Goonyella Riverside and Broadmeadow Mine

Subsidence Management Plan 2015

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25 May 2015	Stuart Pilcher	All
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1 INTRODUCTION

Broadmeadow Mine (BRM) is an underground mining operation located within the boundaries of the open cut Goonyella Riverside Mine leases. The BRM operation is subject to the conditions detailed in the Goonyella Riverside and Broadmeadow Mines Environmental Authority (EA) EPML00853413.

One of the effects of underground longwall mining is that as coal is extracted, the roof strata falls into the void causing the natural ground surface to subside. The environments of the Isaac River, its diversion, adjacent floodplains and hillslopes that exist over the area of the BRM mine plan are the subject of this Subsidence Management Plan (SMP).

In meeting the conditions detailed in the EA, this SMP outlines:

- the current environment for the majority of the mine plan area, including observation of impacts of subsidence to date and the performance of mitigation measures for those impacts as part of the ongoing adaptive management framework;
- assesses potential future impacts related to subsidence within an established impact assessment methodology;
- within the framework of adaptive management proposes strategic level options for mitigation across the full extents of the mine plan that will be further developed on a finer scale as the mine progresses and will be suitably flexible should changes occur to the mine plan.
- the monitoring program in place and future monitoring that forms an integral part of the adaptive management framework.

The SMP will be reviewed within the adaptive management framework. The SMP is suitably encompassing and flexible to accommodate changes to the mine plan layout within the context of the whole mine plan scale.

1.1 SCOPE

The SMP covers all areas which have an interface with the underground mine plan. This includes the Isaac River and diversion, surrounding landscape and infrastructure.

1.2 RELATED DOCUMENTATION

This SMP incorporates recommendations detailed in Draft Central West Water Management and Use Regional Guideline 'Watercourse Subsidence' – Central Qld Mining Industry VI (DERM, 2011).

Underground mine related subsidence at BRM and its impact on the Isaac River and its diversion has been subject to assessment since the development of a Management Strategy in 2005, related documentation includes (but is not limited to) the following:

- Isaac River Subsidence Risk Analysis and Mitigation Options (Alluvium, 2011a)
- Isaac River Subsidence Management – LW109-113 (Alluvium, 2014a)
- Isaac River Subsidence Management – LW106-110 (Alluvium, 2010a)
- Isaac River Operations Monitoring 2014 (Alluvium, 2014b)

- Isaac River Operations Monitoring 2013 (Engeny, 2013)
- Isaac River Operations Monitoring 2012 (Alluvium, 2012)
- Isaac River Operations Monitoring 2011 (Alluvium, 2011b)
- Isaac River Operations Monitoring 2010 (Alluvium, 2010b)
- Isaac River cumulative impact assessment of mine developments (Alluvium, 2008a)
- Management Strategy for Impacts of Mining Related Subsidence on the Isaac River – Broadmeadow Mine (Earth Tech, 2006)

These reports have informed the impact assessment and mitigation options detailed in this SMP.

1.2.1 Isaac River Cumulative Impact Assessment of Mine Developments

The Queensland Government Department of Environment and Resource Management (DERM) were involved as a major stakeholder in the Technical Report: Isaac River Cumulative Impact Assessment of Mine Developments (Alluvium, 2008a), a project jointly funded by BMA and AAMC (hereafter referred to as the IRCIA).

The focus of this investigation was to assess how the river is likely to respond to the physical changes created by subsidence. In particular – is the void created by subsidence significant compared to the sediment transport capacity of the river?

During the assessment a framework for assessing impacts on watercourses by subsidence was developed into the following hierarchy:

- 1st order – direct physical effects of subsidence
- 2nd order – geomorphic response to subsidence
- 3rd order – changes to water quantity and quality
- 4th order – biological response
- 5th order – impacts of human response to other impacts

The outcomes of the IRCIA particular to the Broadmeadow mining operation have been subject to update in this SMP.

The administering authority formally acknowledged that the project met its terms of reference and subsequently utilised the projects outcomes to develop the above guideline and the conditions that are included in the EA.

2 EXISTING ENVIRONMENT

2.1 LOCATION

BRM is an underground operation situated within the existing Goonyella mining lease (ML1763) approximately 200 km west of Mackay and 30 km north of Moranbah in central Queensland (**Figure 2-1**).

2.2 MINING OPERATIONS

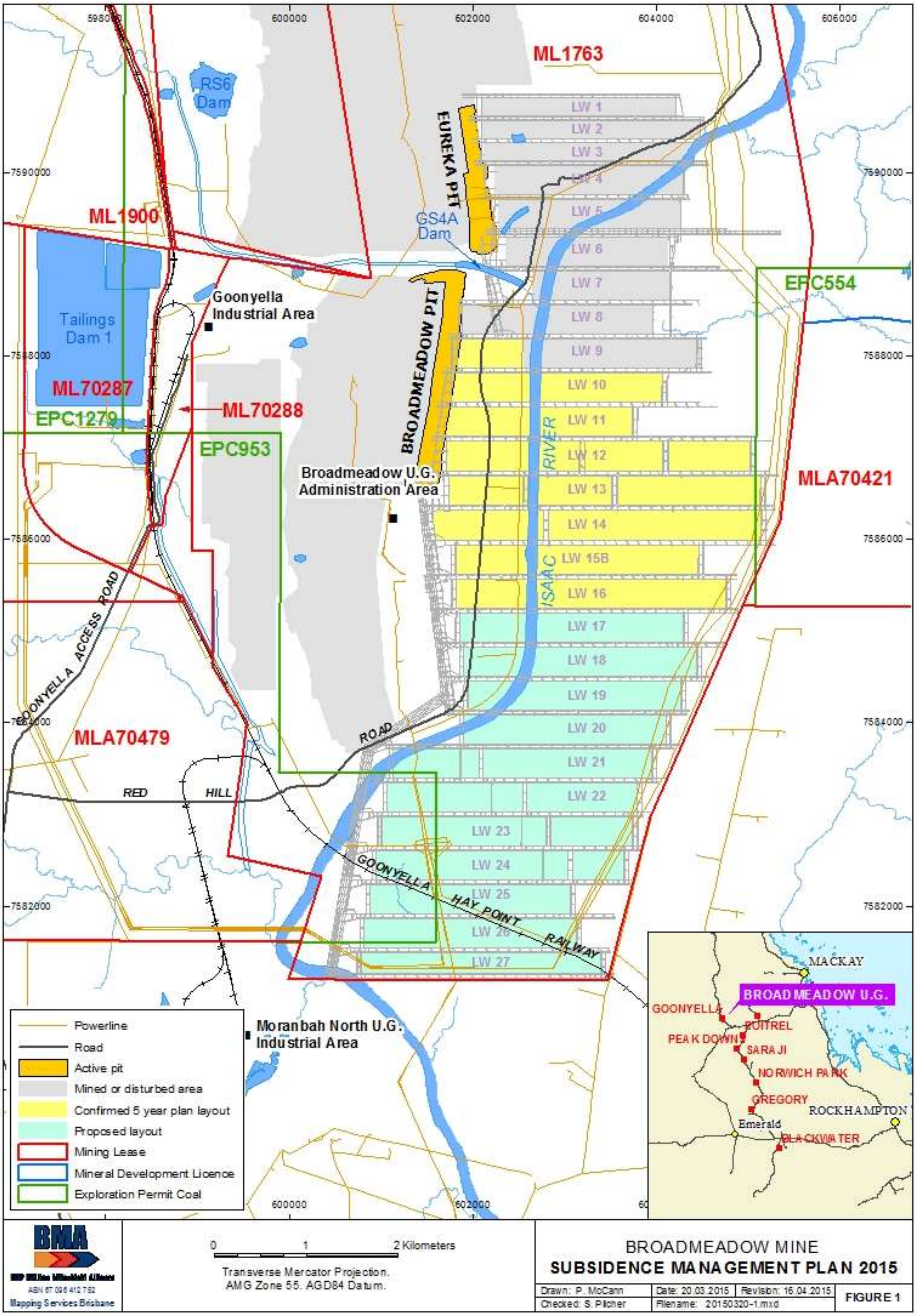
The underground operation extends to the east of the open cut pits. Initially the longwall panels were formed from the Ramp 4 and Ramp 2 open cut pits extending east towards the mine lease boundary. Mining commenced in 2005 in LW101 and has progressed southward to current operations in LW109. Future mining is planned south of this area, east of Ramp 2 pit up to LW127. BRM was commenced as a 'punch longwall' mine, extracting the Goonyella Middle Seam (GMS). The longwall extracts to a maximum height of 4.8m, but generally extracts at 4.3m-4.5m because of increased instability at the higher extraction heights.

Punch longwall extraction has been superseded by the introduction of longwall top coal caving (LTCC) in 2012 in LW108. The LTCC underground mining method is very similar to conventional retreat longwall mining. It has longwall face equipment specifically designed for the extraction of thicker coal measures (> 5.0 metres). A second armoured face conveyor facilitates the controlled capture of broken coal from the roof above the shields which has the ability to extract a greater thickness of resource in one pass. The lower part of the seam is extracted conventionally by a shearer. LTCC improves the level of resource recovery compared to conventional longwall mining methods and as a result, the subsidence is marginally greater than the conventional single pass thick seam longwall mining method used previously at BRM.

The current BRM 5 year mine operation plan does not include LTCC beneath the Isaac River Diversion; this is consistent with the strategy employed for longwall panel 8 and mine plans for panels 9 and10. The LTCC function will be turned off as the Longwall approaches the river and then turned back on once the Longwall has past the river. By turning off the caving function coal extraction under the river is reduced to a similar height as previously mined conventional panels using the High Reach Longwall (HRL).

Reducing coal extraction height under the diversion creates a greater over burden to mined area ratio. Increasing this ratio reduces the connectivity potential between the river and the goaf and provides a greater margin of safety for the mine operation (water ingress), it also minimises potential environmental impacts (stream losses).
As further knowledge is acquired in regard to the interaction of LTCC and the geological and geotechnical features of the Isaac River Diversion, LTCC could potentially be utilised to fully extract the available resource in future mine plans. In this circumstance, the SMP would be reviewed and updated to reflect the change in mining method and any additional considerations to employ the strategy.

Figure 2-1: Broadmeadow Mine Existing Operations



2.3 INFRASTRUCTURE

The following subsections describe the current mine infrastructure in the vicinity of the BRM mine plan.

2.3.1 Public Roads

Red Hill Road, a private road available for use by the public, runs roughly along the western side of Isaac River diversion. Currently, Goonyella Riverside Mine maintains the section beside the diversion channel and for about a kilometre upstream, to where the road turns sharply; north of that the road is an unsealed gravel road with the local Council responsible for maintenance.

Red Hill Road is unsealed above LW105-108, but south after the confluence of Eureka Creek and the Isaac River diversion, the road transitions to bitumen.

The mine's maintenance commitment consists of regrading and repairing the sealing of the road, mainly after the wet season.

2.3.2 Mine Roads

A basic standard unsealed road provides access to dams and power stub lines (short power lines running off the main power line) on the northern Goonyella Pits highwalls. From the western side of the mine, the road is reached via the Eureka Pit Corridor to the south or various accesses north of Riverside Pit. The road is presently maintained on an "as-needs" basis and sections are routinely untrafficable after wet weather.

2.3.3 Power Lines

A transmission line for mine operations runs between the Isaac River diversion and Red Hill Road. South of LW7 the line is being decommissioned in FY15 with an alternate feed now providing electricity to BRM from the south of the lease. North of LW7 the line provides electricity to GS4A pump station

2.3.4 Water Pipe Lines

The current Eungella-Peak Downs water pipeline comprises 450mm diameter rubber ring jointed concrete lined steel pipe buried at about 1m depth.

About 500ML/year is taken off by properties between Eungella Dam and Goonyella Riverside. At the mine, the pipeline runs along the eastern side of the Eastern Pre-strip Landforms and Leightons' Dump, and then continues into the underground project area until it meets, and then follows, the highwall access road. Riverside preparation plant takes off about 2,000ML/year.

The pipeline then continues to Moranbah supplying up to 2,000ML/year. It then continues south to Peak Downs Mine.

The pipeline is subject to landowner agreements but no special regulatory conditions.

2.3.5 Dams

The only permanent surface dam over the mine plan is GS4 located south of LW105 and runs parallel to the Eungella Water pipeline. Panel LW106 was designed around this water body to avoid potential effect of subsidence.

2.3.6 Levees

Two operational levees are located within the mine plan area. The Ramp 4 levee provides flood protection to the Ramp 4 pit, while the Broadmeadow Levee adjacent to Ramp 0 and Ramp 2 provides Broadmeadow Mine flood protection from the Isaac River flood plain.

2.3.7 Goonyella Rail Bridge

Goonyella rail bridge is located at the downstream end of the Isaac River diversion and BRM mine plan area. The bridge provides north/south rail access across the Isaac River.

The bridge has concrete pylons in the bed of the river.

There is a vehicle crossing adjacent the rail bridge with low level culverts and earth/rock fill which provides dry weather vehicle access into the southern extent of the BRM mine area. (**Figure 2-2**).

Figure 2-2: Goonyella Rail Bridge and Vehicle Crossing

2.4 TOPOGRAPHY

The project area includes the Isaac River channel, its floodplain, terrace and adjacent low relief rounded hill slopes with few escarpments. Several tributaries join the river in the project area. Elevation across the area ranges from approximately 250m along the Isaac River east of the project area to approximately 450m along portions of the Denham Range that define the western edge of the Isaac River Valley near the project area.

Eureka Creek is the only creek within the BRM area and is a substantive tributary to the Isaac River which drains from the existing mine in the west. It is a constructed diversion channel with a weir shortly upstream of where it joins the Isaac River diversion. Eureka Creek is a partly managed system for mine affected runoff and serves as a licenced discharge point to the Isaac River.

2.4.1 Isaac River Diversion

The Isaac River was diverted between 1985 and 1987 to allow access to coal deposits by open cut mining. The diversion begins at the same location as LW105 and replaces approximately 11km of river channel with 7.8km of diversion channel including two drop structures of around 2m in height each, which were designed to manage the bed grade due to shortening of the channel. The diversion has bends at its upstream and downstream ends, however the majority of the diversion is a linear north-south channel.

The diversion is largely cut through the Isaac River terrace (described further below), it is presently typically 8-12m deep with a top width of 80-100m.

2.4.2 Surrounding floodplain and terrace

The Isaac River channel is incised into its floodplain by four to eight metres; the floodplain is inset within the broader terrace by a further two to four metres. The terrace, which is essentially a paleo-floodplain, is the dominant feature within the mine plan area. It has low relief with a gentle slope often away from the channel and in a downstream direction. The Isaac River diversion has been constructed within the Isaac River terrace and has no contemporary floodplain around the channel. The excavated sediment from the diversion channel forms an embankment up to 6m above the surrounding terrace along the western bank of the diversion channel.

To the east of the terrace, smooth hill slopes of reasonably low gradient rise up to a local catchment boundary near the eastern extent of the mine plan. There are only a few incised gully systems toward the upper limit of the local catchment. Two minor tributaries from beyond the mine plan area toward the upstream end of the mine plan, only the southern of these two will be over the mine footprint of BRM.

Aerial survey data capture by both photogrammetry and Lidar methods has been captured over time and utilised to create a digital terrain model (DTM) across the mine plan area. This data provides pre-subsidence and post subsidence information which is utilised in the monitoring program.

2.5 GEOLOGY

Tertiary alluvial sediments, clays and sands are typically 5m to 10m thick in the area overlying 2.5m to 10m of weathered Permian clays.

Overburden rock mass comprises 110m to 285m thick Permian coal measures containing the upper section contains the Fort Cooper formation in the east, typically characterised by interbedded soft tuffaceous material, coal, soft mudstone and organic deposits. The section from the Goonyella Middle Seam (GMS) up to the P Seam can be variable with the inclusion of sandstone channel deposits which are laterally and vertically variable in thickness. Sandstones and intercalated siltstones fine up-section from the GMS to the Goonyella Upper Seam (GUS).

The MP41 sandstone is present in areas where the GM rider seam (GM2) is a substantial distance from the GM Seam roof. The MP41 has a variable thickness of 5m to 50m, although it is noted that the MP41 sandstone unit has significant thickness over Longwall 1-6 and mining under a thick channel sequence exists.

Where the GM rider seam (GM2) has split from the GMS, a sandstone unit (MP42) forms the interburden between the GMS and the GM2. The MP42 unit is comprised of two sandstones, SMP1 and SMP3, separated by a siltstone parting. The strength of this unit is typically in the range 30-60MPa through Longwall 8 and 9 with localised increases up to 100MPa. Unit thickness typically ranges up to 30m. Where massive sandstones occur close to the mined seam, there is potential for periodic weighting events on the longwall face due to hanging up of the goaf - likely to affect the magnitude of surface subsidence. However, core samples indicate that these units are quite laminated compared to typical massive channel sequences which may improve fracturing during caving.

The immediate roof strata above the GMS comprises siltstone/mudstones. The GM Seam dips uniformly at about 4˚ to the east and varies in thickness from 6.5m to 7.5m.

The following diagrams show the Goonyella Coal Seam Measures – Coal Seam Stratigraphic Column (**Figure 2-3**), and a typical cross section detailing overburden (**Figure 2-4**).

Figure 2-3: The Goonyella Coal Seam Measures – Coal Seam Stratigraphic Column

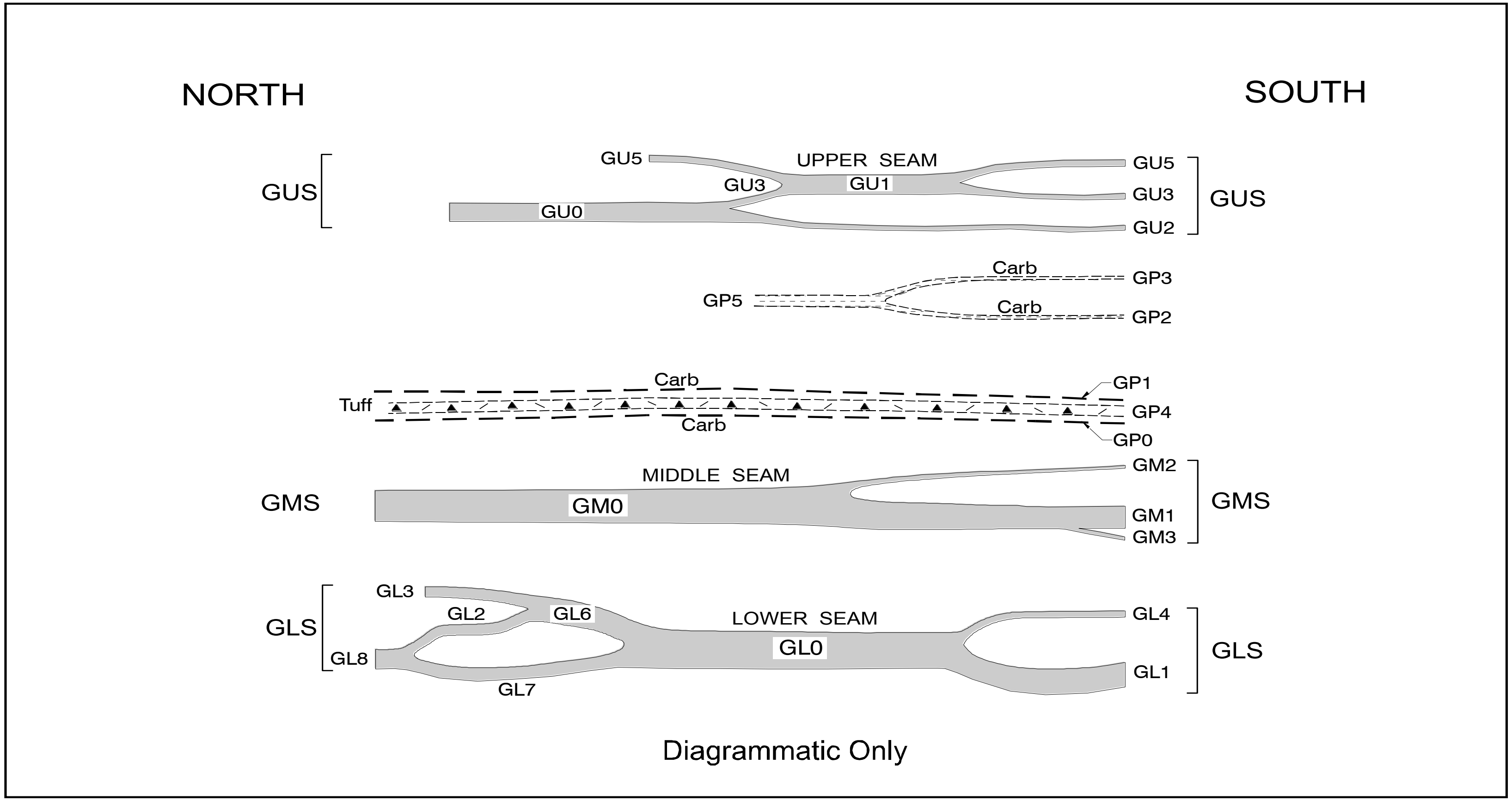
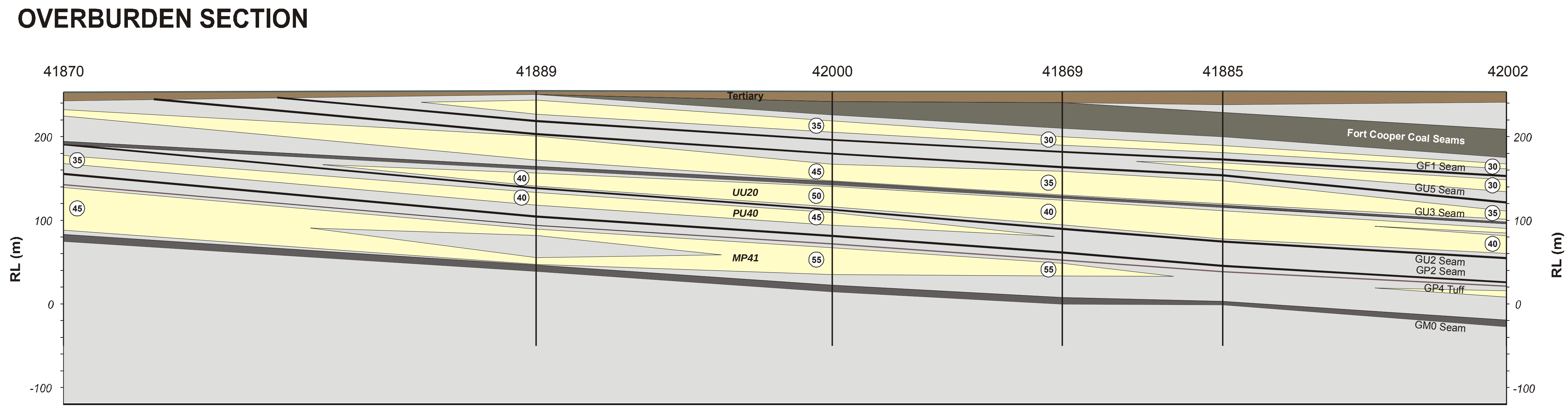
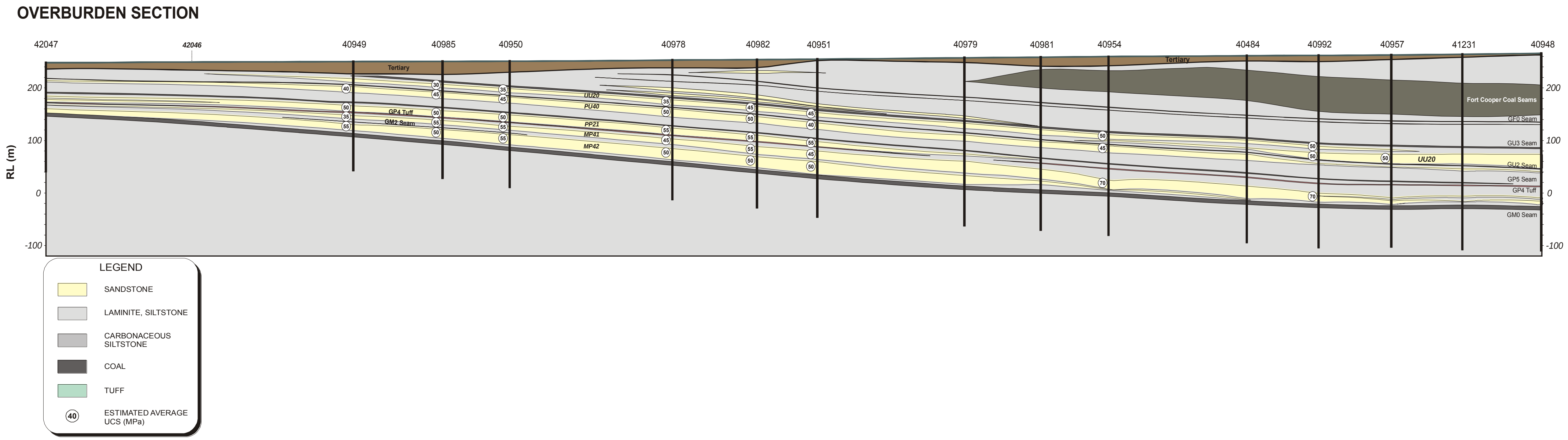


Figure 2-4: Indicative Overburden Cross Sections





2.6 SOILS & LAND SUITABILITY/CAPABILITY

A Soil and Land Suitability Survey over BRM was conducted by GTES Pty Ltd in 2001. A total of six soil major mapping units and corresponding vegetation associations were described in this report and these are summarised in **Table 2-1**. Updated land suitability and capability information will be available in 2012.

Table 2-1: Soil Units & Land Suitability/Capability Ranking (GTES, 2001)

Unit	Description	Major original	Suit.	Cap.	Topsoil
AI	Deep sandy recent alluvia and active channels of the Isaac River.	Forest red gum, Moreton bay ash and associated species	4	VIII	30-120cm highly variable
A2	Higher lying alluvial plain of sandy duplex soils associated with the Isaac River.	Moreton bay ash, bloodwood, poplar box, ghost gum, red bauhinia, narrow leaf ironbark.	2/3	VI	40-50cm
B I	Gilgaied and non gilgaied clay soils developed from weathered non-quartzose Permian sedimentary rocks and Tertiary sediments.	Brigalow, blackbutt with some poplar box and yellowwood.	2	VI	30cm
B2	Thin sandy duplex soils which Overlay Tertiary sediments.	Poplar box, Brigalow with blackbutt, sandalwood, Leichardt bean, Carissa. Includes areas of undulating ridges and stony Yapunyah to the south east.	3/4	VI	20cm
EI	Bleached sandy texture contrast soils with sodic subsoil.	Poplar box and Sandalwood	4	VII	15-25cm
E2	Reddish brown sandy duplex soils with well drained subsoils.	Narrow leaf ironbark with poplar box.	3	VI	40cm

2.7 GROUNDWATER

The groundwater regime in the mine area comprises limited Quaternary alluvial aquifers associated with the waterways in the area, Tertiary sediment and basalt aquifers, and Permian sedimentary rock aquifers. An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in useable quantities. The Quaternary alluvial formations, Tertiary sediment and basalt formations, and the Permian coal measures generally yield low sustainable volumes of poor quality groundwater and are not recognised as significant aquifers in the area.

Studies have identified five (5) aquifers in the region, including the:

- Quaternary / Tertiary alluvial deposits on the surface
- GUS some 110 -120m above the GMS

- GP5 or P Tuff, some 40 -70m above the GMS
- GMS, and
- Goonyella Lower Seam (GLS), 40-60m below the GMS

Modelling and geotechnical studies indicate that these aquifers can interconnect through geological structures, and mining induced or goaf cracking.

2.7.1 Piezometer installation and monitoring

As part of BMA's groundwater monitoring program, piezometers have been installed within and below the Tertiary sediments adjacent to the Isaac River diversion channel above Longwalls 6, 7, 8, 9 & 10. In addition a network of piezometers is installed in association with goaf pumps located at the eastern end of selected longwall panels.

The investigations to date have been aimed at assessing the potential risk of inflows to the mining operation for safety purposes. These existing and future installed piezometers can be used to monitor groundwater behaviour in response to undermining and provide data to be assessed in conjunction with surface water monitoring.

2.8 WATERWAYS

2.8.1 Hydrology

The flow regime of the Isaac River is ephemeral and highly variable both season to season and year to year. There are years when near zero discharge occurs. There is often no flow in the river between April and December. This is consistent with a river response to a monsoonal / cyclonic driver rainfall system where occasional high intensity rainfall events will dominate the flooding regime. The three largest flow events recorded on gauge (Goonyella gauging station maintained by Queensland Government, Gauging Station No. 130414A) for the period of record shown in (**Figure 2-5**) data are from tropical cyclones in the late 1980's-early 1990's. The February 2008 flow event is the largest non-cyclonic and fourth largest recorded at Goonyella gauging station.

A trend is evident in the historic gauging record at Goonyella. This is typically a series of wetter years over a three to five year period, separated by drier years for five to six years. It is important to note there was only one flow event from 1991 to 2008 which would be capable of mobilising substantive bedload sediment quantities as this is significant in terms of geomorphic response to subsidence. Based on observation, flow events under $300m^3/s$ do not mobilise sufficient bedload to infill subsidence voids but do have potential to erode bed and banks in the diversion. These magnitude events are more frequent in the period of record.

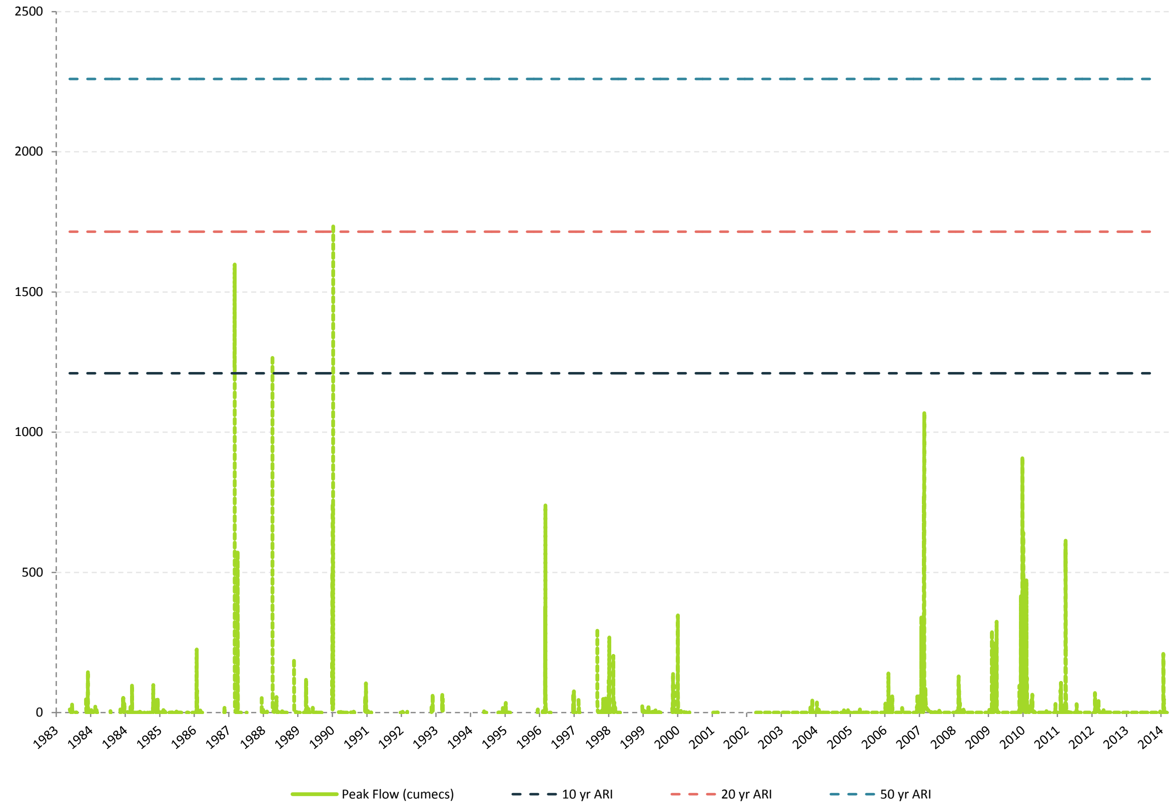
Runoff characteristics in the catchment are likely to have changed with catchment clearing and gully erosion response over the last two centuries. Runoff is likely to be more concentrated and last for shorter durations than might occur if the natural catchment vegetation cover was in place and gully networks had not developed. This is likely to exacerbate the ephemeral characteristics of the flow regime.

There are several storages in the upper Isaac Catchment, which have some attenuation impact on flows, particularly in drier years. Burton Gorge Dam on the Isaac River main channel was constructed in the early 1990s as part of mining developments. Teviot Dam on a tributary in the sandstone escarpment country upstream of that was constructed in 1996. These are fill and spill dams with extractive use. No flow releases are known to occur from these dams until they fill and spill. No other large constructed storages are known in the catchment upstream of the Broadmeadow reach of the Isaac River.

Lake Elphinstone is a natural lake in the upstream extents of the catchment, which also has some attenuation on downstream flows, particularly when dry. Lake Elphinstone was observed to be dry 2003-2007 and has been full or near full for the period since.

The other known storages in the catchment that will impact on runoff characteristics are mine site water management systems, including a substantial number of pits and an unknown number of farm dams throughout the catchment.

Figure 2-5: Peak flows at Goonyella gauge for the period of record (May 1983 – December 2014)



2.8.2 Geomorphic character, behaviour and condition

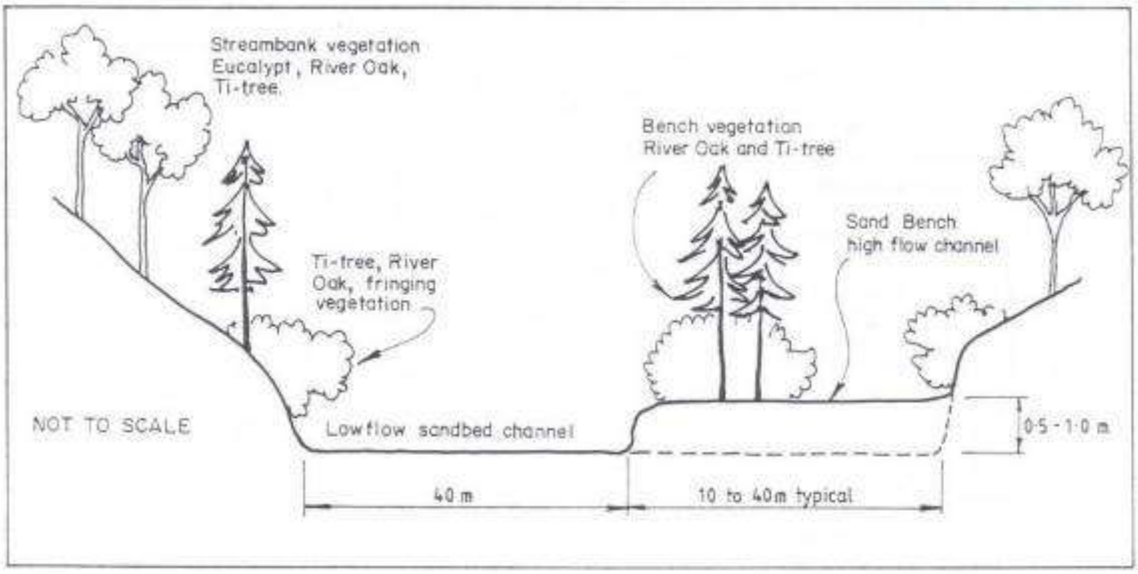
A summary of the geomorphic character, behaviour and condition of the diversion and adjoining reaches is provided to give context to the monitoring results described below for the subsidence. Subsidence will directly and indirectly affect sections of the Isaac River upstream and downstream of the diversion as well. A key point of note here is that diversion, which has been in place for around 30 years, had condition issues prior to subsidence. The impacts and response to subsidence will be superimposed on those condition issues and the character and behaviour of the diversion. The condition, character and behaviour of the diversion is markedly different to the upstream and downstream reaches.

The Isaac River is separated into two distinct reaches where it intersects the BRM plan area. The upstream 1.5km of the river that intersects the mine area is the original channel while the remaining approximately 7km is the constructed Isaac River diversion.

The upstream section is an incised predominantly alluvial channel with a large channel capacity in the vicinity of BRM. The channel has a typical 40-50m bed width and 80-120m top width. It is bounded by either a floodplain or terrace, depending on location within a meander. The floodplain sits 2-4m below the terrace and is a more active surface, engaged by events upward of 20 to 50 year ARI. The terrace is a paleo floodplain that is engaged by extreme events typically upward of a 100 year ARI.

In general the channel has a riparian corridor in moderate to good condition with continuous overstorey and understorey vegetation cover and thick mud drape covered banks due to high sediment load supply from upstream. The channel bed lacks morphologic diversity due to oversupply of sediment from upstream and is a smooth sand bed with all pools infilled. A typical cross section is provided in **Figure 2-6** and views of typical sections of the river provided throughout the report.

Figure 2-6: Typical Isaac River cross section in vicinity of BRM



The Isaac River diversion is in poor to moderate condition and is continuing to evolve since construction in the mid 1980's. The constructed diversion of approximately 8km replaced approximately 11km of pre-existing river with the inclusion of two drop structures to compensate for grade in the reduced length of channel. Large cyclonic driven flow events occurring soon after the construction of the diversion are thought to have roughly doubled the constructed top width of the diversion through severe widening of the channel.

Planform migration of the channel also began at the upstream bend of the diversion, which was stabilised by alignment training in the mid-1990s. The channel then stabilised through a period where no flows greater than ~5 year ARI occurred over the 1991-2007 period. This promoted deposition and vegetation growth in the channel, providing increased visual amenity and habitat value.

Since the stabilisation works near Eureka Creek confluence were implemented, no major flow events (greater than a 10 year Average Recurrence Interval (ARI)) were experienced through the diversion until early 2008. During this period the some stabilisation of the channel occurred with deposition and vegetation growth in the channel, providing increased visual amenity and habitat value.

The early 2008 flow events were of the order of 10-20 year ARI. 2010-11 and 2011-12 wet seasons also had peak flows in the same range and with sustained flows. Very little flow (less than 100 m^3/s events) was registered during the 2012-13 wet season and no flow was registered during the 2013-14 wet season. To date for the 2014-15 wet season, there have only been minor flows up to 200 m^3/s registered at the Goonyella Gauge (130414A).

The 2010-12 flow events have resulted in the infilling of the subsidence panels LW104-106 and part of LW107 with sand. Deepening of the channel bed to underlying bedrock is noted between the two drop structures downstream of those longwall panels, where this has occurred, the bench attached to toe of bank is eroding. Once that bench is eroded, the near vertical 6-8m high banks will begin to erode far more rapidly where the low flow channel impinges on them.

With the present lack of excess bedload sediment, in-channel vegetation and coarse sediment derived from the drop structures being damaged over time, this section of the diversion does provide more diverse aquatic habitat and retains pools longer than much of the rest of the upper Isaac River.

The two drop structures constructed in the diversion suffer damage during flow events and require periodic maintenance or are in need of major repair if they are to be re-instated to their original condition and function. The downstream drop structure is largely redundant in its current condition and erosion adjustments that have occurred with its failure mean that it may no longer be necessary.

The banks along the majority of the diversion are also subject to ongoing pipe, tunnel, rill and gully erosion from direct rainfall and overland flow entry. Gully erosion that has developed from failed overland flow entry chutes continues to erode headward into the adjacent terrace.

The diversion continues beyond the BRM plan area to the Goonyella rail bridge. Condition issues are as discussed above in that section.

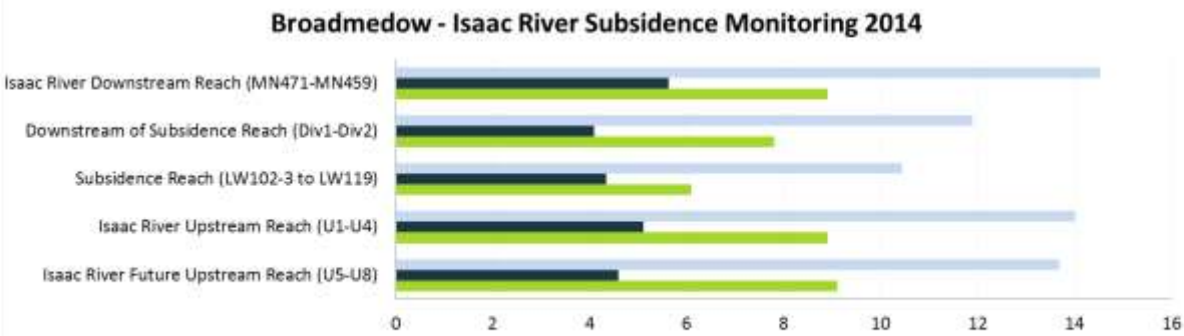
The original channel downstream of the Goonyella-Hay Point rail bridge which is in moderate to good condition with excess sediment inputs aggrading the stream bed and reducing morphologic diversity and suppressed native riparian vegetation being the main detractors from physical and riparian condition. The sediment inputs to the reach have declined in recent years due to the bedload deposition in the LW104-107 panels. This will influence condition in the reach in the future and may be a positive impact.

2.8.2.1 Subsidence monitoring

Monitoring the condition and condition trajectory of the Isaac River through the reaches of BRM mining influence and adjacent upstream and downstream reaches is undertaken annually. The current condition of the subsidence monitoring reaches (shown on Figure 4-1, page 75) of the Isaac River, which in part include the diversion are reproduced here from the 2014 monitoring report.

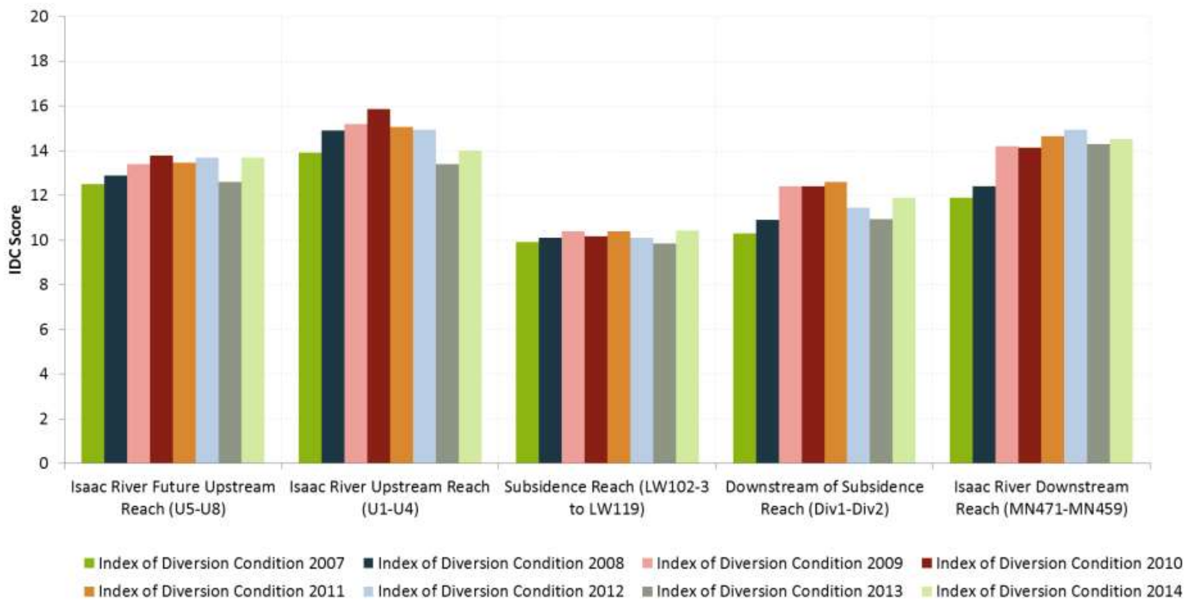
The Index of Diversion Condition (IDC) is the tool utilised to provide quantitative monitoring of the physical aspects of waterways at mine sites in Queensland. While it has been developed for diversions it is also utilised for monitoring of subsidence reaches. The assessment for the subsidence monitoring reaches for 2014 (IDC total, geomorphic and riparian indices are shown in Figure 2-7) show the subsidence reach to have lower IDC than all other reaches largely due to pre-existing condition issues in the diversion. Figure 2-8 shows a comparison of scores over time.

Figure 2-7: 2014 IDC, geomorphic and riparian indices for Broadmeadow Isaac River subsidence



	Isaac River Future Upstream Reach (U5-U8)	Isaac River Upstream Reach (U1-U4)	Subsidence Reach (LW102-3 to LW119)	Downstream of Subsidence Reach (Div1-Div2)	Isaac River Downstream Reach (MN471-MN459)
Index of Diversion Condition	13.7	14.0	10.4	11.9	14.5
Riparian Index	4.6	5.1	4.3	4.1	5.6
Geomorphic Index	9.1	8.9	6.1	7.8	8.9

Figure 2-8: IDC results 2007- 2014 for Broadmeadow Isaac River subsidence



UPSTREAM REACHES

The reaches upstream of the diversion and subsidence used for monitoring (one in close proximity and another further upstream) continue to be in moderate to good condition. IDC scores in these reaches have only really fluctuated with changes in vegetation cover as a result of grazing. Across both upstream reaches the bed remains aggraded as in previous years, with a deep sand sheet present throughout the majority of the reach with the low flow channel often occupying the full base width of the channel, indicative of ongoing excess sediment supply from upstream. Where the channel impinges on the terrace, rill and gully erosion is noted to be contributing pulses of sediment as does 12 Mile Gully shortly upstream of U1. Bank erosion is still occurring between IR-U7 and IR-U8 in response to both flood flows overtopping the inside of the meander and in-channel flows. As this forms a near vertical scarp at the point of attack on a meander, this bank has the potential to migrate further.

Figure 2-9: 2014 observations upstream of Broadmeadow

Downstream view at IR-U5 of typical section

View across channel where channel impinges on terrace

SUBSIDENCE REACH

The subsidence reach in the existing monitoring program extends from LW102-3 pillar downstream to LW119, which includes the majority of the diversion (~6km) and a shorter (~1.5km) section upstream of it. Monitoring points are located on planned and existing pillar zones between longwall panels. Longwalls to interact with the river channel to date are as follows:

- LW103 partially subsided a short section of the right bank of the river in 2007,
- LW104 subsided across the full channel in 2009 (~500m of channel between pillars)
- LW105 subsided the river channel prior to the wet season in mid to late 2010 (~700m of channel between pillars).
- LW106 subsided the river channel during the 2011-12 wet season (~320m of channel between pillars)
- LW107 subsided the river channel during the 2012-13 wet season (~320m of channel between pillars)
- LW108 subsided the river during the 2013-14 wet season (~320m between of channel pillars); and
- LW109, which has commenced, had not yet subsided the river channel at the time of the 2014 inspection.

This section discusses the processes and impacts observed in and shortly downstream of the panels subsided to date that can be related to subsidence (LW103 to ~LW114-15).

All sections of the Isaac River channel bed which had been subsided (LW104-106) prior to 2012 monitoring had been infilled with bedload sediment. This has covered the underlying subsided profile of the firm stratum beneath the mobile sand bed to make a smooth profile on the surface. The deepening which had been noted through what is now the subsided LW106 in previous years monitoring, was infilled during the 2012 flood event. The timber pile fields installed to manage the risk period when the subsided panel is undergoing infilling during major flows have performed successfully to date by maintaining a bench against the toe of bank over the pillar zones as per design intent.

Two further sections of the Isaac River channel bed have been subsided since the 2012 monitoring at LW107 and LW108. Both of these locations have subsided the channel bed by approximately 3m compared to the 2012 DTM and neither of these panels has been infilled, with the downstream extents of the mobile sand bed remaining at approximately the same location as in 2013 (a short distance into LW107 panel). The deepening which has been noted downstream of the subsidence panels remains in a similar location as in 2012, extending nearly as far downstream as the downstream drop structure (~3km downstream of LW106). Deepening since 2008 is up to 2m throughout this section (refer to long section comparisons in Attachment B and Figure 2-13).

The channel bed deepening has reached weathered Permian bedrock in places, this will slow the rate of potential further deepening, depending on rate of weathering of that Permian now that it is exposed. When erosion of the bed is limited by strata, the subsequent response of the river to the bedload starvation by the subsidence upstream (when sediment transport capacity exceeds supply) is to erode the benches against toe of bank. These benches are retreating rapidly in places, such as at LW108-9 where it has mobilised a significant armour layer which was previously used as a crossing, threatening to accelerate erosion of the near vertical 5-8m high diversion banks. A positive impact of the deepening has been the creation of long lived aquatic habitat that does not otherwise exist in much of the upper 300km of the Isaac River. Fish populations in these pools were prevalent at a time of year when they are non-existent through the remainder of the upper and mid Isaac River which is oversupplied with sand and maintains few if any surface water pools.

Timber pile fields have been installed over the pillar zones as far downstream as LW112-3, however no bank erosion protection measures have been implemented through the panels (between the pillars) for the interim period until they're infilled.

The impacts and response to subsidence in LW106, which is the first panel in the diversion are:

- Infilling of the subsided section with subsequent migration of the low flow channel over the top of the former bench (which had pile fields installed mid 1990's and is well vegetated) and into the toe of the high flow near vertical banks of the diversion, resulting in some fluvial bank erosion in the limited flows that have occurred since infilling
- Cracking of the near vertical banks
- Top of bank ponding with subsequent early stage development of pipe, rill, tunnel and gully development in the central parts of the panel along the right (western) bank

There are risks of substantial instability of the right (western) bank in LW106 due to its planform location on the outside of a low angle bend. Works to stabilise this bank will be required to mitigate risks to infrastructure (helipad, access road, drop structure) and the environment (increased suspended sediment export). If flows become concentrated against the toe of bank due to the densely vegetated bench and point bar growth against the left (eastern) bank, it is possible this bend erosion will extend downstream and through the LW106-7 pillar zone. Due to a lack of significant flow events over the past two wet seasons, the bank erosion on the right bank in LW106 has progressed no further, however the tunnel erosion adjacent to the helipad has worsened significantly and the bank is likely to collapse in the near future, forming a large gully.

The impacts and response to subsidence in LW107 to date are:

- Subsidence of the channel bed by approximately 3m, with no infilling having occurred yet due to a lack of substantive flows since the panel was subsided.
- Die-back of riparian trees has occurred, but has been limited to the central parts of the panel and only the right (western) bank.
- Significant damage to the upstream drop structure, which has subsequently undergone repair works in early 2015 following the wet season (discussed later in Section 3.3)

The impacts and response to subsidence in LW108 to date are:

- Subsidence of the channel bed by approximately 3m, with no infilling having occurred yet due to a lack of substantive flows since the panel was subsided.
- Expansion of existing joints/fractures in the sandstone bedrock as well as the formation of new cracking. Significant grouting works were undertaken to fill these cracks, however many cracks remain unfilled.
- Formation of erosion heads in the channel bed. Works had been undertaken prior to the site inspection to reshape the channel bed and protect eroding lower banks utilising the rock which has come out of the drop structure over its life.

The timber pile fields are still successfully managing the bank erosion risk until infilling of the channel bed occurs over the pillar zones which have subsided, however woody vegetation establishment has remained sparse and will need to be enhanced through strategic planting and exclusion of cattle to ensure the benches are stabilised. The pile fields at LW108-09 had been burned during a localised bushfire event, these were repaired as part of the installation of pile fields on pillars through to LW112-3 in late 2014.

Some further riparian vegetation die-back was occurring, particularly with the remaining *Eucalyptus tereticornis* (Queensland blue gum). The reason for death is unknown, but could include drowning from subsidence induced ponding, ring barking by sediment or root shearing.

Figure 2-10: 2014 observations through the subsidence reach

Tree die-back at LW104

Pile fields on LW105-6 pillar zone have maintained a bench against toe of bank during the elevated erosion risk period which has now passed with infilling

Significant worsening of tunnel erosion upstream of LW106-7 near the helipad

Looking upstream at edge of mobile bed sand load immediately downstream of LW106-107 pillar zone

Subsidence cracking on floodplain at LW107-108 pillar zone

Works undertaken in channel bed to fill erosion heads and armour toe of bank with liberated rock from previous drop structure damage in subsided panel LW108

Tree die-back at longwall panel LW107, with extent of sand movement into panel at right of photo

No evidence of tree die-back yet at longwall panel LW108

Cracking of sandstone bedrock at longwall panel LW108

Grouting of sandstone bedrock cracking at longwall panel LW108

Example of channel bed largely stripped of mobile sediment and subsequent erosion of the bench toward the high bank

Subsidence induced deepening has created a pool that has persisted despite very dry conditions

Figure 2-11: LW106 subsidence response

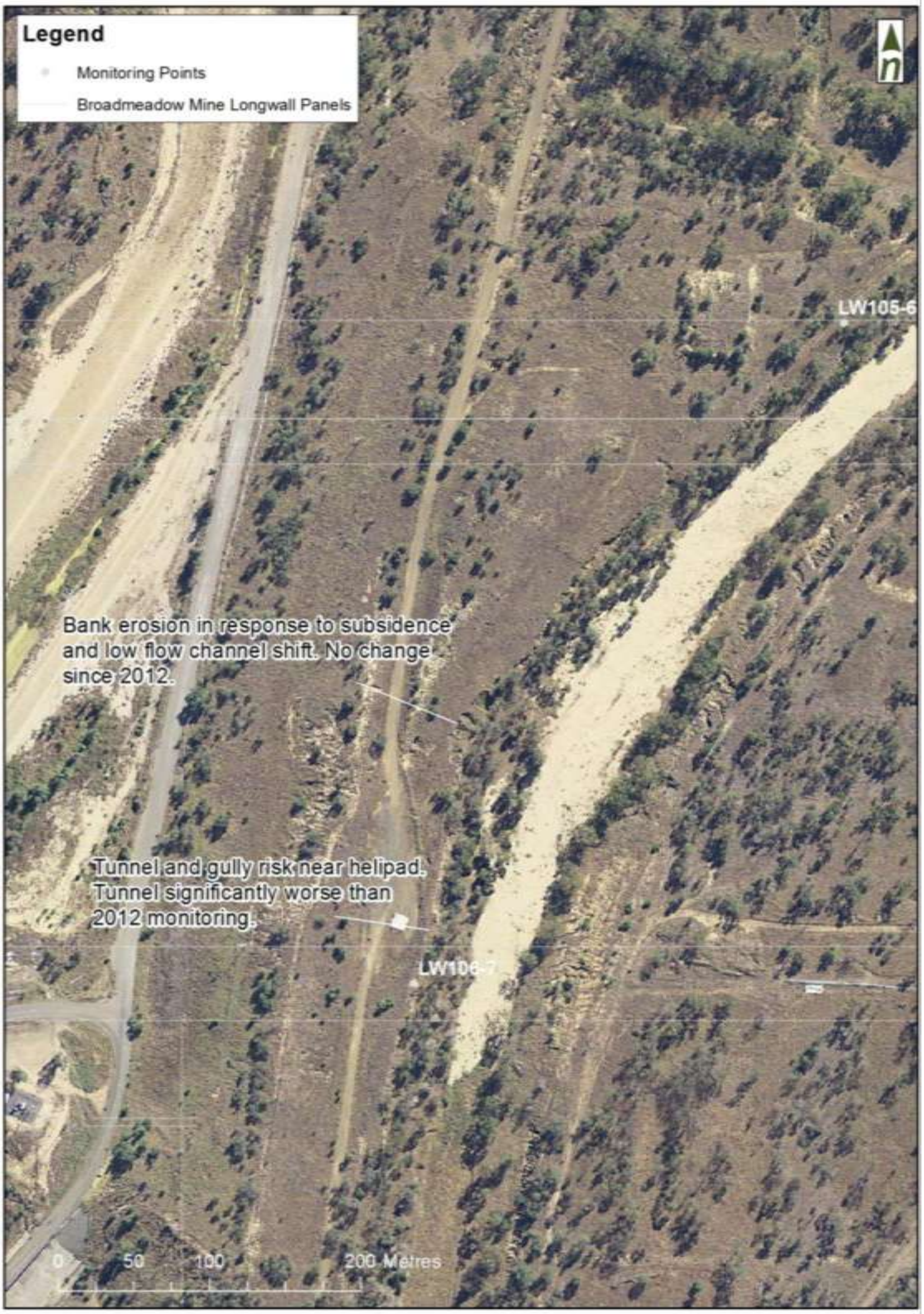


Figure 2-12: Aerial view of infilling of subsided voids and deepening downstream

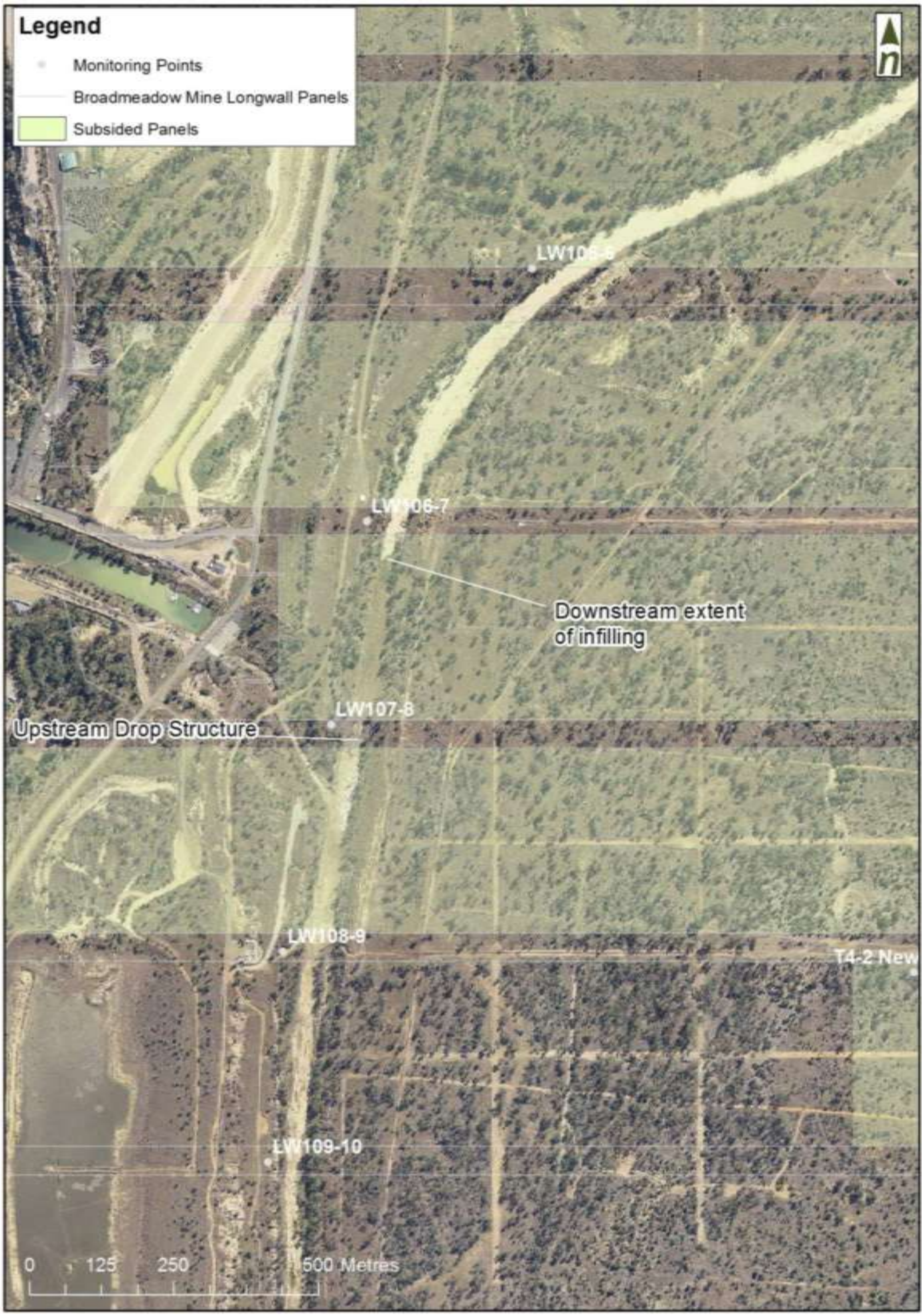
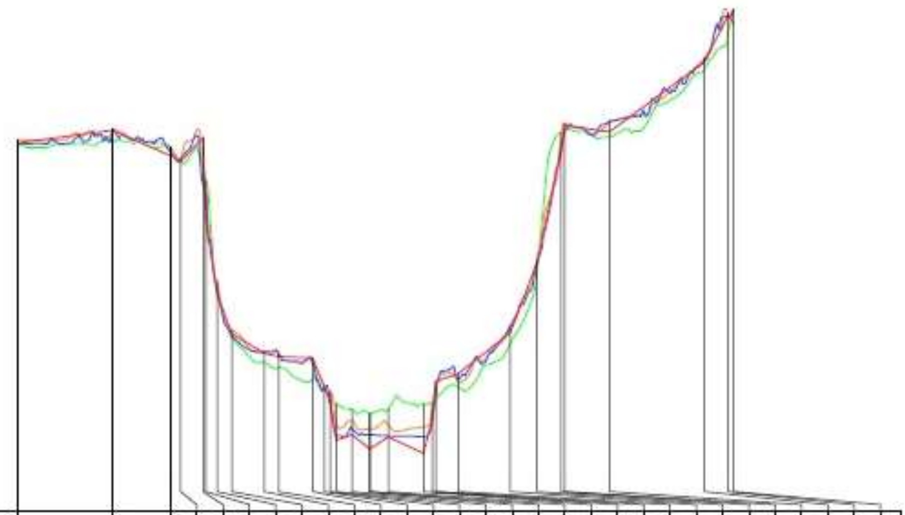


Figure 2-13: Cross section at monitoring point LW111-12 over time



Datum RL 233

2014 LIDAR	247.03	247.51	246.55	246.32	247.23	244.03	241.23	239.77	239.02	238.89	238.84	237.77	237.10	235.71	235.92
2012 LIDAR	247.01	247.58	246.69	246.42	245.49	245.01	241.38	239.68	239.08	238.98	238.64	237.70	237.25	235.87	236.13
2011 LIDAR	247.15	247.42	246.84	246.42	245.79	245.27	241.72	239.90	239.03	239.00	238.76	237.60	237.55	236.30	236.45
2008 LIDAR	246.91	247.03	246.82	246.31	246.08	245.63	241.40	239.68	238.66	238.47	238.03	237.72	237.30	237.09	236.87
OFFSET	−107.41	−78.39	−60.81	−57.68	−50.95	−50.00	−46.50	−42.14	−32.33	−27.86	−17.57	−14.00	−12.22	−10.23	−5.61

2014 LIDAR	235.37	235.39	235.83	235.22	236.50	237.94	238.24	239.79	242.46	246.80	247.70	247.45	250.12	251.90	251.58
2012 LIDAR	235.92	235.92	235.87	235.83	236.58	237.38	238.00	240.04	242.41	246.78	247.57	247.85	250.24	251.87	252.06
2011 LIDAR	236.14	236.14	236.28	236.21	236.99	237.83	237.92	240.01	242.55	247.22	247.77	247.86	250.25	251.98	252.12
2008 LIDAR	236.72	236.72	236.90	237.08	237.16	237.27	237.73	239.38	242.04	247.44	247.56	247.27	249.87	251.22	252.01
OFFSET	−0.19	0.00	5.52	16.13	18.87	19.88	26.76	42.58	50.64	58.08	59.27	72.78	101.71	108.88	110.48

LW111−12 (CH 7176)

DOWNSTREAM REACH

The reach downstream of the diversion utilised for monitoring continues to be in moderate to good condition with excess sediment inputs aggrading the stream bed and reducing morphologic diversity and suppressed native riparian vegetation being the main detractors in the IDC score. The vehicle crossing adjacent the Goonyella-Hay Point rail bridge is inputting coarse road base sediment when it is eroded in most flows.

Channel banks remain stable through this reach and riparian vegetation coverage and continuity is generally good. One minor detractor from riparian vegetation since 2011 is the clearing of a corridor for a set of high voltage power lines.

Figure 2-14: 2014 observations of downstream reach

Corridor cleared for high voltage power lines

Typical aggraded stream bed with limited morphologic diversity

2.8.2.2 Monitoring of in-channel structures/works

The condition and performance of works implemented to manage subsidence are reported in the annual monitoring. This is an integral part of the adaptive management approach.

All pile fields installed in 2007, 2011 and 2014 over pillar zones from LW102-103 through to LW112-3 are performing as intended. They have successfully managed the risk window over the upstream pillars during infilling and in the majority maintain a bench against toe of bank. Some are damaged, but those that are have performed their purpose.

Pile fields installed in the mid-late 1990's on the upstream bend of the diversion have performed to their design intent of establishing a well vegetated (though the vegetation has suffered die back since subsidence) bench against the toe of bank. In general the timbers appear to remain sound. With the subsidence of LW106 and subsequent infilling of the panel with bedload sediment, the low flow channel has migrated over the top of the subsided bench and against the toe of the highly erodible outside of bend bank. The bank will require further mitigation measures to stabilise. The low flow may redevelop back toward the centre of the channel outside the vegetated zone in the future, however the likelihood is not high in the near future.

The upstream drop structure in the diversion was significantly damaged and has since undergone repair works following the 2015 wet season. The damage occurred largely due to the materials used being unsuitable for the conditions in the river. However subsidence will further exacerbate the damage and compromise the functionality of this structure. The drop over this structure is accentuated by the subsidence downstream; a drop of approximately 4.8m now occurs from the crest of the drop structure on the LW107-08 pillar zone to the base of the LW108 subsidence trough. This occurs over a distance of approximately 180m, resulting in a grade of approximately 0.027m/m. This very steep channel grade will result in extremely high hydraulic parameters during the next major flow event with associated erosion risk where channel boundaries are not rock or rock protected.

The downstream drop structure has largely failed and is presently redundant. Works were undertaken to remove the centre of the cut-off wall that was sitting proud in the channel bed to prevent flows from outflanking this and concentrating against the left and right banks, causing scour and bank erosion. Rock and drop structure material were used to fill scour holes adjacent to the left and right bank.

The requirement and function of these drop structures requires review as part of the adaptive management program.

Figure 2-15: 2014 observations of upstream and downstream drop structures

At crest of upstream drop-structing (looking upstream) following repair works. Pool in LW107

At crest of upstream drop-structing (looking downstream at subsided LW108) following repair works

Centre of proud downstream drop structure cut-off wall removed to reduce flow concentration against banks and used to fill adjacent scour holes

Filling of adjacent scour hole at downstream rock structure

Deepening from the Isaac River has progressed upstream toward the GS4 dam spillway in Eureka Creek diversion. Deepening of the channel bed towards its apron would contribute to elevating the risk of structural instability. Works were undertaken by BRM to remove a portion of the right bank from the downstream extents of the now redundant concrete low flow channel. This was undertaken to widen the channel to reduce flow impacts against the right bank of the Eureka Creek diversion main channel. The right bank of the Eureka Creek diversion channel was also reshaped at the confluence as it had already suffered some bank erosion.

Figure 2-16: 2014 observations in Eureka Cree diversion

	
Eureka Creek diversion spillway from GS4 subject to damage and ongoing repairs. Deepening has progressed upstream from the Isaac River diversion channel and will further threaten the spillway stability	Works undertaken to remove downstream portion of concrete low flow channel to expand main channel and reduce flow impacts against the opposite bank

2.8.2.3 In-Stream Waterholes

Pools are becoming more prevalent in the Isaac River diversion due to bedload starvation downstream of the panels subsided to date. The depth and extent of the pools is dependent on the nature and structure of underlying Permian bedrock. Some pool-riffle habitat has developed.

The pools previously created by subsidence up to and including LW106 have been infilled by the elevated sediment inputs from the broader upstream catchment which have resulted in excess bedload supply to the river. LW107 and LW108 have received little to no sediment inputs since their subsidence due to a lack of flow events capable of mobilising the bed sediment from upstream. The bedload starvation downstream of subsidence is likely to continue for some time, as longwall panels LW107, LW108 and the soon to be mined LW109 will require significant sediment inputs to infill and allow sediment to be transported further downstream.

2.8.2.4 Panel catchment ponding and stability

Beyond the river channel, monitoring is undertaken for overland flow, minor tributaries and general land surface conditions following subsidence. This includes terrestrial monitoring sites T3, T4 and T5 at selected locations relative to subsidence across the three Regional Ecosystems over the BRM plan. To date the panels subsided have been within the Isaac River terrace which has very low gradients and limited potential for concentration of runoff. Observations at the terrestrial sites located over LW101-103 through 4 years of monitoring has indicated that the majority of cracks that develop following subsidence seal up and partly infill without developing major tunnel or gully erosion. This is particularly so in the heavier soils associated with the RE11.4.9 Blackbutt – Brigalow association.

The eastern end of LW107 and LW108 are the first panels to subside rising ground to the east of the Isaac River terrace. Cracks have developed from both tension (parallel with longwall) and compression (perpendicular to longwall). Limited rainfall has occurred since these subsided. Additional monitoring effort in these areas is required as identified later in the SMP.

Another aspect of panel catchments that will require monitoring into the future is concentration of flows and where those flows outlet to a waterway, particularly the Isaac River diversion. Prediction of likely post subsidence drainage pathways has been undertaken as part of the assessment work to inform this SMP. These predictions should be validated in future monitoring by inspections. An example of an acceleration of a pre-existing erosion process that has occurred post subsidence is shown in Figure 2-18. The issue of concern is erosion head development at the end of a panel for existing flow paths dropping into the subsidence. Ponding and flow entry changes around where LW107 and LW108 intercept the eastern bank of the Isaac River are shown on Figure 2-19.

Figure 2-17: Ponding and cracking east of Isaac River

Looking east toward eastern end of LW106, shallow ponding in Isaac River terrace in subsided panel, no flow concentration at outlet (2012)

Recent crack over pillar zone between LW106 and 107 in lighter soils associated with RE11.3.2 Poplar Box association (2012)

Figure 2-18. Panel catchment flow behaviour change LW104-105

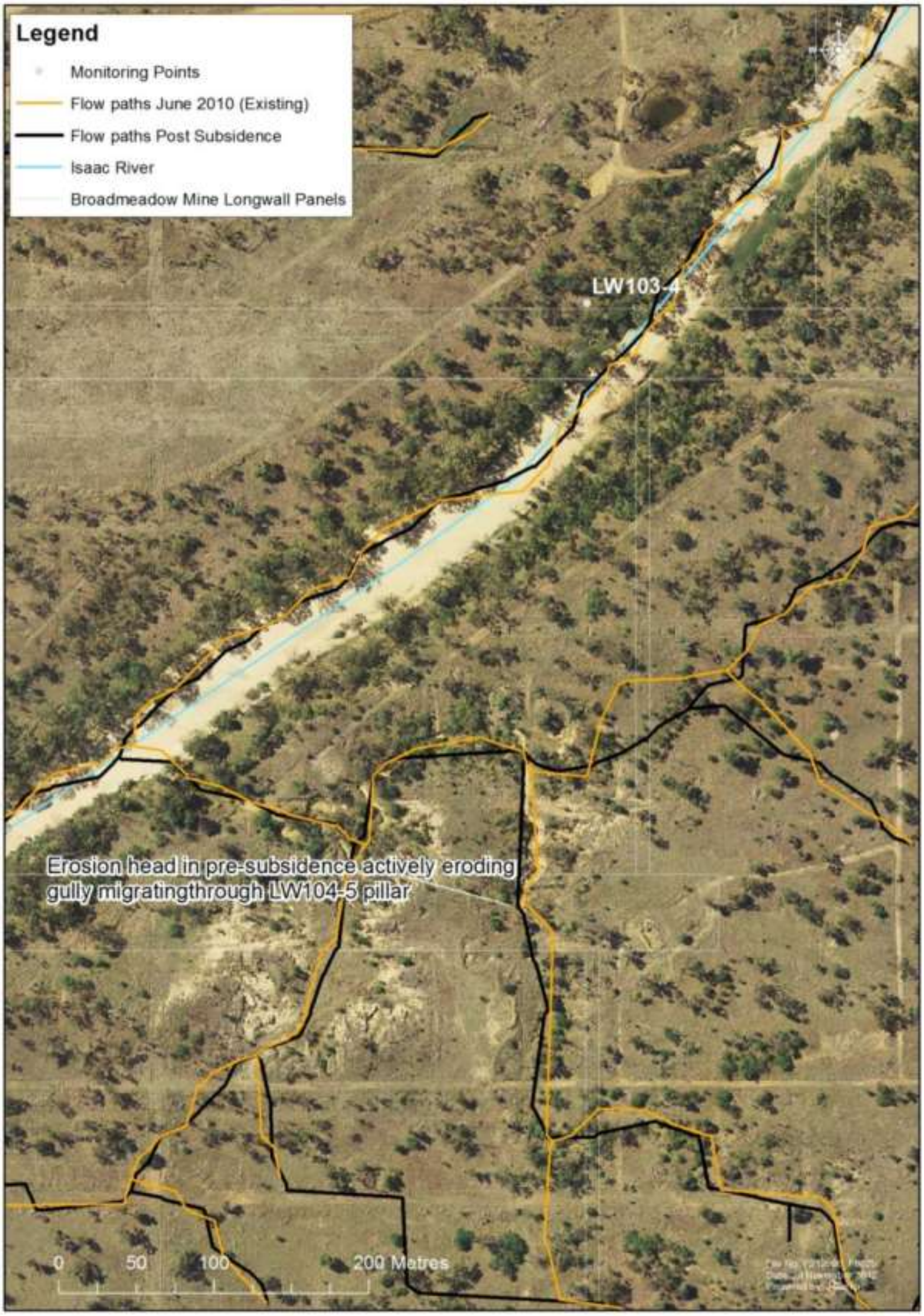
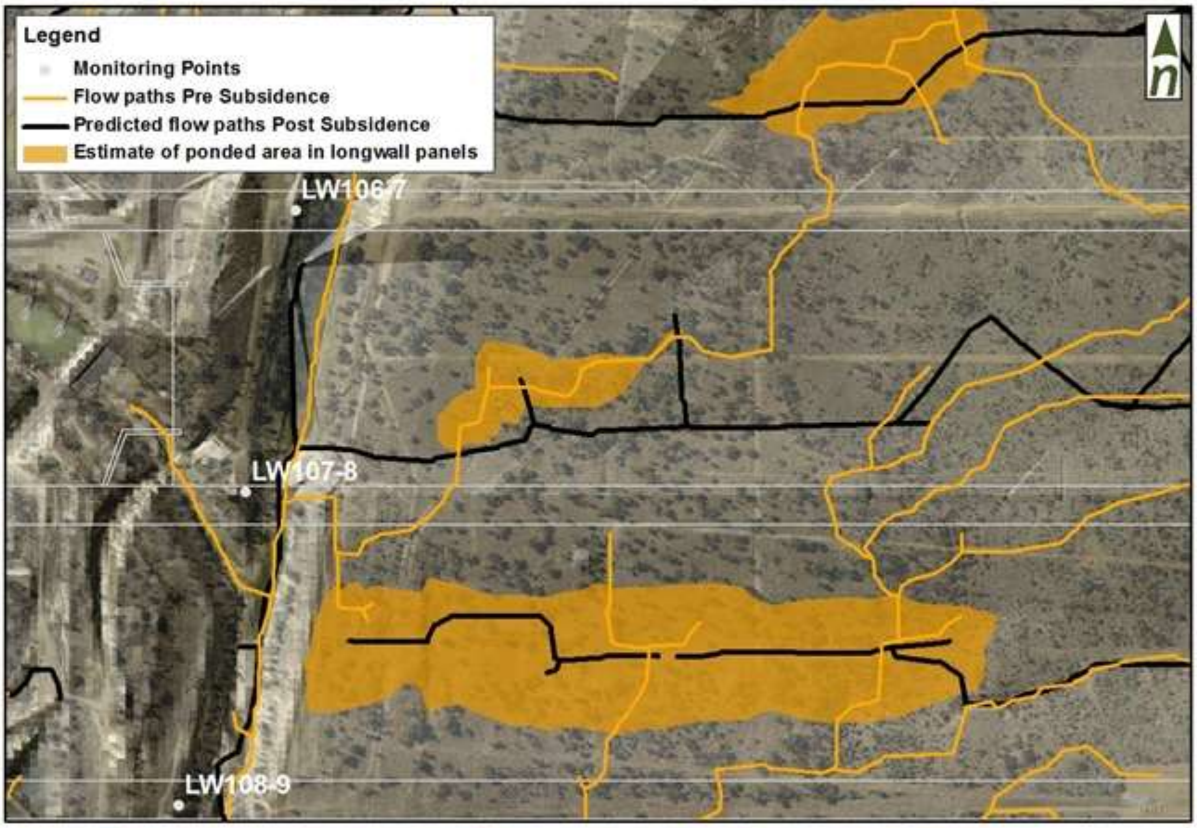
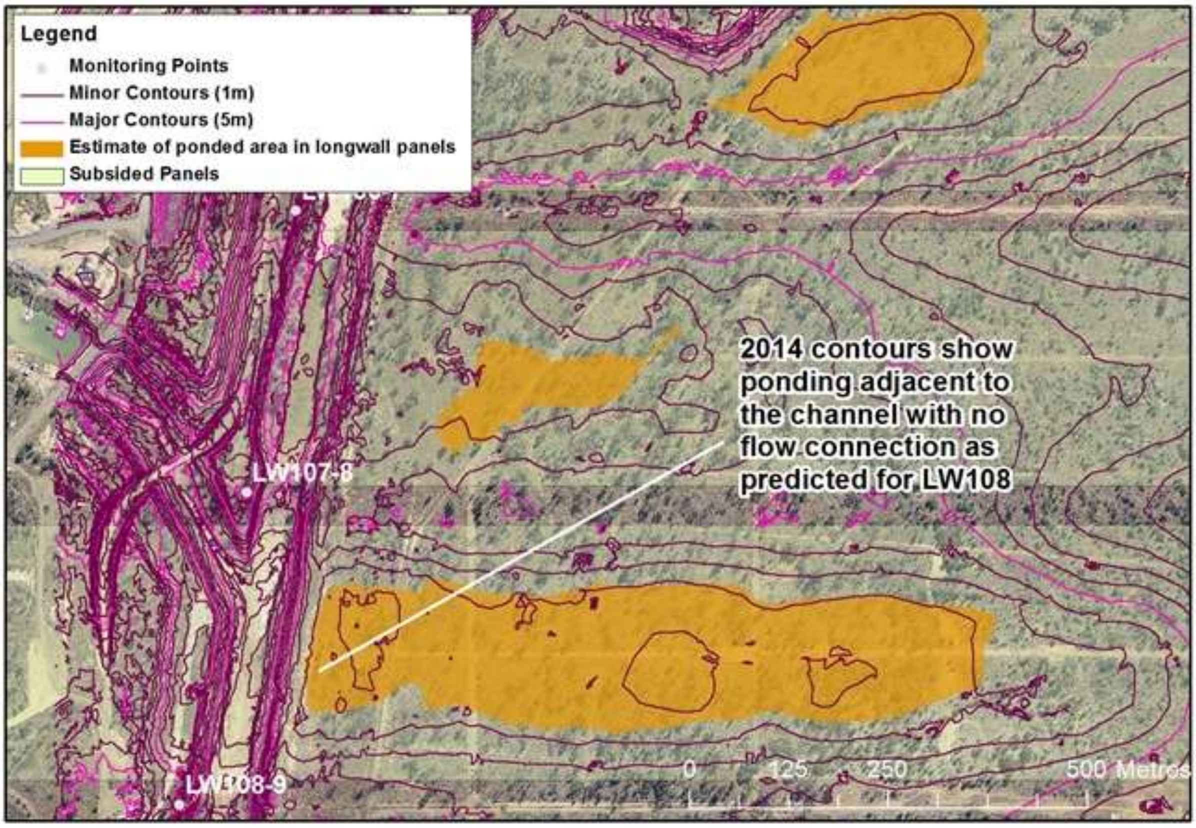


Figure 2-19. Panel catchment flow behaviour change LW107-108





2.9 SURFACE WATER QUALITY

The quality of un-disturbed surface water bodies in the area are considered to be non-saline and have near neutral acidity. An analysis of site monitoring data indicates that salinity may be elevated in Eureka Creek and the Isaac River on occasions, with little or no indication of effects on other creeks. Upstream and downstream water qualities are routinely monitored.

The long term measured water qualities are generally similar in range to those usually found in Central Queensland streams and there are certain parameters that exceed the ANZECC (2000) water quality guideline.

2.10 FLORA & FAUNA

Flora and fauna in the underground mining footprint area has been summarised based primarily on the desktop and field studies conducted by URS in August 2011:

- Goonyella Complex Expansion Terrestrial Fauna Technical Draft Report. (URS, 2011a).
- Goonyella Complex Expansion Terrestrial Flora Technical Draft Report. (URS, 2011b).
- Goonyella Complex Expansion Aquatic Ecology Technical Draft Report. (URS, 2011c).

Additional information was sourced from previous studies of the BRM area:

- Technical Report: Isaac River Cumulative Impact Assessment of Mine Developments, Appendix G: Riparian Vegetation. (Alluvium, 2008a); and
- Management Strategy for Impacts of Mining Related Subsidence on the Isaac River – Broadmeadow Mine (Earth Tech, 2006).

2.10.1 Flora

The ecological values of the area within the BRM mine area are considered typical for the northern Bowen Basin, with large areas of land historically cleared for grazing and cropping. Although some areas of remnant vegetation remain intact, most have been modified to some extent by historical and current land management practices. The most common modification is the removal of the shrub and ground layers and replacement with pasture grass species.

A search of DERM Environmentally Sensitive Areas mapping indicates that there are no category A environmentally sensitive areas near the BRM footprint. Mapping indicates the presence of Endangered Regional Ecosystems (REs; category B environmentally sensitive areas) within and around the BRM footprint.

The URS (2011b) literature review identified seven flora species of conservation significance as potentially occurring in the study area. Of the seven species, field surveys confirmed the presence of one; *Dichanthium setosum* (bluegrass) which is listed as Near Threatened under the Nature Conservation Act (NC Act) and Vulnerable under the Environmental Protection and Biodiversity Conservation Act (EPBC Act). An additional threatened plant species was identified on site; *Cerbera dumicola*, which is listed as Near Threatened under the NC Act. Additional species of conservation significance;

Dichanthium queenslandicum (king bluegrass) and *Digitaria porrecta* (finger panic grass), were identified as being likely to be present given the types of habitat available.

The literature review also identified two Environmental Protection and Biodiversity Conservation (EPBC) Act Threatened Ecological Communities (TECs) likely to be present within the BRM footprint; Natural grasslands of the Queensland Central Highlands and the northern Fitzroy Basin and Brigalow (*Acacia harpophylla* dominant and co-dominant). Parts of the Brigalow community met the condition threshold of 'Good quality' for the EPBC listed community. There are no TEC grasslands identified adjacent to the Isaac River or the diversion.

Field surveys confirmed 19 REs, including five REs listed as Endangered, seven as Of Concern and seven as Not of Concern. Detail regarding REs, riparian communities and weeds are provided as **Appendix A**.

A rapid assessment of riparian and terrestrial vegetation is undertaken as part of the annual Isaac River subsidence monitoring. Tree die-back has been observed from longwall panel LW104 to LW107, particularly *Eucalyptus tereticornis* (Queensland blue gum). The reason for death is unknown, but could include drowning from subsidence induced ponding, ring barking by sediment or root shearing.

2.10.2 Fauna

The 2011 desktop analyses and field surveys determined that a range of habitat values exist. While the majority of the habitat within the area is generally of low conservation value, there are habitats within the area such as the Isaac River riparian and alluvial woodland which act as a wildlife corridor and possess greater potential for supporting significant fauna.

The studies identified a total (including exotic fauna) of 288 fauna species as occurring within the area. This includes 168 bird, 49 mammal, 17 amphibian and 54 reptile species. Of the fauna species recorded, 22 are listed under the NC Act or the EPBC Act. A further five conservation significant species may potentially occur due to the availability of suitable habitat.

The ornamental snake (*Denisonia maculata*) was first recorded in 2006 in the north-west of the BRM mine area. An additional sighting of the ornamental snake was made during the 2011 URS survey, to the east of the BRM footprint.

Six conservation significant fauna including the brigalow scaly-foot (*Paradelma orientalis*) were identified within the broader BRM area during previous surveys. This species was last recorded in 1998 (WBM) and is assumed locally extinct due to the lack of additional records and continued disturbance of the area.

No Endangered or Conservation species are known or expected to occur in the area. Detail regarding habitat specific fauna is provided as **Appendix B**.

2.10.3 Aquatic Ecology

An assessment of the aquatic habitat was undertaken in May 2011 across the broader Goonyella-Riverside and Broadmeadow mine (URS, 2011c). Changes to the ecosystem in the wider catchment have been associated with historical land management and prioritisation of land use. Vegetation clearing for grazing, modification of streams for water infrastructure and mining appear to have impacts on the larger catchment.

In situ water quality results indicated elevated electrical conductivity resulting from mining activity while other parameters showed anthropogenic impacts from the wider catchment use. A total of 48 macro invertebrate taxa and seven fish species were collected during the survey. No exotic species were collected in the survey and no fish collected exhibited any signs of disease.

2.11 CULTURAL HERITAGE

2.11.1 Indigenous Cultural Heritage

The area contains traces of prior Aboriginal habitation and areas retaining Indigenous cultural significance. These include sites with stone artefacts, trees bearing scars caused by deliberate Indigenous bark removal for artefact manufacture, and sites dating from the contact-era. Most of the previously located cultural features were recorded during earlier site clearance associated with coal mining projects in the district (Alfredson 1990, 1991, 1994; Brayshaw 1976).

A detailed heritage assessment was undertaken, with the cooperation of the region's Traditional Owners, to assess potential mine expansion impacts on previously recorded sites, and on unrecorded cultural features.

The heritage assessment entailed an on-site survey of areas potentially affected by expansion of BRM and associated infrastructure. This field survey was conducted by representatives of the Traditional Owner groups, each group assisted by an archaeologist. Located sites, features and cultural landscapes were documented, their significance assessed and management recommendations formulated.

The findings of the detailed heritage assessments were recorded comprehensively in a series of reports that contain evidence of sites and locations of special significance to the Traditional Owner groups. To maintain the confidentiality of these sites and significant areas, and the security of traditional knowledge pertaining to them, the primary site reports will not be made public.

Separate site clearance surveys were conducted with representatives of each Traditional Owner group. As boundaries between the different groups had not been resolved at the time the site clearances were conducted, there was some degree of overlap in survey coverage, resulting in duplication of survey results and differing site assessment and recommendations for heritage protection in the same area.

A summary of the field survey results is as follows:

- A number of large artefact concentrations were found mainly along the gullies running into the Isaac River. Some of these were found in association with fireplaces, knapping floors and stone extraction areas. Two in particular were very extensive and complex, along Cleanskin Creek and around a system of eroded gullies on the eastern side of the river.
- 31 scarred trees thought to be of Aboriginal origin were also recorded throughout the area.

2.11.2 Non-Indigenous Cultural Heritage

The field survey identified 10 sites and places of historic cultural heritage significance and six sites of historical interest within the area. Significant attempts were unable to determine the true extent of the Possible Former Native Police Camp reported to exist within the area.

This was primarily due to the low ground surface visibility as a result of dense grass cover in the described area. Improvement of ground surface visibility along with a well researched and planned systematic survey of the area is required to determine the true nature and significance of this site.

There is some potential for further historic item/places to exist within the project area. These are likely to be remnant sites relating to pastoral and settlement activities, such as historic survey trees and remnant boundary fence lines. From a heritage perspective (and aside from the Possible Former Native Police Camp) the project area is likely to contain, at best, moderate levels of local cultural heritage significance.

With the exception of the possible Former Native Police Camp which requires further quantification, no sites or places were located within the area that contain levels of cultural heritage significance important to Queensland under Section 34 of the Queensland Heritage Act 1992. No sites or places are recommended for nomination to the Queensland Heritage Register as a result of this cultural heritage survey.

3 IMPACT ASSESSMENT

Impacts of subsidence are described based on a framework developed during consultation between industry and Queensland Government in terms of:

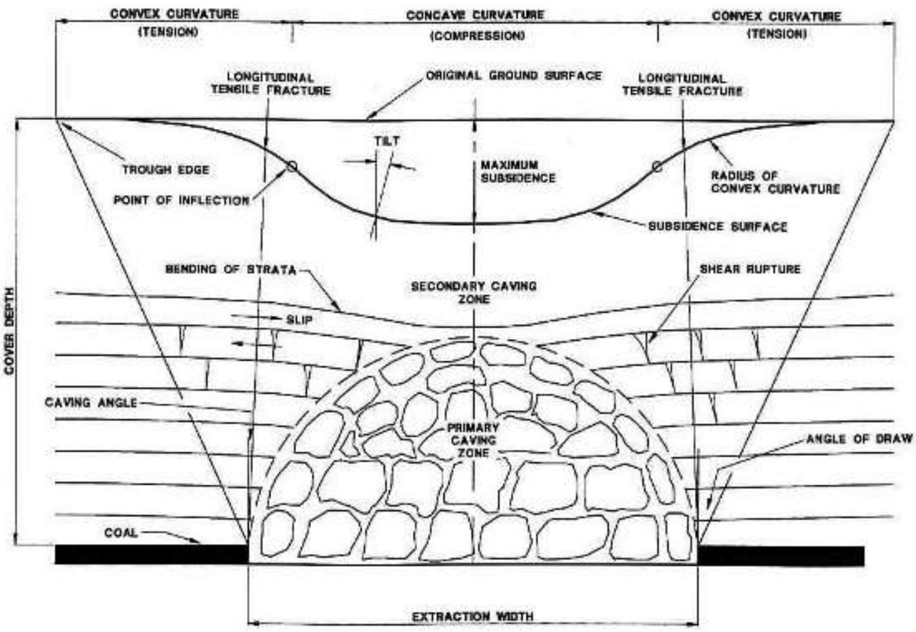
- direct physical effects of subsidence (1st Order);
- geomorphic response (2nd Order) including hydraulics, sediment transport, and land surface cracking;
- water quality and quantity impacts (3rd Order) including in channel ponding, overland flow and water quality;
- flora and fauna (4th Order);
- cumulative impacts; and
- infrastructure.

3.1 Mine Plan and Subsidence Predictions (1ST Order Impacts)

1st order impacts are the direct physical effects of subsidence on the land surface. Longwall panels are typically 300m wide and separated by chain pillars of approximately 60m wide. When mining of the coal in the panel has occurred and the longwall miner advances, the land surface subsides following underground collapse. The amount of subsidence expressed at the surface is largely dependent on strata, depth below surface of mining and thickness of seam mined. The subsidence creates a trough or void superimposed on existing surface topography (**Figure 3-1**).

Maximum predicted subsidence is generally -2.5 m at Broadmeadow with conventional high reach longwall (HRL) mining. However, for thick seem mining (LTCC), which recovers more coal from the seam where the seam is thicker than can be mined by conventional longwall mining, maximum subsidence predictions within the Isaac River increase to almost -4 m.

Figure 3-1: Longwall Subsidence



3.1.1 Current mine plan

The current BRM plan includes a total of 27 longwall panels, 19 of which will directly subside the Isaac River. For longwall panels LW101 to LW107, the GMS has already been mined through using conventional HRL mining. LTCC has been undertaken for longwall panels LW108, LW109 and is planned for LW110 onwards. However, mining under the Isaac River will continue to be undertaken using conventional HRL mining. The rate of mining is typically one panel per year.

Subsidence predictions are created using Surface Deformation Prediction Software (SDPS). Subsidence data for this current mine plan has been provided by SCT on behalf of BMA, **Figure 3-2** shows the predicted land surface following subsidence. Subsidence is primarily controlled by the depth of coal recovered from the seam. The SCT subsidence predictions are a maximum prediction, based on a recovery of 85% of seam thickness from the LTCC mining process. Where the mining process does not achieve this rate of recovery due to operational constraints the actual subsidence will be less than predicted.

Manual survey is undertaken by BMA as the longwall face progresses along the panel. Survey data is collected along the centreline and a crossline for each panel and at repeated time intervals to capture the full subsidence. This data is used in validating the subsidence modelling.

The manual survey shows that the maximum subsidence observed are within 0.2 to 0.6 m of predicted. However, for LW107 and LW108, SCT reported the panel edge subsidence on the start lines is consistently greater in the surveyed subsidence than predicted. The predicted panel edge subsidence is approximately half of the surveyed subsidence (SCT, 2014). These observations will be used to improve future subsidence modelling.

Graphical presentation of survey centreline and a crossline for panels mined by HRL and LTCC are shown in **Figure 3-3**. To date, 8 longwalls have been mined with only LW103 to LW108 subsiding the Isaac River. However, successive substantive wet seasons have resulted in infilling the subsidence voids with sand in LW103 to LW106, with LW107 and LW108 voids remaining to date. The post subsidence DTM for the currently proposed mine plan includes subsidence predictions for panels LW109 to LW127.

It is estimated that the maximum depth of subsidence varies from approximately 2.5 to 4m as shown in the table below and **Figure 3-4**. LW109 is planned to subside the river in 2015, with one panel subsiding the Isaac River diversion approximately each year following until 2028.

The difference between undertaking HRL mining at the Isaac River and LTCC beyond the river is illustrated by changes in the subsidence scale on a grey-shaded terrain model in **Figure 3-5**.

Table 3-1: Total length, areas and approximate maximum depths of longwall panels

Longwall Panel ID	Total Length (km)	Impacted Area (km^2)	Maximum Depth of Subsidence (m)	Maximum Depth within the Isaac River (m)
LW101	2.1	0.4	-2.5	0.0
LW102	2.4	0.5	-2.5	0.0
LW103	2.3	0.5	-2.5	-1.5 (infilled)
LW104	2.1	0.7	-2.5	-2.5 (infilled)

LW105	2.0	0.6	-2.5	-2.5 (infilled)
LW106	1.8	0.6	-2.5	-2.5 (infilled)
LW107	1.6	0.5	-2.5	-2.5 (minor infilling)
LW108	2.1	0.7	-4.0	-2.6
LW109	2.6	0.9	-3.8	-2.8
LW110	2.3	0.8	-3.8	-2.8
LW111	3.0	1.0	-3.8	-2.8
LW112	3.3	1.1	-3.8	-2.8
LW113	3.4	1.1	-3.8	-2.8
LW114	3.4	1.1	-3.6	-2.8
LW115	3.5	1.2	-3.6	-2.8
LW116	2.9	1.0	-3.6	-2.8
LW117	2.3	0.8	-3.6	-2.8
LW118	2.5	0.8	-3.6	-2.8
LW119	2.4	0.8	-3.6	-2.8
LW120	2.2	0.7	-3.6	-2.8
LW121	1.8	0.6	-3.9	-2.9
LW122	2.4	0.8	-3.8	0.0
LW123	2.5	0.8	-3.6	0.0
LW124	2.5	0.8	-3.3	0.0
LW125	2.2	0.7	-3.2	0.0
LW126	2.4	0.8	-3.3	0.0
LW127	2.7	0.7	-3.3	0.0

Figure 3-2: Post Subsidence Contours

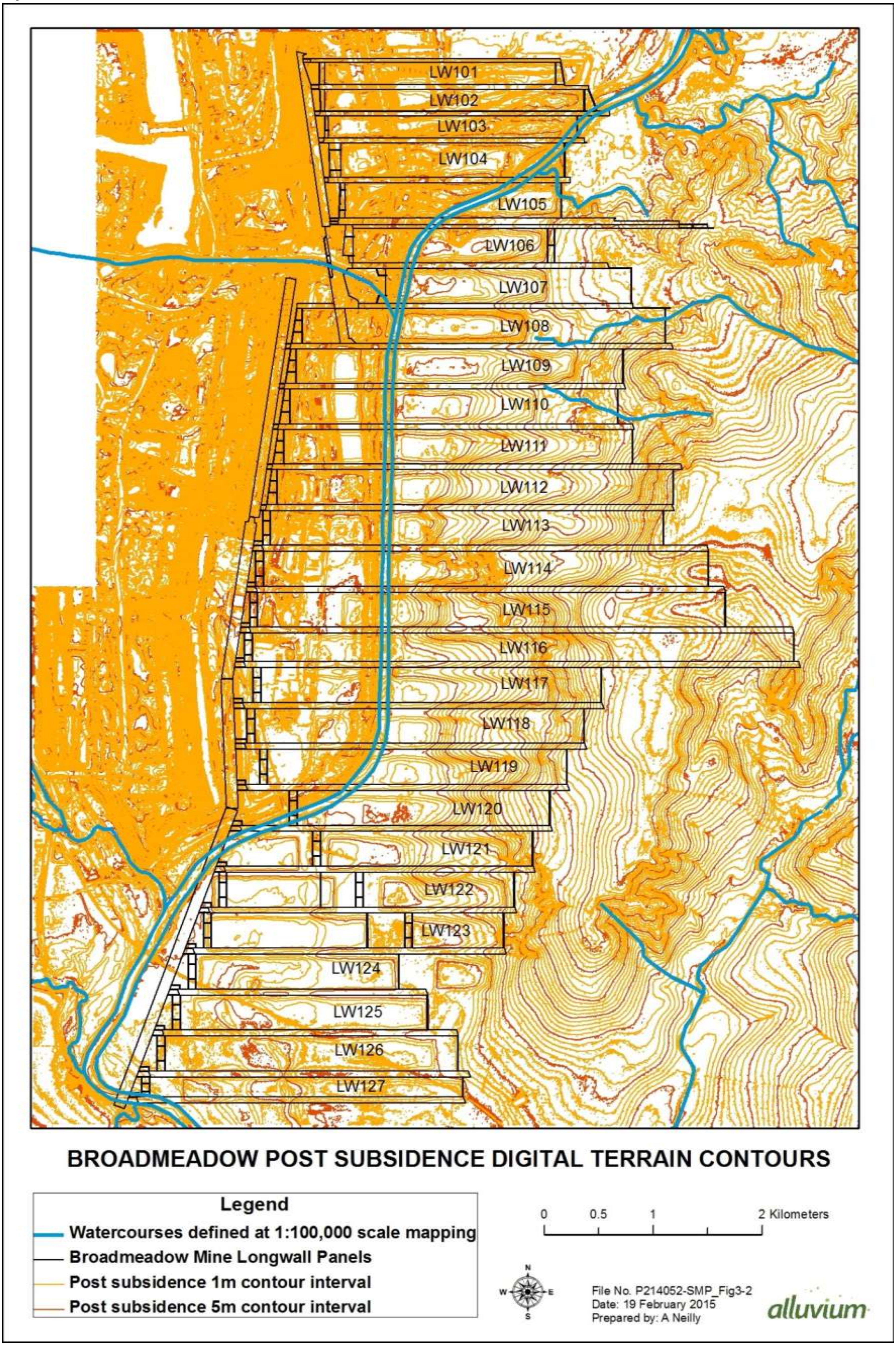
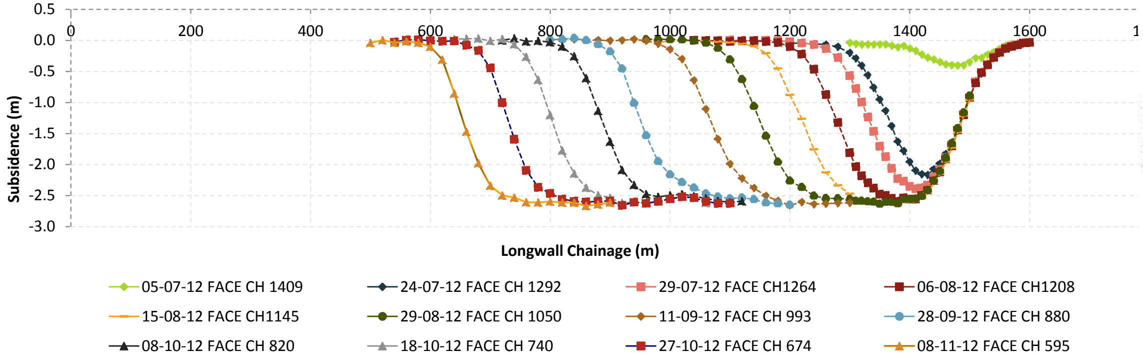


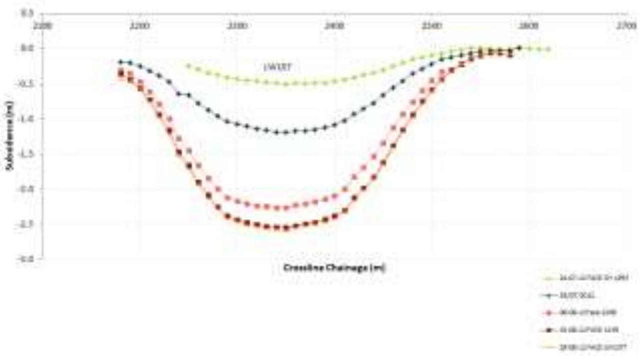
Figure 3-3: Surveyed post subsidence terrain for typical HRL and LTCC methods at BRM

HRL MINING

LW107 – Centreline Survey

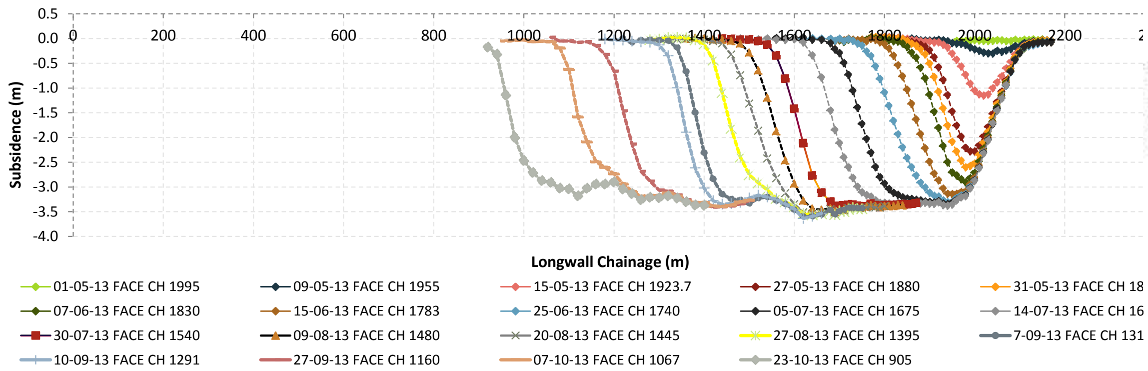


LW107 – Cross-section Survey



LTCC MINING

LW108 – Centreline Survey



LW108 – Cross-section Survey

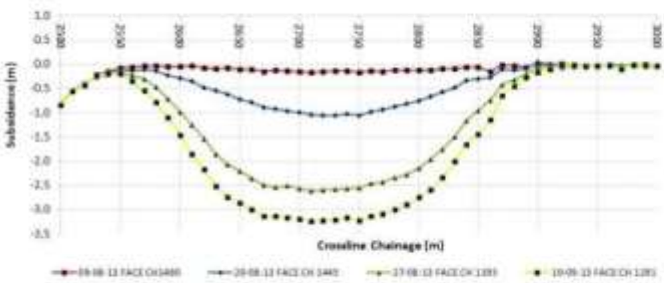


Figure 3-4: Isaac River diversion existing and post subsidence (LW106 – LW120) longitudinal section

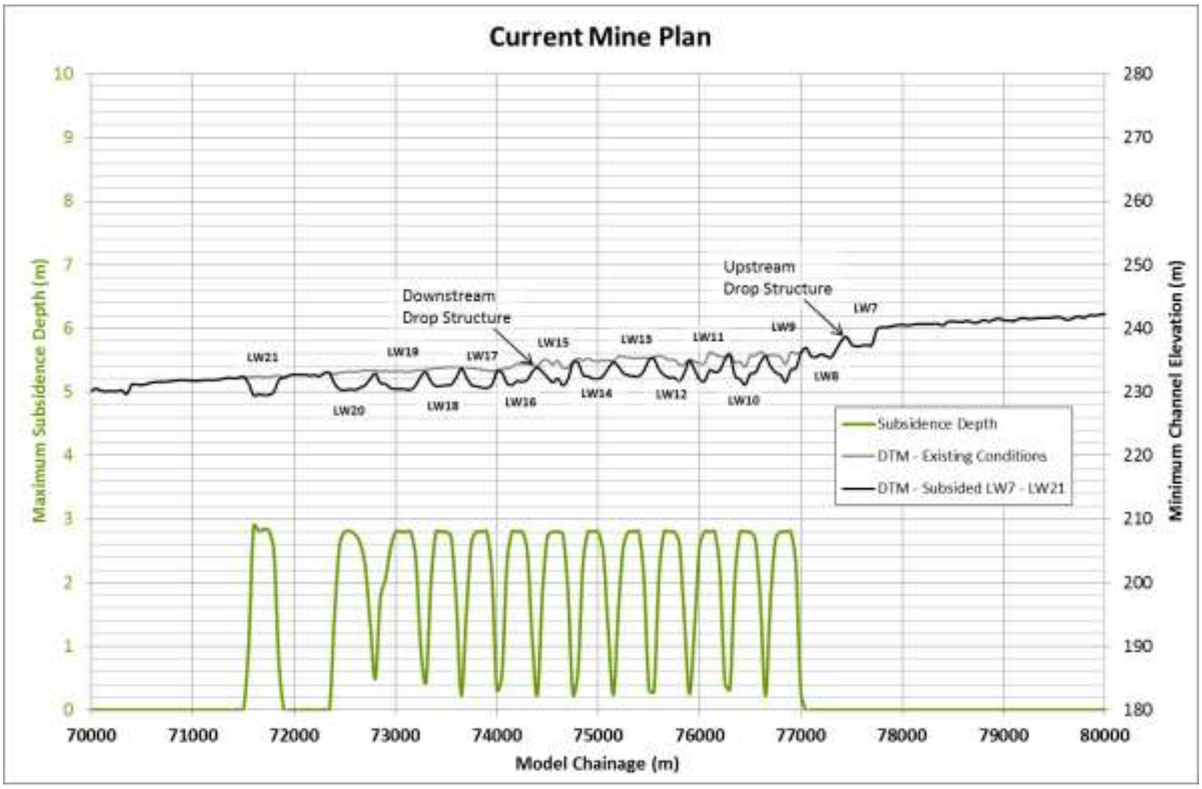
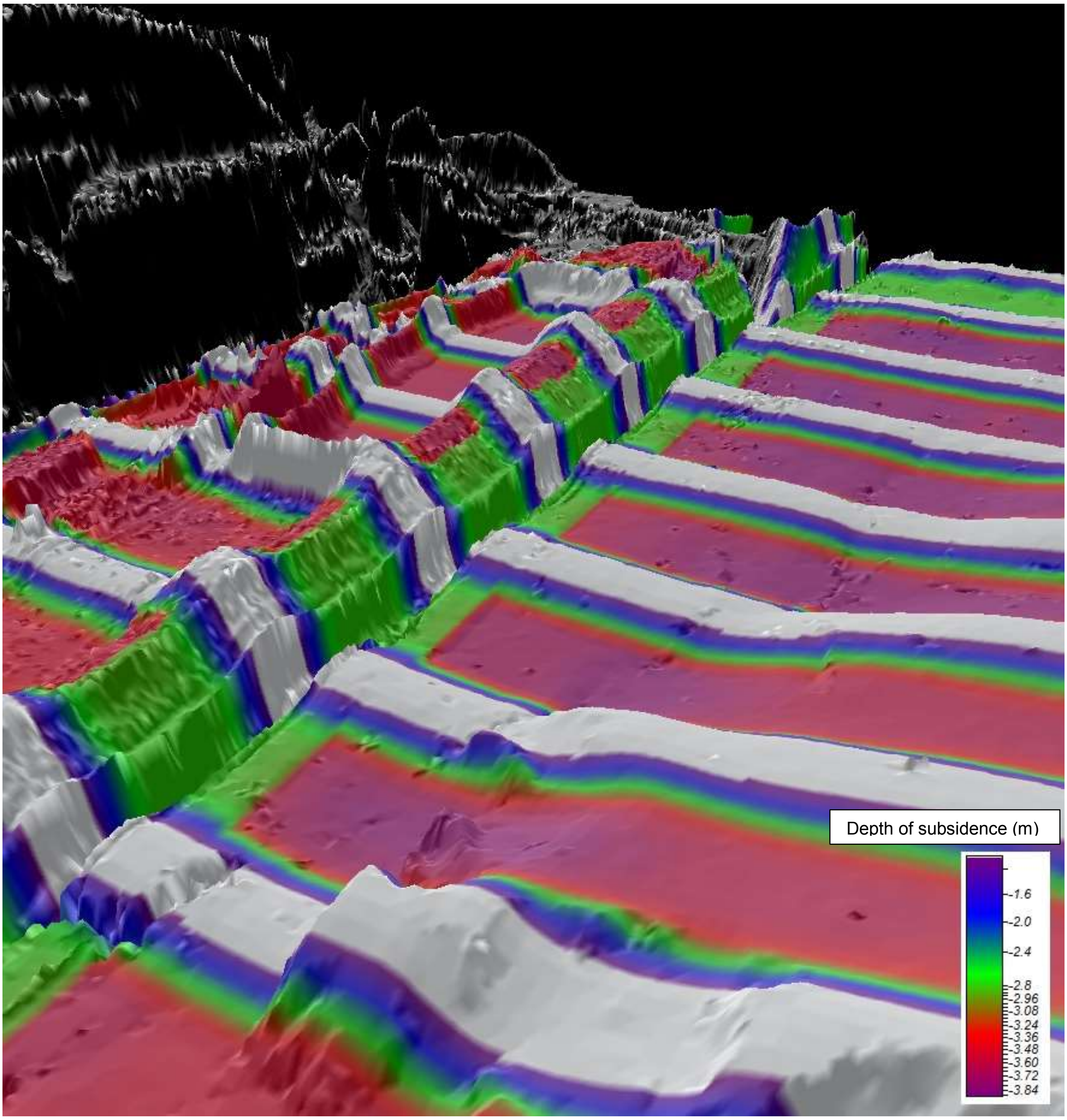


Figure 3-5: Perspective view showing the difference between LTCC and HRL mining along river



The existing subsidence void estimates for the Isaac River channel and that created from future mining under the current scenario is summarised in **Table 3-2**. A comparison of the 2014 current scenario to the 2007 and 2011 mine plans is provided in **Table 3-3**. The 2014-15 mine plan for longwall panels LW107 to LW121 produces a subsidence void in-channel approximately 25,000 m^3 less than the 2011 mine plan. For the purposes of visualisation, the cumulative void volume is also expressed as an equivalent strip depth over the reach.

Table 3-2: Subsidence void volumes for each Broadmeadow longwall panel

Longwall Panel ID	Subsidence void volume (m^3)	Current anticipated Timeframe for Mining
Upstream of Isaac River Diversion		
LW101	-	-
LW102	-	-
LW103	Infilled	-
LW104	Infilled	-
LW105	Infilled	-
LW106	Infilled	-
Isaac River Diversion		
LW107	44,431	-
LW108	27,345	-
LW109	48,719	2015
LW110	37,863	2016-17
LW111	47,661	2017-18
LW112	40,419	2018-19
LW113	48,359	2020
LW114	39,596	2021
LW115	35,857	2022
LW116	30,450	2023
LW117	38,261	2024
LW118	41,964	2025
LW119	71,647	2026
LW120	44,840	2027
LW121	33,712	2028
Sub-total	631,125	

Table 3-3: Existing subsidence voids and future plans for the Isaac River diversion

	2008 IRCIA Scenario (10 longwalls)		2011 Scenario (15 longwalls)		2014-15 (15 longwalls)	
By end year	Cumulative Volume (m^3)	Equivalent Strip Depth (m)	Cumulative Volume (m^3)	Equivalent Strip Depth (m)	Cumulative Volume (m^3)	Equivalent Strip Depth (m)
2013	153,188	0.65	116,410	0.3	-	-
2018	310,523	1.33	289,514	0.8	208,918	0.6
2023	425,245	1.82	445,840	1.2	408,015	1.2
2028	425,245		667,261	1.8	642,714	1.8

3.2 Geomorphic Response (2nd Order Impacts)

The geomorphic response to subsidence voids in an alluvial sand bed stream, such as the Isaac River, was predicted to be similar to that for sediment extraction, which is well understood. The effects of extracting sediment from a sand bed stream are illustrated in **Figure 3-6**.

a) Large sediment load - the pit (or void) migrates downstream, but overall bed lowering is small.

b) Small sediment load - the bed fills in slowly and the bed lowers considerably.

To predict the geomorphic response of the Isaac River to subsidence, it is necessary to quantify the volume of bed sediments transported in comparison to the volume of subsidence voids created in-channel. If the volume of the voids created by the subsidence is found to be insignificant when compared to the volume of sediment transported by the river, then we would expect ongoing sediment transport in the river to overwhelm the voids. Under this scenario the subsidence would be expected to have limited to no impact on geomorphic processes in the Isaac River at a reach scale, impacts would be limited to short terms and a local level.

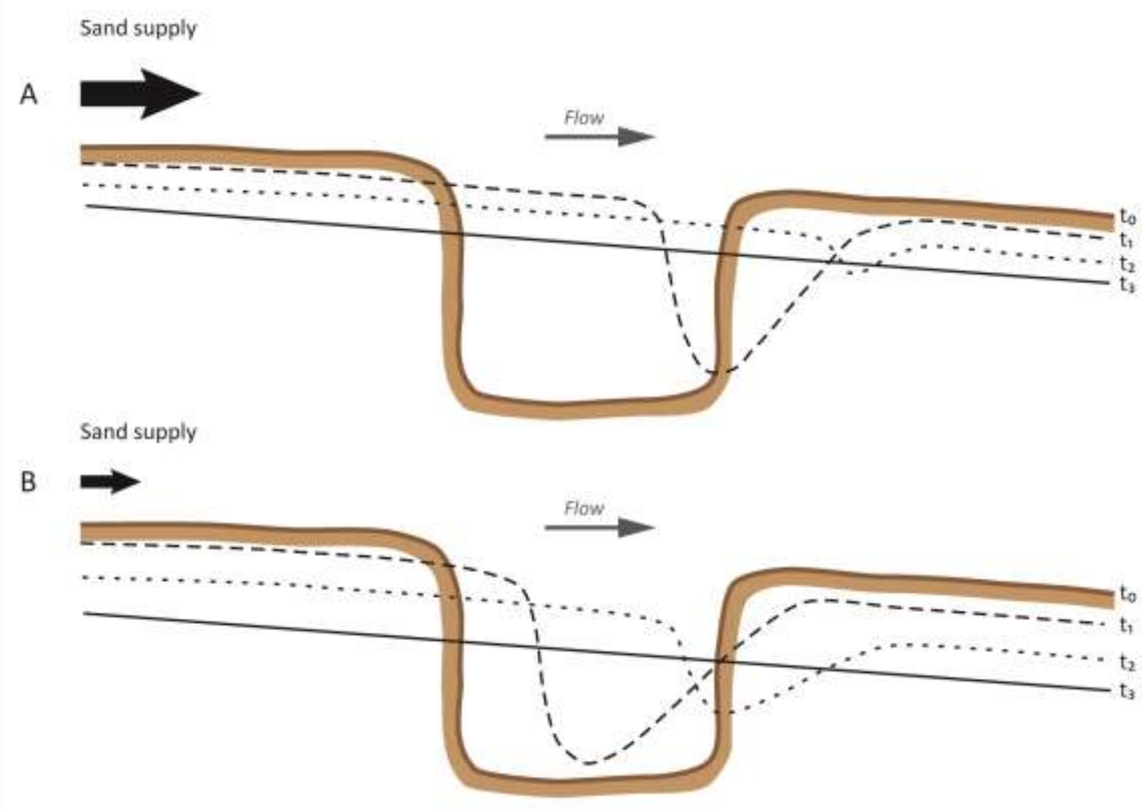
Alternatively if the volume of void created by subsidence is of a similar scale or larger than annual or event sediment transport then we could expect some geomorphic impacts. Positive impacts would include the establishment of pools and a reduction in the available sediment for transport into downstream reaches. Negative impacts could include upstream and downstream progressing stream bed degradation (deepening) and related exposure and potential scour of bank material and damage to infrastructure.

Other potential impacts of subsidence on stream form and geomorphic processes could include:

- Gully incision of minor tributaries
- Stream bed incision of major tributaries and potential subsequent widening and meander migration
- Trunk stream widening associated with deepening.

Hydraulic modelling and an assessment of sediment transport has been undertaken to assist with predicting the geomorphic response of the waterways at BRM. A brief summary of the hydraulic modelling and sediment transport results follows.

Figure 3-6: Typical geomorphic response to sediment extraction



Schematic effects of extracting sediment from a stream bed.
In A, where there is a large sediment load, the pit migrates downstream, but overall bed lowering is small. In B, where sediment load is small, the pit fills slowly and the bed lowers considerably.

Adopted from Rutherford, I.D., Jerie, K. and Marsh, N. 2000. Stream Rehabilitation Manual, Vol.2, Land and Water Australia

3.2.1 Hydraulic impacts

HEC-RAS model for one-dimensional steady flow has been applied to the Isaac River to model existing conditions and post subsidence of BRM.

Modelling results for velocity, shear stress and stream power are provided in Appendix C. Stream flows of 250 m^3/s and 1000 m^3/s have been selected for presentation purposes. These represent flow depths in the Isaac River of approximately 3-4 m (over benches and acting on toe of high bank) and 6-7 m (acting on most of high bank), respectively. The predicted change post subsidence when compared to existing for the key hydraulic parameters is shown graphically in Figure 3-7 and Figure 3-8.

A decrease in value is predicted through the Panel (subsidence void) while the downstream pillar is intact; and an increase in value over the Pillars (remnant raised section) prior to any infilling of the void. The maximum change is predicted to occur over the upstream drop structure which is located on the pillar of LW107-8. The magnitude of change over the panels and pillars is shown in Table 3-4 and Table 3-5. These values are consistent with previous modelling undertaken for HRL mining through the diversion reach.

The modelling highlights the significance of the risk of erosion over pillars.

Figure 3-7: Predicted change in hydraulic parameters post subsidence for 250 m^3/s flow

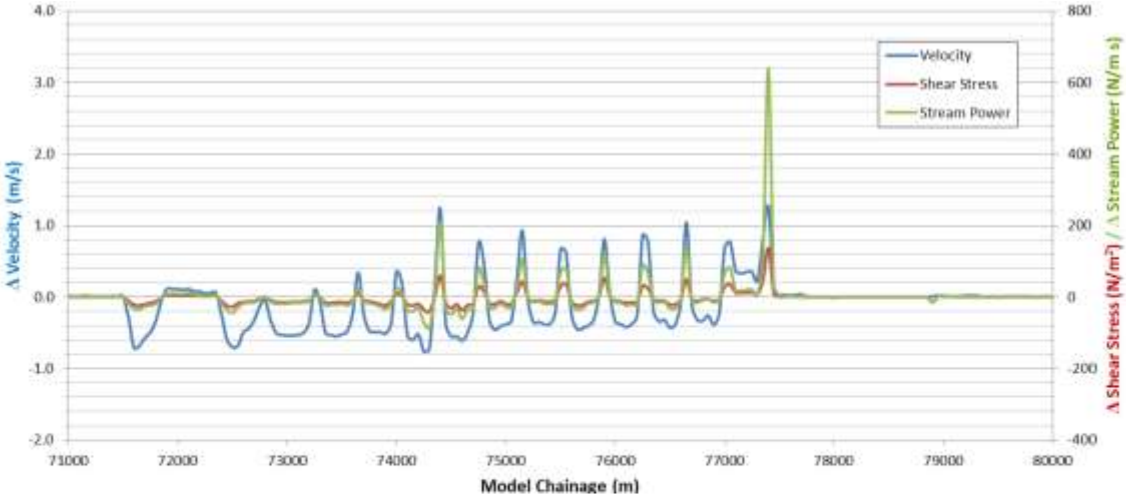


Figure 3-8: Predicted change in hydraulic parameters post subsidence for 1000 m^3/s flow

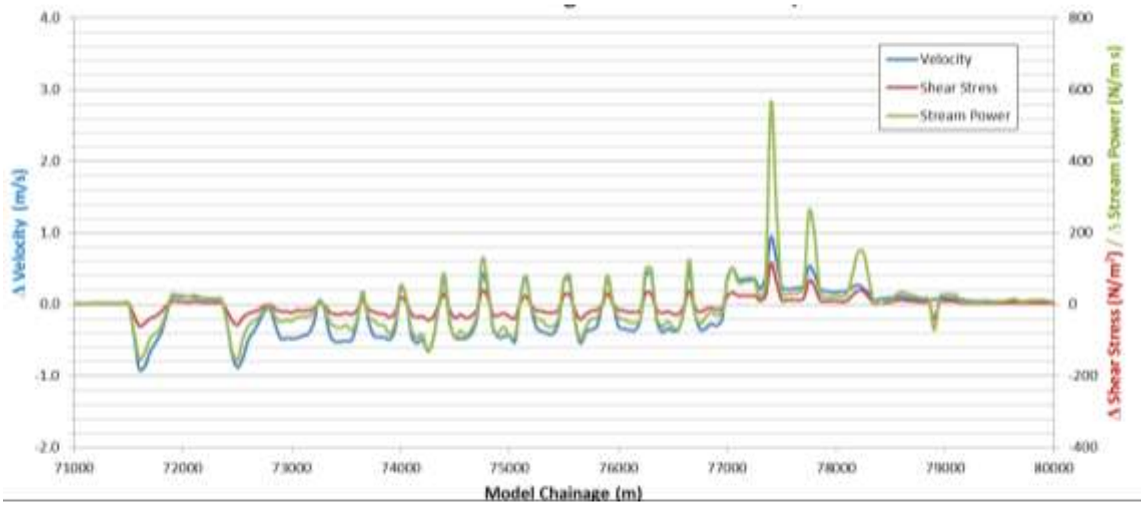


Table 3-4: Predicted change post subsidence when compared to existing for 250 m^3/s flow scenario

PANELS LW109 – LW121	Velocity (m/s)		Shear Stress (N/m²)		Stream Power (N/m.s)	
Maximum Change	-0.8	-55%	-40.5	-80%	-85.8	-90%
Average Maximum	-0.5	-42%	-22.2	-67%	-35.1	-80%
Median Maximum	-0.5	-44%	-21.2	-69%	-31.8	-83%
PILLARS LW107/8 – LW120/21	**Velocity (m/s)**		**Shear Stress (N/m²)**		**Stream Power (N/m.s)**	
Maximum Change	1.2	83%	59.8	218%	208.3	472%
Average Maximum	0.6	52%	29.4	116%	76.9	249%
Median Maximum	0.8	64%	33.0	121%	81.3	254%

Table 3-5: Predicted change post subsidence when compared to existing for 1000 m^3/s flow scenario

PANELS LW109 – LW121	**Velocity (m/s)**		**Shear Stress (N/m^2)**		**Stream Power (N/m.s)**	
Maximum Change	-0.9	-44%	-61.0	-70%	-155.6	-83%
Average Maximum	-0.5	-28%	-35.5	-49%	-89.1	-62%
Median Maximum	-0.5	-28%	-35.7	-49%	-82.7	-63%
PILLARS LW107/8 – LW120/21	**Velocity (m/s)**		**Shear Stress (N/m^2)**		**Stream Power (N/m.s)**	
Maximum Change	0.5	83%	38.9	69%	128.8	119%
Average Maximum	0.3	45%	22.5	39%	67.1	64%
Median Maximum	0.4	43%	25.5	48%	76.6	78%

2D hydraulic modelling of the current BRM mine plan for existing conditions and post subsidence has been undertaken to assess the changes to runoff as result of panel catchments and assist with identifying areas at risk of geomorphic change.

Graphical outputs from the 2D modelling of the 2 year ARI, 50 year ARI and 1000 year ARI are presented as Figure 3-10, Figure 3-11 and Figure 3-12**.**

It should be noted that although this modelling is considered a good representation of the likely pre and post subsidence runoff at a whole of mine plan scale, it is limited by the 10 m grid resolution of the 2D model. Finer resolution assessment would be undertaken to manage post subsidence flow paths as determined by geomorphic risk.

Flow paths generally form down the centre of the subsided panels. With the current panel alignment, LTCC occurring on the floodplain and the natural or artificial levee of the Isaac River, the majority of panels will pond water until they fill and spill into the Isaac River, based on modelling this occurs from events greater than 2 year and less than 50 year. The large gully that has developed in the east bank of the diversion channel (see **Figure 3-9**) in what will be LW114 is likely to have its contributing catchment reduced; however it will remain active and is likely to capture some upstream panels through gully erosion in the future. With panels LW108-113 capturing drainage, they may also develop major gullies from the spill point into the diversion similar to that gully. This will require management to mitigate impacts.

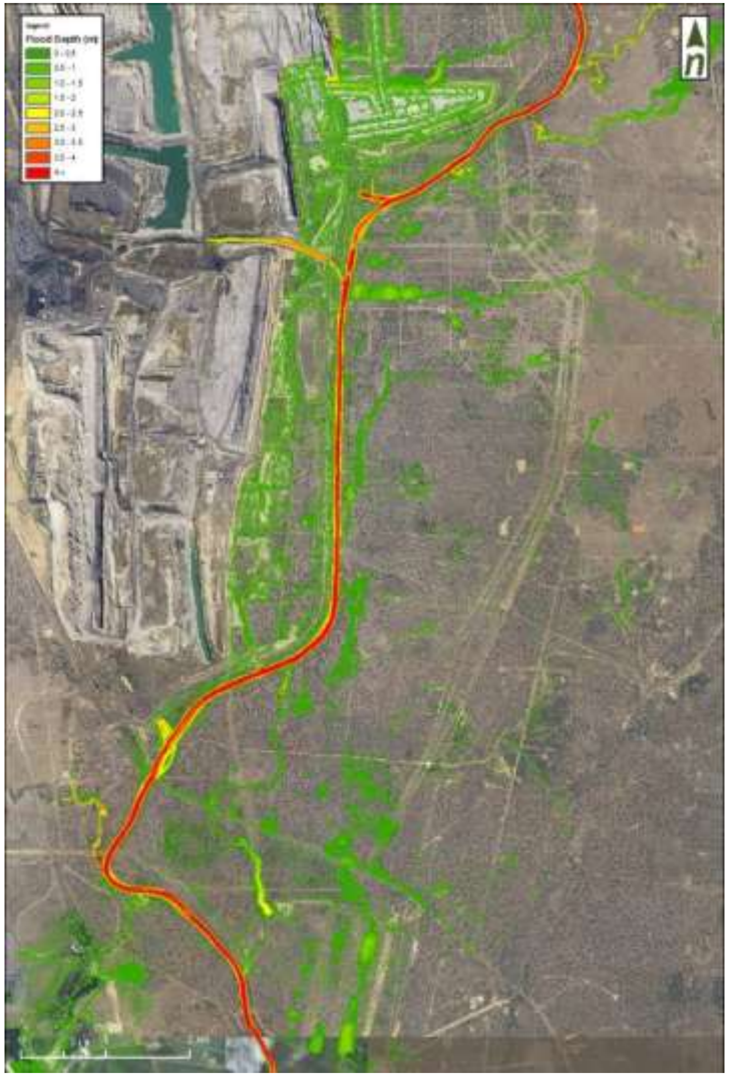
Panels LW120-127 are expected to fill and spill into a discontinuous watercourse which drains to the south, under the Goonyella Rail Line, re-joining the Isaac River approximately 2km downstream. This will produce a significant reduction in flow in this minor tributary. The environmental gain will be the development of ephemeral wetlands.

There is the potential for incision or bed and bank instability to occur where minor tributaries and overland flow paths drop into the subsided panel catchments or over pillar zones (inter-panel). Monitoring of these areas will be incorporated into the subsidence monitoring program progressively to determine if and when management actions are required.

Figure 3-9: Gully developed from diversion channel into eastern terrace

Figure 3-10: Flood depths for a 2 year ARI flow event for existing conditions and post subsidence conditions

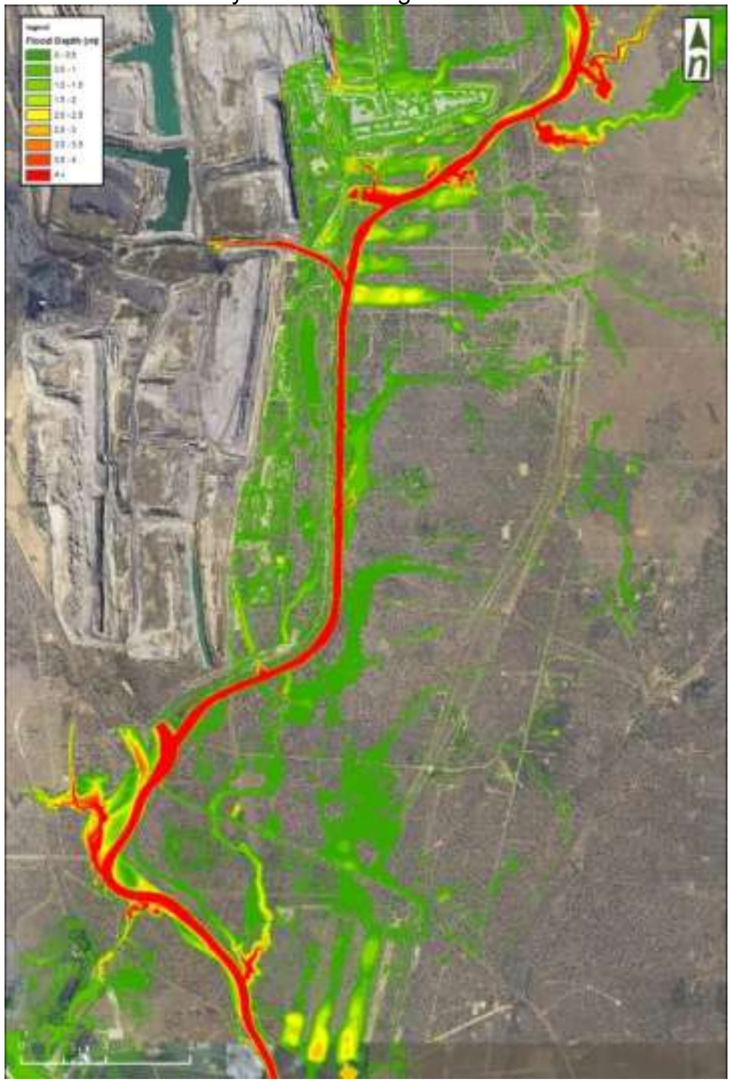
2-yr ARI – Existing Conditions



2-yr ARI - Post subsidence

Figure 3-11: Flood depths for a 50 year ARI flow event for existing conditions and post subsidence conditions

50-yr ARI –Existing Conditions



50-yr ARI - Post subsidence of North Underground

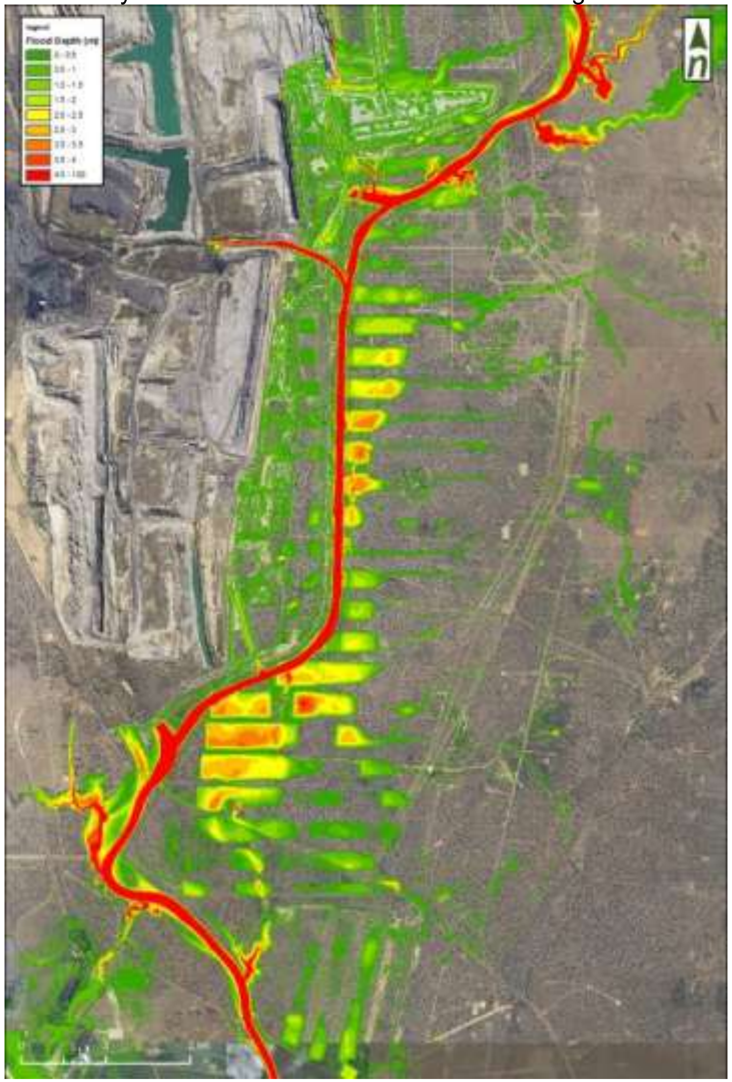
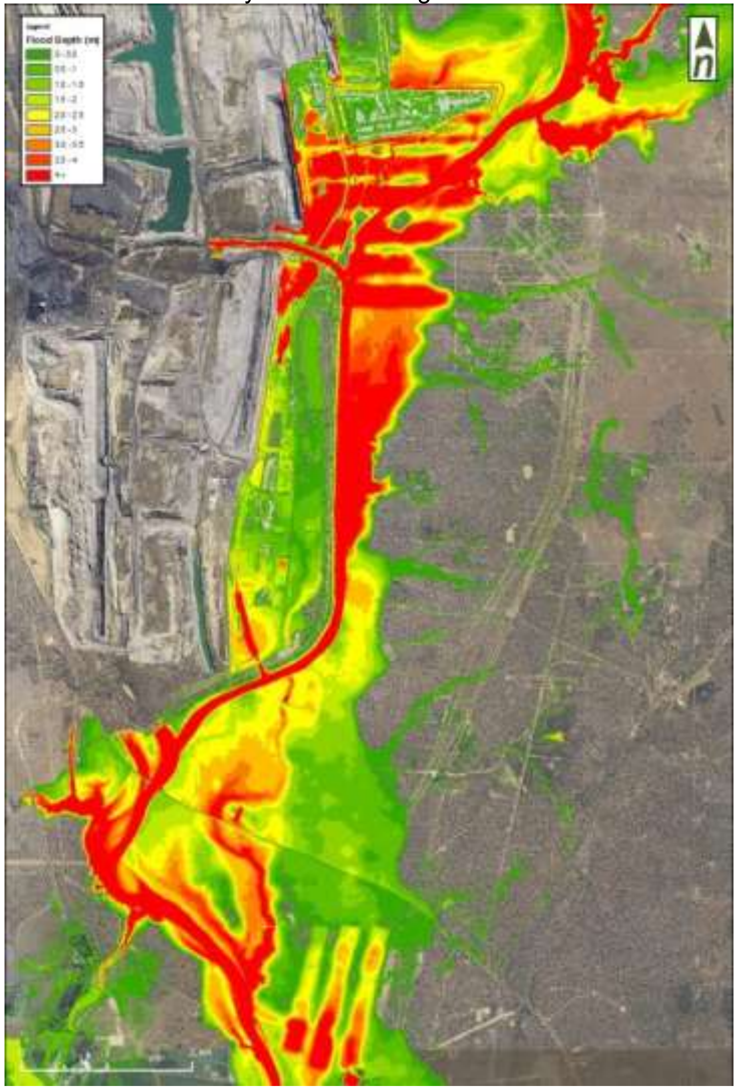
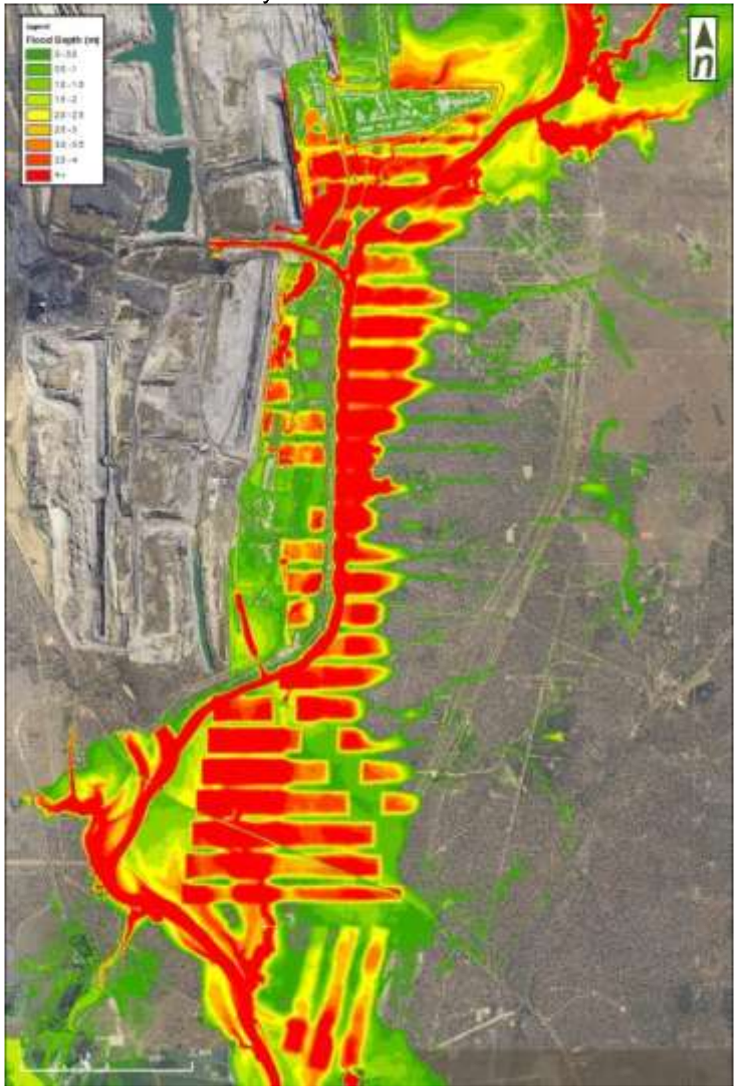


Figure 3-12: Flood depths for a 1000 year ARI flow event for existing conditions and post subsidence conditions

1000-yr ARI – Existing Conditions



1000-yr ARI - Post subsidence



3.2.2 Sediment Transport Assessment

3.2.2.1 Outcomes of the 2008 IRCIA

The IRCIA derived sediment transport rates for the Isaac River for a range of flows to create a flow rate vs. sediment discharge curve for each reach of the Isaac River. This rating curve was then applied to the estimated mean daily flow for the period 1898 to 1995 to provide an estimate of sediment transport over a 97 year period. The analysis provides an estimate of anticipated sediment transport for a 100 year period (approximately) and can be used to provide an indication of potential further sediment transport rates assuming that future flow rates are similar to that for the past 100 years. The results should be used with some obvious cautions and do not account for land use or climate change. In addition sediment transport estimates are very difficult and models are prone to error. Nonetheless, the results provide some indication of the order or magnitude and range of sediment transport rates.

For the Isaac River diversion reach (Reach 3 of IRCIA), it was found that the annual mean sediment transport rate was approximately 52,000 cubic metres per annum (highlighted in **Table 3-6**, below). However, it was found that there is also high inter-annual variability with the annual rates ranging between 0 and 1.2 million cubic metres.

Table 3-6: Sediment Discharge estimates taken from CIA for BRM and reaches upstream

CIA Reach ID	Total sediment discharge 1898 – 1995 (m^3)	Annual mean discharge (m^3)	Annual maximum discharge (m^3)	Annual minimum discharge (m^3)
Reach 1	6,989,051	72,052	1,532,758	0
Reach 2	5,190,302	53,508	1,389,793	0
Reach 3	*5,027,670*	*51,832*	*1,193,143*	*0*

[1] Integrated Quality and Quantity Model (IQQM) Mean Daily Flow Data for 1898 – 1995, provided by DERM.

Overall, the 2008 IRCIA showed that in the long term (>50 years), the amount of sand already in the river system is likely to substantially exceed the volume of the subsidence voids. However, how the river responds in the short term depends largely on the flow regime in relation to amount of subsidence. It may be that there are five years where no flow occurs that is able to mobilise bed sediment into subsidence voids, in which case there could conceivably be multiple longwalls waiting to be infilled. The geomorphic response at the local level could be quite substantive.

The BRM diversion reach was predicted to see the maximum amount of subsidence, equivalent to a 1.82m strip depth (over the reach) resulting after 10-15 years of mining. Based on the analysis of the historical flow record, there was less than a 50% probability of infilling occurring within this period and a possibility that infilling could take up to 25 years after the cessation of mining (2048). Within this period it was identified that there was a significant risk of subsidence induced incision or widening impacting on the stability of the existing Isaac River diversion.

3.2.3 Observations of sediment transport and infilling of subsidence troughs

The infilling of longwall panels LW103, 104, 105 and 106 has been observed during annual physical condition monitoring undertaken since 2007. A brief overview of these observations follows.

Longwall LW104 was the first panel to fully extend beneath the Isaac River in late 2008, creating a subsidence void in-channel of approximately 33,000 m^3. Subsequent stream flow in early 2009 partly infilled this void, moving mobile bed sands approximately 40 m into the subsidence panel. This slug of mobile sediment was noted to be approximately 2 m above the subsidence trough invert as shown in Figure 3-13.

Figure 3-13: Downstream view in channel over sand slug moving into subsidence trough of LW104 (2009 monitoring)

A cluster of small to moderate flows occurred through February to April 2010, infilling the remaining void of subsided panel LW104 and partly infilling the LW105 panel, which subsided the River in late 2009. Upstream and downstream views in Figure 3-14 and Figure 3-15 respectively, taken from near the pillar of LW104-05, show LW104 infilled and bed sediments moved an estimated 150 m into the subsided trough of LW105. In total, these bed sediments were moved approximately 600 m.

Figure 3-14: Upstream view from pillar LW104-05 showing subsidence trough LW104 infilled (2010 monitoring)

Figure 3-15: Downstream view showing slug of mobile bed sands moving into subsidence trough of LW105 (2010 monitoring)

Deepening of the mobile bed downstream of the LW105 trough was also observed during the 2010 monitoring, with approximately 1.5 m of deepening occurring on the 105-106 pillar zone, exposing the Permian bedrock and widening the low flow channel, while the pile fields installed prior to subsidence to protect the toe of the bank, performed as intended (Figure 3-16). This deepening impact, predicted due to clear water erosion (a sediment supply limited situation) from sediment not moving through the subsidence trough, continued downstream with diminishing severity for approximately 500 m as shown in Figure 3-17.

Figure 3-16: Deepening of approximately 1.5m observed over pillar LW105-06 (2010 monitoring)

Figure 3-17: Deepening progressing downstream of LW105 exposing Permian bedrock and widening low flow channel

The extended 2010-11 wet season resulted in large and sustained flows in the Isaac River; up to an estimated 10 year ARI based on the daily mean flow measured at the Goonyella gauge. These large flows for an extended duration had the capacity to transport large volumes of sediment. Greater than 50,000 m3 of bed load sediment was deposited into the subsidence trough of longwall LW105 completely infilling it and re-supplying the section of channel downstream from LW105 that had deepened in the previous wet season.

Longwall LW106 is the first panel in the diversion. It had subsided the Isaac River by late 2011 and was infilled during the March 2012 flows generated by widespread rainfall. The flows were not as great in magnitude as those experienced in the previous wet season but there was an extended duration of mean daily flows greater than 300 m^3/s, sufficient to infill the subsidence trough with near to 70,000 m^3 of sediment.

The downstream progressing deepening was noted to have extended to 3 km downstream of LW106, with bench retreat continuing to occur rapidly in places. Deepening through this section of the diversion since 2008, is of the order of 0.8-1.2 m. A comparison of the diversion channel between 2010 and 2011 monitoring rounds is shown in Figure 3-18.

One of the positive impacts from deepening is the creation of aquatic habitat, with the diversion having some of the most diverse aquatic habitat in the upper Isaac River, which has been noted to persist through extended periods of low and no flow.

Figure 3-18: The Isaac River diversion showing the bed stripped and bench retreat between the 2010 and 2011 monitoring

3.2.3.1 Bed material sediment rating curves

The 2008 IRCIA provided estimates of the Isaac River's capacity to transport bed material based on existing hydraulic modelling of the post subsidence terrain prior to geomorphic response. A range of empirical functions are available in HEC-RAS, the Ackers-White function (A-WF) was selected based on its applicability to fine to coarse sands. Furthermore, substantial flows in 2008 resulted in the infilling of two subsidence troughs at Moranbah North and allowed for a comparison of the A-WF predictions to observations. The A-WF was considered to be over-predicting with estimates approximately double observations of deposition; however, with the limited comparison data available and the uncertainty in sediment transport modelling, the rates were considered reasonable to adopt. This update of the BRM SMP has allowed for these sediment transport rates to be revisited considering:

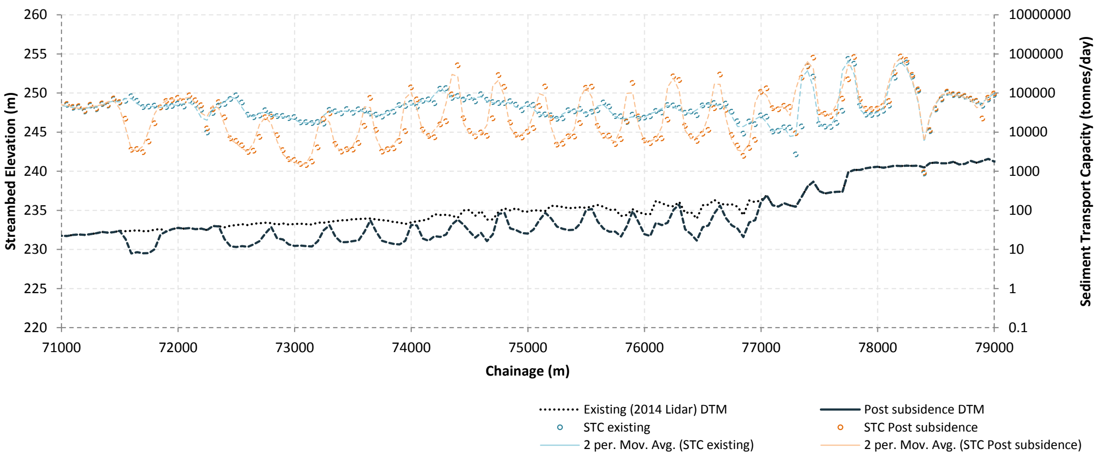
- The availability of LiDAR datasets for the Isaac River in 2008, 2012 and 2014
- Refinement of bed area and manning's roughness based on recent LiDAR, aerial imagery

- Water temperature settings in the model based on monitoring data for the Isaac River

- Also, the modelling results could be tested against field observations of sediment movements and infilling of multiple subsidence troughs at BRM.

The predicted bed material transport capacity (STC) for the selected flow of 500 m^3/s through the BRM reach pre and post subsidence is profiled in Figure 3-19. Similar to the hydraulic modelling results, reduced sediment transport capacity is predicted through subsidence troughs and generally slightly higher values over the intermediary pillar zones. Sediment transport capacities are generally predicted to reduce by greater than an order of magnitude through subsidence troughs.

Figure 3-19: Bed material transport capacities for 500 m^3/s flow through BRM reaches



A bed sediment rating curve for the Isaac River upstream, downstream and through BRM reach has been derived from modelling based on the 2014 LiDAR dataset. The flow discharge relationships shown in **Figure 3-20** are based on mean values.

When applied to the mean daily simulated flow record from 1898 to 1995 as shown in Table 3-7, these STC rating curves produce considerably lower annual average rates than adopted for previous studies at BRM.

Figure 3-20: Bed sediment transport capacity rating curves for the Isaac River

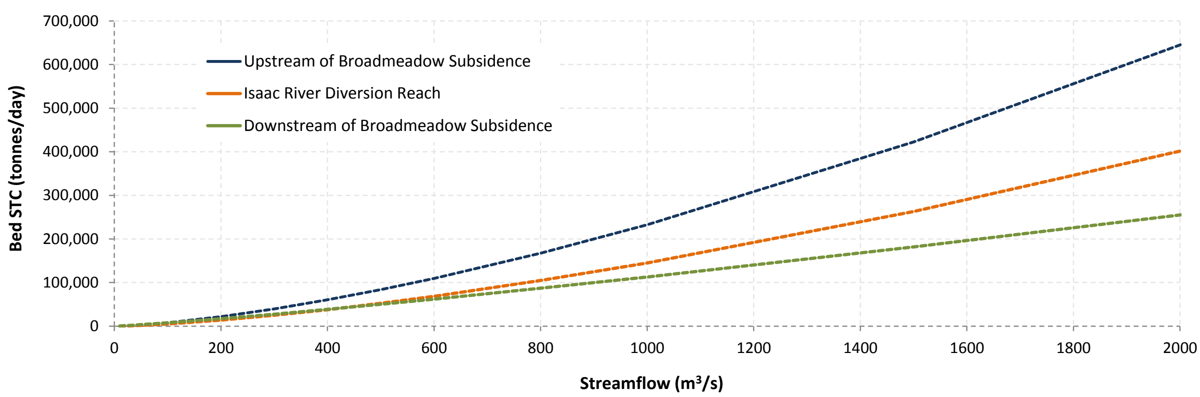


Table 3-7: Sediment Discharge (m3) estimates for Broadmeadow Mine reaches

CIA Reach ID	Annual mean discharge (m^3)	Annual maximum discharge (m^3)	Annual minimum discharge (m^3)
Upstream of Broadmeadow Subsidence	27,975	441,735	0
Isaac River Diversion Reach	17,962	282,973	0
Downstream of Broadmeadow Subsidence	25,101	298,196	0

[1] Integrated Quality and Quantity Model (IQQM) Mean Daily Flow Data for 1898 – 1995, provided by DERM.

Modelling of the infilling of subsidence troughs created by LW104, LW105 and LW106 has been undertaken utilising the revised STC rates and flow data for the corresponding timeframe for infilling. This modelling is presented in Figure 3-21 to Figure 3-23.

The volume of bed sediment transported through these flow events suggests good agreement with the rate of infilling and deepening observed in the field for upstream of the diversion.

Subsidence troughs LW107 and LW108 are not yet infilled so a comparison with the predicted STC rate for the Isaac River diversion reach is not possible at this stage. However, the Isaac River diversion has undergone substantial deepening and bench retreat since the 2008 IRCIA which would reduce the sediment transport rate through this reach as predicted.

Figure 3-21: Modelled infilling of subsidence void LW104 with bed load at BRM

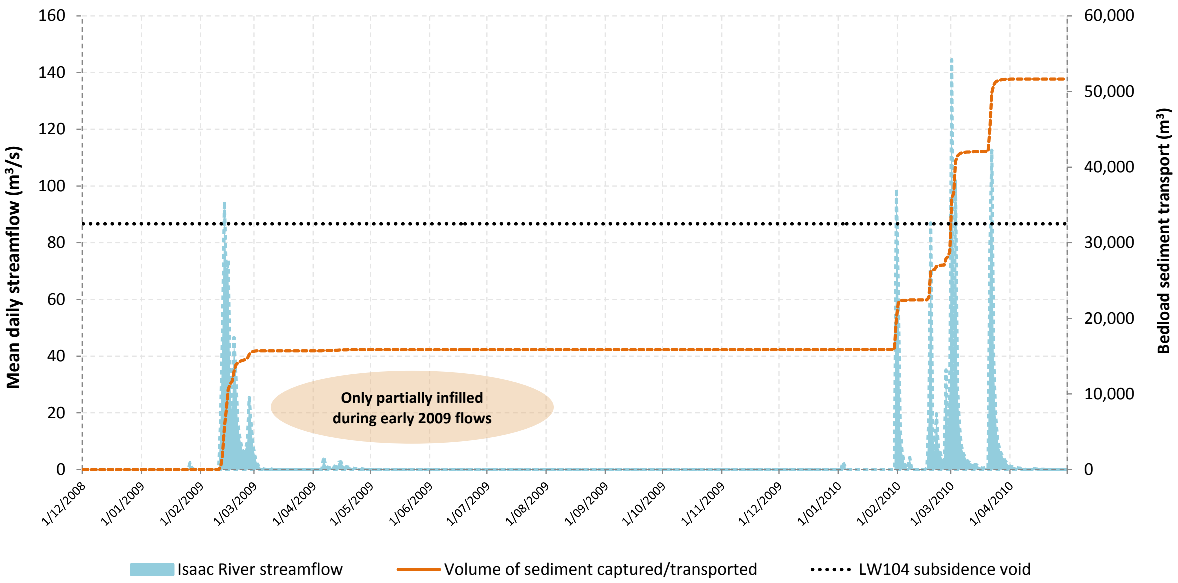


Figure 3-22: Modelled infilling of subsidence void LW105 with bed load at BRM

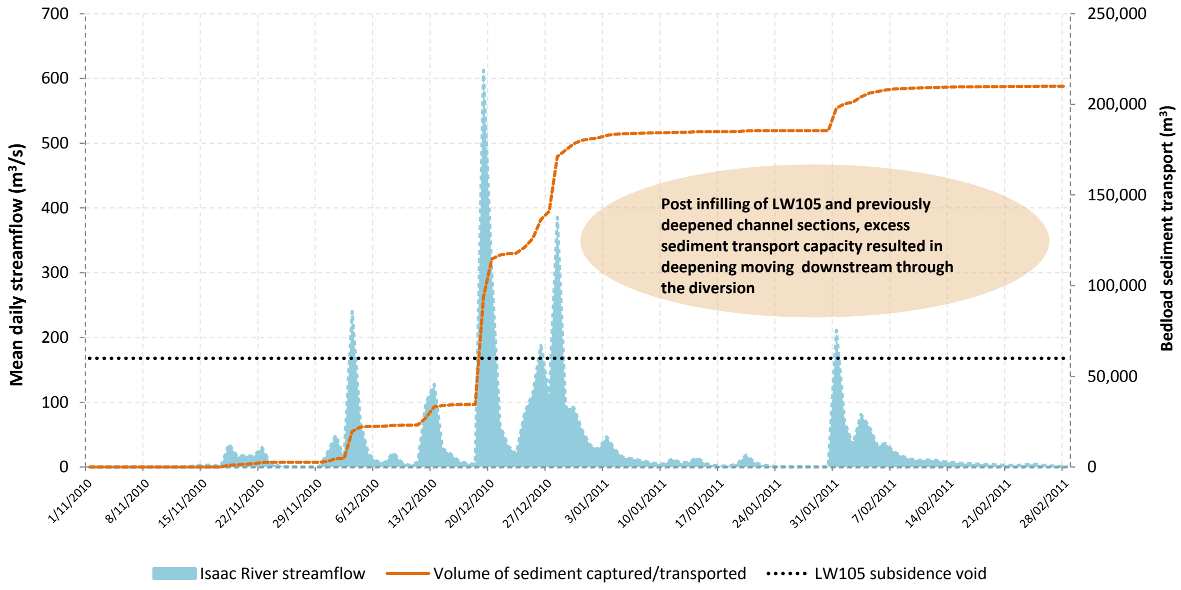
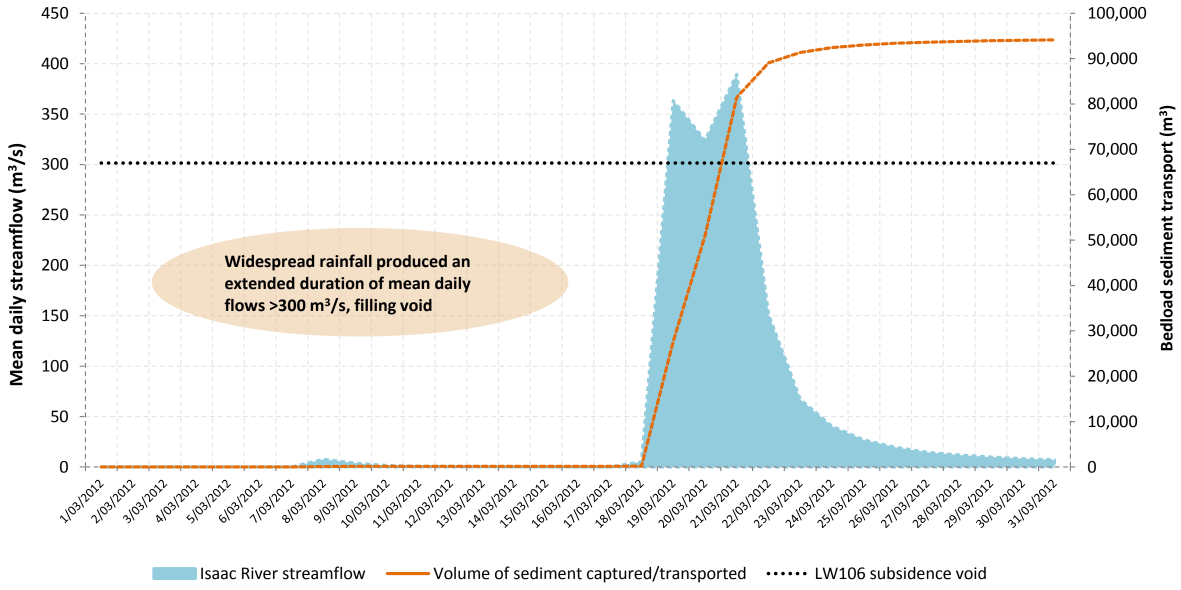


Figure 3-23: Modelled infilling of subsidence void LW106 with bed load at BRM

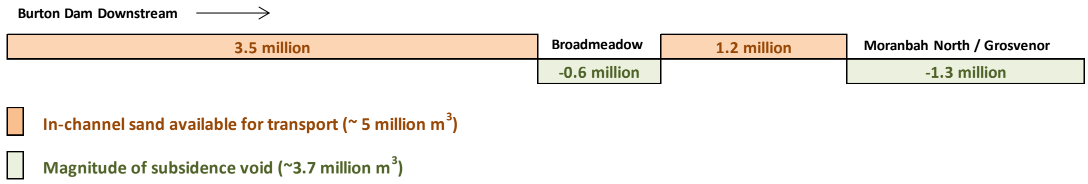


3.2.3.2 Sediment budget analysis

The current amount of mobile bed sediment available for transport in the Isaac River channel upstream of BRM diversion reach has been estimated at approximately 3.5 million m3. This is based on the sand bed area, multiplied by an average depth of 2 m. The 2008 IRCIA adopted an average mobile sand depth of 3 m however, this in now considered an overestimate through the upstream reach based on recent test pit investigations and observations.

The estimated quantity of sand currently available in-channel for sediment transport compared to the predicted subsidence volume in the diversion reach is presented graphically in Figure 3-24.

Figure 3-24: Approximate quantities of in-channel sand compared to the predicted subsidence void



At a macro level there is sufficient mobile bed sediment in the Isaac River upstream of the BRM diversion reach to overwhelm the subsidence voids. However, at the local scale, the interruption to sediment supply post subsidence results in downstream progressing deepening. As previously discussed, the observations during annual monitoring are that substantial deepening through the diversion has already occurred which can be attributed to the subsidence upstream.

Comparison of 2008, 2012 and 2014 LiDAR data was undertaken to determine the volumetric changes in bed sediment from toe of bank to toe of bank across the bed of the channel (which includes any bench retreat that may have occurred). This comparison shows that approximately 155,000 m^3 of deepening occurred over the 4 year period from 2008 to 2012. A further 55,000 m^3 was stripped due to the clear water erosion effect during the 2 year period from 2012 to 2014 as shown in Table 3-8. Figure 2-13, provides the cross section at the LW111-12 pillar that confirms this quantum of response.

Table 3-8: Channel bed response to subsidence 2008-14

LiDAR comparison	2008	2012	2014	Total
2008	0 m^3	-155,000 m^3	-210,000 m^3	
Void created	-	-155,000 m^3	-55,000 m^3	-210,000 m^3

An assessment of the actual observed stripping that has occurred from 2008 to 2014 in the proposed longwall panel LW110 has been utilised to provide an estimate of the potential scale of bench retreat that might occur when a harder control, such as bedrock in the channel bed, be encountered by the channel whilst undergoing clear water erosion.

In the case of LW110, approximately 11,900 m^3 of material was stripped from the bed of the channel from 2008 to 2014. If this same volume of material was removed from the channel benches over the same time period due to the presence of bedrock being encountered prior to the commencement of bed stripping, an estimated 6 m of bench retreat would have occurred on both benches. This is based on an assumed uniform bench height of 3m and no additional work being required by the channel to move bench material compared to bed material. Bed stripping and early stages of bench retreat are shown in Figure 3-25 and Figure 3-29.

In some instances, the bench that supports the 6-8m high steep unstable banks of the diversion is presently no greater than 6-8m wide. Should the benches be removed from the toe of bank, fluvial erosion of those banks is likely to be substantial. In other instances, bench width is 15-20m, with substantial vegetation establishment. The likelihood of bench retreat to the high bank toe in those instances is much lower, hence potential for substantial increase in bank erosion is less.

Based on the observations of sediment movements in the Isaac River and lower sediment transport rates, the timeframes for the infilling of subsidence voids and management of the risk of subsidence induced incision and widening could potentially be longer than the 25 years after cessation of mining that was derived in the 2008 IRCIA from analysis of the historical flow record.

Figure 3-25: Early stage bench retreat toward high bank following near complete stripping of bed sediment

Figure 3-26: Channel bed stripped to weathered weak bedrock and clays

3.2.4 Potential Avulsion and Lateral Migration Risk

Post subsidence and the infilling of subsidence voids with sand, there is increased engagement between the Isaac River and its floodplain. Despite this increased floodplain engagement, the potential for avulsion of the Isaac River through the diversion is low due to terrace confinement and that most panels subside the river perpendicular to flow.

With adoption of HRL mining under the river and LTCC beyond the river, the differential between the infilled channel bed and terrace or floodplain surface ~100m beyond the channel will be ~1m less. This will provide a small incremental increase in the risk of scour in flood flow outside the channel as opposed to a case of either all LTCC or all HRL mining.

The meander bends at the upstream and downstream extents of the Isaac River diversion migrated following consecutive of large flow events in the late 1980s and early 1990s that occurred soon after the diversion's construction. Further migration of the channel in these areas has largely been arrested through the use of pile fields and revegetation establishment, creating a bench at the toe of the near vertical banks and providing them some protection. For the upstream meander bend, the low flow channel shift post subsidence of LW106 in 2011 has increased the risk of bank erosion. At the downstream meander bend, the existing vegetation is expected to continue to provide protection post subsidence, however there are locations where the bench is very narrow and accelerated high bank erosion is likely.

The risk of bench retreat, bank instability and subsequent widening of the straight section of the diversion channel is greatest over the pillar zones between longwall panels, due to the rapid drawdown of the water surface. This risk will reduce as the subsidence voids infill with sand and it is considered a short term issue currently managed with the installation of pile field sets prior to subsidence. Figure 3-28 illustrates the locations in the Isaac River where bank erosion management has been implemented and where bank erosion management will potentially be required on pillar zones. Photographs of pile fields implemented at BRM performing the role of bank erosion management in the Isaac River are shown in Figure 3-27.

Downstream progressing deepening due to clear water erosion is more difficult to manage. However, the resilience of the diversion could be improved with the battering of vertical banks and revegetation. Mitigation works are discussed further in Section 4 with the performance of existing structures outlined Section 2.8.2.2.

Toward the downstream end of the current BRM mine plan toward the end of the diversion, there is potential for interaction of flood flows into subsidence in the adjacent Moranbah North mine lease. The risk of avulsion in this location during a large flood event is mitigated to a large extent by the rail embankment so long as it remains in place.

3.2.5 Changes to existing tributaries and overland flow paths

Longwall mining creates panel catchments with flow paths generally forming down the centre of the panel. With the current panel alignment and the natural or artificial levee of the Isaac River, the majority of panels will pond water until they fill and spill along their existing course or directly into the Isaac River.

Existing conditions and post subsidence terrain and major flow paths are shown in Figure 3-29 and Figure 3-30.

There is the potential for incision or bed and bank instability to occur where minor tributaries and overland flow paths drop into the subsided panel catchments; also at newly formed confluences (where panel catchments spill into the Isaac River) or over pillar zones (inter-panel) as shown in Figure 3-31. Table 3-9 details the number of potential locations identified, consequences and potential mitigation measures. Monitoring of these areas will be incorporated into the subsidence monitoring programme to determine if and when management actions are required.

Table 3-9: Potential locations at risk of instability/erosion, consequences and mitigation measures

Risk	No. of potential locations identified	Consequence	Potential mitigation measures
Potential incision / headcut	33	Progressive upstream erosion	Construction of rock chutes to convey concentrated flows over steep gradients (i.e. from outside longwall panel into the base of longwall panel)
Potential instability from panel catchment flows	28	Formation of bank gully erosion resulting from panel catchment flows into existing tributaries or the Isaac River.	Implementation of bank protection measures such as rock armouring or the construction of rock lined batter chutes to convey concentrated panel flows into existing tributaries or the Isaac River.

		Bank erosion in existing tributaries over pillar zones	Implementation of bank protection pile fields.

Figure 3-27: Photographs of bank erosion management pile fields implemented at BRM

Figure 3-28: Potential areas of instability and accelerated erosion post subsidence – Isaac River

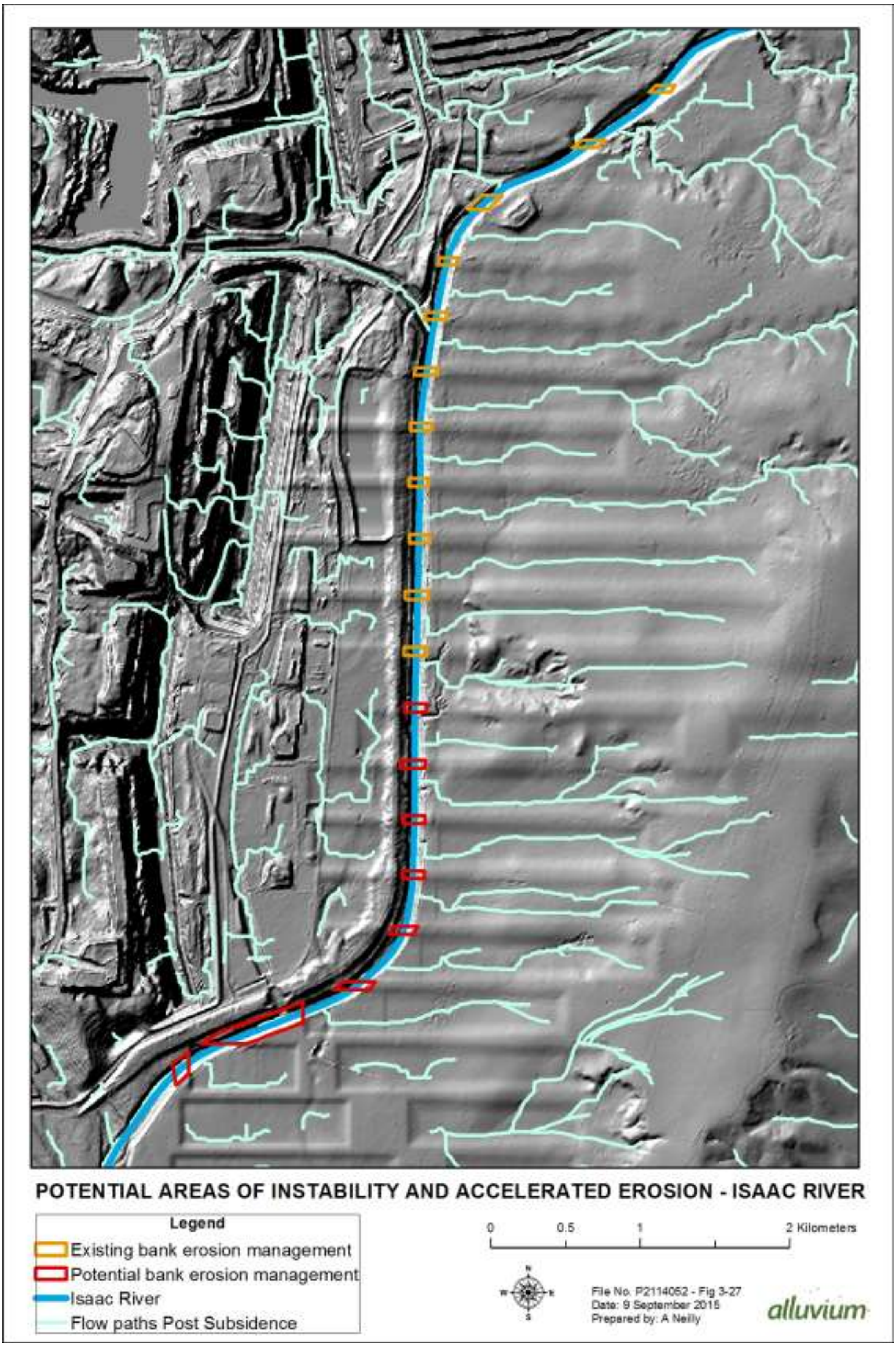


Figure 3-29: Flow paths and existing conditions digital terrain model

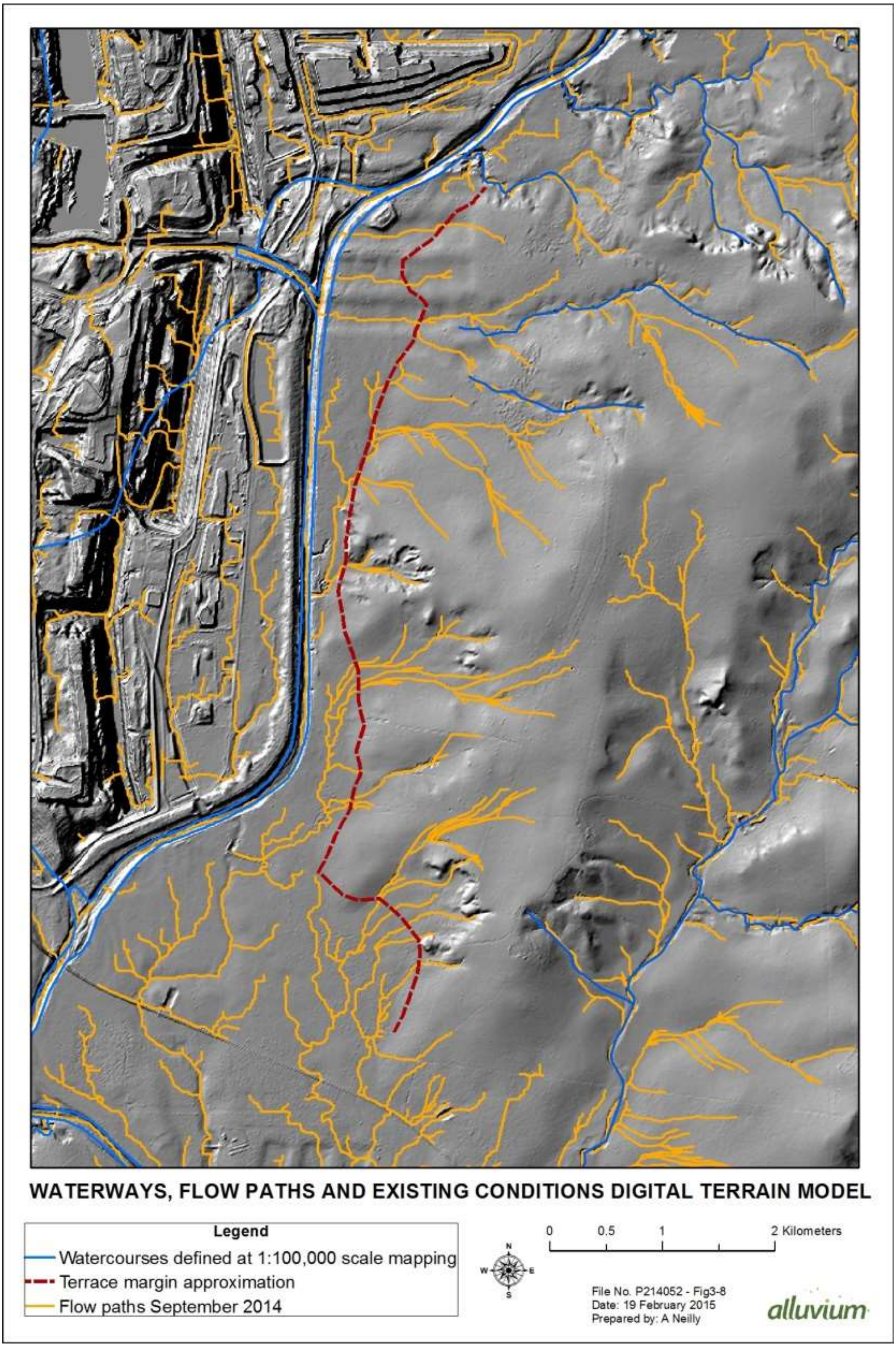


Figure 3-30: Comparison of changes to major flow paths for post subsidence digital terrain model

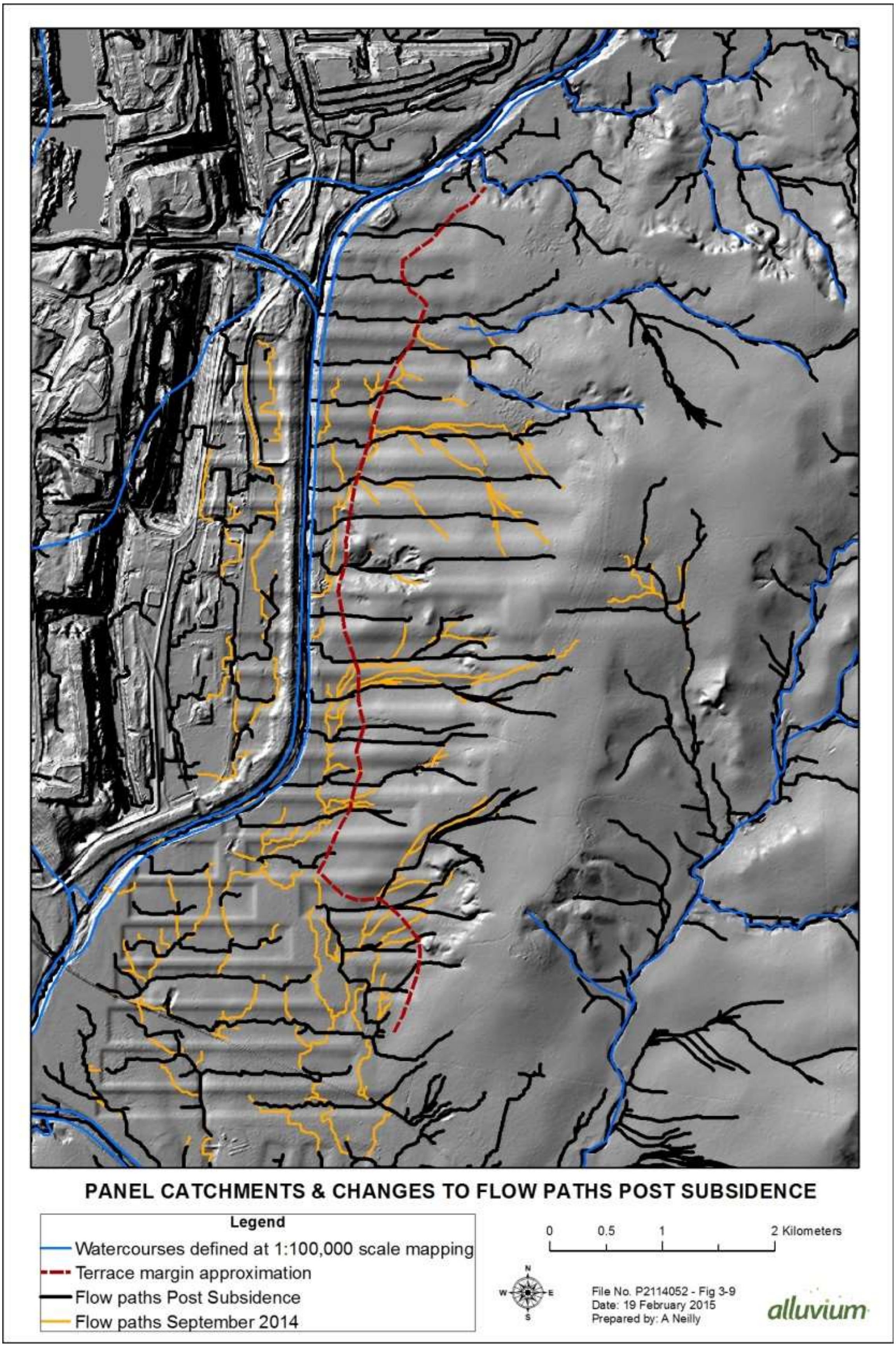
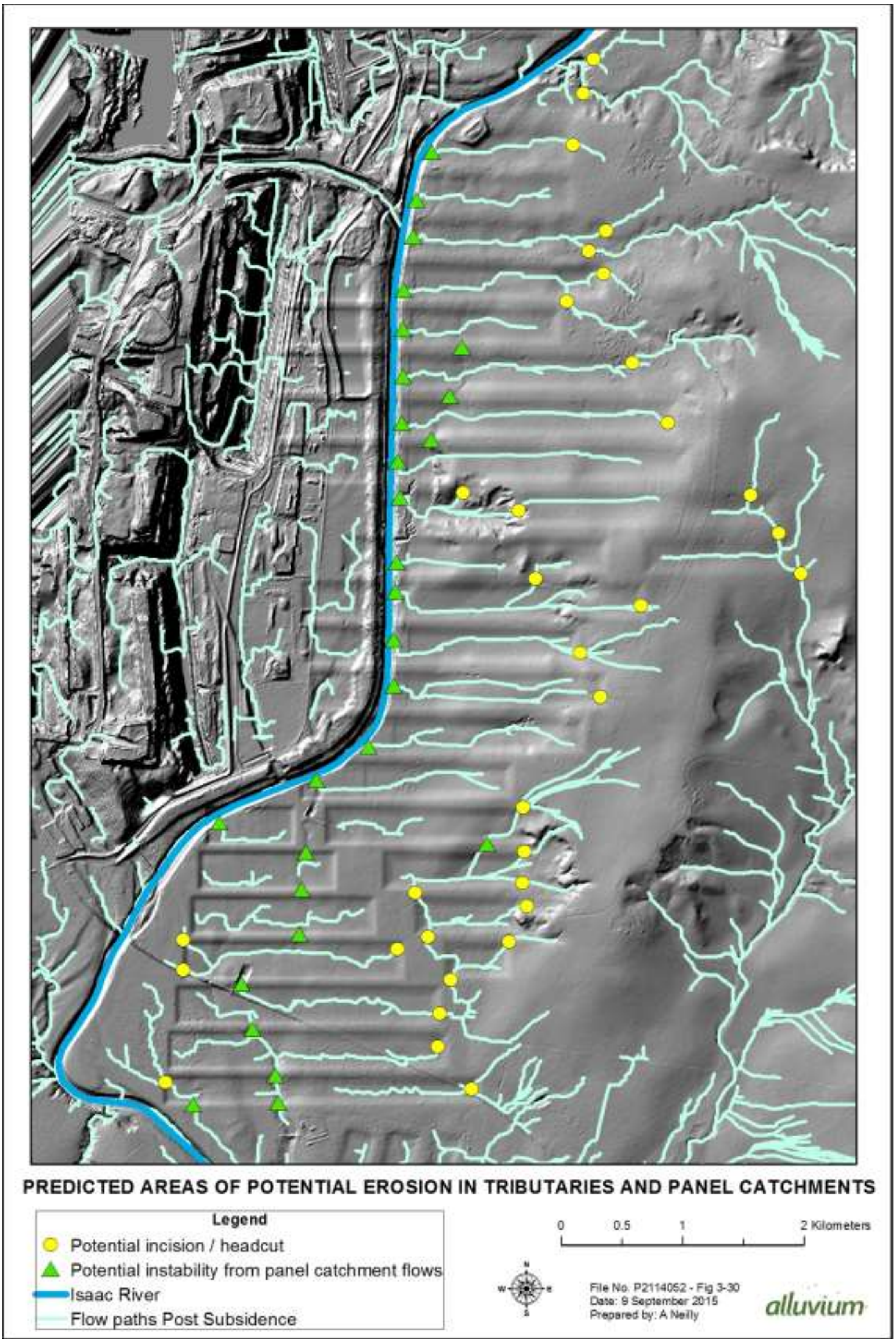


Figure 3-31: Areas identified for potential erosion in tributaries and panel catchments



3.2.5.1 Land Surface Cracking

The formation of a subsidence trough above an extracted longwall panel is explained in Figure 3-1. In simple terms, the tension and compressive forces following coal extraction will result in:

- Tension cracking along the chain pillars in the direction of mining (i.e. parallel), extending approximately 20-40m either side into the panels; and

- Humping and surface cracking across the centre of the panel perpendicular to the direction of mining.

These cracks render the soil profile vulnerable to rill erosion, which in turn can lead to gully erosion. These processes can then lead to the formation of deep fissures.

Changes in soil structure such as the formation of vertical cracks and fissures in the soil profile can lead to below-ground stress on the roots of trees and shrubs. Where voids created by stress fractures occur, there can be localised “root shearing”. This can result in lateral roots being severed from the main tap root. This in turn can lead to the decline and death of trees/shrubs. Cracking can also damage root systems by exposing the roots to heat stress from insolation penetrating the vertical voids in the soil profile created by the cracks, (Earth Tech, 2006).

Although effects on vegetation condition, particularly deep rooted canopy species as a result of subsidence, may take years to manifest, and may even go un-noticed until drought-stress induces crown dieback, current monitoring includes annual observations.

The magnitude of subsidence related effects is linked to a number of dependent and independent variables including but not limited to soil structure and condition, soil type, soil sodicity, groundwater levels, drought and even proposed tension crack amelioration procedure. Therefore the magnitude of the effect of subsidence in the long term is difficult to predict.

Monitoring to date of cracking in LW101-103 which are within the Isaac River terrace with very little relief, is indicating that in the heavier soils, many of the tension and compression cracks sealed and somewhat infilled. Many of the cracks in the lighter soils also sealed and partly infilled but not as comprehensively. The cracks remain in these lighter soils, however due to limited relief in the Isaac River terrace no further erosion such as tunnel or gully development has occurred. This has guided the management of these areas to date, which has been to not undertake clearing and ripping of cracks as is the common approach across underground mines in the Bowen Basin. The treatment of cracks is recommended only where potential for future problems exist.

The eastern end of LW107 and LW108 are the first panels to subside rising ground to the east of the Isaac River terrace. Cracks have developed from both tension (parallel with longwall) and compression (perpendicular to longwall) where there is some slope and dispersive soils. It is in that terrain that erosion issues are likely to develop, as has been observed at other Bowen Basin mine sites. However, limited rainfall has occurred since these subsided. Continued monitoring of pillars and panels post subsidence; and in particular, areas of hill slope, will inform management of cracks in this terrain in the future.

3.3 WATER QUANTITY AND QUALITY (3RD ORDER IMPACTS)

3.3.1 Changes to water quantity

Understanding how much water is potentially captured in subsidence panels and its fate can inform decisions in relation to downstream flow targets and the management actions required to meet them. Capture of water in the landscape or channels has the potential to be both a positive and negative impact, depending on existing conditions, broader catchment conditions and which user is considered.

2D modelling of the 10m digital terrain grids provided by STC (2014) has been used to estimate the ponding of water in the landscape pre and post subsidence.

The 2 year ARI, 50 year ARI and 1:1000 AEP flow events were selected to represent a small event that could be expected to occur frequently; a moderate event and a larger magnitude infrequent event that would be expected to produce maximum ponding within subsided panels. **Figure 3-32** shows the 2, 50 and 1000 year ARI hydrographs extracted from the 2D model for the Isaac River downstream of the BRM subsidence and confluence with the unnamed tributary capturing flow from panels LW120 to LW127 flowing south under the rail line.

With regard to the Isaac River streamflow, the creation of subsidence voids and panel catchments is predicted to result in reductions of 482, 3,430 and 6,513 ML for the 2, 50 and 1000 year events respectively, as shown in **Table 3-10**. Similar volumes are stored in the panel catchment created from subsidence as shown in **Table 3-11**. Please note, an extended model run time would see these values converge so that the change in hydrograph volume should equal the extra volume stored over the panels.

Table 3-10: Predicted changes to Isaac River streamflow

	Predicted volume changes from hydrograph	
ARI	m^3	ML
2 year	- 479,633	-482
50 year	-3,430,716	-3,430
1000 year	-6,512,777	-6,513

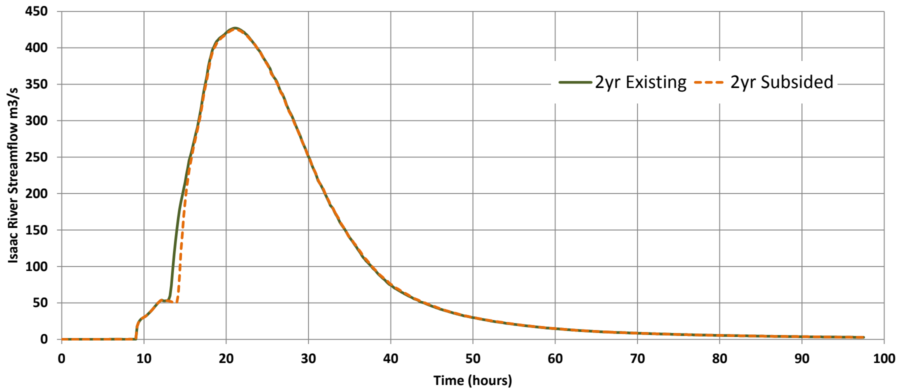
Table 3-11: Residual panel catchment ponding estimates after 2D model runs

	Existing	Subsided	Difference			
ARI	m^3	m^3	m^3	ML	%	Comment
2 year	809,902	1,472,028	662,126	662	82%	2D model run for 100 hours
50 year	1,180,277	5,045,317	3,865,040	3,865	327%	2D model run for 60 hours
1000 year	4,248,259	11,573,244	7,324,985	7,324	172%	2D model run for 60 hours

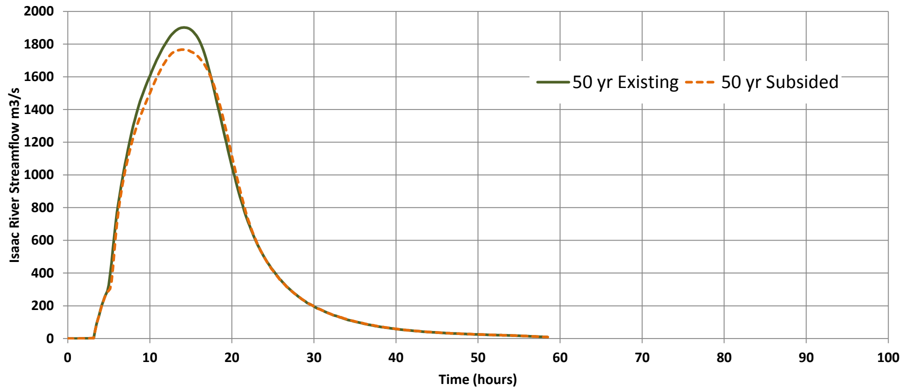
It is possible that the long term rehabilitation strategy for the Isaac River diversion may include utilising subsided terrain and consequently, reduce the amount water stored. However, this assessment does not account for rehabilitation options and should be considered a maximum case scenario for the current mine plan.

Figure 3-32: Estimates of ponding on the floodplain following 2, 50 and 1000 year ARI direct rainfall and Isaac River flow events and predicted changes

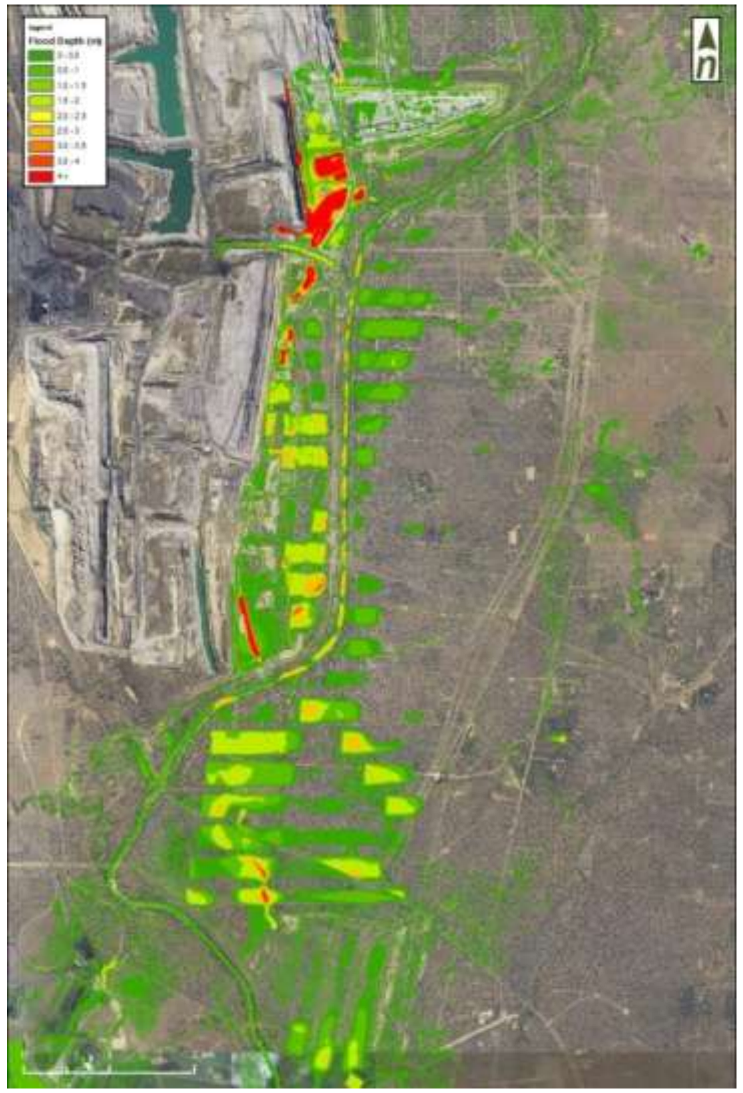
2-yr ARI – Existing Conditions

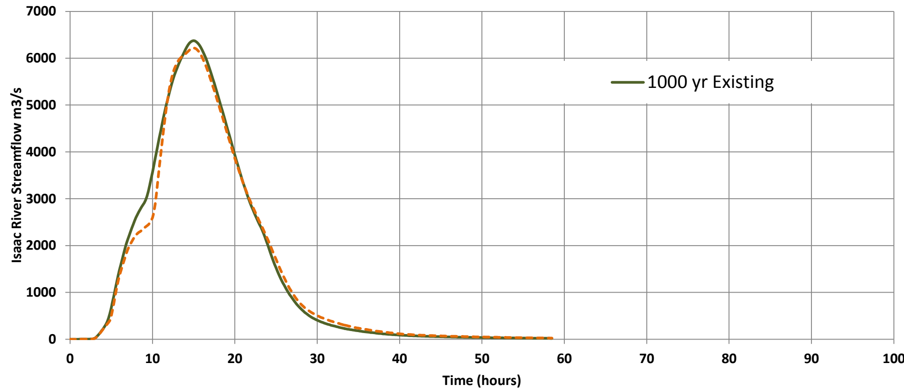


50-yr ARI - Post subsidence



1000-yr ARI - Post subsidence





3.3.2 Loss to shallow or deep strata

Potential for altered surface water – ground water interaction exists due to subsidence related cracking of Tertiary and Permian strata. A monitoring program to assist in quantifying the risk of this potential water loss pathway has commenced and utilises piezometers mentioned in section 2.7.1.

The key area of risk is where Permian strata is exposed in the bed of the river with no weathered Permian or Tertiary clay dominated cover. Where those clay covers exist, self-sealing of cracks is observed to occur, limiting potential for increased flow from surface water to groundwater. For cracks that remain within the Isaac River channel bed, remedial works such as grouting have been undertaken as observed during the 2014 monitoring.

Once relative changes in hydraulic conductivity are quantified, the potential for increased surface water flow to groundwater can be determined and appropriate controls implemented The proportional impact on low and base flow has been identified as the key impact to be assessed by Queensland Government during the IRCIA.

3.3.3 Water Quality

Water quality may be impacted by the processes of erosion or storage in subsided panel catchments. As discussed in previous sections, if subsidence leads to increased erosion then sediment load may increase. A comprehensive surface water monitoring program is currently in place for the Isaac River.

It is possible that water quality may deteriorate in the panel catchments where water may be stored, particularly with stagnant water subject to evaporation.

There are no significant near surface aquifers in the BRM plan area which are likely to have water quality adversely affected by subsidence and subsequent processes.

3.4 FLORA AND FAUNA (4^{TH} ORDER IMPACTS)

Following underground mining, tension cracks may occur on the surface at the start and end of longwall panels. Similarly, cracks may occur over chain pillars running parallel with the centreline of the panel. These tension cracks may affect the terrestrial and riparian vegetation through such impacts as:

- Root sheering of trees and shrubs.
- Drought stress.
- Changes in soil structure and moisture levels.
- Secondary salinisation.
- Erosion (with potential localised and downstream impacts).

These impacts have the potential to alter the environmental quality of terrestrial and riparian vegetation and habitat for aquatic, terrestrial and avian fauna. Observations from the 2014 monitoring are outlined in Section 2.10.

3.4.1 Flora Potential Impacts

The occurrence of root shearing is possible whereby tree/shrub roots are broken or sheared as the subsidence occurs. This may cause localised dieback or reduced vegetation condition quality.

Tension cracking could impact on trees and shrubs bordering the Isaac River. The soil type associated with the river bank may be prone to tension cracking and soil structure breakdown. This in turn will increase the erodibility of the soil and sediment, increasing the potential for sediment transfer down-stream (and potentially off-site). The weakening of the bank substrate may cause mature trees to topple, potentially damaging vegetation within the fall zone. Trees falling into the in-stream area will contribute to large woody debris habitat values and will influence ponding and scouring processes.

3.4.2 Fauna potential impacts

Despite the extensive modification of habitats, remnant hollow bearing trees (eucalypts and bloodwoods) occur throughout the area. Retention of remaining habitats, and existing connectivity between terrestrial habitats and the riparian habitat of the Isaac River is essential for the ongoing viability and survival of terrestrial and avian fauna.

Associated with a potential decline of trees and shrubs, is a change in habitat structure and potentially a loss in the availability of shelter and animal refugia (Earth Tech, 2006) including:

- Loss of low ground cover (through clearing and too frequent burning).
- Loss of nesting hollows (through removal of old trees and dead branches; feral species compete for the use of remaining hollows).
- Loss of mid-canopy layer (through death or dieback of shrubs).
- Change in composition of flora through the introduction of ephemeral grasses as pasture species.
- Overgrazing leading to denudation of landscape and production of “gibber plains”.
- Increased predation by exotic and native predators leading to displacement.
- Loss of breeding sites due to habitat modification.

3.4.3 Aquatic Fauna

The subsidence will create pools in the bed of the Isaac River. The IRCIA findings identified no negative impacts in terms of fauna / habitat on the objectives of the Isaac River. The creation of pools was considered a positive impact as they replaced habitat lost from the system as a result of contemporary sediment input into the river.

In permanent watercourses, connectivity of waterways and therefore flow are the driving forces behind the maintenance of aquatic fauna populations. The greatest threat to the aquatic fauna is cessation of the connectivity and the loss of habitat structure through sedimentation (URS, 2011c). However, as the Isaac River is ephemeral, connectivity is not expected to be any more than seasonal.

3.5 CUMULATIVE IMPACTS

3.5.1 Second order impacts

The current amount of mobile bed sediment available for transport post subsidence in the Isaac River channel has been estimated at approximately 5 million m^3, from Burton Gorge to Moranbah South Mine, approximately 40 km downstream of Broadmeadow. This is based on the sand bed area, upstream and downstream of mine areas, multiplied by an average depth of 2 m for the majority of the study area, with sand over the mine area to be subsided, assumed not to be available for transport. At a macro level the scale of subsidence void created in channel is less than the in-channel sand available for transport. So in the long term, under current catchment conditions, it is highly likely all the subsidence voids will be infilled with sand.

In the short term there are risks of instability at the local scale (within the mine area) which have been identified. However there are other existing and planned longwall mining operations upstream and downstream of the BRM. Red Hill Mine is in the planning stage upstream and Moranbah North mine longwalls are in progress downstream.

The Moranbah North mine longwalls which subside the river are more than 5 km downstream of LW124. Current predictions are that there is not likely to be any impact at BRM due to subsidence at Moranbah North, nor is there likely to be a discernible negative impact on the river in the Moranbah North mine plan from BRM. A reduction in sediment inputs to the section of Isaac River between the two mine plans would be a positive impact in that it would encourage re-establishment of the very deep pool on the bend between the two.

The Red Hill mine is planned upstream of BRM and may at some point reduce sediment supply to the BRM plan. The BRM reach is already subject to instability, both historically due to the diversion and contemporary in response to subsidence. Red Hill will likely exacerbate these conditions in the diversion and the natural channel section between the mine plans. With a stream bed already devoid of mobile sand bed and a potential for deepening of around 2m, it is likely that bench erosion, high bank erosion and meander development will progress through the BRM reach for a period of time in association with mining of Red Hill.

3.5.2 Third order impacts

The IRCIA did not investigate impacts on water quantity across the study area. The impacts on water quantity specific to the current BRM mine plan have been presented in this SMP (refer to Section 3.3). The existing and future potential impacts from the other mine plans have not been assessed.

3.6 INFRASTRUCTURE

3.6.1 Public Roads

Cracking could occur through the pavement in the sealed sections of the road and surface water would be held in each subsided over-panel section, possibly submerging the road.

Corrugations are likely to increase in the unsealed sections of the road due to the movement created by subsidence.

Both of these impacts will be most severe in the section of road maintained by Goonyella Riverside Mine.

3.6.2 Mine Roads

Cracking is likely across the pavement section, mainly over the edge of pillars. In addition to causing rough riding conditions, such cracks would allow ingress of rainfall and subsequent weakening of the road subgrade. However, much of the alignment is thought to have been over melon hole (swelling clay) terrain so the smaller cracks would probably self-seal over time.

Surface water could be held in each subsided over-panel section, submerging the road depending on local drainage.

3.6.3 Power Lines

The most likely potential impact is uneven tension in the power cable(s) caused by vertical movement or tilt of the supports. This would result in unbalanced cable forces at the top of the pole. As a worst case, the additional tension might either snap the cable or pull down the support.

Surface cracking around foundations could lead to erosion or saturation and softening of the foundation material. As a worst case scenario, if a large crack occurred just at the support location, a support could fail.

3.6.4 Water Pipe Lines

Predicted ground movements are sufficient to open joints, and possibly fracture the pipe, over each panel. If damaged, supply to Goonyella Riverside Mine and Moranbah township may be affected.

3.6.5 Dams

If subsidence were to occur below an operable dam, there is potential for uncontrolled release. Therefore, dams will be dewatered based on risk assessment before being undermined.

3.6.6 Levees

Subsidence may reduce the crest level of a levee structure and reduce the flood protection the structure provides. Subsidence cracking may also reduce the integrity of the structure.

3.6.7 Goonyella rail bridge and low level crossing

It is possible that downstream progressive deepening could impact the rail bridge and footings. The possibility would arise later in the BRM plan as it progresses downstream and closer to these structures and would be dependent on events in the interim.

4 SUBSIDENCE MANAGEMENT PLAN

4.1 ADAPTIVE MANAGEMENT APPROACH

This SMP adopts adaptive management as the approach to subsidence impacts, the principles are:

1. Assess the risk
2. Design operational treatments (mitigation measures)
3. Implement treatments
4. Monitor key response indicators
5. Re-evaluate effectiveness of implemented mitigation measures
6. Adjust policies and/or practices

The adaptive management approach accommodates the complexity involved with river processes, including the high variability of flow events and river response to management intervention. The management approach will be a combination of short and long term measures aimed at creating and/or maintaining self-sustaining, healthy functioning waterways through BRM suitable for relinquishment of management responsibility at or before life of mine. A guiding principle for management/mitigation measures will be net gain for the environmental values of the upper Isaac River region.

Identified issues and management actions captured by the monitoring program will be evaluated on an annual basis following annual monitoring data collection and management recommendations. These will then inform any future mitigation measures that will be developed as part of detailed management programs for each longwall or a series of longwalls.

4.2 MONITORING PROGRAM

4.2.1 Waterways

The Isaac River Monitoring Program for BRM was established in 2007 to monitor and report on two mining influences through the Broadmeadow and Goonyella Riverside mine leases, these are:

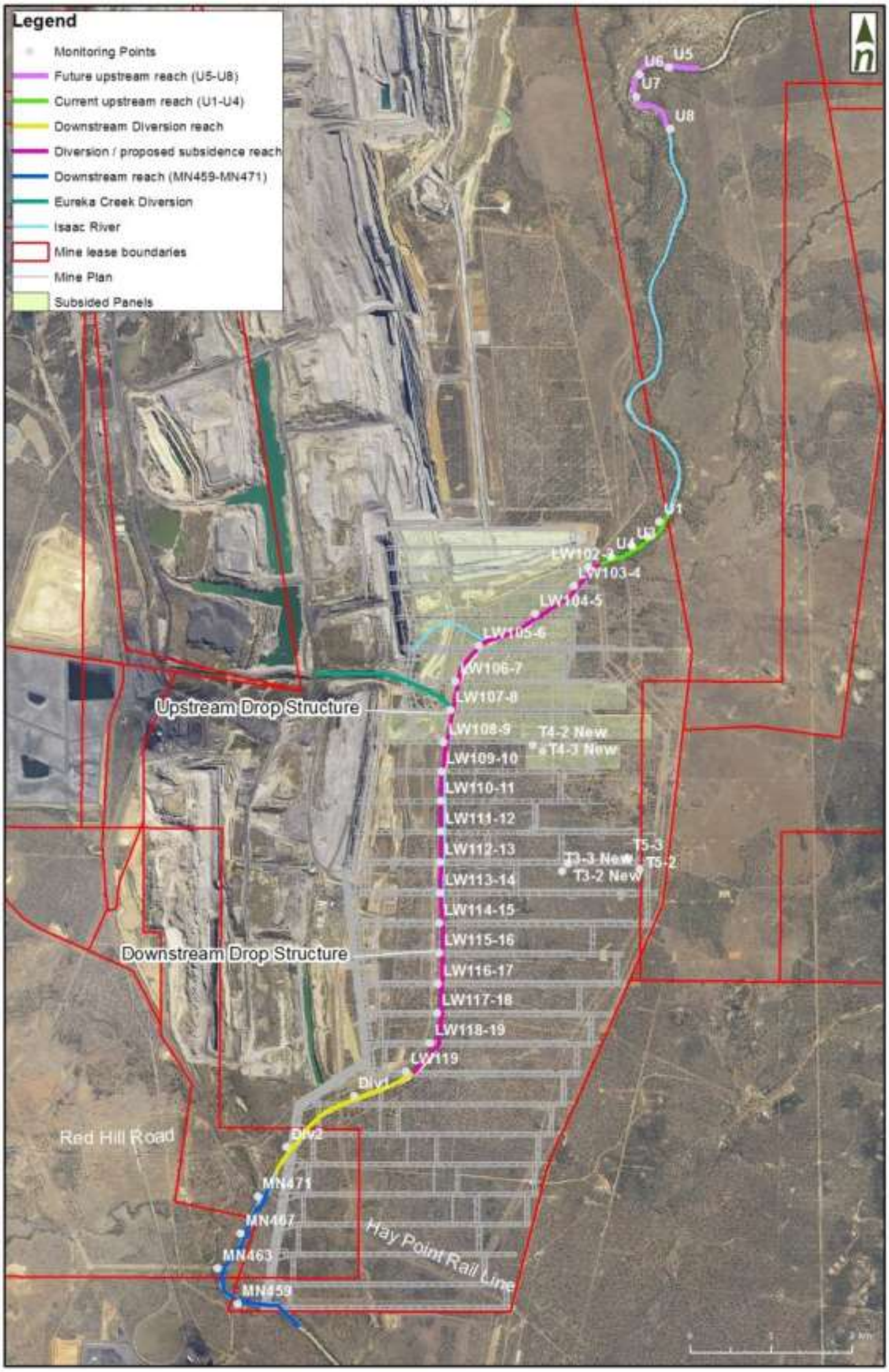
- the condition of the Isaac River that is likely to be affected directly or indirectly from current and future underground longwall mining operations; and
- the condition of the Isaac River diversion, most of which will be affected directly by the planned underground longwall operations.

Monitoring of the diversion and associated works is in accordance with Queensland Government recommended monitoring for Bowen Basin diversions and has been undertaken by highly experienced waterway management professionals. Refer to **Figure 4-1** for existing waterway monitoring points. This monitoring program is also applied to the subsidence reaches.

Refer to “Isaac River Operations Monitoring 2014” (Alluvium, 2014) for full details and outcomes of monitoring to date.

The monitoring program is consistent with the requirements of the Draft Central West Water Management and Use Regional Guideline ‘Watercourse Subsidence – Central Qld Mining Industry VI (DERM, 2011).

Figure 4-1: Waterway Monitoring Points



4.2.2 Land surface

Terrestrial monitoring sites established in the Isaac River terrace across the RE's present in that land zone were re-established in 2012 as an out of pit dump has covered the subsided LW101-103 area were monitoring was previously conducted. Monitoring of the initial sites from 2007-2010 revealed that in the heavier soils, many of the tension and compression cracks sealed and somewhat infilled. Many of the cracks in the lighter soils also sealed and partly infilled but not as comprehensively. Due to limited relief in the Isaac River terrace no further erosion such as tunnel or gully development occurred. This has guided the management of these areas to date.

The terrestrial monitoring sites lost have been re-established over areas which will be subsided in the future, on the east side of the river. It is recommended that additional control sites outside of the extent of planned subsidence are established for each of the existing terrestrial monitoring sites for future comparison of impacts.

4.2.3 Groundwater

As described in **Section 2.7**, the groundwater regime in the mine area comprises Quaternary alluvial formations, Tertiary sediment and basalt formations, and the Permian coal measures. All of these generally yield low sustainable volumes of poor quality groundwater and are not recognised as significant aquifers in the area.

To date, groundwater monitoring data has been collected on an as-needed basis. These programs are summarised in the following reports:

- Vibrating Wire Piezometer Installation. (AGE, 2007). The purpose of this investigation was to assess the impacts of mining on aquifers above the GMS.
- Installation of Goonyella Adit Piezometers and Water Level Data Loggers. (AGE, 1998). The purpose of this investigation was to assess the pressure within the coal seam aquifers.

The development of the goaf and subsidence has resulted in a drop in water levels in the coal seam aquifer. However within the Tertiary self-healing of fractures in the clays may limit dewatering of the perched groundwater in the Tertiary and Quaternary sediments.

Groundwater resources in the area are considered to have limited value, quality is poor, there are no third party users and there is minimal environmental value. On this basis no groundwater monitoring is planned for the area.

4.3 FUTURE MONITORING

4.3.1 Waterways

The current monitoring program will continue to be implemented annually with corresponding monitoring reports produced. These reports will inform and direct future studies, actions and monitoring. Supplementary monitoring may be also be necessary following significant flow events.

Monitoring sites already established through the diversion will allow for monitoring of the performance and condition of any further pile field bank protection works. As mining progresses, additional monitoring points are recommended at potential areas of incision and instability such as where panel catchments drain to the Isaac River or spill into neighbouring panels; and also at the upstream limit of subsidence.

4.3.2 Land surface

Programmed inspections of cracks and development of management options will be required when subsidence of the hillslope areas in the eastern part of the mine plan occurs. This should be undertaken as soon as possible following full deformation of the land surface and following substantial rainfall events.

4.3.3 Vegetation

Riparian and terrestrial vegetation monitoring across the RE's found at BRM is undertaken as part of the annual monitoring program.

4.3.4 Rainfall

Rainfall will continue to be monitored at site and evaluated in annual reporting.

4.4 CURRENT MITIGATION

4.4.1 Isaac River channel

Bank stabilisation and protection measures in the form of pile fields have already been implemented over the pillar zones of mined panels and through to LW112-113 to manage bank erosion risk on pillar zones prior to infilling with sand.

Cracking of sandstone near LW107-108 has been partly grouted to minimise potential for loss of flows and in-rush to underground operations.

Some relocation of rock in LW108 has been undertaken to reduce bank erosion risk in that panel.

4.4.2 Eureka Creek inlet

A concrete chute at the confluence is founded on bedrock and is essentially redundant. Minor reconfiguration works have been undertaken to ensure these old structures do not cause erosion.

4.5 PROPOSED FUTURE MITIGATION

4.5.1.1 Isaac River diversion

Given the existing condition of the diversion reach, further pile fields and bank battering works will be required as mining progresses to manage bank stability risks over the pillar zones.

The upstream drop structure which sits over the proposed LW107/108 pillar zone has been partly repaired in early 2015. It is likely this structure will require further maintenance after flows in future should it be required to maintain current function.

Where riparian vegetation on the benches either dies or is damaged, natural regeneration may need to be supplemented with planting to re-establish dense vegetation on these benches as this is a primary mitigator of the risk of bench retreat into the high bank. This will necessitate removal of cattle from the diversion.

Depending on the sequence of flow events in relation to mining and subsequent infilling of panels, works may be required to mitigate further instability of the diversion banks through panels between pillars. This may include battering and revegetation or batter chutes to manage new overland flow/minor tributary entry to the diversion as a result of subsidence.

4.5.1.2 Eureka Creek inlet

To date only minor deepening in Eureka Creek diversion has occurred in response to deepening in the Isaac River. This is limited by shallow weathered bedrock. Further deepening is likely in response to increased hydraulic grades, depending on the timing of discharges from GS4. Deepening may increase the risk of undermining of the spillway structure and will need to be managed with a flexible rock rip rap apron.

4.5.1.3 Infrastructure

Risk to infrastructure will be assessed and managed by the Broadmeadow Mine on a panel by panel basis. The Second Workings Standard Operating Procedure will address hazards and potential risks prior to commencement of mining in each panel.

Infrastructure will be regularly monitored and mitigation implemented where required. Potential mitigation options are discussed below.

PUBLIC ROADS

- There are options for management depending on the impact. Subsidence depressions can be drained. If a drain has been cut to release surface water from the depressions in any damaged sections, it may be necessary to repair by filling deep cracks, grading over shallow cracks and reconstructing the wearing surface.
- Another option is to raise each subsided section of road with compacted fill and reconstruct the pavement and surface. (Pavement material could be recovered before filling). Further to this, re-grading any sections showing surface cracking and reconstruct the wearing surface ahead of potential subsidence may also be considered.

MINE ROADS

- If only dry weather access is necessary, rip or infill the cracks and re-compact the surface. If wet weather access is required, either:
- Construct an embankment back up to original ground level across the subsided section, and construct the road on that; or
- Construct a drain that will reduce flow over/across the road surface.

POWER LINES

- Assess risk to current and planned power lines within vicinity of potentially subsiding panels.
- Investigate whether power could be supplied instead from an alternate location and remove superfluous stub lines.
- Any risk of support failure is unacceptable, therefore it is suggested that if it is identified that there may be a risk of failure the following should be considered:
- relocate supports. Typically this might result in two supports in the base of each subsidence depression and one or two supports over each pillar; or
- allow extra length of cable between supports to reduce the initial tension in the cable, so that the differential movements can be more readily tolerated.
- These adjustments could be carried out progressively, prior to mining under each section. After each panel has subsided, the line should be inspected and supports jacked or otherwise righted as considered necessary.

- Alternatively, fixing pulleys to the insulators to allow the cable to adjust as supports move may be required.

WATER PIPELINES

- Replace the at-risk section of pipeline with an equivalent HDPE pipe.
- Preliminary advice suggests that HDPE pipe is available to withstand the current rated pressure, however its life could be less than would be the case under lower pressure. With appropriate layout, support, and joint detailing, the flexible polypipe should tolerate the expected strain and curvature. This polypipe line will then be buried after full subsidence has been achieved.

This action could be taken either progressively or as a one-off replacement.

DAMS

Dams will be dewatered based on risk assessment before being undermined.

LEVEES

An inspection and monitoring routine is maintained for operational mine levees. Where an operational levee structure is impacted by subsidence, repairs works will be designed and constructed in accordance with relevant engineering standards.

4.5.1.4 Land Surface

Rapid rehabilitation on a subsided area will reduce potential land surface damage caused by erosion, particularly where there is existing relief in the land surface such as hill slopes. Without rapid rehabilitation, subsidence cracking can degrade further due to removal of material by water which may develop into slump holes or gully erosion.

Rapid rehabilitation will also alleviate land degradation in areas of shallow topsoil which is possible during rectification works to surface cracks.

Annual monitoring will continue and will inform if erosion and therefore management strategies are required.

4.6 RESIDUAL RISK ASSESSMENT

A summary of the potential impacts as described in Section 3 and the associated threats and opportunities, how they could be mitigated and the residual risk is provided in **Table 4-1**. The residual risk will be reviewed on an annual basis following monitoring as part of the adaptive management approach.

It is noted that as part of the feedback in adaptive management that mitigation options and residual risk are somewhat linked to the decision in some instances to allow change from existing conditions. Some impacts from subsidence provide a net environmental gain to the upper Isaac region, implementing management actions to maintain the current condition would be a net loss to environmental values in the region as they ignore the opportunity that subsidence provides. Examples of this are the creation of ephemeral wetlands on the terrace, a feature that has been extensively impacted by gully erosion in the landscape outside of mining influences. The creation of pools in the Isaac River bed due to interruption in bedload transport are another.

The intent of this SMP is to provide overall guidance at the whole of mine plan scale and allow for decisions to be finalised around mitigation on an individual longwall panel plan basis.

The residual risk assessment focuses as much as possible on impacts from subsidence to the existing condition of the Isaac River and diversion through the BRM reach. However, given it is a diversion with known condition issues, they cannot be totally separated.

Table 4-1: Residual Risk Assessment

Feature / process / environmental value	Order and nature of impact	Threats and opportunities (untreated risk) associated with impact	Mitigation options	Residual risk post mitigation
Interruption to bedload sediment transport continuity by subsidence, creating deepening downstream.	2nd -4th order impacts - negative and positive	Isaac River diversion banks downstream of subsided panels waiting to be infilled when substantial flow event (100-500m^3/s) occurs will be subject to increased risk of instability. Risk is elevated where hard controls such as bedrock exist in channel bed that will resist deepening as bench retreat is the next response, meaning the high unstable banks may end up with no toe protection. This mechanism is responsible for creation of pools, which are rare aquatic refugia in the upper Isaac River.	Appropriate channel bed and toe of bank protection and enhanced riparian vegetation over pillars. Battering and revegetation of vertical upper banks through panels when infilled and low flow goes over bench level. This does not address large scale existing diversion condition issues. Rehabilitation of diversion to decrease channel gradient overall, lowers risk.	Dependent on level of intervention, low risk of bank erosion through panels and pillars can be achieved with significant intervention.
Upstream progressing deepening from subsided (but not yet infilled) zone in Isaac River channel	2nd order – negative with low potential for positive	Given the highly elevated sediment inputs to the Isaac River from broader catchment conditions, this response has not yet been observed. Should sediment inputs reduce, some increased potential for bank erosion upstream of subsidence should deepening occur.	Pillar zones presently treated. Overall reduction in mobile sand bed thickness may allow for reintroduction of morphologic diversity and associated aquatic habitat gain. No further mitigation required based on observed response to date.	Low.
Upstream drop structure	2nd order – negative with low potential for positive	Ongoing damage to the structure instigating a deepening phase upstream that may exacerbate existing instabilities in diversion or create new instabilities in upstream reach. Similar to upstream progressing deepening	As per upstream progressing deepening.	Low.
Downstream drop structure	1st order impact.	Becomes redundant as is located in centre of panel and will be subsided below adjacent pillar levels. Structure is largely redundant already. Overall threat posed by gradient of diversion.	Reinstatement of a lower gradient for the diversion as a whole.	Low.
Storage of runoff in subsided zones outside Isaac River channel	3rd and 4th order impact – positive at a local level, some potential for negative at a river system level	Impacts to the hydrograph in flood events shown to be minimal, however in dry years where the river flows can be reliant on localised storm events, may provide discernible reduction in flows. Net gain to environmental values in upper Isaac by creation of ephemeral wetlands that have been lost to gully erosion from various land uses. A change in flora and fauna will occur in the ponded areas.	Maintain the net gain wherever possible by allowing the ephemeral wetlands to remain. Response to consider erosion risks associated with new drainage patterns and address any negative impacts. Response potentially dependent on existing RE condition at the site.	Low. Dependent on objectives for management of RE's at a local level.
Riparian vegetation	3rd order – negative	Tree death in subsided zones in river channel. Response is inconsistent and may take many years. Several possible causes.	Where loss of riparian vegetation occurs, address with revegetation efforts. Facilitate conditions that promote natural regeneration along the river channel by managing cattle grazing regime.	Low
Subsidence cracks	2nd, 3rd and 4th - negative	Loss of flows to cracks in exposed bedrock in-channel. Potential for gully development along tensions cracks in areas of increased relief. Potential for tunnel erosion where ponding conditions created close to diversion channel.	Crack sealing river bed. Land zone based response to cracking outside river channel, utilising results of past monitoring. Assess ponding and tunnel risk along diversion channel and implement drainage as required	Low
Avulsion of Isaac River channel	2nd – 4th order – negative	Low risk given high capacity of channel and orientation of panels perpendicular to channel	None required	Low
Incision of overland flow paths and tributaries around perimeter of mine plan	2nd – 4th order – negative	Gully erosion of tributaries likely where they drop into subsided footprint.	Grade control and increased resilience through enhancement of vegetation which will require grazing regime management.	Dependent on level of management required and implemented and long term land management

4.6.1 Long term management strategy for the Isaac River

In the longer term it is likely that management of subsidence impacts and existing condition issues for the diversion will require intervention to create a self-sustaining waterway that has the resilience to cope with 1st and 2nd order impacts, promotes potential to maintain the positive impacts of subsidence on river health and removes the reliance on drop structures for stability.

Given the extended life of mine, BMA proposes to implement an adaptive management plan for the Isaac River diversion. The plan will be a combination of short term and long term mitigation measures both of which will work towards the long term goal of a self-sustaining, stable waterway, suitable for relinquishment.

The management plan will be adaptive based on future mine plans and the results of monitoring the impacts of subsidence and erosion on the Isaac River.

4.6.2 Rehabilitation of broader landscape

Progressive rehabilitation will be required as panels subside. The planning for this progressive rehabilitation will be informed by the annual monitoring of subsidence and the condition of previously rehabilitated land.

Land zone and vegetation condition based treatment of cracking associated with the differential subsidence of pillar and panel zones is recommended. Selective treatment of cracks in the open plant communities of Land zone 3 and Land zone 5 areas by ripping will be considered before broad scale tree clearing followed by ripping.

5 REFERENCES

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URS, 2011a. Goonyella Complex Expansion Terrestrial Fauna Technical Draft Report. Aug 2011

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APPENDICES

On a broader scale, the area features sections of habitat connected at state and regional scales. The remnant woodland vegetation to the south east of BRM represents significant habitat connectivity within the corridor system at a state scale. Contiguous tracts of vegetation within this broader area, representing local connectivity of habitat, are primarily linked by riparian corridors associated with the local creek and river systems. Connectivity in the east is primarily provided by the Isaac River riparian corridor. The Isaac River corridor joins a large tract of integral vegetation at the Burton Range approximately 10 km to the northwest. The Burton Range represents a contiguous extent of woodland approximately 18km long varying in width from 1km to 5km.

There are no national parks, state forests, or reserve areas within a 50km radius of the BRM footprint. There is one conservation area within 50km of BRM footprint; Lake Elphinstone, a nationally important wetland. Within 100km of the site there are five national parks and six state forests.

A.1 Regional Ecosystems

URS (2011b) field studies confirmed the study area contained a total of 19 REs, including five REs listed as Endangered, seven as Of Concern and seven as Not of Concern. **Table** provides a summary of the classification of vegetation communities and REs identified during the flora survey. Vegetation communities for the study sites have been delineated on the basis of REs. The area of each RE within the study site varies considerably with some REs only marginally represented.

Table A-1: Vegetation Conservation Status

Unit	Community Description	Land zone	Regional Ecosystem Description	QEPA Status		
				EPBC	Biodiv	VMA
1a	*Acacia harpophylla* open woodland on alluvial plains	Quaternary alluvial soils (Landzone 3)	RE 11.3.1	E	E	OC
2b	*Eucalyptus populnea* with *Acacia harpophylla* and/or *Casuarina cristata* Open forest to woodland *on* Cainozoic clay plains	Flat to gently undulating Cainozoic clay plains (Landzone 4)	RE 11.4.7	E	E	E
2c	*Eucalyptus cambageana* woodland to open forest with *Acacia harpophylla* or *A. argyrodendron* on Cainozoic clay plains		RE 11.4.8	E	E	E
2d	*Acacia harpophylla* shrubby open forest to woodland with *Terminalia oblongata* on Cainozoic clay plains		RE 11.4.9	E	E	E
3c	*Acacia harpophylla* and/or *Casuarina cristata* open forest in depressions on Cainozoic sand plains/remnant surfaces	Plains and plateaus on Tertiary land surfaces, with medium to coarse textured soils (Landzone 5)	RE 11.5.16	E	E	E

Unit	Community Description	Land zone	Regional Ecosystem Description	QEPA Status		
				EPBC	Biodiv	VMA
5a	*Dichanthium sericeum* grassland on Cainozoic igneous rocks	Basalt associated with undulating to gently undulating rises (Landzone 8)	RE 11.8.11	E	OC	OC

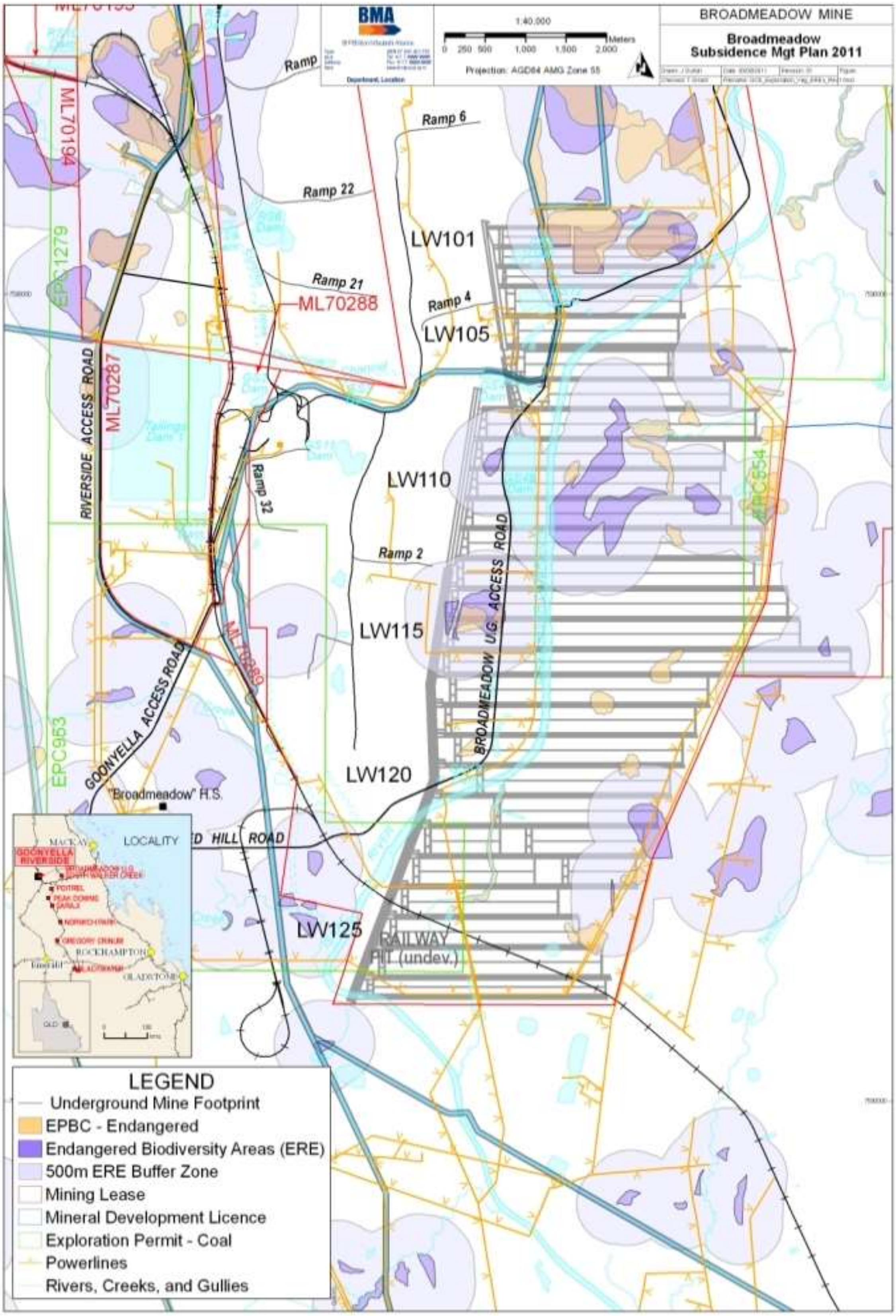
A.2 Riparian communities

In general, the riparian communities of the Goonyella/Riverside and BRM area are confined to the upper banks of the smaller creeks and the upper and lower banks of the Isaac River, with the majority of these areas showing evidence of cattle disturbance (**Figure A-1**). The west of Eureka Creek is dominated by *Acacia harpophylla* (brigalow) and *Casuarina cristata* (belah) open forest (RE 11.3.1), changing to a *Eucalyptus tereticornis* (forest red gum) dominated community (RE 11.3.4) on alluvial plains directly to the south of the mine, before reverting to RE 11.3.1. In the south-west of the study area, Fisher Creek and Platypus Creek are predominantly *E. tereticornis* (forest red gum) dominated community fringing drainage lines (RE 11.3.25). To the east of the mine site, the Isaac River is dominated by tall *E. tereticornis* (forest red gum) and *Casuarina cunninghamiana* (river sheoak) (RE 11.3.25e) fringing the river. Significant alluvial areas adjacent to Isaac River on the north-east of the study area support exclusive stands of *Corymbia tessellaris* (Moreton Bay ash) (RE11.3.25b).

A.3 Weeds of Concern

Forty-six exotic plant species were recorded during the 2011 field surveys. Five species were identified as being of management concern: *Eriocereus martinii* (harrisia cactus), *Parthenium hysterophorus* (parthenium), *Sporobolus fertilis* (giant Parramatta grass), *Opuntia stricta* var. *stricta* (prickly pear) and *Opuntia tomentosa* (velvety tree pear). These are species currently declared as Class 2 pest species under the *Land Protection (Pest and Stock Route Management) Act 2002*.

Figure A-1: Endangered Vegetation Communities Status (Commonwealth EPBC Act and DERM State EP Act)



Appendix B – FAUNA ENVIRONMENTAL VALUES

B.1 Riparian and Alluvial Woodlands Habitat

The riparian and adjacent alluvial woodlands ('Endangered' RE 11.3.1, 'Of Concern' REs 11.3.2, 11.3.3, 11.3.4 and 11.3.36 and 'Not of Concern' REs 11.3.5, 11.3.7 and 11.3.25) along the Isaac River and other waterways provide important local habitat for a number of species, especially arboreal mammals such as possums and gliders. Large, mature forest red gums (*Eucalyptus tereticornis*) present in riparian habitats frequently contain hollow limbs which provide denning sites for arboreal mammals and microbats and nesting sites for many bird species such as parrots, owls and dollarbirds. These trees also act as a food source for insectivorous and nectivorous birds and mammals. Where this habitat forms a continuous corridor, it constitutes a route for migratory and dispersing fauna of all types.

Seasonal inundation and flow along the Isaac River provides habitat and breeding sites for aquatic or semi-aquatic species such as frogs and their predators such as snakes.

The three small waterways on the western side of the area (Eureka, Fisher and Platypus Creeks) and one in the east (12 Mile Gully) are ephemeral streams. Of these, Eureka Creek is the most significant in terms of fauna habitat, as it contains a narrow but well developed riverine forest dominated by Eucalyptus and Acacia species, a dense grassy understorey, and a deep shaded stream channel with small, ephemeral refuge pools.

B.2 Isaac River Diversion Habitat

In the south of the area, the Isaac River diversion differs significantly from the natural river habitat in this area in the following ways:

- The diverted river bed is much wider than the natural river, and banks are deeper and more eroded;
- There is a lack of alluvial plain development (due to insufficient time for it to develop), different substrate type, and because the channel is now contained and no longer overtops and floods;
- There is a lack of mature trees with nesting/denning hollows;
- There is an absence of instream sand/habitat accretions.

The regenerating communities along the diversion therefore do not provide the same habitat opportunities as riparian woodlands upstream and downstream of the diversion.

B.3 Water bodies

Water bodies in the area, both natural and artificial, are attractive as watering points for woodland bird species and provide habitat for a number of waterbird and frog species. They are also important in promoting the survival and proliferation of feral animals such as pigs and cane toads. As all streams (including the Isaac River) are ephemeral, natural waterholes are uncommon and short-lived. Therefore, farm dams and mine dams act as a reliable water source and refuge for fauna throughout the year.

B.4 Amphibians and Reptiles

Amphibians were generally associated with wetter microhabitats, particularly around permanent agricultural dams and natural depressions, swamps or small streams that contained water following rains. The commonest native species observed (URS, 2011a) was ornate burrowing frog (*Opisthodon ornatus*). The green tree frog (*Litoria caerulea*) was recorded from a number of locations, both in close proximity to water, and in woodland and grassland habitats. Other species recorded include (but are not restricted to) the spotted marsh frog (*Limnodynastes tasmaniensis*), the eastern snapping-frog (*Cyclorana novaehollandiae*) and the barking marsh frog (*Limnodynastes fletcheri*).

During the 2011 survey, 35 reptiles were encountered on the project area, featuring representatives of eight families. These included six gecko (*Gekkonidae*), one legless lizard (*Pygopodidae*), four dragon (*Agamidae*), one goanna (*Varanidae*), 16 skink (*Scincidae*), two python (*Pythonidae*), two elapid snake (*Elapidae*) and three colubrid snake (*Colubridae*) species.

Rocky areas and riverine sites along the Isaac River recorded the highest species richness and abundance of reptile species.

B.5 Birds

A total of 133 bird species were recorded from the area during targeted searches and as incidental observations during the survey periods. Species from all habitat and feeding groups were observed with woodland generalists, raptors and waterbirds being particularly prominent. The highest avian diversities were encountered within the riparian and alluvial woodlands where flowering forest red gums (*Eucalyptus tereticornis*) and narrow-leaved ironbarks (*E. crebra*) attracted honeyeaters, canopy gleaners and insectivores. The grasslands also showed high diversity, especially following rain when waterholes and small wetlands attracted wading birds. Brigalow communities displayed the least avian diversity within the site, most likely due to a lack of flowering plants and low floristic and structural diversity.

A diversity of waterbird species were observed on or near the artificial dams in the area. Other than these dams, there are no natural permanent waterholes in the area, although due to some recent rain prior to, and during the surveys, some depressions and river beds did contain water. A total of 27 species of waterbirds and waders were observed on water bodies in the project area during URS surveys. Commonly observed water bird species were; black swan (*Cygnus atratus*), Australian wood duck (*Chenonetta jubata*), cotton pygmy-goose (*Nettapus coromandelianus*), pacific black duck (*Anas superciliosa*), grey teal (*Anas gracilis*), Eurasian coot (*Fulica atra*) and great egret (*Ardea alba*).

B.6 Mammals

Thirty-two native and eight introduced mammal species were identified during the URS surveys.

Arboreal mammals were represented by four species in the project area; common brushtail possum (*Trichosurus vulpecula*), koala (*Phascolarctos cinereus*), sugar glider (*Petaurus breviceps*) and greater glider (*Petauroides volans*). Brushtail possums were observed in relatively high density in the riparian zone adjacent to the Isaac River in the east of the area during the 2011 autumn survey. In spite of the numbers observed along the Isaac River, brushtail possums are considered to occur in very low densities across the area despite a high density of arboreal hollows, especially in the *E. populnea* woodlands. Greater gliders were observed at two locations associated with alluvial woodland; adjacent to the Isaac River in the east and along Fisher Creek in the west of the area. Sugar gliders (*Petaurus breviceps*) were observed in fringing riparian woodland at 12 Mile Gully in the Red Hill area and adjoining the Isaac River.

The eastern grey kangaroo (*Macropus giganteus*) is a common large macropod in the mine area. Individuals and groups of up to five animals were seen in woodland habitats. The rufous bettong (*Aepyprymnus rufescens*) was recorded in two locations; south of the mine complex in tussock grass microhabitat adjacent to an ephemeral swamp and south-east of the mine complex in *Megathyrsus maximus* (guinea grass) microhabitat adjacent to the Isaac River.

Nineteen species of microchiropteran bats were positively recorded by Anabat ultrasonic sampling at 11 sites. In some cases, calls cannot be differentiated to species level in the Anabat system, so four of the identifications cannot be assigned specific names. Based on frequency of calls, the most common call types within the project area have been assigned to Gould's wattle bat (*Chalinolobus gouldii*), chocolate wattled bat (*Chalinolobus morio*), little pied bat (*Chalinolobus picatus*), eastern cave bat (*Vespadelus troughtoni*) and yellow-bellied sheathtail bat (*Saccolaimus flaviventris*). During the 2011 survey, 669 records from the eastern cave bat were identified underneath the railway bridge that crosses the Isaac River. The eastern cave bat is known to roost under bridges and culverts in abandoned fairy martin (*Hirundo ariel*) nests.

B.7 Conservation Significant Fauna Species

Conservation significant fauna species recorded from the project area from all surveys are detailed in **Table B-2** below. No Endangered or Critically Endangered species are known or expected to occur in the area.

Table B-1: Status of Conservation Significant Fauna Species Recorded from the Project area

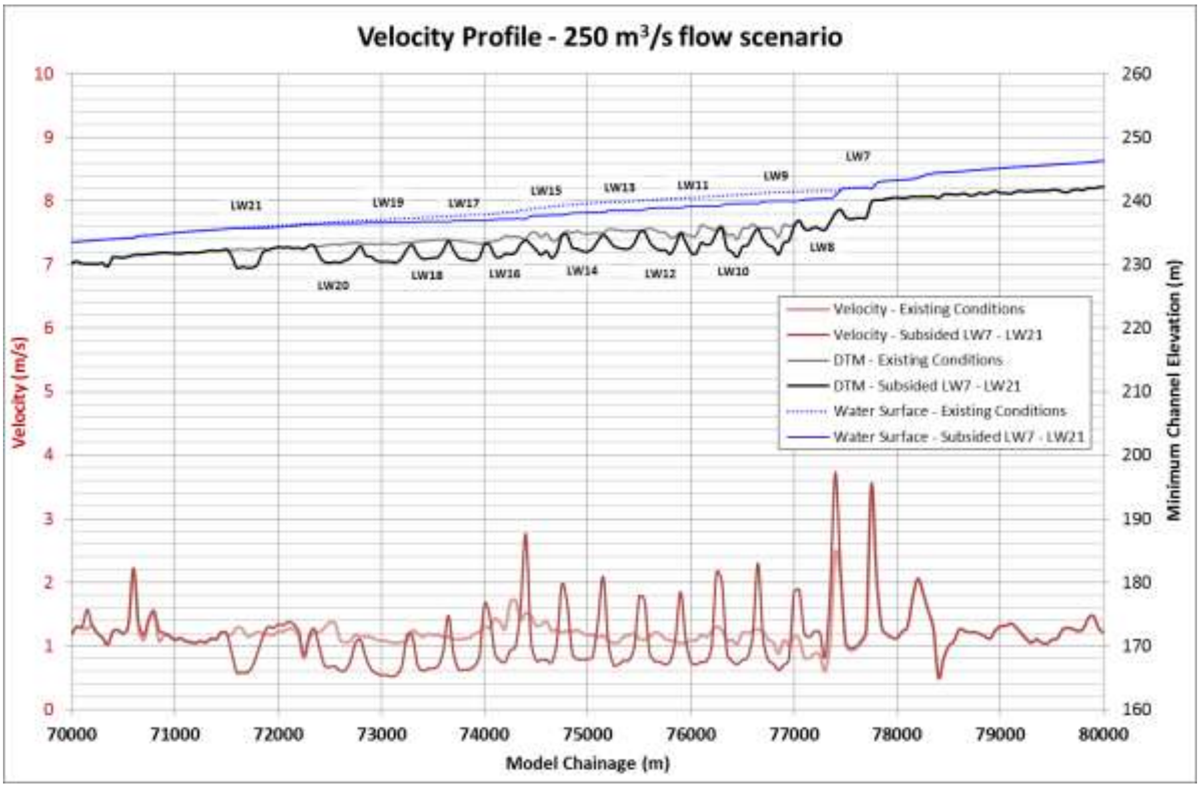
Common Name	Scientific Name	EPBC Act [1]	Qld NC Act [1]
squatter pigeon	*Geophaps scripta scripta*	V	V
cotton pygmy-goose	*Nettapus coromandelianus*	M	NT
rainbow bee-eater	*Merops ornatus*	M, Mi	-
great egret	*Ardea alba*	M, Mi	-
oriental cuckoo	*Cuculus saturatus*	M	-
white-bellied sea-eagle	*Haliaeetus leucogaster*	M, Mi	-
stubble quail	*Coturnix pectoralis*	M	-
black-necked stork	*Ephippiorhynchus asiaticus*	-	NT
brown goshawk	*Accipiter fasciatus*	M	-
nankeen kestrel	*Falco cenchroides*	M	-
Latham's snipe	*Gallinago hardwickii*	M, Mi	-
channel-billed cuckoo	*Scythrops novaehollandiae*	M	-
white-throated needletail	*Hirundapus caudacutus*	M, Mi	-
fork-tailed swift	*Apus pacificus*	M, Mi	-
dollarbird	*Eurystomus orientalis*	M	-
rufous fantail	*Rhipidura rufifrons*	M, Mi	
marsh sand-piper	*Tringa stagnatilis*	M, Mi	-
brigalow scaly-foot	*Paradelma orientalis*	V	V
ornamental snake	*Denisonia maculata*	V	V
little pied bat	*Chalinolobus picatus*	V	NT
koala	*Phascolarctos cinereus*	-	CS
short-beaked echidna	*Tachyglossus aculeatus*	-	CS

[1] V-Vulnerable; NT-Near Threatened; CS-Species of Cultural Significance; Mi-Migratory; M-Marine.

B.8 Introduced Species

Nine introduced vertebrate fauna species were recorded within the area, of which eight are mammals and one an amphibian. The area is used for grazing domesticated horses (*Equus caballus*) and cattle (*Bos taurus*). All other introduced species noted are present as true feral animals. Rabbits (*Oryctolagus cuniculus*) are abundant throughout the area, as are cane toads (*Rhinella marina*). Feral cats (*Felis catus*) were observed, whilst wild dogs (*Canis lupus dingo/familiaris*) were occasionally seen in the east of the area. Signs of feral pigs (*Sus scrofa*) were common in the western portions, especially as wallows in creek beds and dam verges, while one sighting was recorded near a dam in the east during the May 2011 survey. House mice (*Mus musculus*) were trapped in grassland in the north-west of the area and are likely to be widespread over the area. Foxes (*Vulpes vulpes*) were observed during nocturnal surveys.

Appendix C 2014 HYDRAULIC MODELLING RESULTS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Velocity (m/s)
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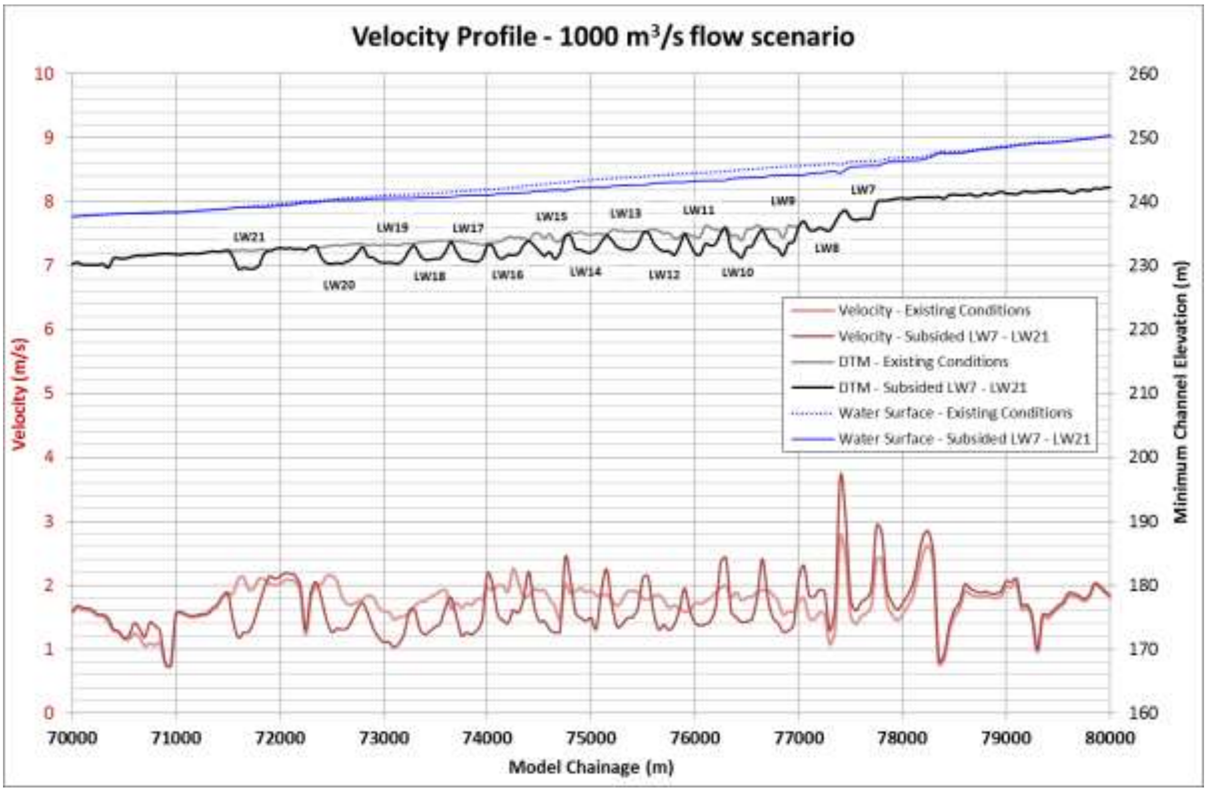
Model Chainage (m)
LW21
LW20
LW19
LW18
LW17
LW16
LW15
LW14
LW13
LW12
LW11
LW10
LW9
LW8
LW7
Velocity - Existing Conditions
Velocity - Subsided LW7 - LW21
DTM - Existing Conditions
DTM - Subsided LW7 - LW21
Water Surface - Existing Conditions
Water Surface - Subsided LW7 - LW21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Velocity (m/s)
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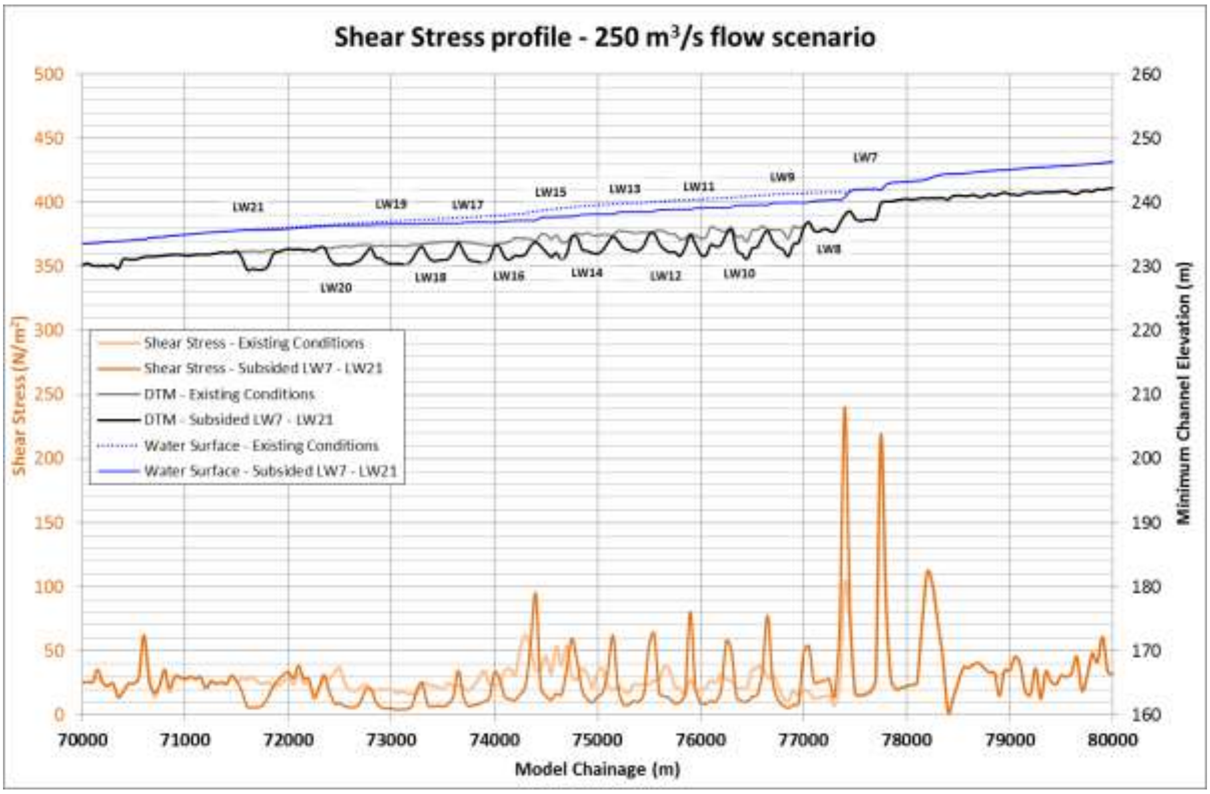
Model Chainage (m)
LW21
LW20
LW19
LW18
LW17
LW16
LW15
LW14
LW13
LW12
LW11
LW10
LW9
LW8
LW7
Velocity - Existing Conditions
Velocity - Subsided LW7 - LW21
DTM - Existing Conditions
DTM - Subsided LW7 - LW21
Water Surface - Existing Conditions
Water Surface - Subsided LW7 - LW21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Shear Stress (N/m²)
Minimum Channel Elevation (m)
Model Chainage (m)
Shear Stress - Existing Conditions
Shear Stress - Subsided LW7 - LW21
DTM - Existing Conditions
DTM - Subsided LW7 - LW21
Water Surface - Existing Conditions
Water Surface - Subsided LW7 - LW21
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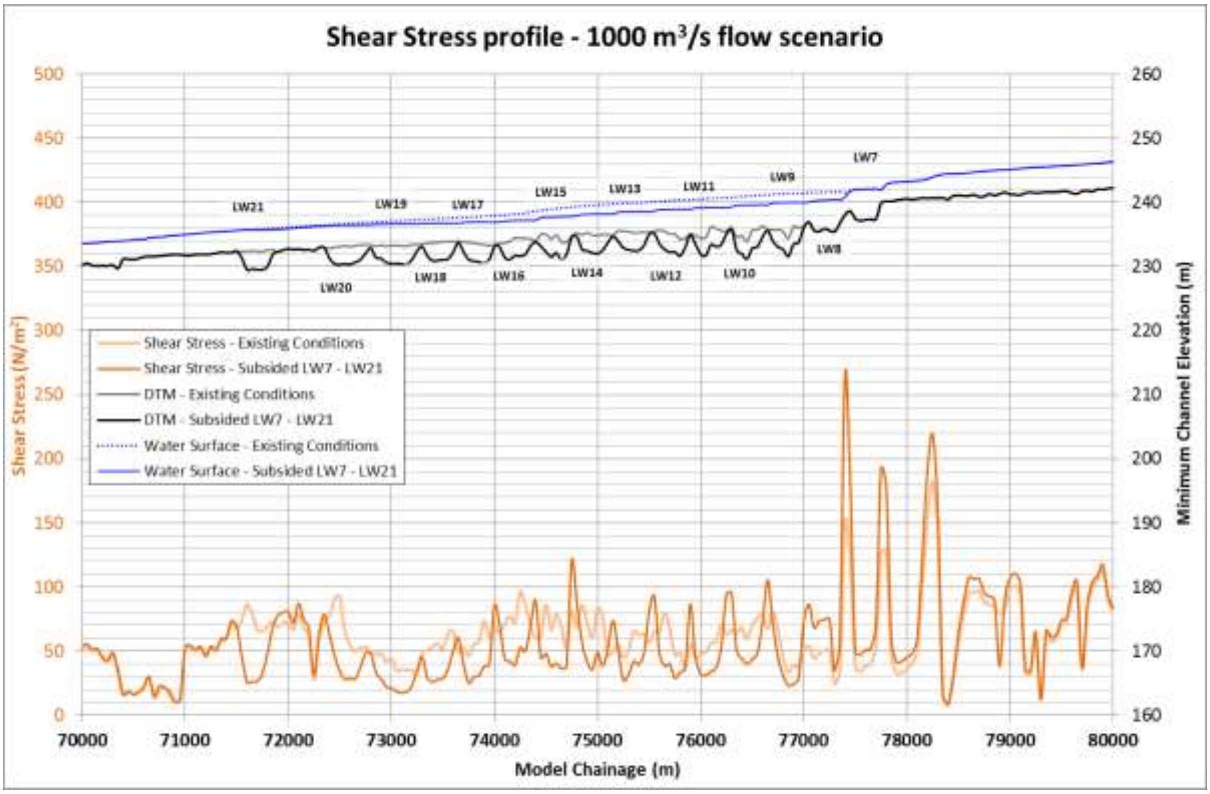
Shear Stress profile - 1000 m³/s flow scenario
Shear Stress (N/m²)
Minimum Channel Elevation (m)
Model Chainage (m)
Shear Stress - Existing Conditions
Shear Stress - Subsided LW7 - LW21
DTM - Existing Conditions
DTM - Subsided LW7 - LW21
Water Surface - Existing Conditions
Water Surface - Subsided LW7 - LW21
LW21
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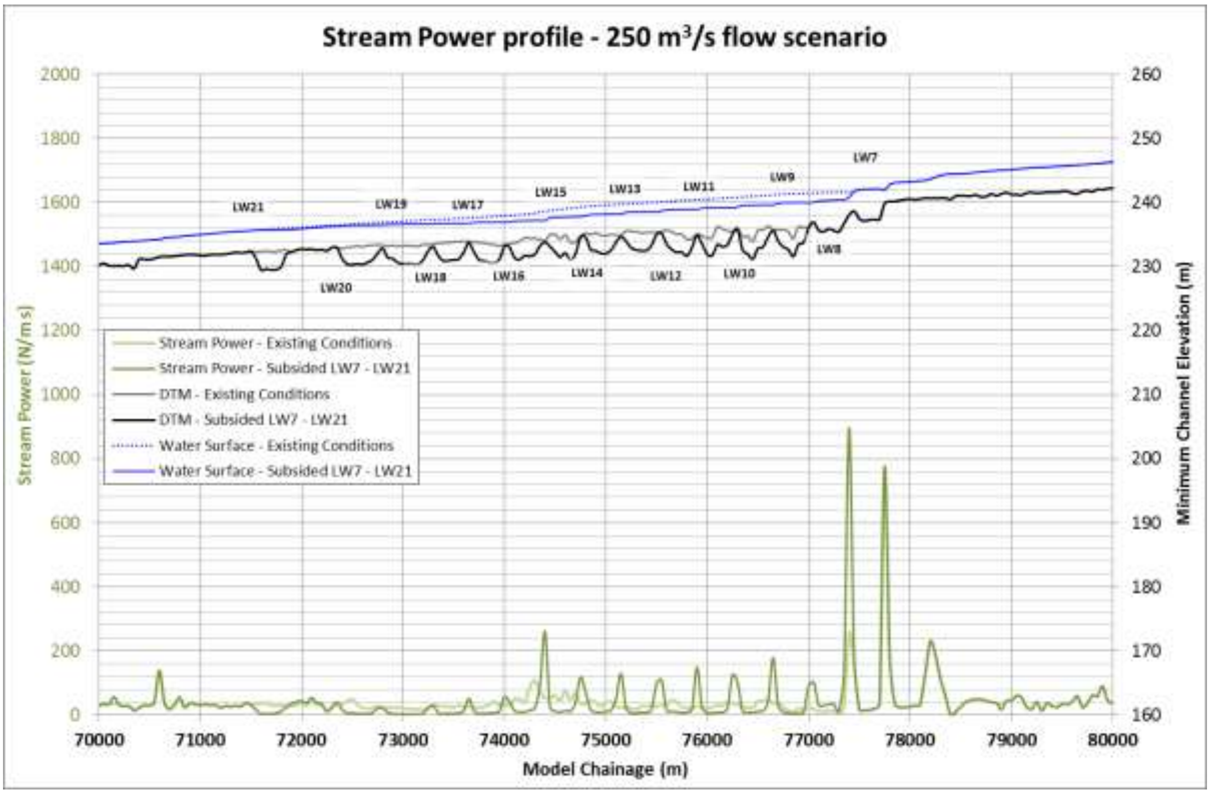
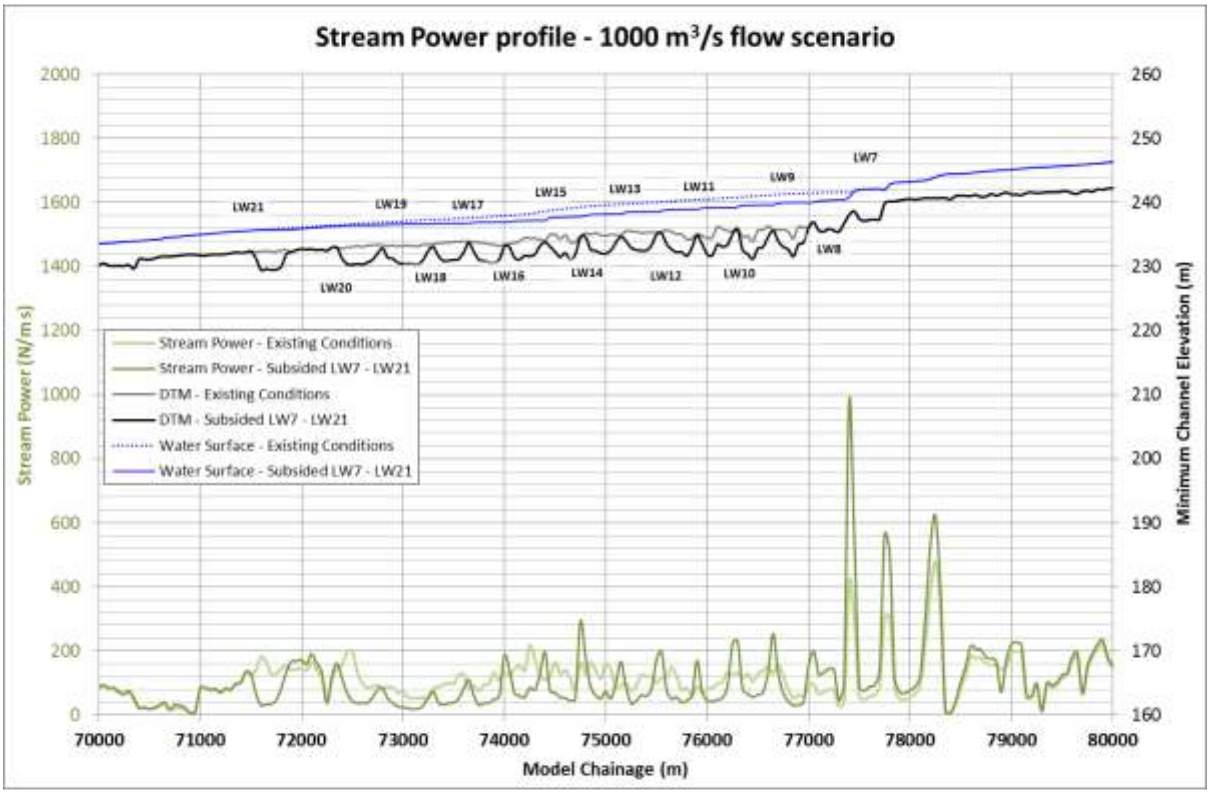
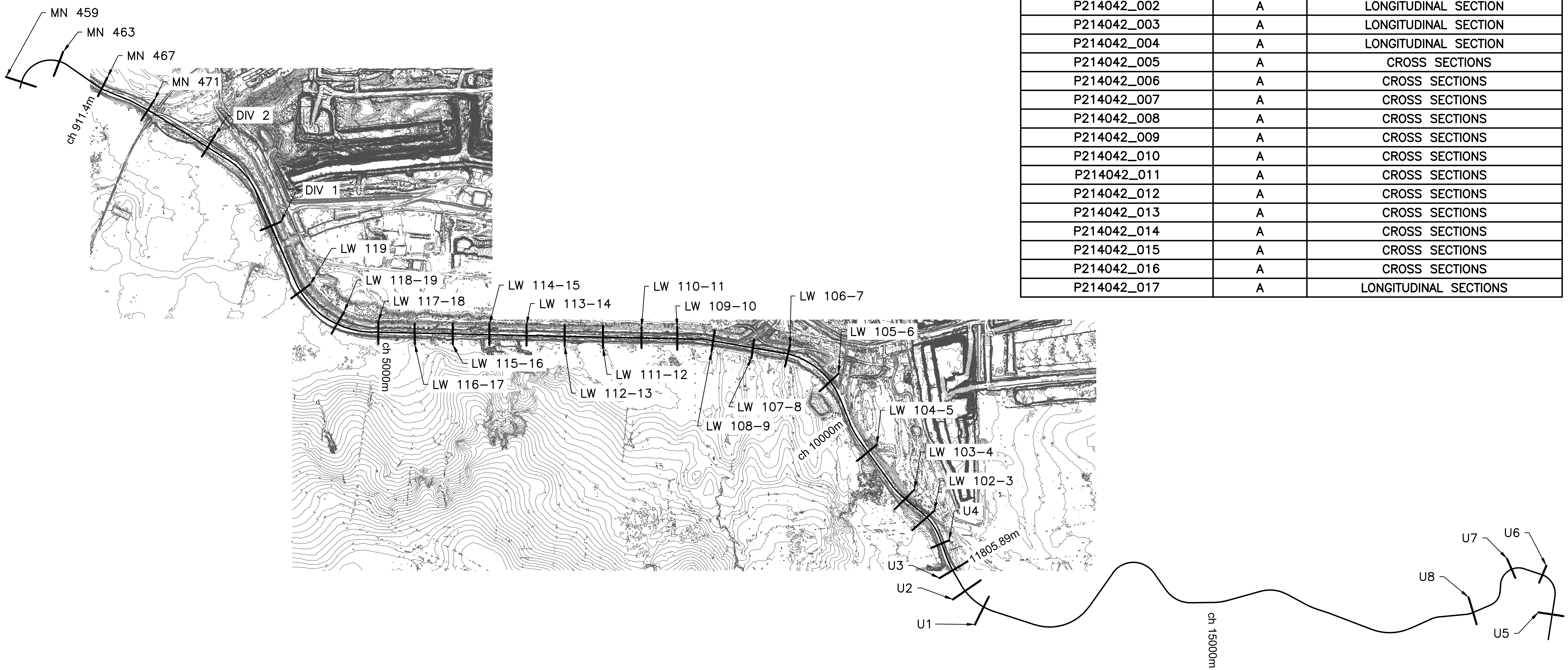
LW8
LW7


Stream Power profile - 250 m³/s flow scenario
Stream Power (N/m s)
Minimum Channel Elevation (m)
Model Chainage (m)
Stream Power - Existing Conditions
Stream Power - Subsided LW7 - LW21
DTM - Existing Conditions
DTM - Subsided LW7 - LW21
Water Surface - Existing Conditions
Water Surface - Subsided LW7 - LW21
LW21 LW20 LW19 LW18 LW17 LW16 LW15 LW14 LW13 LW12 LW11 LW10 LW9 LW8 LW7


Stream Power profile - 1000 m³/s flow scenario
Stream Power (N/m s)
Minimum Channel Elevation (m)
Model Chainage (m)
Stream Power - Existing Conditions
Stream Power - Subsided LW7 - LW21
DTM - Existing Conditions
DTM - Subsided LW7 - LW21
Water Surface - Existing Conditions
Water Surface - Subsided LW7 - LW21
LW21 LW20 LW19 LW18 LW17 LW16 LW15 LW14 LW13 LW12 LW11 LW10 LW9 LW8 LW7

Appendix D – ISAAC RIVER LONG SECTIONS AND CROSS SECTION



SCHEDULE OF DRAWINGS		
DRAWING NUMBER	REVISION	DRAWING TITLE
P214042_001	A	SITE PLAN AND SCHEDULE OF DRAWINGS
P214042_002	A	LONGITUDINAL SECTION
P214042_003	A	LONGITUDINAL SECTION
P214042_004	A	LONGITUDINAL SECTION
P214042_005	A	CROSS SECTIONS
P214042_006	A	CROSS SECTIONS
P214042_007	A	CROSS SECTIONS
P214042_008	A	CROSS SECTIONS
P214042_009	A	CROSS SECTIONS
P214042_010	A	CROSS SECTIONS
P214042_011	A	CROSS SECTIONS
P214042_012	A	CROSS SECTIONS
P214042_013	A	CROSS SECTIONS
P214042_014	A	CROSS SECTIONS
P214042_015	A	CROSS SECTIONS
P214042_016	A	CROSS SECTIONS
P214042_017	A	LONGITUDINAL SECTIONS

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE A 0 400 800 1600 m

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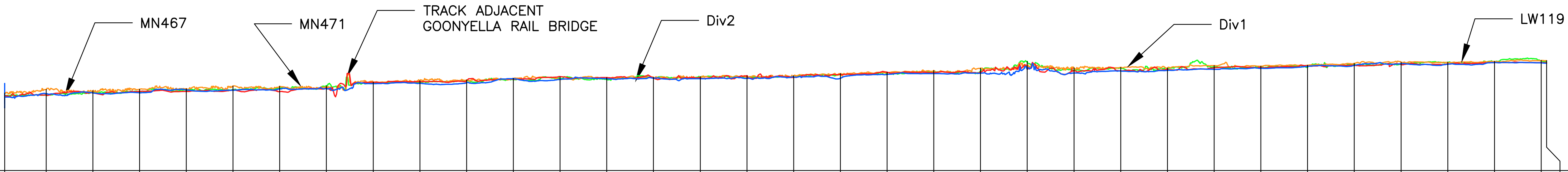
Client: BMA BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
SITE PLAN AND SCHEDULE OF DRAWINGS

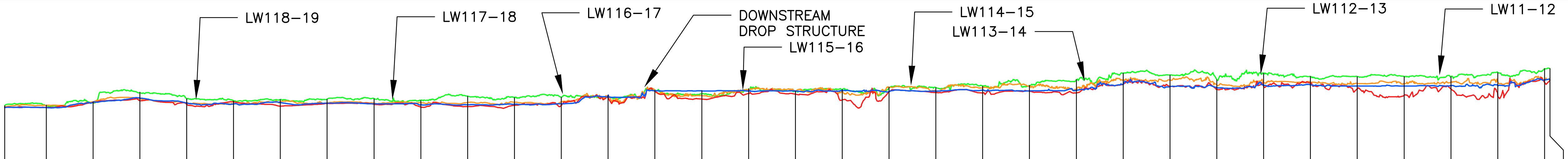
Drawing No. P214042_001 Revision No. A
Sheet No. 1 File Name: P214042_001-016.dwg

A3



Datum RL 222

CHAINAGE	2014	2012	2011	2008
911.41	230.03	229.87	230.31	230.02
1000.00	230.09	230.24	230.70	230.08
1100.00	230.34	230.33	230.57	230.44
1200.00	230.50	230.35	230.72	230.46
1300.00	230.49	230.65	230.78	230.59
1400.00	230.64	230.61	231.07	230.65
1500.00	230.48	230.75	231.03	230.84
1600.00	230.85	230.80	230.95	231.09
1700.00	231.48	231.33	231.48	231.39
1800.00	231.54	231.36	231.64	231.48
1900.00	231.67	231.42	231.73	231.62
2000.00	231.80	231.86	231.89	231.75
2100.00	232.08	231.78	231.78	231.90
2200.00	231.96	231.85	231.98	231.76
2300.00	231.94	231.91	232.00	231.97
2400.00	231.94	231.86	232.07	232.03
2500.00	232.17	231.90	232.07	232.04
2600.00	231.99	232.04	232.18	231.99
2700.00	232.30	231.90	232.40	232.27
2800.00	232.55	232.31	232.49	232.37
2900.00	232.48	232.41	232.74	232.66
3000.00	232.57	232.45	232.98	232.66
3100.00	232.87	232.91	233.16	233.70
3200.00	232.67	232.47	233.02	232.76
3300.00	232.70	232.68	233.07	233.01
3400.00	232.90	232.75	233.02	232.85
3500.00	233.02	232.85	233.26	233.10
3600.00	233.05	232.98	233.19	233.12
3700.00	233.22	233.17	233.30	233.12
3800.00	233.29	233.29	233.50	233.40
3900.00	233.39	233.46	233.62	233.43
4000.00	233.43	233.40	233.60	233.63
4100.00	233.59	233.61	233.71	233.66
4200.00	233.58	233.55	233.80	233.82
4211.41	233.58	233.52	233.80	233.72



Datum RL 228

CHAINAGE	2014	2012	2011	2008
4111.41	233.60	233.56	233.64	233.75
4200.00	233.58	233.55	233.80	233.82
4300.00	234.09	234.12	234.17	234.10
4400.00	234.28	234.59	234.52	235.18
4500.00	233.92	234.04	234.07	234.50
4600.00	234.17	233.94	233.96	234.26
4700.00	233.71	234.09	234.18	234.42
4800.00	233.99	234.02	234.07	234.46
4900.00	233.90	233.96	234.04	234.50
5000.00	233.61	233.85	234.08	234.31
5100.00	233.66	233.86	234.10	234.77
5200.00	233.80	233.92	234.12	234.63
5300.00	233.79	233.96	234.16	234.67
5400.00	234.58	234.86	234.79	234.63
5500.00	235.30	235.35	235.36	235.39
5600.00	234.47	235.35	234.83	235.04
5700.00	235.05	235.33	235.56	235.44
5800.00	234.99	235.34	235.32	235.33
5900.00	234.38	235.38	235.24	235.51
6000.00	235.23	235.27	235.73	235.67
6100.00	235.16	235.31	235.37	235.70
6200.00	235.13	235.42	235.66	235.84
6300.00	235.31	235.35	235.78	235.92
6400.00	235.13	235.38	235.50	236.54
6500.00	236.06	236.07	236.52	237.23
6600.00	235.82	235.80	236.49	237.03
6700.00	235.50	235.69	235.98	236.54
6800.00	235.84	235.96	236.22	237.24
6900.00	236.18	236.00	236.29	236.89
7000.00	235.56	235.86	236.13	236.88
7100.00	234.86	235.86	236.14	236.88
7200.00	235.57	235.90	236.28	236.88
7300.00	234.86	235.88	236.34	237.29
7400.00	236.26	236.51	236.55	237.73
7411.41	236.46	236.55	236.70	237.73

REVISIONS

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	100	200	400	m
B	0	5	10	20	m
C					m

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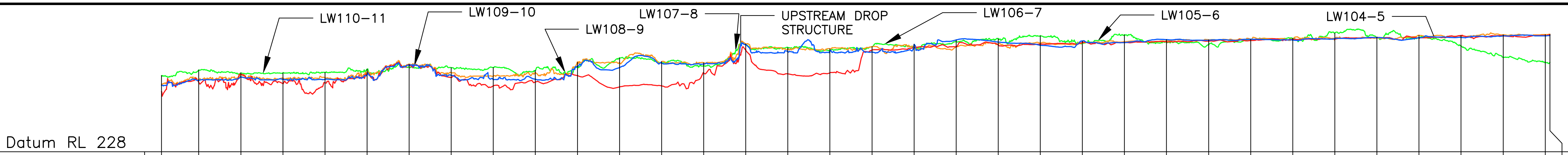
Client: BMA BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE

ISAAC RIVER
OPERATIONS MONITORING
LONGITUDINAL SECTION

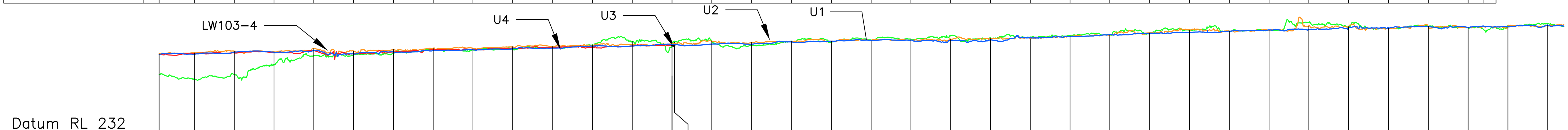
Drawing No. P214042_002 Revision No. A
Sheet No. 2 File Name: P214042_001-016.dwg

A3



Datum RL 228

CHAINAGE	2014	2012	2011	2008
7311.41	235.19	235.91	236.04	237.06
7400.00	236.26	236.51	236.55	237.73
7500.00	237.20	236.92	237.07	237.37
7600.00	236.10	236.61	236.78	237.39
7700.00	236.20	236.61	236.81	237.42
7800.00	237.21	237.16	237.37	237.83
7900.00	238.24	238.32	238.42	238.01
8000.00	236.82	237.10	237.40	238.01
8100.00	235.81	236.58	237.00	238.03
8200.00	236.30	236.62	237.40	237.68
8300.00	237.06	238.16	238.65	238.06
8400.00	235.70	238.01	238.62	239.15
8500.00	235.83	238.51	238.70	238.55
8600.00	237.36	238.43	238.58	238.24
8700.00	240.10	240.76	240.83	240.76
8800.00	237.26	239.88	240.18	240.36
8900.00	237.38	239.99	240.24	240.07
9000.00	240.09	239.87	240.49	240.48
9100.00	240.39	240.77	240.46	240.34
9200.00	240.50	241.29	240.45	241.11
9300.00	240.68	241.05	240.81	241.44
9400.00	240.79	240.66	240.92	241.79
9500.00	241.00	241.16	240.93	240.92
9600.00	240.98	240.98	241.07	241.91
9700.00	241.06	241.33	241.16	241.11
9800.00	241.16	241.26	241.32	240.73
9900.00	241.21	241.38	241.38	241.35
10000.00	241.37	241.28	241.30	241.49
10100.00	241.39	241.44	241.45	242.11
10200.00	241.59	241.57	241.53	241.62
10300.00	241.51	241.54	241.84	241.55
10400.00	241.83	241.59	241.74	240.59
10500.00	241.76	241.78	241.92	239.24
10600.00	241.86	241.78	241.94	238.67
10611.41	241.90	241.83	241.98	238.63



Datum RL 232

CHAINAGE	2014	2012	2011	2008
10511.41	241.72	241.75	241.83	239.23
10600.00	241.86	241.78	241.94	238.67
10700.00	241.93	242.02	242.16	239.27
10800.00	241.95	241.98	242.07	240.41
10900.00	242.24	242.26	242.47	241.54
11000.00	241.83	241.80	242.18	241.67
11100.00	242.06	242.05	242.35	241.91
11200.00	242.35	242.23	242.52	242.39
11300.00	242.38	242.32	242.45	242.29
11400.00	242.51	242.43	242.70	242.38
11500.00	242.60	242.53	242.74	242.55
11600.00	242.65	242.77	242.87	242.92
11700.00	242.81	242.79	242.99	243.35
11800.00	242.86	242.98	243.07	242.80
11805.89	242.83	242.98	243.09	243.40
11900.00		243.04	243.39	243.35
12000.00		243.02	243.25	242.83
12100.00		243.30	243.35	243.40
12200.00		243.38	243.41	243.25
12300.00		243.47	243.48	243.53
12400.00		243.54	243.55	243.63
12500.00		243.45	243.67	244.06
12600.00		243.56	243.71	243.80
12700.00		243.83	243.70	243.92
12800.00		243.97	243.98	244.11
12900.00		244.22	244.18	244.17
13000.00		244.39	244.44	244.41
13100.00		244.47	244.81	244.77
13200.00		244.65	244.65	244.66
13300.00		244.80	244.75	244.74
13400.00		244.83	245.32	245.73
13500.00		245.05	245.24	245.11
13600.00		245.08	245.00	244.95
13700.00		245.21	245.26	245.27
13800.00		245.14	245.10	245.04
13900.00		245.20	245.15	245.37
14000.00		245.39	245.37	245.62

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

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4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE
A 0 100 200 400 m
B 0 5 10 20 m
C m

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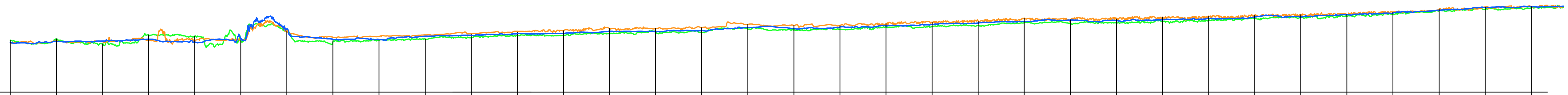
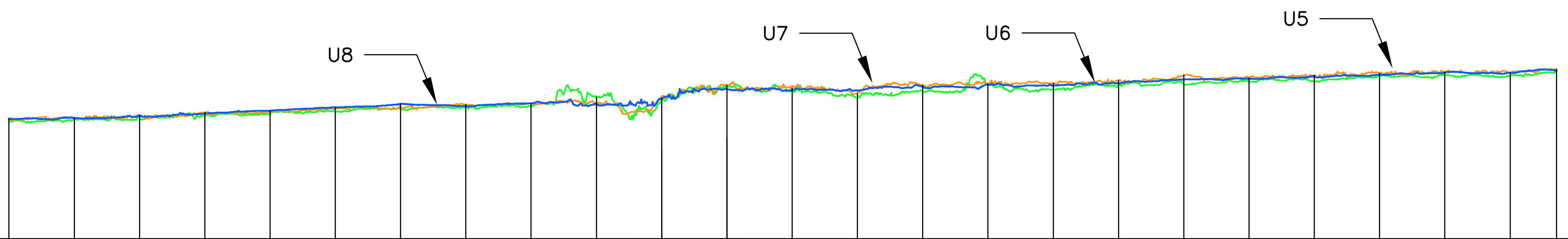
BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
LONGITUDINAL SECTION

Drawing No. P214042_003 Revision No. A
Sheet No. 3 File Name: P214042_001-016.dwg
 A3



Datum RL 236

CHAINAGE	2014	2012	2011	2008
14000.00		245.39	245.37	245.62
14100.00		245.49	245.56	245.74
14200.00		245.53	245.44	245.22
14300.00		245.72	245.56	246.20
14400.00		245.43	245.49	246.04
14500.00		245.79	245.72	245.54
14600.00		246.82	246.66	246.54
14700.00		245.71	245.94	245.43
14800.00		245.70	246.01	245.60
14900.00		246.04	246.20	245.75
15000.00		246.13	246.33	245.89
15100.00		246.33	246.58	246.11
15200.00		246.36	246.65	246.12
15300.00		246.59	246.88	246.29
15400.00		246.54	246.88	246.61
15500.00		246.66	246.96	246.46
15600.00		247.00	247.32	246.82
15700.00		246.87	247.22	246.74
15800.00		247.04	247.20	246.80
15900.00		247.17	247.41	247.06
16000.00		247.33	247.56	247.07
16100.00		247.48	247.68	247.19
16200.00		247.64	248.00	247.50
16300.00		247.81	247.71	247.43
16400.00		247.71	247.91	247.50
16500.00		247.81	248.10	247.64
16600.00		247.98	248.21	247.80
16700.00		248.13	248.33	247.98
16800.00		248.11	248.37	248.08
16900.00		248.39	248.39	248.19
17000.00		248.55	248.66	248.39
17100.00		248.87	248.98	248.82
17200.00		249.15	249.21	248.96
17300.00		249.24	249.22	249.12



Datum RL 244

CHAINAGE	2014	2012	2011	2008
17300.00				
17400.00		249.24	249.22	249.12
17500.00		249.43	249.39	249.16
17600.00		249.58	249.67	249.41
17700.00		249.81	249.69	249.60
17800.00		250.06	249.93	249.71
17900.00		250.32	250.12	249.89
18000.00		250.14	250.27	250.07
18100.00		250.36	250.35	250.14
18200.00		250.34	250.31	250.86
18300.00		250.74	250.76	250.69
18400.00		251.45	251.75	251.63
18500.00		251.36	251.53	251.30
18600.00		251.34	251.20	250.84
18700.00		251.63	251.76	251.29
18800.00		251.79	251.85	251.85
18900.00		251.72	251.91	251.41
19000.00		251.89	252.14	251.79
19100.00		252.19	252.52	251.81
19200.00		252.25	252.33	252.00
19300.00		252.46	252.50	251.99
19400.00		252.54	252.67	252.50
19500.00		252.71	252.78	252.52
19570.94		252.69 / 252.87	252.72 / 252.98	252.50 / 252.78

REV	DESCRIPTION	DATE	INTL
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REVISIONS

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	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	100	200	400	m
B	0	5	10	20	m
C					m

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Client: BMA BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE

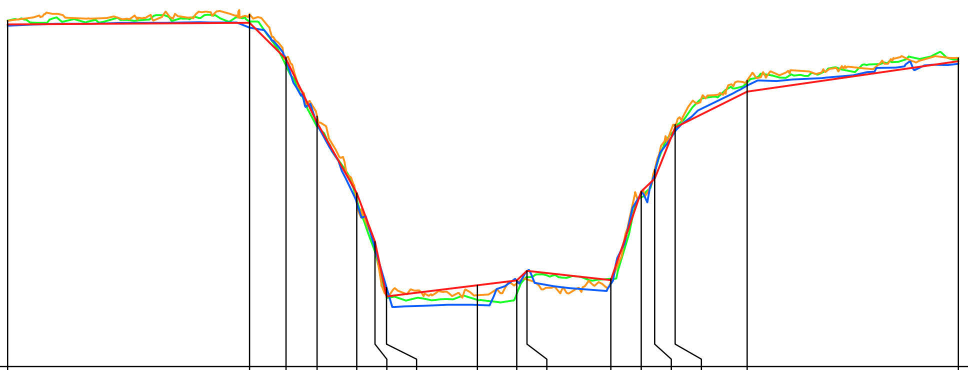
ISAAC RIVER
OPERATIONS MONITORING
LONGITUDINAL SECTION

Drawing No. P214042_004 | Revision No. A
Sheet No. 4 | File Name: P214042_001-016.dwg

A3

LEGEND

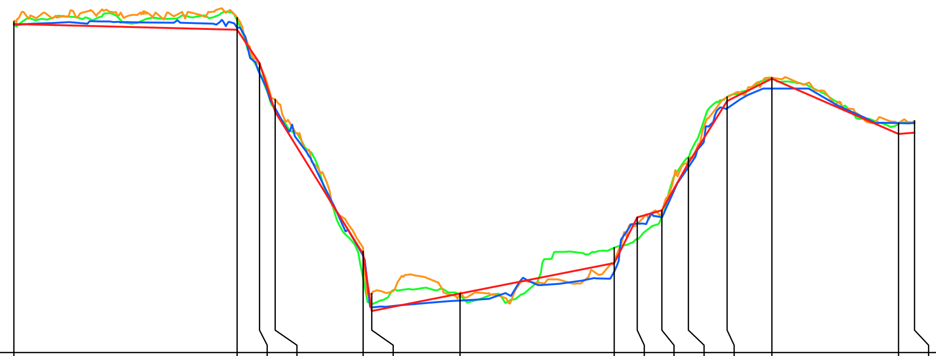
2014 LIDAR
2012 LIDAR
2011 LIDAR
2008 LIDAR



Datum RL 228

2014 LIDAR	239.42	239.47	238.27	236.14	233.79	232.17	230.34	230.71	230.87	231.20	230.89	233.84	234.27	235.98	237.18	238.19
2012 LIDAR	239.38	239.31	238.23	236.08	233.48	231.95	230.64	230.05	230.87	231.18	230.76	233.78	234.40	235.86	237.38	238.10
2011 LIDAR	239.54	239.75	238.31	236.35	233.53	232.06	230.40	230.38	230.78	230.91	230.83	233.79	234.57	236.08	237.55	238.30
2008 LIDAR	239.54	239.52	238.04	236.02	233.57	231.84	230.34	230.23	230.43	230.98	230.93	233.65	234.47	235.92	237.49	238.24
OFFSET	-125.40	-60.78	-51.11	-42.82	-32.19	-27.34	-24.29	0.00	10.53	13.24	35.65	43.76	47.30	52.79	72.06	128.42

MN467 (CH 1040)



Datum RL 229

2014 LIDAR	239.98	239.79	238.68	237.04	232.29	230.39	230.98	231.99	233.52	233.75	235.34	237.41	238.16	236.30	236.35
2012 LIDAR	239.96	239.85	238.33	237.16	232.23	230.51	230.74	231.70	233.32	233.51	235.20	237.16	237.83	236.67	236.68
2011 LIDAR	240.06	240.20	238.64	237.47	232.39	230.98	230.96	232.04	233.30	233.69	235.41	237.54	238.19	236.67	236.75
2008 LIDAR	240.03	240.10	238.37	237.11	231.48	230.63	230.91	232.50	232.80	233.53	235.52	237.55	238.16	236.64	236.65
OFFSET	-119.20	-59.57	-53.57	-49.43	-25.89	-23.64	0.00	41.14	47.33	53.89	60.92	71.29	83.24	117.07	121.31

MN471 (CH 1546)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

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2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	100	200	400	m
B	0	5	10	20	m
C					m

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Client: BMA BHP Billiton Mitsubishi Alliance

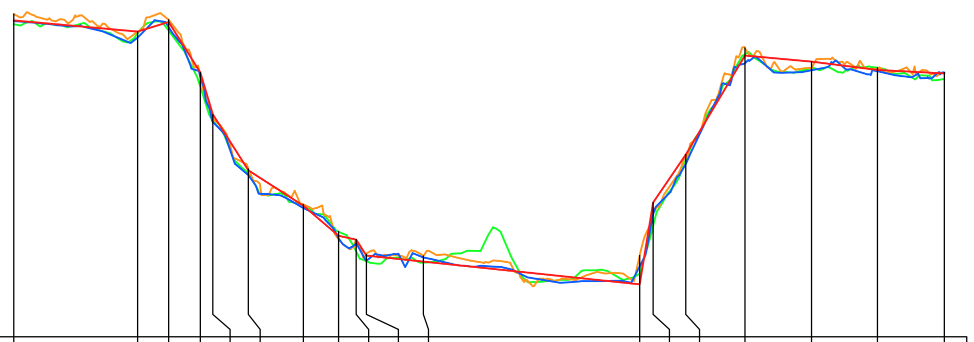
BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_005
Revision No. A
Sheet No. 5
File Name: P214042_001-016.dwg

ABN 45 653 522 596
A3

LEGEND

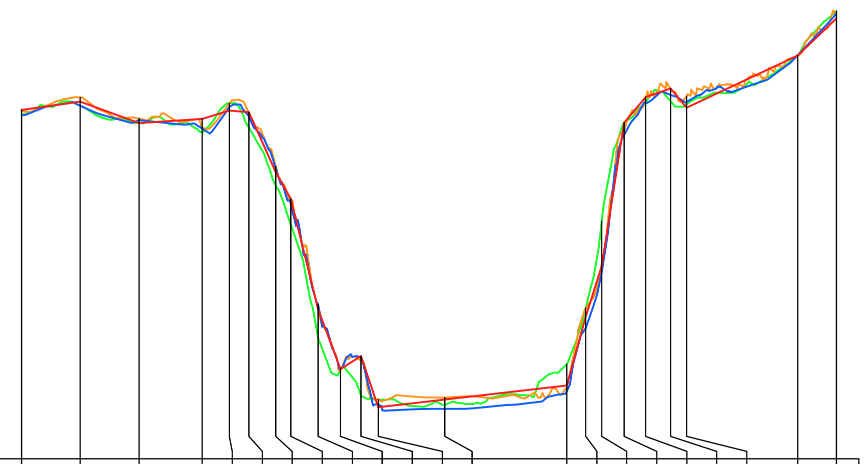
2014 LIDAR
2012 LIDAR
2011 LIDAR
2008 LIDAR



Datum RL 230

2014 LIDAR	240.57	240.20	240.52	238.84	237.44	235.57	234.38	233.38	233.25	232.71	232.51	231.76	234.49	236.10	239.40	239.20	238.92	238.80
2012 LIDAR	240.56	240.00	240.36	238.68	237.18	235.41	234.31	233.30	233.13	232.55	232.65	232.35	234.11	235.77	239.15	238.91	238.88	238.84
2011 LIDAR	240.79	240.19	240.59	238.72	237.31	235.61	234.43	233.26	233.20	232.76	232.71	232.72	234.22	236.07	239.66	238.98	238.97	238.80
2008 LIDAR	240.45	240.13	240.23	238.37	237.24	235.46	234.42	233.52	232.86	232.53	232.48	232.11	233.71	235.91	239.45	238.98	238.99	238.62
OFFSET	-109.32	-76.29	-67.98	-59.54	-56.23	-46.68	-32.03	-22.61	-17.91	-15.21	0.00	57.72	61.34	70.05	85.85	103.60	121.24	139.05

Div2 (CH 2263)



Datum RL 231

2014 LIDAR	242.64	242.93	242.21	242.35	242.62	242.57	240.56	239.67	236.01	233.99	234.43	232.73	232.98	233.45	235.75	237.44	242.22	243.07	243.36	242.72	244.46	245.70
2012 LIDAR	242.46	242.79	242.30	242.02	242.74	242.43	240.67	239.51	236.16	234.01	234.39	232.83	232.67	233.26	235.37	237.22	241.81	242.88	243.15	242.91	244.47	245.86
2011 LIDAR	242.60	243.06	242.35	242.06	242.86	242.54	240.76	239.58	235.99	233.96	234.28	232.98	233.05	233.39	236.03	237.52	241.98	243.03	243.35	243.11	244.44	245.86
2008 LIDAR	242.49	242.79	242.20	241.89	242.87	242.05	240.12	238.81	235.04	233.97	233.12	232.98	232.79	234.16	236.04	238.94	242.22	242.88	242.94	242.84	244.46	245.94
OFFSET	-112.88	-97.28	-81.59	-64.70	-57.49	-52.30	-45.08	-41.06	-33.81	-27.87	-22.35	-17.75	0.00	32.56	37.63	41.90	47.83	53.54	60.28	64.49	94.17	104.48

Div1 (CH 3312)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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Client:

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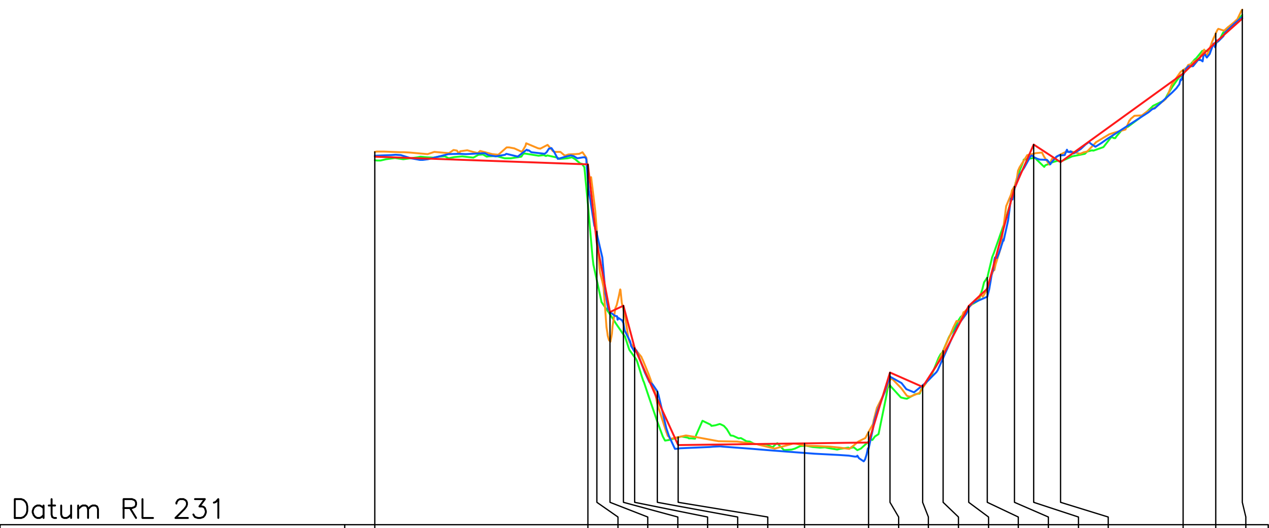
BROADMEADOW MINE

ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_006
Revision No. A
Sheet No. 6
File Name: P214042_001-016.dwg

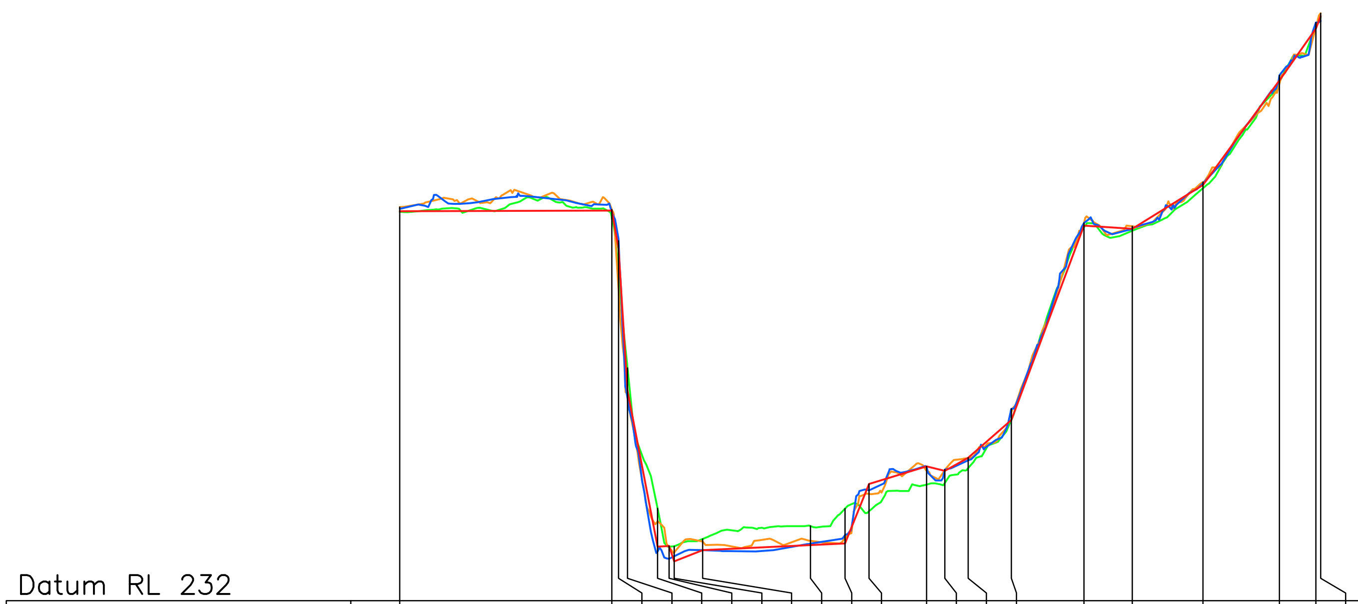
ABN 45 653 522 596
A3

LEGEND
- 2014 LIDAR (red)
- 2012 LIDAR (blue)
- 2011 LIDAR (orange)
- 2008 LIDAR (green)



2014 LIDAR	243.29	243.04	240.40	238.10	238.32	236.90	235.18	233.66	233.71	233.74	236.08	235.60	236.66	238.31	238.88	242.23	243.70	243.11	246.07	247.11	247.90
2012 LIDAR	243.32	242.51	240.71	238.11	237.73	236.77	235.45	233.54	233.39	233.53	235.94	235.65	236.57	238.25	238.61	242.22	243.29	243.33	246.03	247.02	247.96
2011 LIDAR	243.45	242.91	240.79	237.13	238.19	236.88	235.02	233.92	233.64	234.09	235.83	235.57	236.80	238.25	238.92	242.30	243.39	243.37	246.18	247.41	248.20
2008 LIDAR	243.17	241.70	239.15	238.02	237.35	236.59	234.44	233.91	233.63	233.78	235.66	235.58	236.81	238.27	239.26	242.27	243.24	243.14	246.08	247.08	248.03
OFFSET	-114.75	-57.86	-55.45	-51.99	-48.37	-45.34	-39.27	-33.78	0.00	17.08	22.79	31.51	36.96	43.81	48.77	56.06	61.19	68.31	101.06	109.79	116.82

LW119 (CH 4028)



2014 LIDAR	245.00	245.02	243.76	239.01	233.80	233.83	233.31	233.69	233.85	233.91	235.89	236.48	236.33	236.77	238.03	244.53	244.42	245.88	249.37	251.11	251.52
2012 LIDAR	245.09	244.98	244.03	238.77	233.64	233.40	233.48	233.68	233.90	234.19	235.68	236.46	236.38	236.68	238.40	244.61	244.44	245.93	249.55	251.30	251.36
2011 LIDAR	245.15	245.06	242.41	238.84	234.65	233.79	233.61	233.97	234.00	234.08	235.56	236.34	236.35	236.73	238.30	244.61	244.50	245.98	249.27	251.14	251.62
2008 LIDAR	244.99	244.77	242.92	239.77	235.09	233.80	233.82	234.06	234.49	235.07	234.99	235.87	235.93	236.43	238.03	244.47	244.35	245.78	249.32	251.15	251.48
OFFSET	-109.68	-52.98	-51.23	-48.85	-40.82	-37.75	-36.34	-28.78	0.00	9.24	15.70	31.00	35.92	42.17	53.64	73.03	85.92	104.87	125.25	134.98	136.30

LW118-19 (CH 4521)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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Client:
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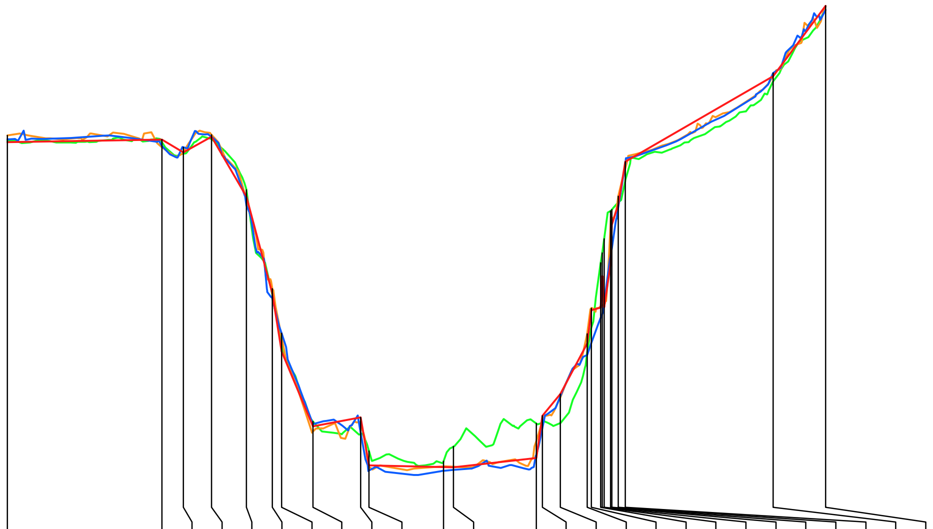
BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_007
Revision No. A
Sheet No. 7
File Name: P214042_001-016.dwg
©Alluvium Consulting Australia
ABN 45 653 522 596
A3

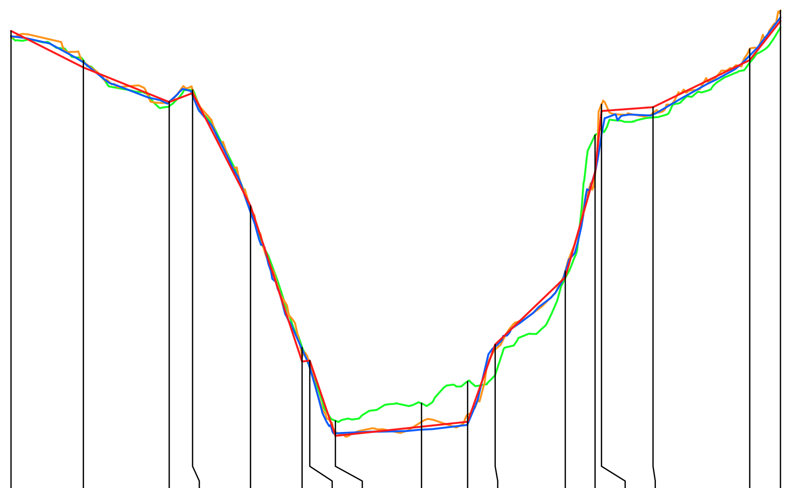
LEGEND
- 2014 LIDAR
- 2012 LIDAR
- 2011 LIDAR
- 2008 LIDAR



Datum RL 232

2014 LIDAR	244.93	245.02	244.59	245.12	243.11	239.88	237.94	235.45	235.74	234.14	234.09	234.08	234.39	235.80	236.52	238.22	239.33	239.41	240.46	239.42	240.88	242.18	242.85	244.28	247.13	249.48
2012 LIDAR	245.03	244.80	244.76	245.11	242.82	239.71	238.56	235.53	235.23	233.97	233.96	233.99	234.50	235.40	236.45	237.83	238.23	239.07	239.19	239.53	241.13	241.39	242.76	244.20	247.23	249.35
2011 LIDAR	245.16	244.76	244.60	245.18	243.01	240.04	238.42	235.28	235.49	234.09	234.11	234.10	234.96	235.63	236.41	238.54	239.39	239.45	239.48	239.52	242.17	242.41	243.13	244.06	247.15	249.46
2008 LIDAR	244.98	244.93	244.55	245.04	243.34	239.80	238.23	235.61	235.19	234.63	234.28	234.77	235.54	235.60	235.56	237.93	238.75	240.91	241.24	241.71	242.63	242.68	242.92	243.64	246.96	249.47
OFFSET	−116.44	−75.14	−69.46	−61.91	−52.59	−45.67	−43.26	−34.83	−22.10	−19.90	0.00	2.68	24.72	26.40	31.19	38.37	39.50	41.97	42.34	42.87	44.57	44.88	46.67	48.50	87.99	101.96

LW117–18 (CH 4943)



Datum RL 232

2014 LIDAR	247.26	246.04	244.89	245.18	241.43	236.24	236.27	233.76	234.07	234.23	236.80	239.05	242.55	244.59	244.72	246.29	247.59
2012 LIDAR	247.08	246.22	244.89	245.11	241.21	236.65	236.04	233.84	233.97	234.16	236.74	239.23	242.55	243.80	244.47	246.44	247.71
2011 LIDAR	247.09	246.22	244.89	245.29	241.28	236.46	236.17	233.90	234.23	234.47	236.64	239.25	242.47	244.81	244.52	246.66	247.94
2008 LIDAR	247.06	246.27	244.75	245.29	241.35	236.71	236.04	234.27	234.85	235.57	235.79	239.03	243.79	243.97	244.37	246.20	247.37
OFFSET	−109.50	−90.15	−67.28	−61.01	−45.55	−31.81	−29.78	−22.92	0.00	12.33	19.64	38.37	46.36	48.06	61.78	87.59	95.78

LW116–17 (CH 5305)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A 0 20 40 80 m
B 0 2.5 5 10 m
C m

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Client: BMA BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_008 Revision No. A
Sheet No. 8 File Name: P214042_001-016.dwg
 ABN 45 653 522 596
A3

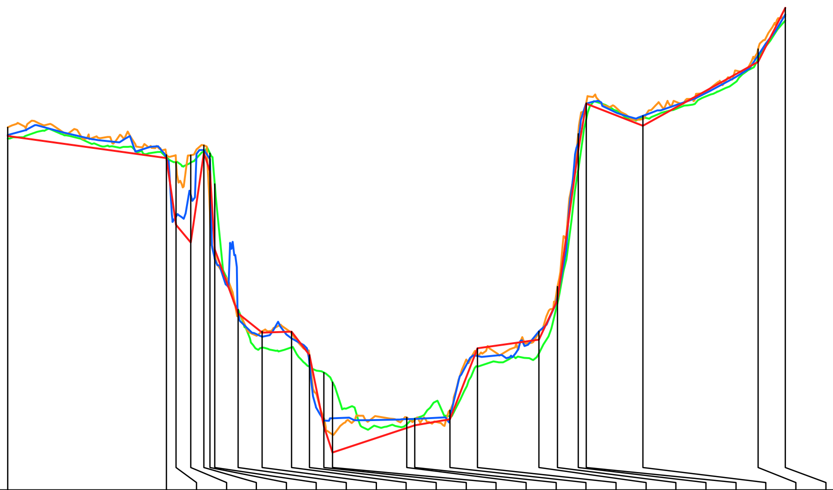
LEGEND

2014 LIDAR

2012 LIDAR

2011 LIDAR

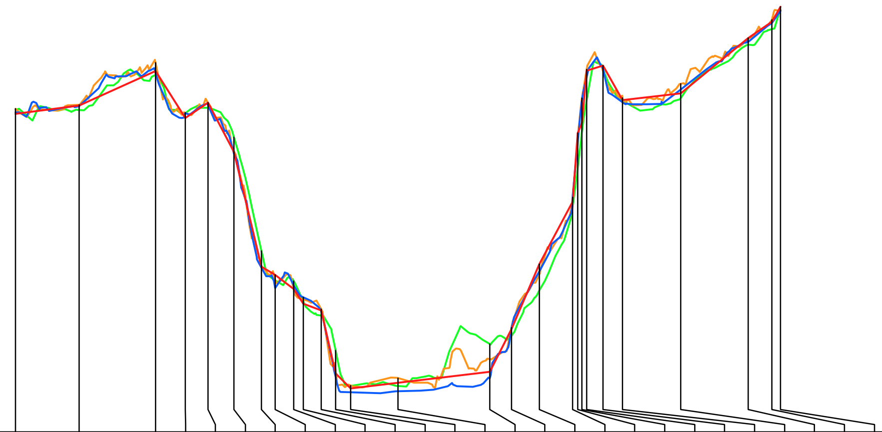
2008 LIDAR



Datum RL 233

2014 LIDAR	244.83	244.09	241.85	241.26	244.26	243.65	241.03	238.89	238.26	238.29	237.51	235.13	234.26	235.07	235.16	235.37	237.74	238.03	239.34	244.36	245.91	245.17	247.30	249.10
2012 LIDAR	244.86	244.08	242.14	242.86	244.36	244.05	240.72	238.94	238.12	238.07	237.21	235.32	235.39	235.36	235.38	235.43	237.47	238.30	239.47	244.59	245.91	245.49	247.51	248.89
2011 LIDAR	245.11	244.19	243.94	244.18	244.51	242.27	240.86	238.80	238.29	238.23	237.47	235.38	234.85	235.42	235.34	235.66	237.51	238.25	239.80	244.89	245.93	245.39	247.72	248.83
2008 LIDAR	244.74	244.10	243.96	243.93	244.31	244.25	243.22	239.02	237.75	237.77	237.12	236.92	236.60	235.19	235.38	235.46	237.13	237.56	239.24	243.69	245.39	245.45	247.39	248.68
OFFSET	−106.50	−64.11	−61.55	−57.67	−54.11	−52.53	−51.24	−45.00	−38.62	−30.70	−25.97	−22.06	−19.75	0.00	2.18	11.59	18.92	35.26	40.28	45.80	47.93	63.02	93.80	101.09

LW115−16 (CH 5683)



Datum RL 234

2014 LIDAR	244.63	244.90	246.06	244.49	245.00	243.35	239.52	239.25	238.78	238.29	238.06	235.96	235.45	235.64	236.01	237.45	239.61	241.69	243.99	244.32	246.07	246.25	245.09	245.31	247.16	247.71	248.20
2012 LIDAR	244.68	244.89	245.99	244.66	244.92	243.30	239.49	238.81	238.89	238.50	238.03	235.85	235.32	235.36	235.80	237.49	239.37	241.84	243.67	245.05	245.87	246.15	245.02	245.44	247.03	247.66	248.07
2011 LIDAR	244.80	244.93	246.34	244.66	244.99	243.38	239.53	239.07	238.76	238.43	238.10	236.07	235.55	235.80	236.43	237.48	239.27	241.78	243.81	245.15	246.11	246.06	245.16	245.63	247.14	247.77	248.08
2008 LIDAR	244.76	244.75	245.93	244.65	244.83	243.84	240.04	239.06	239.04	238.36	237.89	236.72	235.53	235.53	236.94	237.21	238.73	241.54	242.82	244.03	245.09	246.12	245.06	245.15	246.93	247.46	248.11
OFFSET	−102.16	−85.16	−64.76	−56.78	−50.73	−43.82	−36.46	−32.78	−27.85	−25.27	−20.54	−16.69	−12.64	0.00	24.50	30.32	37.78	46.63	48.02	49.13	50.42	54.74	60.00	75.49	93.50	99.88	102.16

LW114−15 (CH 6047)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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BROADMEADOW MINE

ISAAC RIVER

OPERATIONS MONITORING

CROSS SECTIONS

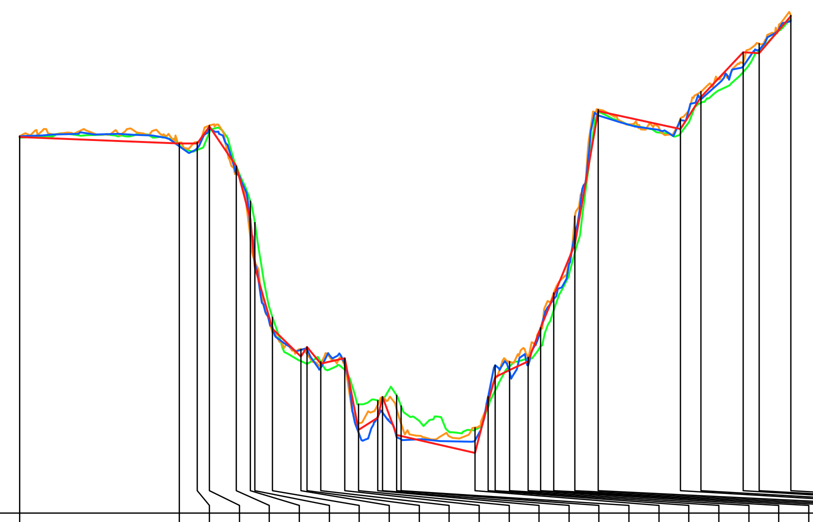
Drawing No. P214042_009 Revision No. A

Sheet No. 9 File Name: P214042_001-016.dwg

A3

LEGEND

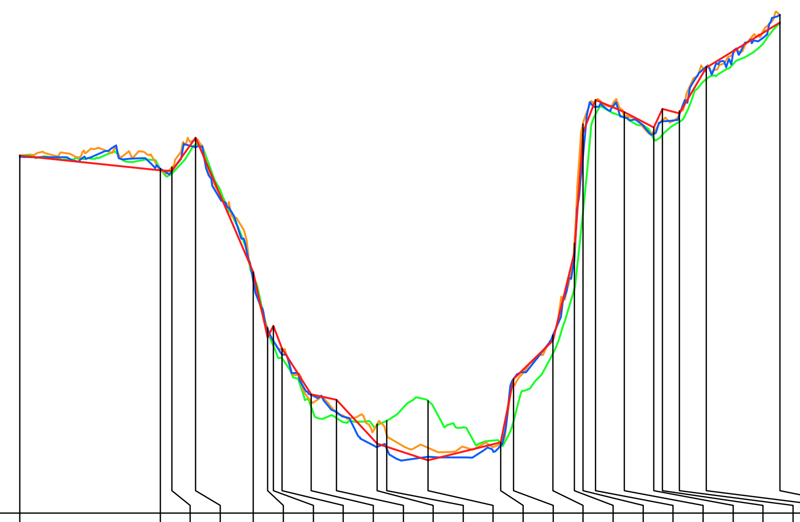
2014 LIDAR
2012 LIDAR
2011 LIDAR
2008 LIDAR



Datum RL 233

2014 LIDAR	245.55	245.33	245.34	245.90	244.57	242.81	241.21	239.15	238.22	238.54	237.98	238.17	235.78	236.18	236.87	235.61	235.57	235.01	236.70	237.53	237.77	238.06	239.18	240.25	241.97	246.41	245.81	246.88	248.38	248.34	249.58
2012 LIDAR	245.57	245.24	245.17	245.83	244.33	242.51	241.33	239.19	238.45	238.47	237.85	237.98	235.69	236.22	236.35	235.53	235.46	235.42	236.88	237.93	237.72	237.93	239.16	240.14	242.32	246.26	246.11	246.81	247.91	248.45	249.43
2011 LIDAR	245.58	245.34	245.38	245.93	244.33	242.20	241.39	239.03	238.46	238.30	237.97	237.89	235.99	236.60	236.87	236.47	235.98	235.85	236.88	237.49	238.05	238.20	239.13	240.34	242.90	246.46	246.16	247.06	248.01	248.66	249.60
2008 LIDAR	245.53	245.29	245.11	245.69	244.58	243.41	242.69	239.53	238.07	237.98	238.05	237.78	236.63	236.75	236.74	236.93	236.58	235.78	236.53	237.08	237.89	238.15	238.57	239.76	241.70	246.34	245.67	246.69	247.72	248.42	249.47
OFFSET	−101.82	−59.16	−54.38	−51.19	−44.02	−40.25	−39.00	−34.31	−26.71	−25.10	−21.45	−15.03	−11.38	−6.26	−4.91	−1.19	0.00	19.72	23.26	25.14	28.98	33.91	37.29	40.78	46.40	52.61	74.60	80.05	91.34	95.59	104.05

LW113–14 (CH 6417)



Datum RL 234

2014 LIDAR	245.93	245.43	245.41	246.52	242.04	239.86	240.24	239.49	237.96	237.78	236.31	236.20	235.76	236.35	238.47	239.75	242.69	246.69	247.79	247.38	246.87	247.48	247.33	248.86	250.36
2012 LIDAR	245.88	245.49	245.44	246.21	241.76	240.12	239.74	239.28	237.95	237.37	236.20	236.12	235.88	236.25	238.48	239.94	242.45	245.90	247.55	247.20	246.65	247.07	247.30	248.89	250.63
2011 LIDAR	245.93	245.46	245.54	246.46	241.87	240.18	239.73	239.45	237.72	237.35	236.96	236.59	236.18	236.29	238.27	239.90	243.00	246.98	247.71	247.27	246.72	247.13	247.42	248.85	250.61
2008 LIDAR	245.94	245.48	245.33	246.28	241.93	240.12	239.59	239.17	237.54	237.17	236.92	237.08	237.75	236.32	237.06	239.33	241.47	244.05	247.30	247.20	246.48	246.62	247.06	248.47	250.32
OFFSET	−97.92	−60.44	−57.33	−51.06	−35.63	−31.82	−30.31	−27.97	−20.23	−13.44	−2.59	0.00	10.95	30.39	33.77	44.33	50.01	52.30	55.65	63.38	71.21	73.49	78.08	85.23	104.82

LW112–13 (CH 6796)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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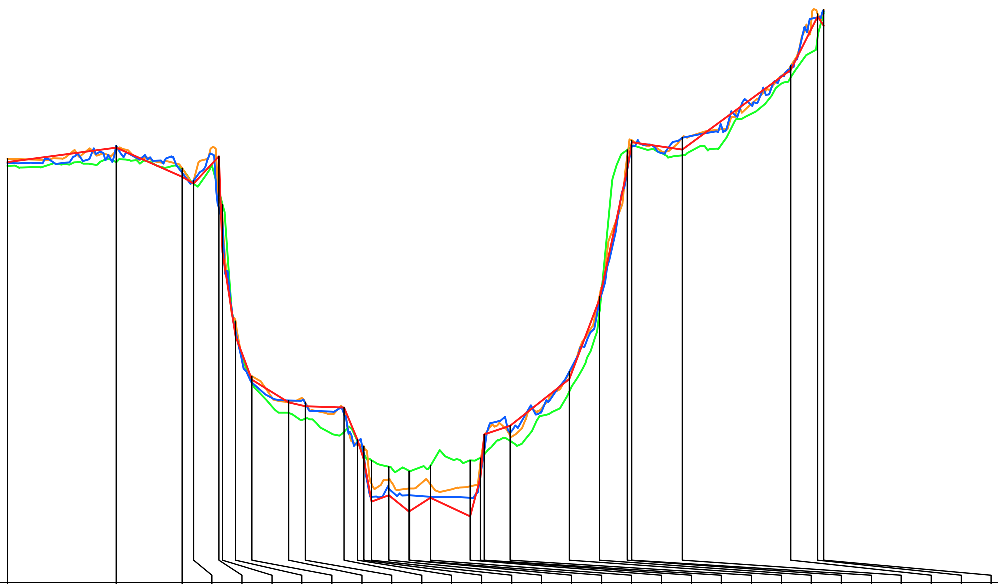
BROADMEADOW MINE

ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_010
Revision No. A
Sheet No. 10
File Name: P214042_001-016.dwg

ABN 45 653 522 596
A3

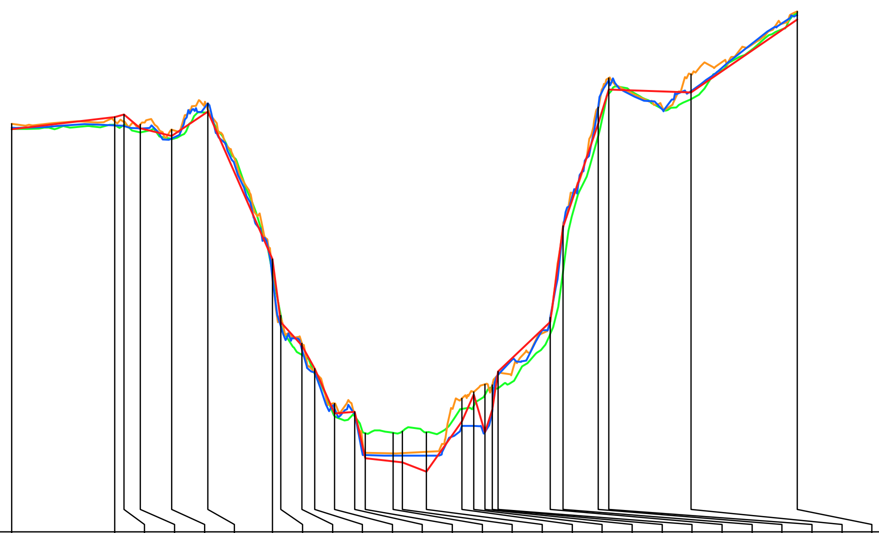
LEGEND	
2014 LIDAR	red line
2012 LIDAR	blue line
2011 LIDAR	orange line
2008 LIDAR	green line



Datum RL 233

2014 LIDAR	247.03	247.51	246.55	246.32	247.23	244.03	241.23	239.77	239.02	238.89	238.84	237.77	237.10	235.71	235.92	235.37	235.39	235.83	235.22	236.50	237.94	238.24	239.79	242.46	246.80	247.70	247.45	250.12	251.90	251.58
2012 LIDAR	247.01	247.58	246.69	246.42	245.49	245.01	241.38	239.68	239.08	238.98	238.64	237.70	237.25	235.87	236.13	235.92	235.92	235.87	235.83	236.58	237.38	238.00	240.04	242.41	246.78	247.57	247.85	250.24	251.87	252.06
2011 LIDAR	247.15	247.42	246.84	246.42	245.79	245.27	241.72	239.90	239.03	239.00	238.76	237.60	237.55	236.30	236.45	236.14	236.14	236.28	236.21	236.99	237.83	237.92	240.01	242.55	247.22	247.77	247.86	250.25	251.98	252.12
2008 LIDAR	246.91	247.03	246.82	246.31	246.08	245.63	241.40	239.68	238.66	238.47	238.03	237.72	237.30	237.09	236.87	236.72	236.72	236.90	237.08	237.16	237.27	237.73	239.38	242.04	247.44	247.56	247.27	249.87	251.22	252.01
OFFSET	-107.41	-78.39	-60.81	-57.68	-50.95	-50.00	-46.50	-42.14	-32.33	-27.86	-17.57	-14.00	-12.22	-10.23	-5.61	-0.19	0.00	5.52	16.13	18.87	19.88	26.76	42.58	50.64	58.08	59.27	72.78	101.71	108.88	110.48

LW111–12 (CH 7176)



Datum RL 234

2014 LIDAR	247.44	247.84	247.93	247.47	247.21	248.02	243.10	241.00	240.22	239.45	237.95	238.01	236.46	236.35	236.32	236.01	237.69	238.59	237.32	238.08	239.36	241.01	244.17	247.63	248.76	248.67	251.10
2012 LIDAR	247.49	247.57	247.55	247.46	247.13	248.30	242.47	240.87	240.09	239.33	238.11	237.93	236.57	236.55	236.55	236.55	237.54	237.53	237.33	238.02	239.24	241.16	244.13	248.17	249.07	248.70	251.25
2011 LIDAR	247.62	247.71	247.69	247.60	247.43	248.09	242.61	241.15	240.30	239.33	238.28	237.91	236.64	236.62	236.63	236.67	238.45	238.67	238.93	238.91	239.25	241.13	244.21	248.15	249.15	249.27	251.36
2008 LIDAR	247.44	247.58	247.58	247.33	247.11	247.99	242.65	241.22	239.90	239.28	237.87	237.85	237.30	237.31	237.36	237.33	238.10	238.20	238.58	238.81	238.80	240.61	242.68	247.22	248.62	248.44	251.32
OFFSET	-101.84	-74.35	-71.84	-67.51	-59.07	-49.44	-32.19	-30.00	-24.35	-20.92	-15.59	-10.28	-7.45	0.00	2.44	8.84	18.37	21.49	24.50	26.44	27.99	41.97	45.33	54.73	57.53	79.54	107.91

LW110–11 (CH 7560)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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BROADMEADOW MINE

ISAAC RIVER

OPERATIONS MONITORING

CROSS SECTIONS

Drawing No. P214042_011 Revision No. A

Sheet No. 11 File Name: P214042_001-016.dwg

A3

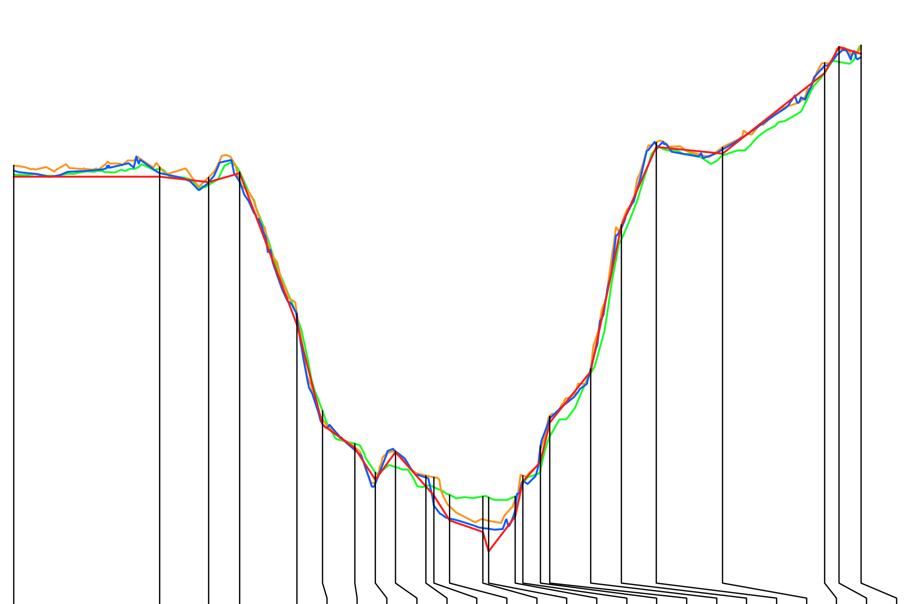
LEGEND

2014 LIDAR

2012 LIDAR

2011 LIDAR

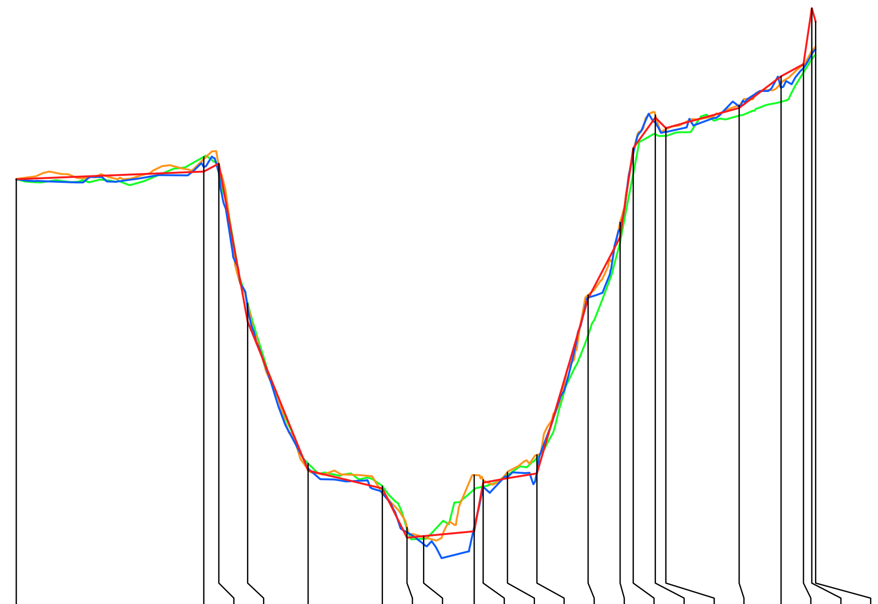
2008 LIDAR



Datum RL 234

2014 LIDAR	248.33	248.33	248.15	248.44	243.38	240.04	239.26	238.20	239.14	237.99	237.69	236.85	236.46	235.81	236.98	238.15	238.81	240.12	241.83	246.69	249.32	249.09	251.79	252.67	252.43
2012 LIDAR	248.53	248.45	248.15	248.17	243.60	240.07	239.19	238.07	239.15	238.29	237.34	236.91	236.60	236.57	237.21	238.18	239.33	240.26	241.91	246.61	249.40	249.23	252.04	252.45	252.32
2011 LIDAR	248.71	248.65	248.30	248.21	243.76	240.22	239.29	238.13	239.10	238.35	238.29	237.32	236.88	236.84	237.52	238.34	239.25	240.33	241.88	246.71	249.47	249.31	252.13	252.60	252.63
2008 LIDAR	248.41	248.58	248.05	248.49	243.65	240.51	239.41	238.45	238.64	237.99	237.96	237.70	237.65	237.62	237.65	238.05	238.53	239.66	241.77	246.24	249.26	249.04	251.80	252.16	252.72
OFFSET	−110.00	−71.05	−58.02	−49.73	−34.36	−27.61	−18.96	−13.46	−8.09	0.00	2.18	6.34	15.24	16.79	23.88	25.88	30.64	33.10	44.04	52.19	61.51	79.22	106.43	110.27	116.21

LW109−10 (CH 7914)



Datum RL 235

2014 LIDAR	249.25	249.50	249.77	244.49	239.51	238.91	237.27	237.32	237.48	239.11	239.26	239.42	245.26	247.31	250.28	251.30	250.95	251.62	252.68	253.08	254.96	254.51
2012 LIDAR	249.23	249.65	249.46	244.91	239.58	238.75	237.45	237.05	237.62	238.97	239.29	239.45	245.29	247.59	250.11	251.14	250.86	251.66	252.30	252.95	253.41	253.58
2011 LIDAR	249.25	249.91	249.58	245.02	239.54	238.74	237.61	237.29	239.36	239.20	239.46	240.04	245.38	247.81	250.10	251.38	250.91	251.71	252.45	253.09	253.52	253.66
2008 LIDAR	249.24	249.99	249.55	245.10	239.74	238.99	237.56	237.24	238.88	238.98	239.37	239.94	244.03	247.13	249.41	250.75	250.69	251.36	251.83	252.81	253.25	253.37
OFFSET	−108.79	−58.73	−54.74	−46.99	−30.86	−11.04	−4.46	0.00	13.49	15.89	22.38	30.22	43.87	52.39	55.88	61.80	64.61	84.17	95.33	101.35	103.61	104.62

LW108−9 (CH 8273)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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BROADMEADOW MINE

ISAAC RIVER

OPERATIONS MONITORING

CROSS SECTIONS

Drawing No. P214042_012 Revision No. A

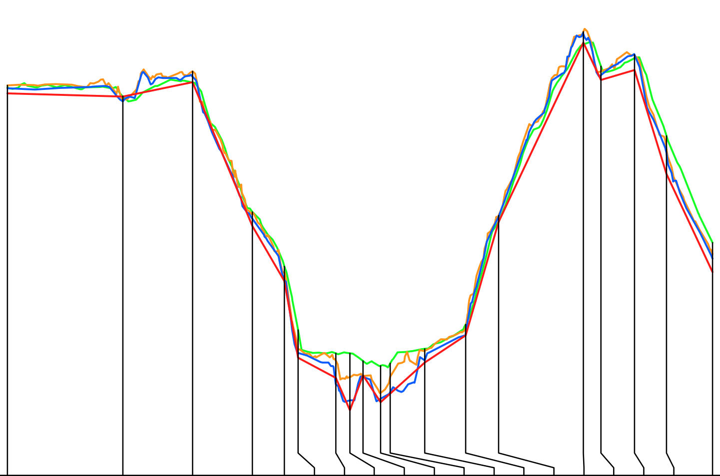
Sheet No. 12 File Name: P214042_001-016.dwg

 ABN 45 653 522 596

A3

LEGEND

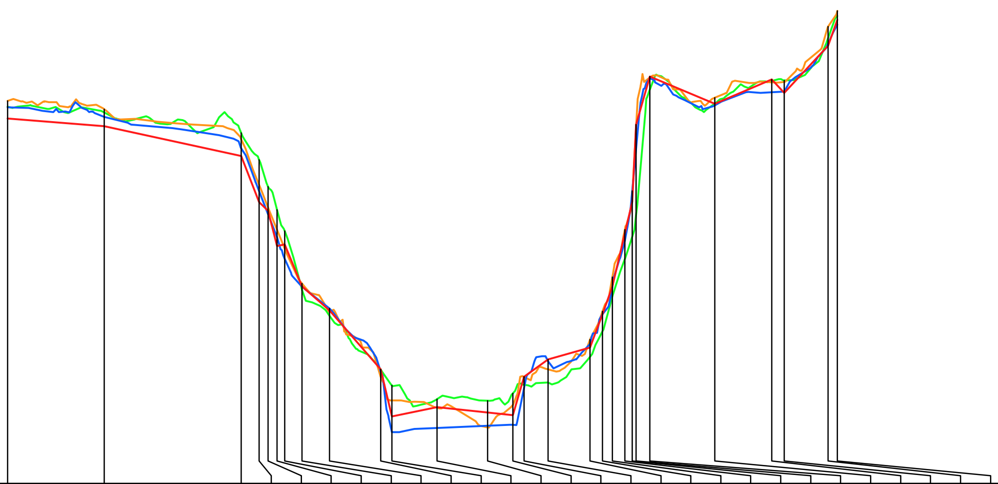
2014 LIDAR
2012 LIDAR
2011 LIDAR
2008 LIDAR



Datum RL 236

2014 LIDAR	248.76	248.65	249.13	244.32	242.49	239.93	239.26	238.18	239.34	238.45	238.73	239.76	240.68	244.47	250.46	249.21	249.54	246.07	242.79
2012 LIDAR	248.93	248.49	249.32	244.58	242.52	240.09	239.04	238.50	239.29	238.56	238.78	239.84	240.69	244.64	250.75	249.36	250.05	246.78	243.24
2011 LIDAR	249.03	248.57	249.50	244.78	242.77	240.22	239.83	239.28	239.32	238.75	239.30	240.17	240.92	244.68	250.82	249.49	250.02	246.89	243.39
2008 LIDAR	248.96	248.66	249.12	244.80	242.99	240.85	240.08	240.08	239.82	239.66	239.74	240.23	241.04	244.46	250.39	249.67	249.93	247.34	243.77
OFFSET	-102.30	-71.47	-52.79	-36.79	-28.27	-24.65	-14.55	-10.75	-7.24	-2.54	0.00	9.25	20.11	28.97	51.60	56.31	65.28	73.81	86.11

LW 107-8 (CH 8674)



Datum RL 238

2014 LIDAR	250.16	249.91	248.91	247.38	247.09	245.91	245.97	244.57	243.77	241.80	240.23	240.54	240.36	240.27	241.56	242.14	242.52	243.64	244.56	246.33	247.38	249.96	251.56	250.65	251.46	251.02	252.58	253.45
2012 LIDAR	250.54	250.22	249.16	247.74	246.97	246.21	245.48	244.55	243.83	241.72	239.71	239.85	239.92	239.95	241.18	242.07	242.65	243.64	244.55	246.08	247.74	249.14	251.51	250.60	251.04	251.06	252.66	253.30
2011 LIDAR	250.74	250.47	249.47	247.95	247.20	246.46	245.82	244.66	243.73	241.54	240.77	240.52	239.86	240.61	241.55	241.80	242.79	243.74	244.87	246.45	247.71	249.87	251.53	250.86	251.37	251.38	253.23	253.75
2008 LIDAR	250.56	250.36	249.68	248.79	247.89	247.11	246.41	244.45	243.58	241.79	241.26	240.80	240.75	241.00	241.28	241.36	242.22	243.07	244.23	245.47	246.22	246.95	251.12	250.66	251.41	251.43	252.84	253.58
OFFSET	-128.13	-102.33	-65.73	-60.97	-58.56	-56.19	-54.16	-49.53	-42.15	-28.50	-25.56	-13.52	0.00	6.73	9.74	16.14	27.34	30.69	33.34	36.65	38.62	39.64	43.32	60.63	75.89	79.16	90.92	93.38

LW106-7 (CH 9028)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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Client:

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BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

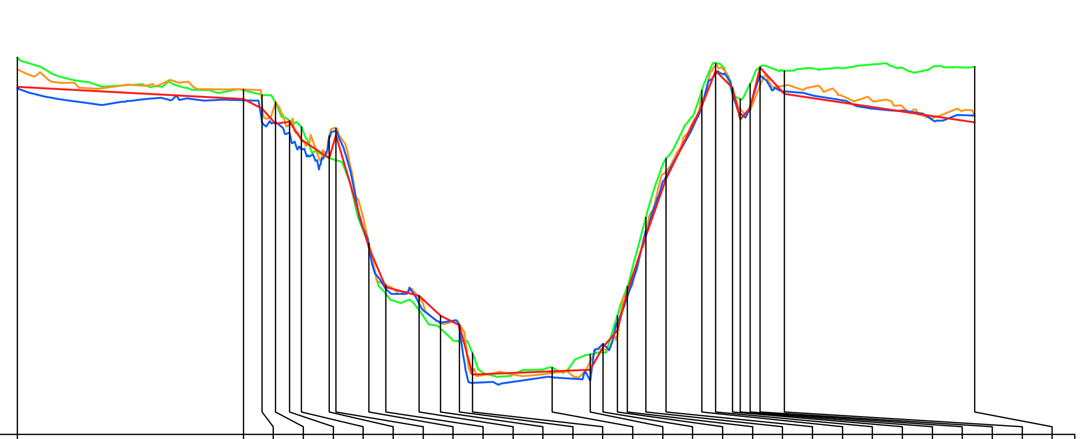
Drawing No. P214042_013 Revision No. A

Sheet No. 13 File Name: P214042_001-016.dwg

A3

LEGEND

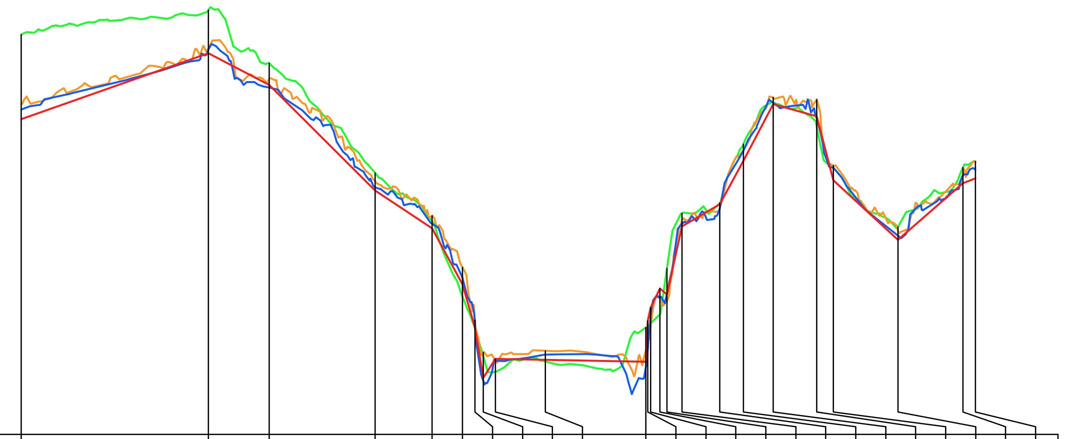
- 2014 LIDAR
- 2012 LIDAR
- 2011 LIDAR
- 2008 LIDAR



Datum RL 239

2014 LIDAR	250.60	250.19	249.87	249.37	249.43	248.84	248.21	248.99	245.24	243.91	243.62	242.96	242.64	241.00	241.11	241.16	241.91	242.46	243.77	245.61	247.52	249.96	251.13	250.56	249.50	249.90	251.24	250.36	249.41
2012 LIDAR	250.54	250.15	249.41	249.40	249.06	248.52	248.88	249.10	245.24	243.84	243.37	242.73	242.55	240.72	240.90	240.79	242.02	242.72	243.59	245.77	247.59	249.95	251.03	250.34	249.71	249.97	250.97	250.44	249.63
2011 LIDAR	251.18	250.51	250.02	250.04	249.35	248.82	248.96	249.21	245.39	243.99	243.56	242.73	242.67	241.09	241.05	241.43	241.83	242.27	243.73	245.66	247.78	250.08	251.29	250.51	249.86	249.83	250.65	250.64	249.64
2008 LIDAR	251.58	250.48	250.33	250.08	249.46	249.26	248.23	248.15	245.26	243.69	243.15	242.53	242.12	241.71	241.23	241.67	241.73	242.96	243.93	246.24	248.20	250.48	251.38	250.36	250.19	250.70	251.26	251.12	251.27
OFFSET	-142.84	-82.44	-77.47	-73.91	-70.10	-66.98	-59.52	-57.72	-48.90	-44.36	-35.52	-29.77	-24.78	-21.27	0.00	10.18	13.62	17.43	20.11	25.04	30.42	39.99	43.67	48.20	50.29	52.91	55.57	62.04	112.89

LW105-6 (CH 9537)



Datum RL 239

2014 LIDAR	249.52	251.72	250.66	247.13	245.88	244.00	242.57	240.89	241.52	241.49	241.42	242.78	243.23	243.87	243.67	245.94	246.67	248.13	250.02	249.61	247.48	245.49	247.38	247.54
2012 LIDAR	249.84	251.84	250.58	247.25	246.02	244.22	242.74	240.79	241.47	241.66	241.24	241.83	243.00	243.57	243.69	246.03	246.52	248.46	250.07	249.55	247.89	245.63	247.63	247.83
2011 LIDAR	250.01	251.88	250.86	247.45	246.30	244.57	242.81	241.73	241.48	241.79	241.78	242.08	242.62	243.52	243.44	246.15	246.55	248.49	250.24	250.17	247.97	245.80	247.72	248.08
2008 LIDAR	252.34	253.16	251.39	247.72	246.12	243.59	242.53	241.61	241.08	241.43	242.56	242.60	242.71	243.01	244.54	246.38	246.72	248.68	250.08	249.27	247.91	245.92	247.91	248.10
OFFSET	-139.92	-89.93	-73.69	-45.47	-30.29	-22.10	-18.83	-16.59	-13.38	0.00	26.85	27.29	28.12	30.61	32.44	36.49	46.51	52.84	60.81	72.41	76.90	94.11	111.43	114.81

LW104-5 (CH 10336)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

1. SCALE A IS THE HORIZONTAL SCALE.
2. SCALE B IS THE VERTICAL SCALE.
3. ACCURACY OF CROSS SECTION INFORMATION IS DEPENDENT ON THE QUALITY OF THE SURVEY DATA SUPPLIED BY BROADMEADOW MINE.
4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE

A	0	20	40	80	m
B	0	2.5	5	10	m
C					m

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Client: BMA BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE

ISAAC RIVER

OPERATIONS MONITORING

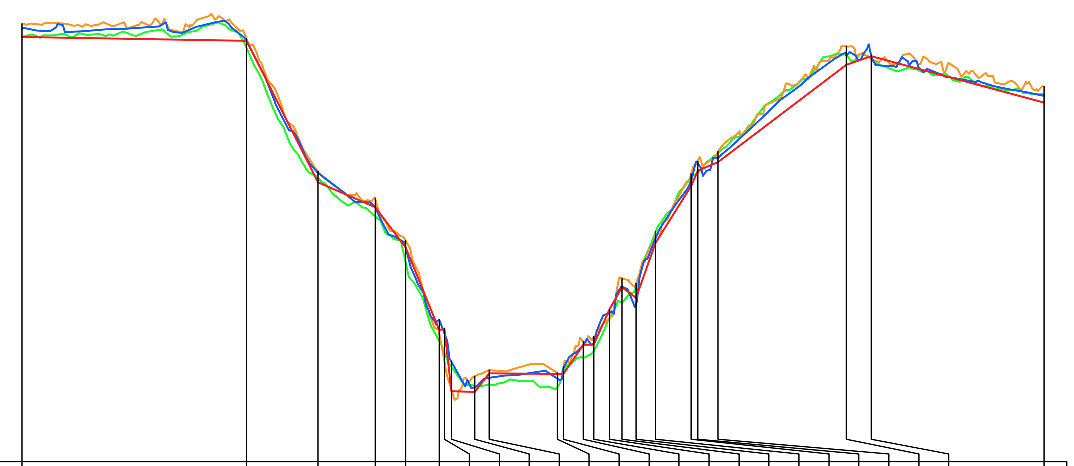
CROSS SECTIONS

Drawing No. P214042_014 Revision No. A

Sheet No. 14 File Name: P214042_001-016.dwg

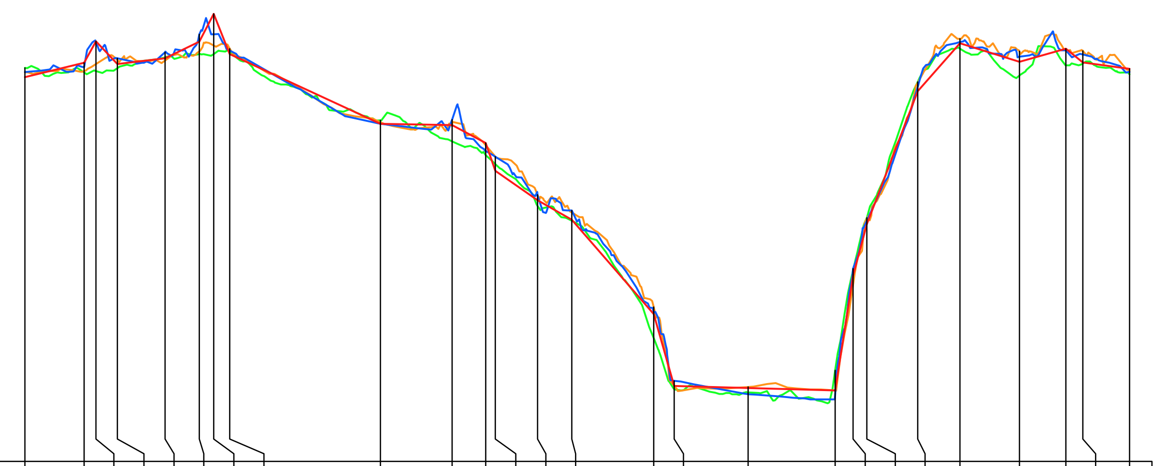
A3

LEGEND
2014 LIDAR
2012 LIDAR
2011 LIDAR
2008 LIDAR



2014 LIDAR	253.17	253.04	248.33	247.49	246.14	243.39	243.44	241.35	241.33	241.95	241.93	241.93	242.90	242.91	244.08	244.81	244.47	246.31	248.19	248.71	248.99	252.24	252.53	250.98
2012 LIDAR	253.43	253.03	248.63	247.48	246.14	243.73	243.29	242.33	241.48	241.79	241.77	242.12	242.89	242.90	243.95	244.83	244.26	246.46	248.35	248.95	249.11	252.54	252.55	251.20
2011 LIDAR	253.61	253.10	248.68	247.78	246.38	243.27	242.37	241.40	241.85	242.05	241.96	242.16	243.00	243.17	243.80	245.12	244.95	246.56	248.60	249.02	249.34	252.86	252.44	251.52
2008 LIDAR	253.21	252.80	248.47	247.18	245.64	243.03	242.64	242.16	241.52	241.57	241.47	241.92	242.47	242.69	243.77	244.31	244.83	246.68	248.51	248.63	249.30	252.57	252.43	251.26
OFFSET	−142.85	−82.96	−63.85	−48.60	−40.47	−31.48	−30.17	−28.23	−21.98	−18.14	0.00	1.61	6.93	9.78	13.92	17.24	21.05	26.26	35.76	37.49	42.93	77.14	83.84	129.97

LW103−4 (CH 10933)



2014 LIDAR	252.83	253.31	254.03	253.27	253.47	254.02	254.95	253.60	251.27	251.23	250.63	249.70	248.72	248.07	244.93	242.52	242.45	242.37	246.20	247.93	252.36	253.96	253.35	253.78	253.33	253.11
2012 LIDAR	253.00	253.16	254.01	253.47	253.67	254.27	254.27	253.72	251.28	251.42	250.36	250.18	248.88	248.38	244.96	242.69	242.24	242.23	246.43	248.04	252.50	254.01	253.51	253.73	253.59	253.01
2011 LIDAR	253.00	253.04	253.28	253.41	253.39	253.69	253.89	253.78	251.33	251.26	250.56	250.17	248.90	248.31	245.15	242.53	242.48	242.36	245.91	248.10	252.64	254.12	253.70	253.72	253.71	253.05
2008 LIDAR	253.15	252.99	253.04	253.13	253.50	253.60	253.61	253.68	251.39	250.68	250.23	249.93	248.53	248.04	244.12	242.42	242.30	243.04	246.38	248.14	252.67	253.79	252.89	253.23	253.29	252.93
OFFSET	−193.05	−177.26	−174.08	−168.36	−155.66	−146.53	−142.63	−138.37	−98.12	−78.97	−70.00	−67.45	−56.16	−47.10	−25.23	−19.75	0.00	23.25	28.04	31.67	45.25	56.52	72.41	84.79	89.39	101.80

LW102−3 (CH 11216)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

REVISIONS

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4. CROSS SECTIONS ARE VIEWED LOOKING IN A DOWNSTREAM DIRECTION.

	NAME	DATE
DESIGNED:	T.BEADLE	20/11/14
DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE
A 0 20 40 80 m
B 0 2.5 5 10 m
C m

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Client:
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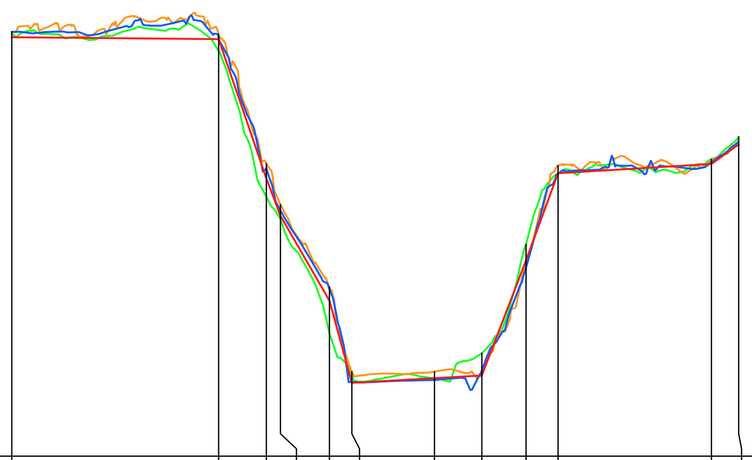
BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_015
Revision No. A
Sheet No. 15
File Name: P214042_001-016.dwg

ABN 45 653 522 596
A3

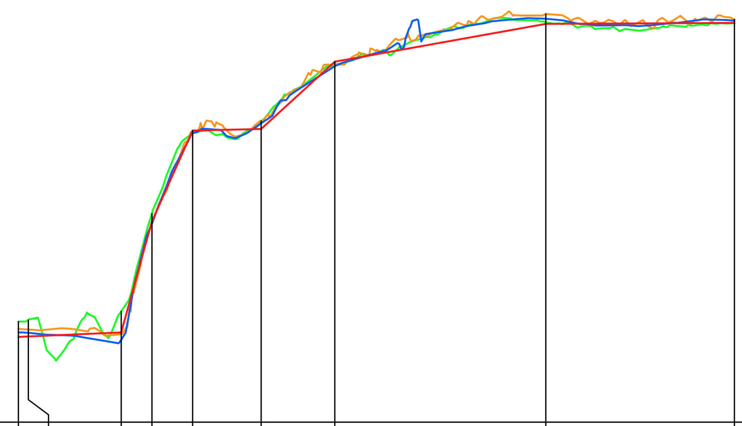
LEGEND
- 2014 LIDAR (red)
- 2012 LIDAR (blue)
- 2011 LIDAR (orange)
- 2008 LIDAR (green)



Datum RL 240

2014 LIDAR	253.98	253.91	249.27	248.03	245.20	242.44	242.60	242.69	246.54	249.44	249.75	250.41
2012 LIDAR	254.17	253.95	249.61	248.20	245.57	242.46	242.55	242.86	246.29	249.43	249.80	250.50
2011 LIDAR	254.15	254.08	249.77	248.40	245.64	242.83	242.82	242.81	246.43	249.70	249.87	250.48
2008 LIDAR	254.11	253.54	248.66	247.90	244.08	242.69	242.59	243.44	247.07	249.42	249.91	250.66
OFFSET	−112.77	−57.60	−44.82	−41.10	−28.01	−22.06	0.00	12.62	24.40	32.95	73.92	81.16

U4 (CH 11517)



Datum RL 240

2014 LIDAR	242.84	242.85	242.99	246.69	249.72	249.77	252.01	253.28	253.31
2012 LIDAR	242.99	242.98	242.75	246.61	249.63	249.96	251.87	253.45	253.38
2011 LIDAR	243.11	243.09	242.94	246.63	249.67	250.04	251.94	253.60	253.42
2008 LIDAR	243.36	243.41	243.69	246.96	249.62	250.01	251.91	253.33	253.29
OFFSET	−2.59	0.00	24.84	33.00	43.84	62.15	81.75	138.05	188.34

U3 (CH 11805)

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

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DRAWN:	T.BEADLE	20/11/14
CHECKED:	R.LUCAS	20/11/14
APPROVED:	R.LUCAS	20/11/14

SCALE
A 0 20 40 80 m
B 0 2.5 5 10 m
C m

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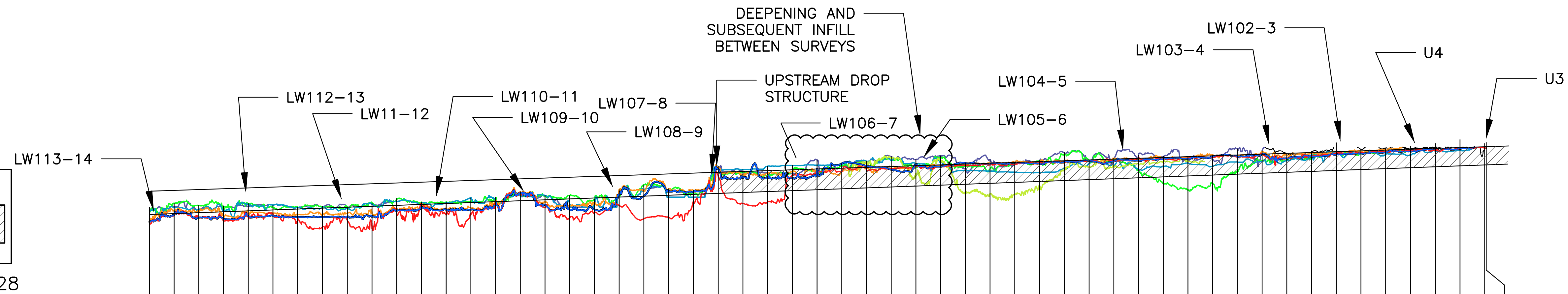
Client: BMA
BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE
ISAAC RIVER
OPERATIONS MONITORING
CROSS SECTIONS

Drawing No. P214042_016
Revision No. A
Sheet No. 16
File Name: P214042_001-016.dwg

ABN 45 653 522 596
A3



LEGEND

STABLE GRADE PROJECTION

Datum RL 228

CHAINAGE	OCT 2014	NOV 2012	NOV 2011	SEPT 2010	MAY 2010	DEC 2008	MAR 2007
6400.00	235.13	235.38	235.50		236.17	236.54	236.84
6500.00	236.06	236.07	236.52		236.83	237.23	236.96
6600.00	235.82	235.80	236.49		236.68	237.03	236.62
6700.00	235.50	235.69	235.98		236.42	236.54	236.96
6800.00	235.84	235.96	236.22		237.10	237.24	236.93
6900.00	236.18	236.00	236.29		237.08	236.89	237.08
7000.00	235.56	235.86	236.13		236.84	236.88	236.84
7100.00	234.86	235.86	236.14		236.89	236.88	236.93
7200.00	235.57	235.90	236.28		236.71	236.88	236.85
7300.00	234.86	235.88	236.34		237.19	237.29	237.19
7400.00	236.26	236.51	236.55		237.45	237.73	237.45
7500.00	237.20	236.92	237.07		237.24	237.37	237.24
7600.00	236.10	236.61	236.78		237.34	237.39	237.34
7700.00	236.20	236.61	236.81		237.82	237.42	237.82
7800.00	237.21	237.16	237.37		237.43	237.83	237.43
7900.00	238.24	238.32	238.42		238.00	238.01	238.00
8000.00	236.82	237.10	237.40		238.06	238.01	237.98
8100.00	235.81	236.58	237.00		237.22	238.03	236.87
8200.00	236.30	236.62	237.40		237.24	237.68	237.24
8300.00	237.06	238.16	238.65		238.05	238.06	238.12
8400.00	235.70	238.01	238.62		238.52	239.15	238.52
8500.00	235.83	238.51	238.70		237.88	238.55	237.88
8600.00	237.36	238.43	238.58		237.88	238.24	237.88
8700.00	240.10	240.76	240.83		240.93	240.76	240.96
8800.00	237.26	239.88	240.18		240.67	240.36	240.48
8900.00	237.38	239.99	240.24		241.02	240.07	240.37
9000.00	240.09	239.87	240.49		241.09	240.48	240.24
9100.00	240.39	240.77	240.46		241.12	240.34	241.66
9200.00	240.50	241.29	240.45		241.23	241.11	240.94
9300.00	240.68	241.05	240.81	241.39	241.53	241.44	241.35
9400.00	240.79	240.66	240.92	241.87	241.58	241.79	241.99
9500.00	241.00	241.16	240.93	240.28	241.27	240.92	241.70
9600.00	240.98	240.98	241.07	241.58	241.41	241.91	242.06
9700.00	241.06	241.33	241.16	238.35	240.56	241.11	240.82
9800.00	241.16	241.26	241.32	238.23	240.53	240.73	241.69
9900.00	241.21	241.38	241.38	238.16	240.42	241.35	241.16
10000.00	241.37	241.28	241.30	239.09	240.38	241.49	241.58
10100.00	241.39	241.44	241.45	240.52	240.77	242.11	242.38
10200.00	241.59	241.57	241.53	240.93	241.28	241.62	241.49
10300.00	241.51	241.54	241.84	240.98	241.10	241.55	241.51
10400.00	241.83	241.59	241.74	241.22	240.69	240.59	242.11
10500.00	241.76	241.78	241.92	241.53	240.98	239.24	242.01
10600.00	241.86	241.78	241.94	241.53	241.31	238.67	241.40
10700.00	241.93	242.02	242.16		241.03	239.27	241.74
10800.00	241.95	241.98	242.07		241.43	240.41	242.76
10900.00	242.24	242.26	242.47		241.48	241.54	242.58
11000.00	241.83	241.80	242.18		241.56	241.67	242.28
11100.00	242.06	242.05	242.35		242.23	241.91	242.39
11200.00	242.35	242.23	242.52		242.45	242.39	243.38
11300.00	242.38	242.32	242.45		242.28	242.29	242.72
11400.00	242.51	242.43	242.70		242.21	242.38	242.86
11500.00	242.60	242.53	242.74		242.10	242.55	243.02
11600.00	242.65	242.77	242.87		242.56	242.92	243.30
11700.00	242.81	242.79	242.99		242.63	243.35	243.71
11800.00	242.86	242.98	243.07		243.20	242.80	243.30
11805.89	242.83	242.98	243.09		243.40	243.40	243.40

SCALE: H = 1:20000 V = 1:500

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	20/11/14	TB

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APPROVED:	R.LUCAS	20/11/14

SCALE
A
B
C
AS SHOWN
m m m

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Client:
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BHP Billiton Mitsubishi Alliance

BROADMEADOW MINE

ISAAC RIVER
OPERATIONS MONITORING
LONGITUDINAL SECTIONS

Drawing No. P214042_017
Revision No. A
Sheet No. 17
File Name: P214042_001-016.dwg

ABN 45 653 522 596
A3