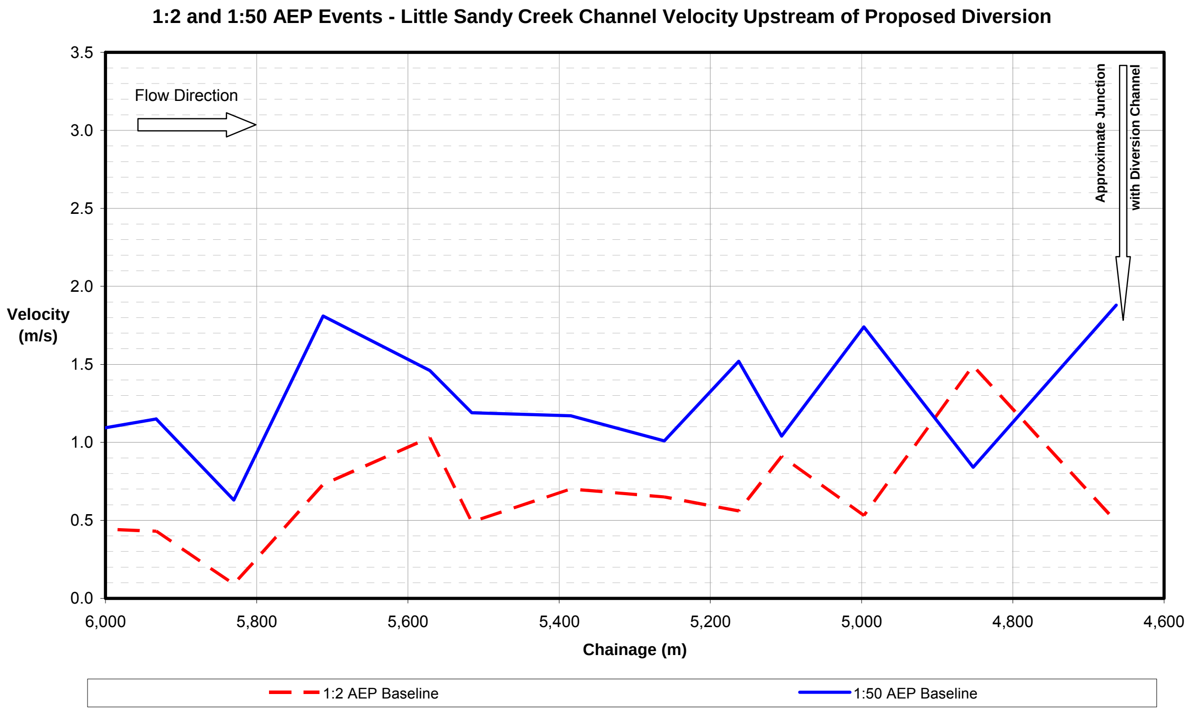


Figure 11-7 stream power results along existing Little Sandy Creek profile

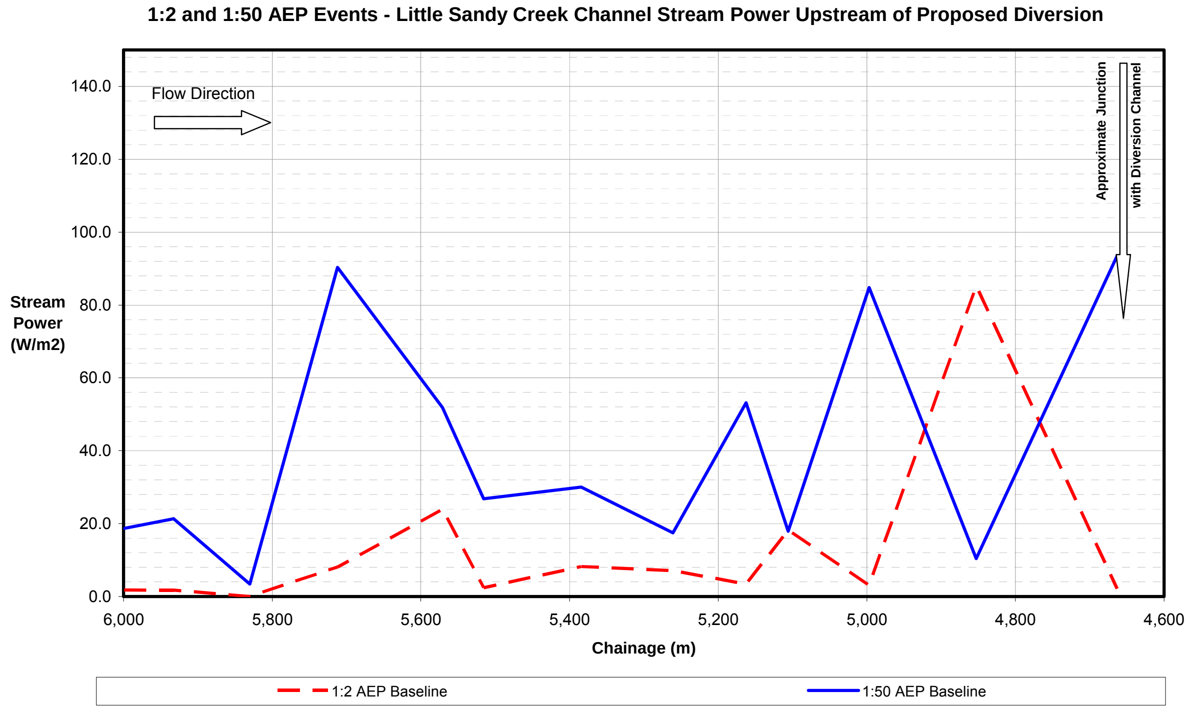


Figure 11-8 Velocity results along existing Rocky Creek profile

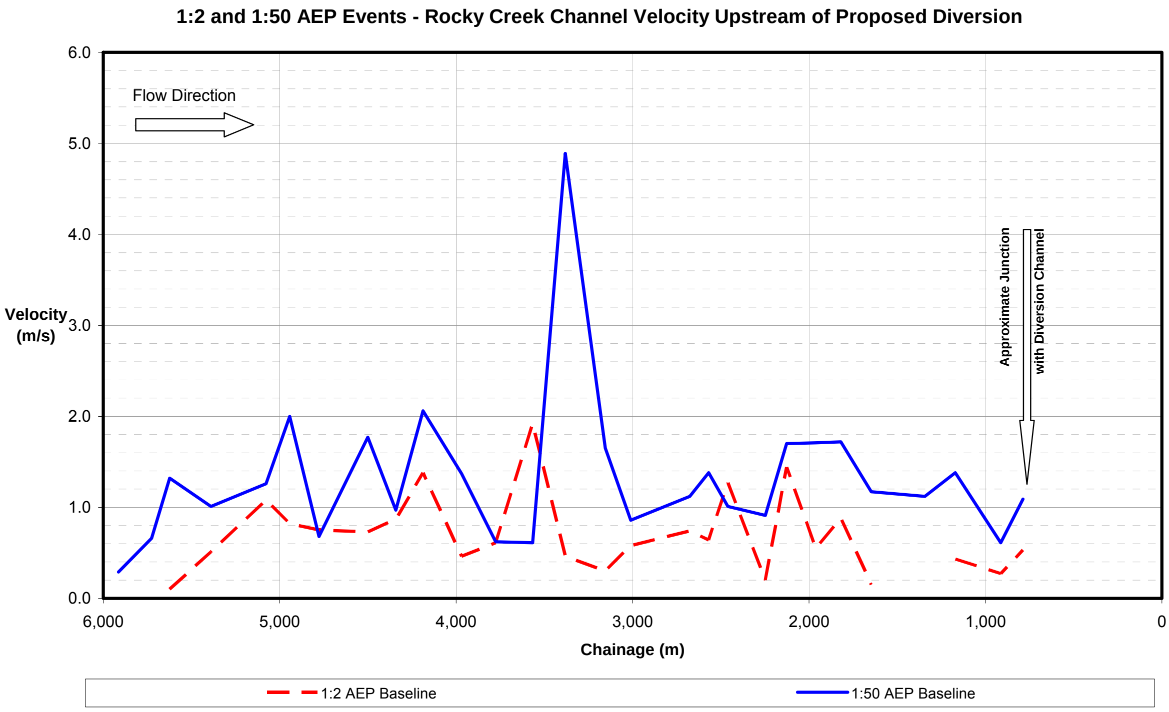


Figure 11-9 Stream power results along existing Rocky Creek profile

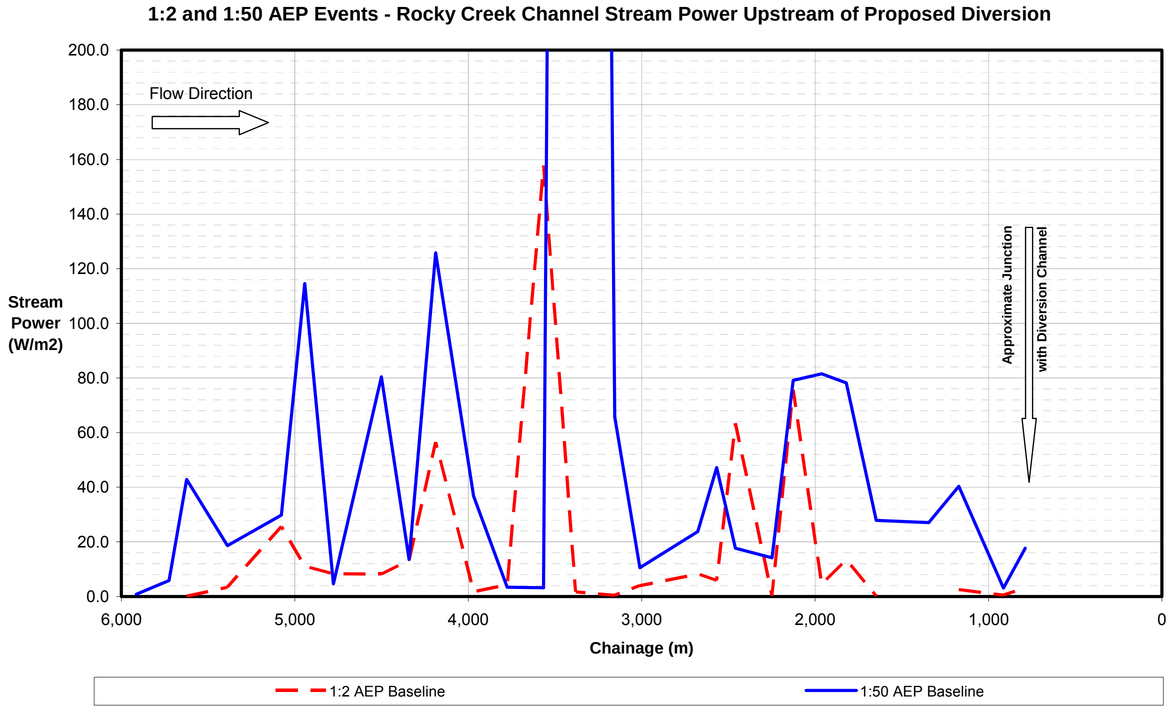


Figure 11-10 Velocity results along existing Middle Creek profile

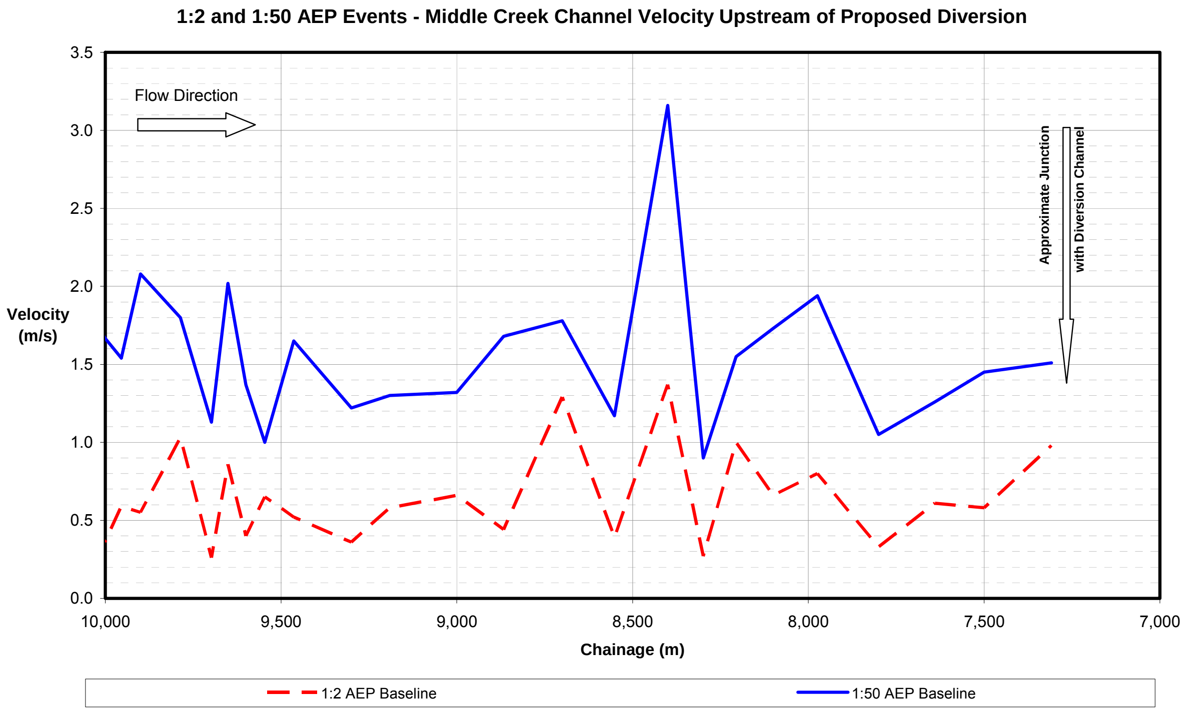


Figure 11-11 Stream power results along existing Middle Creek profile

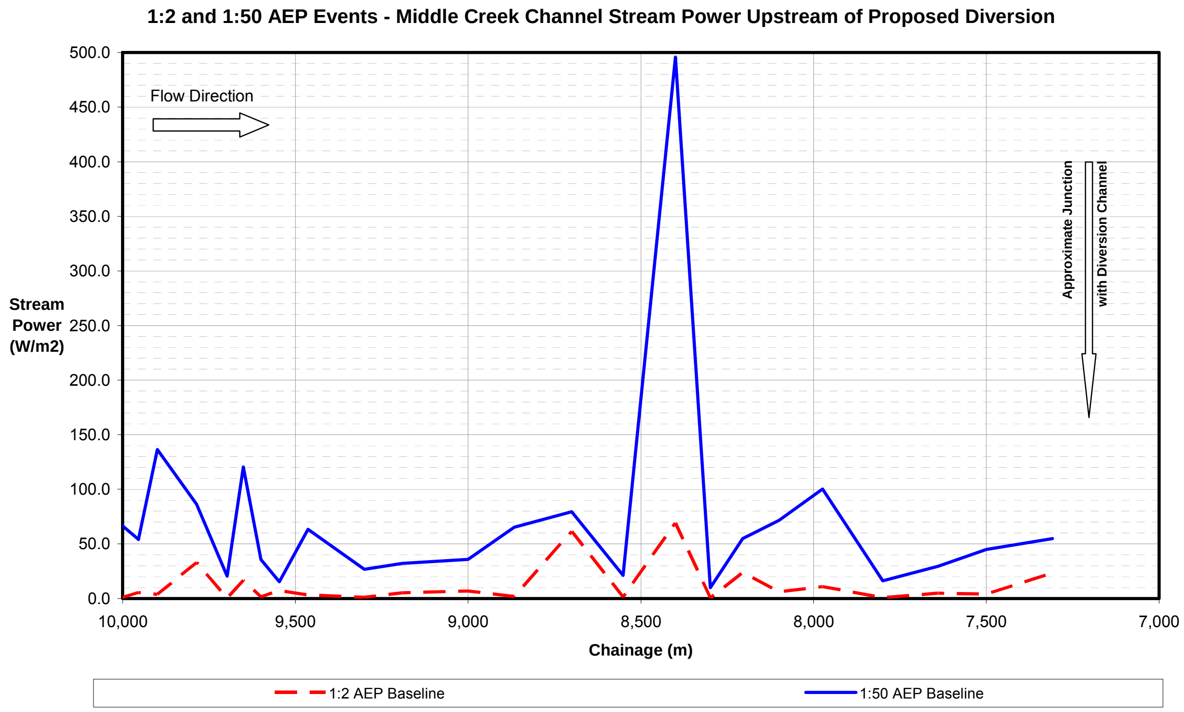


Figure 11-12 Velocity results along existing Well Creek profile

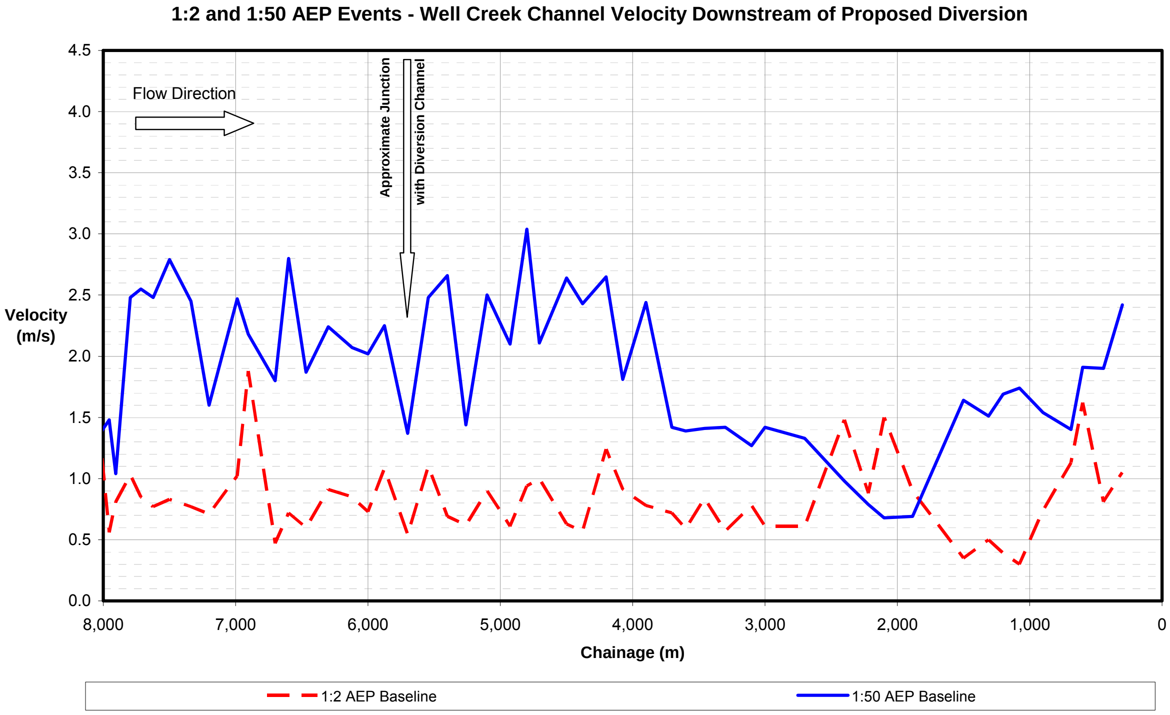
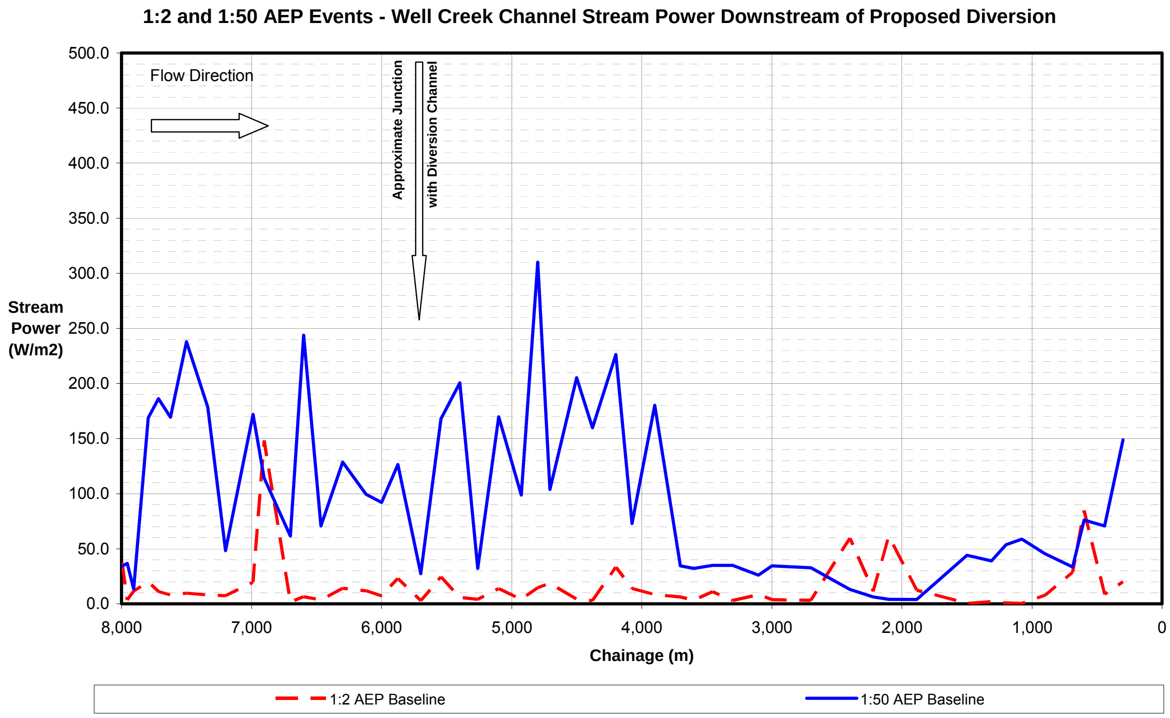


Figure 11-13 Stream power results along existing Well Creek profile



In order to estimate baseline sediment transport capacities for the creeks, the HEC-RAS model results were compared to approximate critical bed shear stresses (i.e. the threshold point at which movement of a sediment particle begins) for particle type and size. Based on observations, the substantial sediment deposition in the creek beds appeared to be a mixture of medium to coarse grained sand to possibly as large as a fine gravel (no samples were taken). Gradations within the channels appeared to be reasonably similar.

Comparison of the critical shear stress, for the assumed particle size transported by the modelled creek channel system, with the average channel shear stress results is summarised in Table 11-10 and in Volume 2, Appendix M2. The comparison indicates high potential for sediment transport, which is also supported by observations of significant sediment deposition during the site visit. Additional information on bed shear stress for each of the creeks is presented in Appendix M2.

Table 11-10 Summary of sediment transport potential for existing creeks

<table>
<tr><th>Creek</th><th>Location</th><th>Channel Forming Event (1:X) AEP</th><th>Shear Stress (N/m2)</th><th>Assumed Particle Classes Present in Reach</th><th>Critical Shear Stress of Assumed Particle Classes (N/m^2)</th></tr>
<tr><td>Sandy Creek</td><td>Upstream of Mine Lease Boundary</td><td>1:5 to 1:10</td><td>3.5 – 21</td><td rowspan="10">Fine Gravel

Very Fine Gravel

Very Coarse Sand

Medium Sand</td><td rowspan="10">2.7

1.3

0.47

0.19</td></tr>
<tr><td>Sandy Creek</td><td>Within Mine Lease Boundary</td><td>1:5 to 1:10</td><td>8.3 – 30</td></tr>
<tr><td>Little Sandy Creek</td><td>Upstream of Diversion</td><td>1:10 to 1:50</td><td>3.5 – 70</td></tr>
<tr><td>Little Sandy Creek</td><td>Downstream of Diversion</td><td>1:10 to 1:50</td><td>4.5 – 47</td></tr>
<tr><td>Rocky Creek</td><td>Upstream of Diversion</td><td>1:20 to 1:50</td><td>5.1 – 88</td></tr>
<tr><td>Rocky Creek</td><td>Downstream of Diversion</td><td>1:20 to 1:50</td><td>13 – 88</td></tr>
<tr><td>Middle Creek</td><td>Upstream of Diversion</td><td>1:5 to 1:10</td><td>2.3 – 55</td></tr>
<tr><td>Middle Creek</td><td>Downstream of Diversion</td><td>1:5 to 1:10</td><td>7.8 – 55</td></tr>
<tr><td>Well Creek</td><td>Upstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>14 – 89</td></tr>
<tr><td>Well Creek</td><td>Downstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>15 – 51</td></tr>
</table>

Note (1): Critical Shear Stress Values from *Erosion and Sedimentation* (Julien 1995)

11.3.6 Flood Modelling Results - Rare and Extreme Events (1:100 AEP to PMF)

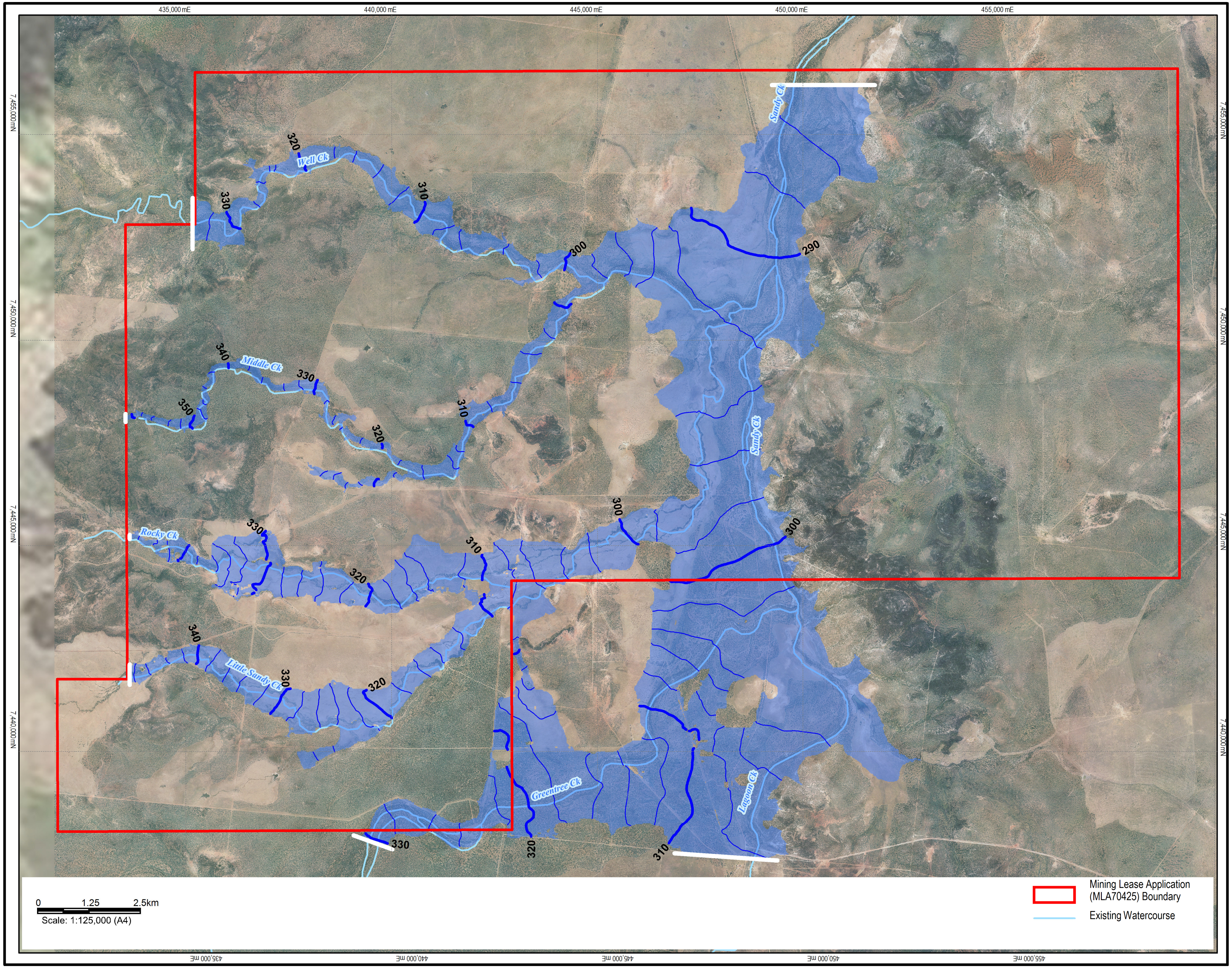
A two-dimensional finite-difference hydraulic model (TUFLOW) was developed to assess the hydraulic conditions of the Sandy Creek and smaller tributary watercourses for existing conditions for the rare to extreme flood events. The purpose of the hydraulic analysis was to quantify maximum flood levels, for a range of flood events from the 1:100 AEP flood event to the PMF. The flood levels would serve as baseline elevations for later comparison to the proposed (developed) condition with mine levees in place to protect the mine infrastructure and estimate any impacts to areas outside the mine lease boundary. Hydraulic input parameters to the model were developed based on site visits and engineering reference manuals for development of the hydraulic model since no stream gauge data was available for model calibration. A description of the model development is presented in the Hydraulic Technical Report (Volume 2, Appendix M2).

Flooding extents for the 1:1,000 AEP flood event for the existing creek system is presented on Figure 11-14 and a summary of the estimated flood elevations at the upstream and downstream boundaries of the mine lease are presented in Table 11-11 (flood elevations for the selected frequent events are included for completeness). Additional hydraulic information for each of the modelled flood events is presented in the Hydraulic Technical Report (Volume 2, Appendix M2).

Table 11-11 Estimation of existing flood elevations in Sandy Creek at mine lease boundary

AEP Event	Flood Elevation at Upstream Mine Boundary (m AHD)	Flood Elevation at Downstream Mine Boundary (m AHD)
1:2	296.6	279.2
1:50	299.1	282.0
1:100	300.8	283.5
1:1,000	301.6	284.4
1:2,000	301.6	284.8
PMF	304.4	288.8

Table note:
m AHD = meters above Australian Height Datum



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1 - References*

Datum: GDA94, MGA Zone55

HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

EXISTING 1:1000 AEP
FLOOD INUNDATION EXTENTS

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-14

File No: 42626660-g-1049.wor

11.3.7 Existing Water Quality

11.3.7.1 Environmental Values

Environmental values (EVs) for the Project area are not specified in Schedule 1 of the EPP Water 2009. As no EVs have been identified by regulatory bodies, EVs for receiving waters in the Project area were derived from a desktop analysis of available information on the watercourses within the Project area and data on downstream water uses.

The watercourses within the Project site are ephemeral in nature and provide seasonal habitat for aquatic fauna and flora. The watercourses are noted to be slightly to moderately disturbed from current grazing activities.

The surrounding land use in the Belyando/Suttor subcatchment is predominantly grazing with some broad acre cereal cropping. Agricultural activities including crop irrigation, stock watering and farm use are the primary uses within the subcatchment. There are areas of conservational value and many of the tributaries are seasonally used as local recreational areas (NQ Dry Tropics, 2011).

Belyando River and Sandy Creek have significant cultural and spiritual values for the Wangan/Jangalingou and Bidjara indigenous peoples, as traditional owners of the land (NQ Dry Tropics, 2011).

Regionally, the Belyando River system also supports secondary contact recreational activities and is used for drinking water. The full derivation of environmental values is presented in the Surface Water Quality Technical Report (Volume 2, Appendix M4).

11.3.7.2 Water Quality Assessment

Relevant water quality objectives (WQOs) for the study area were identified from the QWQG (2009) to support and protect the environmental values identified for watercourses in the Belyando/Suttor catchment. All streams within or adjacent to MLA 70425 were identified as 'upland freshwater streams' which are defined as freshwater streams or stream sections above 150 m in elevation (ANZECC, 2000). Accordingly, physico-chemical indicators were obtained from the Central Coast Region upland stream values (Table 11-11). Salinity guidelines were obtained from Appendix G of the QWQG. It should be noted that these objectives have been developed at a regional scale.

The existing water quality of the watercourses and downstream receiving environment of the Project site was assessed to characterise the baseline water quality conditions. The assessment was based on a review of existing water quality monitoring data from DERM gauging stations and monitoring undertaken as part of this EIS. Sampling data was assessed against the water quality objectives and a comparison is provided in Table 11-12. Elevated turbidity may be attributable to existing land uses in the catchment including open pasture and grazing which has historically involved widespread clearing and subsequently caused sediment mobilisation in waterways. Higher electrical conductivity (EC) values are also likely to be associated with land degradation, soil erosion and tree clearing from surrounding agricultural activities in the catchment. Inorganic nitrogen (NH_4) was consistently much lower than total nitrogen indicating that a significant proportion of the total nitrogen is attributable to organic sources. It should be noted that dissolved oxygen measurements were generally taken up to a week after flow events and may represent lower readings than those observed immediately following a flow event.

Table 11-12 Comparison of baseline water quality data for Kevin's Corner against Queensland Water Quality Objectives for Central Coast Region Upland Streams (slightly to moderately disturbed systems)

Parameter	Units	Guideline Upland Streams (slightly to moderately disturbed)		% of Baseline Sites that Exceed Guideline (median values)
Ammonia	µg/L	10		80%
Oxidised Nitrogen	µg/L	15		80%
Organic Nitrogen	µg/L	225		80%
Total Nitrogen	µg/L	250		84%
Filterable Reactive Phosphorus	µg/L	15		76%
Total Phosphorus	µg/L	30		92%
Chlorophyll-a	µg/L	n/a		0%
Dissolved Oxygen	%sat	Lower	Upper	100% (below low threshold value)
		90	110	
Turbidity	NTU	25		100%
pH	%sat	Lower	Upper	12%
		6.5	7.5	
Conductivity	µS/cm	168		12%
Suspended Solids	mg/L	nd		-
Temperature	°C	Site specific		-

Existing metals concentrations at each site were compared against ANZECC Freshwater Aquatic Ecosystem Guidelines (ANZECC 2000) for toxicants at a 95% level of protection. It showed that median values for aluminium, copper, zinc and chromium exceeded guidelines for more than 50% of the baseline sites. A summary is provided in Table 11-13 Elevated metal concentrations may be attributable to existing agricultural activities in the area or may be naturally high.

Table 11-13 Comparison of baseline water quality data for Kevin's Corner against ANZECC Freshwater Aquatic Ecosystem Guideline for Toxicants at 95% species protection

Parameter	Units	ANZECC Freshwater Aquatic Ecosystem Toxicant Guideline (95% Species Protection)	% of Baseline Sites that Exceed Guideline (median values)
Dissolved Aluminium	mg/L	0.055	84%
Dissolved Arsenic	mg/L	0.013	0%
Dissolved Boron	mg/L	0.37	8%
Dissolved Cadmium	mg/L	0.0002	8%
Dissolved Chromium	mg/L	0.001	12%
Dissolved Copper	mg/L	0.0014	92%
Dissolved Lead	mg/L	0.0034	0%
Dissolved Manganese	mg/L	1.9	0%
Dissolved Mercury	mg/L	0.0006	0%
Dissolved Nickel	mg/L	0.011	0%
Dissolved Zinc	mg/L	0.008	44%
Total Aluminium	mg/L	0.055	84%
Total Arsenic	mg/L	0.013	0%

Parameter	Units	ANZECC Freshwater Aquatic Ecosystem Toxicant Guideline (95% Species Protection)	% of Baseline Sites that Exceed Guideline (median values)
Total Boron	mg/L	0.37	0%
Total Cadmium	mg/L	0.0002	0%
Total Chromium	mg/L	0.001	64%
Total Copper	mg/L	0.0014	84%
Total Lead	mg/L	0.0034	0%
Total Manganese	mg/L	1.9	0%
Total Zinc	mg/L	0.008	40%

A comparison between available water quality data and the WQOs shows that the baseline data exceeds the objectives for the majority of water quality parameters. Given there is a significant amount of historical water quality data for DERM gauging stations at Mistake Creek at Twin Hills (120309A), Mistake Creek at Charlton (120306A), Belyando River at Gregory Development Road (120301B) and Native Companion Creek at Violet Grove (120305A), it is recommended that local trigger values be developed in accordance with the procedures described in QWQG (2009), using further baseline monitoring data at the 20 monitoring sites and DERM gauging data. Further details regarding the derivation of site specific guidelines are included in the Surface Water Quality Technical Report (Volume 2, Appendix M4).

11.3.8 Proposed Project Surface Water Management

11.3.8.1 Overview

The proposed Project surface water management strategies and the potential impacts on the existing surface water environment described in the previous section are assessed and described in this EIS section. This section generally describes the following:

- Construction and operational phase Project water supply and potable water requirements;
- Sewage treatment and stormwater management for areas outside the mine operations;
- Proposed stream diversion designs;
- Proposed flood protection for the mine;
- Subsidence and impacts on natural catchments, proposed stream diversion, and flood protection levees; and
- Proposed mine water management system, including containment/reuse, and proposed discharge criteria.

11.3.8.2 Status of Design

The Project design for surface water management is at concept design stage and is based on the pre-feasibility study mine plan (November 2011) prepared by the Proponent. Mine plan and infrastructure optimisation is being undertaken as part of the bankable feasibility study for the Project. As the mine plan is refined, design for surface water management (including flood protection, stream diversions, and mine water infrastructure) will also be refined and developed to detailed design level. The process to refine surface water design elements of the Project will incorporate the findings and mitigation strategies identified in this EIS.

The current concept designs for surface water management will need to be further developed to detailed design to obtain the approvals required which occur after EIS approval, such as the separate approvals for stream diversions, flood protection levees (as regulated structures), and hazardous dams. As part of the process for developing the detailed design for surface water management infrastructure, further investigations will also be undertaken particularly to assess geotechnical conditions at the various infrastructure locations and suitability of materials for construction.

Although the Project design for surface water management is not finalised, it is considered sufficiently defined to facilitate impact assessment and identify mitigation measures required to protect surface water and associated environmental values. The philosophy adopted was to ensure that concept definition of the surface water management works and operations would be sufficient to demonstrate that environmental impacts can be managed and the required works can be integrated into the Project.

11.3.8.3 Water Supply and Storage Requirements

Construction water supply

Water will be required during the construction phase of the Project for the following demands:

- Dust suppression on cleared construction areas and access roads;
- Moisture conditioning for compaction of engineered fill;
- Concrete mixing; and
- Construction accommodation village potable water requirements.

Water for the construction phase of the Project is proposed to be sourced from boreholes as part of the advanced dewatering of the underground mines and/or supplied from existing storages. As more information on the likely quality of groundwater becomes known proposed storage locations for construction water will be refined. It is currently assumed that groundwater from the advanced dewatering operations will not be of a suitable quality for potable use and will be stored in one of the proposed mine water dams to be constructed early in the construction schedule. Raw water suitable for potable demands will be stored in the proposed raw water dam which will similarly be constructed early in the construction schedule. The means of sourcing construction water supply from groundwater is discussed in Volume 1, Section 12.

Construction phase water demands vary considerably throughout the construction phase and are currently estimated at approximately 148 kL/day^{-1} on average through the construction period; however, it is predicted that demand will peak at 290 kLd^{-1}.

Operational water supply

Operational water demands will be preferentially sourced from water collected within the mine water management system (WMS) which is discussed further in Section 11.4. This will include runoff from all mine operational areas and all active spoil/overburden emplacement areas piles as well as all open-cut and underground mine dewatering operations. Preliminary water balance modelling has indicated that the mine WMS will be unable to meet all of the operational water demands particularly during sustained periods of low rainfall. During this shortfall make-up raw water will augment the supply to ensure mine operations are maintained. Raw water make-up will also satisfy potable, sanitation and wash down demands for which the quality of mine water will be unsuitable. The proposed concept water management system is discussed in detail in Volume 2, Appendix M3.

At the current level of planning it is expected that the supply of raw water make-up will come from a new bulk water pipeline operated by SunWater from Moranbah. The external pipeline water supply will be relied upon to meet potable demands (after treatment) and as a secondary source for make-up water when there is insufficient mine water on the site. The pipeline will terminate in the proposed 1020 ML raw water dam that will serve to store sufficient water reserves in the advent of supply interruptions and will also function as the supply point to facilitate the transfer of raw water to the various on-site demands including fire fighting, Mine Infrastructure Area (MIA) workshops, washdown, Coal Handling and Preparation Plant (CHPP) process make-up and potable. No arrangements for taking of surface water flows from local watercourses will be required.

Potable water requirements

The bulk water supply will be treated on-site to potable quality using a package water treatment plant utilising a suitable technology such as reverses osmosis. Treated water will be reticulated to all the MIA/CHPP areas, the light industrial areas, airport and accommodation village via the proposed dedicated service corridors and will also be stored in header tanks at the WTP, accommodation village and all other MIA and Light Industrial Area (LIA), the CHPP and all other areas where sufficient water reserve is required for fire fighting, and in the event of power disruption. Potable water demand has been based on an average daily demand of 240 litres per day per person. Assuming a peak on-site operational workforce of 1300 the required 350 kL/day WTP will provide an additional capacity up to a workforce of approximately 1460. The 350 kL/day unit will be supplemented by an additional temporary 125 kL/day unit to meet a predicted maximum workforce of approximately 1715 during the construction period. This will give a combined peak supply of 475 kL/day during the construction period and will give a reserve capacity for an additional 264 persons if required. Short term increases to both the operational and construction workforces above the system capacity can be accommodated through the provision of additional supplementary units as required.

Sewage and wastewater management

All sewage water generated during the Project will be collected and treated on-site to Class C effluent standard. Sewage wastewater from across the Project area will either be piped or trucked to the wastewater treatment plant (WWTP) depending on its source. Where piping is not practicable (MIAs, CHPP) holding tanks will store the sewage water prior to transportation. The solids by-product from the WWTP will be periodically removed by a contractor and transported to a licensed disposal facility and the effluent will be re-used for industrial usage. The sewage reticulation and rising mains is planned to be constructed in the dedicated services corridors proposed to be created throughout the MIA/CHPP areas and in a dedicated corridor between the accommodation village and WWTP.

The following design criteria were applied for sizing of the sewage infrastructure:

- Average daily wastewater generation based on 240 litres per person per day with 90% of this water use generating wastewater;

- Peak instantaneous sewage flows on the mine site calculated in accordance with AS.3500, which is based on probable simultaneous use of sewage generating devices such as toilets, showers, kitchens fixtures, etc. An additional loading factor of 20% of the volumetric peak flow is allowed for wet weather infiltration;
- All rising mains designed to have a minimum velocity of 1 m/s to facilitate self cleansing conditions;
- All pump stations and disposal sites located above the 1:1,000 AEP flood event inundation levels as a minimum and to be readily accessible from site roads and the reticulated power supply;
- All pump stations to be submersible below ground installations, with an elevated motor control centre in a weather proof kiosk with visible failure alarm system. All pumps will be controlled on a simple level transducer that will switch pumps off and on; and
- Sewerage pump station sumps will either be provided with emergency storage to contain overflows in the event of a power failure and to contain overflows or will be connected into an emergency power system.

Projected wastewater generation rates are summarised in Table 11-14.

Table 11-14 Projected wastewater generation rates

Phase	Design Flow (kL/day)
Construction	445
Operations	328

Stormwater Management Outside of the Mine Area (Accommodation Village)

The proposed accommodation village is the only Project facility outside the mine area that will require a stormwater management network and treatment devices. All other areas within the mine area (including mine, CHPP, MIAs, tailings storage facility [TSF], and train load-out [TLO] facilities) will be serviced as part of the integrated mine water management system that is described in Section 11.3.8.4.

As the accommodation village will effectively be a small compact residential facility, the stormwater system will be designed in accordance with best practice urban drainage design and incorporate water sensitive urban design principles. Design will be undertaken in accordance with the Queensland Urban Drainage Manual (DERM, 2007), Australian Runoff Quality – A guide to water sensitive urban design (Engineers Australia, 2006), and requirements of the local Regional Council. Planning for the accommodation village stormwater design will consider features such as rainwater tanks, swales, gross-pollutant traps, and basins to mitigate increases in peak flow and filter sediment and nutrients.

11.3.8.4 Mine Water Management System

Overview of the Mine Water Management System

The proposed mine water management system (WMS) comprises runoff containment systems for all disturbed (open-cut pits, spoil/overburden dumps) and all mine-affected (MIA, ROM, CHPP, TLO, product stockpile) areas, mine water dams with a range of functions (runoff capture, water transfers and storage) and a network of pipes, pumps and drains to transfer water around the system. In accordance with current best practice management strategies the mine WMS will satisfy the following key objectives:

- Minimise the generation and containment of mine-affected water by the passive diversion around the WMS of all clean water entering the Project site as well as the on-site segregation of runoff according to its predicted quality;
- Provide sufficient system capacity to capture and contain all mine-affected water during significant rainfall events and to reduce the risk of an uncontrolled release into the receiving environment to an acceptable level; and
- Allow for the preferential reuse of mine-affected water in mine operations (CHPP, underground mining operations, dust suppression, industrial uses) which will:
  - Avoid the need for the controlled release of contaminated water (under modelled historical conditions) by continually drawing down on the site water inventory;
  - Maximise the systems storage capacity for future large inflows to the system;
  - Reduce the reliance on external water sources; and
  - Allow for the dewatering of both the open-cut and underground mines to sustain mining operations including direct pumping of runoff and groundwater from the open-cut pits and groundwater from the underground mines.

Key Design Influences on the Mine Water Management System

The design of the concept mine WMS is influenced by several key factors as outlined below:

- **Catchments, local climate and runoff volumes:**

  The mine plan and corresponding extent of disturbed areas influences the quantity of runoff generated from rainfall events. As the mine progresses catchment extents will vary as the open-cut pits advance, areas of spoil and overburden change and progressive rehabilitation of previously disturbed areas commences. Local climate data shows that the high degree of variability in both the seasonal and annual distribution of rainfall will require the proposed mine WMS to manage a large range of predicted runoff volumes both from individual events and entire wet seasons. Consequently the amount of runoff input into mine WMS is a significant influence on the volume of water storage required to ensure that overflows from the system do not occur during exceptionally wet or prolonged wet seasons.

- **Groundwater dewatering volumes:**

  Water pumped from the proposed underground mines either as part of advanced dewatering to depressurise the coal seams or as drainage pumping to maintain water levels below the D-seam will be a significant input into the mine WMS. At this level of planning underground mine dewater is considered as being contaminated and will need to be contained within the mine WMS where it will be used to supplement other water inputs to meet the various mine water demands. Unlike inputs from rainfall runoff, groundwater inputs remain relatively constant and may be influenced by operational factors such as the timing of borehole commissioning.

- **Discharge Criteria:**

  Criteria governing releases of water from the mine WMS in both a controlled and uncontrolled (overflows) manner are a significant influence on total system storage capacity. The proposed mine WMS has been developed on the basis that controlled releases of water would not occur. This significantly increases the required total amount of storage required to contain inflows during prolonged or exceptional wet seasons. Design criteria for uncontrolled releases (overflows) recognise that any containment system open to rainfall inputs has the potential to overflow. Such criteria directly impact the amount of required storage capacity and are guided by the philosophy that the probability of such releases should be low.

- **Mine water demands and consumption:**

  Demands for mine water (CHPP, dust suppression and industrial uses) are related to levels of production and generally remain constant and predictable. Preferential sourcing of mine water to meet these demands provides a constant draw down on the mine water inventory. In this manner the mine water consumptive demands have a significant influence on the available storage capacity to manage runoff inflows.

- **Other losses:**

  In addition to the losses described above other losses from the mine WMS influence the net water balance. These losses include seepage losses from mine water dams (generally avoided through appropriate design) and evaporative losses from the surface of mine water dams. Evaporative losses, unlike runoff inputs are relatively predictable based on local climate data and provide the greatest influence on the ability of the mine WMS to maintain mine water supply for operational demands during prolonged drought periods.

  The interaction of the all of the influences described above on the mine WMS has been analysed with a water balance model under a range of climatic conditions including droughts, extreme wet seasons and consecutive years of above average rainfall.

Proposed Segregation of Mine Waters

In accordance with current best practice mine water management practices it is proposed to segregate water within the WMS based on its predicted quality in order to optimise the storage and reuse of mine water and to minimise capture and storage of uncontaminated clean water.

The mine WMS will be limited to disturbed and mine affected areas (disturbed catchments, contaminated water sources and contaminating processes). Clean waters (runoff and stream flow) from undisturbed areas on the site and upstream catchments will be diverted to passively flow to downstream waterways. It is envisaged that during the course of the mine life, progressive rehabilitation of available (no longer needed) disturbed areas will be undertaken and once established and demonstrated to produce acceptable quality runoff, these areas will be diverted away from the mine water management system through clean water bypass drains.

The following classifications have been nominated for the site:

- **Clean water management system** – diversion around the WMS of uncontaminated runoff entering the Project site from undisturbed up stream catchments as well as the interception and diversion into the existing natural watercourses of runoff generated from undisturbed areas within the Project site;
- **Contaminated water system** – management of all water originating from all potentially contaminating sources such as open-cut and underground mine dewater as well as runoff from

various mine process areas such as MIAs, product coal stockpiles, TLO and ROM pads and all active spoil and overburden emplacement areas. Runoff from these areas is likely to contain elevated levels of salinity and /or suspended sediments, potentially low pH and possible elevated levels of metals and sulphate concentrations primarily due to contact with coal;

- **Process water management system** – management of all water used in the CHPP, tailings storage facility and the tailings decant and return water system. These waters are expected to contain elevated salinity, potentially elevated sulphate concentrations and have relatively neutral pH; and
- **Groundwater management system** – this includes all groundwater pumped from the underground mines as well as any water extracted from the borefield.

The groundwater management system is not discussed further in this report. Further detail on the Groundwater Management System is provided in the Groundwater Technical Report (Volume 2, Appendix N).

Releases of Water from the Mine Water Management System

The Proponent will not be seeking any arrangements for the controlled release of water from the mine WMS. Critical to achieving this is the provision of adequate storage capacity within the WMS to capture all inflows of water into the WMS including runoff originating from all contaminating catchments as well as inflows of groundwater from the dewatering of the underground mines. Appropriate operating rules ensure that site inventories of mine water are preferentially drawn upon by mine site consumptive demands thus restoring system capacity to contain subsequent inflows. The proposed mine WMS assessed with water balance modelling has indicated that on the basis of historical climate records no controlled releases will need to be made.

It is recognised however, that the performance of the mine WMS is dependant on a range of input data which are subject to some degree of variability and uncertainty at the current level of planning. Critical to the design of the concept mine WMS are inflows of groundwater from the underground mines which heavily influence the ability of the mine WMS to draw down upon the site mine water inventory and restore system capacity to contain future inflows of potentially contaminated runoff. The ability of the mine WMS to meet the key objectives outlined in Section 11.4.2 available. Short term variability in predicted inflows will be managed through the maintenance of dewatering rates and/or utilisation of in-pit storage once mining operations cease in the Northern open-cut pit. In the medium term the establishment of advanced dewatering bores may be brought forward and /or pushed back in order to reduce peak inflows to the WMS. In the advent that longer term additional storage is required additional temporary surface storage locations can be accommodated within the planned underground mine schedule.

Design Criteria to Limit Uncontrolled Discharges

The objective to limit the potential for uncontrolled discharges (overflows) from the mine water management system is to ensure that adequate storage capacity is designed into the mine water management system to provide capacity to contain extreme wet season rainfall and corresponding runoff volumes. In simple terms the objective is to ensure the probability of an uncontrolled overflow is very low.

The criteria to limit the probability of an uncontrolled discharge are applied through conditions in the Environmental Authority for Regulated Dams (otherwise known as Hazardous Dams). The criteria are specified according the hazard category of each dam for the potential hazard of failure to contain the contents of the dams (i.e. hazard of overflow). The hazard category of the mine water dams (and tailings dams) is determined using the *Technical Guidelines for environmental management of mining and exploration activities* (DME, 1995), and in the future will be in accordance with the DERM *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams*, which is currently being prepared and will apply when endorsed by the State Government.

Hazard categories for the proposed dams for the mine water management system will be determined as part of detailed design when the geometry of the dams, their failure hazards, and overflow locations can be defined to the level required to assess the specific hazard for each dam. At this concept stage, it is envisaged that most of the Project mine water dams will be defined as a significant hazard category.

The criterion for storage capacity to limit the probability of overflow can be applied as either a Design Storage Allowance (DSA) to ensure adequate available storage capacity at the start of each wet season to contain runoff from the design probability wet season rainfall, or to limit the probability of an overflow demonstrated through water balance modelling taking account of operating procedures for the mine water management system. The storage criteria for significant hazard dams are expected to be:

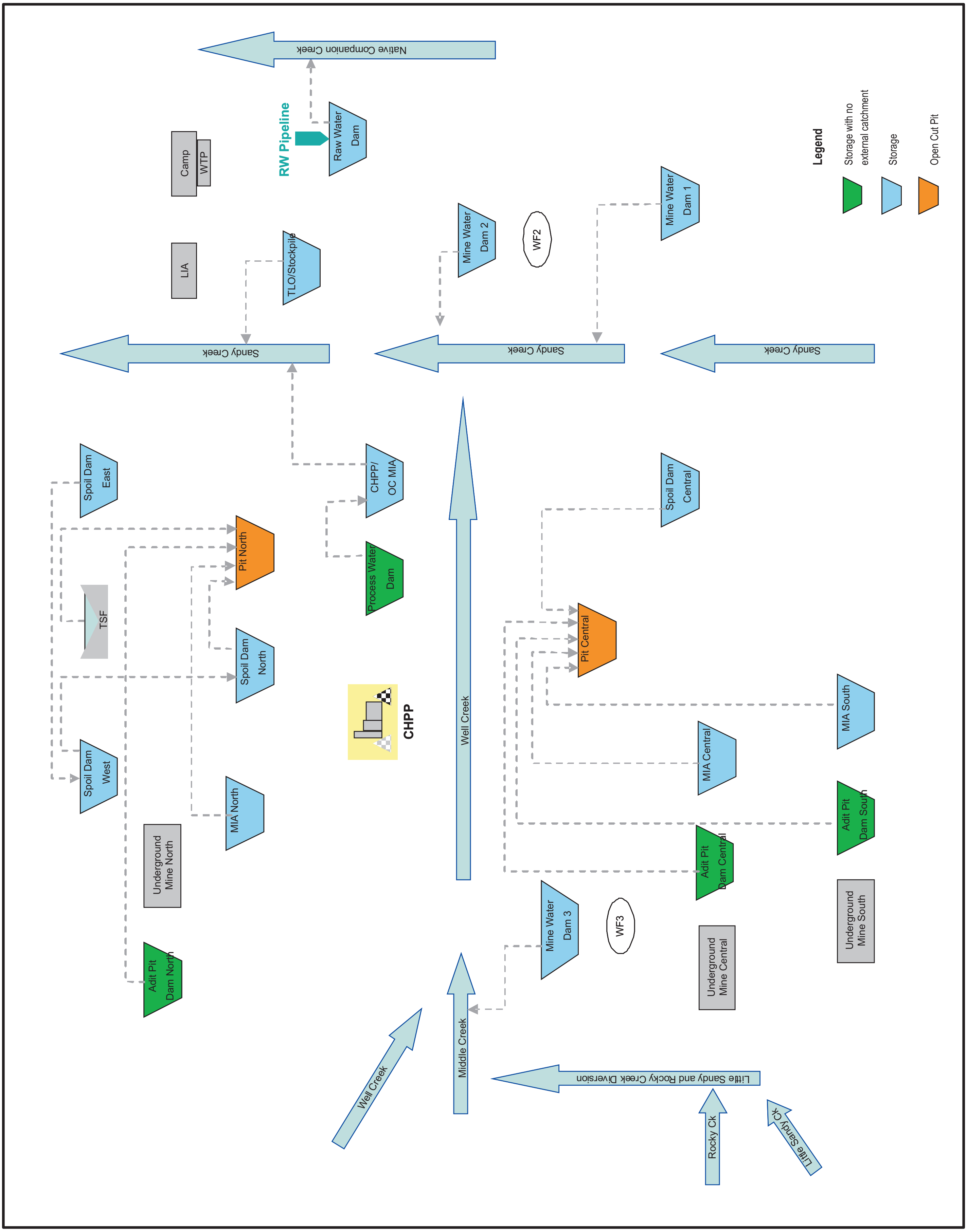
- Sufficient capacity to contain 1:20 AEP wet season rainfall (conservatively assuming 100%) runoff when using the DSA deciles method (as defined in 1995 DME guidelines, and future DERM Manual for Dams); or
- Probability of overflow to be less than 1:100 AEP when assessed using the detailed water balance modelling method (future DERM Manual for Dams when this guideline is endorsed).

The proposed EA conditions for Regulated Dams will also include requirement for annual update of the hazard assessment, and annual review of the mine water system capacity to ensure sufficient storage capacity to limit the potential for uncontrolled discharges. The proposed condition will also require a Mandatory Reporting Level (MRL) to be defined for each dam which controls the operation of the available storage volume below the spillway crest, equivalent to the lower of the 1:100 AEP 72-hour storm or the wave allowance 1:100 AEP wind speed. The conditions will require that DERM must be notified when the MRL level is exceeded.

Overall arrangement of the Mine Water Management system

The proposed mine WMS is described in detail in the Site Water Management System and Water Balance Report (Appendix M3). Figure 11-15 depicts schematics of the mine WMS and Figures 11-16 to 11-18 show the concept layouts of the mine WMS for years 5, 10 and 30.

The concept layouts of the proposed mine water management system are presented to demonstrate that the required mine water management infrastructure can be accommodated in the mine layout plan. Geotechnical and hydro-geological investigations for the mine water dam sites are to be undertaken as part of detailed design to confirm the suitability of the dam locations and to develop the dam designs and mitigation (safety) measures to the standards required for Regulated Dams. The approval process for the Regulated Dams occurs after EIS approval, and the EA conditions will prohibit construction of Regulated (Hazardous) dams unless approved by DERM. Certified detailed design documentation, with geotechnical and hydrological information required to support the design to the required standards will be submitted when applying for approvals for each of the Regulated Dams.



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1- References.*

HANCOCK GALILEE PTY LTD

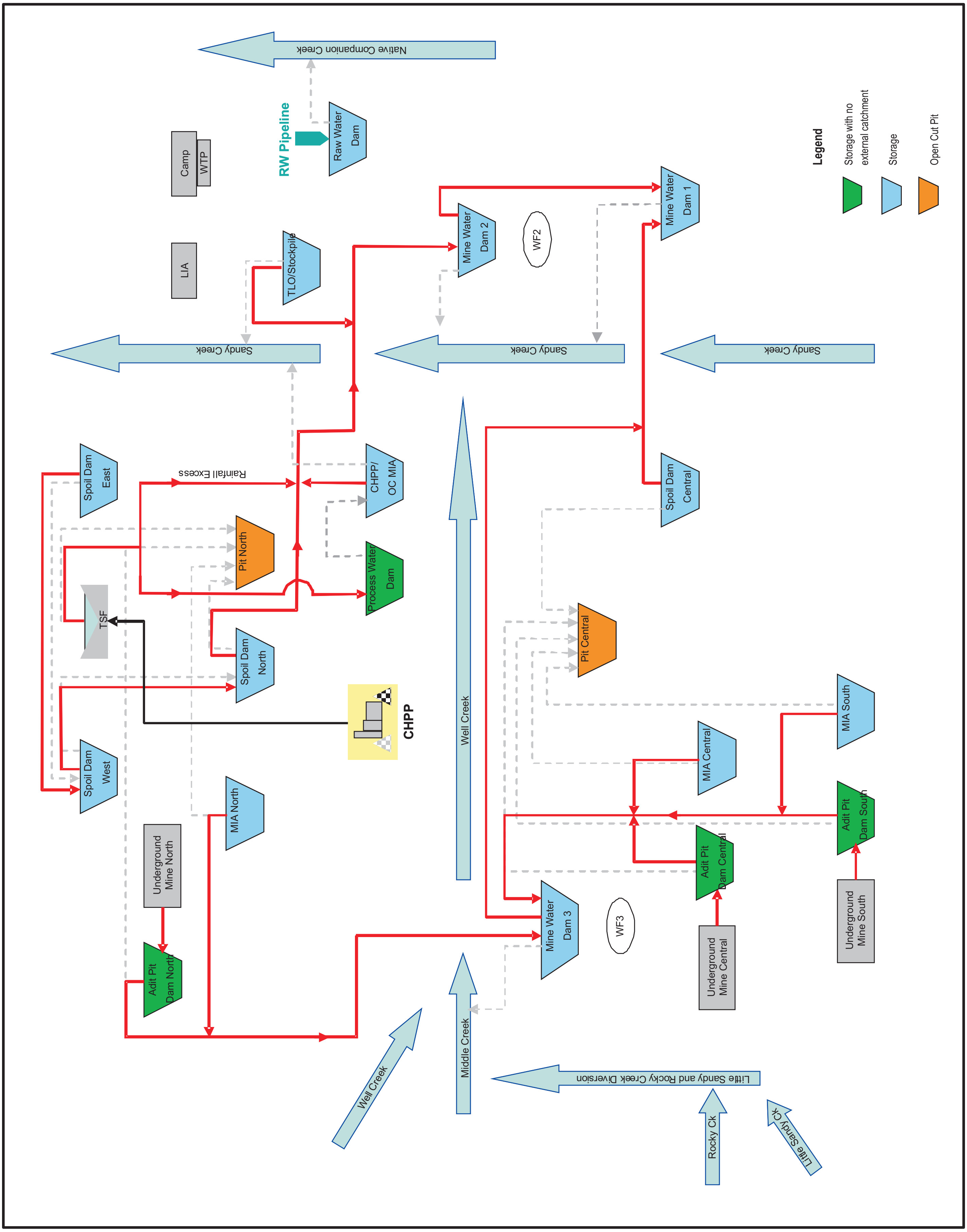
Kevin's Corner Project
Environmental Impact Statement

KEVINS CORNER
CONCEPT WMS SCHEMATIC -
STORAGE OVERFLOW PATHS

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-15a

File No: 42626660-g-1053.cdr



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1- References.*

HANCOCK GALILEE PTY LTD

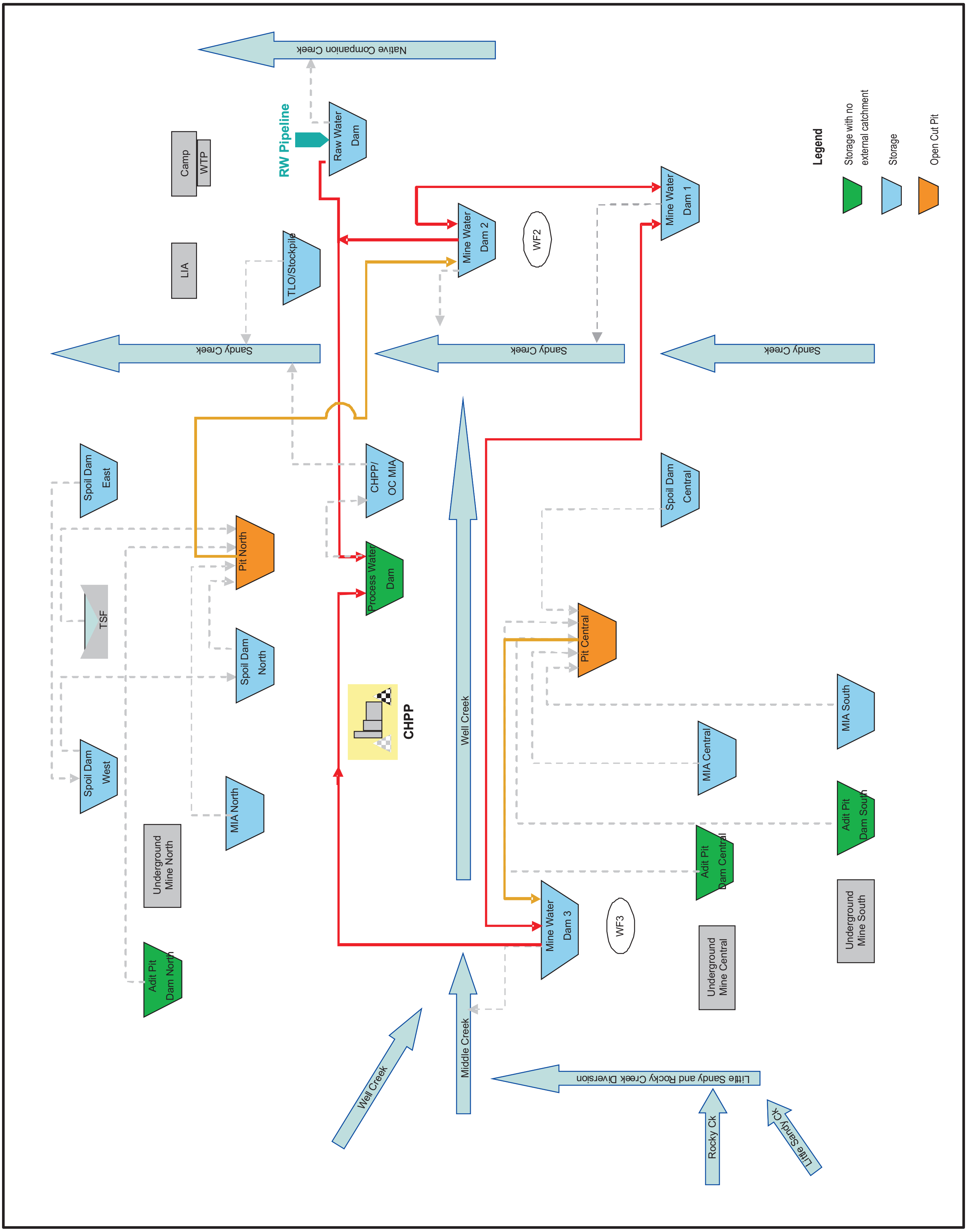
Kevin's Corner Project
Environmental Impact Statement

KEVINS CORNER
CONCEPT WMS SCHEMATIC -
WATER RECOVERY FLOW PATHS

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-15b

File No: 42626660-g-1054.cdr



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1- References.*

HANCOCK GALILEE PTY LTD

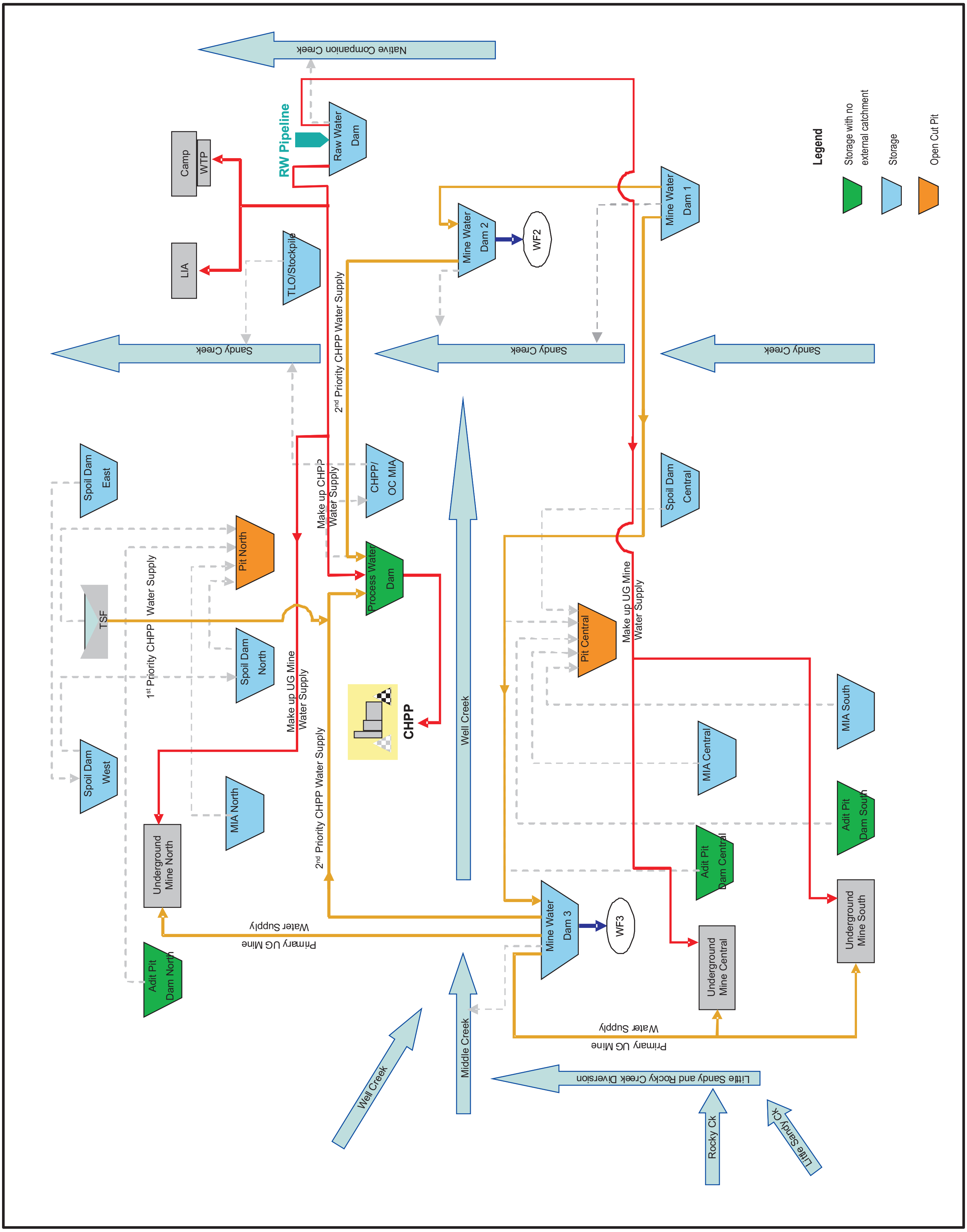
Kevin's Corner Project
Environmental Impact Statement

KEVINS CORNER
CONCEPT WMS SCHEMATIC -
WATER REDISTRIBUTION AND
PIT DEWATERING FLOW PATHS

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-15c

File No: 42626660-g-1055.cdr



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1- References.*

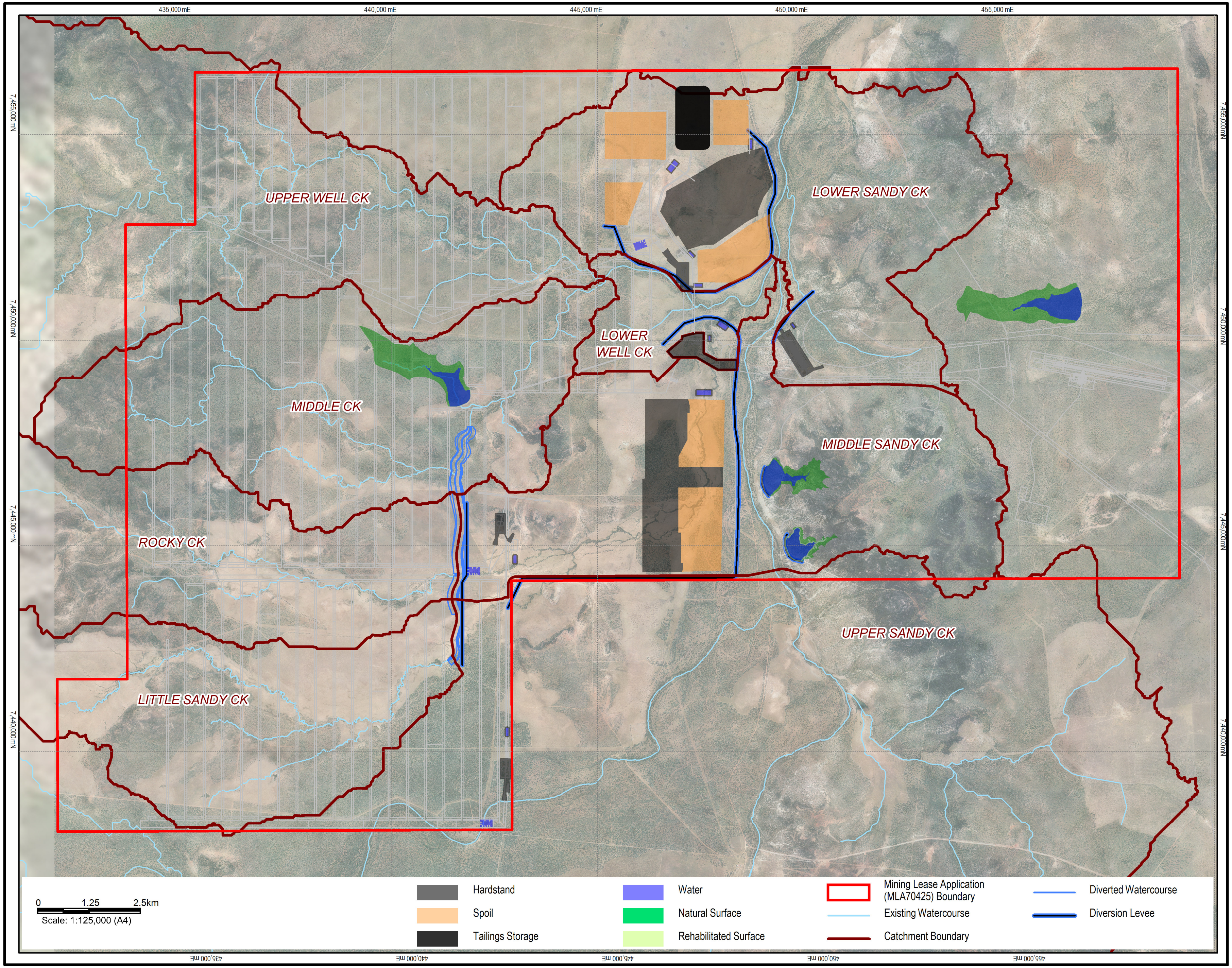
HANCOCK GALILEE PTY LTD
Kevin's Corner Project
Environmental Impact Statement

KEVINS CORNER
CONCEPT WMS SCHEMATIC -
WATER DEMAND FLOW PATHS

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-15d

File No: 42626660-g-1056.cdr



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1 - References*

N W E S

HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

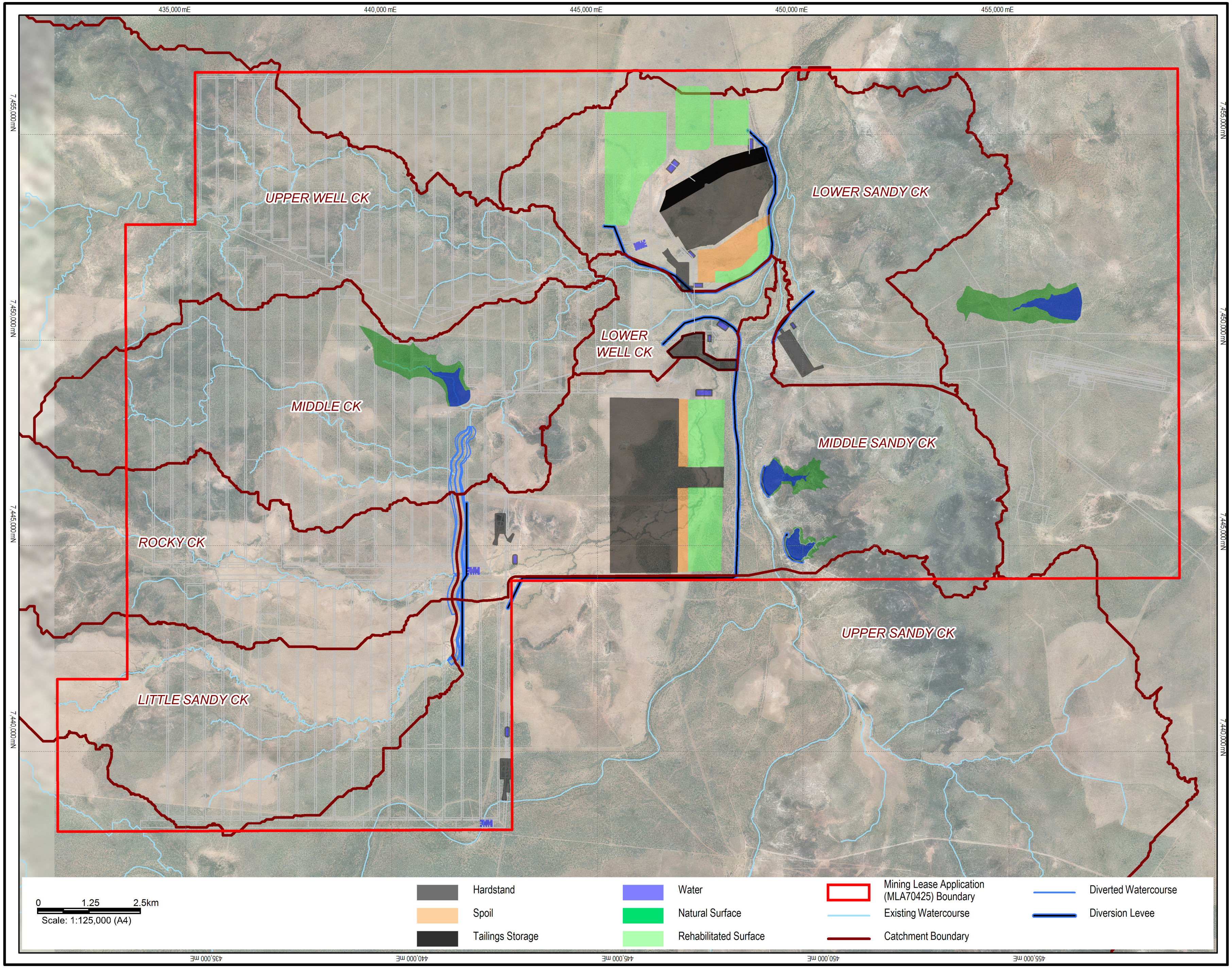
CONCEPTUAL LAYOUT OF THE MINE WMS - YEAR 5

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-16

Datum: GDA94, MGA Zone55

File No: 42626660-g-1057.wor



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1 - References*

N
W E
S

HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

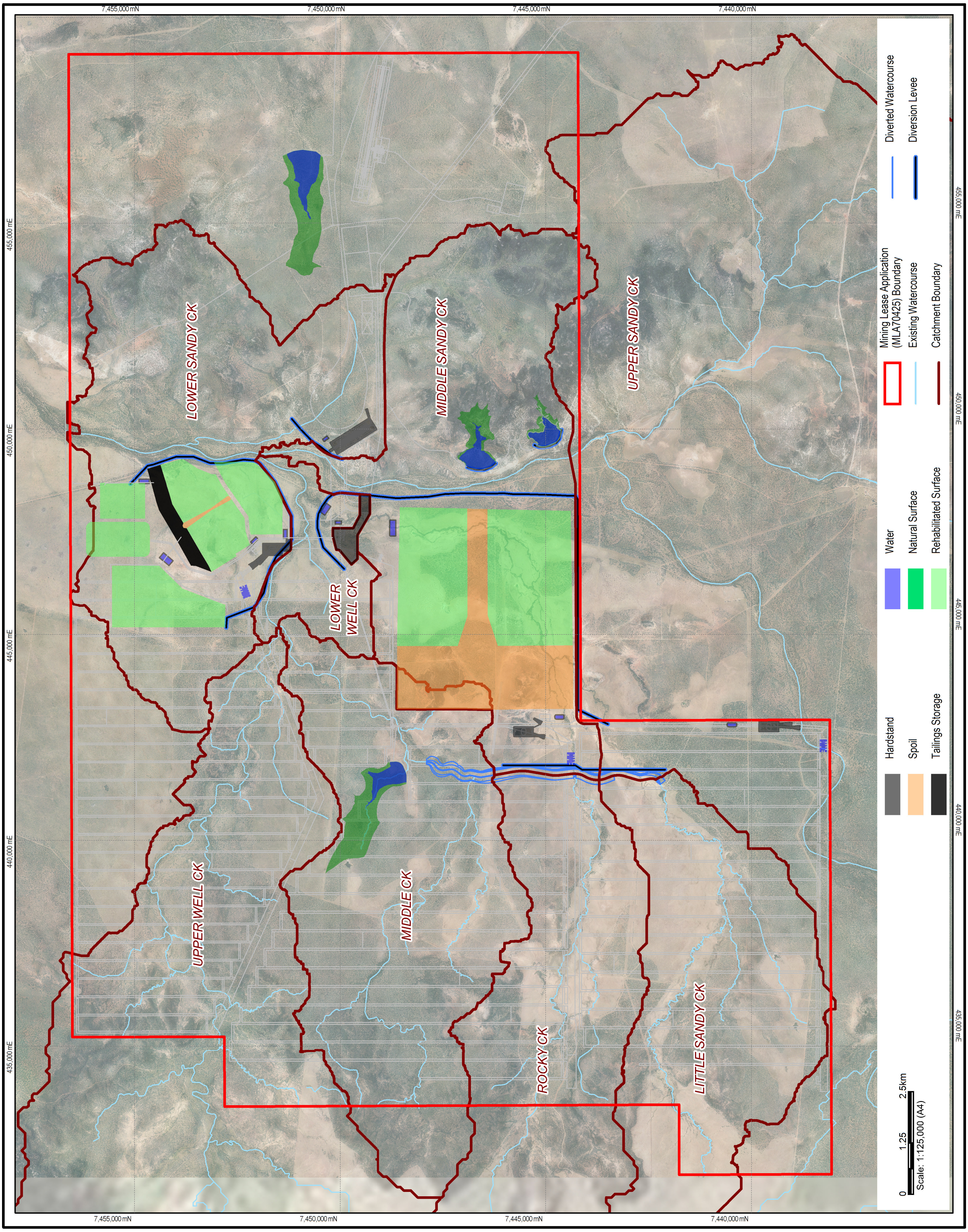
CONCEPTUAL LAYOUT OF THE MINE WMS - YEAR 10

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-17

Datum: GDA94, MGA Zone55

File No: 42626660-g-1058.wor



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1 - References*

Datum: GDA94, MGA Zone55

I HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

CONCEPTUAL LAYOUT
OF THE MINE WMS -
YEAR 30

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-18

File No: 42626660-g-1058.wor

11.3.8.16 Tailings Storage Facility and Process Water System

Out-of-pit tailings storage in a purpose-built TSF will proceed for the first 5 years of the Project whereupon disposal will continue in-pit in the Northern open-cut mine. Water decanted from both the purpose-built and in-pit TSF will be returned, via a system of pipes and pumps to the process water dam from where the CHPP will reuse the water coal processing operations. A seepage interception drainage system will be installed along the external perimeter toe of the purpose-built TSF embankment and any intercepted water will drain into the decant water dam. The purpose-built TSF will be constructed as a 'turkeys nest' configuration which will eliminate inflows of runoff from any external catchments. Similarly the in-pit TSF will utilise both the existing runoff management structures (high wall dams, diversion catch drains, etc.) as well as any additional structures to ensure that runoff from external catchments is unable to enter the TSF.

It is understood that decant water from the TSF will be of a quality suitable for use in the CHPP and will satisfy a significant proportion of total CHPP water demand. Inflows of TSF decant water back into the mine WMS are related to production levels and as such remain relatively constant. The TSF and decant dam will be classified as Regulated (Hazardous) Dams and designed, built and operated to the standards required for Regulated dams including sufficient storage to limit the probability of overflow. The seepage interception system and decant dam will have monitoring and maintenance requirements defined in the mandatory operations plan for the TSF and be included in the annual inspection of the TSF.

11.3.8.17 Clean Water Management System

Runoff generated from undisturbed catchments within the Project site as well as clean water entering the Project area from undisturbed catchments upstream will be diverted around the mine WMS. The clean water system will comprise the following elements:

- Provision of a diversion channel and system of levees to divert flows in Little Sandy Creek and Rocky Creek around the central open-cut pit and into Middle Creek and a system of levees along Sandy Creek and Well Creek to prevent inundation of the open-cut pits and critical mine infrastructure. The diversion channel will be designed to conform with the natural creek system with flood protection levees designed to the 1:1,000 AEP flood event (plus freeboard). Further design details of the levees and creek diversion are described in Section 11.3.10 and in the Hydraulic Technical Report Volume 2, Appendix M2;
- Clean water catch drains will, wherever practicable, direct runoff from undisturbed catchments around the mine WMS. This will include a system of upslope clean water catch drains to minimise the catchments reporting to constructed the proposed mine water and raw water dams;
- Diversion around the WMS of runoff originating from approved rehabilitated areas. As rehabilitation of the spoil dumps progresses and runoff from these areas reaches an acceptable quality for release they will removed from the mine WMS;
- Highwall dams and levees upslope of the open-cut pits to reduce peak runoff inflows and velocities from undisturbed or approved rehabilitated catchments. The location and design of highwall dams has not been considered at this concept level but will be further refined during detailed design;
- Raw water dam to store imported raw water; and

- A system of pumps and pipelines to transfer raw water to various on-site demands including:
  - The CHPP for coal washing;
  - MIA use (workshop, wash down,);
  - Haul road dust suppression;
  - Water treatment plant (for potable applications); and
  - ROM dump/pad dust suppression.

11.3.8.18 Contaminated Water Management System

Water originating from a variety of potentially contaminating sources including dewater from the open-cut and underground mines, runoff from all active spoil and overburden dumps and runoff from various mine process areas will be carefully managed to minimise the volumes of water requiring capture and storage. The main contaminants present are expected to be increased suspended solids and salt loads. The contaminated water system will encompass management of water from the following sources:

- Dewatering of the open-cut pits;
- Dewatering of the underground mines;
- Runoff originating from all ROM pads and dumps, MIAs, CPP, TLO and product stockpile; and
- Runoff originating from all active spoil and overburden dump areas.

Water within the contaminated water system will be preferentially sourced for a variety of uses including process water in the CHPP and for dust suppression. This will ensure the sites contaminated water inventory is optimised and of the demand for raw water is minimised. The contaminated water system will comprise the following elements:

- Open-cut pit sumps to collect local runoff from the pit floor, ramps, high, low and end walls;
- Open-cut pit dewatering pumps and pipelines to transfer water from the central pit sump to either MWD 1 or 3 and from the northern pit sump to MWD 2;
- Underground mine water collection system;
- Underground mine pumps and pipelines to transfer water from each collection system to the associated adit pit dams and then on to MWD 3;
- Appropriate runoff interception and conveyance systems to capture runoff originating from the potentially contaminating mine process areas (MIAs, CHPP, TLO, product stockpile);
- A pump and pipeline system to transfer water from each process area dam to the nearest mine water dam;
- Appropriate runoff interception and conveyance systems to capture runoff originating from the active areas of the spoil and overburden dumps;
- A pump and pipeline system to transfer water from each spoil dam to nearest mine water dam; and
- A return water pump and pipeline system from each mine water dam to deliver stored water to either:
  - A water fill station (for haul road dust suppression, MWD 2 and 3 only);
  - The process water dam (to supply the CHPP); and

— Another mine water dam for the purpose of managing inventory levels during prolonged wet or dry periods.

11.3.8.19 Progressive Rehabilitation of Spoil and Overburden Dumps

Runoff originating from the active overburden and spoil dumps will be considered as contaminated and will be captured and contained within the contaminated water management system as described in Section 11.3. However, as the spoil and overburden dumps are progressively revegetated and runoff is shown, through appropriate monitoring to be suitable for release, it will be allowed to bypass the mine WMS. When no longer required all associated WMS infrastructure (dams, pumps, pipes etc) will be decommissioned.

11.3.8.20 Referrable Dams

The difference between Referrable Dams (Clean water dams) administered under the Water Act (and Regulated dams (hazardous dams) administered under the EP Act (1994) is described in Section 11.1.5. All of the dams containing potentially contaminated mine water will be Regulated Dams and administered under the EP Act.

Only the Raw Water Dam which will contain bulk raw water from a third party supplier will potentially be able to be classified as Referrable under the Water Act. During more detailed design the referrable category of the proposed Raw Water Dam determined through the undertaking of dam failure impact assessment (DFIA) as required under the *Water Supply (Safety and Reliability) Act 2008*. The proposed dam will also need to comply with all relevant approvals conditions as required under the *Sustainable Planning Act 2009* as part of obtaining a development permit for a referrable dam. At the current concept stage of the Project design the Raw Water Dam is predicted to be 1010 ML which would classify it as a referrable dam.

11.3.8.21 Site Water Balance Model

A water balance of the Projects proposed water management system, based on historical climate records, has been undertaken using GoldSim software. GoldSim is extensively used in a wide range of environmental modelling applications including mine site water management. The water balance model has been developed and refined to a level suitable for the concept design of water management infrastructure and is able to assess the performance of the Project's proposed water management system under a range of likely climatic extremes. The model is able to estimate potential runoff volumes, likely site water demands and identify possible water deficits or surpluses as well possible overflows from the Project's water storages.

Runoff parameters for the model have been based on calibration of natural catchment runoff characteristics to available DERM stream gauging data (Native Companion Creek at Violet Grove). Runoff parameters for the mine WMS catchment land use types (spoil, hardstand and rehabilitated) have been adjusted to represent the expected differences in runoff rates. In addition to representation of the proposed mine WMS the model also includes representation of the upstream natural catchments (including the clean water bypass system) to enable an assessment of the downstream hydrological impacts resulting for the removal of a small portion (the mine WMS) from the natural catchment system.

The model has been developed for each of the year 5, 10 and 30 year mine plans using 110 years of input climate data from the Bureau of Meteorology SILO Data Drill and run on a daily time step. Layout schematics for proposed mine water management system are shown on Figures 11-16 to 11-18.

11.3.8.22 Model Catchment Data

Catchment boundaries for the WMS have been delineated using the conceptual mine plans for each of the 5, 10 and 30 year landforms. Natural catchment areas represent the catchments reporting to the three mine water dams and the raw water dam assuming that diversion drains divert the majority runoff around the dam. Table 11-15 summarises the changes in land use types for each of the year 5, 10 and 30 year mine plans. Note that catchments areas classified as rehabilitated will be allowed to bypass the mine WMS and do not contribute runoff into the WMS.

Table 11-15 Changes in land use types

Land Use	Catchment Area (ha)		
	Year 5	Year 10	Year 30
Natural	606	606	606
Rehabilitated	0	783	2129
Spoil	887	215	0
Hardstand	1011	1218	997
Total WMS Catchment	2504	2039	1603
Total Catchment incl. Rehabilitated	2504	2822	3732

11.3.8.23 Model Storage Capacities

All WMS dams with the potential to overflow to the receiving environment have been sized, on the basis of water balance modelling using historical climate data, to have less than a 1% probability overflowing based on 110 years of simulation. This includes the three large mine water dams, the raw water dam and the TLO/product stockpile dam and CHPP/Open-cut MIA dam. Conceptual stage-storage relationships were developed from the existing ground survey data.

All other WMS storages designed to capture runoff from potentially contaminating catchments overflow into either the Northern or Central open-cut pits. Sizing of these dams has been based on balancing the operational availability of the open-cut pits with the practicalities of providing additional storage capacity to contain the predicted volumes of runoff from each catchment. Conceptual stage storage relationships assumed a maximum water depth of 5m and a 1:3 (V:H) internal batter slope.

The three adit pit dams which receive groundwater from the underground mines and the process water dam will be of a 'turkeys nest' configuration (i.e. no external catchment). Adit pit dams have been sized to contain a minimum of two weeks of groundwater inflows without the need to discharge (in the advent of the large mine water dams becoming water bound) and the Process Water Dam has been sized to give sufficient reserve supply for approximately 4-5 days of CHPP gross water demand. Conceptual stage-storage relationships also assume a maximum 5m water depth and a 1:3 internal batter slope.

11.3.8.24 Mine Water Management System Operating Rules

Basic operating rules suitable for concept level design have been incorporated into the water balance model as given below. It is expected that they will be subject to ongoing development and modification as more detailed information regarding aspects such as water make from the underground mines and groundwater seepage into the open-cut pits become known and further refinement of the mine WMS proceeds:

- Pumping to any of the three large capacity mine water dams ceases once they exceed their environmental operating capacity. This ensures sufficient reserve capacity is always maintained to contain inflows from their respective reporting catchment as well as direct rainfall; and
- Pump rules allow Mine Water Dam (MWD) 1 to provide additional storage capacity to MWD 2 and 3 in the advent they exceed their environmental operating capacity during prolonged periods of high rainfall. This water is then returned to MWD2 and 3 to ensure mine consumptive demands for mine water continue to be met.
- The CHPP Process Water Dam is maintained with water sourced in the following priority:
  - — Decant from the TSF;
  - — From either MWD 2 or 3; then
  - — From the raw water dam.
- The underground mine water demand is sourced with the following priority:
  - — From MWD 3; then
  - — The raw water dam.
- Groundwater inflows from the underground mine have been apportioned equally to the three adit pit dams;
- Water demand for potable/sanitation uses and washdown has been sourced from the raw water dam;
- Water for the truck fill points for haul road dust suppression is sourced primarily from MWD 2 and 3 and then the raw water dam if required; and
- Haul road dust suppression is reduced to zero on days where rainfall is in excess of evaporation.

The following pump rates have been adopted in the water balance model. All pump rates have been set at 200 Ls^{-1} with the following exceptions:

- Pit dewatering rates have been set at 300 Ls-1; and
- Transfers of water between the mine water dams and to the Process Water Dam have been set at 300 Ls-1.

11.3.8.25 Model Water Sources

Various water inputs to the mine WMS comprise:

- Surface runoff;
- Groundwater from the underground mine dewatering operations; and
- Imported raw water from the pipeline water supply.

The groundwater volumes presented in Table 11-16 represent the result of a rolling 10-year average of predicted volumes generated from the underground mine dewatering, which is based on the assumption that peaks in groundwater volumes may be better managed through advancing and/or delaying bore establishment and the gradual development of the mine workings.

Table 11-16 Predicted groundwater waste management system (WMS) inflows

Year	Underground Mine Dewater Rate (ML yr-1)
5	5,694
10	4,793
30	3,628

11.3.8.26 Estimated Mine Water Demands

Various water demands exist for the Project and consist of:

- CHPP make-up water;
- Civil construction water for compaction;
- Haul road and hardstand dust suppression;
- Underground mine operations;
- Vehicle washdown and workshop; and
- Potable/sanitation.

CHPP make-up water requirements, net of tailings return water, are provided in Table 11-17. The CHPP water make-up demands roughly equates to 190L per tonne of ROM coal and is comparable to estimates for other coal mines with water efficient operations.

Table 11-17 CHPP make-up water demands

Year	ROM Coal Processed (Mtyr-1)	CHPP Make-up Water Demand (MLyr-1)
5	27.4	5,454
10	35.6	6,677
30	26.1	4,974

Total estimated water demand for dust suppression (haul road, ROM dump/stockpile and hardstand) is shown in Table 11-18.

Table 11-18 Total dust suppression water demands

Year	Total Dust Suppression Water Demand (MLyr-1)
5	1011
10	1011
30	1011

Water will be required to sustain underground mining operations as detailed in Table 11-19 below.

Table 11-19 Underground mine operations water demand

Year	Underground Mine Water Demand (MLyr-1)
5	570
10	544
30	528

Water is required for washdown of plant and equipment at each MIA. Table 11-210 shows the total estimated demand for washdown. It should be noted that the actual demand will be dependent on the number of plant units that are present on-site. Contaminated mine water will be unsuitable for this purpose with demand sourced directly from the raw water dam.

Table 11-20 Mining Industrial Area (MIA) raw water demand

Year	MIA Raw Water Demand (MLyr-1)
5	3.6
10	3.6
30	3.6

Treated raw water will be required to meet the various potable and sanitation water demands. Demand will be sourced from the raw water dam prior to treatment by the on-site WTP. Table 11-21 details the estimated raw water potable demand.

Table 11-21 Raw water potable demand estimates

Year	Potable Raw Water Demand (MLyr-1)
5	142
10	111
30	95

A summary of the total Project water demands is shown in Table 11-22.

Table 11-22 Project water demand summary

Year	CHPP Make-Up Water (ML/yr)	Dust Suppression (ML/yr)	Underground Mine Ops (ML/yr)	MIA (ML/yr)	Potable Water (ML/yr)	Total Site Demand (ML/yr)
5	5,454	1011	570	3.6	142	**7,181**
10	6,677	1011	544	3.6	111	**8,347**
30	4,974	1011	528	3.6	95	**6,612**

11.3.8.27 Results of Water Balance Modelling

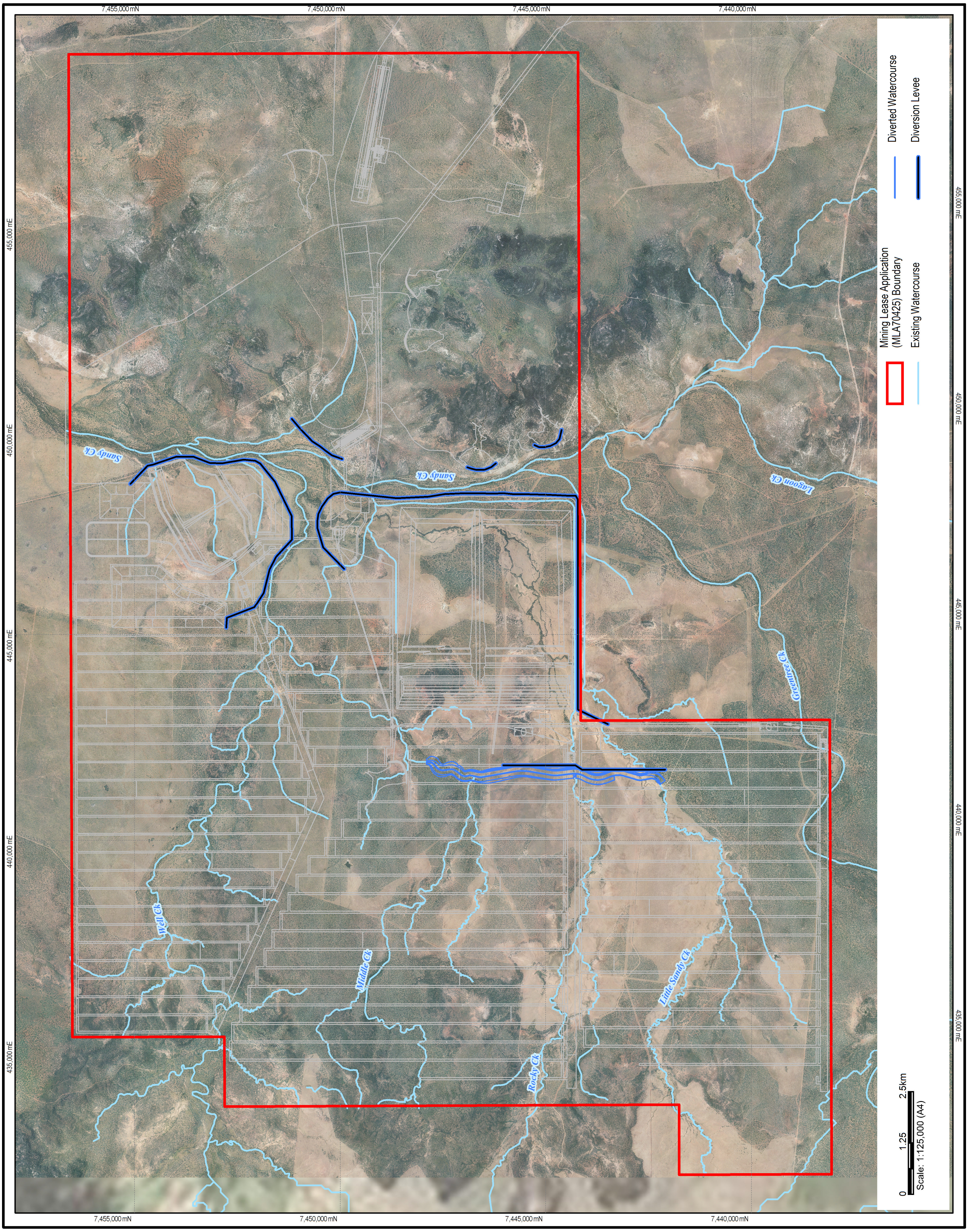
Water balance modelling of the proposed mine WMS using 110 years of climate data indicates that the system has sufficient storage capacity to limit the potential for an uncontrolled discharge to less than 1:100 AEP. Water balance modelling also indicates that the mine will generally operate with a water deficit and will have to import water to make-up the balance. The estimated required raw water make-up is shown in Table 11-23. It can be seen that groundwater inflows from dewatering of the underground mines provides an important source of water for mine consumptive demands. However, it should be noted that the estimated raw water demands are heavily influenced by the volume of groundwater inflow from dewatering of the underground mines and should groundwater inflow estimates reduce the demand for imported raw water will correspondingly increase. Alternatively water demand may be reduced by alternative processing requirements or alternative mining methods.

Table 11-23 Estimated raw water make-up for a 10th percentile dry year

Year	Estimated Imported Raw (ML/yr)
5	655
10	3639
30	3037

11.3.9 Stream Diversions

The diversion of defined watercourses Little Sandy Creek, Rocky Creek and Middle Creek will be required for the Project to gain unimpeded access to coal reserves that would otherwise be inaccessible. To supplement the stream diversion channels, flood protection levee banks will be required to protect the mine from flooding and these are discussed in Section 11.3.11 The locations of the creek realignment (diversion) channel and the flood levees are listed below and shown on Figure 11-19. The proposed concept design of the stream diversions are discussed below.



Source: See Copyright Details below and for full disclosure Please Refer to the EIS ***Volume 1 - References***

Datum: GDA94, MGA Zone55

N E S W

I HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

DIVERTED WATERCOURSES

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-19

File No: 42626660-g-1048.wor

11.3.10 Diversion Design

11.3.10.1 Hydraulic Design Objective

The objective for the hydraulic design of the new Little Sandy Creek, Rocky Creek, and Middle Creek diversion was to establish a hydraulic behaviour that is similar to that of the existing creek system, to ensure that the diverted channel is stable and supportive of revegetation, and to protect the upstream and downstream reaches from any detrimental changes in creek hydraulics.

The selected diversion alignment was determined by the constraints provided by the local topography, the existing channel geometry from each creek, the location of the proposed underground mine longwall mine panels, and the location of the flood protection levee.

11.3.10.2 Diversion Criteria – Channel Alignment

The diversion channel alignment was selected to contain the diversion channel within a single row of longwall panels. This criterion reduces the potential for subsidence of the channel to cause irregular lowering of the channel increasing sediment deposition and reducing channel capacity

The diversion alignment traverses two longwall panels. These two longwall panels would generally be mined within the same timeframe (approximately years 6 to 10), with the northern panel mined first, followed by the southern panel. This sequence would allow the northern panel, or the downstream portion of the diversion channel, to subside first, thereby maintaining positive gravity flow, followed by the southern panel, or the upstream portion of the diversion. Impacts due to subsidence and the management strategy of the diversion channel are discussed in Section 11.4.10.

The diverted alignment of the new Little Sandy Creek, Rocky Creek, and Middle Creek channel are shown on Figure 11-20, a longitudinal profile of the diversion is shown on Figure 11-20, and a typical cross section is shown on Figure 11-21. The realignment of the Little Sandy Creek, Rocky Creek, and Middle Creek will isolate an area of approximately 6,000 ha. It is proposed that 90% of the combined isolated area in the proposed open-cut mine area will be mined. A small portion of isolated area will remain upstream of the mine pit and flood protection levee and will either be discharged through the clean water system in the mining area, or pumped to the diversion channel.

11.3.10.3 Design Criteria – Channel Geometry

Previous studies of creek and river diversions in the Bowen Basin in Queensland (ACARP, 2002) have shown that the more frequent flood events (e.g. the 1:2 to 1:10 AEP events) generally have the greatest geomorphologic influence on re-shaping channel cross-sections and alignments. These more frequently occurring events concentrate the stream flow within the channel banks, and have the potential to produce velocities high enough to induce erosion within the channel. The less frequent flood events, such as the 1:100 AEP, tend to utilise the floodplain for floodwater attenuation, resulting in lower cross-sectional velocities and less potential for erosion (ACARP, 2002).

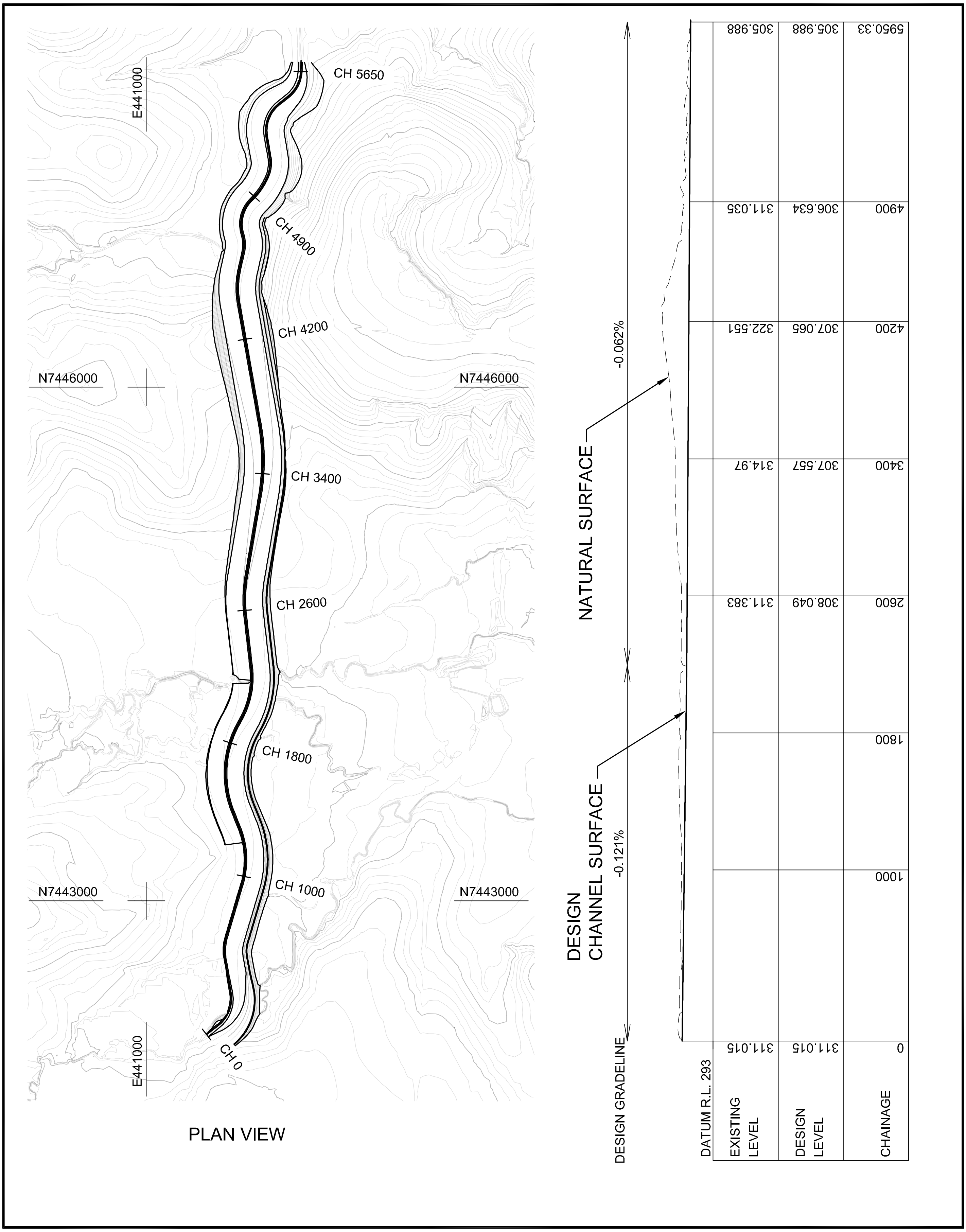
This situation also applies within Little Sandy Creek, Rocky Creek, and Middle Creek where flood flows in excess of the 1:5 to 1:20 AEP events generally overtop the creek banks and spread out over the floodplain. Therefore, a key design condition for the diversion is for the channel flow capacity to replicate the natural creek channel 'bank-full' flow capacity. In this instance the 'bank-full' flow is approximately equivalent to the peak flows of a 1:5 AEP flood event. For larger flood events, such as the 1:100 AEP, floodplain interaction occurs as per the existing creek system.

The new channel design has been developed to mimic the general geometry of the existing creek low flow channels while also ensuring that the new channels will have acceptable hydraulic performance in terms of creek stability (minimal erosion or deposition risk). The channel shape will be generally consistent with the existing creek channels comprising a trapezoidal shape (flat bed), bank slopes at 1(V) in 3(H), and channel depth approximately 2 meters to the terrace (berm) levels.

For the conceptual design of the diversion channel, the following criteria have been adopted for this EIS:

- For modelling purposes, the diversion channel was assumed to in a fully revegetated condition. It is however recognised that the requirement to ensure acceptable hydraulic performance for a range of diversion vegetation stages, and that revegetation of the channel bank will take some time to fully establish and replicate the hydraulic roughness of the existing river system. The hydraulic performance for lower hydraulic roughness conditions than the existing creek for the early years of the open-cut pit Project should be evaluated at the design phase; and
- The diversion channel bottom width is uniform along the entire reach of the diversion channel. A uniform bottom width of 3 meters was utilised at this conceptual level in order simplify the analysis, and demonstrate that the diversion would perform hydraulically. A gradually widening channel, due to increasing contributing catchment area, should be evaluated at the detailed design phase prior to Project Execution.

The upstream and downstream bed levels of the new diversion channel will match the bed levels at their junctions with the existing stream channels, with the exception of Middle Creek, which, with the current conceptual design may require a simple transition. The transition section would be designed to be similar to a rock chute to convey the water from Middle Creek to the diversion without causing scouring of the diversion channel or head-cutting in Middle Creek. The transition of the diversion into Middle Creek will be further evaluated during detailed design.



Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1 - References.*

500 0 500m

Datum: GDA94, MGA Zone55

N W E S

I HANCOCK GALILEE PTY LTD

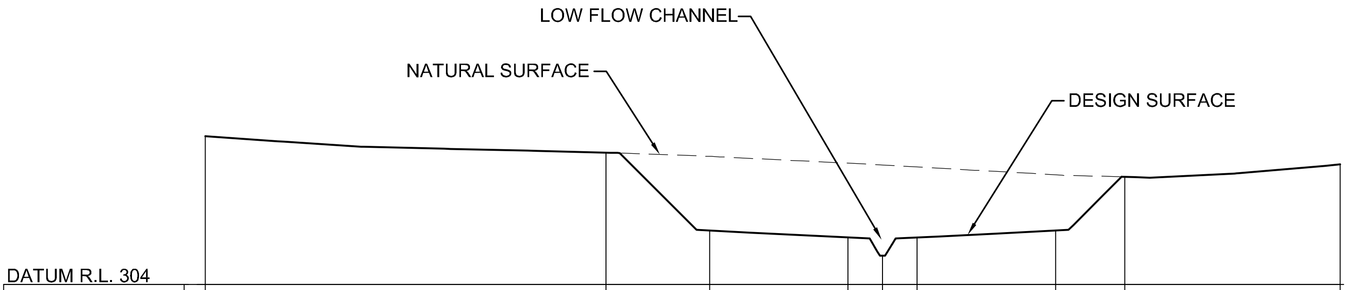
Kevin's Corner Project
Environmental Impact Statement

LITTLE SANDY CREEK DIVERSION CHANNEL PLAN & PROFILE

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-20

File No: 42626000-g-1150.dwg



EXISTING LEVEL	321.177	319.26	318.837	318.045	317.847	317.616	316.686	316.465	317.924
DESIGN LEVEL	321.177	319.26	310.246	309.446	307.321	309.446	310.247	316.465	317.924
CHAINAGE	-391.591	-160	-100	-20	0	20	100	140	264.645

CH 3750 TYPICAL CROSS SECTION

SCALE: EXAGGERATION 1x HORIZONTAL
5x VERTICAL

Source: See Copyright Details below and for full disclosure Please Refer to the EIS *Volume 1 - References.*

500 0 500m

Datum: GDA94, MGA Zone55

N W E S

I HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

LITTLE SANDY CREEK DIVERSION CHANNEL TYPICAL CHANNEL CROSS SECTION

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-21

File No: 42626000-g-1151.dwg

11.3.10.4 Flow Velocity/Shear Stress as Indicators of Erosion Potential

Several methods have been developed to quantitatively compare the existing creek hydraulics to those of the diversion channel for design purposes. The most common method uses channel velocity to estimate shear stress within the channel. The shear stress can then be related to the potential for erosion or sedimentation within the channel based on the characteristics of the channel bed and banks. Guidelines for maximum permissible velocities to minimise erosion can then be established based on the channel bed material.

It is important to recognise that velocity and shear stress provide an indication of local and immediate erosion potential only. Velocity and shear stress parameters generally indicate whether there is erosion potential to cause enlargement of the local channel cross section (depth and width). They generally do not indicate if there are other influences present which try to realign and reshape the channel alignment (e.g. meandering). The long-term stability of a channel's alignment is related to the morphological context of the reach. Stream power is a more useful indicator of hydraulic conditions reflecting the morphology of the channel, particularly for 'bank-full' flows that are commonly known to be 'channel forming' events.

11.3.10.5 Stream Power

The assessment of stream power is considered to be a key parameter in evaluating the interaction of flow hydraulics and stream morphology. Stream power is the potential work that the flowing water performs to modify and reshape the stream. In general, the stream power should be evaluated holistically by comparing the stream power over the entire river reach. Typical river channels show a sinusoidal stream power where it is greater in some areas and less in others.

The estimation of stream power is most valuable for flows in the channel at the bank-full level. This recognises that bank-full flows can occur for extended periods in major flood events, occur more frequently than large floods, and that bank-full flows are relatively confined (whereas larger floods tend to spread out onto adjoining floodplain areas which dissipates energy and power). Overall, the hydraulic conditions during bank-full flows have the greatest potential for stream erosion and re-shaping of the channel alignment.

Although stream power is a valuable and more direct indicator of hydraulic conditions relative to morphological stability (and more useful than velocity and shear stress), there are no firm scientific criteria to guide hydraulic design for stream diversions with respect to how much change in stream power is sustainable. The general approach for current best practice for creek diversions is to design the diversion to avoid excessive increases in stream power and to monitor performance of the diversion during its operation.

Large increases in stream power can result in an excessive imbalance of stream power causing the creek to reform itself (by meandering and changing the channel cross-section geometry) to reach an equilibrium regime. Large increases in stream power are typically the result of:

- Increasing channel slope, resulting from a shortening of the channel between two points (e.g. cutting off a meander to straighten a channel);

- Reducing the width and depth of the floodplain and the potential for flood attenuation in larger floods, thereby increasing flow depth and velocity (e.g. confining the floodwater to a smaller cross section) and potentially increasing the duration of flow; and
- Decreasing the channel resistance (friction) by reducing or eliminating vegetation or other flow obstructions.

Channels will try to reach equilibrium in stream power by increasing overall stream length by forming meanders, and by widening the channel width and decreasing the channel slope by eroding and head cutting. To minimise the change in stream power, diversion channels need to have a similar cross section (channel and floodplain), hydraulic roughness (bed conditions and vegetation) and channel slope as the existing creek system.

For these reasons, stream power has been used as a measure of the potential for long-term stability of the Little Sandy Creek, Rocky Creek, and Middle Creek diversion channel.

The diversion channel hydraulic model results for the 1:2 AEP to the 1:50 AEP will be compared to the following criteria to assess potential impacts:

- Baseline hydraulic results (Volume 2, Appendix M.2.2, Section 6.2)
  - Baseline velocity
  - Baseline stream power
  - Baseline sediment particle transport
- ACARP (2002) Guidelines for Incised type streams since the approximate existing bankfull capacities of Little Sandy Creek, Rocky Creek, and Middle Creek are greater than 1:5 AEP flood events:
  - Recommended channel velocity range
    - 1:2 AEP flood event: 1.0 to 1.5 m/s
    - 1:50 AEP flood event: 1.5 to 2.5 m/s
  - Recommended channel stream power range
    - 1:2 AEP flood event: 20 to 60 W/m^2
    - 1:50 AEP flood event: 50 to 150 W/m^2

11.3.10.6 Geomorphological Factors

All natural creeks constantly erode and deposit sediment relative to the magnitude, frequency and variability of flows. It is the interaction of flow hydraulics and bed/bank erosion/deposition which alters channel geometry and flow hydraulics. These factors vary over time and position in the catchment.

The spatial context of a creek reach relative to the broader catchment and associated landforms is also important for the creek's regime of erosion and/or sedimentation in a local reach. These factors relate to the supply of sediment from upstream, the flow parameters (velocity, shear stress and stream power), and the geometric influences (particularly gradient) for sediment transport within a stream reach.

Erosion is typical in the headwaters of catchments where gradients are steep, and the sediment supply from small upstream catchment area is limited. Deposition (accretion) is typical in lower reaches of catchments where there is substantial sediment supply from upstream and where gradients are flat allowing sediment to deposit and floodplain landforms to develop.

The middle reaches of catchments are typically in a 'net' balance (equilibrium) of erosion and sedimentation. However, these reaches can be dynamic over short-term periods in response to variability in flow hydrology, sediment supply and hydraulics. The dynamics of these reaches means that erosion can occur for some flows (typically floods) and deposition can occur for other flows (receding flows after prolonged rainfall). The balance can also vary between erosion and deposition in individual flood events with erosion during the rising waters of a flood and deposition during the falling waters of a flood. Over the 'long-term' the cumulative hydrologic effect of frequent small flows and infrequent large flows results in a net balance of erosion and sedimentation.

It is not usually possible to evaluate and quantify the dynamics of short-term erosion and deposition cycles/variability (without extensive long-term data on stream geometry, sediment loads and flows over several decades). Hence, the stream power of stream hydraulics for the 'bank-full' flood flow is a valuable indicator of the 'net average' effect of variability in hydrology on the overall morphological stability of a river system.

The reaches of the Little Sandy Creek, Rocky Creek, and Middle Creek in the vicinity of the mine generally have sandy beds in the existing channel and mature vegetation along the creek banks. Given these features and the location of the reach within the broader catchment in the broad transition between the source and transfer zones of MLA 70425 watercourses, the mine reach can be considered as having a long-term equilibrium of erosion and sedimentation with a slight recent trend towards deposition arising from a phase of increased erosion triggered by land use changes. Rocky and Little Sandy Creeks have anastomosing channels the form of which is typically stable given they are formed in cohesive floodplain sediments. Middle Creek is likely to have a more dynamic channel system as it is in a confined valley and lacks a well developed floodplain. Cycles of erosion and deposition are likely to occur naturally in such a system.

The general implication for the stability of the proposed diversion is that some erosion and deposition within the diversion channel will occur and should be expected since the existing creeks exhibit this behaviour. A key issue in assessing the morphological stability of the diversion is the likely effect of erosion to adversely alter the diversion alignment and geometry by means of assessing the likely change to stream power for bank-full flows.

11.3.11 Flood Protection for the Mine

Flood protection levee banks are proposed to protect the mine open-cut and infrastructure areas from flooding. The proposed extents of the flood protection levees are shown on Figure 11-19. Flood levee banks will be required along northern, southern, and eastern perimeter of the open-cut operation to protect the area from flooding from Well Creek, Greentree Creek, and Sandy Creek, respectively. A levee bank will also be required along the Western boundary of the main open-cut mine operation to provide flood protection from the diverted Little Sandy Creek, Rocky Creek, and Middle Creek. Flood protection for the initial North open-cut mine operation and tailings storage facility (TSF) will be provided via a levee bank which will be constructed along the Southern perimeter. An additional levee bank will be provided along the eastern side of Sandy Creek to protect the proposed rail loop from flooding from Sandy Creek.

11.3.11.1 Level of Flood Protection

The flood levee embankments have been designed to provide protection up to the 1:1,000 AEP flood event in accordance with a risk based approach. Consideration has been given to the range of options that could be implemented to recover flooded mine pits in an environmentally responsible manner. For example a flooded mine pit could be recovered with minimal environmental impact if the flood water is appropriately treated to acceptable water quality standards prior to discharge to the waterways, or could be recovered by constructing regulated dams to allow dewatering of the mine pits.

The nominal 1:1,000 AEP level of flood protection will be further reviewed as part of detailed design and subject to a detailed risk assessment including various consequences that may arise from different methods to recover the mine pit(s) in the event of an extreme flood. Discussions will be held with DERM during the detailed design phase to agree on an appropriate risk based level of flood protection.

11.3.11.2 Design, Construction and Maintenance of the Flood Protection Levees

A geotechnical investigation will be required at the detailed design phase to:

- Characterise the subsurface conditions of the levees to estimate the extent of excavation required to construct a suitable cut-off from piping (i.e. formation of an erosion hole from one side of the levee to the other) of the levee foundation. The levee foundation would likely require excavation to rock or an impervious cut-off wall would need to be constructed; and
- Identify sources of material that are suitable for construction of the levee embankments. The levee would be designed to impound water for long durations during flooding and would also need to resist erosion from flooding and direct rainfall.

Borrow pit locations have been identified next to each levee location. The levee embankment would be designed for the following:

- Slope stability;
- Erosion from flooding in the creeks and from direct rainfall;
- Piping failure in the foundation;
- Piping failure through the levee embankment; and
- Ease of maintenance, including sufficiently wide crest for light and heavy vehicle access, if desired, and flat batter slopes for vegetation maintenance.

The flood protection levee banks will be regulated structures with conditions administered through the Environmental Authority. This will require design to be undertaken by a suitably qualified and experienced engineer (as defined by DERM) and certification of the design and construction of the levee bank. The Environmental Authority conditions will also require certified annual surveillance inspections by a suitably qualified and experience engineer and obligation for the EA holder to rectify deficiencies identified in the annual surveillance outcomes.

11.4 Potential Surface Water Impacts and Mitigation Measures

Potential impacts and corresponding mitigation strategies of the proposed Project on surface are described in this section. The potential impacts are described in the following sequence:

- Impacts on hydrology (stream flows in the local water courses);
- Impact on surface water quality;
- Impacts on flooding; and
- Impacts on stream stability (geomorphology).

The impacts are assessed assuming that the proposed management of surface waters and associated control measures as descried in Section 11.5 will be implemented. Additional mitigation measures are also identified to minimise potential significant impacts

11.4.1 Impacts on Hydrology

The catchment hydrology will be impacted by the presence of the mine and the creek diversion, resulting in the following impacts:

- Changes in the catchment extents;
- Changes in the catchment runoff characteristics where the proposed mining operations would occur;
- Impacts of the timing of discharges from the mine to the natural system; and
- Changes to flood discharge estimates through the Project area and downstream.

11.4.1.1 Impact on Watercourse Hydrology

Impacts on Larger Catchment Boundaries (Pre-subsidence)

The proposed diversion, flood protection levees and water management system will have an impact on the larger sub-catchment boundaries. The upper sections of Little Sandy Creek and Rocky Creek will be diverted into Middle Creek, with downstream portion of each creek either isolated between the diversion channel and levee bank, or removed due to the mining works. This diversion will also result in a reduction in the total catchment area of Well Creek as Little Sandy and Rocky Creek currently flow into Well Creek which in turn discharges into Middle Creek. The catchment area changes that will result are presented in Table 11-24 and shown graphically on Figure 11-19.

Table 11-24 Comparison of base and developed conditions catchment areas

Creek	Location	Base Conditions Catchment Area (km^2)	Developed Conditions Catchment Area (km^2)	Difference in Catchment Area (km^2)
Rocky Creek	**Confluence with Little Sandy Creek / Diversion**	52.7	47.0	- 5.7
Little Sandy Creek	**Confluence with Well Creek / upstream end of Diversion**	96.7	42.4	- 54.3
Middle Creek	**Confluence with Well Creek**	53.1	141.2	+ 88.1
Well Creek	**Confluence with Sandy Creek**	454.8	396.2	- 58.6
Greentree Creek	**Confluence with Sandy Creek**	435.6	435.6	0
Sandy Creek	**Upstream of mine lease (Lagoon Creek)**	1,758.1	1,758.1	0
Sandy Creek	**At outlet**	2,737.1	2,727.1	- 10.0

Impacts on Downstream Flow Volumes

As the mine WMS is designed in accordance with best practice to capture and contain all runoff originating from potentially contaminating catchments there will inevitably be some small reduction in the total catchment area that sustains flows to the downstream watercourse.

The greatest potential reduction in to downstream flows will occur in the later stages of the mine when the catchment extents of the WMS are greatest. The mine water catchment area data provided in shows that in year 30 the potential extent of catchment area reporting to the mine WMS is 35.2 km^2 for a worst case assumption that rehabilitated areas are not yet sufficiently established to allow runoff from these areas to be diverted out of the mine water management system.

It can be seen from Table 11-25 that under the worst case scenario the reduction in flows as a result of the mine WMS would be less than 1%. This small reduction will not materially impact on the downstream environmental values identified in the Surface Water Quality Technical Report (Volume 2, Appendix M4). However, the progressive rehabilitation within the constraints of the mine plan of all disturbed areas and spoil and overburden dumps so that runoff from these areas is sufficiently clean to be diverted will reduce the minor impact on downstream flows.

Table 11-25 Impact of mine waste management system (WMS) on downstream flows in Sandy Creek

Description	Existing Conditions	Year 5 Mine WMS Catchment (Excluding Raw Water Dam)	Year 30 Mine WMS Catchment with containment of Runoff from all Rehabilitated areas (Excluding Raw Water Dam)
Sandy Creek catchment (km^2)	2737	2715	2702
Impact on catchment area	n/a	-0.84%	-1.29%
Mean annual flow (ML/yr) (6.5mm mean annual runoff x catchment area)	17,745	17,642	17,562
Impact on mean annual flow	n/a	-0.84%	-1.29%
Reduction in mean annual flow (ML)	n/a	149	229

Impact on Temporal Flow Characteristics

The water management strategy for the Project will allow clean undisturbed areas to passively drain to the local watercourse at similar flow velocities, and with similar flow recession characteristics as the existing catchment. This will result in no measurable change in the temporal characteristics of the watercourse stream flow hydrology and the existing ephemeral flow characteristics will be maintained.

11.4.1.2 Impacts on Flood Hydrology

The Project has the potential to have a number of influences on flood hydrology. These influences tend to compensate each other and as a consequence minimise the net impact of flood flows.

The potential impacts on flood flows include:

- The disturbed mine areas and hardstand areas will tend to produce higher runoff rates during intense storm events. In actual operations this will not impact on the watercourse floods because these impacts will be contained within the mine water management system;
- The mine water management system will contain runoff from the mine areas, and this will result in a reduction in catchment areas contributing to flood hydrograph volumes and peak flows. This will tend to reduce the peak flows in the downstream watercourse;
- The proposed watercourse diversion of little sandy creek, rocky creek, and middle creek flood flows entering well creek and then sandy creek. This will tend to slightly decrease peak flows in sandy creek due small changes in the timing of hydrographs from well creek and sandy creek; and
- The proposed flood protection levees will constrict the floodplain area and result in some loss of floodplain storage and consequent effect on flood routing along the watercourses. This will tend to slightly increase the peak flows in the downstream watercourse and this effect would be greater for larger flood events.

Hydrologic modelling was conducted to assess the differences in hydrology due to the proposed mining operation. A detailed discussion of the modelling and assumptions are presented in the Hydrology technical report (Volume 2, Appendix M2).

- The modelled changes in peak flood discharges as a consequence of the Project, as presented in Table 11-26, show that the peak flood discharge at the northern end (downstream) of the mine lease would be negligible for the more frequent events up to the 1:50 AEP event and would decrease for the more extreme events.

Table 11-26 Impact on peak flood flows in Sandy Creek at the northern mine lease boundary

Flood Event (AEP)	Peak Flows m^3/s		Difference (m^3/s)
	Existing	Proposed	
1:10	331	331	0
1:50	1,110	1,110	0
1:100	3,030	3,010	- 20
1:1,000	5,860	5,840	- 20
1:2,000	7,020	7,000	-20
PMF	28,910	28,780	- 130

11.4.2 Surface Water Quality Impacts and Mitigation

The following section details the potential impacts on surface water quality during construction and operational stages of the Project. A qualitative risk assessment was undertaken to explore the potential impacts on the surface water quality of receiving waters during each stage of the Project. A detailed risk assessment for the Kevin's Corner Surface Water Activities is provided in the Water Quality Technical Report (Volume 2, Appendix M4) and a summary of the key impacts and mitigation measures is provided in this section. All mitigation measures discussed are aimed at maintaining or improving water quality within the creek systems.

11.4.2.1 Construction Phase

The Kevin's Corner coal mine has the potential to adversely impact on surface water resources during construction without proper mitigation. Activities associated with the construction of mine infrastructure, construction of water management infrastructure, and earth moving activities are the main areas of potential impact. These activities may lead to erosion and sediment mobilisation, altered flow characteristics and contaminant mobilisation. Potential impacts on water quality throughout the construction phase are summarised in Table 11-27, and corresponding mitigation measures are provided. Residual impacts are expected to be minimal with the implementation of these management strategies.

Table 11-27 Potential construction impacts on surface water quality and mitigation measures

Impacts During Construction	Mitigation Measures
Sediment mobilised during construction activities may enter surface water runoff during rainfall events and discharge to watercourses leading to adverse effects on water quality. Sediment exposed or generated during construction may also be carried by wind into surface water bodies. Additionally there is the potential for the presence of high levels of metals in soils that may enter watercourses.	• Areas of disturbed or exposed soil should be managed to reduce sediment mobilisation and erosion • An erosion and sediment control plan is prepared and executed (ESCP) • Disturbance by heavy earth moving equipment is minimised especially in riparian areas • The number of passes over water crossings is kept to a minimum • Topsoil is stripped and stockpiled away from drainage lines to protect it from erosion • Bunds are constructed to restrict flow velocities across the site • Vegetation clearing is not carried out during heavy rainfall • Dust suppression measures are adopted such as water sprays or stockpile covers • Vehicle washdowns are located away from drainage lines or watercourses • Construction activities that will affect existing drainage lines and control measures will only be carried out after suitable stormwater management infrastructure has been installed on site as per the construction contractors' Environmental Management Plan (EMP) • Sedimentation dams are constructed to capture dirty water runoff and used preferentially for dust suppression • Vehicle crossings are adequately designed for a range of flow conditions, including under road drainage • All crossings will be in accordance with the DERM guideline – "Activities in a watercourse, lake or spring carried out by an entity" (WAP/2010/4165) • Any site dewatering activities will require treatment or appropriate management prior to discharge • Diversion of watercourse either by low flow diversion or coffer dam with pumping • Groundcovers will be established to rehabilitate areas disturbed by road crossings and slope protection material will be used on road batters • Mitre drains to be used to divert runoff from road shoulders and table drains into sedimentation dams

Impacts During Construction	Mitigation Measures
Potentially contaminated aqueous waste streams from temporary refuelling facilities, chemical storage facilities and vehicle washdown areas could enter into drainage lines, altering the physical and chemical characteristics of the receiving waters.	• Temporary and permanent chemical and fuel storage areas to be appropriately bunded in accordance with AS 1940 • All transfers of fuels and chemicals will need to be controlled to prevent spillage outside bunded areas • Bunds and sumps are frequently drained and treated/disposed of appropriately. • Contaminants and major spillages will be collected by a licensed waste collection and transport contractor for disposal at an offsite licensed facility. • Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in appropriate locations, including inside machinery and vehicles • Refuelling to occur within bunded areas in accordance with AS1940 • In the event of a spill occurring, ensure it is controlled, contained and cleaned up to prevent the mobilisation of pollutants in drainage lines or watercourses • Site selection of storage and refuelling areas to minimise stormwater inundation and reduce the potential for clean runoff to mix with contaminated water • Wastewater from washdown areas will be directed through oil and grease separators and effluent directed to construction ponds for reuse.
A lack of water supply may result in inadequate dust suppression, soil compaction and vehicle washdown, resulting in mobilisation of sediment into nearby watercourses impacting on water quality.	• The development, implementation and maintenance of a Water Supply Strategy and Emergency Plan are recommended. Proposed water supplies during construction include water contained in sedimentation dams and groundwater bores. Implementation of sediment and erosion control measures previously outlined may also help to reduce water demands. Water demand may also be reduced through the modification or reprioritisation of mining methods

Impacts During Construction	Mitigation Measures
Erosion and damage to sediment control infrastructure from significant rainfall events during construction	• Schedule construction works to minimise exposure to flooding during the wet season (October to April) • Stormwater management measures such as drainage diversion and flood defence bunds (designed to 1:100 AEP event) to be implemented before construction commences • Emergency response procedures and flood warning system • Infrastructure should be designed with floor levels above an appropriate AEP flood level • Monitoring equipment with telemetry system on creeks, dams, discharge points • Flexible water management system to cater for a variety of conditions and operational needs - including sufficient storage capacity on-site • Monitoring and maintenance of dams and water management infrastructure (pumps and pipelines) • Separation of clean and dirty water systems • Implementation of Standard operating procedures for water management

11.4.2.2 Operational Phase

During the operational phase of the coal mine, in addition to those identified during construction activities, potential adverse impacts may arise from water management system infrastructure failures (storages, pipes, embankments) and creek diversions. Potential impacts on water quality during the operation of the Kevin's Corner mine are summarised in Table 11-28 together with proposed mitigation measures. The residual impact on surface water quality is expected to be minimal with the implementation of these management strategies.

Table 11-28 Potential operational impacts on surface water quality and mitigation measures

Impacts During Mine Operation	Mitigation Measures
Failure of water storages, storage embankments, pipelines, levees or bunds has the potential to result in non-compliant discharge and environmental impacts for downstream receiving waters, ecosystems and landholders. These may include altered flow regimes in receiving waters; discharge of poor water quality of mine water compared to the water quality of the receiving environment; alteration of riparian vegetation and aquatic species through changed environmental flows; and erosion and sedimentation at discharge points.	• Design of water storages using a Water Balance Model which considers all inputs and outputs which has run through a long-term period of climatic data to test storage capacities particularly in high rainfall wet seasons • Water storages designed in accordance with DME1995 Technical Guidelines • Monitoring equipment will be installed to monitor storage volume during operation combined with a water management system to prevent overfilling • Design and construction supervision of dam embankments undertaken by a Registered Professional Engineer of Queensland (RPEQ) • Regular dam inspections to be undertaken by RPEQ • Regular inspections during operation of water storages, tailings dams levels, integrity of embankment and spillways • Regular pipeline, drain, bund and levee inspections and maintenance will be undertaken during operation
Erosion and sediment mobilisation from mining operations (topsoil stripping, blasting overburden removal, handling and stockpiling) and CHPP can lead to deleterious effects on downstream water quality and aquatic habitats.	• Potential impacts will be mitigated using appropriate design for erosion and scour protection and a comprehensive mine water management plan. • Additionally, swales and buffer strips are proposed to provide stormwater filtration prior to discharge to receiving waters. Swales are open vegetated (generally grass) drains, whilst buffers or filter strips are grassed surfaces aligned perpendicular to the direction of flow, which ware used to filter particulate matter and associated pollutants from stormwater prior to its entry into adjacent receiving waters. Both swales and buffers provide water treatment through physical filtration of water through the vegetation and depending on the retention time some additional pollutants may be taken up by the vegetation. • Progressive rehabilitation of overburden spoil piles will be undertaken to reduce erosion and sedimentation potential. • An on-going monitoring program (outlined in section 7) will be implemented to monitor the impacts of mine operations on the receiving watercourses. Site specific trigger values for assessing water quality data against are proposed to be developed based on the baseline monitoring program.

11.4.3 Impacts of Flooding Levels

The combination of the proposed stream diversion and flood protection levee banks required for the Project may potentially impact on flood levels. Changes in design flood event peak water levels may not be necessarily a concern in a remote area providing that risk to third party infrastructure and facilities are not impacted and the Project design accommodates the design flood levels.

The change in flood level due to a proposed development relative to existing flood levels (base case) is commonly referred to as afflux. A positive afflux indicates an increase in flood level, and a negative afflux indicates a decrease in flood level.

11.4.3.1 Estimated Flood Level with Diversion and Flood Protection Levees

The impact on flood levels was assessed with the hydraulic models that were prepared to assess baseline conditions (refer Hydraulic technical report, Volume 2, Appendix M2). The hydraulic models were modified to include representation of the proposed concept stream diversion works and flood protection levees.

A summary of the predicted changes to flood levels after development are shown as the afflux values in Table 11-29 and Table 11-30 at the upstream and downstream mine boundaries. These results identify that some changes in flood levels are likely as a result of the mine development, but these changes are not considered to change the flood risk to existing infrastructure in the area.

Table 11-29 Comparison of flood elevations in Sandy Creek at upstream mine lease boundary

AEP Event	Flood Elevation at Upstream Mine Boundary – Existing (m AHD)	Flood Elevation at Upstream Mine Boundary – Proposed (m AHD)	Afflux (m)
1:2	296.6	296.6	0.0
1:50	299.1	299.1	0.0
1:100	300.8	301.0	+ 0.2
1:1,000	301.6	301.7	+ 0.1
1:2,000	301.6	302.2	+.0.6
PMF	304.4	307.9	+ 3.5

Table 11-30 Comparison of flood elevations in Sandy Creek at downstream mine lease boundary

AEP Event	Flood Elevation at Downstream Mine Boundary – Existing (m AHD)	Flood Elevation at Downstream Mine Boundary – Proposed (m AHD)	Afflux (m)
1:2	279.2	279.2	0.0
1:50	282.0	282.0	0.0
1:100	283.5	283.5	0.0
1:1,000	284.4	284.4	0.0
1:2,000	284.8	284.8	0.0
PMF	288.8	288.9	+ 0.1

11.4.4 Geomorphic Impacts from Stream Diversion (Pre-subsidence)

11.4.4.1 Overview of Potential Geomorphologic Impacts

Stream diversions for mining projects are historically known to potentially produce adverse impacts on stream channel geomorphology. Best practice stream diversion design implemented over the last eight to ten years, since the research and publication of the ACARP guidelines for stream diversions is now widely recognised to improve the sustainability of modern stream diversions.

The potential adverse impacts of poorly designed stream diversions can include instability of the stream channel with potential for adverse impacts including:

- Excessive erosion leading to water quality impacts, unsustainable downstream sediment loads, and impacts on aquatic ecosystems; and
- Excessive lateral migration of the stream channel with risk to valuable infrastructure, riparian vegetation loss, and impacts on terrestrial ecosystems near the stream.

The most common causes of impacts due to inadequate stream diversion design can include:

- Diversion channels that are too short and / or steep relative to the original stream;
- Channel dimensions not matching the original channel resulting in change of the bank-full flood capacity of the channel which modifies the frequency and energy of bank-full flood events and floodplain interaction;
- Meander design not compatible with the expected channel flow energy and substrate conditions;
- Channel substrates that are markedly different to the original stream resulting in either poor ability to rehabilitate the stream, and / or greater vulnerability to erosion; and
- Excessive constriction of the floodplain corridor resulting in concentration of floodplain flow and higher energy in the stream channel.

11.4.4.2 Impacts of Proposed Diversion Alignment

The proposed diversion of the Little Sandy Creek, Rocky Creek and Middle Creek is described in Section 11.3.10. The diversion channel alignment was selected to contain the diversion channel within a single row of longwall panels. This criterion reduces the potential for subsidence to cause irregular lowering of the channel increasing sediment deposition and reducing channel capacity. The upstream and downstream bed levels of the new diversion channel will match the bed levels at their junctions with the existing stream channels, with the exception of Middle Creek, which, with the current conceptual design may require a simple transition. The transition section would be designed to be similar to a rock chute to convey the water from Middle Creek to the diversion without causing scouring of the diversion channel or head-cutting in Middle Creek. The transition of the diversion into Middle Creek will be further evaluated during detailed design.

11.4.4.3 Impacts of Proposed Diversion Low Flow Geometry

The new channel design has been developed to mimic the general geometry of the existing creek low flow channels while also ensuring that the new channels will have acceptable hydraulic performance in terms of creek stability (minimal erosion or deposition risk). The channel shape will be generally consistent with the existing creek channels comprising a trapezoidal shape (flat bed), bank slopes at 1(V) in 3(H), and channel depth approximately 2 meters to the terrace (berm) levels

11.4.4.4 Impacts of Proposed Diversion Low Flow Meander Design

The low flow channel has been designed to meander within the constraints of the proposed diversion alignment. As discussed previously the diversion alignment has been confined to one panel width of longwall to minimise subsequent subsidence rehabilitation impacts on sediment deposition and capacity of the diversion channel. This has necessitated a different meander design compared with the existing stream meander characteristics.

To ensure appropriate meandering, further investigation and optimisation of the proposed diversion channel meandering characteristics will be required including more detailed geomorphologic assessment and geotechnical investigations to assess the expected subsurface materials to confirm a suitable (sustainable) channel meander characteristics. These assessments will be undertaken as part of detailed design and in consultation with DERM prior to submission of the detailed design plans for approval to construct the stream diversion.

11.4.4.5 Substrate Conditions and Water Quality Impacts

The proposed stream diversion mitigation strategies will ensure that any dispersive soils encountered in the diversion channel excavation will not be left exposed. Surface exposures of dispersive soils will be either treated to minimise dispersion potential, or covered with topsoil to ensure that the dispersive substrates are not left exposed. This will ensure that direct rainfall impact on the diversion surfaces will not adversely impact on water quality.

11.4.4.6 Hydraulic Impacts on the Stability of the Proposed Diversion Channels

The hydraulic impacts of the proposed diversion works and flood protection levees were assessed with the hydraulic models developed for the Project. A detailed description of the hydraulic modelling is presented in the Hydraulic technical report (Volume 2, Appendix M2) and Geomorphology technical report (Volume 2, Appendix M1). Assessment of the results from the hydraulic modelling included impacts on channel flow velocity, stream power, and shear stress. A summary comparison between diverted case and existing channel hydraulic parameters is presented in Table 11-31.

Table 11-31 Summary of flood hydraulics for diversion for Little Sandy, Rocky, and Middle Creeks

Hydraulic Parameter	Flood Event (AEP)	Proposed Reach of Diversion	Average Existing Channel Upstream and Downstream of Diversion	ACARP Guidelines (2002)
Diversion Channel of Little Sandy Creek to Confluence with Rocky Creek				
Velocity (m/s)	1:2 1:50	0.3 – 0.6 0.4 – 1.3	0.3 – 1.1 0.7 – 2.0	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	0.6 – 4.5 1.2 – 28	0.7 – 25 3.5 - 119	20 – 60 50 – 150
Diversion Channel from Rocky Creek to Confluence with Middle Creek				
Velocity (m/s)	1:2 1:50	0.5 – 0.6 0.8 – 1.3	0.3 – 1.5 0.6 – 2.5	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	1.2 – 1.3 18 – 20	0.5 – 80 3.6 – 220	20 – 60 50 – 150
Diversion Channel from Middle Creek to Confluence with Well Creek				
Velocity (m/s)	1:2 1:50	0.2 – 1.2 0.9 – 2.4	0.2 - 1.2 0.9 – 2.2	1 – 1.5 1.5 – 2.5
Stream Power (W/m^2)	1:2 1:50	0.3 – 51 11 - 175	0.3 – 51 12 – 159	20 – 60 50 – 150

The hydraulics results for the Little Sandy Creek, Rocky Creek, and Middle Creek Diversion System generally show the following:

- The predicted hydraulic parameters (velocity and stream power) for the diversion channel are similar to those for the existing Little Sandy Creek, Rocky Creek, and Middle Creek system for the 1:2 AEP flood event, with lower velocities and stream power values for the 1:50 AEP flood event;
- The predicted hydraulic parameters for the diversion channel are generally within the ACARP guidelines for incised channels; and
- The reaches upstream and downstream of the diversion channel show similar velocities and stream powers for the scenarios with and without the diversion and no changes are expected to existing erosion or sedimentation patterns in these areas.

A comparison of the critical shear stress for the size of particle predicted to be transported by the proposed creek channel systems was estimated based on the average shear stress channel results, as summarised in Table 11-32 and in Volume 2, Appendix M.2.2. The results show that although the average shear stresses would be lower in the diversion channel, the diversion channel should be able to mobilise and transport the existing sediment material, based on the assumed grain sizes.

Table 11-32 Summary of sediment transport potential for proposed creeks

<table>
<tr><th>Creek</th><th>Location</th><th>Channel forming event (1:x) AEP</th><th>Shear stress (N/m^2)</th><th>Assumed particle classes present in reach</th><th>Critical shear stress of assumed particle classes (n/m^2)</th></tr>
<tr><td>Sandy Creek</td><td>Upstream of Mine Lease Boundary</td><td>1:5 to 1:10</td><td>3.9 – 21</td><td rowspan="8">Fine Gravel

Very Fine Gravel

Very Coarse Sand

Medium Sand</td><td rowspan="8">2.7

1.3

0.47

0.19</td></tr>
<tr><td>Sandy Creek</td><td>Within Mine Lease Boundary</td><td>1:5 to 1:10</td><td>8.3 – 30</td></tr>
<tr><td>Little Sandy Creek</td><td>Upstream of Diversion</td><td>1:10 to 1:50</td><td>3.0 – 69</td></tr>
<tr><td>Little Sandy Creek</td><td>Downstream of Diversion</td><td>1:10 to 1:50</td><td>6.3 – 19</td></tr>
<tr><td>Rocky Creek</td><td>Upstream of Diversion</td><td>1:20 to 1:50</td><td>4.5 – 81</td></tr>
<tr><td>Middle Creek</td><td>Upstream of Diversion</td><td>1:5 to 1:10</td><td>3.3 - 62</td></tr>
<tr><td>Well Creek</td><td>Upstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>14 – 89</td></tr>
<tr><td>Well Creek</td><td>Downstream of Middle Creek Confluence</td><td>1:10 to 1:20</td><td>9.4 – 62</td></tr>
</table>

Note (1): Values from *Erosion and Sedimentation* (Julien 1995)

The model results show that the diversion as proposed should achieve the adopted design criteria and would not be expected to result in any significant detrimental hydraulic impacts to the Little Sandy Creek, Rocky Creek, and Middle Creek system. Notwithstanding the satisfactory model results there are some potential environmental impacts (risks) due to the diversion channel of Little Sandy Creek, Rocky Creek, and Middle Creek, which include:

- Erosion of the diversion channel due to flooding following construction of the diversion channel and before rehabilitation of the channel with vegetation has had sufficient time to take hold;
- Excessive sedimentation within the diversion channel due to a reduced longitudinal gradient, resulting in:
  - — Reduced flood capacity within the channel system, which reduces the flood immunity of the flood protection levees; and
  - — A reduction in sediment supply to the Sandy Creek system for the more frequent floods and a higher sediment load during the less frequent events, possibly resulting in excessive deposition in Sandy Creek downstream of the confluence with Well Creek.
- Sedimentation at the confluence of each of the creeks and the diversion due to decreased velocities prior to entering the diversion channel;
- The formation of an unstable channel system with a wide floodplain resulting in a reduction in vegetation and riparian habitat; and
- Increased erosion in middle creek and well creek downstream of the diversion channel due to increased catchment area and potential increased frequency of flows in the creek channel.

11.4.5 Diversion Channel Management Strategy – Pre-subsidence

11.4.5.1 Mitigation of Erosion of the Newly Constructed Channel

The diversion channel when first excavated would be susceptible to erosion due to the exposed soil and the absence of vegetation or armouring to protect against erosion. Previous experience with diversion channel design and construction, and recommendations from the ACARP guidelines, show that constructing the diversion channel in stages and having a rehabilitation plan can increase the success of vegetation establishment and reduced the chance of excessive channel erosion. Based on the current mine plan, the diversion channel would be constructed early in the mine development. Stabilisation measures, such as rock riprap or similar works, would be constructed as part of the diversion channel to protect the channel from erosion following construction and commissioning, allowing for vegetation to progressively establish along the diversion channel.

11.4.5.2 Rehabilitation of the Proposed Diversion Channel

Realignment of the Little Sandy Creek, Rocky Creek, and Middle Creek will create an altered creek and riparian environment which will require effective, long-term and sustainable revegetation, consistent with existing vegetation communities in the area. High velocity flows can dislodge young establishing plants with inadequate root systems. Similarly, if plants are unable to establish deep root systems that can access deep soil water during the dry season, they could die. Quickly establishing deep healthy root systems for both artificial and naturally established native plants will be critical to the ecological success of the diversion.

A comparison of the diversion channel to geotechnical information has not been conducted for this study, but it is likely that most of the diverted channel will be cut into softer alluvial soils and some rock. Site preparation requirements, as a prerequisite for vegetation establishment, will be different for each substrate condition.

For sections of the channel excavated into rock, there is a risk that shallow rooted plants will be ripped out during high flows or die during the dry season, due to inadequate root depth which provides anchoring and/or access to soil moisture. Observations of sections of the existing creek show that trees will grow and survive in fractured rock provided they can get their roots down into fine substrates. This observation provides a useful guide to future site preparation along the rocky sections of the channel. Provided there is a reasonable component of fines, rough rock sections would protect the fine material from erosion. Consequently, the infilling of fractured rock voids with clean topsoil is a key requirement for rehabilitation success.

Sections of the diversion channel which are cut into softer alluvial material would require a different set of parameters for vegetation establishment. In particular, instability of topsoil placed on the channel banks can result in young plants being scoured out. Even though soft when wet, the banks can also be compacted during construction thus restricting initial root establishment. Rapid and deep root development must be encouraged. To overcome this problem, adequate soil depth could be created by adding rock cover and infilling with weed free, non-dispersive soil. In addition, in sections of the alluvial channel where there are dispersive soils (if found), geotextile could be placed on the bank before capping with fractured rock. In these sections, the depth of the rock/soil mix could be increased to allow for restricted root growth through the underlying geotextile.

Weeds are another potential impediment to vegetation establishment. Weeds can quickly out-compete slower establishing native species. Diligent weed control, particularly in the stripping, stockpiling and re-spreading of topsoil will be a high priority. Basic machinery hygiene would need to be maintained. Grazing animals may also damage newly revegetated areas and these would need to be excluded by fencing if necessary.

The design of the diversion channel at the transitions with the four creeks would need to consider protection strategies. Protection strategies such as rock armouring should be considered for the bed and banks to ensure that the changes in flow direction do not create scour potential.

11.4.6 Mitigation of Excessive Sedimentation and Erosion

The recommended mitigation strategy to reduce the potential for excessive sedimentation and erosion is to monitor deposition and erosion at fixed control locations with periodic (e.g. bi-annual) photographic surveys:

- Diversion channel;
- Confluences with little sandy creek, rocky creek, and middle creek; and
- Existing middle creek and well creek channels downstream of the diversion channel.

Evidence of impacts on the morphology of the creeks will trigger further investigations of the cause and identification of remedial strategies and/or works. A more detailed description of the proposed Monitoring Programme for the diversion is presented in Section 7 of Appendix M1.

11.4.7 Geomorphic Impacts from Flood Protection Levees

The proposed flood protection levees for the Project are described in Section 11.3.11. The hydraulic impacts of the proposed flood protection levees were assessed with the hydraulic models developed for the Project. A detailed description of the hydraulic modelling of the proposed flood protection levees is provided in the Hydraulic technical report (Volume 2, Appendix M2). Assessment of the results from the hydraulic modelling included impacts on channel flow velocity, stream power, and shear stress.

The hydraulic modelling results for Sandy Creek and Well Creek with the proposed flood protection levees generally show the following:

- Sandy Creek:
  - The predicted hydraulic parameters (velocity and stream power) for the Sandy Creek channel through the mine lease for the floods up to the 1:1,000 AEP event are similar to those for the existing Sandy Creek system for the range of floods modelled;
  - The predicted hydraulic parameters for the Sandy Creek channel through the mine lease are generally within the ACARP guidelines for incised channels;
  - The reaches upstream and downstream of the Sandy Creek channel through the mine lease show similar velocities and stream powers for the scenarios with and without the flood levee and no changes are expected to existing erosion or sedimentation patterns in these areas; and
  - There would be a rise in the predicted flood levels (afflux) in the upstream creek areas due to the reduced floodplain width for the larger flood events as shown in Table 11-29.
- Well Creek:
  - The predicted hydraulic parameters (velocity and stream power) for the Well Creek channel downstream of the confluence with Middle Creek for the floods up to the 1:50 AEP event slightly higher than those predicted for the existing Well Creek system for the range of floods modelled;
  - The predicted hydraulic parameters for the Well Creek channel through the mine lease are generally within the ACARP guidelines for incised channels; and
  - There is the potential for erosion of the existing Well Creek channel due to the increased catchment area from the diversion channel and from the reduced floodplain as a result of the proposed levees on either side of the channel.

11.4.8 Mitigation Strategy for Levees

The recommended mitigation strategy to minimise the potential for increased erosion/sedimentation is to monitor erosion and deposition at fixed control locations with periodic (e.g. bi-annual) photographic surveys. Evidence of impacts on the morphology of the creeks will trigger further investigations of the cause and identification of remedial strategies and/or works. A more detailed description of the proposed Monitoring Programme is presented in Section 11.5.

11.4.8.1 Floodplain Management

The effects of the flood protection levees around the open-cut mine will influence flood levels upstream of the mine lease in the Sandy Creek for floods greater than the 1:100 AEP event. The impacts of the increased water levels during flood events would not necessarily produce adverse environmental impacts on the existing vegetation and ecology along the river; however, it is recognised that the raised water levels could impact on the proposed Alpha mine project. The impacts of increased flood levels through the Kevin's Corner mine lease would not adversely affect the proposed mining operations. All key mine infrastructure (open-cut, concentrator plant and industrial area) will be located within the flood protection levee which would be designed to protect against floods up to the 1:1,000 AEP event.

Discussions have been held with the Alpha mine designers regarding the need for possible additional flood mitigation measures; however, assessing a need for additional floodplain width for the design event (1:1,000 AEP) at the design phase will be implemented.

11.4.9 Subsidence Impacts and Mitigation Measures

In longwall mining, a panel of coal, typically about 400 m wide and 3.5 km to 6 km long and 2.8 to 4.5 m thick, is removed by longwall shearing machinery, which travels back and forth across the coalface. The area immediately in front of the coalface is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata and provide a working space for the shearing machinery and face conveyor. After each slice of coal is removed, the hydraulic roof supports, the face conveyor and the shearing machinery are moved forward.

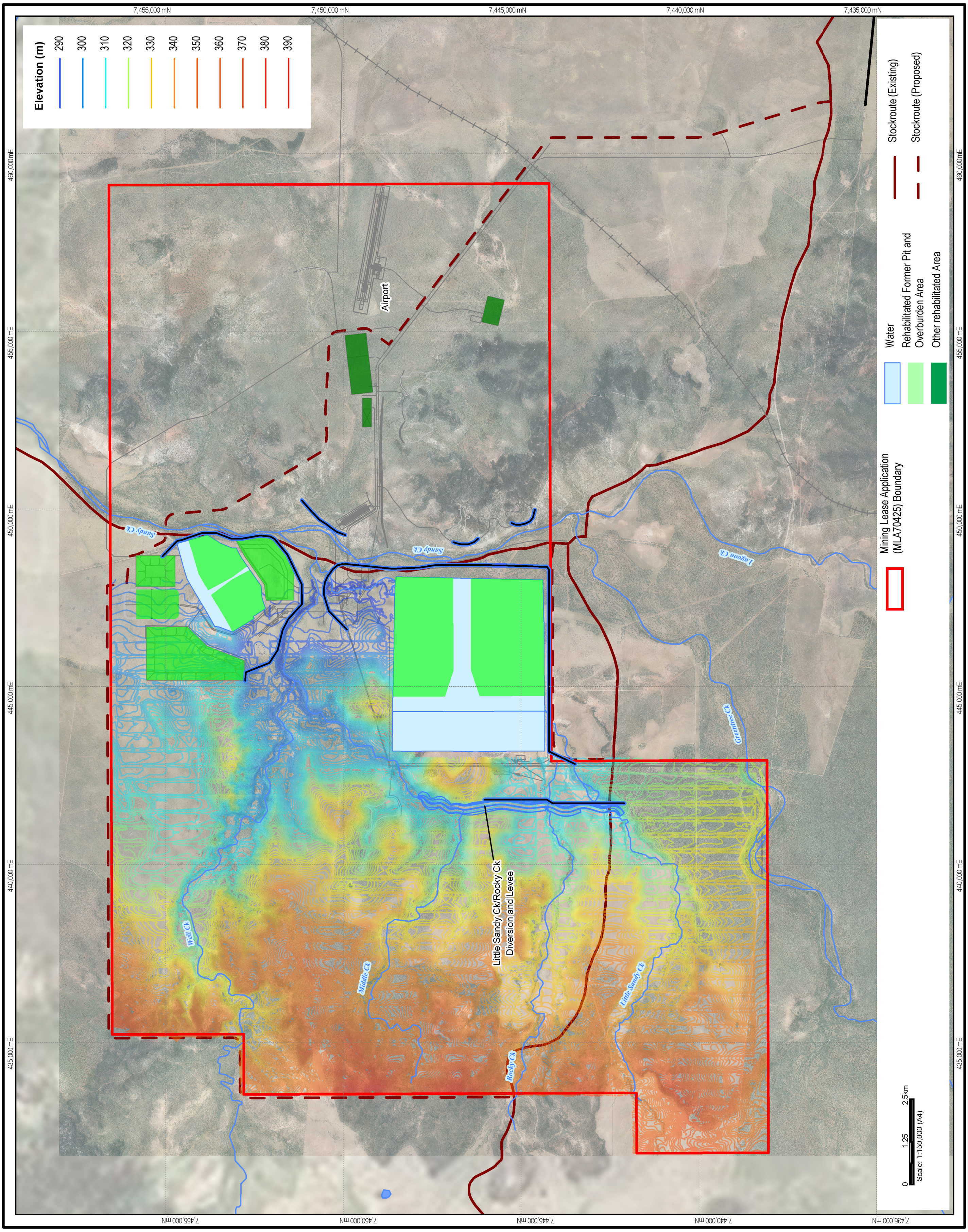
When coal is extracted using this method, the roof above the seam is allowed to collapse into the void that is left as the face retreats. This void is referred to as a goaf. As the roof collapses into the goaf, the fracturing settlement of the rock progresses through the overlying strata and results in sagging and bending of the near surface and subsidence of the ground above.

Generally, subsidence occurs over the centre of the longwall panel and tapers off around the perimeter of the longwall. The subsidence is typically less than the thickness of the coal extracted underground.

Where several panels are mined in a series and chain pillars are left between the panels. The chain pillars crush and distort as the coal is removed from both sides of them, but usually, they do not totally collapse, and hence the pillar provides a considerable amount of support to the strata above them.

The subsidence at the surface does not occur suddenly but develops progressively as the coal is extracted within the area of influence of the extracted panel. As further adjacent panels are extracted, additional subsidence is experienced, above the previously mined panel or panels. However, a point is also reached where a maximum value of subsidence is observed over the series of panels irrespective of whether more panels are later extracted. The subsidence effect at the surface occurs in the form of a very slow moving wave, which is typically 6 m per day.

A map showing the predicted subsidence arising from the proposed longwall mining is shown on Figure 11-22.



Source: See Copyright Details below and for full disclosure Please Refer to the EIS ***Volume 1 - References***

N E S W

I HANCOCK GALILEE PTY LTD

Kevin's Corner Project
Environmental Impact Statement

Datum: GDA94, MGA Zone55

FINAL INDICATIVE
LANDFORM

Job Number	4262 6660
Revision	B
Date	12-09-2011

Figure: 11-22

File No: 42626660-g-1120.wor

11.4.9.1 Overview of Subsidence Impacts

Due to underground mining, channels and floodplains situated directly over longwall panels will subside by approximately 0.5 to 3 m. The potential environmental impacts from subsidence include:

- Impacts to catchment boundaries, potentially resulting in self contained catchment areas where water that would have runoff to the creek channels prior to subsidence would now pool within the subsided area and be lost to groundwater due to percolation;
- Loss of surface water flow through limited surface cracking;
- Change to stream bed profiles between longwall panels, resulting in erosion between adjacent longwall panels and sedimentation over the tops of the longwall panels;
- Potentially reduced flood capacity in channels, resulting in more frequent inundation of floodplain areas;
- Reduce stability of the proposed diversion channel due to subsidence over multiple panels; and
- Reduce stability of the proposed levees within the subsidence area and increasing the risk of a piping failure during a flood event.

11.4.9.2 Impacts on Flows

As the panels subside, there is the potential that the volume of water that would have contributed to the downstream system could be lost of the creek system by:

- Formation of surface depressions which capture direct rainfall and no longer drain to the natural (or diverted) channel; and
- Increased percolation to the groundwater through surface cracking.

Formation of Surface Depressions

However, based on the current underground mine plan and subsidence surface terrain modelling, the reduction in the effective catchment area and catchment yield of the Sandy Creek is expected to be small. The area of the Sandy Creek catchment upstream of the Project area is approximately 2,190 km^2 and the Sandy Creek catchment area to the confluence with Well Creek, is approximately 2,210 km^2. It is predicted that a combined area of approximately 2 km^2 will become isolated from the Sandy Creek catchment through subsidence and will temporarily store ponded water. This represents an effective reduction in the Sandy Creek catchment upstream of the site of approximately 0.7%. The effective reduction in the total catchment area of the Sandy Creek catchment is approximately 0.1%. The reduction in catchment area and downstream catchment yield should therefore not adversely impact the local catchment. Additional mitigation measures will be considered, as outlined in Section 11.4.10, following subsidence and subsequent geomorphologic assessments.

The water quality in the ponded areas will reflect the water quality of natural surface runoff water and would be similar to local stock watering dams.

The residual ponded areas may also impact on vegetation within the ponded area. This is discussed in Volume 1, Section 9 - Terrestrial Ecology.

Surface Cracking

Surface cracking is likely to occur between the longwall panels potentially creating voids in which surface waters may potentially be lost to shallow groundwater. The loss of surface water flows into cracks caused by subsidence is known to be a significant concern for underground longwall mining in some areas of New South Wales. In Queensland, there is less evidence available of known impacts; however, the typically geology of Bowen Basin (primarily alluvial and sedimentary deposits) indicates that potential concern of loss of surface water flow into subsidence cracks is less significant than impacts that have been reported in New South Wales. The high plasticity of the overburden is further likely to mitigate the effects of cracking.

From site visits, the dominant near surface strata of the catchment areas is clayey soils. There is a high likelihood that small cracks (say up to 20mm) will self-seal after a short period of inflow into the cracks and the long-term impact of surface water loss will be minimal. Where cracking occurs through drainage channels and watercourses, the significant bed loads and suspended sediment loads in the channels will naturally fill surface cracks within the stream beds. Cracks that are less than approximately 20 mm are not considered significant and will naturally seal over time.

11.4.9.3 Hydraulic Impacts of Subsidence on Natural and Diverted Channels

Hydraulic modelling of the effects of subsidence on natural and diverted channels and associated floodplains indicates there may be an increase in the velocity, bed shear, and stream power in the creek channels where they cross subsidence areas. Sedimentation is predicted to occur in the troughs that will form above each longwall panel. Additionally, the hydraulic analysis suggests that increase erosion may occur between the longwall panels during the same time period. The results indicate that the relative impact of the erosion and sedimentation between the longwall panels is more pronounced during more frequent events such as the 1:2 AEP to 1:10 AEP storm events when flows approach bankfull conditions, and less pronounced for larger flood events with significant flows on the floodplain.

It is expected that over a medium to long period after subsidence (indicatively say 20 years), that the bed profile would adjust through sedimentation and erosion to form an even graded bed profile at similar slope to the existing creek. As this occurs, the channel hydraulic capacity may be reduced, resulting in more frequent inundation of the floodplain.

11.4.9.4 Impacts of Subsidence on Levees

The proposed alignments of the flood protection levee embankments on the western side of the open-cut operations generally follow the un-subsided areas between longwall panels in order to reduce the potential for structural stability, and to reduce the potential for reconstruction. A subsidence mitigation plan for the levee embankments is presented in Section 11.4.10.5.

11.4.10 Subsidence Management

The management of the impacts of subsidence is described in the following section.

11.4.10.1 Mitigation of Surface Ponding

In order to mitigate the effects of ponded water from self contained catchments, the progressive re-establishment of free drainage in the subsidence area will be completed, as far as practicable. This will include the construction of excavated trapezoidal drainage channels. These will be designed with sufficient capacity to cater for contributing catchments and with stable batter slopes. These channels will enable drainage of subsidence troughs along pre-existing drainage lines. Excavated material from the channels will be used for filling in any nearby ponding areas.

11.4.10.2 Mitigation of Surface Cracking

It is anticipated that any surface cracks less than 20 mm that may form following subsidence will self seal after a short period of inflow into the cracks and the long-term impact of surface water loss will be minimal. However, surface cracks greater than 20 mm, will be treated with deep ripping, infilling with clay, and compaction to reduce water loss. Alternative more expensive treatments such as bentonite injection will be available as fall-back contingency measures in the event that losses continue to occur. A post subsidence drain and waterway monitoring program will be implemented and surface cracks within drains and waterways that have not naturally filled after approximately three storm events will be sealed with clay.

11.4.10.3 Mitigation of Subsidence Impacts on Natural Channels

Hydraulic modelling results indicate that erosion due to subsidence impacts on the channel bed profile will occur in the areas between longwall panel and sedimentation will occur over the middle portion of the longwall panel. This process would naturally continue until the system achieves equilibrium (i.e. bed profile restored to an even slope similar to predevelopment conditions) and the quantity of water that ponds in the channel bed depressions will decrease over time. As part of the subsidence monitoring program, the ponding volumes and/or surface area extent of ponding will be monitored over time.

In the event that natural channel erosion and sedimentation does not reduce the volume of channel bed depressions (and consequent ponded water volumes), remedial works to reinstate an evenly graded bed profile (i.e. free draining channel) can be considered as a contingency measure. This would involve excavating the “high” points in the subsided channel bed profile, typically between the blocks where subsidence is less than the subsidence that occurs within the blocks. If required, the works would be completed to match the existing channel characteristics including geometry, substrate and vegetation. Excavated bank areas would need temporary erosion matting to protect the works until vegetation is established. If this contingency measure is required within Sandy Creek it will be necessary to seek approvals to obtain a Riverine Protection Permit under the *Water Act 2000*. It should be noted that this contingency measure with excavation to drain pooled areas would be extensive and necessitate significant disturbance to the drainage system and vegetation. It would therefore be adopted as a last resort option that will only be considered if triggered by the subsidence monitoring program and demonstrated that unsustainable deleterious effects on environmental values and downstream water resources availability would continue if the works were not undertaken.

11.4.10.4 Mitigation of Subsidence Impacts on the Diversion Channel

The diversion channel is to be constructed across two longwall panels which will be mined sequentially with the downstream panel being mined first. Following extraction of the downstream longwall panel it is possible that there will be a 0.5 to 3 m drop in grade from upstream to downstream following subsidence. The proposed underground mining sequence would allow water would continue to flow by gravity. However, additional structural measures may be required once the upstream panel subsides, including;

- Excavation of the potential "high point" between the downstream subsided panel and the yet to subside upstream panel so that the high point does not remain when the second panel subsides, thereby maintaining continuity of the channel system for water conveyance;
- Addition of a rock chute (i.e. Rock armouring in steep channel section to reduce potential for erosion; and
- After the second panel subsides, the rock armouring should either be removed or arranged so as not to impede flow.

Following subsidence, the diversion channel should be assessed for surface cracking and mitigation measures implements as outlined in Section 11.4.9.2.

11.4.10.5 Mitigation of Subsidence Impacts on Levees

Protection of the mine from flooding up to the design flood event is critical to the operation of the mine for the duration of the mine life. As such, the levee embankment alignments would be aligned on top of the un-subsided areas between the longwall panels. These reaches of levee embankments would be assessed for cracking on a periodic basis and reconstructed where cracking had the potential to create a piping risk and the jeopardise the integrity of the flood protection levees.

11.4.11 Climate Change Impacts

The impacts of climate change (if any) on the proposed Kevin's Corner Project are difficult to assess as experts in the field have presented evidence both for and against the theory. However, in addressing the potential risk of climate change for the purposes of this EIS, it can be noted that Engineers Australia have published a paper entitled, *Implications of Climate Change on Flood Estimation. Discussion Paper for the Australian Rainfall and Runoff Climate Change Workshop No. 2* (February 2011). The paper summarises studies that have been completed or partially completed from Australia and other parts of the globe. The conclusions reached for Australia were generally:

- New South Wales recommends a sensitivity analysis with a 10% to 30% increase in extreme rainfall;
- Queensland is considering adopting a 5% increase per degree temperature change for the 1:100 to 1:500 AEP events; and
- The Bureau of Meteorology has concluded that it was 'not possible to confirm that probable maximum precipitation will definitely increase under a changing climate.'

As a simplified approach to estimate the potential impacts of climate change on the proposed Project, a scenario where all peak discharges increase by 20% has been assumed. The impacts of such an increase in peak discharges would include the following;

- The more frequent events would have higher discharges; however, the relative changes to existing creek system would remain the same;
- Water management infrastructure within the mine areas would need to be upgraded to a larger capacity; and
- The previous 1:2,000 AEP flood event would become the 1:1,000 AEP flood event which still allow the proposed flood levees to provide the proposed level of protection of 1:1,000 AEP, but with less freeboard (approximately 0.5 m, as opposed to 1.0 m).

11.4.12 Cumulative Impacts

The impacts of the Kevin's Corner Project on surface water resources have been assessed assuming that the proposed Alpha Project (MLA 70426), located south of the Kevin's Corner mine lease, was not in operation for the following reasons:

- The mining lease has not been awarded at the time of submission of this report;
- There is the potential that the mine would not gain approval;
- The impacts from the Kevin's Corner Project were assessed on its own right to prevent any biasing due to the adjacent Alpha Coal Project; and
- It was deemed not practical to assess the potential cumulative impacts of the Alpha Coal Project due to the significant number of changes planned to the EIS following the first submission.

However, based on the information provided in the Alpha Coal Project EIS (Parsons Brinckerhoff 2010), which was available from the Proponent at the time of commissioning of this EIS, the following qualitative cumulative impacts can be outlined:

- The Alpha Coal Project showed an increase in the peak discharge of approximately 0.2 to 11% at the downstream end of the mining lease boundary. An updated hydrologic model of the catchment areas in the Kevin's Corner lease area, including inflow hydrographs from the proposed upstream Alpha Coal Project would need to be completed once the proposed Alpha Coal system has been progressed further. The increased peak discharge from the Alpha Coal Project into the Kevin's Corner Project would need to be accounted for in the design of the Sandy Creek flood levees;
- The afflux of water level in Sandy Creek at the upstream end of the Kevin's Corner mine lease would impact on the Alpha Coal diversion design and water levels in Sandy Creek (Lagoon Creek). The extent of impact is unknown, but likely on the order of a kilometre or less upstream from the mine lease boundary. This would potentially require adjustments to the levee embankments for the Alpha Coal Project in this area, and potentially a modified diversion design to be incorporated with the Kevin's Corner Sandy Creek levees; and
- The reduction in the floodplain areas along the Sandy Creek (Lagoon Creek) channel for both the Alpha Coal and Kevin's Corner Projects could result in higher sediment loads due to erosion of the channel for the less frequent floods. A hydraulic model of the complete reach through both mines would need to be completed once the channel system has been progressed further.

Once the Alpha Coal Project gains approval the interaction of the Alpha Coal and Kevin's Corner Projects should be assessed for any significant cumulative effects to the flood hydrology and subsequent river morphology.

11.5 Surface Water Monitoring

The proposed surface water monitoring for the Project will include surface water quality monitoring and monitoring of stream diversion performance. The proposed monitoring programs are outlined in this section.

11.5.1 Surface Water Quality Monitoring

Two programs are proposed for surface water quality monitoring. A baseline monitoring program and an on-going water quality monitoring program are proposed to assess the impact of the Project operations on the receiving environment. Both programs would be undertaken in accordance with the *DERM Monitoring and Sampling Manual 2009,* which provides guidance on techniques, methods and standards for sample collection; sample handling; quality assurance and control; and data management.

11.5.1.1 Baseline Monitoring Program

The baseline monitoring program has commenced as part of this EIS and is proposed to continue until the mine is operational. As limited site specific background water quality data is available, the monitoring program will be used to establish a data set for developing site specific water quality trigger values (see Section 11.3.7.2).

Data collected from reference sites are used to estimate percentile values, which in turn are used to derive guidelines. For slightly to moderately disturbed waters the 20th and 80th percentiles are used. Reference monitoring sites are considered to be a suitable benchmark for comparison and are subject to minimal disturbance (QWQG, 2009).

The proposed 25 reference sites are summarised in Table 11-33 and include:

- Native Companion Creek at Violet Grove (E 470,132, N 7,384,603) (off-site reference). The surrounding land use is comparable to the Project area, being low intensity cattle grazing. No significant intensive activities have been identified upstream of this proposed reference site;
- Twenty (20) sites have been selected as on-site references. The sites are situated upstream and downstream of the Project area along Lagoon Creek, Sandy Creek, Middle Creek, Well Creek, Rocky Creek, Little Sandy Creek and Spring Creek. All locations meet the criteria for suitable reference sites and are currently undisturbed; and
- Four DERM gauging sites have also been selected as reference sites which are within approximately 100 km of the Project site, have similar existing land uses to the Project area and meet the QWQG criteria for reference sites. The gauging stations are Mistake Creek at Twin Hills (120309A), Mistake Creek at Charlton (120306A), Belyando River at Gregory Development Road (120301B) and Native Companion Creek at the Violet Grove (120305A). Available data from these sites will be sourced from DERM at the end of the baseline monitoring program.

Table 11-33 Water quality monitoring reference sites

Site ID	Site Description	Coordinates	
		Easting	Northing
Native	Offsite - Native Companion Creek at Highway	470,132	7,384,603
1	Lagoon Creek Upstream	449,572	7,444,077
2	Lagoon Creek	449375	7,452,007
3	Sandy Creek Downstream	449,949	7,456,564
5	Sandy Creek Upstream	449,044	7,451,960
6	Middle Creek Upstream	437,358	7,448,870
7	Middle Creek	441,295	7,446,882

Site ID	Site Description	Coordinates	
		Easting	Northing
8	Middle Creek	441,891	7,447,772
9	Well Creek Downstream	445,172	7,451,396
10	Rocky Creek Upstream	433,578	7,445,210
11	Rocky Creek Downstream	440,370	7,443,765
12	Little Sandy Creek Upstream	433,185	7,441,413
13	Little Sandy Creek Downstream	440,307	7,441,848
A1	Lagoon Creek Upstream	447,404	7,419,500
A4	Lagoon Creek Upstream	450,953	7,440,678
A5	Greentree Creek	440,563	7,438,562
A7	Rocky Creek	445,089	7,445,122
A8	Little Sandy Creek Downstream	441,055	7,423,849
A9	Spring Creek Upstream	438,989	7,424,345
120309A	DERM Gauge - Mistake Creek at Twin Hills	494,837	7,572,706
120306A	DERM Gauge - Mistake Creek at Charlton	510,285	7,511,825
120301B	DERM Gauge - Belyando River at Gregory Development Road	486,193	7,618,819
120305A	DERM Gauge - Native Companion Creek at the Violet Grove	465,984	7,393,708

11.5.1.2 Monitoring Parameters and Sampling Frequency

The choice of measurement parameters is based on protection of EVs as identified in Section 11.3.7.1. The parameters chosen are those that may be influenced by coal mining operations and in turn negatively impact on the EVs. The Surface Water Quality Technical Report (Volume 2, Appendix M4) provides full details of the parameters and frequency of sampling for the baseline monitoring program.

11.5.1.3 Ongoing Monitoring Program

The on-going monitoring program will be implemented to measure the impact of mine operations by monitoring watercourses upstream and downstream of the mine site. The data will also allow performance reviews of various management plans and mitigation measures implemented to protect the values of the watercourses in the Project area.

The locations for the on-going program are chosen to demonstrate that the quality of water entering the site is the same as water leaving the mine site. The baseline monitoring sites are proposed to be continued in the on-going program for event based sampling (Table 11-33). This will allow direct comparison of the water quality prior to and during operations at identical sites. It is noted that some monitoring sites may become inaccessible or inundated as the mine is developed, hence replacement sites with similar characteristics should be established where practicable.

Stream gauging sites are proposed for high risk areas to enable continuous monitoring of highly variable water quality parameters. Stream gauging sites are proposed for upstream and downstream of the lease on Sandy Creek (sites 1 and 3); upstream and downstream of the creek diversions (8 and 13); and upstream and downstream of potential discharge locations on the mine lease (5 and 14) as described in Table 11-33.

11.5.1.4 Monitoring Parameters and Sampling Frequency

The parameters to be analysed for the on-going monitoring program are selected based on protecting the EVs of the watercourses and include parameters that may be impacted on by coal mining operations. Further details on the monitoring parameters and sample frequency are provided within the Surface Water Quality Technical Report (Volume 2, Appendix M4).

11.5.2 Diversion Monitoring Program

A proposed monitoring program for the Little Sandy Creek, Rocky Creek, and Middle Creek diversion is based on the "Monitoring and Evaluation Program for Bowen Basin Diversions" (ID&A, 2000) undertaken for the Australian Coal Association Research Program (i.e. the ACARP guidelines for stream diversions). The monitoring of the stream diversion would extend from pre-construction to licence relinquishment and comprises four components as shown in Table 11-34.

The goal of the monitoring program is for the diversion to be considered as a reach or stream operating in dynamic equilibrium in order to achieve diversion licence relinquishment. Application for diversion licence relinquishment will occur at mine closure and depend on outcomes of the monitoring program.

Table 11-34 Diversion monitoring requirements

Monitoring package components	Objective
Baseline monitoring	To establish a baseline data set that can be used for comparison when applying for licence renewal and relinquishment. This occurs one year before construction and is to establish data that be used for comparison to assess the performance of the diversion.
Construction monitoring	To demonstrate works have been undertaken to specification.
Operations monitoring	To monitor and evaluate the diversion's performance to ensure it is operating in dynamic equilibrium. Occurs for 10 years after construction.
Relinquishment monitoring	To attain licence relinquishment by demonstrating the diversion is operating in dynamic equilibrium and not adversely impacting on adjoining reaches. Occurs for 10 years after operations preceding application for relinquishment.

Baseline monitoring requirements are presented in Table 11-35. Construction monitoring requirements are presented in Table 11-36. Operation monitoring requirements are outlined in Table 11-37. Relinquishment (i.e. the decommissioning and rehabilitation period) monitoring requirements are shown in Table 11-38.

Following comparison of monitoring data post construction with the baseline data, an evaluation of the stability of the diversion channel (i.e. dynamic equilibrium) and sustainability of the diversion will be undertaken. The evaluation of the channel would include the performance of the diversion for small and large flood events.

If the diversion does not appear to have reached a dynamic equilibrium, mitigation measures will be identified and implemented towards a goal of achieving sustainable long-term stability.

Table 11-35 Baseline monitoring requirements

Baseline monitoring undertaken	
Index of Diversion Condition	Photographs will be taken to record the condition of the stream before works are initiated. Photographs will be taken of the Control reach, the reach to be diverted and the downstream reach. Photographs are to be taken from fixed points along the control and downstream reaches, to allow future comparisons. Refer to Appendix C of ACARP (2001) for an aerial photograph showing recommended photo locations and directions. Further details of fixed photo monitoring points are provided in Appendix C of ACARP – "Monitoring and Evaluation Program for Bowen Basin River Diversions".
Vegetation	The species, abundance and diversity of vegetation in the reach to be diverted will be recorded before the diversion in conducted. This information will be used for revegetating the new diversion and used for comparison during relinquishment monitoring.
Aerial Photographs	Take aerial photos displaying the existing condition of Little Sandy Creek, Rocky Creek, and Middle Creek and also the location of the new diversion before works begin. The scale of the aerial photo will be sufficient to allow accurate measurements of the diversion and adjoining creek. Further details of aerial photographs are provided in ACARP (2001).
Flow Events	Information regarding the size and frequency of flow events may be assessed by checking debris marks and hydrologic data compiled as part of the engineering design process should there not be a flow gauging station. This will be a key part of DERM's assessment process as to what range of flow the diversion has been subjected to.
Survey	Cross-section and long-section surveys are required for all monitoring reaches. The sections generated will be included as part of the monitoring database and will be used to monitor the performance of the diversions during their operation by comparison with future sections. This will also contribute to relinquishment monitoring.

Table 11-36 Construction monitoring requirements

Construction monitoring requirements	
Execution Outputs	An execution output database will be established to record descriptions of the construction activities completed. The date of activity completion should be noted along with details of any accompanying photographs. Construction activities not completed to specification will be recorded in the database along with an explanation and details of the modified design.
Photographs	Photographs will be taken during construction/rehabilitation and immediately after the work is finished. Photographs will be taken from fixed photo monitoring points (refer Appendix C of ACARP - "*Monitoring and Evaluation Program for Bowen Basin River Diversions*").
Aerial Photographs	If practical, an aerial photo will be taken immediately after diversion construction or rehabilitation has been completed. These photographs will accurately display the extent of change and provide a baseline reference for changes that may occur in the future.
"Issued for Construction" Drawings	Design drawings issued to the contractor for construction are to be supplied.
"As Constructed" Drawings	As Constructed Drawings to be supplied upon completion of works to DERM.

Table 11-37 Operations monitoring requirements

Operations monitoring requirements		
Survival of Works	The survival of creek structures and works such as riprap and vegetation will be assessed during this phase of monitoring. Early detection of any damage is likely to increase the options for remedial action.	
Photographs	Photographs will be taken from fixed photo monitoring points along all of the reaches on an annual basis. Refer to Appendix C of ACARP - "*Monitoring and Evaluation Program for Bowen Basin River Diversions*" for more details.	
Aerial Photographs	Aerial photographs of the control reaches, diversion reaches and downstream reaches will be taken on an annual basis.	
Visual Assessment	The control reaches, diversion reaches and downstream reaches will be visually assessed using the IDC, which will be repeated in the following years after construction: 1st, 2nd, 5th, 10th, 15th, 20th years and after significant flow events.	
Index of Diversion Condition	Inspection will include assessment of:	
	bank condition piping bed condition recovery proximity of spoil piles from bank	stability of creek structures structural intactness of vegetation regeneration of vegetation longitudinal continuity of vegetation
Survey	Longitudinal section and cross section surveys will be conducted in the Control reaches, Diversion reaches and Downstream reaches. These surveys will be repeated every 5 years or after a major flood event (e.g. 1:20 AEP event). Refer to Appendix C of ACARP - "*Monitoring and Evaluation Program for Bowen Basin River Diversions*" for more details.	
Flow events	Flow events will be monitored to determine the size of events the diversions have carried. Refer to Appendix C of ACARP – "*Monitoring and Evaluation Program for Bowen Basin River Diversions*" for more details.	

Table 11-38 Relinquishment monitoring requirements

Relinquishment monitoring requirements	
Survey	Long section and cross section surveys will be conducted during the first year of relinquishment monitoring. The surveys will include the Control reaches Diversion reaches and Downstream reaches. Final long section and cross section surveys will be conducted prior to application for licence relinquishment.
Vegetation Assessment	Detailed vegetation assessment will be conducted during the first year of relinquishment monitoring to determine key species absent from the diversion reaches but present in control reaches where this is appropriate. The diversion reaches may therefore have different geomorphic and ecological characteristics than the reaches being replaced.
Photographs	Photographs will be taken from the fixed photo monitoring points in the control, diversion and downstream reaches.
Aerial Photographs	Aerial photos of diversions and controls, diversion and downstream reaches will continue to be taken on an annual basis.
Flow Events	Flow events will be monitored to determine the size of events the diversions have been subjected to.

Relinquishment evaluation requirements are shown in Table 11-39.

Table 11-39 Relinquishment evaluation requirements

Relinquishment evaluation requirements	
Survey	Quantitative assessment of data. Assess against flow data and baseline data. This survey will be compared to the 'as constructed' long sections to assess the changes in bed elevation.
Vegetation Assessment	Qualitative assessment of all data. Assess against flow data and baseline data.
Photographs	Qualitative assessment of all data. Assess against flow data and baseline data. Compare visually with previous photographs.
Aerial Photographs	Qualitative assessment of all data. Assess against flow data and baseline data. Compare with previous years to detect changes in vegetation and topography.
Stage 1 Evaluation	Survey data from baseline and operation monitoring will be compared with data from relinquishment monitoring.
Stage 2 Evaluation	All data will be evaluated and photographs collated for presentation to regulators. An example of relinquishment monitoring and evaluation is presented in Appendix F of ACARP – "*Monitoring and Evaluation Program for Bowen Basin River Diversions*".

11.5.3 Subsidence Monitoring Program

A subsidence monitoring program and corrective actions will be initiated to:

- Document changes to the drainage systems as the underground mining progresses;
- Document any changes to catchment and creeks due to subsidence;
- Document effectiveness of any mitigation measures; and
- Provide triggers in the event that further stream restoration or mitigation measures are needed to maintain or restore stream stability.

The subsidence monitoring program will monitor erosion, sedimentation, and surface cracking. Mapping of the downstream and upstream active subsidence zone will be undertaken to determine if erosion and sedimentation is occurring in the channel to an unsustainable level and/or any significant surface flow losses into cracks are occurring between longwall blocks. The mapping will be used to evaluate the significance of subsidence impacts on the creek environment and trigger the need for any corrective action. The monitoring strategy will include:

- Annual photographic survey of each channel reach downstream and upstream of subsidence panels at the and between the longwall panels to provide a benchmark for future reference;
- Annual GPS mapping and photographic documentation of surface cracking (cracks > 20 mm) that has occurred during subsidence until it is demonstrated that cracks are effectively sealed;
- Repeat surveys (as above) after three flood events have passed through subsidence areas (at which time a reasonably balanced regime of erosion and deposition cycles along the channels should become evident) to provide a secondary benchmark for future reference;
- Aerial survey of the mine lease during the dry season to document the size and potential volume of channel bed depressions (water ponding areas) within subsidence areas and to identify any lateral shifting or sedimentation within the stream beds; and

- In the event that significant erosion and sedimentation is occurring at rates that are not sustainable in the stream systems (i.e. visual loss of riparian vegetation, or rapid bank erosion and undercutting) or in the event that pooled areas are not decreasing between aerial surveys, a stream restoration program will be developed by a qualified fluvial geomorphologist and administrated.

The subsidence monitoring program for potential concerns regarding the ponding of water in channel should be supplemented with periodic ecological surveys to assess responses of vegetation communities, diversity, resilience, and habitat potential. This is recommended to assess any beneficial impacts arising from water ponding in channel bed depressions (such as improved ecological diversity and habitat potential) which may warrant no remedial action to be taken to reduce water ponding.