APPENDIX 17

Surface Water
Impact Assessment

Umwelt (Australia) Pty Ltd

Glendell Continued Operations Project
Surface water impact assessment

November 2019

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

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Glossary

Afflux	An increase in water level
Annual exceedance probability	The likelihood of occurrence of a flood of given size or larger occurring in any one year
Catchment	The area that drains to a particular location
Clean water	Runoff from undisturbed or rehabilitated areas
Coal handling and preparation plant	A facility where coal is crushed, screened and beneficiated (washed)
Dirty water	Runoff from disturbed areas
Ephemeral	Stream that is usually dry, but may contain water for rare and irregular periods, usually after significant rain
Evapoconcentration	Increase in concentration over time as a result of evaporation
Evaporation	The process where liquid water turns into vapour in the air
Floodplain	Land adjacent to a stream or river which experiences inundation
Freeboard	The height or volume between the water level and the spill level of a water storage
Geomorphology	The study of landforms, their processes, form and sediments
Glencore	Glencore Coal Pty Ltd
Headwaters	The upper part of a catchment
Hydrogeology	The study of the distribution and movement of groundwater in the soil and rocks
Hydrology	The study of earth's water, and its movement in relation to land
Mine water	Water exposed to coal or used in coal processing
Mount Owen	Mt Owen Pty Ltd
Overburden	Material above the target coal seams that must be moved to undertake mining
Pan evaporation	Evaporation measured using a pan
Perennial	A watercourse or part of a watercourse that has continuous flow throughout the year
Project	Glendell Continued Operations Project
Proponent	Glendell Tenements Pty Ltd
Reach	Part of a length of a watercourse
Riparian	Land alongside creeks, streams, gullies, rivers and wetlands
Run of mine coal	Coal in its unprocessed state, following mining but before processing
Sensitivity	The degree to which the uncertainty in a model output depends on the uncertainty of a model input
Tributary	A watercourse that flows into another watercourse

Abbreviations

AEP	Annual exceedance probability
ARI	Average return interval
BOM	Bureau of Meteorology
CHPP	Coal handling and preparation plant
EC	Electrical conductivity
EIS	Environmental impact statement
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPA	NSW Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Act 1999*
EPL	Environment protection licence
FTE	full time equivalent
GRAWBM	Greater Ravensworth Area Water Balance Model
GRAWTS	Greater Ravensworth Area Water and Tailings Scheme
HRSTS	Hunter River Salinity Trading Scheme
Hunter Regulated WSP	*Water Sharing Plan for the Hunter Regulated River Water Source 2016*
Hunter Unregulated WSP	*Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*
MIA	Mine Infrastructure Area
MNES	matters of national environmental significance
Mtpa	Million tonnes per annum
POEO Act	*Protection of the Environment Operations Act 1997*
ROM	Run of mine
SEARs	Secretary's Environmental Assessment Requirements
SILO	Scientific Information for Land Owners
SSD	State significant development
SSGV	site-specific guideline value
SWIA	Surface water impact assessment
TDS	Total dissolved solids
TSS	Total suspended solid
WAL	Water access licence
WM Act	*Water Management Act 2000*
WOOP	Western Out-of-pit
WSP	Water sharing plan

1. Introduction

GHD Pty Ltd (GHD) was engaged by Umwelt (Australia) Pty Ltd (Umwelt) on behalf of Glendell Tenements Pty Limited (the Proponent), a subsidiary of Glencore Coal Pty Ltd (Glencore), to prepare a surface water impact assessment (SWIA) for the Glendell Continued Operations Project (the Project). This assessment forms part of an environmental impact statement (EIS) to support a State significant development (SSD) application under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to facilitate the extension of mining at the existing Glendell Mine.

1.1 Background

Glendell Mine is an open cut coal mine that is part of the Mount Owen Complex located in the upper Hunter Valley of NSW. As presented in Figure 1-1, the mine is located approximately 20 km north-west of Singleton and 24 km south-east of Muswellbrook.

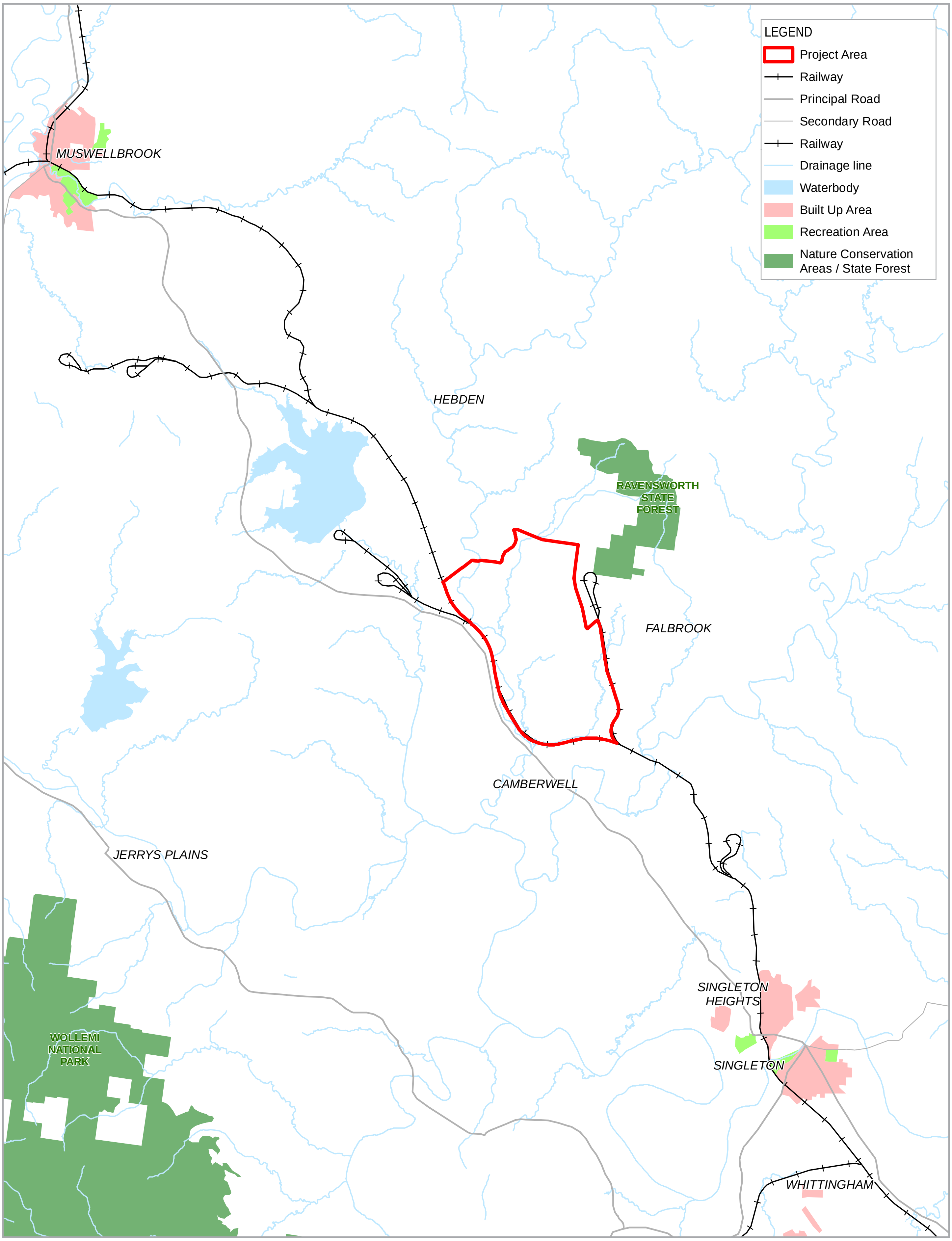
Current and approved operations within the Mount Owen Complex include Mount Owen Mine (North Pit) and Ravensworth East Mine (Bayswater North Pit) in addition to Glendell Mine (Glendell Pit). The Mount Owen Complex also includes the integrated use of the Mount Owen coal handling and preparation plant (CHPP), coal stockpiles and rail load-out facility, as shown in Figure 1-2. The Mount Owen Complex is located adjacent to several other mining operations including Ashton Coal Mine, Integra Underground Mine, Liddell Coal Operations and Ravensworth Operations.

Mt Owen Pty Ltd (Mount Owen) operates the Glendell Mine and Ravensworth East Mine (Bayswater North Pit) mining operations at the Mount Owen Complex, as well as the Mount Owen CHPP and associated infrastructure, with operations at the Mount Owen Mine (North Pit) operated by Thiess Pty Ltd under a contractual arrangement with Mount Owen.

Glendell Mine currently operates under development consent DA 80/952 (Glendell consent), which provides for the mining of up to 4.5 million tonnes per annum (Mtpa) of run of mine (ROM) coal. Mining operations at Glendell Mine are approved until 2024. Processing, handling and transport of coal mined at Glendell Mine is approved under development consent SSD-5850 for the Mount Owen Continued Operations Project (Mount Owen consent), which also provides for mining operations at Mount Owen Mine and Ravensworth East Mine. Mining operations and the operation of the Mount Owen CHPP are approved until 2037.

The Mount Owen Complex manages water through an integrated water management system. The Greater Ravensworth Area Water and Tailings Scheme (GRAWTS) is an integrated water and tailings management system that enables water and tailings to be transferred between the Mount Owen Complex and adjacent Glencore-operated mines of Ravensworth Operations, Liddell Coal Operations and Integra Underground Mine. The integration of water management and tailings disposal systems with other sites allows for greater flexibility in water use and management at the Mount Owen Complex and other operations linked as part of the GRAWTS.

Current and approved operations within the Mount Owen Complex lie in the catchment of Bowmans Creek to the west and Glennies Creek to the east. Over the history of the Mount Owen Complex, a number creek diversions have been developed and are managed to redirect watercourses around disturbed areas.



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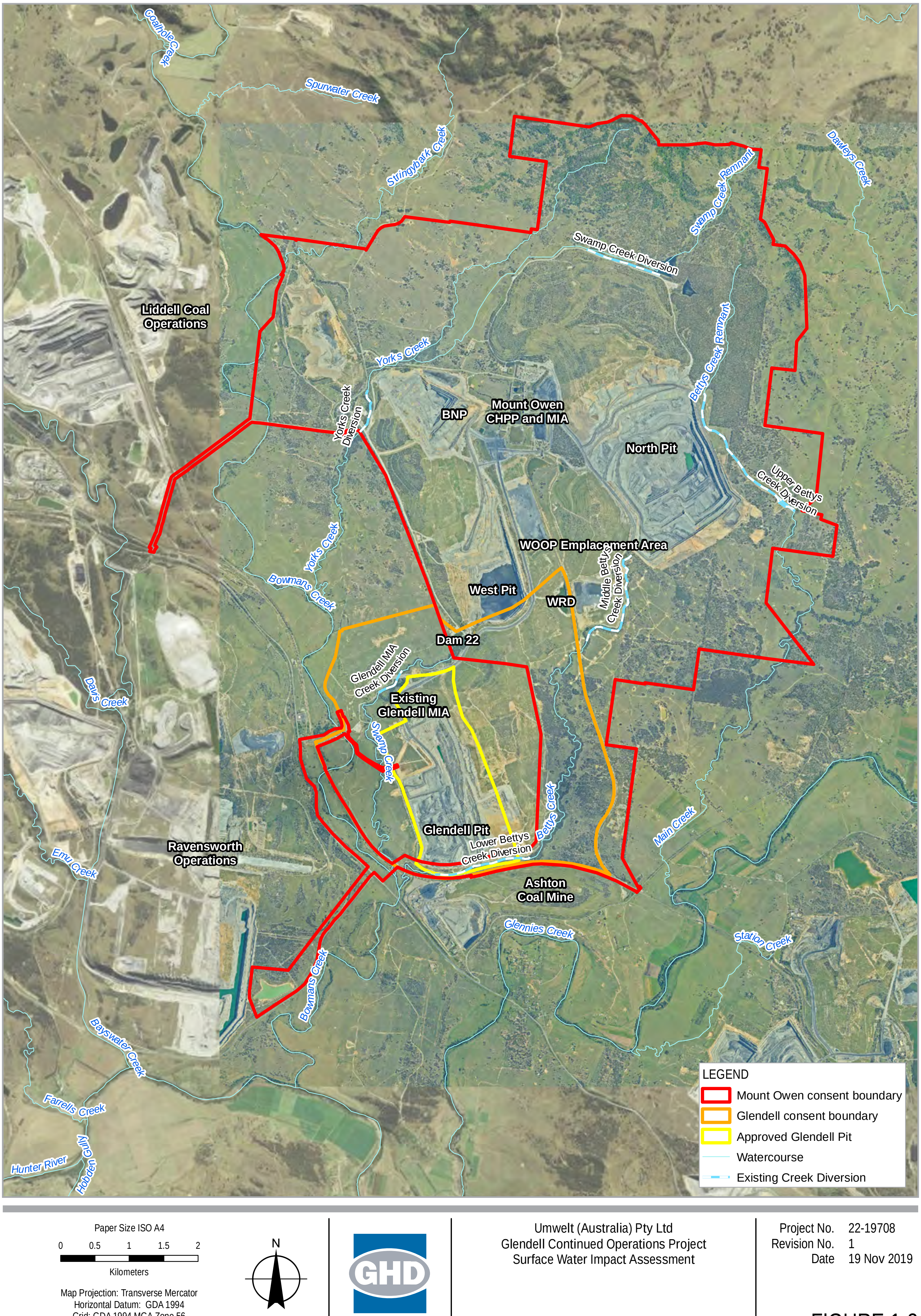
Glendell Continued Operations Project
Surface Water Impact Assessment

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

Locality plan

FIGURE 1-1

Data source: Commonwealth of Australia (Geoscience Australia): 250K Topographic Data Series 3, 2006 . Created by: kpsroba, tmorton, TMorton



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Glendell Continued Operations Project
Surface Water Impact Assessment

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

Existing operations

FIGURE 1-2

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

1.2 Proposed project

Glendell Tenements Pty Ltd, (the Proponent), proposes to extend open cut mining operations north from the existing Glendell Mine, as shown in Figure 1-3 (the Project). The proposed extension to the Glendell Pit (the Glendell Pit Extension) would extract approximately 135 million tonnes more ROM coal down to and including the Hebden seam and extend the life of mining operations to approximately 2044. ROM coal from the Glendell Pit Extension would continue to be processed by the Mount Owen CHPP and associated infrastructure and be transported using the Mount Owen rail load-out facility. The Project does not involve any changes to mining operations approved under the Mount Owen consent but will extend the life of the Mount Owen CHPP and associated coal handling facility until 2045.

As the Glendell Pit Extension will mine through the existing Glendell Mine Infrastructure Area (MIA), the Project includes demolition of the existing Glendell MIA and the construction and use of a new MIA and associated infrastructure. The associated infrastructure includes the construction and use of a Heavy Vehicle Access Road from the active pit area to the new MIA.

The Project will also include the realignment of a section of Hebden Road, realignment of the lower reach of Yorks Creek, and the relocation of Ravensworth Homestead.

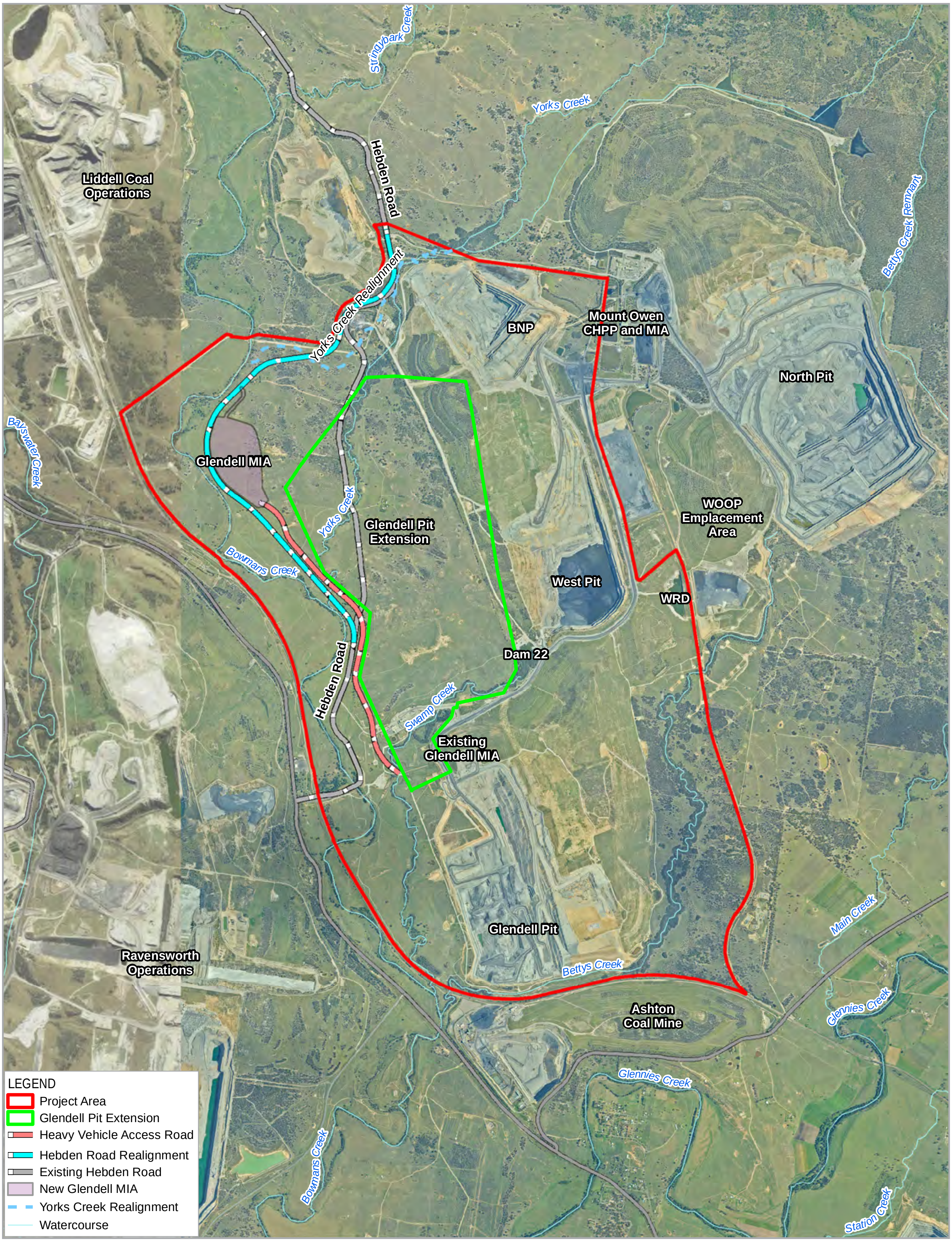
Further details of the Project are provided in Section 2.

1.3 Report objectives and scope of work

The SWIA has been developed to address the water components of the Secretary's Environmental Assessment Requirements (SEARs) for the Project (refer to Appendix A), as well as other State and Federal government agency requirements (refer Section 3.1). To satisfy the assessment requirements, a detailed assessment of potential impacts of the Project on the surface water environment is required.

The scope of work for the SWIA includes:

- Review existing assessments and data relevant to the Project.
- Review relevant statutory requirements.
- Establish the baseline existing and approved conditions for the surface water environment.
- Identify components of the Project with the potential to impact the surface water environment.
- Undertake an assessment of the potential impacts of the Project on:
  - Water and salt balance.
  - Flooding.
  - Surface water quality.
  - Downstream licensed surface water users and basic landholder rights.
- Undertake an assessment of the cumulative impacts of the Project in association with other existing and approved operations.
- Determine the water licensing requirements for the Project.
- Identify measures to avoid, minimise and mitigate potential impacts of the Project and recommend management, monitoring and reporting requirements.



Paper Size ISO A4

0 320 640 960 1,280 1,600

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

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Key Project features

FIGURE 1-3

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Data source: LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: tmorton

1.4 Report structure

Table 1-1 provides a description of the structure of the SWIA.

Table 1-1 Report structure

Section		Content
Section 1	Introduction	Purpose of the report and scope of work.
Section 2	Project description	Description of the Project.
Section 3	Regulatory context	Legislative requirements, policies and guidelines relevant to the assessment of surface water management and potential impacts.
Section 4	Regional environment	Description of site land use, topography, soils, geology, climate, hydrology, hydrogeology and regional setting.
Section 5	Water management system	Description of the existing and proposed clean, dirty and mine water management systems.
Section 6	Water and salt balance	Summary of the water and salt balance for the water management system under existing and proposed conditions.
Section 7	Final void	Assessment of the approved and proposed final void water level and quality.
Section 8	Catchments and flow regimes	Assessment of the flows in watercourses affected by the Project.
Section 9	Flooding assessment	Summary of the flood assessment of watercourses affected by the Project.
Section 10	Water quality	Assessment of existing surface water quality at the site.
Section 11	Impact assessment	Identification of the potential impacts of the Project and measures to avoid, minimise or mitigate these impacts.
Section 12	Management, monitoring, licensing and reporting	Description of the management, monitoring, licensing and reporting requirements recommended.
Section 13	Summary	Summary of the key findings.
Section 14	References	A list of the documents referenced within the report.

2. Project description

2.1 Approved operations

Mining operations at the Mount Owen Complex commenced at the Ravensworth East Mine (previously known as Swamp Creek Mine) and date back to the early 1960s. Ravensworth East Mine has been subject to various modifications including:

- Integration with the Mount Owen and Glendell Mines in 2008 to allow efficient processing and haulage of coal to the Mount Owen CHPP.
- The emplacement of tailings within the Ravensworth East voids from the Mount Owen CHPP.

Mining in the Ravensworth East Mine is currently limited to the Bayswater North Pit and tailings emplacement in the West Pit void; these activities are regulated by the Mount Owen consent, which also allows for the emplacement of tailings in the Bayswater North Pit void and North Pit void.

Mining operations within the Mount Owen Mine (North Pit) commenced in 1993 under the management of Hunter Valley Coal Corporation Pty Ltd. The Mount Owen consent, granted in 2016, brought the Mount Owen and Ravensworth East Mines under a single development consent with the former consents for these operations surrendered. A modification to the Mount Owen consent was recently approved that extended the life of mining in the North Pit by six years until 2037.

The Glendell consent was granted on 2 May 1983. A modification of the Glendell consent granted in February 2008 approved the integration of the Glendell Mine with the Mount Owen Mine. This modification removed the duplication of coal processing, handling and transport infrastructure and enabled integrated water and tailings management at the operations forming the Mount Owen Complex.

The Glendell Mine forms part of the broader Mount Owen Complex with integrated coal handling and processing facilities, product transport, tailings disposal and water management systems. ROM coal extracted from the Glendell Pit is transported to the Mount Owen CHPP for processing. The Mount Owen CHPP is currently approved for up to 17 Mtpa ROM coal throughput. Product coal is transported from the Mount Owen Complex using the Mount Owen Rail Loop or to the Liddell or Bayswater Power stations by conveyor. Up to 2 Mtpa ROM coal and/or crushed gravel can also be transported by conveyor from the Mount Owen Complex to the Liddell Coal Mine or Ravensworth Coal Terminal.

The approved operations are summarised in Table 2-1.

Table 2-1 Summary of approved operations at the Mount Owen Complex

Element	Mount Owen Consent	Glendell Consent
Development consent	SSD-5850	DA 80/952
Mining area	North Pit – 10 Mtpa Bayswater North Pit – 4 Mtpa	Glendell Pit – 4.5 Mtpa
Mining method	Truck and excavator	Truck and excavator
Mine life	2037	2024
Previously mined areas	Eastern Rail Pit (ERP), Tailings Pit 1 (TP1), Western Rail Dam (WRD) formerly known as Tailing Pit 2 (TP2), RW Pit, North Void Stage 1, (NVS1), North Void Stage 2 (NVS2), West Pit	None
Tailings emplacement (including former tailings facilities)	West Pit Bayswater North Pit North Pit ERP, NVS1, NVS2, TP1, RW Pit Transfer to Liddell Coal Operations via GRAWTS	None – tailings generated by the processing of coal at the Mount Owen CHPP is emplaced under the Mount Owen consent
Overburden emplacement	In-pit emplacement (Bayswater North Pit and North Pit) Out-of-pit emplacement at Western Out-of-pit (WOOP) emplacement area, and parts of Ravensworth East emplacement area Tailings capping of former tailings facilities and West Pit	In-pit emplacement and out of-pit emplacement adjacent to Glendell Pit
Approved final voids	North Pit Bayswater North Pit	Glendell Pit
Coal processing	Mount Owen CHPP (up to 17 Mtpa) and Liddell CHPP (up to 2 Mtpa ROM)	None – coal is processed at the Mount Owen CHPP and transported under the Mount Owen consent
Coal transportation	Mount Owen Rail Loop and conveyor to Liddell Coal and/or Ravensworth Coal Terminal	
MIA	Mount Owen MIA and Ravensworth East MIA	Glendell MIA
Workforce	Approximately up to 920 full time equivalent (FTE) positions	Approximately up to 300 FTE positions
Operation	7 days per week, 24 hours per day	7 days per week, 24 hours per day
Creek diversions and Realignments	Upper reaches of Bettys Creek diverted into Main Creek Middle reach of Bettys Creek diverted around the WOOP emplacement area Upper reaches of Swamp Creek diverted to Yorks Creek Yorks Creek diverted as part of former Swamp Creek Mine around current Ravensworth East MIA	Lower reach of Bettys Creek diverted around southern extent of Glendell Pit Lower reach of Swamp Creek diverted around to Glendell MIA
Water discharge	None – excess water is managed as part of the GRAWTS	None – excess water is managed as part of the GRAWTS

2.2 Project summary

The Project proposes the extension of mining at Glendell Mine to the north of the current Glendell Pit. Mining operations would extend the existing open cut operations to the north with mining down to and including the Hebden seam. Estimated ROM coal reserves in the proposed mining area are approximately 135 Mt. Mining operations would be undertaken using truck and excavator mining methods.

Mining operations would initially proceed at the current approved production rate (up to 4.5 Mtpa) with production increasing during the life of the operations as production at Bayswater North Pit and North Pit decline and eventually cease. Maximum annual production from the Glendell Pit Extension would be up to 10 Mtpa ROM coal.

ROM coal would be transported by truck from the Glendell Pit Extension to the Mount Owen CHPP for washing, consistent with current operations. The Project will not result in any increase to the currently approved 17 Mtpa ROM coal throughput at the Mount Owen CHPP, however the Project will extend the life of the Mount Owen CHPP and associated coal handling and transport infrastructure by an additional 8 years beyond that currently approved under the Mount Owen consent.

Overburden removed as part of the mining operations will be emplaced in-pit to the south of the mined area as mining progresses to the north. Overburden emplacement would also occur on existing Glendell emplacement areas and areas disturbed as part of the Ravensworth East operations. The final emplaced landform will be developed using natural landform techniques and will be progressively rehabilitated over the life of the Project.

Water and tailings management associated with the Project will be integrated with the Mount Owen Complex water management system and GRAWTS. The existing water transfer pipeline between the Mount Owen Complex to Ravensworth Operations will be impacted by the Glendell Pit Extension, necessitating a realignment of the easement that is subject to a separate modification application.

As the Glendell Pit Extension will mine through the existing Glendell MIA, the Project includes demolition of the existing Glendell MIA and the construction and use of a new MIA and associated infrastructure. The associated infrastructure includes the construction and use of a Heavy Vehicle Access Road from the active pit area to the new MIA. The Project will also include the realignment of a section of Hebden Road, realignment of the lower reach of Yorks Creek, and the relocation of Ravensworth Homestead.

The Project is summarised in Table 2-2.

Table 2-2 Project summary

Element	Summary of Project
Mining area	Glendell Mine (Glendell Pit Extension) - up to about 4.5 Mtpa increasing to 10 Mtpa ROM coal as production rates in Bayswater North Pit and North Pit decline
Mining method	Truck and excavator
Mine life	Glendell Mine – to approximately 2044 (Glendell Pit currently approved to 2024).
Coarse rejects and tailings emplacement	Coarse rejects and tailings generated by the processing of coal at the Mount Owen CHPP will be managed in accordance with the Mount Owen consent.
Overburden emplacement	Emplacement of overburden in-pit and on existing emplacement areas at Glendell Mine and areas disturbed as part of the Ravensworth East Mine. Areas of out-of-pit emplacement to assist in final landform development.

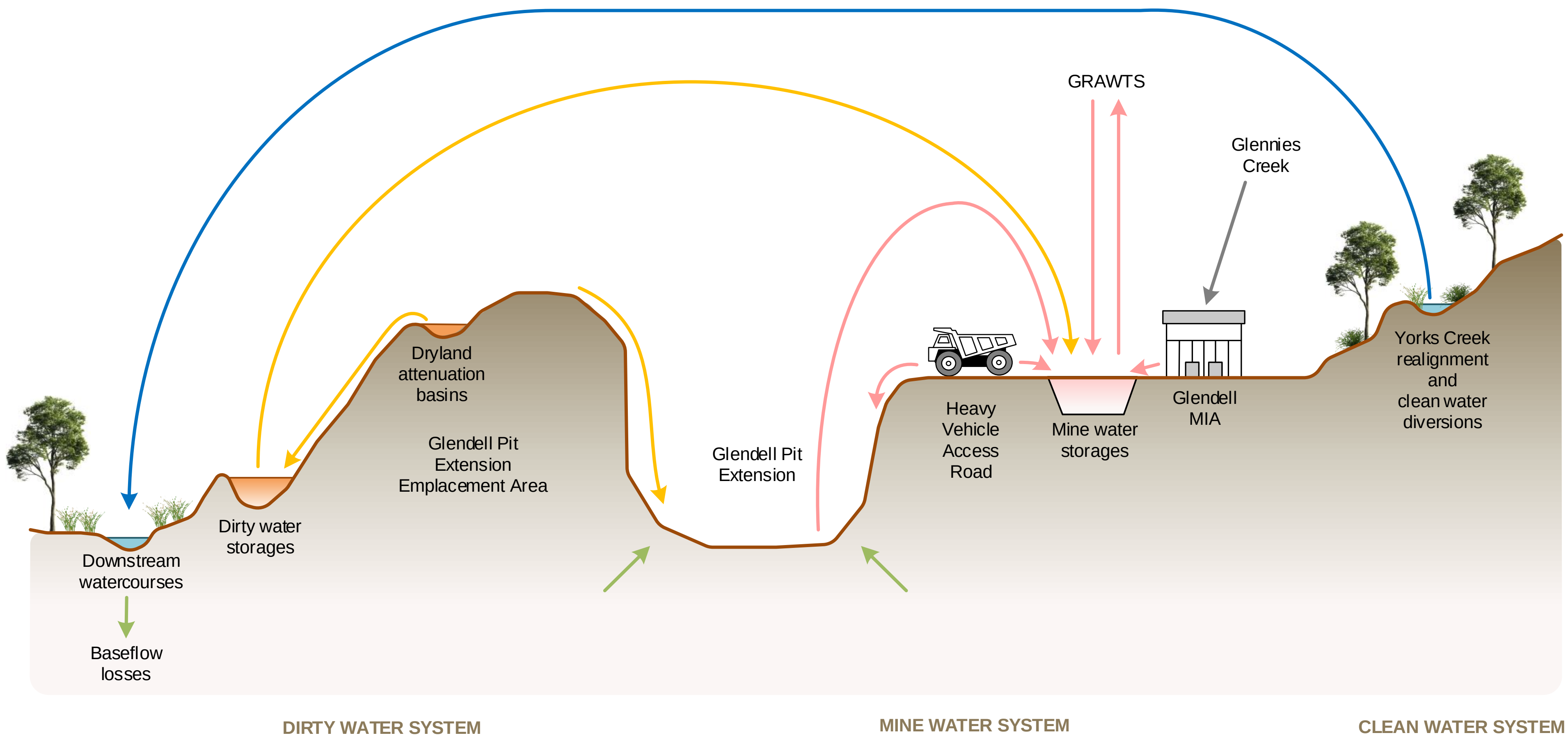
Element	Summary of Project
Final voids	Glendell Pit. No additional void in final landform.
Coal processing	ROM coal from Glendell Pit Extension will be processed at the Mount Owen CHPP in accordance with the Mount Owen consent. CHPP throughput will remain unchanged at up to 17 Mtpa. Extension of operating life of Mount Owen CHPP and associated coal handling infrastructure to 2045.
Coal transportation	Current export coal transportation via rail will remain the same.
MIA	Demolition of existing Glendell MIA. New MIA constructed to northwest of Glendell Pit Extension. Heavy Vehicle Access Road to be established for new MIA.
Workforce	Overall workforce at the Mount Owen Complex will remain similar to current workforce numbers of approximately 1 220 FTE positions during concurrent operations. This will reduce following cessation of mining operations at Mount Owen Mine (circa 203-7). Glendell workforce numbers will progressively increase over the duration of the Project from approximately 300 FTE to approximately 690 FTE aligned with production. The increasing workforce at Glendell coincides with a reduced workforce at the Bayswater North Pit and North Pit as production declines and then stops.
Operation	No change – 7 days per week, 24 hours per day.
Creek diversions	Lower reach of Yorks Creek realigned to new confluence with Bowmans Creek approximately 4 km upstream of the existing confluence.
Water discharge	No change – no off-site discharges proposed, excess water will continue to be managed as part of the GRAWTS.

For the purposes of the surface water assessment and the analysis of cumulative impacts and the overlap with operations approved under the Mount Owen Consent, it has been assumed that operations associated with the Project commence in 2021.

2.3 Potential impacts to surface water

The Project has the potential to have an impact on the surrounding surface water environment. Potential impacts have been identified in the context of the conceptual water cycle of the Project, as shown in Figure 2-1. Notwithstanding the mitigation measures incorporated in the Project, the key potential impacts are:

- Increased area of disturbance during the operation of the Project and associated impacts from reduced catchment run-off and management of water quality from areas impacted by the Project.
- Changes to the water management system and water balance at the Mount Owen Complex, and subsequent impacts to the GRAWTS.
- Permanent realignment of the lower reach of Yorks Creek, resulting in changes to catchments, flood regimes, flooding behaviour and downstream water quality.
- Changes to the final void, resulting in changes in water level recovery and water quality.
- Changes to final landform catchments and potential impacts on downstream catchments from changes to flow regimes and flooding.



Legend

- Clean water
- Dirty water
- Mine water
- Groundwater flows
- Raw water

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Glendell Continued Operations
Surface Water Impact Assessment

Conceptual water cycle schematic

Project No. 22-19708
Revision No. 0
Date 10/10/2019

FIGURE 2-1

Created by: Tyler Tinkler

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3. Regulatory context

3.1 Legislation

3.1.1 Environmental Planning and Assessment Act 1979

The *Environmental Planning and Assessment Act 1979* (EP&A Act), administered by the NSW Department of Planning, Industry and Environment (formerly NSW Department of Planning and Environment), is the core legislation relating to planning and development activities in NSW and provides the statutory framework under which development proposals are assessed. The EP&A Act aims to encourage the proper management, development and conservation of resources, environmental protection and ecologically sustainable development.

The SWIA forms part of an EIS to support an application under Section 4.55 of the EP&A Act to facilitate the extension of the existing Glendell Mine.

3.1.2 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the NSW Environment Protection Authority (EPA), which is an independent statutory authority and the primary environmental regulator for NSW. The objectives of the POEO Act are to protect, restore and enhance the quality of the environment. Some of the mechanisms that can be applied under the POEO Act to achieve these objectives include programs to reduce pollution at the source and monitoring and reporting on environmental quality. The POEO Act regulates and requires licensing for environmental protection, including for waste generation and disposal and for water, air, land and noise pollution.

Environment protection licences

Under the POEO Act, an environment protection licence (EPL) is required for premises at which a 'scheduled activity' is conducted. Schedule 1 of the POEO Act lists activities that are scheduled activities for the purpose of the act. Licence conditions relate to pollution prevention and monitoring and can control the air, noise, water and waste impacts of an activity.

Mount Owen currently holds EPL 12840 for Glendell Mine (Glendell EPL), which authorises coal mining and coal works. No licensed discharge points are specified by the EPL and the site is not permitted to discharge any water that may pollute the downstream environment, in accordance with Section 120 of the POEO Act. Excess water at Glendell Mine and the Mount Owen Complex is managed within the GRAWTS, with off-site discharges managed by Ravensworth Operations in accordance with EPL 2652 or by Liddell Coal Operations in accordance with EPL 2094.

Mount Owen also hold EPL 4460 for the Mount Owen and Ravensworth East Mines (Mount Owen EPL). It is expected the that boundaries of the premises for the purpose of the Mount Owen EPL and the Glendell EPL will be varied through the life of the Project to reflect changes in disturbance areas and responsibilities of the two operations.

Hunter River Salinity Trading Scheme

The Hunter River Salinity Trading Scheme (HRSTS) is implemented under the *Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2002*. The HRSTS is a market-based instrument that uses a cap-and-trade mechanism to control the discharge of salt into the Hunter River. Licence holders can buy and trade salt credits to discharge saline water into the river when there is adequate river flows (typically during higher flow events) to dilute the salt and maintain water quality. The scheme ensures that salinity in the Hunter River is maintained at an appropriate level that is suitable for local primary producers to use for irrigation and to manage the impact of saline discharges on the health of the river. The scheme is operated by WaterNSW under a service agreement with the EPA.

As discussed above, excess water at the Mount Owen Complex is managed by the GRAWTS, with discharges off-site managed by Ravensworth Operations or Liddell Coal Operations. Any discharges from Ravensworth Operations or Liddell Coal Operations licenced discharge points are undertaken in accordance with the HRSTS under the applicable EPL at each site.

3.1.3 Water Management Act 2000

The *Water Act 1912* has historically been the main legislation for managing water resources in NSW, however, is currently being progressively phased out and replaced by water sharing plans (WSPs) under the *Water Management Act 2000* (WM Act). Once a WSP commences, existing licences under the *Water Act 1912* are converted to water access licences (WALs), water supply works and use approvals under the WM Act.

The aim of the WM Act is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and in-stream uses as well as to provide for protection of catchment conditions.

Water sharing plans

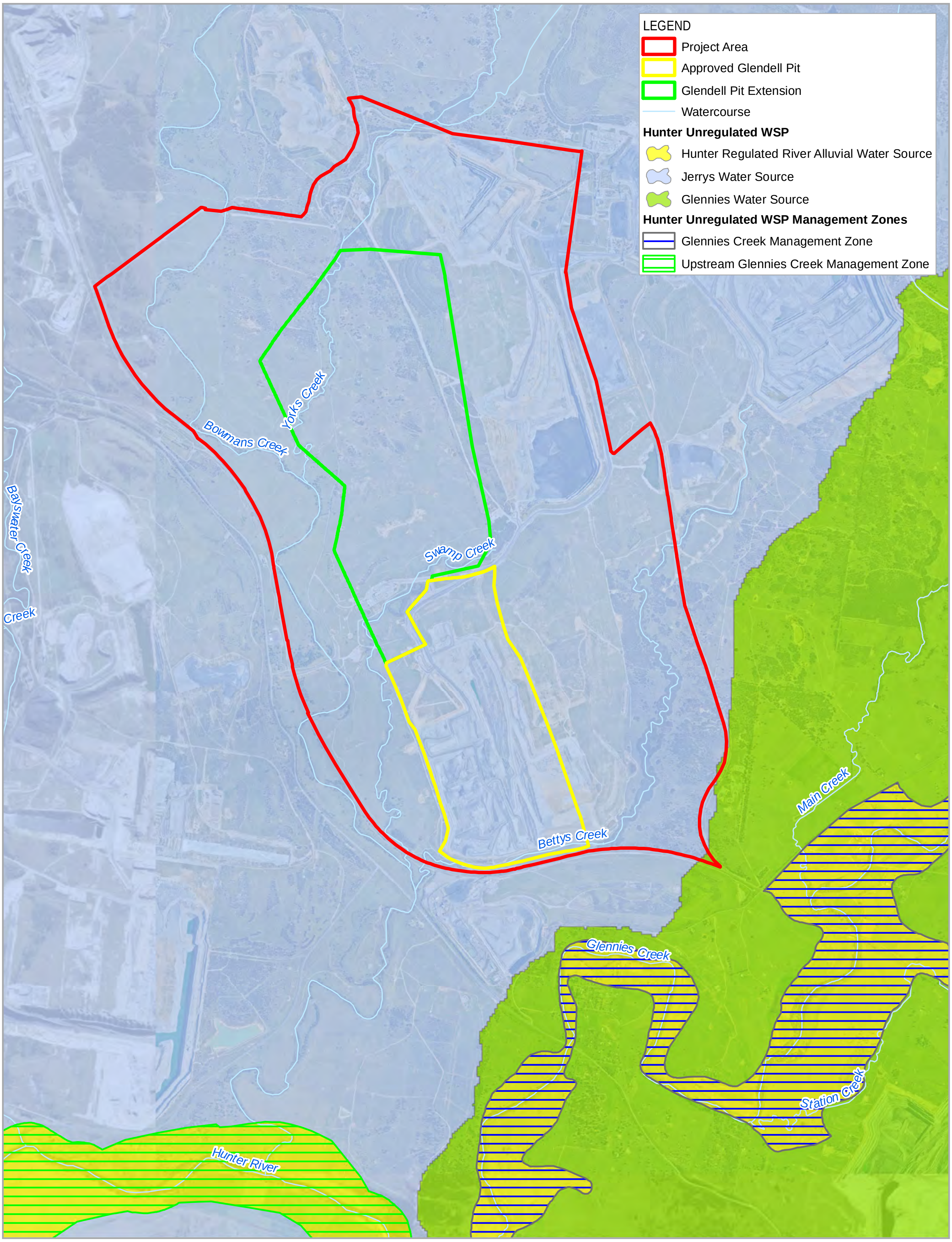
Water sources in NSW are managed via WSPs under the WM Act. Provisions within WSPs provide water to support the ecological processes and environmental needs of groundwater dependent ecosystems and waterways. WSPs also regulate how the water available for extraction is shared between the environment, basic landholder rights, town water supplies and commercial uses. Key rules within the WSPs specify when licence holders can access water and how water can be traded.

WALs entitle licence holders to specified share components in the available water that may be sustainably extracted from a particular water source. The actual volume of water available to be extracted may vary, dependent on available water determinations made under the WM Act. Available water determinations are made for each WAL category in each water source and are generally made at the start of a water year, although may be altered at any time.

The Project is located within the area regulated by the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (Hunter Unregulated WSP). As shown in Figure 3-1, the Project is located within the Jerrys Water Source. The Jerrys Water Source is divided into two management zones, the Project is located in the Jerrys Management Zone. The eastern parts of the Mount Owen Complex are located within the Glennies Water Source.

The *Water Sharing Plan for the Hunter Regulated River Water Source 2016* (Hunter Regulated WSP) applies to a single water source the covers the surface water flows and highly connected alluvials of the Hunter River and Glennies Creek. The Hunter Regulated Water Source is divided into management zones. The zones are defined from a single common point, which is the confluence of Glennies Creek with the Hunter River. The Project is located adjacent to and to the north of the Glennies Creek Management Zone (Zone 3A). This zone extends from the upper reaches of Glennies Creek Dam to the Hunter River junction.

The Hunter Regulated River Alluvium Water Source is regulated under the Hunter Unregulated WSP. The water source extends from the top of the high bank of the Hunter Regulated River or Glennies Creek to the boundary of the alluvial aquifer covering the unconsolidated alluvial sediments, excluding the alluvial sediments covered by the Hunter Regulated WSP.



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0 500 1,000 1,500

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Glendell Continued Operations Project
Surface Water Impact Assessment

Project No. 22-19708
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Water sharing plan boundaries

FIGURE 3-1

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Data source: LPI: DTDB, 2017. NSW Water: WSP data, 2013. © Department of Finance, Services & Innovation 2017. Created by: tmorton

Glencore holds a number of WALs under the WM Act, as summarised in Table 3-1, for the extraction of water from Glennies Creek, the Hunter River and surface flows within the Jerrys Water Source. Several water supply works and water use approvals are also held for the diversions of Bettys Creek and Swamp Creek.

Basic landholder rights

Under the WM Act, extraction of water for basic landholder rights is protected by allocating and prioritising water for basic landholder rights. There are three types of basic landholder rights in NSW under the WM Act:

- Domestic and stock rights.
- Native title rights.
- Harvestable rights.

Domestic and stock rights

Landholders are entitled to take water from a river, estuary or lake which fronts their land or from an aquifer which is underlying their land for domestic consumption and stock watering, without the need for a licence. However, a water supply work approval is generally required to construct a dam or a groundwater bore, unless an exemption applies.

Native title rights

Anyone who holds native title with respect to water, as determined by the *Native Title Act 1993*, can take and use water for a range of purposes, including personal, domestic and non-commercial communal purposes. There are currently no extractions under native title rights in either the Hunter Unregulated WSP or the Hunter Regulated WSP.

Harvestable rights

Landholders are entitled to collect a portion of runoff from their property and store it in one or more dams up to a certain size, known as a 'harvestable right', which is determined from the total contiguous area of land ownership. In the Central and Eastern Divisions of NSW (where the Project is located), landholders may capture and use up to 10% of the average regional runoff for their property without requiring a licence under the WM Act. If the maximum harvestable right for property is exceeded, licensing for the volume of water extracted from the surface water source exceeding the harvestable right is required under the WM Act.

The following classes of dam are exempt from the calculation of the maximum harvestable right:

- Dams solely for the control or prevention of soil erosion, provided no water is reticulated or pumped from the dams and the size of the dam is the minimum necessary to fulfil the erosion control function.
- Dams solely for flood detention and mitigation, provided no water is reticulated or pumped from the dams.
- Dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by regulation to prevent the contamination of a water source.
- Dams endorsed for specific environmental management purposes.
- Dams without a catchment (i.e. turkey nest dams).

Table 3-1 Summary of water access licences

Category	Water access licence	Associated approval	Share components (units)	Water sharing plan	Water source	Management zone
Regulated river (high security)	704	20CA200608	3	Hunter Regulated River Water Source	Hunter Regulated River Water Source	Zone 3a (Glennies Creek)
	1118	20CA201623	3			
	9521	20WA201228	50			
	7814*	20WA200723	1 000			
	13324	20CA200384	132			
Regulated river (general security)	612	20CA200382	147			
	613	20CA200390	192			
	637	20CA200445	384			
	705	20CA200608	27			
	1119	20CA201623	60			
	1215	20CA201862	48			
	11084	20WA201499	1			
Supplementary water	1364	20CA201623	2.2			
	1420	20CA200382	29			
Domestic and stock	706	20CA200608	8			
	754	20WA200727	16			
	1218	20WA201868	3			
	7823	20WA201677	9			
	7817	20CA200779	3			
	13750	20AL203449	1			
Unregulated river	18310	20WA210993	200	Hunter Unregulated and Alluvial Water Sources	Jerrys Water Source	Jerrys Management Zone
	18000	20CA207387	17		Glennies Water Source	NA

* Mount Owen Complex and Integra Underground (both owned by Glencore) share the access rights under this licence.

Controlled Activity Approvals

Any works proposed within the defined riparian zone of a creek are to be carried out in accordance with the WM Act. Works undertaken on waterfront land (i.e. near a river, lake or estuary) require a controlled activity approval, unless defined as exempt. SSDs and activities within a mining lease do not require controlled activity approvals. As the Project is a SSD and regulated under a mining lease, no controlled activity approvals are required.

3.1.4 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) lists the threatened species, populations and ecological communities that must be considered when assessing the effects of an activity as described in Section 5.5 of the EP&A Act.

A permit for any dredging and reclamation undertaken as part of the Yorks Creek Realignment under Section 201 of the FM Act is not required for SSDs due to the operation of Section 4.55 of the EP&A Act. The potential impacts and proposed mitigation measures of the construction and operation of the Yorks Creek Realignment are considered in this assessment.

3.1.5 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Act 1999* (EPBC Act) is administered by the Commonwealth Department of the Environment and Energy and provides a legal framework to protect and manage nationally important flora, fauna, ecological communities and heritage places defined as ‘matters of national environmental significance’ (MNES). The EPBC Act identifies water resources, in relation to large coal mining development, as a MNES.

An action that ‘has, will have or is likely to have a significant impact on a matter of national environmental significance’ is deemed a ‘controlled action’ and may not be undertaken without prior approval from the Commonwealth Environment Minister. Approval under the EPBC Act is also required where actions are proposed on, or will affect, Commonwealth land and its environment.

The Project was referred to the Department of Environment and Energy in April 2019 and determined to be a controlled action under the EPBC Act due to potential impacts on water resources, in relation to largescale coal mining activities.

3.2 Policy

3.2.1 NSW State Rivers and Estuaries Policy

The NSW State Rivers and Estuaries Policy (NSW Water Resources Council 1993) provides objectives and principles to achieve sustainable management of rivers and estuaries in NSW to ensure resource use is consistent with the long-term biological and physical function of the natural system. The objectives of the policy are “To manage the rivers and estuaries in NSW in ways which: slow, halt or reverse the overall rate of degradation in their systems; ensure the long-term sustainability of their essential biophysical functions; and maintain the beneficial use of these resources”. The policy details six guiding principles for sustainable management of rivers and estuaries.

3.3 Guidelines

3.3.1 Significant impact guidelines

The significant impact guidelines provide over-arching advice on determining whether an action is likely to have a significant impact on a MNES protected by the EPBC Act and requires referral to the Commonwealth Department of the Environment and Energy for assessment and approval. Potential impacts on any MNES are subject to assessments of significance pursuant to the *Significant Impact Guidelines 1.1* (DoE 2013a). If a significant impact is considered likely, a referral under the EPBC Act must be submitted to the Commonwealth Environment Minister.

The *Significant Impact Guidelines 1.3* (DoE 2013b) includes significant impact criteria to assist in determining whether the impacts on a water resource from a proposed action associated with a coal seam gas or large coal mining development are likely to be significant, and therefore whether the action will require referral, assessment and approval. An action is likely to have a significant impact on a water resource if there is the possibility that it will directly or indirectly result in changes to the hydrology or water quality of a water resource.

The significant impact criteria defined by the *Significant Impact Guidelines 1.3* (DoE 2013b) are presented in Appendix A, along with where each aspect has been assessed in the SWIA.

3.3.2 IESC information guidelines

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) is a statutory body established under the EPBC Act in 2012. The IESC provides independent scientific advice to Australian government regulators on proposed coal seam gas or large coal mining developments that are likely to have a significant impact on water resources. Information guidelines (IESC 2018) outline the information requirements of the IESC to adequately assess a proposal and provide scientific advice on the potential water-related impacts.

The SWIA has been undertaken based on the information guidelines specified by the IESC (2018) and specific advice provided by the IESC to the NSW Mining and Petroleum Gateway Panel (IESC 2019). Appendix A presents the information requirements as well as where each requirement has been addressed in the SWIA.

3.3.3 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) provide guidance for assessing and managing ambient water quality in a wide range of water resource types and according to specified environmental values, such as aquatic ecosystems, primary industries, recreation and drinking water. A revised *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) was published in 2018 after a scientific review of the ANZECC (2000a) guidelines. The Water Quality Management Framework (ANZG 2018) provides the key requirements for determining appropriate guideline values or performance criteria to evaluate the results of water quality monitoring programs.

The ANZG (2018) guideline adopts a risk-based approach to assessing ambient water quality by providing the framework to tailor water quality guidelines to local environmental conditions. ANZG (2018) currently recommends continued use of the guidelines values found in ANZECC (2000a). Guideline values can be modified into regional, local or site-specific guideline values (SSGVs) by taking into account factors such as the variability of the particular ecosystem, soil types, rainfall and level of exposure to contaminants. Guideline values are applied to the receiving environment at the edge of the mixing zone and do not apply to dirty or mine water within the water management system.

The methodology outlined by the ANZG (2018) guidelines have been used to derive SSGVs for surface water quality monitored at the Mount Owen Complex, discussed further in Section 10.2.

3.3.4 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (DECCW 2006) are the agreed environmental values and long-term goals for each catchment in NSW. The objectives are intended to be considered in assessing and managing the potential impacts of activities on waterways.

The water quality objectives for the Hunter River catchment at Glendell Mine are for the protection of: aquatic ecosystems; visual amenity; primary and secondary contact recreation; livestock, irrigation and homestead water supply; drinking water at point of supply; and aquatic foods (cooked). The water quality objectives are consistent with the ANZG (2018) national framework for assessing water quality and have been considered in the development of SSGVs for surface water quality monitored at the Mount Owen Complex, discussed further in Section 10.2.

The river flow objectives for the Hunter River catchment at Glendell Mine are to: protect pools in dry times; protect natural low flows; protect important rises in water levels; maintain wetland and floodplain inundation; maintain natural flow variability; manage groundwater for ecosystems; and minimise effects of weirs and other structures. Conditions on water extractions specified by WALs (refer Section 3.1.3) and the design objectives of the Yorks Creek Realignment provide for these objectives to be met with respect to surface water. The Groundwater Impact Assessment (AGE 2019) and Aquatic Impact Assessment (Umwelt 2019) consider impact on groundwater dependent ecosystems.

3.3.5 Using the ANZECC Guidelines and Water Quality Objectives in NSW

The document *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC 2006) provides guidance on applying the ANZECC (2000a) framework for assessing water quality, including the use of water quality objectives for NSW.

3.3.6 Australian Guidelines for Water Quality Monitoring and Reporting

The *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC 2000b) sets out a framework and guidance for the monitoring and reporting of fresh and marine surface water and groundwater. ANZECC (2000b) provides information for all aspects of a water quality monitoring program, including setting objectives, designing monitoring and sampling programs, laboratory analyses, data analysis and interpretation and reporting of results and conclusions.

The water quality monitoring program at the Mount Owen Complex has been established in accordance with the framework presented by ANZECC (2000b).

3.3.7 Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales

The document *Approved Methods for the Sampling and Analysis of Water Pollutants in New South Wales* (DEC 2004) lists the sampling and analysis methods to be used when sampling water quality for compliance with environmental protection legislation, a relevant licence or relevant notice. All sample collection, handling and analyses are undertaken in accordance with the requirements outlined by DEC (2004).

3.3.8 Managing Urban Stormwater: Soils and Construction

Managing Urban Stormwater: Soils and Construction – Volume 1 (The 'Blue Book'; Landcom 2004) outlines the basic principles for the design, construction and implementation of sediment and erosion control measures to improve stormwater management and mitigate the impacts of land disturbance activities on soils and receiving waters. This document relates particularly to urban development sites; however, it is relevant to the Project as it provides guidance on the configuration of erosion and sedimentation controls required during construction.

Additional guidelines on specific aspects of development and the application of erosion and sediment controls are also available. The relevant guidelines relating to the Project are:

- *Managing Urban Stormwater: Soils and Construction – Volume 2C Unsealed Roads* (DECC 2008) provides specific guidelines, principles and minimum design standards for good management practice in erosion and sediment control during the construction and operation of unsealed roads.
- *Managing Urban Stormwater: Soils and Construction – Volume 2E Mines and Quarries* (DECC 2008) provides specific guidelines, principles and minimum design standards for good management practice in erosion and sediment control during the construction and operation of mines and quarries.
- *Managing Urban Stormwater: Source Control* (EPA 1998) provides guidance to local and state government agencies and developers, as well as community and business groups, on a range of source control (water quantity and quality) techniques that can be adopted to minimise impacts of works on surface water environments.
- *Managing Urban Stormwater: Treatment Techniques* (EPA 1997) provides guidance to stormwater planners and designers on the selection and functional (or conceptual) design of a range of stormwater treatment measures.

3.3.9 Floodplain Development Manual

The *Floodplain Development Manual* (DIPNR 2005) was developed to support the NSW Flood Prone Land Policy to reduce the impact of flooding and flood liability on owners and occupiers of flood-prone property and reduce public and private losses. The policy recognises the benefits of the use, occupation and development of flood-prone land. The manual (DIPNR 2005) guides councils in the development and implementation of floodplain risk management plans. The *manual* has been considered in the preparation of the flooding assessment for the Project.

3.3.10 Floodplain Risk Management Guidelines

The *Floodplain Risk Management Guidelines* complement the *Floodplain Development Manual* (DIPNR 2005) and are aimed at assisting councils prepare and implement floodplain risk management plans. Guidance is provided on scoping flood projects, flood modelling, assessing flood damage and supporting emergency management. The guideline *Incorporating 2016 Australian Rainfall and Runoff in studies* (OEH 2018) has been used to incorporate the 2016 update of *Australian Rainfall and Runoff* (Ball et al. 2016) into the flooding assessment for the Project.

3.3.11 Guidelines for controlled activities

The NSW Department of Planning, Industry and Environment – Water (DPIE Water) has published a number of guidelines on types of controlled activities and the protection of waterfront land. The guidelines provide recommendations for the design and construction of instream works and an indication of the width of riparian zones to be considered. The guidelines (NOW 2012a; 2012b) focus on the following key requirements:

- Maintaining the natural geomorphic processes through the accommodation of the existing watercourse, allow for the natural movement of sediment, woody debris and not allowing for an increase or the construction of scour and erosion within the existing watercourse.
- Maintaining the existing watercourse hydrologic function through accommodation of low flows and not altering the natural bank full or flood flows.
- The use of scour protection when required for the protection of existing banks, using placed rock.
- Visual inspections and maintenance on the watercourse during the works.

As discussed in Section 3.1.3, the Project is a SSD and as such does not require any controlled activity approvals. However these guidelines have been considered in the design objectives of the Yorks Creek Realignment (refer to Section 6.2.1).

4. Regional environment

4.1 Climate

For this assessment, a long term record of the key climatic variables relating to surface water (precipitation and evaporation) were obtained in the form of a patched point data set from the Scientific Information for Land Owners (SILO) database operated by the Queensland Department of Science, Information Technology and Innovation (DSITI). SILO patched point data is based on observed historical data from a particular Bureau of Meteorology (BOM) station with missing data 'patched in' by interpolating with data from nearby stations (DSITI 2018). The data were obtained for the nearest station location (Ravensworth (Hillview), 61028). The SILO data used in this assessment covers a historical period from 1 January 1889 to 25 April 2019 (a total of 130 years).

Figure 4-1 presents the comparison of cumulative frequency of the annual totals of rainfall and of evaporation from the historical record and compares recent annual rainfall totals from the SILO record compared to the site rainfall reported in the 2018 Annual Review (Glencore 2019).

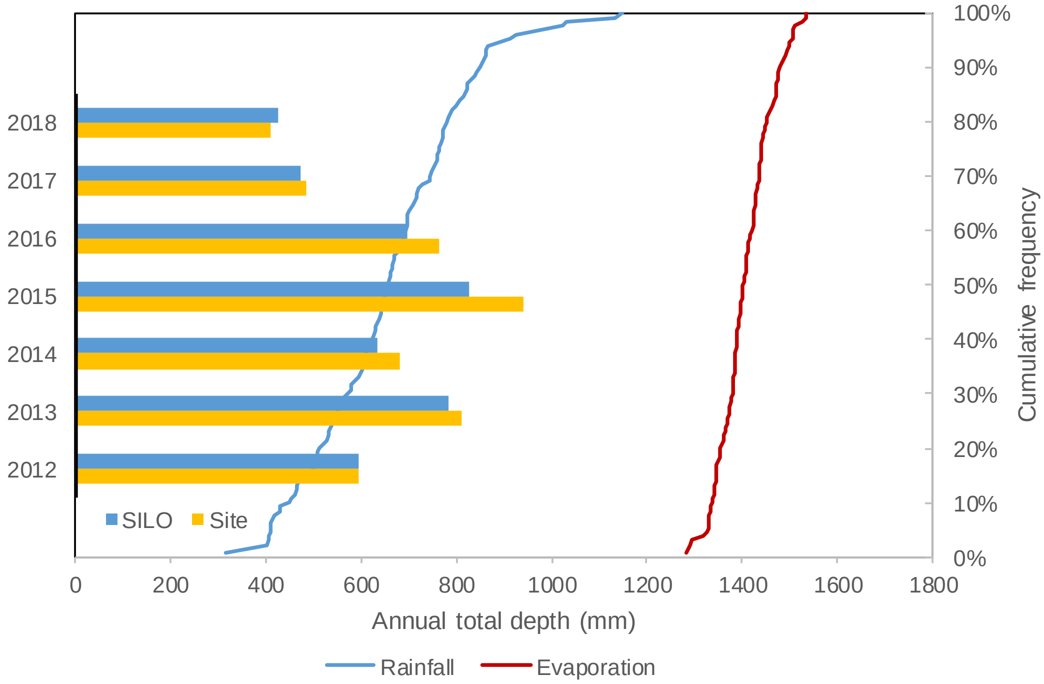


Figure 4-1 Annual rainfall and evaporation

Figure 4-1 shows that the historical record of annual totals of rainfall varied from a minimum of 293 mm (1944), to a maximum of 1 150 mm (1950), with a median of 658 mm. Median annual evaporation was 1 403 mm, corresponding to a median rainfall deficit of 745 mm. Figure 4-1 also shows an adequate fit between SILO and site rainfall data in recent years with rainfall observed during 2017 and 2018 well below average, at or below the 10th percentile of the historical record.

Figure 4-3 shows the comparison between the average monthly pan evaporation and the monthly rainfall from the historical record.

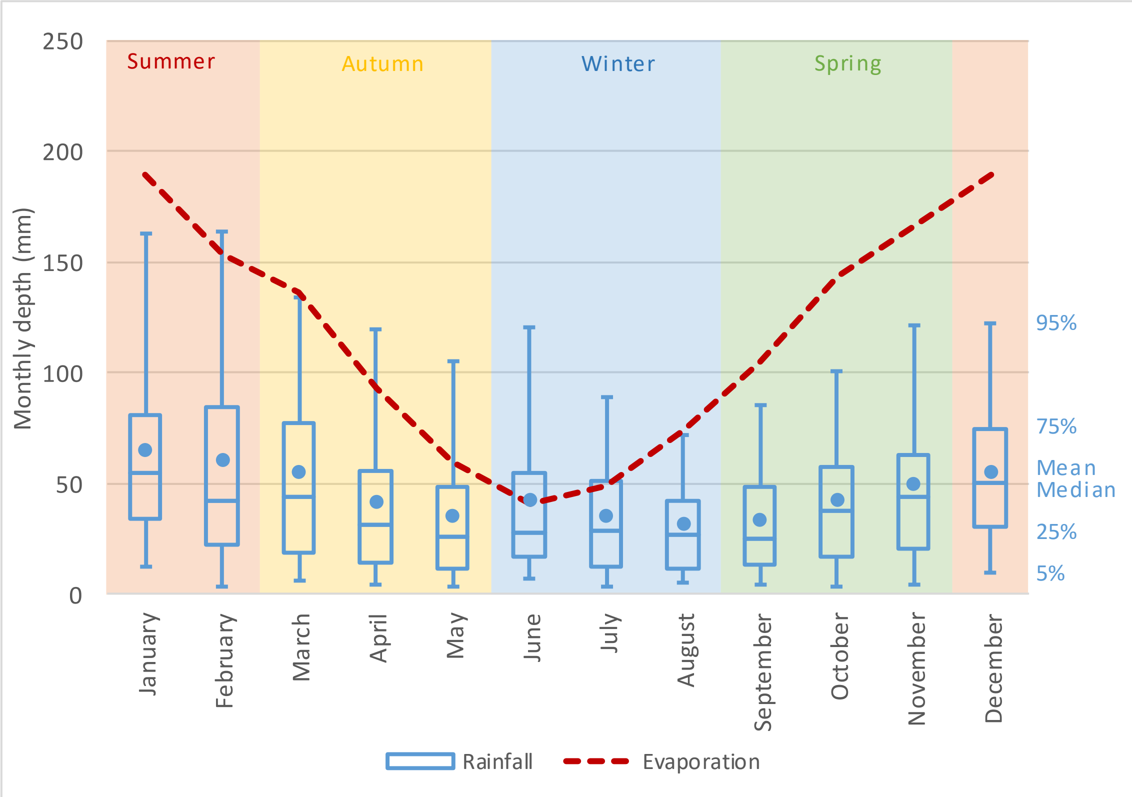


Figure 4-2 Monthly rainfall and evaporation

Figure 4-2 shows that the site experiences seasonal rainfall and evaporation patterns typical of a mild temperate climate, with average rainfall distributed across the year, but with higher average rainfall during the summer months. Evaporation exceeds median rainfall in all months of the year.

4.2 Topography and watercourses

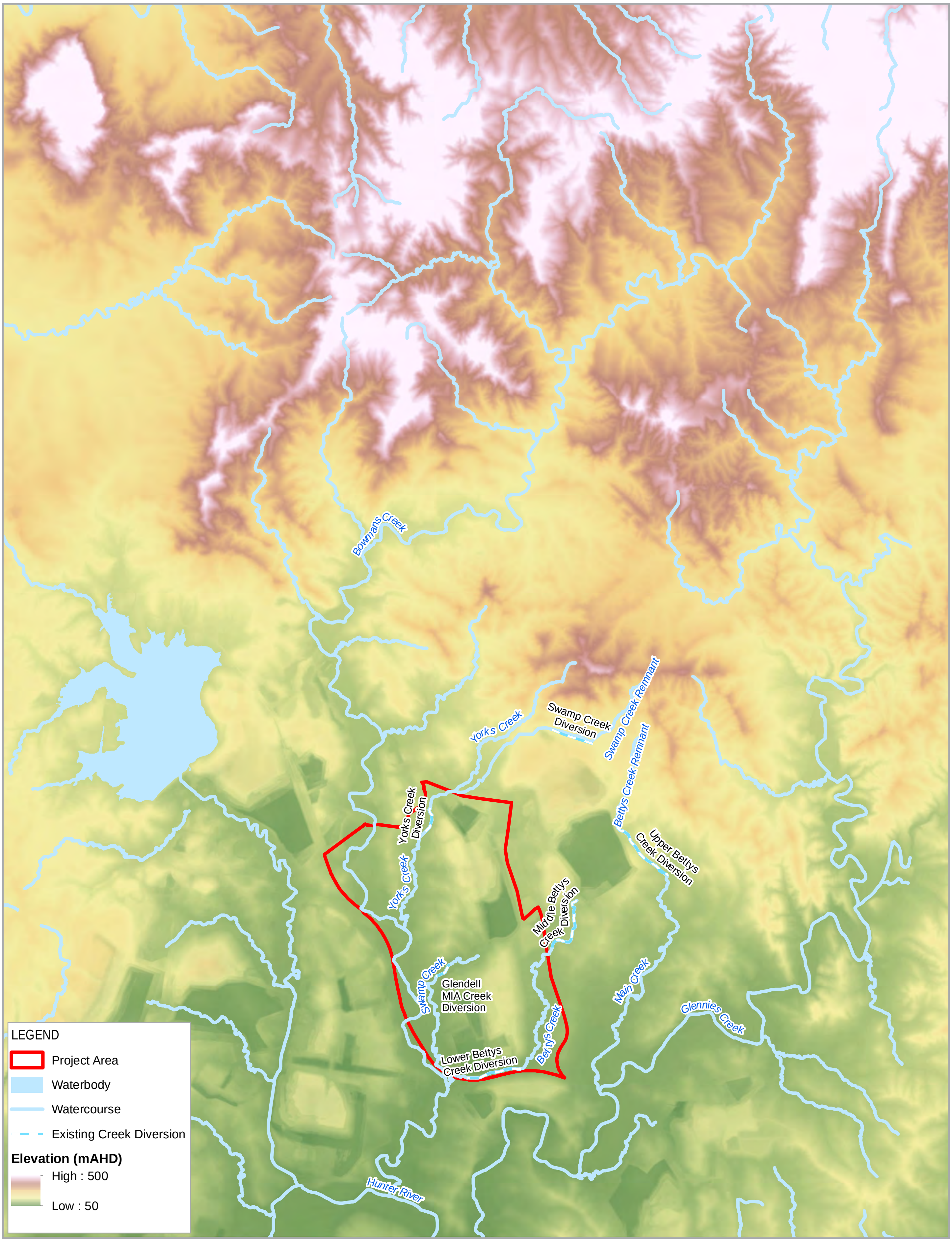
The Mount Owen Complex, and its water management system, are located within the catchments of Bowmans Creek and Glennies Creek and their tributaries: Yorks Creek, Swamp Creek and Bettys Creek (all sub catchments of Bowmans Creek) and Main Creek (a sub catchment of Glennies Creek).

The Mount Owen Complex straddles the Hunter Thrust geological feature. Terrain to the south west of the thrust is typically gently undulating. Terrain to the north of the Hunter Thrust typically shows more incised gully features.

Land uses within and surrounding the Mount Owen Complex include other mining operations, State Forest, biodiversity offset areas, grazing, pasture cropping and rural residential land holdings. Previous mining operations have modified local catchments through the capture of runoff from mining areas within the water management system and diversion of upslope runoff around the mining operations.

All aspects of the Project are located within the catchment area of Bowmans Creek, including the realignment of the lower reach of Yorks Creek. Aspects of the Mount Owen Complex within the Glennies Creek catchment are not affected by the Project.

The topography and watercourses are shown in Figure 4-3.



Paper Size ISO A4

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Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Topography and watercourse

FIGURE 4-3

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Print date: 19 Nov 2019 - 19:56

Data source: LPI: DTDB/DCDB, 2017. . Created by: tmorton

4.2.1 Yorks Creek

Yorks Creek is an ephemeral tributary of Bowmans Creek. Generally, the creek system is dry in between rainfall events, however, some pools of standing water tend to be present in the downstream reaches. The lower reaches of Yorks Creek are typically narrow, variable width floodplain with a notch-shaped channel about 2 m wide and 2 m deep. The channel has relatively steep banks formed in cohesive sediment, with stability enhanced by surface grass cover on the bank tops and bank sides fortified by tree and shrub root mats.

Before mining was undertaken in the Yorks Creek catchment, the land use within the catchment was typically farming and grazing. The existing Yorks Creek catchment includes the existing diversion of the upper catchment of Swamp Creek (approximately 500 ha) to Yorks Creek. Approximately 120 ha of the catchment is currently managed as part of the water management system for the Mount Owen Complex.

A 1.5 km long section of Yorks Creek was replaced with a 1.4 km long diversion channel during the 1970s as part of the former Swamp Creek Mine (predating Ravensworth East Mine). The diverted section runs from just south of the Mount Owen access road to below the heavy vehicle access road servicing the Ravensworth East MIA.

The Project includes the realignment of lower reach of the Yorks Creek north of the Glendell Pit Extension. The realignment will commence at a similar point to the existing Yorks Creek Diversion and enter Bowmans Creek approximately 4 km upstream of the existing confluence. The Project will effectively remove the entire length of Yorks Creek downstream from the existing diversion however runoff from parts of the conceptual final landform will be directed into Bowmans Creek at the existing confluence with Yorks Creek.

A detailed discussion of the geomorphology of the existing Yorks Creek is reported in Fluvial Systems (2019).

4.2.2 Swamp Creek

Swamp Creek is an ephemeral tributary of Bowmans Creek. Generally, the creek system is dry in between rainfall events, however, some pools of standing water tend to be present in the downstream reaches. These pools typically exhibit high salinity as a result of evapo-concentration and possibly also localised aquifer recharge from coal measures.

The catchment of Swamp Creek is highly modified, and a large proportion of Swamp Creek catchment is currently incorporated into the Mount Owen Complex water management system. Parts of the upper catchment of Swamp Creek have been diverted to the east of the Mount Owen Mine into Yorks Creek. The middle reaches of Swamp Creek have been entirely removed by the Mount Owen, Ravensworth East and Glendell Mine. The lower reaches of Swamp Creek have been diverted around the existing Glendell MIA.

4.2.3 Bettys Creek

Bettys Creek is an ephemeral tributary of Bowmans Creek. Generally, the creek system is dry in between rainfall events, however, some pools of standing water tend to be present in the downstream reaches. These pools typically exhibit high salinity as a result of evapo-concentration and possibly also localised aquifer recharge from coal measures.

The catchment of Bettys Creek is highly modified, and a large proportion of Bettys Creek catchment is currently incorporated into the Mount Owen Complex water management system. Approximately 490 ha of the upper catchment of Bettys Creek has been diverted to the east of the Mount Owen Mine into Main Creek. The middle reaches of Bettys Creek have also been diverted to the east around the WOOP emplacement area. The lower reaches of Bettys Creek were diverted to the south of the existing Glendell Pit.

Further diversion and remediation works associated with subsidence impacts will be undertaken as necessary as part of the approved Integra Underground Mine.

Part of the approved Mount Owen North Pit final void is located within the historical Bettys Creek catchment. The conceptual landform for the Project includes diversion of part of the pre-mining catchment of Swamp Creek to Bettys Creek.

4.2.4 Bowmans Creek

The headwaters of Bowmans Creek are in the Mt Royal Range and the upper catchment is deeply incised in steep bedrock terrain. The lower reaches of Bowmans Creek meander through a broad alluvial floodplain and terrace sequence that is up to 1 km wide. Bowmans Creek has a catchment area of approximately 250 km^2.

Bowmans Creek has four major tributaries in the vicinity of the Mount Owen Complex, namely Stringybark Creek, Yorks Creek, Swamp Creek, and Bettys Creek. Prior to mining, the land use within the Bowmans Creek catchment was typically farming and grazing. Although previously disturbed by agriculture and mining activities, Bowmans Creek has a catchment that has historically been sufficient to maintain flows under most climate conditions and has a well-established channel.

The Project includes an increase in the disturbance area, mining operations and associated water management in the Bowmans Creek catchment, and the catchment of its tributaries, including the realignment of Yorks Creek to a new confluence with Bowmans Creek. The proposed conceptual final landform will also alter the final catchments of Bettys and Swamp Creek relative to the landform contemplated under current approvals.

4.2.5 Glennies Creek

Glennies Creek flows from headwaters in the Mt Royal Range to the Hunter River. Glennies Creek has a catchment area of approximately 515 km^2. The upper 45% of this catchment area is regulated by Glennies Creek Dam, located about 17 km upstream of the confluence of Main Creek with Glennies Creek.

Glennies Creek Dam is an ungated earth and rock fill embankment dam, constructed from 1980 to 1983. The dam impounds Lake Saint Clair. Water from Glennies Creek Dam is managed to meet downstream requirements for environmental, irrigation, stock and domestic, town water and water conservation usages. As such the flow regimes in Glennies Creek downstream of Glennies Creek Dam are highly regulated.

Glencore currently holds WALs to extract water from Glennies Creek as a raw water supply to the Mount Owen Complex. No change to the catchment of Glennies Creek, including its tributary Main Creek is proposed as part of the Project.

4.2.6 Main Creek

Main Creek is an ephemeral tributary of Glennies Creek. Main Creek flows in a southerly direction and joins Glennies Creek downstream of Glennies Creek Dam and approximately 6.5 km upstream of the Glennies Creek confluence with the Hunter River. The majority of the catchment is open grasslands, and the riparian zone is mostly well vegetated along the mid portion with a well-defined creek line. The lower portion of the catchment is used for grazing.

The upper catchment of Bettys Creek, upslope of the Mount Owen Mine has been diverted via the Upper Bettys Creek Diversion into the Main Creek catchment through a channel and dam system increasing the Main Creek catchment area by approximately 490 ha. Approval was given for the Upper Bettys Creek Diversion as part of the 2004 Mount Owen Project development consent. In the currently approved conceptual final landform, approximately part of the upper Swamp Creek catchment is also diverted to Main Creek via the Upper Bettys Creek Diversion.

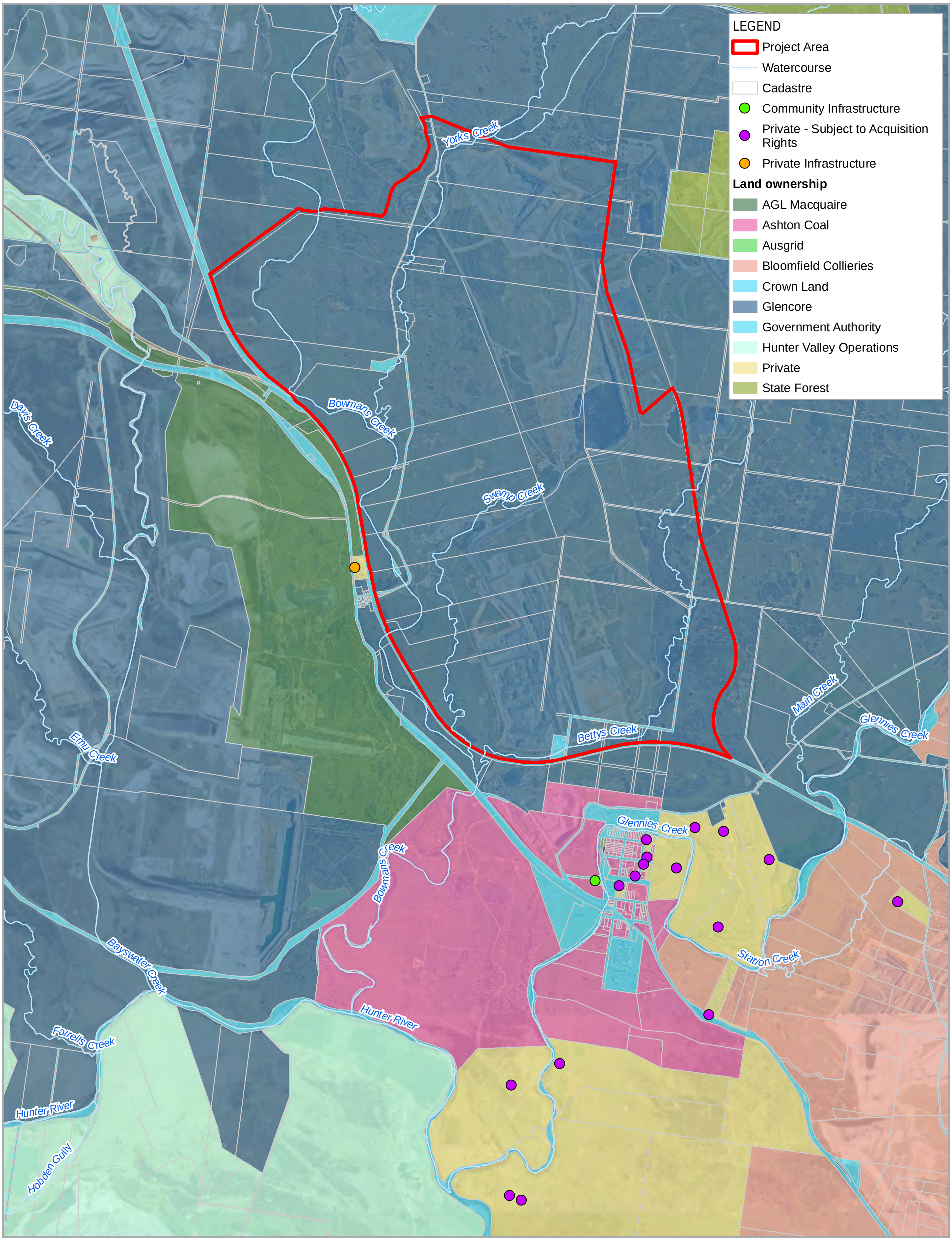
Part of the approved Mount Owen North Pit final void is located within the historical Main Creek catchment.

4.3 Downstream landholders and water users

The Project has the potential to affect the quality and quantity of water available for extraction by downstream water users and the extent of flooding in Bowmans Creek. The majority of land adjacent to the Project is owned by the Proponent, through the subsidiaries of its parent company Glencore. The downstream landholders are shown in Figure 4-4.

A search of the NSW Water Register (WaterNSW 2019) identified works approvals and associated water access licences held by private landholders and Ashton Coal Mine downstream of the Project on Glennies Creek. The water access licences are for the Hunter Regulated River Water Source. There is only one lot not owned by Glencore downstream of the Project on Bowmans Creek, which is owned by Ashton Coal Mine. This lot has a works approval and associated water access licence for the Jerrys Water Source. This lot is also adjacent to the Hunter River and Glennies Creek and has a works approval and an associated water access licence for the Hunter Regulated River Water Source.

The potential impacts of the Project on downstream landholders and water users is assessed in Section 11.8.4.



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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Downsteam landholders and water users

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FIGURE 4-4

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

5. Water quality

5.1 Monitoring program

Surface water quality monitoring at Glendell Mine is undertaken in accordance with the *Surface Water Management and Monitoring Plan* for the Mount Owen Complex (Glencore 2019a) within the dirty and mine water management systems as well as surrounding watercourses upstream and downstream of the site, including in Bowmans Creek, Yorks Creek, Swamp Creek, Bettys Creek and Main Creek. Table 5-1 provides the location of the existing surface water monitoring locations, relevant to the Project. Details of the monitoring locations and the period of record assessed as part of the SWIA are provided in Table 5-1.

All locations are monitored monthly for physiochemical stressors pH, electrical conductivity (EC) and total suspended solids (TSS). Monitoring in surrounding watercourses occurs during flow. Project specific monitoring of nutrients and metals has also previously been undertaken.

Table 5-1 Surface water quality monitoring details

System	Monitoring location	Period of record reviewed
Dirty water management system	Various	04/08/2009–24/06/2019
Mine water management system	Various	04/08/2009–03/06/2019
Bowmans Creek	BMC1	04/08/2009–24/06/2019
	BMC2	04/08/2009–24/06/2019
	BMC3	04/08/2009–24/06/2019
	BMC4	11/08/2009–24/06/2019
	BMC5	07/04/2016–24/06/2019
Yorks Creek	YC1	04/08/2009–24/06/2019
	YC2	04/08/2009–24/06/2019
	YC3	04/08/2009–24/06/2019
Swamp Creek	SC1	04/08/2009–24/06/2019
	SC2	04/08/2009–24/06/2019
	SC3	11/08/2009–24/06/2019
	SC4	11/08/2009–24/06/2019
Bettys Creek	BC1	04/08/2009–24/06/2019
	BC2	04/08/2009–24/06/2019
	BC3	11/08/2009–24/06/2019
	BC4	11/08/2009–24/06/2019

Paper Size ISO A4

0 0.35 0.7 1.05 1.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

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Existing surface water monitoring

FIGURE 5-1

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

5.2 Surface water quality guideline values

Site specific guideline values have been developed for the watercourse monitoring locations at the Mount Owen Complex, as described in Glencore (2019a). The guideline values were derived from the 80th percentile of data collected at reference sites (and 20th percentile for pH which is reported as a range), over a period greater than two years of monthly sampling, to cover a range of seasonal, climatic and flow conditions.

The catchments surrounding the Project are considered to be 'slightly to moderately disturbed' systems, as the waterways have been adversely affected by human activities by a small to measurable degree.

Table 5-2 presents the SSGVs for the Mount Owen Complex, which are consistent with the ANZG (2018) guidelines.

Table 5-2 Site specific guidelines values for the Mount Owen Complex

Location	pH	EC (µS/cm)	TSS (mg/L)
BMC1	7.7 - 8.1	1288	10
BMC2	7.8 - 8.1	1386	26
BMC3	7.8 - 8.1	1950	24
BMC4	7.5 - 8	1257	17
BMC5	7.7 - 8	2430	14
YC1	7.1 - 7.7	5286	25
YC2	7 - 7.8	7222	20
YC3	7.3 - 7.9	8852	33
SC1	7.7 - 8.6	824	21
SC2	7.4 - 8.2	1700	35
SC3	7.5 - 8.4	8824	34
SC4	7.1 - 7.8	1750	30
BC1	7.1 - 7.8	1882	16
BC2	7.4 - 8.3	6680	40
BC3	7.1 - 7.9	2686	52
BC4	7.1 - 7.8	2176	52

5.3 Existing surface water quality

Median water quality values for EC, pH and TSS observed within the dirty and mine water management systems as well as at watercourse monitoring sites are presented in Table 5-3. Nutrient and metals statistics are summarised by water management system in Table 5-4. Time series graphs for physiochemical stressors in each of the creeks, and box and whisker plots of other results are provided in Appendix D. Where the analytical result for a particular parameter was below the limit of reporting, then the value of the detection limit was used in its place.

Table 5-3 Median observed water quality – physiochemical stressors

System	Monitoring location	pH		EC		TSS	
		Count	Median	Count	Median (µS/cm)	Count	Median (mg/L)
Dirty water management system	Various	1356	8.4	1356	1610	1356	14
Mine water management system	Various	936	8.8	936	4880	922	24
Bowmans Creek	BMC1	114	7.9	114	1040	112	5
	BMC2	114	7.9	114	1036	113	12
	BMC3	109	8.0	109	1380	109	13
	BMC4	126	7.7	126	1195	126	8
	BMC5	37	7.9	37	2040	37	11
Yorks Creek	YC1	62	7.6	62	3435	62	9
	YC2	73	7.6	73	2730	73	6
	YC3	59	7.5	59	2400	59	9
Swamp Creek	SC1	111	8.1	111	393	111	7
	SC2	113	7.7	113	315	113	11
	SC3	67	8.2	67	5070	67	11
	SC4	29	7.4	29	969	29	19
Bettys Creek	BC1	36	7.6	36	904	36	6
	BC2	37	7.7	37	257	37	10
	BC3	52	7.4	52	477	52	17
	BC4	80	7.4	78	482	78	15

Table 5-4 Median observed water quality – nutrients and metals

Monitoring location	Clean water system		Dirty water system		Mine water system	
	Count	Median	Count	Median	Count	Median
Total Nitrogen as N (mg/L)	23	0.06	18	5.5	243	7.7
Total Phosphorus as P (mg/L)	23	0.01	18	4.05	209	0.1
Total Aluminium (mg/L)	23	0.15	45	0.135	33	0.18
Total Arsenic (mg/L)	23	0.001	45	0.002	33	0.007
Total Beryllium (mg/L)	23	0.001	45	0.001	31	0.001
Total Barium (mg/L)	23	0.049	45	0.05675	31	0.073
Total Cadmium (mg/L)	23	0.0001	45	0.0001	31	0.0001
Total Chromium (mg/L)	23	0.001	20	0.001	24	0.001
Total Cobalt (mg/L)	23	0.001	45	0.001	32	0.002
Total Copper (mg/L)	23	0.001	45	0.002	33	0.002
Total Lead (mg/L)	23	0.001	45	0.001	32	0.001
Total Manganese (mg/L)	23	0.02	45	0.0085	33	0.011
Total Mercury (mg/L)	23	0.0001	45	0.0001	31	0.0001
Total Nickel (mg/L)	2	#N/A	45	0.002	21	0.00725
Total Iron (mg/L)	23	0.145	45	0.165	34	0.225
Total Selenium (mg/L)	23	0.01	45	0.01	31	0.01
Total Zinc (mg/L)	23	0.005	45	0.005	32	0.006

The water quality monitoring results indicate that the dirty and mine water management systems are generally higher in EC, pH and TSS compared to the clean water system, with the mine water management system typically elevated compared to the dirty water management system.

The monitoring data indicates that water quality within each creek system is generally consistent at locations upstream and downstream of the Mount Owen Complex, indicating that the existing disturbance does not impact on water quality. The exception is SC3, which has elevated EC, but relatively low TSS and circumneutral pH consistent with the downstream SC4. This is likely attributable to SC3 having effectively no upstream catchment and therefore water quality samples are likely to be taken from standing pools subject to evapoconcentration and infrequent flushing by stream flows.

There are no visible temporal trends in the data available for physiochemical systems, with the exception of upward trends in EC in Bowmans Creek, likely attributable to the no flow conditions recently experienced during the current drought (refer to Section 9.5).

In regard to nutrients and metals, no additional monitoring has been undertaken since Engeny (2018). The key findings in that assessment were:

- Total nitrogen and phosphate are higher in the dirty and mine water system compared to the clean water monitoring locations.
- Aluminium in all systems is typically higher than the ANZECC 95% ecosystem protection level.
- Arsenic, barium, copper, cobalt, iron, nickel and zinc were all generally higher in the dirty and mine water systems than the clean water system.
- Minimal to no cadmium, lead, mercury or selenium were recorded in any of the water quality samples.
- Manganese levels are typically higher in the clean water systems than the dirty or mine water systems.

6. Water management system

The Mount Owen Complex has an integrated and extensive existing water management system, which includes mine dewatering systems, water storages, sedimentation and retention basins, settling and tailings ponds and diversion drains.

The Greater Ravensworth Area Water and Tailings Scheme (GRAWTS) is an integrated water and tailings management system that enables water and tailings to be transferred between the Mount Owen Complex and adjacent Glencore-operated mines of Ravensworth Operations, Liddell Coal Operations and Integra Underground Mine. The GRAWTS also includes some capability to transfer water between neighbouring mines: Hunter Valley Operations and Rixs Creek. The integration of water management and tailings disposal systems with other sites allows for greater flexibility in water use and management by Glencore at the Mount Owen Complex while also maximising water recycling and sharing to minimise the total volume of water extracted from Glennies Creek and the Hunter River and excess water discharges to the Hunter River under the HRSTS.

The use and management of water within the Mount Owen Mine and Ravensworth East Mine does not form part of the Project and will continue to be managed under the existing Mount Owen consent. The water management system proposed for the Project allows for the continued integration across the Mount Owen Complex and the GRAWTS.

6.1 Approved water management system

The approved Mount Owen Complex water management system has the following objectives and functions:

- Diversion of clean water around mining operations to minimise capture of upslope runoff and separate clean water runoff from mining activities.
- Segregating mine impacted water from better quality runoff from undisturbed and revegetated areas in order to minimise the volume of mine impacted water that requires management.
- Reuse of mine impacted water within the water management system and within the GRAWTS to reduce reliance on raw/clean water (e.g. extraction from Glennies Creek and the Hunter River).
- Minimising adverse effects on downstream waterways (i.e. hydraulic and water quality impacts).
- Reducing the discharge of contaminants from the mine to the environment.

Water management at the Mount Owen Complex considers three categories of water, each with different potential to cause environmental harm. The target design criteria for each of the three categories of water are summarised in Table 6-1. In Table 6-1, annual exceedance probability (AEP) is the chance of a certain event being equalled or exceeded in any given year, and is approximately inverse to the average return interval (ARI), for example a 1% AEP event has a 1% chance of occurring in any given year and occurs *on average* once every 100 years.

Construction activities associated with the Mount Owen Complex are undertaken from time to time. These activities may occur outside of the permanent Mount Owen Complex water management system, and are managed with construction specific erosion and sediment control plans in accordance with the relevant guidelines (including the Blue Book (Managing Urban Stormwater: Soils and Construction Volume 1 and Volume 2E).

Table 6-1 Water management system – design criteria

Water category	Description	Target design criteria
Clean	Runoff from undisturbed or rehabilitated areas where vegetation is fully established and where the water quality is suitable for release/discharge; and raw water imported under licence.	Release, where practicable, to downstream environment. Permanent clean water diversions designed to convey the 1% AEP (100 year ARI) design storm event.
Dirty	Runoff from disturbed areas, such as active overburden emplacement areas or overburden emplacement areas where vegetation is not fully established. These areas have the potential for elevated suspended solids.	Managed in line with the Blue Book (Managing Urban Stormwater: Soils and Construction Volume 1 and Volume 2E). Water storages and dewatering sized to manage runoff from the 5 day, 95th percentile rainfall event.
Mine	Water exposed to coal or used in coal processing and runoff from areas that are used to maintain coal mining equipment. Mine water includes water associated with groundwater inflows into open cut pits. This water may be saline and/or contain pollutants such as hydrocarbons.	Water storages sized to contain up to and including the 1% AEP (100 year ARI) 24 hour design storm event.

The water management system at the Mount Owen Complex includes diversions, drains, water storages, pumps and pipelines. The layout of the existing water management system is shown in Figure 6-1.

The water management system will evolve over the life of the approved operations at the Mount Owen Complex as mining in North Pit progresses to the south and runoff from rehabilitated areas is of adequate water quality to be released as clean catchment. This progression of the Mount Owen components of the water management system has already been assessed and approved under the Mount Owen consent. The existing Glendell Pit is near to its approved extent under the Glendell consent and no major changes to the existing water management system are expected for the remaining life of the operations approved under the Glendell consent, apart from the some sediment dams with relatively small catchments above the highwall of the approved Glendell Pit.

6.1.1 Clean water management system

The clean water management system at the Mount Owen Complex includes creek diversions and a series of clean water diversion drains and dams that divert clean water around disturbed areas.

Over the history of the Mount Owen Complex, six creek diversions have been developed and are managed, including the Yorks Creek Diversion, Swamp Creek Diversion, Glendell MIA Diversion and Bettys Creek (Upper, Middle and Lower) Diversions. Creek diversions redirect watercourses around disturbed areas or into adjacent creeks (in the case of the Upper Bettys and Swamp Creek Diversions).

In addition to the creek diversions, clean water diversions are in place around the northern edge of the Mount Owen Complex, to divert clean runoff into Yorks and Main Creek. Where limited by topography, clean water diversion dams are required to collect clean water for return by pumping.

For the remainder of the Mount Owen Complex, including the approved Glendell Mine, the natural topography generally drains away from the disturbed areas, towards Bowmans Creek to the west and lower Bettys Creek to the east and south. Therefore, clean water separation is maintained with small perimeter bunds as required.

6.1.2 Dirty water management system

The objective of the dirty water management system is to manage the risks associated with runoff from disturbed areas, such as active overburden emplacement areas or rehabilitated overburden emplacement areas where vegetation is not fully established. These areas have the potential for elevated suspended solids.

The dirty water management system at the Mount Owen Complex includes a series of dirty water drains that direct runoff from disturbed areas to sediment dams, with associated pumps and pipelines. The sediment dams are typically located around the toe of the waste emplacement areas across the Mount Owen Complex and are dewatered by pump and pipelines, and report to the mine water management system. As disturbed areas are progressively rehabilitated, the dirty water drains and sediment dams will transition to form part of the final rehabilitated landform.

Additional dirty water drains and sediment dams are planned as part of the approved mining operations at Mount Owen Complex.

6.1.3 Mine water management system

The objective of the mine water management system is to manage the risk associated with water exposed to coal or used in coal processing and runoff from areas that are used to maintain coal mining equipment. This water may be saline and/or contain pollutants such as hydrocarbons, although hydrocarbons are rare and generally volatise rapidly.

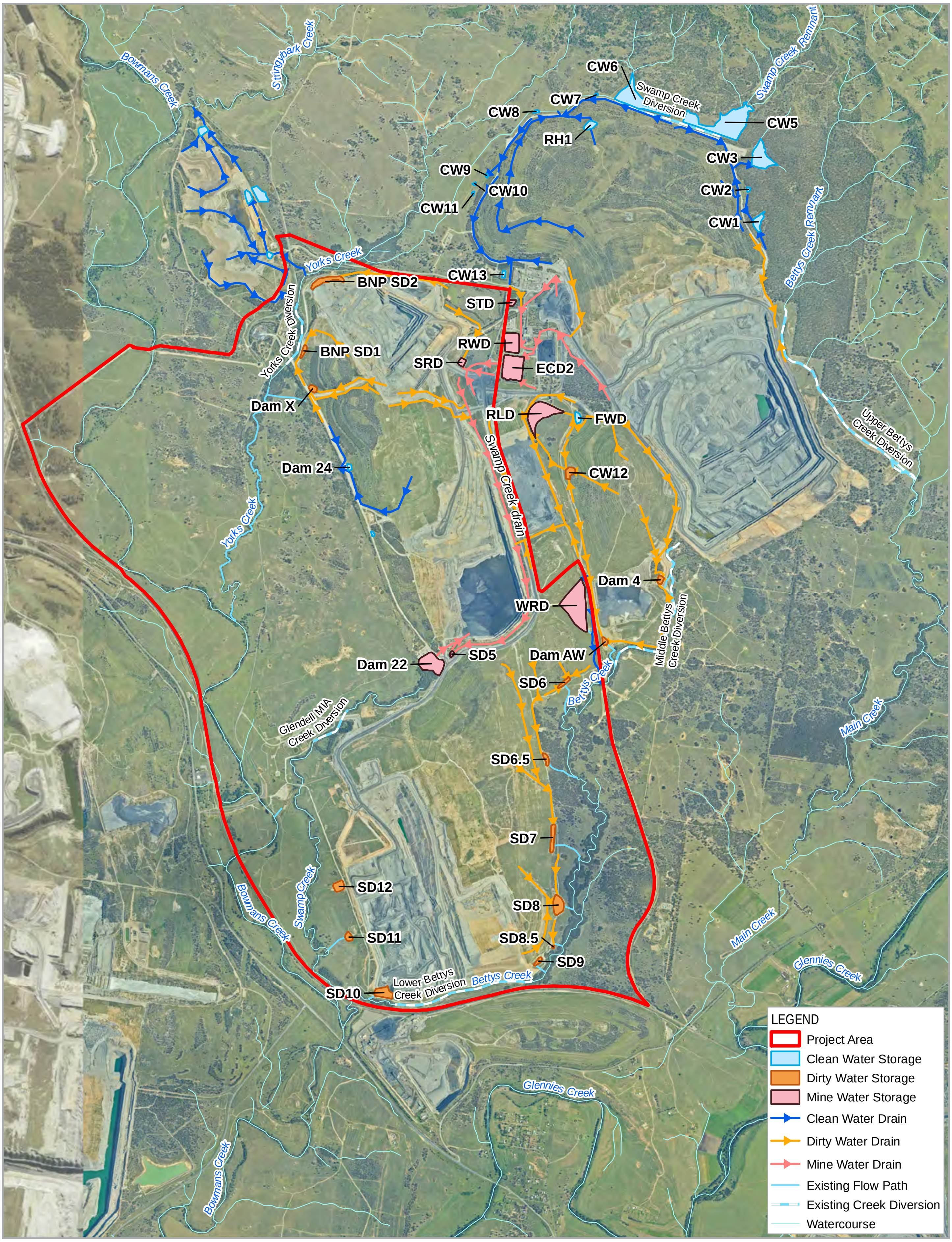
The mine water management system at the Mount Owen Complex includes the mine water storages, tailings dams and open cut pit sumps, with associated pumps and pipelines. The mine water management system contains runoff from coal contact areas and supplies water for mining operations. It includes the transfers to and from other sites as part of the GRAWTS and receives transfers of excess water from the dirty water management system.

The mine water management system is well established, centralised around the Mount Owen, Glendell and Ravensworth East MIAs. Under the Mount Owen consent, Bayswater North Pit is expected to be available for use as a mine water storage or tailings emplacement area following the completion of mining (approximately 2023) and North Pit will become available as a mine water storage or tailings emplacement area following completion of mining in North Pit in approximately 2037.

6.1.4 Rehabilitation and approved conceptual final landform

As mining operations progress, previously disturbed areas are progressively shaped into a final landform and rehabilitated by stabilising flow paths and establishing vegetation. Runoff from rehabilitated areas continues to be managed as part of the dirty water system until adequate water quality of catchment runoff is achieved such that the rehabilitated areas may be released as clean catchment.

As mining operations cease, progressive rehabilitation continues until the final landform is established. The approved conceptual final landform includes two final voids under the Mount Owen consent: Bayswater North Pit and Mount Owen North Pit; and the Glendell Pit final void under the Glendell consent. The final landform is designed to minimise the catchment area reporting to the final voids, to minimise reductions in catchment runoff.



Paper Size ISO A4

0 320 640 960 1,280 1,600

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Surface water management system
Existing conditions

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 6-1

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Print date: 19 Nov 2019 - 19:57

6.2 Proposed conceptual water management system

The proposed conceptual water management system is an extension of the existing water management system of the Glendell Pit maintaining the connection to the broader Mount Owen Complex water management system. The dirty water management system will be extended north along the western boundary of the Glendell Pit Extension, with a series of sediment dams and pumps that will be integrated into the Mount Owen Complex water management system with pipelines to either WRD or Bayswater North Pit. The existing Glendell MIA will be demolished and replaced by the new Glendell MIA. The new Glendell MIA will be integrated into the Mount Owen Complex water management system by pipelines connecting it to the Mount Owen MIA to supply raw water and allow dewatering of mine water. In addition to the realignment of Yorks Creek upstream of the Glendell Pit Extension (refer to Section 6.2.1), some small clean water diversions are proposed to minimise interception of water from undisturbed catchments.

The conceptual water management system has been assessed using a set of “snapshot” years: Year 6, Year 13 and Year 18. These years are representative of the progression of mining associated with the Glendell Pit Extension. From when it is approved (approximately 2021, Year 1) until approximately 2024 (Year 4), all disturbance areas associated with the mining operations will be largely within the approved disturbance area for the existing approved operations. Therefore little change to the Mount Owen Complex water management system will be required in these years. Accordingly, the conceptual water management system for this stage is essentially unchanged from the currently approved operations (refer to Figure 6-1) and therefore is not expected to have any additional impacts from the currently approved operations under the current Glendell consent.

However, prior to the first snapshot in Year 6, the construction of the Hebden Road realignment, the new Glendell MIA and associated Heavy Vehicle Access Road will occur and the construction of the Yorks Creek Realignment may also commence. The potential impacts associated with construction are temporary and largely limited to elevated levels of suspended solids in runoff from disturbed areas. All construction activities will be managed according to the principles of the Mount Owen Complex Erosion and Sediment Control Plan (in accordance with the ‘Blue Book’), and specific construction environmental management plans will be prepared for each construction activity, prior to the commencement of the works. The potential impacts associated with construction are temporary and considered minor compared to the proposed disturbance as part of the Project. As the potential impacts from these construction activities and the demolition of the Ravensworth East MIA, and the associated management controls, are well understood, these constructions activities are not considered in details in this assessment.

The proposed conceptual water management system for the snapshot Year 6, Year 13 and Year 18 are presented in Figure 6-2, Figure 6-3 and Figure 6-4 respectively. The conceptual drainage system for the proposed conceptual final landform is presented in Figure 6-5.

The plans presented in this section are concept designs. While the concept designs establish the design objectives and performance standards, the detailed designs will be determined by construction and mining schedules. The water management system will be constructed and modified as and when required so as to support the infrastructure and mine development. Further, the conceptual plans indicate only the components of the water management system which are required for a particular stage of the mine and does not preclude the construction of some components earlier than required.

Similarly, the components of the water management system have been sized for the purposes of achieving environmental compliance requirements. The actual configuration and geometry will be determined during future detailed engineering design stages. The potential disturbance area considered as part of the Environmental Impact Statement includes an allowance for larger dam footprints than are shown in the conceptual water management system plans to allow this flexibility.

The conceptual water management system plans show existing and proposed sediment dams in place over the whole duration of the Project. In reality, as progressive rehabilitation proceeds across the Mount Owen Complex, some areas are expected to have the final free draining landform established before the completion of the Project.

6.2.1 Yorks Creek Realignment

The Glendell Pit Extension requires the realignment of the lower reach of Yorks Creek. Yorks Creek is proposed to be realigned to the north, to join Bowmans Creek approximately 4 km upstream of the existing confluence. The realignment of Yorks Creek will require the demolition of the Ravensworth East MIA and coal handling infrastructure (including conveyor and surge bin) and removal of the existing heavy vehicle access, both of which are within the extent of the Yorks Creek Realignment works area. These Yorks Creek Realignment works will also include the development of a levee to prevent flood flows up to the 1000 year ARI design flood from Yorks Creek entering the Glendell Pit Extension mining area or final void.

The detailed conceptual design of the Yorks Creek Realignment includes design elements to achieve geomorphic design objectives within the site constraints, as discussed in Fluvial Systems (2019). The design objectives were developed with reference to the Queensland Department of Natural Resources and Mines 2014 Guideline: *Works that interfere with water in a watercourse—watercourse diversions* (DNR 2014), with reference to the Australian Coal Association Research Program (ACARP) design and monitoring criteria.

A set of design objectives were established for the realignment. The objectives were based on a philosophy of maintaining environmental values, incorporating natural geomorphological forms and processes typical of the existing Yorks Creek or alternative regional reference reaches, achieving an acceptable degree of physical stability, minimising risks to downstream riverine environments and cost effectiveness. The design objectives include:

- Minimise the risk of excessive erosion of the bed and bank in the realignment.
- Maintain hydrological integrity of the flood and low flows from the upper reaches of Yorks Creek to Bowmans Creek.
- Maintain sediment transport from the upper reaches of Yorks Creek to Bowmans Creek.
- Provide habitat in the riparian zone for vegetation, aquatic invertebrates, fish, reptiles and mammals typical of the existing ephemeral system.

Design elements have been incorporated into the concept design or have been identified to be investigated during the refinement of the detailed design. The key design elements and how they relate to the design objectives are summarised in Table 6-2.

Table 6-2 Key design elements of the Yorks Creek Realignment

Design element	Primary design objective
Appropriately sized rock will be placed to improve stability for major flood events, considering the relevant ACARP hydraulic guidelines, with particular attention to the risk of excessive valley wall erosion in the lower half of the diversion.	Minimise excessive erosion Maintain sediment transport
Where the bed shear stress exceeds the range of the existing creek, erosion resistant materials will be included. The bed material used in the upper low gradient zone will be free of contamination and have high cohesivity.	Minimise excessive erosion Maintain sediment transport
Measures of bank and bed variability in cross-section and long-profile similar to the existing Yorks Creek.	Provide habitat
Large wood will be sustainably supplied to the diversion channel by the riparian trees. Until such time that the trees are large enough to create significant wood loading, the realignment should be stocked with suitable anchored wood.	Provide habitat Minimise excessive erosion
Riparian vegetation will be similar to the existing Yorks Creek or other local drainage lines not currently disturbed by agriculture.	Provide habitat
An alluvial fan to capture sediment at the beginning of the alignment upstream of the low gradient zone between major flood events.	Maintain sediment transport
Bridge at the Hebden Road realignment crossing will minimise constraints on the movement of water and sediment.	Hydrological integrity Maintain sediment transport
Detailed design of backfill zone, including the levee, to minimise the risk of failure.	Hydrological integrity
Detailed design of confluence of Yorks Creek Realignment with Bowmans Creek, considering a possible plunge pool for the management of high stream power in the lower reach of the realignment and replicate existing relatively high habitat value at the existing confluence with Bowmans Creek.	Hydrological integrity Provide habitat
Incorporate natural analogue features within rock cuttings.	Provide habitat
Investigate the potential loss of baseflow through the higher permeability bed and bank materials. Yorks Creek is intermittent, which means that its main contribution to the hydrology of Bowmans Creek is flood flow, rather than baseflow. The permeability of the bank and bed materials is expected to decrease over time.	Hydrological integrity
Appropriate erosion and sediment controls during construction (refer to Section 6.2).	Minimise excessive erosion Maintain sediment transport

6.2.2 Conceptual water management system - Year 6

The conceptual water management system for Year 6 is presented in Figure 6-2. The existing water management system around the Glendell Mine will be extended as the Glendell Pit Extension progresses north. Sediment dam SD10 approximately marks the transition from the approved to proposed conceptual final landform.

Clean water management system

During this stage of mining, the Glendell Pit Extension will proceed generally down slope towards the existing Yorks Creek, meaning that clean water diversions are not required ahead of the pit as no clean catchment runoff will be intercepted by the pit. A succession of temporary minor dirty water storages may be required depending on the duration of disturbance and configuration of prestrip operations.

The proposed Glendell MIA and associated Heavy Vehicle Access Road run across the hillslope falling towards Bowmans Creek. Clean water diversion drains CWD1, CWD2 and CWD3 are proposed to divert runoff around the Heavy Vehicle Access Road and Glendell MIA towards Bowmans Creek and Yorks Creek.

Dirty water management system

The existing dams, SD11 and SD12, will be enlarged or replaced to manage dirty water runoff from the Glendell Pit Extension overburden emplacement area. Dryland attenuation basins, DB11A, DB11B, DB11C, DB11D will be established on the conceptual final landform as dirty water storages to provide part of the storage capacity requirement for the catchment reporting to SD11. These storages will be dewatered by gravity to SD11, which will be dewatered by pumping to WRD or Bayswater North Pit into the existing Mount Owen Complex water management system.

Proposed dams, SD13 and SD14 will be established as the Glendell Pit Extension progresses north. Like the existing SD11 and SD12, these storages will initially have relatively small catchments and may be progressively enlarged to their ultimate required size. These storages will be dewatered by pumping to WRD or Bayswater North Pit into the existing Mount Owen Complex water management system.

Mine water management system

The progression of the pit will require the demolition of the existing Glendell MIA and the pipeline from Dam 22 to the Narama Dam at Ravensworth Operations. This will make Dam 22 obsolete as a key transfer dam of the water management system, with its function replaced by WRD which, by this time, will be connected by a new pipeline to the Narama Dam. The new pipeline from WRD to the Narama Dam is being assessed separately. Dam 22, or an equivalent water storage in a similar location, will then function as a sediment dam. Until mined through, the Narama Pipeline will remain in place for use as an emergency or augmentation connection between the Mount Owen Complex and the Narama Dam.

The existing Swamp Creek drain currently reports to SD5 and the West Pit void. This presents a flood inrush risk for the Glendell Pit Extension. Therefore, it is proposed to redirect the Swamp Creek drain into WRD. This, combined with the repurposing of WRD as a focal point for water management at the Mount Owen Complex, may require an enlargement of its water storage capacity, to provide greater operating flexibility to transfer excess water from the Mount Owen Complex to the GRAWTS. The SRD storage near the Mount Owen CHPP is also proposed to be configured to overflow into the Bayswater North Pit void to reduce potential flows in the Swamp Creek drain.

Once the haul road along the west side of the Ravensworth East emplacement area is required for coal contact heavy vehicle use, the existing Dam 24 and Dam X (or equivalent storages in similar locations) will be enlarged and recommissioned as mine water storages.

Runoff from the Heavy Vehicle Access Road will report to the mine water storages HVAR1 and HVAR2. Runoff from the Glendell MIA will report to two mine water storages MIA East and MIA West, with clean runoff from the road areas and workforce parking areas reporting as stormwater via a clean water storage adjacent to MIA West. The Heavy Vehicle Access Road and MIA mine water storages will be dewatered via the proposed pipeline into the existing Mount Owen Complex water management system, initially via the Ravensworth East MIA and later directly to the Bayswater North Pit void. The proposed Glendell MIA is expected to be supplied with raw water from the existing Mount Owen Complex water management system, supplemented by clean water runoff captured from within MIA.

6.2.3 Conceptual water management system - Year 13

The conceptual water management system for Year 13 is presented in Figure 6-3.

Clean water management system

As the Glendell Pit Extension progresses north, CWD3 and its upslope clean water catchment will be mined through. Once the pit crosses the existing alignment of Yorks Creek and begins to proceed up slope, the local topography will prevent the diversion of runoff from the clean catchment between the Yorks Creek Realignment and the pit, apart from a small catchment in the north-west corner (CWD4). Clean runoff intercepted by the pit will be captured and managed as part of the dirty and mine water management system, either by a succession of storages that impounded the existing alignment of Yorks Creek, or through dewatering of the pit.

Dirty water management system

As the Glendell Pit Extension emplacement area progresses, dryland attenuation basins DB5A and DB11E may be constructed and managed by gravity dewatering to SD5 and SD11 respectively, while SD13 will be required to be enlarged to its ultimate capacity. Progressive rehabilitation may allow SD10 to be released as clean water by this time.

Mine water management system

As the Glendell Pit Extension progresses, Dam 24 will be mined through, with its mine water catchment reporting to the pit.

6.2.4 Conceptual water management system - Year 18

The conceptual water management system for Year 18 is presented in Figure 6-4.

Clean water management system

No changes to the clean water management system are expected at this stage of the Project.

Dirty water management system

As the Glendell Pit Extension proceeds north, SD14 will be required to be enlarged to its ultimate capacity, while the clean water catchment between the Yorks Creek Realignment flood levee and the pit will diminish. As the conceptual final landform is established, the location of Dam 22 will be filled, in order to integrate with the capping of West Pit and drainage back towards WRD. The catchment previously reporting to Dam 22 will report to an enlarged SD5. Dirty water runoff from the capping of West Pit will be managed by a localised depression or dam at the location of Dam WP.

Progressive rehabilitation may allow SD11 and SD12 and possibly SD13 to be released as clean water by this time.

Mine water management system

No changes to the mine water management system are expected at this stage of the Project. However, both North Pit and Bayswater North Pit would be available to be used as a mine water storage at this stage.

6.2.5 Conceptual final landform

When the final landform is achieved, all operations will be complete, and the disturbance areas will be completely rehabilitated. The conceptual final landform drainage system is shown in Figure 6-5. The conceptual final landform drainage systems includes re-established drainage paths and dryland attenuation basins. Under the approved conceptual final landform, a significant portion of the current disturbance area of the Mount Owen and Ravensworth East mines reports to Swamp Creek. Under the proposed conceptual final landform, this catchment is instead directed to Bettys Creek via the retention basin formed by WRD.

WRD will be retained in the conceptual final landform as a retention basin, to attenuate flows into Bettys Creek Towards the completion of the Project, further shaping of WRD may be required to enable its operation as a retention basin. These works will be detailed in the Mining Operations Plan (or Rehabilitation Management Plan) prepared closer to the time of these works. North Pit and Bayswater North Pit would be available to be used as a mine water storage if required during this time.

A final void will be retained in the northern end of the Glendell Pit Extension following the completion of mining. The catchment area of the final void will be minimised by permanent perimeter drains. The potential impacts of the final void are assessed in Section 8.

A free draining landform will be established on the final parts of the rehabilitated emplacement areas, and around the perimeter of the Glendell Pit Extension final void (with the exception of the small area of catchment between the void and Yorks Creek Realignment flood levee), in order to convey upstream catchment runoff away from the final void and to downstream watercourses: Bowmans and Swamp Creek to the west, Yorks Creek to the north and Bettys Creek to the south and east.

Dryland attenuation basins are proposed in the conceptual final landform to reduce flow velocities whilst maintaining drainage and creek line stability and as such will not permanently store water. Former sediment dams may be retained as permanent water storages or converted to dryland attenuation basins in the conceptual final landform, depending on the final land use and surface water licensing requirements at the time.

The final detail of dam configuration, design of the drainage systems and associated licencing will be further investigated and resolved during preparation of the relevant stages of the Mining Operations Plan and in the detailed closure planning process.

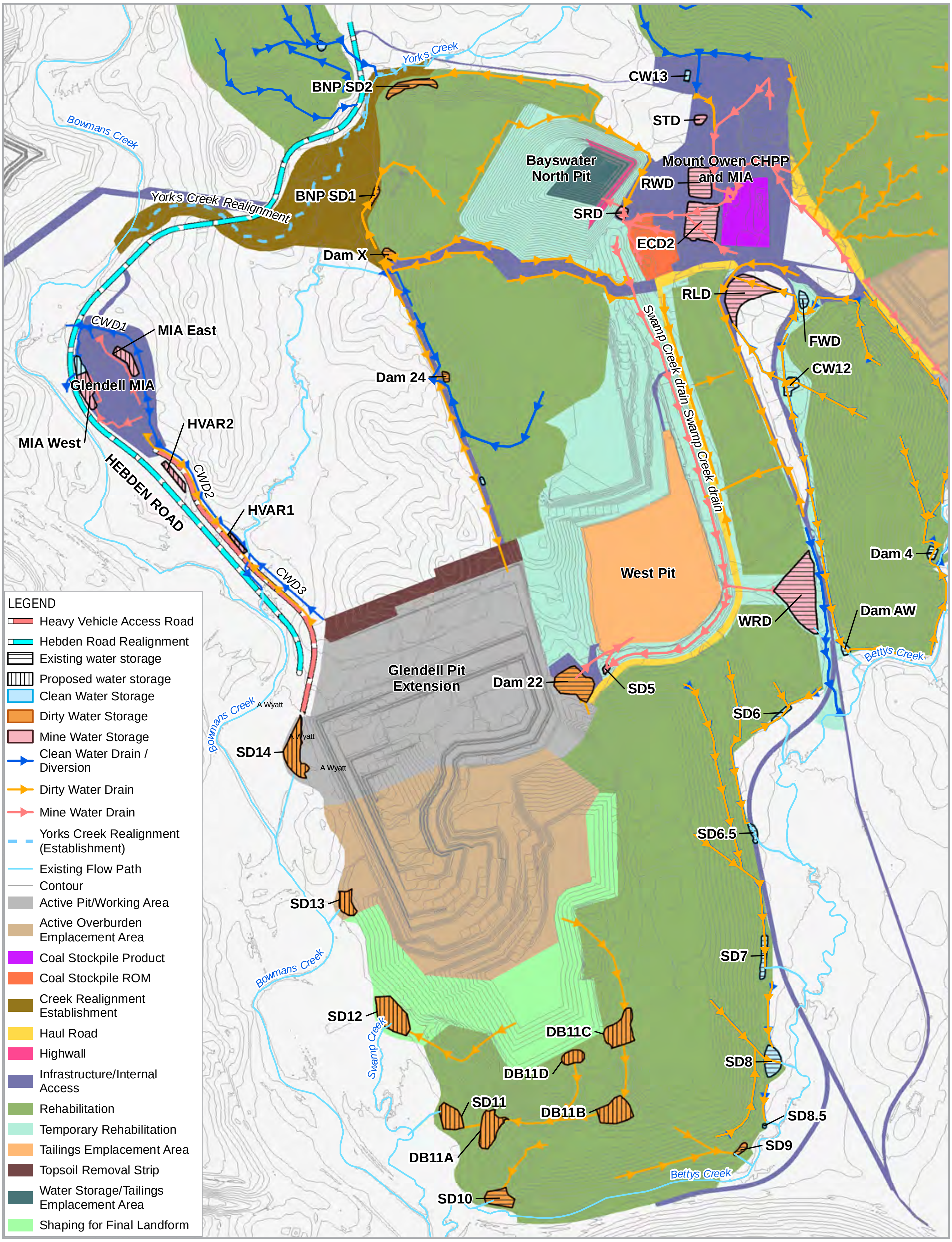
6.2.6 Conceptual water management infrastructure

The proposed conceptual water management system includes a series of modified or new mine water and dirty water storages, as well as associated pumping and pipeline infrastructure. The conceptual design sizes of these elements are summarised in Table 6-3. Concept sizing of the SRD is not included as this storage reports to the Bayswater North Pit void, and therefore no design criteria applies. The staging of the Project is such that minimum required capacity of some infrastructure increases over time. Table 6-3 provides the maximum conceptual design sizing over the entire Project, staged construction is subject to detailed design.

Table 6-3 Conceptual water management infrastructure

Storage	Design criteria	Settling volume (ML)	Sediment volume (ML)	Total volume (ML)	Nominal dewatering rate (L/s)
SD10	Dirty water 5 day 95th percentile	8.2	4.1	12.3	19
SD11		4.3	2.1	6.4	123[#]
SD12		24.1	12.1	36.2	56
SD13		5.9	3.0	8.9	14
SD14		23.9	12.0	35.9	55
DB11A		10.5	5.3	15.8	NA
DB11B		8.7	4.3	13.0	NA
DB11C		19.2	9.6	28.8	NA
DB11D		2.8	1.4	4.2	NA
DB11E		7.5	3.8	11.3	NA
DB5A		16.7	8.3	25.0	NA
Dam 22		21.4	10.7	32.1	50
SD5		31.2	15.6	46.8	111
Dam WP		38.0	19.0	57.0	88
Dam BNP2		10.8	5.4	16.2	25
Dam BNP1		17.2	8.6	25.8	40
Dam 24		6.1	1.2	7.3	23
HVAR1	Mine water 1% AEP 24 hour duration	9.3	1.9	11.2	36
HVAR2		9.8	2.0	11.7	38
MIA (East and West)		40.1	8.0	48.1	155
Dam X		15.3	3.1	18.3	59
WRD		379.8	76.0	455.7	293*

[#] In practice, pumps rates greater than 100 L/s are unlikely to be practical in the dirty water management system and it is likely that a 10 day or 20 day design criteria will be adopted for detailed design
* 15 day dewatering period



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Meters

Map Projection: Transverse Mercator
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GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Conceptual water management system
Year 6

Project No.	22-19708
Revision No.	0
Date	10 Oct 2019

FIGURE 6-2

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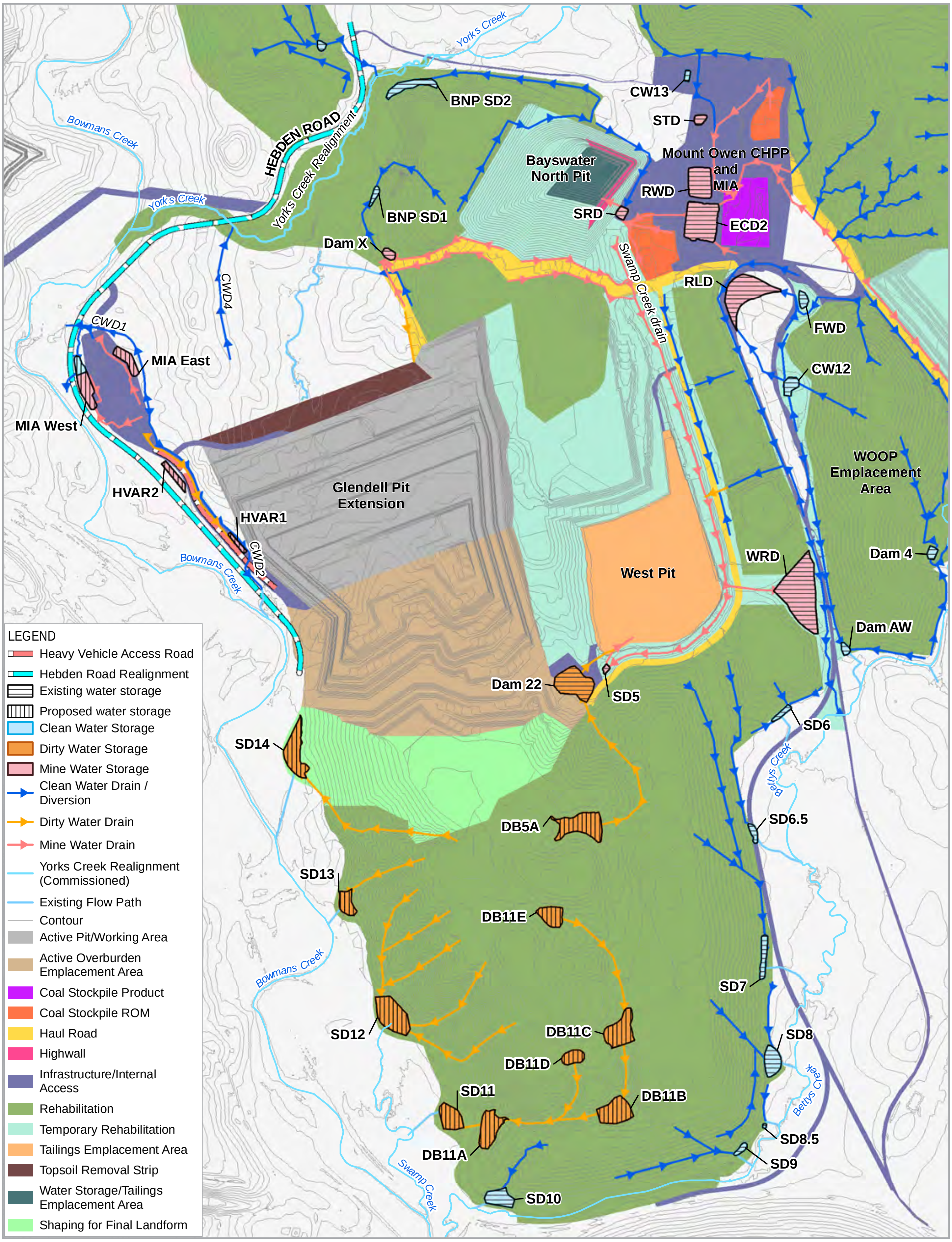

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Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Conceptual water management system
Year 13

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 6-3

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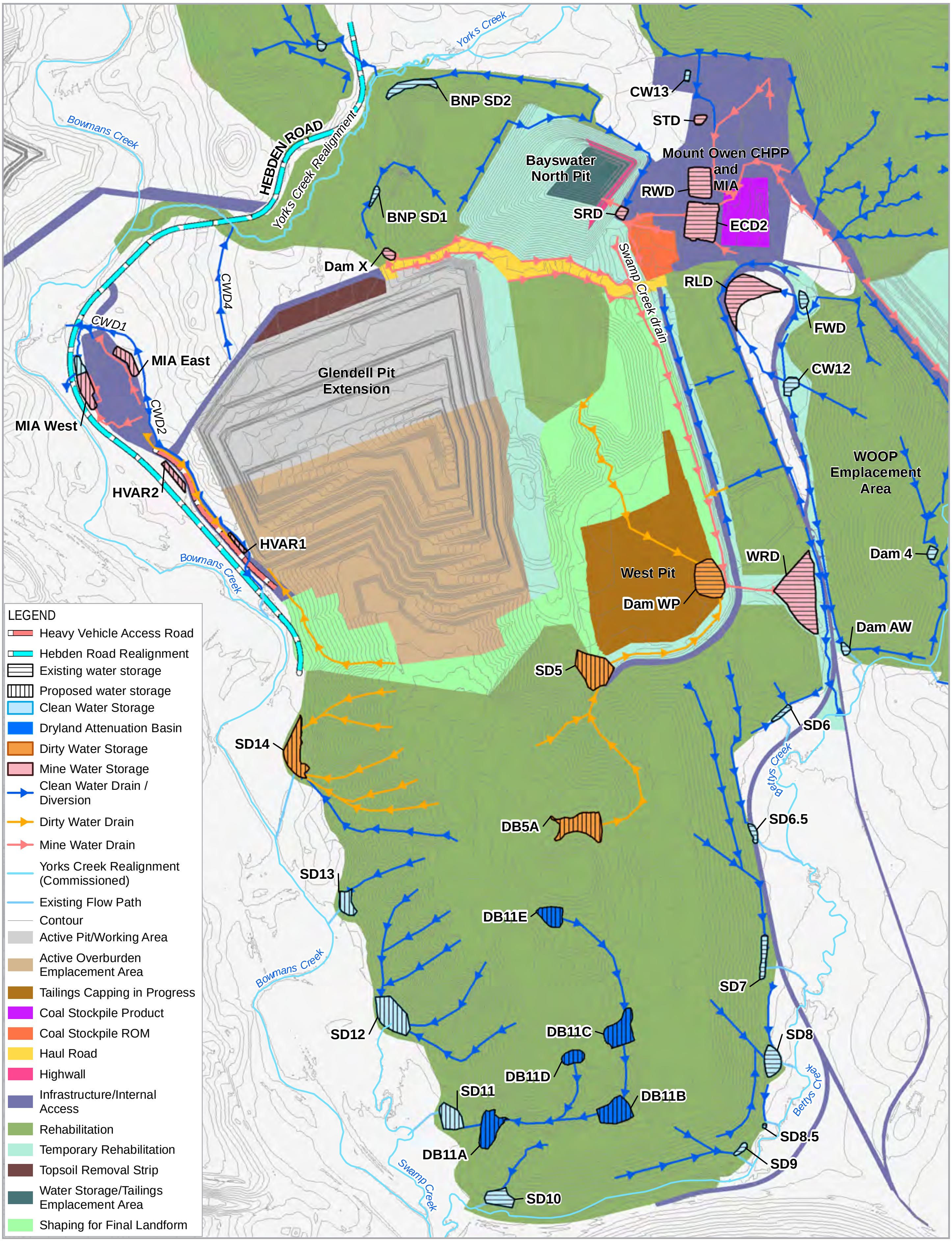

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Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 56

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GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Conceptual water management system
Year 18

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 6-4

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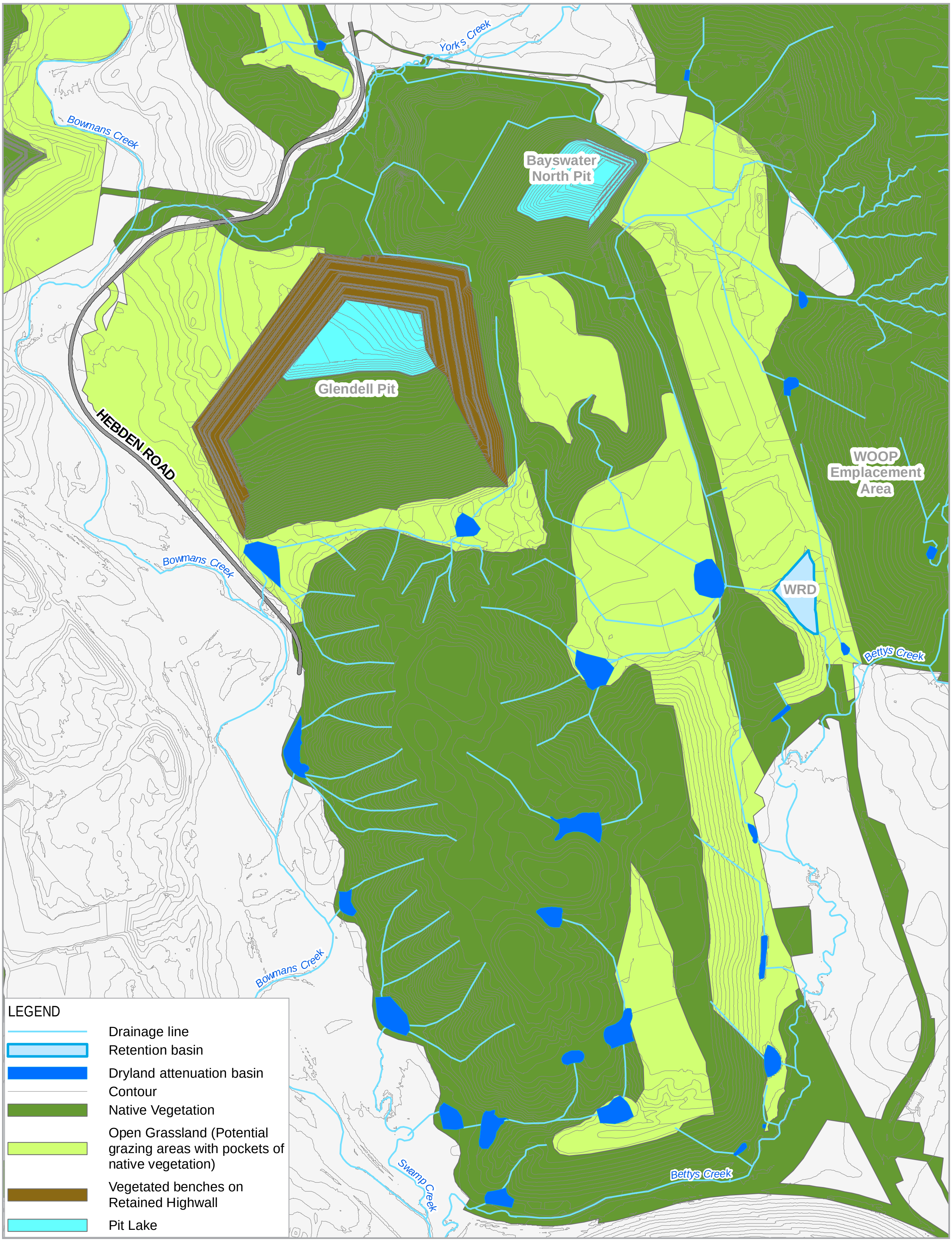

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Conceptual water management system
Conceptual final landform

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 6-5

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Data source: LPI: DTDB, 2017. . Created by: tmorton

7. Site water and salt balance

The Project is proposed to increase the total disturbance area and extend the life of operations of the Mount Owen Complex. The impact of the Project on the site water and salt balance of the Mount Owen Complex and the GRAWTS was assessed using the existing Greater Ravensworth Area Water Balance Model (GRAWBM). The potential impact of rainfall variability was assessed by sampling simulated rainfall from the historical rainfall record (refer to Section 4.1), which was looped as required. Further details on the modelling methodology and input data are included in Appendix B.

7.1 Modelling methodology

The GRAWBM was modified to represent the conceptual water management system (refer to Section 5), predicted groundwater inflows from the Groundwater Impact Assessment (AGE 2019) and estimated production rates. The modelling assumes that emplacement of tailings in West Pit will continue until 2030, after which tailings from the Mount Owen CHPP would be emplaced at neighbouring Liddell Coal Operations, subject to the relevant approvals. Bayswater North Pit is assumed to be available for water storage from 2023 and North Pit from 2038. The modified GRAWBM was used to forecast the likely water surplus or deficit, represented as a simulated change in water storage, based on:

- Inflows to the Mount Owen Complex:
  - Direct rainfall onto water storages.
  - Runoff from catchments within the water management system. Runoff is simulated using the Australian Water Balance Model. The baseflow component of the runoff model is considered to include infiltration of rainfall through spoil into the open cut pits.
  - Groundwater inflows to open cut pits, based on the predictions of the groundwater modelling (AGE 2019).
  - Bleed water recovered from tailings dams.
  - Water extracted from Glennies Creek.
- Outflows from the Mount Owen Complex:
  - Evaporation from water storages.
  - Water entrained in coal processed at CHPPs.
  - Water used for on-site dust suppression of haul roads and stockpiles.

The model does not explicitly consider losses from vehicle washdown or irrigation of treated wastewater, however these flows are considered minor and therefore reported as part of dust suppression usage. The model also simulated the site water balance at other Glencore sites in the GRAWTS, as well as the transfer of water between sites, which are reported as imports to and exports from the Mount Owen Complex. The GRAWBM included a coupled salt balance, which simulated the movement of salt associated with each water transfer.

7.2 Modelling results

The GRAWBM was used to forecast the water balance of the Mount Owen Complex, as part of the GRAWTS over the proposed life of the Project. The average annual water balance results are presented in Table 7-1 and compared to the approved water balance for the Mount Owen Complex (Engeny 2018).

Table 7-1 Approved and proposed average annual water balance

Water balance element	Approved conditions (Engeny 2018) (ML/year)			Proposed conditions (ML/year)		
	2020 (Mount Owen consent Year 2)	2026 (Mount Owen consent Year 8)	2033 (Mount Owen consent Year 15)	2026 (Year 6)	2033 (Year 13)	2038 (Year 18)
Inputs						
Direct rainfall and catchment runoff	2531	2511	2175	3329	3225	2844
Groundwater inflows into open cut pits	543	449	424	407	570	204
Imports from GRAWTS	2281	2875	2534	3073	2882	2138
Extractions from Glennies Creek	135	120	117	412	412	292
Bleed water recovered from tailings	7719	1120	0	4184	0	0
Total inputs	**13,209**	**7075**	**5250**	**11,406**	**7088**	**5477**
Outputs						
Evaporation from storages	1306	1700	1017	1364	219	312
Net CHPP usage	5871	3231	1446	6026	4242	2784
Dust suppression usage	983	561	572	1325	1336	845
Exports to GRAWTS	3832	3459	3037	2597	1158	893
Total outputs	**11,992**	**8951**	**6072**	**11,312**	**6995**	**4834**
Change in storage						
Change in storage	**1 217**	**-1 876**	**-822**	**94**	**133**	**644**

The results presented in this section are statistical summaries of the forecasts under a range of rainfall conditions and do not reflect a specific historical rainfall sequence. For the purpose of the site water balance modelling, it has been assumed that Year 1 of the Project is 2021, in order to align the Project with other existing and approved operations in the GRAWTS.

Table 7-1 shows that the Project is not expected to have a significant impact on the overall water balance, other than the impacts associated with extending the proposed life of the Project.

Direct rainfall, catchment runoff and evaporation

The Project will increase the overall disturbed area at the Mount Owen Complex, and therefore is expected to increase the volume of catchment runoff captured and managed within the Mount Owen Complex water management system. Similar to the approved conditions, this volume is expected to reduce over time as rehabilitated catchment runoff is returned to the surrounding catchments.

The modelling indicates that by Year 13 of the Project, evaporation from storages for proposed conditions is less than the approved conditions. It is considered that this reduction is the result of the assumed change of the destination of tailings from the Mount Owen CHPP from West Pit to Liddell Coal Operations. Comparable evaporation losses from the tailings emplacement are expected to occur at Liddell Coal Operations.

Groundwater inflows into open cut pits

Total groundwater inflows at the Mount Owen Complex are expected to increase due to the Project, as described in the Groundwater Impact Assessment (AGE 2019). This change is small relative to the overall water balance at the Mount Owen Complex.

Extractions from Glennies Creek

Water for the new Glendell MIA is proposed to be supplied from Glennies Creek. Total extraction from Glennies Creek is expected to increase as a result of the Project, relative to the existing approved conditions, while the Mount Owen and Glendell MIA are operated simultaneously until around 2037. After 2037, the Mount Owen MIA is expected to cease to operate, and extraction from Glennies Creek is expected to reduce. The peak forecast extraction from Glennies Creek of 416 ML/year is within the entitlements already held for the Mount Owen Complex (refer to Section 3.1.3).

Dust suppression usage

Peak dust suppression usage at the Mount Owen Complex is expected to increase as a result of the Project, in proportion to the estimated haul road lengths, based on the conceptual mine plans. Dust suppression demand is also expected to increase at Mount Owen Mine, as North Pit proceeds away from the CHPP and MIA, until mining ceases at Mount Owen North Pit around 2037 and dust suppression demand reduces.

Coal processing and tailings

CHPP usage is expected to increase as a result of the Project, as the life of the Mount Owen CHPP is extended to process the additional coal from the Project. Bleed water recovered from tailings is forecast to increase in proportion to the increase in CHPP usage, until 2030, when tailings emplacement in West Pit at the Mount Owen Complex is expected to cease, and be substituted with tailings emplacement at Liddell Coal Operations. The bleed water recovered after 2030 is reported in the imports from GRAWTS after 2030.

GRAWTS transfer and change in storage

The Project will continue to import and export water as part of the GRAWTS. The version of GRAWBM used for this assessment reflects operational refinements to the planned use of existing infrastructure, resulting in smaller magnitudes of average change in water volumes over the Project, compared to the approved conditions. Following the completion of approved mining in North Pit in 2037, the total volume of water at the Mount Owen Complex is expected to increase as the water level in the final void begins to recover.

The forecast water inventory at the Mount Owen Complex and in the GRAWTS is compared to the total water storage capacity in Figure 7-1 (shown on a logarithmic scale below 10 000 ML for clarity). Results are presented for the 5th percentile, the median and 95th percentile to indicate potential variability with rainfall.

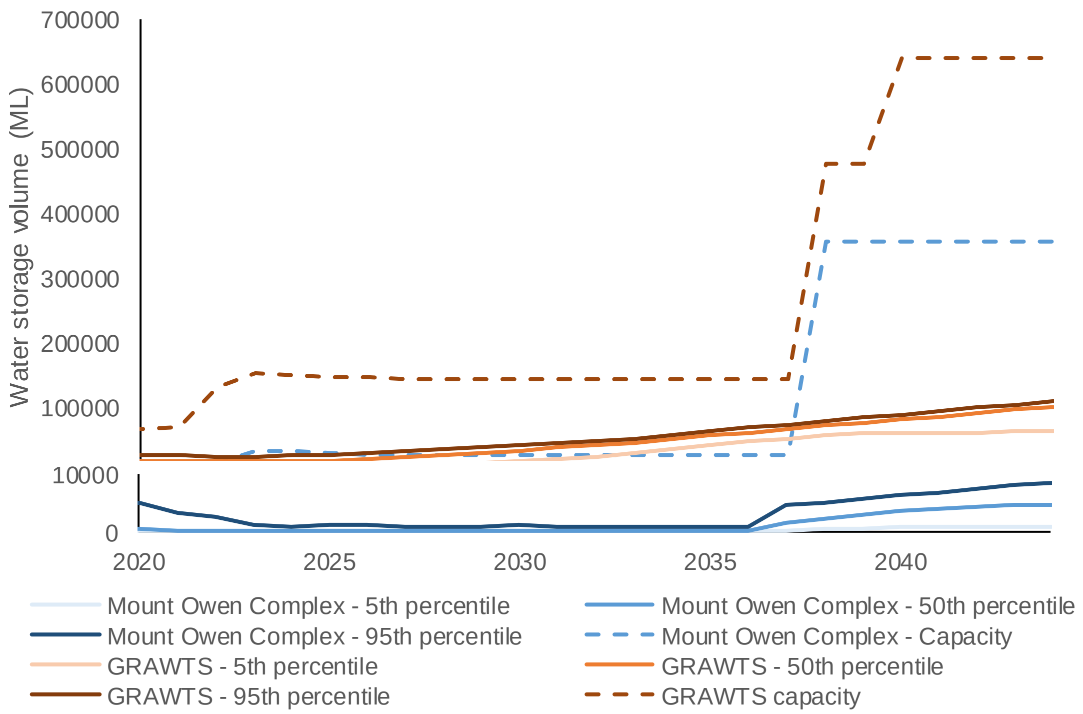


Figure 7-1 Forecast water inventory

Figure 7-1 shows the forecast water inventory at the Mount Owen Complex is expected to be small compared to the available storage capacity at the Mount Owen Complex. The available storage capacity is expected to increase in 2023, when mining is expected to conclude in Bayswater North Pit, providing additional water storage capacity. Following the completion of approved mining in North Pit in 2037, the total water storage capacity at the Mount Owen Complex will increase, while the forecast water volume also increase as the water level in the final void begins to recover.

The overall water volume in the GRAWTS is expected to remain well below the total water storage capacity, especially following the conclusion of mining at Liddell Coal Operations and Bayswater North Pit at the Mount Owen Complex at around 2023. This is even more so the case in the late 2030s as mining is completed in Mount Owen North Pit and Ravensworth Operations North Pit, corresponding to an increase in the total water storage capacity within the GRAWTS. The increasing trend in total water volume across the GRAWTS is largely the result of the expected recovery of water levels in the final voids as mining is completed in various pits.

HRSTS discharges from the GRAWTS

The Project, as part of the Mount Owen Complex, does not propose to discharge water. The Proponent proposes to continue to share water within the GRAWTS, including the use of existing water storages and, where necessary, utilise existing approved discharge points under the HRSTS at Ravensworth Operations and Liddell Coal Operations. The cumulative modelled volume discharged under the HRSTS are summarised in Figure 7-2. The modelled discharges are less than 1% of the average annual flows in the Hunter River.

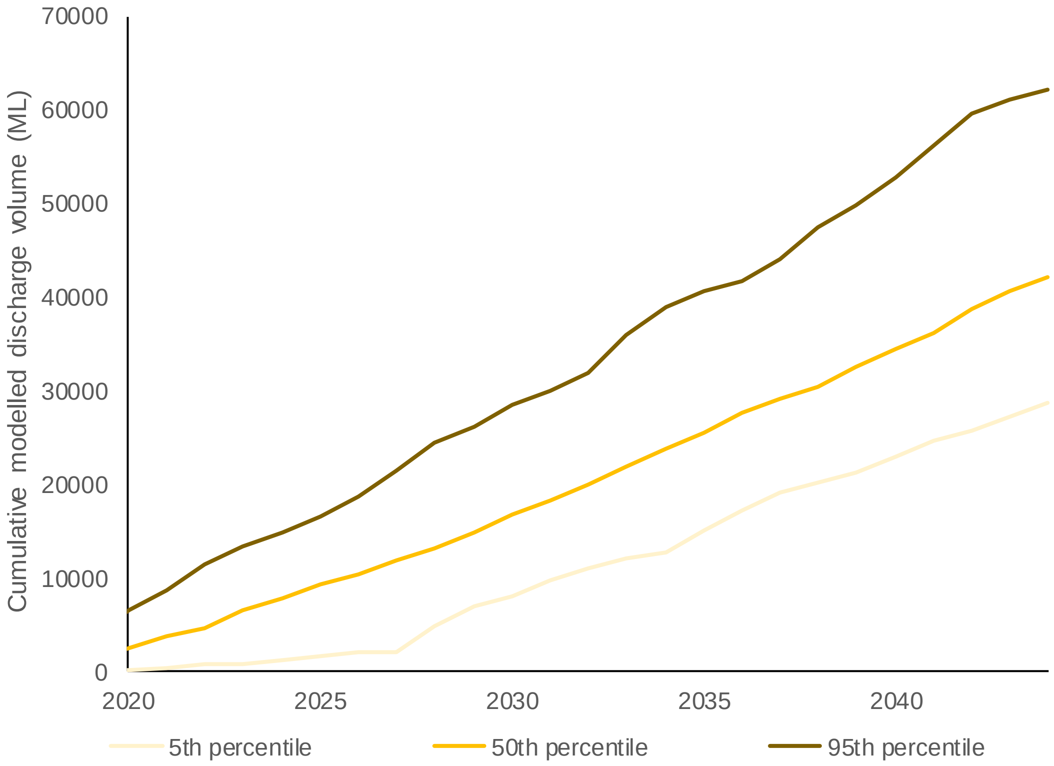


Figure 7-2 Forecast HRSTS discharges from the GRAWTS

Figure 7-2 shows that the likely range of cumulative discharges volume under the rules of the HRSTS are expected to remain similar over the life of the Project. The cumulative volume shown in Figure 7-2 is small compared to the storage capacity shown in Figure 7-1, indicating that there is sufficient water storage capacity in the GRAWTS throughout the life of the Project. Therefore the discharge volumes in Figure 7-2 reflect the potential discharges volume within HRSTS rules and the water demand in the GRAWTS, rather than discharges that are required as part of mining operations. Overall, as the Project is essentially an extension through time of the existing operations under the Glendell consent, no increase to annual discharge volumes under the HRSTS are expected as a result of the Project.

The GRAWTS includes a number of large water storages used to manage water from the various operations. Surplus water transferred from the Mount Owen Complex to the GRAWTS will be stored in these water storages and reused within the GRAWTS in preference to being discharged.

Average site salinity

The GRAWBM was used to forecast the salt balance for the Project as part of the Mount Owen Complex. The average site salinity for the Mount Owen Complex is shown in Figure 7-3 (expressed at electrical conductivity). Average site salinity is the volume weighted average of the salinity of all water storages at the Mount Owen Complex. The forecast average site salinity is compared to the median observed electrical conductivity of the different elements of the water management system (refer to Section 5).

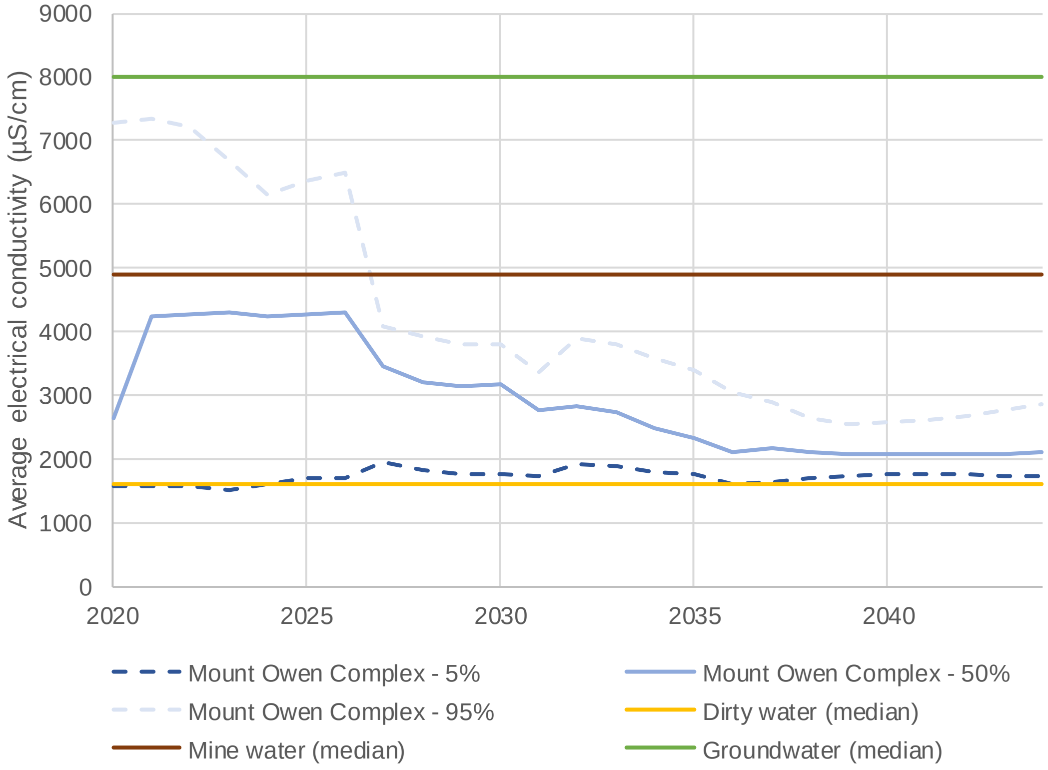


Figure 7-3 Forecast average site salinity at Mount Owen Complex

Figure 7-3 shows that average site salinity at the Mount Owen Complex is generally expected to remain between the observed salinity of the dirty water and mine water management systems. The modelling forecasts a peak in average site salinity in the early to mid 2020s. This reflects the modelled low site water inventory (refer to Figure 7-1) during potential periods of below average rainfall. In these circumstances water from Integra Underground Mine (which has a generally higher electrical conductivity) is expected to make up a larger proportion of the site water inventory and thus increase the average site salinity. Following this period, average site salinity is expected to remain between the observed salinity of the dirty water and mine water management systems and generally trend down throughout the remainder of the life of the Project, reflecting the progressive rehabilitation of the Mount Owen Complex.

Overall, as the Project is essentially an extension through time of the existing operations under the Glendell consent, any changes as a result of the Project to the site water and salt balance at the Mount Owen Complex are not expected to affect the annual volume or water quality of potential discharges under the HRSTS.

8. Final void

The conceptual final landform of the Project includes a final void following completion of mining in the Glendell Pit Extension. A final void is approved under the current Glendell consent.

The conceptual final landform has been designed to minimise the catchment contributing to the proposed final void, with a catchment area slightly smaller than that of the approved final void. The final void is expected to act as a long term groundwater sink, as described in the Groundwater Impact Assessment (AGE 2019). As such, the final void will be effectively hydrologically self-contained, in order to minimise potential impacts on downstream water quality and the surrounding groundwater environment. Therefore, the water quality in the final void will reflect the chemistry of the geology in which it is situated.

The Geochemical Assessment (EGI 2019) concluded that, based on leach column tests of the overburden and interburden, the vast bulk of the surrounding geology is likely to produce excess alkalinity, with low metal or metalloid concentrations but initially moderate salinity dominated by sulphate and chloride salts. This conclusion is consistent with the observed water quality at the Mount Owen Complex (refer to Section 5), which has a neutral to slightly basic pH in both the dirty and mine water management system (8.4 and 8.8 respectively) but has an elevated salinity (measured as electrical conductivity) especially the mine water system, with a median salinity of 4 880 µS/cm compared to typical salinity of surrounding water courses in the order of 1 000 µS/cm. However, the salinity in mine water system remains lower than the typical groundwater salinity of approximately 11 500 µS/cm.

EGI (2019) reports that the alkalinity is expected to report to infiltrating waters in overburden and interburden dumps, providing an additional factor of safety in acid rock drainage management through interaction with potentially acid forming materials and any associated acid leachate. EGI (2019) forecast that the initial moderate salinity concentrations are expected to decrease over time with continued flushing, and overburden and interburden materials have an overall low salinity potential and therefore it is not expected to have a significant impact on pit water quality or require modification of the Mount Owen Complex water management system during operations. However, the self-contained hydrology of the final void has the potential to concentrate the dissolved solids in the final void lake over time, through evaporation.

The long term potential impact of the Project on water levels and quality in the final void was assessed, using a water and salt balance model, distinct from, but consistent in methodology with the site water and salt balance described in Section 7. pH was not considered in this assessment, as potentially acid forming materials are not considered a concern in terms of water quality impacts and therefore the water in the final void is expected to remain circumneutral. Total dissolved solids (TDS) was used as an aggregate indicator of the presence of broad array of dissolved solids in final void lake.

8.1 Modelling methodology

A water and salt balance model was developed to assess the behaviour of the approved and proposed final void. The model sampled potential rainfall variability from the historical record and used the Australian Water Balance model to estimate catchment runoff, as described further in Appendix B. The model considered:

- The geometry of the approved and proposed final voids, based on the approved and proposed conceptual final landforms (refer to Figure 9-3 and Figure 9-4).
- Direct rainfall onto and evaporative losses from the final void pit lake surface, based on the same historical rainfall, sampling pattern and rainfall TDS as the GRAWBM (Section 7.2).

- Runoff from the local catchment area reporting to the final void and spoil. The catchment runoff was estimated for the rehabilitated land use from the GRAWBM (Appendix B). The catchment area of the approved and proposed final voids are compared in Table 8-1.
- Runoff TDS was estimated to commence at 2710 mg/L (80th percentile TDS for dirty water systems in the water management system water quality records) and improve to 520 mg/L (80th percentile TDS for dirty water storages with largely rehabilitated catchments in the water management system water quality records) over a 10 year rehabilitation period.
- Estimates of groundwater flows and seepages between the host rock, final void and spoil, based on the hydrogeological model described in the Groundwater Impact Assessment (AGE 2019). Groundwater TDS concentrations are assumed to be 7700 mg/L based on average historical water quality data for Permian water quality.
- Consistent with the GRAWBM, the salt balance model assumes instantaneous and complete mixing.

The model was simulated from the end of mining (2025 and 2045 for approved and proposed conditions respectively) with the water volume in the void and spoil initially empty, reflecting dewatering during operations.

The input parameters for the model are summarised in Table 8-1 and the geometry of the final voids are compared in terms of stage storage curves in Figure 8-1.

Table 8-1 Final void input parameters

Aspect	Approved conditions	Proposed conditions
Final void catchment (ha)	339	321
Final landform spoil catchment (ha)	181	258
Initial catchment runoff salinity (mg/L)	2710	2710
Long term catchment runoff salinity (mg/L)	520	520
Groundwater salinity (mg/L)	7700	7700
Year of completion of mining	2025	2045
Groundwater flows	Varies over time, refer to Figure 8-2 (AGE 2019)	

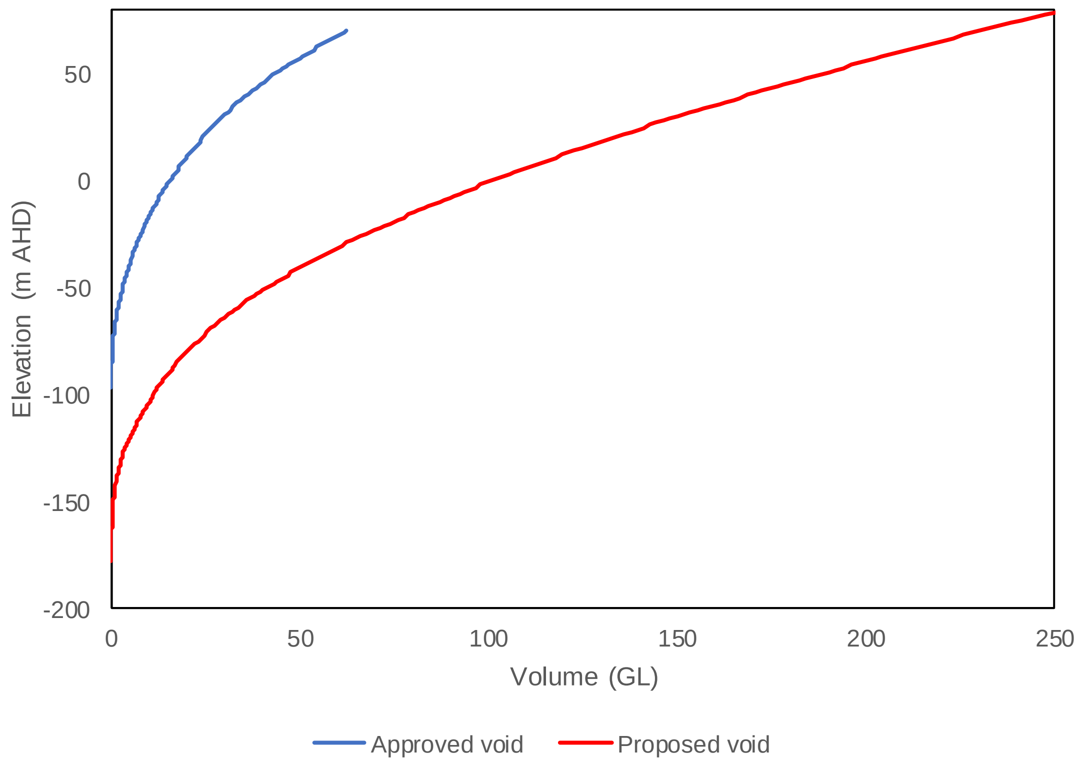


Figure 8-1 Geometry of approved and proposed final void

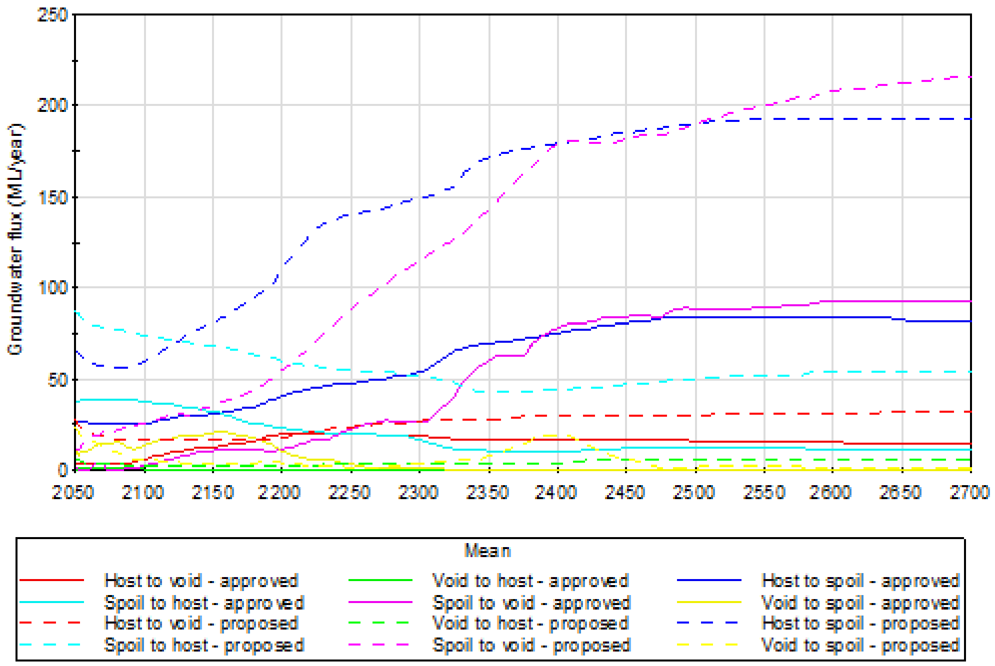


Figure 8-2 Modelled groundwater flows (AGE 2019)

8.2 Modelling results

Based on the modelling results, the forecast water level and TDS in the final void from the completion of mining until the time of equilibrium water level (defined as when the average rate of increase was simulated to be less than 50 mm/year) for the approved and proposed final void are compared in Figure 8-3, with the key results summarised in Table 8-2.

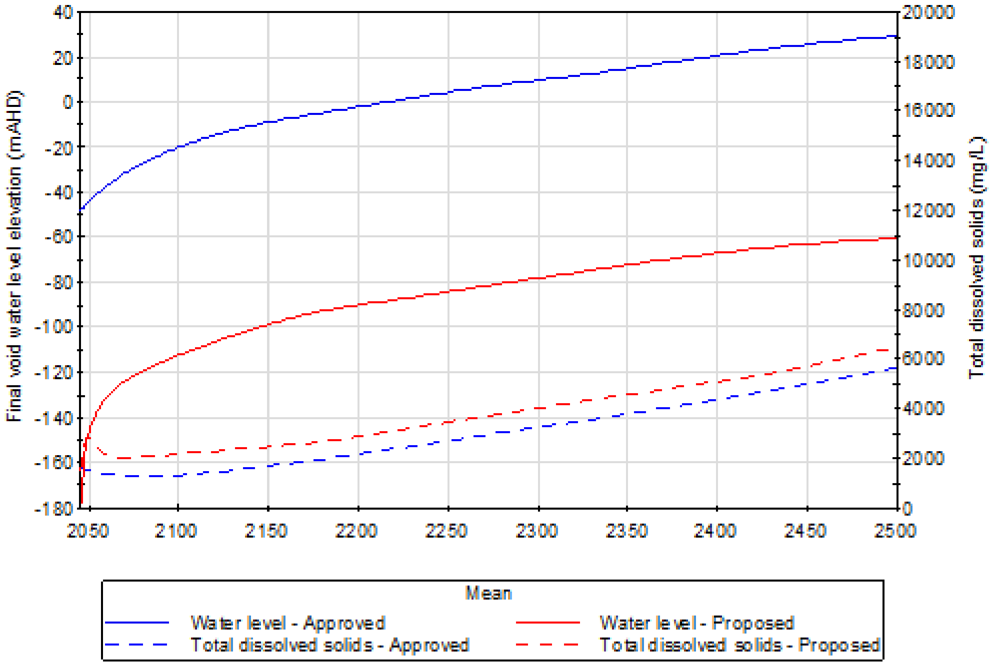


Figure 8-3 Forecast water level and TDS in approved and proposed final void

Table 8-2 Summary of final void modelling results

Aspect	Approved conditions	Proposed conditions
Equilibrium water level (m AHD)	29	-60
Freeboard at equilibrium water level (m)	41	140
Time to reach equilibrium water level (years)	450	450
TDS of water in final void at equilibrium water level (mg/L)	5700	6500

Table 8-2 shows that the proposed final void is expected to reach equilibrium water level in a similar time frame to the approved final void, reflecting the similar catchment areas and regional hydrogeology. The equilibrium water level of the proposed final void is lower in absolute terms, reflecting the difference in geometry (refer to Figure 8-1), which is also reflected in the greater freeboard for the proposed final void compared to the approved final void.

Given the significant freeboard in the proposed final void, there is no risk of discharge of water from the pit lake to the downstream environment (refer to Section 10.7). Salinity in the pit lake also remains below groundwater salinity levels during the period modelled.

The forecast TDS at the equilibrium water level for the proposed final void is higher than the approved final void. The difference is considered slight, compared to the inherent uncertainty in long term modelling, and within the range of year to year variation forecast by the modelling. Therefore, the TDS of the water in the approved and proposed final voids is considered similar and no measurable change to the potential beneficial uses are expected as a result of the Project. The expected water quality would not impair potential beneficial uses into the foreseeable future, including recreation and energy generation, however, like the regional groundwater (which has a higher salinity to that expected in the final void, refer to Table 8-1) treatment to reduce salinity would be required for irrigation and stock water purposes.

The time to reach equilibrium and forecast TDS at the equilibrium water level for the approved and proposed final voids are comparable to or less than most similar open cut coal mining projects recently approved in the upper Hunter Valley (refer to Table 8-3).

Table 8-3 TDS of water in final void at equilibrium water level for comparable mining projects

Project	Time to reach equilibrium	TDS of water in final void at equilibrium water level (mg/L)
Mount Owen Continued Operations (Engeny 2018)	400 years	5200 mg/L
Bengalla Mine Continuation (WRM 2013)	1000 years	20,000 µS/cm (~13,000 mg/L) [A]
United Wambo Open Cut Coal Mine Project – United Void (HEC 2017)	350 years	10 000 mg/L
Warkworth Continuation (WRM 2014)	1000 years	30,000 µS/cm (~20,000 mg/L) [A]

[A] assuming 1 µS/cm = 0.67 mg/L

9. Catchments and low flow regimes

Mining operations have the potential to impact on flow regimes in watercourses due to changes to surface water runoff and baseflow contributions.

The Project will change the catchments of Bowmans Creek, Yorks Creek, Swamp Creek and Bettys Creek, and also realign the lower reach of Yorks Creek to a new confluence with Bowmans Creek. Groundwater modelling reported in the Groundwater Impact Assessment (AGE 2019) also predicts changes to baseflow in Bowmans Creek, Glennies Creek and the Hunter River associated with a delay in the recovery of the groundwater system, however the incremental changes to baseflow for Yorks Creek, Swamp Creek and Bettys Creek were predicted to be negligible and overall baseflow is predicted to increase following the cessation of mining as regional groundwater systems recover.

The potential impacts on flow regimes in Yorks Creek, Swamp Creek, Bettys Creek and Bowmans Creek have been assessed using a catchment scale water balance model. The model sampled potential rainfall variability from the historical record and used the Australian Water Balance model to estimate catchment runoff, as described further in Appendix B. This model included the catchments of Bowmans Creek, Yorks Creek, Swamp Creek and Bettys Creek. Four scenarios were considered:

- Existing conditions, based on the existing water management system.
- Proposed conditions (Year 13), based on the Year 13 conceptual water management system (refer to Section 6.2.3). This snapshot was selected as it has the maximum potential impact on surface runoff catchment areas during operations.
- Approved conceptual final landform: based on the final landform approved under the Mount Owen consent and the Glendell consent, assuming that all catchments have been rehabilitated and a free draining landform (apart from the final voids) has been achieved.
- Proposed conceptual final landform: based on the final landform conceptual water management system, assuming that all catchments have been rehabilitated and a free draining landform (apart from the final voids) has been achieved. This scenario included the retention basin formed by WRD in the final landform.

The model used the Australian Water Balance Model (AWBM), with parameterisation of undisturbed catchment consistent with the GRAWBM, except for a site specific calibration for Bowmans Creek, based on gauge 210130 (refer to Section 9.5).

9.1 Catchment areas

The catchment areas of the creeks for each scenario are summarised in Table 9-1. The existing and proposed (Year 13) catchments exclude areas within the proposed dirty and mine water management systems at the Mount Owen Complex. This is conservative for low flows, as it assumes all runoff from the mine is intercepted and managed as part of the water management system. The catchment of Bowmans Creek has been subdivided into Upper Bowmans Creek (upstream of the potential impacts of the Project), its tributaries of Yorks Creek, Swamp Creek and Bettys Creek and Lower Bowmans Creek down to the Bowmans Creek gauge (210130). The Lower Bowmans Creek was further subdivided into five subcatchments. The catchments for the existing, proposed (Year 13) approved conceptual final landform and proposed conceptual final landform are shown in Figure 9-1, Figure 9-2, Figure 9-3 and Figure 9-4.

Table 9-1 Impact to catchment areas

Catchment	Pre-mining (ha) (Engeny 2018)	Existing conditions (ha)	Proposed conditions (Year 13) (ha)	Approved conceptual final landform (ha)	Proposed conceptual final landform (ha)
Upper Bowmans Creek	19,635	15,495	15,495	15,495	15,495
Lower Bowmans Creek (1-5)		3458	3428	4564	4586
Yorks Creek (existing)	1230	1656	14	1884	184
Yorks Creek (proposed realignment)		NA	1400	NA	1505
Swamp Creek	2380	267	50	1237	348
Bettys Creek	1810	530	679	865	1946
Total	25,055	21,406	21,067	24,046	24,064

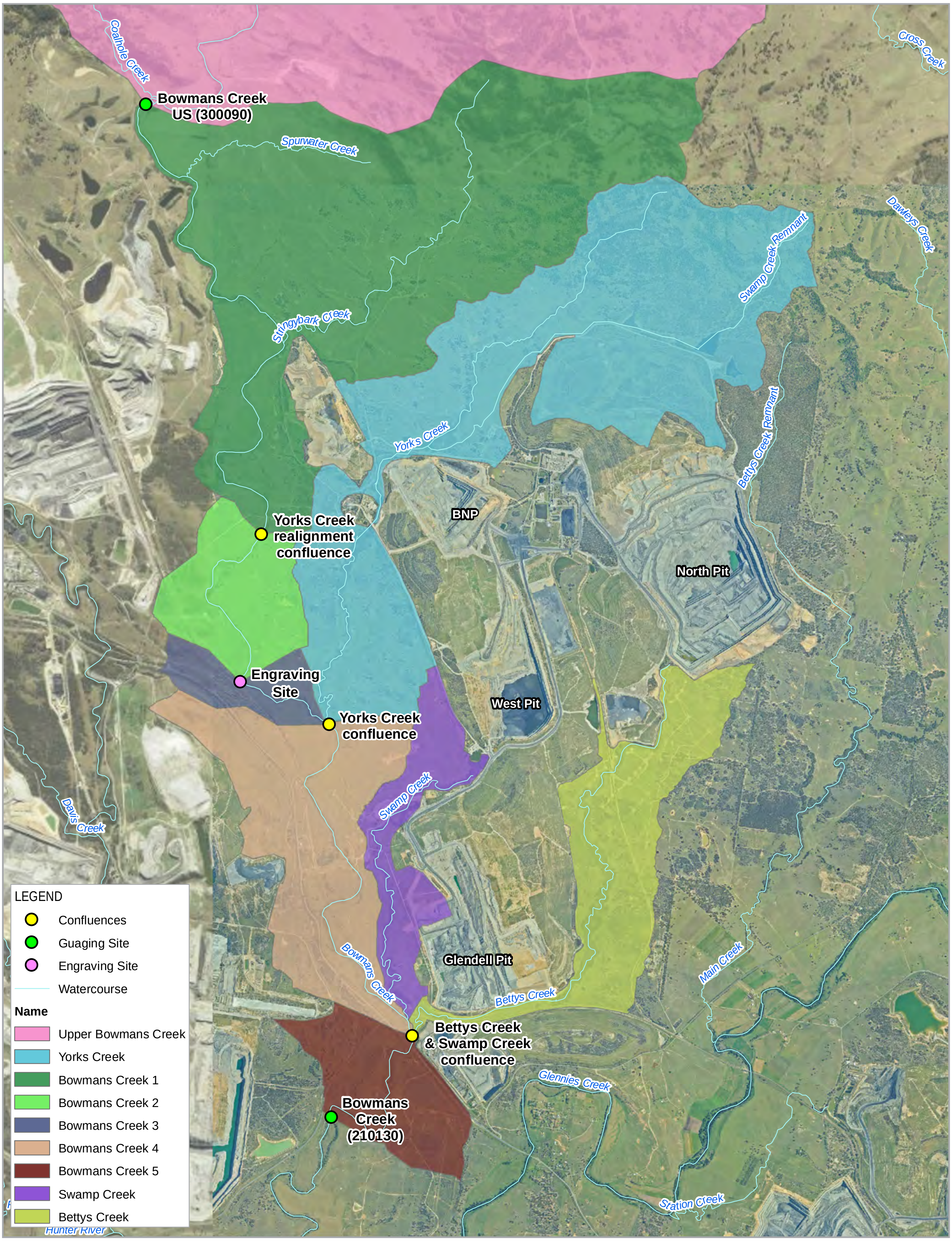
Table 9-1 shows that the Lower Bowmans Creek catchment is proposed to temporarily reduce during the operation of the Project before increasing as the rehabilitated catchment at the Mount Owen Complex and neighbouring operations is returned. The predicted cumulative decrease in catchment in proposed conditions (Year 13) (approximately 339 ha) is smaller than the additional disturbance area associated with the Project in Year 13 due to the increased clean catchment from rehabilitated areas at the Mount Owen Complex and neighbouring operations during this period. This temporary reduction due to the Project is small (less than two per cent) compared to the total catchment of Bowmans Creek. Overall, the total catchment of Bowmans Creek will increase in both the approved and proposed conceptual final landform compared to existing conditions, with a slight difference reflecting the catchment areas of the approved and proposed final voids.

The realignment of Yorks Creek is expected to reduce the catchment of the remnant lower reach of Yorks Creek reporting to its current outlet to Bowmans Creek. This is offset in terms of streamflow contribution to Bowmans Creek, by the 1400 hectares of the Yorks Creek catchment (approximately 85% of the existing catchment) being diverted to the Bowmans Creek upstream of the current confluence point. In the proposed conceptual final landform, some catchment will be restored to the existing Yorks Creek, but most will continue to be diverted via the Yorks Creek Realignment.

The existing catchment of Swamp Creek is expected to temporarily reduce during the operation of the Project, as part of the remnant reach is mined through, before returning to a similar catchment area in the proposed conceptual final landform. The proposed final catchment of Swamp Creek is substantially less than in the approved conceptual final landform, as most of the rehabilitated former Swamp Creek catchment is proposed to be diverted to Bettys Creek.

The catchment area of Bettys Creek is expected to increase as rehabilitated areas are returned during the operation of the Project, with the catchment proposed to be substantially increased in the proposed conceptual final landform due to the diversion of part of the former Swamp Creek catchment to Bettys Creek via WRD. This increase is comparable to the reduction in the catchment area of Bettys Creek due to the existing Upper Bettys Creek Diversion with the overall catchment of Bettys Creek in the conceptual final landform remaining smaller than the pre-mining Bettys Creek catchment. This increase is greater than the apparent decrease in the catchment of Swamp Creek, due to the change in the location of the final void and change in the landform of the east of the Glendell Pit Extension.

The apparent reduction in the total catchment area in the proposed final landform in Table 9-1 compared to the pre-mining catchment is due to increases in the catchment of Glennies Creek and Main Creek, as approved under the Mount Owen Consent, but not affected by the Project.



Paper Size ISO A4
0 0.45 0.9 1.35 1.8
Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

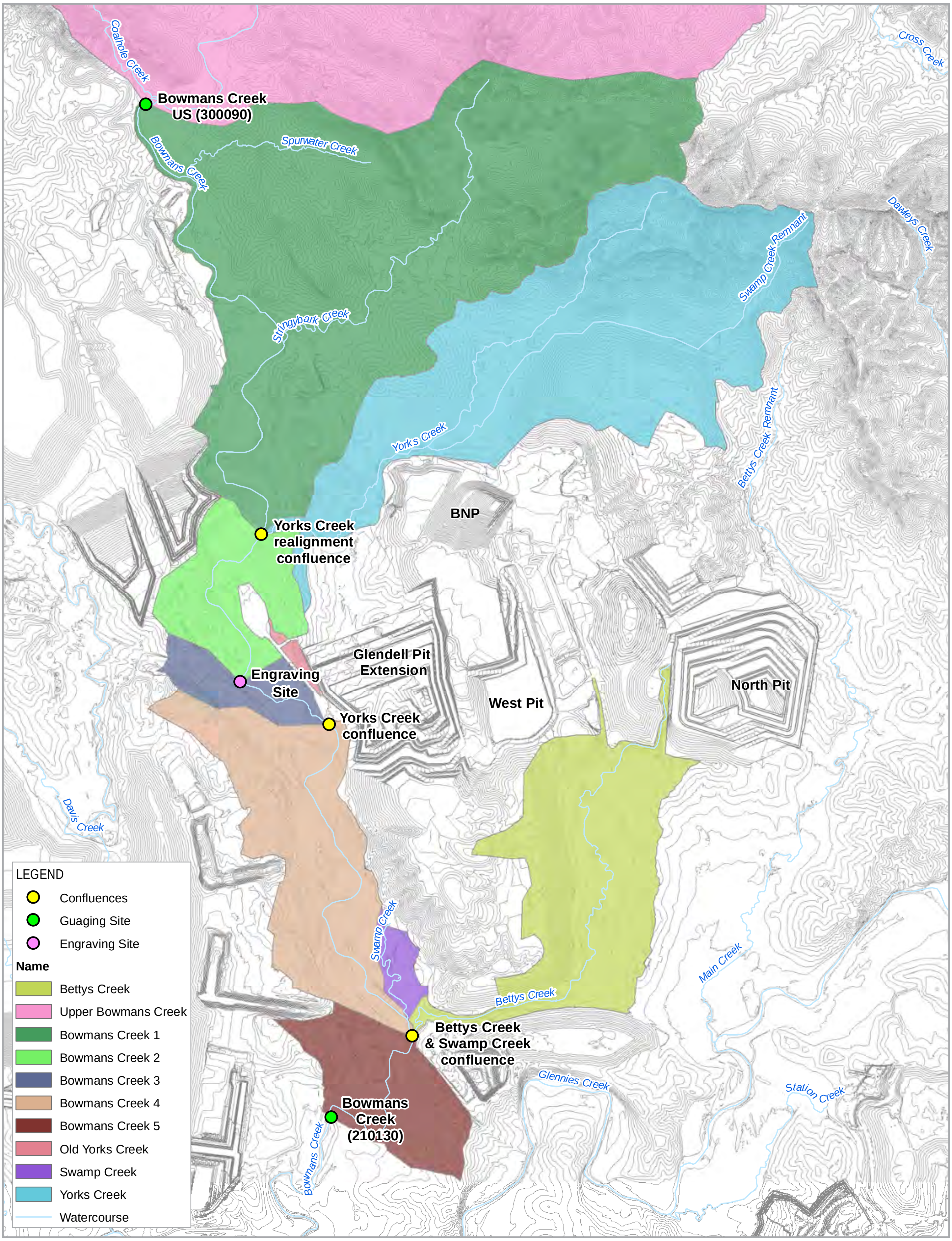
N

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Low flow catchments
Existing conditions

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 9-1



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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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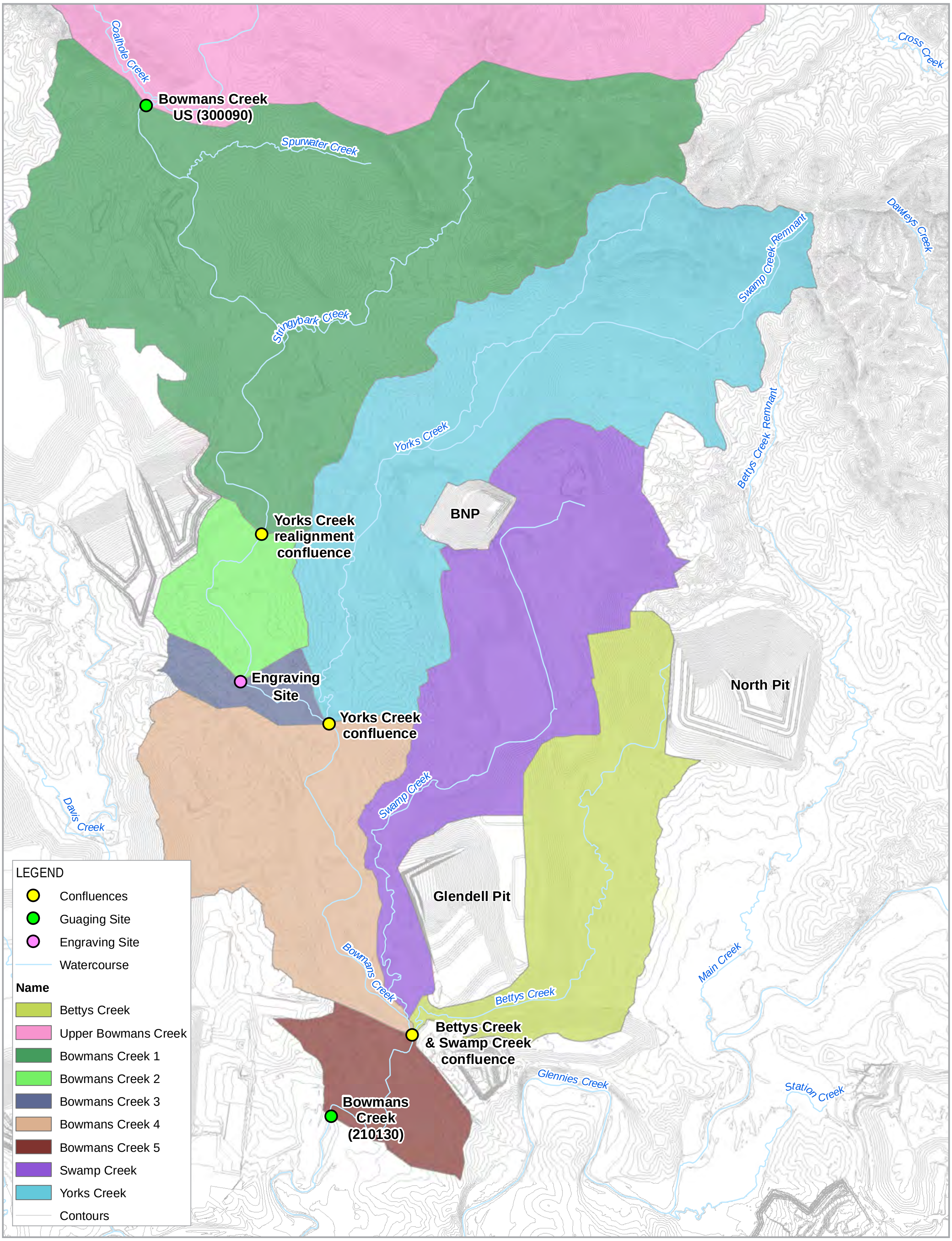
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Low flow catchments
Proposed conditions (Year 13)

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 9-2

Data source: LPI: DTDB, 2017 . Created by: ttinkler



Paper Size ISO A4

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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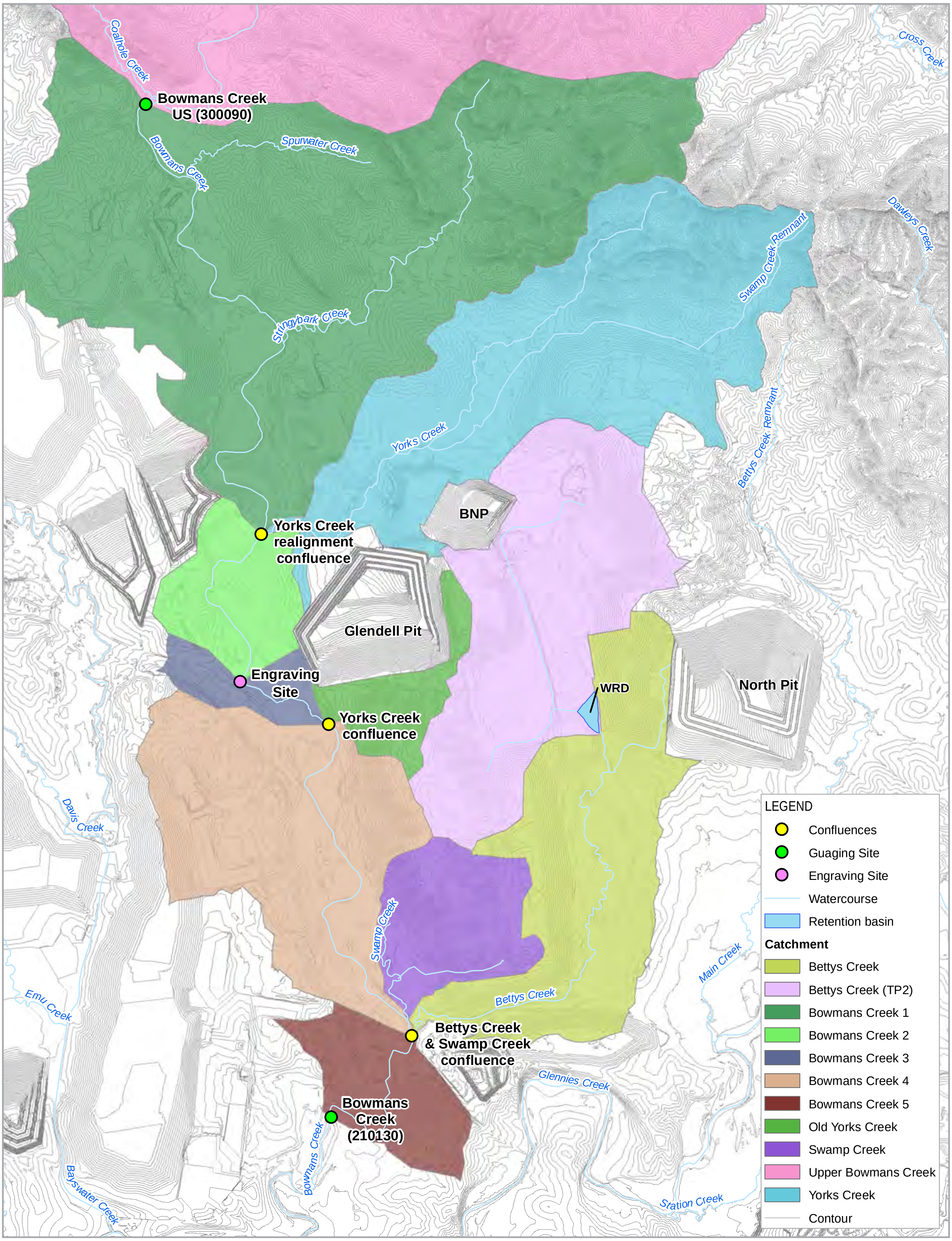
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Low flow catchments
Approved conceptual final landform

Project No.	22-19708
Revision No.	1
Date	19 Nov 2019

FIGURE 9-3

Data source: . Created by: ttinkler



Paper Size ISO A4

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Low flow catchments
Proposed conceptual final landform

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 9-4

Data source: . Created by: ttinkler

9.2 Yorks Creek

The modelled daily average streamflow in Yorks Creek is compared in Figure 9-5. The streamflow presented is expected to be indicative of the total streamflow, a portion of which may report as subsurface flow and therefore surface flow is unlikely to be observable at all times.

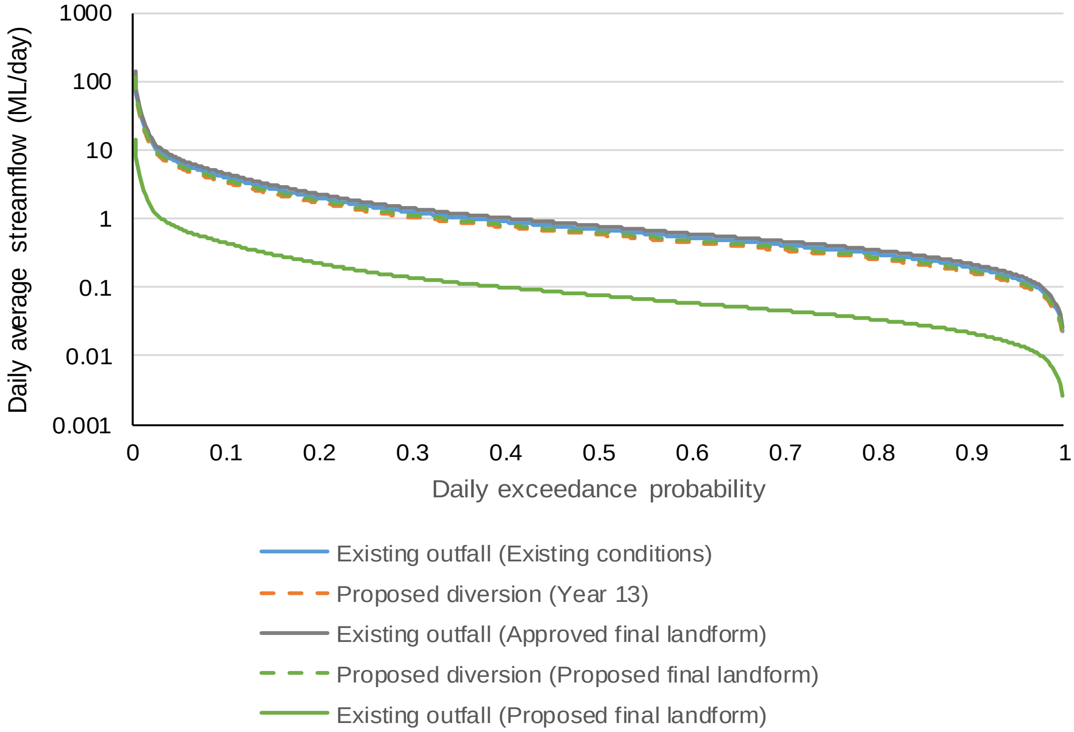


Figure 9-5 Potential impact on Yorks Creek flow regime

Figure 9-5 shows that the streamflow in the existing Yorks Creek is expected to reduce due to the Project, in proportion to the reduction in catchment area associated with the realignment. The design of the Yorks Creek Realignment considers the expected range of flows and includes design elements to provide aquatic and riparian habitat (refer to Section 6.2.1).

In the conceptual final landform, some flow will be returned to Bowmans Creek at the location of the existing outlet of Yorks Creek, however the flows entering Bowmans Creek at this location are expected to be significantly less than under existing conditions. The Yorks Creek Realignment is expected to provide similar streamflow input into Bowmans Creek as compared to the existing Yorks Creek, although at a location further upstream.

9.3 Swamp Creek

The modelled daily average streamflow in Swamp Creek is compared in Figure 9-6. The streamflow presented is expected to be indicative of the total streamflow, a portion of which may report as subsurface flow and therefore surface flow is unlikely to be observable at all times.

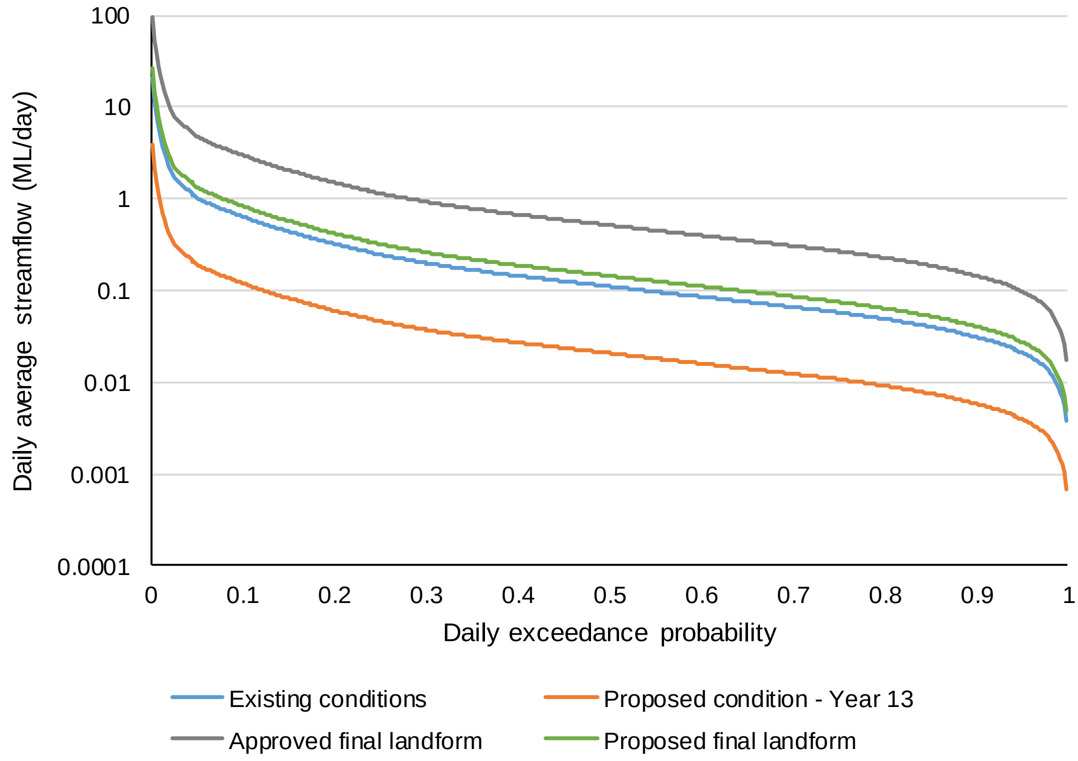


Figure 9-6 Potential impact on Swamp Creek flow regime

Figure 9-6 shows that the streamflow in Swamp Creek is expected to temporarily reduce during the operation of the Project, due to mining through most of the remaining catchment and the creek itself, before increasing and remaining above the streamflow under existing conditions in the approved and proposed conceptual final landform. Under the approved conceptual final landform, much of the rehabilitated Swamp Creek catchment will be restored, however under the proposed conceptual final landform much of the rehabilitated catchment is proposed to be diverted to Bettys Creek.

The upper and middle reaches of Swamp Creek have been diverted and disturbed by what is now the Mount Owen Complex since mining operations began in the 1960s. The continuation of this diversion in the proposed conceptual final landform is therefore not expected to have a significant impact on the remnant lower reaches of Swamp Creek.

9.4 Bettys Creek

The modelled daily average streamflow in Bettys Creek is compared in Figure 9-7. The streamflow presented is expected to be indicative of the total streamflow, a portion of which may report as subsurface flow and therefore surface flow is unlikely to be observable at all times.

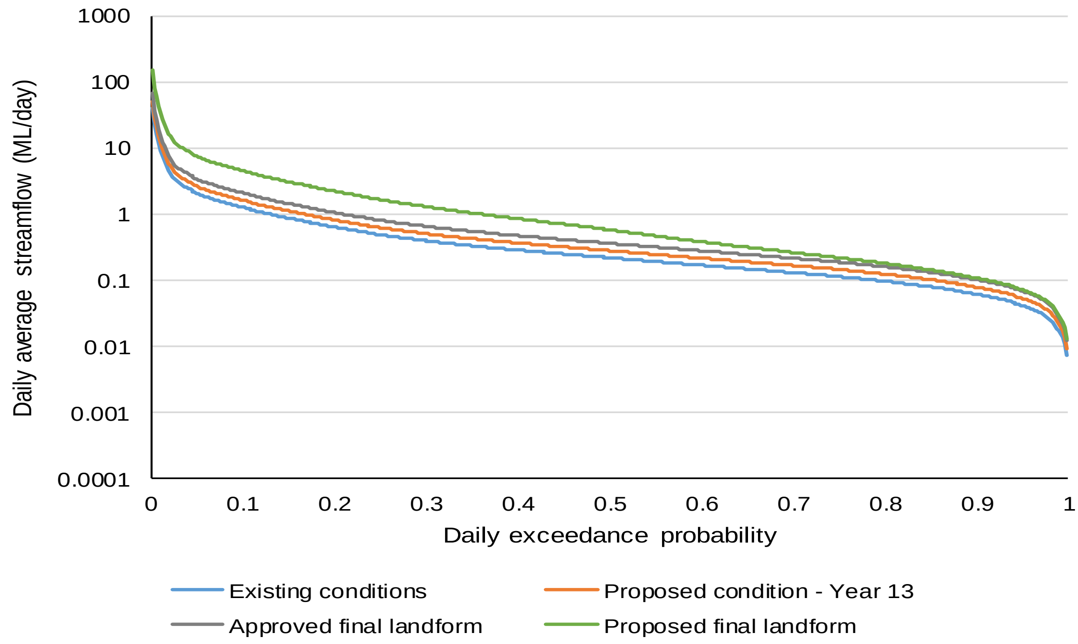


Figure 9-7 Potential impact on Bettys Creek flow regime

Figure 9-7 shows that under approved conditions, the streamflow in Bettys Creek is expected to increase in proportion to the return of rehabilitated catchment from the approved mining areas. Under the proposed conceptual final landform, the increase in streamflow is expected to greater, as much of the rehabilitated mine site catchment is proposed to be diverted from Swamp Creek to Bettys Creek. The modelled increase to low flows is less than the modelled increase in high flows for the proposed conceptual final landform case, due to the attenuation effects of WRD.

9.5 Bowmans Creek

The streamflow in Bowmans Creek has the potential to be affected by both the change in catchment areas and the change in baseflow as a result of the Project. Table 9-1 shows that the peak reduction in the total catchment area of Bowmans Creek under proposed conditions (Year 13) is 339 ha, less than 2% of the total catchment area. This change in catchment area is not expected to result in a measurable reduction in streamflow due to catchment changes in Bowmans Creek at different locations. Similarly, the proposed change to the location of the Yorks Creek confluence is not expected to result in a measurable reduction in streamflow.

The Groundwater Impact Assessment (AGE 2019) predicts a reduction in baseflow in Bowmans Creek compared to existing conditions, part of which is attributable to the Project. Following the cessation of mining, baseflows are predicted to recover with baseflows modelled to recover to existing levels within 20 years of the cessation of mining. While the Project will have an ongoing negative impact on baseflows there remains an overall recovery in groundwater systems such that baseflow is expected to recover to a level higher than existing conditions within 20 years of the cessation of mining and will continue to increase post mining as the regional groundwater system recovers.

These predicted changes in baseflow over the life of the Project are based on a model run applying average annual rainfall over the predictive phase of the model. This approach enable an accurate assessment of the predicted changes in baseflow related to groundwater flux in the alluvial system but does not take into account the natural variability in baseflow which is heavily influenced by high rainfall and high flow events which provide increased recharge to the Bowmans Creek alluvial system. For example, the groundwater model during the calibration phase of modelling incorporates actual rainfall data into the modelling. Based on a review of modelled baseflows during the calibration period, the modelled cumulative changes in groundwater levels associated with mining is less than 10% of the natural variability in baseflows modelled when climatic variability is considered. These natural fluctuations also show increases of up to 0.4 ML/day and a subsequent decline of 0.4 ML/day modelled over the 12 month period in 2013. The modelled changes over the life of the Project are therefore considered to be unlikely to be discernible from the natural variability in the system. Notwithstanding, in periods of very low rainfall or low stream flow, these small changes may have an impact on persistent pools.

In order to investigate the potential impacts of the Project, a conceptual stream flow model was developed to account for streamflow in Bowmans Creek. The conceptual model is presented in Figure 9-8.

Streamflow from runoff from the upper reaches of Bowmans Creek was conceptualised as consisting of surface and subsurface components. In the lower reaches of Bowmans Creek, baseflow from the underlying Permian strata and local runoff contribute to streamflow. Both flow components flow through the persistent pools, that are also subject to direct rainfall and evaporation (consistent with the site water balance model, refer to Section 7.1). The surface component is conceptualised as being measured at the Bowmans Creek gauge (210130).

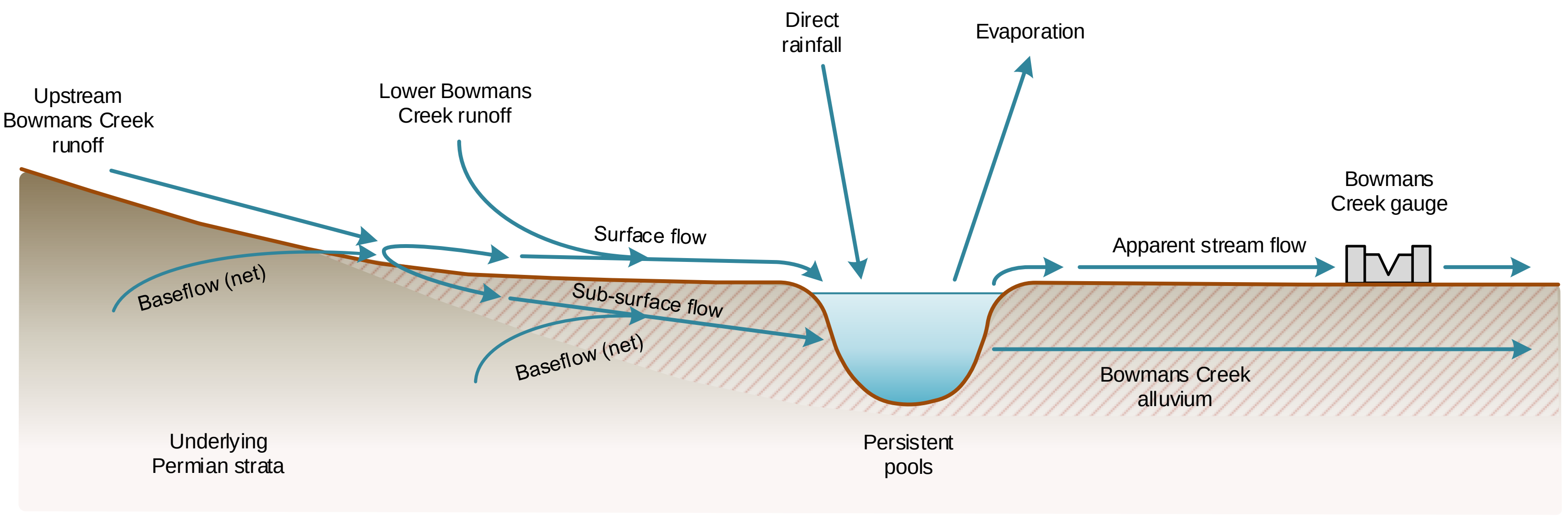
The small predicted baseflow reduction during operations is expected to accumulate along the lower reaches of Bowmans Creek adjacent to the approved Glendell Pit and Glendell Pit Extension but has been conservatively applied at all locations potentially affected by the Project. Therefore, the potential streamflow impacts discussed in this section are considered to apply to all locations in Bowmans Creek potentially affected by the Project.

The catchment scale water balance model used to estimate the streamflow in Bowmans Creek was calibrated to the observed surface flow at the Bowmans Creek gauge (210130). A calibration to the Bowmans Creek US gauge (3000090) was not considered viable with the short duration of observations available (less than 3 years). The calibration accounted for the inferred subsurface flows in the lower part of Bowmans Creek.

An adequate fit to the entire stream flow record was not able to be achieved. This is likely due to the limitations of the industry standard approach using a spatially lumped hydrology model, which cannot account for:

- The spatial variability of rainfall.
- Storage effects in farms dams and watercourses in the upper catchment and pools in the lower reaches of Bowmans Creek.
- Storage effects in the alluvium in the lower parts of Bowmans Creek.
- Actual changes in regional groundwater levels, rather than the simplistic subsurface partitioning approach.

Despite these limitations, a parameter set was found that provided a reasonable match for the lower 10% of the flow duration curve, which are considered most relevant for assessment of potential baseflow reductions. Figure 9-9 shows the fit of the flow duration curve and best fitting parameter sets are summarised in Table 9-2.



Legend

Water flow

Umwelt (Australia) Pty Ltd
Glendell Continued Operations
Surface Water Impact Assessment

Conceptual streamflow model for lower Bowmans Creek

Project No. **22-19708**
Revision No. **0**
Date **10/10/2019**

FIGURE 9-8

Created by: Tyler Tinkler

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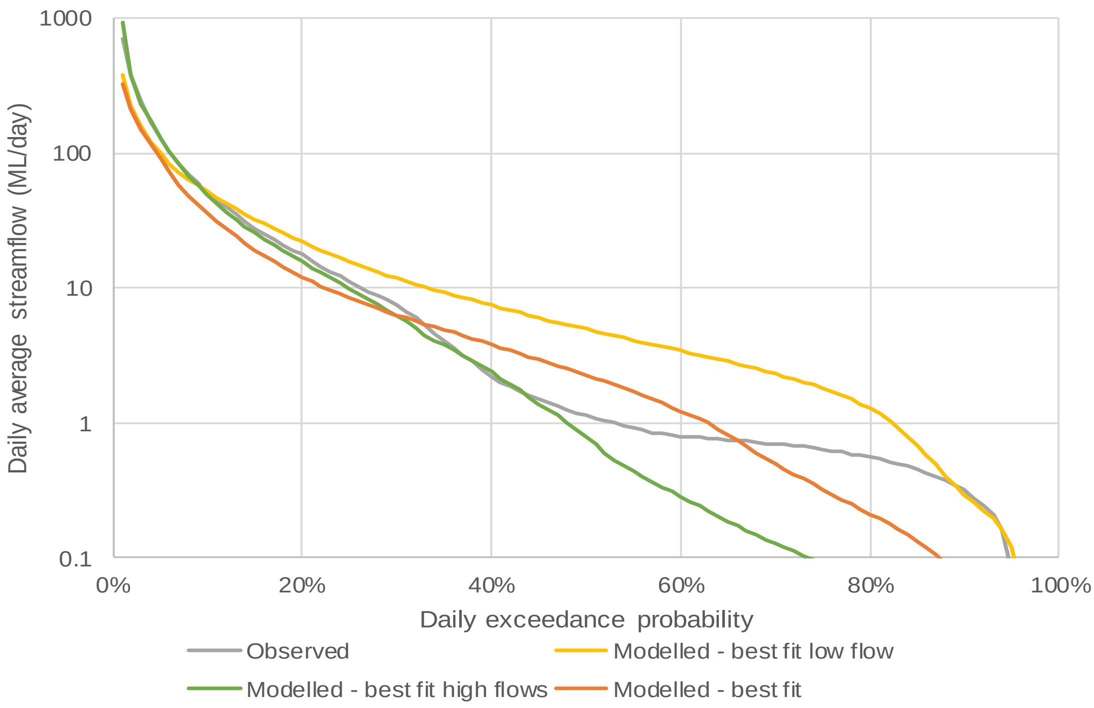


Figure 9-9 Calibration results for Bowmans Creek gauge (210130)

Table 9-2 Best fitting parameter sets

Parameter	Low flows	High flows	All flows
C_{ave}	105	125	119
BFI	0.36	0.16	0.30
Kb	0.99	0.96	0.98
Cf_2	0.53	0.26	0.55
A_2	0.19	0.74	0.58

The calibrated model was used to simulate the streamflow in the lower reaches of Bowmans Creek, using the baseflow predicted by the hydrogeological modelling used for the Groundwater Impact Assessment (AGE 2019), as summarised in Table 9-3.

Table 9-3 Modelled baseflow in Bowmans Creek (AGE 2019)

Scenario	Baseflow (ML/day)
Existing	0.27
Proposed conditions (Year 13)	0.23
Approved conceptual final landform	0.53
Proposed conceptual final landform	0.45

The baseflows presented in Table 9-3 are total baseflows for the purpose of this low flow regime assessment and do not directly correspond to the potential impacts presented in the Groundwater Impact Assessment (AGE 2019) or the surface water licensing assessment presented in Section 12.4.

The simulated daily average streamflow in the lower part of Bowmans Creek is compared in Figure 9-10.

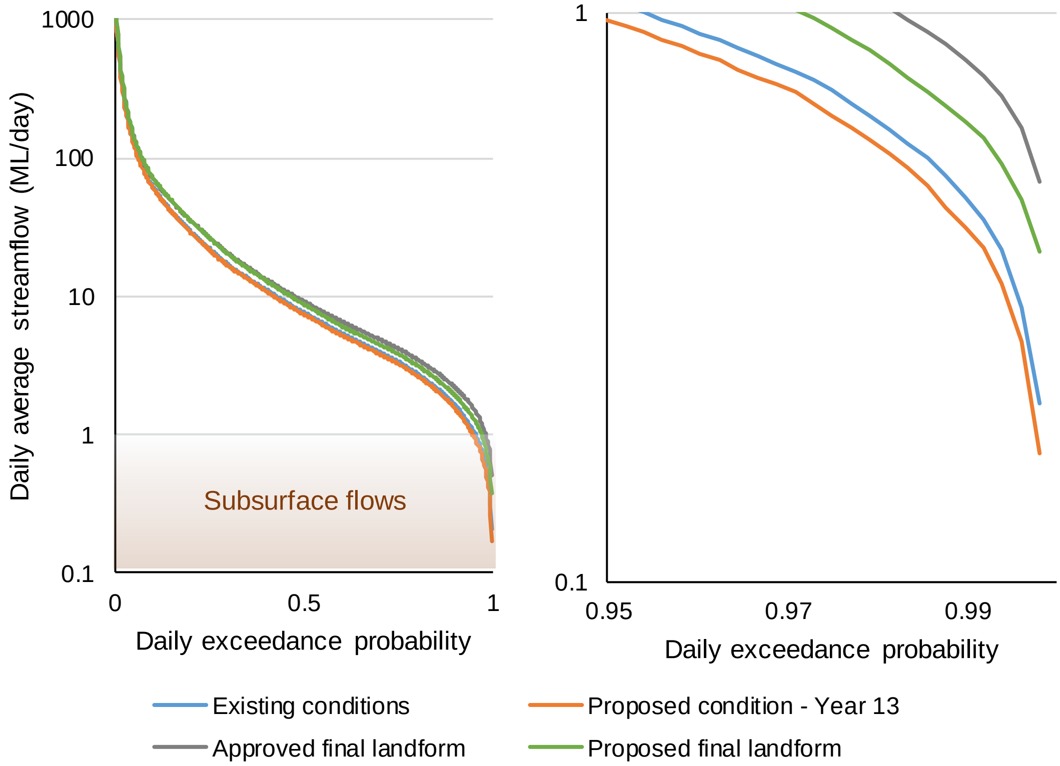


Figure 9-10 Potential impact on Bowmans Creek flow regime

Figure 9-10 shows that for high flows, the results for existing conditions and proposed conditions (Year 13) are very similar, as are the results for the approved and proposed conceptual final landform. This reflects that the proposed changes to catchments are minor, relative to the total catchment of Bowmans Creek.

For low flows, Figure 9-10, shows that the results for existing conditions and proposed conditions (Year 13) are very similar. Taking the subsurface flow threshold of 1.0 ML/day during operations, Figure 9-10 indicates that the baseflow reduction may reduce the number of days with no surface flow in Bowmans Creek by about 0.5%, or 2 days per year on average. Similarly, for the conceptual final landform, Figure 9-10 indicates that the baseflow reduction may reduce the number of days with no surface flow in Bowmans Creek by about 1%, or 3 days per year on average, however the number of no surface flow days for the both the approved and proposed conceptual final landform are lower than the existing conditions.

A feature of Bowmans Creek, particularly during period of low flows, are persistent pools throughout its lower reaches. The streamflow model was used to model a characteristic “unit” pool, with depth 600 mm, and considering direct rainfall and potential evaporation from the open water surface (refer to Figure 9-8). The modelled depth duration curves are compared in Figure 9-11.

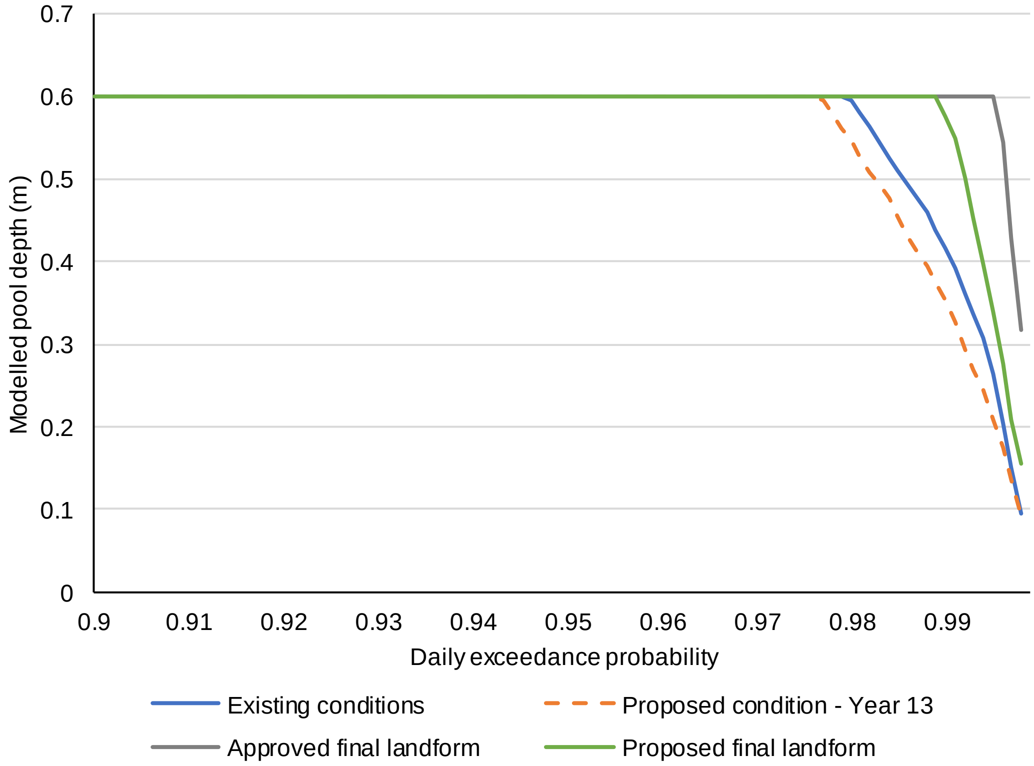


Figure 9-11 Potential impact on Bowmans Creek pools

Figure 9-11 shows the potential impacts to water levels in persistent pools is expected to be consistent with potential impacts to low flows, with a reduction in the average number of days per year when persistent pools levels may be lower than typical estimated to increase by 0.4% (1 day per year) for proposed conditions (Year 13) compared to existing conditions and by about 0.6% (2 days per year) for the proposed conceptual final landform compared to the approved conceptual final landform. The modelling results did not forecast a complete drying of the characteristic unit pool, and pool levels are expected to be higher than existing conditions in both the approved and proposed conceptual final landform.

Overall, no measurable impact on the persistent pools in the lower part of Bowmans Creek is expected as a result of the Project.

9.6 Glennies Creek

The Groundwater Impact Assessment (AGE 2019) predicts a peak baseflow reduction of 0.041 ML/day in Glennies Creek as a result of the Project. No changes to the Glennies Creek catchment are proposed as part of the Project. The flow duration curve from the observed flow at gauge 210044 from 27 January 1956 to 12 March 2019 is shown in Figure 9-12. As a simple and conservative estimate of potential impacts, the peak baseflow reduction was deducted from the observed flow duration curve and compared in Figure 9-12.

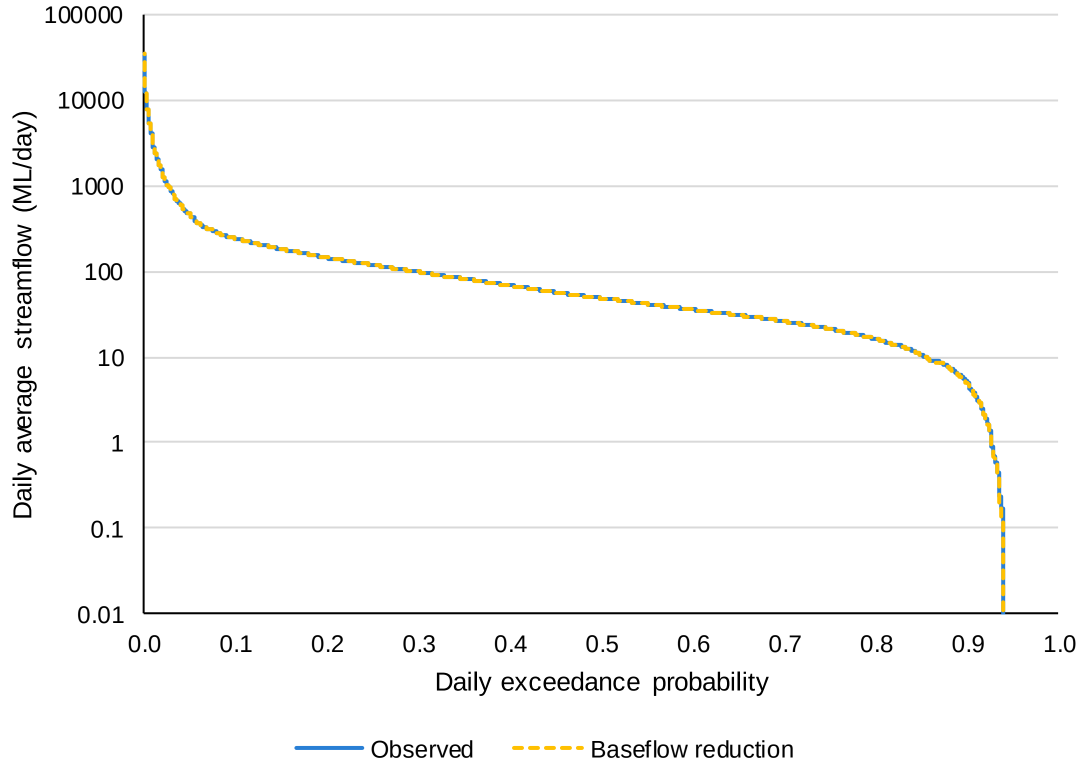


Figure 9-12 Potential impact on Glennies Creek flow regime

Figure 9-12 shows that the flow duration curves are essentially identical and that there is no measurable change to the flow regime expected in Glennies Creek as a result of the Project. Glennies Creek is a regulated system and the licensing requirements of the Project are discussed in Section 12.4.

9.7 Hunter River

The Groundwater Impact Assessment (AGE 2019) predicts a cumulative peak baseflow reduction of 0.175 ML/day in the tributaries of the Hunter River as a result of the Project. The changes to mine site catchments are negligible compared to the catchment of the Hunter River (in the order of one part in a million). The flow duration curve from the observed flow at gauge 210128 from 27 July 1993 to 12 March 2019 is shown in Figure 9-13. As a simple and conservative estimate of potential impacts, the peak baseflow reduction was deducted from the observed flow duration curve and compared in Figure 9-13.

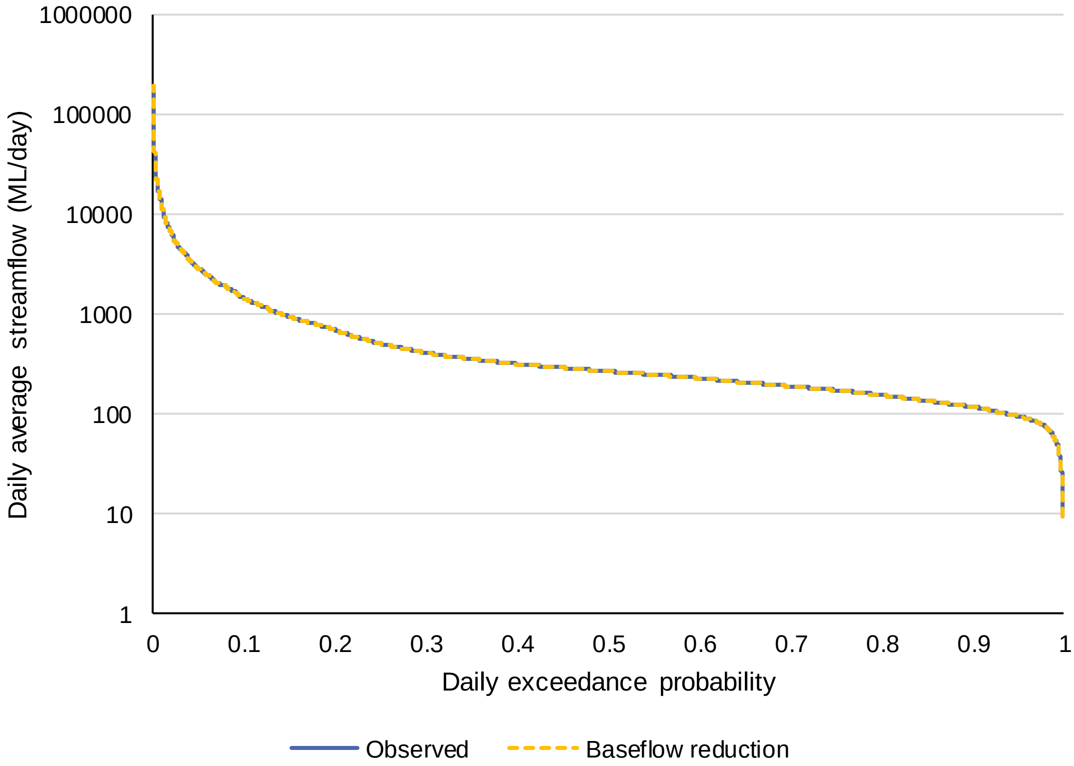


Figure 9-13 Potential impact on Hunter River flow regime

Figure 9-13 shows that the flow duration curves are essentially identical and therefore there is no measurable change to the flow regime in the Hunter River expected as a result of the Project. The Hunter River is a regulated system and the licensing requirements of the Project are discussed in Section 12.4.

10. Flood assessment

The Project has the potential to impact flood levels and velocities in watercourses surrounding the Mount Owen Complex. The potential impacts were assessed using a hydrological and hydraulic model of Bowmans Creek and its tributaries, allowing the comparison of flooding behaviours for the proposed operations and conceptual final landform to existing conditions. The impacts assessed are therefore cumulative, with the dominant driver of change in many locations the change to landform over time associated with other approved neighbouring operations. The modelling results have been interpreted to identify the impacts that are likely to be attributable to the Project.

10.1 Modelling methodology

The potential flood impacts of the Project on the lower reaches of Bowmans Creek were assessed using a combination of:

- A lumped hydrology model, implemented in XP-RAFTS, to estimate the inflow hydrographs from upper Bowmans Creek, upper Yorks Creek and catchments surrounding lower Bowmans Creek.
- A two dimensional hydraulic model, implemented in TUFLOW, to estimate the flood depths, velocities and shear stresses in the Yorks Creek Realignment, Swamp Creek, Bettys Creek and the lower reaches of Bowmans Creek.

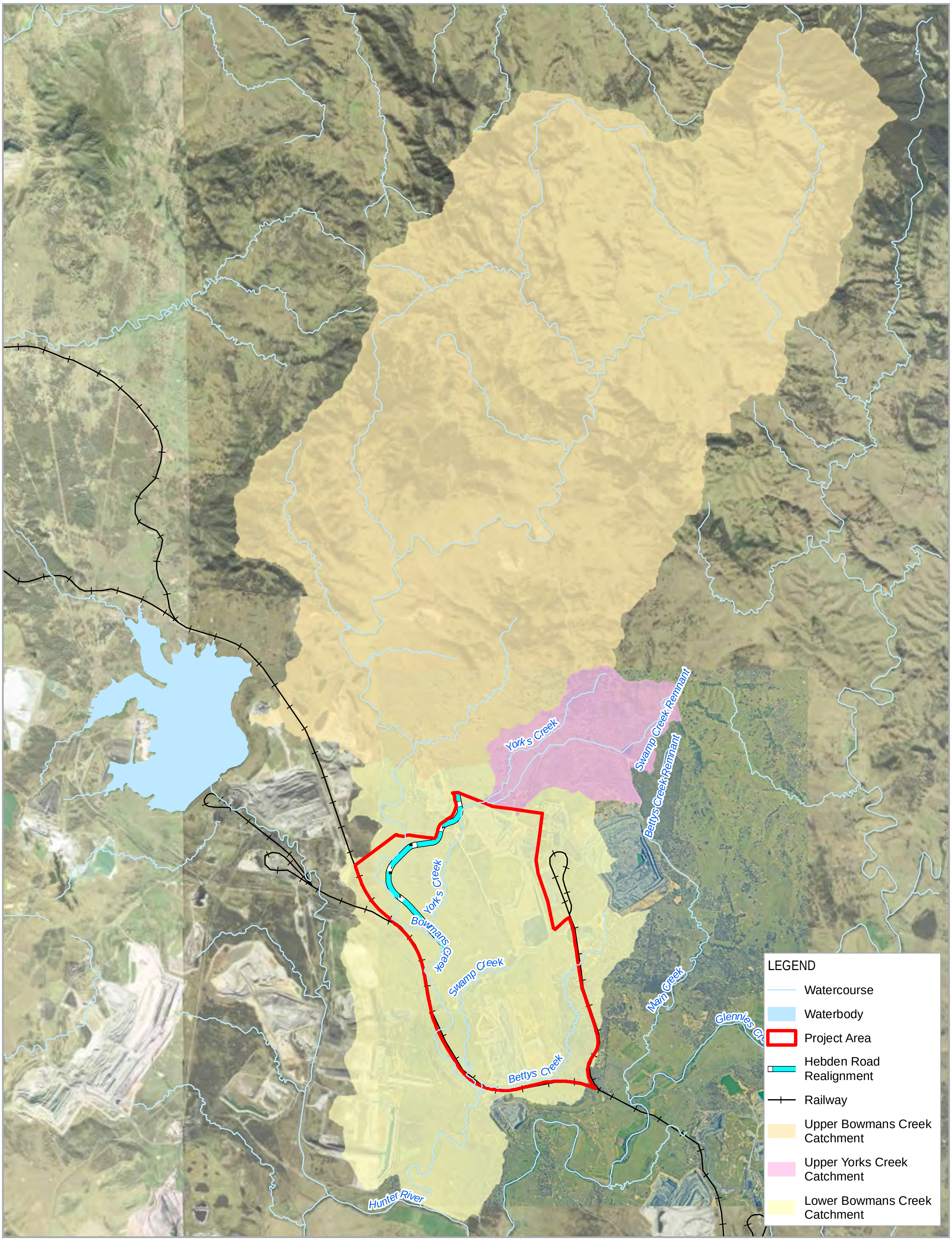
The modelling considered:

- A digital elevation model of the catchment, considering the existing surface, and the design of key Project features: Glendell Pit Extension, Yorks Creek Realignment, Hebden Road realignment, Heavy Vehicle Access Road and earthworks for the Glendell MIA.
- Design rainfall and losses for the 10%, 5%, 1%, 0.2% and 0.5% AEP design floods, as well at the probable maximum flood (PMF).
- Land use, based on aerial imagery.
- Hydraulic structures such as culverts and bridges.

Three scenarios at different stages of the mine life were modelled to assess the flooding impacts over time. These included:

- Existing conditions based on the existing landform (2019).
- Proposed conditions (Year 6). The flooding impacts for the Year 13 and Year 18 snapshots are expected to be similar.
- Conceptual final landform, based on the proposed conceptual final landform.

The flood model extent is shown in Figure 10-1 and modelling methodology is detailed in Appendix C



Paper Size ISO A4

0 0.95 1.9 2.85 3.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Flood model extent

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

FIGURE 10-1

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

10.2 Project infrastructure

The flood modelling results were used to assess the potential for overtopping of the Glendell MIA pad, the associated Heavy Vehicle Access Road and the Hebden Road realignment. The Glendell MIA and Heavy Vehicle Access Road were found to be immune from regional flooding for design floods up to and including the 1% AEP design flood. The modelling results indicate that the Hebden Road realignment is immune from regional flooding for design floods up to an including the 5% AEP design flood, which represents an improvement from the existing alignment which sees overtopping in the 10% AEP design flood. The proposed relocation of the Ravensworth Homestead is located above the extent of the probable maximum flood.

10.3 Public infrastructure

The Project has the potential to affect the New England Highway, existing Hebden Road and the Main Northern Railway. Flood modelling results indicate significant increases to velocity and water levels for the 10% and 5% AEP design flood adjacent to the Main Northern Railway as a result of the Project, however there is no significant change to the velocities for the assumed design criteria of the Main Northern Railway of the 1% AEP design flood and therefore no adverse impacts on the Main Northern Railway are expected.

10.4 Engraving site

The shift of the confluence point of Yorks Creek and Bowmans Creek upstream as part of the Yorks Creek Realignment will increase flows in Bowmans Creek at the AHIMS recorded Aboriginal site Bowmans Creek 16, 37-3-0722, relative to existing and existing approved conditions. This site is an engraving on a rock face which outcrops on the southern bank near a sharp bend on Bowmans Creek (adjacent to the Main Northern Railway).

The results of the flood modelling were used to assess whether flows associated with the relocation of the Yorks Creek confluence upstream of this point has the potential to increase erosion at this site. The results indicate that no significant changes to peak velocities are expected as a result of the Project under all flood scenarios modelled. The Project is therefore not expected to increase impacts on this site.

10.5 Downstream landholders and flood planning

Changes to any catchment has the potential to affect the flood planning. As described in Section 4.3, there are no private landholders or residences not associated with existing mining operations in the area potentially affected by the Project with respect to flooding. No flood planning study or floodplain management plan has been undertaken for Bowmans Creek. Given that no potential impacts are expected with respect to flooding for private landholders, detailed mapping of flood planning areas is not considered necessary, however it is noted that:

- Flood prone land is generally consistent with the inundation extent of the probable maximum flood (PMF).
- The flood planning area is generally consistent with the inundation extent of the 1% AEP design flood.

Inundation extents are included in Appendix C.

10.6 Watercourse stability

The Project has the potential to affect watercourse stability, as a result of changes in landform and the realignment of the lower reach of Yorks Creek. These potential impacts can be mitigated or avoided through the incorporation of measures in both landform design and works in potentially affected areas of the watercourses.

The modelled increase in the peak velocity for the 1% AEP design flood was used to identify potentially affected areas in the realignment of the lower reach of Yorks Creek (in proposed conditions (Year 6) and the proposed conceptual final landform) and sections of Bettys Creek (in the proposed final landform only). Appropriate erosion control measures, such as rock armouring, should be considered in the detailed design of the Yorks Creek Realignment and in the closure planning for lower Bettys Creek. The design of WRD as a retention dam in the final landform can also be used to mitigate downstream flow velocities in rare rainfall events.

The flood modelling results indicate localised increases in peak velocity in the order of 0.1 m/s are expected in sections of Bowmans Creek as a result of the Yorks Creek Realignment. These changes are considered minor and within the natural variation of Bowmans Creek. The potential geomorphological impacts are considered in Section 11.1.

10.7 Final void

The final void formed by the Glendell Pit Extension in the final landform may potentially be impacted by flooding in Yorks Creek, at the proposed levee as part of the Yorks Creek Realignment, or by flooding in Bowmans Creek, near the outfall of the existing Yorks Creek. The levee has been designed for the 0.1% AEP design flood, and therefore, as expected, the flood modelling results indicated that overtopping would occur in the PMF. The flood modelling results (based on the conceptual final landform) also identified the potential for flooding of the final void from Bowmans Creek in the PMF.

Interpretation of the flood modelling results indicates that more than 100 m of freeboard would remain in the final void in the event of overtopping from either Yorks Creek or Bowmans Creek. Therefore no impacts of the final void flooding on downstream water quality are expected. As part of the detailed design of the final landform, further flood modelling should be undertaken to assess opportunities to further reduce the potential for flooding of the final void, however this is not necessary in order to avoid potential downstream water quality impacts.

10.8 Climate change

The potential impacts of climate change were assessed by modelling the 0.2% and 0.5% AEP design flood events. The flood modelling results for these scenarios are generally similar in both pattern and magnitude to the 1% AEP design flood. Therefore, the potential impacts of the Project with respect to flooding are not expected be sensitive to climate change.

11. Impact assessment

11.1 Hydrology and geomorphology

The Project has the potential to impact on flow regimes in watercourses due to changes to surface water runoff and reductions in baseflow. Potential impacts were assessed with flow regime water balance modelling (Section 9) that considered baseflow reductions predicted in the Groundwater Impact Assessment (AGE 2019).

The Project will disturb the catchment of Bowmans Creek and its tributaries (Yorks Creek, Swamp Creek and Bettys Creek) but return slightly more catchment to Bowmans Creek in the final landform compared to approved conditions, as a result of a slightly smaller final void catchment area. As part of the Project, Yorks Creek will be realigned to a new confluence with Bowmans Creek and much of the rehabilitated site will be returned to the Bettys Creek catchment rather than the Swamp Creek catchment.

The realignment of Yorks Creek will remove approximately 2 km of the lower reaches of Yorks Creek and direct creek flows through a constructed channel. Results of the flow regime modelling (Section 9) show that the flows in the Yorks Creek Realignment are expected to be slightly lower than the existing Yorks Creek, due to a reduction in the catchment reporting to the realignment compared to the existing Yorks Creek. In the final landform, some catchment (outside of the Glendell Pit Extension final void) will be returned to Bowmans Creek at the location of the existing outfall.

The channel of Bowmans Creek was found to have highly variable morphology through hydrologically homogeneous reaches, suggesting complex local channel adjustment to erosive and depositional processes. As a result, there was no statistically significant change in channel dimensions downstream of the existing Yorks Creek junction. Given the inherent stability of the channel, rapid and large magnitude adjustment of Bowmans Creek channel downstream of the proposed realignment would not be expected. Rather, adjustment would take place incrementally over decades (Fluvial Systems 2019).

In the lower tributaries of Bowmans Creek, results of the flow regime modelling (Section 9) show that flows in Swamp Creek are expected to decrease temporarily as a result of the Project before returning to a flow regime similar to existing conditions. The catchment of the rehabilitated site is proposed to be diverted to Bettys Creek rather than Swamp Creek, where flows are expected to increase. The additional catchment area reporting to Bettys Creek under the Project is comparable to the catchment area diverted by the existing Upper Bettys Creek Diversion to Main Creek. Results of the flow regime modelling (Section 9) indicate that the increase in low flows will be attenuated due to WRD being maintained in the conceptual final landform as a retention basin.

Results of the flow regime modelling (Section 9) indicate that the reductions in the total catchment area of Bowmans Creek during the operation of the Project and in the conceptual final landform are minor and not expected to have a measurable impact on the flow regime of Bowmans Creek. Predicted cumulative impacts on baseflows described in the Groundwater Impact Assessment (AGE 2019) indicate that the changes are well within the natural variation in baseflows when climatic conditions are considered. The flow regime modelling was used to estimate the potential impacts to low flows (surface and subsurface) and the water levels in persistent pools, assuming that the regional water table was sufficiently high that subsurface flow moved through the pool. Based on the results of the flow regime modelling, no measurable impact on total low flows or persistent pools in the lower part of Bowmans Creek is expected as a result of the Project.

The Groundwater Impact Assessment (AGE 2019) also predicts some baseflow reductions in Glennies Creek and the Hunter River as a result of the Project. Cumulative reductions were compared to the long term stream flow record in these watercourses, which showed that no measurable impacts on flows in Glennies Creek or the Hunter River are expected.

11.2 Flooding and stability

The Project has the potential to impact the extent of flooding and stability of downstream watercourses, through changes in landform (including the proposed realignment of Yorks Creek) and changes to catchment area. The flood modelling indicates that the realignment of Yorks Creek slightly increases the flood depths and velocities in Bowmans Creek between the confluence with the proposed realignment of Yorks Creek and the existing Yorks Creek confluence. However, the changes are considered minor and are not expected to have a significant impact on the stability or water quality in Bowmans Creek.

The conceptual Yorks Creek Realignment design includes detailed consideration of the geomorphic requirements of the creek system including the need to ensure that there is adequate flow through the creek system to prevent siltation in Yorks Creek and mimic natural sediment transfer processes to the downstream environment. The detailed design of the Yorks Creek Realignment will also include design features to avoid scouring at the point of confluence with Bowmans Creek and areas downstream. The results of the flood modelling indicate that these design elements are likely to mitigate the potential impact of erosion on downstream water quality.

The proposed conceptual final landform includes the diversion of the currently highly disturbed catchment of Swamp Creek to the adjacent Bettys Creek. This proposed increase to the catchment area of Bettys Creek is comparable to the previous reduction in the pre-mining catchment due to the existing Upper Bettys Creek Diversion to Main Creek. Consequently, the flows and flood extents are expected to be closer to the pre-mining conditions under the proposed conceptual final landform than the approved conceptual final landform.

Overall, the results of the flood modelling indicate no significant changes to flood affectation of private property or infrastructure as a result of the Project. Therefore, the Project does not affect consistency with floodplain risk management plans, flood hazard, hydraulic functions, beneficial inundation, emergency management, risk to life from flood or social and economic costs as a consequence of flooding.

11.3 Surface water quality

The existing and approved water management system at the Mount Owen Complex (refer to Section 5) is extensive and includes mine dewatering systems, water storages, sedimentation and retention basins, settling and tailings ponds and diversion drains.

The extension to the water management system, as part of the Project, will be integrated into the existing water management system to limit the potential impacts on downstream water quality by managing water that has the potential to cause environmental harm. The conceptual water management system has been designed to continue to divert clean water around mining operations (where practical) and segregate, store and reuse dirty and mine impacted water to minimise adverse effects on water quality from mining operations to downstream waterways. The conceptual water management system has been designed considering appropriate criteria, including:

- Management (capture and storage) of mine water exposed to coal and/or coal processing for events up to and including the 1% AEP 24-hour storm event.

- Management of runoff from disturbed areas, based on the Blue Book requirements (Landcom, 2004 and DECC, 2008).

Surface water quality monitoring is undertaken in accordance with the *Surface Water Management and Monitoring Plan* for the Mount Owen Complex (Glencore 2019a) in surrounding watercourses upstream and downstream of the site, including in Bowmans Creek, Yorks Creek, Swamp Creek, Bettys Creek and Main Creek. The monitoring data indicates that water quality within each creek system is generally consistent at locations upstream and downstream of the Project. Observed EC, pH and TSS levels were largely found to be below or within the relevant SSGVs.

Consistent with approved operations at the Mount Owen Complex, no discharges will occur from the Mount Owen Complex as part of the Project. Surplus water on site will be transferred via the GRAWTS to the other Glencore managed sites that form part of the GRAWTS.

The approved conceptual water management system is designed to manage water to meet licence conditions within the requirements of the POEO Act, taking account of both historical and current water qualities in the surrounding watercourses, and current and future downstream water users. The risk of potential adverse water quality impacts associated with overflows during events that exceed the design criteria is currently managed by the water management plan (WMP) for Mount Owen Complex (refer to Section 12.1).

The Yorks Creek Realignment has been designed to provide flood conveyance while including scour and erosion control protection during construction and operation. These design elements are intended to minimise the potential for erosion which could result in adverse downstream water quality impacts.

11.4 Downstream water users

No measurable change to the flow regime or water quality of Bowmans Creek is expected as a result of the Project, and therefore no impacts to licensed water users or basic landholder rights are expected.

The negligible modelled reductions in stream flows and impacts to downstream water users on Glennies Creek associated with groundwater recovery will be managed by appropriate licencing under the WM Act. The Project is not expected to result in any impacts on water quality in Glennies Creek.

11.5 Riparian and ecological values

As discussed in Section 11.1, the expected changes to flow regimes are considered minor in the context of ephemeral Yorks Creek, Swamp Creek and Bettys Creek. No measurable impacts to flow regimes and persistent pools in Bowmans Creek are expected. No measurable impacts to flow regimes in Glennies Creek or the Hunter River are expected as a result of the Project.

The realignment of Yorks Creek will remove approximately 2 km of the riparian habitat in the lower reaches of Yorks Creek. A design objective of the Yorks Creek Realignment is to provide riparian and aquatic habitat. The lower reaches of the realignment have relatively steep grades (up to 4%), however these are comparable to other locations further up Yorks Creek, including knick points and waterfalls, which present comparable natural obstructions to fauna movement. The Project is therefore not expected to affect riparian and aquatic ecosystems.

11.6 Final void

The conceptual final landform of the Project includes a final void following completion of mining in the Glendell Pit Extension. A final void is approved under the current Glendell consent.

The conceptual final landform has been designed to minimise the catchment contributing to the proposed final void, with a catchment area slightly smaller than the approved final void. The final void is expected to act a long term groundwater sink. As such, the final void will be effectively hydrologically self-contained, in order to minimise potential impacts on downstream water quality and the surrounding groundwater environment. Therefore, the water quality in the final void will reflect the chemistry of the geology in which it is situated.

The Geochemical Assessment (EGI 2019) concluded that the vast bulk of the surrounding geology is likely to be non-acid forming and therefore potentially toxic metal species are unlikely to be generated. The geology was also found to have relatively low salinity potential, not likely to have a significant impact on pit water quality or require modification of the Mount Owen Complex water management system during operations. However, the self-contained hydrology of the final void has the potential to concentrate the dissolved solids in the final void lake over time, through evaporation.

The impact of the Project on the long term water levels and water quality of the final void was assessed using a water and salt balance model (Section 8), considering predictions of the Groundwater Impact Assessment (AGE 2019). The results of the modelling show that water level in the proposed final void is forecast to reach equilibrium in a similar timeframe to the approved final void, but at a lower elevation, reflecting the difference in geometry. Overall the proposed final void is considered equivalent to the approved final void and comparable to other recently assessed final void in the upper Hunter Valley, in terms of hydrology and water quality and therefore potential beneficial uses.

The proposed final void has some 140 m of freeboard and will remain a self-contained system with no surface spills to downstream watercourses for design flood up to the probable maximum flood.

11.7 Summary of mitigation measures

The potential impacts of the Project with respect to surface water will be mitigated by:

- The design features of the Yorks Creek Realignment to achieve the design objectives (refer to Section 6.2.1).
- The appropriate design of the water management system at the Mount Owen Complex (refer to Section 5), consistent with the design and operation of the existing water management system. This includes the management of runoff from haul roads and unsealed roads with the Mount Owen Complex water management system.
- Excess mine affected water due to the Project will be managed through integration with the GRAWTS, which eliminates the need to discharge mine affected water at the Mount Owen Complex (refer to Section 7).

Potential surface water impacts of mining operations and creek diversions have been managed by the Mount Owen Complex water management system. It is expected that integration of the Project into this established management system will adequately mitigate the potential surface water impacts associated with the Project.

11.7.1 Erosion and sediment control measures

Erosion and sediment control will continue to be undertaken in accordance with the Mount Owen Complex Erosion and Sediment Control Plan (ESCP), which will be updated if the Project is approved. The ESCP provides a framework for the management of erosion and sedimentation at the Mount Owen Complex.

The objective of the ESCP is to ensure that appropriate structures and programs of work are in place to:

- Identify activities that could cause erosion and generate sediment.
- Describe the location, function and capacity of erosion and sediment control structures required to minimise soil erosion and the potential for transport of sediment downstream.
- Ensure erosion and sediment control structures are appropriately maintained.
- Fulfil the statutory conditions of the project approval.
- Meet industry standards and best practice, specifically:
  - Landcom 2004. Managing Urban Stormwater – Soils and Construction, Volume 1, 4th Edition.
  - Department of Environment and Climate Change (DECC) 2008. Managing Urban Stormwater – Soils and Construction, Volume 2E – Mines and Quarries.
  - Draft Guidelines for the Design of Stable Drainage Lines on Rehabilitated Minesites in the Hunter Coalfields (DIPNR undated).

11.8 Cumulative impacts

Land use within the catchment of Bowmans Creek includes mining operations, quarrying, grazing and rural residential holdings. Outside of the Mount Owen Complex, established mining operations within the catchment of Bowmans Creek include Liddell Coal Operations to the north-west; Ravensworth Operations to the south-west, Integra Underground Mine to the south-east, and Ashton Coal Mine to the south.

11.8.1 Catchments and flow regimes

The Project will result in changes to the catchment areas of Yorks Creek, Swamp Creek and Bettys Creek compared to the currently approved final landform at the Mount Owen Complex. The catchment and flow regime modelling considered the cumulative impacts of changes to landform approved as part of neighbouring operations. Overall, the potential impacts of the Project are considered negligible relative to currently approved operations.

11.8.2 Flooding and stability

The Project will alter the catchments of the lower tributaries of Bowmans Creek: Yorks Creek, Swamp Creek and Bettys Creek. The flood modelling considered the cumulative impacts of changes to landform approved as part of neighbouring operations and indicates that no significant changes to flood extent or watercourse stability are expected as result of the Project. The design objectives and features of the Yorks Creek Realignment has had regard to the management of the potential impact of erosion on water quality in downstream watercourses.

11.8.3 Surface water quality

The potential water quality impacts of the Project will be managed as part of the existing water management system and through its integration with the GRAWTS. The water management system has been designed to appropriate standards to capture and contain mine affected water and protect downstream watercourses from potential water quality impacts. Results of the water balance modelling indicate that sufficient capacity is expected to be available within the GRAWTS over the life of the Project. Discharges will not be required at the Mount Owen Complex, with discharges occurring at neighbouring Ravensworth Operations and Liddell Coal Operations in accordance with existing practice under the HRSTS.

The site water and salt balance modelling considered the cumulative impact of the Project, considering the operation of other neighbouring sites in the GRAWTS. Overall, as the Project is essentially an extension through time of the existing operations under the Glendell consent, any changes as a result of the Project to the site water and salt balance at the Mount Owen Complex are not expected to affect the annual volume or water quality of potential discharges under the HRSTS.

The design of the Yorks Creek Realignment includes elements to mitigate the potential for erosion resulting in downstream water quality impacts. Overall, the cumulative potential impacts on water quality in downstream watercourses is negligible.

11.8.4 Downstream water users

As the Project and adjacent mining operations operate in a highly regulated water system, any water take associated with the Project or existing approved operations will need to meet the requirements of the WM Act in regard to licensing of water take. As such, the Project is considered to have negligible cumulative impacts on downstream water users.

11.8.5 Bioregional assessment

The Project lies in the Hunter subregion, which was subject to a bioregional assessment (DEE 2018). The Project lies in an area of potential hydrological impacts, however the assessment did not identify any large change in flow regimes in watercourses near the Project. The findings of this assessment are consistent with the bioregional assessment findings.

12. Management, monitoring, licensing and reporting

12.1 Management

The existing *Mount Owen Complex Water Management Plan* (WMP) (Glencore 2019a) was approved in 2019. The WMP includes, as sub plans, Erosion and Sediment Control Plan, Surface Water Management and Monitoring Plan, Groundwater Management and Monitoring Plan, Surface Water and Groundwater Response Plan and Creek Diversion Plan.

The WMP allows for the ongoing assessment of risk as mining operations progress and the implementation of improvements and changes where required. The WMP is an adaptive and responsive document with regular annual reviews and reviews triggered by incidents, audits or regulatory and operational changes.

Following approval of the Project, the Proponent will update the existing WMP to reflect the changes to water management associated with the Project. A detailed Yorks Creek Realignment Plan will be prepared as part of the detailed design prior to construction which includes consideration of flow velocities and sediment movement.

12.2 Monitoring

12.2.1 Surface water quality monitoring

The existing surface water quality monitoring program at the Mount Owen Complex includes locations in surrounding watercourses upstream and downstream of the site. The existing monitoring program should continue to monitor physio-chemical parameters of pH, EC and TSS (as turbidity). The monitoring is considered to adequately consider stressors on aquatic biota, consistent with industry practice, given that no discharges will occur from the Mount Owen Complex. The following changes to the surface water quality monitoring program are recommended:

- Following the realignment of Yorks Creek, the existing location YC3 should be replaced by a new location, YC4, located along the realignment. Observations from this location may be used to assess the performance of the realignment in providing habitat (refer to Section 6.2.1)
- A new monitoring location, BMC6 (alternatively named BMC3.5), should be established downstream of the confluence of the Yorks Creek Realignment with Bowmans Creek. BMC6 should be a similar distance downstream of the new Yorks Creek confluence as BMC4 is downstream of the existing confluence, so that the two sites are comparable. Observations from BMC6 location may be used to assess the performance of the realignment in minimising adverse impacts of water quality in Bowmans Creek (refer to Section 6.2.1).
- Monitoring of SC3 would cease following disturbance of this area by the Glendell Pit Extension. The existing SC4 would provide adequate coverage for the remnant lower reach of Swamp Creek.

Site specific guideline values for YC4 should be adopted from YC2 and YC3, and for BMC6 from BMC3 and BMC4, until 24 observations have been made to establish site specific guideline values for these new locations.

The recommended changes to the surface water quality monitoring locations are summarised in Figure 12-1. Monitoring of new dirty and mine water storages should be integrated into the existing surface water monitoring program at the Mount Owen Complex, as these storages are commissioned.

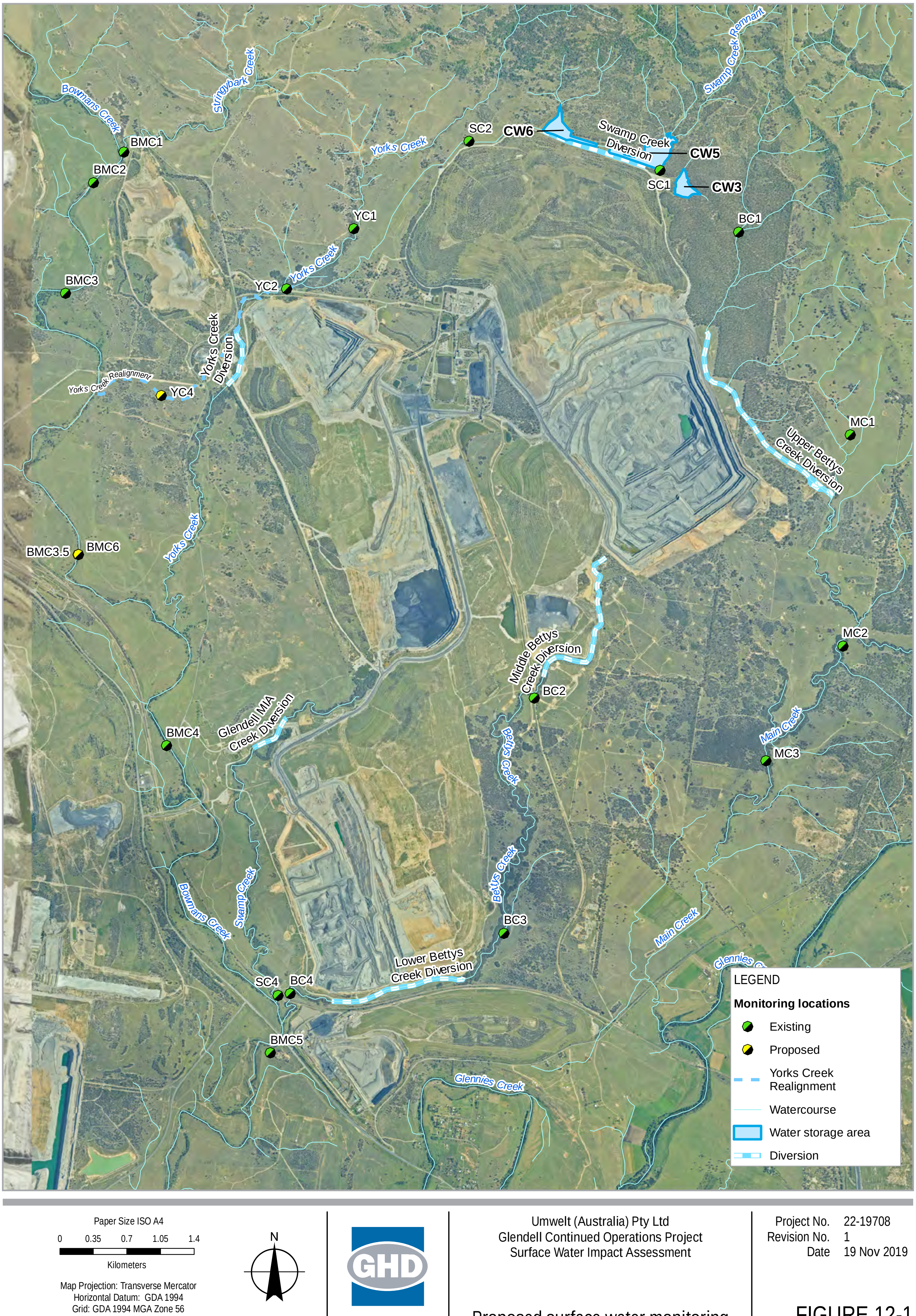
12.2.2 Yorks Creek Realignment

A monitoring program for the Yorks Creek Realignment should be developed as part of the detailed design and be incorporated in the Creek Diversion Plan.

The performance of the Yorks Creek Realignment should be measured against the design objectives through a monitoring program. Based on the recommendations of the Fluvial Systems (2019), the monitoring program for channel morphology should be of a before-after and control-impact design. The before-after criteria will set the absolute limits of allowable change in channel dimensions and position. The control-impact criteria will allow change in the diversion to be within the range observed in a control site. The monitoring methodology should avoid rapid visual assessment approaches and use objectively measured data, such as bed material size distribution, longitudinal bed profile and cross section form. The sampling design should provide sufficient statistical power to have the capacity to detect change.

Where there is poor or no relevant natural analogue, such as the hydraulically steep lower section and hydraulically flat section in deep cutting, a control-impact design is unlikely to be achievable. However, it is expected that for most of these areas which rely on a rocky bed or rock lining for stability, a change in design intent or stream functionality will be largely self-evident, such as erosion of the rocky lining, or a failure in the rocky side slopes. Therefore, visual inspections supported by objective measurements of physical changes in form are expected to a suitable form of monitoring.

Separate flow gauging of Yorks Creek is not considered necessary, as it is reasonable to assume that for the larger flood events the Bowmans Creek gauge (210130) will provide reasonable data that can be interpreted to understand the significant of the flood event that may have occurred on Yorks Creek.



GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Surface Water Impact Assessment

Project No. 22-19708
Revision No. 1
Date 19 Nov 2019

Proposed surface water monitoring

FIGURE 12-1

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

12.3 Environment protection licence

Licensing requirements for the Mount Owen Complex under the POEO Act remain unchanged with the Project. Administrative changes to the EPL boundaries may be required throughout the life of the Project.

12.4 Surface water licensing

The Proponent is required to hold adequate water entitlements to account for take from water sources as a result of the Project at the time the take occurs. The key surface water licensing issues associated with the Project are:

- During the operation of the Project, the interception of the remnant downstream reach of Yorks Creek (downstream of the Yorks Creek Realignment) will result in a temporary and diminishing take from the Jerrys Water Source.
- Following the completion of the Project, the dams proposed to remain in the conceptual final landform may be accounted for under harvestable rights, on the basis of the water storage volume, or under a water access licence, on the basis of the losses from the dam.
- As described in the Groundwater Impact Assessment (AGE 2019), during the operations and in the final landform, depressurisation of the Permian groundwater system is predicted to induce take from the Quaternary alluvial system. Additionally, the Project's interception with the Quaternary alluvium in Swamp Creek and Yorks Creek has the potential to result in direct take from the alluvial aquifer system. Changes in alluvial groundwater levels and flows can affect surface water flows. This indirect take of surface water will require licensing during operations and in the final landform. As this indirect take is not measurable, licensing requirements should be quantified based on appropriate numerical modelling.

For the purpose of this assessment, available water determinations of 1.0 ML/unit has been assumed, meaning that 1 share component is equivalent to 1 ML/year. This section is limited to the surface water licensing requirements of the Project, for groundwater licensing requirements, refer to the Groundwater Impact Assessment (AGE 2019).

12.4.1 Water access licences

Surface water licences (and associated approvals) currently held at the Mount Owen Complex are summarised in Section 3.1.3. Existing surface water access licences under the Hunter Unregulated WSP are associated with the Mount Owen consent and are therefore not considered in the licensing assessment for the Project.

12.4.2 Net harvestable rights

The total contiguous landholdings at the Mount Owen Complex are currently approximately 8 560 ha. Based on the maximum harvestable rights calculator (DNR 2019), this entitles the Proponent to capture up to 10% of the annual average runoff from the property by means of dams sited on first or second order streams with a total volume of not more than 599 ML. Existing water storages on the contiguous landholdings outside of the water management system at the Mount Owen Complex have an total catchment area of about 20.6 ha, with an estimated volume of 165 ML, based on a typical average depth of 2 m. This total volume is well within the maximum harvestable rights of the Proponent, based on the current contiguous landholdings, affording an estimated net harvestable rights entitlement of 434 ML.

12.4.3 Hunter Unregulated WSP – during operations

One of the key objectives of the Mount Owen Complex water management system is the diversion of clean water around mining operations to minimise capture of upslope runoff and separate clean water runoff from mining activities. As part of the Project, Yorks Creek is proposed to be realigned upstream of the Glendell Pit Extension. However, during the course of the Project, the lower reach of Yorks Creek downstream of the realignment will be intercepted by the Glendell Pit Extension. The interception is expected to occur in approximately Year 10, when the intercepted catchment will be at its maximum extent of approximately 245 ha. Based on the regional runoff rates implied by the Maximum Harvestable Rights Calculator (DNR 2019) of 0.7 ML/ha/year, the peak clean water take for the Mount Owen Complex during the operation of the Project is estimated to be 172 ML/year. The additional clean water take is located entirely in the Jerrys Water Source.

The licensing requirements for surface flows during operations under the Hunter Unregulated WSP are summarised in Table 12-1. Table 12-1 also shows the total number of share components currently allocated to these water sources (WaterNSW 2019).

Table 12-1 Hunter Unregulated WSP – requirements during operations

Project element	Jerrys Water Source (ML/year)	Glennies Water Source (ML/year)
		Unregulated river
Lower reach of Yorks Creek	172 (peak occurs in Year 10)	N/A
Baseflow losses (AGE 2019)	5 (peak occurs between Year 22 and 25)	0
Total surface water requirement	**187**	**0**
Total surface water share components in water source	3343	446

Table 12-1 shows that a total of 187 ML/year may be required to be licensed in the Jerrys Water Source as a result of the Project during operations. The timing of peak requirement for the different project elements may not coincide, meaning that the actual licencing requirement at any specific time may be less. The Jerrys Water Source allocation is likely to be readily sourced given the volume of entitlement available and the nature of land use in this water source.

For the lower reach of Yorks Creek take, given the temporary nature of the take, which will peak in approximately Year 10 and diminish to zero at the completion of the Project, the take may also be accounted with the entitlement implied by net harvestable rights entitlement at the Mount Owen Complex during operations of 434 ML instead of surface water entitlements from the Jerrys Water Source. The licensing requirements should be reassessed prior to the interception of the lower reach of Yorks Creek by the Glendell Pit Extension in approximately Year 10, considering revised groundwater modelling predictions and the relevant licencing requirements at the time.

Table 12-1 shows no additional water access licences are required in the Glennies Water Source during operations.

The Project is not predicted to have any impact on surface flows in the Hunter Regulated River Alluvium Water Source during operations as a result of depressurisation of Permian aquifer systems.

12.4.4 Hunter Regulated WSP – during operations

The water balance assessment (refer to Section 7) indicates that the existing licence allocations are sufficient to meet the water requirements of the Project as part of the Mount Owen Complex of up to 416 ML/year. The results of the water balance modelling indicate that this annual volume is not sensitive to rainfall variability.

At the Mount Owen Complex, licences are currently held to extract up to 1188 ML/year of high security, 478 ML/year of general security, 31.2 ML/year of supplementary and 40 ML/year of domestic and stock from Glennies Creek under the Hunter Regulated WSP (assuming 1 ML/year per share component). The neighbouring Integra Underground Mine also extracts approximately 120 ML/year of water from Glennies Creek under a shared licence arrangement with the Mount Owen Complex. The total expected surface water requirements of the Project and Integra Underground Mine of 536 ML/year are well within these entitlements and therefore, no additional WALs are expected to be required under the Hunter Regulated WSP as a result of the Project.

12.4.5 Hunter Unregulated WSP – final landform

Dams in final landform

As part of the conceptual final landform, dams may be required for:

- Long term management of drainage in the final landform, for ongoing use as dryland attenuation basins or detention areas to reduce flow velocities downslope and continue the operation of the established clean water management systems whilst maintaining drainage and creek line stability.
- Use to support final land users such as farm dams for stock watering.
- Environmental purposes, such as retention of dams with developed ecosystems which have biodiversity value in the final landform.

The total design volume of water storages on first and second order streams shown in the conceptual final landform is estimated to be 444 ML, based on the concept sizing of sediment dams and dryland attenuation basins for the Project (refer to Section 6.2.6) and the assessments for the Mount Owen consent (Umwelt 2016), as modified (Engeny 2018). This total volume slightly exceeds the net harvestable rights entitlement of 434 ML, based on the existing contiguous landholdings at the Mount Owen Complex.

The actual volume of dams in the final landform will depend on the detailed design of the final landform and land use which will be progressively developed and refined over the life of the Project. All dams to be retained in the final landform will be fully licensed in accordance with licensing requirements at the time. The volume of dams in the final landform may be reduced by removing dams or lowering dam spillways. In the event that total volume of dams exceeds the harvestable rights entitlement, the losses associated with the volume of dams in excess of the harvestable rights entitlement will be appropriately licenced with a water access licence. All dams in the conceptual final landform as part of the Project are located in Jerrys Water Source.

WRD is proposed to be retained in the conceptual final landform as a retention basin to attenuate flows in Bettys Creek and expected to remain generally full and regularly flow to Bettys Creek. At WRD, Bettys Creek will effectively be a third order stream in the conceptual final landform, and therefore the volume of WRD may not be accounted for by harvestable rights entitlements. The surface area of this storage is currently approximately 5.2 ha (but may increase as part of an enlargement of WRD). Based on a net evaporation of 745 mm/year (refer to Section 4.1), the net evaporative losses from this storage are expected to be approximately 39 ML/year, which would require surface water licensing in the Jerrys Water Source following the establishment of the final landform.

Final void

The catchment area of the proposed Glendell Pit Extension final void in the conceptual final landform is approximately 321 ha, which is slightly less than the catchment area of the approved final void of 339 ha. As the Glendell Pit final void was approved prior to the commencement of the Hunter Unregulated WSP, there are no additional licensing requirements associated with the proposed final void as part of the Project.

Baseflow and alluvial losses

Peak cumulative take from the Jerrys alluvial system is predicted to occur during the life of the operations. The mining void created by the Project is predicted to slow the recovery of the Permian groundwater system and quaternary alluvial system relative to the approved final landform. The Groundwater Impact Assessment (AGE 2019) predicts that flows into the alluvium and base flow to the surface will be lower than would otherwise be the case without the Project, but the overall recovering trend is not affected by the Project; that is, overall base flows will continue to increase post closure.

Net groundwater flow from the Glennies water source attributable to mining operations is predicted to return to 2009 levels in approximately 2200. The maximum licensable take attributable to the Project is predicted to peak in approximately 2200 at 22 ML/year of which 4 ML/year (approximately 0.01 ML/day) will manifest as baseflow reductions. The Projects overall contribution to changes in groundwater flows will continue to increase beyond 2200 however overall cumulative take associated with all mining operations modelled will be below 2009 levels and continue to decline (AGE 2019).

Licensing requirements

The licensing requirements for the conceptual final landform under the Hunter Unregulated WSP are summarised in Table 12-2, compared to the total number of share components currently allocated (WaterNSW 2019).

Table 12-2 Hunter Unregulated WSP – requirements for final landform

Project element	Jerrys Water Source (ML/year)	Glennies Water Source (ML/year) (Unregulated river)
Final void	0	N/A
Dams in final landform	0	N/A
WRD evaporative losses	39	N/A
Baseflow losses (AGE 2019)	4 (peak in 2200)	0
Total surface water requirements	**43 (peak in 2200)**	**0**
Total surface water share components in water source	3343	446

Table 12-2 shows that a peak of 43 ML/year may be required to be licensed in the Jerrys Water Source in approximately 2200 as a result of the Project in the final landform.

The Jerrys Water Source allocation is likely to be readily sourced given the volume of entitlement available and the nature of land use in this water source.

The Hunter Regulated River Alluvium Water Source (Glennies Creek alluvium) is slower to recover than the Jerrys Water source with flows returning to 2009 levels at the start of the WSP approximately 300 years post mining. Similar to the Jerrys Water Source the contribution of residual water take attributable to the Project increases slowly post mining, however overall cumulative take associated with mining operations continues to decline. The surface water take associated with this impact on the alluvial system is regulated under the Hunter Regulated Water Sharing Plan which commenced in 2004. Cumulative baseflow are predicted to return to 2004 levels in approximately 2500, at which point the water take attributable to the Project is 14 ML/year. This predicted take is well within the current Mount Owen licence allocation from this water source.

The Hunter Unregulated WSP is being reviewed during 2019. The licensing requirements should be reassessed following this review and again prior to the completion of the Project, considering revised groundwater modelling predictions and the relevant licencing requirements for the water sources at the time.

12.4.6 Hunter Regulated WSP – final landform

No take under the Hunter Regulated WSP will occur in the final landform.

12.5 Reporting

A summary of the surface water monitoring results will continue to be provided in the Annual Review for the Mount Owen Complex. The Annual Review includes:

- A summary of monitoring results.
- An analysis of monitoring results against impact assessment criteria and historical monitoring results.
- Annual site water and salt balance and comparison to the forecast annual average site water and salt balance.
- Identification of any trends in the monitoring results.
- Any non-compliances reported during the year.
- Actions taken to address any non-compliances.

13. Summary

Glendell Mine is an open cut coal mine located in the upper Hunter Valley of NSW. Glendell Mine is operated as part of the Mount Owen Complex, which integrates the production and water management of Glendell Mine, Mount Owen Mine and Ravensworth East Mine. The Mount Owen Complex is in turn integrated with neighbouring operations under the Greater Ravensworth Area Water and Tailings Scheme.

Glendell Mine currently operates under development consent DA 80/952 and is reaching the extent of its approved mining extent. The proposed extension to the Glendell Pit would extract about 135 million tonnes more ROM coal down to and including the Hebden seam and extend the life of mining operations to approximately 2044. This Surface Water Impact Assessment has been prepared to address the assessment requirements through a detailed assessment of the potential impact of the Project with respect to surface water.

The Project is located in the lower catchment of Bowmans Creek and its ephemeral tributaries: Yorks Creek, Swamp Creek and Bettys Creek. There are no non-mining related landholders or water users downstream of the Project on Bowmans Creek.

The water management system at the Mount Owen Complex will be extended, incorporating additional water storage dams, pumps and pipelines to manage water and protect downstream watercourses from potential water quality impacts. No discharge of mine affected water is proposed; excess water will continue to be managed with the Greater Ravensworth Area Water and Tailings Scheme, which allows for discharge from the neighbouring Ravensworth Operations and Liddell Coal Operations under the Hunter River Salinity Trading Scheme.

The Project includes measures to minimise the interception of clean water, including clean water drains and the permanent realignment of Yorks Creek. The realignment of Yorks Creek has been designed to mitigate the potential impact of erosion on downstream water quality and modelling indicates that no significant flooding impacts are expected due to the realignment.

Based on the results of the flow regime modelling, no measurable impact on total low flows or persistent pools in the lower part of Bowmans Creek is expected as a result of surface water impacts of the Project. The conceptual final landform proposed by the Project includes the transfer of the some of the rehabilitated site to Bettys Creek rather than Swamp Creek, via a retention basin formed by the existing mine water storage WRD. This restoration of catchment to Bettys Creek is comparable to catchment removed by the existing Upper Bettys Creek Diversion to Main Creek and is expected to restore the floodplain of the remaining lower Bettys Creek.

Like the approved conceptual final landform for Glendell Mine, the proposed conceptual final landform includes a final void, with a similar catchment area but located further north. Based on modelling, the long term recovery and water quality of the proposed final void is considered equivalent to the approved final void and comparable to other final voids recently assessed in the upper Hunter Valley. The expected water quality would not impair potential beneficial uses into the foreseeable future, including recreation and energy generation, however, like the regional groundwater (which has a higher salinity to that expected in the final void) treatment to reduce salinity would be required for irrigation and stock water purposes. The proposed final void will remain a self-contained system with no surface spill to downstream watercourses.

Flood modelling indicates that no significant change to downstream flooding as a result of the Project are expected, however appropriate erosion and scour control should be considered in the detailed design of the Yorks Creek Realignment and the closure planning for the existing Lower Bettys Creek Diversion.

The mitigation measures integrating into the design of the Project mean that no significant impacts on downstream watercourses or water users are expected as a result of the Project. The Proponent will continue to manage and monitor surface water in an adaptive and responsive manner at the Mount Owen Complex. The interception of clean water associated with the Project during operations, dams in the final landform and baseflow losses, will be appropriately accounted for with net harvestable rights entitlements or water access licences.

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Appendices

Appendix A – Supporting assessment requirements

Department of Industry – Water requirements

Assessment requirement	Where addressed
The identification of an adequate and secure water supply for the life of the project. This includes confirmation that water can be sourced from an appropriately authorised and reliable supply. This is also to include an assessment of the current market depth where water entitlement is required to be purchased.	Section 7 Section 12.4
A detailed and consolidated site water balance.	Section 7
Assessment of impacts on surface and ground water resources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land and groundwater dependent ecosystems (GDEs), and measures proposed to reduce and mitigate these impacts.	Section 11 For GDEs, refer to Groundwater Impact Assessment (AGE 2019) Section 11.7
Proposed surface and groundwater monitoring activities and methodologies.	Section 12.2
Consideration of relevant legislation, policies and guidelines, including the Aquifer Interference Policy (2012), the DPI Water Guidelines for Controlled Activities on Waterfront Land (2012) and the relevant Water Sharing Plans.	Section 3

DPI - Fisheries

Assessment requirement	Where addressed
The complete design of the creek diversion including changes in slope, length and habitat structures proposed in the diversion compared to the existing creek line.	Section 6.2.1
A detailed outline on how a "natural" system can be created in this landscape.	Section 6.2.1
Identification of how the design will mitigate or offset the areas of aquatic habitat that is lost due to the shortening of the creek by the proposed diversion.	Section 6.2.1 Section 11.7
A complete assessment of the fish population in Yorks Creek to determine the presence or absence of any threatened fish species. Reliance on past assessments may not give a complete picture as the species are small and similar species in inland waters have been shown to be quite mobile in ephemeral streams. This information is required to complete the required test of Significance under Part 7a of the Fisheries Management Act 1994.	Refer to Biodiversity Development Assessment Report
An assessment of the diversion shall also include an assessment on the changes in flows entering Bowmans Creek at the proposed junction and ascertain how these flows can be introduced to the stream without creating erosion and turbidity issues in Bowmans Creek.	Section 10.6 Section 11.1

EPA requirements

Assessment requirement	Where addressed
Describe proposal	
Describe the proposal including position of any intakes and discharges, volumes, water quality and frequency of all water discharges.	Section 2
Demonstrate that all practical options to avoid discharges have been implemented and environmental impact minimised where discharge is necessary.	Section 6.2

Assessment requirement	Where addressed
Where relevant include a water balance for the development including water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options.	Section 7
Describe how all mine water storage dams, creek diversions, erosion and sediment control structures and other treatment systems will be constructed and managed to ensure that water discharges from these water management systems comply with the requirements of the *Protection of the Environment Operations Act 1997* and the *Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2002*.	Section 5
Background conditions	
Describe existing surface and groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal. Issues to be discussed should include but are not limited to: • a description of any impacts from existing industry or activities on water quality • a description of the condition of the local catchment e.g. erosion, soils, vegetation cover, etc. • historic river flow data	Section 10.2 Section 4.2
State the Water Quality Objectives for the receiving waters relevant to the proposal. These refer to the community's agreed environmental values and human uses endorsed by the NSW Government as goals for ambient waters.	Section 3.3.4
State the indicators and associated trigger values or criteria for the identified environmental values. This information should be based on the ANZECC (2000) Guidelines for Fresh and Marine Water Quality as a minimum.	Section 5
State any locally specific objectives, criteria or targets which have been endorsed by the NSW Government.	Section 3.1.2
Impact assessment	
Describe the nature and degree of impact that any proposed discharges will have on the receiving environment, both surface water and groundwater.	Not applicable. No discharges proposed.
Detail contractual or other arrangements that will be put in place to prevent pollution from haul roads and unsealed roads, particularly rights of carriageways not owned by the proponent.	Section 11.7
Assess impacts against the relevant ambient water quality outcomes. Demonstrate how the proposal will be designed and operated to: • protect the Water Quality Objectives for receiving waters where they are currently being achieved • contribute towards achievement of the Water Quality Objectives over time where they are not currently being achieved	Section 11.3
Where a discharge is proposed that includes a mixing zone, the proposal should demonstrate how wastewater discharged to waterways will ensure the ANZECC (2000) water quality criteria for relevant chemical and non-chemical parameters are met at the edge of the initial mixing zone of the discharge, and that any impacts in the initial mixing zone are demonstrated to be reversible.	Not applicable. No discharges proposed.
Propose water quality limits for any discharge(s) that adequately protects the receiving environment.	Not applicable. No discharges proposed.

Assessment requirement	Where addressed
Assess impacts on groundwater and groundwater dependent ecosystems.	Refer to Groundwater Impact Assessment (AGE 2019)
Describe how stormwater will be managed both during and after construction.	Section 6.2
Assess the potential for acid forming materials to generate acid mine drainage.	Refer to Geochemistry Impact Assessment (EGI 2019)
Monitoring	
Describe how predicted impacts will be monitored and assessed over time.	Section 12.2

OEH requirements

Assessment requirements	Where addressed
Water and soils	
The EIS must map the following features relevant to water and soils including: a. Acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Planning Map). b. Rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method). c. Wetlands as described in s4.2 of the Biodiversity Assessment Method. d. Groundwater. e. Groundwater dependent ecosystems. f. Proposed intake and discharge locations.	Rivers and streams are mapped in Section 4 Acid sulfate soils, wetlands, estuaries are not relevant For groundwater and GDEs refer to Groundwater Impact Assessment (AGE 2019) No new intake or discharge locations proposed as part of the Project
The EIS must describe background conditions for any water resource likely to be affected by the development, including: a. Existing surface and groundwater. b. Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations. c. Water Quality Objectives (as endorsed by the NSW Government) including groundwater as appropriate that represent the community's uses and values for the receiving waters. d. Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	Section 4 Section 3.3.4 Section 5

Assessment requirements	Where addressed
The EIS must assess the impacts of the development on water quality, including: a. The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction. b. Identification of proposed monitoring of water quality.	Section 11.3 Section 12.2
The EIS must assess the impact of the development on hydrology, including: a. Water balance including quantity, quality and source. b. Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas. c. Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems. d. Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches). e. Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water. f. Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options. g. Identification of proposed monitoring of hydrological attributes.	Section 7 For groundwater and GDEs refer to Groundwater Impact Assessment (AGE 2019) Section 11.2 Section 11.4 Section 11.7 Section 12.2
Flooding and coastal erosion	
The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: a. Flood prone land. b. Flood planning area, the area below the flood planning level. c. Hydraulic categorisation (floodways and flood storage areas).	Section 10
The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.	Section 10
The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios: a. Current flood behaviour for a range of design events as identified above. This includes the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 10
Modelling in the EIS must consider and document: a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. b. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories. c. Relevant provisions of the NSW Floodplain Development Manual 2005.	Section 10

Assessment requirements	Where addressed
The EIS must assess the impacts on the proposed development on flood behaviour, including: a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure. b. Consistency with Council floodplain risk management plans. c. Compatibility with the flood hazard of the land. d. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. e. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site. f. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses. g. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council. h. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council. i. Emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES. j. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	Section 11.2

Independent Expert Scientific Committee requirements

Assessment requirement	Where addressed
Surface water	
Context and conceptualisation	
Describe the hydrological regime of all watercourses, standing waters and springs across the site including: • geomorphology, including drainage patterns, sediment regime and floodplain features • spatial, temporal and seasonal trends in streamflow and/or standing water levels • spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides) • current stressors on watercourses, including impacts from any currently approved projects	Section 4.2 Section 10.2
Describe the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	Section 10 Appendix C
Provide an assessment of the frequency, volume, seasonal variability and direction of interactions between water resources, including surface water/ groundwater connectivity and connectivity with sea water.	Section 4.2

Assessment requirement	Where addressed
Analytical and numerical modelling	
Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Section 7 Section 10
Describe and justify model assumptions and limitations, and calibrate with appropriate surface water monitoring data.	Section 7 Section 10
Use methods in accordance with the most recent publication of Australian Rainfall and Runoff (Ball et al. 2016).	Section 10
Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	Appendix B Appendix C
Develop and describe a program for review and update of the models as more data and information becomes available.	Section 12.5
Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	Not applicable
Impacts to water resources and water-dependent assets	
Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider: • impacts on streamflow under the full range of flow conditions • impacts associated with surface water diversions • impacts to water quality, including consideration of mixing zones • the quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets • landscape modifications such as subsidence, voids, post rehabilitation landform collapses, on-site earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities	Section 11 No discharges proposed as part of the Project.
Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Section 3.3.4
Identify processes to determine surface water quality guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets.	Section 5
Propose mitigation actions for each identified significant impact.	Section 11.7
Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	Section 11.7
Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and reasonably foreseeable) are considered in combination.	Section 11.8
Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	Section 11.2

Assessment requirement	Where addressed
Data and monitoring	
Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	Section 12.2
Develop and describe a surface water monitoring program that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions, and assess the effectiveness of mitigation and management measures. The program will: • include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals) • comparison of physico-chemical data to national/regional guidelines or to site-specific guidelines derived from reference condition monitoring if available • identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required	Section 12.2
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Section 3.3
Describe the rationale for selected monitoring parameters, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	Section 12.2
Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and describe data methods, including whether missing data have been patched.	Section 4.1
Develop and describe a plan for ongoing ecotoxicological monitoring, including direct toxicity assessment of discharges to surface waters where appropriate.	Not applicable. No discharges proposed.
Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	Section 12.2
Water and salt balance, and water quality	
Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Section 7
Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	Not applicable. No discharges proposed.
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	Section 6.2 Section 7
Provide salt balance modelling that includes stores and the movement of salt between stores, and takes into account seasonal and long-term variation.	Section 7

Assessment requirement	Where addressed
Cumulative impacts	
Context and conceptualisation	
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 11.8
Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	Section 11.8
Impacts	
Provide an assessment of the condition of affected water resources which includes: • identification of all water resources likely to be cumulatively impacted by the proposed development • a description of the current condition and quality of water resources and information on condition trends • identification of ecological characteristics, processes, conditions, trends and values of water resources • adequate water and salt balances • identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown)	Section 4.2
Assess the cumulative impacts to water resources considering: • the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally • all stages of the development, including exploration, operations and post closure / decommissioning • appropriately robust, repeatable and transparent methods • the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts • opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts	Section 11.8
Mitigation, monitoring and management	
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	Section 11.7
Identify cumulative impact environmental objectives.	Section 11.8
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	Section 12.2
Describe appropriate reporting mechanisms.	Section 12.5
Propose adaptive management measures and management responses.	Section 12.1

Assessment requirement	Where addressed
Final landform and voids – coal mines	
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Section 5 Section 8
Provide an assessment of the long-term impacts to water resources and water-dependent assets posed by various options for the final landform design, including complete or partial backfilling of mining voids. Assessment of the final landform for which approval is being sought should consider: • groundwater behaviour – sink or lateral flow from void • water level recovery – rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation) • seepage – geochemistry and potential impacts • long-term water quality, including salinity, pH, metals and toxicity • measures to prevent migration of void water off-site For other final landform options considered sufficient detail of potential impacts should be provided to clearly justify the proposed option.	Section 8
Assess the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	Section 8.2
Provide an evaluation of stability of void slopes where failure during extreme events or over the long term (for example due to aquifer recovery causing geological heave and landform failure) may have implications for water quality.	Refer to EIS main report and Rehabilitation and Closure Strategy
Evaluate mitigating inflows of saline groundwater by planning for partial backfilling of final voids.	Refer to EIS main report
Assess the probability of overtopping of final voids with variable climate extremes, and management mitigations.	Section 11.6

Independent Expert Scientific Committee advice to the NSW Mining and Petroleum Gateway Panel

IESC advice	Where addressed
13. At this stage of the approvals process, the lack of quantitative information provided on streamflows and runoff prevents reliable assessment of the likelihood and significance of surface water impacts. While the surface water systems are ephemeral in the project area, the importance of ephemeral systems is now recognised (Datry et al. 2018). Useful information could be obtained from a variety of techniques including observations of flows made during the water quality monitoring, from water level recording of on-site water storages and stream pools, and from images from Water Observations from Space (WOfS) (Mueller et al. 2016). Information used in the “detailed analysis and calibration” of the site water balance modelling (Glencore, 2018) would also be useful in this regard. The quantitative analysis of such information would allow the impacts of altered catchment areas and other mining-related activities on surface water resources to be assessed.	Available baseline information is included in Section 4.2. The calibration of the site water balance modelling relates to the catchment with the Mount Owen Complex water management system and is not relevant to watercourses surrounding the Project.

IESC advice	Where addressed
14. More information on the proposed diversion of Yorks Creek will be needed in the EIS. This information should demonstrate how the proposed diversion plans to address the guidelines developed by White et al. (2014) and should also address the following issues.	Refer to Section 6.2.1
a. Detailed design specifications and a geotechnical and geomorphological assessment of the proposed diversion are required. This information will be essential for determining the suitability of the proposed diversion and its likely long-term stability.	The EIS main report and the Yorks Creek Realignment Constraints Analysis (Fluvial Systems 2019) includes a detailed assessment of the geomorphic characteristics of the existing Yorks Creek environment and includes detailed design recommendations for the Yorks Creek Realignment.
b. The proposed diversion appears to be shorter and straighter than the current path of Yorks Creek and will enter Bowmans Creek some four river-kilometres upstream of the current confluence. This is likely to change sediment transport processes (including erosion and deposition) within Yorks Creek and the section of Bowmans Creek immediately downstream of the new confluence. The proponent should consider lengthening the hydraulic path and incorporating meanders in the diversion to more closely replicate hydraulic environments and flow velocities of the current creek. The proponent also needs to assess how the altered location of the confluence will impact flow and sediment processes, flow volumes and fish habitat in Bowmans Creek, especially immediately downstream.	Refer to EIS main report and the Yorks Creek Constraints Analysis (Fluvial Systems 2019). A detailed conceptual design for the Yorks Creek Realignment is included in the EIS which incorporates additional meanders relative to the indicative alignment shown in the figures considered by the IESC. The detailed conceptual design has been used in flood modelling undertaken for the SWIA. The detailed conceptual design has had regard to the management of sediment load in Yorks Creek. Consistent with existing management plan requirements, a detailed Yorks Creek Realignment Plan will be prepared for the detailed design prior to construction which includes consideration of flow velocities and sediment movement.
c. A shorter stream length will also reduce available aquatic habitat and may affect the formation of instream habitats such as pools and riffles. Aquatic biota (including fish) in Yorks Creek should be sampled during periods of flow and in refugial pools to provide baseline data against which to compare changes in community composition resulting from altered habitat in the diverted section. The EIS should explain how the diversion will affect the ecological function of Yorks Creek and propose mitigation and management measures to ensure the establishment and maintenance of ecological function in the new channel (e.g. White et al. 2014).	Refer to EIS main report and Aquatic Ecology Assessment (Umwelt 2019).

IESC advice	Where addressed
d. Diversion of Yorks Creek is likely to result in disconnection from its alluvium, with repercussions for associated GDEs (see Paragraphs 22 and 23) and in-stream ecological function supported by exchanges of surface water and groundwater from the alluvium. To reduce these impacts, the proponent should consider including alluvial material below and along the diversion to help establish a new alluvial corridor along the diversion.	Refer to EIS main report and the Yorks Creek Realignment Constraints Analysis (Fluvial Systems 2019).
e. Similarly, ecological continuity along the riparian corridor of Yorks Creek will be disrupted by the diversion. The riparian corridors present at the project site are likely to provide important habitat and refuges for native flora and fauna that would be valuable during rehabilitation as a source of plant and animal colonists. To minimise impacts, riparian vegetation should be established as rapidly as possible along the diversion and should be connected with existing riparian zone vegetation upstream and downstream to enhance ecological connectivity along the corridor and improve the other contributions of riparian zone vegetation to ecological function in the diverted channel.	Refer to EIS main report and the Yorks Creek Realignment Constraints Analysis (Fluvial Systems 2019).
f. Information on current shear stresses and rates, volumes and timings of flows in Yorks Creek and those expected in the diverted channel are required for assessment of likely changes. Previous diversions at the Mount Owen Complex may have resulted in large changes to these characteristics (Glencore 2019b, pp. 18-19) but the impacts of these are unclear.	Section 10.6
15. Flood modelling for the project is needed in the EIS. This modelling should:	Refer to Section 10
a. explicitly consider the proposed Glendell void over a range of flood exceedance probabilities up to and including the Probable Maximum Flood (PMF) as previous flood modelling has not done this (Glencore 2019a, p. 18). This is needed to understand potential impacts posed by the final void to both flooding characteristics and water quality;	Refer to Section 10.7
b. include the proposed diversion so that changes in flood levels and velocities that occur as a result of the diversion can be assessed;	Refer to Section 10.6
c. determine the likelihood of uncontrolled discharges from each water storage and identify if controlled discharge will be required from any of them under any of the examined rainfall and flood runoff scenarios. If any potential discharge is identified, then the receiving environment and potential impacts should be described, along with appropriate management and mitigation measures; and	No controlled discharges are proposed as part of the Project. Uncontrolled discharges may only occur in the event of a rainfall event exceeding the relevant design criteria, refer to Section 6.1.
d. include the realignment of Hebden Road and the proposed MIA to assess how these may be impacted by flooding and how these structures may alter flood behaviour.	Section 10.2

IESC advice	Where addressed
16. An assessment of the potential changes to flow regimes of all creeks that may be impacted by the project is needed in the EIS. This assessment should include data on the baseline flow regime and analysis of how these will be altered due to the project. This analysis needs to be undertaken using data collected at a suitable temporal scale to understand the seasonality of ecologically important flow components (e.g. low flows, durations of zero-flow periods). These data are needed to inform selection of mitigation options and development of monitoring and management plans. These data should also be used by the proponent to support conclusions on the likelihood and significance of potential impacts.	Section 9
17. The proponent needs to provide a comprehensive assessment of surface water quality that incorporates all existing monitoring data. These data are needed to establish the baseline condition of creeks that could be impacted by the project, to inform selection of mitigation options and to assist development of monitoring and management plans.	Section 5
18. Updated schematics for the water management system (WMS) are required. These schematics should clearly show how the project and any additional water management infrastructure associated with the project will be integrated into the WMS and the GRAWTS. The benefits of the GRAWTS for water and waste management should be presented in more detail. Quantitative information on flows and storage under various management scenarios is needed for the scheme.	Section 2.3 Section 6
19. A comprehensive water balance is needed for the project. The IESC notes that the proponent has committed to undertake this work in the EIS (Umwelt 2018, p. 89). The proponent should consider using:	Section 7
a. the Minerals Council of Australia – Water Accounting Framework (2014) to identify the uncertainties in the water balance inputs; and	Appendix B
b. the water balance as evidence to support their conclusion that no changes to current discharge arrangements will be needed to accommodate the project (Umwelt 2019a, p. 52).	Section 7.2
20. More information on potential North Pit Void water storage is needed to understand potential risks and impacts associated with this storage under current and future climatic conditions. Information provided in the EIS should include a long-term quantitative assessment of: a. the likely water quality in the void and changes over time while it is used as a storage; b. groundwater inflows to the storage and whether the storage will be a sink; and c. the volume of water that may be stored within the North Pit Void.	Assessed as part of the Mount Owen Continued Operations Project (Umwelt 2016)
21. The proposed monitoring and management program should be detailed in the EIS to enable an assessment of its likely effectiveness. The proponent should:	Section 12
a. provide a summary of any changes or additions to the monitoring network that would be required due to the project;	Section 12.2

IESC advice	Where addressed
b. determine site-specific guideline values for all water quality analytes (see Huynh and Hobbs 2019). Currently, guideline values have only been determined for pH, EC and total suspended solids (TSS); and	Section 5
c. update TARPs to include specifics on the implementation of proposed responses, management options available and timeframes for action and response. Currently, timeframes are only provided for reporting to regulatory authorities.	Section 12.1

Appendix B – Water and salt balance model methodology

Umwelt (Australia) Pty Ltd

Glendell Continued Operations Project
Water and salt balance model methodology

November 2019

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1. Introduction

1.1 Background

Glendell Mine is an open cut coal mine that is part of the Mount Owen Complex located in the upper Hunter Valley of NSW, located approximately 20 km north-west of Singleton and 24 km south-east of Muswellbrook.

Glendell Tenements Pty Ltd (the Proponent) proposes to extend open cut mining operations north from the current Glendell Mine as part of the Glendell Continued Operations Project (the Project). This modelling report forms part of an environmental impact statement (EIS) to support a State significant development (SSD) application under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to facilitate the extension of mining at the existing Glendell Mine.

There is an existing site water and salt balance model for the Mount Owen Complex, which forms part of the Greater Ravensworth Area Water Balance Model (GRAWBM). The potential impacts of the Project were assessed against this model.

1.2 Purpose

The purpose of this report is to summarise the modelling methodology and input data used in the water and salt balance modelling undertaken as part of the Surface Water Impact Assessment for the Project. This report is intended to be read only as an appendix to the Surface Water Impact Assessment.

The methodology common to all water and salt balance modelling undertaken as part of the Surface Water Impact Assessment is described in Section 2, with further details on input data specific to the Mount Owen Complex site water and salt balance modelling included in Section 3. An assessment of the uncertainty inherent in the data used in the modelling is summarised in Section 4.

2. Modelling methodology

2.1 Water and salt mass balance

A water and salt balance model was a semi-lumped mass balance. For each water storage, at each time step, the inflow, outflows and change in water volume were calculated under the assumption of conservation of mass. The water balance model was coupled with a salt mass balance model. The mass of salt in each storage and mass flux of each transfer was modelled assuming complete and instantaneous mixing. A conceptual illustration of the relationship between the water and salt mass balance is shown in Figure 2-1.

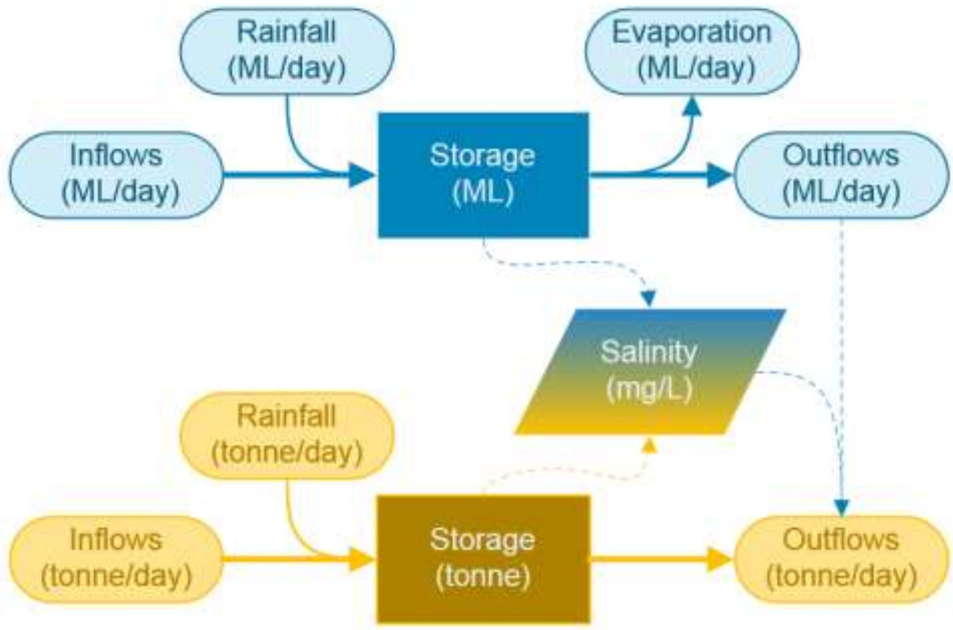

Figure 2-1 Conceptual water and salt mass balance

2.2 Hydrological model

The Australian Water Balance Model (AWBM), as described in Boughton (1993), was used to estimate catchment runoff. The AWBM is a partial area saturation overland flow model. The use of partial areas divides the catchment into regions (contributing areas) that produce runoff during a rainfall-runoff event and those that do not. These contributing areas vary within a catchment according to antecedent catchment conditions, allowing for the spatial variability of surface soil moisture storage in a catchment. The use of the partial area saturation overland flow approach is simple, and provides a good representation of the physical processes occurring in most Australian catchments (Boughton, 1993). This is because daily infiltration capacity is rarely exceeded, and the major source of runoff is from saturated areas. A schematic layout of the AWBM is shown in Figure 2-2.

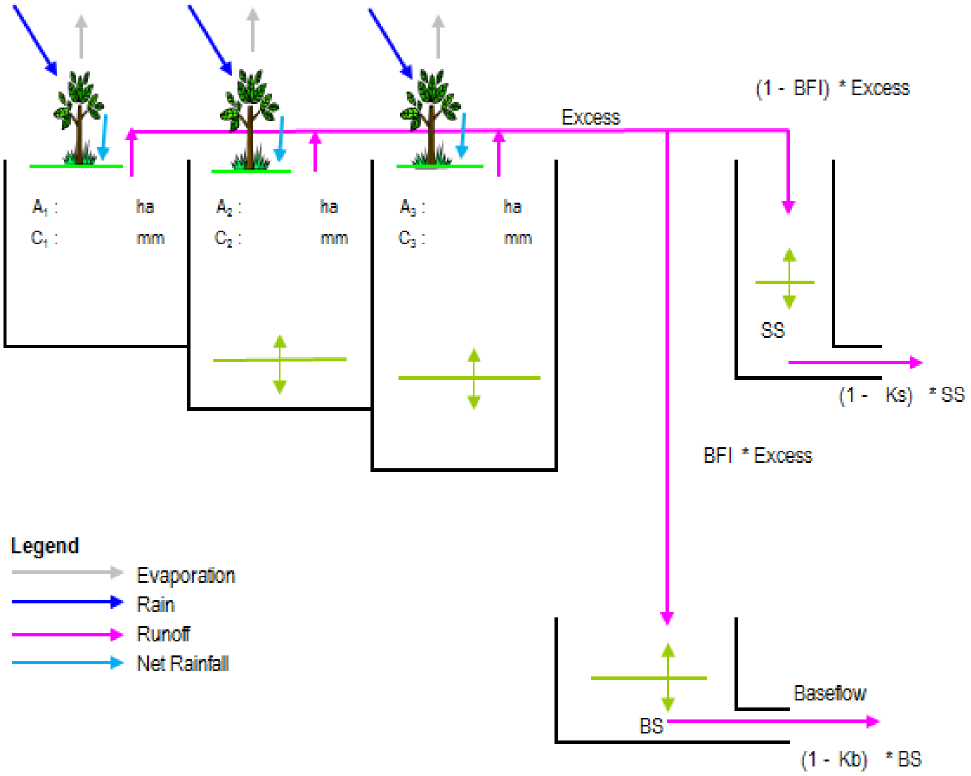

Figure 2-2 AWBM model schematic

Figure 2-2 shows that for an individual catchment, the model consists of three soil moisture stores (with surface areas A_1, A_2 and A_3). Rainfall enters these storages and once a storage element is full, any additional rainfall is considered excess rainfall. Of this excess rainfall a proportion is routed to the baseflow storage (BS) while the remainder is routed to the surface storage (SS). The discharge from the baseflow storage and surface storage is calculated using the respective recession constants. The total runoff is the sum of the outflow from these two storages. The definition of the parameters used in the AWBM is provided in Table 2-1.

Table 2-1 AWBM parameters

Parameter	Description
A_1, A_2, A_3	The partial areas of the overall catchment contributing to storages 1, 2 and 3 respectively.
C_1, C_2, C_3	The capacity of storages 1, 2 and 3 respectively.
BFI	The proportion of excess rainfall flowing to the baseflow.
K_b	The proportion of the volume of the baseflow storage remaining in the storage at the end of each day.
K_s	The proportion of the surface storage remaining in the storage at the end of each day.

2.3 Climatic variability

In order assess the variability of the results due to the key climatic variables of precipitation and potential evapotranspiration, the historical record was used to simulate a series of 130 climatic sequences, or realisations. Each realisation began with a different year of the historical record, to maintain seasonality. The historical record was looped where required. This series of realisations collectively constituted the "probabilistic" climatic conditions and therefore the results were interpreted statistically.

2.4 Numerical implementation

The water and salt balance model was implemented using GoldSim 12.1. GoldSim is computer simulation software widely used for mine site water balance studies. GoldSim uses the forward Euler method to solve the ordinary differential equations derived from the mass balance model described in Section 2.1. A basic timestep of 1 day was used, consistent with the daily rainfall data used in the model.

3. Site water and salt balance data

3.1 Catchment runoff

The catchment areas and land uses were derived from the conceptual water management system included in the Surface Water Impact Assessment.

The adopted AWBM parameter values for the different land use types at the Mount Owen Complex are summarised in Table 3-1.

Table 3-1 Adopted AWBM parameter values

Land use type	C1	C2	C3	A1	A2	A3	BFI	Kb	Ks
Hardstand	5.0	5.0	0.0	0.5	0.5	0.0	0.0	NA	0.0
Undisturbed	9.0	92.2	184.4	0.134	0.433	0.433	0.25	0.978	0.5
Open cut	5.0	22.0	0.0	0.1	0.9	0.0	0.0	NA	0.2
Tailings	0.0	20.0	0.0	0.2	0.8	0.0	0.0	NA	0.0
Spoil	17.6	167.5	0.0	0.05	0.95	0.0	0.7	0.975	0.1
Rehabilitation	9.0	75.0	140.0	0.1	0.3	0.6	0.25	0.978	0.2

3.2 Water storage properties

For minor storages for which stage storage relationships based on bathymetry or survey data were not available, the geometry was approximated using the power law relationships described in Brooks and Hayashi (2002). This approach is considered suitable for estimating evaporation losses from water storages that are typically maintained at low levels or empty.

This approximation was validated by fitting the known storage - surface area relationships for two storages at the Mount Owen Complex, Dam 22 and FWD to the geometric approximation. The validation is shown in Figure 3-1, which indicates that the power law approximation provides a reasonable fit to the known storage - surface area relationships.

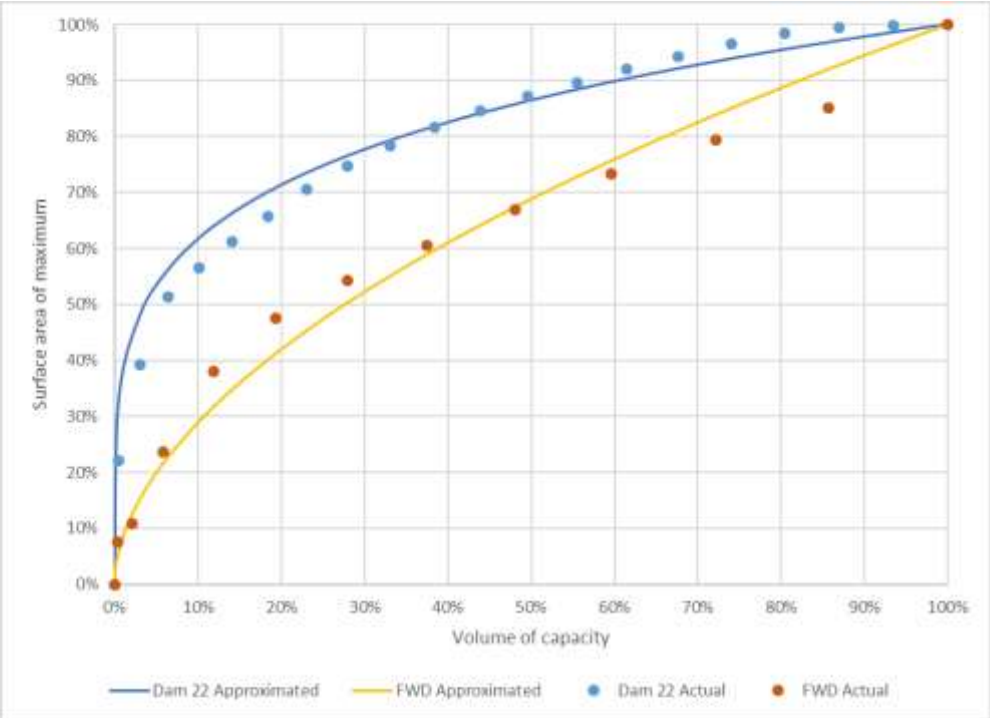

Figure 3-1 Validation of geometric approximation

For major storages, the stage storage relationship based on bathymetric survey was used. The largest water storage currently at the Mount Owen Complex is West Pit. A stage storage relationship for West Pit was derived from bathymetric survey (conducted in June 2016) up to 12 m AHD and extended with analysis of existing land surface up to an assumed spill level of 85 m AHD. The relationship is plotted in Figure 3-2.

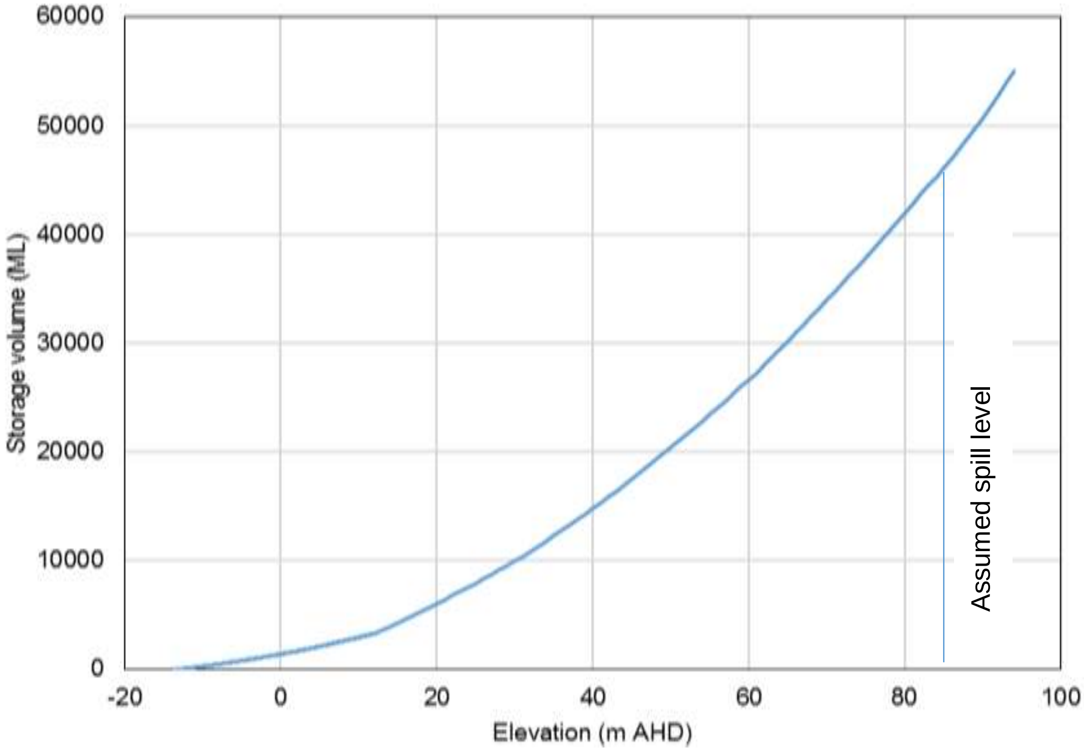

Figure 3-2 West Pit stage storage relationship

To account for the change in water surface area as West Pit is filled with tailings, the volume of tailings at the base of West Pit was simulated based on the tailings production schedule and an assumed tailings dry density of 0.7 tonne/m^3. A plot of the simulated elevation of the surface of the tailings in West Pit is shown in Figure 3-3.

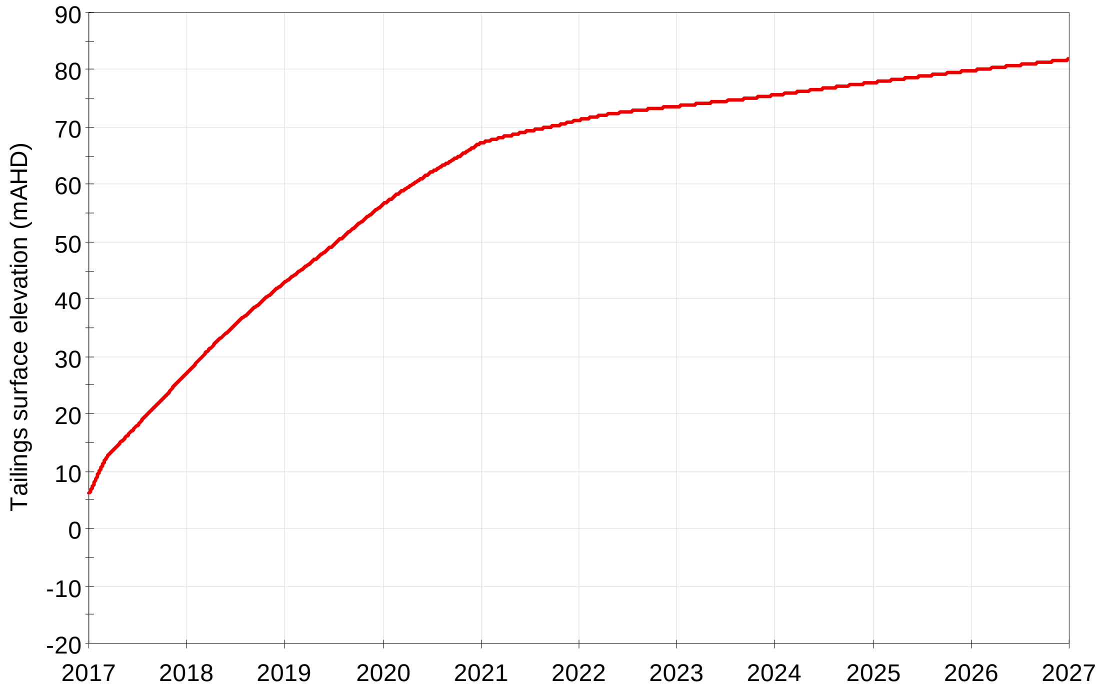

Figure 3-3 Modelled tailings surface elevation

3.3 Salinity

The salinity of surface water sources are summarised in Table 3-2. These parameters represent average salinity in runoff from this surface over the time the material is at the surface and does not correspond directly with salinity of the water entrained in the material at one particular time.

Table 3-2 Summary of surface water salinity

Water source	Salinity as TDS (mg/L)
Direct rainfall	20
Runoff from natural surfaces	250
Runoff from rehabilitated surfaces	1000
Runoff from hardstand surfaces	1500
Runoff from tailings	1500
Runoff from spoil	2000
Runoff from open cut pits	2000
Imports from GRAWTS	3300
Imports from Integra	5360
Imports from Glennies Creek	350

Some water quality monitoring data used in the development of the salt balance model was reported as electrical conductivity; however, the salt mass balance requires gravimetric concentrations. The actual conversion factor is a property of the chemistry of the water, which may vary for different sources. In the absence of data to derive a source specific relationship, an uniform conversion factor 0.67 (mg/L)/(µS/cm) was adopted (Watling 2007).

4. Uncertainty assessment

4.1 Site water and salt balance

The results of the site water and salt balance modelling are subject to uncertainty, associated with climatic variability, groundwater modelling predictions and operational rules. The modelling results consider a wide range of climatic conditions foreseeable based on the historical record. The GRAWTS is subject to annual reviews at each of the constituent sites, so there is higher than industry average confidence in the model parameters adopted for hydrological and tailings consolidation processes. The groundwater inflow predictions are subject to uncertainty as described in the Groundwater Impact Assessment (AGE 2019), however, this is a minor component of the site water and salt balance, and therefore the overall results are not considered sensitive to this uncertainty. Other key inputs to the modelling, such as catchment areas and water storage volumes are based on spatial measurement of existing or design quantities, and are considered to have a low level of uncertainty.

A key outcome of the site water and salt balance modelling is the forecast water inventory relative to the maximum water storage capacity, which in turn affects the potential for the Project to affect the GRAWTS discharges under the HRSTS. Given the magnitude of ratio between these quantities over the Project, this outcome is considered insensitive to the uncertainties of the site water and salt balance model.

4.2 Final void water and salt balance

The results of the quantitative modelling are considered suitable for comparative purposes only, as they are subject to considerable uncertainty, not in the least due to the long forecast period required. The key driver of uncertainty are the predicted groundwater flows, as discussed in AGE (2019), which drive the water level recovery. The uncertainty due to the surface water elements are considered secondary, as the results are less sensitive to these elements and these elements are based on directly measurable quantities: rainfall, evaporation and catchment area. This uncertainty does not detract from the expected qualitative behaviour of the system, as a hydraulic sink, and increasing trend in TDS over time due to evapoconcentration.

4.3 Creek hydrology

The results of the quantitative modelling of the low flow regimes within the creeks are subject to varying levels of uncertainty.

- For the ephemeral minor streams, Yorks Creek, Swamp Creek and Bettys Creek, the results are considered suitable as indicative estimates, as no suitable stream flow record exists to validate the stream flow estimates. As any impacts to these catchments are expected to be proportional to changes to catchment area, this approach is considered adequate.
- For the major regulated streams, Glennies Creek and the Hunter River, the only potential impacts relate to baseflow changes, which are subject to the uncertainty described in the Groundwater Impact Assessment (AGE 2019). However, given the relative magnitude of these estimates to the directly measured stream flow, the key outcomes are not considered sensitive to these uncertainties.

- For Bowmans Creek, the results are considered as indicative estimates, as an adequate fit between the observed and modelled flows in Bowmans Creek was not achieved (refer to Section 8.5 of the Surface Water Impact Assessment). As the changes to catchment areas are small compared to the total catchment of Bowmans Creek, the dominant driver of uncertainty is the baseflow estimates, which are subject to the uncertainty described in the Groundwater Impact Assessment (AGE 2019).

5. References

Brooks & Hayashi (2002) Depth-area-volume and hydroperiod relationships of ephemeral (vernal) forest pools in southern New England. *Wetlands, 22*(2), pp. 247-255.

Watling, K. (2007) *Measuring Salinity*, The State of Queensland (Department of Natural Resources and Water).

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2219708-32855/https://projects.ghd.com/oc/newcastle1/glendellcontinuedope/Delivery/Documents/2219708-REP-GCOP-Water_and_Salt_Balance_Modelling.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	T Tinkler	S Gray	SGray	S Gray	SGray	20/11/2019

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Appendix C – Flooding Assessment

Umwelt (Australia) Pty Ltd

Glendell Continued Operations Project
Flooding Assessment

November 2019

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Appendices

1. Introduction

1.1 Background

Glendell Mine is an open cut coal mine that is part of the Mount Owen Complex located in the upper Hunter Valley of NSW, located approximately 20 km north-west of Singleton and 24 km south-east of Muswellbrook.

Glendell Tenements Pty Ltd (the Proponent) proposes to extend open cut mining operations north from the current Glendell Mine as part of the Glendell Continued Operations Project (the Project). This assessment forms part of an environmental impact statement (EIS) to support a State significant development (SSD) application under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) to facilitate the extension of mining at the existing Glendell Mine.

The Project has the potential to have an impact on the surrounding surface water environment. This includes the permanent realignment of Yorks Creek, resulting in changes to catchments, flood regimes and flooding behaviour. To quantify the magnitude and extent of any potential impacts resulting from the Project, a flood assessment has been undertaken. This includes hydrological models of the greater Bowmans Creek catchment and hydraulic models incorporating the Glendell Mine, important infrastructure and nearby landowners. The study area and model extents are presented in Figure 1-1.

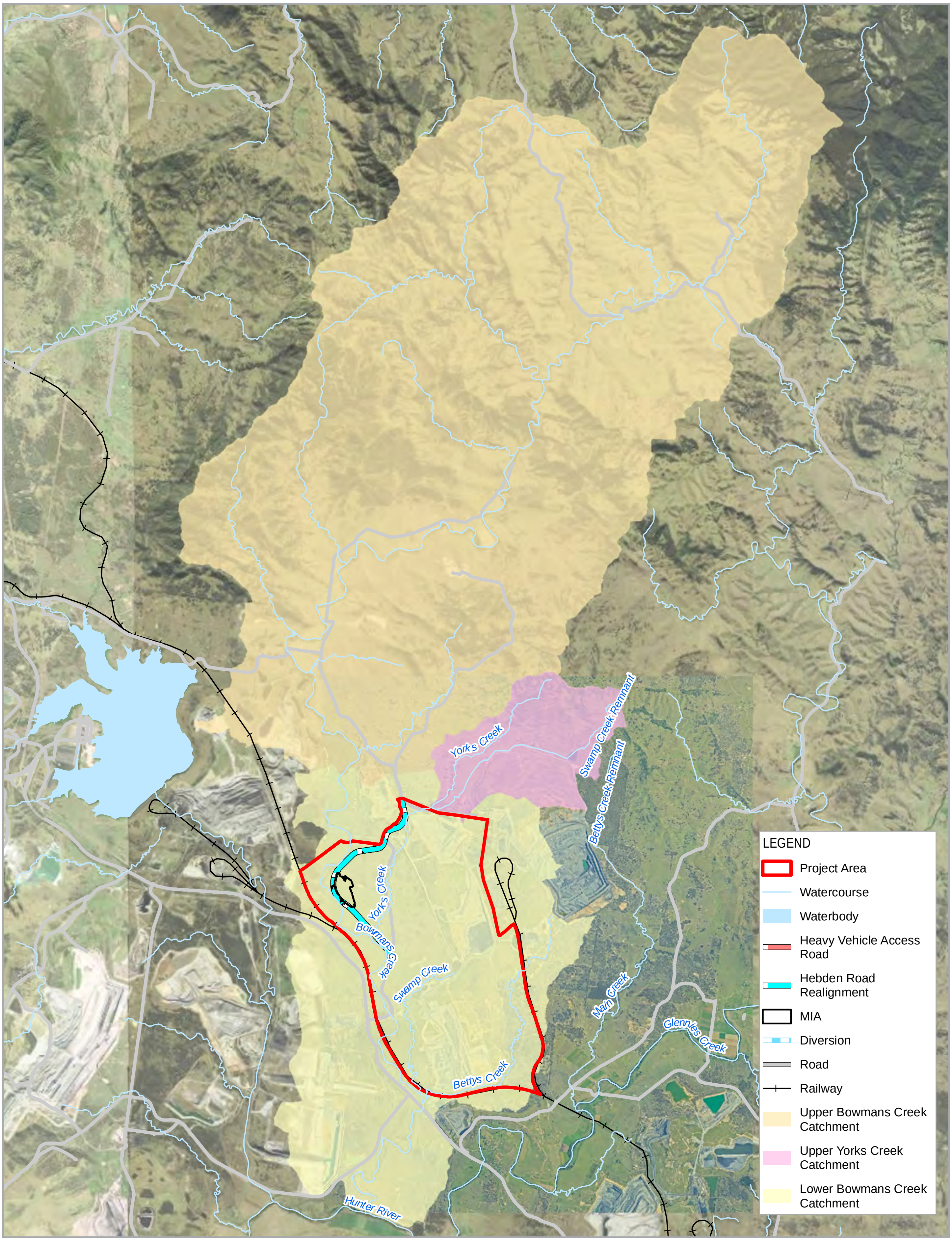
1.2 Purpose of this report

The purpose of this report is to summarise the flooding assessment. This includes the assumptions, input and methodology used to develop the models and their outcomes.

1.3 Assumptions

The following modelling assumptions have been made.

- To model the conservative case for potential flooding impacts, all water storages in the water management system were assumed to be full at the commencement of the design flood event, with the exception of final voids and open cut pits. In reality, the Mount Owen Complex water management system will retain and manage water from flood events without discharge, up to the relevant design criteria.
- The model results use a depth cut off of 50 mm. The raw modelling results for all variable were removed from the presented results in areas were the modelled flood depth was less than 50 mm. This is to screen out negligible flood areas within the modelling margin of error.
- The earthworks associated with the Heavy Vehicle Access Road and Glendell Mine Infrastructure Area (MIA) remain in the proposed conceptual final landform.
- The Main Northern Railway has a design criteria for flooding of at least 1% AEP.



Paper Size ISO A4

0 0.95 1.9 2.85 3.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding assessment

Flood model extent

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE 1-1

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

2. Input data

2.1 Elevation data

Several sources of elevation data and geometry were used to perform both the hydrologic and hydraulic modelling. These data, including the source and date received, are outlined in Table 2-1.

Table 2-1 Elevation data

Elevation data	Source	Date received
SRTM-derived hydrological 1 second digital elevation model (taken 2000)	FSDF 2019	12/09/2018
1 m and 2 m LiDAR (taken 2017)	FSDF 2019	12/09/2018
5 m proposed landform contours (2019, 2026, conceptual final landform)	Provided by Umwelt	13/12/2018
Yorks Creek Realignment design	Provided by Glencore	13/06/2019
Hebden Road realignment design	Provided by Glencore	13/06/2019
Heavy Vehicle Access Road design	Provided by Glencore	13/06/2019
Glendell Mining Infrastructure Area (MIA) earthworks design	Provided by Glencore	13/06/2019

2.2 Rainfall data

This study assessed the 10%, 5%, 1%, 0.5%, 0.2% and Probable Maximum Flood (PMF) Annual Exceedance Probability (AEP) events for durations of 15 minutes up to 168 hours. The 10%, 5% and 1% AEP events were modelled to assess flooding impacts under likely conditions. The 0.5% and 0.2% AEP events were modelled to assess flooding impacts under potential climate change conditions. The PMF was modelled to assess the maximum extent of potential flood impacts.

2.2.1 Rainfall depths and IFDs

Rainfall depths for the 10%, 5%, 1%, 0.5% and 0.2% AEPs were sourced from the Australian Bureau of Meteorology 2016 Intensity-Frequency-Duration (IFD) dataset (BOM 2019). PMF rainfall depths were determined using the GSAM (BOM 2006), GSDM (BOM 2003a) and GTSMR (BOM 2003b) guidelines. The adopted rainfall depths are presented in Figure 2-1, showing design durations up to 36 hours that were considered following preliminary modelling indicating that this provided a sufficient upper bound on the critical duration. Spatial distribution of rainfall depths was accounted for by the application of areal reduction factors calculated from parameters that were obtained from the ARR data hub.

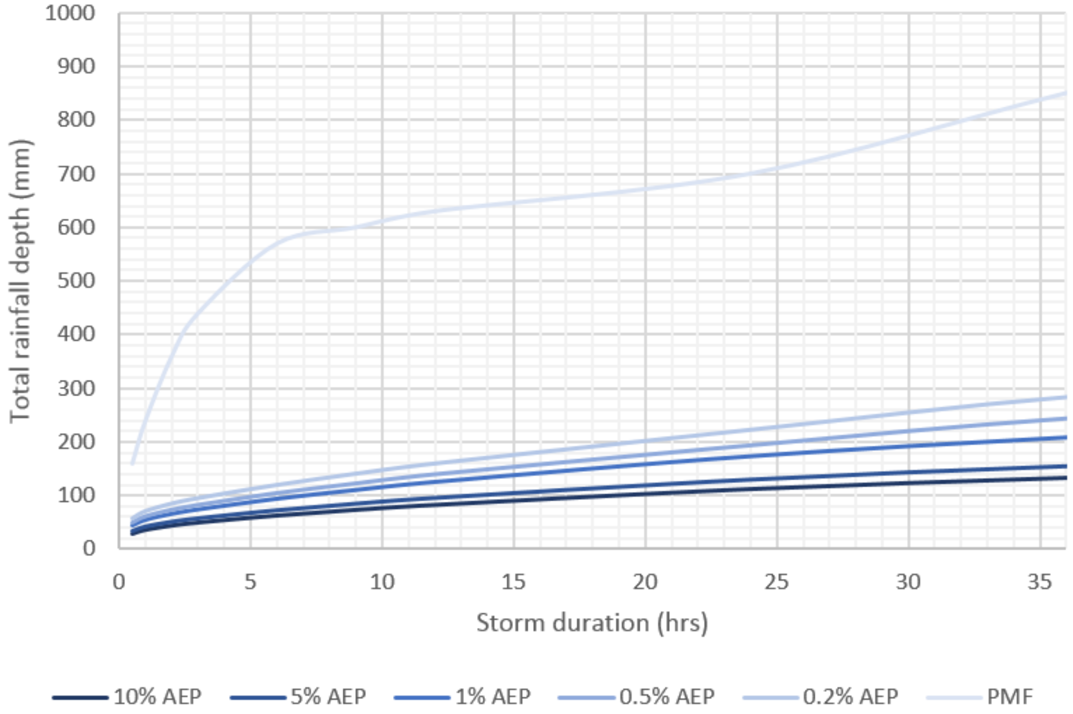


Figure 2-1 Total rainfall depth vs storm duration

2.2.2 Temporal patterns

Ensemble temporal patterns were applied to each duration as recommended by the ARR 2016 guidelines (Ball et al 2016). The 10%, 5% and 1% AEP events applied areal temporal patterns sourced from the ARR 2016 data hub. The 0.5%, 0.2% and PMP applied ensemble temporal patterns sourced from Jordan et al (2005) for short and intermediate durations (3 to 18 hours) and GTSMR for longer durations.

2.2.3 Pre-burst depths

The pre-burst rainfall depths adopted by the modelling are presented in Figure 2-2. The 10% to 1% AEP pre-burst depths were all obtained from the ARR (2016) data hub. The pre-burst depths for the 0.5% AEP and 0.2% AEP were obtained by extrapolations along a log-log distribution between the 1% AEP pre-burst depths (from ARR data hub) and the PMP pre-burst depths (assumed to be equivalent to the initial loss value). This is considered a conservative method in ARR 2016 by which to determine the pre-burst depths for very rare to extreme events.

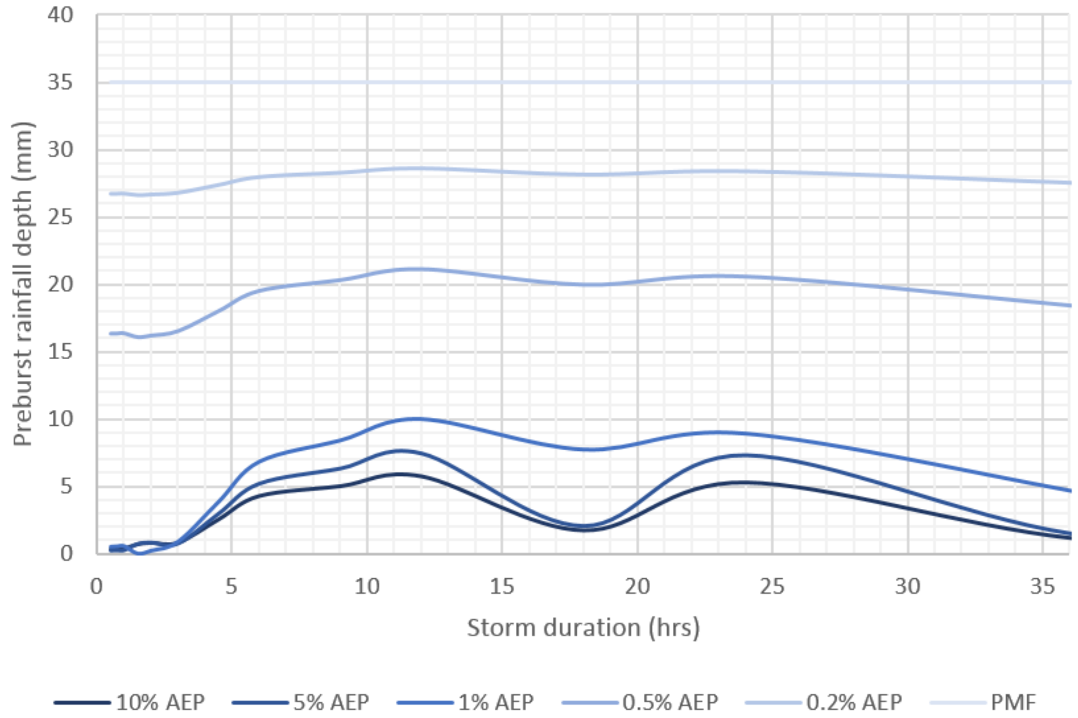


Figure 2-2 Adopted pre-burst rainfall depths

2.2.4 Losses

The initial loss and continuing loss were obtained via calibration of the combined hydrological and hydraulic models to a flood frequency curve developed from 24 years of observational data at the downstream Bowmans Creek gauge (210130). Annual maxima series of the observed data at the Bowmans Creek gauge was used to develop a Gumbel distribution from which the expected water level for each design event could be estimated. The Gumbel distribution is used to model the distribution of maximum of a number of sample of various distributions. Models were subjected to the rainfall depth, pre-burst depths and median temporal patterns described above and the initial and continuing losses adjusted until a reasonable fit could be achieved. The estimated water level distribution and the levels resulting from the calibration process at the Bowmans Creek gauge are presented in Figure 2-3.

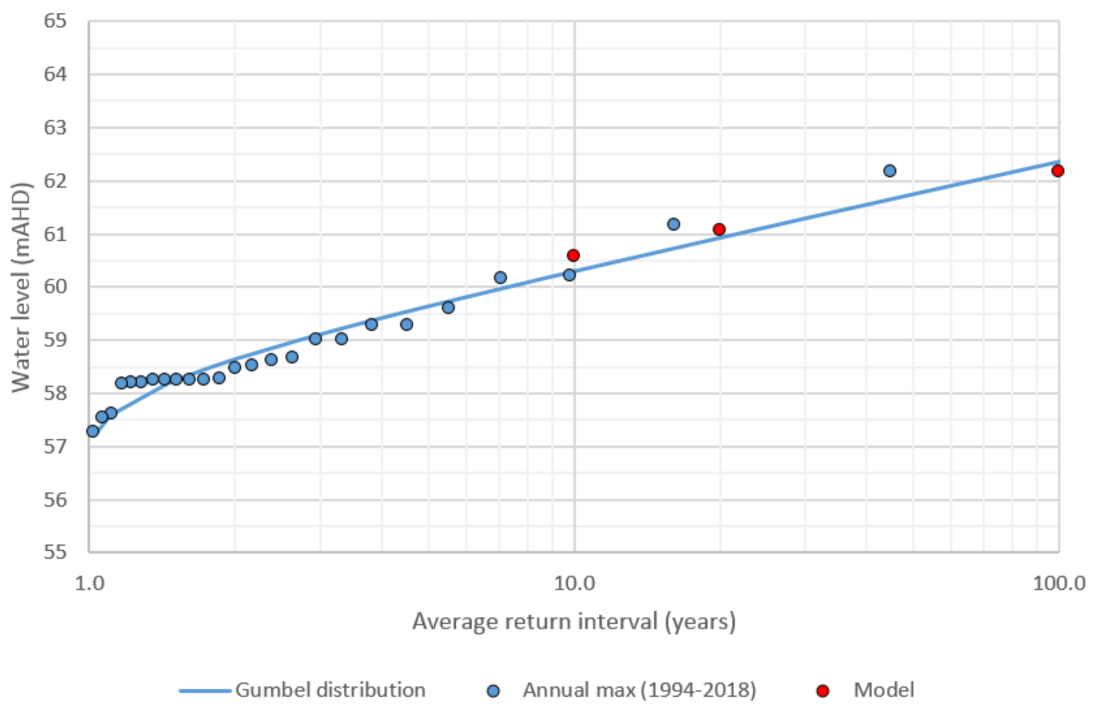


Figure 2-3 Gumbel distribution of annual maxima series at Bowmans Creek gauge vs the calibrated model results

The loss parameters yielded from the calibration process and adopted in the modelling are presented in Table 2-2.

Table 2-2 Adopted loss parameters

Parameter	Value
Pervious initial loss (mm)	35.0
Pervious continuing loss (mm/hr)	2.0
Impervious initial loss (mm)	1.5
Impervious continuing loss (mm/hr)	0.0

2.3 Land use data

The channel and catchment roughness adopted in both hydrological and hydraulic models were sourced from averages of the ARR 2016 recommended values. These are presented in Table 2-3 below.

Table 2-3 Adopted manning's roughness parameters

Catchment material category	Catchment Manning's n
Thick vegetation	0.095
Moderate vegetation	0.06
Mix of moderate to minimal vegetation	0.05
Minimal vegetation/pasture/grass	0.04
Lakes and waterbodies	0.015
Grassed channel	0.03
Partially vegetated channel	0.05

2.4 Culverts and bridges

The hydraulic model incorporated both bridges and culverts. Data for these structures was obtained from a number of sources. The majority of the culvert and bridge data was provided by Glencore, the previous flood modelling (WSP, 2017) or the provided Heavy Vehicle Access Road and Hebden Road realignment designs. Additional bridge and culvert locations not provided by Glencore were identified from the aerial imagery and dimensions estimated from Google Maps photography, aerial imagery and from similar nearby structures. Estimated structures were at the periphery of the model domain or conveyed only minor secondary cross drainage flows. All key major drainage structures for Bowmans Creek, Swamp Creek and Bettys Creek were based on survey or design information. Therefore the results are not considered sensitive to the estimated structures. The culvert and bridge data adopted in the modelling are provided in Appendix A. Blockage factors were estimated based on georeferenced photographs provided by Glencore where appropriate.

3. Methodology

The greater Bowmans Creek catchment is in excess of 21 km^2. This catchment area is too large to efficiently model hydraulically. As a consequence the modelling was divided into two parts:

- A hydrological model of the entire catchment to identify critical durations and temporal patterns and estimates of flood hydrographs from the upstream catchments.
- A 2D hydraulic model of the lower part of the catchment that encompasses the areas potentially affected by the Project.

3.1 Scenarios

Three scenarios at different stages of the mine life were modelled to assess the flooding impacts over time. These included:

- Existing conditions based on the existing landform (2019).
- Proposed conditions (Year 6). The flooding impacts for the Year 13 and Year 18 snapshots are expected to be similar.
- Proposed conceptual final landform.

3.2 Hydrological model

The hydrological model was performed using the program XP-Rafts (Version 2016). It models the entire greater Bowmans Creek catchment all the way to the confluence with the Hunter River. The total extent of the hydrological model is shown in Figure 1-1 and includes the Upper Bowmans Creek, Lower Bowmans Creek and Upper Yorks Creek catchments.

The greater catchment was divided into approximately 40 sub-catchments which were connected by links. The model methodology uses the Laurenson runoff routing procedure coupled with the initial loss and continuing loss determined in the calibration to estimate sub-catchment runoff. Channel routing between sub-catchments adopted the Muskingum-Cunge method which is a function of channel length and cross section.

3.2.1 Input data

Adopted input data such as elevation data, rainfall, losses and roughness are outlined in Section 2.

3.2.2 Catchments

Sub-catchments were delineated using the software program CatchmentSIM from the SRTM-derived hydrological 1 second digital elevation data. CatchmentSIM was also used to extract other input data for the XP-Rafts model including, slopes and river reach lengths.

3.2.3 Model structure

The structure of the model sub-catchments and links are presented in Figure 3-1 to Figure 3-4. A separate XP-Rafts model was constructed for each of the three scenarios. The Upper Bowmans Creek and Upper Yorks Creek catchment presented in Figure 3-1 remained unchanged between the three scenarios. The most significant catchment changes between scenarios occur in the Lower Bowmans Creek catchment. This area includes mining activities including the northward progression of the Glendell Pit Extension and progressive rehabilitation of the Glendell Pit Extension emplacement area result in changing catchment morphology.

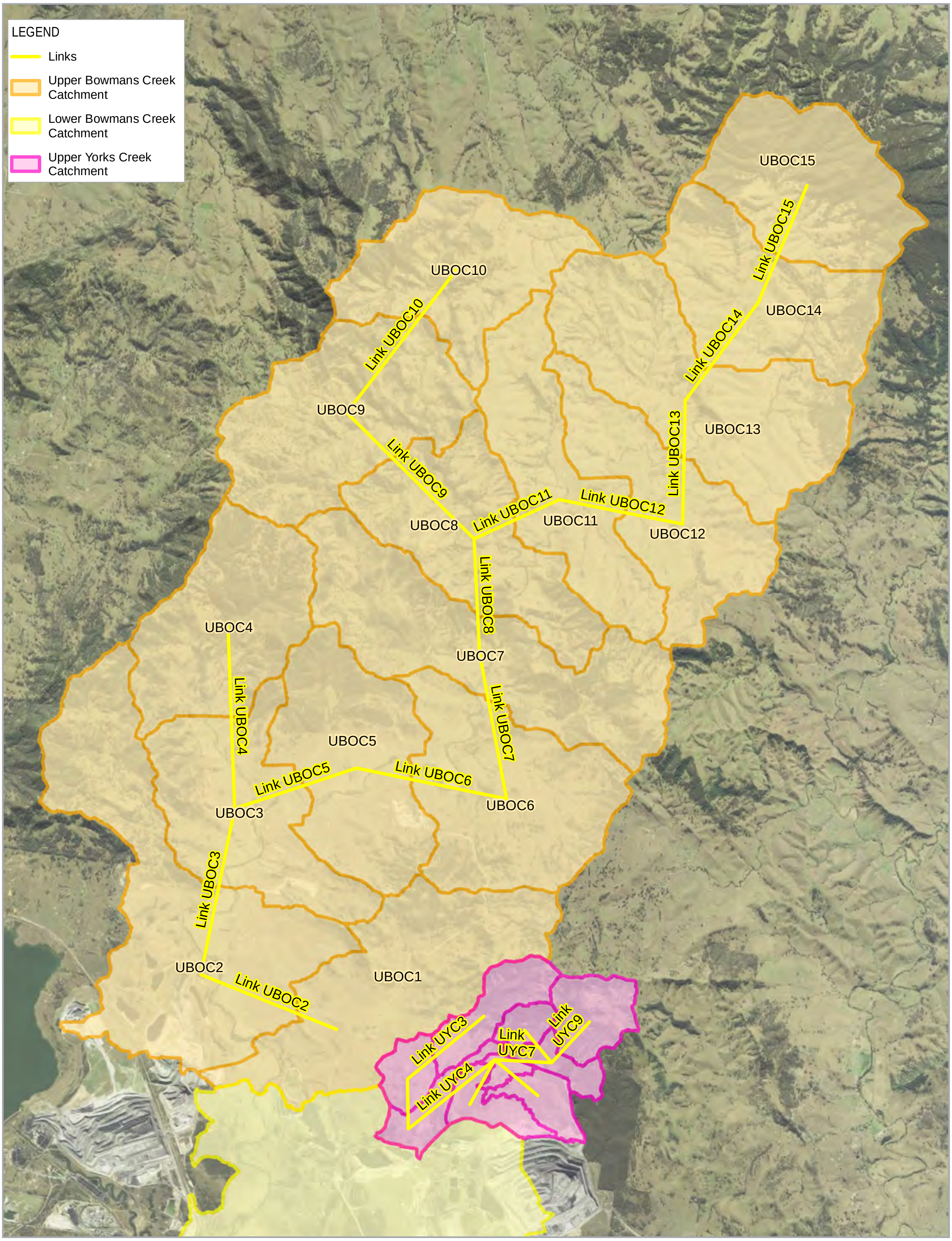
The sub-catchment and link structure adopted in the XP-Rafts model for the existing conditions, proposed conditions (Year 6) and the proposed conceptual final landform are presented in Figure 3-2, Figure 3-3 and Figure 3-4 respectively. The rehabilitation of mining disturbance in AGL-Macquarie owned land and Ravensworth Operations to the west of the lower Bowmans Creek results in a significant addition of catchment area in the proposed conceptual final landform.

Input data for each sub-catchment and link is provided in Appendix B.

3.2.4 Modelling procedure

The hydrological model was used to identify the critical duration events and provide inflow hydrograph data at upstream boundaries. Each model was run for the full set of duration and temporal pattern combinations described in Section 2. The critical durations (durations resulting in the highest peak flow) at a range of sub-catchments were identified. Associated model output data from each critical duration such as rainfall and inflow hydrographs at boundaries were exported for use in the hydraulic models. The locations from which critical durations were identified included:

- Upper Yorks Creek catchment outlet (UBOC1)
- Upper Bowmans Creek catchment outlet (UYC1)
- The confluence of Bowmans Creek and Yorks Creek (BOC3, BOC5 or BOC6)
- Outlet from the Mount Owen Complex site during rare flood events (MS1 under existing conditions; BEC4 under proposed conditions)
- Swamp Creek outlet (SC1)
- Bettys Creek outlet (BEC1)
- The confluence of Bowmans Creek with the Hunter River (HR1)



Paper Size ISO A4

0 0.7 1.4 2.1 2.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

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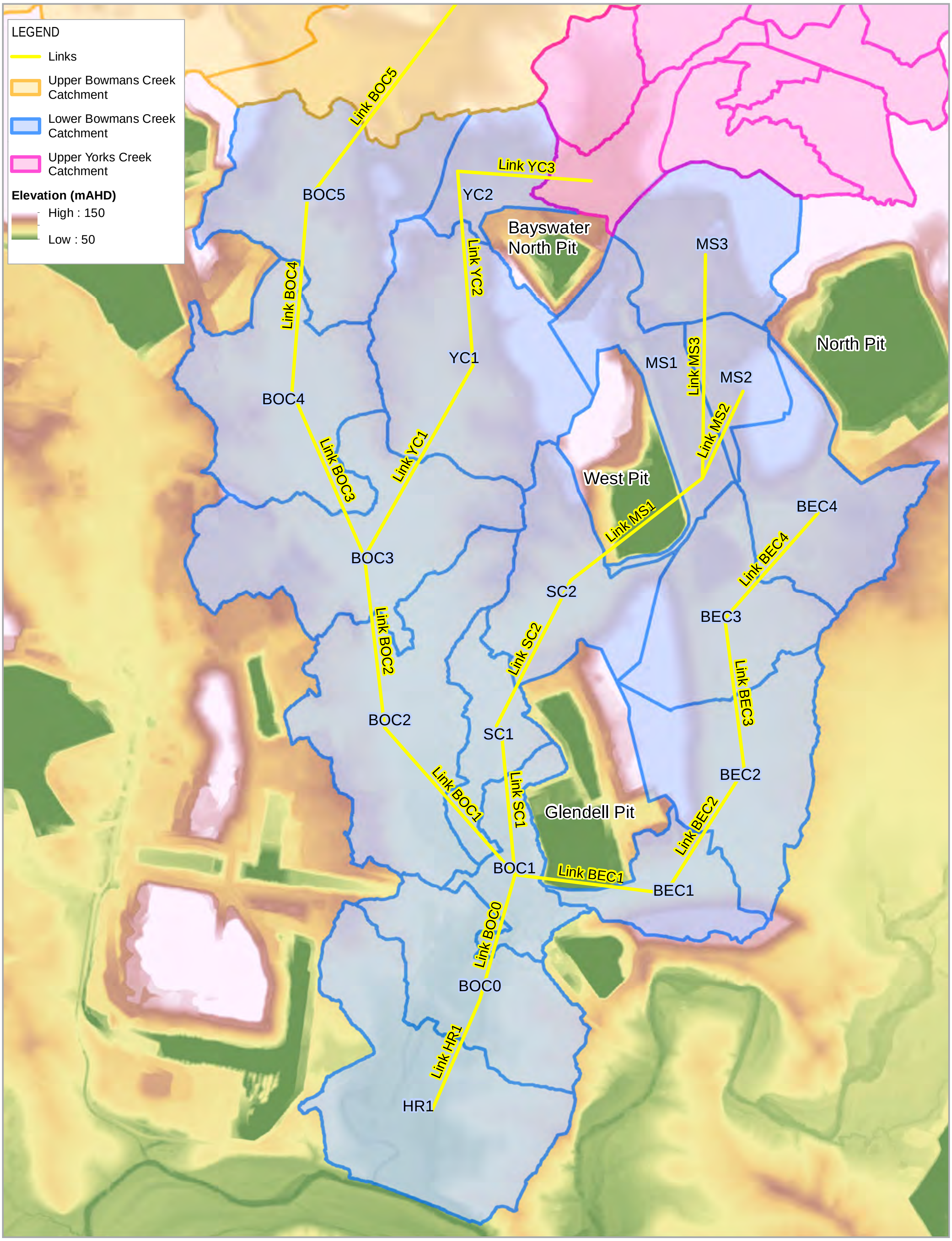
Flooding Assessment

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

Hydrologic model
Upper Bowmans Creek and Yorks Creek

FIGURE 3-1

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton



Paper Size ISO A4

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

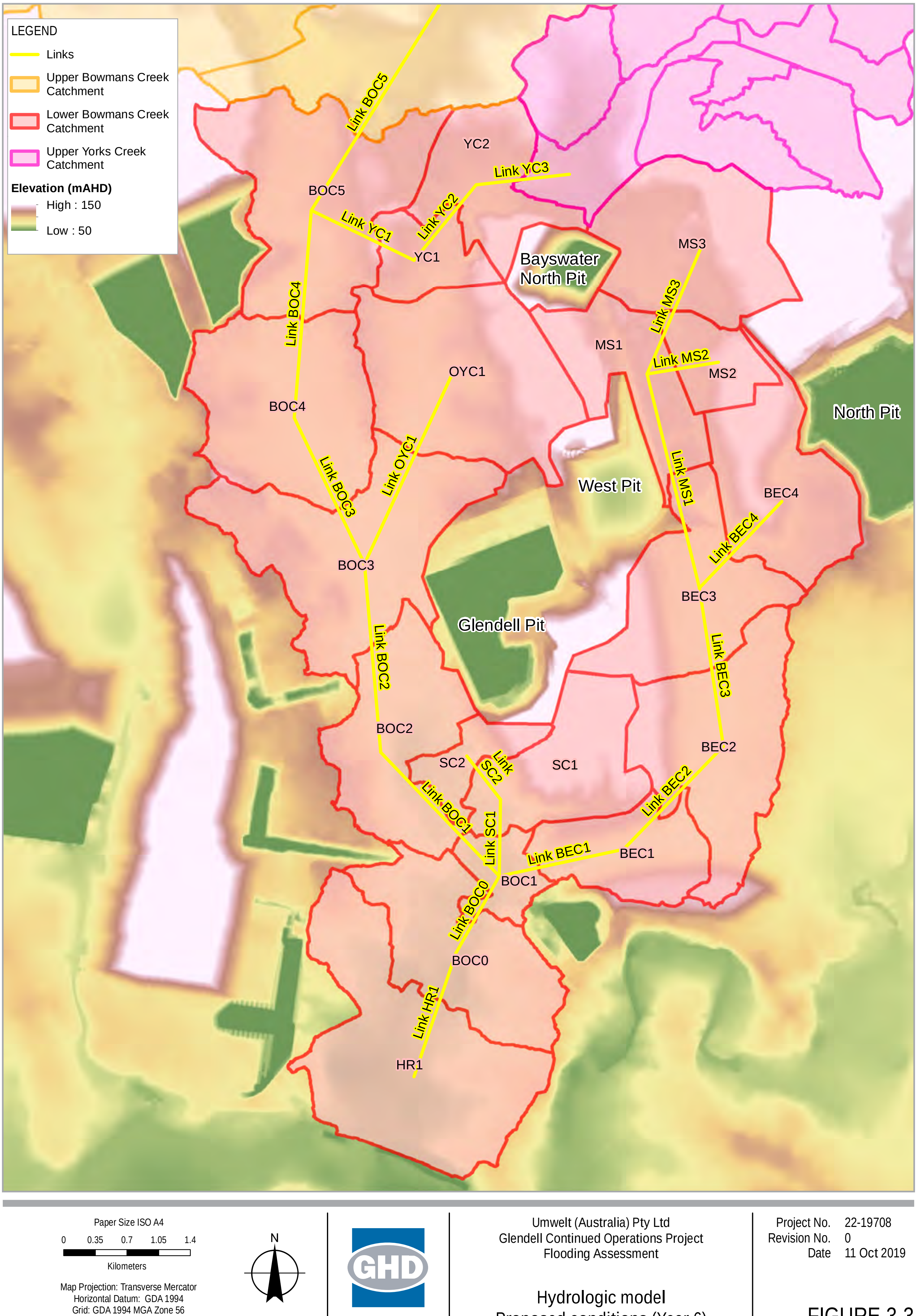
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Hydrologic model
Existing conditions

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE 3-2

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton



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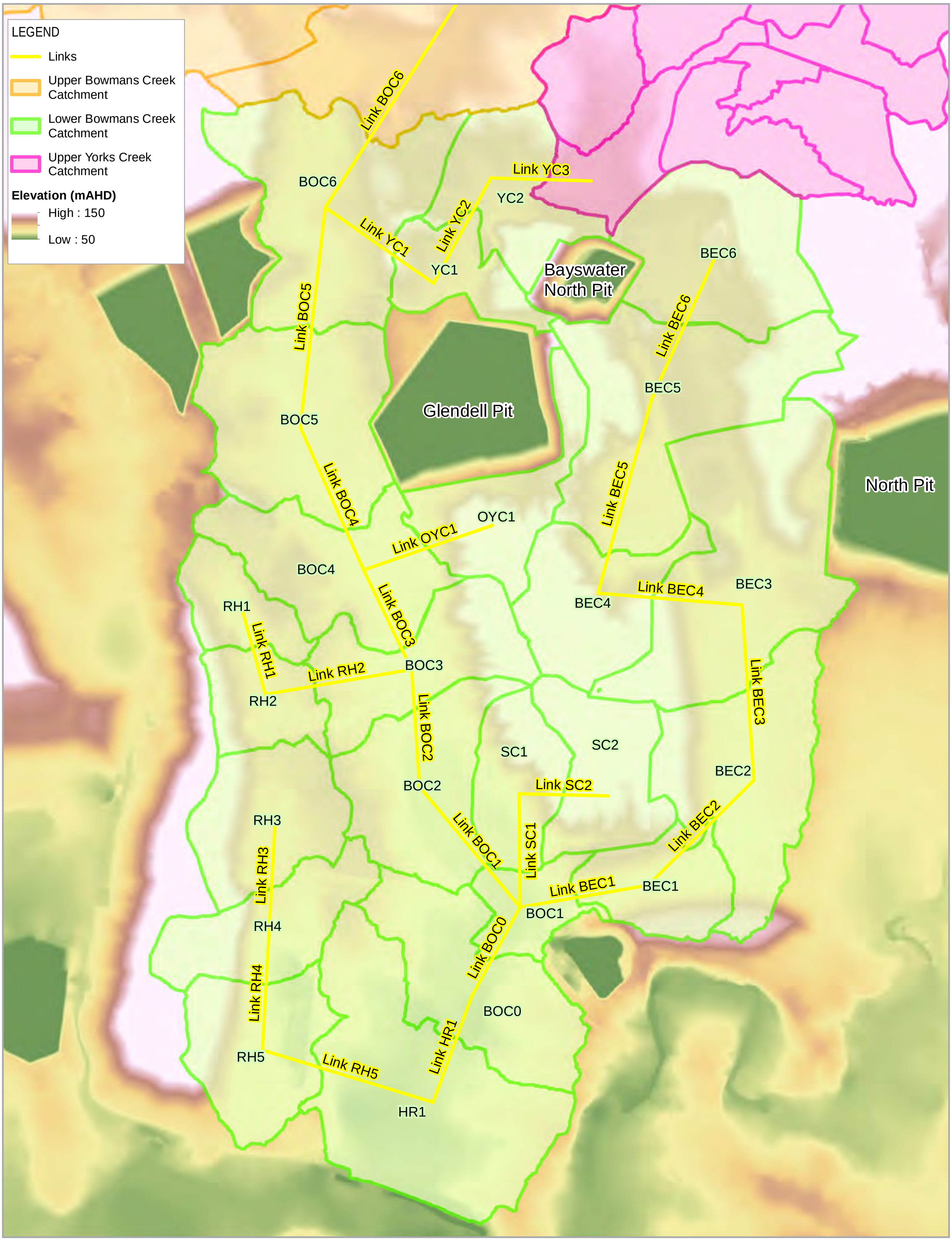
Glendell Continued Operations Project
Flooding Assessment

Hydrologic model
Proposed conditions (Year 6)

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE 3-3



Paper Size ISO A4

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Hydrologic model
Proposed conceptual final landform

Project No. 22-19708
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Date 11 Oct 2019

FIGURE 3-4

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. © Department of Finance, Services & Innovation 2017. Created by: kpsroba, tmorton

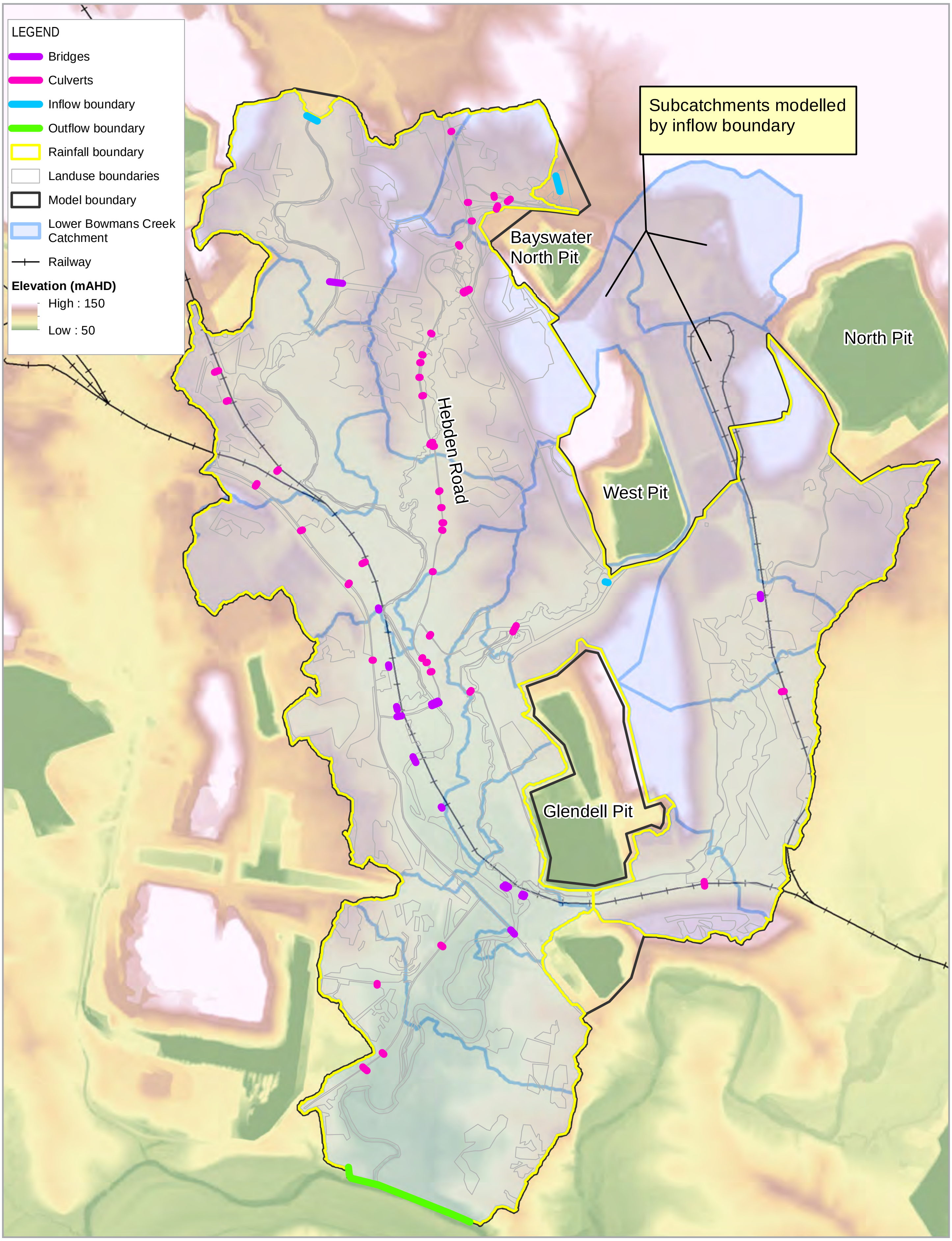
3.3 Hydraulic model

The 2D hydraulic modelling was simulated using the Heavily Parallelised Compute (HPC) method in the software program TUFLOW (Version 2018). TUFLOW is an implementation of the numerical 1D and 2D solutions of the free surface flow equations to simulate flood and tidal wave propagation. A rain on grid approach was used and a 5 m grid size adopted. The hydraulic model was limited to the Lower Bowmans Creek catchment as to enable efficient computation.

Each TUFLOW model consists of the following input files:

- Bridges and culverts
- Inflow boundary conditions
- Outflow boundary conditions
- Rainfall boundary
- Landuse boundary
- Model boundary

The TUFLOW model configurations for each of the scenarios modelled are presented in Figure 3-5 to Figure 3-7.



Paper Size ISO A4

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

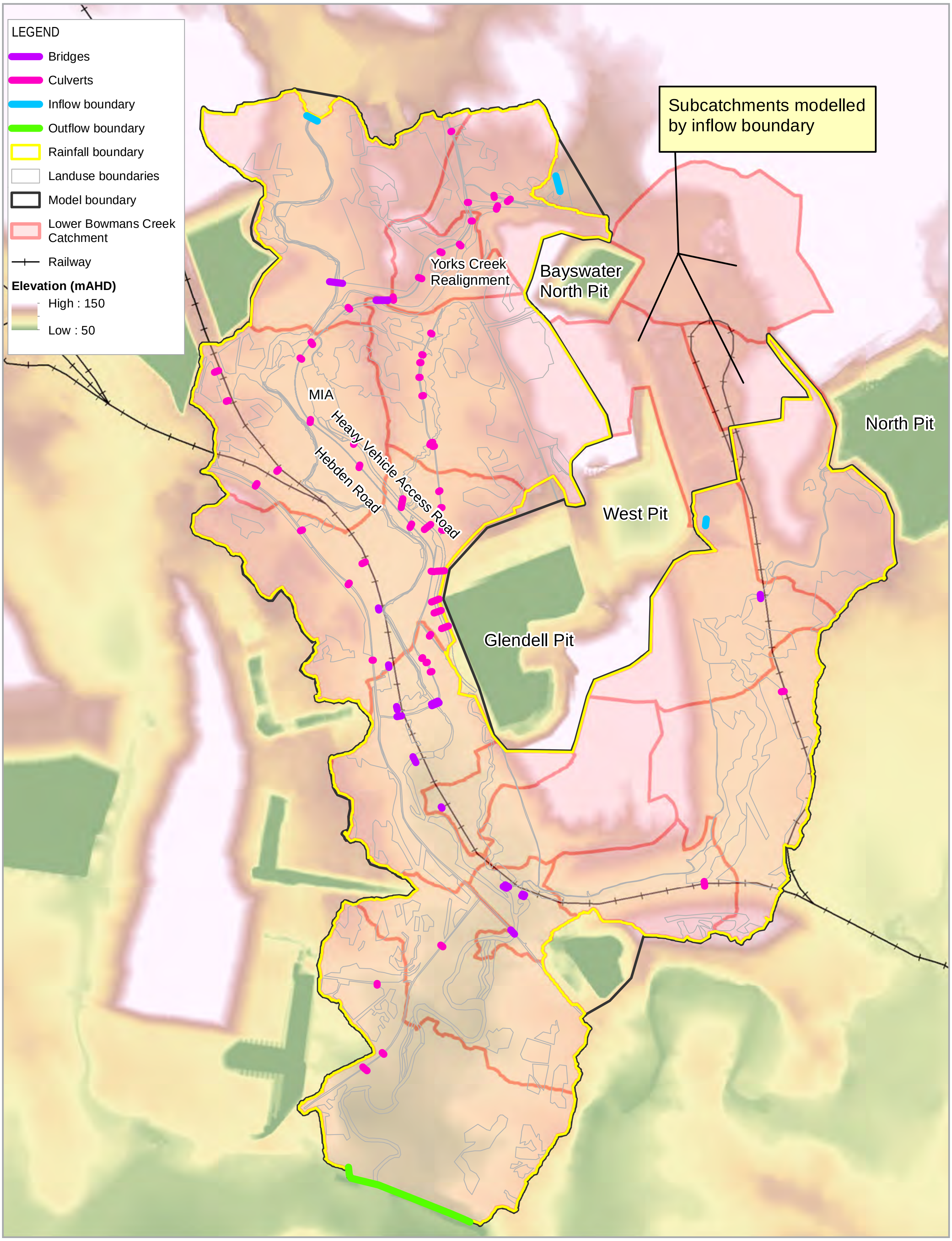
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Hydraulic model
Existing conditions

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE 3-5

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. . Created by: kpsroba, tmorton



Paper Size ISO A4

0 0.35 0.7 1.05 1.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

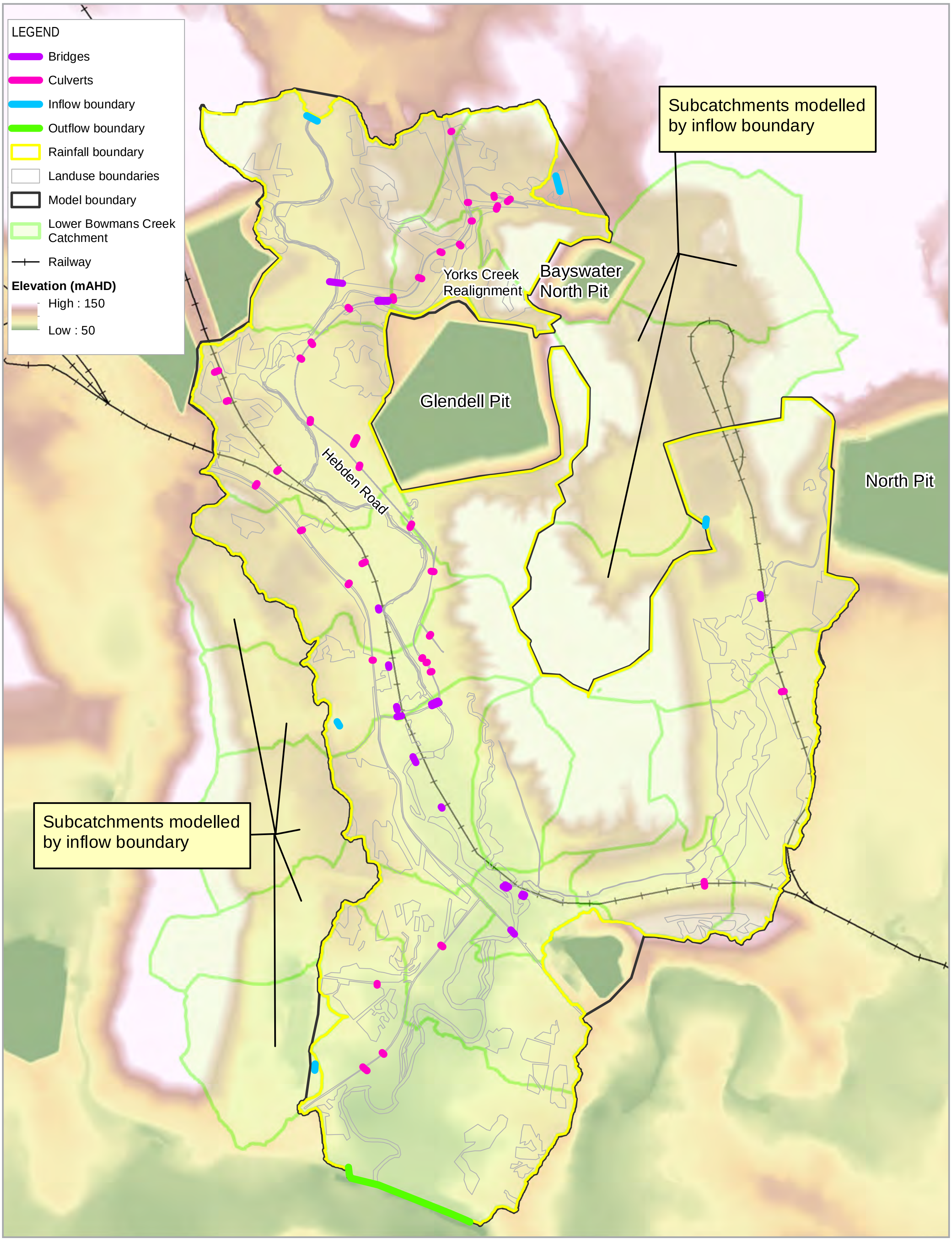
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Hydraulic model
Proposed conditions (Year 6)

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE 3-6

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. . Created by: kpsroba, tmorton



Paper Size ISO A4

0 0.35 0.7 1.05 1.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Hydraulic model
Proposed conceptual final landform

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE 3-7

Data source: Glencore: MOCO, 2016. Umwelt: Aerial imagery, 2018. LPI: DTDB, 2017. . Created by: kpsroba, tmorton

3.3.1 Bridges and culverts

Culverts and bridges were digitised into the TUFLOW model using the data described in Section 2.4.

3.3.2 Inflow boundary condition

The hydraulic model was truncated to exclude modelling of the upstream catchments (upper Bowmans Creek and upper Yorks Creek). Where these catchments were truncated, inflows were simulated using the hydrograph results developed in the hydrological modelling.

3.3.3 Outflow boundary condition

The peak flood levels along the lower reaches of Bowmans Creek will be influenced by the water levels in the Hunter River. To account for these impacts the downstream boundary condition in the TUFLOW model is represented as a static water level. In order to assign a downstream boundary condition for the design flood events, a flood frequency analysis was undertaken for the Hunter River Upstream Glennies gauge (210127). The gauge is located approximately 2.3 km downstream of the confluence between Bowmans Creek and the Hunter River and commenced recordings in 1993.

As part of previous flood studies, analysis of streamflow gauges located on the Hunter River identified significant shifts in the derived stage discharge relationship (i.e. rating curve) information for a number of gauging stations (BMT WBM 2016). As a consequence of the uncertainty surrounding reported stream flows, the flood frequency analysis was based on annual maxima recorded in water levels rather than derived streamflows.

The annual maximum water level series used for the frequency analysis has been derived from the gauging station records in the WaterNSW database for the period 1994-2018. The flood frequency distribution was calculated using the Gumbel distribution approach and is presented in Figure 3-8.

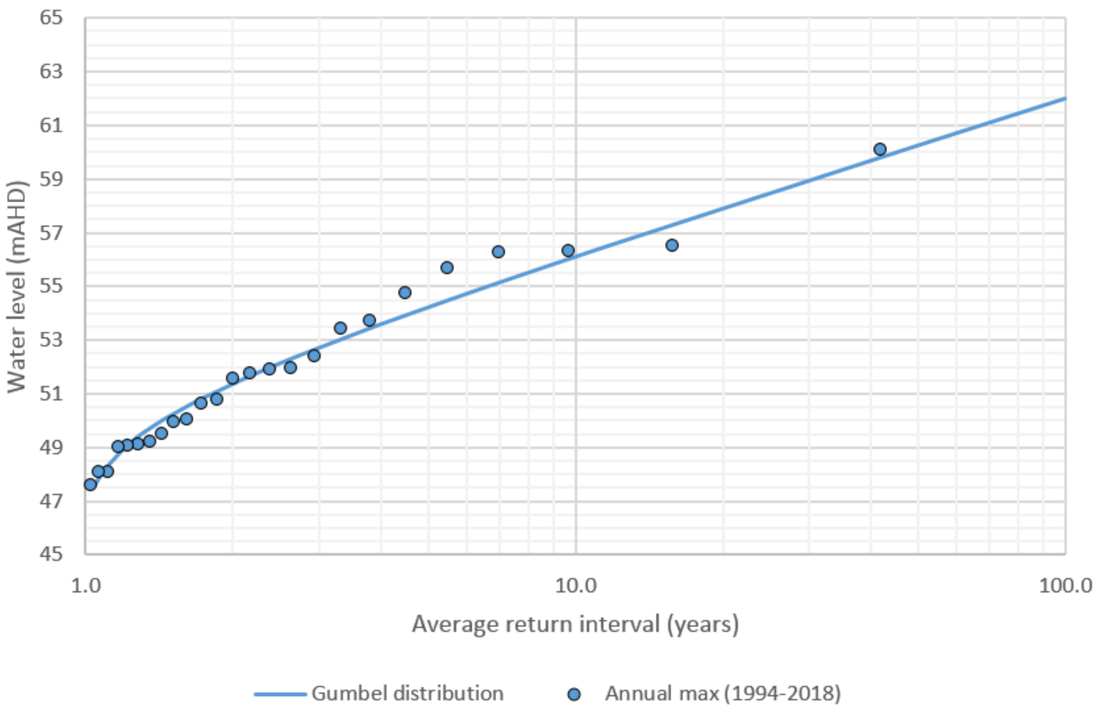


Figure 3-8 Hunter River U/S Glennies gauging station (210127) observed annual maximum flood level and fitted Gumbel distribution

As the Hunter River U/S Glennies gauge is 2.3 km downstream of the Bowmans Creek confluence an adjustment to the water levels was performed. This involved simulating a section of the Hunter River in a separate TUFLOW model. The model extended approximately 4.6 km upstream and 9.1 km downstream of the Bowmans Creek and Hunter River confluence. This section of the Hunter River was subjected to steadily increasing flows in a step wise pattern. From the model the flow rate to water level relationship at both the gauging station and Bowmans Creek confluence were estimated. From these relationships the water levels at the gauging station were converted to water levels at the Bowmans Creek confluence. These water levels are presented in Table 3-1.

It is unlikely that a 1% AEP event would occur simultaneously in Bowmans Creek and the Hunter River. As a consequence, the design flood magnitude combinations presented in Table 3-1 have been adopted for this study. These are the same combinations adopted by the Wollombi Brook Flood Study (BMT WBM 2016).

Table 3-1 Coincident flood event combinations and adopted downstream boundary condition water levels

Bowmans Creek AEP	Hunter River AEP	Hunter River peak water level at gauge (mAHD)	Hunter River peak water level at Bowmans Creek confluence (mAHD)
10%	2yr ARI	51.36	53.20
5%	20%	54.20	55.21
1%	5%	57.91	59.63
0.5%	2%	60.26	61.61
0.2%	1%	62.01	63.32
PMF	1%	62.01	63.32

3.3.4 Rainfall boundary

The rainfall boundary (Figure 3-5 to Figure 3-7) designates the area of the model which is subject to the rainfall. The model applies the rainfall data described in Section 2.2.

3.3.5 Land use boundary

The land use boundary (Figure 3-5 to Figure 3-7) was delineated using aerial imagery and applies manning roughness values to the model surface. The roughness data applied to the model is described in Section 2.3.

3.3.6 Model boundary

The model boundary (Figure 3-5 to Figure 3-7) determines the limits of the model domain.

4. Results

4.1 Hydrological modelling

The critical duration was the design storm duration that resulted in the highest average peak flow at the location of interest across all 10 temporal patterns. The adopted temporal pattern was the first pattern exceeding the median. Complete results of the hydrological modelling at all critical locations is provided in Appendix C. The combination of critical durations, temporal patterns and AEP events identified as part of the hydrological modelling for simulation in the hydraulic modelling are summarised in Table 4-1.

Table 4-1 Critical durations and temporal patterns identified from the XP-RAFTS modelling

Design frequency	Duration (hrs)	Temporal pattern
10% AEP	9	4756
10% AEP	12	16
5% AEP	9	4763
5% AEP	9	4764
5% AEP	12	16
1% AEP	9	4763
1% AEP	9	4764
1% AEP	12	16
0.5% AEP	6	4529
0.5% AEP	9	4657
0.2% AEP	1.5	4395
0.2% AEP	6	4596
0.2% AEP	9	4743
PMF	1.5	4430
PMF	2	4611
PMF	3	4647

A prefeasibility study of the Yorks Creek Realignment was performed by WSP (2017), which also consisted of an XP-RAFTS model using ARR 2016 guidelines. A comparison of the XP-RAFTS results of this study with the WSP study are presented in Table 4-2. It shows very similar peak discharges between the studies and provides a reasonable check for model robustness in conjunction with the model calibration.

Table 4-2 Comparison between XP-Rafts results with WSP (2017)

Storm event	Peak discharge volume (m^3/s)			
	Upper Yorks Creek		Upper Bowmans Creek	
	This assessment	WSP (2017)	This assessment	WSP (2017)
10% AEP	17.0	16.0	197.7	189.8
1% AEP	36.2	38.3	428.3	412.3

4.2 Hydraulic modelling

The impacts to flooding resulting from the Project are summarised in this section. Flood mapping is provided in Appendix D.

4.2.1 Reporting locations

The results of the hydraulic flood modelling are summarised at a number of reporting locations. These locations have been selected as they are close to important infrastructure (such as rail lines or roads) or locations of interest. These locations are summarised in Table 4-3 below and can be observed in the flood maps in Appendix D.

Table 4-3 Summary of reporting locations

ID	Name	Description
1	Upper Yorks Creek	Located on Yorks Creek on the downstream side of the Mount Owen access road. This reporting location reflects upstream impacts caused by the Yorks Creek Realignment.
2	Bowmans Creek at the confluence with Yorks Creek Realignment	Located just downstream of the confluence between Bowmans Creek and Yorks Creek Realignment. This reporting location reflects potential impacts to Bowmans Creek in this area.
3	Bowmans Creek at the engraving site (Bowmans Creek 16, 37-3-0722)	Located on a major bend of Bowmans Creek close to the Main Northern Railway. This reporting locations reflects potential impacts to the identified engraving site (Bowmans Creek 16) and the nearby Main Northern Railway in this area.
4	Bowmans Creek at the confluence with Yorks Creek	Located on Bowmans Creek at the confluence with Yorks Creek. This reporting location reflects potential impacts on the nearby Hebden Road realignment in this area.
5	Bowmans Creek upstream of Hebden Road bridge	Located on a major bend of Bowmans Creek approximately 1 km upstream from Hebden Road bridge. This reporting location reflects potential impacts on the Main Northern Railway in this area.
6	Bowmans Creek at Hebden Road bridge	Located on Bowmans Creek at the Hebden Road bridge crossing. This reporting location reflects potential impacts to Hebden Road and the Main Northern Railway in this area.
7	Bowmans Creek at rail bridge	Located on Bowmans Creek at the rail bridge crossing. This reporting location reflects potential impacts to the Main Northern Railway in this area.
8	Bowmans Creek upstream of New England Hwy bridge	Located on Bowmans Creek approximately 1.6 km upstream of the New England Highway bridge crossing between the Main Northern Railway and the New England Highway. This reporting location reflects potential impacts to the nearby Main Northern Railway and New England Highway in this area.
9	Swamp Creek at rail bridge	Located on Swamp Creek at the Main Northern Railway bridge crossing. This reporting location reflects potential impacts to the rail line in this area.
10	Bettys Creek at rail bridge	Located on Bettys Creek at the Main Northern Railway bridge crossing. This reporting location reflects potential impacts to the rail line in this area.
11	Lower Bettys Creek Diversion	Located in the Lower Bettys Creek Diversion. This reporting location reflects potential impacts in the Lower Bettys Creek Diversion.
12	Upper Bettys Creek	Located in Bettys Creek approximately 1.7 km downstream of TP 2. This reporting locations reflects potential impacts in Bettys Creek.
13	Bowmans Creek at New England Hwy bridge	Located in Bowmans Creek at the New England Highway bridge crossing. This reporting location reflect the potential impacts to the New England Highway in this area and also the Ashton Coal Mine MIA.
14	Lower Bowmans Creek	Located on Bowmans Creek approximately 3 km upstream from the confluence with the Hunter River. This reporting location reflects potential impacts to land owned by Ashton Coal Mine and Lemington Road.

4.2.2 10% AEP flooding impacts

A summary of the impacts under 10% AEP flooding for both the proposed conditions (Year 6) and the proposed conceptual final landform compared to existing conditions are presented in Table 4-4. The results demonstrate some significant changes to both water level and velocity. These impacts are largely confined to Bowmans Creek between the confluence with Yorks Creek Realignment (location 2) and the confluence with Yorks Creek (location 4) and lower Bettys Creek (location 11). Only two of the reporting locations (3 and 10) are associated with sensitive areas, infrastructure or land not owned by Glencore. All other areas show either negligible impacts from the Project or are located well within the Glencore owned land.

The engraving site (location 3) is considered to be sensitive to changes in peak velocity but not flood levels. Therefore the changes to flooding from the Project under a 10% AEP are not expected to affect the engravings at reporting location 3 as there are negligible changes to velocity. Location 3 is also in close proximity to the Main Northern Railway. The increase in water levels here (0.11 m) are not expected to affect the Main Northern Railway with freeboard to the top of the rail embankment in excess of 6 m.

Significant increases in both water level (about 0.5 m) and velocity (about 0.3 m/s) occur at reporting location 10 which is adjacent to the Main Northern Railway. The freeboard to the top of the rail embankment remains in excess of 1 m and no significant change to the 1% AEP water level is expected (refer to Section 4.2.4). Similarly, although there is a significant increase in velocity at this location it remains below the existing 1% AEP velocity. Considering the expected design criteria for this infrastructure of at least 1% AEP, there is unlikely to be any impacts due to increased water levels and velocity for the 10% AEP design event.

Table 4-4 10% AEP flooding results

Reporting location	Change in water level (m)		Change in peak velocity (m/s)	
	Proposed conditions (Year 6)	Proposed conceptual final landform	Proposed conditions (Year 6)	Proposed conceptual final landform
1	-0.15	-0.15	-0.34	-0.34
2	+0.07	+0.07	+0.16	+0.16
3	+0.11	+0.11	+0.02	+0.02
4	-0.01	-0.02	+0.01	0.00
5	0.00	-0.01	0.00	0.00
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00
9	-0.05	-0.05	-0.16	-0.16
10	+0.46	+0.55	+0.27	+0.28
11	+0.45	+0.51	+0.46	+0.58
12	+0.49	+0.50	+0.18	+0.18
13	0.00	+0.02	0.00	+0.01
14	0.00	+0.02	0.00	0.00

4.2.3 5% AEP flooding impacts

A summary of the impacts under 5% AEP flooding for both the proposed conditions (Year 6) and the proposed conceptual final landform compared to existing conditions are presented in Table 4-5. Like the 10% AEP results, the results demonstrate some significant changes to both water level and velocity. These impacts are largely confined to Bowmans Creek between the confluence with Yorks Creek Realignment (location 2) and the confluence with Yorks Creek (location 4) and all of Bettys Creek. Only two of the reporting locations (3 and 10) are associated with sensitive areas, infrastructure or land not owned by Glencore. All other areas show either negligible impacts from the Project or are located well within Glencore owned land.

Like the 10% AEP design event, some changes to peak water levels and velocities are expected for the 5% AEP design event at location 10, while location 3 shows only a change to peak water levels. However, as discussed for the 10% AEP design event, when these changes are considered in the context of the 1% AEP design event, no significant impacts are expected.

Table 4-5 5% AEP flooding impacts

Reporting location	Change in Water level (m)		Change in peak velocity (m/s)	
	Proposed conditions	Proposed conceptual final landform	Proposed conditions	Proposed conceptual final landform
1	-0.26	-0.26	-0.14	-0.14
2	+0.09	+0.09	+0.10	+0.10
3	+0.10	+0.10	0.00	0.00
4	-0.01	-0.01	+0.03	+0.02
5	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00
9	-0.07	-0.06	-0.19	-0.19
10	+0.60	+0.62	+0.16	+0.17
11	+0.65	+0.68	+0.48	+0.51
12	+0.41	+0.43	+0.10	+0.11
13	0.00	0.02	0.00	+0.01
14	0.00	+0.02	0.00	0.00

4.2.4 1% AEP flooding impacts

A summary of the impacts under 1% AEP flooding for both the proposed conditions (Year 6) and the proposed conceptual final landform compared to existing conditions are presented in Table 4-6.

Similar to the results for the 10% and 5% AEP design events, the results indicate some significant changes to both water level and velocity. These impacts are largely confined to Bowmans Creek between the confluence with Yorks Creek Realignment (location 2) and the confluence with Yorks Creek (location 4) and lower Bettys Creek (location 11). Only one of the reporting location (location 3) potentially has significant impacts on sensitive areas, infrastructure or land not owned by Glencore. All other areas show either negligible impacts from the Project or are located well within Glencore owned land.

Minor increase to peak water levels are expected for the 1% AEP design event at location 3, however, the modelling results show changes to peak velocity which indicates no change to potential erosion and therefore no significant impacts with respect to erosion are expected.

Table 4-6 1% AEP flooding impacts

Reporting location	Change in Water level (m)		Change in peak velocity (m/s)	
	Proposed conditions	Proposed conceptual final landform	Proposed conditions	Proposed conceptual final landform
1	-0.45	-0.45	-0.10	-0.10
2	+0.13	+0.13	+0.12	+0.12
3	+0.12	+0.12	0.00	0.00
4	-0.02	-0.03	+0.03	+0.01
5	0.00	0.00	0.00	+0.01
6	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00
8	-0.03	+0.04	0.00	+0.04
9	-0.03	+0.04	0.00	+0.04
10	-0.03	+0.06	+0.07	+0.08
11	+0.60	+0.61	+0.55	+0.63
12	+0.37	+0.37	+0.27	+0.27
13	-0.02	+0.03	0.00	0.00
14	-0.01	+0.01	0.00	0.00

4.2.5 Sensitivity to climate change

A summary of the impacts under the 0.5% and 0.2% AEP flooding for both the proposed conditions (Year 6) and the proposed conceptual final landform compared to existing conditions are presented in Table 4-7 and Table 4-8 respectively. The impacts are generally similar in both pattern and magnitude to the 1% AEP impacts. Like the 1% AEP impacts, the only location with the potential to negatively impact sensitive areas is reporting location 3. Despite this, the freeboard to the top of the rail line remains above 4 m and velocities are unchanged in both scenarios. Therefore the Project is not expected to negatively impact either the engraving site or the Main Northern Railway line under potential climate change scenarios.

Table 4-7 0.5% AEP flooding impacts compared to 1% AEP impacts

Reporting location	Change in water level (m)		Change in peak velocity (m/s)	
	Proposed conditions (1% impact)	Proposed conceptual final landform (1% impact)	Proposed conditions (1% impact)	Proposed conceptual final landform (1% impact)
1	-0.42 (-0.45)	-0.42 (-0.45)	-0.46 (-0.10)	-0.46 (-0.10)
2	+0.12 (+0.13)	+0.12 (+0.13)	+0.09 (+0.12)	+0.09 (+0.12)
3	+0.11 (+0.12)	+0.11 (+0.12)	0.00 (0.00)	0.00 (0.00)
4	-0.03 (-0.02)	-0.03 (-0.03)	+0.02 (+0.03)	+0.01 (+0.01)
5	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (+0.01)
6	0.00 (0.00)	+0.01 (0.00)	0.00 (0.00)	0.00 (0.00)
7	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
8	0.00 (-0.03)	0.00 (+0.04)	+0.01 (0.00)	+0.01 (+0.04)
9	-0.02 (-0.03)	+0.02 (+0.04)	0.00 (0.00)	+0.02 (+0.04)
10	-0.01 (-0.03)	+0.02 (+0.06)	+0.01 (+0.07)	+0.02 (+0.08)
11	+0.53 (+0.60)	+0.62 (+0.61)	+0.54 (+0.55)	+0.60 (+0.63)
12	+0.38 (+0.37)	+0.41 (+0.37)	+0.20 (+0.27)	+0.25 (+0.27)
13	-0.02 (-0.02)	+0.02 (+0.03)	0.00 (0.00)	0.00 (0.00)
14	-0.01 (-0.01)	+0.01 (+0.01)	0.00 (0.00)	0.00 (0.00)

Table 4-8 0.2% AEP flooding impacts compared to 1% AEP impacts

Reporting location	Change in water level (m)		Change in peak velocity (m/s)	
	Proposed conditions (1% impact)	Proposed conceptual final landform (1% impact)	Proposed conditions (1% impact)	Proposed conceptual final landform (1% impact)
1	-0.61 (-0.45)	-0.61 (-0.45)	-0.46 (-0.10)	-0.46 (-0.10)
2	+0.17 (+0.13)	+0.17 (+0.13)	+0.02 (+0.12)	+0.02 (+0.12)
3	+0.12 (+0.12)	+0.12 (+0.12)	0.00 (0.00)	0.00 (0.00)
4	-0.06 (-0.02)	-0.06 (-0.03)	+0.09 (+0.03)	+0.09 (+0.01)
5	-0.01 (0.00)	-0.01 (0.00)	0.00 (0.00)	0.00 (+0.01)
6	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
7	-0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
8	-0.01 (-0.03)	-0.01 (+0.04)	-0.01 (0.00)	-0.01 (+0.04)
9	-0.01 (-0.03)	+0.02 (+0.04)	+0.01 (0.00)	+0.02 (+0.04)
10	0.00 (-0.03)	+0.03 (+0.06)	+0.02 (+0.07)	+0.02 (+0.08)
11	+0.58 (+0.60)	+0.72 (+0.62)	+0.57 (+0.55)	+0.67 (+0.63)
12	+0.36 (+0.37)	+0.37 (+0.37)	+0.20 (+0.27)	+0.23 (+0.27)
13	-0.02 (-0.02)	+0.03 (+0.03)	0.00 (0.00)	+0.01 (0.00)
14	0.00 (-0.01)	0.00 (+0.01)	+0.01 (0.00)	+0.01 (0.00)

4.2.6 Probable maximum flood

The probable maximum flood (PMF) is the largest flood that could conceivably be expected to occur at a particular location. For the purpose of this assessment, the design flood resulting from the probable maximum precipitation (PMP-DF) has been assumed to be equivalent to the PMF. The PMF is far in excess of a reasonable design or performance criteria of any element of the Project, and is considered for the purpose of defining the maximum extent of the flood plain.

The maximum extent of the PMF for existing conditions, proposed conditions (Year 6) and the proposed final landform are provided in Appendix D. The design for the Yorks Creek Realignment includes a flood levee to prevent flows from Yorks Creek entering the Glendell Pit Extension or final void up to a 0.1% AEP design flood. In the highly unlikely event of a flood exceeding this criteria, it is expected that the flood waters in the realigned section of Yorks Creek would overtop the levee and flow into the Glendell Pit Extension or final void.

The results shows that the Project is expected to have a negligible impact on the extent of the Bowmans Creek floodplain downstream of areas impacted by surface mining. Changes to the floodplain are expected to be consistent with the approved final landform of neighbouring Liddell Coal Operations and Ravensworth Operations. The diversion of the existing mine site catchment to Bettys Creek will restore the Bettys Creek floodplain to comparable pre-mining conditions.

4.2.7 Glendell MIA

The results of the Glendell MIA flood immunity are presented in Table 4-9. These indicate that the current design of the Glendell MIA is above flood levels for all AEP events except the PMF.

Table 4-9 Glendell MIA flood immunity

Design flood	Overtopping of MIA pad
10% AEP	No
5% AEP	No
1% AEP	No
0.5% AEP	No
0.2% AEP	No
PMF	Yes

4.2.8 Heavy Vehicle Access Road

The results of the Heavy Vehicle Access Road flood immunity are presented in Table 4-10. These indicate that the current design of the Heavy Vehicle Access Road is above flood levels for all AEP events except the PMF.

Table 4-10 Heavy Vehicle Access Road flood immunity

Design flood	Overtopping of Heavy Vehicle Access Road
10% AEP	No
5% AEP	No
1% AEP	No
0.5% AEP	No
0.2% AEP	No
PMF	Yes

4.2.9 Hebden Road realignment

The results of the realigned Hebden Road flood immunity are presented in Table 4-11. These indicate that the current design of Hebden Road is immune to 10% and 5% AEP design flood events. Overtopping of the road occurs for rarer flood events. The modelling indicates that the existing Hebden Road formation flood at multiple locations under the 10% AEP event. Therefore the realigned Hebden Road provided significant additional flood immunity relative to the existing road.

Table 4-11 Hebden Road realignment flood immunity

Design flood	Overtopping of Hebden Road realignment
10% AEP	No
5% AEP	No
1% AEP	Yes
0.5% AEP	Yes
0.2% AEP	Yes
PMF	Yes

The modelling results indicate that overtopping of Hebden Road for the 1% AEP design flood occurs at 2 locations. The first is where the new alignment crosses Yorks Creek and the second locations is at the existing entrance to the Ravensworth East MIA. These areas are depicted in Figure 4-1 and Figure 4-2 respectively. Overtopping is located at local sags in road elevation, does not fully cover the carriageway. The maximum depth and velocity of the overtopping does not exceed is 0.1 m and 0.9 m/s respectively at either location. This classifies it as H1 (relatively benign conditions with no restrictions) in the flood hazard category according to the Australian Institute for Disaster Resilience (2012) and therefore does not limit traffic flows.

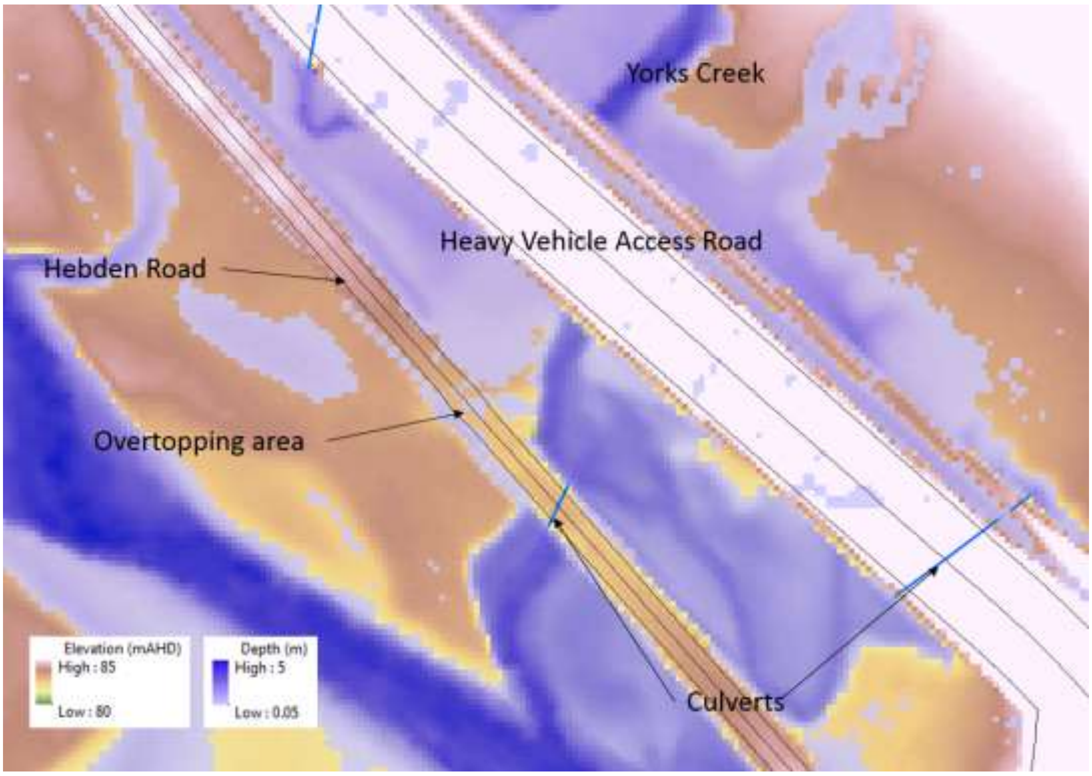


Figure 4-1 Hebden Road overtopping near existing Yorks Creek confluence

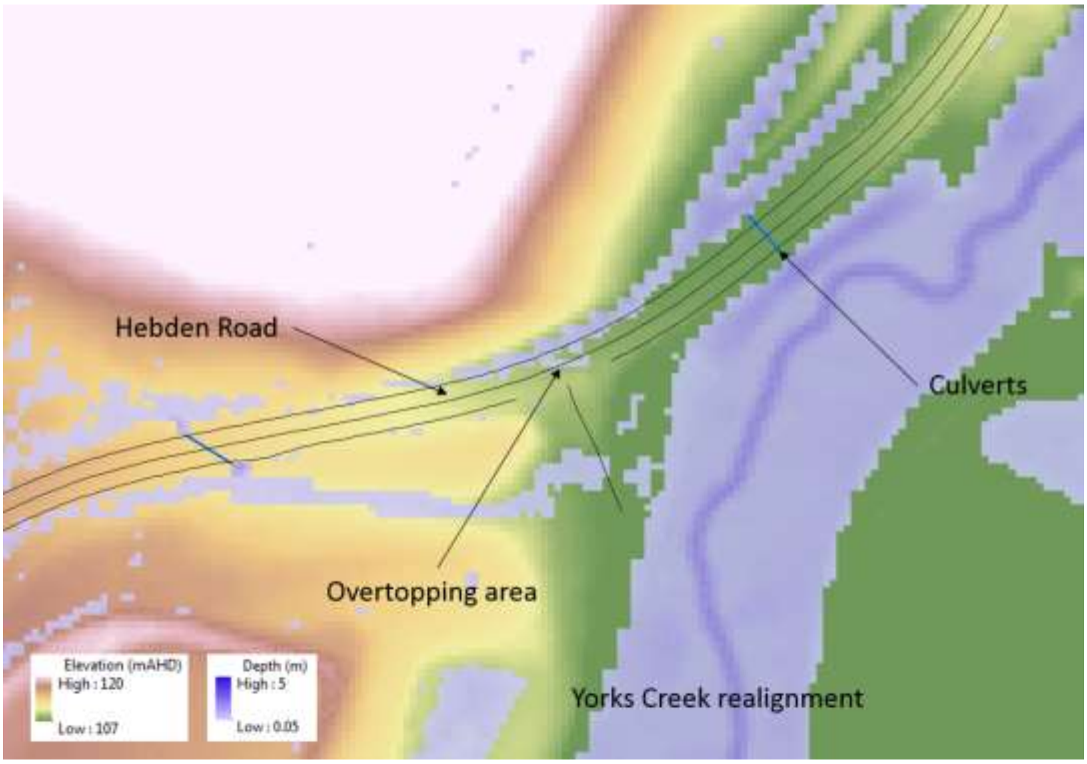


Figure 4-2 Hebden Road overtopping near Ravensworth East MIA entrance

4.2.10 Yorks Creek Realignment levee

A major component of the Yorks Creek Realignment is the southern levee that cuts across the existing Yorks Creek and contains flow within the Yorks Creek Realignment floodplain. The peak water level in Yorks Creek Realignment at the levee under various design events is presented in Table 4-12. Based on a design elevation for the levee of 108.5 m AHD, the flood modelling results indicate that the proposed Yorks Creek Realignment and levee design are adequate to contain all modelled events except for the PMF.

Table 4-12 Yorks Creek Realignment peak water level

Design flood	Peak water level (m AHD)
10% AEP	104.00
5% AEP	104.25
1% AEP	104.71
0.5% AEP	105.08
0.2% AEP	105.28
PMF	111.40

In the very rare instance of overtopping of flood protection levee, there is the potential for flows from Yorks Creek to enter the Glendell Pit Extension or final void. Even under the highly conservative assumption of complete interception of all rainfall for the longest duration design duration considered for the probable maximum precipitation (1460 mm over 5 days) over the entire Yorks Creek (1884 ha) and final void catchment (321 ha), the total inflows would amount to 32 GL, just 13% of the total volume of the final void. With the volume in addition to the long term equilibrium water level (refer to the Surface Water Impact Assessment), approximately 100 m of freeboard would remain.

4.2.11 Final void flooding

A sufficiently large flood event could exceed the approximately 85 m AHD ground level at the south western corner of the final void resulting in flooding of the final void. The maximum flood level at the potential flooding location for various design floods are summarised in Table 4-13.

Table 4-13 Final void flooding

AEP event	Maximum flood level (m AHD)
10% AEP	80.60
5% AEP	80.99
1% AEP	81.63
0.5% AEP	81.84
0.2% AEP	82.11
PMF	85.66

Table 4-13 indicates that flooding from Bowmans Creek to the final void may occur in the PMF. However unlike the case for the Yorks Creek Realignment levee, the final void would not intercept the entire flow of Bowmans Creek. Considering a broad crested weir with conservative width of 44 m and flow depth of 1 m, the peak discharge of 85 m^3/s over the longest design duration considered (5 days), would amount to total inflows of 32 GL. This represents just 13% of the total volume of the final void under highly conservative assumptions. Considering this volume in addition to the long term equilibrium water level (refer to the Surface Water Impact Assessment), approximately 100 m of freeboard would remain.

4.2.12 Watercourse stability

The Project has the potential to affect watercourse stability. The modelled increase in the peak velocity for the 1% AEP design flood was used to identify the Yorks Creek Realignment (in proposed conditions (Year 6) and the proposed conceptual final landform) and lower Bettys Creek (in the proposed conceptual final landform only) as areas where watercourse stability may potential be affected. For these areas, the peak cross sectional shear stress was also assessed, and it and peak velocity were compared against the stability thresholds provided in Fischenich (2001), in order to identify indicative equivalent rock armouring, as summarised in Table 4-14.

Table 4-14 1% AEP peak velocity and shear stress

Location	Peak velocity (m/s)	Peak cross sectional shear stress (N/m^2)	Indicative d_{50} rock armouring (mm)
Yorks Creek Realignment	5.1	654	600+
Lower Bettys Creek Diversion	2.9	321	250-450
Bettys Creek between WRD and the Lower Bettys Creek Diversion	2.4	479	250-450

The peak results shown in Table 4-14 are indicative of the main channel. The detailed design of the Yorks Creek Realignment will consider more detailed modelling of the realignment in order to specify the appropriate mitigation measures, which may include rock armouring.

5. Uncertainty assessment

The predicted flood behaviour presented in this assessment is subject to uncertainty. The primary sources of uncertainty relate to:

- The resolution of DEM has a vertical accuracy of 0.3 m (95% confidence interval) and the accuracy of the absolute elevation reported in the modelling results is considered comparable to this.
- Design rainfall datasets are inherently probabilistic in nature, and are intended to be an estimate of the likelihood of a specific rainfall depth being recorded at a particular location within a defined duration. The sensitivity of the results to uncertainty in these estimates, or potential future changes due to climate change, have been assessed by considering rarer design flood events. This is considered to provide robustness in the interpretation of the flood modelling results.
- The hydrological model, including losses and routing, has been calibrated to the annual maximum series of peak flows, which is considered adequate for the purpose of estimating flood extents and peak velocity.

6. References

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Appendices

Appendix A – Culvert and Bridge data

Table A1 Culvert input data

Culvert ID	U/S invert (m AHD)	D/S invert (m AHD)	Dimensions (mm)	No. of barrels	Length (m)	Blockage (%)
Heb Rd9	86	86	2.1×1.2	3	11	10
Heb rd11	87.07	86.55	0.45	1	17	50
Heb Rd10	85.25	85	1.2×0.75	3	8.5	5
Yorks Ck3	105.6	106.8	1.2	1	12.1	0
Yorks Ck4	104.5	104.5	0.9	2	34.2	0
Mt Owen2	106.47	106.38	1.5	2	21.2	0
Mt Owen1	107.65	107.5	1.35	1	15	0
Rail lp1_1	87.4	87.4	0.7	3	14	0
ARTC7	77.4	76.8	1.2×0.9	2	21.5	0
ARTC8	76.6	76.1	1.2×0.9	2	17.5	0
Lem Rd5	63.8	63.7	1.5×1.2	3	29.3	0
NEHWY2	82.25	82.25	0.6×0.45	2	23.2	0
NEHWY3	88.9	88.7	0.6	1	25.2	0
Lem Rd2	60.3	60.1	1.2×0.9	3	26.5	0
Lem Rd3	59.75	59.75	1.05	4	7.6	0
Lem Rd4	60.55	60.35	1.85×1.75	3	16	0
Rail lp1_2	87.8	87.4	0.3	3	10.1	0
Heb Rd1	125.2	124.8	0.58	2	11.6	0
Heb Rd2	112.5	112.5	0.6	2	13	80
Heb Rd4	95.55	95.4	2.45×0.45	1	7.6	10
Heb Rd5	93.7	93.6	0.45	2	9.5	0
Heb Rd6	95	94.8	0.6	1	17	0
Heb Rd7	95.9	95.85	0.6	1	7.5	0
Heb Rd8	93.95	93.9	0.6	1	10	0
Heb Rd12	88.8	88.65	0.9	2	13	0
Heb Rd13	90.45	90.34	0.38	1	14.5	0
Heb Rd14	90.8	90.7	0.45	1	13	0
Heb Rd15	89.9	89.7	0.68	1	18	0
Heb Rd16	83.46	83.26	0.52	5	14.18	0
Glen1	75.45	75.3	0.9	3	19.8	0
Heb Rd17	74.5	74.4	1.35	1	19	5
Heb Rd18	76.3	76.2	0.45	1	15	20
Heb Rd19	77.3	77.2	0.45	1	12.5	5
HC 0.790	79.71	79.35	0.9	3	71.06	0
HC 0.970	78.81	78.46	0.75	2	70.6	0
HC 1.100	78.44	78.05	0.9	3	77.8	0
HC 1.420	84.85	84.09	0.9	4	75.55	0
HC 1.935	80.76	80.4	0.9	3	71.07	0
C 0.575	78.92	78.65	2.4×1.5	3	42.2	0
HC 2.300	81.38	80.81	2.4×1.5	3	94.75	0
C 1.410	85.2	85.08	0.9	4	23.89	0
HC 3.145	86.41	86.02	0.6	6	77.65	0
C 2.130	86.15	86	1.2	3	29.5	0
C 2.845	89.2	88.98	0.6	1	21.9	0

Culvert ID	U/S invert (m AHD)	D/S invert (m AHD)	Dimensions (mm)	No. of barrels	Length (m)	Blockage (%)
C 3.590	102.54	101.78	0.75	2	24.9	0
C4.080	110.3	109.6	1.2	1	31.56	0
C4.478	114.25	112.89	1.05	1	32.25	0
Yorks Ck1	98	98.3	3.46	1	60.41	0
Yorks Ck2	97.2	97.4	0.6	1	68.23	50
Smp Ck2	77	76.6	1.5	2	76.8	0
Smp Ck1	73.5	73.5	0.65	1	19.5	0
Heb Rd20	104.65	104.6	0.45	1	17.4	10

Table A2 Bridge input data

Bridge ID	Invert (m AHD)	Soffit (m AHD)	Top of bridge (m AHD)	Width (m)	Pier blockage factor (%)
ARTC (1)	74.68	75.64	76.64	7.5	10
ARTC (2)	76.06	80.06	80.56	24.8	0
ARTC (3.1)	66.3	68.19	68.85	7.5	5
ARTC (3.2)	66.3	68.18	69.5	4.8	5
ARTC (4)	65.4	68.37	69.17	8.7	5
ARTC (5)	65.4	68.41	69.21	4.8	0
ARTC (6)	68.91	72.85	73.35	9.5	5
ARTC (7)	75.40	77.4	78.4	18.3	0
ARTC (8)	69.00	71.8	72.8	12	0
Bowmans Creek (1)	86.55	92.45	94.45	3	0
Hebden Rd (20)	75.78	82.2	86.07	12	0
Hebden Rd (21)	71.23	76.4	79.07	12	5
Hebden Rd (22)	71.48	75.2	77.1	5.5	5
Rail Loop (2)	91.75	93.8	94.8	5	0
New England Hwy (1)	62.33	67.93	71.2	10	5

Appendix B – XP-Rafts input data

Table B1 Existing condition XP-Rafts sub-catchment data

Subcatchment ID	Area (ha)	Impervious (%)	Slope (%)	Pervious mannings n
HR1	468	1	0.39	0.04
BOC0	281	1	0.41	0.04
BOC1	139	10	2.37	0.04
BOC2	457	5	0.18	0.06
BOC3	423	1	0.65	0.04
BOC4	365	1	0.59	0.04
BOC5	328	1	0.71	0.06
SC1	133	5	1.71	0.04
SC2	260	5	1.08	0.04
YC1	449	5	1.29	0.06
YC2	197	5	1.04	0.06
BEC1	148	1	1.22	0.04
BEC2	330	1	0.82	0.06
BEC3	276	5	1.63	0.05
BEC4	289	5	2.46	0.05
MS1	201	10	3.18	0.04
MS2	106	5	1.17	0.04
MS3	303	25	3.05	0.05
UBOC1	1345	5	1.37	0.06
UBOC2	1966	5	0.86	0.06
UBOC3	1049	5	1.73	0.06
UBOC4	1044	1	6.66	0.095
UBOC5	1107	5	2.63	0.06
UBOC6	1259	1	1.77	0.06
UBOC7	1442	1	3.84	0.06
UBOC8	1059	1	2.95	0.06
UBOC9	1277	1	3.74	0.06
UBOC10	999	1	3.74	0.06
UBOC11	1005	1	3.73	0.04
UBOC12	1009	1	2.25	0.04
UBOC13	1473	1	2.29	0.06
UBOC14	1007	1	4.15	0.06
UBOC15	1001	1	5.97	0.095
UYC1	96	5	1.29	0.04
UYC2	126	1	1.65	0.04
UYC3	228	0	2.99	0.06
UYC4	40	1	3.05	0.06
UYC5	135	1	3.95	0.06
UYC6	129	1	2.69	0.06
UYC7	103	15	2.53	0.095
UYC8	77	0	6.30	0.095
UYC9	227	0	4.38	0.095

Table B2 Existing condition XP-Rafts link data

Link ID	Length (m)	Average slope (%)	Manning's n
Link HR1	3070	0.26	0.03
Link BOC0	2440	0.22	0.03
Link BOC1	1410	0.21	0.03
Link BOC2	3130	0.11	0.03
Link BOC3	2150	0.21	0.03
Link BOC4	2990	0.28	0.03
Link BOC5	3350	0.34	0.05
Link SC1	1440	0.44	0.03
Link SC2	2630	0.29	0.03
Link YC1	2500	0.50	0.03
Link YC2	3820	1.08	0.05
Link YC3	1100	0.10	0.05
Link BEC1	1420	0.54	0.05
Link BEC2	1890	0.41	0.03
Link BEC3	2260	0.38	0.05
Link BEC4	1320	0.57	0.05
Link MS1	1930	0.67	0.03
Link MS2	3230	0.76	0.03
Link MS3	3230	0.76	0.03
Link UBOC2	1490	0.33	0.03
Link UBOC3	5192	0.34	0.03
Link UBOC4	4273	2.55	0.03
Link UBOC5	2911	0.42	0.03
Link UBOC6	3077	0.29	0.03
Link UBOC7	2637	1.04	0.03
Link UBOC8	2127	0.78	0.05
Link UBOC9	5177	2.48	0.05
Link UBCO10	2255	2.24	0.05
Link UBOC11	1507	0.56	0.03
Link UBOC12	2658	1.16	0.03
Link UBOC13	2339	0.75	0.03
Link UBOC14	3743	1.1	0.03
Link UBOC15	2306	1.73	0.05
Link UYC2	840	0.82	0.03
Link UYC3	1230	1.74	0.03
Link UYC4	3722	1.56	0.03
Link UYC5	185	0.6	0.03
Link UYC6	1060	1.1	0.03
Link UYC7	378	1.56	0.03
Link UYC8	270	0.01	0.03
Link UYC9	1505	0.01	0.03

Table B3 Proposed conditions (Year 6) XP-Rafts sub-catchment data

Subcatchment ID	Area (ha)	Impervious (%)	Slope (%)	Pervious mannings n
HR1	468	1	0.39	0.04
BOC0	278	1	0.41	0.04
BOC1	77	25	0.25	0.04
BOC2	275	5	1.04	0.06
BOC3	400	1	0.80	0.04
BOC4	360	1	0.56	0.04
BOC5	337	1	0.68	0.06
SC1	219	1	3.14	0.04
SC2	71	1	1.59	0.04
YC1	100	15	2.29	0.04
YC2	253	1	1.17	0.06
OYC1	388	5	1.68	0.04
BEC1	166	1	1.03	0.06
BEC2	330	1	1.43	0.06
BEC3	272	5	1.63	0.05
BEC4	256	5	2.46	0.05
MS1	187	10	3.63	0.04
MS2	92	5	8.36	0.04
MS3	344	25	3.20	0.05
UBOC1	1345	5	1.37	0.06
UBOC2	1966	5	0.86	0.06
UBOC3	1049	5	1.73	0.06
UBOC4	1044	1	6.66	0.095
UBOC5	1107	5	2.63	0.06
UBOC6	1259	1	1.77	0.06
UBOC7	1442	1	3.84	0.06
UBOC8	1059	1	2.95	0.06
UBOC9	1277	1	3.74	0.06
UBOC10	999	1	3.74	0.06
UBOC11	1005	1	3.73	0.04
UBOC12	1009	1	2.25	0.04
UBOC13	1473	1	2.29	0.06
UBOC14	1007	1	4.15	0.06
UBOC15	1001	1	5.97	0.095
UYC1	96	5	1.29	0.04
UYC2	126	1	1.65	0.04
UYC3	228	0	2.99	0.06
UYC4	40	1	3.05	0.06
UYC5	135	1	3.95	0.06
UYC6	129	1	2.69	0.06
UYC7	103	15	2.53	0.095
UYC8	77	0	6.30	0.095
UYC9	227	0	4.38	0.095

Table B4 Proposed conditions (Year 6) XP-Rafts link data

Link ID	Length (m)	Average slope (%)	Manning's n
Link HR1	3070	0.26	0.03
Link BOC0	2440	0.22	0.03
Link BOC1	1410	0.21	0.03
Link BOC2	3130	0.11	0.03
Link BOC3	2150	0.21	0.03
Link BOC4	2990	0.28	0.03
Link BOC5	3350	0.34	0.05
Link SC1	1280	0.62	0.03
Link SC2	640	0.22	0.03
Link YC1	1040	1.44	0.03
Link YC2	1740	0.25	0.03
Link YC3	1100	0.10	0.05
Link OYC1	2790	0.36	0.05
Link BEC1	1420	0.54	0.05
Link BEC2	1890	0.41	0.03
Link BEC3	2260	0.38	0.05
Link BEC4	1320	0.57	0.05
Link MS1	2690	0.87	0.03
Link MS2	2630	0.91	0.03
Link MS3	2650	1.05	0.03
Link UBOC2	1490	0.33	0.03
Link UBOC3	5192	0.34	0.03
Link UBOC4	4273	2.55	0.03
Link UBOC5	2911	0.42	0.03
Link UBOC6	3077	0.29	0.03
Link UBOC7	2637	1.04	0.03
Link UBOC8	2127	0.78	0.05
Link UBOC9	5177	2.48	0.05
Link UBCO10	2255	2.24	0.05
Link UBOC11	1507	0.56	0.03
Link UBOC12	2658	1.16	0.03
Link UBOC13	2339	0.75	0.03
Link UBOC14	3743	1.1	0.03
Link UBOC15	2306	1.73	0.05
Link UYC2	840	0.82	0.03
Link UYC3	1230	1.74	0.03
Link UYC4	3722	1.56	0.03
Link UYC5	185	0.6	0.03
Link UYC6	1060	1.1	0.03
Link UYC7	378	1.56	0.03
Link UYC8	270	0.01	0.03
Link UYC9	1505	0.01	0.03

Table B5 Proposed conceptual final landform XP-Rafts sub-catchment data

Subcatchment ID	Area (ha)	Impervious (%)	Slope (%)	Pervious mannings n
HR1	495	1	0.39	0.04
BOC0	283	1	0.41	0.04
BOC1	95	25	0.34	0.04
BOC2	258	1	0.71	0.06
BOC3	222	1	1.61	0.04
BOC4	265	1	0.77	0.04
BOC5	360	1	0.59	0.04
BOC6	347	1	0.62	0.06
SC1	149	1	5.10	0.04
SC2	190	1	3.90	0.06
YC1	119	1	2.88	0.04
YC2	259	1	1.34	0.04
OYC1	182	1	4.43	0.04
BEC1	145	1	1.51	0.06
BEC2	334	1	1.42	0.06
BEC3	489	1	2.53	0.05
BEC4	213	1	4.13	0.04
BEC5	438	1	2.83	0.04
BEC6	345	1	2.05	0.06
RH1	105	1	4.62	0.04
RH2	120	1	2.25	0.04
RH3	214	1	1.95	0.04
RH4	192	1	4.63	0.04
RH5	218	1	2.63	0.04
UBOC1	1345	5	1.37	0.06
UBOC2	1966	5	0.86	0.06
UBOC3	1049	5	1.73	0.06
UBOC4	1044	1	6.66	0.095
UBOC5	1107	5	2.63	0.06
UBOC6	1259	1	1.77	0.06
UBOC7	1442	1	3.84	0.06
UBOC8	1059	1	2.95	0.06
UBOC9	1277	1	3.74	0.06
UBOC10	999	1	3.74	0.06
UBOC11	1005	1	3.73	0.04
UBOC12	1009	1	2.25	0.04
UBOC13	1473	1	2.29	0.06
UBOC14	1007	1	4.15	0.06
UBOC15	1001	1	5.97	0.095
UYC1	96	5	1.29	0.04
UYC2	126	1	1.65	0.04
UYC3	228	0	2.99	0.06
UYC4	40	1	3.05	0.06
UYC5	135	1	3.95	0.06
UYC6	129	1	2.69	0.06
UYC7	103	15	2.53	0.095

Subcatchment ID	Area (ha)	Impervious (%)	Slope (%)	Pervious mannings n
UYC8	77	0	6.30	0.095
UYC9	227	0	4.38	0.095

Table B6 Proposed conceptual final landform XP-Rafts link data

Link ID	Length (m)	Average slope (%)	Manning's n
Link HR1	3070	0.26	0.03
Link BOC0	2440	0.22	0.03
Link BOC1	1410	0.21	0.03
Link BOC2	2460	0.11	0.03
Link BOC3	670	0.11	0.03
Link BOC4	2150	0.21	0.03
Link BOC5	2990	0.28	0.03
Link BOC6	3350	0.34	0.05
Link SC1	1280	0.62	0.03
Link SC2	590	2.39	0.03
Link YC1	1090	1.29	0.03
Link YC2	1550	0.54	0.03
Link YC3	1100	0.10	0.05
Link OYC1	1670	0.30	0.03
Link BEC1	1420	0.54	0.05
Link BEC2	1890	0.41	0.03
Link BEC3	2260	0.38	0.05
Link BEC4	2630	0.91	0.03
Link BEC5	150	0.25	0.03
Link BEC6	2430	0.90	0.03
Link RH1	1330	0.49	0.03
Link RH2	1030	1.81	0.03
Link RH3	1100	2.70	0.03
Link RH4	1040	0.05	0.03
Link RH5	2550	0.58	0.03
Link UBOC2	1490	0.33	0.03
Link UBOC3	5192	0.34	0.03
Link UBOC4	4273	2.55	0.03
Link UBOC5	2911	0.42	0.03
Link UBOC6	3077	0.29	0.03
Link UBOC7	2637	1.04	0.03
Link UBOC8	2127	0.78	0.05
Link UBOC9	5177	2.48	0.05
Link UBCO10	2255	2.24	0.05
Link UBOC11	1507	0.56	0.03
Link UBOC12	2658	1.16	0.03
Link UBOC13	2339	0.75	0.03
Link UBOC14	3743	1.1	0.03
Link UBOC15	2306	1.73	0.05
Link UYC2	840	0.82	0.03
Link UYC3	1230	1.74	0.03
Link UYC4	3722	1.56	0.03
Link UYC5	185	0.6	0.03
Link UYC6	1060	1.1	0.03

Link ID	Length (m)	Average slope (%)	Manning’s n
Link UYC7	378	1.56	0.03
Link UYC8	270	0.01	0.03
Link UYC9	1505	0.01	0.03

Appendix C – XP-Rafts results

Table C1 Existing conditions XP-Rafts critical durations and peak flows

Subcatchment ID	AEP	Critical Duration (hrs)	Temporal pattern ID	Peak flow (m3/s)
UBOC1	10%	12	16	197.7
UBOC1	5%	12	16	269.6
UBOC1	1%	12	16	428.3
UBOC1	0.5%	9	4657	553.5
UBOC1	0.2%	9	4743	669.3
UBOC1	PMF	3	4647	6987.4
UYC1	10%	12	16	17.0
UYC1	5%	9	4763	23.5
UYC1	1%	9	4442	36.2
UYC1	0.5%	6	4529	44.0
UYC1	0.2%	6	4596	55.3
UYC1	PMF	2	4611	576.6
BOC3	10%	9	4756	12.4
BOC3	5%	9	4764	16.8
BOC3	1%	6	4694	21.9
BOC3	0.5%	6	4529	25.1
BOC3	0.2%	1.5	4395	33.7
BOC3	PMF	1.5	4430	349.0
MS1	10%	12	16	227.4
MS1	5%	12	16	307.8
MS1	1%	12	16	487.7
MS1	0.5%	9	4657	624.9
MS1	0.2%	9	4743	765.9
MS1	PMF	3	4647	7940.3
SC1	10%	9	4756	17.0
SC1	5%	9	4763	21.0
SC1	1%	9	4442	34.0
SC1	0.5%	6	4529	39.5
SC1	0.2%	6	4596	48.2
SC1	PMF	2	4611	524.7
BEC1	10%	12	16	13.1
BEC1	5%	12	16	17.2
BEC1	1%	12	16	26.0
BEC1	0.5%	6	4529	36.0
BEC1	0.2%	6	4596	44.4
BEC1	PMF	2	4611	450.6
HR1	10%	12	16	250.9
HR1	5%	12	16	338.5
HR1	1%	12	16	544.4
HR1	0.5%	9	4657	681.2
HR1	0.2%	9	4743	857.3
HR1	PMF	3	4647	8749.4

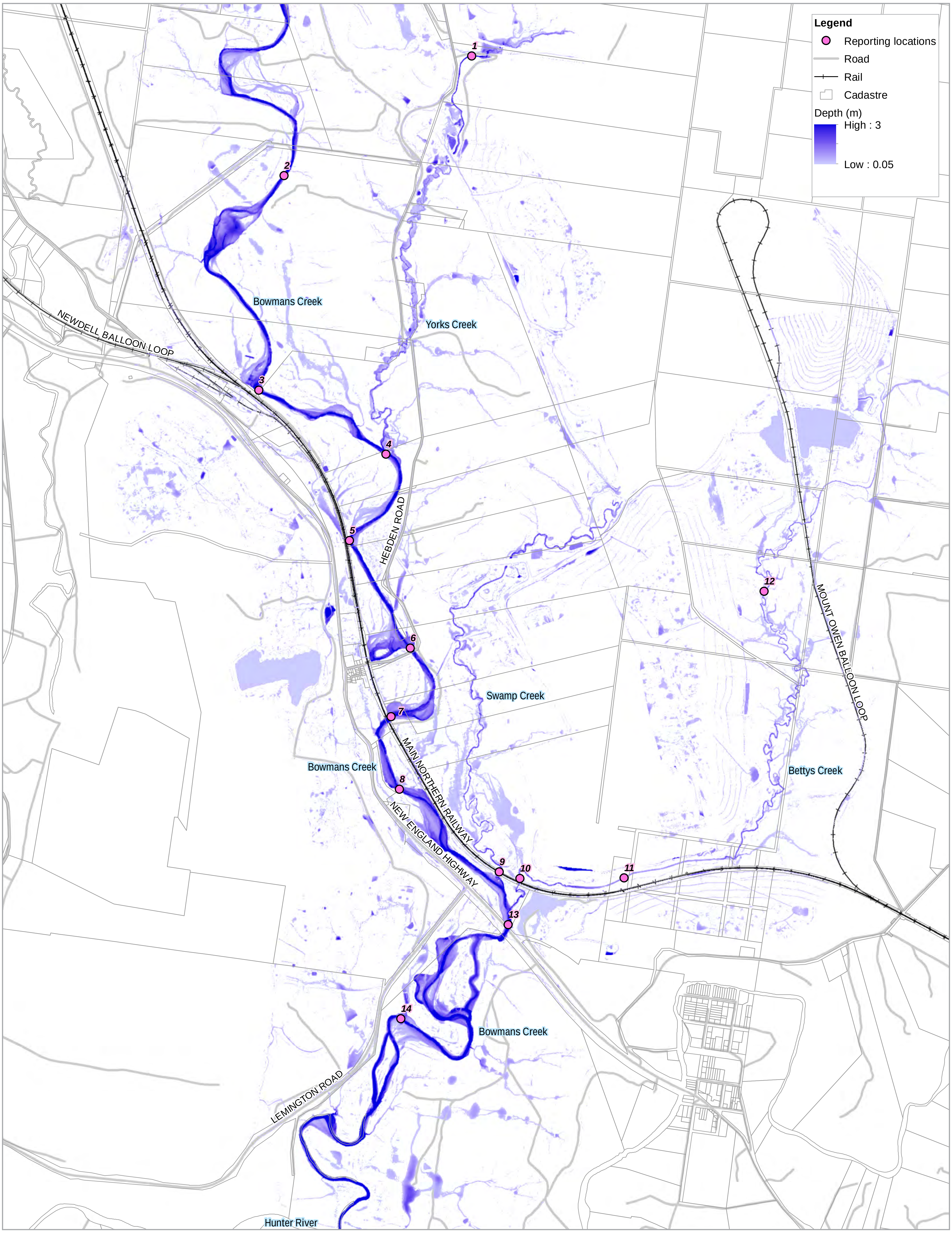
Table C2 Proposed conditions (Year 6) XP-Rafts critical durations and peak flows

Subcatchment ID	AEP	Critical Duration (hrs)	Temporal pattern ID	Median Peak flow (m3/s)
UBOC1	10%	12	16	197.7
UBOC1	5%	12	16	269.6
UBOC1	1%	12	16	428.3
UBOC1	0.5%	9	4657	553.5
UBOC1	0.2%	9	4743	669.3
UBOC1	PMF	3	4647	6987.4
UYC1	10%	12	16	17.0
UYC1	5%	9	4763	23.5
UYC1	1%	9	4442	36.2
UYC1	0.5%	6	4529	44.0
UYC1	0.2%	6	4596	55.3
UYC1	PMF	2	4611	576.6
BOC5	10%	12	16	226.6
BOC5	5%	12	16	308.1
BOC5	1%	12	16	489.4
BOC5	0.5%	9	4657	619.5
BOC5	0.2%	9	4743	762.7
BOC5	PMF	3	4647	7925.9
MS1	10%	9	4756	14.2
MS1	5%	9	4764	18.7
MS1	1%	6	4694	28.4
MS1	0.5%	26	4529	27.6
MS1	0.2%	1.5	4395	45.7
MS1	PMF	1.5	4430	396.3
SC1	10%	9	4756	5.8
SC1	5%	9	4764	8.5
SC1	1%	6	4694	12.4
SC1	0.5%	6	4529	13.4
SC1	0.2%	1.5	4395	19.9
SC1	PMF	1.5	4430	195.8
BEC1	10%	12	16	24.9
BEC1	5%	12	16	31.2
BEC1	1%	12	16	45.2
BEC1	0.5%	6	4529	64.2
BEC1	0.2%	6	4596	78.2
BEC1	PMF	2	4611	829.3
HR1	10%	12	16	250.1
HR1	5%	12	16	337.1
HR1	1%	12	16	541.1
HR1	0.5%	9	4657	671.2
HR1	0.2%	9	4743	848.8
HR1	PMF	3	4647	8765.3

Table C3 Proposed conceptual final landform XP-Rafts critical durations and peak flows

Subcatchment ID	AEP	Critical Duration (hrs)	Temporal pattern ID	Median Peak flow (m3/s)
UBOC1	10%	12	16	197.7
UBOC1	5%	12	16	269.6
UBOC1	1%	12	16	428.3
UBOC1	0.5%	9	4657	553.5
UBOC1	0.2%	9	4743	669.3
UBOC1	PMF	3	4647	6987.4
UYC1	10%	12	16	17.0
UYC1	5%	9	4763	23.5
UYC1	1%	9	4442	36.2
UYC1	0.5%	6	4529	44.0
UYC1	0.2%	6	4596	55.3
UYC1	PMF	2	4611	576.6
BOC6	10%	12	16	220.5
BOC6	5%	12	16	301.2
BOC6	1%	12	16	480.0
BOC6	0.5%	9	4657	603.9
BOC6	0.2%	9	4743	745.9
BOC6	PMF	3	4647	7737.9
BEC4	10%	9	4756	16.6
BEC4	5%	9	4763	21.2
BEC4	1%	6	4694	32.9
BEC4	0.5%	6	4529	38.1
BEC4	0.2%	1.5	4395	49.5
BEC4	PMF	1.5	4430	543.5
SC1	10%	9	4756	7.2
SC1	5%	9	4764	10.0
SC1	1%	6	4694	14.7
SC1	0.5%	6	4529	15.1
SC1	0.2%	1.5	4395	24.2
SC1	PMF	1.5	4430	219.5
BEC1	10%	12	16	27.5
BEC1	5%	12	16	35.7
BEC1	1%	12	16	53.1
BEC1	0.5%	6	4529	73.8
BEC1	0.2%	6	4596	91.6
BEC1	PMF	2	4611	953.1
HR1	10%	12	16	251.6
HR1	5%	12	16	340.9
HR1	1%	12	16	554.4
HR1	0.5%	9	4657	673.7
HR1	0.2%	9	4743	875.2
HR1	PMF	3	4647	8871.0

Appendix D – Flood maps



Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

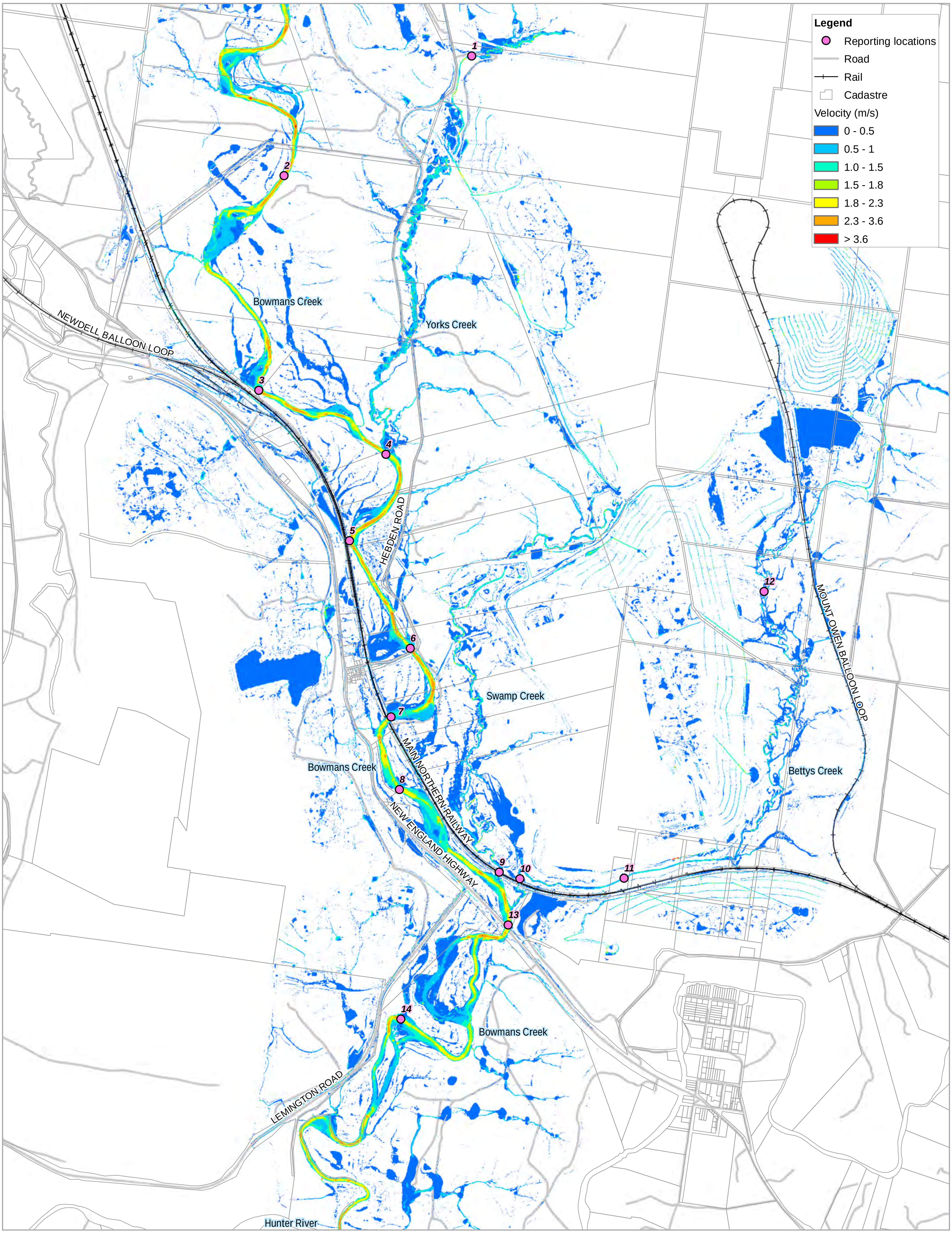
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Existing Conditions
10% AEP Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D1

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



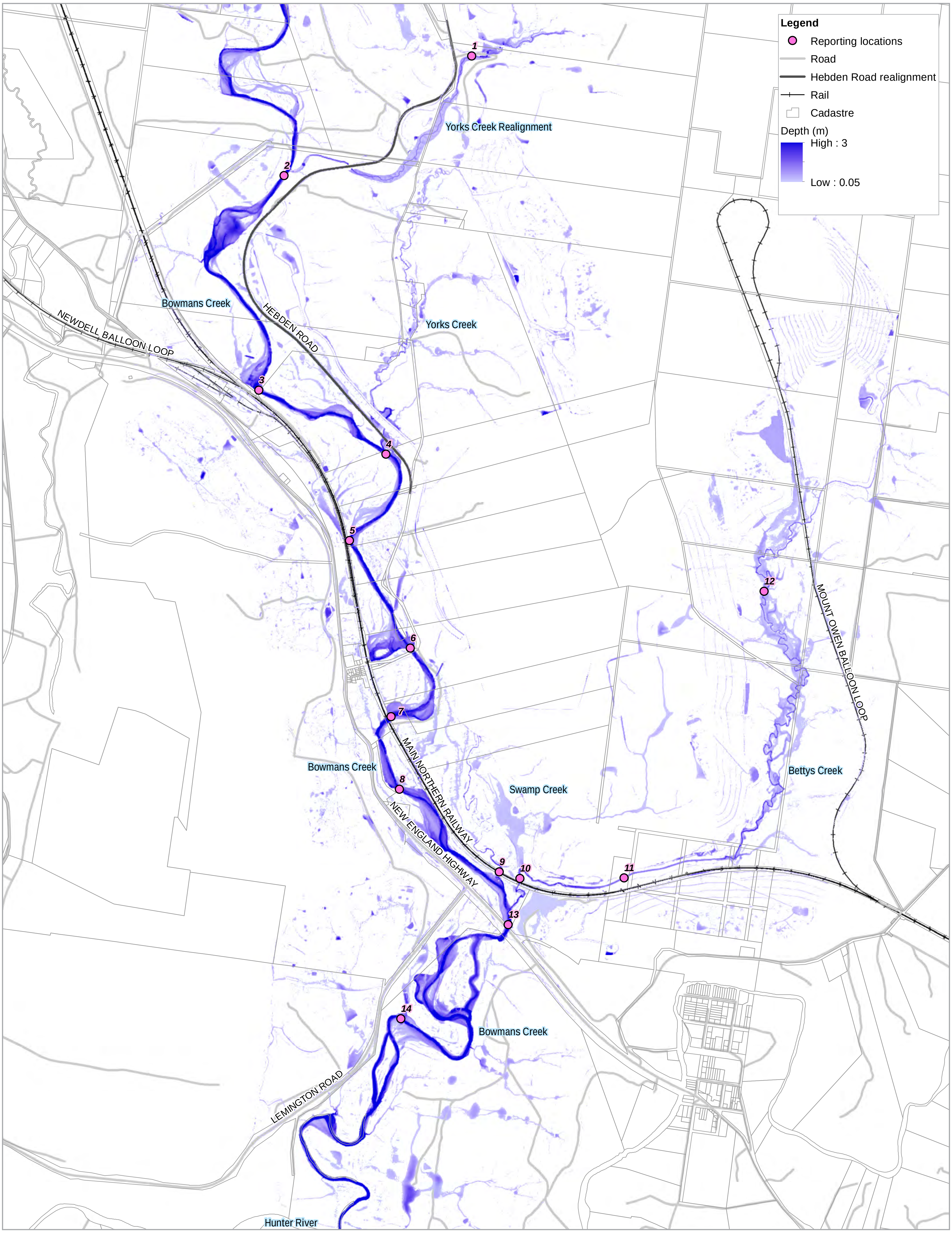
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Existing Conditions
10% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D2

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

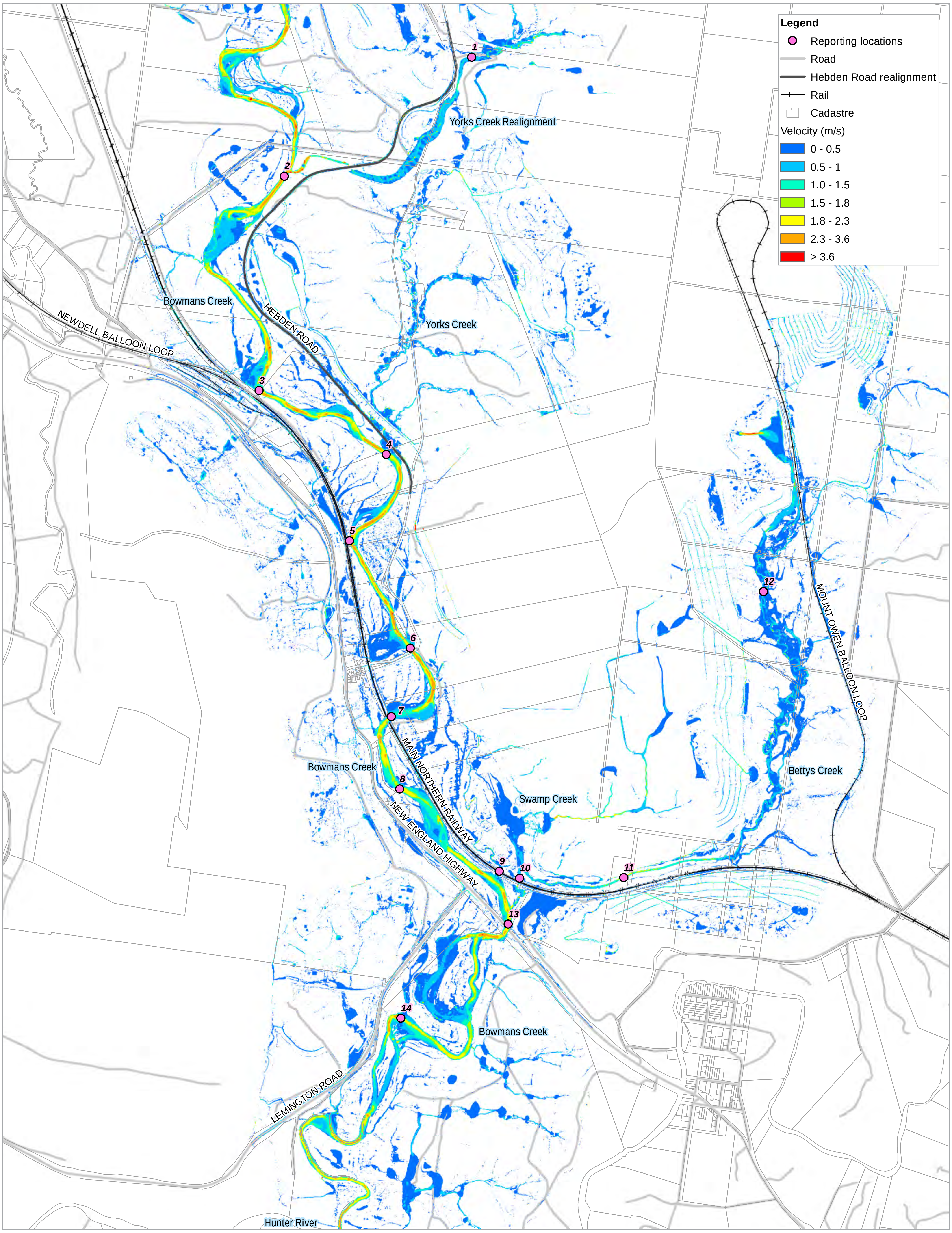
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed conditions (Year 6)
10% AEP Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D3

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

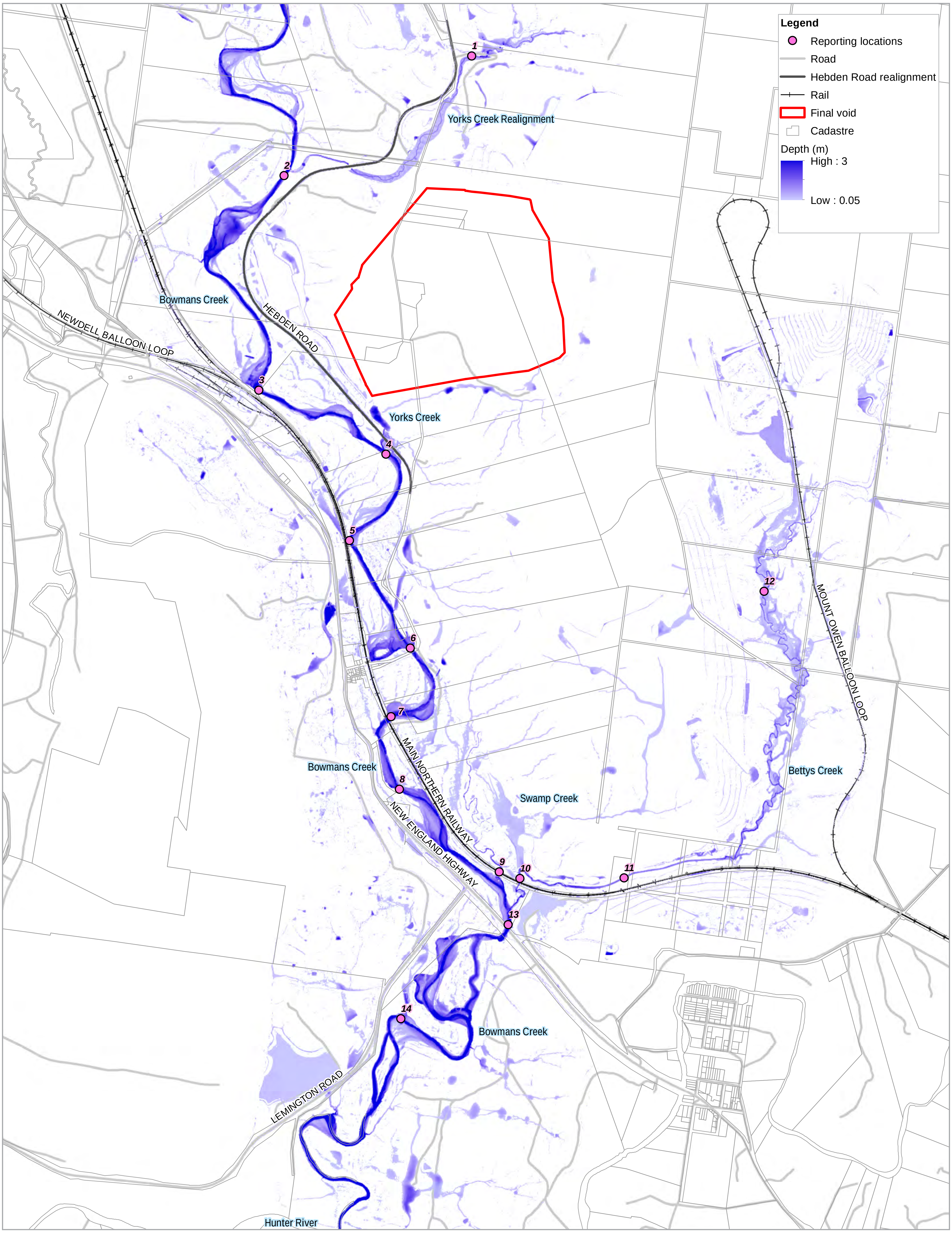
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed conditions (Year 6)
10% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D4

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



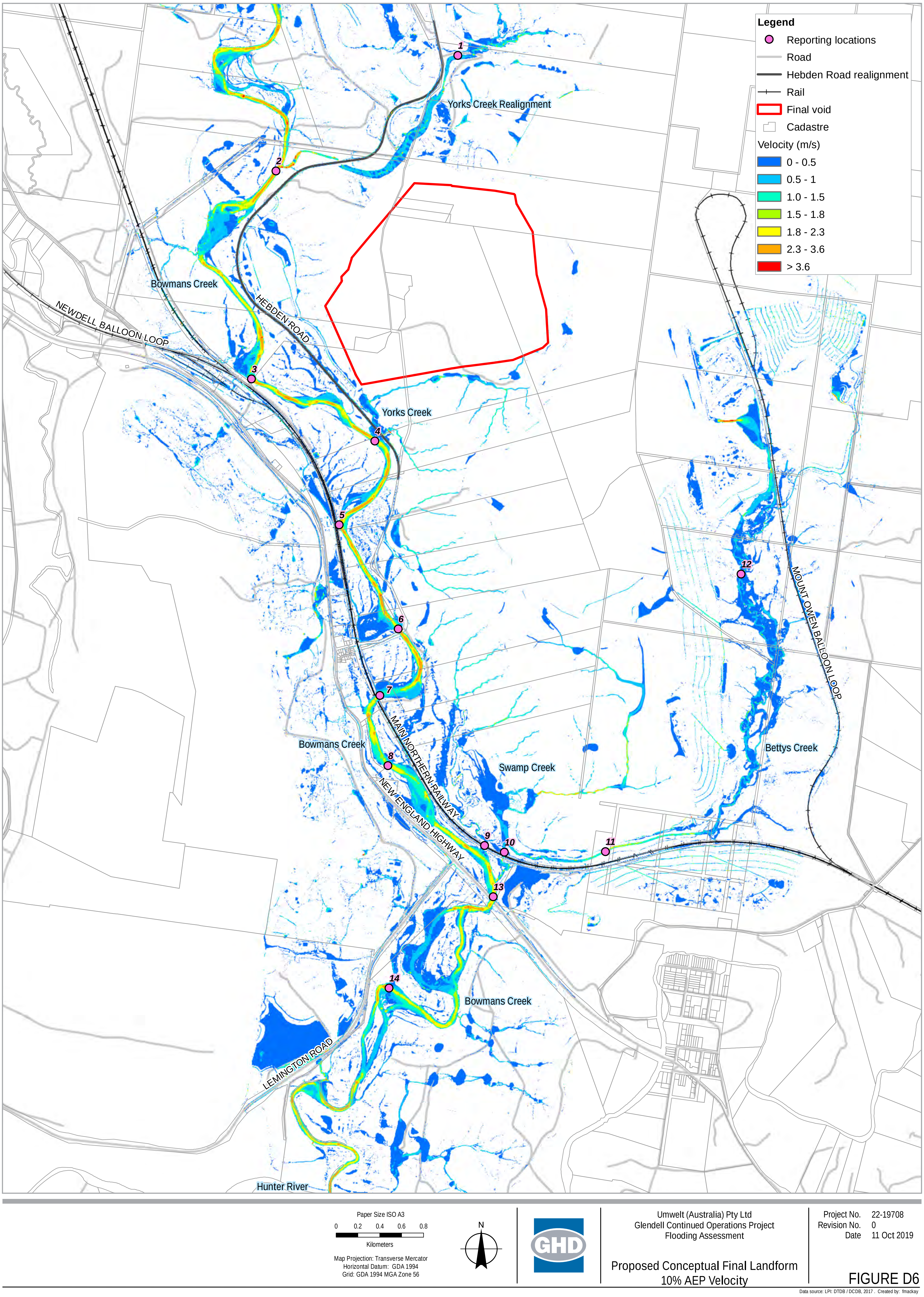
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

Proposed Conceptual Final Landform
10% AEP Water Level and Depth

FIGURE D5

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



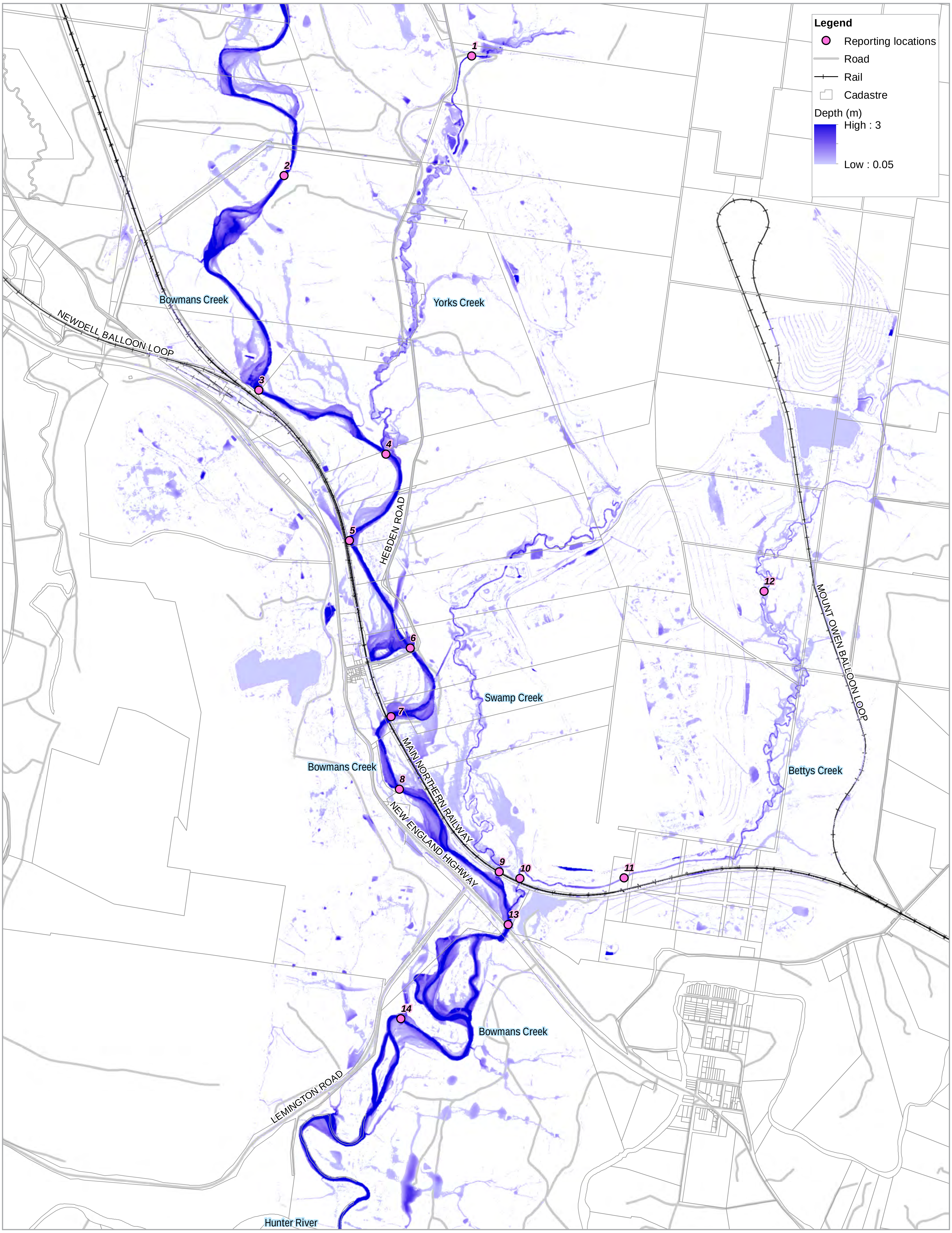
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed Conceptual Final Landform
10% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D6

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

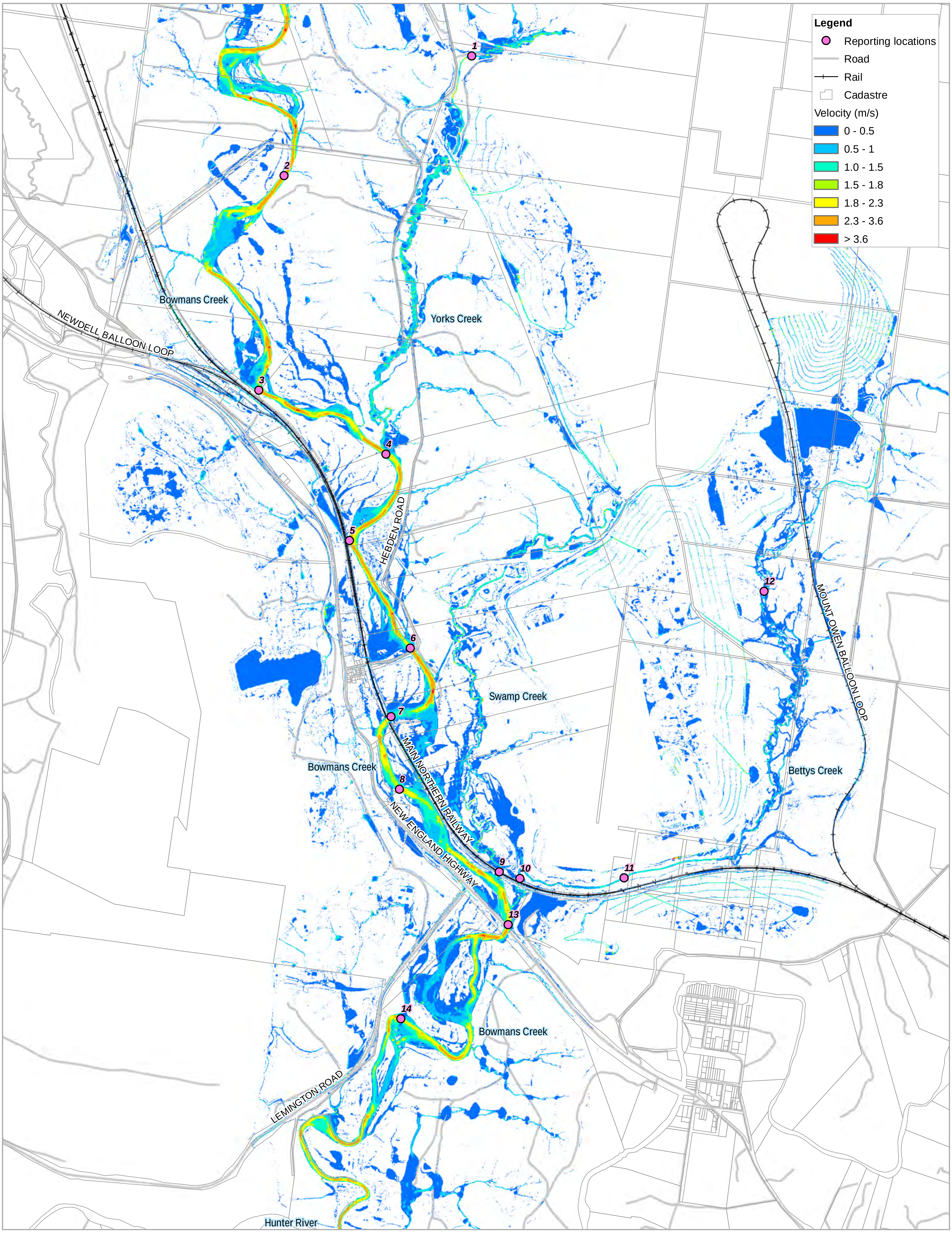
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Existing Conditions
5% AEP Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D7

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

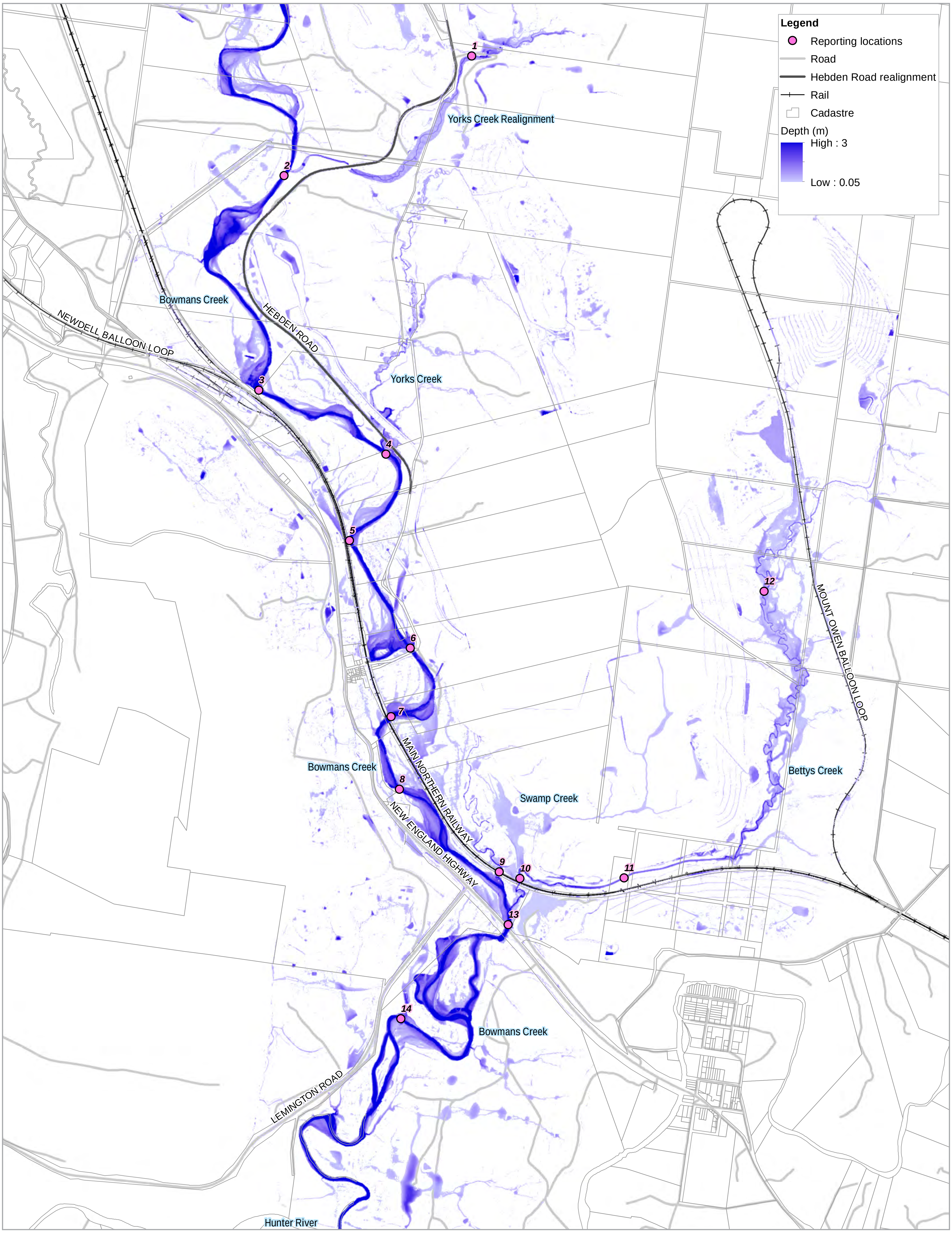
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Existing Conditions
5% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D8

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

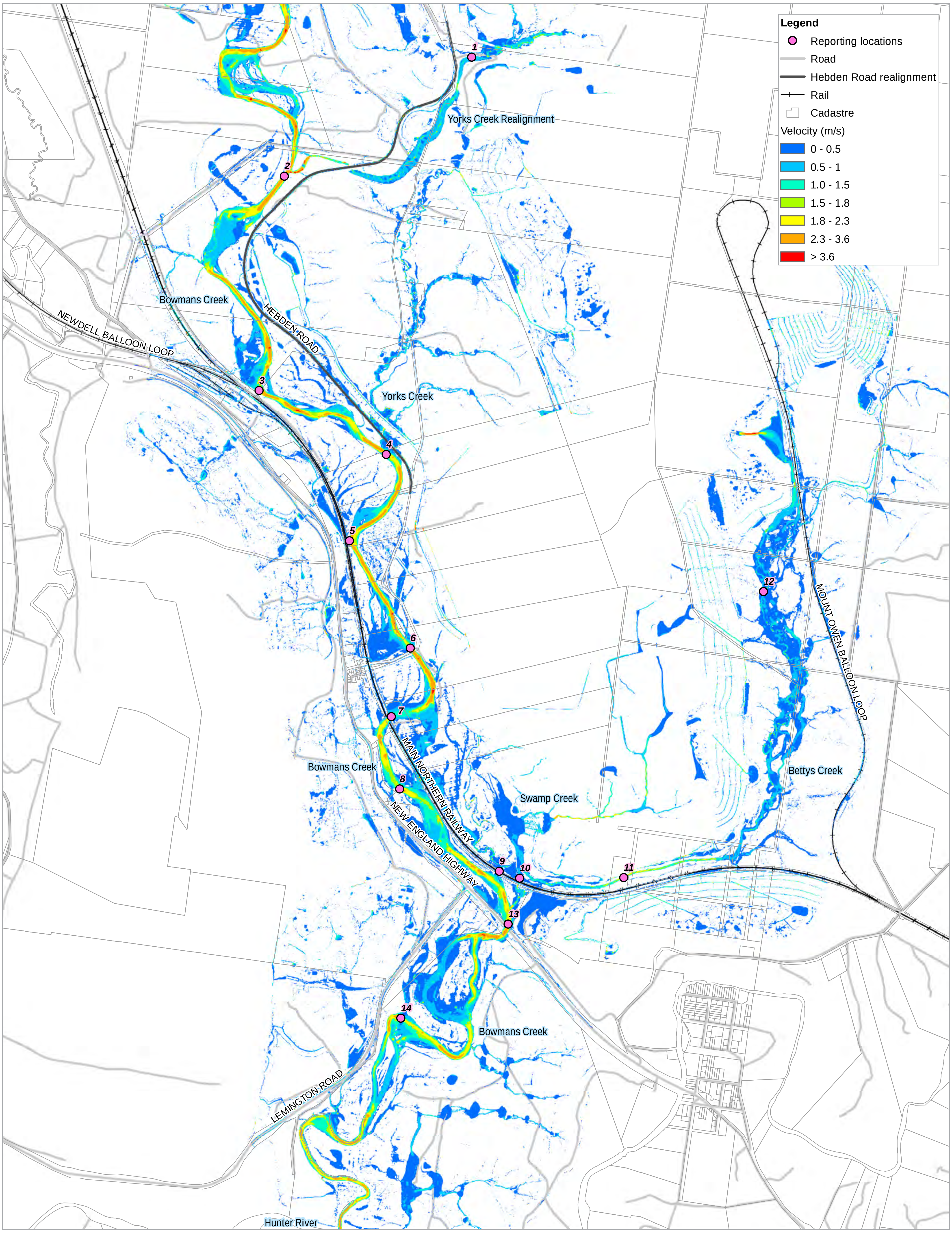
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

Proposed conditions (Year 6)
5% AEP Water Depth

FIGURE D9

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

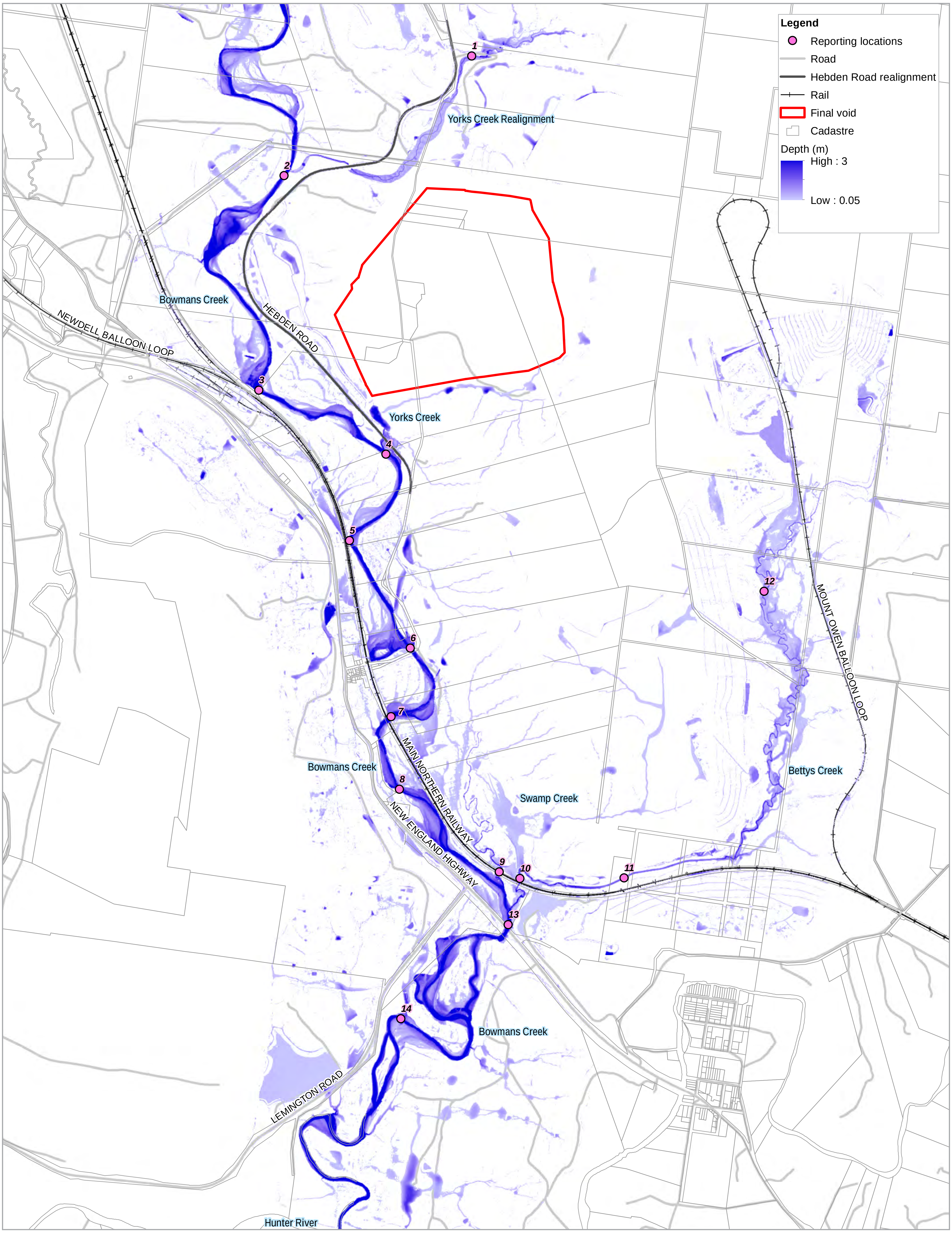
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed conditions (Year 6)
5% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D10

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

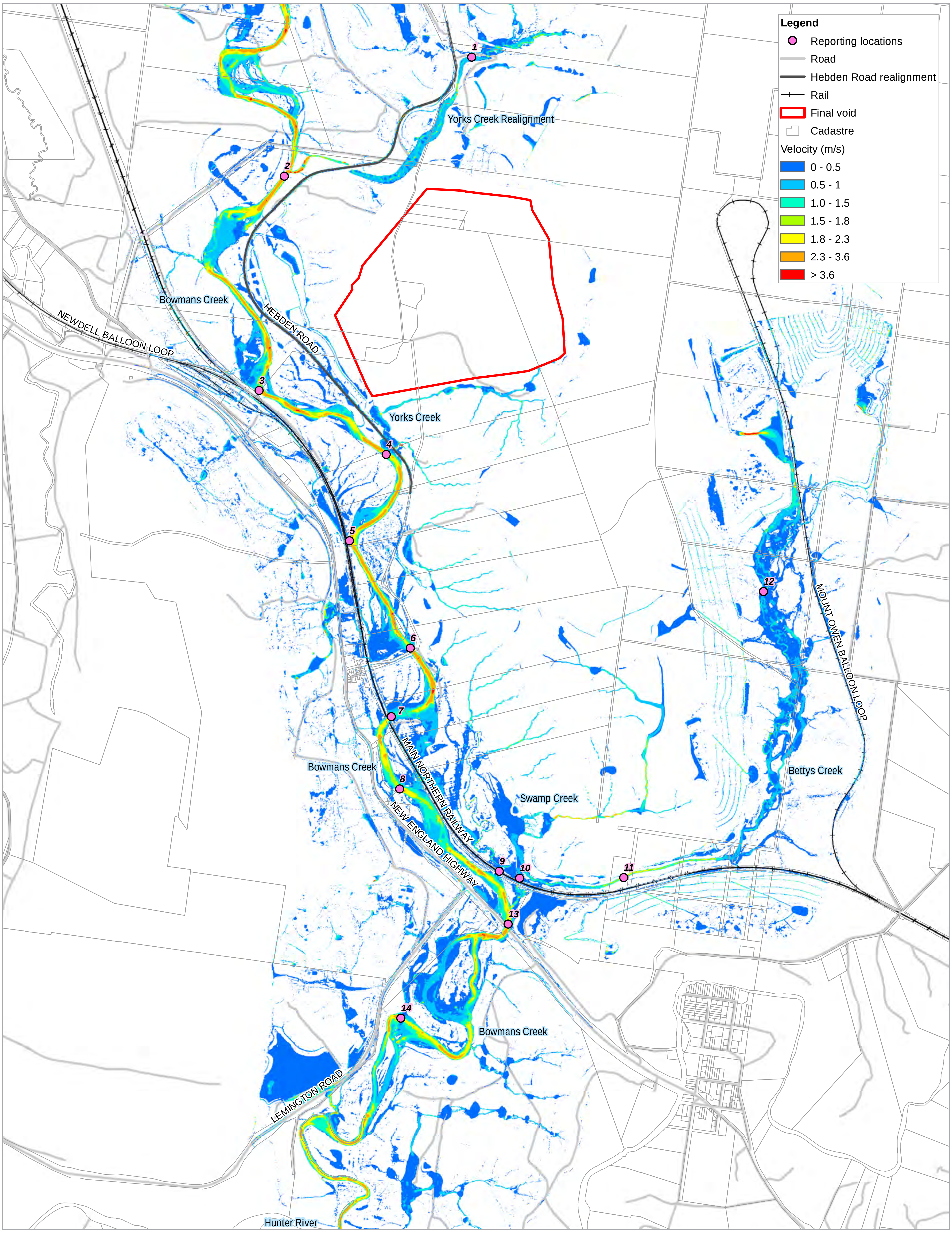
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed Conceptual Final Landform
5% AEP Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D11

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

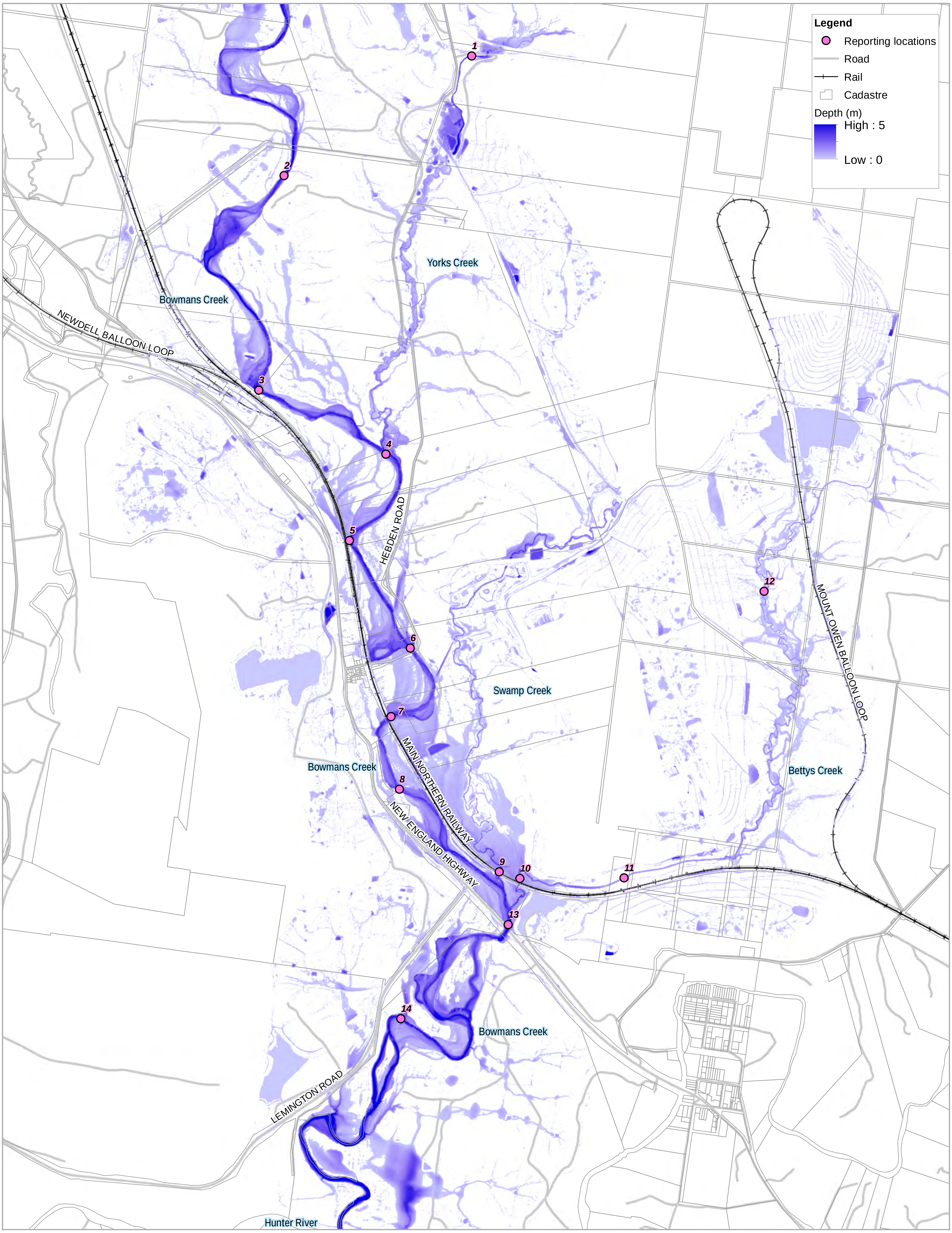
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed Conceptual Final Landform
5% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D12

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

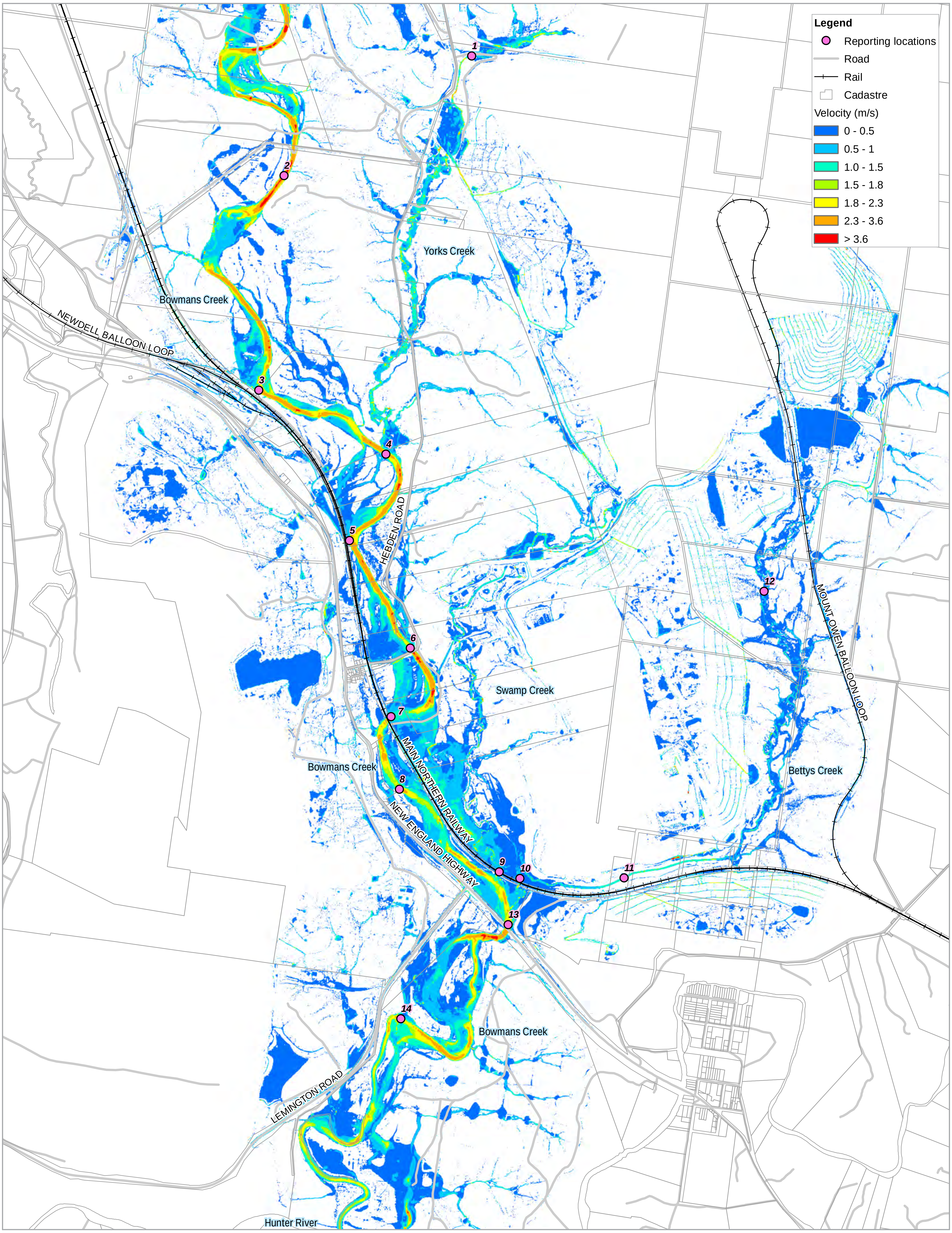
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Existing Conditions
1% AEP Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D13

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

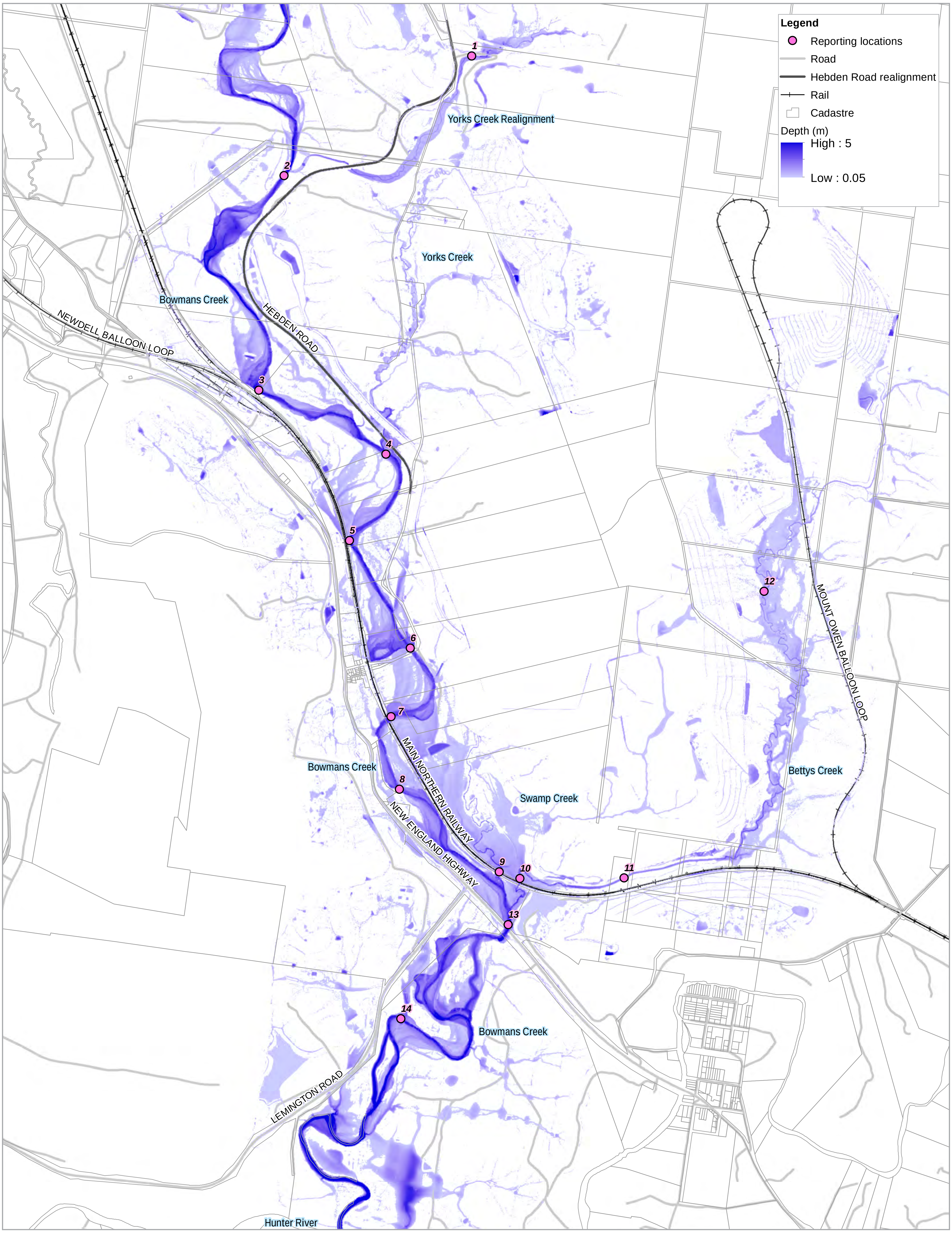
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

Existing Conditions
1% AEP Velocity

FIGURE D14

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

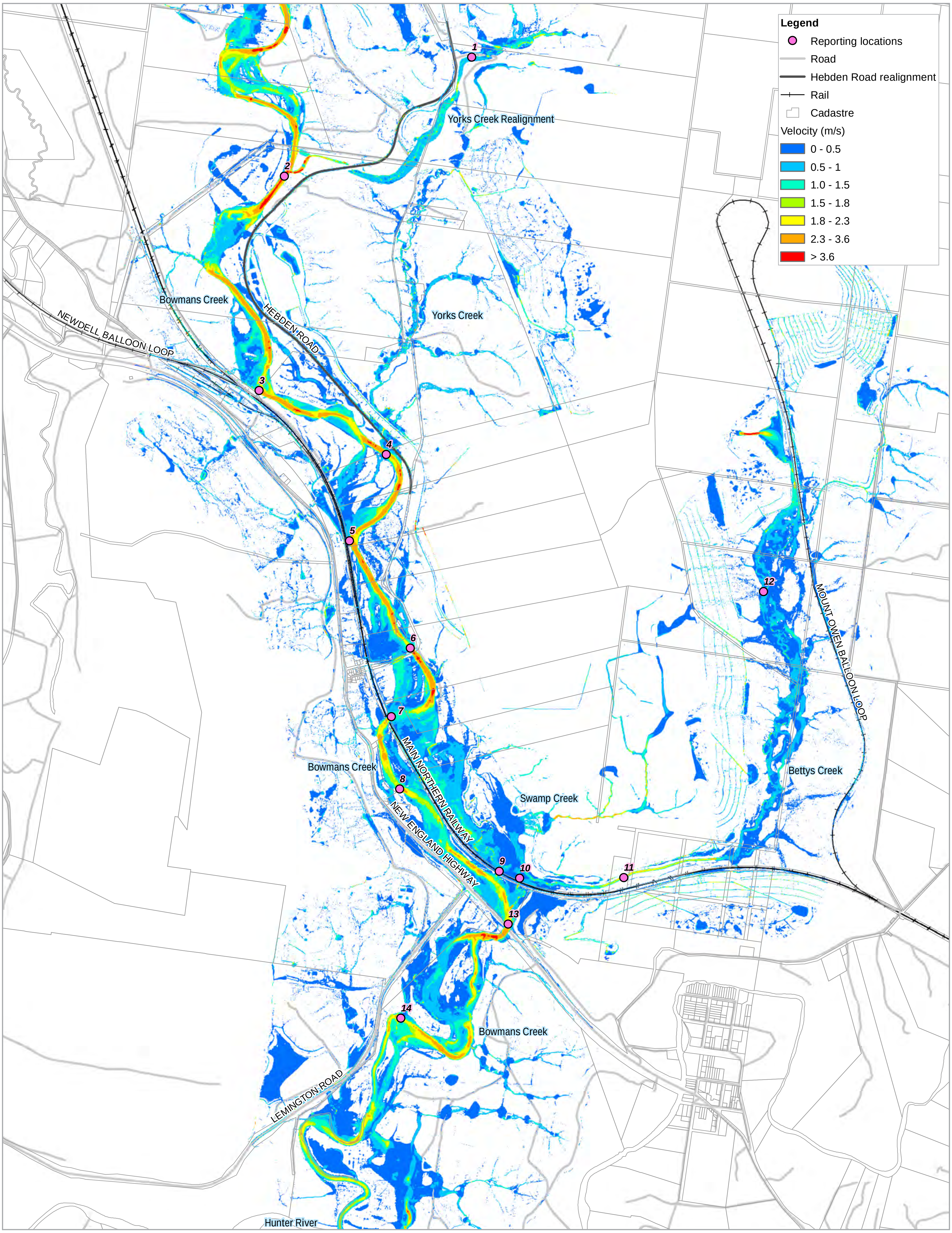
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

Proposed conditions (Year 6)
1% AEP Water Depth

FIGURE D15

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

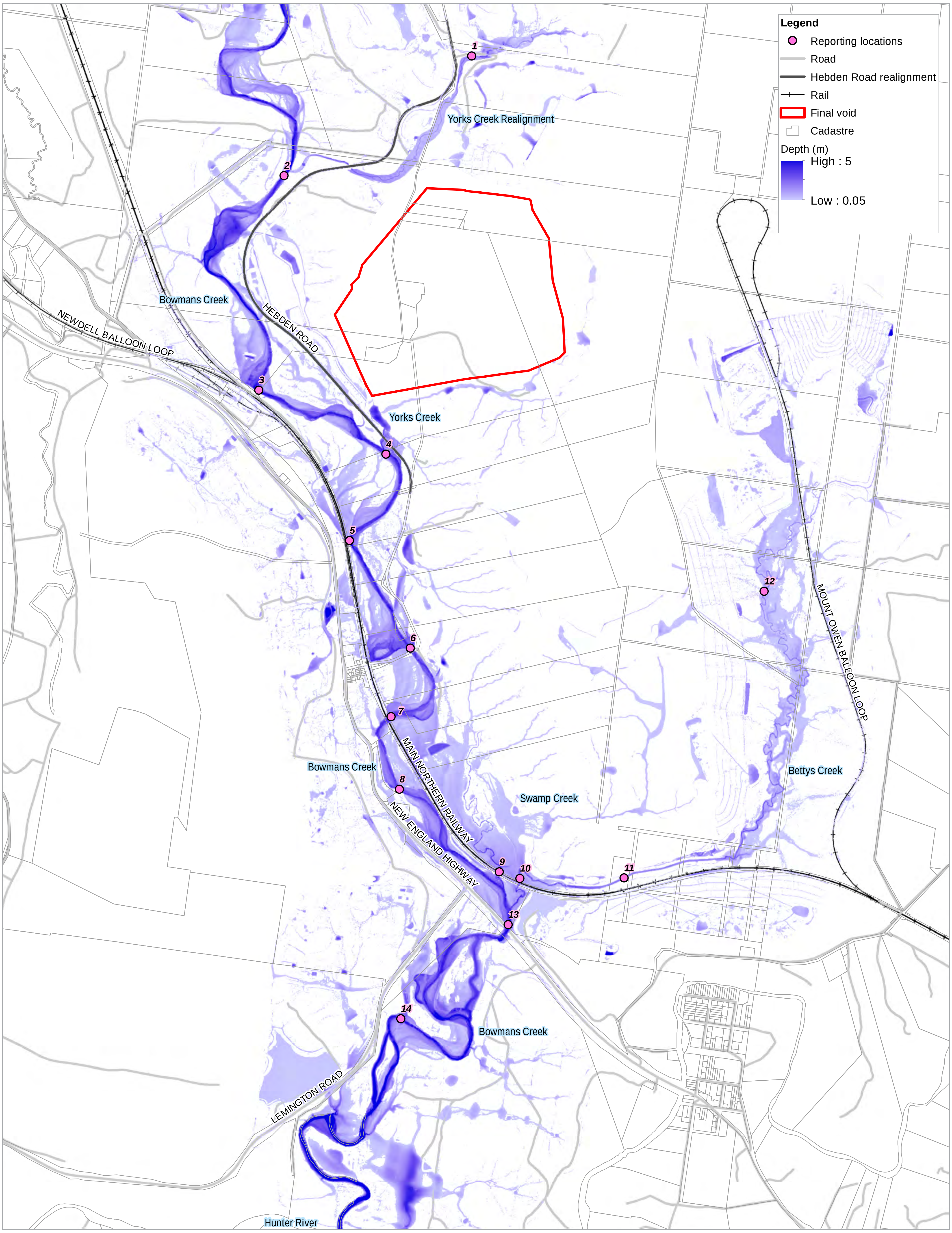
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed conditions (Year 6)
1% AEP Velocity

Project No.	22-19708
Revision No.	0
Date	11 Oct 2019

FIGURE D16

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

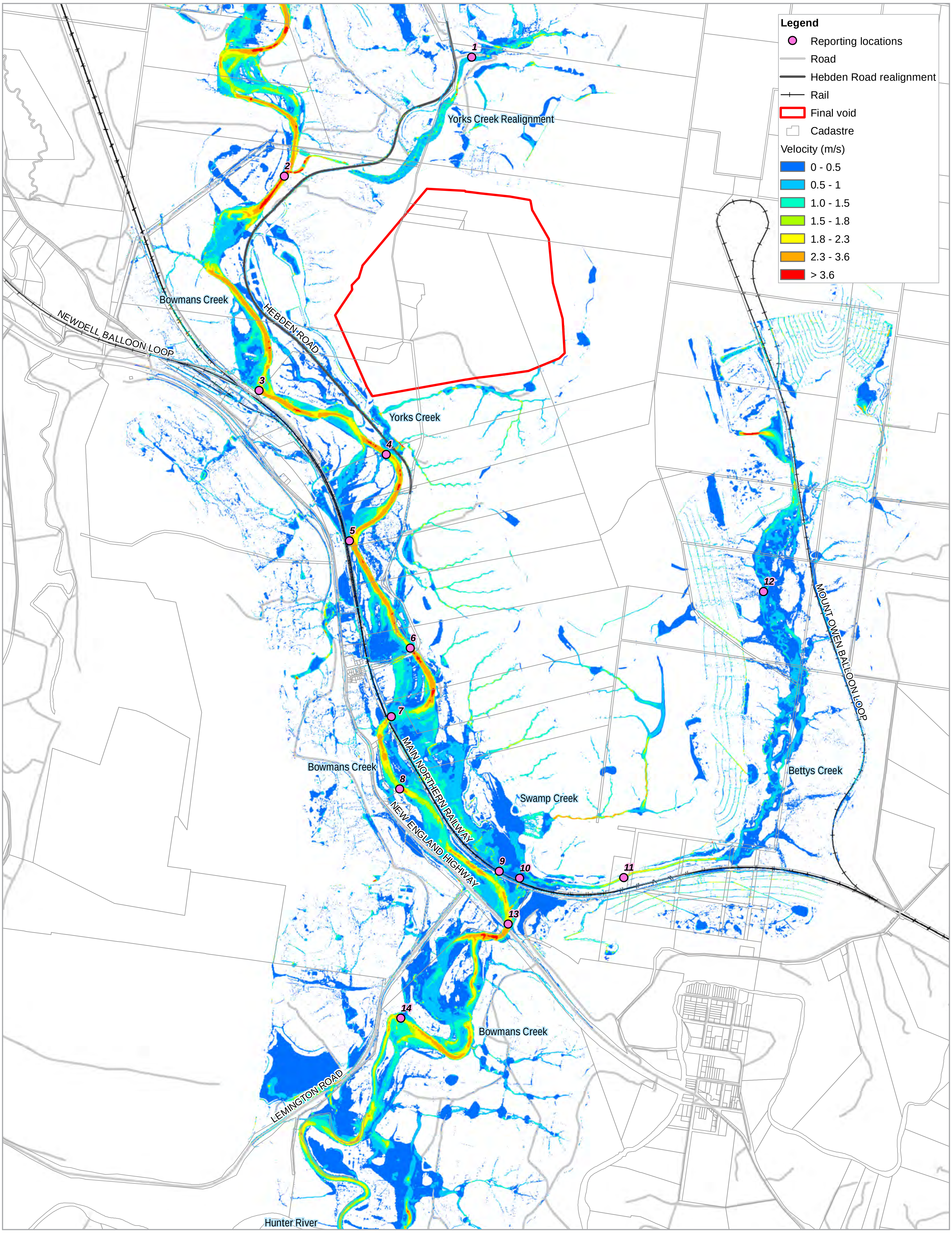
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

Proposed Conceptual Final Landform
1% AEP Water Depth

FIGURE D17

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

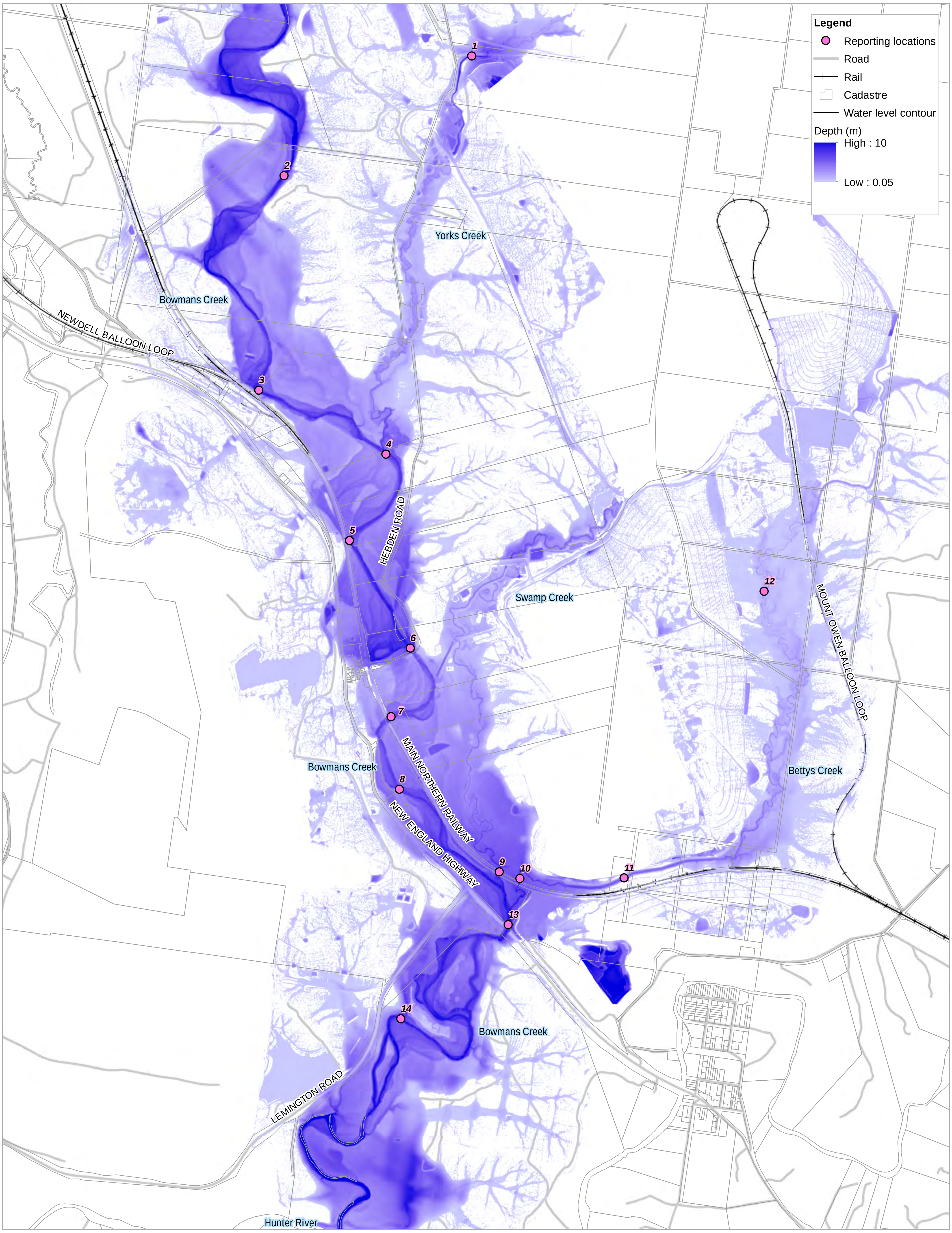
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed Conceptual Final Landform
1% AEP Velocity

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D18

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

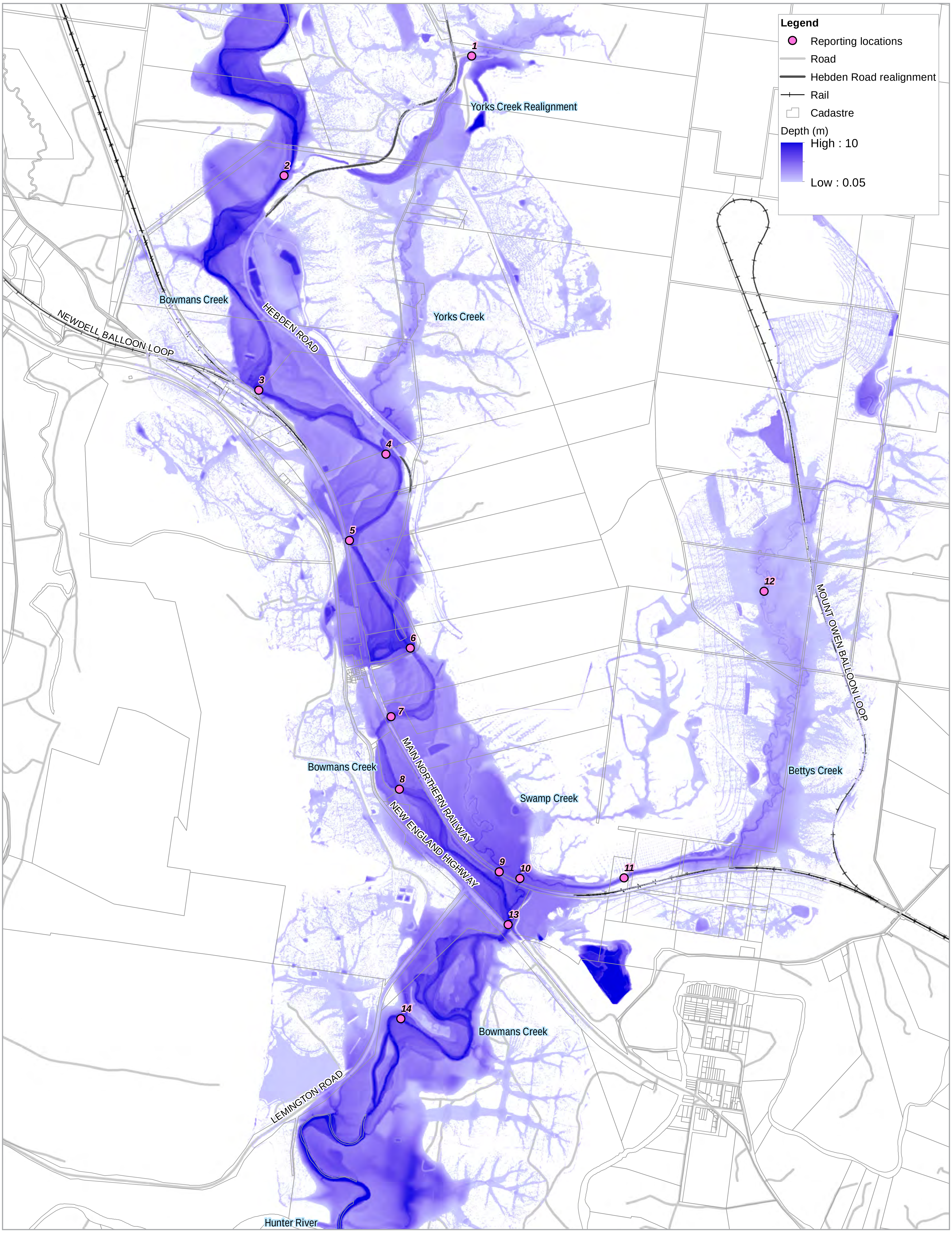
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Existing Conditions
PMF Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D19

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3
0 0.2 0.4 0.6 0.8
Kilometers
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

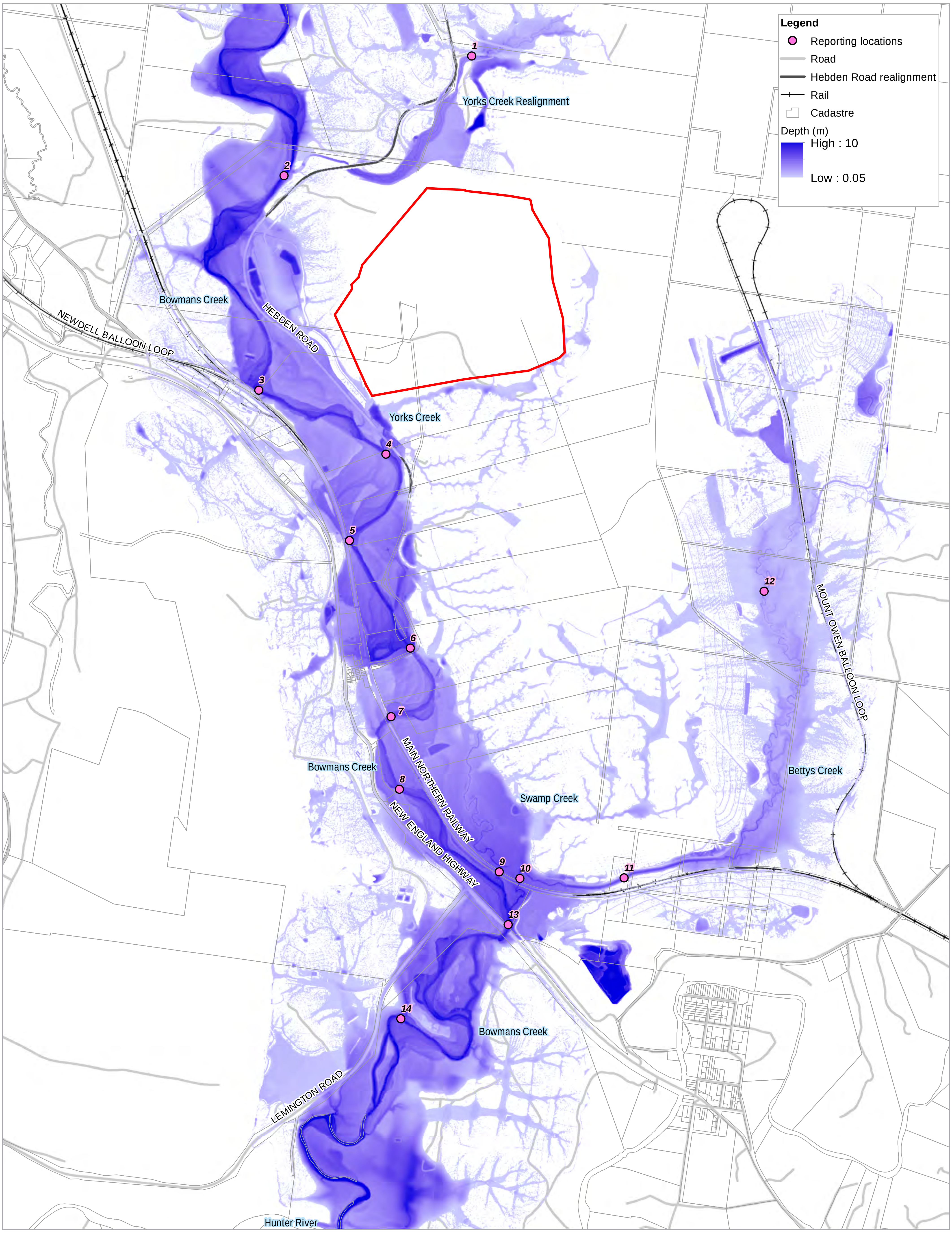
Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed conditions (Year 6)
PMF AEP Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D20

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay



Paper Size ISO A3

0 0.2 0.4 0.6 0.8

Kilometers

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

Umwelt (Australia) Pty Ltd
Glendell Continued Operations Project
Flooding Assessment

Proposed Conceptual Final Landform
PMF Water Depth

Project No. 22-19708
Revision No. 0
Date 11 Oct 2019

FIGURE D21

Data source: LPI: DTDB / DCDB, 2017 . Created by: fmackay

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https://projects.ghd.com/oc/newcastle1/glendellcontinuedope/Delivery/Documents/2219708-REP-GCOP-Flood_Impact_Assessment.docx

Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	S Anderson	A Wyatt		A Wyatt		11/10/2019
1	S Anderson	S Gray		S Gray		20/11/2019

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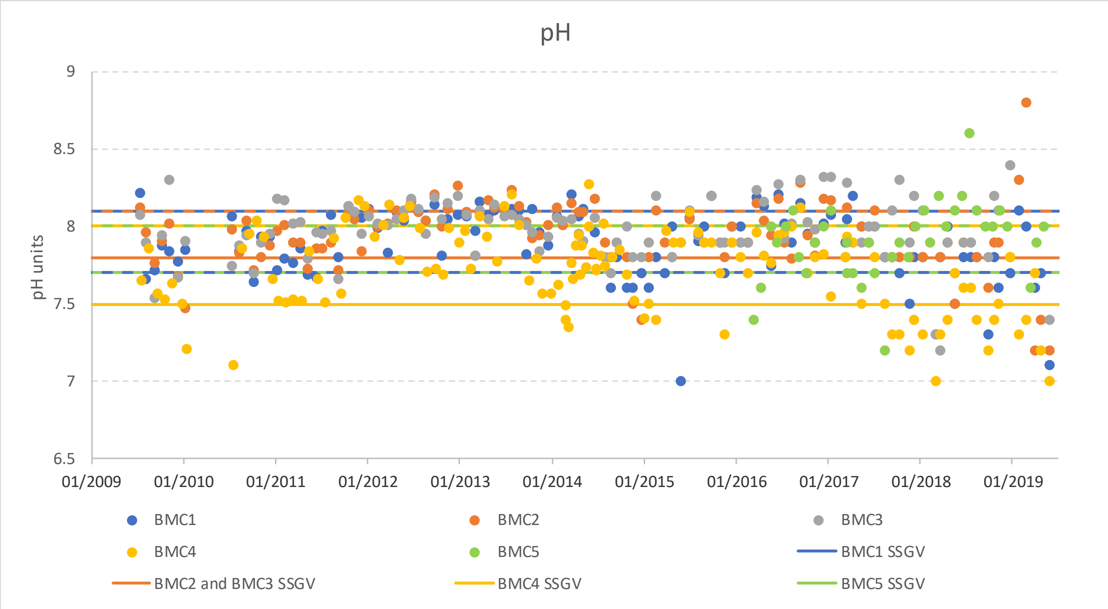
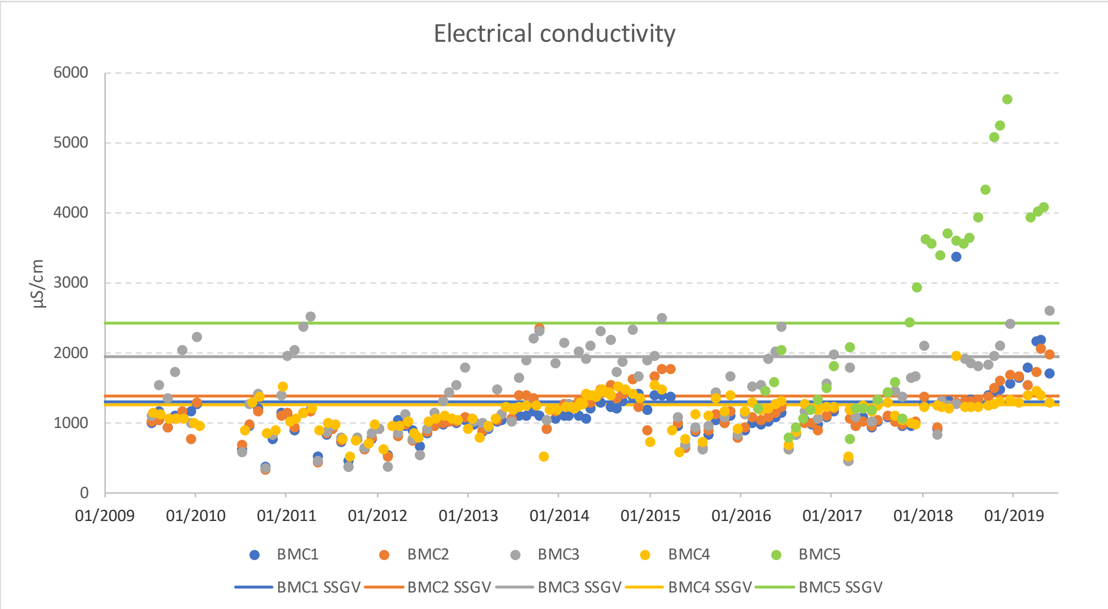
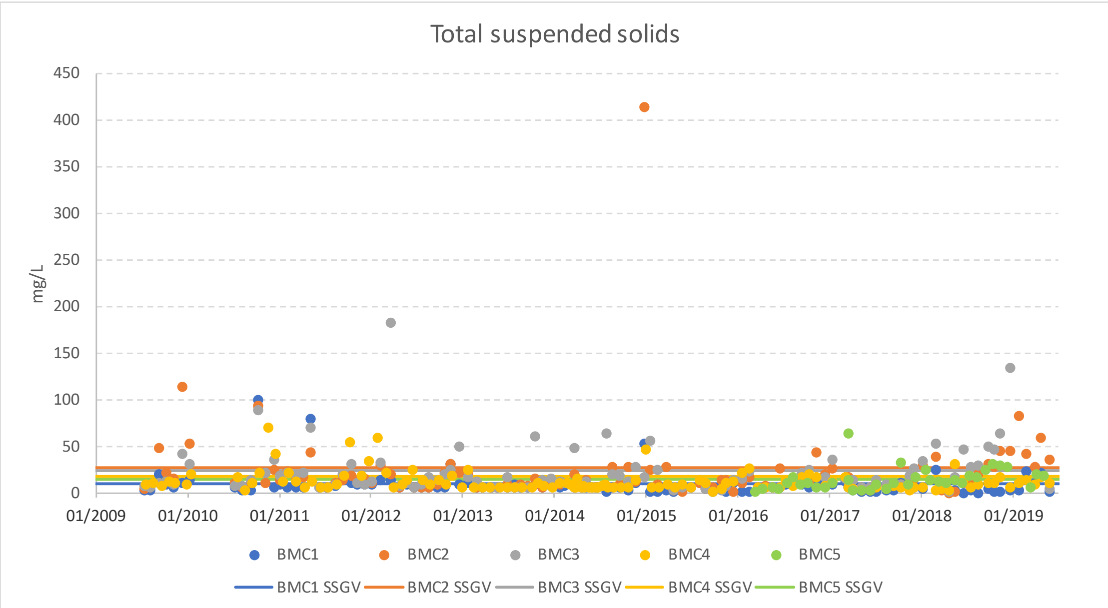
Appendix D – Surface water quality data

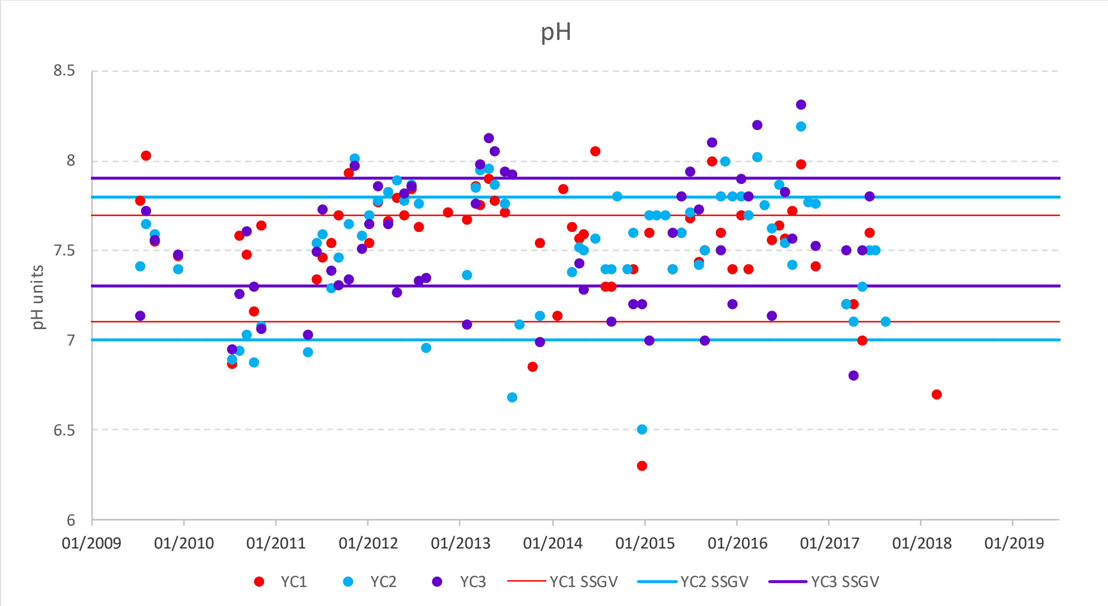
Bowmans Creek

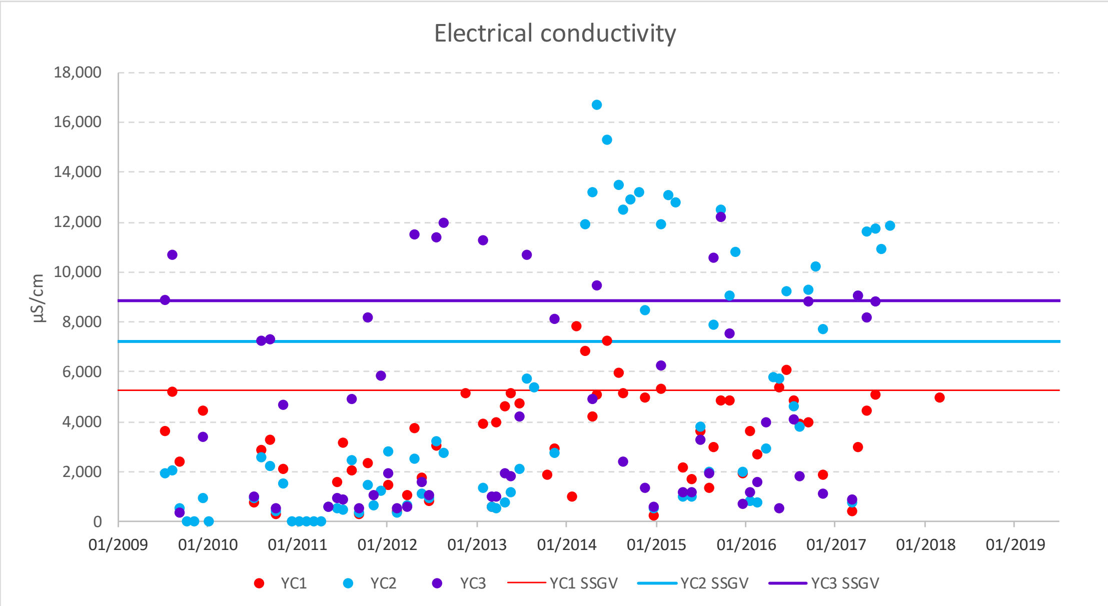


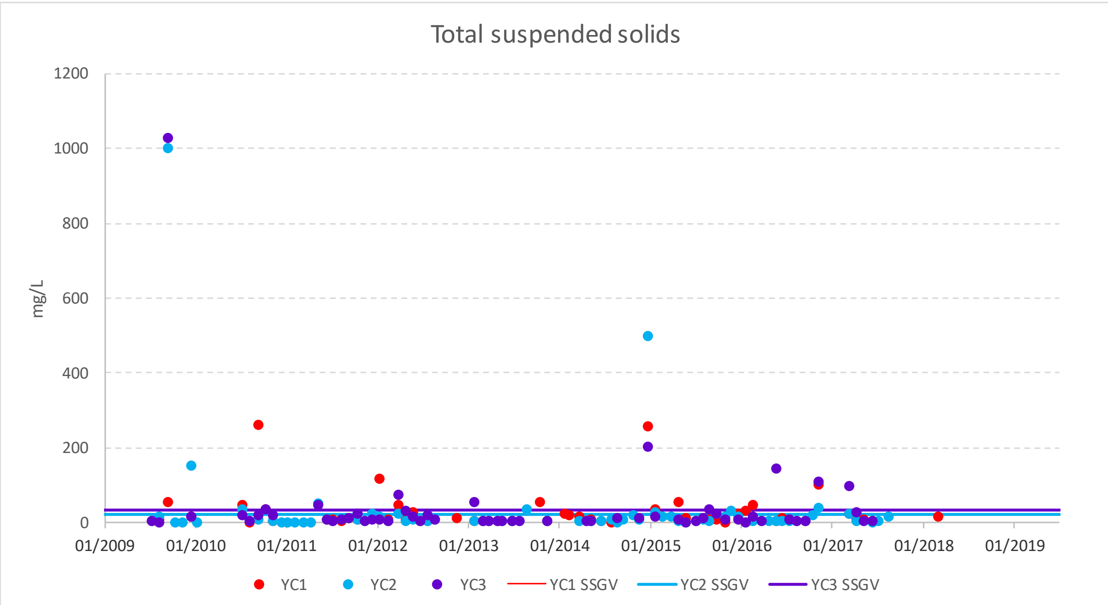




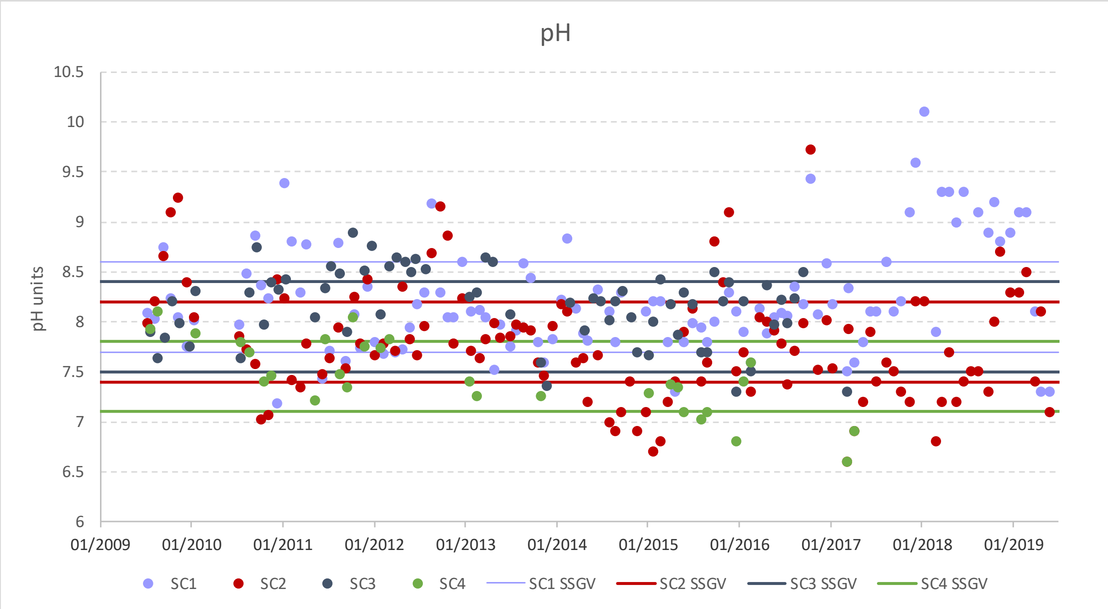
Yorks Creek


pH
pH units
8.5
8
7.5
7
6.5
6
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
YC1
YC2
YC3
YC1 SSGV
YC2 SSGV
YC3 SSGV

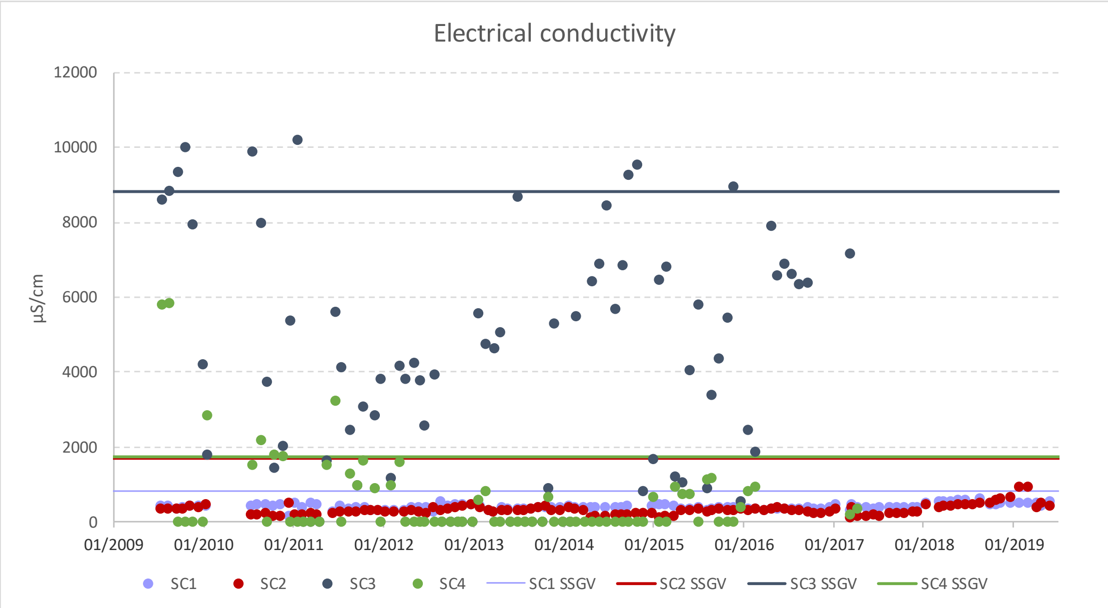

Electrical conductivity
µS/cm
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
YC1
YC2
YC3
YC1 SSGV
YC2 SSGV
YC3 SSGV


Total suspended solids
mg/L
1200
1000
800
600
400
200
0
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
YC1
YC2
YC3
YC1 SSGV
YC2 SSGV
YC3 SSGV

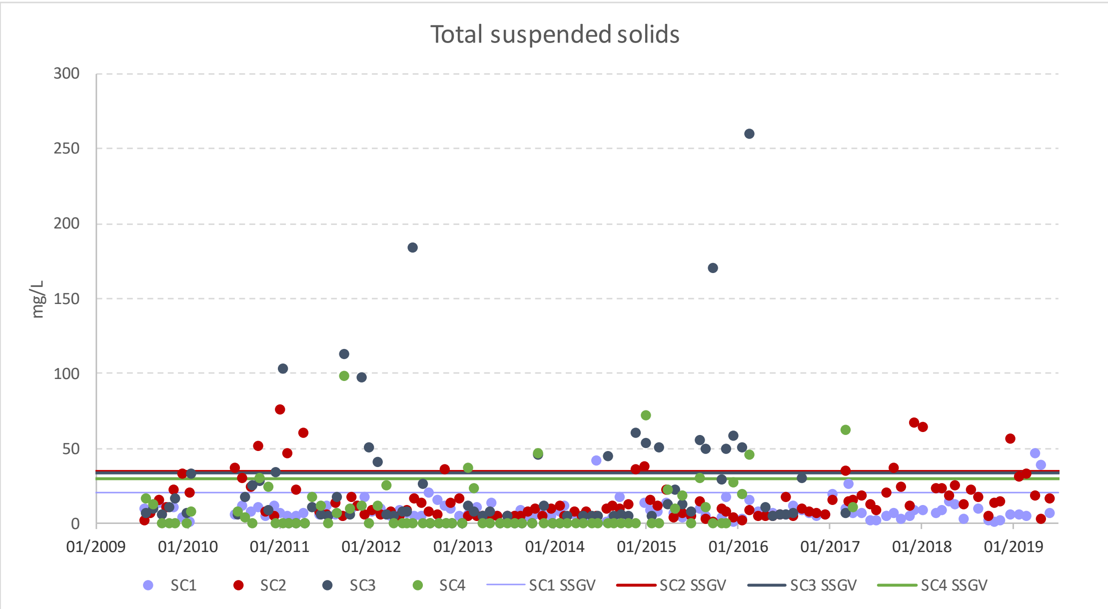
Swamp Creek



pH
pH units
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
SC1
SC2
SC3
SC4
SC1 SSGV
SC2 SSGV
SC3 SSGV
SC4 SSGV

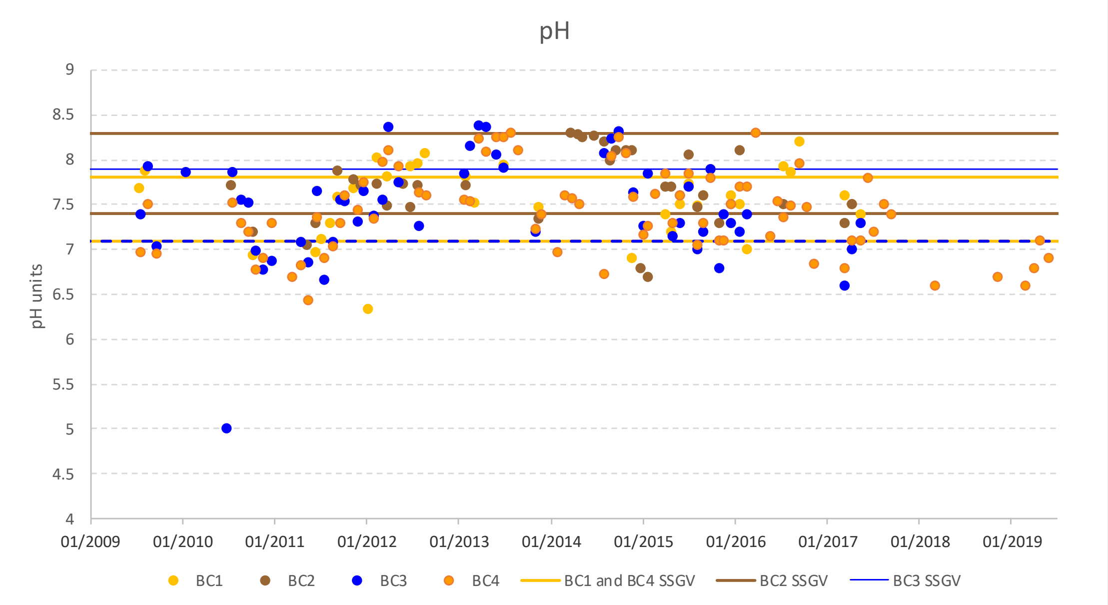


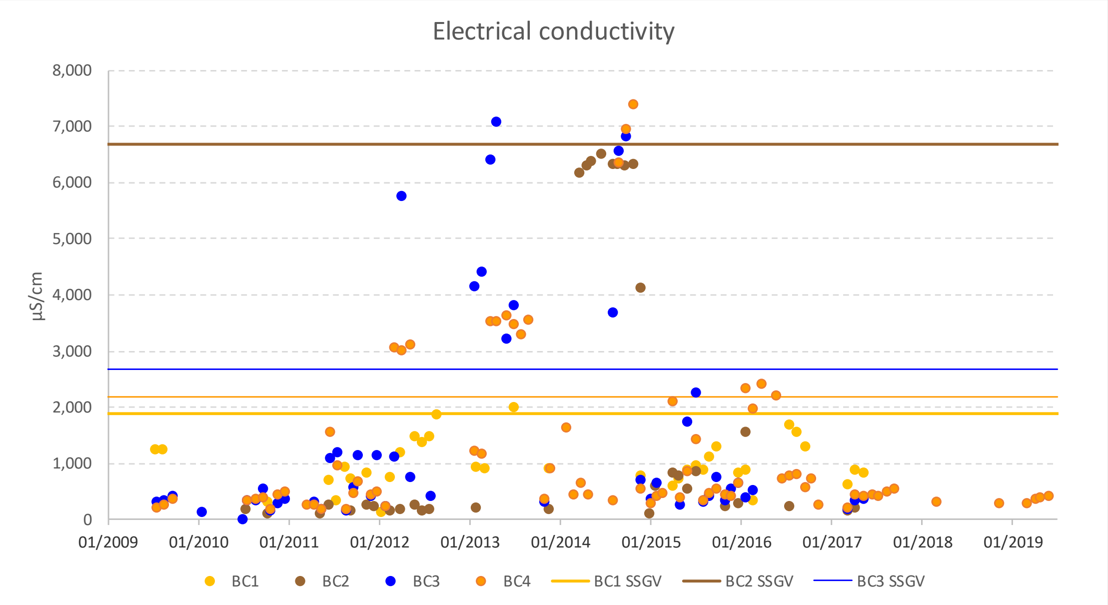
Electrical conductivity
µS/cm
12000
10000
8000
6000
4000
2000
0
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
SC1
SC2
SC3
SC4
SC1 SSGV
SC2 SSGV
SC3 SSGV
SC4 SSGV

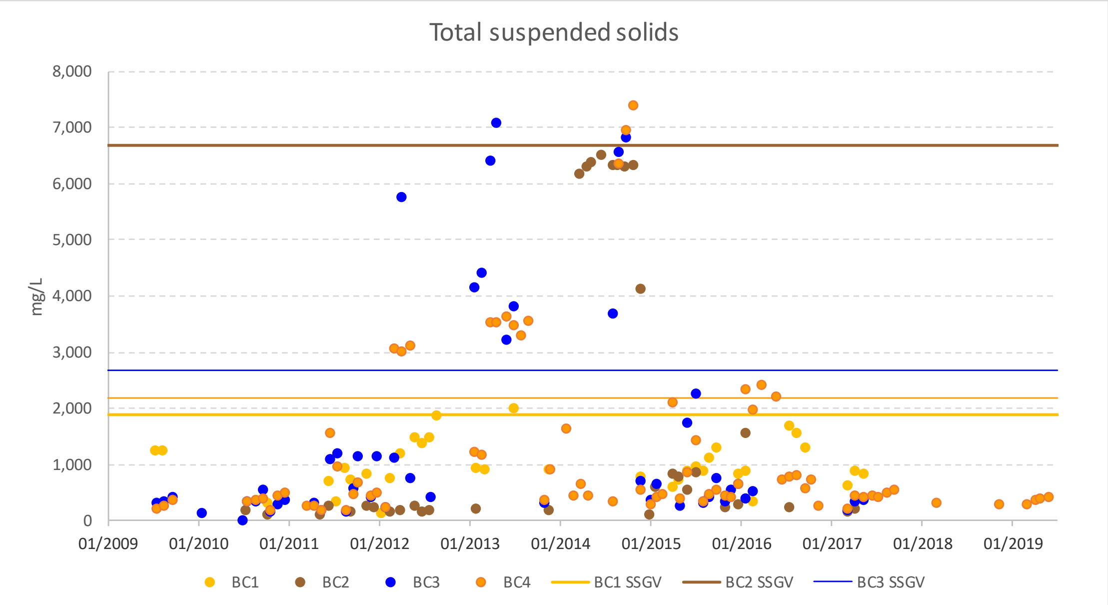


Total suspended solids
mg/L
300
250
200
150
100
50
0
01/2009
01/2010
01/2011
01/2012
01/2013
01/2014
01/2015
01/2016
01/2017
01/2018
01/2019
SC1
SC2
SC3
SC4
SC1 SSGV
SC2 SSGV
SC3 SSGV
SC4 SSGV

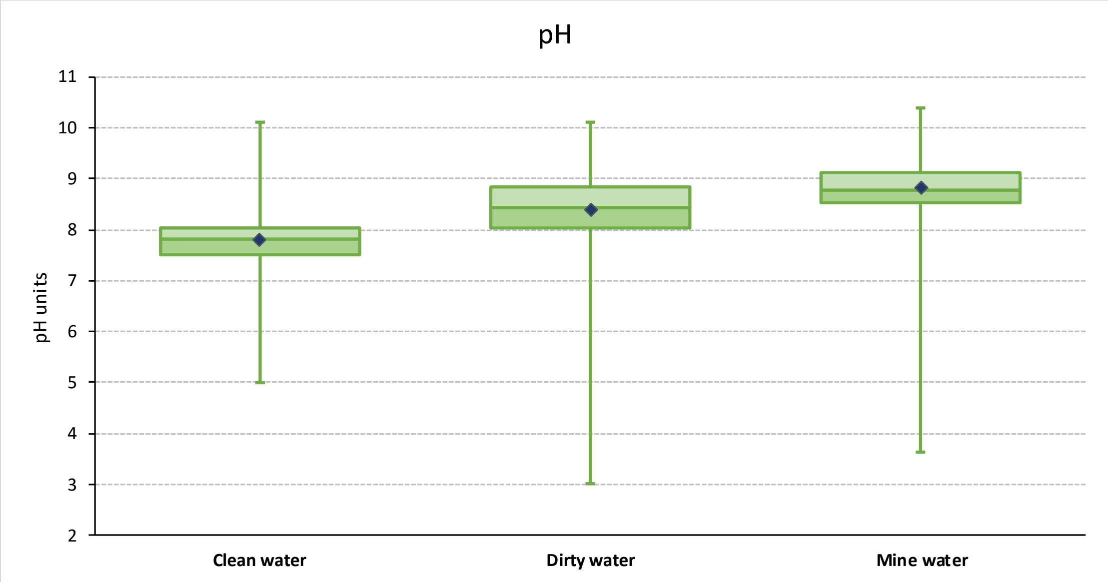
Bettys Creek

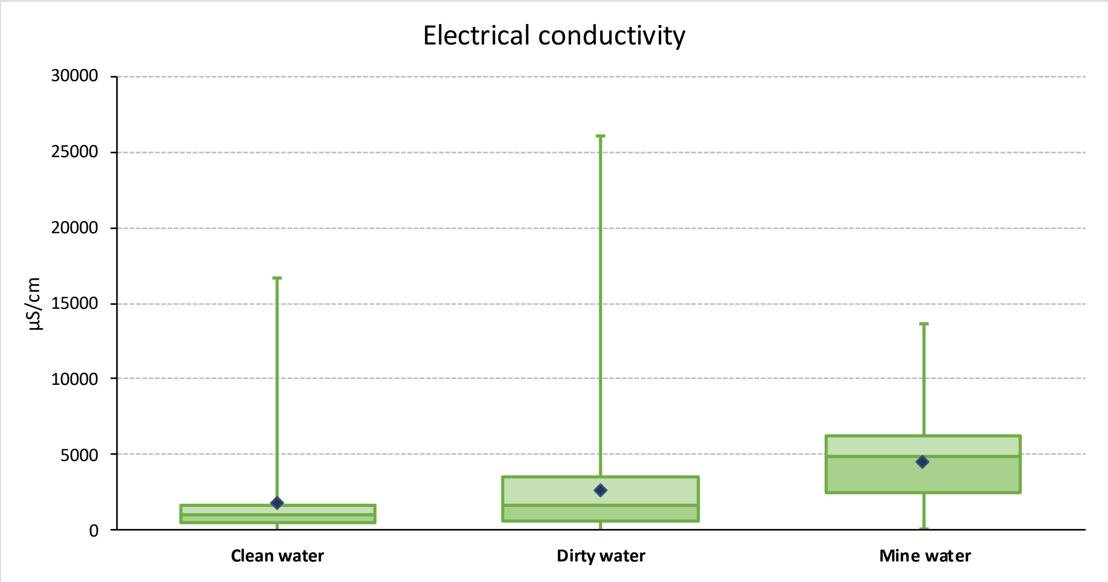


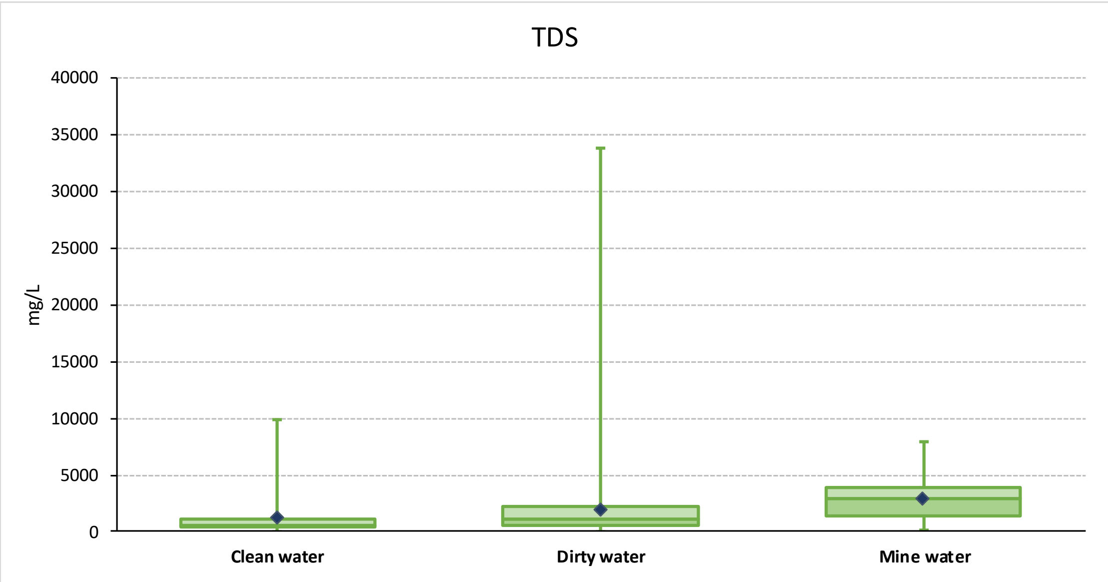


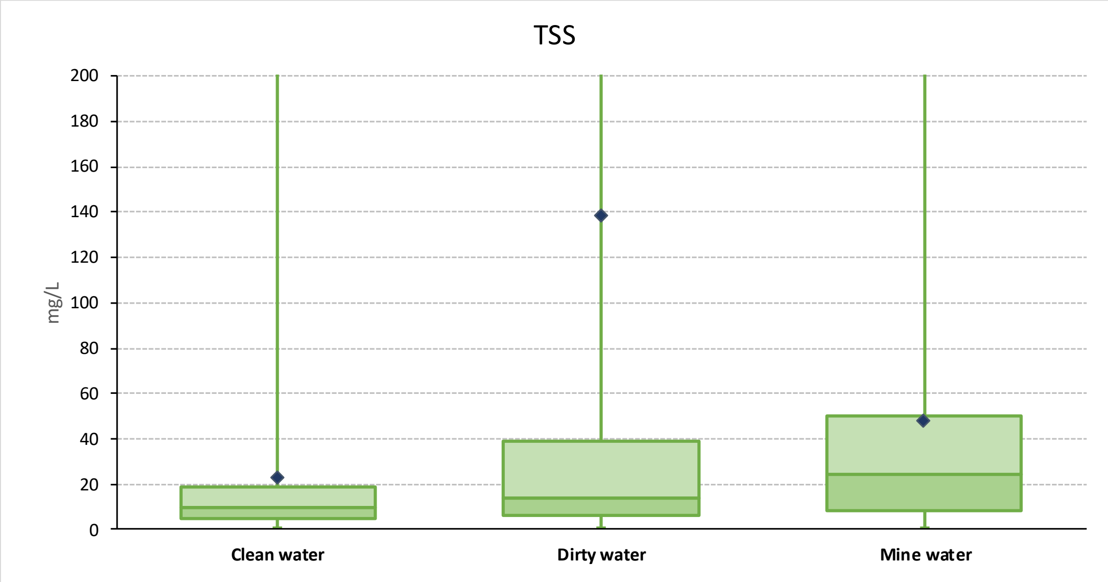


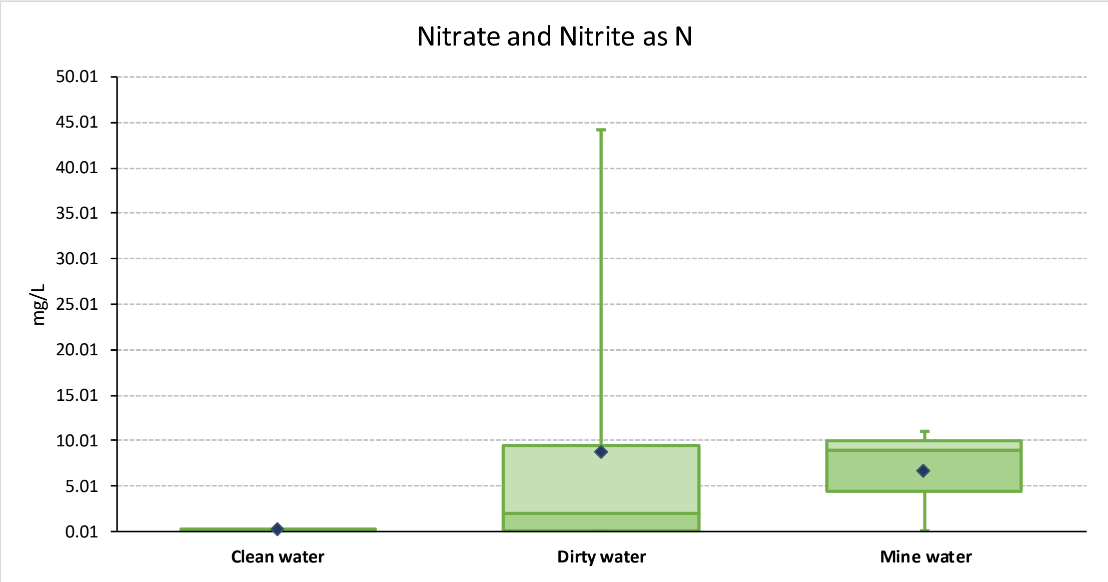
Dirty and mine water management systems

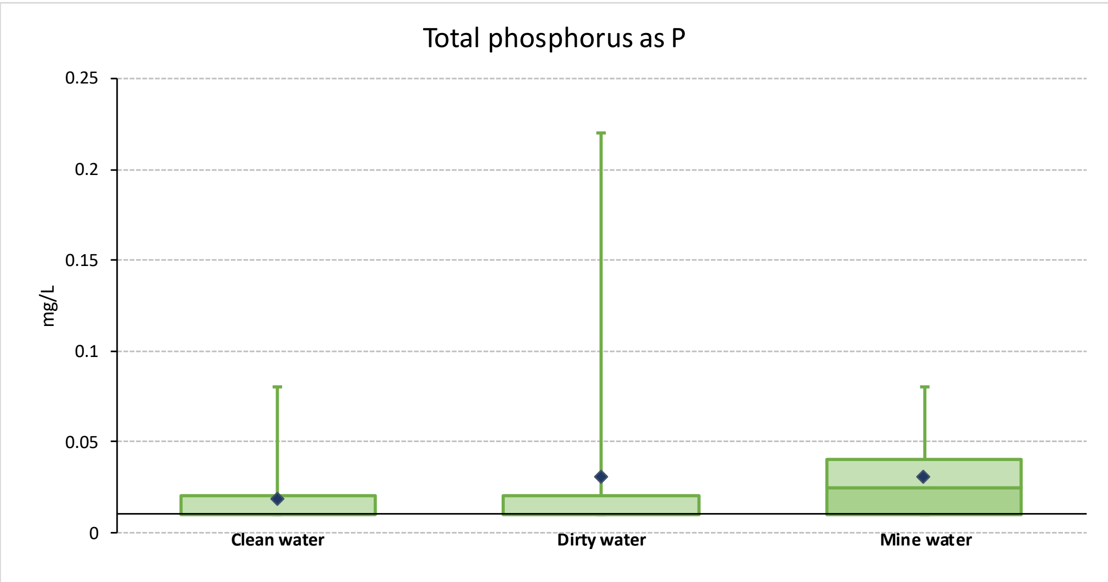


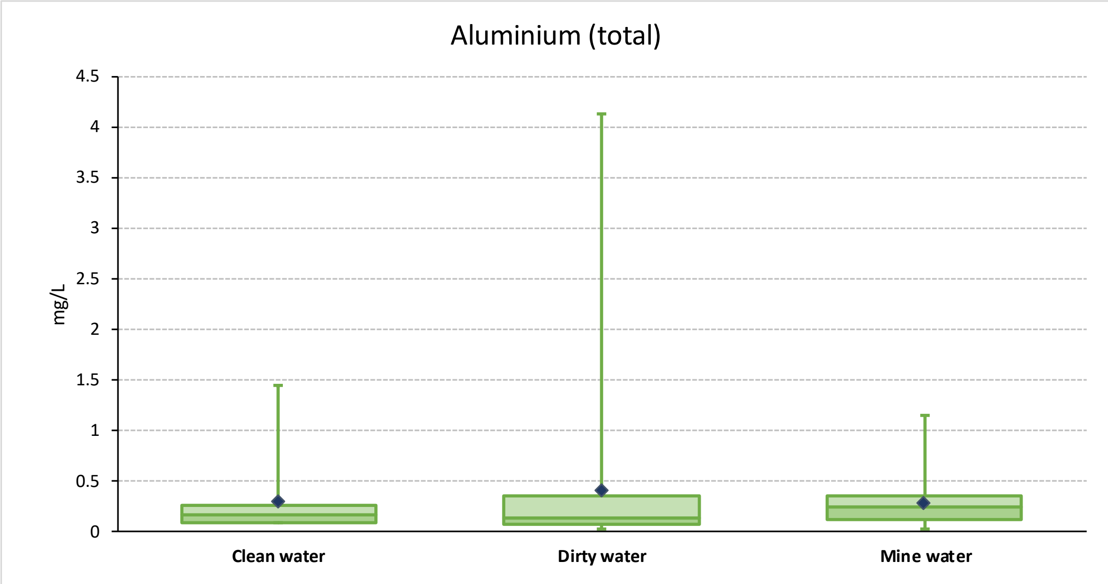


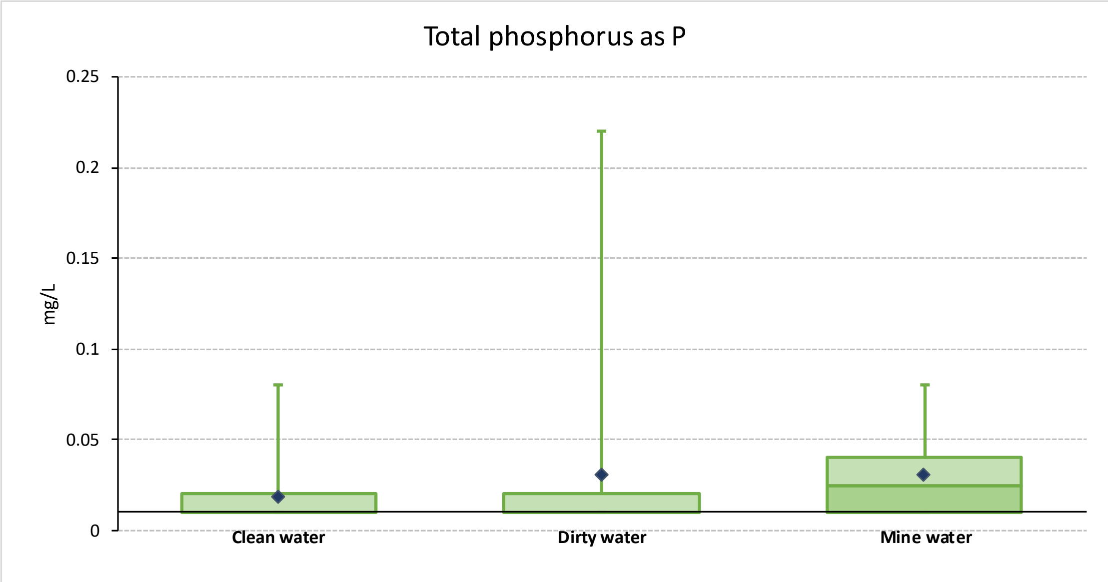


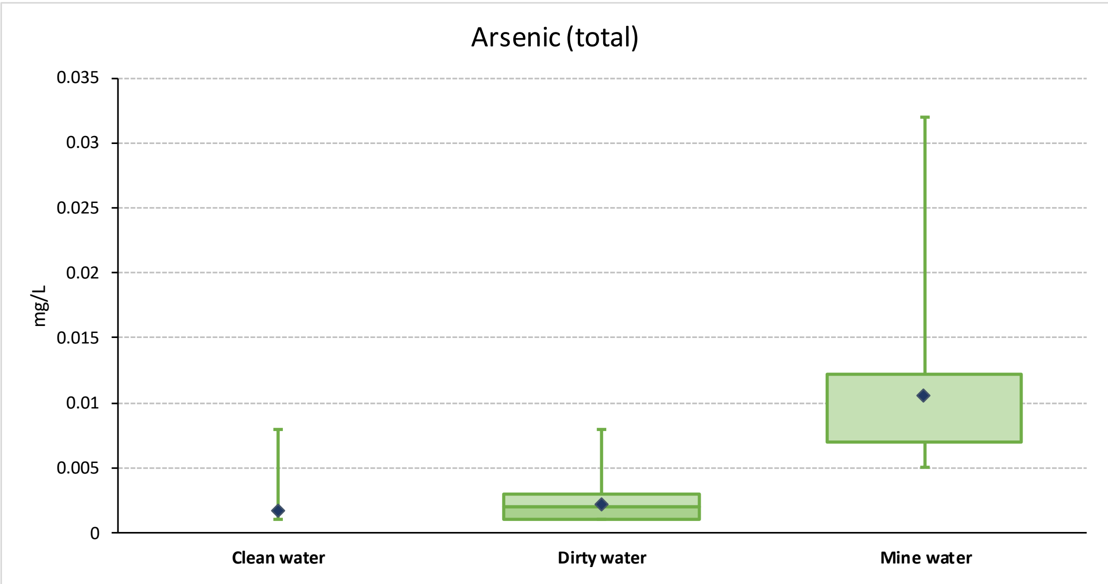

TSS
mg/L
200
180
160
140
120
100
80
60
40
20
0
Clean water
Dirty water
Mine water

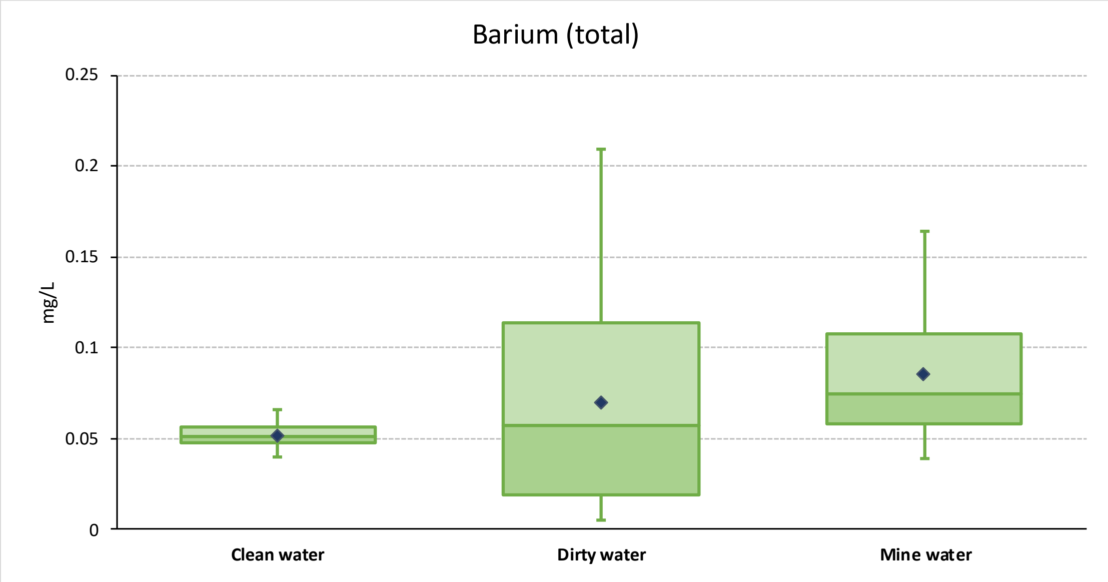

Nitrate and Nitrite as N
mg/L
50.01
45.01
40.01
35.01
30.01
25.01
20.01
15.01
10.01
5.01
0.01
Clean water
Dirty water
Mine water

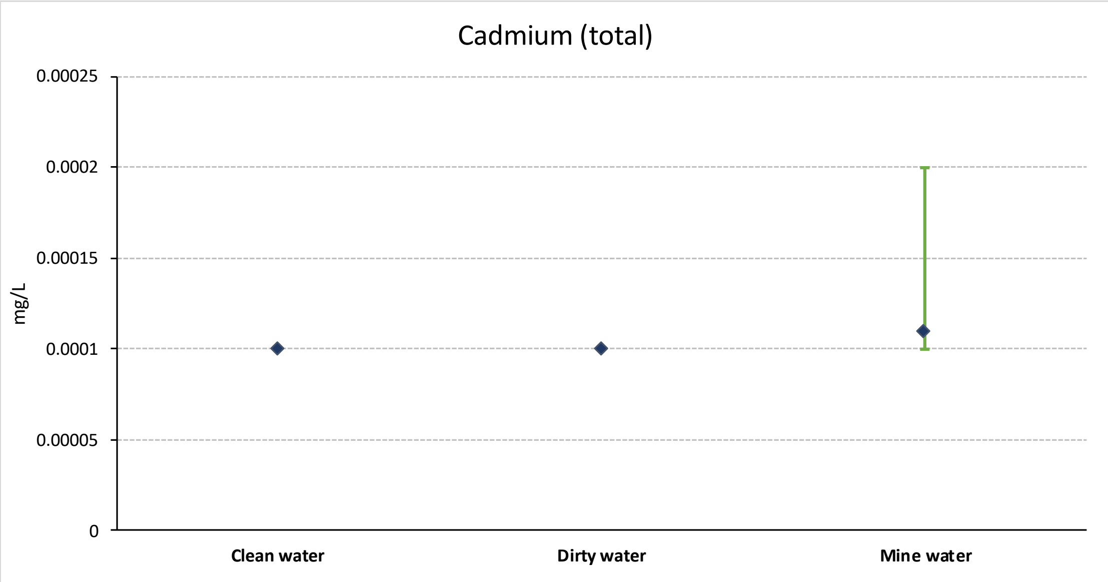

Total phosphorus as P
mg/L
0.25
0.2
0.15
0.1
0.05
0
Clean water
Dirty water
Mine water

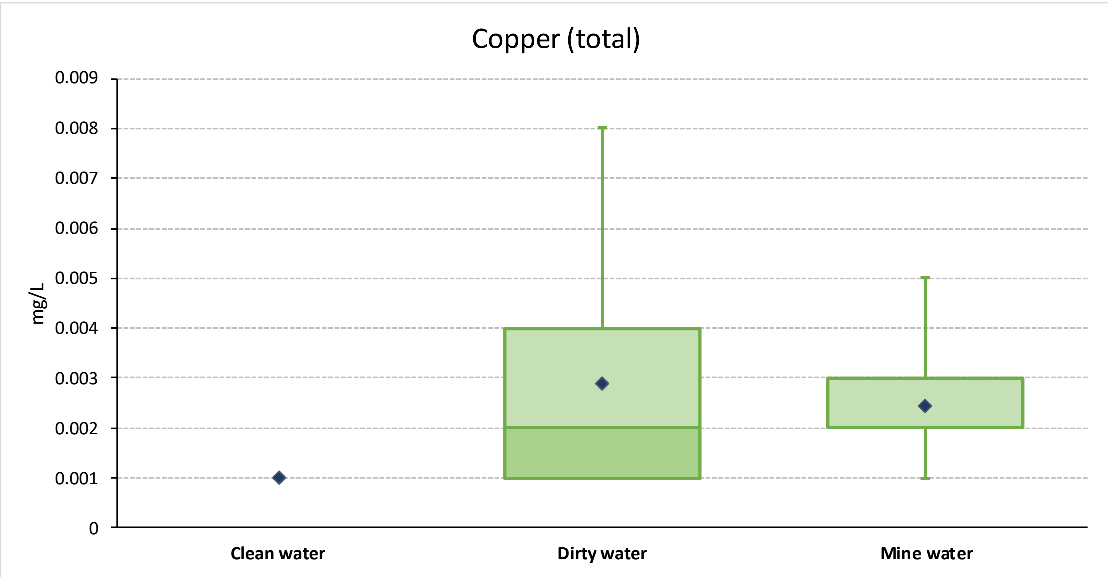

Aluminium (total)
mg/L
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Clean water
Dirty water
Mine water

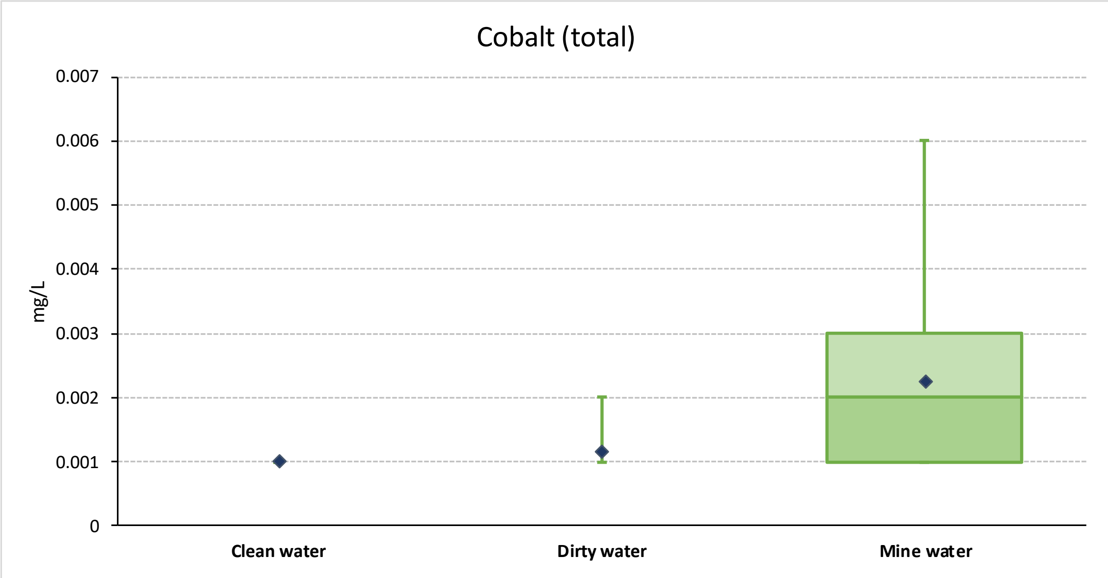

Total phosphorus as P
mg/L
0.25
0.2
0.15
0.1
0.05
0
Clean water
Dirty water
Mine water

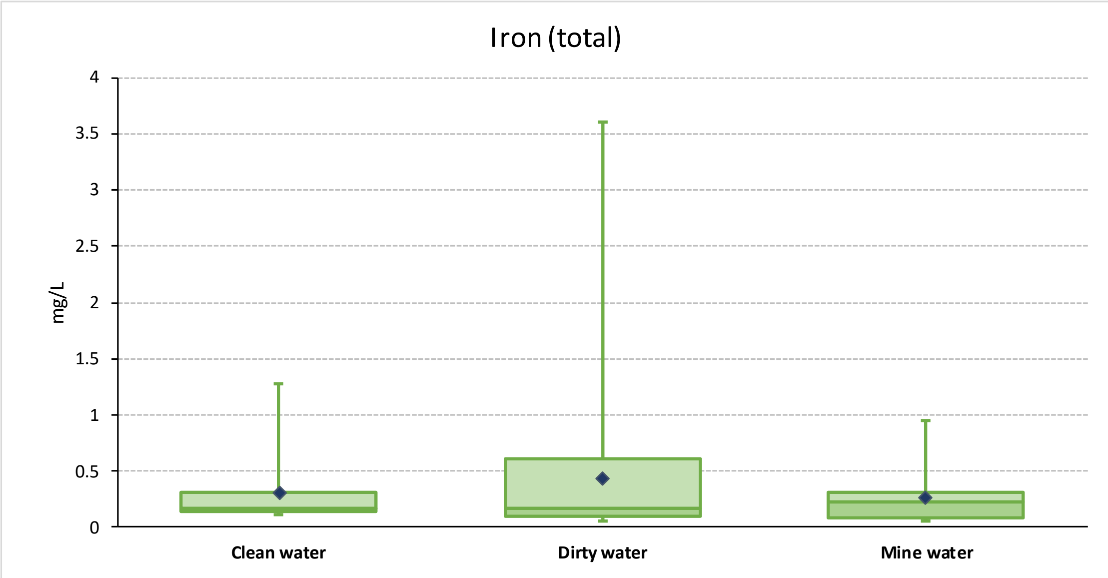

Arsenic (total)
mg/L
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Clean water
Dirty water
Mine water

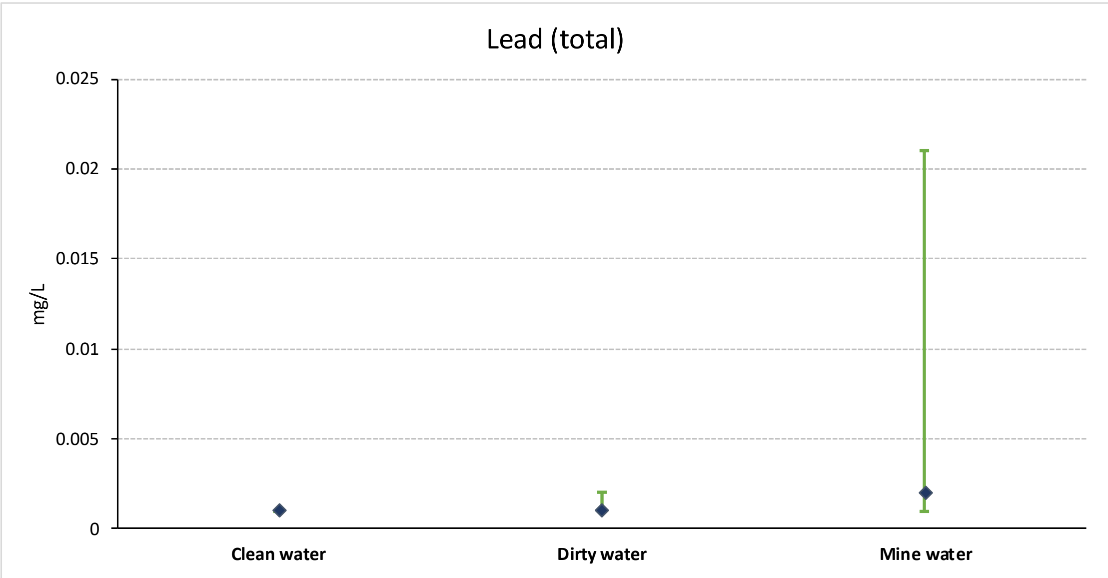

Barium (total)
0.25
0.2
0.15
0.1
0.05
0
mg/L
Clean water
Dirty water
Mine water

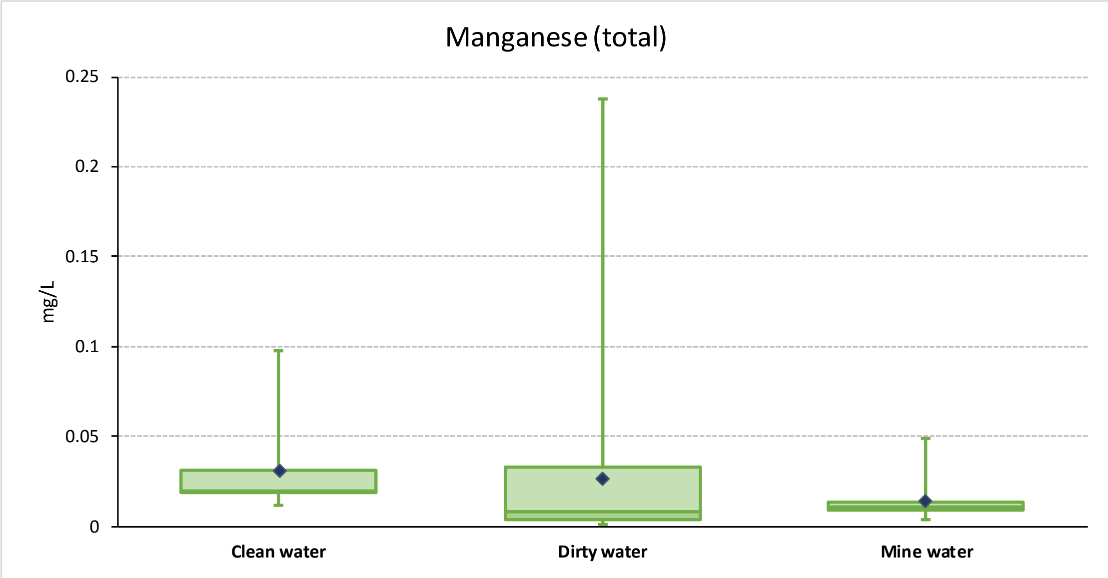

Cadmium (total)
0.00025
0.0002
0.00015
0.0001
0.00005
0
mg/L
Clean water
Dirty water
Mine water

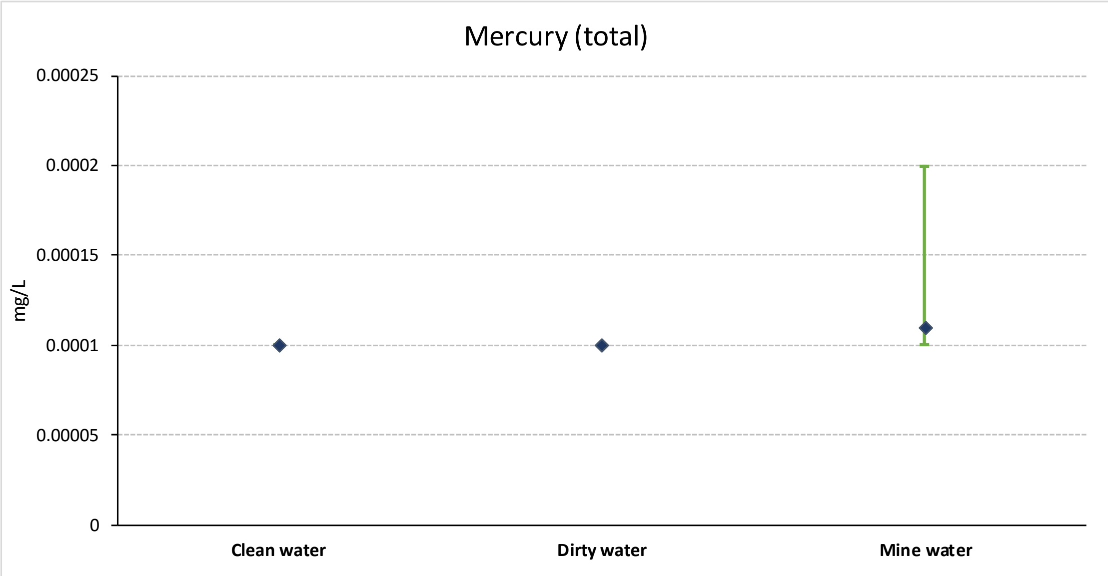

Copper (total)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
mg/L
Clean water
Dirty water
Mine water

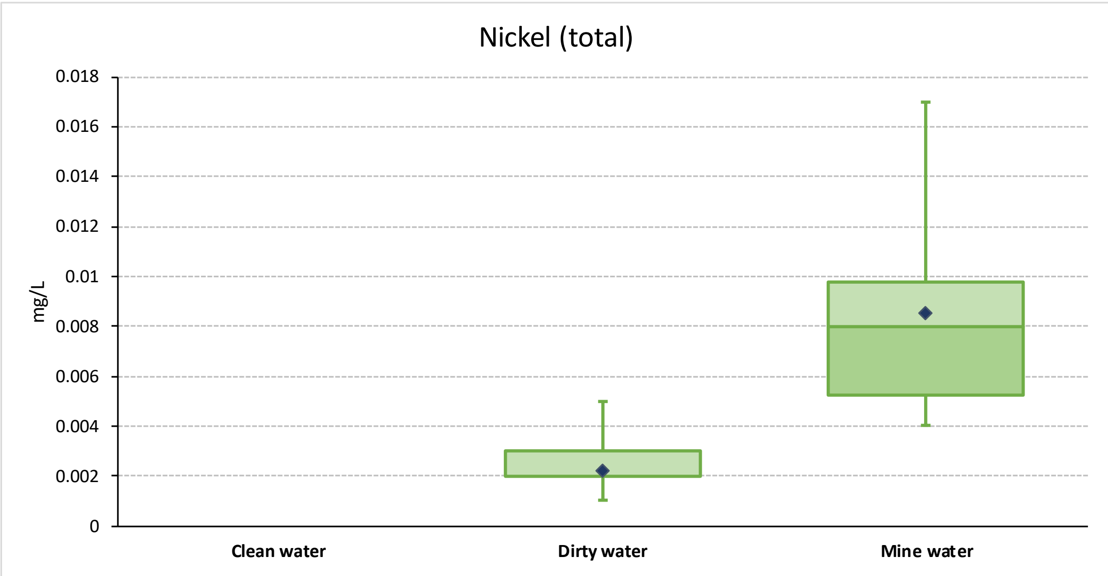

Cobalt (total)
mg/L
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Clean water
Dirty water
Mine water

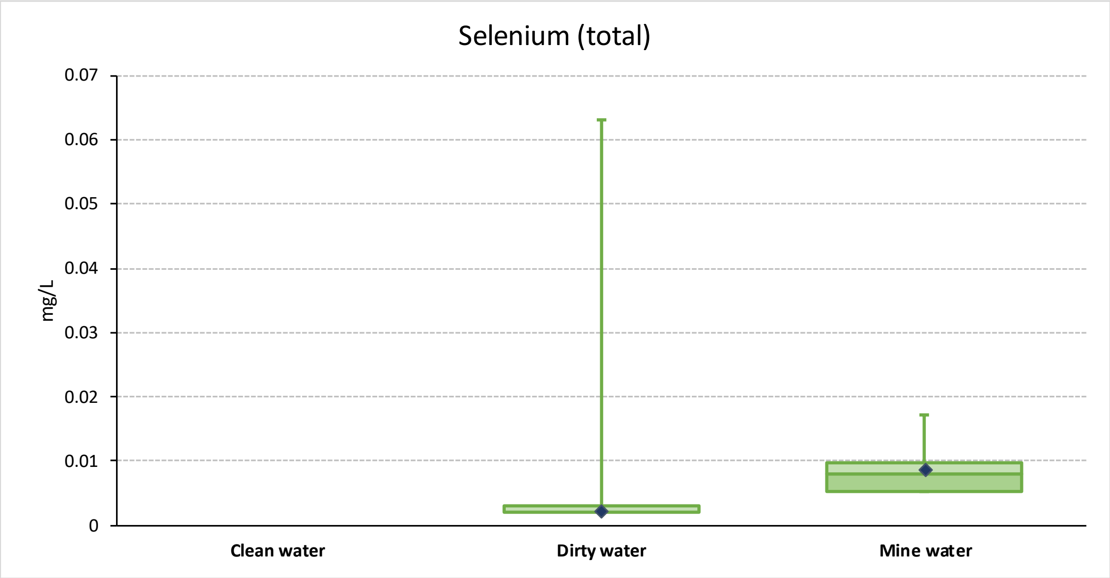

Iron (total)
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
Clean water
Dirty water
Mine water

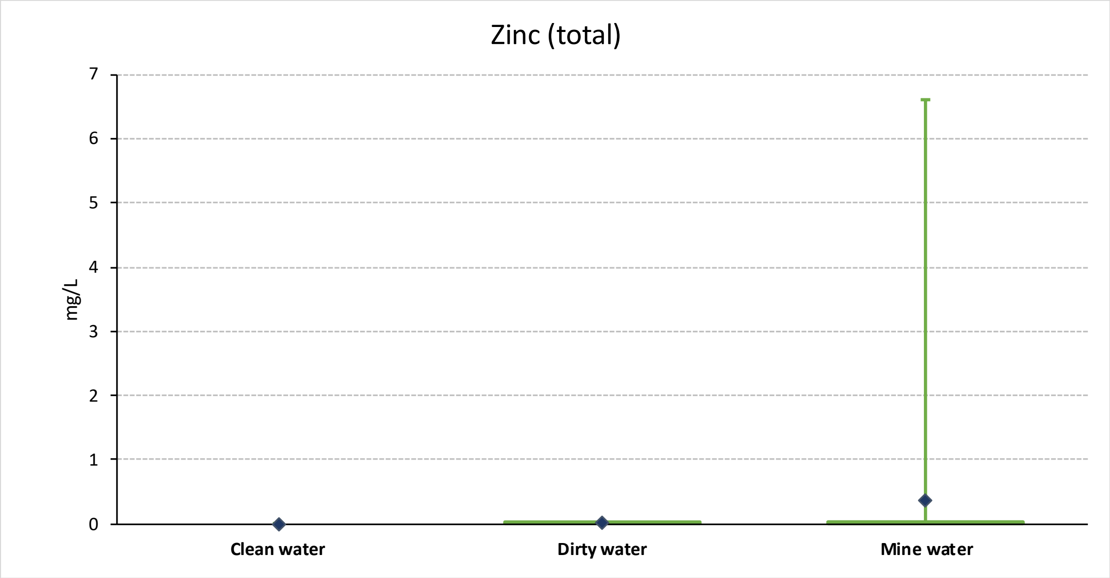

Lead (total)
mg/L
0.025
0.02
0.015
0.01
0.005
0
Clean water
Dirty water
Mine water


Manganese (total)
mg/L
0.25
0.2
0.15
0.1
0.05
0
Clean water
Dirty water
Mine water


Mercury (total)
mg/L
0.00025
0.0002
0.00015
0.0001
0.00005
0
Clean water
Dirty water
Mine water


Nickel (total)
mg/L
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Clean water
Dirty water
Mine water


Selenium (total)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
mg/L
Clean water
Dirty water
Mine water


Zinc (total)
7
6
5
4
3
2
1
0
mg/L
Clean water
Dirty water
Mine water

This report has been prepared by GHD for Umwelt (Australia) Pty Ltd and may only be used and relied on by Umwelt (Australia) Pty Ltd for the purpose agreed between GHD and the Umwelt (Australia) Pty Ltd as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Umwelt (Australia) Pty Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (Section 1.4 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

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GHD has not been involved in the preparation of the Environmental Impact Statement and has had no contribution to, or review of the Environmental Impact Statement other than in the Surface Water Impact Assessment. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the Environmental Impact Statement.

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https://projects.ghd.com/oc/newcastle1/glendellcontinuedope/Delivery/Documents/2219708-REP-GCOP-Surface_Water_Impact_Assessment.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	T Davies S Anderson T Tinkler	A Wyatt		A Wyatt		11/10/2019
1	T Davies S Anderson T Tinkler	S Gray		S Gray		20/11/2019

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