Memo

Subject	Response to information request from DEHP
From	Rohan Lucas
Distribution	BMA
Date	12 February 2016
Project	Broadmeadow EA amendment – Watercourse Subsidence

1 Isaac River condition, condition trajectory and management

1.1 Request

The administering authority requires more information relating to the proactive management strategies that BMA will adopt to ensure the condition trajectory of the diversion is not negatively impacted by subsidence.

1.2 Response

Understanding the incremental risk posed by subsidence

The Isaac River diversion, constructed in the mid 1980's was undertaken to a different standard to that which would be adopted today. The diversion underwent major erosional adjustment in the 1980's and 1990's (see Figure 2). Following some management intervention in the mid-late 1990's (including timber pile fields) and a period without any major flow events from 1991 to 2007 (refer to Figure 1), the diversion underwent substantial recovery. This recovery included the deposition of benches against toe of bank and colonisation of those benches with riparian vegetation, providing a near continuous coverage along the diversion. These vegetated benches protect the near vertical, erodible upper banks from erosion in the majority of flow events (refer Figure 3).

The diversion, which reduced river length by several kilometres, was constructed with two drop structures to compensate for the increase in gradient. One of these structures is now largely redundant and the other has been subject to damage from flow events and repair on numerous occasions. The remaining functional structure performs its design intent during smaller flows but is ineffective in larger flows in reducing energy conditions sufficiently. This means the diversion is subject to energy conditions that are greater than is suitable for the material through which it is constructed. An outcome of the damage to these structures in the diversion is that coarse armouring rock has been distributed along the diversion by high energy conditions, assisting in creation of pools and riffles. Pools are rare in the Isaac River due to the excess sediment inputs from catchment conditions and land use. The diversion, with elevated energy conditions and some rock inputs, provides some rare aquatic habitat refugia in the system (refer Figure 4). This habitat creation is enhanced by subsidence such as in Figure 3 (also refer to numerous photos in the SMP and the longitudinal section on page 117 of the SMP).

The main threat posed to the pre-subsidence condition and condition trajectory of the diversion by subsidence is the erosion of the benches that protect the toe of bank. This threat comes about when bedload sediment transport continuity is interrupted by subsidence. It is essentially the same 'clear water' effect created by weirs and dams that starve the immediate downstream reach of bedload sediment. If there are subsidence voids present and flows occur that are insufficient in magnitude and duration to infill those voids but do have the sediment transport potential to mobilise the bedload, they can strip the mobile bed sediment downstream of the void. This in itself is not a negative impact, as it creates pools. The threat comes about in the diversion where the channel bed is stripped to a resistant strata such as weathered bedrock. In this case, if the flow has the potential to mobilise sediment but cannot obtain it from the channel bed, it is likely to erode the benches, particularly where vegetation is thin. This process has been observed in the diversion (see Figures 3-18 and 3-

25 in the SMP). Once those benches erode, the near vertical unstable upper banks will be exposed to fluvial erosion processes that could lead to further instability.

Based on observation (monitoring of the diversion and subsidence has been in place since 2007), it is flows in the order of 100-500m^3/s that elevate this threat. Larger and sustained flows that infill the subsidence voids, have a short risk window until they mobilise enough sediment into the subsided sections from upstream to mitigate the threat from being ongoing.

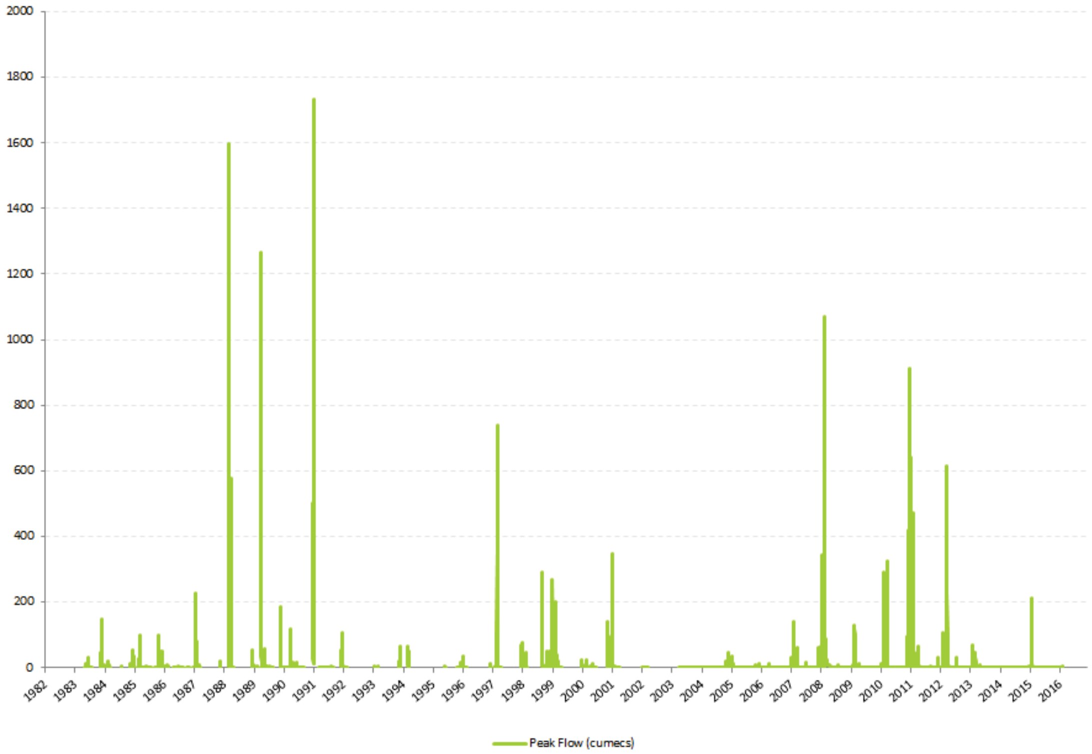


Figure 1 – Isaac River peak flow record at the Goonyella Gauge at downstream end of diversion

Figure 2 - Upstream view from top of bank near upstream drop structure of eroding outer bank of diversion with no vegetated bench, 1995

Figure 3 - Upstream view from channel bed on upstream drop structure of densely vegetated bench, 2015. Pool created by LW106 and LW107 subsidence

Figure 4 - Pool-riffle habitat in mid-section of diversion prior to subsidence influence

Management response to the incremental risk

Proactive management of the threat posed to the benches, on the pillar zones between the subsided panels, has been undertaken at Broadmeadow and the downstream Moranbah North Mine since subsidence of the Isaac River commenced. This is in the form of timber pile fields that provide for hydraulic conditions that maintain sediment against the toe of bank and allow vegetation establishment. The vegetation will ultimately supersede the timber piles. These measures have been proven effective over the last decade and are documented in the SMP and in the monitoring reports produced for the diversion and subsidence (Alluvium, 2014).

Management of bank stability through the subsided panels between the pillars, over the panels, has not yet been undertaken in the diversion. An increased risk to bank instability comes about when the panels infill with sand and the benches are no longer elevated above the low flow channel/mobile sand bed. In this case, the toe of the near vertical erodible bank may be subject to increased erosion risk (refer Figure 5). As much of the diversion is near straight, and should the vegetation on the benches survive when the subsided panel infill, this increased erosion risk is somewhat mitigated by the vegetation and deposition may occur through that vegetation. Where a bend is present, such as the upstream section of the diversion or where vegetation is thin or dies, additional bank stabilisation works may be required. There are options for this, mainly further use of timber pile fields and/or battering and revegetation of the near vertical upper banks. This is consistent with recommended management response and measures in the SMP and BMA TARP.

Figure 5 - Example of low flow channel migration to toe of bank where LW106 has infilled with mobile bedload, subjecting unstable upper banks to more frequent potential for erosion

2 Cumulative impacts – Red Hill

2.1 Request

The administering authority requires more information regarding the current and potential cumulative impacts on the Isaac River diversion. In particular, in relation to the proposed Red Hill Mine upstream of Broadmeadow.

2.2 Response

An assessment of the potential cumulative impacts to the upper Isaac River associated with Broadmeadow, Red Hill and the Anglo American mines Moranbah North, Grosvenor and Moranbah South has been undertaken in consultation with the administering authority. The *Isaac River cumulative impact assessment of mine developments* (Alluvium, 2009) provided outcomes that have been utilised in the subsidence guidelines published by the administering authority and the basis for which many of these mines have been approved in relation to risks to the Isaac River. Building on that work, the Red Hill EIS provides a cumulative impacts assessment for it and Broadmeadow.

The Red Hill and Broadmeadow cumulative impacts work was undertaken utilising the methodologies endorsed by the administering authority. The assessment of sediment transport dynamics for the Red Hill EIS and AEIS (links follow) was undertaken utilising an assumed mine schedule for the two mines. This assigned a number of panels to 5 year intervals on which the impact assessment is undertaken. The assessment indicated potential for a maximum of ~2.2m of river bed deepening over 20km of river (including the diversion) to occur during the mining sequence prior to potential for infilling. This approximates to the depth of mobile bed sand already in the undiverted reaches of the Isaac River through Red Hill and Broadmeadow.

This impact was approved in the EIS process, with mitigation measures to reduce residual risk to acceptable levels. Those mitigation measures are as recommended in the SMP for Broadmeadow, such as the timber pile fields on pillar zones, which have been proven effective over the last decade (and longer considering their role in rehabilitating the diversion channel bend in Figure 2 to what is shown in Figure 3). The monitoring and the adaptive management approach that has been undertaken at Broadmeadow since 2007 demonstrates that the predicted cumulative impacts from Red Hill and Broadmeadow will be manageable with appropriate allocation of resources and expertise.

http://www.statedevelopment.qld.gov.au/assessments-and-approvals/red-hill-mining-lease-project.html

http://eisdocs.dsdip.qld.gov.au/Red%20Hill%20Mining%20Lease/AEIS/Appendix%20T%20-%20Addendum%20to%20the%20EIS%20-%20Environmental%20Assessment.pdf

Figure 6 provides an illustration of the river bed deepening process described in Section 1, the benches maintained at toe of bank by timber pile fields and the subsequent re-establishment of bedload continuity (infilling) by large flows. Deepening of the river bed at this location was ~1.6m. This highlights that deepening of up to 2.2m will be manageable.

Upstream view from LW105-6 pillar in 2010. River bed deepening of ~1.6m to resistant strata

Upstream view from LW105-6 pillar in 2012. Large and extended duration flows infilled LW105 in the 2010-11 wet season and re-established bedload tranport to this site and downstream.

Figure 6 – Deepening following subsidence and subsequent infilling with bench maintained by pile fields, protecting diversion bank

3 Panel orientation and avulsion risk

3.1 Request

The administering authority requires clarification regarding the potential to re-orient some of the later panels in the Broadmeadow mine plan. These could potentially be altered from an orientation perpendicular to the Isaac River to parallel it, which could alter the potential for an avulsion of the Isaac River.

3.2 Response

Under the current mine plan there is a low probability of an avulsion occurring through the Broadmeadow mine plan reach. The dominant factors for this are the capacity of the channel and orientation of the panels. Other contributing factors are the nature of the hydrology of the catchment, the vegetation along the terrace surface and the presence of the Goonyella-Hay Point rail line embankment. Beyond the Broadmeadow mine lease, the presence and orientation of subsidence at Moranbah North mine requires consideration as it is in close proximity.

Under existing conditions, it is a flow event of approximately a 1:50 year AEP or greater to exceed channel capacity in the diversion. That is, flow events that could have the potential to cause an avulsion have a less than 2% chance of occurrence in any given year. To generate an avulsion, the rare events that are capable of engaging the floodplain would also need to be sustained in duration to scour a channel in the floodplain. These higher magnitude flows in the Isaac River catchment are generally short in duration. The other possible driver would be a number of out of channel flood events in the same year. This is also of low probability.

The magnitude of event to engage the floodplain will decrease slightly once all panels are subsided and the channel bed becomes infilled with sediment through the subsidence voids (the 1:50 and 1:1000 AEP events are provided below comparing 2015 conditions with full subsidence (no infilling) conditions). Where panels are perpendicular to flows, the pillar zones will form ridges between panels that will not provide for preferential concentration of flow. Should the panels be oriented parallel with flow, which has not been modelled for Broadmeadow, the potential for flood flow concentration increases. Hence the potential for avulsion increases if the materials are erodible. In the instance of the Isaac River terrace, the materials will be erodible.

The Red Hill mine EIS, which has panels oriented close to parallel to the river, highlighted panels where avulsion potential would be increased by subsidence. Management of the avulsion potential should be undertaken through a risk assessment considering likelihood and consequence. For Broadmeadow, given the likelihood of required events is low, a qualitative assessment of the risk indicates it will be moderate to low. Mitigation of the risk can consider a number of passive and active management interventions. Maximising vegetation coverage on the floodplain/terrace surface would be a recommended passive management action. More active management may involve earthworks.

Should the mine plan change the orientation of the panels appropriate modelling would be undertaken to assess the likelihood of occurrence of an avulsion by assessing the the hydraulic conditions on the floodplain/terrace surface.

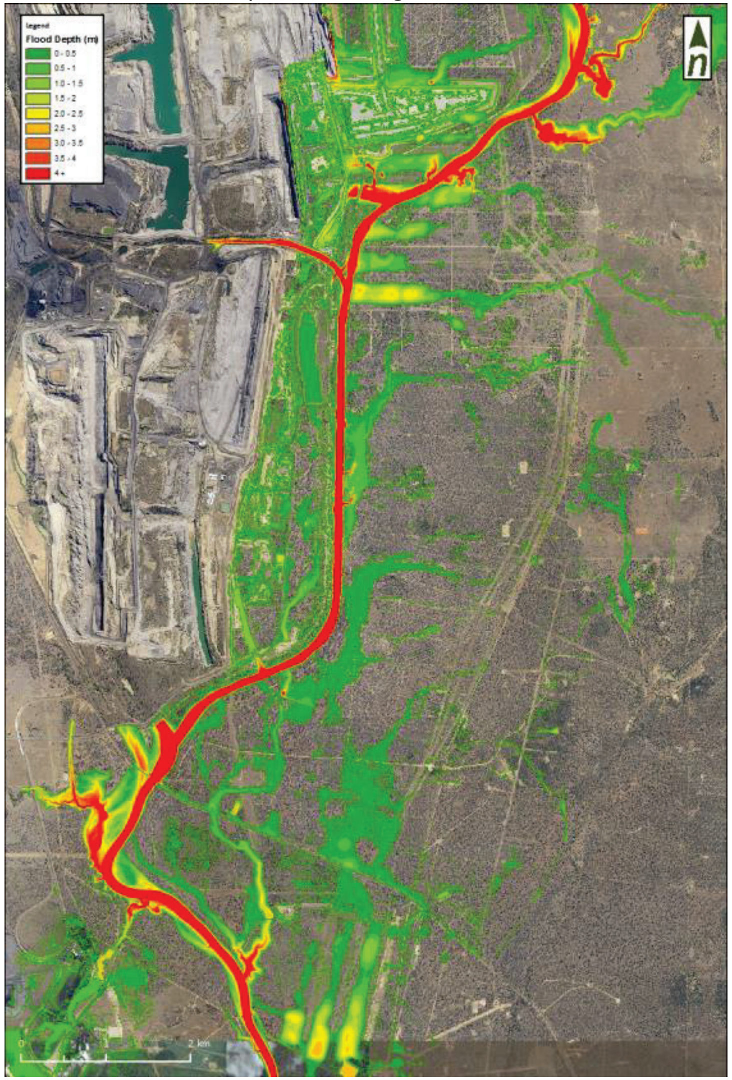
4 References

Alluvium, 2009. *Isaac River cumulative impact assessment of mine developments.* Technical Report to Queensland Government, BMA and AAMC.

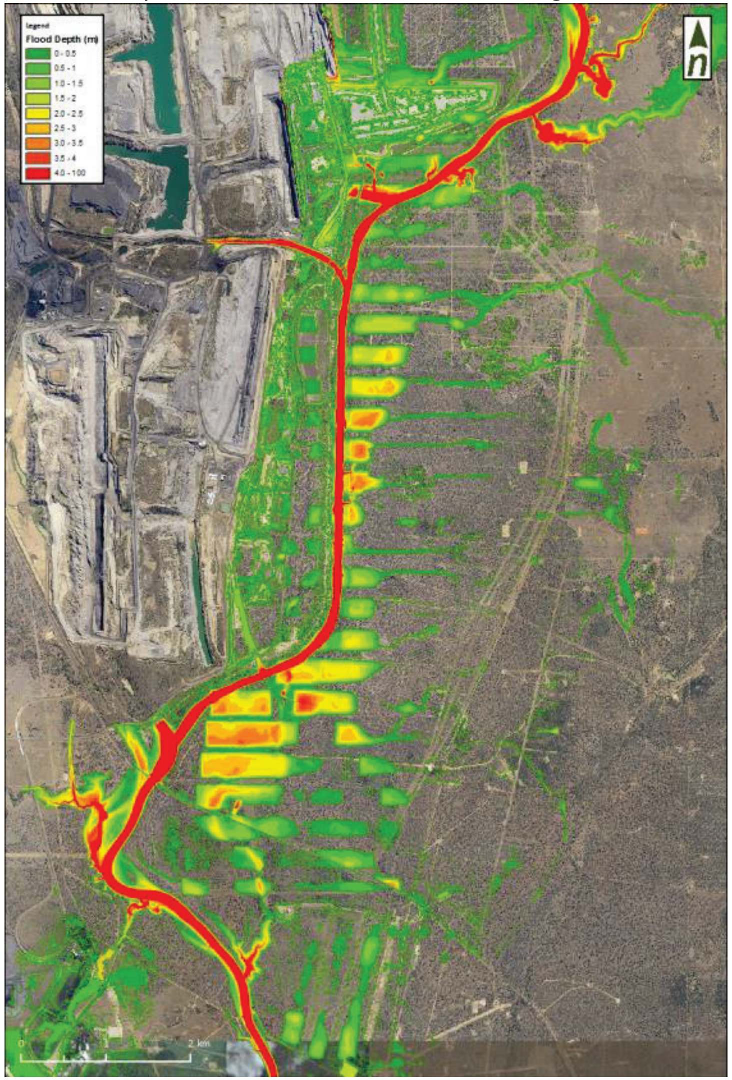
Alluvium, 2014. *Isaac River Operations Monitoring 2014*. Report by Alluvium Consulting for BMA Broadmeadow Mine.

Lucas, R, Crerar, J and Neilly, A (2015). *Broadmeadow and Goonyella Riverside Mines Subsidence Management Plan, 2015*.

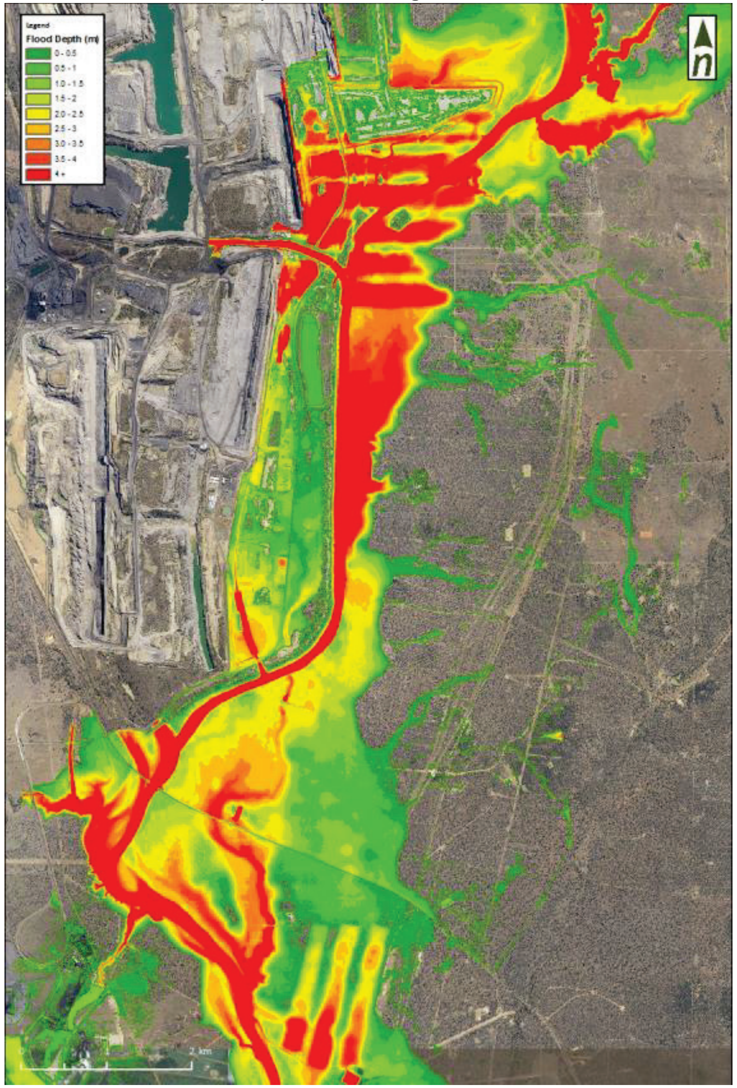
50-yr ARI –Existing Conditions



50-yr ARI - Post subsidence of North Underground



1000-yr ARI – Existing Conditions



1000-yr ARI - Post subsidence