Appendix X

Pipeline development water assessment

REGIS RESOURCES LTD


Pipeline Development Water Assessment

McPhillamys Gold Project

Prepared for LFB Resources NL
August 2019




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1 Introduction

1.1 Overview

LFB Resources NL, a 100% owned subsidiary of Regis Resources Limited (herein referred to as Regis), is seeking development consent for the construction and operation of the McPhillamys Gold Project (the project), a greenfield open cut gold mine and water supply pipeline in the Central West of New South Wales (NSW). The project application area is illustrated at a regional scale in Figure 1.1.

As shown in Figure 1.1, the McPhillamys Gold Project comprises two key components; the mine site where the ore will be extracted, processed and gold produced for distribution to the market (the mine development), and an associated water pipeline which will enable the supply of water from approximately 90 km away near Lithgow to the mine site (the pipeline development). This report assesses the potential water resource impacts associated with the pipeline development component of the McPhillamys Gold Project. References to 'the project' throughout this report are therefore referring to the pipeline development only.

The mine development component of the project (mine development) is approximately 8 km north-east of Blayney within the Blayney and Cabonne local government areas (LGAs). The mine development is in the upper reaches of the Belubula River catchment, within the greater Lachlan River catchment. The preferred mine water supply is a proposed Water Offtake Agreement comprising a pipeline transferring surplus water from Centennial's Angus Place Colliery (Angus Place) and Springvale Coal Services Operations (SCSO), and Energy Australia's (EA) Mt Piper Power Station (MPPS) near Lithgow. The supply of water from Angus Place, SCSO and MPPS will enable a beneficial use of otherwise surplus water and provide a reliable water source for the project. The alignment of the approximately 90 km pipeline (the pipeline development) is illustrated in Figure 1.2.

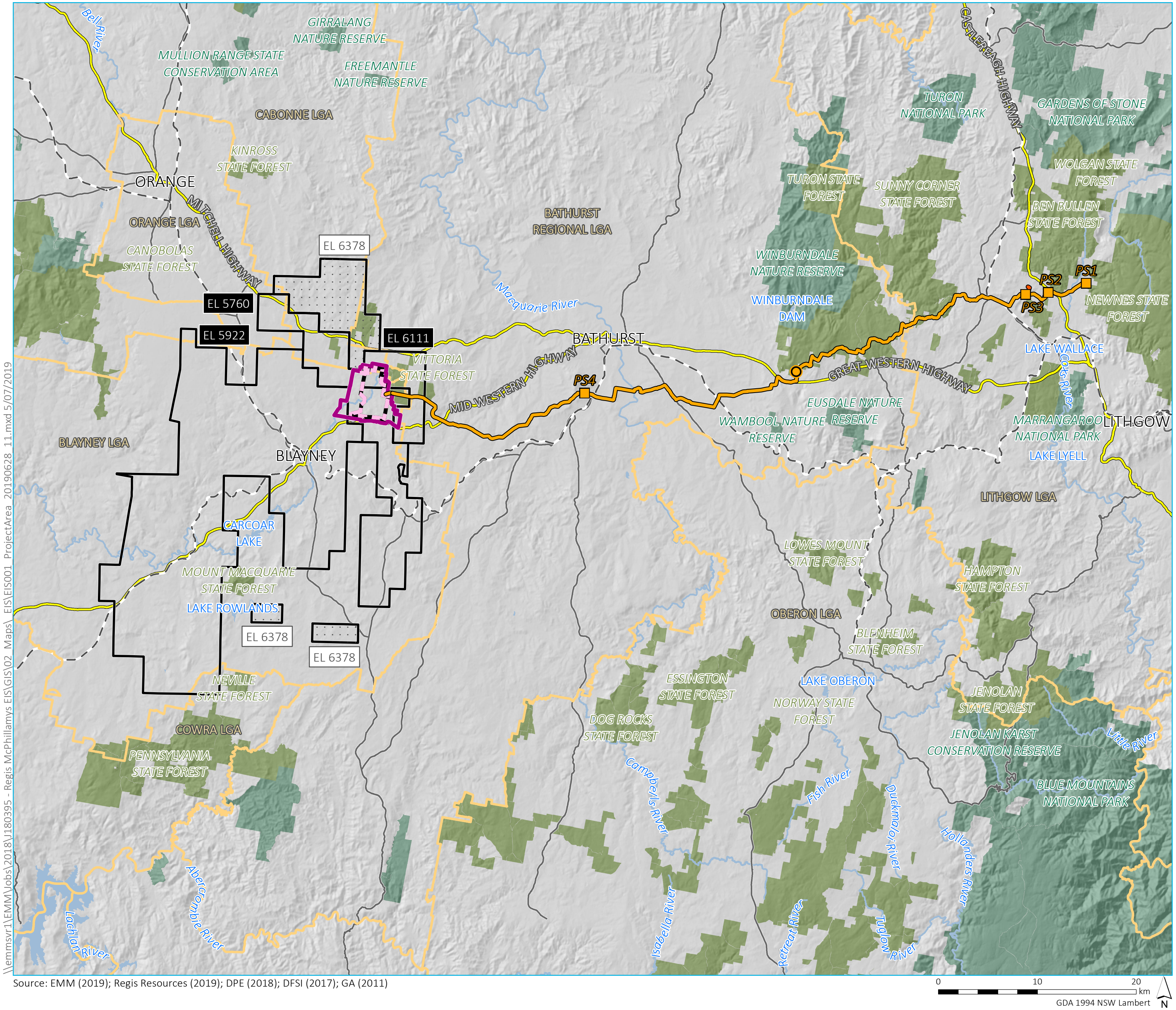
This pipeline water assessment report forms part of the EIS. It documents the assessment methods, results and the initiatives built into the project design to avoid and minimise water related impacts, and the additional mitigation and management measures proposed to address residual impacts which cannot be avoided. Separate technical water assessments have been prepared for the mine development component of the project (HEC 2019) and (EMM 2019).

1.2 Project overview

A detailed description of the project, comprising both the mine and pipeline development, is provided in Chapter 2 of the EIS (EMM 2019). In relation to the mine development, the project is seeking approval for the development and operation of an open cut gold mine and associated infrastructure, comprising one to two years of pre-development works and construction, approximately 10 years of mining and processing, and a closure period (including the final rehabilitation phase) of approximately two to three years, leading to a total project life of 15 years. The project will involve the extraction and processing of ore to produce approximately 200,000 ounces, and up to 250,000 ounces, per annum of product gold.

This pipeline water assessment relates to the pipeline development component of the project, which comprises the construction and operation of a water supply pipeline between the mine and the Western Coalfields. The pipeline development will include four pumping station facilities, a pressure reducing system and control system. On average, 13 ML/day (up to a maximum of 15.6 ML/day) will be transferred for mining and processing operations.

A summary of the pipeline development is provided in the following sub-sections.



KEY

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pressure reducing system
- Pumping station facility
- Pipeline corridor
- Pipeline corridor (Blowdown Pond)

Existing environment

- Rail line
- Primary road
- Arterial road
- River
- Waterbody
- NPWS reserve
- State forest
- Local government area

Exploration lease boundaries (of interest)

- Held by LFB Resources NL (Regis)
- Held by others

Source: EMM (2019); Regis Resources (2019); DPE (2018); DFSI (2017); GA (2011)

Regional setting - project application area

McPhillamys Gold Project
Pipeline water assessment
Figure 1.1

EMM creating opportunities

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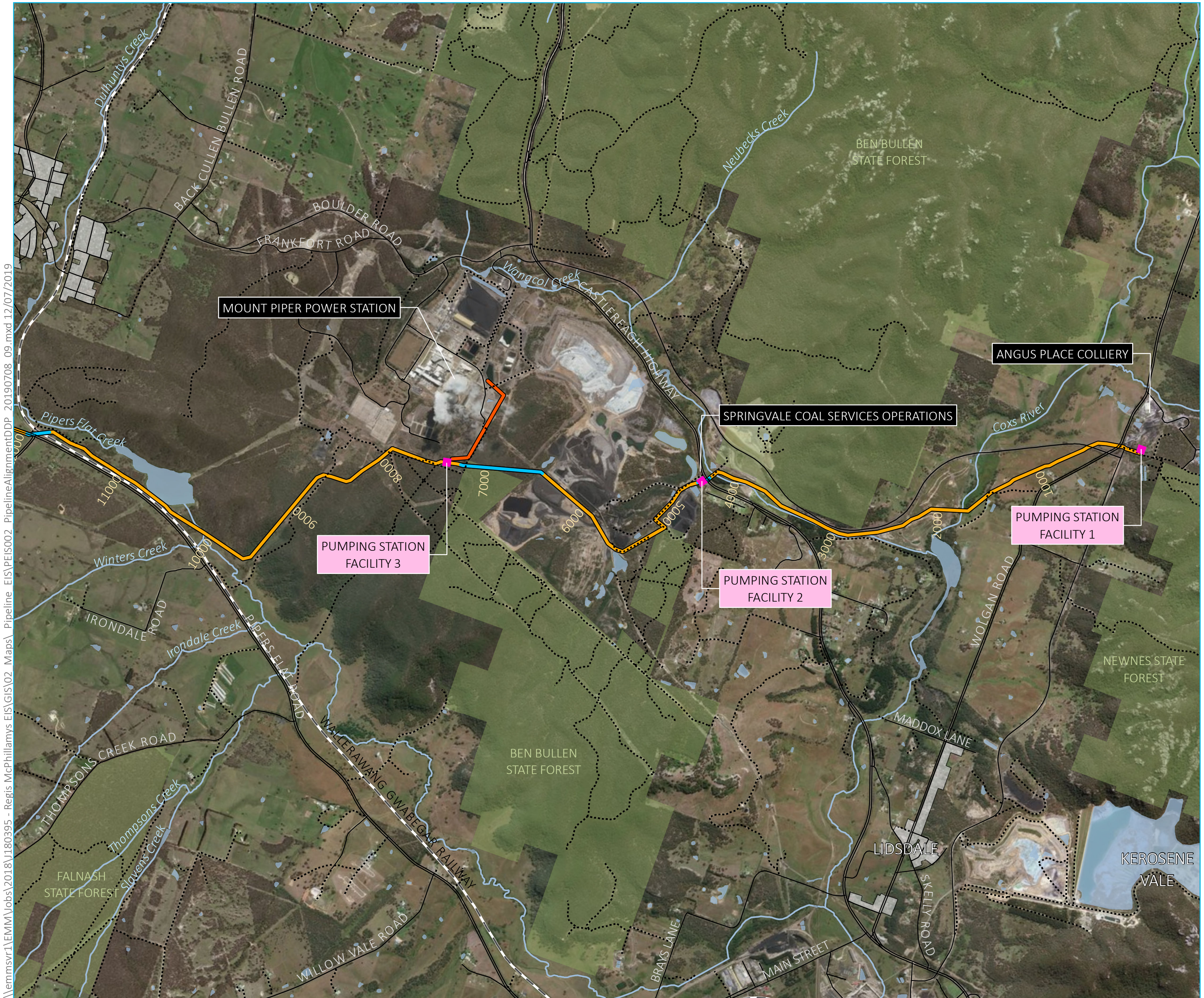

Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

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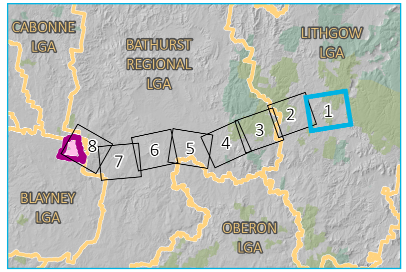

KEY

- Rail line
- Main road
- Local road
- Vehicular track
- Named watercourse
- Built up area
- Waterbody
- NPWS reserve
- State forest
- Local government area

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pipeline corridor
- Pipeline corridor - underbore section
- Pipeline corridor (Blowdown Pond)
- Pumping station facility

Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2a

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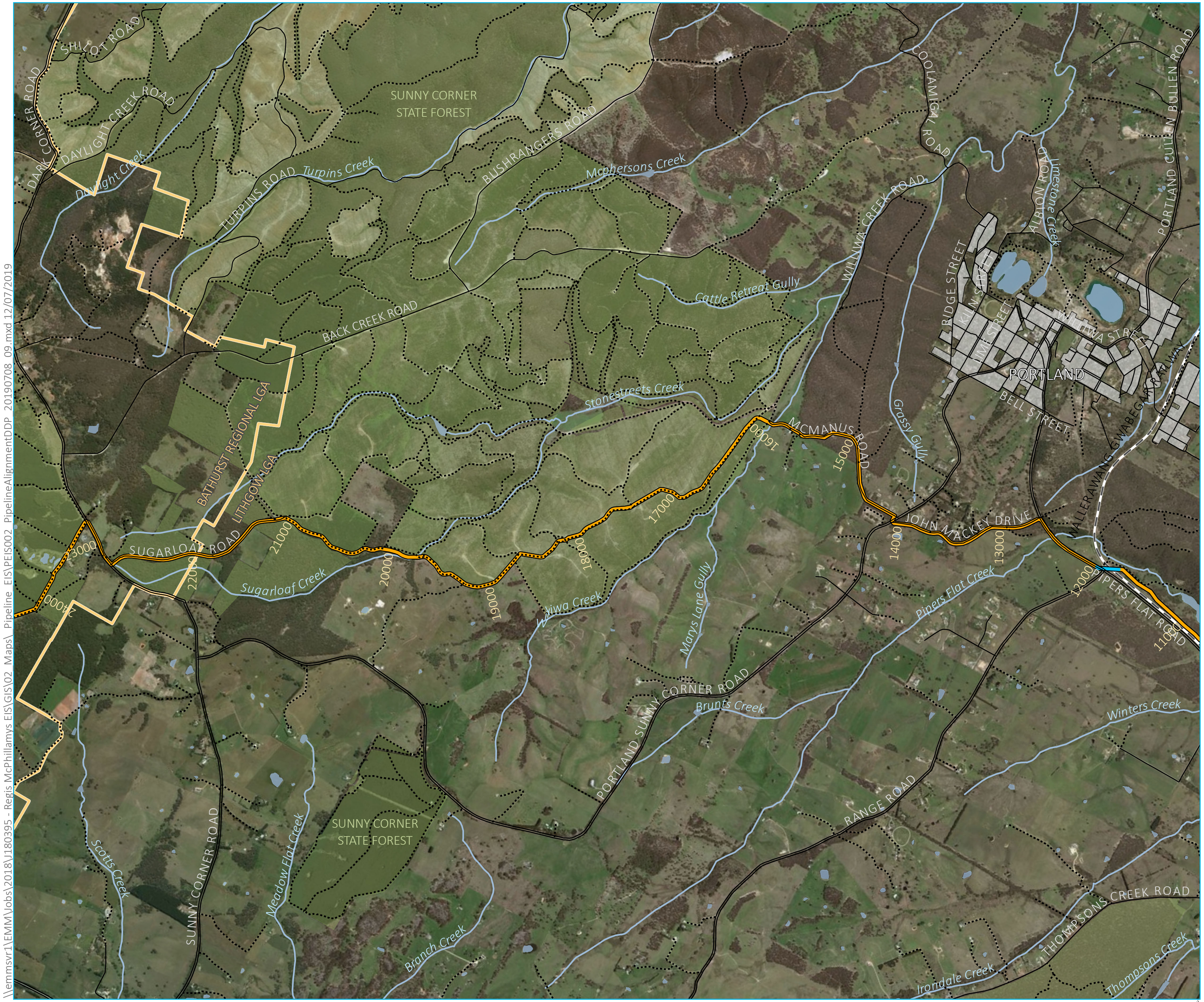

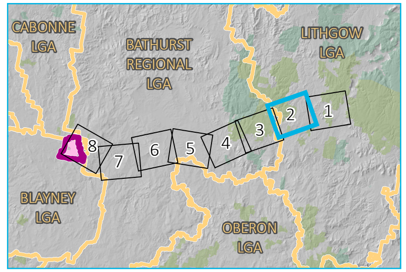

KEY

- Rail line
- Main road
- Local road
- Vehicular track
- Named watercourse
- Built up area
- Waterbody
- NPWS reserve
- State forest
- Local government area

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pipeline corridor
- Pipeline corridor - underbore section

Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

0 1 2 km

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Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2b

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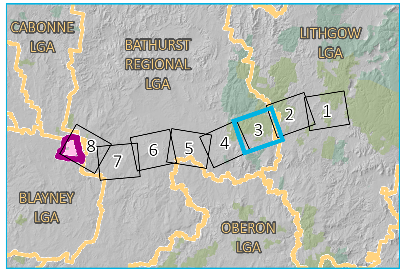

KEY

- Main road
- Local road
- Vehicular track
- Named watercourse
- Gas pipeline
- Waterbody
- NPWS reserve
- State forest
- Local government area

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pipeline corridor

Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

0 1 2 km

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Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2c

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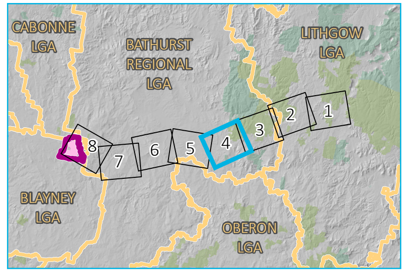

KEY

- Rail line
- Main road
- Local road
- Vehicular track
- Named watercourse
- Gas pipeline
- Waterbody
- NPWS reserve
- State forest
- Local government area

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pressure reducing system
- Pipeline corridor - existing gas pipeline crossing
- Pipeline corridor
- Pipeline corridor - underbore section

Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

0 1 2 km
GDA 1994 NSW Lambert

Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2d

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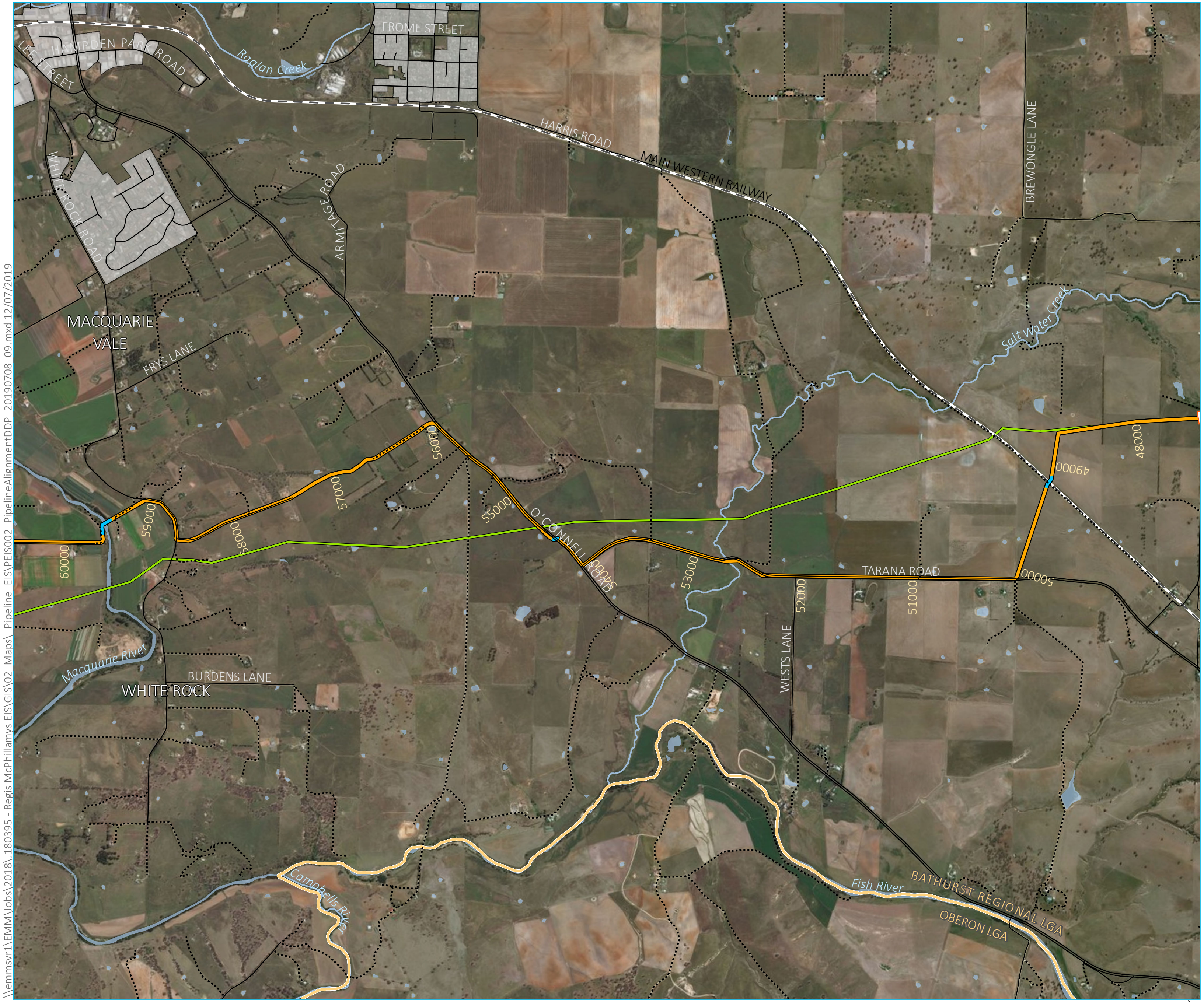

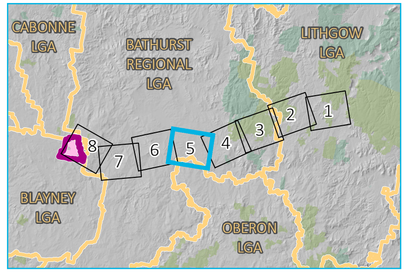

KEY

- Rail line
- Main road
- Local road
- Vehicular track
- Named watercourse
- Gas pipeline
- Built up area
- Waterbody
- NPWS reserve
- State forest
- Local government area

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pipeline corridor - existing gas pipeline crossing
- Pipeline corridor
- Pipeline corridor - underbore section

0 1 2 km

GDA 1994 NSW Lambert

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Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

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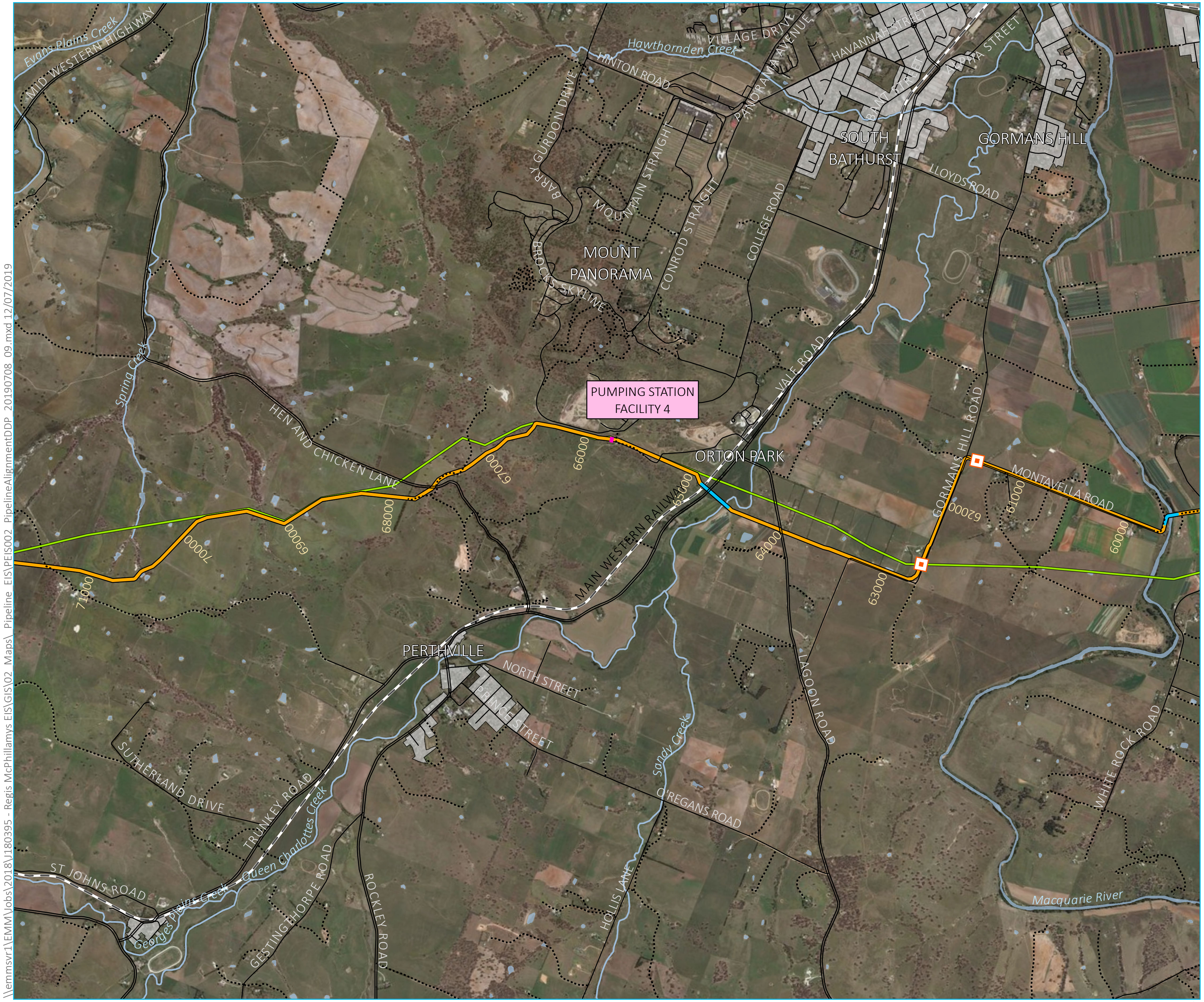
Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2e

EMM creating opportunities



KEY

- Rail line
- Main road
- Local road
- Vehicular track
- Named watercourse
- Gas pipeline
- Built up area
- Waterbody
- NPWS reserve
- State forest
- Local government area

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pipeline corridor - existing gas pipeline crossing
- Pipeline corridor
- Pipeline corridor - underbore section
- Pumping station facility

Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

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Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2f

Source: EMM (2019); Regis Resources (2019); DFSI (2017); GA (2011)

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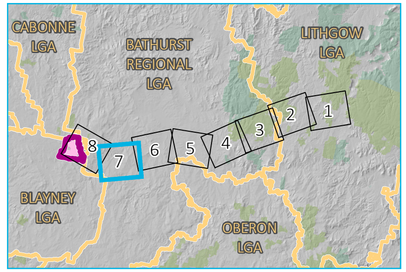

KEY

- Rail line
- Main road
- Local road
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- NPWS reserve
- State forest
- Local government area

Project application area

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- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pipeline corridor - existing gas pipeline crossing
- Pipeline corridor
- Pipeline corridor - underbore section

Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2g

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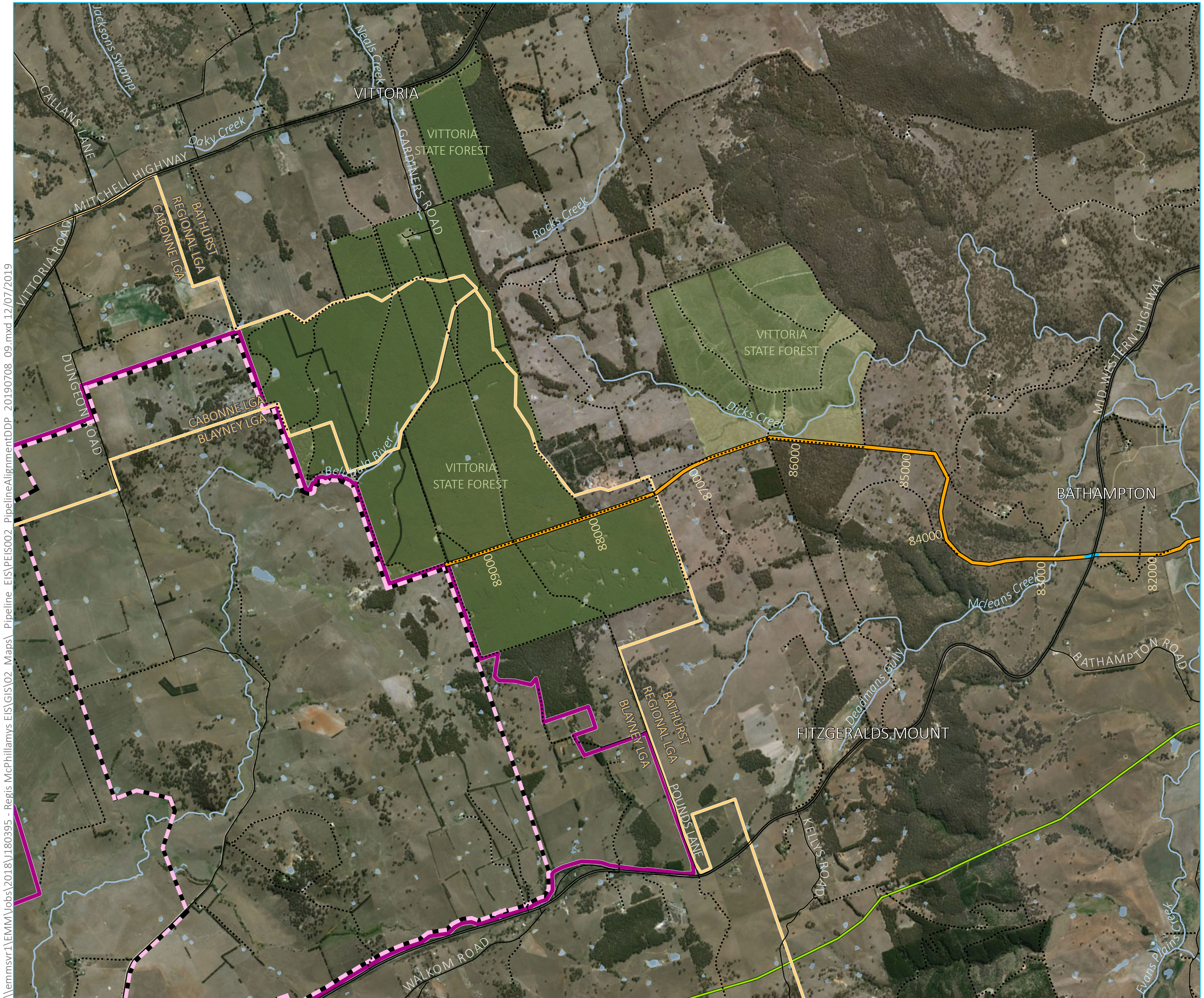

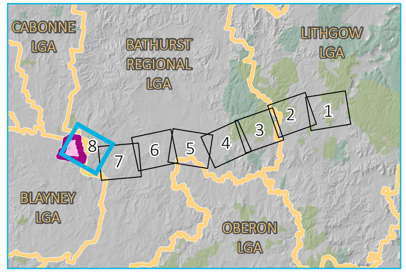

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0 1 2 km

GDA 1994 NSW Lambert

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Pipeline corridor

McPhillamys Gold Project
Pipeline water assessment
Figure 1.2h

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1.2.1 Pipeline corridor

The pipeline corridor (Figure 1.3) is guided by an avoidance policy for sensitive land uses and environmental impacts. The pipeline will traverse through various types of land including state forests, road reserves and private agricultural land. As outlined above, the pipeline will be approximately 90 km long, transferring surplus water from Angus Place and SCSO, and MPPS near Lithgow, to the mine.

The corridor width varies from approximately 6 m up to approximately 20 m in width, excluding the four pumping stations facilities. At these facilities, the corridor width extends to an area of up to 75 m x 75 m to accommodate the construction and operation of these facilities.

The width of the corridor has been defined in consideration of property and environmental constraints. Where there are constraints the width of the corridor has been narrowed to 6 m to avoid these as far as practicable. In areas where there are no identified constraints the pipeline corridor is up to 20 m wide to allow the flexibility to refine the pipeline alignment during detailed design as well as to accommodate ancillary areas, such as construction compounds, during the construction phase.

1.2.2 Components

The components of the pipeline development are described in the following sub-sections. This description is based on a concept design for the pipeline development and as such will be subject to refinement during the detailed design and construction phases. These refinements may include minor changes to the proposed technology of the water supply pipeline or pumping station facilities, or minor changes of the alignment of the pipeline within the defined pipeline corridor.

i Water supply pipeline

The pipeline will have a nominal diameter of between 300–650 mm.

The majority of the pipeline will be laid underground in a trench ranging from 1.5–2 m deep, with a minimum cover of 800 mm. Where under boring of roadways, rail lines or watercourses is required, the specific engineering design for that location will dictate the depth of the pipeline. The pipeline material will be confirmed during detailed design, but may be ductile iron, heavy duty polyethylene, steel or glass reinforced plastic.

An additional pipeline is required to transfer water from the MPPS Blowdown Pond to the pumping station facility No.3 (MPPS). This pipeline will be approximately 1 km in length and will also have a nominal diameter of between 300 mm and 650 mm.

Ancillary pipeline infrastructure is described in the following sub sections.

a Valves

Isolation, scour and air release valves will be located as required along the pipeline. Isolation or section valves will be provided to isolate the pipeline into discrete sections and allow only part of the whole pipeline to be dewatered for maintenance, or to provide security in an event such as a pipe burst. Isolation valves will also typically be installed on either side of main crossings, such as a watercourse crossing. Valves will be typically buried in the ground at the same depth as the pipeline and fitted with a spindle that rises to the surface which opens and closes the valve. The spindle is enclosed in a small valve box, approximately 200 mm^2. The valve box will be installed to be flush with the existing ground level.

Scour valves will be located at low points of the pipeline to facilitate maintenance and emergency drainage of the pipeline. Scour valves will be buried and fitted with a spindle and valve box flush with the existing ground level. The valves will discharge to a nominal 750 mm diameter scour pit. Scour pits will be approximately 1–3 m deep and finished flush with the existing ground level where possible.

Air release valves are designed to automatically release the small amounts of air that will accumulate in high points of the pipeline during operation. They will also discharge or admit air during the filling or draining process. Air release valves will be typically enclosed within 1.2 m^2 concrete pits with steel lids, and will be located below ground, finishing flush with the existing ground level.

Scour valves and air release valves will be installed approximately every 1–2 km as required by the prevailing topography. The final location and design of the respective valves will be determined during detailed design.

b Other pipeline infrastructure

Tapping points may be required along the pipeline for cleaning purposes. If required, cleaning (or 'pigging') stations will also be located as required along the pipeline. At the cleaning stations, which would be fabricated from concrete, cylindrical cleaning apparatus known as 'pigs' will be inserted into the pipeline during maintenance periods. Each cleaning station will be located below ground and will be approximately 5 m wide, 10 m long and 1–2 m deep. The requirement for tapping points or cleaning stations will be confirmed during detailed design.

Anchor or thrust blocks will be used as necessary to mitigate the hydraulic 'shock' which occurs when pumps commence or cease operation. This hydraulic effect could result in movement of the pipeline or breakage, particularly at sharp changes in direction, unless the pipeline is held in place securely.

ii Pumping station facilities

Four pumping station facilities will be required to ensure efficient transfer of water through the pipeline. They will be located at approximate chainages:

- pumping station facility No.1 (Angus Place) – chainage 0.0;
- pumping station facility No.2 (SCSO) – chainage 4,250;
- pumping station facility No.3 (MPPS) – chainage 7,200; and
- pumping station facility No.4 (Bathurst Bike Park) – chainage 65,800.

Each pumping station facility will occupy a maximum area of approximately 0.56 ha (except pumping station facility No.4 which will occupy an area of approximately 0.17 ha), which will be fenced for public safety and security purposes. Within each pumping station facility there will be the following:

- a water storage tank with a capacity of approximately 750 kL, approximate dimensions of 6–9 m high and diameter of between 11–14 m. The tank will be constructed of concrete or steel;
- above ground and underground pipework and valving connecting to the water supply pipeline;
- monitoring and control equipment, including flow meters, tank level detection and automated valves;
- a pump and motor building, typically comprising electric motor and pump sets in a duty–standby configuration;
- a pad mounted power transformer and incoming high voltage electricity supply;
- a control room / electric switchroom housing:
    - supervisory control and data acquisition (SCADA) instrumentation for the remote control of the system;

- high voltage circuit breakers;
- low voltage switch gear;
- variable voltage variable frequency drives for pump speed control;
- fire suppression equipment; and
- supervisory control and data acquisition equipment for remote control of the system;

• bunding and water collection systems (collection sump and pump) depending on the environmental requirements at the pump station location; and

• an access road and small parking area.

The buildings at each pumping station will be rectangular, single storey structures, fabricated from either tilt-up concrete, moulded concrete, block work or brick work, and will be fitted with a structural steel or concrete roof. The facility will have fencing and access gates (typically galvanised pipe posts and rails with chain mesh wire).

iii Pressure reducing system

In the vicinity of Sunny Corner (CH38,500) a pressure reducing system will be installed to protect the pipeline from excessive pressure. It will comprise pressure reduction valves, a water storage tank, vents and electrical controls, as required in accordance with the detailed design. A pressure reducing system is typically enclosed in a building with noise mitigation measures depending on the noise attenuation requirements for the site. An additional pressure reduction system may be required further along the pipeline corridor depending on refinements made to the design and choice of materials, which will be determined during detailed design. Additional pressure reducing systems, if required, will be accommodated within the defined pipeline corridor.

iv Power supply infrastructure

Power required for the pipeline development, particularly the pumping station facilities and pressure reducing system will be sourced from the relevant electricity network distributor, either Endeavour Energy or Essential Energy. Applications will be made to the distributor for the new network connections when the detailed power requirements are understood.

v Communications System

An end to end communications system will be required to control the operation of the pumps and pressure reducing system. The communications system will comprise either fibre optic cable, radio telemetry, mobile network connection or a combination. A fibre optic cable system could be installed in the same trench as the pipeline connecting each pumping station facility and pressure reducing system to the control centre at the mine site.

A radio telemetry system, or mobile network system, could be implemented provided the required reliability of the systems can be demonstrated. These systems will require the construction of a small mast and antenna at each pumping station and the pressure reducing system.

1.2.3 Construction methodology

i Pipeline trenching - construction methodology

The indicative construction sequence for installation of the pipeline will involve:

- consultation with landowners regarding access;
- establishing site environmental controls;
- erecting temporary stock fences where required;
- creating temporary access tracks where required;
- clearing vegetation and removing and stockpiling topsoil;
- trench excavation;
- stringing of pipes along route;
- placing bedding material;
- installing pipework;
- casting and pouring of concrete thrust blocks;
- installing valves (e.g. scour valves and pits, air valves and pits);
- backfilling the trench; and
- site restoration.

It is anticipated that the majority of the pipeline will be constructed using open trenching techniques. However, rail crossings and some road and watercourse crossings will be undertaken using under boring. The typical trench will be approximately 1 m wide and 1.5 m to 2 m deep with a minimum cover of 800 mm.

The area that will be directly impacted by construction activities within the pipeline corridor will range in width from 6 m, such as along forestry tracks, to 20 m in open farmland, depending on a range of factors such as presence of significant vegetation, constructability, construction management and safety considerations, landform, slopes and anticipated sub-soil structures. The final disturbance zone, within the pipeline corridor, will be confirmed during detailed design.

During construction, erosion and sediment controls will be installed and maintained prior to the start of construction activities in accordance with the *NSW Soils and Construction – Managing Urban Stormwater Volume 1 "the Blue Book"* (Landcom 2004) and *Volume 2* (DECC 2008). In steep locations during heavy rainfall events, there may be a risk of water entering the trench, building up pressure and scouring backfill material. To reduce the risk of this occurring, trench stops or impermeable barriers will be installed at strategic locations to divert surface water away from the trench. At trench stop locations, side trenches will fan out and away from the pipeline trench. Side trenches will not be deployed where the corridor has been narrowed on account of constraints.

Side trenches will be filled with granular material and will permit water collected in the trench to be directed out of the trench and above ground. This will prevent water in the trench from building up sufficient pressure that backfill scouring occurs. The locations of trench stops will be determined during detailed design.

Clearing and grading will be minimised where practicable to the extent necessary for construction of the pipeline and ancillary infrastructure and will not exceed the pipeline corridor. Topsoil and other obstacles such as rocks will be removed with a bulldozer, motor grader or excavator. The trench will then be excavated using a tracked excavator, backhoe, tracked chain trencher or other similar mechanical equipment. Where rock is encountered, hydraulic breaking and/or blasting may be required. Topsoil and spoil will be stockpiled adjacent to the excavated trench.

Pipe sections will be stockpiled within the pipeline corridor approximately 2–4 km apart adjacent to an existing road or access which will be suitable for a semi-trailer or truck access. The pipes will be transported along the corridor and strung out along the edge of the proposed trench alignment. Regis has obtained NSW Forestry's permission to use existing disturbed areas within NSW Forestry lands as construction ancillary areas such as material and equipment laydown areas.

Pipeline construction will be a progressive operation with a number of workfronts potentially being constructed concurrently. The trenching rate will be variable depending upon ground conditions and machinery used. In rocky conditions, for example on forestry tracks through Sunny Corner State Forest, the trenching rate may be around 40 m-80 m/day, compared to open farmland where the rate may be 600–650 m/day. Trench excavation, pipe installation and backfilling will generally occur within the same day for pipe laying and backfilling of the open trench within the same day. Appropriate construction techniques and safety controls will be utilised, including safety barriers, as required, for open trenches.

Once a trench has been excavated, granular bedding material will be placed in the base of the trench by an excavator (or similar plant) and levelled. The pipeline segments will then be lowered into the trench. Where ductile iron or steel pipes are used, a plastic sleeve may be wrapped around the pipe to provide corrosion protection. Each pipe segment will then be joined to the pipeline. Valves and concrete thrust blocks will then be installed as required.

Once the pipe has been laid and joined, backfill will be placed around the pipe with an excavator (or similar plant) and compacted, typically with a hand-held vibrating plate compactor. Backfill material will comprise a combination of excavated trench material (depending on condition) and imported fill.

Imported fill will be delivered to site via a tipping truck. Excess excavated material unsuitable for use as backfill will be removed from the site to a suitable landfill via a tipping truck.

Tipping trucks (for spoil movement) and flatbed trucks (for movement of pipes and equipment) will shuttle between the stockpiles and pipeline construction sites. The trucks will be loaded by an excavator (or similar plant). Bulk supplies of material will be delivered to the stockpile sites via semi- trailer.

Site rehabilitation will be undertaken progressively following construction. Typical rehabilitation activities will include spreading topsoil and revegetation. In some areas, tree replacement will be undertaken.

ii Trenched crossings - waterways

The pipeline corridor crosses 112 creeks and drainage lines. Most of these are minor streams and gullies which are ephemeral and only flow after large rainfall events. Nine pipeline crossings are associated with perennial watercourses being:

- Coxs River;
- Wangcol Creek;
- Pipers Flat Creek;
- Salt Water Creek (two crossings);

- Macquarie River;
- Queen Charlottes Creek (Vale Creek);
- Evans Plains Creek; and
- McLeans Creek.

It is noted that mine discharge water from Angus Place contributes to flow in the Coxs River at the location where the pipeline corridor will cross. Discharges from Angus Place to the Coxs River will cease by 31 December 2019, after which this portion of the Coxes River is expected to experience lower flows.

Regis proposes to cross the above watercourses via open trenching, with the exception of the Macquarie River and Queen Charlottes Creek, which will be under bored and Wangcol Creek where the pipeline will be fixed to the existing causeway.

Watercourse trenched crossings will be scheduled as far as practicable to occur during drier periods and low flow conditions.

Trenching methods confirmed during detailed design and will depend on several factors including:

- type and/or strength of the creek bed material;
- volume of flow in the creek;
- steepness of the ground on either side of the crossing;
- whether a scour valve will be required in close proximity to the crossing; and
- potential environmental impacts.

A generalised approach involves installation of coffer dams, as required, to enable trenching of these watercourses. The coffer dams will be sized to provide sufficient water storage to allow the trench to be excavated, the pipeline to be laid and the protective concrete encasement to be placed. If the flow rate and gradient of the creek is such that insufficient storage volume is available, a bypass pumping system around the dam may be established.

A typical crossing using this method will take approximately two to four days.

iii Trenchless technology - construction methodology

Underboring (such as horizontal directional drilling or micro-tunnelling) will be employed to cross the following waterways:

- Macquarie River; and
- Queen Charlottes Creek.

Horizontal directional drilling (HDD) will generally involve the following activities:

- Excavation of drill launch site and drill reception site (approximately 6 m x 6 m). The drill launch site will contain the drilling rig and a control room. Launch and reception pits will also capture drilling mud prior to solids removal and reuse.

- Drilling of a pilot hole by a rotating, remotely-controlled drilling head attached to hollow drilling rods. The rotating and steerable drill will be launched from the surface or a shallow excavation at the drill launch site. The drill launch site will be preferably at the downstream end of the proposed drill line.

- Water, a drilling fluid, or drilling mud, will be used to lubricate the drilling head and flush the drilled hole. Drill cuttings are removed in the drilling fluid or drilling mud, which travels down the hollow drilling rod string back to the drill launch site where it is contained, collected and passed through sets of screens and liquid cyclones to remove the abrasive drill cuttings so that the "mud" can be recirculated. The mud cleaning and recycling plant will be self-contained and powered by an onsite generator.

- Reaming (i.e. enlarging) the pilot hole by attaching a back reamer or forward reamer to the string of rods will be used to progressively enlarge the pilot hole.

- When the required diameter of the hole is reached, the new pipe will be attached to the string of drill rods and pulled through the hole.

- The annulus surrounding the installed liner pipe is back grouted at each entrance.

A typical underboring installation will take approximately three weeks. Underboring crossings in more sensitive locations such as the Macquarie River will take approximately four to six weeks.

1.3 Water availability and security

1.3.1 Rights to water

Rights to the above water sources will be authorised through the proposed Water Offtake Agreement. The existing water access licences (WALs) held by Centennial and respective water sources relevant to the pipeline development are summarised in Table 1.1. As shown in Table 1.1, the WALs are of varying sizes as a result of having been established as a result of progressive mining development.

Table 1.1 Water Access Licences held by Centennial

WAL #	Sydney Basin Coxs River (ML/year)	Sydney Basin (ML/year)
36443	585	-
36446	3,300	-
36445	2,701	-
41881	1,471	-
37340	329	-
36383		5,958
36449		2,523
37343		35

1.3.2 Ongoing water availability

The ongoing operation of the mine development relies on the continued supply of water. The proposed water offtake agreement has been drafted with the intent of securing a reliable water supply to the McPhillamys Gold Mine. The McPhillamys raw water storage dam within the mine project area will have the capacity to store enough water to meet demand for up to two weeks in the event of a water supply interruption, such as a planned or unplanned shutdown, and an additional two weeks storage buffer could be transferred to provide up to four weeks supply (or 400 ML) in total.

1.4 Assessment requirements

This pipeline water assessment has been prepared following the appropriate guidelines, policies and industry requirements, and following consultation with stakeholders including community members and relevant government agencies.

The relevant guidelines and policies are:

- NSW Aquifer Interference Policy (AIP) (DPI Water 2012c);
- Guidelines for laying pipes and cables in watercourses on waterfront land (DPI Water 2012d);
- relevant Water Sharing Plans (WSP);
- Guidelines for controlled activities on waterfront land - Riparian corridors (DoI 2018);
- NSW State Groundwater Quality Protection Policy (DLWC 1998); and

NSW State Groundwater Policy Framework Document (DLWC 1998). This assessment has been prepared in accordance with requirements of the NSW Department of Planning and Environment (DPE). These were set out in DPE's Environmental Assessment Requirements (EARs) for the Project, issued on 24 July 2018 and revised on 19 December 2018. The EARs identify matters which must be addressed in the EIS and essentially form its terms of reference. Table 1.2 lists individual requirements relevant to this pipeline water assessment and where they are addressed in this report.

Please note that this report does not include an assessment of aquatic ecology, and this is addressed within the Biodiversity Development Assessment Report (OzArk 2019) contained in Appendix Y of the EIS and in Chapter 26 of the EIS.

Table 1.2 Pipeline water assessment related EARs

Requirement	Section addressed
An assessment of the likely impacts of the development on the quantity and quality of surface, and groundwater, having regard to the NSW Aquifer Interference Policy	Section 2.3 and Sections 5 and 6
An assessment of the hydrological characteristics of the site and downstream	Section 3.2
An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure and systems and other water users, including impacts to water supply from Carcoar Dam, riparian and licensed water users, use and discharge of water during construction, commissioning and maintenance of the pipeline infrastructure.	Section 5 and 6 Flows to Carcoar dam will not be affected by the pipeline development.

Table 1.2 Pipeline water assessment related EARs

Requirement	Section addressed
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	Buried pipeline does not require a water management system. Management and mitigation measures in Sections 5.4 and 6.2.
A description of construction erosion and sediment controls, how the impacts of the development on areas of erosion, salinity or acid-sulphate risk, steep gradient land or erodible soils types would be managed and any contingency requirements to address residual impacts.	Section 4.6 and 5
An assessment of the potential flooding impacts of the project	Section 7

To inform the preparation of the EARs, DPE invited other government agencies to recommend matters to be address in the EIS. These matters were taken into account by the Secretary for DPE when preparing the EARs. Copies of the government agencies' advice to DPE were attached to the EARs.

The Cabonne Council, Department of Industry (DoI), DPI Fisheries, Office of Environment and Heritage (OEH) and the EPA raised matters relevant to the pipeline water assessment. The matters raised are listed in Table 1.3, and have been taken into account in preparing this assessment, as indicated in the table.

Table 1.3 Agency project specific assessment recommendation

Requirement	Section addressed
Cabonne Council	
Environmental characteristics of the site	Section 3
Environmental impact of the proposed development upon the natural environment, in particular the existing hydrology of the landscape and any impact posed by the development proceeding.	Section 5 and 6
Water management • Impact assessment (surface water run-off) • Impact assessment (groundwater system)	Section 5.4 Section 6.2
• Environmental monitoring	Section 5.4 and 6.2
DoI – Water	
Assessment of impacts on surface and groundwater sources (both quality and quantity), related infrastructure, adjacent licensed water users, basic landholder rights, watercourses, riparian land, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts.	Sections 5 and 6
Assessment of the hydrological characteristics of the site and downstream, and an impact assessment of the project on downstream water users and the environment	Section 3.2 and Section 5.3
An assessment against the rules of the groundwater and surface water sharing plans relevant to the site.	Section 1.3
Proposed surface and groundwater monitoring activities and methodologies	Section 5.4 and 6.2

DPI Fisheries	
Details of the location of all waterways crossings and construction designs, such as bridges or culverts, mine access tracks, or pipeline waterway crossings	Pipeline will be buried for its full length. Crossings assessed in Section 4 and Appendix B.
Aspects of the management of the proposal, both during construction and after completion, which relate to impact minimisation e.g. Environment Management Plans	A Construction Environmental Management Plan (CEMP) and Operational Environmental Management Plan (OEMP) will be prepared as a condition of approval
EPA	
Describe any drainage lines, creek lines etc that will be impacted by the project	Crossings assessed in Section 4 and Appendix B
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. Where groundwater may be impacted, the assessment should identify appropriate groundwater environmental values.	River flow and water quality objectives discussed in Sections 5.1 and 5.2. No regional groundwater impacts are expected. Assessment of groundwater impacts are addressed in Section 6.1
State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the ANZECC (2000) Guidelines for Fresh and Marine Water Quality.	Section 5.3, 5.4 and 6.2
Describe the nature and degree of impact that any proposed discharges will have on the receiving environment	No planned discharges. Accidental discharges are addressed in Section 5.3.
Whether the project will significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	No significant impact. Section 5.3
Identify potential impacts on watercourses and the management/mitigation measures that will be implemented where mining activities occur in proximity to or within a watercourse.	No mining activities associated with the pipeline development. Impacts and mitigation measures in Sections 5.3 and 5.4.
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 5.2 and particularly Table 5.2.
Assess impacts on groundwater and groundwater dependent ecosystems	Section 6.1
Describe in detail how stormwater will be managed both during and after construction	General description in Section 5.3. Further detail to come in CEMP and OEMP.
The proponent should develop a water quality and aquatic ecosystem monitoring program to monitor the responses for each component or process that affects the Water Quality Objectives that includes, for example: • Adequate data for evaluating compliance with water quality standards and/or Water Quality Objectives • Measurement of pollutants identified or expected to be present in any discharge	CEMP and OEMP will be prepared as a condition of approval

OEH	
The EIS must map the following features relevant to water and soils including:	
Acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Planning Map)	Chapter 32 and Appendix W of EIS
Rivers, streams, wetlands, estuaries (as described in s4.1 of the Biodiversity Assessment Method (Pipeline) and s.4.1 of the Framework for Biodiversity Assessment (Mine Site)).	Figure 1.3 and 2.1
Wetlands as described in s4.1 of the Biodiversity Assessment Method (Pipeline) and s.4.1 of the Framework for Biodiversity Assessment (Mine Site)	Figure 1.3
Groundwater	Figure 2.2
Proposed intake and discharge locations	Section 1.2
The EIS must describe background conditions for any water resource likely to be affected by the McPhillamys Gold Project, including:	
• Existing surface and groundwater	Section 3
• Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations	Section 5
• Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Section 5.2
• 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 5.2
The EIS must assess the impacts of the project on water quality, including:	
• The nature and degree of impact on receiving waters for both surface and groundwater demonstrating how the project 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.	Sections 5 and 6
• Identification of proposed monitoring of water quality	CEMP and OEMP will be prepared as a condition of approval
The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including: • Flood prone land • Flood planning area, the area below the flood planning level • Hydraulic categorisation (floodways and flood storage areas).	Section 7
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 probably maximum flood, or in an equivalent extreme event	Section 7

2 Legislative context

2.1 Overview

The primary statutes that apply to water management in NSW are the *Water Act 1912* (Water Act) and the *Water Management Act 2000* (WM Act). The provisions of each act are applied in accordance with their attendant regulations including relevant water sharing plans (WSPs).

The requirements of the applicable legislation and policies and the assessment of the project against these key policy requirements are discussed in this report. Relevant water sharing plans and the *NSW Aquifer Interference Policy* (AIP) (DPI Water 2012c) are key documents dictating the assessment of the potential impacts of the project on water resources.

2.2 Water Sharing Plans

Water sharing plans WSPs are statutory documents under the WM Act dictating the management and sharing of individual water sources. The WSPs set the water management vision and objectives, management rules for water access licences (WALs), what water is available within the various water sources, and procedures for dealing in licences and water allocations, water supply works approvals and the extraction of water. WSPs are designed to establish sustainable use and rules for the management of water resources annually and are applicable for 10 years upon commencement.

WSPs describe the basis for water sharing and document the water available and how it is shared between environmental, extractive, and other uses. The WSPs then outline the water available for both the environment and for extractive uses within different licence categories, such as: local water utilities, domestic and stock, basic rights, and access licences.

The relevant WSPs and water sources that underlie the project are:

- Macquarie Bogan Unregulated and Alluvial Water Sources 2012
  - Fish River Water Source;
  - Turon Crudine River Water Source;
  - Winburndale Rivulet Water Source;
  - Macquarie River above Burrendong Water Source;
  - Queen Charlottes Vale Evans Plains Creek Water Source;
- Lachlan Unregulated and Alluvial Water Sources 2012
  - Belubula River above Carcoar Dam Water Source;
- NSW Murray Darling Basin Fractured Rock Groundwater Sources 2011
  - Lachlan Fold Belt Murray Darling Basin (MDB) Groundwater Source;

- NSW Murray Darling Basin Porous Rock Groundwater Sources 2011
  - Sydney Basin Murray Darling Basin (MDB) Groundwater Source;
- Greater Metropolitan Region Unregulated River Water Sources 2011
  - Upper Nepean and Upstream Warragamba Water Source (Wywandy management zone);
- Greater Metropolitan Region Groundwater Sources 2011; and
  - Sydney Basin Coxs River Groundwater Source.

The water sharing plans and water sources relevant to the project are delineated in Figure 2.1 (surface water) and Figure 2.2 (ground water). The take of water to be used for Regis' mining activity is associated with water recovered from Centennial's Angus Place and SCSO; and EA's MPPS operations are outlined on section 1.3. Centennial and EA will provide an average of 13 ML/ day as agreed to in the proposed Water Offtake Agreement between Regis, Centennial Coal and Energy Australia.

2.3 NSW Aquifer Interference Policy

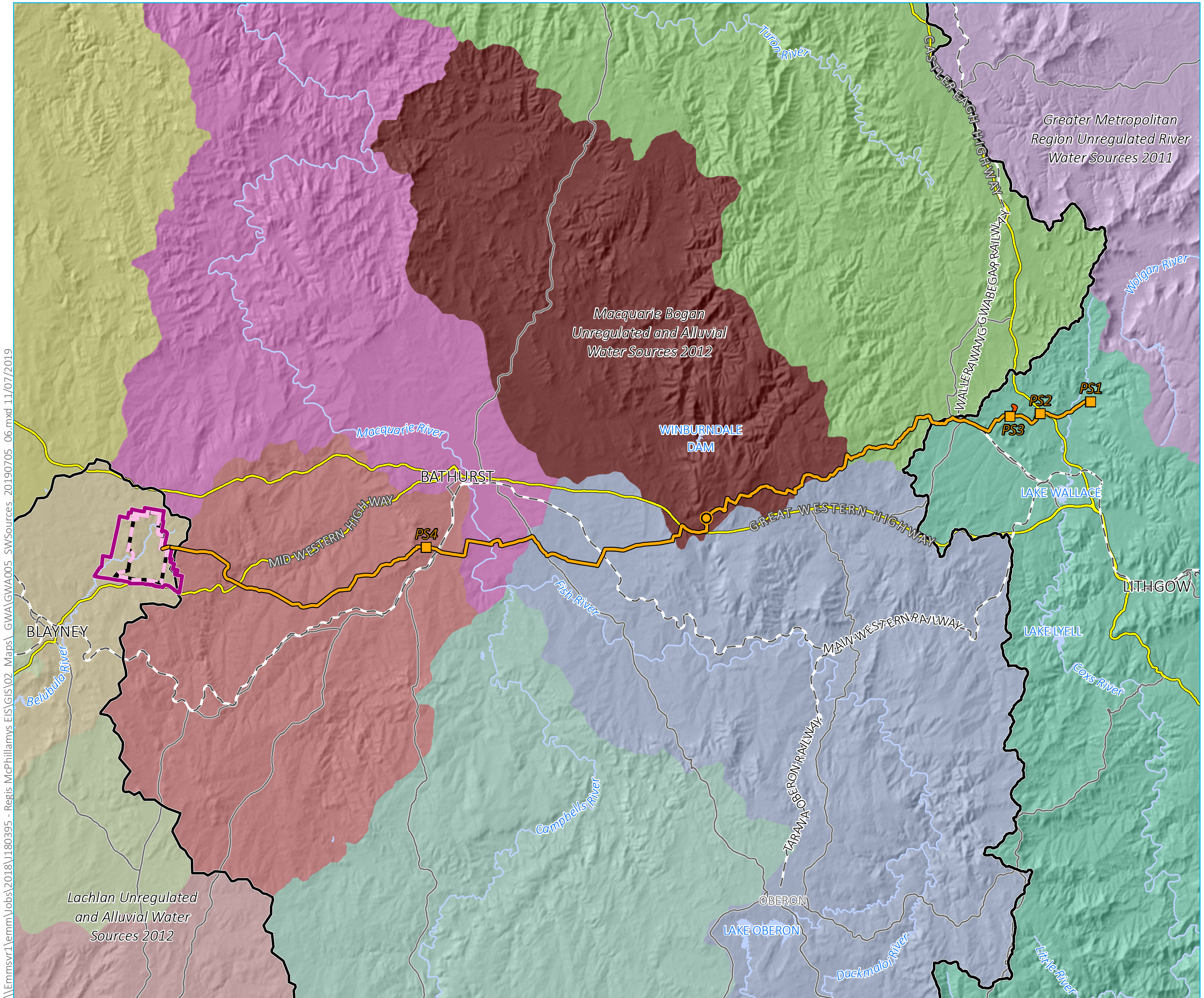
The AIP is the policy with respect to groundwater interference activities. The policy explains the role and requirements of the Minister in determining applications for aquifer interference activities under the WM Act.

The AIP specifically refers to water take that is 'required to allow for the effective and safe operation of an activity, for example dewatering to allow mining'. All projects in NSW are required to licence their water take subject to the WM Act. This remains the case whether water is taken to supply part of the activity or incidentally. The AIP provides an example of incidental water take as *'required to allow for the effective and safe operation of an activity, for example dewatering to allow mining*'.

The AIP establishes and objectively defines considerations in assessing and providing advice on whether more than minimal impacts might occur to a key water-dependent asset. Importantly, the AIP defines trenching and pipelines intersecting the water table (if a water access licence is not required) as minimal impact aquifer interference activities.

The AIP categorises groundwater sources as being either 'highly productive' or 'less productive' based on levels of salinity and average yields from bores; the mapped distribution of the highly productive and less productive groundwater sources in NSW are included in DPI Water (2012e). The AIP then further defines water sources by their lithological character, being one of: alluvium, coastal sand, porous rock, or fractured rock. For each category, the AIP identifies thresholds for minimal impact considerations. These thresholds relate to impacts on the water table, water pressure and water quality, and are ranked as being either 'level 1 minimal impact' or 'level 2 exceeding minimal impact'.

The pipeline will be located at shallow depth; a maximum of 1.5–2 m below ground level (mbgl) in open trenched areas and an approximate maximum 10 mbgl at river and creek crossings that are underbored. The pipeline open trench areas are unlikely to intercept the water table in the various geologies along the pipeline corridor (see Section 3.3), and underboring does not take groundwater, and therefore is not considered to be an aquifer interference activity.



Source: EMM (2019); Regis Resources (2019); DFSI (2017); DPI (2013); GA (2011)

KEY

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pressure reducing system
- Pumping station facility
- Pipeline corridor
- Pipeline corridor (Blowdown Pond)

Water Sharing Plan - surface water sources

- Abercrombie River above Wyangala Water Source
- Belubula River above Carcoar Dam Water Source
- Belubula Tributaries below Carcoar Dam Water Source
- Campbells River Water Source
- Fish River Water Source
- Hawkesbury and Lower Nepean Rivers Water Source
- Macquarie River above Burrendong Water Source
- Queen Charlottes Vale Evans Plains Creek Water Source
- Summerhill Creek Water Source
- Turon Crudine River Water Source
- Upper Nepean and Upstream Warragamba Water Source
- Winburndale Rivulet Water Source
- Water Sharing Plan boundary

Existing environment

- Rail line
- Primary road
- Arterial road
- River
- Waterbody

Surface water management

McPhillamys Gold Project
Pipeline water assessment
Figure 2.1

EMM
creating opportunities

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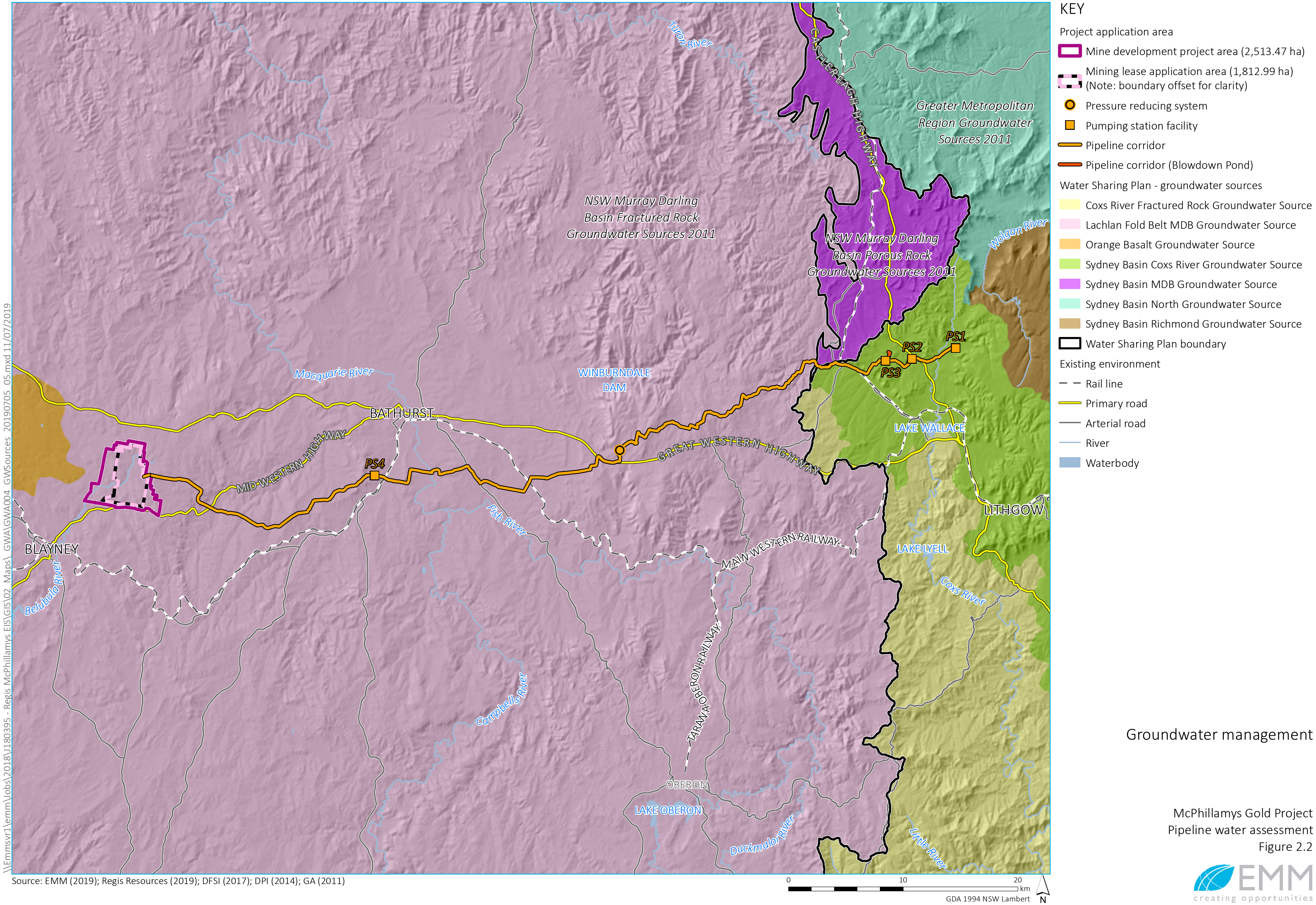

Source: EMM (2019); Regis Resources (2019); DFSI (2017); DPI (2014); GA (2011)

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Groundwater management

McPhillamys Gold Project
Pipeline water assessment
Figure 2.2

EMM creating opportunities

2.4 Licensing and approvals requirements

2.4.1 Licensing exemptions

The project will be State significant development (SSD). As such certain approvals under the following sections of the WM Act will are not be required in accordance with requirements of section 4.41(1)(1)(g) of the EP & A Act which would be required if the project was not state significant:

- water use approvals under section 89;
- water management works approval under section 90; and
- activity approvals under section 91 (other than an aquifer interference approval).

2.4.2 Aquifer interference

The requirement to obtain an aquifer interference approval under Section 91 of the WM Act is triggered when an activity intercepts groundwater, and a proclamation has been made under Section 88A. To date, no proclamation has been made specifying that an aquifer interference approval is required in any part of NSW, therefore (irrespective of the SSD exemptions) Regis does not require one for the pipeline development.

The pipeline does not constitute 'aquifer interference' as defined in the AIP, as regional groundwater sources will not be intersected by the pipeline construction and operation activities.

Watercourse crossings will require individual assessment to determine whether localised shallow groundwater is present. If perched or alluvial groundwater is present, then appropriate management and mitigation measures to protect water levels and water quality will be adopted during the construction program. No groundwater take will occur during trenching or underboring.

3 Existing environment

This chapter describes the physical attributes of the primary surface water features and multiple groundwater systems that underlie the pipeline route from Angus Place to the mine site .

3.1 Topography

The pipeline route straddles three major catchments: the eastern Hawkesbury-Nepean River Basin and the western Macquarie River Basin, and then the uppermost portion of the Lachlan River Basin. Elevations range from about 900 m AHD at the start of the pipeline at Angus Place Colliery to around 1,200 m AHD at the coastal/inland catchment divide south of Sunny Corner, decreasing to around 1,000 m AHD towards the end of the pipeline situated to the south of Vittoria State Forest on the eastern border on the mine development project boundary.

Streams located to the east of Sunny Corner are part of the Coxs River catchment and eventually flow into Lake Burragorang impounded by (and upstream of) Warragamba Dam. Stream crossings located west of Sunny Corner are part of the numerous creeks and rivers that flow into the Turon-Crudine River, Fish River, Macquarie River or Queen Charlottes/Vale/Evans Plains and McLeans Creek catchments. The last segment of the pipeline route is located in the Belubula River catchment but there are no associated creek crossings.

3.2 Surface water

There are multiple watercourse crossings along the pipeline route. The geomorphological survey (Appendix A) identified 112 drainage line intersections using an automatically digital elevation model (DEM)-generated drainage line approach. Of these, eight locations were associated with permanent streams.

Numerous minor streams and gullies along the pipeline route are non-perennial and only have flow after large rainfall events. Flow and water quality of surface water in these small-scale watercourses is unknown.

Each of the permanent streams (from east to west) is associated with the following surface water sources:

- Coxs River – Upper Nepean and Upstream Warragamba Water Source (Wywandy Management Zone)
- Pipers Flat Creek – Upper Nepean and Upstream Warragamba Water Source (Wywandy Management Zone);
- Wangcol Creek – Upper Nepean and Upstream Warragamba Water Source (Wywandy Management Zone)
- Salt Water Creek – Fish River Water Source;
- Macquarie River – Macquarie River upstream of Burrendong Dam Water Source (including the Macquarie River above Bathurst and Macquarie River Tributaries Management Zones);
- Queen Charlottes Creek – Queen Charlottes Vale Evans Plains Creek Water Source (including the Queen Charlottes Vale Evans Plains Creek Downstream and Queen Charlottes Vale Evans Plains Creek Tributaries Management Zones);
- Evans Plains Creek – Queen Charlottes Vale Evans Plains Creek Water Source (including the Queen Charlottes Vale Evans Plains Creek Downstream and Queen Charlottes Vale Evans Plains Creek Tributaries Management Zones); and

- McLeans Creek – Queen Charlottes Vale Evans Plains Creek Water Source (including the Queen Charlottes Vale Evans Plains Creek Downstream and Queen Charlottes Vale Evans Plains Creek Tributaries Management Zones).

The following is a desktop assessment of the surface water conditions in the permanent streams located along the pipeline route using data from the NSW surface water database (WaterNSW 2019) and water quality reports from 2010 (DECCW 2010a, 2010b, 2010c). No field surveys to confirm stream conditions such as water levels, flows and water quality have been carried out.

3.2.1 Coxs River

The pipeline will cross the upper reaches of the Coxs River. The nearest flow station on the Coxs River is approximately 7 km downstream, immediately downstream of Lake Wallace which records a perennial flow. The field inspection during the geomorphology assessment (refer Appendix A) identified that the Coxs River where the pipeline corridor will traverse is a perennial minor stream, with a partly confined valley setting, marshy floodplain and mud bed material. The geomorphology assessment also noted that the Coxs River also receives mine discharge water.

3.2.2 Wangcol Creek

Wangcol Creek is a tributary of Coxs River in the upper Nepean catchment. There are no known stream gauges on Wangcol Creek to confirm water levels and flow volumes (WaterNSW 2019). There are numerous stream gauges on the Coxs River but these are located too far downstream to provide any useful indication of flows in the upper catchment.

3.2.3 Pipers Flat Creek

Pipers Flat Creek is a tributary of the Coxs River in the upper Hawkesbury-Nepean catchment. There are no known stream gauges on Pipers Flat Creek to confirm water levels and flow volumes (WaterNSW 2019). The closest stream gauge is located downstream of the creek's confluence with the Coxs River at Wallerawang.

Long-term water quality monitoring in the Upper Coxs River sub-catchment is limited to only a few sites. There is no long-term monitoring location along Pipers Flat Creek or any of its tributaries. The closest water monitoring site is located downstream along the Coxs River at Wallerawang immediately upstream of Lake Lyell. In the lower portion of the Upper Coxs Creek catchment there is water quality monitoring undertaken by a number of organisations involved in mining, power generation, water supply, and catchment management.

The majority of river reaches in this sub-catchment (especially the lower reaches) are degraded and water quality is only fair (DECCW 2010a).

3.2.4 Saltwater Creek

Saltwater Creek is a tributary of the Fish River in the upper Macquarie catchment. There are no known stream gauges on Saltwater Creek to confirm water levels and flow volumes (WaterNSW 2019). There are also no known gauges on the Fish River downstream of Saltwater Creek's confluence with the Fish River.

There is no publicly available surface water quality data for Saltwater Creek, however judging by its name it is probably receiving slightly saline baseflow from groundwater springs higher in the catchment. There are references to upstream water quality for the Fish River at Tarana Bridge which suggest elevated nutrients in surface water in the catchment (DECCW 2010b).

3.2.5 Macquarie River

The Macquarie River upstream of Bathurst is the main permanent watercourse in the upper Macquarie catchment. There are no known stream gauges on the Macquarie River upstream of Bathurst to confirm water levels and flow volumes (WaterNSW 2019). There are numerous stream gauges downstream of Bathurst but these are located too far downstream to provide any useful indication of flows in the upper catchment.

There is no publicly available surface water quality data for the Macquarie River upstream of Bathurst. Water quality is expected to be fresh although potentially impacted by the predominantly agricultural surrounding land use.

3.2.6 Queen Charlottes Creek

Queen Charlottes Creek is a major tributary of the Macquarie River in the upper Macquarie catchment. There are no known stream gauges on this creek to confirm water levels and flow volumes (WaterNSW 2019). In dry periods the creek is sustained by baseflow inflows from pockets of alluvium and regional groundwater discharge (e.g. springs) from the fractured rock aquifers in the granitic rocks of the catchment.

There is no publicly available surface water quality data for Queen Charlottes Creek. Water quality is expected to be fresh to brackish.

3.2.7 Evans Plains Creek

Evans Plains Creek is a major tributary of the Macquarie River in the upper Macquarie catchment. There are no known stream gauges on this creek to confirm water levels and flow volumes (WaterNSW 2019). The creek is sustained by baseflow inflows from regional groundwater discharge (e.g. springs) from the fractured rock aquifers in the granitic rocks of the catchment.

There is no publicly available surface water quality data for Evans Plains Creek. Water quality is expected to be fresh to brackish.

3.2.8 McLeans Creek

McLeans Creek is a tributary of Evans Plains Creek which in turn is a major tributary of the Macquarie River in the upper Macquarie catchment. There are no known stream gauges on this creek to confirm water levels and flow volumes (WaterNSW 2019). The creek is sustained by baseflow inflows from regional groundwater discharge (eg springs) from the fractured rock aquifers in the granitic rocks of the catchment.

There is no publicly available surface water quality data for McLeans Creek. Water quality is expected to be fresh to brackish.

3.3 Groundwater

There are multiple geologies along the pipeline route. The proposed pipeline route transects three groundwater sources (Figure 2.2), namely the:

- Sydney Basin Coxs River Groundwater Source. This porous rock groundwater source covers an area of approximately 529 km^2 (DPI Water 2012b). The geology consists of sedimentary sandstone and siltstone formations with intervening coal seams. The groundwater source is bounded to the south west by the Coxs River Fractured Rock Groundwater Source and to the east by the Sydney Basin Richmond and Sydney Basin Blue Mountains Groundwater Sources.

- Sydney Basin Murray Darling Basin (MDB) Groundwater Source. This porous rock groundwater source covers an area of 2,120 km^2 (DPI Water 2012b). The proposed pipeline route crosses this water source for a very short distance near Portland, NSW. The geology comprises Carboniferous to Triassic formations with areas to the south, near Portland, resting on a Palaeozoic basement of granitic and metamorphic rocks and late Devonian sequences. The western and southern boundaries are defined by the Lachlan Fold Belt, the north eastern boundary by the Hunter Thrust and the north western boundary by the Mount Coricudgy Anticline. The western boundary is the Lachlan Fold Belt MDB Groundwater Source.

- Lachlan Fold Belt Murray Darling Basin (MDB) Groundwater Source. This very large fractured rock groundwater source covers an area of 167,220 km^2 (DPI Water 2012c). The geology consists of Cambrian to Lower Carboniferous rock successions. The eastern margin is truncated by the southern NSW coastal and inland catchment divides and to the north is overlapped by the Permian-Triassic succession of the Sydney-Gunnedah Basin. The northern inland margin is overlain by the Mesozoic Great Artesian Basin succession and the southern margin is truncated by the Victorian border. The western and southern margins are covered by Cainozoic Murray Basin and associated inland alluvial groundwater sources.

The Orange Basalt Groundwater Source overlies the Lachlan Fold Belt MDB Groundwater Source west of the proposed mine site and will not be transected by the proposed pipeline.

The following section is a desktop assessment of the groundwater conditions expected along the pipeline route using existing geological mapping and data from the NSW groundwater database (WaterNSW 2019). No field surveys to investigate site conditions, identify spring locations or to measure groundwater levels in nearby private bores have been carried out.

3.3.1 Regional groundwater level, flow and resources

Regional groundwater level and flow is influenced by geology and topography. The groundwater level is typically a muted reflection of topography with shallow groundwater flow toward surface drainage features. When a stream exhibits permanent flow there is likely to be a baseflow component generated by regional groundwater discharge.

The proposed pipeline alignment is predominantly contained within the Lachlan Fold Belt MDB Groundwater Source. The aquifers within this groundwater source are restricted to areas of secondary porosity (fracture flow/faulting) where reasonable groundwater yields can be achieved. Water table depths are generally deeper than 10 mbgl.

Minor alluvium that is permanently saturated is associated with some of the major streams such as the Macquarie River and Queen Charlottes Creek. This alluvium is likely to be in connection with the regional water table in the underlying fractured rock. These permanent shallow groundwater systems are recharged directly by rainfall and indirectly through leakage from surface watercourses and overbank flow and underlie the small floodplain areas.

In addition, there are thin alluvial/colluvial sediments associated with some creeks and rivers in the upper catchments that occasionally contain perched groundwater (ie very shallow and localised groundwater that is disconnected from the three regional groundwater sources described above). These perched systems are recharged directly by rainfall. The localised perched systems either discharge to surface watercourses, providing an important source of delayed flow between rainfall events, or are used as a water source by adjacent terrestrial vegetation. Those perched groundwater systems associated with minor ephemeral creeks are also likely to be ephemeral. When they are present after rain, the depth to the perched water table is generally 1.5 - 2 mbgl.

3.3.2 Sydney Basin Coxs River Groundwater Source Characteristics

The Sydney Basin Coxs River Groundwater Source groundwater source occurs from Angus Place Colliery to south of Portland for approximately 20 km along the pipeline route. The shallowest groundwater contained in these sandstone, siltstone and coal rocks generally occurs in aquifers 25–50 mbgl (slightly shallower at low lying sites and slightly deeper at elevated sites). Most of the porous rock aquifers along the alignment are semi-confined. Historical groundwater levels in private bores located within 2 km of the pipeline alignment generally have groundwater at depths greater than 5 mbgl (WaterNSW 2019) (refer XX).

Consequently, given the depth to the shallowest regional aquifers and the depth to the regional water table, regional groundwater is extremely unlikely to be encountered in open trenches ranging 1.5–2 mbgl along this section of the pipeline route.

There are relatively few minor creek crossings in this section of the pipeline route. Consequently, very shallow perched groundwater is not expected, except perhaps where the pipeline crosses Pipers Flat Creek due to the relatively low topography at this location.

3.3.3 Sydney Basin Murray Darling Basin (MDB) Groundwater Source Characteristics

The Sydney Basin Murray Darling Basin (MDB) Groundwater Source is located around Portland and adjoins the Coxs River Groundwater source on the east and the Lachlan Fold Belt MDB Groundwater Source on the west. Where the pipeline route crosses this water source, it is only a few hundred metres wide. It is expected to have the same groundwater characteristics as the Lachlan Fold Belt MDB Groundwater Source.

3.3.4 Lachlan Fold Belt Murray Darling Basin (MDB) Groundwater Source Characteristics

This groundwater source occurs from south-west of Portland to the end of the pipeline at the mine site for a total distance of approximately 70 km. There are a variety of geologies along this section of the pipeline route. Most are intruded igneous rocks and fractured and folded metasediments comprising granite and granodiorite and also lithic sandstone, siltstone, shale, minor volcanics, tuff, and other volcaniclastics.

The shallowest groundwater contained in these fractured rocks generally occurs in aquifers 30–75 mbgl (slightly shallower at low lying sites and slightly deeper at elevated sites). Most of the fractured rock aquifers along the alignment are semi-confined i.e. the groundwater in the aquifer(s) is under pressure and rises in the borehole on completion. Groundwater levels in private bores located within 2 km of the pipeline alignment generally are greater than 10 mbgl (WaterNSW 2019) (refer).

Quaternary sandy alluvium is associated with the major river and creek crossings. The alluvium is unconsolidated and relatively thin (less than 15 m thick) but groundwater levels can be high with water tables generally 1.5–3 mbgl.

Consequently, underboring of the pipeline is proposed at the Macquarie River and Queens Charlottes Creek (Vale Creek) to protect stream flows and to minimise disturbance to shallow groundwater. Underboring will allow the pipeline to be specifically positioned at the base of the alluvium or into the weathered rock profile so as to not affect groundwater flows or water quality. The detailed design phase will confirm whether additional watercourses, particularly Evans Creek and Saltwater Creek, warrant underboring.

At minor creek crossings that are not incised, shallow perched groundwater may also be present in shallow alluvium/colluvium or weathered rock after rain at a depth of 1.5–2 mbgl. If encountered, this water will appear as a slow seepage into the base of the open trench. Careful laying of the pipeline and associated backfilling of the trench (avoiding any trench collapse) will not impact the shallow perched groundwater or regional groundwater systems.

3.3.5 Groundwater quality and users

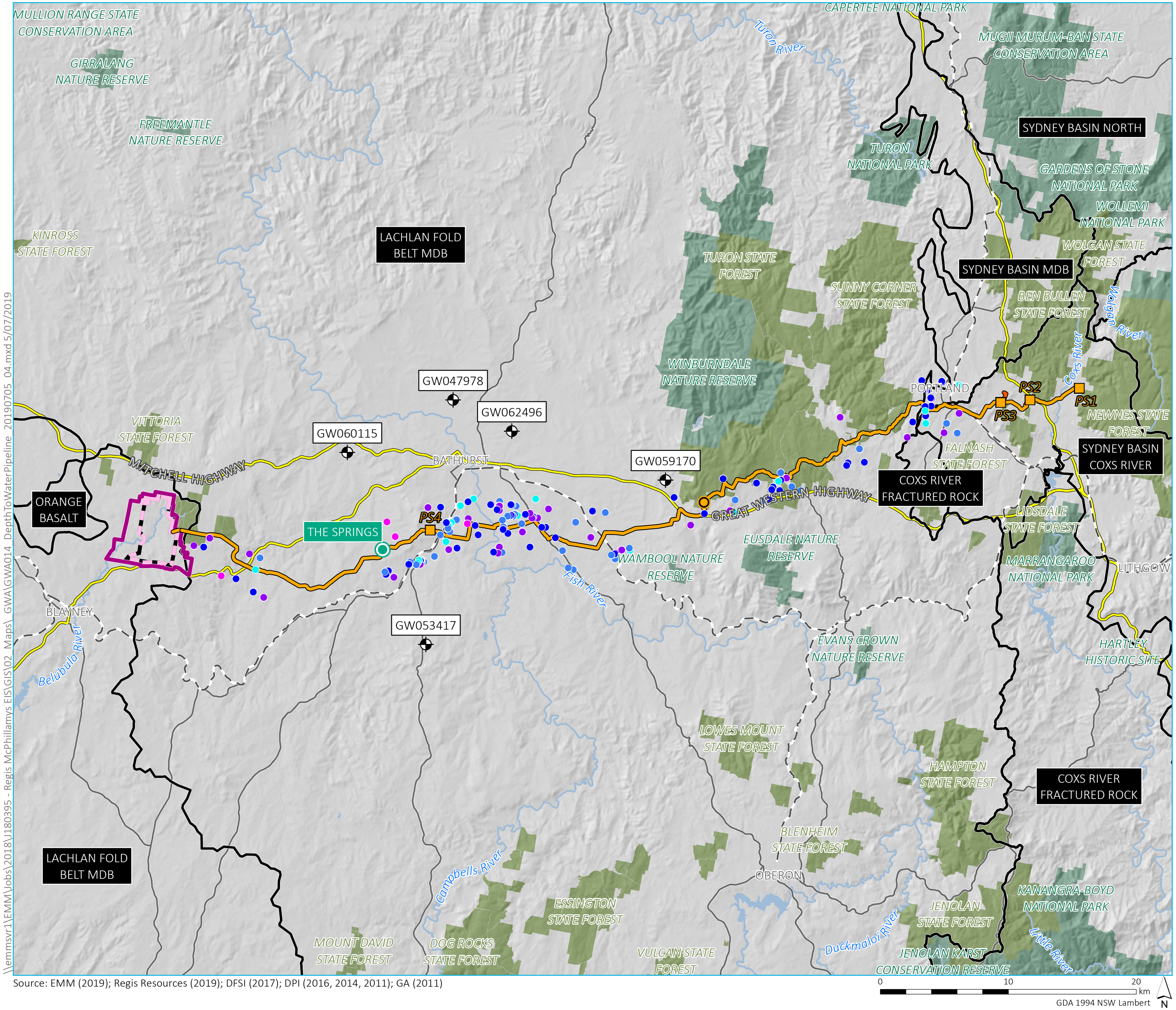
Groundwater quality varies across the water sources and is impacted by rock type and historical land use. The groundwater quality in the Lachlan Fold Belt ranges from fresh (0–1,500 mg/L total dissolved solids (TDS)) to saline (above 14,000 mg/L TDS) (MDBA 2012). In the areas adjacent to the proposed pipeline, the natural groundwater quality in both the sedimentary rock aquifers and the fractured rock aquifers is expected to vary from fresh to slightly saline. Typically, the salinity range would be 500–2500 mg/L TDS.

Groundwater use along the proposed pipeline route is typically for stock and domestic purposes (WaterNSW 2019).

3.3.6 Groundwater dependent ecosystems

The WSP for the NSW MDB Fractured Rock Groundwater Sources (2011) lists one high priority groundwater dependant ecosystem (GDE) (a spring) within the local Lachlan Fold Belt water source and within 2.5 km of the proposed pipeline. This high priority GDE (called The Springs) is located west of Perthville and is approximately 180 m from the proposed pipeline corridor. The Springs is likely to be regional groundwater discharge at a local geological structural feature in the Bathurst Granite.

The Bureau of Metrology (BoM) GDE Atlas describes several tributaries crossed by the proposed pipeline as having high potential for an ecosystem that relies on the surface expression of groundwater. This classification is based on a national desktop assessment that has not been ground-truthed to identify localised GDEs. The biodiversity development assessment report (BDAR) carried out for the pipeline development (OzArk 2019) contained in Appendix Y of the EIS considered that, based on regional vegetation mapping, there is a low to moderate potential; for terrestrial GDEs to be present in and around the vicinity of the pipeline corridor however was likely to be limited to terrestrial vegetation along watercourse that opportunistically access groundwater under dry conditions. The BDAR concluded that GDEs are unlikely to be impacted by construction of the pipeline due to the shallow excavations required.



\\emmsvr1\EMM\Jobs\2018\J180395 - Regis McPhillamys EIS\GIS\02_Maps_GWA\GWA014_DepthToWaterPipeline_20190705_04.mxd 5/07/2019

Source: EMM (2019); Regis Resources (2019); DFSI (2017); DPI (2016, 2014, 2011); GA (2011)

KEY

- High-priority groundwater dependent ecosystem
- Selected metered bore
- Water sharing plan - groundwater sources (2014)

Registered bores (to 2 km from pipeline)

Depth to groundwater (m)

- 0 - 5
- 6 - 10
- 11 - 20
- 21 - 35
- 36 - 56

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pressure reducing system
- Pumping station facility
- Pipeline corridor
- Pipeline corridor (Blowdown Pond)

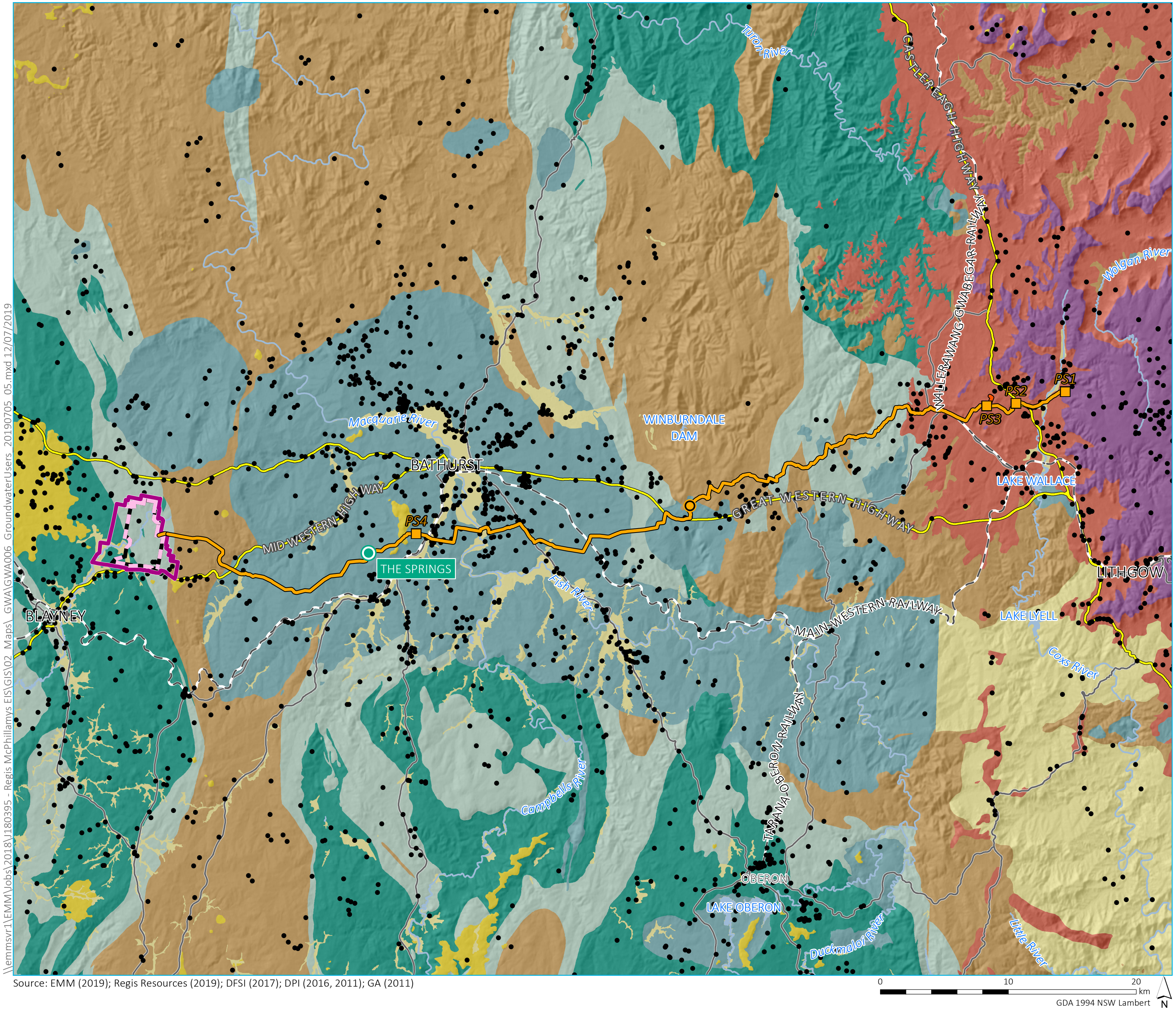
Existing environment

- Rail line
- Primary road
- Arterial road
- River
- Waterbody
- NPWS reserve
- State forest

Depth to water plan

McPhillamys Gold Project
Pipeline water assessment
Figure 3.1

EMM
creating opportunities



Source: EMM (2019); Regis Resources (2019); DFSI (2017); DPI (2016, 2011); GA (2011)

KEY

- Registered bore (PINEENA, 2016)
- High-priority groundwater dependent ecosystem

Project application area

- Mine development project area (2,513.47 ha)
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pressure reducing system
- Pumping station facility
- Pipeline corridor
- Pipeline corridor (Blowdown Pond)

Surface geology (1:250k) by period

- Quaternary
- Tertiary
- Triassic
- Permian
- Carboniferous
- Devonian
- Silurian
- Ordovician

Existing environment

- Rail line
- Primary road
- Arterial road
- River
- Waterbody

Groundwater users

McPhillamys Gold Project
Pipeline water assessment
Figure 3.2

EMM
creating opportunities

4 Geomorphology assessment

The construction and operation of the pipeline presents a negligible to low risk to the geomorphology of the watercourses traversed along the pipeline corridor. EMM engaged Chris Gippel, of Fluvial Systems Pty Ltd, to assist in the preparation of a geomorphology assessment for creeks crossed by the proposed pipeline route. The full geomorphology report is included in Appendix B, with key information summarised in this chapter.

4.1 Assessment approach

The assessment focused on geomorphic characteristics of the watercourses in the vicinity of the pipeline intersections that were relevant to the main risks associated with the pipeline during its operational phase, which are:

- geomorphic change may lead to exposure of the pipeline to fluvial forces, thereby putting the integrity of the pipeline at risk; and
- the presence of the pipeline (usually in combination with being exposed through geomorphic change) will interfere with natural geomorphic processes.

The existing environment was assessed using a two-staged approach:

- a desktop assessment; and
- a field assessment.

The desktop assessment was used to prioritise streams for field inspection based on the summary considerations below:

- the number of hydroline intersections with the proposed pipeline corridor;
- revised and verified hydroline intersections using GIS tools;
- classification of hydrolines based on stream order and catchment size;
- classification of minor and major streams, and
- the main risks associated with the pipeline during its operational phase with regard to geomorphology.

Of the 131 hydrolines identified during the initial desktop assessment that were intersected by the pipeline corridor, 112 have been verified using industry standard Geographic Information System (GIS) assessment tools. The 112 hydrolines were classified by stream order (one to eight) and catchment area. For the purpose of assessing the potential geomorphic impact of the pipeline, the 112 streams were then filtered based on size using the 1:25,000 topographic maps to identify streams that were Third Order and higher as these can be described as larger, more likely to have permanent flow within a defined channel. First and Second Order streams usually characterised by drainage depressions, gullies or no defined channel were excluded from further assessment as they are less significant in geomorphological terms and relatively resilient to human disturbance.

The desktop assessment further classified the watercourses as either minor/small size, medium or large. Pipeline crossings of minor/small size watercourses generally present a low risk and predictable impact to geomorphic processes and were therefore considered lower priority for detailed field inspections. Pipeline crossings of medium or larger size watercourses were considered higher priority and consequently more time was allocated for detailed field inspections.

Table 4.1 summarises the 20 prioritised field inspection locations. These locations are illustrated in Appendix A.

Table 4.1 Watercourse crossings prioritised for field inspection

No.	Easting	Northing	Catchment Area (km^2)	Strahler Stream Order	Chainage (m) [1]	Priority	Watercourse Name	Perennialism [2]	Hierarchy [2]
14	722991.7	6291288.8	11.1	4	7.1	1	McLeans Ck	Perennial	Minor
16	724138.1	6290859.0	126.9	5	8.3	1	Evans Plains Ck	Perennial	Minor
25	726304.3	6290280.9	14.4	4	10.6	1		Non Perennial	Minor
31	726304.3	6290280.9	4.2	3	13.4	2		Non Perennial	Minor
45	738777.9	6293622.8	313.5	6	25.4	1	Queen Charlottes Ck	Perennial	Minor
46	738946.8	6293565.7	6.7	3	25.6	1		Non Perennial	Minor
50	742729.9	6294316.1	2,415.1	8	30.5	1	Macquarie R	Perennial	Major
59	748196.2	6293153.4	61.7	5	37.2	1	Salt Water Ck	Perennial	Minor
64	752647.2	6293751.1	8.9	4	42.5	1		Non Perennial	Minor
68	754521.2	6294206.0	2.1	3	44.5	2		Non Perennial	Minor
70	757245.4	6295610.3	1.3	2	48.0	2		Non Perennial	Minor
76	759122.4	6295528.8	1.9	3	50.4	2	Saint Anthonys Ck	Non Perennial	Minor
87	763136.7	6298475.3	2.0	3	56.9	2		Non Perennial	Minor
89	764240.4	6298383.6	2.0	3	58.2	2	Kirkconnell Ck	Non Perennial	Minor
100	772738.8	6301698.2	2.8	3	69.6	2	Sugarloaf Ck	Non Perennial	Minor
103	775360.2	6303873.2	6.1	4	73.5	1	Williwa Ck	Non Perennial	Minor
111	778078.5	6303750.4	11.5	4	76.8	1	Pipers Flat Ck	Perennial	Minor
115	780240.1	6302991.7	14.6	4	79.2	1	Pipers Flat Ck	Perennial	Minor
124 [3]	784042.1	6303486.7	2.4	3	83.9	2		Non Perennial	Minor
126A [4]	784396.4	6304049.8	3.6	3	84.7	2		Non Perennial	Minor
126B [4]	784532.1	6304179.0	3.6	3	84.9	2		Non Perennial	Minor
126C [4]	784599.4	6304194.6	3.6	3	84.9	2		Non Perennial	Minor
127 [3]	784679.6	6304274.2	23.2	4	85.1	1	Wangcol Ck	Perennial	Minor
131	786932.9	6304300.1	47.3	5	87.5	1	Coxs R	Perennial	Minor

Notes: 1. Chainage is distance along pipeline from west to east.
2. Perenniality and Hierarchy are attributes from hydrolines.
3. Inaccessible at the time of the field inspection.
4. 126A, 126B and 126C are within 250 m of the same reach and are represented in the field by 126B.

The following tasks were undertaken during the field assessment:

- photographs of the site in the downstream and upstream directions;
- estimation of structure and cover of riparian vegetation;
- estimation of bed sediment material calibre; and
- estimation of the depth of sand in the bed of sand-bed streams.

The locations of the sites visited are shown in Appendix A.

4.2 Site investigation outcomes

The geomorphic character of the watercourse crossing locations for the 20 surveyed sites are detailed in Table 4.2.

Those streams that exhibit perennial flow (from east to west) are considered to be the most important watercourse crossings. These are:

- Coxs River (site 131)
- Wangcol Creek (site 127);
- Pipers Flat Creek (sites 111 and 115);
- Salt Water Creek (site 59);
- Macquarie River (site 50);
- Queen Charlottes Creek (site 45);
- Evans Plains Creek (site 16); and
- McLeans Creek (site 14).

The key findings of the study were:

1. Only one site (site 68 – a non perennial watercourse to the east of Salt Water Creek -refer Appendix A), showed evidence of a knickpoint with potential to migrate upstream to the pipeline intersection. Downstream of site 68, the channel was incised, with three knickpoints of 0.8 m to 1.5 m depth present within 1,000 m downstream of the intersection.
2. Four sites (sites 16, 31, 45 and 59) had sand beds that could be probed;
3. Site 25 had extensive bedrock outcrops present, with some acting as hydraulic controls for pools;
4. Site 115 was close to the hydraulic control of a 200 m long pool; and
5. There was little evidence of recent bank or bed erosion at any site. Most sites had at least moderate combined vegetation cover, even if the tree cover was poor at most sites.
6. The apparent stability of the beds and banks of the watercourses was unremarkable for streams in these disturbed settings.

Due to the assessment method (visual inspection with no sampling or laboratory testing) it was not possible to develop graded estimates of bank stability. It appeared that at each of the visited sites crossing design resulting in stable creek banks could be completed by a competent civil or geotechnical engineer utilising site specific data such as soil particle size distribution data and surveyed cross sections and appropriate design methods.

4.3 Geomorphic impact pathways

Buried pipelines may be exposed by stream bed incision. This could involve episodic scour of mobile bed sediments during floods, even though the bed might return to the same elevation between floods, or upstream migration of a head cut, or knickpoint. Scour during flood flows is expected in sand bed streams, but those with cohesive clay-rich beds, or gravel/cobble, boulder or bedrock are expected to have relatively stable beds. Knickpoints are a local steep fall in channel bed elevation and are a common, natural feature of streams. Stable (or fixed) knickpoints occur on river profiles due to a local control, such as a resistant lithological unit, fault, or large coarse sediment supply. Unstable (or mobile) knickpoints are initiated by a downstream event that lowers the hydraulic control, with erosion propagated upstream as a head cut.

Lateral channel migration may occur due to slow meander migration or rapid avulsion. In general, channels confined within valley walls migrate slowly, while those set within extensive floodplains are expected to naturally migrate through the alluvial sediments. Riparian vegetation locally increases the resistance of banks to fluvial scour.

Table 4.2 Key geomorphic characteristics observed in the field

Crossing	Easting (m)	Northing (m)	Catchment Area (km^2)	Strahler Stream Order	Stream Name[1]	Perennialism	Bed Material	Tree cover index	Vegetation cover index	Comment
14	722990	6291290	11.1	4	McLeans Ck	Perennial	**Mud**, sand, gravel, cobble	1 - 5%	25 - 50%	
16	724140	6290860	126.9	5	Evans Plains Ck	Perennial	**Sand**, mud, gravel	<1%	25 - 50%	Sand depth 0.3 m
25	726300	6290280	14.4	4		Non Perennial	**Mud**, bedrock	5 - 25%	25 - 50%	Extensive exposed bedrock forming pool hydraulic controls
31	726300	6290280	4.2	3		Non Perennial	**Sand**	<1%	25 - 50%	Sand depth 1.2 m
45	738780	6293620	313.5	6	Queen Charlottes Ck	Perennial	**Sand**, mud	<1%	25 - 50%	Sand depth 1.3 m
46	738950	6293570	6.7	3		Non Perennial	**Mud**	<1%	5 - 25%	
50	742730	6294320	2,415.1	8	Macquarie R	Perennial	**Sand**, mud	<1%	50 - 75%	
59	748200	6293150	61.7	5	Salt Water Ck	Perennial	**Sand**, mud, gravel	<1%	25 - 50%	Sand depth 0.6 m
64	752650	6293750	8.8	4		Non Perennial	**Mud**	1 - 5%	50 - 75%	
68	754520	6294210	2.1	3		Non Perennial	**Mud**, sand, cobble, bedrock	<1%	25 - 50%	Minor knickpoint in bed, 0.5 m high
70	757250	6295610	1.3	2		Non Perennial	**Mud**	<1%	5 - 25%	
76	759120	6295530	1.9	3	Saint Anthonys Ck	Non Perennial		<1%	25 - 50%	
87	763140	6298480	2.0	3		Non Perennial	**Mud**	25 - 50%	25 - 50%	
89	764240	6298380	2.0	3	Kirkconnell Ck	Non Perennial	**Mud**	50 - 75%	75 - 100%	
100	772740	6301700	2.8	3	Sugarloaf Ck	Non Perennial	**Mud**	25 - 50%	50 - 75%	
103	775360	6303870	6.1	4	Williwa Ck	Non Perennial	**Gravel**, mud, sand, cobble	5 - 25%	25 - 50%	
111	778080	6303750	11.5	4	Pipers Flat Ck	Perennial	**Mud**	<1%	25 - 50%	
115	780240	6302990	14.6	4	Pipers Flat Ck	Perennial	**Mud**	25 - 50%	50 - 75%	200 m long pool upstream of crossing, nearby hydraulic control
126	784530	6304180	3.6	3		Non Perennial	**Cobble**	5 - 25%	5 - 25%	
131	786930	6304300	47.3	5	Coxs R	Perennial	**Mud**	<1%	25 - 50%	

Notes: 1. Some observed streams were unnamed.

4.4 Geomorphological impact management measures

The following points summarise proposed geomorphological impact management measures:

- at sites with sandy beds (crossings 14, 31 and 59), the pipeline construction trench depth will be below the base of the sand bed. The depth of sand will be comprehensively surveyed as part of the geotechnical assessment to be undertaken during detailed design stage;
- the creek crossing near site 25 (on unnamed non-perennial watercourse) is located near a hydraulic control point (extensive bedrock outcrop). This crossing will need to be assessed further in detailed design to assess if trenching is practical and can be done with care to avoid disturbing the hydraulic control point;
- construction of the pipeline at site 68 (on unnamed non-perennial watercourse) is unlikely to impact the knickpoints identified approximately 1,000 m downstream of the crossing. The rate of upward progression of these knickpoints is unknown. The knickpoints can be stabilised using structural works or the crossing can be relocated further upstream;
- the creek crossing on perennial Pipers Flat Creek near site 115 is also located near a hydraulic control point. Given that Pipers Flat Creek is perennial, the construction at this crossing may need to be underbored, however, this will need to be assessed further in detailed design to ensure that construction will not disturb the control point;
- annual visual inspection of the priority sites listed in Table 4.1 will be undertaken to document any changes in geomorphological conditions, with bank and bed stabilisation works undertaken if required;
- a geomorphological inspection will be undertaken as soon as possible following a 1 in 5-year Average Recurrence Interval (ARI) or greater regional storm event, when erosion processes may be exacerbated by fast flowing water; and
- backfill material will be composed of the same material that was excavated (in layers, as appropriate), and compacted.

Potential geomorphic impacts during the construction phase would primarily relate to occurrence of a significant storm runoff event flood when a trench is exposed, and/or ground surrounding the site is disturbed from the action of machinery. These impacts would be mitigated through avoiding work prior to forecast storm events, operating under a sediment and erosion management plan, and application of the NSW Office of Water (2012b) *Guidelines for laying pipes and cables in watercourses on waterfront land*. Management measures described in this guideline include:

- preparation of rehabilitation plans for disturbed beds and banks;
- locating pipes across the watercourse on the downstream side of channel bedrock outcrops and through the drop deposit zone if a plunge pool is present;
- avoiding bends;
- placing infrastructure below calculated bankfull flow scour depths with a safety margin;
- avoiding concrete caps and casings at shallow depths which may become exposed by bed lowering;
- ensuring backfilling restores the channel shape and bed level to preconstruction condition;

- ensuring trenches are open for the minimal length of time;
- avoiding stopping the flow of a permanent watercourse by staging the trench across the channel, or minimise the time involved in stopping or intercepting flows; and
- addressing additional disturbances from temporary coffer dams or diversion of flows around work site, vehicle or machinery access and crossings and material stockpiles.

4.5 Residual geomorphic impacts

Pipeline crossings constructed using underboring present a negligible risk of geomorphic impact. Whereas, trenched crossings present a low risk of residual geomorphic impact.

Storms or heavy rainfall may result in bed or bank mobilisation of waterways, which if left unattended over successive erosion events, could develop into geomorphic impacts.

The likelihood of bed and bank mobilisation developing will be reduced through the monitoring regime, such that bed stabilisation works will occur within an appropriate timeframe and prevent either damage to the pipeline or bed movements beyond the immediate site.

4.6 Mitigation and monitoring

To mitigate potential impacts during the construction and operation phases of the pipeline (including erosion and sediment control), Regis will follow:

- the management measures set out in section 4.1.4 above;
- *Guidelines for laying pipes and cables in watercourses on waterfront land* for design, construction and operation phases;
- recommendations provided in Witheridge (2017) *Erosion and Sediment Control Field Guide for Pipeline Projects*;
- Landcom (2004) *Managing Urban Stormwater soils and construction Vol 1 4th edition;* and
- International Erosion Control Association (IECA) Australasia (2008) *Best Practice Erosion & Sediment Control*.

Monitoring of geomorphic aspects of the pipeline watercourse crossings will focus on significant storm runoff events, as impacts are only likely under conditions of heavy rainfall and fast flowing deep water in the channel. An inspection will be undertaken as soon as possible following a 1 in 5-year ARI regional storm event. In addition, an annual visual inspection of the priority sites listed in Table 4.1 will detect any significant geomorphic change during operation.

5 Surface water assessment

The construction and operation of the pipeline involves water course crossings in the Hawkesbury-Nepean and Macquarie River Basins. The pipeline is also located within the Lachlan River Basin but there are no watercourse crossings.

Overall the potential impact to both the quantity and quality attributes of local surface water sources are considered very low. This section addresses these attributes in the context of catchment river flow and water quality objectives.

5.1 River Flow Objectives

There are six River Flow Objectives for uncontrolled streams in the Macquarie-Bogan River Basin (DPE 2019). There is no differentiation between small headwater streams in the upper catchment, larger unregulated streams in the mid catchment areas, or minor streams on floodplains in the lower catchment. The six Objectives are:

- protect natural water levels in pools of creeks and rivers and wetlands during periods of no flows;
- protect natural low flows;
- protect or restore a proportion of moderate flows ('freshes') and high flows;
- maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems;
- maintain groundwater within natural levels and variability, critical to surface flows and ecosystems; and
- minimise the impact of instream structures.

Table 5.1 indicates how construction and operational management procedures will address each of these six river flow objectives.

Table 5.1 Upstream permanent stream crossings assessed against River Flow Objectives

River Flow Objective	Pipeline Construction/Operation Management Response
Protect natural water levels in pools of creeks and rivers and wetlands during periods of no flows	No water take is proposed during pipeline construction and underboring will not induce water entry so that any pools present at each of the crossings will be unaffected. Pipe sections will be buried at sufficient depth so as to not obstruct flow so pools will be unaffected when the pipeline is operational.
Protect natural low flows	No water take is proposed during pipeline construction and underboring will not induce water entry so that natural low flows at each of the crossings will be unaffected. Pipe sections will be buried and will not obstruct flow so natural low flows will be unaffected when the pipeline is operational.

Table 5.1 Upstream permanent stream crossings assessed against River Flow Objectives

River Flow Objective	Pipeline Construction/Operation Management Response
Protect or restore a proportion of moderate flows ('freshes') and high flows	No water take is proposed during pipeline construction and work will be suspended during moderate and high flow events so flows will be unaffected. Pipelines will be buried at sufficient depth so as to not obstruct moderate and high flow events when the pipeline is operational.
Maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems	These permanent stream crossings are located in the upper catchment areas where the size of the catchments is relatively small and there is minimal inundation associated with flood events. There are no known natural wetland or floodplain ecosystems adjacent to each of the major creek crossings.
Maintain groundwater within natural levels and variability, critical to surface flows and ecosystems	Regional groundwater will not be impacted by the pipeline constructed using trenching or underboring, where it is deeper than the buried pipeline. Shallow or perched groundwater may be present at some locations, but levels will be maintained during construction other than within the open portion of trench during construction. There will be no groundwater take during pipeline operations. There will be no impact on regional groundwater flows once the pipeline is operational. Any shallow or perched groundwater will be able to migrate around the pipeline. Compacted trench backfill material will have a similar hydraulic conductivity to insitu material, limiting groundwater flow along the pipeline through the backfilled trench. There will be no impact on groundwater dependent ecosystems.
Minimise the impact of instream structures	Temporary instream structures are only proposed if open trenching is used and low flows need to be captured or diverted for a brief period (see Section 4.1.4.) Temporary structures used during construction will be avoid during rainfall events and removed as soon as that segment of the pipeline is completed. There will be unimpeded flow during operational periods.

5.2 Water Quality Objectives

The NSW Water Quality Objectives (WQO) are the agreed environmental values and long-term goals for surface waters across NSW. They have been assessed and determined on a river basin and a water source basis.

There are eight primary WQO for uncontrolled streams in the Macquarie-Bogan River Basin (OEH 2006). There is no differentiation between small headwater streams in the upper catchment, larger unregulated streams in the mid catchment areas, or minor streams in the lower catchment. The eight WQO are:

- maintain or improve the ecological condition of waterbodies and their riparian zones over the long term;
- maintain aesthetic qualities of waters;
- maintain or improve water quality for activities such as boating and wading, where there is a low probability of water being swallowed;

- maintain or improve water quality for activities such as swimming in which there is a high probability of water being swallowed;
- protect water quality to maximise the production of healthy livestock;
- protect water quality for domestic use in homesteads, including drinking, cooking and bathing;
- maintain or improve the quality of drinking water drawn from the raw surface and groundwater sources before any treatment; and
- protect water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.

Table 5.2 lists how construction and operational management procedures will address each of these eight WQO.

Table 5.2 Upstream permanent stream crossings assessed against Water Quality Objectives

Water Quality Objective	Pipeline Construction/Operation Management Response
Maintain or improve the ecological condition of waterbodies and their riparian zones over the long term	River banks and beds will be reinstated to their pre-construction condition as much as possible. There will be no change in the soil/sediment profile that would cause a change in the ecological condition of these features. Once operational, there will be no impact on these features (unless a pipeline break occurs) as the pipeline will be buried. If the pipeline leaks and scouring occurs, then the section will be quickly identified and repaired and the soil/sediment profile reinstated to its natural condition.
Maintain aesthetic qualities of waters	There will be no discharges to watercourses during construction. Underboring is a low impact technique that does not affect the water quality in surrounding groundwater or overlying surface water. There will be no impact to stream water quality unless a break occurs in the pipeline. The section of the pipeline that is leaking will be quickly identified and losses minimised though isolation valves.
Maintain or improve water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Boating is not possible at these watercourse crossings and there are minimal recreational uses. Wading would be minimised during construction and there would be no impact on water quality. There will be no impact on any recreation use once the pipeline is operational.
Maintain or improve water quality for activities such as swimming in which there is a high probability of water being swallowed	Swimming and other recreational uses where the water could be ingested is not possible at these watercourse crossings. There will be no impact on any recreation use once the pipeline is operational.

Table 5.2 Upstream permanent stream crossings assessed against Water Quality Objectives

Water Quality Objective	Pipeline Construction/Operation Management Response
Protect water quality to maximise the production of healthy livestock	There will be no discharges to watercourses during construction. Underboring is a low impact technique that does not affect the water quality in surrounding groundwater or overlying surface water. There will be no impact to stream water quality unless a break occurs in the pipeline. The section of the pipeline that is leaking will be quickly identified via telemetry and losses minimised though isolation valves. Released water will be diluted or infiltrate, so stock water issues are unlikely.
Protect water quality for domestic use in homesteads, including drinking, cooking and bathing	There will be no discharges to watercourses during construction. Underboring is a low impact technique that does not affect the water quality in surrounding groundwater or overlying surface water. There will be no impact to stream water quality unless a break occurs in the pipeline. The section of the pipeline that is leaking will be quickly identified and losses minimised though isolation valves. Locals will be advised to not use any discharged water for domestic purposes.
Maintain or improve the quality of drinking water drawn from the raw surface and groundwater sources before any treatment	It is extremely unlikely that any water from these streams or regional groundwater at depth will be used as a raw drinking water source because of salinity, and bacterial and nutrient pollutants. In any event there will be no discharges to watercourses during construction. Underboring is a low impact technique that does not affect the water quality in surrounding groundwater or overlying surface water. There will be no impact to stream water quality unless a break occurs in the pipeline. The section of the pipeline that is leaking will be quickly identified via telemetry and losses minimised though isolation valves.
Protect water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.	There will be no discharges to watercourses during construction. Underboring is a low impact technique that does not affect the water quality in surrounding groundwater or overlying surface water. There will be no impact to stream water quality unless a break occurs in the pipeline. The section of the pipeline that is leaking will be quickly identified via telemetry and losses minimised though isolation valves.

5.3 Impact assessment

5.3.1 Surface water flow impacts

Surface water flow impacts during construction are expected to be negligible as pipeline trenching rate will vary to allow for trenching and backfilling of the open trench within the same day. Backfill will be compacted and site rehabilitation will be undertaken progressively following construction to minimise further disturbance. Work areas will be protected by silt fencing and bunding as appropriate. No laydown or storage areas will be located in gullies or floodways to avoid disturbing stormwater runoff after rain.

During operations the following features will be located above ground:

- scour, air and isolation valves;
- pumping station facilities; and
- pressure reducing system compound.

Valves will occupy a small footprint and will not impede surface flows.

The pumping station facility compounds will occupy up to 75 m by 75 m footprints, and the pressure reducing system compound will occupy approximately 20 m by 20 m footprints. These compounds will be located outside creek and river flood extents, and so will not interact with flood flows. Local stormwater drainage from these compounds will be designed in accordance with water sensitive urban design (WSUD) principles. In particular, the stormwater management systems will be designed to prevent erosion at the point of discharge from these sites.

5.3.2 Surface water quality impact pathways

Potential pathways through which surface water quality could be affected by the pipeline development include:

During construction / decommissioning

- mobilisation of soil into watercourse, leading to increased turbidity;
- unexpected release of contaminants/pollutants during construction activities (such as hydrocarbon spills from machinery and vehicles or drilling fluid from underboring activities); and
- creek bed erosion at watercourse crossing locations, leading to altered creek bed and bank profile.

During operations

- managed pipeline scour operations, potential to discharge saline water to watercourses; and
- unmanaged pipe leaks, leading to discharge of saline water to watercourses.

Each of these potential pathways will be monitored and managed through a series of measures designed to reduce the likelihood and where possible the magnitude of impacts.

5.3.3 Raw water quality characterisation

As outlined in Section 1.2, raw water will be sourced from Centennial Coal's Angus Place and SCSO and EA's MPPS near Lithgow.

The contribution of each water source will vary dependent on the operational requirements of SCSO and MPPS, and Centennial Coal's coal processing and mine dewatering requirements. The pipeline is designed to accommodate a nominal flow of approximately 13 ML/day (5 GL/year) up to a maximum of 15.6 ML/day.

The water quality of the three proposed water sources currently ranges from around 600 mg/L total dissolved solids (TDS) to 7,000 mg/L with a likely average of approximately 3,500 mg/L.

It is noted that the quality specifications for each water source will vary over time as a result of climatic conditions, operational circumstances at SCSO and the operational philosophy of the, yet to be commissioned, Reverse Osmosis (RO) water treatment plant at the MPPS. For reference, it is noted that the NSW Department of Primary Industries fact sheet Water Requirements for Sheep and Cattle (2014) identifies salinity suitable for stock drinking water (TDS mg/L) in the following ranges:

- sheep: 5,000 – 10,000, and up to 13,000 for limited periods; and
- beef cattle: 4,000 – 5,000, and up to 10,000 for limited periods.
-

Any spill of raw water from the pipeline will trigger monitoring and remedial action. Further details are provided in Section 5.4 and full details will be provided in the OEMP that will be prepared once the project is approved. Fault detection systems will be incorporated within the pipeline design. If a pipeline leak occurs, the fault detection systems will shut down the water transfer and isolate the leak via isolation or section valves.

5.3.4 Existing surface water quality characterisation

No water sampling has been undertaken to assess the current water quality in the permanent streams along the pipeline route. However, based on a desktop assessment of data sources and riverine water quality expectations (see Section 3.2), surface water salinities are expected to be fresh to brackish (i.e. less than 500 mg/L to around 1500 mg/L TDS).

5.3.5 Residual surface water quality impacts

No residual surface water quality impacts are expected as an outcome of the construction program. All trenches will be reinstated to grade and revegetated to avoid erosion. All creek/river crossings will be rehabilitated and revegetated as required.

Residual surface water quality impacts are expected to be limited to the scenario of uncontrolled release of raw water resulting from a pipeline leak during operations. In the event of a pipeline leak, the volume discharged into the local landscape would vary depending on the severity of the break and the time taken to isolate the leak via operation of isolation valves.

An estimate of the total volume which may be released in such an event is provided in Equation 5.1 (assuming different pipe diameters, 2 km between isolation valves and a 30-minute response time):

Equation 5-1 Pipe leak spill volume estimate

$$\begin{aligned} Volume &= Pipe\ volume\ between\ isolation\ valves + Volume\ pumped\ during\ response\ time \\ &= \pi \frac{D^2}{4} L + tQ \\ &= \pi\,(0.3\ m\ to\ 0.65\ m)^2 . 2000\ m + 30 \min . 13 \frac{ML}{day} \\ &= 0.4\ to\ 0.9\ ML \end{aligned}$$

Where:

- *D* is pipe internal diameter
- *L* is approximate distance between isolation valves
- *t* is time for isolation valves to be closed
- *Q* is the pipeline flow rate at the time of the burst

For a 300 mm diameter pipe, the maximum loss would be 0.4 ML, and for a 650 mm diameter pipe, the maximum loss would be 0.9 ML. These are very conservative (over-estimated) volumes as it is extremely unlikely that all the water between isolation valves would be lost to the environment.

Without baseline water quality data for the catchments along the alignment, it is not possible to quantitatively determine the magnitude of any impact to receiving waterways in the event of uncontrolled discharge from the pipeline.

A large pipe rupture with an uncontrolled release of all the water in a pipeline segment will cause localised erosion. Released water would likely flow over land and then potentially enter a farm dam or local creek. Groundwater impacts are unlikely given the depth to the regional water table (see Section 6.1.1). This leak would represent a pulse of water into the environment. Attenuation and dilution effects would occur if there was water in the farm dam or local creek. In a creek or river with flowing water, site and downstream water quality would be restored within hours or days.

If the leak was insufficient to flow over land to a receiving water body, then the released water would infiltrate the soil and weathered rock profile. The salinity of the raw water may impact pasture and crops depending on the salt tolerance of the planted species. If the spill was adjacent to native vegetation or forested areas then the impacts are likely to be less given their deeper rooting. Rainfall over time would dilute any salt accumulation in the soil profile.

5.4 Management and mitigation measures

The potential risk to surface water sources is considered low and periodic monitoring of water quality is proposed along the pipeline route at permanent stream locations.

Mobilisation of soil during construction will be managed through industry standard erosion and sediment control practices, and minimising the time that trenches are open. These controls could take the form of sediment traps, silt barriers, and bunding or covering of soil stockpiles. These controls and landscape rehabilitation measures on completion of trenching will reduce the likelihood and magnitude of erosion, scour and redeposition. Oil and fuel spillage, and migration of construction materials such as bedding material and concrete are also potential events that could impact water quality.

During construction, the following measures will be implemented to manage the potential impacts to surface water:

- refuelling of plant and equipment will be constrained to designated/bunded areas or will be off site;
- chemicals and construction materials will be stored appropriately in designated/bunded areas;
- waste management plans will be developed and implemented for the control and storage of waste at work sites; and
- operations at work sites will be reviewed and audited to ensure management measures are being implemented accordingly.

During operation, isolation or section valves will isolate the pipeline into discrete sections and allow individual sections to be dewatered for maintenance, or to provide security in an event such as a pipeline leak. Isolation valves will also be installed on either side of major watercourse crossings.

During commissioning, the pipeline would be pressure tested and monitored for any leaks. To minimise the risk of uncontrolled discharge to the environment only the highest quality of water would be used for pressure testing. Emptying of the pipeline would occur at scour valves located at intermediate low points along the alignment and water would be removed via tanker trucks and taken back to either Centennial’s operations at Lithgow or Regis’ mine operations at Blayney.

During pipeline maintenance, raw water removed from the pipeline via scour valves will not be discharged to rivers or creeks. It is anticipated that raw water held in the pipeline sections that require maintenance would be removed via tanker trucks and taken back to either Centennial’s operations at Lithgow or the mine development at Blayney. All measures will be detailed in a Pipeline Water Management Plan.

The likelihood of a pipeline leak will be reduced through detailed modelling of pipeline pressures during detailed design, together with quality assurance and checking during and post construction. Periodic inspections and leak detection monitoring will be part of the ongoing operation and maintenance procedures.

A surface water quality impact to the environment is only expected to occur if there was a pipeline leak. With leak detection measures, such events considered to be rare and the risk is assessed to be low.

6 Groundwater assessment

6.1 Impact assessment

6.1.1 Overview

The Australian National Water Commission (NWC) framework (Moran et al 2010) defines the following four direct groundwater effects arising from mining related activities:

1. Altered **groundwater quantity** (groundwater levels, pressures and fluxes). <u>It has been determined that the pipeline development is unlikely to result in altered groundwater levels, pressures or fluxes.</u>

2. Altered **groundwater quality** (concentration of salts and other important water quality constituents). There is the potential for the pipeline development to alter groundwater quality during construction and operational phases. <u>It has been determined that the pipeline development is unlikely to result in altered groundwater quality.</u>

3. Altered **surface water – groundwater interaction.** Due to the distance to the pipeline and depth to the regional water table, the identified high priority GDE (The Springs) will not be affected by shallow trenching into the weathered rock. <u>It has been determined that the pipeline development is unlikely to result in altered surface water-groundwater interaction.</u>

4. **Physical disruption of aquifers** (excavation of mine pits and underground works). Due to the proposed construction methodologies and proposed management measures (discussed below), the pipeline development has limited potential to physically disrupt aquifers as it rarely intercepts them. Most of the trenching is above the regional aquifers and there is a small potential that some perched groundwater systems and shallow groundwater systems may be intercepted in proximity to rivers. <u>It has been determined that the pipeline development is unlikely to result in physical disruption of aquifers.</u>

The potential pathways through which groundwater could be affected by the pipeline development are discussed below under construction and operations.

6.1.2 During construction

During trenching activities, regional groundwater is not expected to be intercepted along the majority of the pipeline route. Should some isolated perched groundwater be intercepted during trenching, this water will appear as a slow seepage into the base of the open trench and will not be removed. Careful laying of the pipeline and associated backfilling of the trench (avoiding any trench collapse) will not relocate or impact the shallow perched groundwater or deeper regional groundwater systems.

Underboring is proposed at Macquarie River, and Queen Charlottes Creek (Vale Creek). The pipeline will be constructed below the alluvium to protect groundwater baseflows and water quality.

During pipeline construction the following potential impacts to groundwater have been identified:

- Underboring below major rivers and creeks has the potential to intercept shallow groundwater. The impacts are expected to be minimal due to the small footprint and the temporary nature of the works. No water take will occur and impacts of the pipeline will be negligible as the pipeline is unlikely to impede groundwater flow. The individual crossings with alluvial sediments will be comprehensively assessed during detailed design.

- Proposed open trenching to a depth of up to 1.5–2 m will be above the regional water table in both the porous rock and fractured rock aquifer areas. Trenching may however intercept shallow perched water at low lying sites. No groundwater dewatering is anticipated, as intercepted water will be managed in-situ; it will not be moved, pumped or removed from the trench. The pipeline is unlikely to impede the flow of perched groundwater at the few locations where it is encountered along the pipeline route.

- The unexpected release of contaminants/pollutants during construction activities (such as hydrocarbon spills from machinery and vehicles) has the potential to impact on the groundwater resources if not quickly contained and recovered.

  The extent and degree of groundwater contamination is largely dependent on geology (including the permeability), depth to groundwater, the properties, volume and characteristics of the pollutant and the speed and effectiveness of the clean-up. Pollutants such as insoluble hydrocarbons would be preferentially retained in the soil profile and unlikely to contaminate groundwater. Soluble pollutants such as nitrates (fertilisers), salts and soluble hydrocarbons can infiltrate soils and potentially contaminate groundwater.

6.1.3 During pipeline operation

During operation of the pipeline, groundwater related impacts are expected to be limited to the uncontrolled release of water during a pipe leak event. In the event of a pipeline leak, the volume discharged would vary depending on the nature of the leak and the timeframe until detection. An estimate of the volume which may be released in such an event is provided in Section 5.3.5.

Most of the released water would likely flow over land before entering a gully, creek or farm dam as a pulse of slightly saline water. A relatively small portion of released water may infiltrate the shallow soil profile however it is unlikely to reach the regional water table if quickly contained. There is a slightly increased risk to groundwater in the underbored creek/river crossing locations in situations where the pipeline is located within the shallow alluvial groundwater system.

6.2 Management and mitigation measures

The potential risk to regional groundwater sources from the pipeline development is considered negligible and no groundwater monitoring is proposed along the pipeline route.

During construction, the following measures will be implemented to manage the potential impacts to groundwater:

- refuelling of plant and equipment will be constrained to designated/bunded areas or will be off site;

- chemicals and construction materials will be stored appropriately in designated/bunded areas;

- waste management plans will be developed and implemented for the control and storage of waste at work sites; and

- operations at work sites will be reviewed and audited to ensure management measures are being implemented accordingly.

During operation, isolation or section valves will isolate the pipeline into discrete sections and allow individual sections to be dewatered for maintenance, or to provide security in an event such as a pipeline leak. Isolation valves will also typically be installed on either side of major watercourse crossings.

During pipeline maintenance, raw water removed from the pipeline via scour valves will not be discharged to rivers or creeks It is anticipated that raw water held in the pipeline sections that require maintenance would be removed via tanker trucks and taken back to either Centennial's operations at Lithgow or the mine development at Blayney. All measures will be detailed in a Pipeline Water Management Plan.

The likelihood of a pipeline leak will be reduced through engagement of competent pipeline engineering design and construction firms. Monitoring of pipeline flows and operation of isolation valves will reduce the magnitude of water released to the environment in the event of a pipeline leak. The risk of raw water migrating to the regional water table is considered negligible. There is a slightly increased (but still low) risk to groundwater in the underbored creek/river crossing locations where the pipeline is located within the shallow alluvial groundwater system.

7 Flooding assessment

7.1 Overview

This chapter describes an assessment of the potential impacts of floodwaters on the pipeline, and the potential impact of the pipeline on floodwaters. As pipeline infrastructure will be located below ground and impacts are anticipated to be negligible or low, hydrology and flood modelling studies were not undertaken, and the flood risk assessment was undertaken via a desktop review of published flood studies.

7.1.1 Surface water flooding impact pathways

Potential pathways through which flooding could affect or be affected by the pipeline development include:

During construction / decommissioning

- flooding of work sites, leading to risk to plant and personnel

During operations

- inundation of above ground assets, leading to possible failure of pipeline control system and shutdown of pumping station facilities, leading to discharge of raw water to the environment

Flooding has the potential to result in scouring and changes to the bed and banks of watercourses, which is discussed in Section 4.

7.1.2 Above ground assets

As the pipeline will be installed below ground, above ground pipeline assets will be limited to:

- pump station facilities; and
- valves (air valves, scour valves, isolation valves and pressure reducing valves).

Each of these assets with the exception of some scour and isolation valves, will be located outside of the 1 in 100-year flood extent, as defined by available data (discussed further below).

7.2 Historical flood studies

The *Australian Flood Risk Information Portal* hosted by Geoscience Australia[1] lists 10 flood studies completed in the vicinity of the pipeline corridor, as detailed in Table 7.1. The most recent of the published studies was completed 19 years ago. Between the time that these studies were completed and April 2019 the field of hydrology in Australia has advanced considerably with larger historical rainfall data sets, increased computing power and modelling packages, and updated flood assessment guidelines. In some locations land use and rainfall runoff relationships will have changed since the completion of the historical flood studies. Due to these factors, flood levels and extents in the vicinity of the pipeline route may vary from the published data, and flooding in locations pertinent to the project may be omitted from the published studies due to the limits of scope addressed at the time.

[1] https://www.ga.gov.au/earch?from=0&query=flood&index=geoscience_site_crawl

Of the historical flood studies publicly available, the Bathurst Floodplain Management Plan (1993) contains a 1 in 100 year flood extent map for the Bathurst region, which is presented together with the pipeline corridor in Figure 7.1. The other studies do not include inundation extents.

Figure 7.1 shows the 1 in 100-year flood extent intersects two sections of the pipeline, south of Bathurst. One of the flood extent areas is around the intersection of Queen Charlottes Creek Vale Road and the other centres around the Macquarie River. Pipeline construction through these areas will be mainly be using underboring techniques.

Table 7.1 Flood studies completed in the vicinity of the pipeline

Year	Name	Author
1984	Urban Area Assessment - Bathurst, Macquarie Valley Floodplain Management Study	Sinclair Knight and Partners
1984	Regional Assessment Upstream of Burrendong Dam, Macquarie River Floodplain Management Study	Sinclair Knight and Partners
1984	Macquarie Valley Floodplain Management Study	Sinclair Knight and Partners
1987	Bathurst Flood Study Report	Public Works
1988	Bathurst Floodplain Management Study	Kinhill Engineers
1992	Lithgow Floodplain Management Study	Kinhill Engineers
1993	Computer Based Floodplain Model	Willing and Partners
1993	Bathurst Floodplain Management Plan	Willing and Partners
1994	Perthville Floodplain Management Study	Willing and Partners
2000	Flood Investigation and Model Review	Willing and Partners

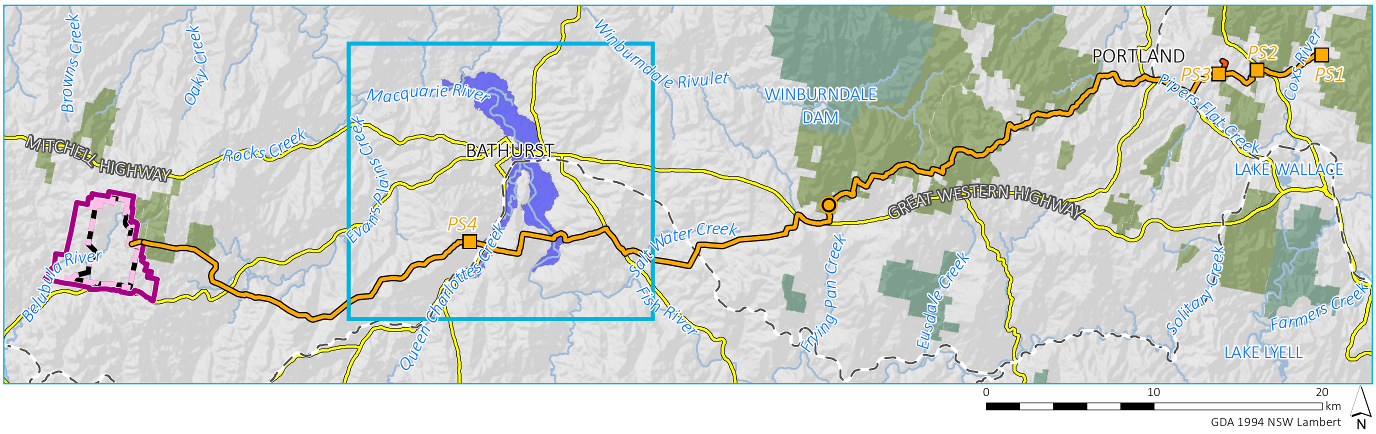
7.3 Surface water flooding management measures

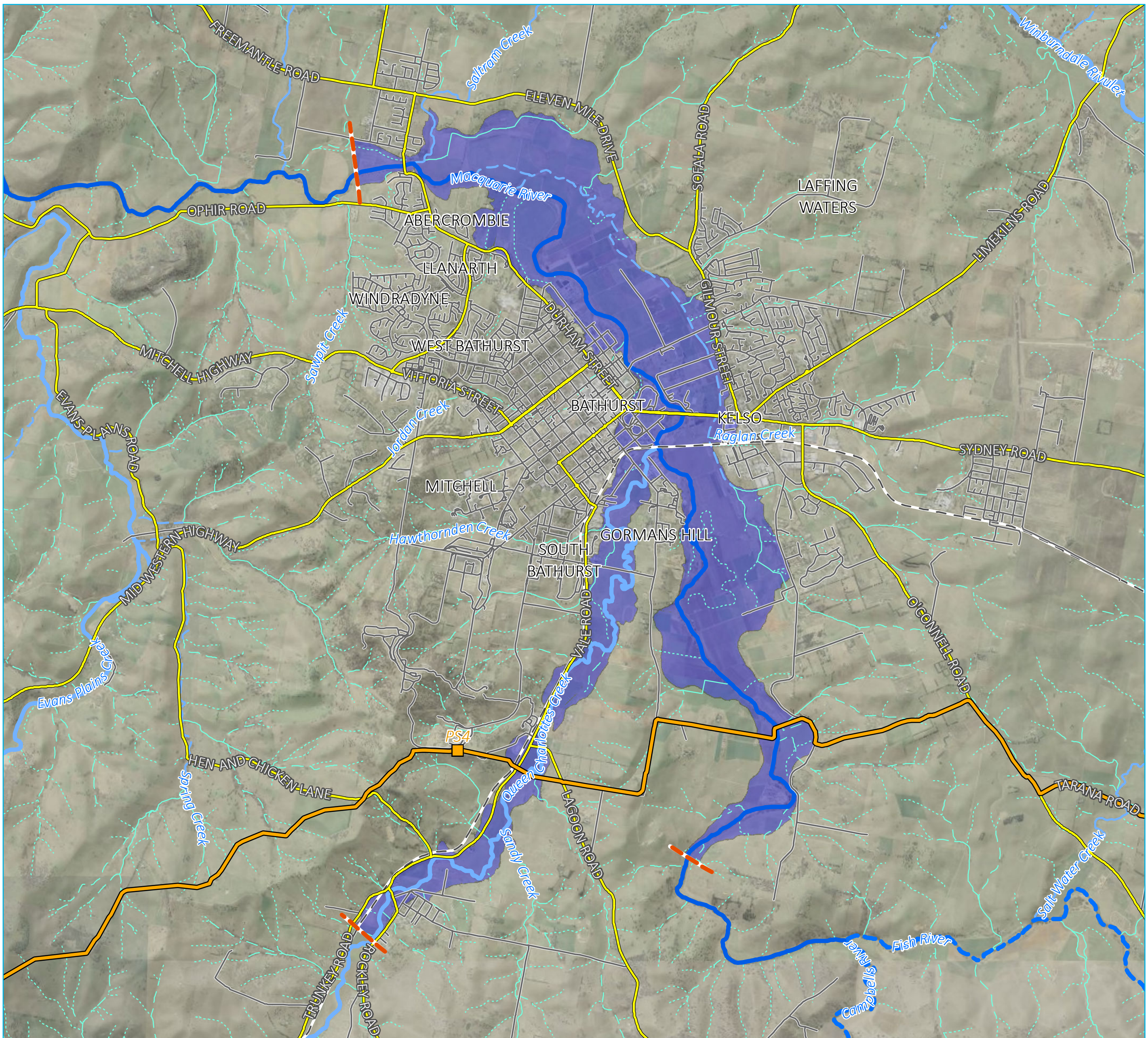
The risk of above ground assets being affected by or affecting flooding is low. Flooding concerns will be mitigated during detailed design by ensuring that critical assets are located outside the 1 in 100-year flood extent.

The risk of flooding affecting work sites during construction is limited to locations adjacent to or within creeks, and on riverine floodplains. Laydown areas and equipment compounds will be located away from flood prone areas. This risk will be managed by monitoring weather conditions, weather forecasts, and river levels. When flood risk is notified, active work sites will be secured and personnel moved off site.

7.4 Residual surface water flooding impacts

Residual surface water flooding impacts are expected to be negligible.





Source: EMM (2019); Regis Resources (2019); DFSI (2017); DPE (2015); GA (2011)

0 1 2 km
GDA 1994 MGA Zone 55

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KEY

Limit of inundation extent data

1 in 100 year Macquarie River flooding extent

Existing environment

- Rail line
- Main road
- Local road
- NPWS reserve
- State forest

Project application area

- Mine development project area
- Mining lease application area (1,812.99 ha) (Note: boundary offset for clarity)
- Pressure reducing system
- Pumping station facility
- Pipeline corridor
- Pipeline corridor (Blowdown Pond)

Strahler stream order

- 1st order
- 2nd order
- 3rd order
- 4th order
- 5th order
- 6th order
- 7th order
- 8th order

1 in 100 year Macquarie River flooding extents (including pipeline infrastructure)

McPhillamys Gold Project
Pipeline water assessment
Figure 7.1

EMM
creating opportunities

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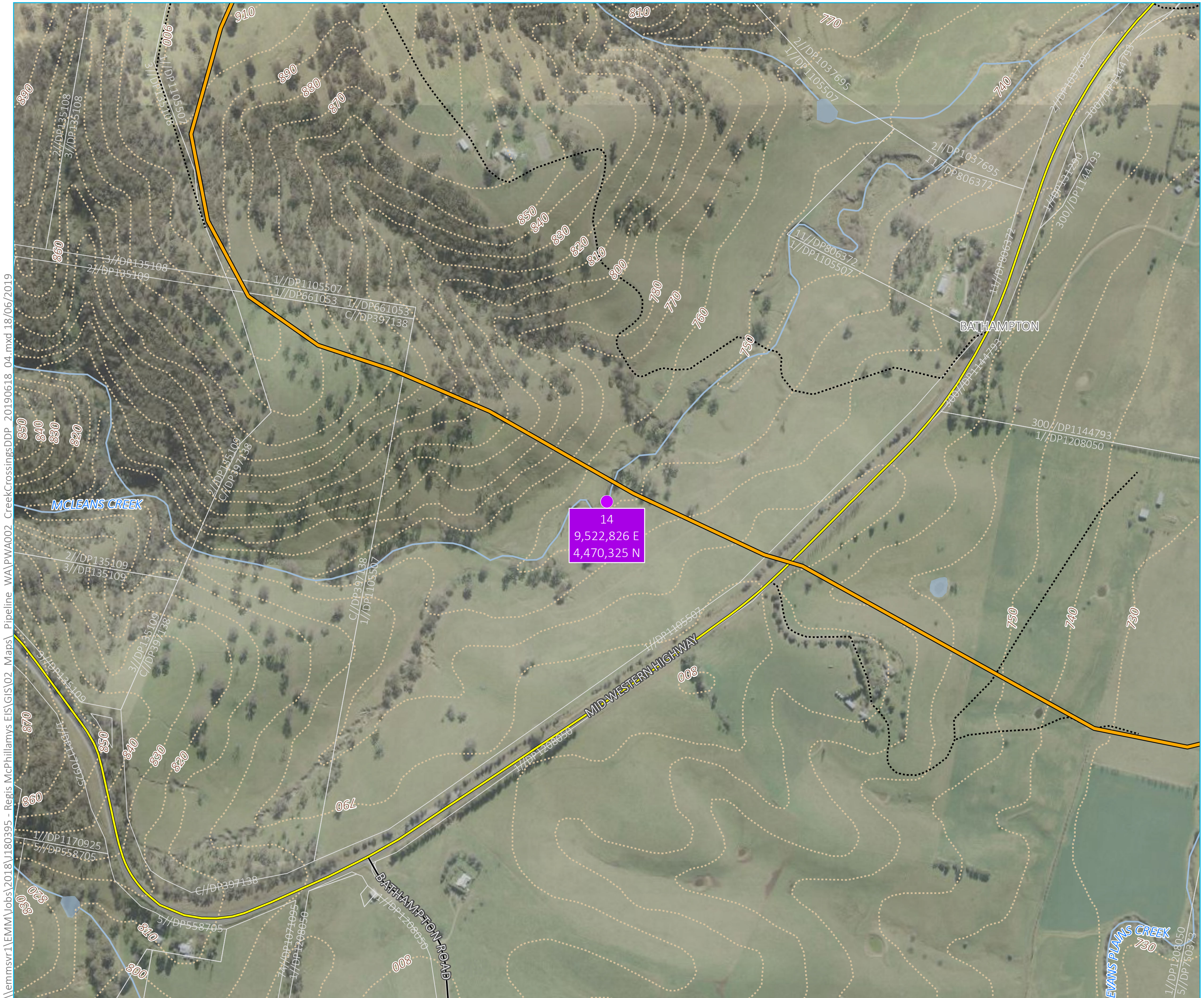
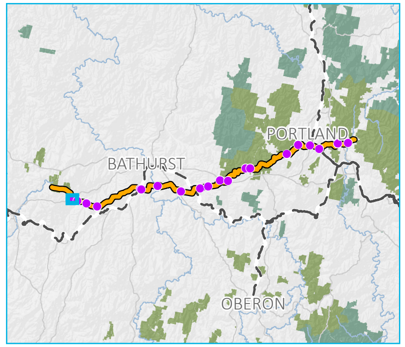
Appendix A

Survey Creek Crossing Locations





Source: EMM (2019); REGIS (2019); DFSI (2017); DPE (2013); GA (2011)

0 250 500 m

GDA 1994 NSW Lambert

N

KEY

- Pipeline creek crossing (coordinates in GDA 1994 NSW Lambert)
- Pipeline corridor
- Main road
- Local road
- Vehicular track
- Watercourse/drainage line
- Contour (10 m)
- Cadastral boundary
- Waterbody
- NPWS reserve
- State forest

Pipeline creek crossing investigations

McPhillamys Gold Project - Pipeline
Pipeline water assessment
Map 1 of 20

EMM creating opportunities

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Appendix B

Geomorphology Assessment




McPhillamys Gold Project

Environmental Impact Statement

Fluvial Geomorphology

Dr Christopher J Gippel

Final

March 2019

Regis Resources Ltd

FLUVIAL SYSTEMS

McPhillamys Gold Project

Environmental Impact Statement

Fluvial Geomorphology

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March 2019

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			Name/Position	Signature
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Executive Summary

Regis Resources Ltd is seeking State significant development consent under Division 4.1 of Part 4 of the EP&A Act to develop and operate an open cut gold mine, associated mine infrastructure and a water supply pipeline (the Project). The vast majority of the water supply for the Project would be sourced from the Springvale area near Lithgow via a buried pipeline constructed by Regis. The pipeline, traversing an approximately 90 km long corridor between 5 and 20 metres wide (Pipeline Corridor), would be 300 – 650 mm diameter.

This report contributes the fluvial geomorphology component of the Environmental Impact Statement (EIS) prepared in accordance with the Department of Planning and Environment (DPE)'s Environmental Assessment Requirements (EARs), including requirements from other government agencies. The scope of this report is limited to assessment of fluvial geomorphologic aspects of watercourses and their corridors, which includes bed, banks and floodplains, where present, at their intersections with the Project pipeline route. The existing environment was assessed using a two-stage approach. A desktop assessment of all watercourse/pipeline intersections was undertaken to classify the watercourses as minor or major. Pipeline crossings of minor watercourses were expected to present a low, predictable risk of impact to geomorphic processes.

The assessment focused on geomorphic characteristics of the watercourses in the vicinity of the Project pipeline intersections that were relevant to the main risks associated with the pipeline during its operational phase:

- Geomorphic change will lead to exposure of the pipeline to fluvial forces, thereby putting the integrity of the pipeline at risk, and
- The presence of the pipeline (usually in combination with being exposed through geomorphic change) will interfere with natural geomorphic processes.

The Project pipeline intersected 131 hydrolines Given the inadequacies of the hydroline ('blue line') network, a revised drainage network was automatically generated in the catchments of watercourses intersecting the pipeline route using GIS (Geographic Information System). Reassessment of the watercourse/pipeline intersections using automatically DEM-generated drainage lines resulted in 112 intersections. Watercourses intersecting the Project pipeline route were classified into three groups on the basis of Stream Order and catchment area.

- Minor and small-size watercourses: Stream Orders 1 and 2, or catchment area (A) $A < 1.33\ km^2$
- Medium-size watercourses: Stream Order 3 or higher and catchment area (A) $1.33\ km^2 \leq A < 5\ km^2$
- Large-size watercourses: Stream Order 3 or higher and catchment area (A) $A \geq 5\ km^2$

Minor and small-size watercourses were likely to be resilient headwater streams, and were low priority for field inspection. Medium- and large-size watercourses were medium and high priority, respectively, for field inspection. This prioritization was intended mainly to assist planning the field inspection, with more time allocated to inspection of large-size watercourses.

The field assessment included:

- Photograph the site in the downstream and upstream directions
- Estimate structure and cover of riparian vegetation
- Estimate bed sediment material calibre
- Estimate the depth of sand in the bed of sand-bed streams

Twenty watercourse crossing sites were inspected in the field.

The key findings of the study were:

1. Only one site showed evidence of a knickpoint with potential to migrate upstream to the pipeline intersection. Downstream of intersection 68, the channel was incised, with three knickpoints of 0.8 – 1.5 m depth present within 1000 m downstream of the intersection.
2. Four sites had sand bed that could be probed. If trenching is to be employed at these sites, the base of the sand bed should be regarded as the top of the trench. The depth of sand should be comprehensively surveyed as part of the geotechnical assessment.
3. Site 25 had extensive bedrock outcrops present, with some of these acting as hydraulic controls for pools. If trenching is to be employed, care will be required to avoid disturbing these hydraulic control points. Site 115 was close to the hydraulic control of a 200 m long pool. If trenching is to be employed, care will be required to avoid disturbing the hydraulic control point.
4. There was little evidence of recent bank or bed erosion at any site. Most sites had at least moderate combined vegetation cover, even if the tree cover was poor at most sites.
5. Provided the pipeline is buried a sufficient distance from the consolidated bed and banks of the watercourses, the backfill is composed of the same material that was excavated (in layers, as appropriate), and the backfill is compacted, trenched crossings present a low risk of geomorphic impact during the operational phase.
6. Pipeline crossings constructed using directional drilling present a negligible risk of geomorphic impact during the operational phase.
7. Potential geomorphic impacts during the construction phase would primarily relate to occurrence of a significant storm runoff event flood when a trench is exposed, and/or ground surrounding the site is disturbed from the action of machinery.
8. Monitoring of geomorphic aspects of the pipeline watercourse crossings should focus on significant storm runoff events, as impacts are only likely under conditions of heavy rainfall and fast flowing deep water in the channel. An inspection should be undertaken as soon as possible following a 1 in 5 yr ARI regional storm event, otherwise an annual visual inspection of the priority sites determined by this study will detect any significant geomorphic change.

1 Introduction

1.1 Project background

Regis Resources Ltd (Regis) is seeking State significant development consent under Division 4.1 of Part 4 of the EP&A Act to develop and operate an open cut gold mine, associated mine infrastructure and a water supply pipeline (the Project). The mine development component of the Project is located approximately 8 kilometres from the town of Blayney.

The vast majority of the water supply for the Project would be sourced from the Springvale area near Lithgow via a buried pipeline constructed by Regis (the Pipeline Development). The Pipeline Development consists of a pipeline and ancillary infrastructure to transfer water from Centennial's Angus Place Colliery & Springvale Coal Services Operations and Energy Australia's Mt Piper Power Station operations near Lithgow to the Project Mine Site near Blayney during the operational phase of the project (**Figure 1**). The pipeline, traversing an approximately 90 km long corridor between 5 and 20 metres wide (Pipeline Corridor), would be 300 – 650 mm diameter, designed to accommodate a nominal flow of approximately 13 ML/day up to a maximum of 16 ML/day.

A range of heavy plant including excavators and trenchers would be required to access the Project Pipeline Corridor to enable construction. It is anticipated that the majority of the pipeline development will be installed by trenching to a total depth of 1500 - 2000 mm, with a minimum cover of 300 mm for pipe sections not subject road traffic to up to 750 mm under an unsealed road. This allows for the placement of embedment material under the pipe. Crossings of the Macquarie River, Evans Creek, Saltwater Creek and Queen Charlottes Creek (Vale Creek) are anticipated to require under-boring to install the pipeline.

A Preliminary Environmental Assessment for the McPhillamys Gold Project Pipeline Development (Pipeline PEA) was completed by Blakelys Environmental (2018). At that time, investigations were continuing to determine the specific pipeline route. The pipeline route assumed in this report was current at 22 January 2019. Minor alterations to the pipeline route made since that time do not impact the conclusions and recommendations made in this report.

This report contributes the fluvial geomorphology component of the Environmental Impact Statement (EIS) prepared in accordance with the EARs from the Department of Planning and Environment NSW (DPE), including requirements from other government agencies.

1.2 Environmental Assessment Requirements (EARs) and Agency requirements

The Department of Planning and Environment (DPE)'s Environmental Assessment Requirements (EARs) require that the EIS assess the likely impacts of the development on the environment, including a description of the existing environment likely to be affected, using sufficient baseline data; assessment of the potential impacts, including cumulative impacts, taking into consideration relevant laws, environmental planning instruments, guidelines, policies, plans and industry codes of practice; a description of the measures that would be implemented to avoid, mitigate or offset the impacts of the development; and a description of the measures that would be implemented to monitor and report on the environmental performance of the development.

The EARs did not itemise specific fluvial geomorphic matters for assessment. However, these matters are understood here to fall within the scope of the sub-heading "Water":

> "*- and assessment of the likely impacts of the development on aquifers, **watercourses**, riparian land, water-related infrastructure, and systems and other water users*…" (my emphasis)

Separate requirements for the EIS were provided by various relevant agencies, some of which directly or indirectly included fluvial geomorphic issues:

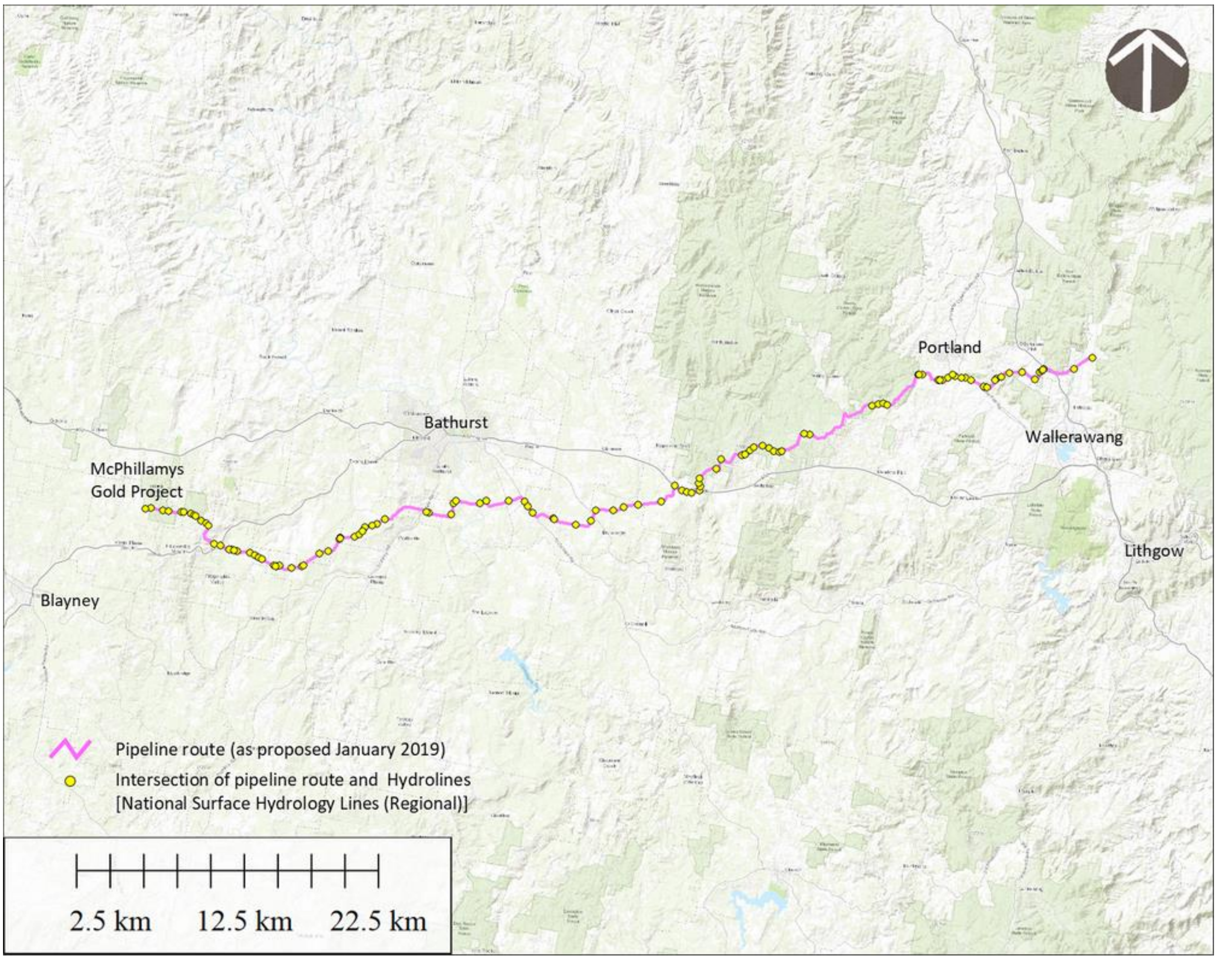

Figure 1. Route of the Project Pipeline Development, showing points of intersection with DEM-generated watercourses that emulated hydrolines ('blue lines').

Carbonne Council:

Assess "…*Environmental characteristics of the site (land ownership, meteorology, topography,* ***drainage****, geology, water resources*…" (my emphasis)

NSW Department of Industry (DoI Water):

"…*Assessment of impacts on surface water and groundwater sources (both quantity and quality), related infrastructure, adjacent licenced water users, basic landholder rights,* ***watercourses****, riparian land, and groundwater dependent ecosystems, and measures proposed to reduce and mitigate these impacts*…" (my emphasis)

NSW Planning & Environment, Resources & Geosciences:

No items were included that are relevant to fluvial geomorphology

NSW EPA:

Under "Water" "*5. Describe any* ***drainage lines****,* ***creek lines*** *etc that will be impacted by the project*"; under "Impact Assessment" "*10. Whether the project will significantly adversely affect the environment or cause avoidable* ***erosion****,* ***siltation****, destruction of riparian vegetation, or a reduction in the* ***stability of river banks or watercourses***", "*11. Identify potential impacts on* ***watercourses*** *and the* *management/mitigation measures that will be implemented where mining activities occur in proximity to or within a* ***watercourse***" (my emphasis)

Lithgow City Council:

No items were included that are relevant to fluvial geomorphology

NSW Government, Heritage Council of NSW:

No items were included that are relevant to fluvial geomorphology

NSW Government, Office of Environment & Heritage:

Under "Water and soils" "*8. 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 Soils Planning Map). b.* ***Rivers, streams,***[1] *wetlands and estuaries (as described in s4.1 of the Biodiversity Assessment Method (Pipeline) and s4.1 of the Framework for Biodiversity Assessment (Mine Site)…*" (my emphasis)

NSW Government, Roads and Maritime Services:

No items were included that are relevant to fluvial geomorphology

1.3 Definitions of 'watercourse' and 'river'

The principal legislation regulating a State Significant Development is Section 4.12(8) of the Environmental Planning and Assessment Act 1979 (EP&A Act). The Environmental Planning and Assessment Regulation 2000 (EP&A Regulation) (NSW Government, 2016a) contains details for the various processes set out under the EP&A Act.

In the EP&A Regulation – Schedule 3, Part 4 - What do terms used in this Schedule mean? Under item 38 Definitions 'waterbody' is defined as:

"(a) a natural waterbody, including:

(i) a lake or lagoon either naturally formed or artificially modified, or

(ii) a river or stream, whether perennial or intermittent, flowing in a natural channel with an established bed or in a natural channel artificially modifying the course of the stream, or

(iii) tidal waters including any bay, estuary or inlet, or

(b) an artificial waterbody, including any constructed waterway, canal, inlet, bay, channel, dam, pond or lake, but does not include a dry detention basin or other stormwater management construction that is only intended to hold water intermittently."

In this report, 'natural' is interpreted to mean that the work to form the channel was done by flowing water, with the water source being essentially unimpaired by direct human activity at the time the watercourse was formed (i.e. no diversions, dams or other significant works that alter that part of the flow regime which has sufficient power to mobilise the materials within which the watercourse is formed); and the sediment, soil or rock material transported to and by the waterbody, as well as through which it flows, experiencing essentially no direct interference from human activity at the time the watercourse was formed (i.e. no earthworks, sediment extraction or sediment dumping).

EP&A Regulation did not provide a definition of the terms 'perennial' and 'intermittent'. The binary stream hydrological classification 'perennial and intermittent' is equivalent to 'permanent and temporary', and the hydrological class 'ephemeral' is a sub-type of the primary intermittent class. Furthermore, the intermittent

[1] This requirement of the Biodiversity Assessment Method specifies mapping of rivers and streams according to the Strahler Stream Ordering system.

class can be subdivided into several sub-types, not just 'ephemeral', depending on degree of intermittency (Gordon et al., 2004). Following from that, this report assumes that EP&A Regulation, in defining a natural waterbody as "*a river or stream, whether perennial or intermittent…*", does not exclude any river or stream on the basis of its flow regime.

For the purpose of application of the EP&A Regulation, the requirement for an 'established bed' is a necessary condition of identifying a natural waterbody, not an alternative to the hydrological condition of 'perennial or intermittent'. The term 'established bed' appears rarely in academic literature, and when it has appeared, a definition was not supplied. An example is Taylor and Stokes (2005) who quoted the EP&A Regulation but did not elaborate in a direct way on the specific meaning of 'established bed'. The meaning of "established bed" has been the subject of debate in the courts, but no simple resolution has emerged. Dictionaries consistently suggest that 'established' in the context of a stream bed means that it has 'existed for a long time' (assuming a historical time scale ~10^0 – 10^2 years, not geological time). While such a stream bed could at the most simplistic level be considered stable, it is well accepted by geomorphologists that stream bed morphology can be highly variable over time, even if in the long-term it has a stable average condition. If a stream has a bed, then it logically follows that it also has 'banks', which together form a 'channel'. These terms lack standard definitions within the water resources industry. Merriam-Webster dictionary defines 'streambed' as "*the channel occupied or formerly occupied by a stream*", where a 'stream' is "*a body of running water (such as a river or creek)*". Collins dictionary defines 'streambed' as "*the channel in which a stream flows or formerly flowed*" (American) and "*the bottom of a stream*" (British). These typical dictionary definitions are based on hydraulics, suggesting that a streambed occurs in association with confined flow, as opposed to unconfined flow that is not within banks, which is referred to as sheetflow.

The above brief review suggests that, regardless of flow regime, and regardless of the materials forming the channel or its shape, the EP&A Regulation does not exclude any linear landform feature that conveys confined flow from being a 'waterbody'.

The focus of the Water Management Act 2000 (WM Act) (NSW Government, 2016b) is to provide for the sustainable and integrated management of the water sources. In the Dictionary of the WM Act, "river" is defined as:

> "*(a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved, and*
>
> *(b) any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows, and*
>
> *(c) anything declared by the regulations to be a river,*
>
> *whether or not it also forms part of a lake or estuary, but does not include anything declared by the regulations not to be a river*."

In administering the WM Act, it is common practice to accept the existence of a watercourse if it is represented by a blue line on a topographic map published by Land & Property Information, NSW Government. The density of blue lines on maps that designate watercourses varies with map scale. The largest scale maps available for an area, generally 1: 25,000, have more blue lines marked than smaller scale maps, such as 1:50,000 and 1:100,000. This conventional practice was recognised by Taylor and Stokes (2005), who wrote that: "*Disputes regarding the determination of a watercourse are often dealt with by the Department of Infrastructure, Planning and Natural Resources (DIPNR)* [now the responsibility of NSW Department of Industry (DoI Water)]*, which currently uses two informal methods to determine whether a watercourse is a bona fide river or stream sensu the RFIA. If a blue line (indicating a watercourse) is present on a 1:25 000 topographic mapsheet and/or if the catchment has a minimum area of 20 ha then DIPNR expects a natural channel to be present*."

The practice of using 1:25,000 topographic mapsheets to identify watercourses under the WM Act is not specified in the Act itself, but is specified in associated documents. For example, in the document NSW Office of Water (2010) "*Application for approval for water supply works and/or water use, Application for Minister's consent under section 92 of the Water Management Act 2000*", the official definition of "river" under the WM Act is given, followed by the statement "*For the practical purposes of this application, NOW* [NSW Office of Water] *defines 'river' as any blue line on the largest topographical map of that area (ie. at least 1:25,000)*". In another example, the document "*Controlled activities on waterfront land, Guidelines for riparian corridors on waterfront land*" (NSW Office of Water, 2012a) described a system of setting the width of vegetated riparian zones (VRZs) "…*based on watercourse order as classified under the Strahler System of ordering watercourses and using current 1:25 000 topographic maps*". Since the time when Taylor and Stokes (2005) wrote that the practice of identifying rivers using mapped blue lines was an informal method used by the responsible agency, it is has been established as a formal method used in application of the WM Act "…*to assess the impact of any proposed controlled activity to ensure that no more than minimal harm will be done to waterfront land as a consequence of carrying out the controlled activity*" (NSW Office of Water, 2012a).

Under an Order of the Water Act 1912 signed 16 March 2006, a 'river' is defined as is a Third Order or higher stream indicated by a blue line on a 1:25,000 Department of Lands topographic map, or a mapped First or Second Order stream that "…*maintains a permanent flow of water (being a visible flow which occurs on a continuous basis, or which would so occur if there were no artificial abstractions of water or obstruction of flows upstream)*" (State of New South Wales, 2006, p. 1500), which covers the definitions of Schedule 2 and 3 streams of DIPNR (2005). "Minor watercourses" have been defined as "*first-order or second-order watercourses that do not permanently flow*" (NSW Office of Water, 2014), which is the same definition as that of Schedule 1 streams of DIPNR (2005). NSW Department of Planning (2008, p. 112) suggested identifying stream risk management zones on streams Third Order and higher.

The above classifications are generally adopted in mining development impact assessments in NSW to define the watercourses of main interest. This explains the usual assumption in such assessments that streams of Third Order and higher have greater importance than First and Second Order streams. The basis of the assumption is that permanence of water flow is more significant than ephemeral or intermittent flow, and Third Order streams will generally flow more often than First and Second Order streams. Importance could relate to some aspect/s of ecosystem values, aesthetic values, or reliability of water supply for consumptive use, or in the case of DIPNR (2005), the more dynamic and complex geomorphic character of Third and higher Order streams.

In this report, for the purpose of assessing potential geomorphic impact of the Pipeline Development, the convention was adopted that streams marked by blue lines on 1:25,000 topographic maps as Third Order and higher have greater importance than First and Second Order streams. This convention was adopted as a simple way to separate smaller from larger streams. Smaller First and Second Order streams are likely to be found in headwaters, be relatively resilient to human disturbance (Cook and Schneider, 2006; Brierley et al., 2011), have intermittent flow, and often lack regular alluvial bedforms and floodplains. Streams of Third Order and higher are usually larger, are more likely to have permanent flow or pools (with potential for providing refugia during droughts), and could possess regular bedforms formed in unconsolidated sand, gravel or cobble (that might have particular habitat significance), and continuous or discontinuous floodplains (that might have an important ecosystem function). This classification was adopted mainly for practical reasons. It is acknowledged that its link to geomorphic or hydrologic theory is tenuous, and is not part of the core definition of 'river' under the WM Act.

1.4 Scope of this report

The scope of this report is limited to assessment of fluvial geomorphologic aspects of watercourses and their corridors, which includes bed, banks and floodplains, where present, at their intersections with the Project pipeline route. Thus, the Study Area for this geomorphic investigation is discontinuous, and excludes valley slopes between pipeline/watercourse intersections, even though these slopes might drain towards the intersected watercourses. Assessment of the impact of the Pipeline Development on valley slopes and other land that is not within the watercourse corridor falls within the scope of other expert reports, principally soils.

In this report, watercourses to be assessed were defined by blue lines on 1:25,000 topographic maps, or their digital equivalent, termed hydrolines. Hydrolines do not include every drainage path that conveys confined water flow through a landscape. Thus, the pipeline route would intersect a number of small drainage lines not marked by hydrolines, and therefore not specifically considered here. These crossings can be managed during construction and operation phases according to the recommendations made for the smaller streams that were included in the assessment. Also, hydrolines are a simplified representation of the alignment of drainage paths, particularly for small streams, and some of them might be incorrect due to alterations of landforms and drainage since the date of mapping. Thus, hydrolines guided identification of watercourses for inclusion in the geomorphic assessment, but the detailed location of the watercourse/pipeline intersection points were determined independently of hydrolines.

The scope of the assessment included description of the existing environment, assessment of potential impacts, and recommendations for mitigation and monitoring. The existing environment was assessed using a two-stage approach. A desktop assessment of all watercourse/pipeline intersections was undertaken to classify the watercourses as minor or major. Pipeline crossings of minor watercourses were expected to present a low, predictable risk of impact to geomorphic processes. For these watercourses, it was appropriate to base assessment of potential impacts, and recommendations for mitigation and monitoring, on generic principles. Pipeline crossings of major watercourses could present a higher, and less predictable, risk of impact to geomorphic processes. These watercourses were also observed in the field to assess geomorphic risk factors specific to each site.

1.5 Geomorphic risks associated with pipelines crossing streams

Possible stream crossing methods will involve either open trenching or trenchless techniques (for example, horizontal directional drilling). The crossing methods will be confirmed during detailed design and will depend on several factors:

- type and or strength of the creek bed material
- volume of flow in the creek
- steepness of the ground on either side of the crossing
- whether a scour valve will be required in close proximity to the crossing
- environmental issues.

The Pipeline Development will routinely use trenching, but horizontal directional drilling could be an option to cross large channels in alluvial settings. Exposed pipe crossings suspended over channels could be an option in situations where the steepness of the approach in and out of the stream presented practical difficulties for trenching, the channel was incised, and there was no floodplain. Surface crossings would not normally be considered in floodplain settings due to the risk of interference with flood flows.

A number of studies have highlighted the geomorphic risks and impacts associated with pipeline crossings, during the construction and operational phases (e.g. Reid et al., 2002; CAPP, CEPA and CGA, 2005; Lévesque and Dubé, 2007, Fogg and Hadley, 2007; Castro et al., 2015), and how to mitigate risks (e.g. Swatsky et al., 1998; Witheridge, 2017). The following summary of geomorphic risks associated with pipelines crossing streams provides the basis for selecting an appropriate methodology for this investigation.

A geomorphic risk that applies to all modes of crossing is lateral channel migration, either through rapid avulsion (Brizga and Finlayson, 1990) or meander migration (Thorne, 1991). In general, channels confined within valley walls migrate slowly, while those set within extensive floodplains would be expected to naturally migrate through the alluvial sediments.

In addition to the naturally dynamic unconfined setting presenting a risk to pipeline crossings, riparian vegetation locally influences the resistance of banks to fluvial scour (Abernethy and Rutherfurd, 2000).

Buried pipelines may be exposed by stream bed incision. This could involve episodic scour of mobile bed sediments during floods (Colby, 1964), even though the bed might return to the same elevation between floods, or upstream migration of a head cut, or knickpoint. Scour during flood flows would be expected in sand bed streams, but those with cohesive clay-rich beds, or gravel/cobble, boulder or bedrock would be expected to have relatively stable beds. Knickpoints are a local steep fall in channel bed elevation and are a common, natural feature of streams (Cook and Schneider, 2006, pp. 46-47). Stable (or fixed) knickpoints occur on river profiles due to a local control, such as a resistant lithological unit, fault, or large coarse sediment supply; unstable (or mobile) knickpoints are initiated by a downstream event that lowers the hydraulic control, with erosion propagated upstream as a headcut (Brush and Wolman, 1960; Gardner, 1983; Wolman, 1987; Bishop et al., 2005; Crosby and Whipple, 2006).

1.6 Guidelines for laying pipes and cables in watercourses on waterfront land

The laying of pipes and cables in or across a watercourse is a controlled activity under the Water Management Act 2000 (WM Act). NSW Office of Water (2012b) *Guidelines for laying pipes and cables in watercourses on waterfront land* listed a number of design consideration for laying pipes across watercourses:

- Identify the width of the riparian corridor in accordance with the NSW Office of Water guidelines for riparian corridors.
- Consider the full width of the riparian corridor and its functions in the location and installation of any pipes and cables. Where possible, the design should accommodate fully structured native vegetation.
- Minimise the design and construction footprint and proposed extent of disturbance to soil and vegetation within the watercourse or waterfront land.
- Utilise existing easements. Pipes and cables should be incorporated within existing cleared or disturbed areas with or adjacent to other crossing points such as roads, particularly if future maintenance and on-going access is required.
- Maintain existing or natural hydraulic, hydrologic, geomorphic and ecological functions of the watercourse. Demonstrate that the pipe and cable installations will not have a detrimental impact on these functions.
- Identify alternative options for works and detail the reasons for selecting the preferred option or options.

The Guideline (NSW Office of Water, 2012b) indicates that proposals for directional boring should seek to:

- minimise or avoid disturbance to channel bed and banks
- minimise or avoid rehabilitation, maintenance and on-going costs after construction
- minimise risks associated with cave-ins, bed collapse or frac-outs during boring
- ensure depth does not result in exposure of assets if channel experiences bed or bank degradation
- locate bore entry and exit points outside designated riparian corridors and existing vegetation
- address the recovery and removal of construction plant and materials, including drilling mud.

The Guideline (NSW Office of Water, 2012b) indicates that proposals for trenching should:

- prepare rehabilitation plans for disturbed bed and banks
- locate or lay pipes or cables across the watercourse on the downstream side of channel bedrock outcrops and through the drop deposit zone if a plunge pool is present
- avoid outside bends. Choose a straight section of the watercourse to cross
- place infrastructure below calculated bankfull flow scour depths and allow a safety margin

- avoid concrete caps and casings at shallow depths which may become exposed by bed lowering
- ensure backfilling restores the channel shape and bed level to preconstruction condition
- ensure a trench is open for the minimal length of time
- avoid stopping the flow of a permanent watercourse by staging the trench across the channel or minimise the time involved in stopping or intercepting flows
- address additional disturbances from temporary coffer dams or diversion of flows around work site, vehicle or machinery access and crossings and material stockpiles
- prevent potential water quality issues such as turbidity or spills
- address the recovery and removal of construction plant and materials.

2 Methodology

2.1 Variables of interest

The assessment focused on geomorphic characteristics of the watercourses in the vicinity of the pipeline intersections that were relevant to the main risks associated with the pipeline during its operational phase:

- Geomorphic change will lead to exposure of the pipeline to fluvial forces, thereby putting the integrity of the pipeline at risk, and
- The presence of the pipeline (usually in combination with being exposed through geomorphic change) will interfere with natural geomorphic processes.

In consideration of the established risks associated with pipeline crossings of watercourses, and the guidelines of NSW Office of Water (2012b), the variables of interest in this investigation were:

- Stream Order
- The degree of confinement of the channel and extent of floodplain in unconfined, or partially confined settings,
- The calibre of the bed material,
- The depth of sand in mobile sand-bed streams,
- The structure and extent of riparian vegetation cover, and
- The presence of knickpoints that could potentially migrate upstream to the crossing.

No attempt was made to ascertain, on the basis of a rapid visual assessment, the historical or current rate of channel migration, rate of erosion or deposition, or stability of bed and banks relative to what would be expected for the stream in an undisturbed setting.

2.2 Desktop assessment

2.2.1 Topographic data

The delineation of watercourses and their catchments was based on the best available topographic data. The area of the Pipeline Development is covered by DEM (digital elevation model) tiles produced by NSW Spatial Services, Department of Finance, Services and Innovation, available from ELVIS - Elevation and Depth - Foundation Spatial Data, Version 0.1.1.0 (http://elevation.fsdf.org.au/). The DEMs were produced using the TIN (Triangular Irregular Network) method of averaging ground heights to formulate a regular grid and are not hydrologically enforced.

In the study area, the data sets contained ground surface models in grid format at 1 m, 2 m and 5 m resolutions. The 1 m data were derived from C3 LiDAR (Light Detection and Ranging) from an ALS50ii (Airborne Laser Scanner). The 2 m data were derived from Spatial Services Category 2 (Classification Level 3) LiDAR from an ALS80 (SN8250) sensor. The data used to create the 1 m and 2 m DEMs has an accuracy of ±0.3 m (95% Confidence Interval) vertical and ±0.8 m (95% Confidence Interval) horizontal. The 5 m data were derived from Leica-Geosystems Airborne Digital Sensor (photogrammetry). The processed data was manually edited to achieve ICSM standard category 3 whereby the ground class contains minimal non-ground points such as vegetation, water, bridges, temporary features, jetties etc. This data has a vertical accuracy of ±0.9 metre on bare open ground (95% Confidence Interval 1.96 x RMSE) and horizontal accuracy of ±1.25 metre (95% Confidence Interval 1.96 x RMSE) on bare open ground.

The DEMs in the study area were from the Blayney (5 m DEM tiles), Bathurst (2 m DEM tiles), Orange (5 m DEM tiles), Oberon (5 m DEM tiles) and Wallerawang (1 m and 2 m DEM tiles) regions. In areas of overlap, the higher resolution DEMs were preferred. In Blayney and Bathurst regions, the 1 m and 2 m data were collected in Oct-Nov 2015; in Wallerawang region the 1 m data were collected in August 2008 and the 2 m data were collected Apr-Jul 2017; in Blayney and Orange regions the 5 m data were collected Feb-Jul 2014; in Oberon region the 5 m data were collected Nov 2013 – May 2014.

The DEM tiles were downloaded over an area about 80 km long and 12 km wide that contained the Project pipeline route and the majority of the catchments of watercourses that intersected the pipeline. The catchments of the larger rivers extended beyond the DEM tiles. These areas were covered by the Geoscience Australia 1 second SRTM derived DEM-H Version 1.0, a 1 arc second (~30 m) gridded DEM that has been hydrologically conditioned and drainage enforced. The low resolution and low accuracy SRTM DEM was used as supplementary data in the procedure to delineate catchment areas. Watercourse delineation in the vicinity of the pipeline development was based on the higher resolution DEMs.

2.2.2 Mapped hydroline (blue line) network

The blue line drainage network was represented by National Surface Hydrology Lines (Regional) downloaded from Australian Government (https://data.gov.au/dataset/surface-hydrology-lines-regional). The dataset is a collaborative effort by Geoscience Australia and state governments. Geoscience Australia manages a data aggregation from multiple jurisdictional sources. The scale of the data ranges from 1:25,000 to 1: 250,000 across the continent. Geoscience Australia aggregates the data into a National Model and forms the surface water components of the Foundation Spatial Data Framework. In the area covered by the Project, these lines correspond to the hydrolines ('blue lines') on the 1:25,000 topographic map sheet.

The blue lines on topographic maps, and thus the National Surface Hydrology Lines (Regional), would have been drawn mainly on the basis of whether a channel was visible on the aerial photographs available at the time of production, perhaps also guided by vegetation structure. Some important factors impact how well the mapped blue lines represent the existing channel network:

- The blue lines represent the channel network visible or assumed from aerial photographs; the resolution and quality of the photographs limits the scale of mapping.
- Distortion inherent in the original aerial photographs makes precise transfer of the locations of the stream lines to a undistorted map difficult.
- The blue lines are typically depicted as a smoothed representation of the actual stream lines.
- Channels can change in size and position over time.

Given these factors, the National Surface Hydrology Lines (Regional), referred to here as hydrolines were not expected to accurately represent the existing drainage lines. Nevertheless, the hydroline network is the conventional standard used in impact assessments to identify streams of interest, and to classify streams by size using Strahler Stream Order. In this Report, the hydrolines were used for this purpose, and also to guide the terrain analysis procedure to generate an accurate representation of the existing watercourse positions.

2.2.3 Automatic watercourse delineation

Given the inadequacies of the hydroline network, a revised drainage network was automatically generated in the catchments of watercourses intersecting the pipeline route using Global Mapper™ GIS (geographic information system). The new drainage networks and catchment areas were generated by flow accumulation using the standard 8-direction pour point algorithm (D-8) (Jenson and Domingue, 1988). The drainage network was evaluated at 1 × 1 m resolution for the majority of catchments, and at 5 × 5 m resolution in the largest catchments. Depressions in the topography were filled prior to flow accumulation. Some drainage lines would have been inaccurate around road culverts and bridges that were not edited into the DEM, but this problem was unlikely to have affected the delineation of watercourse positions near pipeline intersections.

The automatically generated drainage network was intended to emulate the hydroline network. In some cases, hydrolines had no equivalent automatically generated watercourses. This arose because the hydroline drainage was grossly incorrect, a hydroline was not drawn on a significant catchment, or the area of land had been mined or impounded since the hydrolines were drawn.

The automatically generated drainage networks were different in detail to the hydroline networks, but each watercourse intersecting the pipeline route was assigned the same Strahler Stream Order as the hydroline that it emulated. Catchment area was calculated on the basis of the DEM data.

2.2.4 Classification of watercourses

Watercourses intersecting the Project pipeline route were classified into three groups on the basis of Stream Order and catchment area. Catchment area was used in addition to Stream Order because Stream Order was assigned on the basis of mapped hydrolines, not the existing drainage network, and could have been unreliable as a guide to stream size in some cases. Also, in connection with sediment supply, sediment transport, channel adjustment, and stream discharge processes, catchment area has a stronger theoretical link to geomorphic and hydrologic theory than Stream Order.

Watercourses of Stream Order 1 or 2 were automatically classified by convention as Minor. The Minor watercourses at pipeline intersections all had catchment areas less than 1.33 km^2, so this was set as a threshold area to classify watercourses as 'small', regardless of Stream Order. There was one exception to this rule – a watercourse with a catchment area of 1.27 km^2 at the pipeline intersection number 70 that was opportunistically assessed in the field. Watercourses of Stream Order 3 and higher were subdivided on the basis of catchment area using an arbitrary threshold of 5 km^2:

- Minor and small-size watercourses: Stream Orders 1 and 2, or catchment area (A) $A < 1.33$ km^2
- Medium-size watercourses: Stream Order 3 or higher and catchment area (A) 1.33 $km^2 \leq A < 5$ km^2
- Large-size watercourses: Stream Order 3 or higher and catchment area (A) $A \geq 5$ km^2

Minor and small-size watercourses were likely to be resilient headwater streams, and were low priority for field inspection. Medium- and large-size watercourses were medium and high priority, respectively, for field inspection. This prioritization was intended mainly to assist planning the field inspection, with more time allocated to inspection of large-size watercourses.

2.3 Field assessment

The field assessment included:

- Photograph the site in the downstream and upstream directions
- Estimate structure and cover of riparian vegetation
- Estimate bed sediment material calibre
- Estimate the depth of sand in the bed of sand-bed streams

Vegetation cover and continuity were estimated using the Braun-Blanquet rank scale, which provides a rapid, robust and repeatable estimate of cover abundance (Wikum and Shanholtzer, 1978). Cover refers to foliar projective cover of the ground. The Braun-Blanquet scale was the same as the original, except that the lowest class was sub-divided to provide a class (<1% cover) to describe the situation where cover was essentially absent, as used by Causton (1988):

- <1% score = 0
- 1 – 5% score = 1
- 6 – 25% score = 2
- 26 – 50% score = 3
- 51 – 75% score = 4

- >75% score = 5

At each sampling site, the cover abundances of riparian trees, *T*, shrubs, *S*, and ground cover, *G*, were rapidly estimated at plots approximately 5 × 5 m in size, with cover scored as an integer from 0 to 5. Vegetation cover of the left and right sides of the channel were measured separately. A cover index was devised to rate both the degree of coverage of the ground by plants, and the vegetation structure. A high degree of cover was rated higher than a low degree of cover, and trees were rated more valuable than shrubs, and shrubs rated more valuable than ground cover. The coverage rating was based on the higher geomorphic stability, habitat availability, and energy and nutrients provided by greater plant abundance. The plant structure rating was based on the different capacity of trees, shrubs and ground cover to provide these same services, as well as the additional ability of trees to provide shade. For each plot, the raw cover abundance scores for trees, shrubs and ground cover were factored and summed, and then converted to a riparian cover abundance (*C*) score between 0 and 1 by dividing the total by 24.

$$C = \frac{3T+2S+G}{24} \qquad (1)$$

An index score of at least 1.0 would be achieved if tree, shrub and ground cover were all in the 50 – 75% or >75% cover classes. A very well vegetated site might achieve a combined factored score exceeding 1.0, in which case the score would be rounded down to 1.0. The index scores were converted to combined cover classes equivalent to the classes used to collect the original data (Figure 2).

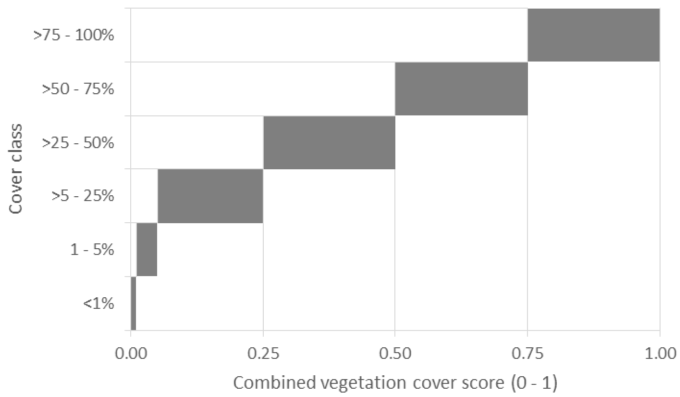

Figure 2. Scale for conversion of combined riparian vegetation cover index score to class.

Bed material calibre was estimated visually as presence of, and dominant, material for 7 classes (adapted from Brakensiek et al., 1979):

- Mud (silt and clay)
- Sand (0.06 - 2 mm)
- Gravel (2 - 64 mm)
- Cobble (64 - 256 mm)
- Boulder (exceed 256 mm)
- Exposed bedrock slab
- Artificial (hard lined)

The depth of sand in sand-bed watercourses was estimated by inserting a stainless steel rod into the bed in at least six locations, measuring the depth to the underlying consolidated layer, and recording the greatest depth.

3 Existing environment

3.1 Desktop assessment

3.1.1 Hydroline intersections

The Project pipeline intersected 131 hydrolines, but 20 of these were excluded on the basis of a preliminary comparison with the automatically generated drainage network, the topography, and recent aerial imagery:

- In 8 cases the hydroline did not match the position of the main drainage line, which was not intersected by the pipeline
- In 4 cases the intersection was in close proximity to another intersection on the same watercourse
- In 3 cases the intersection occurred within 50 m of the top of the hydroline, close to the ridge crest
- In 3 cases the drainage line indicated by the hydroline had been modified by mining activities
- In 2 cases the hillslope drainage had been diverted by contour drains

Of the above excluded hydroline crossings, sixteen were on watercourses of Stream Order 1 and four were on watercourses of Stream Order 2, so all were minor watercourses. The remaining 111 intersections were potentially valid. Of these, 67 were Stream Order 1, 18 were Stream Order 2, 14 were Steam Order 3, 7 were Steam Order 4, 3 were Stream Order 5, 1 was Stream Order 6 and 1 was Stream Order 8.

3.1.2 Auto-generated drainage network intersections

Reassessment of the watercourse/pipeline intersections using automatically DEM-generated drainage lines resulted in 112 intersections (**Figure 1**). Most of these intersections emulated, and were in close proximity to, a hydroline intersection, although some had no equivalent hydroline intersection. Two new catchments and watercourses were added. One of these was formed because the auto-generated drainage split the hydroline-based catchment into two separate catchments, and the other was added because it was similar in area, slope and shape to other catchments that did have watercourses marked by blue lines. For three hydrolines that did intersect the pipeline, the equivalent DEM-generated watercourses ran adjacent to the pipeline, but did not intersect. For one hydroline that intersected the pipleline at one location, the equivalent DEM-generated watercourse intersected at three locations.

Overall, the Project pipeline intersected the automatically DEM-generated drainage lines at 112 points. Of these, 68 were Stream Order 1, 18 were Stream Order 2, 14 were Steam Order 3, 7 were Steam Order 4, 3 were Stream Order 5, 1 was Stream Order 6 and 1 was Stream Order 8.

As expected, Stream Order was related to catchment area, but there was a large range of catchment areas within each Stream Order group (Figure 3).

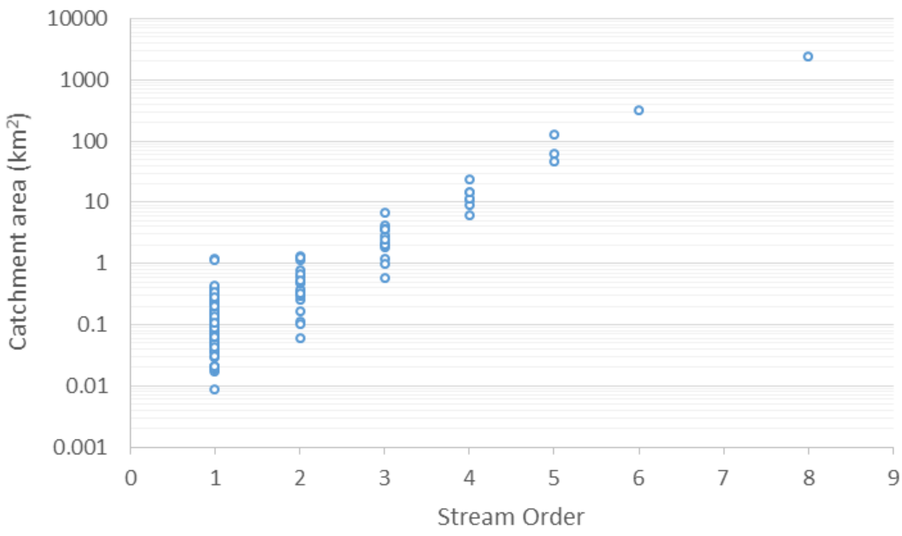

Figure 3. Relationship between Stream Order and catchment area at intersection points of the auto-generated drainage network and the Project pipeline.

3.1.3 Classification of intersections

Of the 112 intersections distributed along the 89.3 km long pipeline route, 26 were of Order 3 or higher and 12 were Order 4 or higher (Table 1, Figure 4). Thus, the majority of intersections were in the Minor or small-size class, 10 were in the medium-size class and 13 were in the large-size class (Table 1). The Minor or small-size class included three Order 3 streams with small catchment areas. All Medium-size intersections were Order 3, and large-size intersections ranged from Order 3 to Order 8 (Table 1). As expected, the larger streams were located at lower elevations in the landscape (Figure 4). Overall, the classification prioritized 23 intersections for field inspection, with 13 of these high priority (Table 2, Figure 4). Note that one Order 2 watercourse intersection (No. 70) was included opportunistically during the field inspection.

Table 1. Distributions of watercourse/pipeline intersections classified by Stream Order and catchment area.

Stream Order	All intersections	Minor and small-size	Medium-size	Large-size
1	68	68	0	0
2	18	18	0	0
3	14	3	10	1
4	7	0	0	7
5	3	0	0	3
6	1	0	0	1
7	0	0	0	0
8	1	0	0	1
Total	112	89	10	13

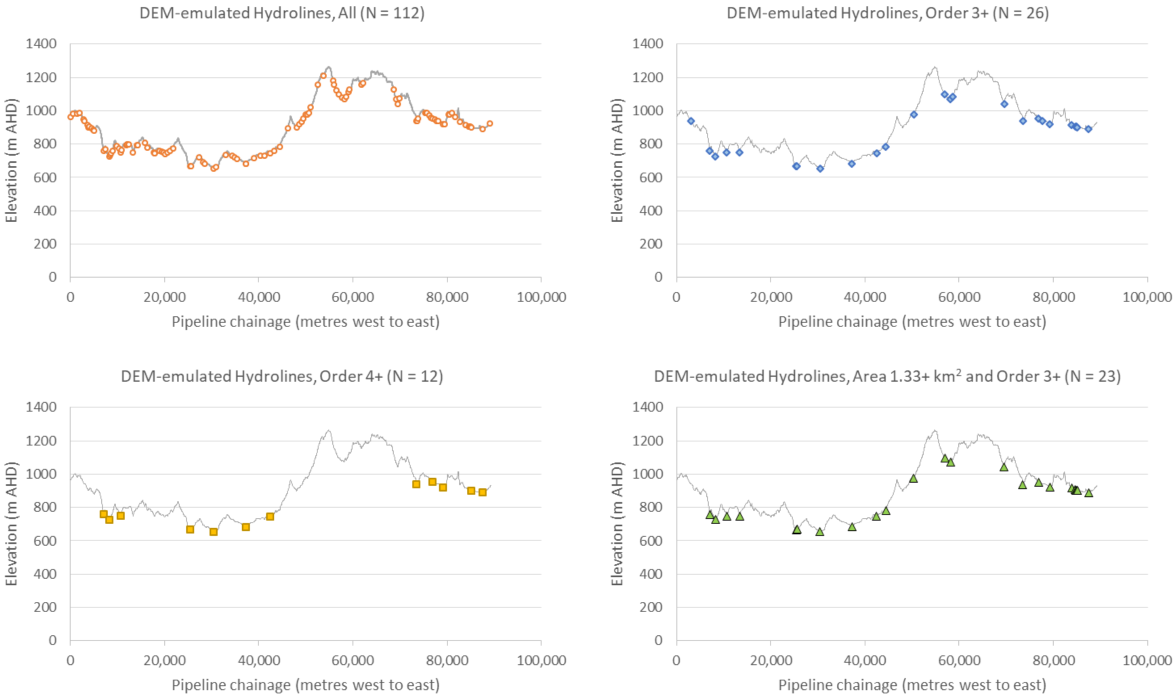

Figure 4. Profile of intersection points of the auto-generated drainage network and the Project pipeline.

Table 2. Watercourse/pipeline intersections prioritized for field inspection. Priority is 1 (first) and 2 (second). Chainage is distance along pipeline from west to east. Perenniality and Hierarchy are attributes of hydrolines.

No.	Easting	Northing	Area (km^2)	Order	Chainage (m)	Priority	Name	Perenniality	Hierarchy
14	722991.723	6291288.8	11.14	4	7.05	1	McLeans Ck	Perennial	Minor
16	724138.081	6290859.0	126.85	5	8.30	1	Evans Plains Ck	Perennial	Minor
25	726304.313	6290280.9	14.35	4	10.64	1		Non Perennial	Minor
31	726304.313	6290280.9	4.15	3	13.36	2		Non Perennial	Minor
45	738777.857	6293622.8	313.54	6	25.41	1	Queen Charlottes Ck	Perennial	Minor
46	738946.761	6293565.7	6.69	3	25.59	1		Non Perennial	Minor
50	742729.854	6294316.1	2415.06	8	30.47	1	Macquarie R	Perennial	Major
59	748196.214	6293153.4	61.68	5	37.21	1	Salt Water Ck	Perennial	Minor
64	752647.226	6293751.1	8.84	4	42.51	1		Non Perennial	Minor
68	754521.240	6294206.0	2.12	3	44.46	2		Non Perennial	Minor
70	757245.387	6295610.3	1.28	2	48.02	2		Non Perennial	Minor
76	759122.385	6295528.8	1.87	3	50.36	2	Saint Anthonys Ck	Non Perennial	Minor
87	763136.654	6298475.3	1.98	3	56.93	2		Non Perennial	Minor
89	764240.437	6298383.6	2.02	3	58.16	2	Kirkconnell Ck	Non Perennial	Minor
100	772738.837	6301698.2	2.83	3	69.55	2	Sugarloaf Ck	Non Perennial	Minor
103	775360.192	6303873.2	6.05	4	73.52	1	Williwa Ck	Non Perennial	Minor
111	778078.482	6303750.4	11.45	4	76.84	1	Pipers Flat Ck	Perennial	Minor
115	780240.095	6302991.7	14.64	4	79.22	1	Pipers Flat Ck	Perennial	Minor
124†	784042.064	6303486.7	2.41	3	83.92	2		Non Perennial	Minor
126A‡	784396.364	6304049.8	3.58	3	84.68	2		Non Perennial	Minor
126B‡	784532.064	6304179.0	3.58	3	84.87	2		Non Perennial	Minor
126C‡	784599.419	6304194.6	3.58	3	84.94	2		Non Perennial	Minor
127†	784679.566	6304274.2	23.21	4	85.06	1	Wangool Ck	Perennial	Minor
131	786932.928	6304300.1	47.30	5	87.49	1	Coxs R	Perennial	Minor

† Inaccessible at the time of the field inspection.

‡ 126A, 126B and 126C intersections were within 250 m on the same reach, and represented in the field by 126B.

3.1.4 Mapping of pipeline intersections prioritized for field inspection

Each site prioritized for field inspection was mapped (Section 7 - Appendix 1, **Figure 5** to **Figure 14**).

3.1.5 Long-profiles of pipeline intersections prioritized for field inspection

For each site prioritized for field inspection, long-profiles were drawn by extracting elevation and chainage from the DEM-generated drainage line thalwegs at 1 m spacing (Section 8 - Appendix 2, **Figure 15** to **Figure 20**). Knickpoints were identified by searching the thalweg for significant falls in elevation over short distances, using the unit vertical fall in metres per 2 metres downstream distance. At most sites the data were extracted for a distance of >500 m upstream, and a distance of >1000 m downstream, from the pipeline intersection (Section 8 – Appendix 2, **Figure 15** to **Figure 20**).

Only one site showed evidence of a knickpoint with potential to migrate upstream to the pipeline intersection. Downstream of Site 68, the channel was incised, with three knickpoints of 0.8 – 1.5 m depth present within 1000 m downstream of the intersection (**Figure 9**, **Figure 17**). The rate of upward progression of these knickpoints is unknown. The risk can be mitigated by monitoring the position of the knickpoints, stabilising the knickpoints using structural works, or re-locating the crossing further upstream. Site 64 also indicated presence of a 1 m deep knickpoint 530 m downstream of the pipeline intersection (**Figure 17**), but the aerial photograph suggested that this reach had undergone rehabilitation by revegetation, and the knickpoint appears to have been stabilised by a concrete structure (**Figure 8**).

3.2 Field assessment

Sites 124 and 127 were inaccessible at the time of the field inspection. Sites 126 A, 126B and 126C were within 250 m on the same reach, and represented in the field by 126B. Each site inspected in the field was photographed (Section 9 - Appendix 3, **Figure 21** to **Figure 25**). The prioritised intersection sites covered a range of geomorphic stream types and bed materials (**Table 3**). Four sites had sand bed that could be probed, with a maximum depth of 1.3 m recorded. If trenching is to be employed at these sites, the base of the sand bed should be regarded as the top of the trench. The depth of sand should be comprehensively surveyed as part of the geotechnical assessment. The Macquarie River (site 50) likely had a sand bed, but the depth of water prevented probing.

Site 25 had extensive bedrock outcrops present, with some of these acting as hydraulic controls for pools (**Table 3**, **Figure 21**). If trenching is to be employed, care will be required to avoid disturbing these hydraulic control points. Site 115 was close to the hydraulic control of a 200 m long pool (**Table 3**, **Figure 25**). If trenching is to be employed, care will be required to avoid disturbing the hydraulic control point.

The apparent stability of the beds and banks of the watercourses was unremarkable for streams in these disturbed settings. There was little evidence of recent bank or bed erosion at any site. Most sites had at least moderate combined vegetation cover, even if the tree cover was poor at most sites (**Table 4**).

Table 3. Geomorphic character of watercourse/pipeline intersections observed in the field.

No.	Valley setting	Floodplain extent	Bed material (present)	Bed material (dominant)	Maximum sand depth (m)	Comment
14	Partly Confined	Pockets	Mud, sand, gravel, cobble	Mud		
16	Laterally unconfined	Extensive	Mud, sand, gravel	sand	0.3	
31	Confined		Sand	Sand	1.2	
25	Confined		Mud, bedrock	Mud		Extensive exposed bedrock forming pool hydraulic controls
45	Laterally unconfined	Extensive	Mud, sand	Sand	1.3	
46	Confined		Mud	Mud		Swale morphology
50	Laterally unconfined	Extensive	Mud, sand	Sand		Bed not visible. Sand on bank top. Some exposed rock in bed
59	Partly Confined	Moderate	Mud, sand, gravel	Sand	0.6	
64	Partly Confined	Moderate	Mud	Mud		
68	Confined		Mud, sand, cobble, bedrock	Mud		Minor knickpoint in bed fill, 0.5 m high
70	Confined		Mud	Mud		Ferruginous material on bed (likely from road embankment)
76	Confined					Bed not readily accessible
87	Confined		Mud	Mud		
89	Confined		Mud	Mud		
100	Confined		Mud	Mud		
103	Partly Confined	Moderate	Mud, sand, gravel, cobble	Gravel		
111	Partly Confined	Moderate	Mud	Mud		
115	Partly Confined	Moderate	Mud	Mud		200 m long pool upstream of intersection
126B	Confined		Cobble	Cobble		Artificial channel. Site of pumping station facility
131	Partly Confined	Moderate	Mud	Mud		Marshy floodplain; river transfers mine wastewater

Table 4. Riparian cover index values of watercourse/pipeline intersections observed in the field.

No.	Riparian tree cover index	Riparian vegetation cover index
14	1 - 5%	25 - 50%
16	<1%	25 - 50%
31	<1%	25 - 50%
25	5 - 25%	25 - 50%
45	<1%	25 - 50%
46	<1%	5 - 25%
50	<1%	50 - 75%
59	<1%	25 - 50%
64	1 - 5%	50 - 75%
68	<1%	25 - 50%
70	<1%	5 - 25%
76	<1%	25 - 50%
87	25 - 50%	25 - 50%
89	50 - 75%	75 - 100%
100	25 - 50%	50 - 75%
103	5 - 25%	25 - 50%
111	<1%	25 - 50%
115	25 - 50%	50 - 75%
126B	5 - 25%	5 - 25%
131	<1%	25 - 50%

4 Impacts

Provided the pipeline is buried a sufficient distance from the consolidated bed and banks of the watercourses, the backfill is composed of the same material that was excavated (replaced in layers, as appropriate), and the backfill is compacted, trenched crossings present a low risk of geomorphic impact during the operational phase. Disturbance of the bank soil could expose it to enhanced risk of erosion if a significant storm runoff event occurred before vegetation had time to establish good coverage. This impact would be more likely at sites with steep bed and banks, and can be avoided by fortifying the banks with gabions or rip-rap.

Pipeline crossings constructed using directional drilling present a negligible risk of geomorphic impact during the operational phase.

Only Site 68 (**Figure 23**) had valley walls and banks steep enough that a surface crossing above the channel might be considered as a lower impact alternative to trenching. There would be no difficulty locating the pipe higher than flood levels, and there is no significant floodplain pocket present, so there would be negligible risk of geomorphic impact during the operational phase. This should be interpreted as information to assist design and construction, not a recommendation to use a surface crossing.

Potential geomorphic impacts during the construction phase would primarily relate to occurrence of a significant storm runoff event when a trench was exposed, and/or ground surrounding the site was disturbed from the action of machinery. When soils and sediments are exposed, there is a risk of suspended sediment entering the streams at an accelerated rate at any time that the streams are flowing, especially when It is raining.

5 Mitigation and Monitoring

The risk of geomorphic impacts can be mitigated by following NSW Office of Water (2012b) *Guidelines for laying pipes and cables in watercourses on waterfront land* for design, construction and operation phases (Section 1.6). Also, Witheridge (2017) provided a comprehensive set of recommendations for mitigation measures, and standard techniques of erosion and sediment control outlined in International Erosion Control Association (IECA) Australasia (2008) *Best Practice Erosion & Sediment Control* should be followed during construction. If trenching is employed at sites with sand beds, the base of the sand bed should be regarded as the top of the trench. The risk of an upwards migrating knickpoint impacting the crossing at site 68 can be mitigated by monitoring the position of the downstream knickpoints, stabilising the knickpoints using structural works, or re-locating the crossing further upstream

Monitoring of geomorphic aspects of the pipeline watercourse crossings should focus on significant storm runoff events, as impacts are only likely under conditions of heavy rainfall and fast flowing deep water in the channel. An inspection should be undertaken as soon as possible following a 1 in 5 yr ARI regional storm event, otherwise an annual visual inspection of the priority sites determined by this study will detect any significant geomorphic change. The inspections should include photographs, which should be compared with those presented in this report and from previous inspections, plus written documentation of observations and comparison with previous inspections.

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7 Appendix 1. Prioritized watercourse intersections - locations

Legend:

Blue dashed line: DEM generated stream line

Pink solid line: Project pipeline route

Red X: Priority 1 intersection for field inspection

Yellow X: Priority 2 intersection for field inspection

Figure 5. Location of intersections 14 and 16.

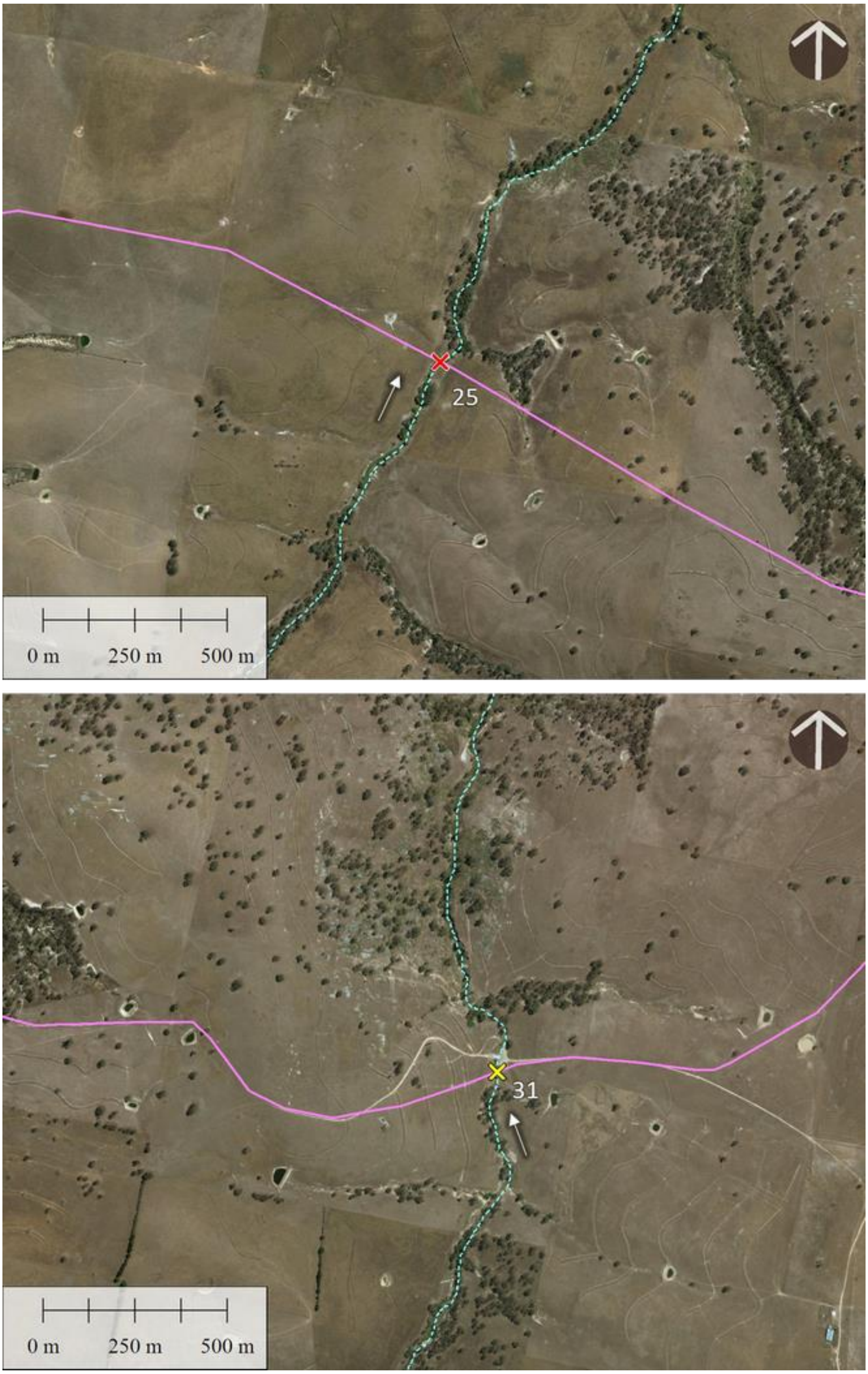
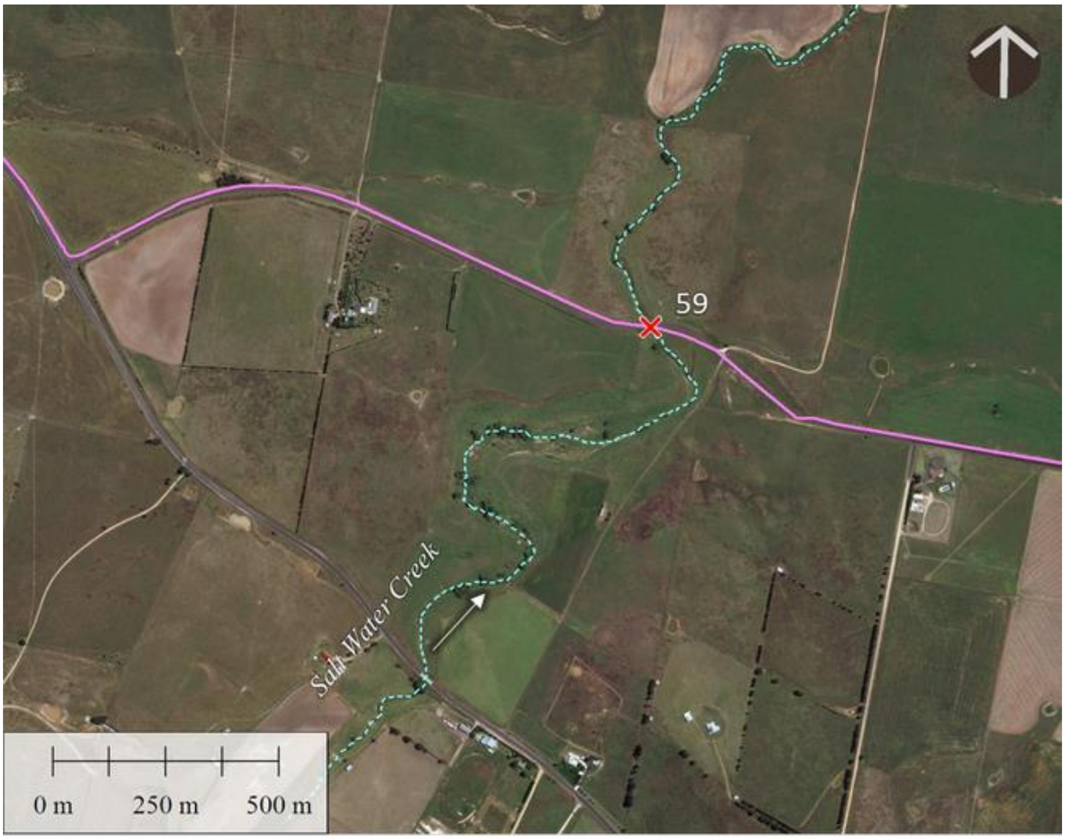


Figure 6. Location of intersections 25 and 31.

Figure 7. Location of intersections 45, 46 and 50.



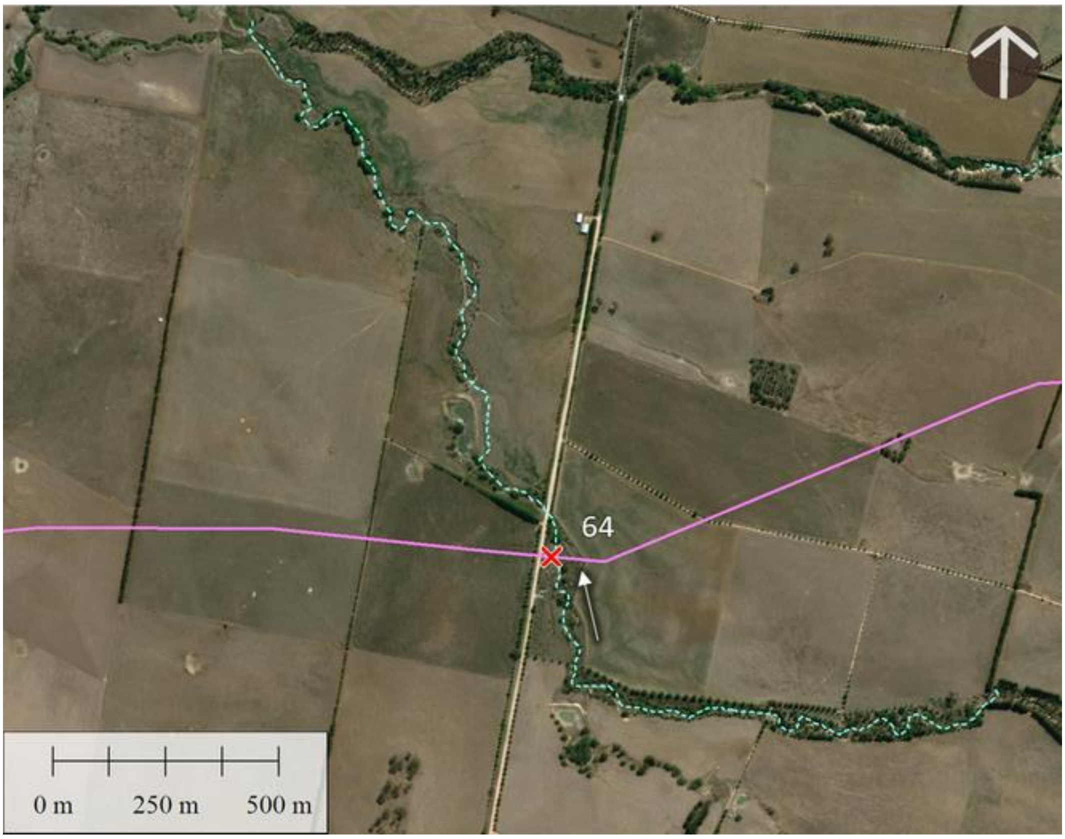


Figure 8. Location of intersections 59 and 64.

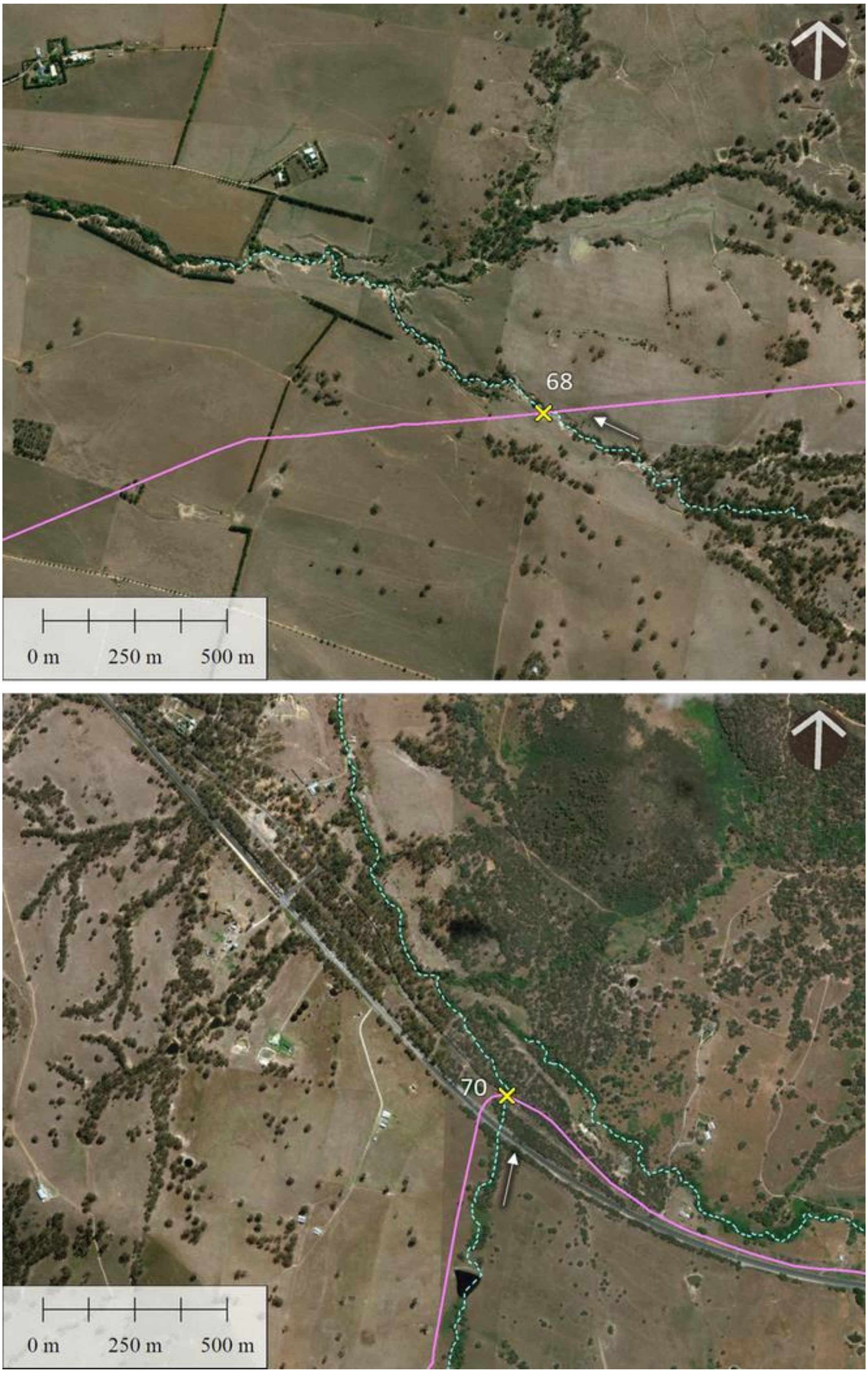


Figure 9. Location of intersections 68 and 70.

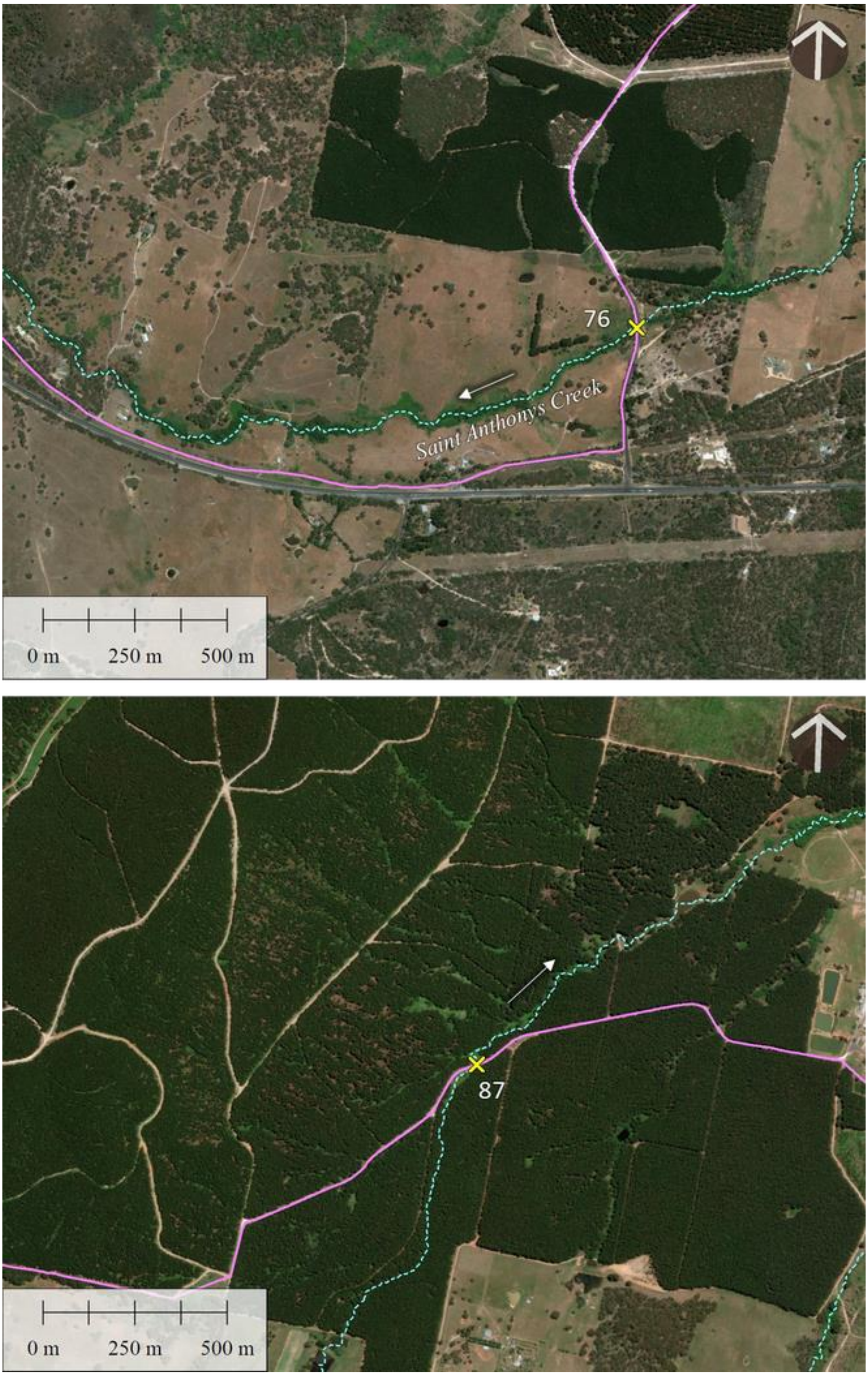
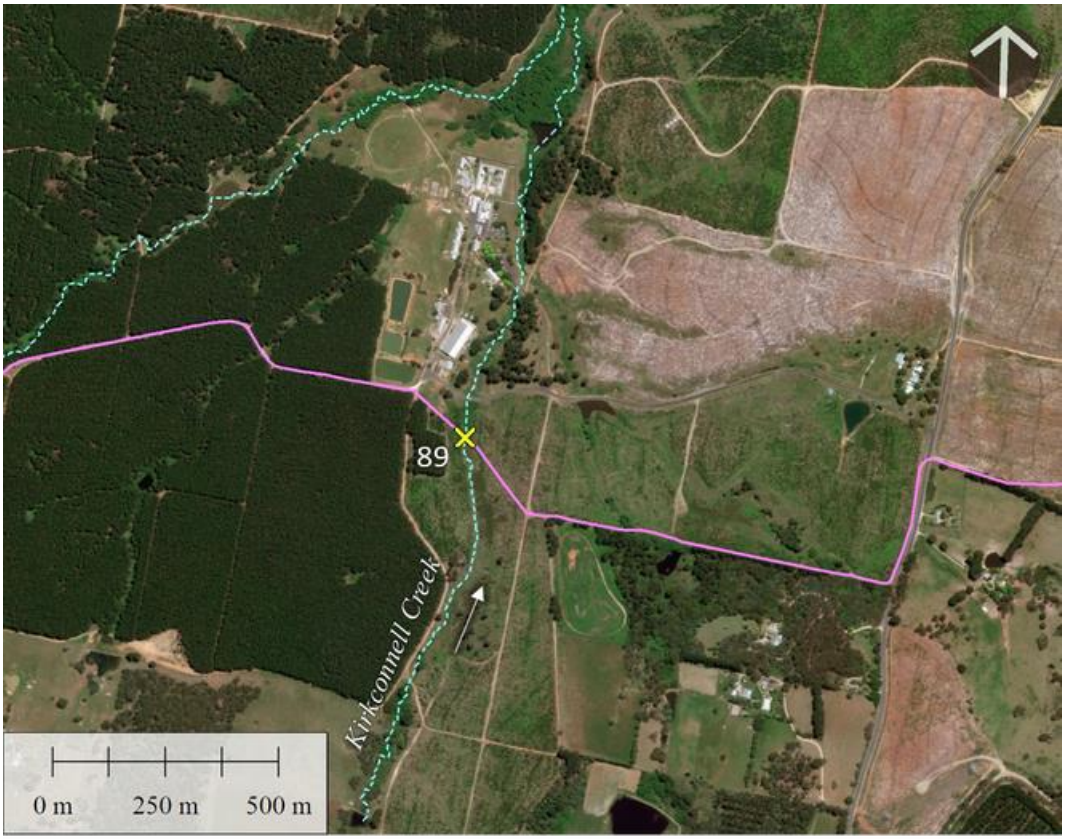


Figure 10. Location of intersections 76 and 87.



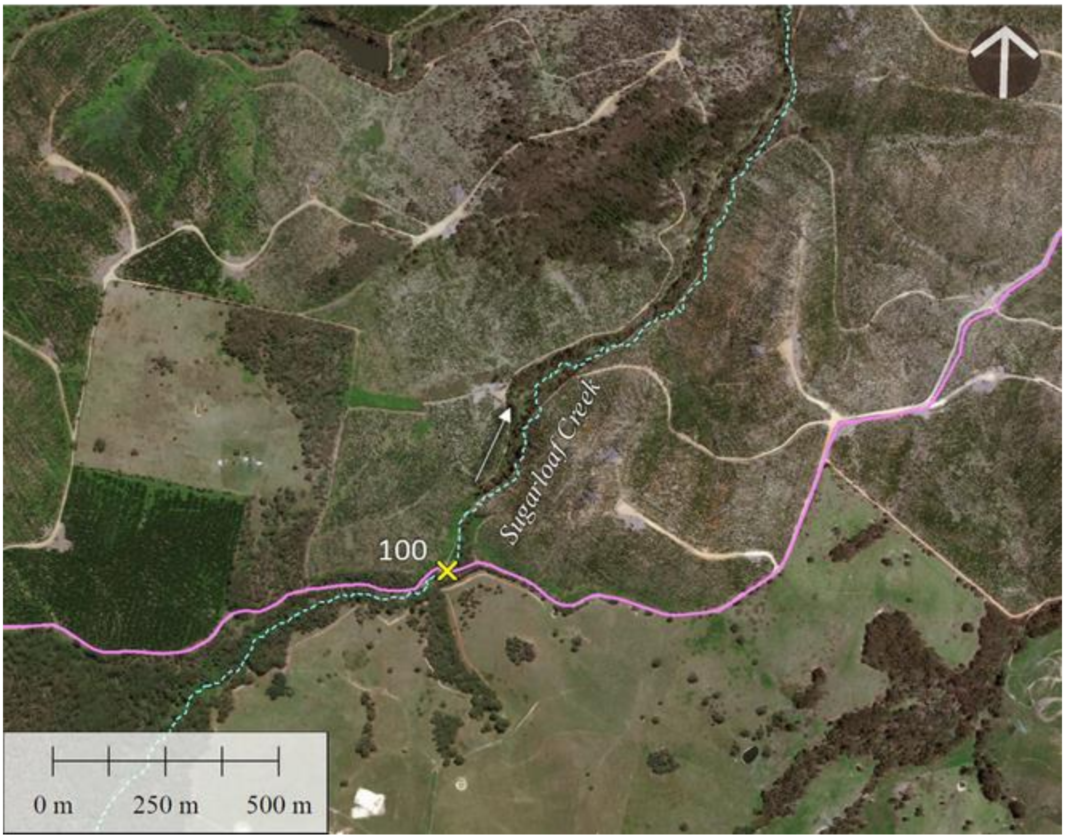


Figure 11. Location of intersections 89 and 100.

Figure 12. Location of intersections 103 and 111.

Figure 13. Location of intersections 115, 124, 126 and 127.

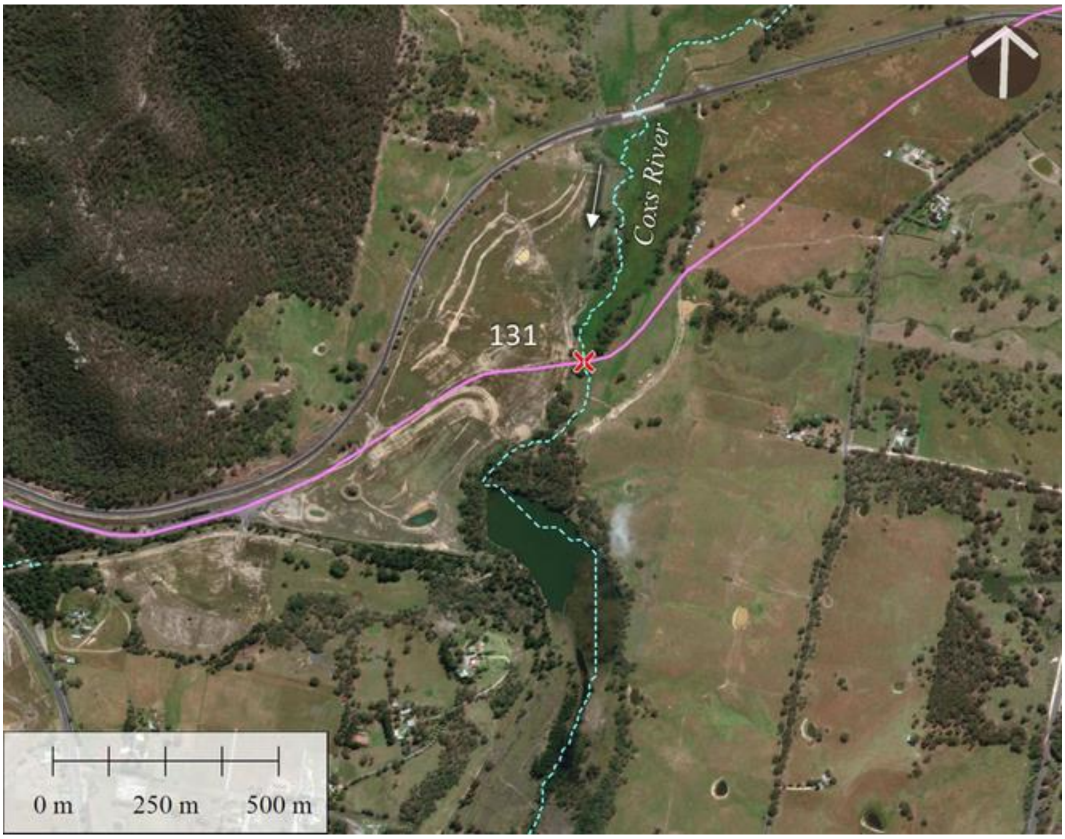


Figure 14. Location of intersection 131.

8 Appendix 2. Prioritized watercourse intersections - long profiles

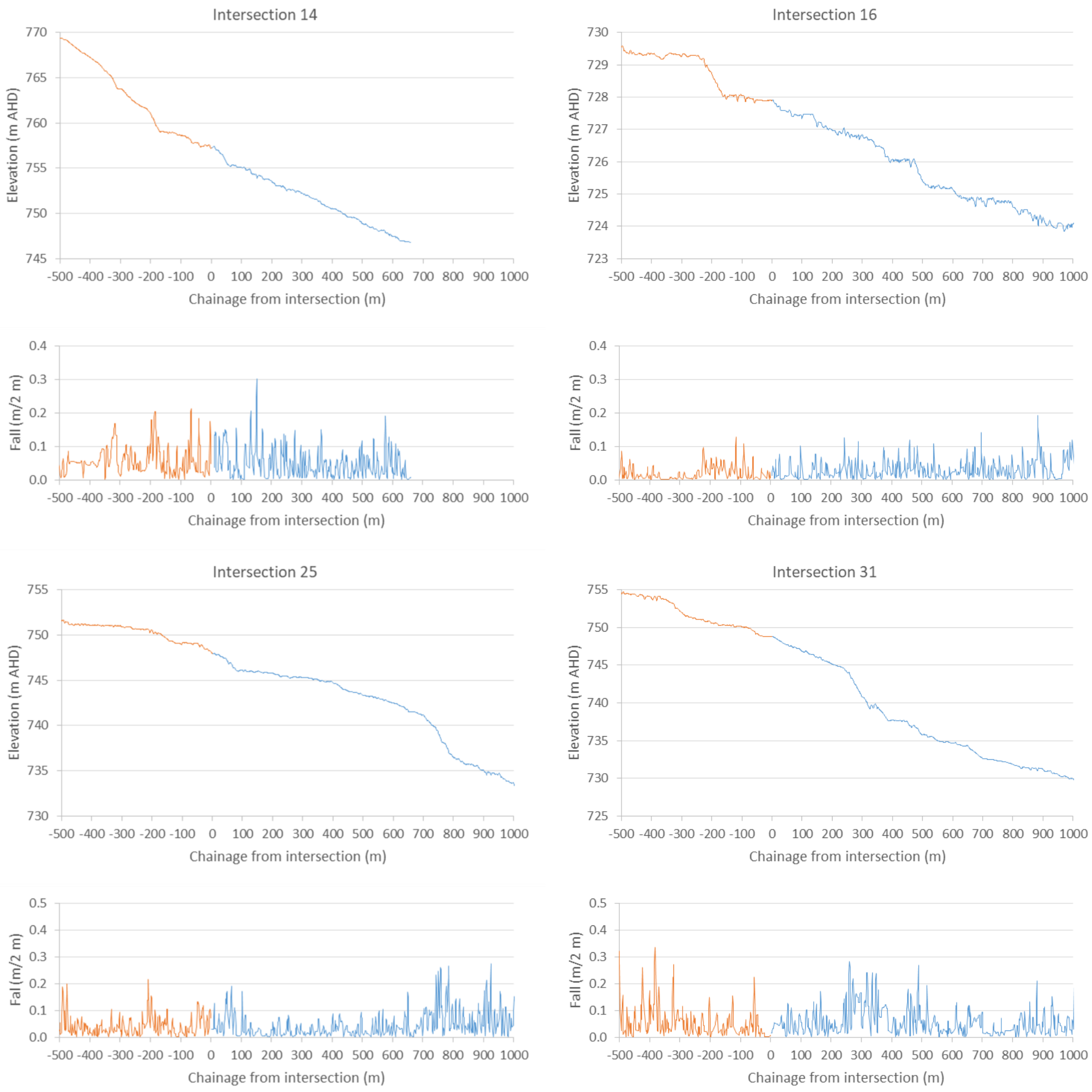


Figure 15. Long profiles of stream thalweg through intersections 14, 16, 25 and 31.

Figure 16. Long profiles of stream thalweg through intersections 45, 46, 50 and 59.

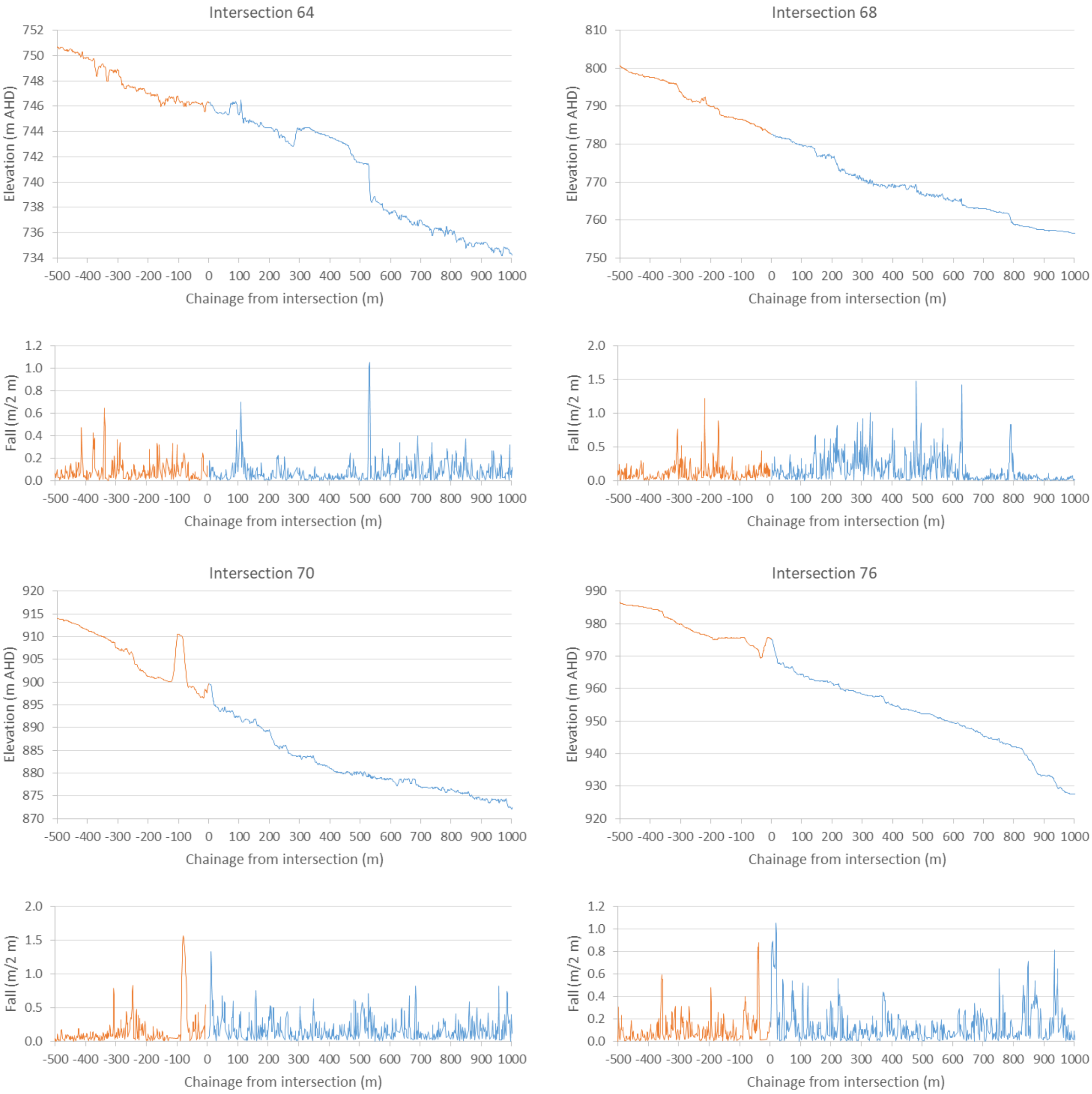


Figure 17. Long profiles of stream thalweg through intersections 64, 68, 70 and 76.

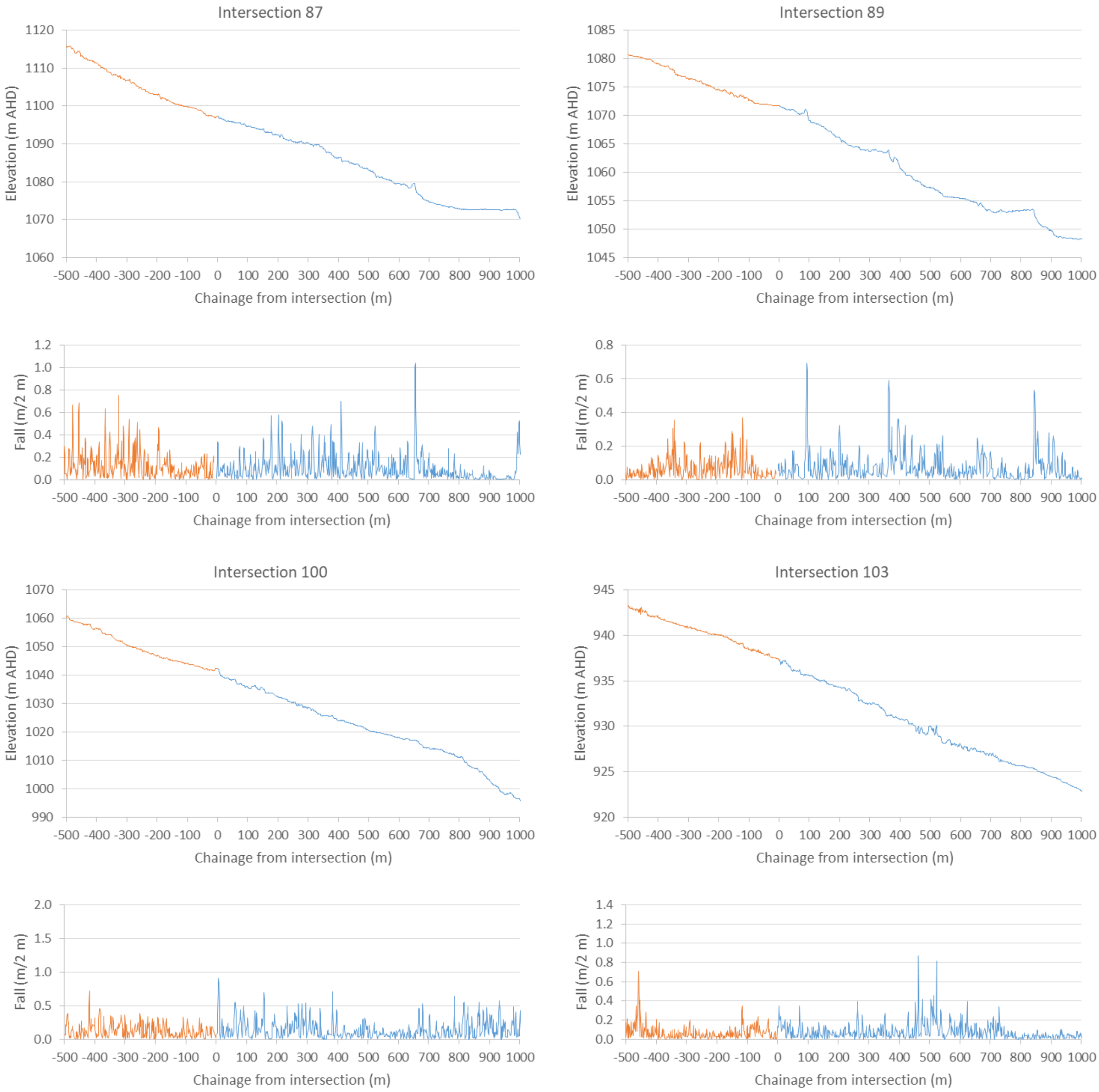


Figure 18. Long profiles of stream thalweg through intersections 87, 89, 100 and 103.

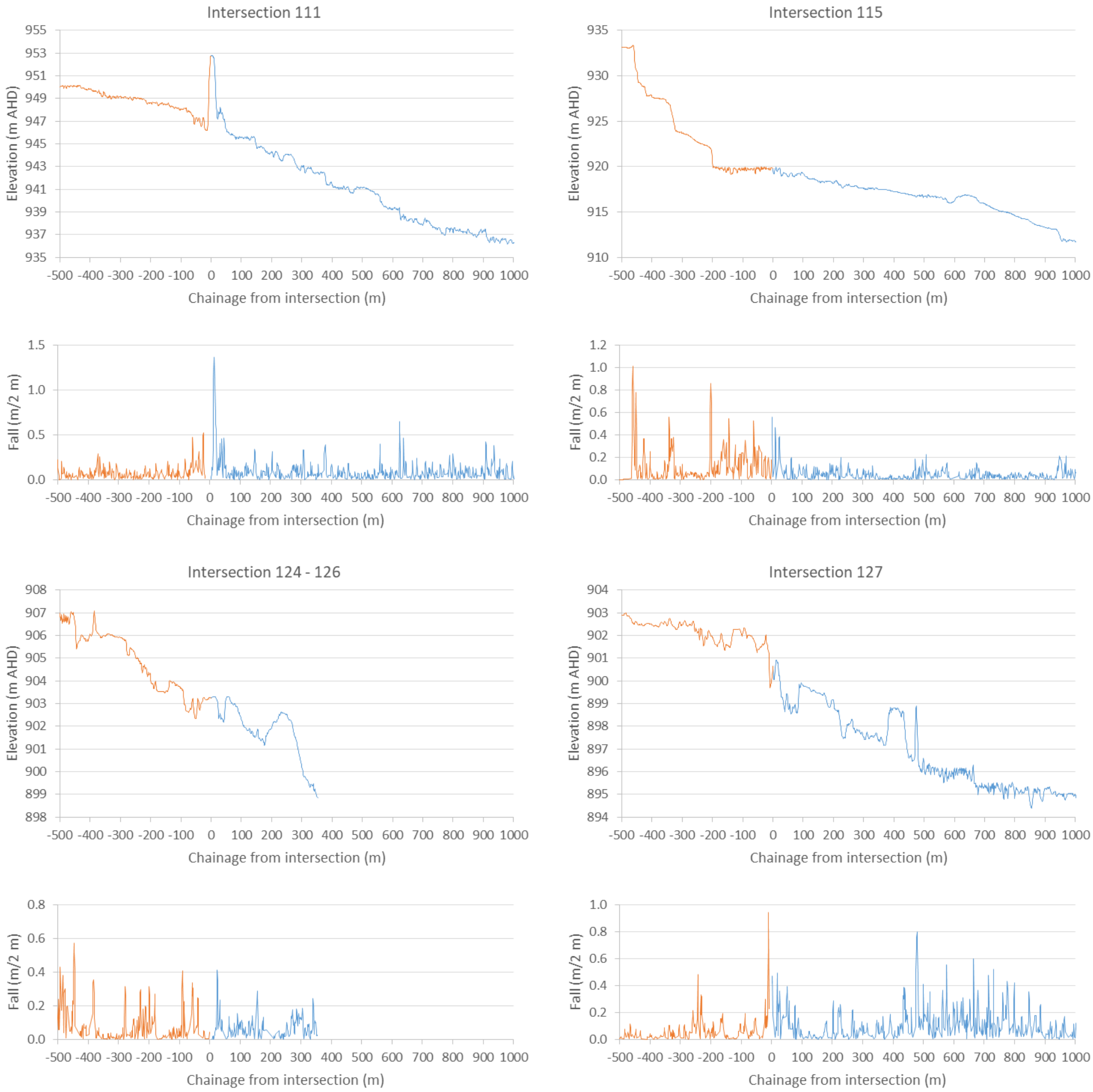


Figure 19. Long profiles of stream thalweg through intersections 111, 115, 124, 126 and 127.

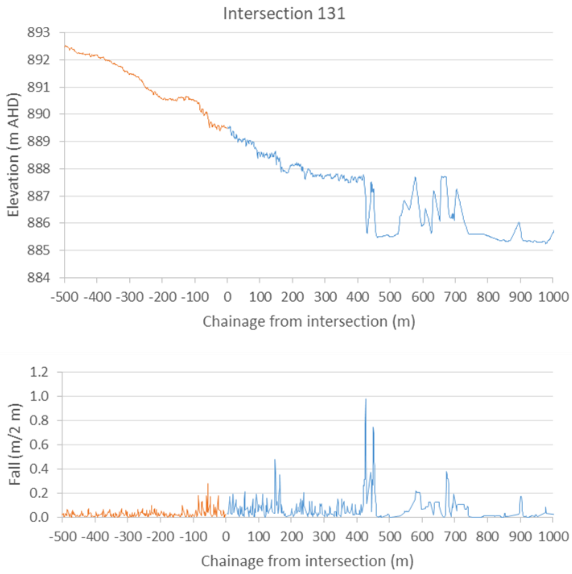


Figure 20. Long profile of stream thalweg through intersection 131.

9 Appendix 3. Site inspected watercourse intersections – ground photographs

Figure 21. Photographs of intersections 14, 16, 25 and 31

Figure 22. Photographs of intersections 45, 46, 50 and 59.

Figure 23. Photographs of intersections 64, 68, 70 and 76.

Figure 24. Photographs of intersections 87, 89, 100 and 103.

Figure 25. Photographs of intersections 111, 115, 126B and 131.

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