11.0 Flooding and geomorphology

11.1 Introduction

This chapter discusses the outcomes of the flood hydrology and geomorphology assessments completed for the Ensham Life of Mine Extension Project (the proposed project, hereafter referred to as ‘the Project’). The chapter includes assessment of potential geomorphic impact of the Project on the Nogoa River channel, floodplain and tributaries, and the consequential impacts on environmental values (EVs) of the Nogoa River system.

The flood hydrology technical report is presented in Appendix E-3 (Hydrology and flooding). The supporting Hydrology and flooding report in Appendix E-3 has been prepared based on an earlier project definition. The project definition presented in this chapter supersedes that definition and does not require any additional changes to the study.

Environmental objectives and outcomes

The Project seeks to protect environmental values in the vicinity of the Project Site relating to water. Within the Project Site, environmental values specifically relate to the those set out under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP WWB) and include aquatic ecosystems, irrigation, farm supply/use, stock water, aquaculture, human consumer, primary recreation, secondary recreation, visual recreation, drinking water, industrial use, and cultural and spiritual values.

As the Project is an extension of the current underground mining operation at Ensham Mine, impacts to water are not considered to be significant. However, given the potential risks to downstream water resources, flooding and geomorphology has been assessed as a critical matter in the environmental impact statement (EIS) on a precautionary basis.

The existing Ensham Mine currently manages impacts to water in accordance with the requirements of Environmental Authority (EA) EPML00732813. As the Project is not expected to have any flooding or geomorphological impacts on water values in the Project Site, no additional mitigation measures are proposed.

11.2 Legislation and policy

11.2.1 Water Act 2000

In Queensland, the Water Act 2000 (Qld) (Water Act) is the primary statutory document that establishes a framework for the planning, allocation and use of non-tidal water. With respect to the geomorphic aspects of the Project, the Water Act provides a framework for sustaining the health of ecosystems, water quality, water-dependent ecological processes and biological diversity associated with watercourses, lakes, springs, aquifers and other natural water systems, including, where practicable, reversing degradation that has occurred.
11.2.2 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The EPP WWB is the primary instrument for surface water management under the *Environmental Protection Act 1994* (Qld). The EPP WWB governs discharge to land, surface water and groundwater, aims to protect EVs and sets water quality guidelines and objectives.

EVs for waterways draining the Project Site are provided in the Nogoa River Sub-basin EV and water quality objectives scheduling document, prepared pursuant to the EPP WWB. The Project is located within the Lower Nogoa and Theresa Creek tributaries and Lower Nogoa main channel.

The EVs for waterways draining the Project Site are:

- aquatic ecosystems
- irrigation
- farm water supply
- stock watering
- aquaculture (main channel only)
- human consumers of aquatic foods
- primary recreation
- secondary recreation
- visual recreation
- drinking water supply
- industrial use
- cultural and spiritual values.

The geomorphic impacts of the Project have been assessed with consideration to the EVs.

11.3 Methodology

11.3.1 Flooding

The hydrology and flooding assessment for the Project draws upon a number of previous studies undertaken in the Project Site. Previous flood studies applicable to the Project include:

- Flood study of the Nogoa River catchment upstream and downstream of the Ensham Mine (KBR, 2013))
- Flood study of the rehabilitation and closure planning for Ensham Mine’s existing operations (HEC, 2019).

The initial flood study (KBR, 2013) comprised of both hydrological and hydraulic modelling to simulate rainfall runoff (XP-RAFTS) and flow depths and velocities within the catchment (TUFLOW). Modelling was calibrated against previous high rainfall events at Ensham Mine, including the December 2010/2011 event which is the largest event to have been recorded in the region in recent history. The modelling was also peer reviewed independently as part of the Ensham Coal Mine flood levee certification.

Supplementary flood modelling undertaken for the Ensham Mine rehabilitation and closure planning (HEC, 2019) built upon the previous models developed by KBR. The updated model predicted stream flow across
the Ensham Mine and the resulting peak flow rates near the Duck Ponds gauging station, located on the Nogoa River downstream of the Project Site. Further calibration of the hydraulic model was undertaken which confirmed the validity of the model in predicting flood events at the Duck Ponds gauging station.

Model simulations were undertaken to forecast peak flood levels, depths, afflux and velocities for the range of annual exceedance probability (AEP) flow events at Ensham Mine. A flood frequency analysis was performed on the peak annual flows recorded at the Duck Ponds gauging station based on 24 years of available data.

As the subsidence assessment undertaken for the Project (Appendix B-2 (Subsidence)) predicts that subsidence in the Project Site will be negligible, previous flood modelling results are considered applicable to the Project and therefore remain unchanged from the approved operations at the existing Ensham Mine.

### 11.3.2 Geomorphology

The geomorphic properties and dominant erosion mechanisms of the Nogoa River have been characterised to assist in the assessment of potential impacts on river and anabranch geomorphology within the Project Site. The assessment relies upon site inspections and the results of detailed hydraulic modelling of the river and floodplain under existing conditions and following development of the Project (HEC, 2019).

The flood modelling informs the flooding characteristics of relevance to the assessment of morphology of the Nogoa River floodplain. For this study, the ‘regional’ model was modified by reducing the grid size from 30 metres (m) to 10 m to improve the model resolution within the channel (WRM model). The WRM model was then re-run without altering the hydrology or other hydraulic model parameters derived in the regional model. No other parameters in the model were reviewed or altered as part of this assessment.

The modelling has been used to define the capacity of the Nogoa River channel together with the frequency at which the various flood channels receive Nogoa River flows. The distribution of flow in the flood channels has also been determined. Velocity and shear stress have been used to characterise hydraulic conditions of relevance to the floodplain morphology.

The modelling included:

- An assessment of the 10 per cent AEP design flood to represent the behaviour of the river at bank full flow conditions. The bank full flow is the maximum flow that the channel can carry before it overflows onto the adjacent floodplain. In geomorphologic studies, the bank full flow is often considered to be the stream-forming flow, because it often exerts the greatest influence on channel geometry.

- An assessment of the 1 per cent AEP design flood to represent the behaviour of the river during large floods.

### 11.4 Description of environmental values

#### 11.4.1 Drainage characteristics

The main drainage feature in the Project Site is the Nogoa River. There are several significant upper tributaries of the Nogoa River with the two of relevance to the Project being Theresa Creek and Crinum Creek, which drain into the Nogoa River about 29 kilometres (km) and 21 km upstream of Ensham Mine respectively. The Comet River drains into the Nogoa River about 8 km downstream of Ensham Mine. The Nogoa River and the Comet River combine to form the Mackenzie River, which then becomes the Fitzroy River.

Fairbairn Dam was constructed on the Nogoa River 40 km upstream of the Theresa Creek confluence. Releases are made from the dam to deliver supplies to downstream riparian water users and to maintain
supplies from Bedford and Bingegang weirs to various towns, mines and irrigators. Since the construction of Fairbairn Dam, regulated releases are made to supply downstream users on most days.

Figure 11-1 shows the local drainage characteristics of the Nogoa River floodplain from the Theresa Creek confluence to the Comet River confluence, which includes the Project Site. The Nogoa River drains through the floodplain from west to east. There are also a number of flood channels across the floodplain that become active as floodwaters rise. The most notable active channel is called the Anabranch, which is located immediately to the east of Zone 1 of the Project Site.

The existing Ensham Mine has developed open-cut pits on the northern and southern sides of the Nogoa River channel. The pits extend into the floodplain and are protected from flooding by earth levees as shown in Figure 11-1. The levees provide flood protection for the open-cut pits (and underground mine portals) up to the 0.1 per cent AEP event.

Two flood channels drain across the southern floodplain, one of which drains into Winton Creek. These flood channels have been called Flood Channel 1 and 2 in this assessment and are likely paleochannels of the Nogoa River. Another flood channel called Mosquito Creek drains along the northern floodplain downstream of the Crinum Creek confluence.

Nogoa River within the reach consists of a well-defined 10 m deep channel that is carved through a relatively flat floodplain channel. It is generally about 500 m wide from crest to crest to the adjacent floodplain except adjacent to the Anabranch, where it narrows to about 300 m. Vegetation within the channel varies from very mature eucalypts (demonstrating low rates of lateral movement) on the islands to immature trees and pioneer species within the lower bench flood channels.

The Anabranch is slightly narrower than the main Nogoa River channel and is about 150 m wide and is also slightly shorter and steeper. The Anabranch is characterised by a low flow channel that has a pool and riffle sequence with a relatively defined lower bench and moderate bank slopes.

Flood Channel 1 consists of a broad and ill-defined channel adjacent to the Nogoa River and becomes more defined as it drains into Winton Creek. The upper reaches are bound by floodplain infrastructure. The bed gradient in Winton Creek is almost twice as steep as the upstream Flood Channel 1. However, water levels in Winton Creek are significantly impacted by backwater flows from Nogoa River.

Flood Channel 2 consists of a well-defined channel that is up to 5 m deep and 40 m wide. It is bound by floodplain infrastructure for much of its length.

Mosquito Creek, which bifurcates from Crinum Creek, drains along a relatively incised valley that is about 5 m deep and up to 200 m wide.

11.4.2 Floodplain characteristics

The Nogoa River floodplain varies in width from about 4 km at the location of Ensham Mine (currently narrowed to 1.5 km by the mine levees) to about 13 km near the Crinum Creek confluence. The floodplain consists of quaternary alluvium and lacustrine deposits of a mix of sand, silt, clay and gravel. Hansen Consulting (2006) characterised the alluvium as a strongly structured alkaline heavy (cracking) clay soil classified as a grey or brown vertosol soil. The soils are non-sodic but are moderately dispersive.

The alluvial soils are bound to the south by eroded sediments from the elevated Tertiary Emerald formation and to the north-west by late tertiary colluvium and late Permian sandstone and silty sandstone at the location of Ensham Mine.
Figure 11-1
Local drainage characteristics

Legend
- Project Area
- Watercourse
- Main Road
- Other Road
- Mining leases
- Mining leases
- Mineral development licence

Existing levee
Cross section
Duckpond monitoring gauge
Approved underground
Proposed underground

Elevation (m AHD)
292
48

ENSHAM LIFE OF MINE EXTENSION PROJECT

Projection: GDA 1994 MGA Zone 55
Scale: 1:125,000
Source: State of Queensland, 2019
Imagery: State of Queensland, 2017
Indemnity RFI 2019
AECOM 2020
11.4.3 Existing flood conditions

The terrain in the Project Site is generally flat, with the area to the west of Ensham Mine a floodplain of the Nogoa River, a tributary of the Fitzroy River. Fairbairn Dam was constructed on the Nogoa River upstream of Emerald in 1973 and supplies water to various industrial, agricultural and residential users. The dam has significantly changed the flow regime in the downstream reaches of the Nogoa and Mackenzie Rivers. A flood event in December 2010/2011 event was the largest event to have been recorded since the Fairbairn Dam was commissioned.

The Department of Natural Resources, Mines and Energy (DNRME) records flows in the Nogoa River at the Duck Ponds gauging station (130219A). The Bureau of Meteorology classifies flood levels at the Duck Ponds gauging station as minor, moderate and major for water level at respectively 9, 10 and 11 m above the riverbed. According to this classification, January 2008 and December 2010 have been two major flood events and January 2012 has been a moderate flood event. The latest flood event in July 2016 was minor (see Figure 11-2).

Figure 11-2 Maximum monthly level for Nogoa River (Source: DNRME, 2020)
As part of the hydrology and flooding assessment undertaken for the Project (Appendix E-3 (Hydrology and flooding)), flooding behaviour such as inundation, flow depth and flow velocity in the Nogoa River have been forecast based on previous flood modelling. The modelling considered the 10 per cent AEP, 5 per cent AEP, 1 per cent AEP and 0.1 per cent AEP maximum inundation areas and peak flow depths for existing conditions. Flood modelling of the Nogoa River floodplain shows that:

- The Anabranch is highly connected to the river receiving flows potentially multiple times per year
- The flood channels would receive flows once every 5 to 10 years, on average when the main Nogoa River channel overflows
- The channel capacity, or the channel-forming flow of the Nogoa River is equivalent to an event between the 18 per cent and 10 per cent AEP events
- For the 10 per cent AEP event, the majority of flows are conveyed by the Nogoa River channel (54 per cent) with the Anabranch conveying 36 per cent and Flood Channel 2 10 per cent. Very little flow is conveyed by Flood Channel 1.
- For the 1 per cent AEP event, Flood Channel 1 and 2 convey the majority of the flow (52 per cent) followed by the main Nogoa River channel (26 per cent).

Figure 11-3 illustrates the maximum flood depth for the 0.1 per cent (1 in 1,000 year) AEP event for existing conditions. Figure 11-4 illustrates the peak flow velocities for the 0.1 per cent (1 in 1,000 year) AEP event for existing conditions. The range of flood scenarios are presented and discussed in Appendix E-3 (Hydrology and flooding).
Figure 11-3  Existing conditions flood depths for the 0.1% (1 in 1,000 year) AEP event
Figure 11-4  Existing conditions peak flow velocities for the 0.1% (1 in 1,000 year) AEP event
11.5 Potential impacts

The Project will operate using the same bord and pillar mining method currently being used at Ensham Mine. This mining system forms a regular array of stable coal pillars and roadways in each panel and does not cause large scale overburden fracturing and subsidence. Due to the nature of the bord and pillar mining method, subsidence is predicted to be typically less than 40 millimetres (mm) in the Project Site. This level of subsidence is too small to have any detectable effect on surface flow. This is supported by findings in the Project Subsidence Assessment (Gordon Geotechniques, 2020) noting that the Australian Government states that seasonal variation in surface levels can be as high as 50 mm as a result of changes in moisture content.

The Project Subsidence Assessment (Gordon Geotechniques, 2020) also states that the expected low levels of subsidence are unlikely to result in the formation of significant depressions in the surface topography where ponding of the surface drainage may occur which is consistent with experience at the existing Ensham Mine operations where no surface cracking or ponding has been observed above the operating bord and pillar mine areas. As such, potential changes to surface water flow and flooding including instability and erosion of waterways due to predicted subsidence is not expected.

The Project does not require additional material surface infrastructure above what is already provided at the existing Ensham Mine. The Project is not expected to have a significant impact on the flood regime. Impacts to flooding will be managed within the existing disturbance areas at Ensham Mine. The existing surface infrastructure (flood levee) will be used to provide flood protection from 1 in 1000 year flood event, which is in accordance with the current EA. Furthermore, the analysis indicates that there would not be additional flooding impacts at the Project Site as a result of the Project.

No assessment of regulated structures is made in this EIS as there are no regulated structures associated with the Project.

11.5.1 Operational flood conditions

Flooding impacts as a result of the Project have been assessed by comparing the existing conditions against the operational flood conditions. As no changes to the surface topography is predicted, the existing flood conditions presented in Section 11.4.3 are considered applicable to the Project operational conditions and hence remain unchanged from approved operations at the Ensham Mine. The flood modelling undertaken for the Project is presented in Appendix E-3 (Hydrology and flooding). The modelling shows the shows changes the existing and operational conditions as a result of the Project.

Overall, the Project is not expected to have any additional impact on the flows or flow regime of the Nogoa River compared to existing approved operations. The model predictions for the existing operation and the Project indicates that a similar annual extraction volume of between 600 ML and 700 ML is required in both scenarios. This is less than the current annual extraction allocation from the Nogoa River of 1500 ML/yr. A negligible increase in flows is expected to result from the Project during flow events due to licensed water release during operations over the extended mine life.

The potential impacts resulting from these changes are discussed in Chapter 10 (Surface water resources).

11.5.2 Geomorphology

Underground mining can potentially affect geomorphological behaviour through:

- Changes in surface levels due to subsidence. Subsidence can alter surface gradients affecting in-stream velocities and the distribution of floodplain flow. In high-subsidence areas this can potentially lead to a channel avulsion, where flow is directed to a new flow path that becomes the main channel.
The changes in flow velocity and distribution can affect surface water EVs through increased erosion or sediment deposition.

- Loss of surface water through stream bed cracking caused by mine subsidence. Stream bed cracking can affect surface water EVs by reducing surface water flow volumes and diverting surface water, along with potential contaminants, to groundwater.
- Surface infrastructure such as roads, culverts, dams, conveyors or vent shafts that can interfere with surface drainage and flood flows. Resulting changes in flow velocity and direction can potentially affect surface water EVs through increased erosion or sediment deposition, or increased in flood levels.

The Project is a continuation of the existing underground mining, using existing surface infrastructure located on the existing approved mining leases (MLs). Zone 2 may have a need for some minor support infrastructure which would not be located on Strategic Cropping Areas.

The underground mining method is bord and pillar. Unlike longwall mining, pillars will remain after mining to support the roof, with the mined areas of the coal seam remaining as a permanent void. The predicted subsidence above the panel pillars following secondary coal recovery in the Project Site is typically less than 40 mm. This is within the 50 mm seasonal variation in surface levels as a result of changes in moisture content as stated by the Department of Agriculture, Water and the Environment (IESC, 2015). This reduces to typically less than 20 mm above the bell out pillars (Gordon Geotechniques, 2020). Subsidence of this magnitude would be undetectable because natural process such as changes in vegetation, soil shrinkage or swelling due to variations in moisture content, or fluvial processes of erosion and deposition could produce similar (or greater) variations in surface levels. This means that the Project is not predicted to cause any measurable surface subsidence, which is consistent with the experience from the existing underground mine. With no measurable subsidence, there will be no potential for cracking of stream beds.

### 11.5.3 Impacts on environmental values

The Project will not cause any material change in flood velocities and shear stresses from existing conditions because there will be no measurable change in ground surface levels. The morphology of the river channel and floodplain, including the sediment transport characteristics and erosion potential, will not be impacted by the Project. Therefore, impacts on surface water EVs relevant to geomorphology as a result of the Project are considered unlikely.

### 11.6 Mitigation measures

As the Project is an extension of the current underground operation at Ensham Mine with no material changes to site infrastructure, impacts to water are not considered to be significant. The management of impacts to surface water is primarily achieved through the design of the site water management system. The existing Ensham Mine already has in place a number of flood protection measures, including a flood levee to protect the operations during the 0.1 per cent AEP (1 in 1,000 year) event. As no changes to the surface topography are required, the existing flood conditions are expected to continue for the Project.

The existing Ensham Mine currently manages impacts to water in accordance with the requirements of EA EPML00732813. In accordance with condition G5 of the EA, Ensham Mine currently have measures in place to ensure that dangerous goods and hazardous substances are stored in a secure manner to prevent loss of containment during flooding events. As the Project is not expected to have any flooding impacts on water values in the Project Site, no additional mitigation measures are proposed.

As there are no predicted geomorphological impacts as a result of the Project, no specific mitigation measures are required.
11.7 Summary and conclusions

The assessment of flooding and geomorphology for the Project is based on hydraulic modelling undertaken during previous studies at Ensham Mine. The assessment also draws on the mine water balance assessment undertaken for the Project (Chapter 10 (Surface water resources)). The assessment demonstrates that, as the Project is an extension of existing operations at Ensham Mine and requires no additional surface disturbance or infrastructure, the existing flooding conditions are expected to remain unchanged.

Ensham Mine’s existing water management system, which comprises water storages, water reticulation and water release facilities, should be adequate to meet the operational requirements of the Project without augmentation (HEC 2020). Potential changes to surface water flow and flooding, including the stability and erosion of waterways, as a result of subsidence is not predicted. Therefore, the Project is not expected to have any additional impact on the flows or flow regime of the Nogoa River compared to existing approved operations.