

Appendix 3

Surface Water Assessment - Updated

prepared by

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Part 6

Updated Surface Water Assessment

State Significant Development No. 5765

Prepared by:

WRM Water and Environment Pty Ltd

February 2022

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COMMONLY USED ACRONYMS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment Conservation Council
AWBM	Australian Water Balance Model
DECC	Department of Environment and Climate Change
DPIE	Department of Planning Industry and Environment
EC	Electrical Conductivity
ESC	Erosion and Sediment Control
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EP&A Act	Environmental Planning and Assessment Act
EPL	Environment Protection Licence
EV	Environmental Value
GCL	geosynthetic clay liner
GL	Gigalitres
ML	Megalitres
NAF	Non-acid forming
PAF	Potential-acid forming
PMP	Probable maximum precipitation
PZ	Primary Zone
ROM	Run-of-mine
SEARs	Secretary's Environmental Assessment Requirements
SILO	Scientific Information for Land Owners
TSF	Tailings Storage Facility
WAL	Water Access Licence
WRE	Waste Rock Emplacement
WSP	Water Sharing Plan

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EXECUTIVE SUMMARY

This Surface Water Assessment has been amended to assess the potential impacts of the Bowdens Silver Project's integrated water management and supply strategy. This strategy has been iteratively developed since public exhibition of the Project's Environmental Impact Statement and Specialist Consultant Studies Compendium to identify measures that reduce the Project's water demand via changes to operational and processing strategies and the inclusion of advanced dewatering of the open cut pit. This optimisation process has secured the Project's water supply by increasing the capacity to recover, recycle and re-use processing water. Additional basic landholder (harvestable) rights dams have also been incorporated into the Mine Site layout to capture stormwater runoff for dust suppression activities. However, water balance modelling has identified that the environmental outcomes and surface water impacts for the Project remain consistent with those predicted in the Environmental Impact Statement.

As the Project's water supply has been secured via on-site water sources, a key outcome of the optimisation process has been the removal of the previously proposed water supply pipeline. By removing the pipeline, the optimisation process has reduced the Project's environmental footprint.

In addition, updated modelling of the final void pit lake has been undertaken in light of recent Intergovernmental Panel on Climate Change publications. The implications of the updated final void pit lake and advanced dewatering on local and regional groundwater resources are considered in the Updated Groundwater Assessment (Jacobs, 2022).

The principal changes to this report from that which was placed on exhibition are therefore associated with the water balance modelling (operations and closure), the key features and operation of the site water management system and the flow regime of Lawsons and Hawkins Creeks (due to changes in the Updated Groundwater Assessment (Jacobs, 2022)).

However, the data sources, data ranges, potential surface water impacts of the Project and the regulatory paradigm by which these impacts are assessed remains unchanged from the original assessment.

Site Water Management

A conceptual design of the site water management system has been developed to manage potential impacts on surface water in the receiving environment within and around the Mine Site. The proposed system comprises three distinct water management zones: the containment zone, the erosion and sediment control (ESC) zone and the clean water zone, as described below.

- **Containment zone**

Groundwater seepage and surface runoff from the open cut pit areas, the tailings storage facility (TSF), processing plant area, oxide ore stockpile and waste rock emplacement (WRE) are likely to have elevated concentrations of dissolved metals. This water would be managed within a closed water management system.

Potentially acid forming (PAF) waste rock would be placed within the engineered WRE, overlain by a geosynthetic clay liner (GCL), compacted subsoil, forming (NAF) waste rock and a capping layer of topsoil and subsoil which would then be revegetated/rehabilitated. During operations, runoff from exposed PAF waste rock within the WRE, as well as WRE leachate would be conveyed to a dedicated leachate management dam via a buried pipeline.

To minimise water accumulating within the leachate management dam, the completed cells of the WRE would be progressively rehabilitated. In order to further reduce stored volumes, the WRE leachate, TSF decant and groundwater inflows to the open cut pits that would be captured within the containment system would be the first priority water source for recycling in processing operations.

- **ESC zone**

Runoff from areas disturbed by Project-related activities but outside of the containment zone, including the southern barrier and TSF NAF waste rock stockpile area, which would be constructed using NAF waste rock, would be directed to sediment dams. This would include surface runoff from out-of-pit areas situated within Blackmans Gully upslope of the southern barrier and downslope of the mine access road, which would be directed through the base of the southern barrier itself.

Bowdens Silver's long-term objective is to discharge as much water collected within the sediment dams to the downstream environment to assist in maintaining environmental flows.

It is anticipated that after the settlement of suspended sediment in these dams, the water would be suitable for release in accordance with the discharge conditions of the environment protection license (EPL) for the Project which would be issued by the NSW Environment Protection Authority (EPA). However, a program of water quality monitoring would be undertaken to characterise runoff from the NAF Waste Rock in the field. Discharges would not occur until it was confirmed that runoff water derived from the placed/stockpiled NAF waste rock is suitable for release, i.e. in accordance with the Project's EPL.

As a minimum, the sediment dams would be sized and operated in accordance with the NSW design guidance document "Managing Urban Stormwater, Soils and Construction, Volume 2E Mines and quarries" (DECC, 2008), (hereafter referred to as the "Blue Book") requirements for Type F sediment basins. However, if the ongoing program of geochemical testing and characterisation of runoff determines that the runoff must be contained on site to ensure the water source is not contaminated, sufficient storage capacity would be provided to minimise the likelihood of discharge by returning captured runoff to the Containment Zone.

- **Clean water zone**

A clean water diversion channel upslope of the mine access road is proposed to divert runoff from the upper catchment of Blackmans Gully into Price Creek during operations. This channel would largely follow the natural contours of the hill slopes and have a gentle gradient. At the end of operations, the channel would be decommissioned to return flow to Blackmans Gully.

Clean water diversion channels are also proposed to divert Blackmans Gully and its associated tributary catchments away from the main open cut pit both during operations and after mine closure. Two smaller satellite pits would be backfilled following the cessation of mining operations within them.

Site Water Balance

A daily timestep water balance model was used to assess the site water balance over the Project life under the range of historical rainfall and evaporation conditions.

The principal water use on the Mine Site would be the processing plant, which (including allowance for minor losses within the plant area) would require a total throughput of up to approximately 1 092 ML/a (3.0 ML/d). This requirement has been significantly reduced compared to the originally proposed plant demand, by incorporating dewatering of the tailings to a paste consistency before deposition into the TSF. As the proposed tailings paste would have a very low moisture content, tailings bleed water would be minimal.

Water would also be required for dust suppression on site haul roads and minor miscellaneous site water demands. Haul road watering demands would vary with haul road length and climate conditions, with average annual demands expected to range between 98 ML/a and 204 ML/a. Haul road water use would be minimised through the use of sealants for dust suppression.

While the processing plant is operating, average annual total site water demands would range between 1 092 ML/a (in Year 2) and 1 303 ML/a (in Year 9).

Advanced dewatering of the aquifers intersected by the open cut pit will enable groundwater to be used as a water supply in the early years of the Project. This advanced dewatering would occur via production bores that would provide up to 10 L/s and supply between 376 ML/a to 408 ML/a. During mining operations, (after allowance for pit face evaporation) residual groundwater inflows to the main open cut pit are expected to range between approximately 174 ML/a and 662 ML/a.

Clean water captured in basic landholder (harvestable) rights dams within Bowdens' landholding would be used as the primary supply source for dust suppression on out-of-pit haul roads. During dry periods, any dust suppression demand shortfall would be made up using groundwater sourced from advanced dewatering. This means that all demand for dust suppression would be met throughout the Project-life.

Groundwater and surface water collected in the main open cut pit would be used as the first preference for meeting processing plant water demands. Water captured in the water management system, including runoff water collected in the TSF decant pond would make up the remainder.

During processing operations, site water would be transferred to a proposed dedicated "turkey nest dam". When incoming supplies exceed demand (for example following wet weather), the excess would be transferred to the TSF for later reuse. Following prolonged wet weather, TSF excess water would be transferred from the TSF to the mine pit as a contingency action to prevent overflow.

The results of the site water balance model show that the Project can be reliably supplied over the full Project life. The modelled average volumetric supply reliability is 99.4% (and the reliability in the worst case 17 year project period is 94.9%)

The site water balance model shows that under historical conditions, water captured in the other parts of containment zone can be also contained without discharge or significant interruption to mining operations throughout the Project life. The model also suggests TSF spillway overflows would be avoided under historical climate conditions.

Impact on downstream water flows

There are two mechanisms whereby the Project could potentially impact on downstream surface water flow:

- Interception of runoff in the water management system

- Operational period

Water impacted by the mining activities and captured in the water management system would be contained within the Mine Site and re-used in processing operations (in the case of the containment zone) or in the case of the ESC zone, released, provided it meets EPL limits. However, Bowdens Silver may choose to also utilise the water stored in one or more of the sediment dams. This water, and that collected for dust suppression, would be stored under the maximum harvestable rights provisions of the NSW Water Management Act, 2000.

The catchment area of this containment system would vary over the Project life, and is expected to peak at 550 ha (comprising 300 ha in the TSF catchment and 250 ha in the remainder of the water management system) or 2.0% of the Lawsons Creek catchment (of 272 km² downstream of the Walkers Creek confluence) would be removed over the Project life. Based on the estimated average undisturbed area runoff in the local catchment, this equates to an average annual loss of flow of 177 ML/a.

It is proposed to divert part of the undisturbed upslope catchment of Blackmans Gully east to Price Creek. The effect of this diversion is to slightly increase streamflow in Price Creek and the reach of Hawkins Creek between the Price Creek and Blackmans Gully confluences. The area diverted is approximately 50 ha.

- Post Mine Closure

At the completion of mining operations, the WRE and the TSF would be capped and rehabilitated, so that runoff can be allowed to flow to the receiving environment once water quality allows. Thus, reinstating some of the catchment area removed during mining operations.

Flows from the upslope catchment of Blackmans Gully would be reinstated by decommissioning of the diversion to Price Creek.

The final landform would comprise a final void, which would capture runoff and incident rainfall from the immediate catchment. Modelling of the long-term behaviour of the final void lake shows that water would not overflow from the void. The catchment area of the final void after the completion of mining and rehabilitation would be approximately 53.1 ha or 0.2% of the Lawsons Creek catchment (of 272 km² downstream of the Walkers Creek confluence). Based on the estimated average undisturbed area runoff in the local catchment, this equates to an average annual loss of flow of 17 ML/a.

- Loss of baseflow contributions to streamflow due to impacts on the local groundwater profile

- Operational period

The groundwater assessment (Jacobs, 2022) predicts that drawdown of the groundwater table induced by groundwater inflow to the main open cut pit would result in a reduction in baseflow to both Hawkins Creek and Lawsons Creek.

The reduction in baseflow would increase during operations, as the development of the open cut pits progresses, near the conclusion of mining operations, the peak baseflow losses are expected to be up to approximately 0.026 ML/d (9.5 ML/a) and 0.014 ML/d (5.1 ML/a) for Hawkins Creek and Lawsons Creek respectively.

The peak baseflow losses from each creek do not coincide. The maximum predicted take from the Lawsons Creek Water Source, and therefore the volume of share components required to be held by Bowdens Silver as a water access licence issued under the Water Sharing Plan for Macquarie Bogan Unregulated and Alluvial Water Sources: Lawsons Creek Water Source (2012) during mining is 14.0 ML/a (Jacobs, 2022).

– Post mining

The reduction in baseflow would increase as the cone of drawdown grows, and is expected to peak approximately 11.5 to 16 years post mining at approximately 0.031 ML/d (11.4 ML/a) and 0.022 ML/d (8.1 ML/a) for Hawkins Creek and Lawsons Creek respectively.

The total average annual loss of flow from the Macquarie Bogan Unregulated and Alluvial Water Sources is estimated to be:

- Operational period (peak) – 189 ML/a; and
- Post mining – 35 ML/a.

In summary, the results show that the Project would not impact on:

- Hawkins Creek upstream of the cone of groundwater drawdown, which extends approximately 3.5 km upstream of the Mine Site;
- Lawsons Creek upstream of the Hawkins Creek confluence.

During operations, the maximum impact of the Project on downstream flow would decrease flows in:

- a 3.5 km section of Hawkins Creek extending upstream from the Lawsons Creek confluence by up to 4.5%;
- Lawsons Creek, between the Hawkins Creek confluence and upstream of the Walkers Creek confluence by up to 1.2%; and
- Lawsons Creek downstream of the Walkers Creek confluence by up to 2.2%.

Post mining, the maximum impact of the Project on downstream flow would decrease flows in:

- a 3.5 km section of Hawkins Creek extending upstream from the Lawsons Creek confluence by up to 1.4%;
- Lawsons Creek, between the Hawkins Creek confluence and upstream of the Walkers Creek confluence by up to 0.3%;
- Lawsons Creek downstream of the Walkers Creek confluence by up to 0.4%.

The relative impact on Lawsons Creek would reduce significantly with increasing distance downstream due to the contribution of other tributaries to total streamflow in Lawsons Creek.

Impact on Availability of Water to Downstream Surface Water Users

The Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources states that water must not be taken under an access licence when there is no visible flow or where an access licence permits take from an in river pool, when the volume in that pool is less than its full capacity.

The principal mechanism by which the Project would affect the quantity of water supplies available to other surface water users in the Lawsons Creek Water Source of the Macquarie Bogan Unregulated and Alluvial Water Sources is by reducing flows such that the frequency and duration of cease-to-flow periods is increased.

The impact of the Project on the frequency of flows greater than 1 ML/d (approximately 12 L/s), which occur about 81.0% of the time downstream of the Walkers Creek confluence, is expected to be negligible. Therefore, the impact of the loss on the availability of water to downstream water users would be negligible.

Impact on Downstream Water Quality

The proposed engineered mitigation and management measures (i.e. liners, capping and cover systems) proposed for storing and encasing the tailings and PAF waste rock have been designed (see ATCW [2020], Advisian [2020a, 2020b]) to be effective in limiting seepage and managing leachate. The receiving waters are therefore unlikely to be impacted by the tailings or PAF waste rock either during operations or after closure and decommissioning of the Project.

Geochemical assessment of NAF suggests it would likely be relatively benign. During operations, runoff from the TSF outer embankment, WRE and southern barrier is to be captured and treated in sediment dams sized in accordance with Bluebook requirements for Type F basins (DECCW, 2008) before offsite release under the EPL. However, based on the testing of leachate from kinetic testing of NAF waste rock samples, there is a possibility that runoff and seepage from NAF would contain dissolved metals.

The southern barrier would be decommissioned during closure and rehabilitation activities, leaving the outer embankment of the TSF, which would be vegetated once the 3rd embankment raise has been completed, and the vegetated store-and-release cover of the WRE as potential sources of NAF runoff. Sediment dams would remain in place until vegetative cover was sufficiently established to control erosion from these areas.

A site water quality monitoring plan would be implemented during operations to verify that the captured water quality is suitable for off-site release in accordance with the conditions of an EPL, and to monitor receiving water conditions. It is proposed to continue the current ambient water quality monitoring program at the existing locations, and in on-site sediment dams located at release points. If water quality is found to be unsuitable for release during operations (outside the EPL limits) sediment dams would be dewatered and the water re-used for dust suppression.

Potential Impacts on Flooding

A detailed flood impact assessment was carried out for the Project.

Key points with regards to predicted peak flood levels and depths across the model domain are summarised below:

- The Project disturbance area is located outside of the predicted Lawsons Creek flood extent for all events up to the probable maximum precipitation (PMP) design event.
- The area along the southeastern Mine Site boundary is affected by flooding from Hawkins Creek. However, the proposed open cut pit, WRE and leachate management dam are located outside of the predicted flood extent for Hawkins Creek for all design events.
- Flooding along the Hawkins Creek and Lawsons Creek tributaries within the Mine Site is characterised by shallow overland flows. Flows in these tributaries are generally confined within narrow flood flow paths, with no breakouts occurring except near the confluences of these tributaries with Hawkins and Lawsons Creeks. Due to the narrow flood flow paths, the difference in predicted flood extents along these tributaries between the 1% Annual Exceedance Probability (AEP) and PMP design events is not significant.
- Predicted peak flood depths along the overbank areas of the Hawkins and Lawsons Creek tributaries are generally below one metre for events up to and including 0.2% (1 in 500) AEP. Peak flood depths of up to 1.5 m for the PMP design event are predicted in some sections along these tributaries.

Key points with regards to predicted peak velocities within the model domain are summarised below:

- Flows in the Hawkins and Lawsons Creeks tributaries are generally confined within narrow flood flow paths with relatively steep ground slopes. This results in relatively high predicted peak flood velocities of up to 2.5 m/s along the channel and overbank areas of these tributaries for events up to and including 0.2% AEP. The proposed mine infrastructure would increase flood velocities in localised areas, and mitigation works would be required to manage erosion risks along the lower perimeter embankment of the WRE during operations and after mine closure. Where necessary, mitigation measures for managing the risk of erosion where velocities are increased, such as the appropriate size of rock armouring on the floodplains of Hawkins and Lawsons Creeks would be developed during detailed design to ensure minimal scour in the 10% AEP flood.
- Existing peak flood velocities in Hawkins Creek for events up to and including 0.2% AEP are generally less than 3 m/s, with peak velocities greater than 4 m/s predicted in some sections. The Project results in some redistribution of tributary inflows to Hawkins Creek, and as a result there would be a minor increase (less than 0.1 m/s) in flood velocities immediately adjacent to the Mine Site. Some areas on the margins of the floodplains would experience reductions in flow velocity. However, the areas affected are small, and would not result in any significant reduction in the transport of sediment.
- Existing peak flood velocities in Lawsons Creek are relatively high for all modelled events. For events up to and including 0.2% AEP, peak flood velocities greater than 4 m/s are predicted in many sections along the Lawsons Creek channel and floodplain. The proposed mine infrastructure would have minimal impact on Lawsons Creek flood velocities.

In summary, the works associated with the proposed WRE would result in localised minor flood level increases. The more significant flood level impacts are constrained to within the lease, and would not result in significant impacts to other properties, assets or infrastructure. The proposed WRE would also locally increase flood velocities in its immediate vicinity. Local scour protection measures would need to be developed during detailed design to mitigate the potential erosion impacts in this area. Any expected increases in flood velocities in Hawkins Creek and Lawsons Creek are negligible and would not adversely impact offsite property or infrastructure.

Following public exhibition of the EIS and consultation with relevant NSW Government agencies (DPIE-Water and NRAR), Bowdens Silver investigated and adopted a bridge crossing of Lawsons Creek as part of the proposed relocation of Maloneys Road. Key points with regards to flood conditions at the proposed relocated Maloneys Road crossing of Lawsons Creek are summarised below.

- The bridge crossing would provide conveyance in the main Lawsons Creek channel up to 5% AEP (bankfull discharge) and with 0.3 m freeboard.
- The predicted increase in peak flood levels upstream of the crossing would be localised and within 550 m of the proposed crossing.
- Breakout flows in the northern overbank area would be conveyed by box culverts under the road. These overflows would drain to the northwest parallel to Lawsons Creek before re-joining Lawsons Creek downstream of the proposed crossing.
- The predicted increases in peak flood levels and flood extents would not affect any existing dwellings. It is noted that Bowdens Silver owns all properties that are predicted to be affected by an increase in flood levels.
- The crossing would be designed to manage the risk of scour induced by increased velocities, for example through the use of dumped rock or other erosion protection measures.

Final Void Pit Lake Behaviour

Based on the proposed open cut pit design, the final void would be up to 141 m deep, with a floor level of 456 mAHD and an overflow level of approximately 597 mAHD. The total potential storage volume to this elevation is approximately 22 GL.

A daily timestep water balance model was prepared for the final void pit lake which would form in the main open cut pit. The model used estimates of long-term groundwater inflows derived as part of numerical modelling undertaken to inform the groundwater assessment for the Project. Permanent clean water diversions would be provided to minimize the catchment runoff draining to the void. Climate-change adjusted climate data developed as part of the Queensland Government Department of Environment and Science (DES) Consistent Climate Scenarios (CCS) project were used for the analysis. The analysis was based on the most conservative carbon emission rate (RCP8.5) available in the CCS dataset, and expected climate as at 2070. The findings of the analysis were as follows.

- Under the existing (HI.H) climate scenario (which yields equilibrium water levels closest to the average of all CCS scenarios) - the modelled water level reaches around 570 mAHD after 100 years and varied in a 7 m band (from 565 mAHD to 572 mAHD) throughout the remainder of the simulation.

- The maximum modelled water level was below 572 mAHD – or about 25 m below the void overflow level of 597 mAHD.
- Under the modelled climate change scenarios, the equilibrium water level would be lower than the existing (SILO) climate scenario (peak water level 574.5 mAHD).. Over the period of simulation, the average groundwater inflow is 112 ML/a (ranging between approximately 0.2 ML/a and 166 ML/a). Direct rainfall averages 188 ML/a, and runoff contributes 50 ML/a on average. These inflows are balanced by average evaporation of 350 ML/a.
- On the basis of the analysis the final void would not overflow to the surface and remain a groundwater sink post-mining.

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1. INTRODUCTION

1.1 BACKGROUND

Bowdens Silver Pty Limited (Bowdens Silver) is seeking approval to develop and operate an open cut silver mine near Lue, NSW (the Project). The Mine Site is located approximately 26 km east of Mudgee, NSW and is currently an undeveloped site. **Figure 1.1** shows the location of the Mine Site.

R.W Corkery & Co. Pty Limited (R.W. Corkery & Co), on behalf of Bowdens Silver, commissioned WRM Water & Environment Pty Ltd (WRM) to undertake a surface water assessment forming part of the Environmental Impact Statement for the Project.

This report addresses the Secretary's Environmental Assessment Requirements for the Project, as they relate to surface water. In particular this report consolidates the results of the following assessments:

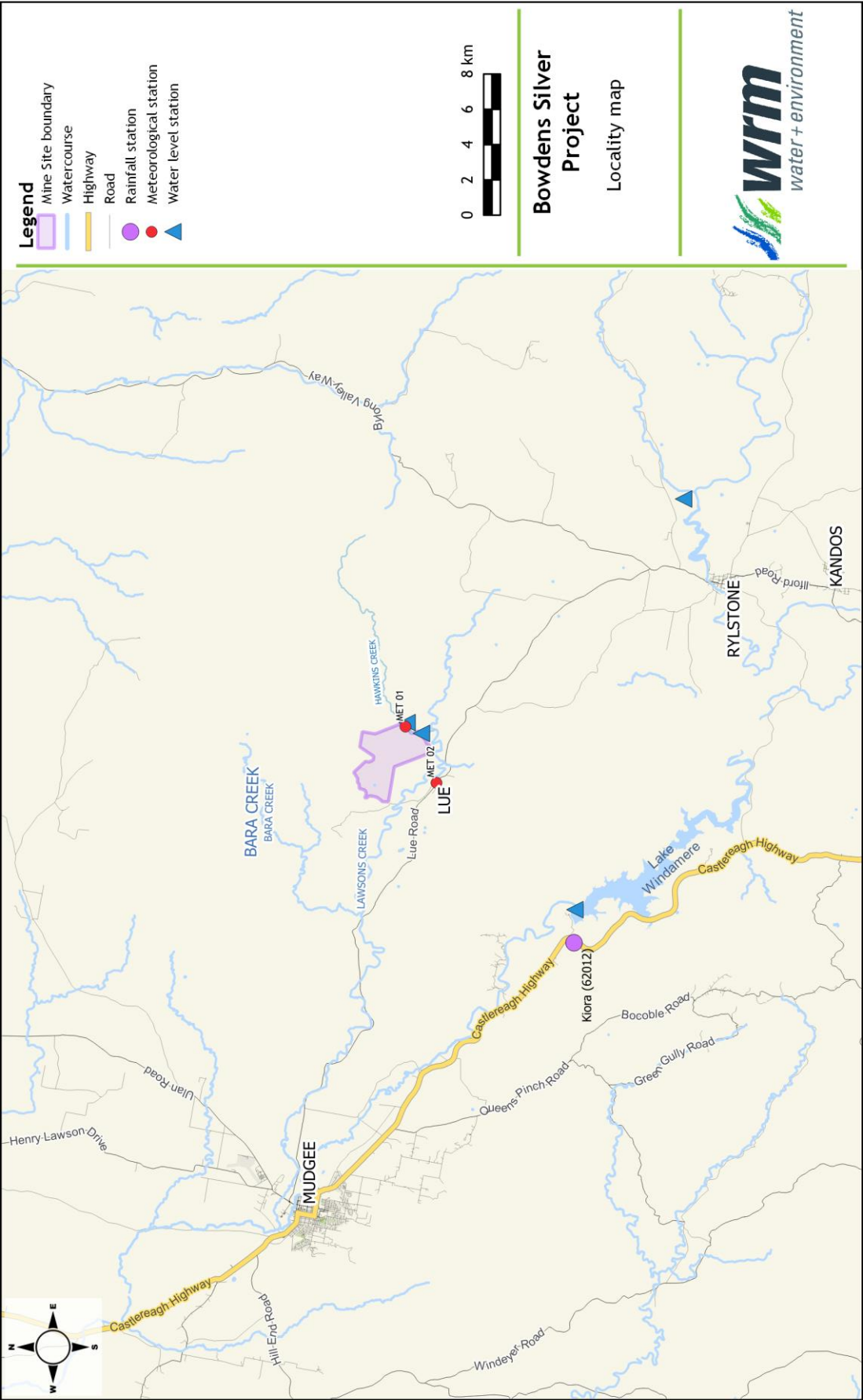
- A baseline assessment of the geomorphological condition of watercourses within the project area (R.W. Corkery & Co, 2020) (**Annexure A**);
- A baseline water quality assessment (R.W. Corkery & Co, 2020) (**Annexure A**);
- A flood impact assessment (**Annexure B**);
- A detailed and consolidated site water balance (Section 5);
- An assessment of the impact of the Project on water resources – especially in the adjacent reaches of Hawkins Creek and Lawsons Creek, in terms of water quality and quantity.

This Surface Water Assessment has been amended to assess the potential impacts of the Bowdens Silver Project's integrated water management and supply strategy. This strategy has been iteratively developed since public exhibition of the Project's Environmental Impact Statement and Specialist Consultant Studies Compendium to identify measures that reduce the Project's water demand via changes to operational and processing strategies and the inclusion of advanced dewatering of the open cut pit. This optimisation process has secured the Project's water supply by increasing the capacity to recover, recycle and re-use processing water. Additional basic landholder (harvestable) rights dams have also been incorporated into the Mine Site layout to capture stormwater runoff for in dust suppression activities. However, water balance modelling has identified that the environmental outcomes and surface water impacts for the Project remain consistent with those predicted in the Environmental Impact Statement.

As the Project's water supply has been secured via on-site water sources, a key outcome of the optimisation process has been the removal of the previously proposed water supply pipeline. By removing the pipeline, the optimisation process has reduced the Project's environmental footprint.

In addition, updated modelling of the final void pit lake has been undertaken in light of recent Intergovernmental Panel on Climate Change publications. The implications of the updated final void pit lake and advanced dewatering on local and regional groundwater resources are considered in the Updated Groundwater Assessment (Jacobs, 2022).

Figure 1.1 Locality Plan



The principal changes to this report from that which was placed on exhibition are therefore associated with the water balance modelling (operations and closure), the key features and operation of the site water management system and the flow regime of Lawsons and Hawkins Creeks.

However, the data sources, data ranges, potential surface water impacts of the Project and the regulatory paradigm by which these impacts are assessed remains unchanged from the original assessment.

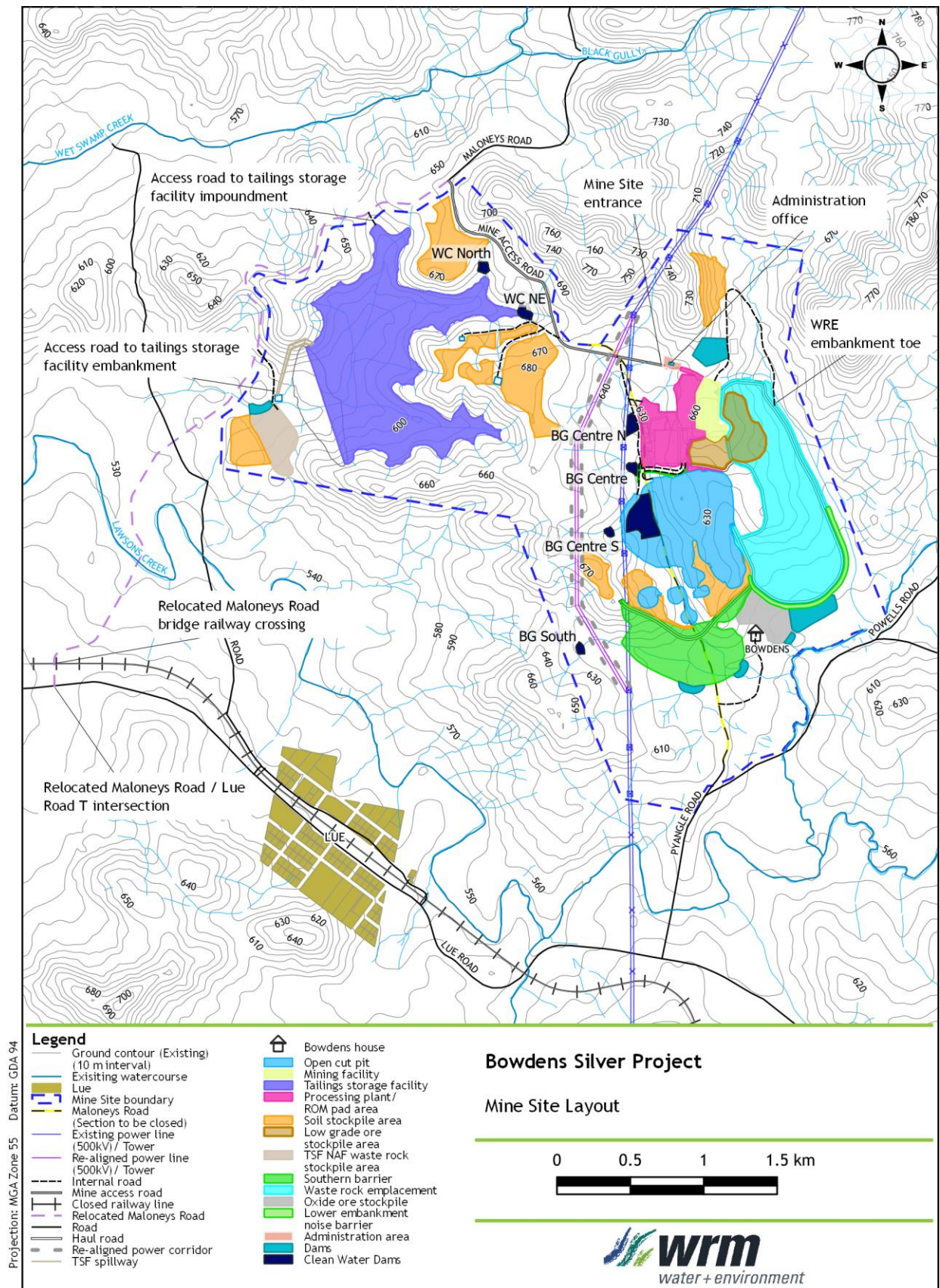
1.2 PROJECT DESCRIPTION

Figure 1.2 shows the proposed Mine Site layout. The seven principal components within the Mine Site are:

- i) a main open cut pit and two satellite open cut pits, collectively covering approximately 52ha;
- ii) a processing plant and related infrastructure covering approximately 22ha;
- iii) a waste rock emplacement (WRE) covering approximately 77ha;
- iv) a low grade ore stockpile covering approximately 14ha (9ha above WRE);
- v) an oxide ore stockpile covering approximately 8ha;
- vi) a tailings storage facility (TSF) covering approximately 117ha; and
- vii) the southern barrier to provide visual and acoustic protection to properties south of the Mine Site covering approximately 32ha.

The above components would be supported by a range of on-site and off-site infrastructure. The on-site infrastructure comprises haul roads, water management structures, power/water reticulation, workshops, stores, compounds and offices/amenities. The off-site infrastructure comprises a relocated section of Maloneys Road (including a new railway crossing and new crossing of Lawsons Creek).

Figure 1.2 Mine Site Layout



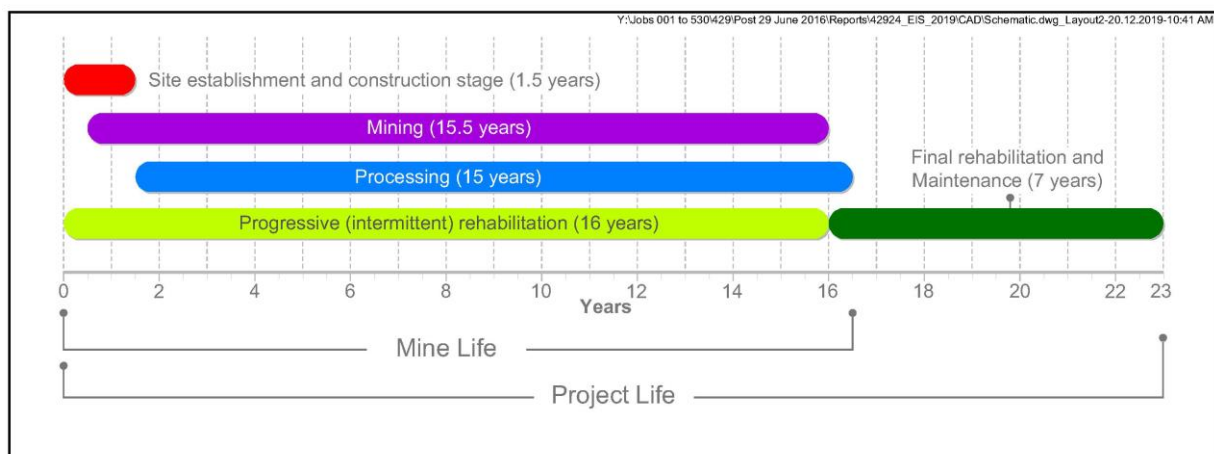
Mining would be undertaken using conventional open cut drill and blast, load and haul mining methods. This would involve the sequential removal/storage or mulching of vegetation, the removal and stockpiling of topsoil and subsoil, the removal and placement or stockpiling of waste rock and the recovery of ore.

Development of the main open cut pit would commence during the site establishment and construction stage with vegetation clearing, followed by the stripping and stockpiling of topsoil and subsoil. This stage is referred to as the open cut pit pre-strip. Emphasis would be placed in this stage upon the recovery of sufficient non-acid forming (NAF) waste rock (WZ1) for the construction of the initial TSF embankment, WRE perimeter embankments and the leachate management dam and ancillary mine infrastructure as well as the accumulation of sufficient ore on the run-of-mine (ROM) pad to enable the processing plant to be commissioned. Excess NAF waste rock extracted during this period would also be used for construction of the initial barrier of the southern barrier.

Any low-grade ore recovered during this stage would be transported by haul truck to the low-grade ore stockpile area that would be located immediately to the east of the ROM pad. During the open cut pit pre-strip, all potential acid forming (PAF) waste rock would be recovered and transported by haul truck and placed in the first cell of the WRE.

The Project would also involve construction of a relocated section of Maloneys Road that would provide access to the Mine Site from an intersection that would be located west of Lue. The relocated Maloneys Road would cross Lawsons Creek and effectively replace 4.5 km of the existing Maloneys Road that would be closed to the public to allow for the development of the Mine Site and mine access road.

The Project would require a site establishment and construction period of approximately 18 months during which the processing plant and all related infrastructure and the initial embankment of the TSF would be constructed. Once operational, Bowdens Silver anticipates the mine would produce concentrates for approximately 15 years. In total, it is proposed the mine life would be approximately 16.5 years, i.e. from the commencement of the site establishment and construction stage to the completion of concentrate production. It is envisaged rehabilitation activities would be completed over a period of approximately 7 years, i.e. from Year 16 to Year 23. The graphic below displays the duration of each of the main components throughout the mine life and Project life.



2. SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS FOR EIS – SURFACE WATER

All mining projects in NSW must be assessed under the Environmental Planning and Assessment Act 1979 (EP&A Act 1979).

The Project is classified as a State Significant Development (SSD) in accordance with the State Environmental Planning Policy (State and Regional Development) 2011.

An Environmental Impact Statement must be prepared in response to the requirements set out by the Secretary of the NSW Department of Planning, Industry and Environment (DPIE). These requirements are known as the Secretary's Environmental Assessment Requirements (SEARs).

The SEARs for the Project (SSD7565), were originally issued to Bowdens Silver by the then NSW Department of Planning and Environment on 23 December 2016 and have most recently been updated on 21 June 2019. The SEARs are prepared in consultation with relevant State and local government agencies and take into consideration concerns and issues raised by community groups and individuals. The key issues identified in the SEARs, government agency correspondence, and the Lue and district community relating to surface water are provided in **Table 2.1**, which also identifies the relevant section(s) where the issues have been addressed in this report.

Table 2.1
Coverage of SEARS and other requirements for the Project – Surface Water

Page 1 of 8

Relevant Requirement	Coverage
The EIS must include an assessment of:	
the likely impacts of the development on the quantity and quality of the region's surface and groundwater resources (including but not limited to, Lawsons Creek and Price Creek), having regards to EPA's, DPI's and OEH's requirements; and	Section 8
- the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure and other water users, including: - a detailed site water balance, including an assessment of the reliability of water supply imported to the site, and management of excess water, supported by sensitivity analysis; and	Section 8 Section 5
an assessment of the water quality and management of the imported water, including spill/leak management.	No longer applicable
Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources	Section 8
NSW State Rivers and Estuary Policy (NOW)	By others
NSW Government Water Quality and River Flow Objectives (EPA)	By others
Water Quality Objectives in NSW (EPA)	Section 3.1
ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ)	Section 3.7 (superseded by ANZG (2018))
National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ)	Section 9.2
Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA)	Section 9.2

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 2 of 8

Relevant Requirement		Report Section
Managing Urban Stormwater: Soils & Construction Volume 2E (DECC, 2008)		Section 4.6.2
Floodplain Development Manual (OEH)		Section 6.2
Floodplain Risk Management Guideline (OEH)		Section 3.6
Relevant Requirements Nominated by Other Government Agencies		
Water – General		
Department of Primary Industry – Water	Details of the water to be taken (including through inflow and seepage) from each surface and groundwater source as defined by the relevant water sharing plan.	Sections 8 and 5.4
	Assessment of any volumetric water licensing requirements (including those for ongoing water take following completion of the project such as evaporative loss from open voids or inflows).	Section 8
	The identification of an adequate and secure water supply for the life of the project. Confirmation that water can be sourced from an appropriately authorised and reliable supply. This is to include an assessment of the current market depth where water entitlement is required to be purchased.	Section 8
	Applicability of any exemptions under the Water Management (General) Regulation 2011 to the project	Section 8.1.2
	A detailed and consolidated site water balance	Section 5
	An assessment of impacts on surface and groundwater sources (both quality and quantity), related infrastructure, adjacent licensed users, basic landholder rights, watercourses, riparian land and groundwater dependent ecosystems and measures proposed to reduce and mitigate these impacts	Section 8 and Jacobs (2022)
	Full technical details and data of all surface and groundwater modelling and an independent peer review.	Section 5 and Annexure C
	Proposed surface and groundwater monitoring activities and methodologies.	Section 9
	Proposed management and disposal of produced or incidental water.	Section 4
	Details surrounding the final landform of the site, including final void management (where relevant) and rehabilitation measures.	Section 7
	Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts.	Section 8
	Consider relevant Legislation, Water Sharing Plans, Policies and Guidelines.	Section 8
	Legislation	
	<i>Water Management Act 2000 (WMA) and Water Act 1912. In particular, Objects (s.3) and Water Management Principles (s.5) of the WMA.</i>	Section 8

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 3 of 8

Relevant Requirement		Report Section
Relevant Requirements Nominated by Other Government Agencies (Cont'd)		
Water – General (Cont'd)		
Department of Primary Industry – Water (Cont'd)	Water Sharing Plans	
	Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources	Section 8
	The EIS is required to include the following issues relating to water:	
	Identify water demand and determine whether an adequate and secure water supply is available for the Project;	Sections 5.2 and 5.4
	Identify water sources (surface and groundwater), water disposal/discharge methods and water storage structures in the form of a detailed and consolidated water balance.	Sections 4.2, 4.7.1, 4.6.1, 4.6.2, 5 and 8.7
DPI – Water & NRAR	Assessment of any potential cumulative impacts on water resources, and any proposed options to manage the cumulative impacts	Not Applicable
	The identification of an adequate and secure water supply for the life of the project.	Section 4.2
	A detailed and consolidated site water balance.	Section 5
	Assessment of impacts on surface and ground water 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.	Section 8 and Jacobs (2022)
	Proposed surface and groundwater monitoring activities and methodologies.	Sections 9.2 and 9.3
Environment Protection Authority	Describe the proposal including position of any intakes and discharges, volumes, water quality and frequency of all water discharges.	Section 5.4
	Demonstrate that all practical options to avoid discharge have been investigated and implemented and outline measures that have been taken to reduce the pollutant load of the discharge so that the environmental impact minimised where a discharge is necessary.	Sections 4.6.1, 4.6.2, 4.4.2.1, 4.4.2.3 and 4.7.7
	Provide a water balance...including water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options.	Section 5
	If the discharge requires treatment prior to disposal, any treatment measures should be described and the predicted water quality outcomes documented. Include a detailed process diagram/flowchart of the proposal specifying all water inputs, outputs and discharge points.	Section 4.7
	Describe the existing surface and groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the project.	Section 3.7
	Where the proponent intends to undertake the assessment using site specific water quality trigger values, detail the water quality of a reference site that has been selected based on the site specific considerations outlined in ANZECC (2000).	Annexure A (Section 1.1)

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 4 of 8

Relevant Requirement		Report Section
Relevant Requirements Nominated by Other Government Agencies (Cont'd)		
Water – General (Cont'd)		
Environment Protection Authority (Cont'd)	State the Water Quality Objectives for the receiving waters relevant to the proposal...Where groundwater may be impacted the assessment should identify appropriate groundwater environmental values	Annexure A (Section 2.2)
	State the indicators and associated trigger values or criteria for the identified environmental values.	Annexure A (Section 2.3)
	State any locally specific objectives, criteria of targets which have been endorsed by the NSW Government.	Annexure A (Sections 2.1, 2.2 and 2.3)
	Provide detailed water management strategies for all disturbance areas, paying particular attention to the waste rock emplacement areas and potential impacts to groundwater and off site surface water resources including particular reference to the management of channel and overland flows into and within the disturbance area.	Section 4
	Describe how predicted impacts on surface water, groundwater and aquatic ecosystems would be monitored and assessed over time, including monitoring locations, relevant parameters and sampling frequency. The EIS should:	Section 9.2
	• Include a ... response management plan, to identify appropriate trigger values and criteria and provide appropriate response actions if impacts are identified through the monitoring program.	Annexure A (Section 9.5)
	• Identify the process for identifying any trends in the monitoring data obtained.	Annexure A
Office of Environment and Heritage	The EIS must map the following features relevant to water ... including: • Rivers, streams, wetlands, estuaries (as described in Appendix 2 of the Framework for Biodiversity Assessment).	Section 3
	• Proposed intake and discharge locations.	Section 4.7
	The EIS must describe background conditions for any water resource likely to be affected by the development, including: • Existing surface and groundwater.	Section 3
	• Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	Sections 4.6.2 and 5.5
	• Water Quality Objectives (as endorsed by the NSW Government including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Annexure A (Section 2.2)
	• Indicators and trigger values/criteria for the environmental values identified 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	Annexure A (Section 2.3)

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 5 of 8

Relevant Requirement		Report Section
Relevant Requirements Nominated by Other Government Agencies (Cont'd)		
Water – General (Cont'd)		
Office of Environment and Heritage (Cont'd)	The EIS must assess the impacts of the development on water quality, including: The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water Quality Objectives over time where they are currently not being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.	Sections 4.6.1 and 8
	Identification of proposed monitoring of water quality	Section 9.2
NSW Division of Resources & Energy 23/01/15 Department of Resources and Energy 23/12/16	Assess surface water flow and flooding regimes and how these will be impacted and mitigated by the project both during and after mining has ceased. This is to include an evaluation of potential impacts from the final void on both surface and groundwater quality and flow regimes	Section 7
	Where a void is proposed to remain as part of the final landform, include...outcomes of the surface and groundwater assessments in relation to the final water level in the void. This should include an assessment of the potential for fill and spill along with measures required to be implemented to minimise associated impacts to the environment and downstream water users.	Section 7
Mid-Western Regional Council 15/01/15	The assessment clearly identifies the source of water, amount required and proposed method of reticulation to the mine site.	Sections 4.2 and 5.2
Water – Surface Water		
Department of Primary Industry – Water 19/12/14	Identification of all surface water sources as described by the relevant water sharing plan.	Section 8
	Identification of all surface water features including watercourses, wetlands and floodplains transected by or adjacent to the proposed project.	Section 3
	Scaled plans showing the location of: Wetlands/swamps, watercourses and top of bank;	Annexure A Figure 3
	Existing riparian vegetation surrounding the watercourses (identifying any areas to be protected or proposed to be removed);	SCSC Part 10
	The site boundary, the footprint of the proposal in relation to the watercourses and riparian areas; and	Figure 3
	Geomorphic and hydrological assessment of watercourses including details of stream order (Strahler system), river style and energy regimes both in channel and on adjacent floodplains.	Annexure A (Sections 1.5.3, 1.6.3 and 2.6.3) Annexure B
	Information on the purpose, location, construction and expected annual extraction volumes including details on all existing and proposed water supply works which take surface water	Section 4.7

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 6 of 8

Relevant Requirement		Report Section
Water – Surface Water (Cont'd)		
Department of Primary Industry – Water (Cont'd) 19/12/14	Details on existing dams/storages (including date of construction, location, purpose, size and capacity) of any proposal to change the purpose of existing dams/storages	Not Applicable
	Details on the location, purpose, size and capacity of any new proposed dams/storages.	Section 4.7
	Details of all works and surface infrastructure that will intercept, store, convey or otherwise interact with surface water resources	Section 4.7
	An assessment of the impacts to existing surface water systems in terms of potential modifications to natural ecological, hydrological and hydraulic function and potential impacts to local water users and the environment. This needs to be addressed for both during and post mine life with the use of stabilised landforms and mitigation of impacts.	Section 8
Environment Protection Authority 14/05/19	Describe any drainage lines, creeks lines etc. that will be impacted by the Project.	Section 3
	Assessment for discharge to surface waters guided by using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006).using local Water Quality Objectives determined from the NSW Water Quality and River Flow Objectives (DEC, 2006). Demonstrate how the Project will be designed and operated to: • protect the Water Quality Objectives for receiving waters where they are currently being achieved; and • contribute towards achievement of the Water Quality Objectives over time where they are not currently being achieved.	Section 8.8
	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.	Section 8
	Identify whether any discharge, or the location of the Project, will cause erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Section 8
	Describe how stormwater will be managed both during and after construction including a layout of the proposed stormwater system in accordance with Managing Urban Stormwater, Volume 2E (DECC, 2008), The EIS should:	Section 4
	• Provide the proposed general location of all water management structures. ... Clearly indicated on appropriately scaled maps.	Figures 4.4 to 4.7
	• Demonstrate how clean, dirty and contaminated water will be managed (separated) on site throughout the life of the Project.	Section 4
	• Provide detailed water management strategies for all disturbance areas including the management of channel and overland flows into and within the disturbance area.	Section 4
	• Provide the proposed sizing of all water storage dams, sediment dams and other dams as required and justification for the sizing utilised.	Section 4.7

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 7 of 8

Relevant Requirement		Report Section
Water – Surface Water (Cont'd)		
Environment Protection Authority (Cont'd) 14/05/19	Identify contingency measure which may be implemented during extreme rainfall events.	Section 9
	Where the management of sediment basins requires the use of flocculants, the EIS should include information about the type, toxicity and management of flocculants proposed to treat captured water before discharge.	TBA
	Provide plans for any proposed relocation/realignment of all creeks and/or drainage lines including design, timelines and completion criteria and sufficient evidence to demonstrate that the proposed plans are achievable/sustainable, reasonable and feasible in the short and the long term.	To be included in Water Management Plans
Office of Environment and Heritage 14/05/19	The EIS must assess the impact of the development on hydrology, including: Water balance including quantity, quality and source.	Section 5
	Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas.	Section 8
	Changes to environmental water availability, both regulated/licensed and unregulated/rules based sources of such water.	Section 8
	Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.	Section 8
	Identification of proposed monitoring of hydrological attributes.	Section 9
Water – Flooding		
Office of Environment and Heritage 13/12/16	The EIS must map the following features relevant to flooding as described in the NSW Floodplain Development Manual 2005 including: - Flood prone land. - Flood planning area, the area below the flood planning level. - Hydraulic categorisation (floodways and flood storage areas). - Flood hazard.	Annexure B
	The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.	Section ,6 Annexure B
	The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios: Current flood behaviour for a range of design events as identified above. This includes the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 6, Annexure B

Table 2.1 (Cont'd)
Final SEARS for the Project – Surface Water

Page 8 of 8

Relevant Requirement		Report Section
Water – Flooding (Cont'd)		
Office of Environment and Heritage (Cont'd) 13/12/16	Modelling in the EIS must consider and document: - The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. - Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories. - Relevant provisions of the NSW Floodplain Development Manual 2005.	Section 6, Annexure B
	EIS must assess the impacts on the proposed development on flood behaviour, including: Whether there will be detrimental increases in the potential flood affection of other properties, assets and infrastructure.	Section 6, Annexure B
	Consistency with Council floodplain risk management plans.	No Plans Exist
	Compatibility with the flood hazard of the land	Section 3.6
	Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	Section 6, Annexure B
	Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Sections 6.2, 6.3 and Annexure B
	Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council.	Section 6, Annexure B
	Whether the proposal incorporates specific measures to manage risk to life from flood.	EIS Section 4.7
	These matters are to be discussed with the SES and Council.	EIS Section 4.7
	Emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES.	EIS Section 4.7
	Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	EIS Section 4.7

Table 2.2
Additional Information Requests from Lue and District Community

Page 1 of 2

Issue(s)	Coverage in Report
Baseline levels in groundwater and surface water of metals e.g. arsenic and pH.	Annexure A (Sections 2.4 to 2.6)
The need for clean water (meeting potable drinking water guidelines) for the production of extra virgin olive oil.	Location is upstream - Unaffected by surface water runoff
Waste water containment procedures, including tailings storage facility design, based on applicable criteria including material selection and protocols to accommodate significant environmental events.	Section 4.6
Impact to water supply of Windamere Dam arising from sourcing water from the Cudgegong River system. Reference given to drought management water plans.	Windamere Dam is upstream in another catchment - unaffected by surface water runoff
Tailings Storage Facility capacity to prevent overflow and contamination of downstream waterways.	Section 4.7.9
Consider ANZFA food safety guidelines re use of potable water in the processing of extra virgin olive oil.	Location is upstream - unaffected by surface water runoff
Consider the responsibility for the potable drinking water in the town of Lue and surrounding area.	Drinking water is not drawn from the creek system
Potable water supplies for the Rylstone Australian Olive Oil processing plant, situated at Monivae, 8km southeast of Lue.	Location is upstream - unaffected by surface water runoff
Will tailings/water storage dams reduce the flow of water into creeks and rivers downstream.	Yes - Section 8
Effect of the mine to runoff water.	Section 8
When did monitoring of surface water commence? Is this sufficient data to base modelling on?	Section 3.7
What impact will mine water use have on the town's water supply?	None
Will mining activities result in the drawdown of surface water?	Section 8
Where does Bowdens Silver propose to source water during the developmental and operational phases of the Project? Is this sustainable?	Section 4
Will water be sourced from Dunns Swamp?	No
What is the daily consumption projection for water that Bowdens Silver will need during operations?	Section 5.2
How much water will be diverted around the mine?	Section 4.6.3
How much water will be prevented from entering the natural system (i.e. Lawsons Creek)?	Section 8
I rely on Lawsons Creek for stock watering – will mining result in reduced flow and access?	Section 8.5
Have studies been conducted on potential impacts on the Lawsons Creek catchment?	Section 8
Surface water supplies are already unreliable – how will the mine impact us?	Section 8
What contingencies are in place if Bowdens Silver causes reduced flows in Lawsons Creek?	None proposed

Table 2.2 (Cont'd)
Additional Information Requests from Lue and District Community

Page 2 of 2

Issue(s)	Coverage in Report
Will diverted water remain within the same catchment or be diverted to another catchment?	No out-of-catchment diversions
Will water quality be impacted by mine runoff?	Section 8
Will the mine cause reduced flows on neighbouring properties?	Section 8
What impacts will mining activities have on surface water quality?	Section 8
What is the area of impact for surface water?	Section 7 and 8
What parameters will be monitored (e.g. pH, metals) and what kind of changes to water quality could potentially occur?	Sections 8 and 9
Will background surface water quality data include concentrations of lead and other heavy metals?	Section 9
What are the potential impacts of mining on Lawsons Creek and what measures will be put in place to prevent potentially contaminated water entering the creek?	Section 8
How will you prevent cyanide from entering Lawsons Creek and affecting my water supply?	Section 8.7 (Table 8.2)
Will Bowdens Silver be conducting ongoing water quality monitoring?	Section 9
Will background pH levels of Lawsons Creek be included in the EIS?	Section 9
Will monitoring be self-reported or independent/audited?	Sections 9.2 and 9.3
Will surface water monitoring results be made available on the website?	Yes
Will historical surface water sampling data be made available?	Yes
What extreme weather event planning will be undertaken during the design and ongoing operation of the mine?	Section 6 and Annexure B (Section 7.9)
What mitigation measures will be implemented to prevent any surface water quality issues?	Section 4
How will water be accessed for infrastructure and development before the water storage dams are operational?	Section 4.2
What will the capacity of the dams be on the mine site and what will they be used for?	Section 4.7
What size storm event will the dams be made to withstand?	Section 4.7
How many peer reviews will be conducted?	The Surface Water Assessment has been peer-reviewed (see Annexure C)
Will a detailed Hazard Assessment be included in the EIS?	See Part 4 of SCSC
What reduction in flow in Hawkins Creek and Lawsons Creek will occur as a result of the Mine?	Section 8
Can I access water from water supply pipeline for my stock?	No
I am concerned about the transfer of water from Goulburn River sources to the Mine Site.	No longer applicable
“you are taking water out of the environment”	Section 8

3. EXISTING SURFACE WATER ENVIRONMENT

3.1 ENVIRONMENTAL VALUES AND OBJECTIVES

The NSW Water Quality Objectives set out the agreed environmental values (EVs) and long-term goals for NSW's surface waters. They set out:

- the community's values and uses for rivers, creeks, estuaries and lakes; and
- a range of water quality indicators to help assess whether the current condition of waterways supports those values and uses.

The Watercourse Assessment (R.W. Corkery & Co., 2020) included in **Annexure A** identifies the following water quality objectives reflecting the ecological, social and economic and ecosystem function values applicable to the receiving waters of the Project:

- Aquatic Ecosystem: Maintaining or improving the ecological condition of waterbodies and their riparian zones over the longer term.
- Visual Amenity (Aesthetic): quality of waters.
- Primary Contact Recreation: Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.
- Secondary Contact Recreation: Maintaining or improving water quality for activities such as boating and wading in which there is a low probability of water being swallowed.
- Livestock Water Supply: Protecting water quality to maximise the production of healthy livestock.
- Irrigation Water Supply: Protecting the quality of waters applied to crops and pasture.
- Homestead Water Supply: Protecting water quality for domestic use in homesteads including drink, cooking and bathing.
- Drinking Water (disinfection only or clarification and disinfection): Protecting the quality water at, and upstream of, offtake points for town water supply and specific sections of rivers that contribute to drinking water storages.
- Aquatic Foods (cooked): Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.

3.2 LOCAL CLIMATE - RAINFALL AND EVAPORATION DATA

For the purposes of this assessment, long term daily rainfall and evaporation data for the Mine Site from January 1889 to December 2018 (130 years) was obtained from the Queensland Department of Environment and Science's SILO data service.

SILO can provide a continuous daily time series of data at grid points across Australia SILO "accesses grids of data derived by interpolating the BOM's station records. Interpolations are calculated by splining and kriging techniques" (Jeffrey et al). The data are all synthetic; there are no original meteorological station data left in the calculated grid fields. Daily rainfall gridded

datasets are derived from interpolated monthly rainfall by partitioning the monthly total onto individual days. Partitioning requires estimation of the daily distribution throughout the month. The distribution is obtained by direct interpolation of daily rainfall data throughout the month. At the end of the month, the interpolated monthly rainfall is then partitioned onto individual days according to the computed distribution.

These SILO data sets are well suited for use in water balance modelling. The key advantage of adopting the SILO data is that it has been adjusted to remove accumulated totals over multiple days and to fill periods of missing data using rainfall from nearby stations. However, the interpolation techniques may result in some reduction in the variance of the climate record compared to the observed data.

Data was obtained for a point located at latitude 32.60 degrees S and longitude 149.85 degrees E, which is located 1.6 km north of the Mine Site. Annual rainfall totals from the adopted dataset are presented in **Figure 3.1**, and monthly averages are shown in **Figure 3.2**. Average annual rainfall is 673 mm/a and average annual (pan) evaporation is 1 518 mm/a. Evaporation from the surface of open water bodies was modelled using point estimates of Morton's Lake evaporation from the gridded SILO data (average annual Morton's Lake evaporation is 1 351 mm/a).

Bowdens Silver operates two meteorological stations one within the proposed Mine Site (Met 01) and another in Lue (Met 02), as shown in **Figure 1.1**. The records from these stations are relatively short (less than 5 years). The monthly rainfall data recorded at the proposed Mine Site is compared to the SILO data in **Figure 3.3**. The figure shows that data are well correlated and the SILO data is suitable for use in this surface water assessment.

Figure 3.1 Annual rainfall at the Mine Site - 1889 to 2018 (source: SILO point dataset - Qld Department of Environment and Science)

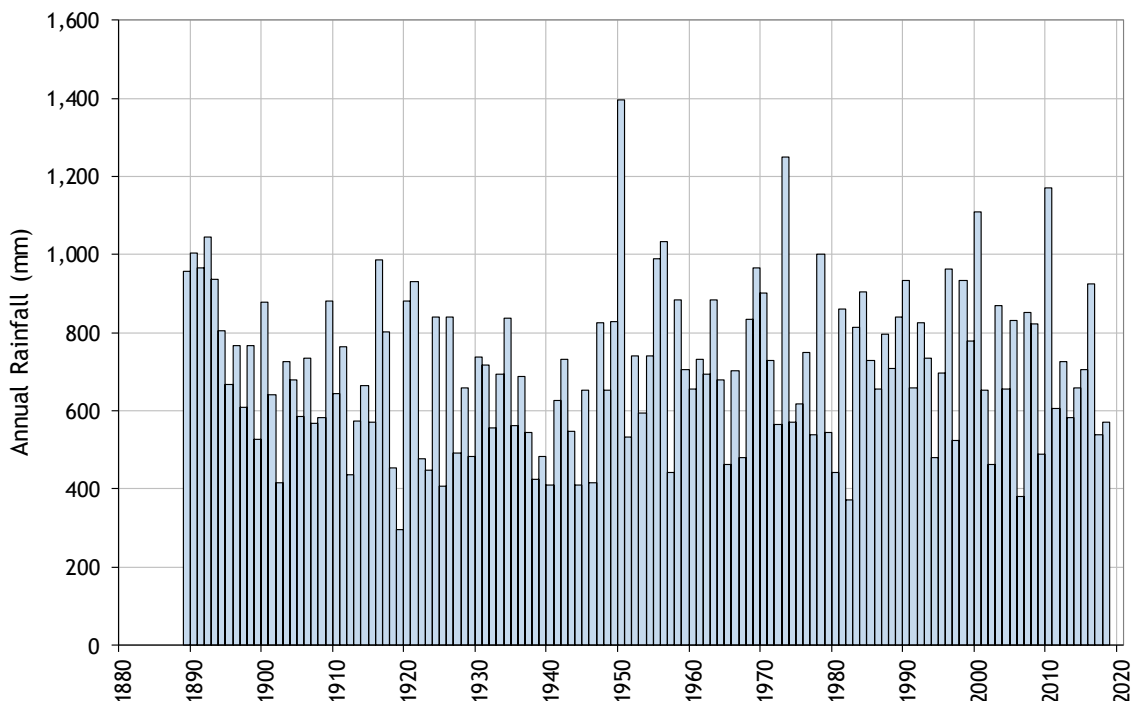


Figure 3.2 Average monthly rainfall and pan evaporation at the Mine Site - 1889 to 2018
(source: SILO point dataset - Qld Department of Environment and Science)

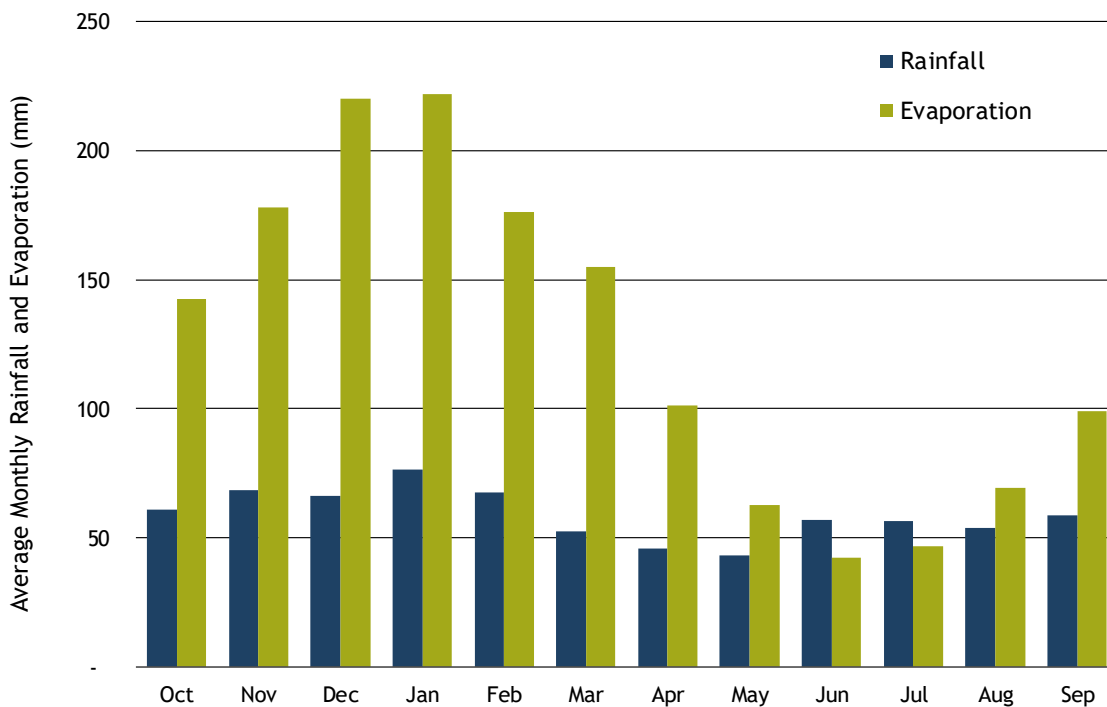
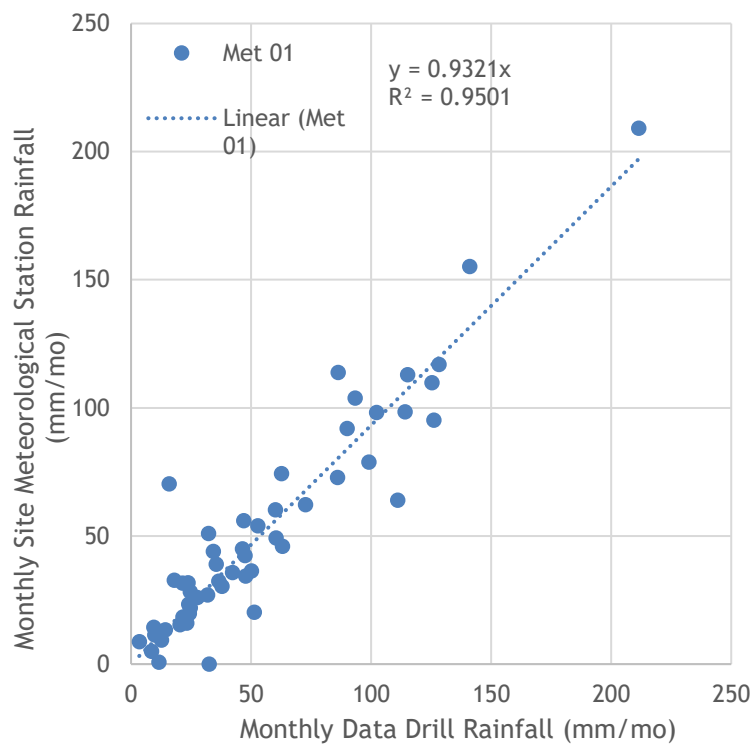


Figure 3.3 Comparison of monthly rainfall data from Bowdens Silver meteorological station and SILO data



3.3 REGIONAL DRAINAGE

Figure 3.4 shows the regional drainage features in the vicinity of the Mine Site. The Mine Site is located within the Lawsons Creek catchment, in the eastern headwaters of the Macquarie River basin. Lawsons Creek flows in a northwesterly direction and drains to the Cudgegong River near Mudgee. The Cudgegong River flows in a northwesterly direction from Mudgee, before turning to the southwest and eventually draining to Lake Burrendong. Lawsons Creek has a catchment area of approximately 507 km² to the Cudgegong River confluence (near Mudgee). Lake Burrendong has catchment area of approximately 13 900 km².

3.4 LOCAL DRAINAGE

Figure 3.5 shows the Lawsons Creek catchment to a point downstream of Lue. **Figure 3.6** shows the local drainage characteristics within and in the immediate vicinity of the Mine Site boundary.

Hawkins Creek, a tributary of Lawsons Creek, flows in a southwesterly direction near the southeastern boundary of the Mine Site. The boundary of the Mine Site is set back 20 m from the hydroline depicting the alignment of Hawkins Creek as presented on the NSW SEED (Sharing and Enabling Environment Data) Map database. Hawkins Creek has a catchment area of 61 km² upstream of the confluence with Lawsons Creek.

The Mine Site is traversed by the following named tributaries of Hawkins Creek and Lawsons Creek (refer to **Figure 3.6** for their locations):

- Price Creek (a south-flowing tributary of Hawkins Creek), which has a catchment area of 5.2 km² upstream of the Hawkins Creek confluence;
- Blackmans Gully (a south-flowing tributary of Hawkins Creek), which has a catchment area of 2.3 km² upstream of the Hawkins Creek confluence;
- Walkers Creek (a west-flowing tributary of Lawsons Creek), which has a catchment area of 4.9 km² upstream of the Lawsons Creek confluence. The proposed TSF would be located in Walkers Creek.

A number of minor unnamed tributary gullies also cross the Mine Site. Baseline geomorphological conditions in drainage features crossing the Mine Site were assessed as part of the *Watercourse Assessment for the Bowdens Silver Project* (R.W. Corkery & Co, 2020) (included as **Annexure A**).

The groundwater assessment for the Project (Jacobs, 2022) identified a number of springs and seeps, including, Wet Swamp Creek and Black Gully to the northwest of the Mine Site, and Blackmans Gully. A number of ephemeral seeps and partial wetlands are also present, particularly in the upper reaches of the minor drainages. These ephemeral swamps and seeps are often developed as farm dams for stock water supply.

In the vicinity of the Mine Site, these seeps are inferred to be the ephemeral expression of a saturated soil profile and result from sub-surface flows (or inter-flow) through the soil profile expressing at surface either due to a break in slope or a barrier to flow such as sub-cropping bedrock (Jacobs, 2022).

Figure 3.4 Regional Drainage Features

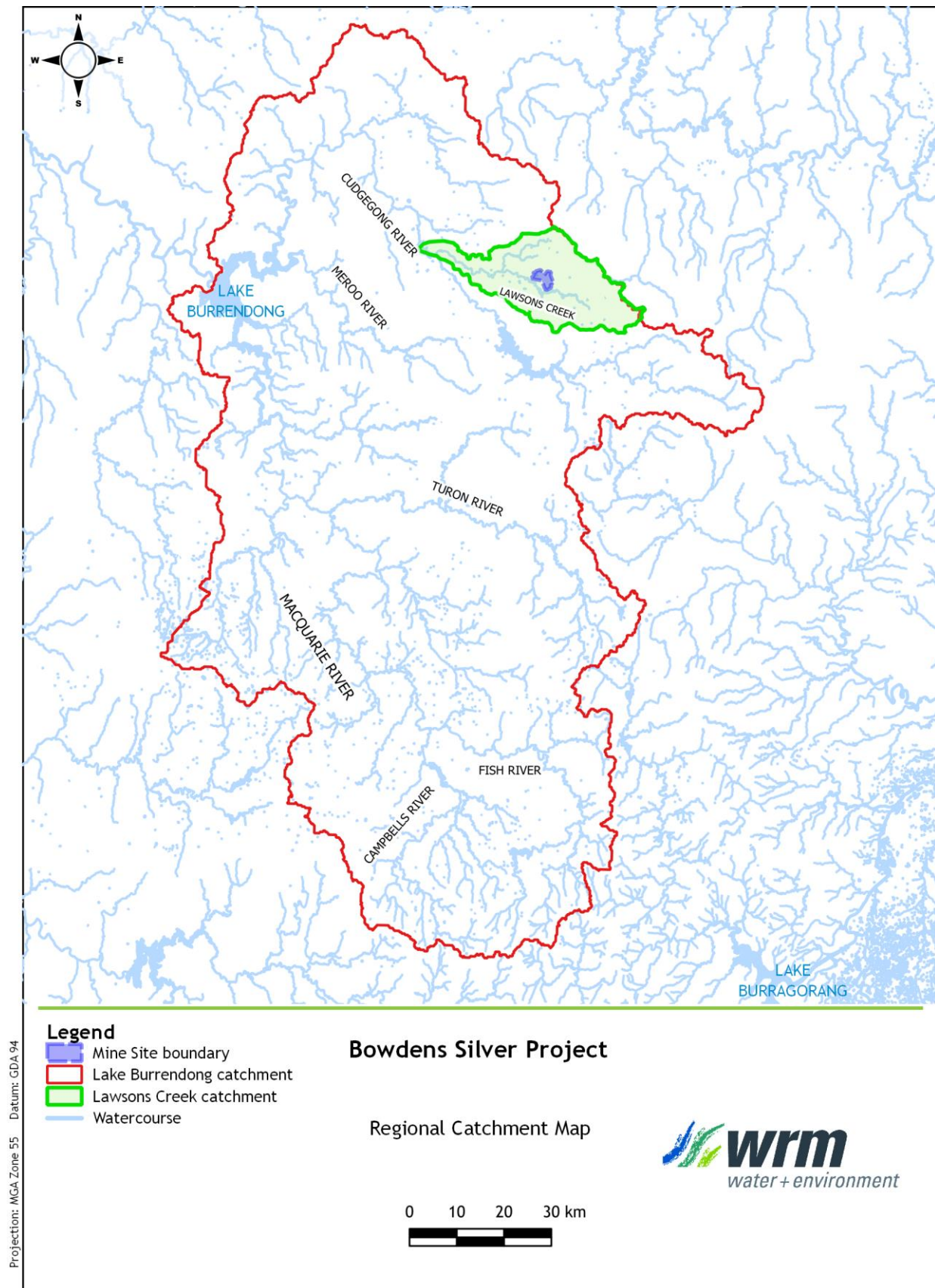
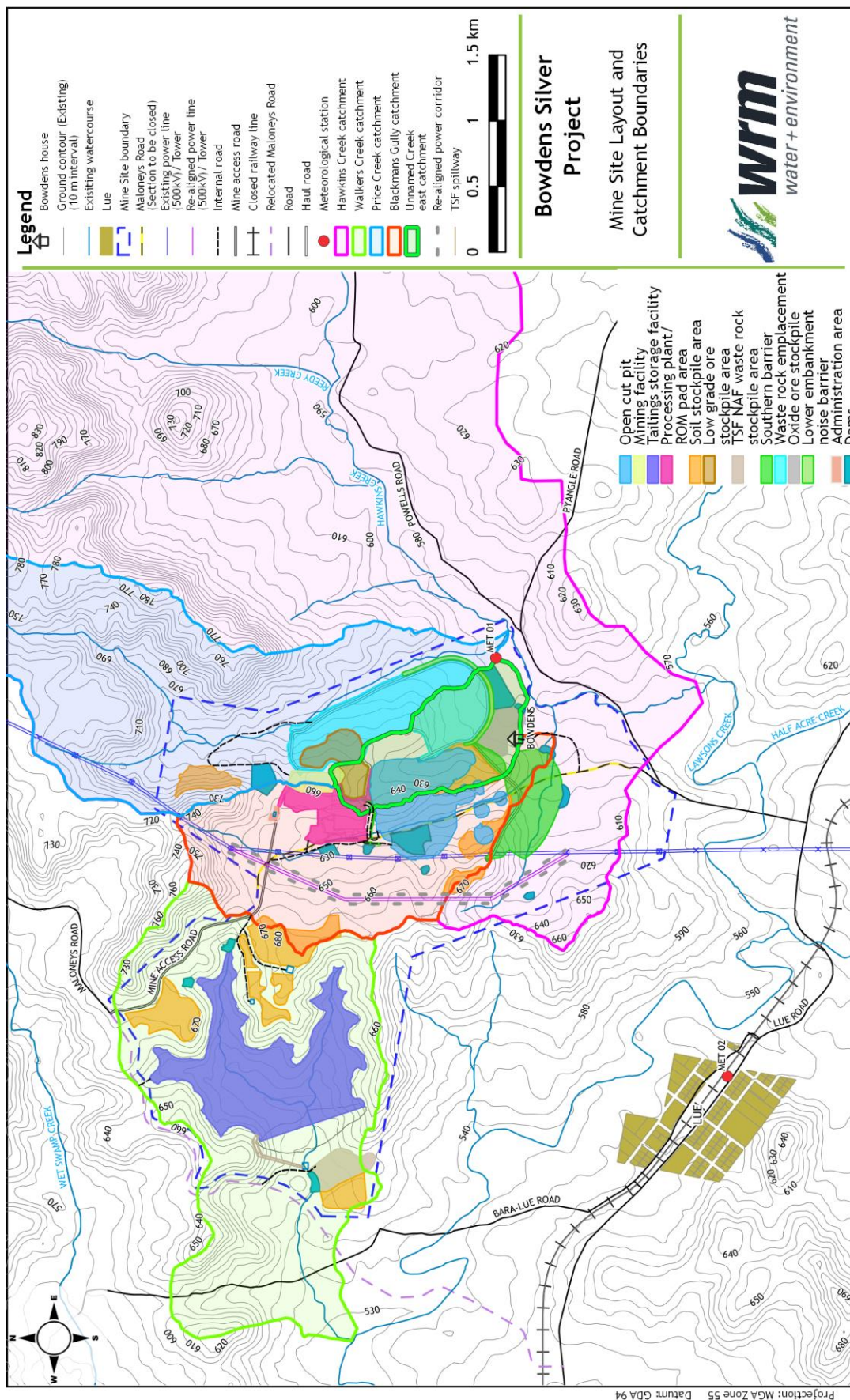


Figure 3.6 Site layout and local catchments crossing the Mine Site



3.5 STREAMFLOW

3.5.1 Streamflow Data

There are no WaterNSW or Bureau of Meteorology (BOM) streamflow recording stations in the immediate vicinity of the Mine Site. Bowdens Silver records water level at two continuous recording stations on Hawkins Creek adjacent to the Mine Site (shown in **Figure 3.5**), and provided the following data:

- Powells Road (Station No. 421195) - 3.2 year record from 26 March 2014 to 30 May 2017; and
- Bingmans Crossing (Station No. 421194) - 4 year period from 16 June 2013 to 30 May 2017.

These stations comprise a v-notch weir mounted on a concrete weir crossing the bottom of the channel. The invert level of the v-notch weir is at 0.5 m gauge height (GH) at both stations.

Figure 3.7 shows recorded water levels in Hawkins Creek at the Bingmans Crossing station (Station No. 421194) over the period of record. As shown in **Figure 3.8**, the period of record includes a period of very wet weather commencing in July 2016, preceded by a period of very dry weather.

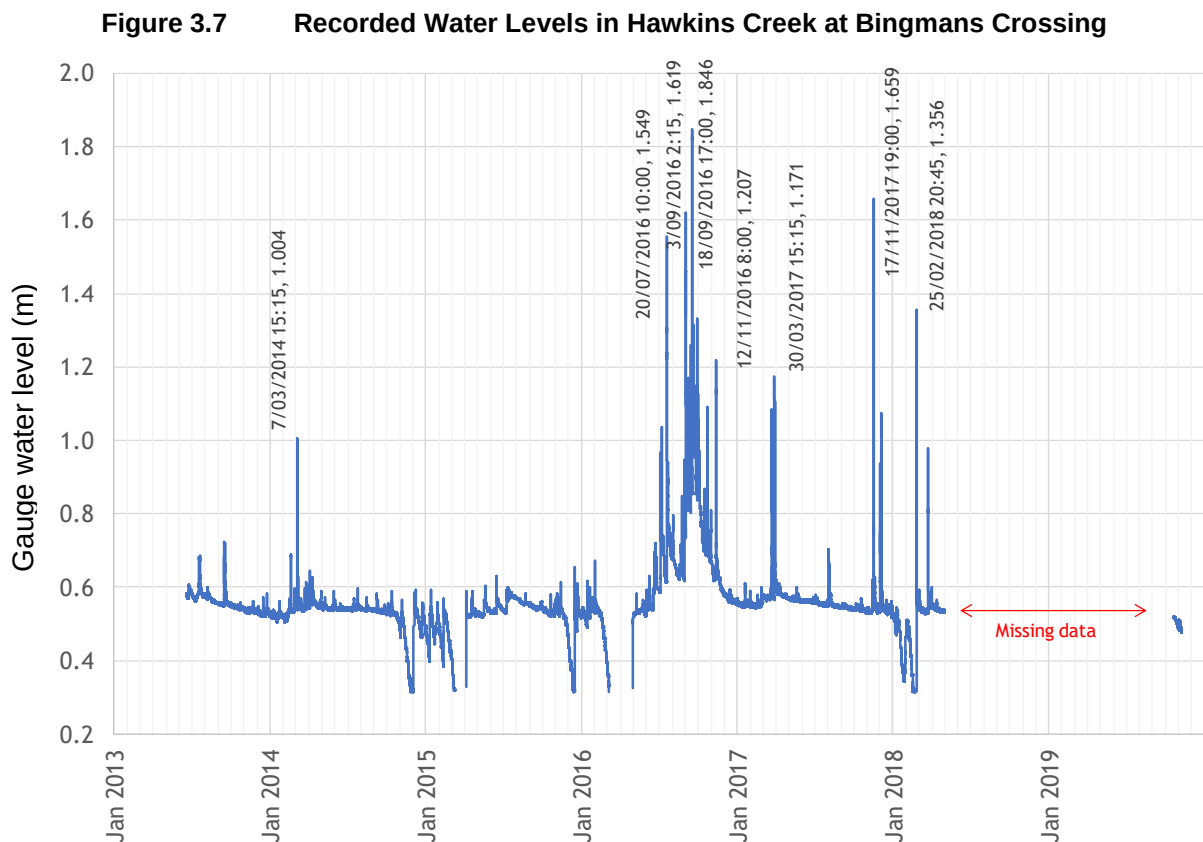
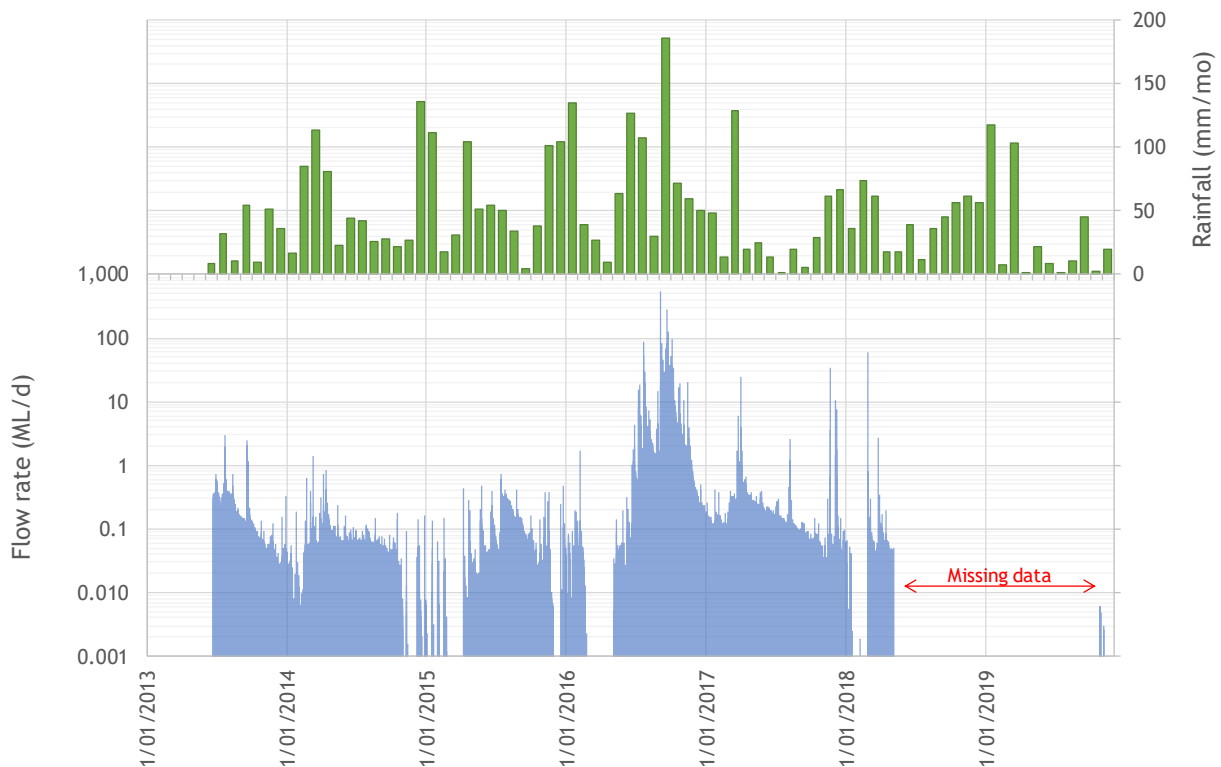


Figure 3.8 Streamflow recorded in Hawkins Creek at Bingmans Crossing

3.5.2 Characterisation of Streamflow

The first order drainage catchments present in the Mine Site are ephemeral in nature with negligible groundwater baseflow (Jacobs, 2022). Baseflow derived from groundwater discharge and bank storage is however considered likely to contribute year round to flows in Hawkins Creek and Lawsons Creek. Groundwater levels can be important in maintaining flows or pools that sustain ecosystems, particularly during times of drought.

3.5.2.1 Hawkins Creek

Figure 3.7 shows that baseflow generated depths of more than 100 mm over the v-notch weir between July and November 2016, and flow peaks exceeding 1 m gauge height (0.5 m above the v-notch weir crest) occurred several times over this period. There are also a number of periods of no flow during the period of record.

Based on this relatively short period of data, Hawkins Creek streamflow could be characterised as ephemeral to semi-perennial at this location.

Hawkins Creek is likely sustained by groundwater baseflow, as indicated by continued flow (or the presence of 'waterholes') anecdotally observed during the drier seasons. Jacobs (2022) estimated the baseflow contribution calculated from the gauged streamflow data as generally less than 0.2 ML/d.

Average daily flow in Hawkins Creek over the period of record was approximately 1.95 ML/d or 712 ML/a, which equates to approximately 0.12 ML/ha/a over the 61 km² catchment to Bingmans Crossing. This is only 1.7% of total rainfall over that period (which was close to the median 4 year total).

3.5.2.2 Lawsons Creek

Lawsons Creek is an unregulated watercourse. The headwaters of the Lawsons Creek system are situated on Mount Graham (elevation approximately 910mAHD) which is approximately 20km east of the Mine Site. The northern and eastern extents of the Lawsons Creek catchment are heavily vegetated and underlain by Permian sediments of the Sydney Basin. The southwestern extent of this catchment is also heavily vegetated but underlain by meta sediments and volcanics associated with the Lachlan Orogen (R.W. Corkery & Co, 2020).

The bulk of the Lawsons Creek catchment has been altered (cleared) to support agricultural activities. Historically, Lawsons Creek was likely to have been an intermittent to perennially discharging watercourse however, subsequent land use changes and the construction of water capture and storage structures to support agriculture have altered the hydrologic regime such that Lawsons Creek may now be described as an intermittent to ephemeral watercourse (R.W. Corkery & Co, 2020).

Based on the hydrological modelling outlined in the following section (using parameters established by calibration to long-term streamflow records in the upper catchment of the nearby Cudgegong River), average daily flows in Lawsons Creek downstream from Hawkins Creek are estimated at 19.5 ML/day or 7 136 ML/a.

3.5.3 Simulated Catchment Runoff and Streamflow

In the absence of site-specific long-term data to characterise streamflow in Hawkins Creek and Lawsons Creek, the Australian Water Balance Model (AWBM) model was used to represent the runoff characteristics of local catchments.

The AWBM uses a group of connected conceptual storages (3 surface storages) to represent catchment runoff. Water in the conceptual storages is replenished by rainfall and reduced by evaporation. Simulated surface runoff occurs when any of these storages fill and overflow. The model parameters define the depth and relative area of each of the storages, as well as the rate of water flux from/between storages. The AWBM model adopted for the Project uses the point estimates of Morton's Wet evapotranspiration (ET) from the SILO gridded dataset.

There are no rainfall stations located within Hawkins Creek catchment upstream of the Mine Site, and the available flow record is of relatively short duration. As a consequence, while the Hawkins Creek stream gauge data was used to validate the flood model results (see **Annexure B**), it was not considered suitable for calibration of catchment yield models to extend the streamflow time series. AWBM parameters were instead adopted based on the following approaches:

Base case modelling of Mine Site runoff and receiving water runoff

The parameters used for modelling Hawkins Creek and Lawsons Creek streamflow, as well as Mine Site runoff, were selected based on calibration to data collected at the Cudgegong River Upstream of Rylstone streamflow

gauge (421184) operated by WaterNSW, which is the nearest NSW government streamflow gauge to the Mine Site. The representation of low flows was improved by applying a constant loss of 0.0025 mm/d (to account for instream flow losses). Key statistics of the calibration over the period 27/6/2009 to 30/12/2017 (which excludes recent very dry weather when instream losses appear to be most pronounced) are as follows:

- Total runoff: modelled 183.6 mm, observed 182.9 mm (observed/modelled = 99.4%);
- Correlation co-efficient (monthly) – 0.86;
- Root mean square error (monthly) – 1.17 mm/mo;
- Nash Sutcliffe co-efficient (monthly) - 0.73.

Figure 3.9 compares the flow frequency curves for runoff recorded at the Cudgegong River Upstream of Rylstone with the AWBM model runoff. The resulting average annual catchment runoff (prior to instream losses) is approximately 0.39 ML/ha/a or 4.9% of long-term rainfall (when applied to the Patched Point climate dataset for the Olinda (Springdale) rainfall station (62023)). The location of the catchment to the streamflow gauge is shown in **Figure 3.10**.

Figure 3.9 Comparison of Recorded and Modelled Runoff (Cudgegong River Upstream of Rylstone)

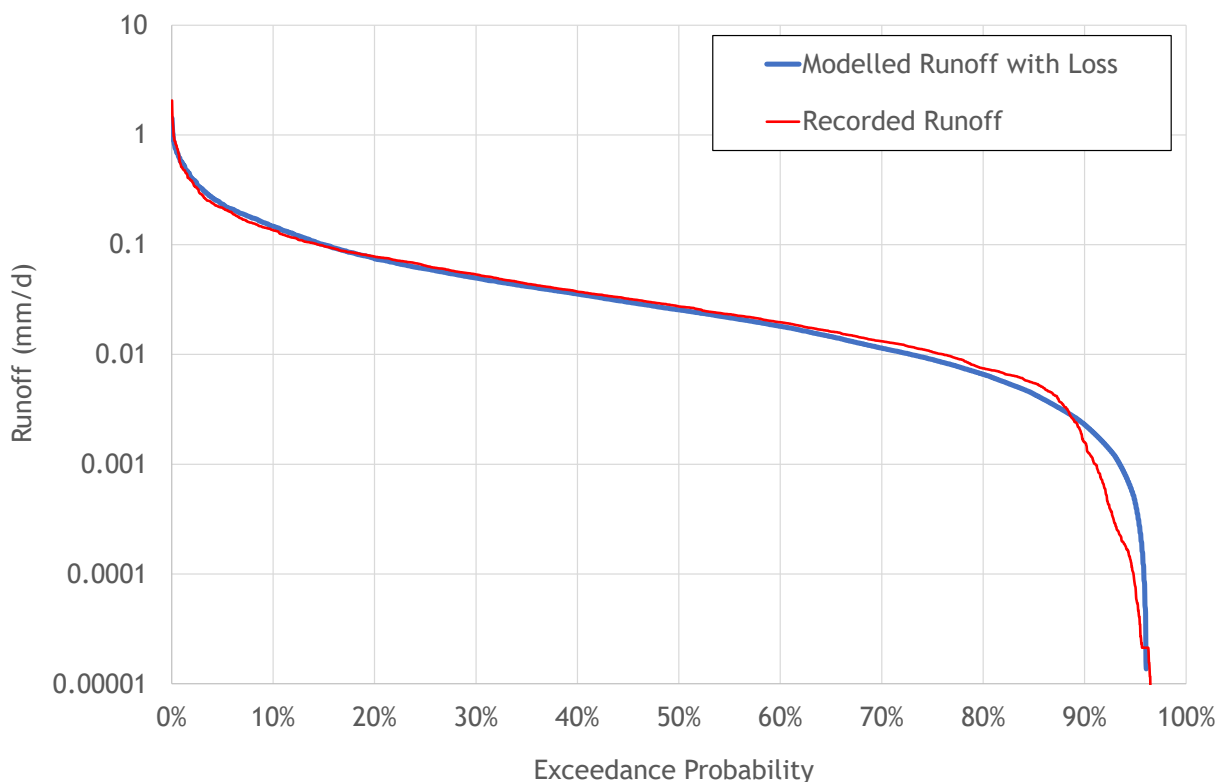
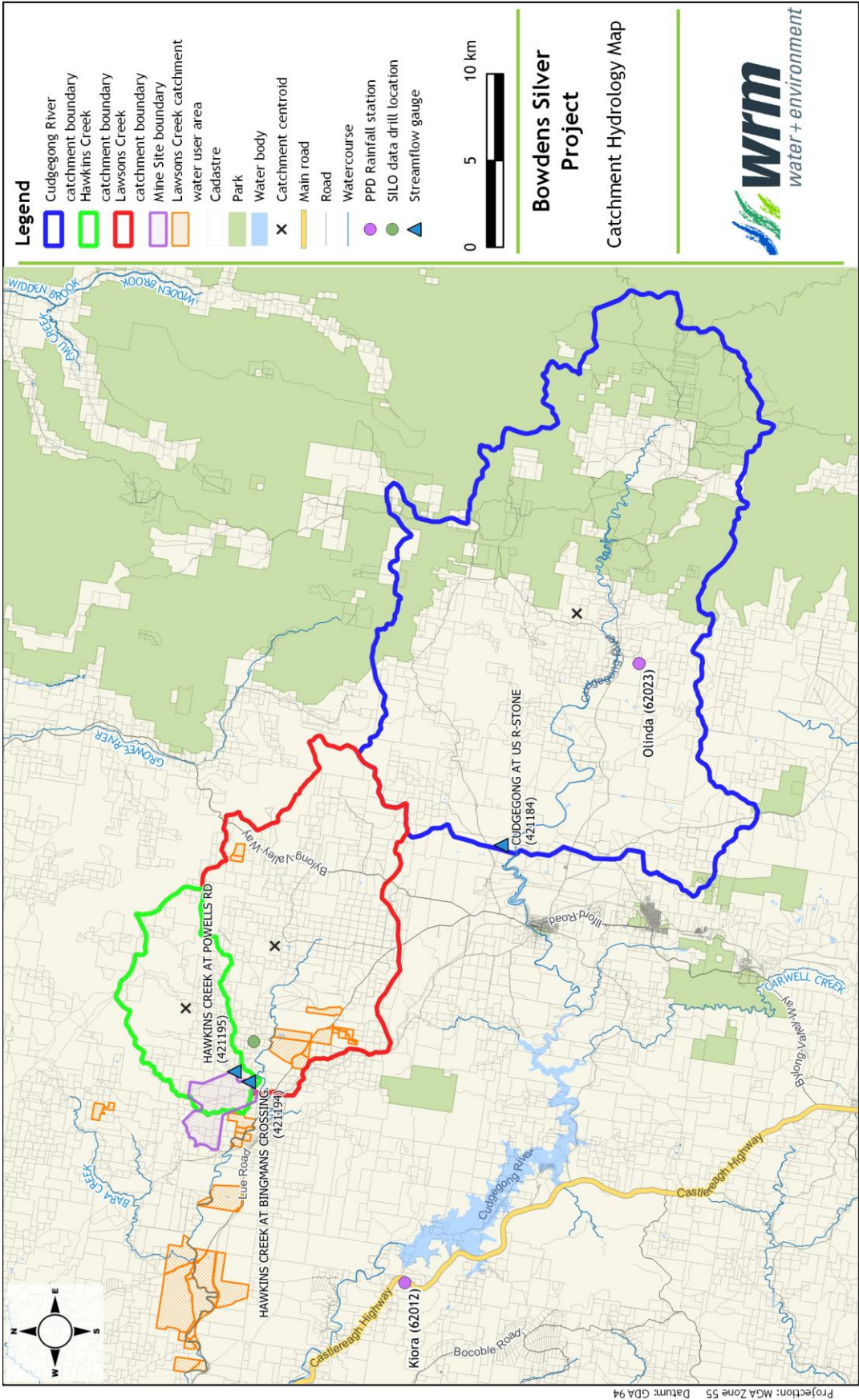


Figure 3.10 Locations of Project Area Catchments and the Cudgegong River at Upstream of Rylstone Streamflow Gauge



- Sensitivity testing of water management system to changes in Mine Site catchment response:
 - low runoff scenario- from experience with catchment modelling in the nearby upper Hunter Valley. The AWBM parameters selected were based upon a calibration to observed mine water inventory data at Moolarben Coal Mine, approximately 38 km north of the Mine Site, with catchments yielding 2.7% of rainfall as runoff (or 0.18 ML/ha/a);
 - high runoff scenario- an artificial parameter set similar to the base case parameters but with the A1 parameter increased and the C3 parameter decreased to generate comparatively high runoff quantities for the area (8.7% of rainfall) (0.62 ML/ha/a).

The AWBM parameters adopted for modelling Lawsons Creek catchment and undisturbed Mine Site area runoff are summarised in **Table 3.1**.

Table 3.1
Adopted AWBM Parameters – Undisturbed Catchments

Parameter	Base Case Mine Site Runoff and Lawsons/Hawkins Creek ¹	Sensitivity Testing of Mine Site Runoff from Undisturbed Areas	
		Low Runoff	High Runoff
A1	0.134	0.2	0.2
A2	0.433	0.2	0.2
A3	0.433	0.6	0.6
C1 (mm)	25	90	25
C2 (mm)	184	170	95
C3 (mm)	214	200	150
C _{avg} (mm)	176	172	114
BFI	0.45	0.6	0.55
K _{base}	0.982	0.7	0.7
K _{surf}	0.820	0.4	0
Average Annual Runoff/ Rainfall ² (%)	4.9	2.7	8.7
Runoff ² (ML/ha/a)	0.33	0.18	0.62

¹ Applied a constant loss of 0.0025mm/d for instream loss for creek flows

² Over period of climate record from 1889 to 2019 – varies slightly with catchment climate data

3.6 FLOODING

A detailed assessment of flooding has been carried out to establish the extent of flooding in the reaches of Lawsons Creek, Hawkins Creek adjacent to the Mine Site, as well as the main tributaries crossing the Mine Site.

An XP-RAFTS hydrologic model was developed for the catchments of Hawkins Creek and Lawsons Creek and their tributaries and validated using data from the stream gauges. A TUFLOW hydraulic model was then developed for these watercourses to determine the existing flood behaviour based on existing conditions in the vicinity of and within the Mine Site.

The extent, depth and velocity of flooding across the model domain in the 1% AEP flood are shown in **Figure 3.11** and **Figure 3.12**.

Key findings from the flood modelling with regards to predicted peak flood levels and depths across the model domain are summarised below:

- No flood prone land is mapped in the Mid-Western Regional Local Environmental Plan 2012 in the vicinity of the Mine Site.
- The Mine Site disturbance area is located outside of the Lawsons Creek flood extent for all events up to the PMP design event.
- The area along the southeastern Mine Site boundary is affected by flooding from Hawkins Creek. However, the proposed open cut pits, WRE and leachate management dam are located outside of the predicted flood extent for Hawkins Creek for all design events. It is noted that the embankment crests of the WRE and leachate management dam are above the water level of the PMP design event.
- Flooding along the Hawkins Creek and Lawsons Creek tributaries within the Mine Site is characterised by shallow overland flows. Flows in these tributaries are generally confined within the narrow floodplains, with no breakouts occurring except near the confluences of these tributaries with Hawkins Creek and Lawsons Creek. Due to the narrow floodplains, the difference in predicted flood extents along these tributaries between the 1% AEP and PMP design events are not significant.
- Predicted peak flood depths along the overbank areas of the Hawkins Creek and Lawsons Creek tributaries are generally below one metre for events up to and including 0.2% AEP (1 in 500). Peak flood depths of up to 1.5 m for the PMP design event are predicted in some sections along these tributaries.

Key findings with regards to predicted peak velocities across the model domain are summarised below:

- Flows in the Hawkins and Lawsons Creeks tributaries are generally confined within narrow floodplains with relatively steep ground slopes. This results in relatively high predicted peak flood velocities of up to 2.5 m/s along the channel and overbank areas of these tributaries for events up to and including 0.2% AEP (1 in 500).
- Predicted peak flood velocities in Hawkins Creek for events up to and including 0.2% AEP are generally less than 3 m/s, with peak velocities greater than 4 m/s predicted in some sections.
- Predicted peak flood velocities in Lawsons Creek are relatively high for all modelled events. For events up to and including 0.2% AEP, peak flood velocities greater than 4 m/s are predicted in many sections along the Lawsons Creek channel and floodplain.

Full details of the methodology and mapping of baseline flood conditions are provided in the flood impact assessment report in **Annexure B**. The methodology was developed in consideration of the recommendations in the NSW floodplain risk management guideline.

Figure 3.11 Existing Conditions 1% AEP Flood Depths and Water Level Contours

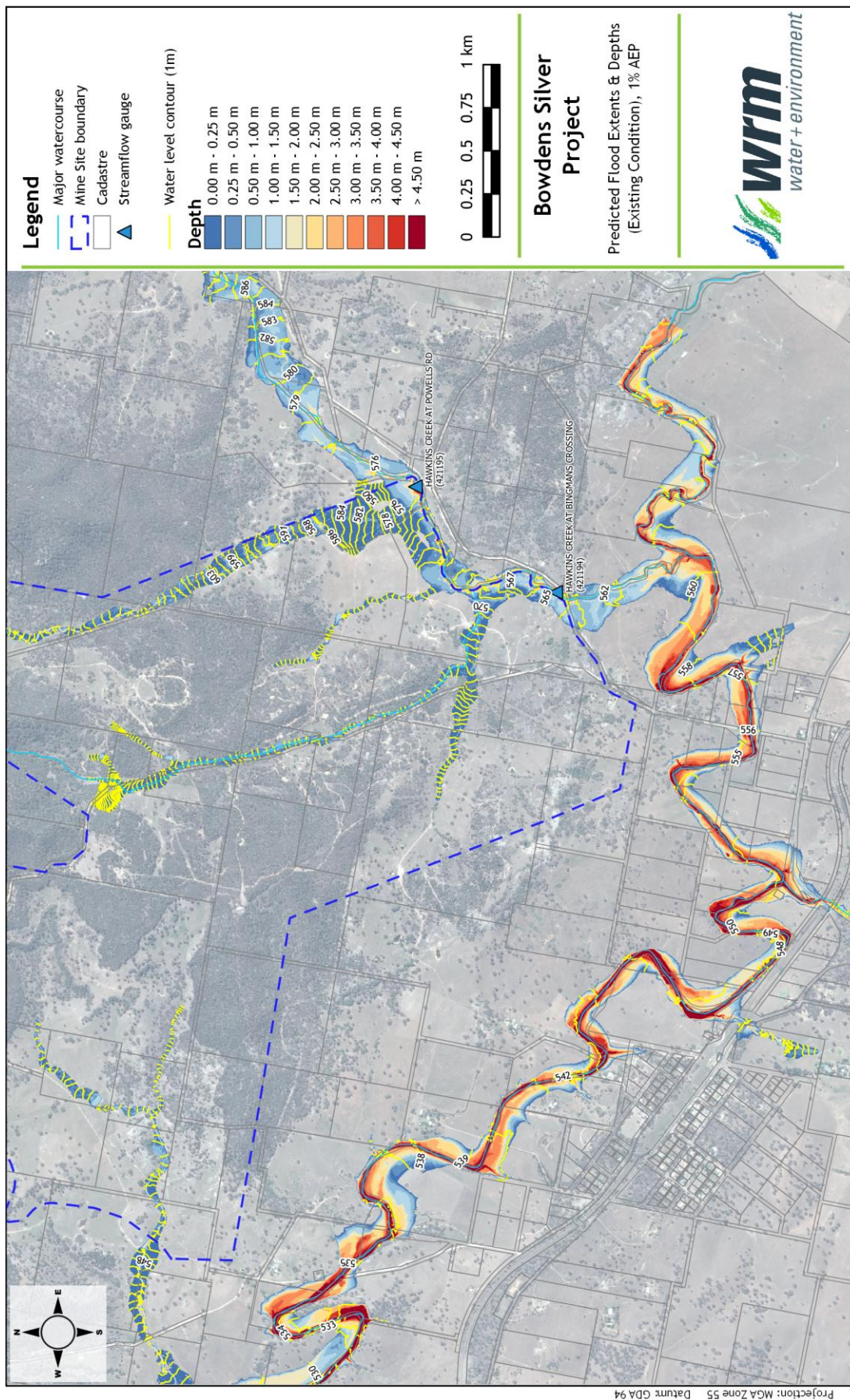
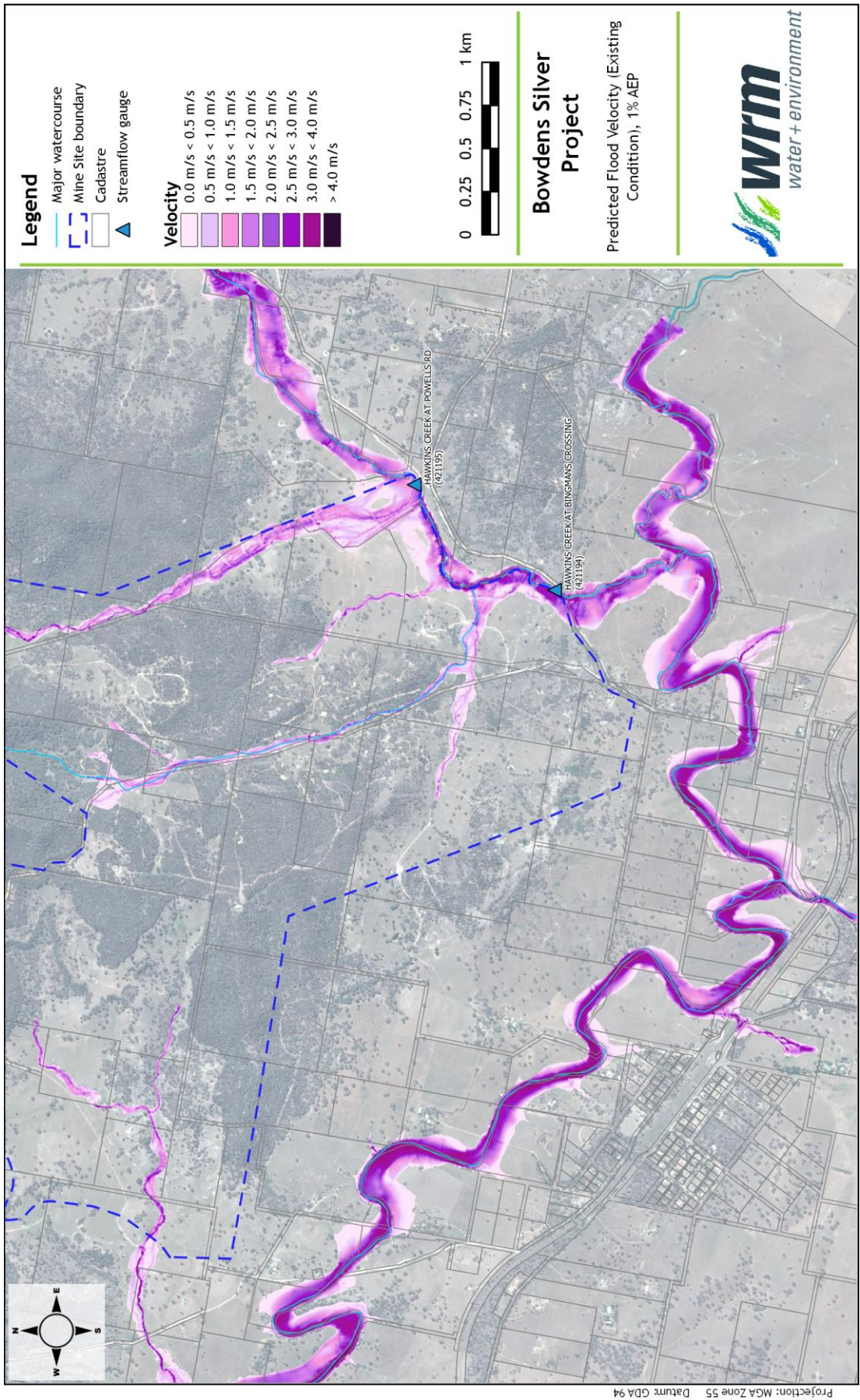


Figure 3.12 1% (1 in 100) AEP Peak Flood Velocities – Existing Conditions - Complete Extent



3.7 WATER QUALITY

Monitoring of surface water in Lawsons Creek, Hawkins Creek and its tributaries has been undertaken since 2012. Full details of the baseline water quality assessment are presented in **Annexure A** (R.W. Corkery & Co, 2020).

The principal guideline for water quality in Australia is ANZG (2018). Most of this guideline relies upon guidance developed by the Australian and New Zealand Environment and Conservation Council (ANZECC) in collaboration with the Agriculture and Resources Management Ministerial Council of Australia and New Zealand (ARMCANZ) and which was published in the (then) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). ANZG (2018) sets quantitative and qualitative guideline values for a range of water quality parameters for the protection of aquatic ecosystems, aquaculture, recreation, drinking and agricultural values.

The baseline water quality assessment concludes water quality in the receiving waters of the Mine Site has been altered as a result of the agricultural activities in the contributing catchment, particularly with regard to nutrients and electrical conductivity (EC). The median values for:

- ammonia exceed the default guideline value at all sampling locations.
- nitrate exceed the default guideline value at all sampling locations.
- total nitrogen is above the default guideline value at all sampling locations.
- total phosphorous exceed the default guideline value at all sampling locations.
- pH is within the desired range for upland rivers although the results for monitoring locations on Lawsons Creek are generally at the upper end of this range.
- sulphate concentrations are below the default guideline value at all locations.
- electrical conductivity is above the desired range.

The assessment also concludes that median (50th percentile) metal concentrations are generally below current default guideline values. **Table 3.2** compares the median percentile of metal concentrations to the default guidelines for protection of aquatic ecosystems. The table shows exceedance for zinc and copper (although copper concentrations do not exceed the hardness modified guideline value) in both Hawkins Creek and Lawsons Creek, but all other metals are at or below the guideline value. Full details of the baseline water quality assessment are presented in **Annexure A** (R.W. Corkery & Co, 2020).

3.8 LICENSED SURFACE EXTRACTION

3.8.1 Water Sharing Plan for Macquarie Bogan Unregulated and Alluvial Water Sources

Water Sharing Plans provide the basis for equitable sharing of surface water and groundwater between water users, including the environment. The Water Management Act (2000) requires:

- a water access licence (WAL) to take water;
- a water supply works approval to construct a work; and
- a water use approval to use the water.

Table 3.2
Summary of Background Dissolved Metal Concentrations and Guideline Levels (µg/L)

Analyte	ANZG Default Guideline Value ¹	50 th Percentile from Water Quality Monitoring Data							
		Lawsons Creek				Hawkins Creek			
		BSW28	BSW22	BSW21	BSW20	BSW7	BSW11	BSW12	BSW13
Mn	1900	88.0	87.0	262.0	512.8	225.5	218.5	138.5	293.0
Zn	8	7.0	6.5	7.0	16.0	10.0	9.0	10.0	8.0
Cd	0.2	0.1	0.1	1.0	0.1	0.2	0.1	0.2	Below LOR
Pb	3.4	2.0	Below LOR	Below LOR	Below LOR	Below LOR	Below LOR	Below LOR	Below LOR
Co	N/A	2.0	1.0	1.0	2.0	1.0	2.0	2.0	2.0
As	13	2.0	1.5	2.0	4.0	1.0	2.0	1.0	1.0
Cu	1.4	2.0	2.0	1.0	3.0	2.0	2.0	1.0	2.0
Ni	11	2.0	1.0	1.0	3.0	2.0	3.5	2.0	4.0
LOR – limit of reporting									
¹ – for protection of aquatic ecosystems									

Surface water in the vicinity of the Project is managed under the Water Sharing Plan (the Plan) for Macquarie Bogan Unregulated and Alluvial Water Sources (2012): Lawsons Creek Water Source. Water taken from the Lawsons Creek Water Source is required to be licensed by way of a water access licence granted under the Plan.

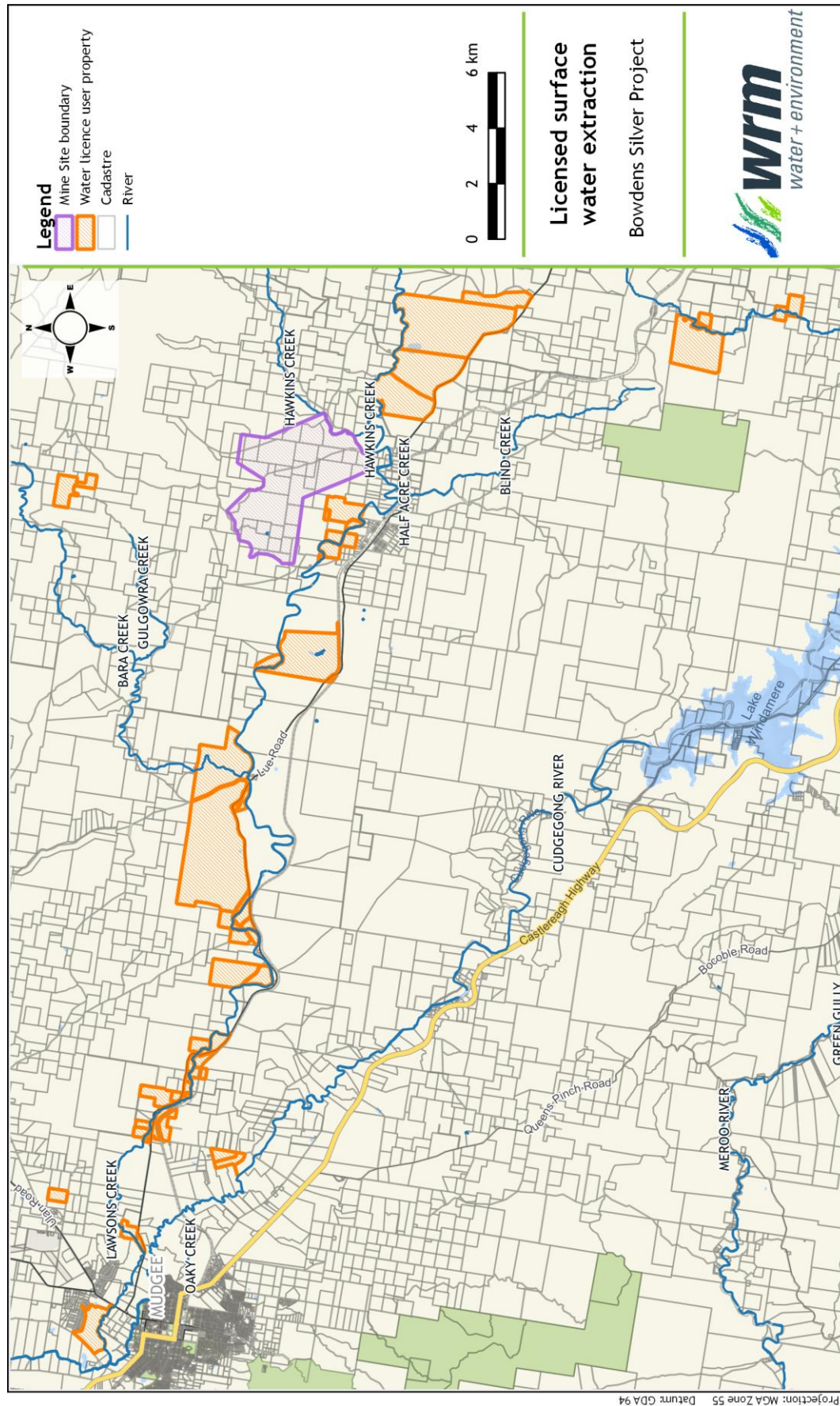
While not detailed in the Plan Maps of the associated Water Sharing Plans, shallow alluvial deposits are present in the vicinity of Hawkins Creek and Lawsons Creek. Drilling along Hawkins Creek has recorded alluvial thickness ranging from 4 m to 6 m with variable saturation, and these alluvial deposits are not considered to be highly productive on the basis of the Aquifer Interference Policy (AIP) yield criteria. Notwithstanding, thicker saturated sequences of alluvium still have potential to be highly productive and the alluvial deposits will be considered as such for the purposes of the groundwater assessment prepared in accordance with the AIP. Alluvial groundwater extraction in this alluvium can therefore potentially impact on surface water flows in the adjoining reaches of Hawkins and Lawsons Creek (Jacobs, 2022).

3.8.2 Water Access Licences Currently Granted in the Lawsons Creek Water Source

Details of existing Water Access Licences held by landholders in the vicinity of the Mine Site were obtained from the NSW Water Register. Surface water in Lawsons Creek is used mainly for irrigation and stock watering.

The total share component for the Lawsons Creek Source is 1 496 unit shares (at 1 ML/a per share). A total of 48 water access licences (comprising 36 unregulated river licences and 12 domestic and stock licences) have been granted from the Lawsons Creek Water Source. Of the 42 licences which have associated works approvals, extraction is approved at 29 properties located downstream of the Project, and account for 970 unit shares granted from the water source. The locations of the Works Approvals are shown in **Figure 3.13**. There are no approved extraction points on Hawkins Creek.

Figure 3.13 Licensed Surface Water Extraction from the Lawsons Creek Water Source



4. WATER MANAGEMENT STRATEGY

4.1 WATER MANAGEMENT OBJECTIVES

On-site water management within the Mine Site would be required to achieve the following objectives:

- Maximising the recovery of water from contaminated on-site water sources to support processing operations to meet the on-site water demand (for processing ore, dust suppression, etc).
- Maximising the redirection of upslope surface runoff around operational areas, and where water quality is suitable, maximising the release of runoff.
- Minimising the disruption to mining operations caused by the inflow of groundwater or surface water to the open cut pits.
- Protecting the downstream waters from potential contaminants in Mine Site runoff by:
 - Capturing contaminated seepage from the WRE, tailings decant water, or runoff that may be in contact with potentially reactive material within the site water management system for recycling and reuse in the processing circuit;
 - Minimising the volume of water coming into contact with PAF waste rock or other potentially reactive material by diverting runoff from upstream undisturbed areas around operational areas; and
 - Directing sediment-laden disturbed-area runoff (that has not come into contact with PAF waste rock or other potentially reactive material) to sediment dams for containment on site unless the water quality is adequate for release to the receiving waters after sediment removal.

4.2 WATER SUPPLY

Water for mining operations (processing and dust suppression) would be obtained from the following sources listed preferentially in order and type of use:

1. Paste thickener reclaim water.
2. Surface water collected by the leachate management dam for recycling and reuse in processing operations.
3. Surface water collected in TSF decant pond for recycling and reuse in processing operations.
4. Groundwater and surface water accumulating within the open cut pit for recycling and reuse in processing operations.
5. Surface water collected within the sediment dams (but unsuitable for release).
6. Surface water collected under harvestable rights entitlements for use in dust suppression activities.
7. Advanced dewatering

Potable water requirements during the site establishment and construction stage would be delivered to the Mine Site by water tanker until such time as a reverse osmosis (RO) plant is installed. The RO plant would be used during operations to treat a combination of groundwater, surface water and mine water to produce potable water. Brine from the RO plant would be returned to the processing plant dams for reuse.

Subject to obtaining the appropriate Water Management Act approvals, there is potential to access additional groundwater supply, if required to make up temporary shortfalls in the availability of water from other sources, via the installation of additional groundwater bores within the Mine Site and surrounds.

4.3 MANAGEMENT OF GROUNDWATER INFLOWS TO MINE PIT

Advanced dewatering would occur via two production bores located immediately northeast and northwest of the open cut pit. Each bore would be approximately 300 m deep and produce up to 10 litres per second. The abstracted groundwater would be pumped directly, either to the processing plant area via the Turkey Nest Dam for make-up water supply or to a standpipe. This standpipe would be for water cart filling and subsequent dust suppression activities around the Mine Site.

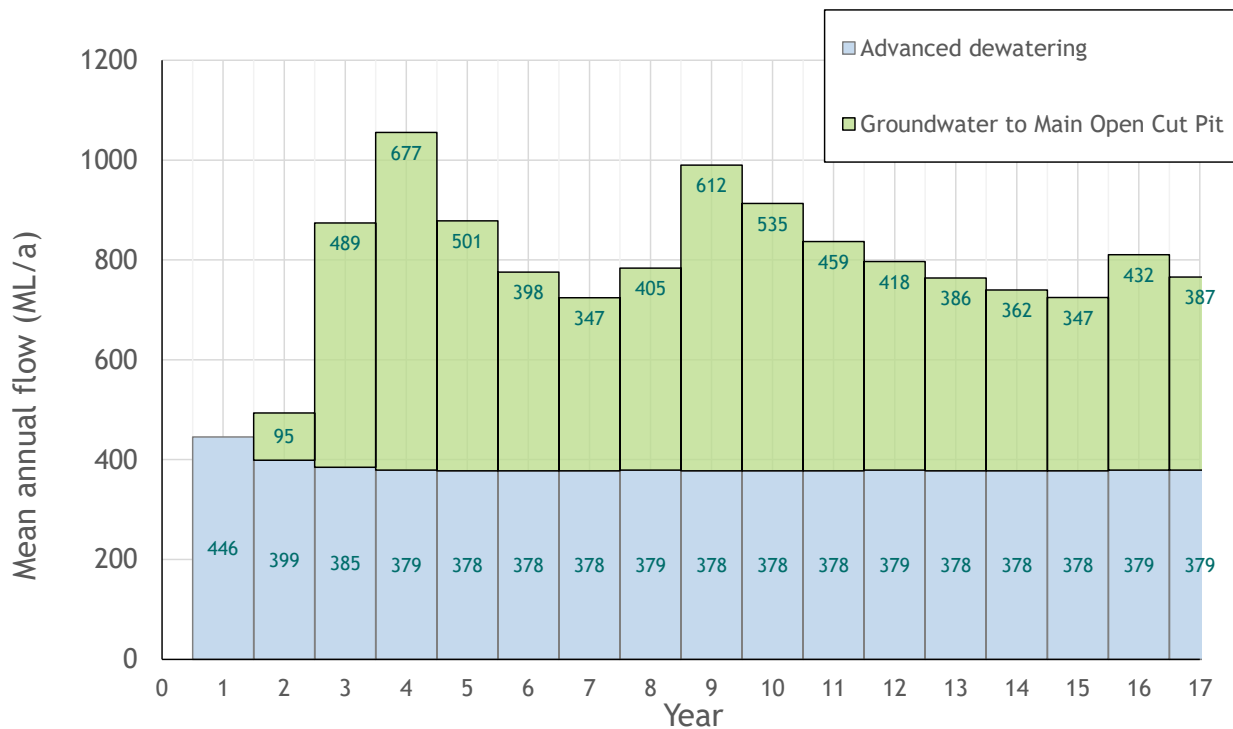
The production bores would be installed prior to the commencement of site establishment and construction activities to provide water for these activities (including dust suppression) and the subsequent mining operation. Predictive modelling (Jacobs, 2021) of the potential groundwater implications have identified that, as the proposed production bores would be located within the open cut pit's zone of groundwater impact, there is no significant increase to the extents of groundwater drawdown as the result of both advanced dewatering and open cut pit development. This means that the timing and magnitude of any reduction in groundwater contributions to flows in either Hawkins or Lawsons Creeks or other groundwater users would remain generally consistent with the predictions presented in the EIS.

Whilst it is recognised that advanced dewatering would reduce groundwater inflows to the open cut pit, these inflows would still form a component of the Project's overall water supply strategy. However, the reduced open cut pit inflows resulting from advanced dewatering would also reduce evaporative losses from the pit face, therefore optimising the recovery of licensed groundwater inflows and providing a more efficient use of groundwater resources.

Inflow rates to the open cut pits have been estimated by Jacobs Australia Pty Ltd (Jacobs, 2022) using a numerical groundwater model. The predicted average annual groundwater inflows (after allowance for evaporation (20% reduction) (after Jacobs, 2022) from the open cut pit faces) are presented in **Figure 4.1**.

Groundwater accumulating in the open cut pits would be pumped from an in-pit sump to the open cut pit dewatering pond adjacent to the processing plant for reuse.

Figure 4.1 Groundwater Inflow Rate to Open Cut Pit (after Evaporative Losses) and Advanced Dewatering



4.4 WASTE ROCK RUNOFF AND SEEPAGE MANAGEMENT

4.4.1 Geochemical Characteristics of Waste Rock and Tailings

The physical and chemical properties of the waste rock and tailings to be generated for the Project have been established by Graeme Campbell and Associates (GCA, 2020) based on static and kinetic geochemical testing of material extracted from exploration drilling core samples. Kinetic testing was carried out to examine the weathering behaviour of a range of waste rock and ore samples representing the expected range of lithological units to be encountered. The results of laboratory testing of leachate samples were compiled by R.W. Corkery & Co. Pty. Ltd. The following sections outline R.W. Corkery & Co. Pty. Ltd.'s conclusions regarding the waste rock as it relates to surface water runoff and seepage.

4.4.1.1 PAF Waste Rock

Approximately 57% of waste rock is expected to be potentially acid forming (PAF) due largely to the presence of iron sulphide minerals (FeS_2) such as pyrite and marcasite leading to sulphide concentrations greater than 0.3% (as S). This material would be extracted from both the weathered zone (i.e. top 20 m to 30 m below ground level) of the ore body and known as "WZ2" and the primary (unweathered) zone of the ore body which is known as "PZ3" (GCA, 2020).

The tailings that would be generated in the processing plant have been identified as PAF, due to the occurrence of traces of pyrite with traces of rhodochrosite (MnCO_3) and an absence of reactive carbonate minerals (e.g. calcite).

4.4.1.2 NAF Waste Rock

The remaining 43% of waste rock is expected to be non-acid forming (NAF) in that it contains either no sulphides (i.e. material from the weathered zone, known as “WZ1”) or contain low concentrations of sulphides and ankerite, a carbonate mineral that provides for circum-neutral buffering during weathering (i.e. material known as either “PZ1” [Total-S $\leq 0.1\%$] or “PZ2” [Total $0.1\% < S < 0.3\%$]).

The principal NAF waste rock that would be used for construction activities during the site establishment and construction stage (e.g. the initial TSF embankment, WRE and leachate management dam) would be “WZ1”. WZ1 waste rock has been characterised as “benign” (GCA, 2020), and this material would also be utilised as much as practicable during the 2nd and 3rd raises of the TSF embankment. However, it is possible that runoff from NAF waste rock from the primary zone (i.e. PZ1 and PZ2), that would be stockpiled in the southern barrier for use in closure and rehabilitation activities may contain elevated concentrations of some dissolved metals. In particular, the geochemical testing indicates that manganese enrichment is a characteristic feature of mineralisation within the Mine Site, so that soluble forms of manganese may accompany weathering reactions.

The results of laboratory testing of leachate from kinetic and static testing of NAF waste rock samples are summarised in **Table 4.1** (after GCA, 2020) which shows a sample of average analyte concentrations measured in the various forms of NAF identified within the Mine Site.

Table 4.1

Average Dissolved Metal Concentrations in Leachate from Kinetic Testing of NAF Waste Rock Samples Compared to Background Water Quality and Guideline Levels ($\mu\text{g/L}$)

Analyte	Average Leachate Concentration		ANZG Default Guideline Value	80 th Percentile from Background Water Quality Monitoring Data							
	WZ1	PZ1/PZ2		Lawsons Creek				Hawkins Creek			
				BSW28	BSW22	BSW21	BSW20	BSW7	BSW11	BSW12	BSW13
Al	<0.01	<0.02	55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mn	390	1 606	1 900	136.2	164.6	453.2	512.8	449.8	419.0	286.0	838.2
Zn	35	66	8	14.2	8.8	12.4	16.0	22.2	28.2	23.8	16.6
Cd	0.17	0.32	0.2	0.1	0.1	1.0	0.1	0.2	0.2	0.2	Below LOR
Pb	<0.5	1.0	3.4	2.0	Below LOR	Below LOR	Below LOR	Below LOR	Below LOR	Below LOR	Below LOR
Co	6.6	12.5	N/A	2.0	1.0	1.0	2.0	2.0	3.0	2.0	4.8
As	21.4	2.2	13	3.0	2.0	2.0	4.0	1.4	2.0	1.4	2.8
Cu	<10	<10	1.4	2.0	2.0	2.0	3.0	4.0	5.0	2.0	3.6
Ni	<20	27	11	2.0	2.4	2.0	3.0	2.0	5.0	2.0	6.4
LOR – limit of reporting											

The table shows that the average leachate concentrations from WZ1, the principal construction material, are below the ANZG default guideline value (where available) (with the exception of zinc, arsenic, nickel (and possibly copper)). However, dissolved concentrations of all metals in the table (except potentially copper and lead) exceed the 80th percentile of background water quality data at some locations.

The table also shows that with the exception of zinc, cadmium and nickel (and possibly copper), leachate from the NAF waste rock from the primary zone is below ANZG default guideline values (where available). However, dissolved concentrations of all metals in the table (except potentially copper) exceed the 80th percentile of background water quality data at all locations.

Metal concentrations measured in laboratory-generated column leachates can overestimate concentrations in runoff because column testing tends to lead to the near-complete elution of solutes from the samples. In practice, this would be unlikely in real-world waste rock emplacements.

R.W. Corkery & Co. Pty. Ltd reviewed the analysis of leachate derived from stream sediment samples collected in the vicinity of the surface water monitoring locations, and concluded that the current concentration of readily mobilised metals in sediment in downstream watercourses are of similar quality to the leachate derived from NAF waste rock (as would be anticipated given the host geology in the contributing catchments). This indicates that the impact of releases of sediment dam water is likely to be small. However, as the average concentrations of zinc, arsenic, cadmium and nickel in the above table exceeded the default guideline values, the potential exists for elevated concentrations in runoff collected in sediment dams. As the metal concentrations above have been established over a comparatively short period of kinetic testing, there would be benefit in further testing to understand the likely longer term dissolved metal concentrations in the NAF waste rock runoff.

4.4.2 Management of Tailings and Waste Rock

4.4.2.1 Tailings Storage Facility

Tailings generated as part of processing activities would be pumped as a slurry and deposited within a down valley deposition tailings storage facility (TSF).

Based on the geochemical assessment (GCA, 2020), the tailings water and decant in the TSF is expected to be neutral-to-alkaline and of low salinity with soluble manganese concentrations in the low tens-of-mg/L range.

The TSF would be designed, constructed and operated in accordance with the Australian National Council on Large Dams (ANCOLD) 2012 Guidelines on Tailings Dams under the supervision of Dams Safety NSW (refer: ATCW, 2020).

The water management of the TSF would include as a minimum the following aspects.

- Installation of an appropriate liner and seepage collection system to minimise water losses through seepage.
- Minimising the stored water volume on the TSF by maximising the recovery of water and decant which would be subsequently returned to the processing plant for reuse.

- Designing the embankment crest level on the basis of a Consequence Category of High C to contain the expected pond levels obtained from the water balance together with wave run-up and additional contingency freeboard.
- Allowing for storm storage, plus allowances for wave run-up and additional freeboard based on the ANCOLD guidelines on top of the expected maximum operating pond (with 50% probability of non-exceedance).
- Construction of an emergency spillway as part of the initial TSF embankment and both subsequent raises to facilitate discharge of rainfall runoff during extreme rainfall events to prevent overtopping of the embankment.
- Following the completion of tailings deposition at the end of the Project life, the TSF would be rehabilitated and material placed to establish a vegetated store-and-release cover that has been designed to minimise rainfall runoff infiltrating into the deposited tailings profile. Minimising infiltration reduces the risk of mobilising potential contaminants and their potential transport in seepage from the TSF.
- After decommissioning, the store-and-release capping layers and various seepage management measures would manage seepage from the TSF post mining operations (refer: ATCW, 2020, and Advisian, 2020b).

Relevant aspects of the current TSF design as they relate to the site water balance have been summarised in detail in Section 4.7.9.

4.4.2.2 PAF Waste Rock

PAF waste rock would be compacted and encapsulated in the WRE, a landform designed (Advisian, 2020a) for the long-term storage and containment of this material and any leachate generated within it.

The WRE would form an integrated landform between the ridge immediately east of the main open cut pit and west of Price Creek, and would comprise store-and-release capping layers that would be installed on each completed WRE cell as part of progressive rehabilitation and to reduce the volumes of leachate generated. These layers would prevent rainfall and surface water from ponding and subsequently infiltrating into the encapsulated PAF waste rock. Leachate collected from the WRE would report to the leachate management dam which would then be pumped to the process water circuit for processing operations. The management of runoff and leachate from the WRE cells during the development of the WRE is described in detail in Section 4.7.7.

4.4.2.3 NAF Waste Rock

NAF waste rock would be used as a construction material, particularly in the site establishment and construction stage and for rehabilitation of the final landform, in particular at the:

- **WRE:** construction of the upper and lower embankments and the haul road which would include the flood bund and noise barrier as well as the progressive rehabilitation to create the final landform at the end of the Project life;
- **TSF:** staged construction of the embankment and the retained landform at the end of the Project life;

- **Southern Barrier:** staged construction and landform removed at the end of the Project life comprising two staged components;
 - **Initial Barrier:** Comprising the initial Stage 1 development of the Southern Barrier, constructed by end of Year 5 and retained until the end of Project life when material would be removed and utilised for rehabilitation;
 - **Extended Barrier:** progressively developed in stages over the Project life (beyond Year 5) and utilised for the stockpiling of construction material for the staged development of the TSF embankment raises or the closure and capping of the WRE and TSF. The southern face of this temporary landform would be progressively rehabilitated and retained over the Project life.

Rainfall runoff from the external slopes of the placed NAF waste rock would be collected by drainage infrastructure and directed to a sediment dam to prevent discharge of sediment-laden water. It is anticipated that water stored in this sediment dam would be utilised for dust suppression on the Mine Site or (if necessary, flocculated) and released from site.

4.4.2.4 Capping of TSF and WRE

Prior to mine-closure, the TSF and WRE would be covered and vegetated to protect the downstream environment. The proposed cover (Advisian, 2020b) has been designed to reduce seepage by limiting the percolation of water into encapsulated PAF waste rock in the WRE and tailings deposited in the TSF. It would also provide a suitable revegetation media, while limiting the ingress of oxygen into the underlying waste materials and the upward movement of water in the tailings profile.

The proposed cover design is a combination of the following approaches:

- ‘store-and-release’ – moisture storage in the near-surface soil cover is maximised, so that it can be removed by evapotranspiration; and
- ‘water shedding’ – percolation of rainfall into the encapsulated PAF waste rock in the WRE or tailings deposited in the TSF is minimised through the use of a low permeability layer.

The proposed cover system includes the following layers:

- Topsoil, 0.3 m minimum; underlain by
- Subsoil, 0.3 m minimum; underlain by
- NAF waste rock (0.5-30 cm diameter), 0.4 m minimum; underlain by
- NAF waste rock (30-40 cm diameter), 0.4 m to 1.6 m; underlain by
- compacted subsoil, 0.4 m minimum; underlain by
- a geosynthetic clay liner (a thin bentonite layer sandwiched between geotextiles).

4.5 SITE WATER TYPES

Based on the above geochemical characterisation, land disturbance associated with mining has the potential to adversely affect the quality of surface runoff in downstream waters.

For the purpose of site water management, site water has been classified into the types shown in **Table 4.2**, on the basis of the likely water quality characteristics.

Table 4.2
Site Water Types

Water Type	Definition
Mine-affected water	Mine-affected water means the following types of water: 1. groundwater and surface water accumulating in the open cut pits; 2. water from advanced mine dewatering activities; 3. TSF decant water; 4. processing plant water; 5. WRE leachate and runoff from uncapped PAF waste rock. Groundwater extracted using the advanced dewatering system would not come into contact with the mining activities and is expected to be suitable for road watering purposes, however, it will generally be stored and managed in a similar manner to mine-affected water. Mine-affected water would be captured within the Mine Site, contained and re-used within the processing plant, eliminating the need for release to the receiving environment.
Sediment-laden water	Surface water runoff from areas that are disturbed by mining operations (including out-of-pit NAF waste rock emplacement). Sediment-laden water excludes water that has come into contact with PAF or other reactive material. It may contain high sediment loads but not contain elevated levels of other water quality parameters (e.g. electrical conductivity, pH, metals, metalloids, non-metals that may be deleterious to receiving waters). This runoff would be managed to ensure adequate sediment removal prior to release to receiving waters. Given the potential for manganese concentrations to be elevated in sediment -laden water (GCA, 2020), monitoring would be required to ensure that sediment-laden water would only be released if manganese or other metalloid concentrations are within limits to be specified in the EPL. If water quality is unsuitable for release, it would either be treated prior to release, or recycled in Mine Site applications.
Clean catchment water	Surface runoff from those areas unaffected by mining operations. Clean catchment water includes runoff from undisturbed areas and fully rehabilitated areas. Runoff will be captured in small dams distributed across the Bowdens landholding under the harvestable rights entitlement – and may be used for dust suppression on roads within the operation.
Potable water	Treated water suitable for human consumption.

4.6 WATER MANAGEMENT SYSTEM ZONES

The proposed strategy for the management of surface water within the Mine Site is based on the separation of water from different sources based on anticipated water quality.

On the basis of the predicted runoff and groundwater inflow quality, the site water management system (WMS) comprises three distinct water management zones, the containment zone, erosion and sediment control (ESC) zone and clean water zone, as defined in the following sections.

4.6.1 Containment Zone

Groundwater seepage and surface runoff from the open cut pit areas, the TSF, processing plant area, oxide ore stockpile and WRE are likely to have elevated dissolved metals levels. This (mine affected) water would be managed within a closed water management system.

PAF waste rock would be deposited within the active WRE cell, which, once complete in each cell, would be overlain by NAF waste rock and a cover and capping layer would be installed as part of progressive rehabilitation activities. Runoff from exposed rock within the WRE, as well as leachate would be conveyed to a dedicated leachate management dam via a buried pipeline.

To minimise water accumulating within the leachate management dam, TSF and open cut pits, water captured within the containment zone system would be the first priority water source for recycling in the processing plant.

4.6.2 Erosion and Sediment Control (ESC) Zone

Runoff (sediment-laden water) from disturbed areas within the Mine Site but outside of the containment zone, including the southern barrier, would be directed to sediment dams. This would include surface runoff from out-of-pit areas upslope of the southern barrier, which would be directed beneath the barrier itself via pipes or box-culverts.

Bowdens Silver's long-term objective is to discharge as much water collected within the sediment dams to the downstream environment to assist in maintaining environmental flows. However, the predicted and assessed impacts to downstream flows considers this water as retained within the Mine Site.

All disturbed areas would be rehabilitated and revegetated as soon as practicable to reduce the potential for sediment-laden runoff generation. It is therefore anticipated that after the settlement of suspended sediment in these dams, the water would be suitable for release in accordance with the discharge conditions of the environment protection license (EPL) for the Project which would be issued by the NSW Environment Protection Authority (EPA). However, a program of water quality monitoring would be undertaken characterise runoff from the NAF Waste Rock in the field. Discharges would not occur until it was confirmed that runoff water derived from the placed/stockpiled NAF waste rock is suitable for release, i.e. in accordance with the Project's EPL.

If necessary, Bowdens Silver would use an environmentally inert flocculant to remove suspended sediment and enable the water to be released within 5 days. Details of the flocculant and its management would be included in the Project's Water Management Plan.

As a minimum, the sediment dams would be sized and operated in accordance with "the Blue Book" (DECC, 2008) requirements for Type F sediment basins. However, if the ongoing program

of geochemical testing and characterisation of runoff determines that runoff must be contained on site to ensure the water source is not contaminated, sufficient storage capacity would be provided to minimise the likelihood of discharge by returning captured runoff to the Containment Zone. The proposed design storage capacity would be sufficient to contain runoff resulting from the 1 in 20 AEP 72 hour design storm (with a design volumetric runoff coefficient of 0.75) (equivalent to 1.2 ML/ha). In addition, sediment storage equivalent to 50% of the water storage capacity would be provided with each dam. Pumping infrastructure would be provided to enable the water to be transferred into the containment system within 5 days.

The key sediment dams within the Mine Site (and their approximate capacities if sized in accordance with 'Blue Book' (alternative 1 in 20 AEP 72 hour storm containment design in brackets)) would be located:

- downstream from the TSF embankment: (9.0 ML (26 ML for containment));
- adjacent to the TSF NAF waste rock stockpile area (6.5 ML (19 ML for containment));
- downslope from the southern barrier (two dams):
 - east (13.5 ML (40 ML for containment));
 - west (8.5 ML (25 ML for containment));
- downslope from the oxide ore stockpile (4.5 ML (13 ML for containment));
- within the footprint of the WRE at variable locations (varies – typically 5 ML (15 ML for containment)); and
- adjacent to the lower embankment haul road around the perimeter of the WRE (temporary) (4 ML (12 ML for containment)).

The outlets from the sediment dams would be rock-protected, and designed to promote the spread of flow, such that velocities are non-erosive downstream.

4.6.3 Clean Water Zone

The clean water zone water would ensure the volume of water potentially impacted by the Project is minimised by diverting (clean water) runoff from undisturbed areas away from disturbed areas.

During operations, a clean water diversion channel would divert the upper catchment of Blackmans Gully that would be unaffected by Project-related activities into Price Creek. The channel would largely follow the natural contours of the hill slopes and have a gentle gradient. This channel would result in the average annual diversion of approximately 10 ML/a of water from Blackmans Gully to Price Creek during operations.

Clean water diversion channels are also proposed to divert Blackmans Gully and its associated tributary catchments away from the main open cut pit both during operations and after mine closure.

4.7 WATER MANAGEMENT SYSTEM COMPONENTS AND LAYOUT

4.7.1 Water Storages

Table 4.3 lists the water storage structures that form part of the proposed Bowdens Silver water management system. The table includes capacity information (where available) as well as commentary regarding how these structures are represented within the site water balance model.

Table 4.3
Summary of Water Storages within Water Management System

Page 1 of 2

Location	Name	Nominal Capacity	Comments
Processing plant area*	Raw Water Dam	8 ML	The capacities would be reviewed during the detailed design of the processing plant area. Modelling assumes that satellite open cut pits would not store water, and would pump excess to main open cut pit as required.
	Open Cut Pit Dewatering Pond	1 ML	
	Runoff collection dams	100 ML	
	Turkey Nest Dam	130 ML	
WRE	Leachate Management Dam	80 ML	Storage characteristics for leachate management dam based on design by Advisian (2020a).
	WRE Sediment Dam(s)	Varies	Sediment dams would be constructed/relocated as part of each WRE stage, and (unless on the basis of further ongoing geochemical studies, a higher containment standard is required) sized in accordance with Blue Book requirements to accommodate the maximum contributing area of upstream capped (unvegetated) catchment area. (unless on the basis of further ongoing geochemical studies, a higher containment standard is required) (refer 4.6.2).
TSF	Decant pond	Varies	Varies over the life of the TSF depending on the current embankment height, and elevation of tailings against the embankment. Based on details provided by ATC Williams (2020). Decant water would be returned to the processing plant via a fixed pumping system, leaving a depth of approximately 0.5 m inaccessible for reuse.
Other	Oxide ore stockpile dam	4.5 ML (12 ML for containment)	Sized in accordance with Blue Book requirements (unless on the basis of further ongoing geochemical studies, a higher containment standard is required) (refer 4.6.2).
Sediment dams	TSF embankment sediment dam	9.0 ML (26 ML for containment)	Sized in accordance with Blue Book requirements (unless on the basis of further ongoing geochemical studies, a higher containment standard is required) (refer 4.6.2).
	TSF NAF waste rock stockpile sediment dam	6.5 ML (19 ML for containment)	
	Southern barrier external embankment sediment dams	13.5 ML, 8.5 ML (40 ML, 25 ML for containment)	
	Haul road sediment dam	4.0 ML (12 ML for containment)	

Table 4.3 (Cont'd)
Summary of Water Storages within Water Management System

Page 2 of 2

Location	Name	Nominal Capacity	Comments
Harvestable rights dams	WC North	2.2 ML	Constructed and operated in accordance with maximum harvestable rights provisions of the Water Management Act 2000 ¹ . The locations of these dams are shown in Figure 1.2.
	WC Northeast	2.4 ML	
	BG Centre (North)	4.3 ML	
	BG Centre	3.0 ML	
	BG Centre (South)	1.3 ML	
	BG South	1.6 ML	
	Water Storage Dam (Clean, Turkey Nest)	130 ML	
TBC = To be confirmed			
1 = No approvals required and based on Bowdens Silver's entitlement of 180.6 ML from contiguous landholding of 2 580 hectares (as described in Section 8.1.2).			

Catchment runoff from NAF waste rock would be captured in sediment dams, as described in Section 4.6.2. Several catchments have been identified on the periphery of the disturbance area where runoff would be routed to a sediment dam. These catchments, which are indicated in the stage plans in **Figure 4.4** to **Figure 4.7**, include:

- the outer embankment of the TSF;
- the outer catchment of the southern barrier;
- the haul road that bounds the southern and eastern extent of the WRE.

4.7.2 System Configuration

A schematic diagram of the integrated Project water management system configuration is shown in **Figure 4.2**. A summary of the proposed storages within the integrated WMS and their operating strategies are summarised in the following sections.

4.7.3 Development of Key System Components

Figure 4.3 summarises the development sequence for the various mine infrastructure elements throughout the course of the mine life. Four development snapshots presented in **Figure 4.4** to **Figure 4.7** are indicative catchment and land use plans for four discrete points in time. These figures generally correspond to operational years, namely year 0 (site establishment and construction stage), year 3, year 8 and year 10 respectively. The Project year corresponding to each of these snapshots has been highlighted in **Figure 4.3**.

Table 4.4 lists the catchment areas reporting to various water storages, sediment dams and other reference points (clean catchment release points etc) over the mine life.

Figure 4.2 Proposed Integrated Water Management System Schematic

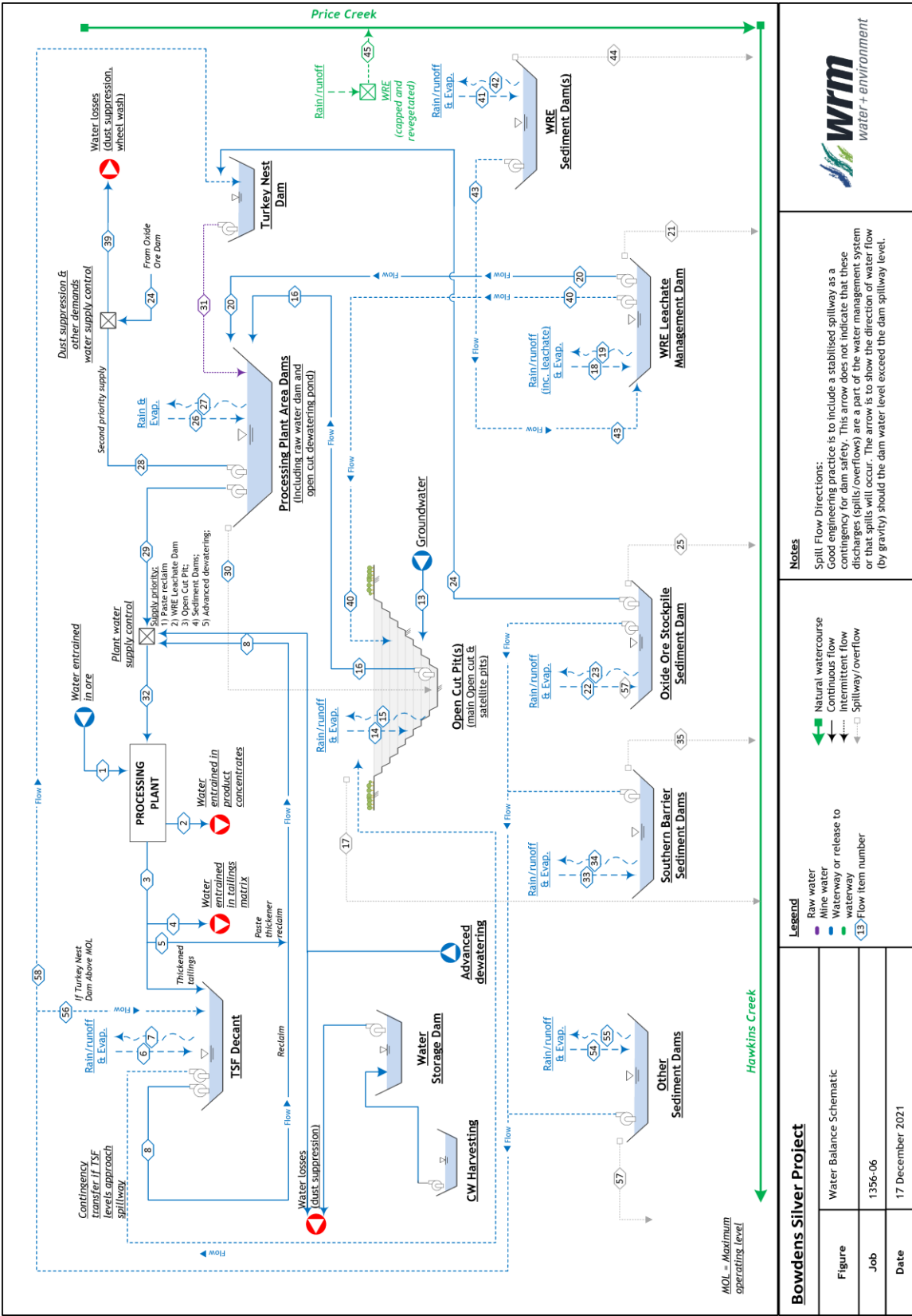


Figure 4.3 Summary of Project Timing

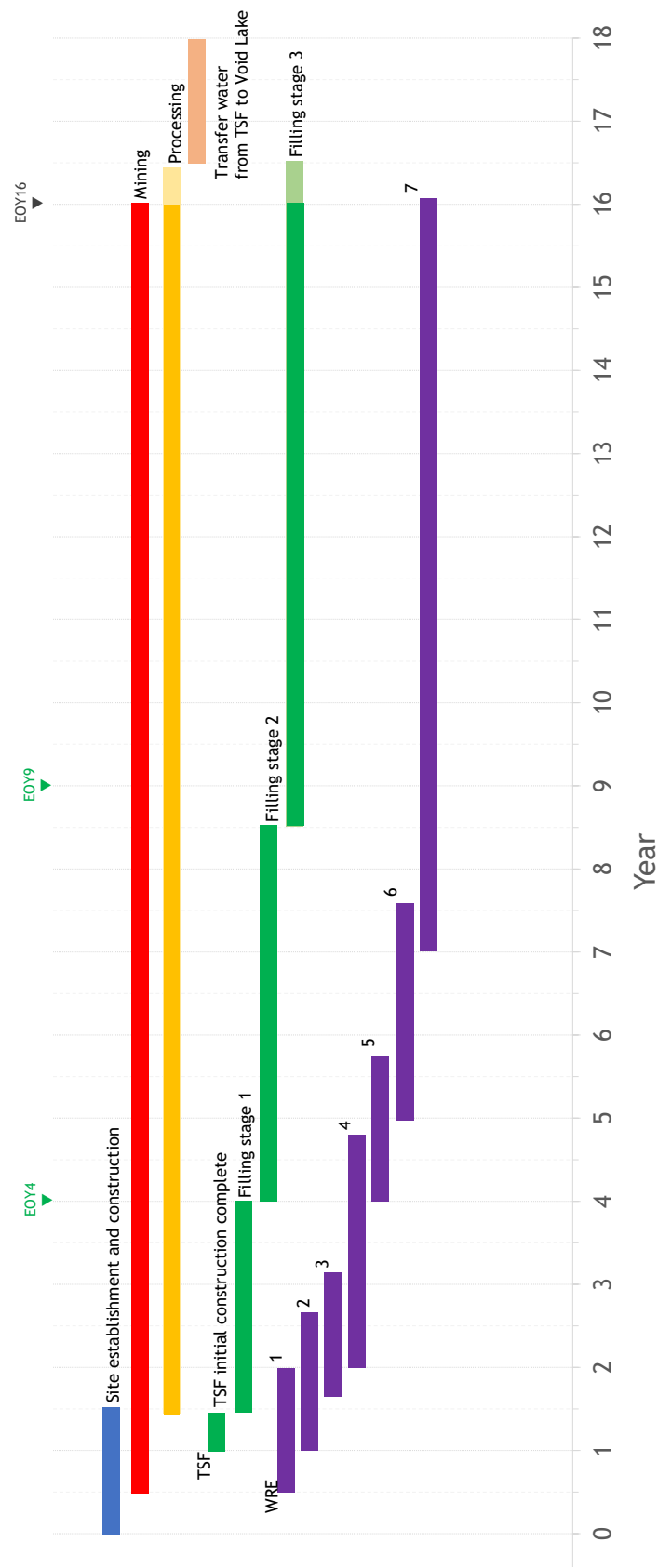


Figure 4.4 Catchment and Land Use Plan – Year 0 (site establishment and construction stage)

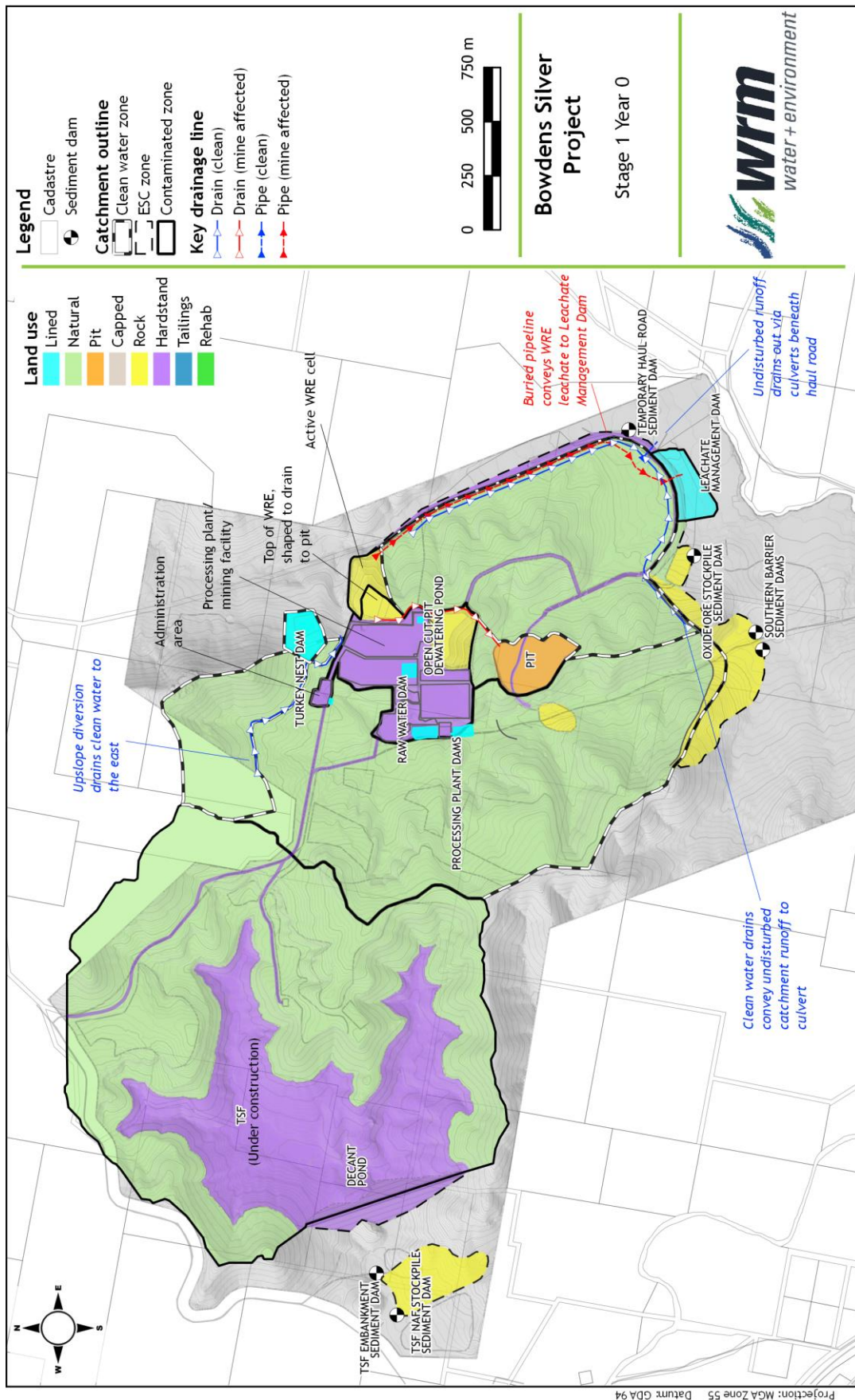


Figure 4.5 Catchment and Land Use Plan – Year 3

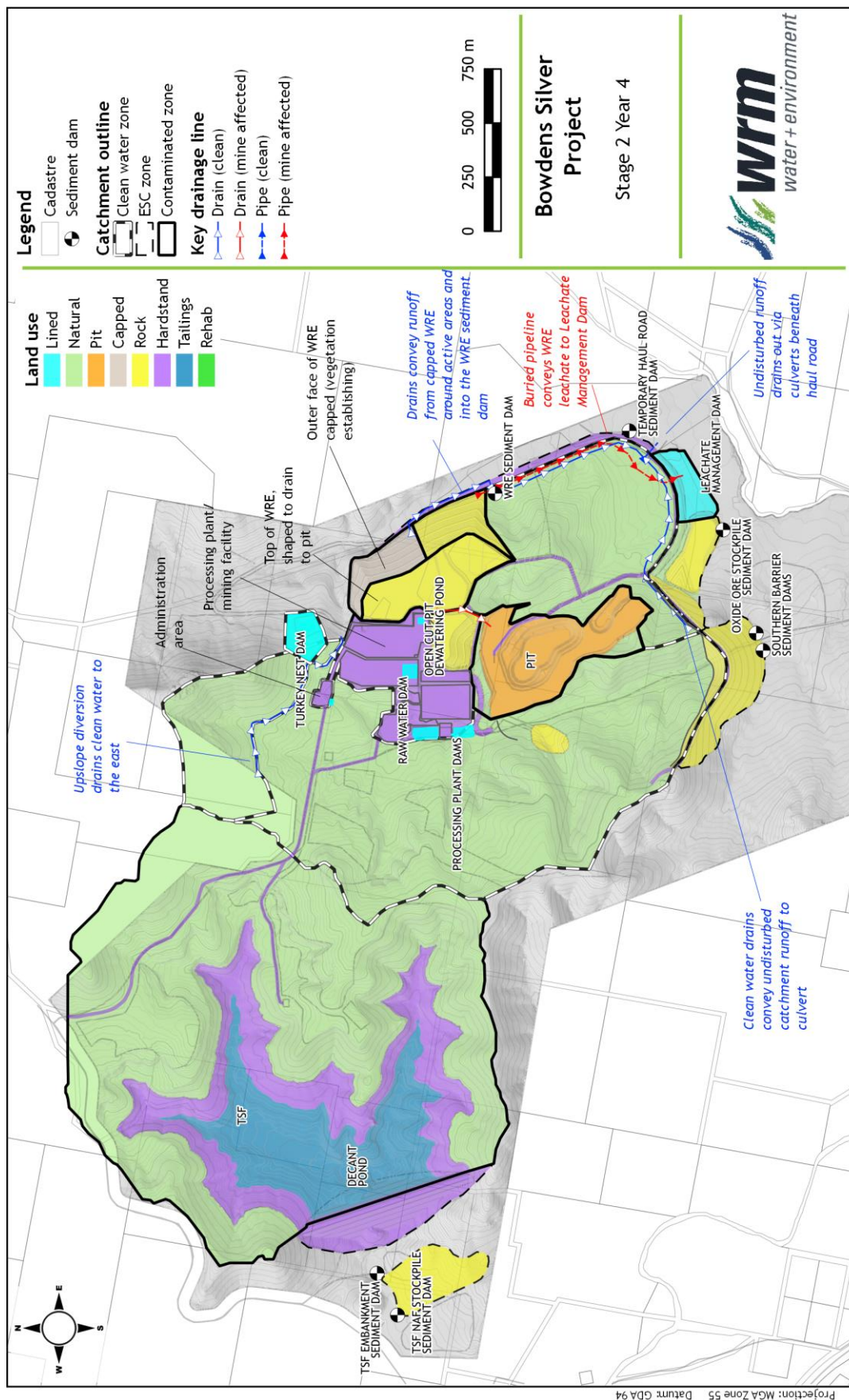


Figure 4.6 Catchment and Land Use Plan – Year 9

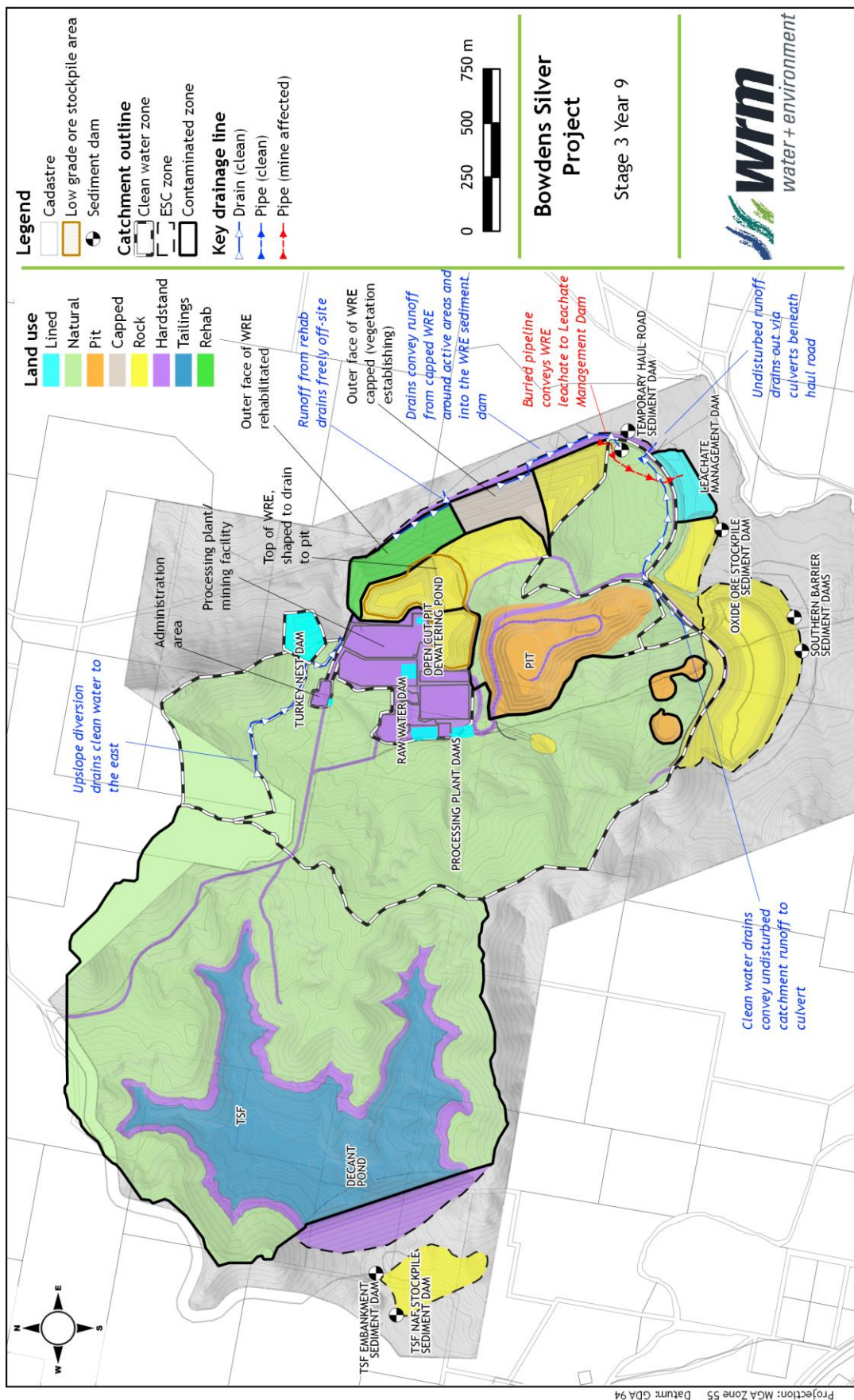


Figure 4.7

Catchment and Land Use Plan – Year 10

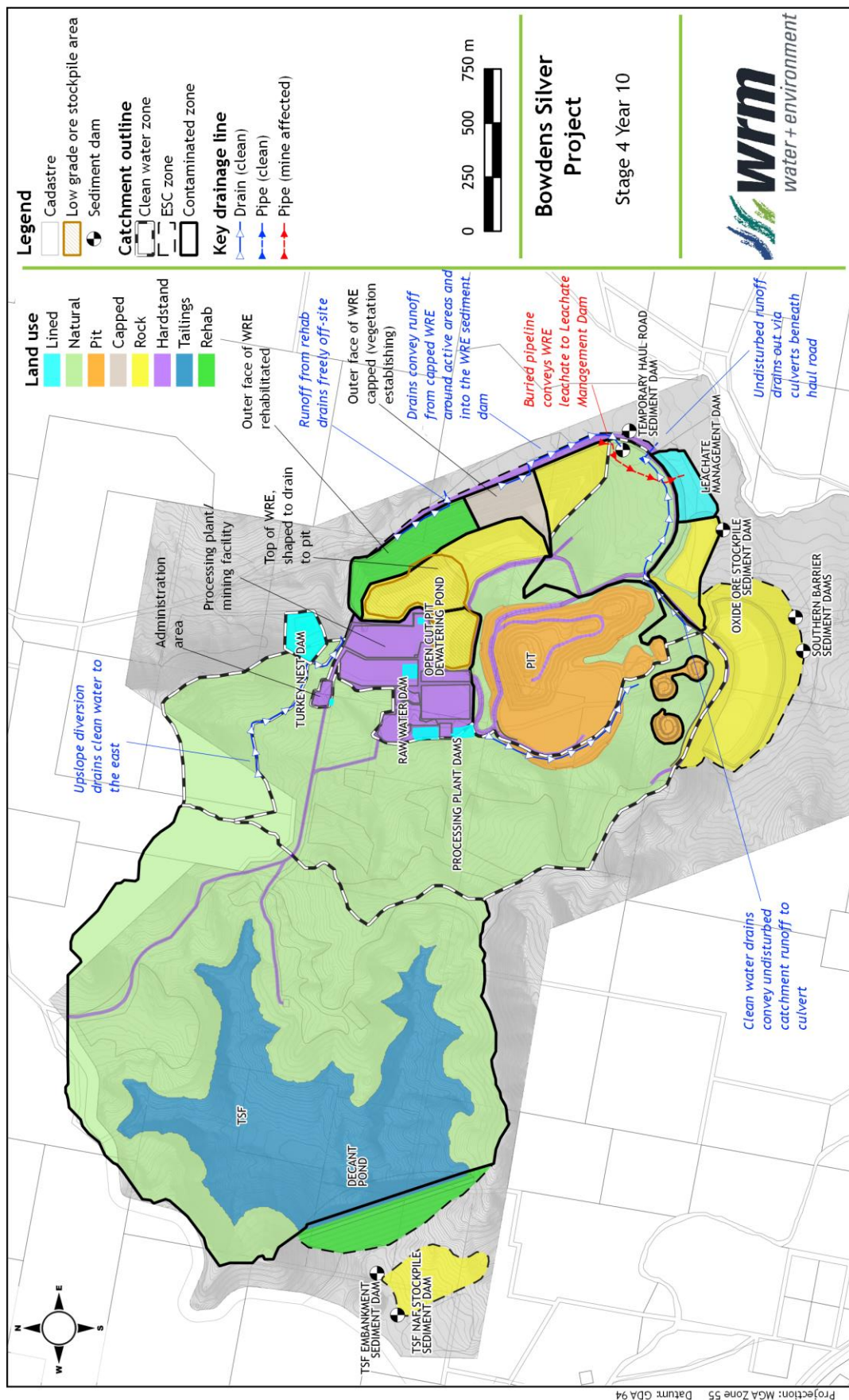


Table 4.4
Catchment Area Breakdown by Year of Mine Development (units: hectares)

Operational Year	Mine Water Management System						Clean Catchment Release			Sediment Dams				Clean Water Harvesting
	Processing Plant Area	Main Open Cut	Satellite Pit(s)	TSF	WRE Leachate Management Dam	Oxide Ore Dam	WRE Rehab	Southern Barrier Valley	LHR(C7)* Outlet	TSF Outer Embankment	Southern Barrier Outer Embankment	WRE Sediment Dam	Haul Road	
0.5-1.5	30	12.5	-	301.2	10.5	5.3	-	164.1	92.6	-	11.4	1.4	4.3	144.5
1.5-2.5	30	14.5	-	301.2	19.5	9.1	-	164.1	77.2	5.2	11.4	5.7	4.3	144.5
2.5-3.5	30	22.5	-	301.2	7.7	9.1	-	164.1	77.2	5.2	11.4	9.8	4.3	144.5
3.5-4.5	30	22.5	-	301.2	15.4	9.1	-	164.1	68.0	5.2	11.4	11.2	4.3	144.5
4.5-5.5	30	26.5	-	301.2	15.3	9.1	-	164.1	60.1	13.4	11.4	14.8	4.3	144.5
5.5-6.5	30	62.8	-	301.2	7.5	9.1	0.7	159.4	32.1	13.4	11.4	18.3	4.3	144.5
6.5-7.5	30	62.8	3.4	301.2	30.7	9.1	4.4	156.3	6.7	13.4	31.6	17.1	4.3	144.5
7.5-8.5	30	62.8	3.4	301.2	26.6	9.1	9.0	156.3	6.7	13.4	31.6	16.0	4.3	144.5
8.5-9.5	30	62.8	3.4	301.2	24.5	9.1	10.6	156.3	6.7	13.4	31.6	16.5	4.3	144.5
9.5-10.5	30	83.8	-	301.2	22.4	9.1	13.7	132.9	6.4	13.4	31.6	15.5	4.3	144.5
10.5-11.5	30	83.8	-	301.2	20.2	9.1	18.4	132.9	6.4	13.4	31.6	12.9	4.3	144.5
11.5-12.5	30	83.8	-	301.2	18.1	9.1	20.8	132.9	6.4	13.4	31.6	12.7	4.3	144.5
12.5-13.5	30	83.8	-	301.2	16.0	9.1	24.5	132.9	6.4	13.4	31.6	11.1	4.3	144.5
13.5-14.5	30	83.8	-	301.2	13.9	9.1	26.6	132.9	6.4	13.4	31.6	11.1	4.3	144.5
14.5-15.5	30	83.8	-	301.2	11.8	9.1	28.7	132.9	6.4	13.4	31.6	11.1	4.3	144.5
15.5-16.5	30	83.8	-	301.2	9.7	9.1	30.8	132.9	6.4	13.4	31.6	11.1	4.3	144.5
16.5-17.5	30	83.8	-	301.2	9.7	9.1	30.8	132.9	6.4	13.4	31.6	11.1	4.3	144.5

Note: * LHR(C7) denotes the lower haul road (future WRE cell 7 area) – this is the basin immediately north of the proposed Leachate Management Dam

Further details of key components (open cut pit, southern barrier, WRE, low grade ore stockpile, processing plant area, TSF) of the water management system are described in the following sections.

4.7.4 Processing Plant Area

The processing plant area includes the processing plant, mining facility, ROM ore stockpiles, primary jaw crusher, crushed ROM stockpile and administration area. These elements would be constructed on a series of terraced pads, which are situated on the eastern side of Blackmans Gully – the mine's central drainage feature (upstream of the southern barrier – see **Figure 3.6** and **Figure 4.4**).

Prior to construction of the processing plant and mining facility pad, the upstream undisturbed catchment of Blackmans Gully would be diverted east to Price Creek.

The alignment and specifications of the various drains/bunds/pipelines required to manage processing plant area runoff would be confirmed as part of mine detailed design. Runoff would generally be drained to dams located to the west of the processing plant area. Dam overflows resulting from very large runoff events would be directed to the main open cut pit. However, all dams would be sized to minimise the possibility of overflows, with water collecting in these dams recycled and re-used in the processing circuit.

4.7.5 Southern Barrier

NAF waste rock would be placed across the southern invert of Blackmans Gully, to form an embankment. A low level pipe or box culvert would allow water to drain from Blackmans Gully beneath the barrier.

The southern barrier would then be developed as a NAF construction material stockpile for NAF waste rock that is surplus to the construction requirements of the Project over the course of the operational Project life (i.e. TSF embankment, raises and progressive rehabilitation of completed WRE cells). The full height of the southern barrier would be achieved as part of the initial stage (by the end of Year 5). The subsequent stage would entail placing additional waste rock against the outer face of the southern barrier, increasing its thickness and overall footprint but not its height.

Based on the installation of a low level pipe or culvert outlet at the invert of Blackmans Gully, water would not pond for long periods upstream of the southern barrier. Bowdens Silver proposes to selectively place waste rock with low metals leachate potential at the base of the embankment such that any seepage through this material does not leach metals exceeding background concentrations.

4.7.6 Open Cut Pit Development

Development of the open cut pits can be described as follows.

- The first 6 years entail widening and deepening of the eastern section of the main open cut pit, located to the south of the processing plant area.
- The next two years entail opening two satellite pits to the south-west of the main open cut pit, in the area immediately north of the southern barrier.
- The remaining years entail additional excavation within the western section of the main open cut pit.

The main open cut pit is centred on the ridgeline separating the catchments of:

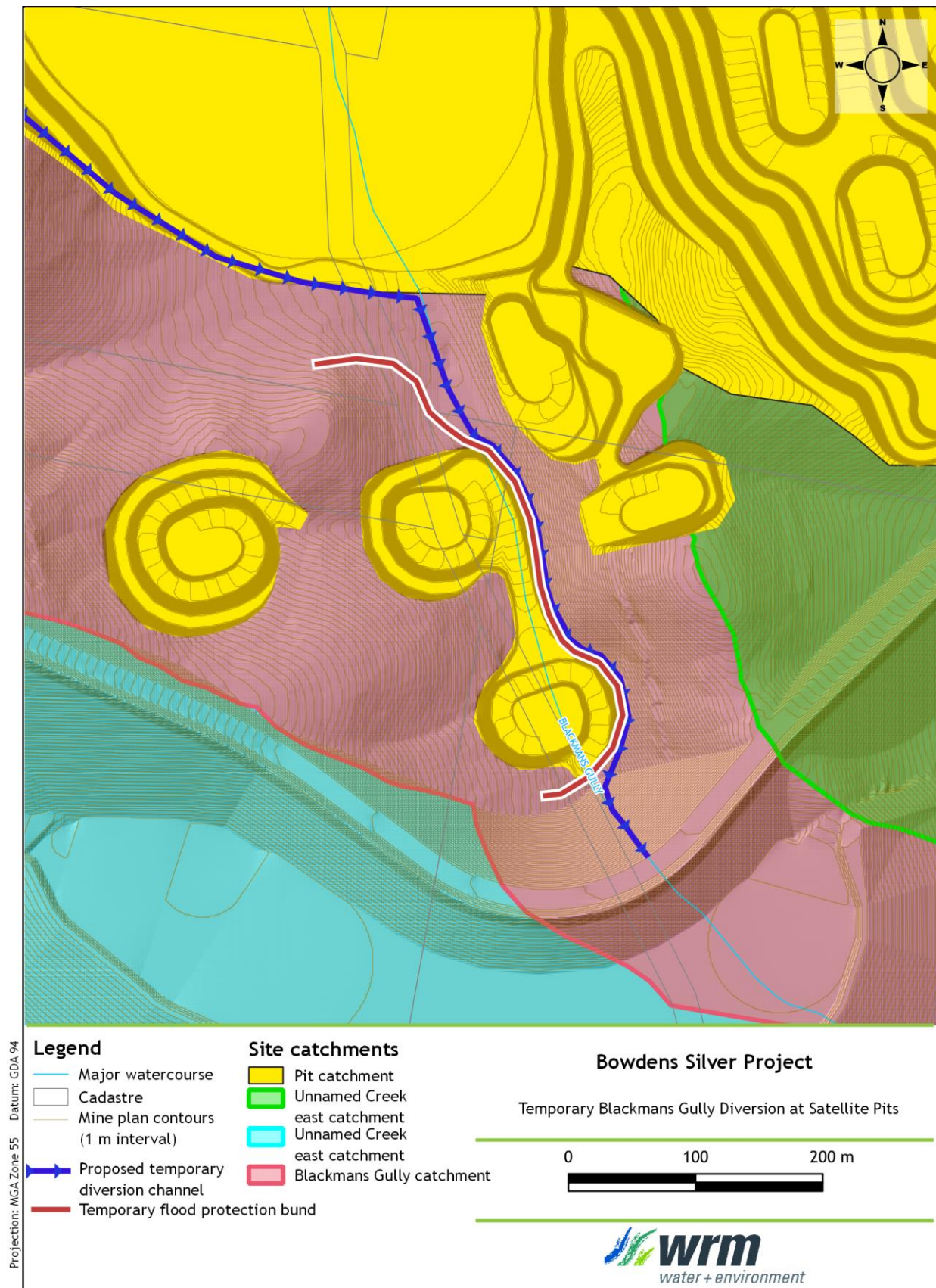
- Blackmans Gully (to the west); and
- an unnamed minor gully (and ultimately the southern portion of the WRE (WRE Cell 7 – (to the east).

The impacts of the open cut pit development on these sub-catchments develop as follows:

- The main open cut pit would expand, with corresponding reductions in the two sub-catchments (noting that parts of the upstream catchment of Blackmans Gully would be diverted east or captured in the processing plant dams).
- Initially, the undisturbed portion of Blackmans Gully to the west and northwest of the open cut pit would drain unimpeded towards (and beneath) the base of the southern barrier.
- The satellite pits would be developed across Blackmans Gully upstream of the southern barrier. Bowdens Silver would construct temporary diversion and levee works to ensure runoff in Blackmans Gully does not enter the satellite pits. These works, which are shown indicatively in **Figure 4.8**, would be detailed fully as part of detailed design.
- The main open cut pit would then expand west through the floor of Blackmans Gully leading to the removal of the Water Storage Dam. The satellite open cut pits would also be progressively backfilled with NAF waste rock from the main open cut pit at this time. A diversion channel would be constructed to divert runoff around the main open cut pit to the southern barrier. The diversion channel would be retained after mine closure and after the removal of the southern barrier.

Elevated sections of the WRE (and adjacent minor catchments) would drain west to the open pit as the WRE develops, however any runoff from these catchments would also be diverted around the main open cut pit. Refer to Section 4.7.7 for further information regarding these areas.

Figure 4.8 Temporary diversion of Blackmans Gully around Satellite Pits



4.7.7 Waste Rock Emplacement

The WRE covers an area of approximately 77 ha, bounded by the lower perimeter embankment that would include a haul road, flood bund and, (in some sections) a noise barrier. The final WRE landform would be constructed across seven discrete stages/cells. PAF waste rock would be placed within the active WRE cell and, upon completion of the active cell, overlain by the capping and cover system. Runoff from exposed PAF waste rock within the active WRE cell, as well as any water infiltrating through the PAF waste rock (referred to herein as leachate) would be collected at the lowest point in each cell and directed via a buried pipeline to the leachate management dam for temporary storage and subsequent transfer to the processing plant. Sufficient storage would be provided in the leachate management dam to ensure no discharge of leachate to the receiving environment.

Surface runoff from sections of the WRE that have been capped would be routed around the active WRE cell and into a sediment dam that would be constructed in the cell immediately downstream of the active cell. Runoff volumes exceeding the capacity of the sediment dam would overflow to the environment. If water intercepted by the sediment dam was unsuitable for release, it would be pumped to the mine water management system. After vegetation has re-established on the capped sections of the WRE, surface runoff would be routed away from the active WRE cell towards Price Creek.

Any water infiltrating through the cover and capping layer would report to the leachate management dam via the buried pipeline. This would allow for the monitoring of leachate volumes so as to establish the effectiveness of the capping and cover system. The upper sections of the WRE would be flat and shaped to drain back towards the main open cut pit during operations and diverted upon closure, once rehabilitation criteria have been met. As described in Section 4.7.8, low grade ore is also proposed to be stockpiled on the surface of Cells 1 to 3 of the WRE, and as a result, would not be capped immediately. For the purpose of the water balance model, the baseflow component of runoff from the upper (low grade ore) section of the WRE is directed to the leachate management dam, and the surface runoff component is directed to the main open cut pit.

The perimeter embankments (including haul roads), buried leachate pipeline, and leachate management dam would be developed as part of the initial WRE construction. The following points generally describe the development of a typical (intermediate) cell, with respect to drainage and water management.

- An internal embankment would be constructed to bound the footprint of the cell and anchor the high-density polyethylene (HDPE) liner.
- A new sediment dam would be constructed downstream of internal embankment, and drainage would be constructed to connect the new dam with capped sections of the WRE upstream.
- Following the installation of the HDPE liner, an inspection pit(s) would be constructed to allow runoff from within the cell to drain into the buried pipeline that runs to the leachate management dam.
- PAF waste rock would be placed in the cell in accordance with the WRE design specification, nominally in a sequence of raises.

- Following completion of each raise, any sections of waste rock that would eventually form the outer face of the final WRE would be covered with the store-and-release cover and capping layer and then seeded.
- Bunding/drainage would be progressively modified to direct runoff from the capped sections of the WRE into the downstream sediment dam (while vegetation establishes).
- Following completion of the final raise, when the cell reaches its maximum height, the top section of the cell would be reshaped, capped and covered to drain back towards the main open cut pit.

4.7.8 Low-grade Ore Stockpile

Depending on commodity prices, a percentage of the mined ore may not be economic to process. Any such low grade ore would be stockpiled so that it could be processed in future, when commodity prices are more amenable. Current mine planning proposes to stockpile low grade ore in two stages. The first of these stages would be located adjacent to the processing plant area (see **Figure 4.6**), to the south of the open cut pit dewatering pond. The subsequent stage would be constructed on the completed upper surface of Cells 1 to 3 of the WRE that drains back towards the main open cut pit.

4.7.9 Tailings Storage Facility

The TSF embankment would be constructed in a staged approach, with an initial embankment and two subsequent downstream type embankment raises. Deposition of tailings within the valley behind the TSF embankment would occur continuously over the operations stage of the Project life. A decant pond would be situated atop the lower tailings beach, adjacent to the TSF embankment. **Table 4.5** summarises the timing of each stage, and key control levels including the invert level of the spillway constructed in the embankment, and the crest level of the embankment. **Table 4.5** (source: ATCW, 2020) shows how the level of the tailings against the embankment increases as more tailings are added to the TSF.

The depth of water in the decant pond would be managed to maximise dewatering and leaving a depth of approximately 0.5 m inaccessible for reuse. Pond dewatering would occur via a fixed pumping system for returning water to the processing plant to be recycled as part of the ore processing operation.

Table 4.5
TSF Key Control Levels by Development Stage

Stage	Implemented	Timing (tailings tonnage)	Spillway level (mAHD)	Crest level (mAHD)
Stage 1	Year 0	0 to 6 Mt	599.50	601.50
Stage 2	Year 3	6 to 16 Mt	609.25	611.00
Stage 3	Year 8	16 to 30 Mt	618.20	620.00

Following wet weather, the decant pond may accumulate additional water. In very wet periods, transfers from the TSF to the main open cut pit would be initiated if TSF decant pond water levels rise above the TSF Transfer Level. The TSF Transfer level would be set 0.75 m below the TSF spillway crest level. In the final year of processing, decant pond water levels would be drawn down via decreasing the TSF Transfer Level by 1.95 metres to become 2.7 m below the spillway crest level.

The potential water storage capacity of the TSF is at its greatest immediately following construction/raises of the embankment. In contrast, the potential water storage capacity of the TSF is at its lowest immediately prior to an embankment raise (when the distance between the tailings beach and embankment crest is at a minimum).

5. SITE WATER BALANCE

5.1 OVERVIEW

The overall Project water balance has been assessed through detailed site water balance modelling.

The performance of the water management system (WMS) was assessed using the GoldSim water balance model. GoldSim is a computer-based operational simulation model that can be used to assess the dynamics of the water balance under varying rainfall and catchment conditions throughout the development of the Project.

The GoldSim model dynamically simulates the operation of the WMS and keeps complete account of all site water volumes and representative water quality on a daily time step. The model was configured to simulate the operations of all major components of the WMS. The simulated inflows and outflows included in the model are given in **Table 5.1**.

Table 5.1
Simulated Inflows and Outflows to WMS

Inflows	Outflows
Direct rainfall on water surface of storages	Evaporation from water surface of storages
Catchment runoff	Processing Plant demand
Groundwater inflow to open cut pits	Dust suppression demand
Advanced dewatering	Losses to tailings entrainment
Ore moisture	Overflows or discharges from storages

The site water balance covers the Months 7 to 18 of the site establishment, 15 years of processing operations (and tailings deposition) and the initial two years of final rehabilitation activities. The model was used to predict the performance of the following aspects of the site water balance:

- Overall water balance - the average inflows and outflows of the WMS for a number of representative realisations.
- Mine water inventory – the accumulation of water in the open cut pits, TSF decant pond and leachate management dam as well as the raw water dam and the pit dewatering pond.
- Uncontrolled releases (spillway discharges) – the risk of uncontrolled releases from the surface water storages to the receiving environment.

Key aspects of the site water balance are described in detail in the following sections.

5.2 SITE WATER DEMAND

5.2.1 Processing Plant and TSF Balance

When operating at its design capacity of 2 Mtpa ore feed, the processing plant is expected to require approximately 3.0 ML/d (1 092 ML/a) of total make up water.

Water would be transferred to the TSF in the tailings slurry at a rate of approximately 3.17 ML/d (1 156 ML/a). Flow streams associated with the processing plant are summarised in **Table 5.2**.

Table 5.2
Processing Plant Flow Balance (at design 2 Mtpa Ore Feed)

Direction	Flow stream	Flow Rate		
		m ³ /h	ML/d	ML/a
Outflows	Water entrained in concentrates	0.7	0.02	6
	Tailings slurry water (@ 63% w/w solids)	144.5	3.17	1 156
	Other losses	1.7	0.04	14
Inflows	Water entrained in ROM	10.4	0.23	83
	Process water	136.5	2.99	1 092
Note: annual/daily flow rates calculated based on 8 000 hours per year plant operation				

Paste thickening would result in tailings with a very low moisture content and minimal bleed water would report to the TSF decant pond.

Processing plant makeup water demands would be sourced from the following locations, in order of priority:

- Paste thickener reclaim;
- WRE leachate management dam;
- TSF decant pond;
- Open cut pit
- Sediment dams; and
- Advanced dewatering.

5.2.2 Haul Road Dust Suppression

Water would be applied to haul roads to suppress dust generation during construction and operations. Haul road water demands would vary over time due to the changes in the length of haul roads as the Project develops. More water would also be required during dry weather when evaporation is high.

Haul road dust suppression demands would be reduced through the use of an approved chemical suppressant / sealant. Based on experience at nearby operations, daily haul road watering demands were reduced by the following percentages:

- May, Jun, July – 10%
- April and August – 25%
- September to March – 40%

Dust suppression water for out-of-pit haul roads would be drawn from the harvestable rights dams as a first priority, and then from the Oxide Ore Dam or advanced dewatering, if required. Based on the demand reductions achieved from use of a chemical suppressant / sealant, the estimated haul road demands throughout the Project life are shown in **Table 5.3**.

Table 5.3
Modelled Haul Road Watering Demands

Year	Watered Road Area (ha)	Average Annual Demand (ML/a)
0.5-1.5	16.5	121
1.5-2.5	18.2	133
2.5-3.5	19.7	144
3.5-4.5	20.1	148
4.5-5.5	19.2	140
5.5-6.5	16.1	118
6.5-7.5	15.1	111
7.5-8.5	19.6	144
8.5-9.5	28.1	206
9.5-10.5	19.6	144
10.5-11.5	16.2	119
11.5-12.5	13.5	99
12.5-13.5	14.2	104
13.5-14.5	15.1	114
14.5-15.5	16.3	127
15.5-16.5	18.3	135
16.5-17.5	18.3	135

5.2.3 Potable Water Demands

Potable water requirements during the site establishment and construction stage would be delivered to the Mine Site by water tanker until such time as the reverse osmosis (RO) plant is installed. The RO plant would be used during operations to treat a combination of groundwater, surface water and mine water to produce potable water. Brine from the RO plant would be returned to the processing plant dams for reuse.

The administration area and amenities would require up to 14 ML/a of potable water, based on 250 L per day per person and a workforce of up to 150 people on-site on any one day.

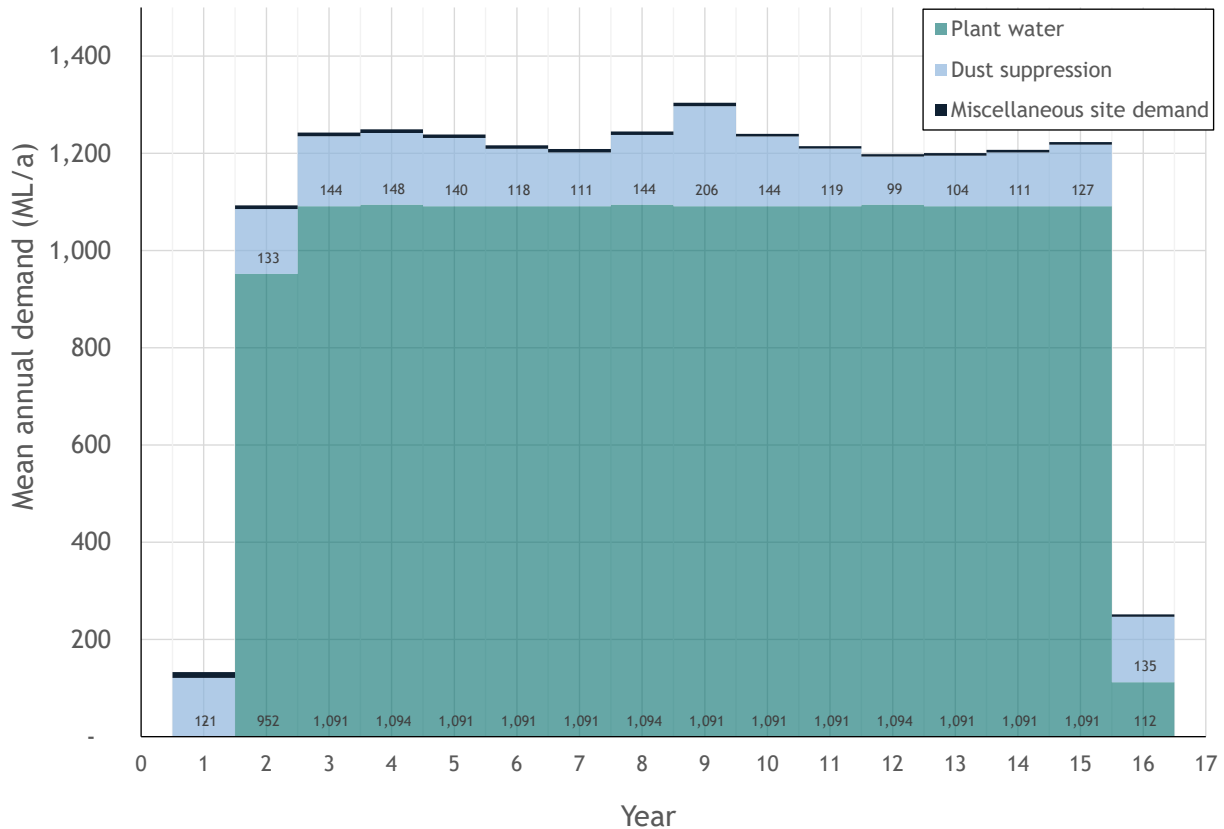
5.2.4 Miscellaneous Water Demands

There would also be minor quantities of water used for miscellaneous purposes around the Mine Site, including for the wheel wash station that would be used for trucks carrying NAF waste rock to the TSF for embankment raises. An allowance has been made for loss rate ranging between 0.2 ML/a and 7.5 ML/a.

5.2.5 Total Water Demand

The makeup of the total site water demand throughout the Project life is illustrated in **Figure 5.1**. Note that plant demand reduces during the 15th year of processing because at the assumed production rate, all ore would be processed in that year.

Figure 5.1 Average Annual Project Demands



5.3 MODELLING OF CATCHMENT YIELD

5.3.1 Overview

The Australian Water Balance Model (AWBM) model was used to represent the runoff characteristics of Mine Site catchments. AWBM uses a group of connected conceptual storages (3 surface storages) to represent catchment runoff. Water in the conceptual storages is replenished by rainfall and reduced by evaporation. Simulated surface runoff occurs when any of these storages fill and overflow. The model parameters define the depth and relative area of each of the storages, as well as the rate of water flux from/between storages. The AWBM model adopted for this Project uses the point estimates of Morton's Wet ET from the SILO gridded dataset.

5.3.2 Land Use Types

Runoff characteristics vary by land use. Land use types within each of these catchments are shown in **Figure 4.4** to **Figure 4.7**. The land use mapping discretises the mine catchment into the following land use types:

- Lined (e.g. HDPE or bituminous geomembrane liner or equivalent);
- Natural/undisturbed, representing areas in their current state;
- Pit, representing the walls and floor of the open cut pit;
- Hardstand, representing pads, processing plant areas and roads;
- Rock, representing placed NAF/PAF waste rock;
- Capped, representing a soil capping layer installed over PAF waste rock placed in the WRE;
- Rehab, representing fully rehabilitated/revegetated areas; and
- Tailings, representing the tailings beach within the TSF.

For the purposes of GoldSim modelling, the land use types listed above have been consolidated as follows:

- Lined, natural/undisturbed, rehab and tailings remain as they are;
- Pit and hardstand have been consolidated to roads/hardstand/pits; and
- Rock and capped have been consolidated to **spoil**.

The GoldSim model simulates development of the WRE based on the following assumptions, which illustrated in the diagram in **Figure 5.2**:

- The percentage of each cell's footprint covered by rock increases from 0% to 100% over the course of the cell's operational life;
- Redirection of the area at the top of the cell into the pit catchment occurs instantaneously at the completion of the cell (prior to this point, this area reports to the leachate pond);
- The extent of area to be capped within each cell is assumed to be everything except the top surface (i.e. the area that would be shaped to drain to pit) in addition to any area that would be dumped over as part of the next WRE cell (typically the face of the southern embankment). The percentage of this area to be capped increases from 0% to 100% over the course of the cell's life, however a three-month delay has been applied; and
- Capped areas are assumed to be fully revegetated and suitable for release off-site after a five-year delay.

5.3.3 AWBM Model Parameters

Runoff from undisturbed site catchments have been modelled using the approach described in Section 3.5.3. The adopted parameters are summarised in **Table 5.4**.

In the absence of site-specific data, AWBM parameters for disturbed areas have been adopted based on experience with catchment modelling at upper Hunter Valley mine sites.

The tailings impoundment area of the TSF would be lined with a bituminous geomembrane, and the AWBM model parameters for this area reflect the low permeability of that surface. Note that runoff from the wet component of the tailings beach is calculated assuming zero losses. Any rainfall falling on the wet beach (estimated as 35% of the total beach area) is assumed to be wholly converted to runoff.

Figure 5.2 Land use types – WRE

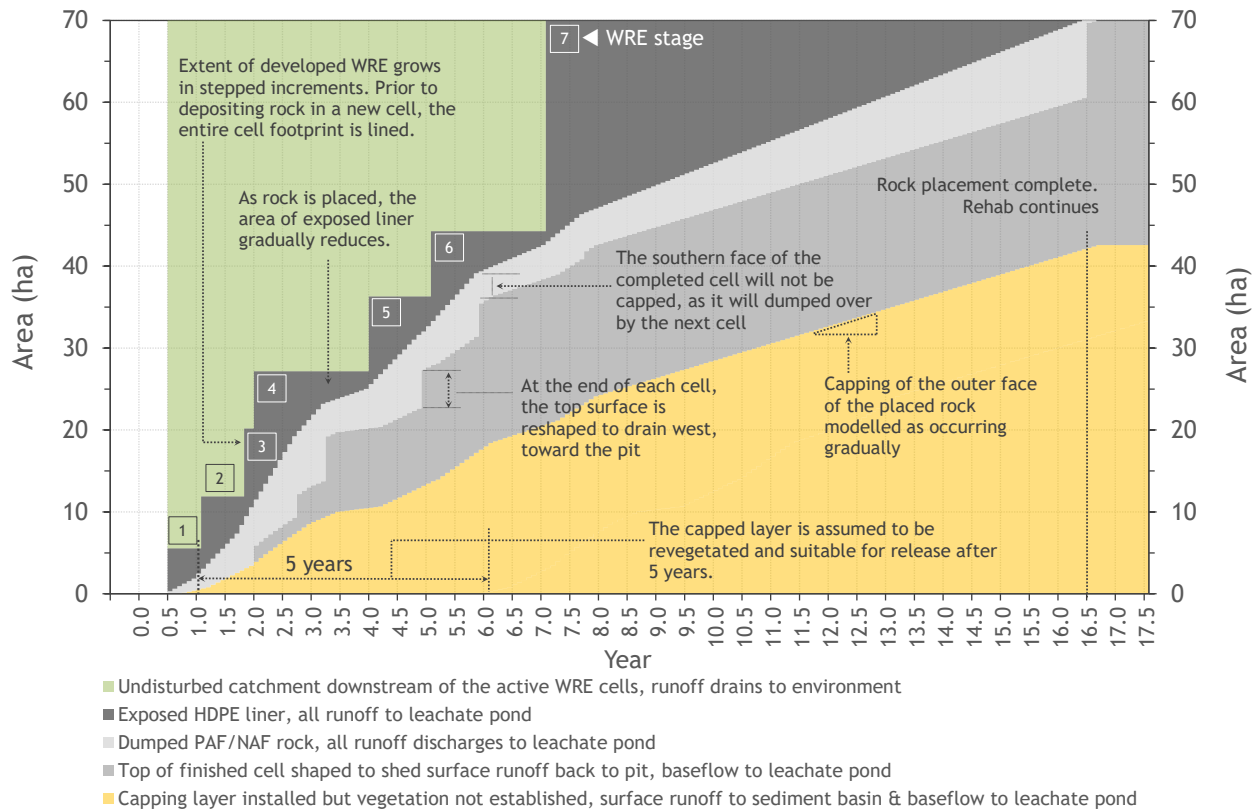


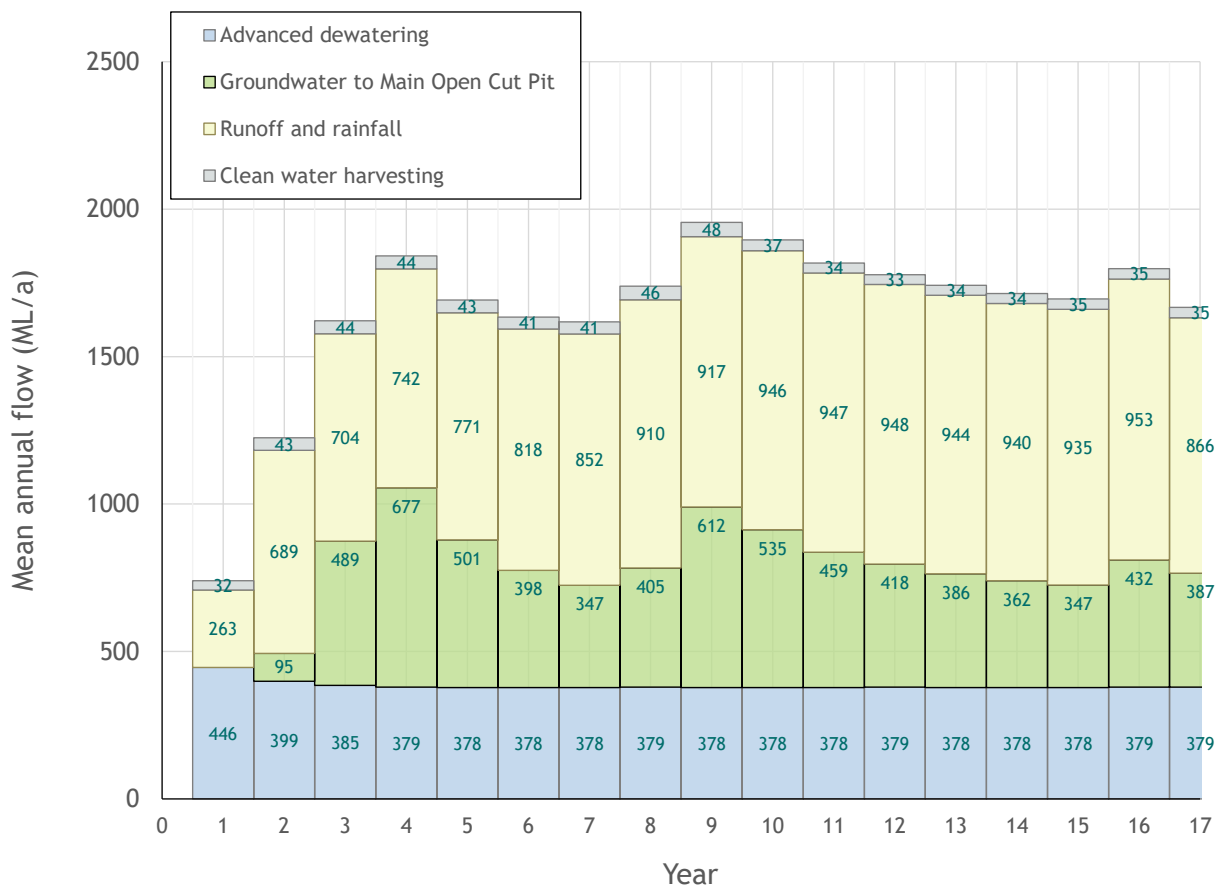
Table 5.4
Adopted AWBM Parameters – Base Case Scenario

Parameter	Dry Tailings Beach (TSF)	Natural/ Undisturbed	Roads/ Hardstand/ Pits	Waste Rock Emplacement	Rehabilitation	Lined
A1	1.0	0.134	0.134	0.2	0.2	1.0
A2	0.0	0.433	0.433	0.2	0.2	0.0
A3	0.0	0.433	0.433	0.6	0.6	0.0
C1 (mm)	8	25	5	90	90	8
C2 (mm)	-	184	20	170	170	-
C3 (mm)	-	214	40	200	200	-
C _{avg} (mm)	8	176	27	172	172	8
BFI	0	0.368	0	0.6	0.6	0
K _{base}	0	0.982	0	0.7	0.7	0
K _{surf}	0	0.820	0	0.4	0.4	0
Average Annual Runoff/ Rainfall (%)	44.6	4.6	26.6	2.7	2.7	44.6
Average Annual Runoff (ML/ha/a)	3.00	0.30	1.79	0.18	0.18	3.00

5.4 TOTAL PROJECT WATER BALANCE

A daily timestep water balance model was used to assess the site water balance over the Project life under the range of historical rainfall and evaporation conditions. **Figure 5.3** presents the modelled average annual volumes from each of the principal water sources.

Figure 5.3 Average Annual Main Water Source Inflows



The principal water use on the Mine Site would be the processing plant, which (including allowance for minor losses within the plant area) would require a total throughput of up to approximately 1 092 ML/a (3.0 ML/d). Much of the water used in the processing plant would be reclaimed via the paste thickener before tailings are deposited into the TSF. As the proposed moisture content of the tailings would be very low, tailings bleed water draining to the tailings decant pond would be minimal.

Water would also be required for dust suppression on site haul roads and minor miscellaneous site water demands. Haul road watering demands would vary with haul road length and climate conditions, with average annual demands expected to range between 98 ML/a and 204 ML/a.

While the processing plant is operating, average annual total site water demands would range between 1 092 ML/a (in Year 2) and 1 303 ML/a (in Year 9).

During mining operations (after allowance for pit face evaporation), groundwater inflows to the main open cut pit are expected to range between approximately 174 ML/a and 662 ML/a.

The total site water balance for the mine water management system of the Mine Site over the Project life is summarised in **Table 5.5**. All water captured in the containment (mine affected) zone water system is contained without storage overflows throughout the Project life.

The site water balance model also shows that under historical conditions, water captured in the other parts of containment zone would be contained without discharge or significant interruption to mining operations throughout the Project life. This is described in further detail in the following sections.

Table 5.5
Average Annual Site Water Balance – Years 1 to 14

Item	Inflow	Outflow
	ML/a	ML/a
Rainfall and runoff	856	
Net groundwater inflows to open cut pit	431	
Advanced dewatering	380	
Clean water harvesting	40	
Ore moisture	83	
Retained tailings moisture		1 141
Evaporation		448
Dust suppression demands supplied		131
Concentrate moisture		18
Other plant losses		20
Dam overflows		0
Annual increase in stored volume		31
Total	1 789	1 789

5.5 DAM OVERFLOWS AND MAXIMUM STORED WATER VOLUMES

Table 5.6 summarises the maximum stored water volume modelled in each dam. **Table 5.7** summarises the stored TSF decant water volumes modelled during each TSF stage. The model shows that all water in the containment (mine affected) zone water system can be contained on the Mine Site without release under the modelled historic climate conditions. Further details are provided in Section 5.7.

Table 5.6
Maximum Modelled Stored Water Volumes

Dam	Nominal Design Capacity (ML)	Maximum Modelled Stored Water Volume (ML)
TSF Decant	Varies	3 340 ¹
Pit – final year before filling	N/A	1 157
Pit - prior to final year	N/A	387
WRE leachate management dam	80	60
Oxide ore dam	9 ²	9
Processing plant dams	100	95
Other combined sediment dams (modelled as containment structures)	80 ²	75
¹ Occurs during Year 8		
² Excludes sediment storage		

Table 5.7
TSF Modelled Decant Storage at Each Stage

	Spillway Level (mAHD)	99th Percentile Elevation (m AHD)	Maximum Elevation (m AHD)	99th Percentile Volume (ML)	Maximum Volume (ML)
Stage 1	599.50	597.85	598.18	2,078	2,225
Stage 2	609.25	608.09	608.25	2,821	3,269
Stage 3	618.20	615.89	616.02	3,298	3,517
Note that the above elevations don't necessarily occur on the same date as the corresponding volumes					

5.6 WATER SUPPLY RELIABILITY

With the exception of extreme drought periods, the proposed water management system yields sufficient water volumes to supply all site water demands. **Table 5.8** summarises the volumetric supply reliability for the Project. Volumetric supply reliability is the total water supplied expressed as a percentage of total demand. The table shows the average volumetric supply reliability over all historical climate periods as well as the reliability for the worst case model realisation (simulated 17 year period).

On average, the 99.4% of the total processing plant water demand could be supplied from the water management system, with the worst-case reliability being 94.5%. Supplies for dust suppression are slightly more reliable than processing plant supplies.

In practice, the water balance would be reviewed periodically, and during dry periods, contingency water saving measures implemented to further reduce the likelihood of water shortfalls impacting operations.

Table 5.8
Project volumetric water supply reliability

Demand	Volumetric water supply reliability	
	Average	Lowest
Processing plant	99.4%	94.5%
Dust suppression	99.8%	99.5%

Simulated System Behaviour

The simulated behaviour of various aspects of the site water management system under the low and high runoff scenarios shows that:

- In-pit water volumes would be unlikely to accumulate to the extent that they would interfere with mining. Even in the first and last (during Year 14) years of mining, when processing plant demands are limited, stored water volumes are unlikely to significantly exceed 500 ML (see **Figure 5.4**).
- Water would slowly accumulate in the TSF over time. Accumulated water volumes in the TSF vary widely depending on the prevailing climate conditions. The median stored volume at the end of mining is more than 1000 ML (refer **Figure 5.5**).
- TSF water levels are expected to remain well below the spillway level throughout the project life. Water levels would be continuously monitored and if necessary, water would be transferred to the mine pit to maintain freeboard to the spillway crest as a contingency measure. This is apparent from the model results in **Figure 5.4** and **Figure 5.6** just prior to the second raising and at the end of the project life, after processing ceases.

Figure 5.4 Modelled Open Cut Pit Water Inventory

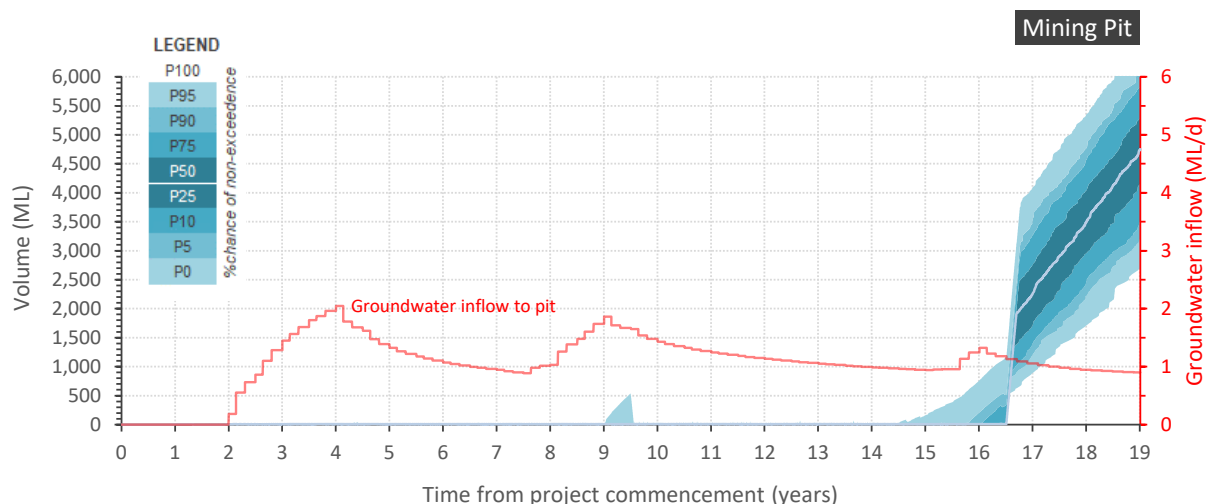


Figure 5.5 TSF Water Inventory

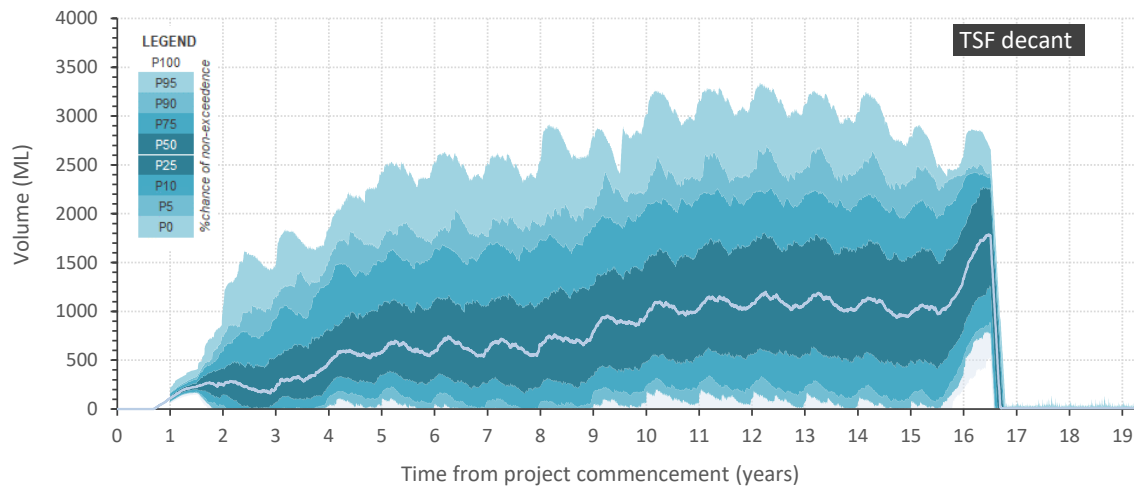
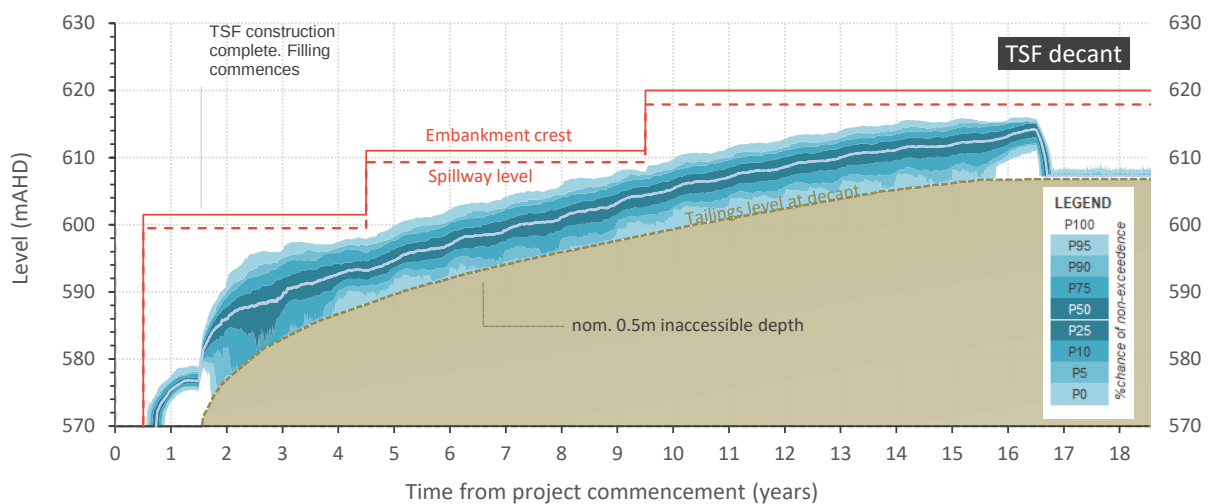


Figure 5.6 TSF Water Levels



5.7 SENSITIVITY ANALYSIS

The sensitivity of the water balance to changes in catchment response was tested using two sets of AWBM parameters, representing low and high runoff scenarios.

The adopted parameters are summarised in **Table 5.9** and **Table 5.10**. The resultant average annual site water balances for these scenarios are summarised in **Table 5.11** and **Table 5.12**.

Table 5.9
Adopted AWBM Parameters – Low Runoff Scenario

Parameter	Dry Tailings Beach (TSF)	Natural / Undisturbed	Roads / Hardstand / Pits	Waste Rock Emplacement	Rehabilitation	Lined
A1	0.134	0.2	0.134	0.2	0.2	1.0
A2	0.433	0.2	0.433	0.2	0.2	0.0
A3	0.433	0.6	0.433	0.6	0.6	0.0
C1 (mm)	5	90	5	90	90	8
C2 (mm)	10	170	20	170	170	-
C3 (mm)	20	200	40	200	200	-
C _{avg} (mm)	13.7	172.0	26.7	172.0	172.0	8.0
BFI	0	0.6	0	0.6	0.6	0
K _{base}	0	0.7	0	0.7	0.7	0
K _{surf}	0	0.4	0	0.4	0.4	0
Average Annual Runoff/ Rainfall (%)	38.5	3.1	26.6	3.1	3.1	46.0
Average Annual Runoff (ML/ha/a)	2.72	0.22	1.79	0.22	0.22	3.25

Table 5.10
Adopted AWBM Parameters – High Runoff Scenario

Parameter	Dry Tailings Beach (TSF)	Natural / Undisturbed	Roads / Hardstand / Pits	Waste Rock Emplacement	Rehabilitation	Lined
A1	1.0	0.2	0.134	0.134	0.134	1.0
A2	0.0	0.2	0.433	0.433	0.433	0.0
A3	0.0	0.6	0.433	0.433	0.433	0.0
C1 (mm)	8	25	5	10	11	0
C2 (mm)	-	95	10	50	60	-
C3 (mm)	-	150	20	120	130	-
C _{avg} (mm)	8.0	114.0	13.7	75.0	83.7	2.0
BFI	0	0.55	0	0.35	0.35	0
K _{base}	0	0.7	0	0.6	0.6	0
K _{surf}	0	0	0	0.1	0.1	0
Average Annual Runoff/ Rainfall (%)	46.0	8.7	38.5	14.3	12.7	60.1
Average Annual Runoff (ML/ha/a)	3.25	0.62	2.71	1.01	0.90	4.21

Table 5.11
Average Annual Site Water Balance – Years 1 to 14 – Low Runoff Scenario

Item	Inflow	Outflow
	ML/a	ML/a
Rainfall and runoff	740	
Net groundwater inflows to open cut pit	431	
Advanced dewatering	380	
Clean water harvesting	22	
Ore moisture	82	
Retained tailings moisture		1 130
Evaporation		356
Dust suppression demands supplied		131
Concentrate moisture		19
Other plant losses		19
Dam overflows		0
Annual increase in stored volume		1
Total	1 655	1 655

Table 5.12
Average Annual Site Water Balance – Years 1 to 14 – High Runoff Scenario

Item	Inflow	Outflow
	ML/a	ML/a
Rainfall and runoff	1 109	
Net groundwater inflows to open cut pit	431	
Advanced dewatering	380	
Clean water harvesting	58	
Ore moisture	83	
Retained tailings moisture		1 141
Evaporation		614
Dust suppression demands supplied		132
Concentrate moisture		18
Other plant losses		20
Dam overflows		0
Annual increase in stored volume		136
Total	2 061	2 061

Under the high runoff scenario, all site water storages (including sediment dams) are able to be operated without any overflows.

Under the low runoff scenario the water supply reliability is reduced slightly. On average, 98.4% of the total processing water demand could be supplied from the water management system, with the worst-case reliability being 90.0%.

A further scenario was developed in which groundwater inflows were assumed to be half the predicted values. The resultant average annual site water balance for this scenario is summarised in **Table 5.12**. Under this scenario, on average, 86% of the total processing water demand could be supplied from the water management system, with the worst-case reliability being 65%.

Table 5.13
Average Annual Site Water Balance – Years 1 to 14 – Low Groundwater Inflow Scenario

Item	Inflow	Outflow
	ML/a	ML/a
Rainfall and runoff	811	
Net groundwater inflows to open cut pit	215	
Advanced dewatering	190	
Clean water harvesting	40	
Ore moisture	72	
Retained tailings moisture ¹		989
Evaporation		211
Dust suppression demands supplied		119
Concentrate moisture		15
Other plant losses		17
Dam overflows		0
Annual increase in stored volume		-23
Total	1 328	1 328
¹ Note that limited water supply would constrain production by approximately 15% on average under this scenario		

6. FLOOD IMPACT ASSESSMENT

6.1 MINE AREA INFRASTRUCTURE POTENTIALLY IMPACTING FLOODING

Proposed mine related infrastructure which could potentially interact with flood flow paths includes the following.

- **WRE and associated haul road, flood bund and noise barrier** - these works have the potential to impact flood conditions on the western margin of the Price Creek floodplain and would interact with existing contour banks and other drainage structures. For the purpose of this assessment, and for conservatism, the impacts of the Project in conjunction with existing structures has been assessed. During detailed design of the WRE, consideration would be given to the mitigation of these impacts in conjunction with the decommissioning of existing drainage works.
- **WRE leachate management dam** - the proposed WRE leachate management dam would be located on the margin of the Lawsons Creek floodplain. The potential effect of this structure on the Lawsons Creek flooding and local runoff from Price Creek has been assessed by incorporating the design surface into the hydraulic model.
- **Southern barrier** - the southern barrier would be constructed across Blackmans Gully, with a low-level pipe or culvert outlet beneath the barrier, and during operations would attenuate flood flows entering Hawkins Creek downstream. Runoff from adjacent (downstream) clean catchments would be diverted around the toe of the southern barrier. The southern barrier would be decommissioned during closure and rehabilitation activities post-mining, and the pre-mine flow paths would be reinstated.
- **Clean water diversion system from Blackmans Gully to Price Creek** - the upper part of the Blackmans Gully catchment would be diverted east to Price Creek, to reduce the potential for clean water to enter the active mining areas. The channel conveying this flow would be decommissioned post-mining. The effect of this channel has been modelled by directing the upper sub-catchment inflows to Price Creek instead of Blackmans Gully.

6.2 FLOOD IMPACTS ADJACENT TO THE MINE SITE

The footprint of the Mine Site would be largest during operations. At the completion of mining operations and following rehabilitation of the Mine Site, some of the mining-related infrastructure would be decommissioned (i.e. the southern barrier and WRE haul road). The flood impact, assessment has been based on two scenarios – maximum disturbance, and post-closure.

The results are summarised briefly in the following sections. Full details, including flood maps showing design peak flood levels, depths and velocities for the 10% AEP (1 in 10), 5% AEP (1 in 20), 2% AEP (1 in 50), 1% AEP (1 in 100), 0.5% AEP (1 in 200), 0.2% AEP (1 in 500), and probable maximum precipitation (PMP) design events are provided in **Annexure B**.

The approach to assessing and managing flood risks is consistent with the approach of the NSW Floodplain Development Manual. The manual supports the NSW Government's Flood Prone Land Policy in providing for the sustainable development and use of the floodplain by considering risk management principles based upon a hierarchy of avoidance, minimisation and mitigation. This approach examines the frequency of flooding, flood consequences, the vulnerability of the community, and its resilience to recover from flood events.

6.2.1 Maximum Disturbance Scenario

Figure 6.1 shows predicted peak flood levels and depths for the 1% AEP event under the Maximum Disturbance Scenario in the vicinity of the proposed WRE. **Figure 6.2** shows the predicted 1% AEP peak velocities along Price Creek adjacent to the WRE for the Maximum Disturbance Scenario. The modelled impacts of the Project on peak 1% AEP flood levels are shown in **Figure 6.3**.

The model results for this scenario indicate the following.

- The surface of the proposed haul road at the toe of the proposed WRE would have immunity from flooding for all events up to the PMP design event.
- The northeastern section of the proposed haul road embankment would constrict flows in Price Creek. As a result, high peak velocities are predicted here. The predicted maximum velocities just downstream of this constriction range from 3.2 m/s for 10% AEP event to 4.9 m/s for the 1% AEP event. Mitigation measures for managing the short-term risk of erosion in these areas, such as the appropriate size of rock armouring would be developed during detailed design of the WRE.
- Some sections of the proposed haul road and WRE encroach into the edge of the Price Creek floodplain. As a result, the toe of the haul road located within the Price Creek flood extent would potentially be affected by high velocities. The predicted maximum velocities along the eastern edge of the proposed haul road range from 3.2 m/s for the 10% AEP event to 3.5 m/s for the 1% AEP event.
- There would be generally no increases in peak flood levels and velocities in Price Creek upstream of the proposed WRE for all modelled events.
- Flood levels would be increased at a number of locations in the Price Creek and Hawkins Creek channel and associated floodplain as described below.
 - Along the Price Creek floodplain adjacent to the WRE, there are predicted increases in peak flood levels of up to 0.3 m for the 10% AEP event, up to 0.4 m for the 1% AEP event and up to 0.5 m for the 0.2% AEP event. This is due to the proposed WRE forcing more water to flow along the western floodplain of Price Creek.
 - In Hawkins Creek, there would be minor increases in peak flood levels of up to 0.05 m for the 10% AEP event, up to 0.04 m for the 1% AEP event and up to 0.03 m for the 0.2% AEP event. These impacts dissipate to less than 0.01 m about 150 m upstream and downstream of the Bingmans Crossing stream gauge.

Figure 6.1 1% (1 in 100) AEP Peak Flood Levels and Depths in the Vicinity of the Proposed WRE - Maximum Disturbance Scenario

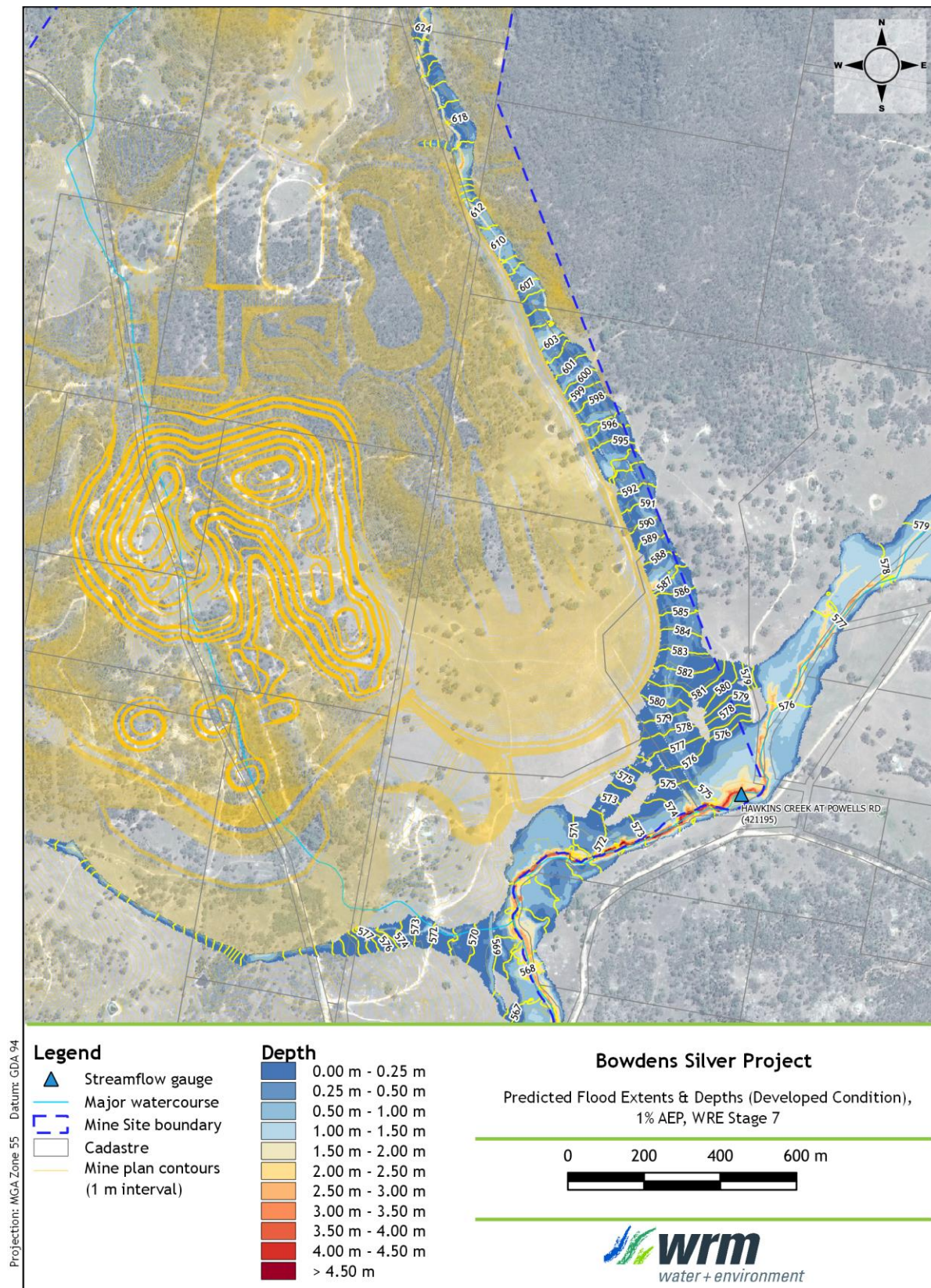


Figure 6.2 1% (1 in 100) AEP Peak Velocities along Price Creek adjacent to the Proposed WRE - Maximum Disturbance Scenario

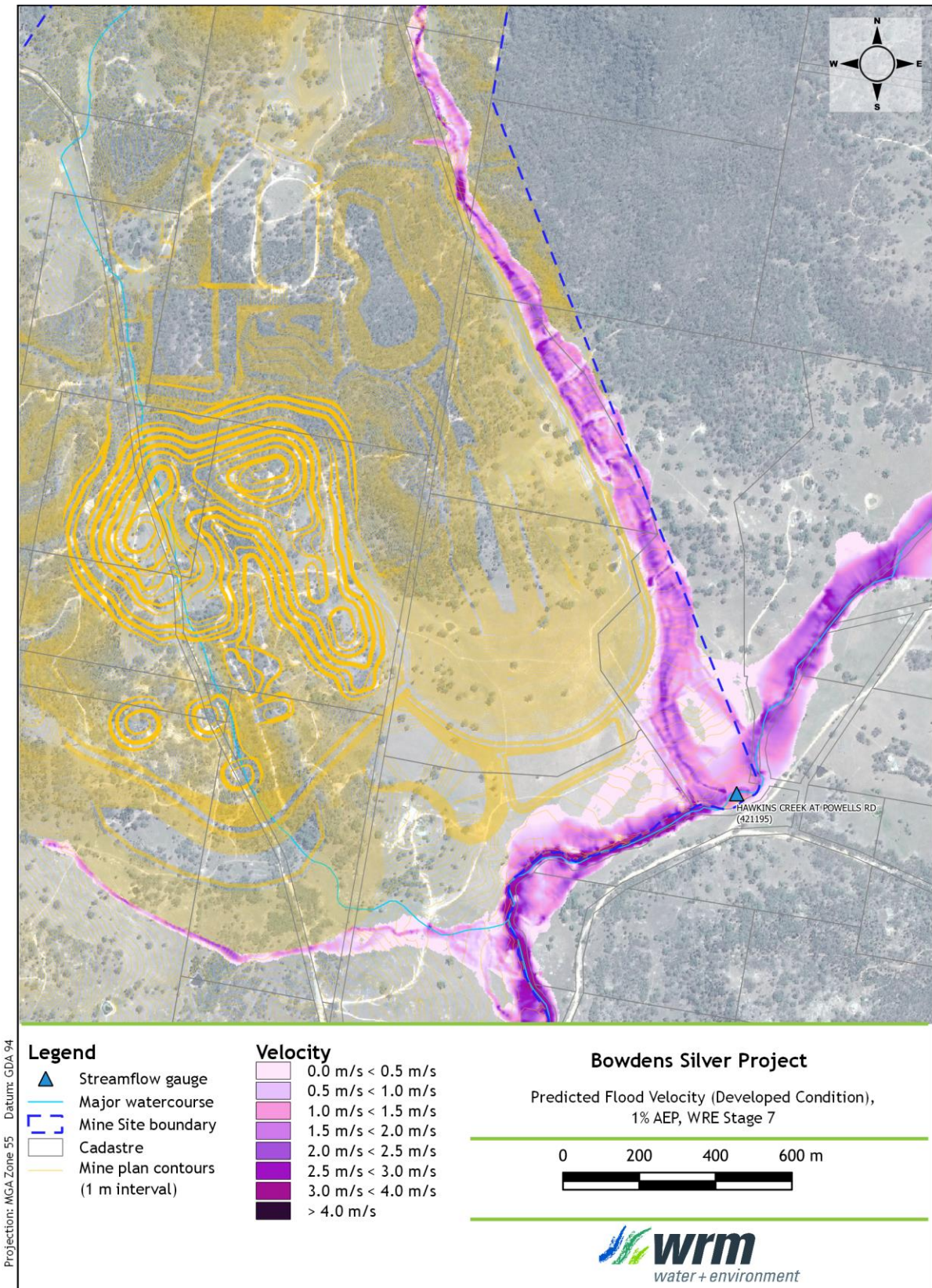
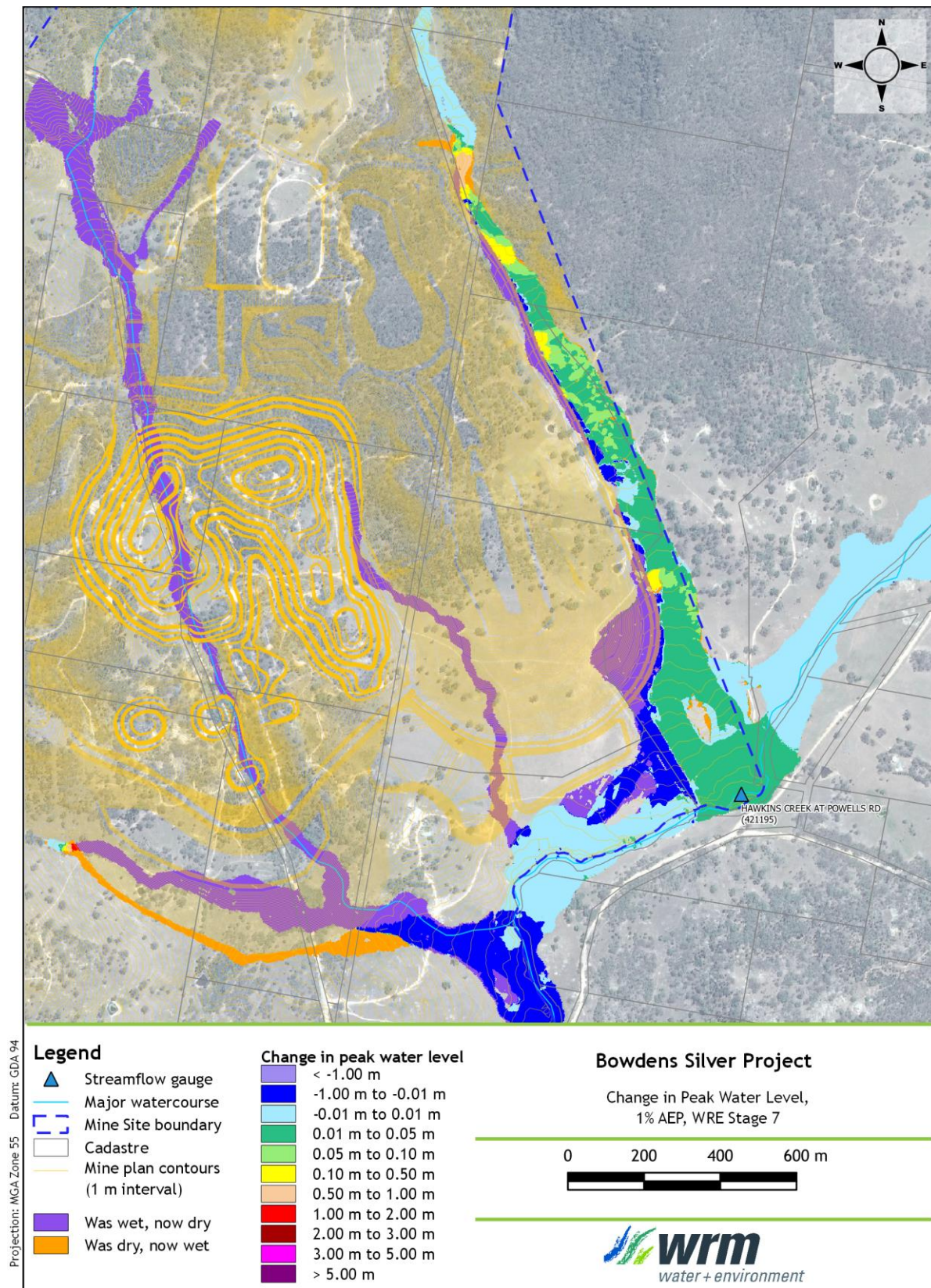


Figure 6.3 1% (1 in 100) AEP Predicted Impacts on Peak Flood Levels along Price Creek Adjacent to the Proposed WRE - Maximum Disturbance Scenario



- Flood velocities would also be increased at number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below.
 - There would be increases in peak velocities along the Price Creek floodplain of up to 1.8 m/s for the 10% AEP event and up to 1.1 m/s for the 1% and 0.2% AEP events. This is due to the proposed WRE forcing more water to flow along the western floodplain of Price Creek.
 - Just downstream of the constriction at the northeastern corner of the proposed WRE lower embankment haul road flood bund, there would be localised increases in peak velocities of up to 3.1 m/s for the 10% AEP event, up to 3.5 m/s for the 1% AEP event and up to 3.7 m/s for the 0.2% AEP event.
 - Where necessary, mitigation measures for managing the risk of erosion in these areas, such as the appropriate size of rock armouring would be developed during detailed design to ensure minimal scour in the 10% AEP flood.
 - Along the eastern toe of the WRE lower embankment haul road flood bund (along the western side of the Price Creek floodplain), there would be localised increases in peak velocities of up to 1.4 m/s, 1.1 m/s and 1.1 m/s for the 10%, 1% and 0.2% AEP events respectively.
 - There would be increases in peak velocities of up to 0.9 m/s for the 10%, up to 0.6 m/s for the 1% AEP event and up to 0.5 m/s for the 0.2% AEP event near the southeastern corner of the proposed WRE lower embankment haul road flood bund/noise barrier toe.
 - In the Hawkins Creek floodplain, there would be minor increases in peak velocities of up to 0.14 m/s for the 10% AEP event, up to 0.08 m/s for the 1% AEP event and up to 0.07 m/s for the 0.2% AEP event. These impacts dissipate to less than 0.01 m/s about 550 m downstream of the Bingmans Crossing stream gauge.

6.2.2 Post Closure Scenario

Figure 6.4 shows the predicted 1% AEP peak velocities along Price Creek adjacent to the WRE for the Post Closure Scenario. The modelled impacts of the Project on peak 1% AEP flood levels and velocities are shown in and **Figure 6.5** and **Figure 6.6** respectively. The model results for this scenario indicate the following:

- The proposed haul road, flood bund and noise barrier (where constructed) would be reshaped from the toe of the WRE towards the existing ground level at the edge of the Price Creek floodplain as part of rehabilitation at mine closure. However, the predicted flood extent, depths and velocities along Price Creek are very similar to those predicted for the Maximum Disturbance Scenario and therefore the rock protection that would be installed along the toe of the haul road embankment would be retained.

Figure 6.4 1% (1 in 100) AEP Peak Velocities along Price Creek Adjacent to the Proposed WRE – Final Landform Scenario

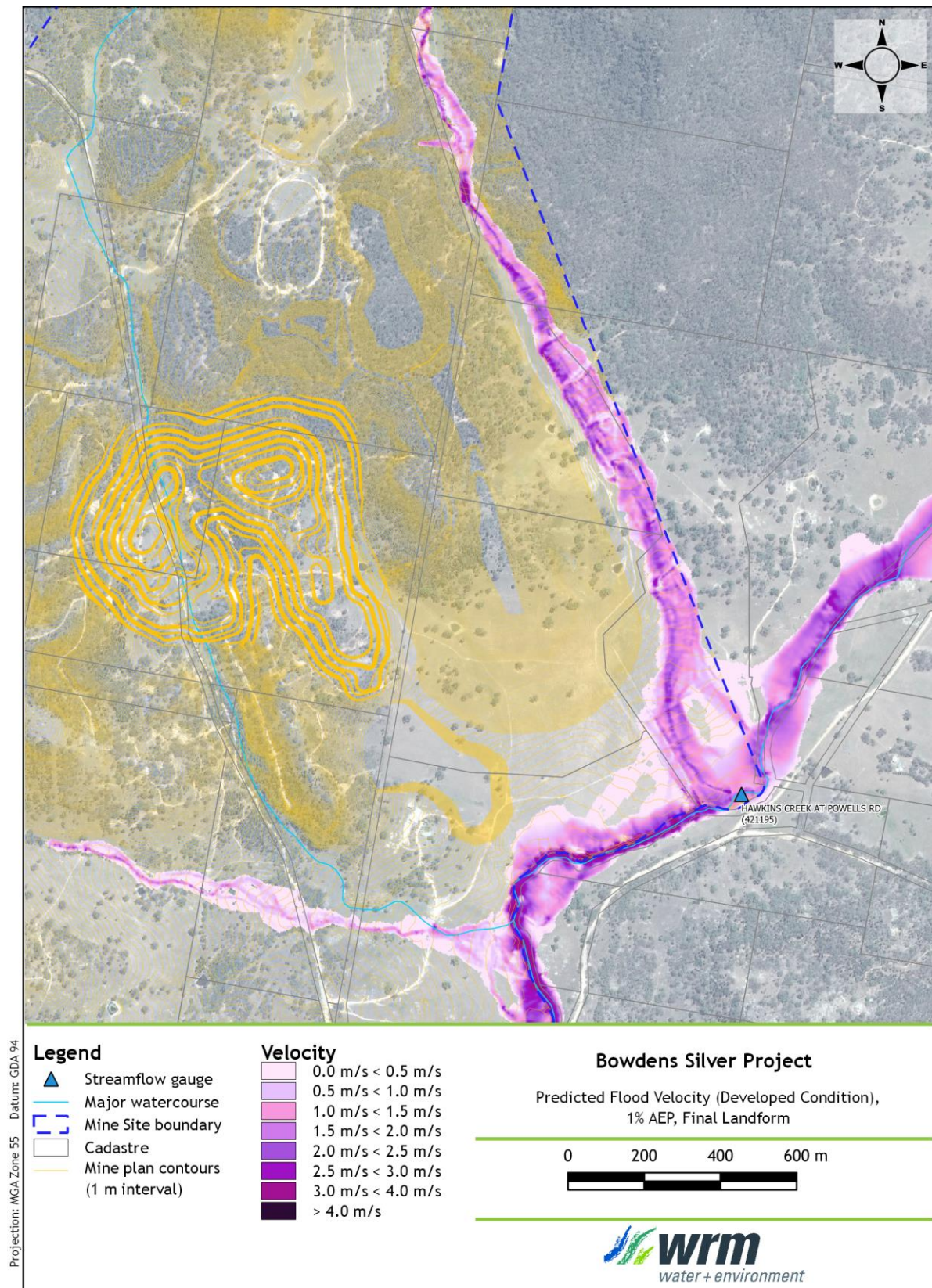


Figure 6.5 1% (1 in 100) AEP Predicted Impacts on Peak Flood Levels along Price Creek adjacent to the Proposed WRE – Post Closure Scenario

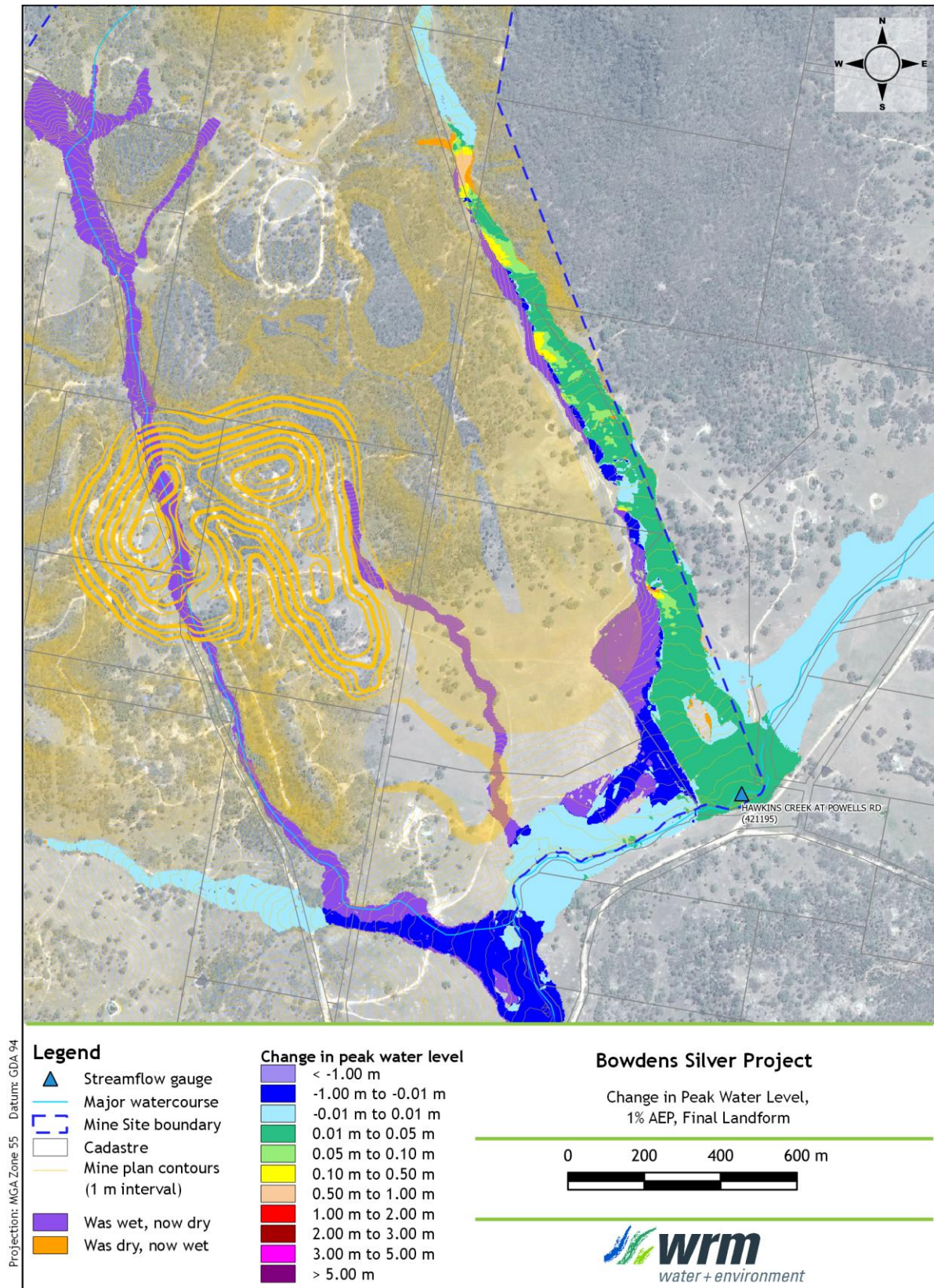
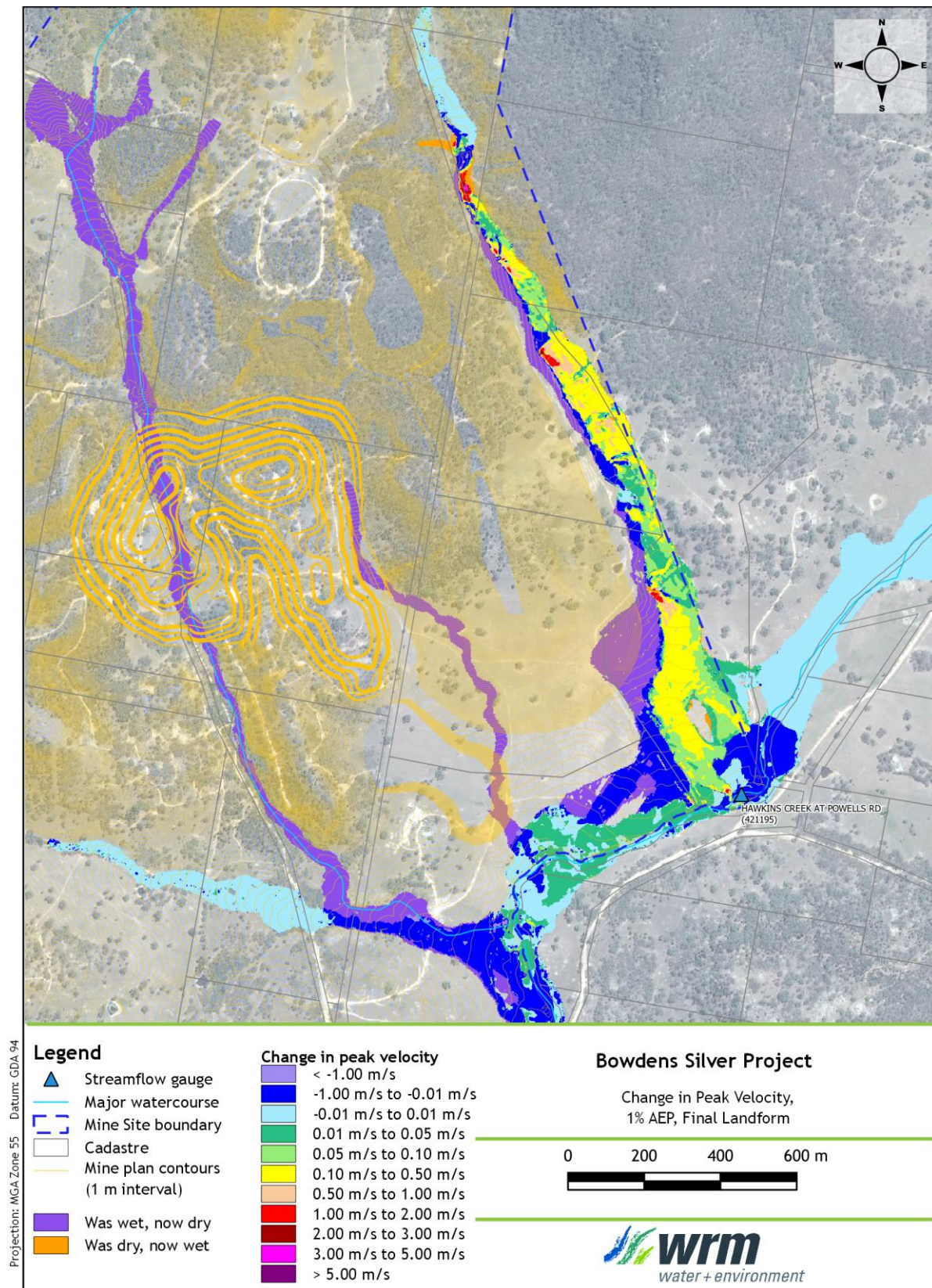


Figure 6.6 1% (1 in 100) AEP Predicted Impacts on Peak Flood Velocities along Price Creek adjacent to the Proposed WRE – Post Closure Scenario



- The constriction at the northeastern corner of the WRE would remain in the Post Closure Scenario. As a result, high peak velocities are also predicted here. The predicted maximum velocities just downstream of this constriction range from 3.2 m/s for the 10% AEP event to 4.9 m/s for the 1% AEP event. Therefore, the rock protection that would be installed along the toe of the haul road embankment would need to be retained as a long-term measures for mitigating the consequent risk of erosion and would be incorporated into the final WRE rehabilitation design.
- Some sections of the WRE would still encroach into the Price Creek floodplain. As a result, the toe of the WRE located within the Price Creek flood extent would potentially be affected by high velocities. The predicted maximum velocities along the eastern edge of the proposed haul road range from 2.5 m/s for the 10% AEP event to 3.4 m/s for the 1% AEP event. Therefore, the rock protection that would need to be installed along the toe of the haul road embankment would be retained as a long-term measure for mitigating the consequent risk of erosion and would be incorporated into the final WRE rehabilitation design.
- The predicted impacts for the Post Closure Scenario are generally similar to those observed for the Maximum Disturbance Scenario.
- There would be generally no increases in peak flood levels and velocities in Price Creek upstream of the proposed WRE for all modelled events.
- Flood levels would be increased at number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below:
 - Along the Price Creek floodplain adjacent to the WRE, there are predicted increases in peak flood levels of up to 0.3 m for the 10% AEP event, up to 0.4 m for the 1% AEP event and up to 0.5 m for the 0.2% AEP event. This is due to the proposed WRE forcing more water to flow along the western floodplain of Price Creek.
 - In Hawkins Creek, there would be minor increases in peak flood levels of up to 0.05 m for the 10% AEP event, up to 0.03 m for the 1% AEP event and up to 0.03 m for the 0.2% AEP event. These impacts dissipate to less than 0.01 m about 150 m upstream and downstream of the Bingmans Crossing stream gauge.
- Flood velocities would also be increased at a number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below:
 - There would be increases in peak velocities along the Price Creek floodplain of up to 1.8 m/s for the 10% AEP event and up to 3.2 m/s for the 1% and 0.2% AEP events. This is due to the WRE forcing more water to flow along the eastern floodplain of Price Creek.
 - Just downstream of the constriction at the northeastern corner of the proposed WRE and haul road, there would be localised increases in peak velocities of up to 2.7 m/s for the 10% AEP event, up to 4.5 m/s for the 1% AEP event and up to 5.2 m/s for the 0.2% AEP event.
 - Along the eastern toe of the WRE and haul road (along the western side of the Price Creek floodplain), there would be localised increases in peak velocities of up to 1.7 m/s, 3.1 m/s and 3.6 m/s for the 10%, 1% and 0.2% AEP events respectively.

- There would be increases in peak velocities of up to 0.8 m/s for the 10% AEP event, up to 2.4 m/s for the 1% AEP event and up to 2.7 m/s for the 0.2% AEP event near the southeastern corner of the proposed WRE.
- In the Hawkins Creek floodplain, there would be minor increases in peak velocities of up to 0.2 m/s for the 10% AEP event and up to 0.08 m/s for the 1% AEP and up to 0.2% AEP events. As these impacts are minor and dissipate to less than 0.01 m/s about 550 m downstream of the Bingmans Crossing stream gauge, i.e. before the confluence with Lawsons Creek, no works are required to mitigate erosion risks in this area.

6.2.3 Conclusion

The proposed works associated with the WRE would result in localised minor flood level increases. The more significant flood level impacts are constrained to within the Mine Site, and would not result in significant impacts to other properties, assets or infrastructure.

The proposed WRE would locally increase flood velocities in its immediate vicinity. Local scour protection measures would need to be developed during detailed design to mitigate the potential erosion impacts in this area. Any expected increases in flood velocities in Hawkins Creek and Lawsons Creek would be negligible and would not adversely impact offsite property or infrastructure.

6.3 RELOCATED MALONEYS ROAD CROSSING OF LAWSONS CREEK

6.3.1 Proposed Configuration

Following public exhibition of the EIS and consultation with NSW Government agencies (DPIE-Water and NRAR), Bowdens Silver has adopted a bridge crossing of the relocated Maloneys Road over Lawsons Creek. Full details of the crossing would be established during detailed design, however, for the purposes of this assessment the following key design features were adopted:

- A road crest level of 531 mAHD (i.e. above the existing 5% (1 in 20) AEP flood level);
- A 1 m thick bridge deck;
- Two 30 m deck spans;
- One central pier, 1.2 m thick;
- A road width of 7 m;
- 1 m high rails;
- An approach road embankment (cut and fill) slope of 1V:3H; and
- Reinforced concrete box culverts on the northern approach road (one bank with 2 barrels and one single barrel, all barrels would be 0.9 m high by 1.2 m wide).

The road crest level would have a minimum height of 1.3 m above the bankfull discharge water level of the Lawsons Creek main channel (529.7 mAHD at 430 m³/second). The proposed bridge crossing would significantly reduce the frequency of overtopping when compared to the existing low-level of crossing of Lawsons Creek.

6.3.2 Design Flood Conditions

Updated design flood conditions in the vicinity of the crossing are described in detail in the Flood Impact Assessment report included as **Annexure B**.

6.3.3 Impact on Peak Flood Conditions

Figure 6.7 shows the 5% AEP predicted changes to peak flood levels, depths and extents in Lawsons Creek with the proposed crossing in place. **Figure 6.8** shows the corresponding change to 5% AEP peak flood velocities.

The model results show that the proposed road crossing would not be overtopped during a 5% AEP flood event. Therefore, the proposed road crossing would be trafficable for light and / or heavy vehicles during a 5% AEP event.

The impacts of the crossing for a range of flood events are presented in the Flood Impact Assessment in **Annexure B**. The model results indicate the following.

- The proposed road crossing would increase peak flood levels upstream of the road:
 - For the range of modelled events (10% to 1% AEP), peak flood levels would increase by up to 0.2 m. These impacts decrease in magnitude further away from the road crossing, dissipating to less than 0.1 m approximately 550 m upstream of the crossing.
 - Peak flood levels downstream of the proposed crossing are predicted to reduce.
 - The predicted increase in peak flood levels upstream of the crossing for the 2% AEP event would cause flows in Lawsons Creek to overtop the northern creek bank upstream of the crossing. These overflows would drain to the northwest parallel to the Lawsons Creek before re-joining Lawsons Creek about 680 m downstream of the proposed crossing as is the case under existing conditions.
 - The proposed road crossing would have a negligible impact on peak velocities in a 10% AEP flood event with minor increases (0.2 m/s) predicted for the 5% AEP event. Increased velocities would only occur near the bridge abutments.
 - Peak velocities along the Lawsons Creek main channel downstream of the proposed crossing would generally be increased by up to 0.2 m/s in the 1% and 2% AEP events. Given that existing conditions velocities here are generally more than 4 m/s, the predicted increases in velocities are not considered significant.

Figure 6.7 Predicted changes in Peak Flood Levels due to the proposed Lawsons Creek crossing, 5% (1 in 20) AEP Event

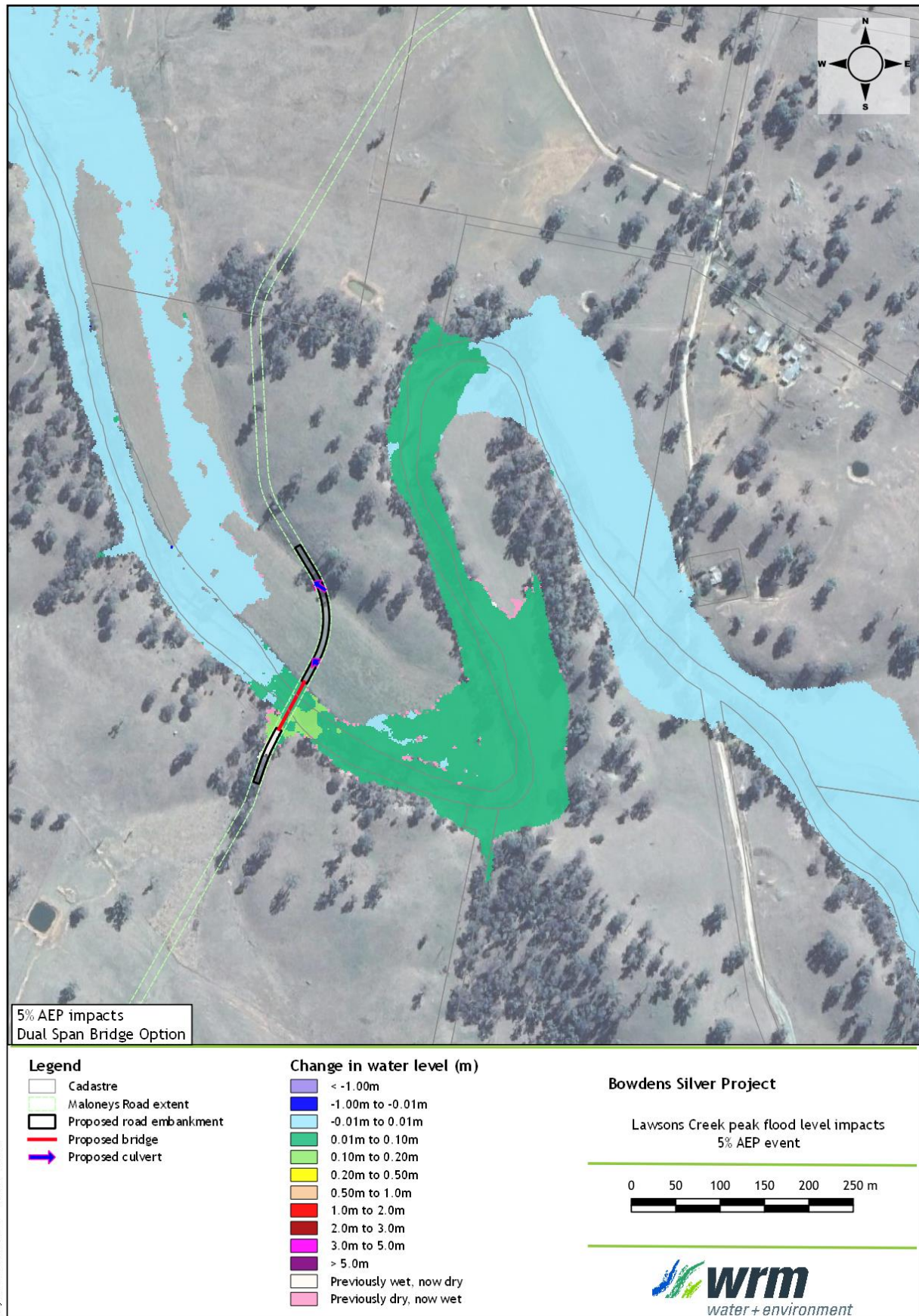
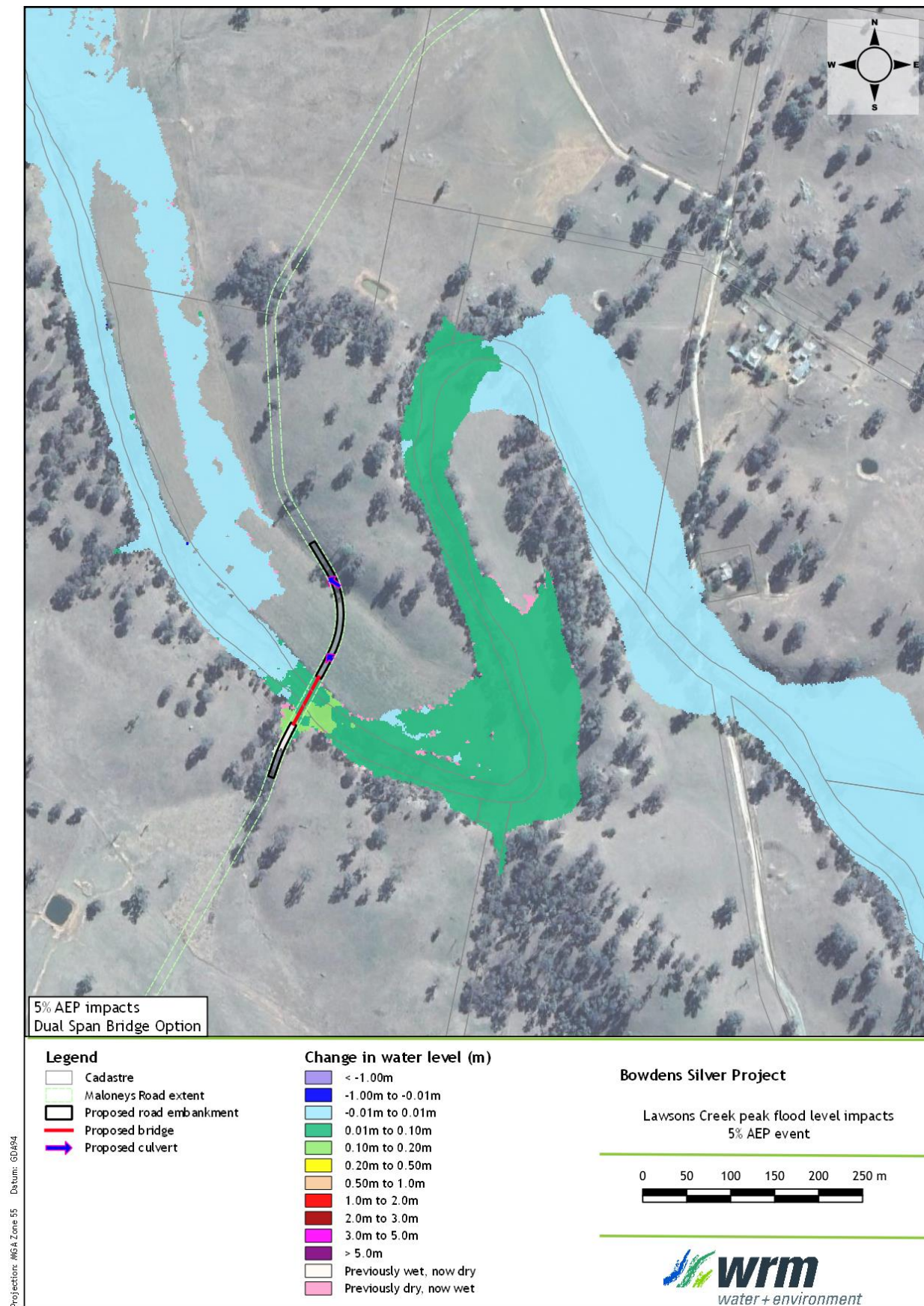


Figure 6.8 Predicted changes in Peak Flood Velocities due to the Proposed Lawsons Creek Crossing, 2% (1 in 20) AEP Event



- There are localised increases in velocities of up to 2.8 m/s predicted at the Lawsons Creek channel banks near the proposed bridge abutments for the 1% and 2% AEP events. The impact of these increases in velocity would be investigated further during detailed design. However, the predicted peak velocities in these areas are within the range of velocities predicted for existing conditions.
- The predicted increases in peak flood levels, extents and velocities do not appear to affect any existing dwellings for all events up to and including 1% (1 in 100) AEP. It is noted that all increases in flood levels, as the result of the relocated Maloneys Road crossing of Lawsons Creek, would occur on land owned by Bowdens Silver.

The road crossing would be designed to manage the risk of scour induced by increased velocities, for example through the use of dumped rock or other erosion protection measures.

7. FINAL VOID PIT LAKE BEHAVIOUR

7.1 OVERVIEW

Water levels in the final main open cut pit void would vary over time, depending on the prevailing climatic conditions, and the balance between evaporation losses and inflows from rainfall, surface runoff and groundwater.

A separate GoldSIM model was used to assess the likely long-term behaviour of the final void pit lake. The historical rainfall and evaporation sequences were repeated five times to create a long-term climate record for use in the model.

The potential effects of climate change were also assessed using climate-change adjusted SILO climate data developed as part of the Consistent Climate Scenarios (CCS) Project by the Queensland Government's Department of Environment and Science (DES).

7.2 FINAL VOID CONFIGURATION

The final void configuration and contributing catchment area are shown in **Figure 7.1**. **Figure 7.2** shows the extent of the PMP design event for the Post Closure Scenario.

The proposed final landform limits the contributing catchment of the final void to its own surface area, with all upslope catchments being diverted around the final void. This implies that all final diversion and levee structures are sufficiently robust to exclude all diverted inflows after mine closure.

Based on the proposed open cut pit design, the final void would be up to 141 m deep, with a floor level of 456 mAHD and an overflow level of approximately 597 mAHD. It is predicted that once equilibrium is achieved, the final level of the pit lake would vary in elevation from 565 mAHD to 572 mAHD with an average elevation of 569 mAHD. The theoretical total potential storage volume to 597 mAHD is approximately 22 GL.

7.3 CONCEPTUAL MODEL

It is predicted that the final void would remain a groundwater sink following mine closure (Jacobs, 2022), thereby preventing discharge to the surrounding aquifers as well as limiting the oxidation of any remaining sulphide minerals on the terminal walls of the open cut pit.

This would be achieved by limiting the amount of surface water directed to the final void such that the evaporation exceeds the long-term rate of rainfall and runoff in the final void.

A representative schematisation of a conceptual final void water balance is presented in **Figure 7.3**.

The figure shows that key water inputs include rainfall on the pit lake water surface, runoff from pit faces (runoff from upstream areas is to be largely diverted around the final void), and groundwater inflow. Outflows are limited to evaporation.

Figure 7.1 Final Landform and Final Void Catchment

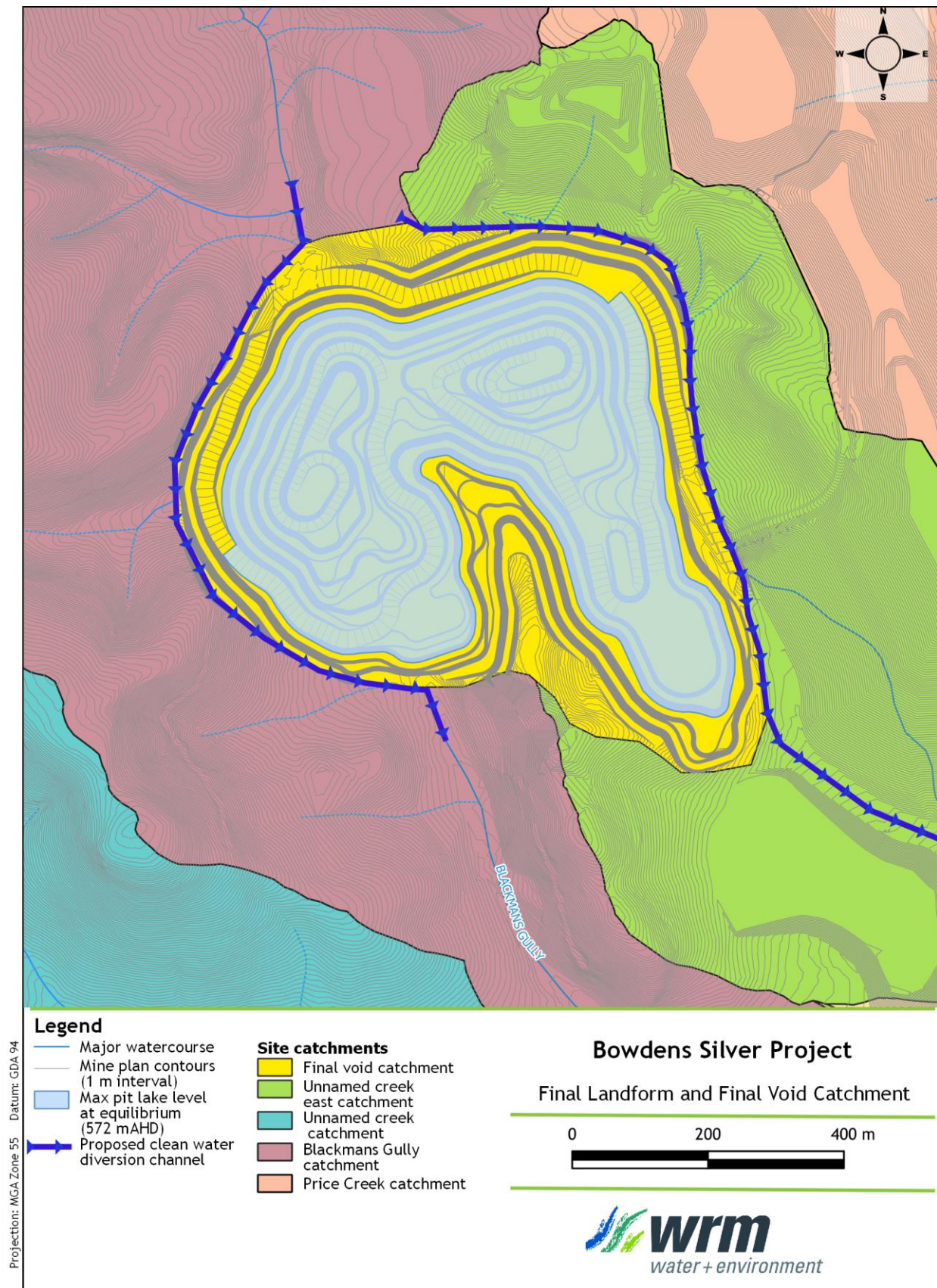


Figure 7.2 Final Landform and Flood Levels in Probable Maximum Flood

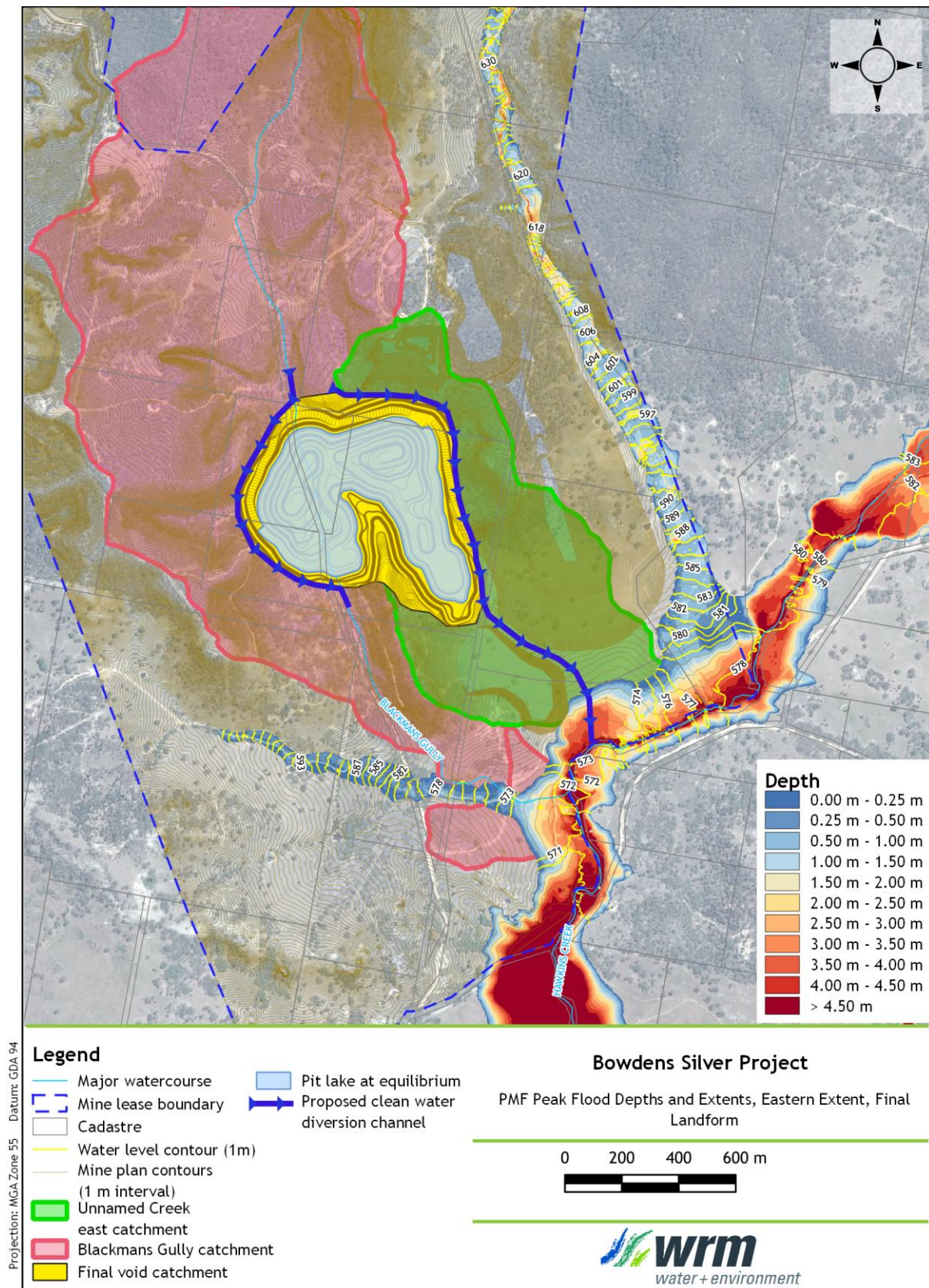
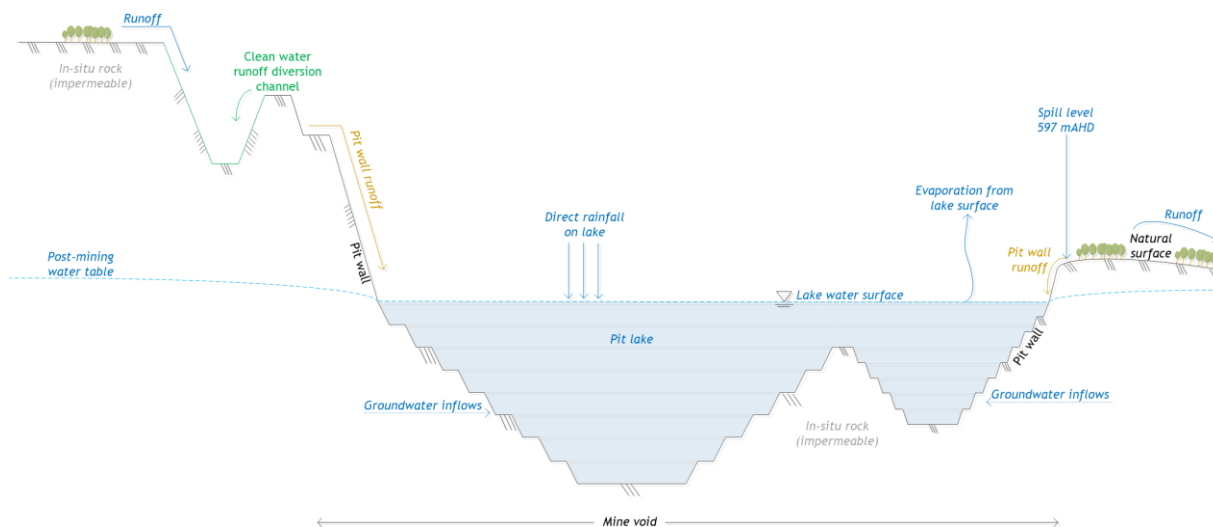


Figure 7.3 Final Void Model Schematic

Sources of salt include chemical constituents dissolved in groundwater and catchment runoff. In the absence of any seepage or surface outflows to the environment, there is generally no removal of chemical constituents from the system, and thus, chemical constituents are expected to accumulate over time.

In principle, for an initially empty void, water is expected to accumulate until evaporative losses from the wetted surface area balance the combined influence of catchment runoff, rainfall and groundwater inflow. Where catchment inflows are limited, over a sufficiently long time-scale, water levels are expected to reach a nominal steady state, with some variation about the steady state level during prolonged periods of wet or dry climate bias. This principle works in reverse for any voids that are filled (e.g. by pumping) above their steady state level prior to relinquishment; water levels would reduce due to evaporation until the wetted surface contracts to a point where evaporative losses balance all inflows.

7.4 NUMERICAL MODELLING APPROACH

The GoldSIM model simulates the generation, movement and loss of water on a daily time-step within the final void, over a 400-year period. The volume of water in the void is calculated at each time step as the sum of direct rainfall to the void surface, catchment runoff, and groundwater inflows, less evaporation losses.

The model also tracks the quantity of salt captured and stored within the final void. Key components of the model are summarised in the following subsections, including descriptions of key model inputs, assumptions and sensitivity parameters.

7.5 STAGE-STORAGE CHARACTERISTICS

The stage-storage and stage-area curves for the void were estimated from the final open cut pit plan for the Project (AMC, 2018).

7.6 CATCHMENT RUNOFF

Surface runoff catchment areas draining to the final void were determined based on the adopted final landform. It was assumed that the surface catchment draining to the void would be minimised by:

- Diverting Blackmans Gully around the western margin of the final void; and
- Diverting the undisturbed areas to the north and east of the void around the eastern margin of the final void.

The AWBM was used to model surface water runoff. After diversion of the above catchments, the remaining surface catchment is essentially all pit wall and pit lake surface. The AWBM parameters adopted for the open cut pit in the operational water balance were also used for the final void analysis. The surface water catchment is 53.1 ha.

For estimating the contribution of catchment runoff to void lake salinity, a catchment runoff salinity of 130 $\mu\text{S}/\text{cm}$ (based on the results of waste rock leachate sample data GCA (2020)) was adopted.

7.7 PIT SURFACE EVAPORATION

Evaporation from the final void pit lake water surface was modelled using estimates of Morton's Lake evaporation. The reduced evaporation resulting from shading and wind shielding provided by the pit walls was modelled using an adjustment factor referred to herein as the 'pit factor'. A linearly varying depth-dependent storage evaporation factor was applied to the final void to simulate the change in evaporation as void water levels increase. The storage evaporation factors are as follows:

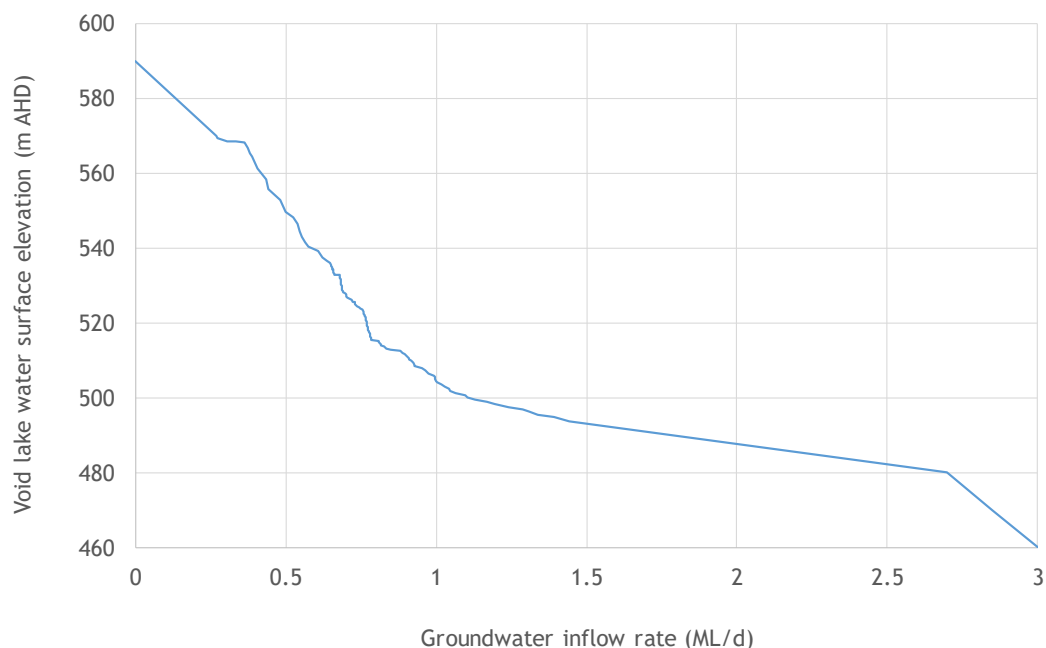
- Bottom of void – 0.5; and
- Top of void (597 mAHD)– 0.95.

7.8 GROUNDWATER

Groundwater inflows to the final void were based on the results of groundwater modelling undertaken by Jacobs (2022). **Figure 7.4** shows the pit lake water level versus groundwater inflow rates provided by Jacobs and used in the analysis.

The curve shows that for void lake water levels up to approximately 500 mAHD, the expected inflow rate exceeds 1 ML/d. At higher levels, the inflow rate would reduce, eventually reaching zero at an elevation of approximately 579 mAHD.

For estimating the contribution of groundwater to void lake salinity, a groundwater inflow salinity (EC) of 1 420 $\mu\text{S}/\text{cm}$ (which is the median of site bore samples) was adopted.

Figure 7.4 Water Elevation vs Groundwater Inflow Relationship

7.9 CLIMATE CHANGE IMPACTS

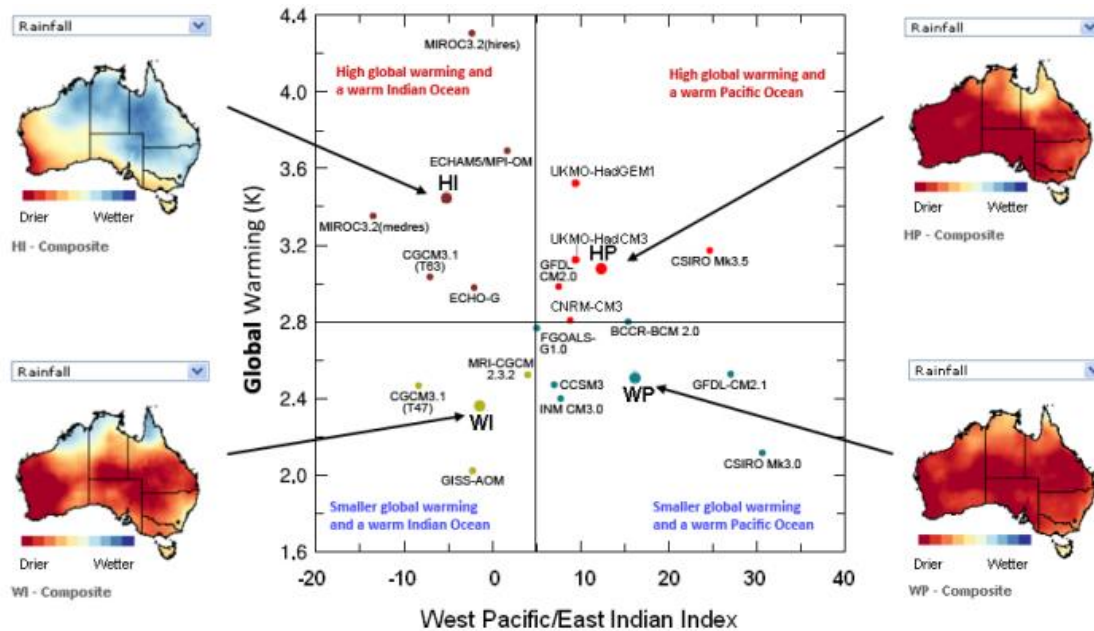
Climate-change adjusted SILO climate data are available from the Queensland Government Department of Environment and Science (DES), and were developed as part of the Consistent Climate Scenarios (CCS) project. The CCS project hosts data from 19 separate global climate models (GCMs), which explore four emissions scenarios, three timing horizons and three climate warming sensitivities. The nineteen separate models can be split into four Representative Future Climate (RFC) partitions, defined below:

- **HI:** a high level of global warming, where the Eastern Indian Ocean (EIO) warms faster than the Western Pacific Ocean (WPO);
- **HP:** a high level of global warming, where the WPO warms faster than the EIO;
- **WI:** a low level of global warming, where the EIO warms faster than the WPO; and
- **WP:** a low level of global warming, where the WPO warms faster than the EIO.

Figure 7.5 is an excerpt from the CCS project user guide (DSITIA, 2015) showing the four RFC quadrants, component models and indicative rainfall trends. The caption associated with the original version of this figure has been reproduced as a footnote to **Figure 7.5**.

Data based on the mean result of all models within each RFC quadrant is offered by the CCS for applications where considering the output of all 19 models is not feasible/practical. This approach has been followed for the purposes of assessing climate change sensitivity as part of current investigations. **Table 7.1** and **Table 7.2** list the percentage change in evaporation and rainfall respectively, based on mean output for the four RFC quadrants. Data is based on the most conservative carbon emission rate (RCP8.5) available in the CCS dataset, and expected climate as at 2070. Data has been listed for the low, medium and high sensitivities. Information is for the Mine Site location.

Figure 7.5 A partition of Global Climate Models for Future Climate using Global Warming Sensitivity and Ocean Warming Indices (source: DSITIA, 2015)



Note: From DSITIA, 2015 – Figure 8.1 (verbatim): A partition of CMIP3 Global Climate Models (GCMs) for future climate using global warming sensitivity and ocean warming indices (adapted from Watterson, 2011). Values for nineteen individual GCMs (forced by the SRES A1B emissions scenario) are represented by the small dots and labelled by their GCM model code (Table 8.2). The central horizontal and vertical lines separate the four Representative Future Climate (RFC) partitions. The larger dots indicate the CCS composite means for GCMs within each of the four RFC responses: (HI) high global warming and a warmer Indian Ocean; (HP) high global warming and a warmer Pacific Ocean; (WP) lower global warming and a warmer Indian Ocean and (WP) lower global warming and a warmer Pacific Ocean. The maps show projected 21st Century changes in rainfall for the GCMs clustered in each of the four (HI, HP, WI and WP) RFC partitions.

The adjustments listed in **Table 7.1** and **Table 7.2** have been applied to the long-term SILO daily climate time-series, and passed through the AWBM rainfall runoff sub-model to produce daily estimates of runoff (rehabilitated land use AWBM parameter set used). Annual average runoff depths have been plotted against average annual net evaporation depths (evaporation minus rainfall) in **Figure 7.6** to illustrate the potential to impact long-term water levels in the final void pit lake. Note the naming convention used in the figure, and henceforth in this document, is XX.Y where XX is the scenario (e.g. HI) and Y is the sensitivity (medium).

Table 7.1
Percentage change in Evaporation by Model and Sensitivity

Model*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
HI (high)	4.5	8.5	12.1	14.8	11.2	4.3	15.9	29.8	30.4	29.6	23.3	14.2	17.1
HI (med)	2.5	5.1	7.1	8.8	6.7	2.7	10.2	18.6	18.6	18.2	14.2	8.5	10.8
HI (low)	1.2	2.6	3.7	4.5	3.5	1.5	5.7	10.2	10.0	9.8	7.6	4.4	6.2
HP (high)	13.2	10.2	13.8	17.0	16.2	11.3	18.7	27.2	33.2	34.7	21.6	15.4	19.9
HP (med)	8.2	6.3	8.6	10.4	10.2	7.4	12.0	17.3	21.0	21.8	13.5	9.6	12.8
HP (low)	4.5	3.4	4.6	5.6	5.6	4.2	6.7	9.6	11.6	12.0	7.4	5.3	7.5
WI (high)	13.9	16.7	15.4	17.1	13.2	13.0	19.3	23.6	28.6	24.2	20.1	18.1	19.7
WI (med)	8.6	10.4	9.6	10.5	8.1	8.5	12.3	14.8	17.9	15.0	12.6	11.3	12.6
WI (low)	4.7	5.7	5.2	5.6	4.4	4.8	6.9	8.1	9.8	8.1	6.9	6.2	7.3
WP (high)	11.8	14.0	16.3	27.1	16.2	11.8	23.7	28.6	35.8	39.0	27.6	15.5	22.7
WP (med)	7.3	8.8	10.1	17.0	10.0	7.7	15.3	18.0	22.4	24.1	17.1	9.6	14.5
WP (low)	3.9	4.8	5.5	9.3	5.4	4.4	8.6	9.9	12.2	13.0	9.3	5.2	8.4

Note: * model is RFC partition, text in brackets is the sensitivity

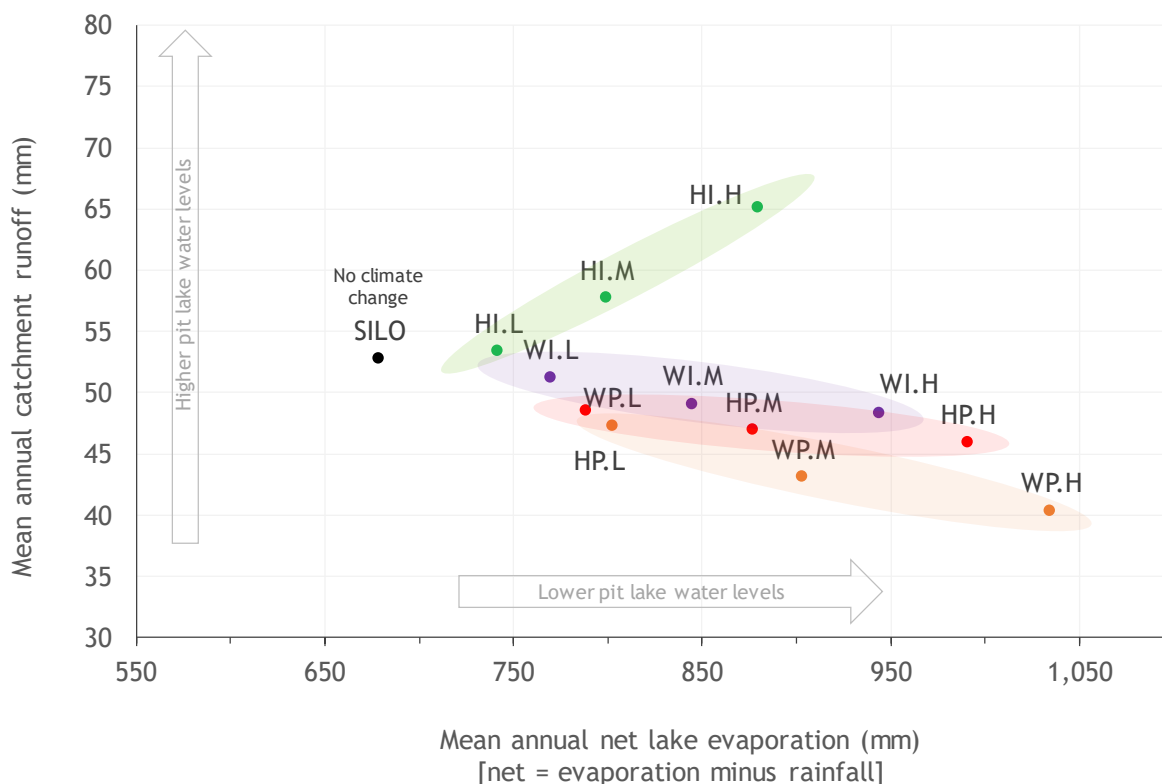
Table 7.2
Percentage change in Rainfall by Model and Sensitivity

Model*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
HI (high)	68.9	35.5	14.8	9.4	-1.1	-22.1	-58.4	-73.7	-13.4	-30.3	3.0	62.6	4.2
HI (med)	46.2	23.8	9.9	6.3	-0.7	-14.8	-39.2	-49.4	-9.0	-20.3	2.0	42.0	2.8
HI (low)	26.8	13.8	5.8	3.6	-0.4	-8.6	-22.7	-28.7	-5.2	-11.8	1.2	24.4	1.6
HP (high)	22.9	17.4	11.5	-2.3	-22.6	-22.9	-17.8	-28.7	-41.3	-35.3	-5.3	8.8	-7.6
HP (med)	15.3	11.7	7.7	-1.6	-15.1	-15.4	-11.9	-19.3	-27.7	-23.7	-3.6	5.9	-5.1
HP (low)	8.9	6.8	4.5	-0.9	-8.8	-8.9	-6.9	-11.2	-16.1	-13.7	-2.1	3.4	-3.0
WI (high)	-1.5	2.6	6.9	-0.1	-11.3	-17.0	-16.6	-0.7	-8.1	9.0	6.9	0.5	-1.7
WI (med)	-1.0	1.8	4.6	0.0	-7.6	-11.4	-11.2	-0.4	-5.4	6.0	4.6	0.3	-1.1
WI (low)	-0.6	1.0	2.7	0.0	-4.4	-6.6	-6.5	-0.3	-3.2	3.5	2.7	0.2	-0.7
WP (high)	17.4	-5.7	-6.8	-40.5	-47.1	5.5	-36.6	-6.8	-8.6	-16.0	-23.1	34.4	-8.8
WP (med)	11.7	-3.8	-4.6	-27.2	-31.6	3.7	-24.6	-4.5	-5.7	-10.7	-15.5	23.0	-5.9
WP (low)	6.8	-2.2	-2.6	-15.8	-18.3	2.1	-14.3	-2.6	-3.3	-6.2	-9.0	13.4	-3.4

Note: * model is RFC partition, text in brackets is the sensitivity

Figure 7.6 shows that all scenarios predict increases in net evaporation, and that (with the exception of the HI models) all scenarios predict reductions in runoff. The sensitivity of final void pit lake water levels to changes in future climate change have been assessed by modelling all the above scenarios.

Figure 7.6 Plot of Net Evaporation versus Runoff for HI, HP, WI and WP GCM Groupings



7.10 MODEL RESULTS

Figure 7.7 shows the simulated long-term water levels in the main final open cut pit void. The results show the following:

- Under the existing (HI.H) climate scenario (which yields water level results closest to the mean of all climate change scenarios), the water level would reach around 569.8 mAHD after 100 years and vary in a 7 m band throughout the remainder of the simulation. At this elevation, the stored water volume is approximately 13.0 GL.
- The maximum modelled water level is below 572 mAHD – or about 25 m below the void overflow level of 597 mAHD.
- As there are no outflows from the void, salinity would increase over time. Assuming an initial salinity of 1,420 $\mu\text{S/cm}$, **Figure 7.8** shows that the modelled salinity after 500 years is approximately 8 500 $\mu\text{S/cm}$. The following pit lake salinities are predicted to develop over time:
 - 100 years – 2 400 $\mu\text{S/cm}$
 - 200 years – 4 000 $\mu\text{S/cm}$
 - 300 years – 5 500 $\mu\text{S/cm}$
 - 400 years – 6 500 $\mu\text{S/cm}$
 - 500 years – 8 500 $\mu\text{S/cm}$
- Under the climate change scenarios, the equilibrium water level would be lower than the existing climate scenario as the result of the increased evaporation.

Table 7.3 summarises the simulated long-term water balance under the HI.H scenario,. Under this scenario, at equilibrium the water level fluctuates between 564.7 mAHD and 571.9 mAHD. The table shows that over the period of simulation, the average groundwater inflow is 112 ML/a (ranging between approximately 0.2 ML/a and 165 ML/a). Direct rainfall averages 188 ML/a, and runoff contributes 50 ML/a on average. These inflows are balanced by average evaporation of 350 ML/a.

7.11 SENSITIVITY ANALYSIS

The sensitivity of the (HI.H) equilibrium water level to uncertainty in the key input parameters was tested by:

- reducing the evaporation factor to 0.8 at the maximum void water; and
- reducing the AWBM USC values for pit wall catchments to half their original values ($C_{av} = 13.3 \text{ mm}$) – to increase runoff to the void.

Under these conditions, the maximum modelled water level is 578.9 mAHD for existing climate conditions. If the groundwater inflow relationship is also increased (noting that this is unlikely (Jacobs, 2022)), the maximum water levels increase to the following:

- GW inflow x 1.5 = 581.6 mAHD (18.1 m below overflow) (87 ML/a on average at equilibrium).
- GW inflow x 2.0 = 583.7 mAHD (16.0 m below overflow) (95 ML/a on average at equilibrium).

Figure 7.7 Results of Final Void Modelling – Lake Water Levels

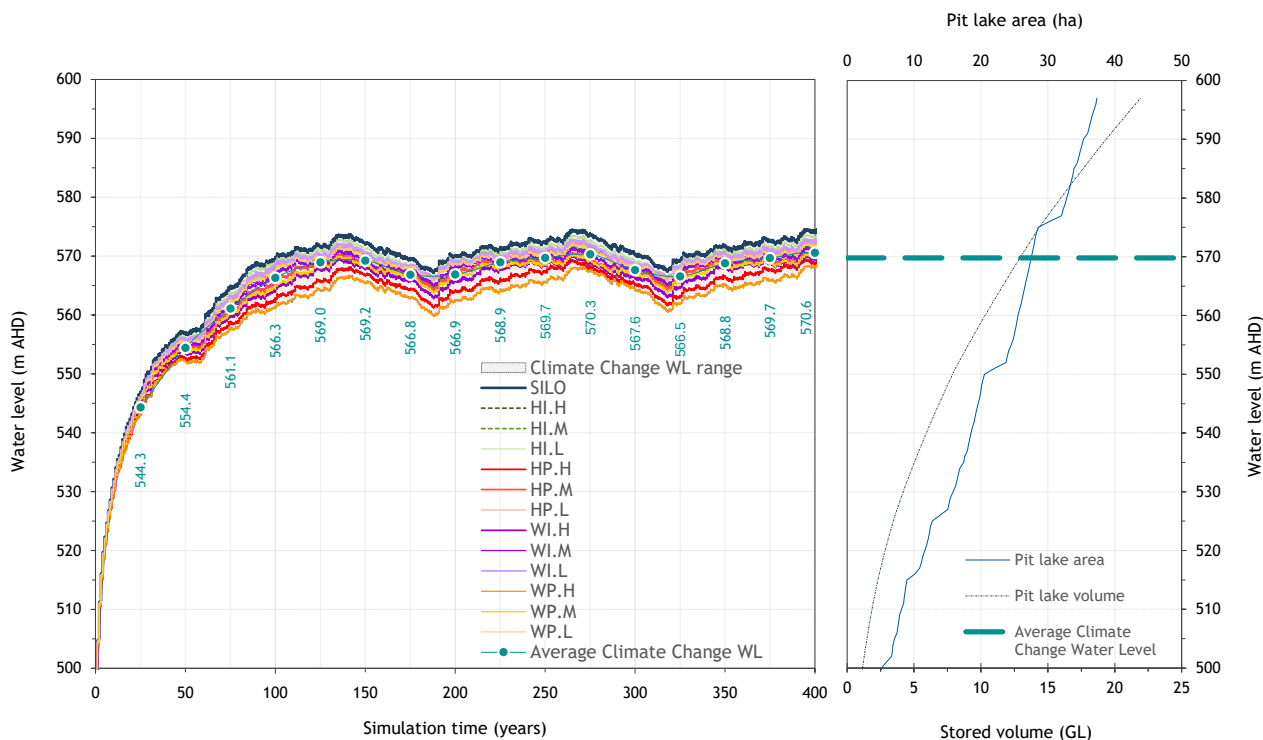


Figure 7.8 Results of Final Void Modelling – Lake Salinity (Existing Climate Scenario)

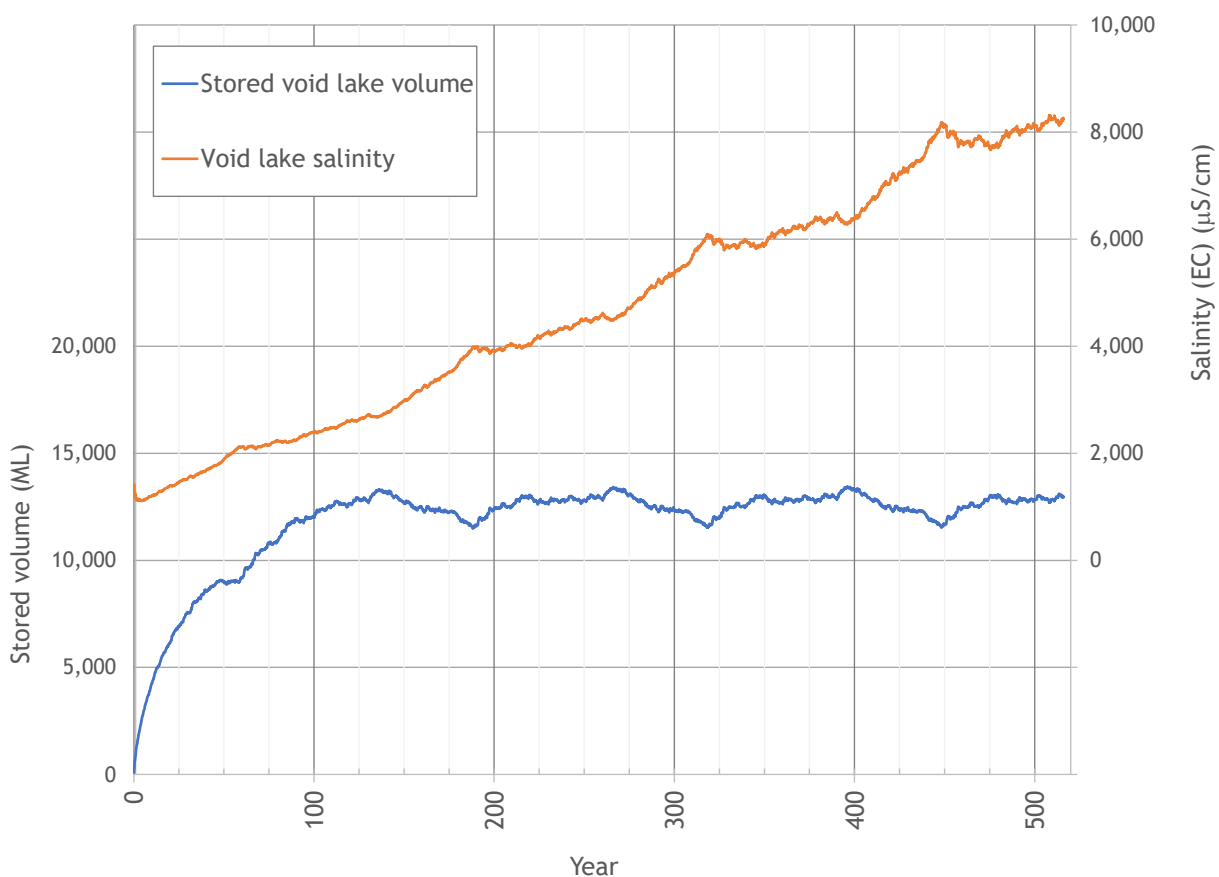


Table 7.3
Average Annual Final Void Water Balance – at Equilibrium

		Climate Scenario	
		Existing (SILO)	Average Climate Change (HI.H)
Climate Averages			
Evaporation	mm/a	1 354	1 501
Rainfall	mm/a	674	689
Runoff characteristics			
Pit Wall Runoff	mm/a	178.5	192.7
Pit Wall runoff/rainfall		26.5%	28.0%
Inflows			
Direct Rainfall	ML/a	188	188
Pit runoff	ML/a	45	50
GW inflow	ML/a	92	112
Outflows			
Pit evaporation	ML/a	325	350

Bowdens Silver is giving consideration to increasing the rate of initial fill of the final void to reduce the extent of the cone of groundwater drawdown and minimise oxidation of the exposed mineralisation on the pit walls. This could be achieved by transferring excess water from the TSF prior to its decommissioning and by temporarily directing runoff from the upslope Blackmans Gully catchment (150 ha) to the final void. Based on sensitivity testing of the final void water balance, runoff from the additional catchment would see the stored water level rise a further 8 m (approximately 1,200 ML (modelled range +/- 1.8 m depending on prevailing weather conditions)) in the first 10 years post-mining compared to the base case. This additional rise in water level would limit the generation of acidic drainage from the exposed faces within the main open cut pit, a feature that would limit the dissolved metal content in the final pit void lake.

8. POTENTIAL SURFACE WATER IMPACTS AND MITIGATION MEASURES

There are a number of mechanisms whereby the Project could potentially impact on downstream surface water flow in Lawsons Creek and its tributaries:

- interception of runoff by the mine water management system;
- change in runoff characteristics in areas disturbed by the mining and related activities; and
- loss of baseflow recharge to streamflow due to impacts on the local groundwater profile.

These impacts, and associated licensing requirements are quantified for the operational and post-mining periods in the following sections.

8.1 WATER ENTITLEMENT REQUIREMENTS

Surface water intercepted by the project is required to be licensed by way of a water access licence (WAL) granted under the Water Sharing Plan (the Plan) for Macquarie Bogan Unregulated and Alluvial Water Sources (2012): Lawsons Creek Water Source.

There are two main mechanisms by which the Project could reduce surface water flows in the Lawsons Creek Water Source:

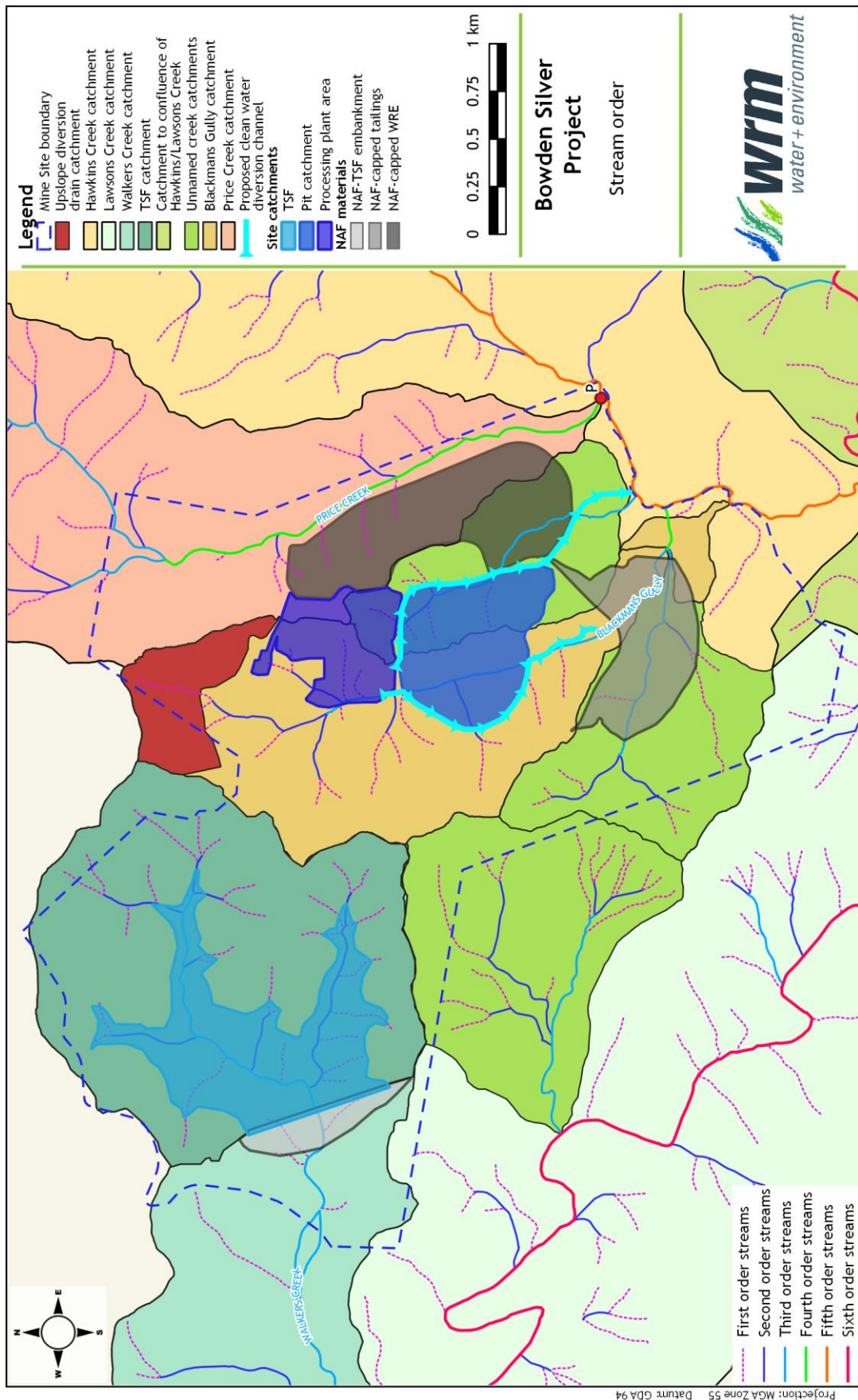
- Loss of baseflow contributions to streamflow, due to the impact of drawdown on the local groundwater profile by the open cut pit; and
- Interception of runoff in the water management system.

However, exemptions apply to the Project where water is taken from a minor stream (a first or second order stream (under the Strahler system) (that does not maintain a permanent flow of water), and is defined in the hydroline spatial data published on the Department's website).

Figure 8.1 shows (based on the hydroline spatial data) the Strahler stream order for streams crossing parts of the Mine Site where water would be intercepted during operations. The figure shows that all proposed water storages would be off-stream storages, except that:

- Walkers Creek is a third order stream where it would be crossed by the proposed TSF embankment.
- Blackmans Gully and the unnamed gully to the east are both third order streams where they would be crossed by the proposed open cut pit. However, these streams are to be diverted around the pit.

Figure 8.1 Strahler stream order of existing streams crossing the Mine Site



8.1.1 Exemptions under the Water Management Regulation 2018 (the Regulation)

Schedule 5 of the Water Management (General) Regulation 2018 (the Regulation) provides a water access licence is not required for water take that is caused by an “excluded work” as outlined in Schedule 1 of the Regulation. Schedule 1, lists a number of exemptions, two of which potentially apply to this Project:

- 1 *Dams solely for the control or prevention of soil erosion—*
 - (a) *from which no water is reticulated (unless, if the dam is fenced off for erosion control purposes, to a stock drinking trough in an adjoining paddock) or pumped, and*
 - (b) *the structural size of which is the minimum necessary to fulfil the erosion control function, and*
 - (c) *that are located on a minor stream.*
- 3 *Dams solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a public authority (other than Landcom or the Superannuation Administration Corporation or any of their subsidiaries) to prevent the contamination of a water source, that are located on a minor stream.*

8.1.2 Harvestable Rights

Under the Water Management Act 2000, landholders in most rural areas are permitted to collect a proportion of the rainfall runoff on their property and store it in one or more dams up to a certain size. This is known as a 'harvestable right'. A dam can capture up to 10 percent of the average regional rainfall runoff for their landholding without requiring a licence. The harvestable rights provisions are based on the assumption that the dam capacity is the same as this portion of the annual runoff. Harvestable rights dams must be located off-stream or on a minor stream.

The NSW Office of Water Harvestable Rights calculator identifies the harvestable right dam capacity at the Mine Site as 0.07 ML/ha. This capacity represents 10% of the mean regional annual runoff of 0.7 ML/ha or 70 mm.

Using the Bowdens Silver landholding area of 2,580 ha and the above multiple of 0.07 ML/ha the maximum harvestable rights capacity permissible volume is 180.6 ML.

Bowdens' landholding includes approximately 91 existing farm dams, the total capacity of which is estimated at 60.1 ML. A total of 48 dams with a combined capacity of approximately 27.8 ML would be removed during the Project life. This would leave a total of 41 dams, with a total capacity of approximately 32.3 ML.

The harvestable right dam capacity for the remainder of the Bowdens Silver property would therefore be $180.3\text{ML} - 32.3\text{ML} = 148.3\text{ML}$.

8.1.3 Proposed WAL Requirements

8.1.3.1 Sediment Dams

Water captured in sediment dams would be released in accordance with best practice, and would therefore be exempt from licensing.

In the event that (even after the addition of a flocculant) the quality of water captured in the Containment Zone was such that it could not be released it would be contained on site. No sediment dams would be constructed on a major stream. Therefore, these dams would be used “solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a public authority to prevent the contamination of a water source”, and the captured runoff would be exempt from licensing.

8.1.3.2 Water Management Dams Within the Containment Zone

None of the dams within the Water Management System’s Containment Zone would be constructed on major streams. As these dams would be constructed “solely for the capture, containment and recirculation of drainage and/or effluent, consistent with best management practice or required by a public authority to prevent the contamination of a water source”, water captured in these dams would be exempt from licensing.

8.1.3.3 Open Cut Pit

Similarly, while Blackmans Gully is a 3rd order stream where it crosses the proposed main open cut pit, it would be permanently diverted to minimise the quantity runoff captured in the open cut pit. Rainfall and runoff captured within the Open Cut Pit and its final void would be contained within the site water management system to prevent contamination of the water source, and would therefore be exempt from licensing. As water would not be allowed to pond in the diversion, the water diverted by the diversion would be exempt from requiring a water entitlement.

8.1.3.4 Tailings Storage Facility

As the TSF embankment would be constructed across a 3rd order stream, WAL exemptions do not apply. Bowdens Silver have secured WALs for water captured in the TSF prior to decommissioning and rehabilitation. These WALs account for the 80th percentile of annual runoff (estimated as 0.41 ML/ha based on modelling of catchment runoff using the AWBM calibrated as described in section 3.5) from the pre-mine catchment area (up to 301.2 ha), i.e. an entitlement equivalent to 123 ML/a. Bowdens Silver would also capture clean runoff (in accordance with its Harvestable Rights) in additional clean water dams to be constructed upslope of the TSF on minor streams.

8.1.3.5 Baseflow Loss due to Groundwater Drawdown

Due to the impact of drawdown on the local groundwater profile by the open cut pit. The groundwater assessment (Jacobs, 2022) predicts the reduction in baseflow would increase during operations such that at the conclusion of mining operations, the baseflow loss would be

up to approximately 14.0 ML/a, increasing to up to 19.3 ML/a post mining. Bowdens Silver has obtained water access licencing to account for this loss as described in the groundwater assessment (Jacobs, 2022).

8.1.3.6 Total WAL Required

Based on the above estimates, the total entitlement required for the Project would be as follows:

- During operations – 137 ML/a;
- Post closure – 19.3 ML/a.

As noted above, Bowdens Silver has secured WALs to account for the predicted requirements.

8.2 INTERCEPTION OF RUNOFF IN THE WATER MANAGEMENT SYSTEM

8.2.1 Operational Stage

Water impacted by the mining-related activities and captured in the water management system would be contained on site and re-used.

The catchment area of this containment system would vary over the Project life, and is expected to peak at approximately 550 ha (comprising approximately 300 ha in the TSF catchment and 250 ha in the remainder of the water management system), i.e. or 2.1% of the Lawsons Creek catchment (of 272 km² downstream of the Walkers Creek confluence) would be lost. Based on the estimated average undisturbed area runoff in the local catchment, this equates to an average annual loss of flow of 177 ML/a.

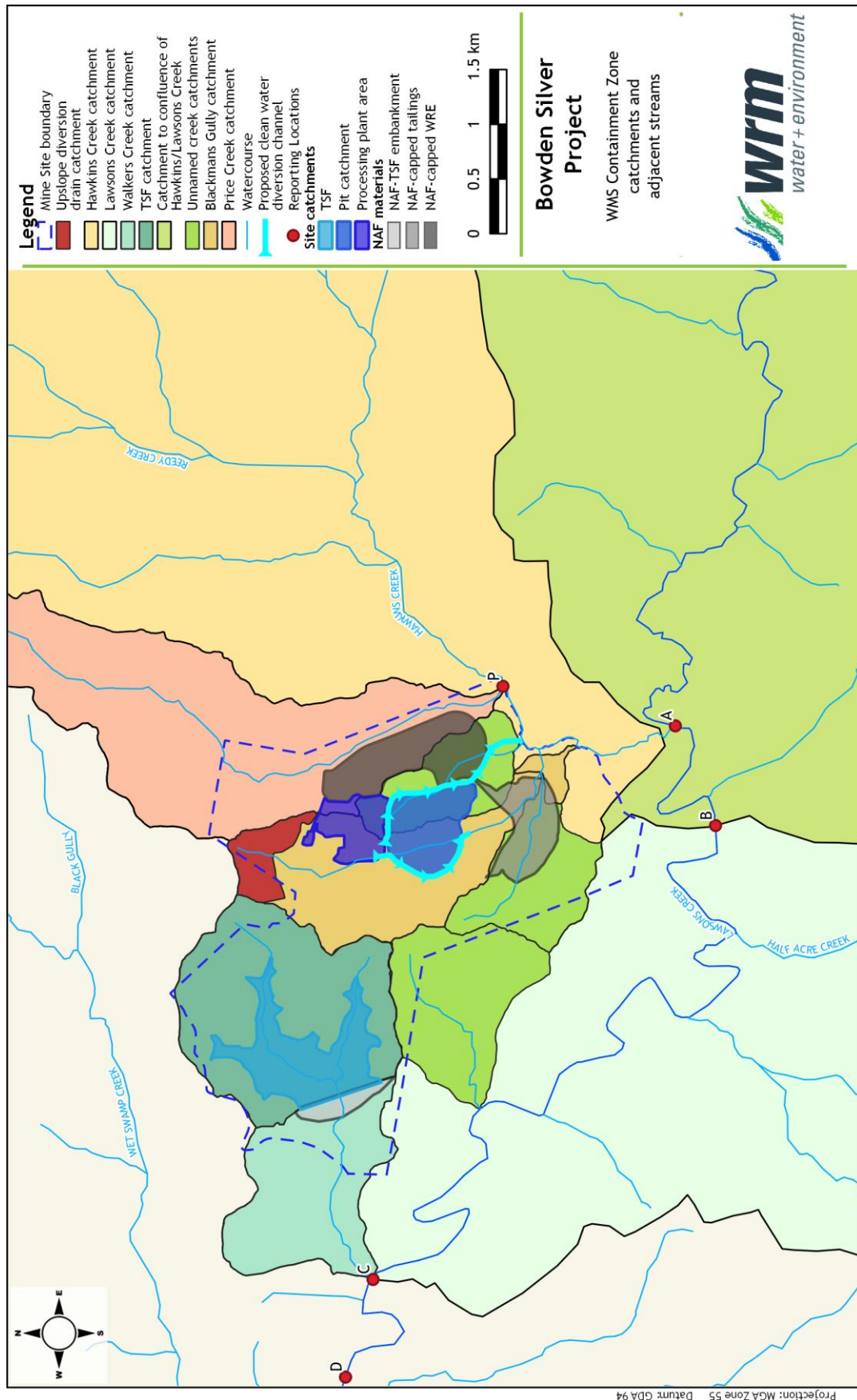
Note also that during operations, part of the undisturbed upslope catchment of Blackmans Gully would be diverted east to Price Creek. The effect of this diversion is to slightly increase streamflow in Price Creek and the reach of Hawkins Creek between the Price Creek and Blackmans Gully confluences. The area diverted is approximately 50 ha. In an average year, approximately 10 ML would be diverted from the Blackmans Gully catchment. As this minor change in flow distribution between Blackmans Gully and Price Creek is small, no mitigation measures are proposed for this temporary change.

8.2.2 Post-mining Period

At the completion of mining and processing operations, the WRE and the TSF would be capped and rehabilitated, so that runoff, once rehabilitation criteria relating to water quality have been met, would be allowed to freely discharge to the receiving environment.

The final post-mining landform would comprise a final void, which would capture runoff from the immediate surface catchment. Modelling of the long-term behaviour of the final void pit lake shows that water would not overflow from the final void, and runoff from this area would be lost from the surface catchment contributing to downstream flow. The catchment area of the final void after the completion of closure and rehabilitation activities would be approximately 53 ha or 0.2% of the total 272 km² Lawsons Creek catchment that is downstream of the Walkers Creek confluence (see **Figure 8.2**). Based on the estimated average undisturbed area runoff in the local catchment, this equates to an average annual loss of flow of 17 ML/a.

Figure 8.2 WMS Containment Zone catchments and reaches of adjacent streams potentially impacted by the Project



8.3 CHANGE IN RUNOFF CHARACTERISTICS POST-MINING

8.3.1 Post-mining Period

The rehabilitated WRE and TSF landforms would be capped, covered and revegetated, and the runoff characteristics of the post mining landform are expected to be similar to those existing prior to the development of the Project.

As a result, the post-mining change in surface runoff volume from these landforms to the downstream waters is expected to be minimal.

8.4 LOSS OF BASEFLOW

8.4.1 Operational Period

The groundwater assessment (Jacobs, 2022) predicts that drawdown of the local groundwater system that would be induced by groundwater inflow to the open cut pits would result in a reduction in baseflow contributions to both Hawkins Creek and Lawsons Creek. The reduction in baseflow would increase during operations, and near the conclusion of mining, the peak baseflow losses are expected to be up to approximately 0.026 ML/d (9.5 ML/a) and 0.014 ML/d (5.1 ML/a) for Hawkins Creek and Lawsons Creek respectively.

The peak baseflow losses from each creek would not coincide. The maximum predicted take from the Lawsons Creek Water Source, and therefore the volume of share components required to be held by Bowdens Silver as a water access licence (WAL) issued under the Water Sharing Plan (WSP) for Macquarie Bogan Unregulated and Alluvial Water Sources: Lawsons Creek Water Source (2012) during mining is 14.0 ML/a (Jacobs, 2022).

Impacts on baseflow would reduce with distance upstream of the cone of groundwater drawdown. At the end of mining, the 1 m drawdown contour extends to a point on Hawkins Creek approximately 3.5 km upstream from the Lawsons Creek confluence. The impacts of the Project on upstream flow conditions would be minimal.

8.4.2 Post-mining Period

The reduction in baseflow is predicted to increase as the cone of groundwater drawdown grows post-mining, and is expected to peak approximately 11.5 to 16 years post mining at approximately 0.031 ML/d (11.4 ML/a) for Hawkins Creek and 0.022 ML/d (8.1 ML/a) for Lawsons Creek.

Impacts on baseflow would reduce with distance upstream of the cone of groundwater drawdown. Fifty years post-mining, the 1 m drawdown contour would extend to a point on Hawkins Creek approximately 3.5 km upstream from the Lawsons Creek confluence. The impacts of the Project on upstream flow conditions would be minimal.

For the purpose of this assessment, impacts have been assessed for the following locations shown in **Figure 8.2**:

- The 2.1 km reach of Hawkins Creek from Price Creek to the confluence with Lawsons Creek, i.e. P - A.

- The 12 km reach of Lawsons Creek from Hawkins Creek confluence to upstream of the confluence with Walkers Creek A - C (based on the catchments to B).
- The reach of Lawsons Creek, immediately downstream of the Walkers Creek confluence (C - D) (based on the catchments to location C).

Table 8.1 shows the estimated combined peak impact of the Project on mean annual streamflow in each of the effected reaches. The analysis includes the following key assumptions:

- Areas intercepted by the water management system are the maximum areas over the Project life.
- No water is released from the containment (mine affected) zone water management system.
- Water captured in sediment dams is conservatively assumed to be returned to the water containment system.
- Mean annual runoff (prior to application of instream losses) is approximately 4.9% of mean annual rainfall (based on the runoff model parameters described in **Table 5.4**).

Any additional licensed water extractions under entitlement have been excluded.

Table 8.1
Impact of Project on Mean Annual Streamflow in Downstream Waters

Reach Number	Unit	Operations			Post closure		
		1	2	3	1	2	3
Watercourse and reach		Hawkins Creek	Lawsons Creek	Lawsons Creek	Hawkins Creek	Lawsons Creek	Lawsons Creek
		P - A	B - C	C - D	P - A	B - C	C - D
Pre-mining catchment area	km ²	61.0	222.3	272.1	61.0	222.3	272.1
Catchment area contained in WMS	km ²	2.50	2.50	5.50	0.53	0.53	0.53
Mean annual flow							
Pre-mining	ML/a	1 958	7 136	8 735	1 958	7 136	8 735
Loss due to Mine Site WMS Capture*	ML/a	80.3	80.3	176.6	17.0	17.0	17.0
Potential baseflow reduction*	ML/a	9.5	5.1	14.0	11.2	8.0	19.3
Total change due to the Project	ML/a	-88.9	-84.9	-189.3	-27.2	-24.3	-34.6
Percent change due to the Project		-4.5%	-1.2%	-2.2%	-1.4%	-0.3%	-0.4%
Note that in low flow the reduction reduces to zero on zero flow days The baseflow losses from each creek would not coincide							

In summary, the results show that:

- The total average annual loss of flow from the Macquarie Bogan Unregulated and Alluvial Water Sources is estimated to be:
 - Operational period (peak) – 189 ML/a; and
 - Post mining – 35 ML/a.

Bowdens Silver has WALs and harvestable rights entitlement in excess of these predicted losses during operations.

- The Project would not impact on:
 - Hawkins Creek upstream of the cone of groundwater drawdown, which extends approximately 3.5 km upstream of the Project;
 - Lawsons Creek upstream of the Hawkins Creek confluence.
- During operations, the maximum impact of the Project on downstream flow would be to decrease flows in:
 - the downstream 3.5 km of Hawkins Creek to the Lawsons Creek confluence by up to 4.5%;
 - Lawsons Creek downstream of Hawkins Creek and the Mine Site and upstream of the Walkers Creek confluence by up to 1.2%;
 - Lawsons Creek downstream of the Walkers Creek confluence by up to 2.2%. The relative impact on Lawsons Creek would reduce significantly downstream due to the contribution of other tributaries in the 235 km² catchment downstream of Point C to total streamflow.
- Post mining, the maximum impact of the Project on downstream flow would be to decrease flows in:
 - the 3.5 km reach of Hawkins Creek upstream of the Lawsons Creek confluence by up to 1.4%;
 - Lawsons Creek downstream of Hawkins Creek and the Mine Site and upstream of the TSF by up to 0.3%;
 - Lawsons Creek downstream of Walkers Creek and the TSF by up to 0.4%. The relative impact on Lawsons Creek would reduce significantly downstream due to the contribution of other tributaries in the 235 km² catchment downstream of Point C to total streamflow.

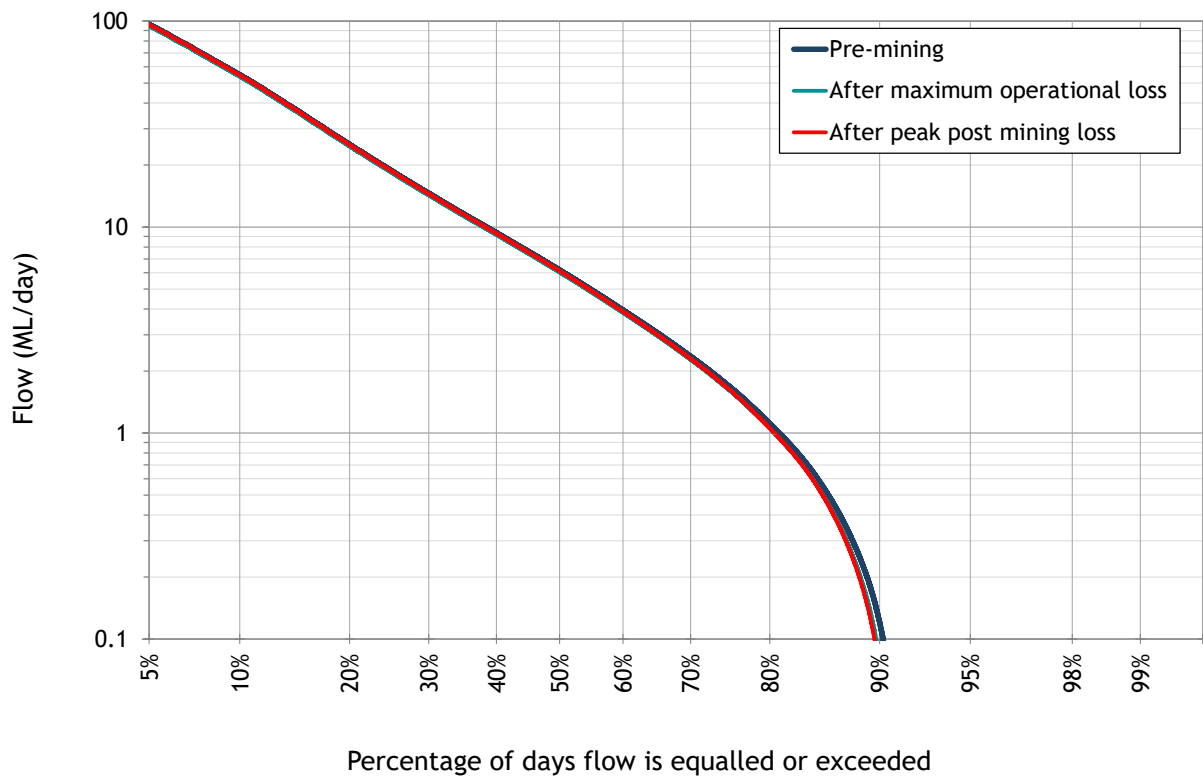
8.5 IMPACTS OF STREAMFLOW LOSS ON OTHER SURFACE WATER USERS

The Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Sources states that water must not be taken under a WAL when there is no visible flow or where, a licence permits, take from an in-river pool, when the volume in that pool is less than its full capacity.

The principal mechanism by which the Project would affect the quantity of water supplies available to other surface water users in the Lawsons Creek Water Source of the Macquarie Bogan Unregulated and Alluvial Water Sources is by reducing flows such that the frequency and duration of cease-to-flow periods is increased.

Figure 8.3 shows the estimated impact of the Project on the frequency of flows at location C in Lawsons Creek that was conducted by comparing the outputs of the AWBM model of the pre-mining catchment areas (described in Section 3.5.3) with the corresponding results of a model with the reduced catchment area.

Figure 8.3 Effect of Loss on Lawsons Creek Streamflow Frequency - Location C



At this location, flows greater than 1 ML/d (approximately 12 L/s) occur about 81.0% of the time. The results show that the impact of the Project on the frequency of flows greater than 1 ML/d is expected to be minimal (flows greater than 1 ML/day would occur for approximately 80.5% of the time, i.e. a reduction of 0.5% of the time or up to 2 days per year on average) and therefore the impact of the loss on the availability of water to downstream water users would be negligible.

Similarly, the impact on cease-to-flow periods would be minimal, with flows greater than 0.1 ML/d reducing in frequency from 90.2% to 89.8% of the time during operations, and 89.6% of the time after decommissioning.

8.6 POTENTIAL SOURCES OF RUNOFF CONTAMINANTS

The potential sources of contaminants to the surface water environment during operations and after mine closure are listed in **Table 8.2** and **Table 8.3** respectively. The tables list the source catchment and receiving waters for each source and the mitigation measures proposed to prevent contamination of the receiving waters.

Table 8.2
Potential Contaminant sources and Mitigation Measures during Operations

Source Component	Mitigation Measure	Source Catchment / Receiving Waters
Processing Area		
Processing area runoff	Processing plant dams and water management system operation	Blackmans Gully/ Hawkins Creek/ Lawsons Creek
ROM pad – ore stockpile	Processing plant dams	Blackmans Gully/Hawkins Creek
Oxide ore stockpile		
Oxide ore stockpile runoff	Oxide ore stockpile dam	Hawkins Creek/Lawsons Creek
WRE Outer Embankment		
NAF outer embankment runoff	Haul road sediment dam	Price Creek/ Hawkins Creek/ Lawsons Creek
PAF waste rock runoff	PAF waste rock encapsulation and WRE design	Price Creek/ Hawkins Creek/ Lawsons Creek
PAF waste rock leachate	WRE liner and encapsulation design and leachate management dam design	Price Creek/ Hawkins Creek/ Lawsons Creek
Southern Barrier		
Blackmans Gully upslope runoff flowing beneath NAF waste rock in southern barrier	Low level size and culvert	Blackmans Gully/ Hawkins Creek/ Lawsons Creek
NAF waste rock outer embankment runoff	Southern barrier sediment dam	Blackmans Gully/ Hawkins Creek/ Lawsons Creek
TSF		
NAF waste rock embankment runoff	TSF embankment sediment dam	Walkers Creek/ Lawsons Creek
NAF waste rock stockpile area runoff	NAF waste rock stockpile sediment dam	Walkers Creek/ Lawsons Creek
Tailings seepage	TSF liner	Walkers Creek/ Lawsons Creek
Tailings surface runoff	TSF decant design & operation	Walkers Creek/ Lawsons Creek
Tailings liquid fraction containing cyanide and other process reagents	All tailings decant and paste thickener reclaim water is returned to the processing plant	Walkers Creek/ Lawsons Creek

Table 8.3
Potential Post-closure Contaminant Sources

Source Component	Mitigation Measure	Source Catchment / Receiving Waters
WRE Outer Embankment		
NAF outer embankment runoff	Vegetated store-and-release cover Haul road sediment dam	Price Creek/ Hawkins Creek/ Lawsons Creek
PAF waste rock leachate	WRE liner and encapsulation	Price Creek/ Hawkins Creek/ Lawsons Creek
TSF		
NAF waste rock outer embankment runoff	Embankment covered with soil and revegetated	Walkers Creek/ Lawsons Creek
Tailings seepage	Vegetated store-and-release cover to eliminate seepage	Walkers Creek/ Lawsons Creek
Tailings surface runoff	Vegetated store-and-release cover to encapsulate tailings	Walkers Creek/ Lawsons Creek
Final Void		
Void lake	Upstream catchment diversion to minimise surface catchment and prevent surface or seepage overflows	Blackmans Gully/ Hawkins Creek/Lawsons Creek

8.6.1 Potential for Contamination due to PAF Waste Rock and Tailings Runoff, Leachate or Seepage

Operations Stage

During operations, runoff, leachate and seepage from PAF waste rock and tailings would be contained in the WRE and TSF respectively. Runoff from the processing plant, mining facility and ore stockpiles would be captured and contained within the containment (mine affected) zone water management system, which would be designed and operated such that any discharge from these sources is directed to the main open cut pit and away from the external surface water environment.

Post-mining Period

At the end of mining and processing operations, any retained low grade ore would be encapsulated above the WRE and similarly covered with a store and release cover. The southern barrier, and processing areas would be decommissioned with all NAF waste rock used to rehabilitate the WRE and TSF. All processing areas would be decommissioned and a final undulating landform created.

The final void pit lake water balance shows that, with the expected groundwater inflows (Jacobs, 2022), and effective catchment diversions in place, the final void would remain a groundwater sink and would not overflow under either the historic climate or the projected climate change scenarios.

All PAF waste rock would be encapsulated in the final WRE landform that would include a vegetated store-and-release capping and cover system, and assuming the liner and capping system are effective, seepage and leachate collection would be eliminated. Similarly, in

conjunction with the liner and seepage collection system, the vegetated store-and-release capping and cover system of the TSF would also eliminate runoff and seepage from tailings. The effectiveness of the proposed closure and rehabilitation measures would be trialled, monitored and evaluated during operations, as part of progressive rehabilitation of the Mine Site

With the above mechanisms effectively managing seepage, leachate and runoff, the receiving waters are unlikely to be impacted by seepage, leachate or runoff from the PAF material either during operations or after closure and decommissioning.

8.6.2 Potential for Contamination due to NAF Waste Rock Runoff and Seepage

During operations, runoff from the TSF NAF waste rock stockpile area, TSF outer embankment (which would be vegetated upon the completion of the 3rd embankment raise), WRE lower embankment (which would be vegetated following construction in the site establishment and construction stage) and southern barrier would be captured and treated in sediment dams sized as described in Section 4.6.2.

The southern barrier would be decommissioned after closure, leaving the outer embankment of the TSF, and the store-and-release cover of the WRE as potential sources of NAF runoff. Sediment dams would remain in place until vegetative cover was sufficiently established to control erosion from these embankments.

9. WATER MANAGEMENT PLAN

9.1 INTRODUCTION

Prior to the commencement of the site establishment and construction activities, Bowdens Silver would be required to prepare a Water Management Plan for approval by DPIE and NRAR. The Water Management Plan would include (but not be restricted to) the following elements.

9.2 WATER QUALITY MONITORING PROGRAM

The existing downstream ambient water quality monitoring program would be retained until the commencement of the site establishment and construction stage. Once operations commence, regular monitoring of Mine Site water storages within both the containment (mine affected) zone and ESC zone would be undertaken to ascertain the characteristics of Mine Site runoff and leachate.

Water quality monitoring would be undertaken in a manner that is consistent with the National Water Quality Management Strategy. Samples would be initially collected monthly (in the case of ambient water quality) or during a flow event, where possible. The monitoring program would be implemented in accordance with the Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (EPA). The sample locations, frequency of sampling and analytes tested would be reviewed annually, and the monitoring results would be reported in accordance with the requirements of the EPA and the DPIE.

9.3 WATER VOLUME MONITORING PROGRAM

The Water Management Plan would document the methods by which all inflows (raw water or groundwater inflows) and transfers within the Mine Site would be recorded for comparison with the volumes predicted in the site water balance. The recorded volumes would then be used to refine the site water balance.

It is also anticipated that all inflows would be documented and recorded under the conditions of any water access licences required to account for groundwater as well as surface water storages that exceed the maximum harvestable rights provisions of the Water Management Act 2000.

9.4 WATER MANAGEMENT INFRASTRUCTURE MONITORING PROGRAM

The Water Management Plan would document the frequency and scope under which all water management infrastructure would be inspected. Inspections would include infrastructure in the containment (mine affected) zone, ESC zone as well as clean water diversions. The inspections program presented in the Water Management Plan would not cover the TSF which would be separately managed via plans approved by the Dams Safety NSW.

9.5 TRIGGER ACTION RESPONSE PLANS

The Water Management Plan would include specific reference to the required actions should established triggers be reached with regards to the management of water captured within the containment (mine affected) zone and the ESC zone. This may include water levels that, once reached, would require active pumping and transfers between the various components of the water management system in order to prevent discharge from the Mine Site.

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Annexures

(Total No. of pages including blank pages = 366)

Annexure A	Watercourse Assessment (120 pages)
Annexure B	Flood Impact Assessment and Updated Lawsons Creek Crossing (236 pages)
Annexure C	Peer Reviews – 2020 and 2022 (8 pages)

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Annexure A

Watercourse Assessment

(Total No. of pages including blank pages = 120)

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ABN: 37 009 250 051

Bowdens Silver Project

Watercourse Assessment

Prepared by

R.W. Corkery & Co. Pty Limited

January 2020

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GLOSSARY OF COMMONLY USED TERMS AND ACRONYMS

AHD	Australian Height Datum.
AMTD	Adopted Middle Thread Distance: measured from the outlet (mouth) of a given watercourse.
ANZG	Australian and New Zealand Guidelines
ARMCANZ	Agriculture and Resources Management Ministerial Council of Australia and New Zealand
Bed Aggradation	Channel bed is accumulating sediment
BoM	Bureau of Meteorology
Box and Whisker Plot	A method for graphically depicting statistical groups derived from numerical data. The boxes depict variability within a given percentile range (20 th and 80 th) that is considered to be within the range of temporal and seasonal variability (ANZG) whilst the whiskers present the variability outside of the range of temporal and seasonal variability.
BSW	Bowdens Surface Water
Left Bank	Left hand bank of a watercourse when viewed looking downstream
NWQMS	National Water Quality Management Strategy
RCP	Reinforced Concrete Pipe
Right Bank	Right hand bank of a watercourse when viewed looking downstream
SILO	Scientific Information for Land Owners
TSF	tailings storage facility
Unregulated Watercourse	A watercourse that is allowed to freely discharge due to the absence of substantial hydraulic controls having been placed in its flow path (i.e. dams or weirs)
WRE	waste rock emplacement

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1. WATERCOURSE CONDITION ASSESSMENT

1.1 BACKGROUND

The watercourses within and surrounding the Mine Site are situated predominantly within the Hawkins Creek sub-catchment of the regional Lawsons Creek catchment. Hawkins Creek drains in a south-westerly direction prior to entering Lawsons Creek approximately 0.8km south of the Mine Site (**Figure 1**). Lawsons Creek generally flows in a westerly direction prior to entering the regulated Cudgegong River at Putta Bucca, approximately 1.6km north of Mudgee and approximately 26km west of the Mine Site.

RWC and Bowdens Silver personnel conducted physical inspections of the subject watercourses during the period between 17 July 2017 and 19 July 2017 and 23 May 2019. The purpose of the physical inspections was to establish the physical condition of each watercourse and place them into a geomorphologic context.

Water quality data collected over the period between June 2012 to November 2018, was assessed and subjected to exploratory data analysis via statistical interpretation recommended in Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) and graphically using box and whisker plots. This type of plot is extremely useful in providing a visual representation of the statistical interpretations for condition assessment. All plots present data as maximum, minimum, median, 20th and 80th percentiles with the median value chosen for comparison to trigger values. This is the current approach recommended in ANZG (2018).

An important factor in the assessment of future water quality in the watercourses downstream from the Mine Site would be the chemical composition of runoff from the structures and landforms constructed around the perimeter of the Mine Site. Those structures would comprise the TSF embankment, the southern barrier, oxide ore stockpile and the noise barrier and lower embankment haul road around the WRE. Given these structures would be constructed using non-acid forming (NAF) waste rock, this report includes a brief summary of the likely runoff water quality from these structures and landforms, drawn principally from the results of leachate testing on:

- NAF waste rock by Graeme Campbell & Associates (2019); and
- Stream sediments.

1.2 METHODOLOGY

The subject watercourses were identified based on their location and position within their respective catchments with respect to the principal components of the Bowdens Silver Project (see **Figure 1**).

The watercourse inspections were used to:

- identify the physical features present at the inspection locations (see **Figure 2**);
- identify the origin and development of the watercourse over time; and
- subsequently establish the geomorphic characterisation of each watercourse,

Figure 1 Indicative Mine Site Layout and Catchments Boundaries

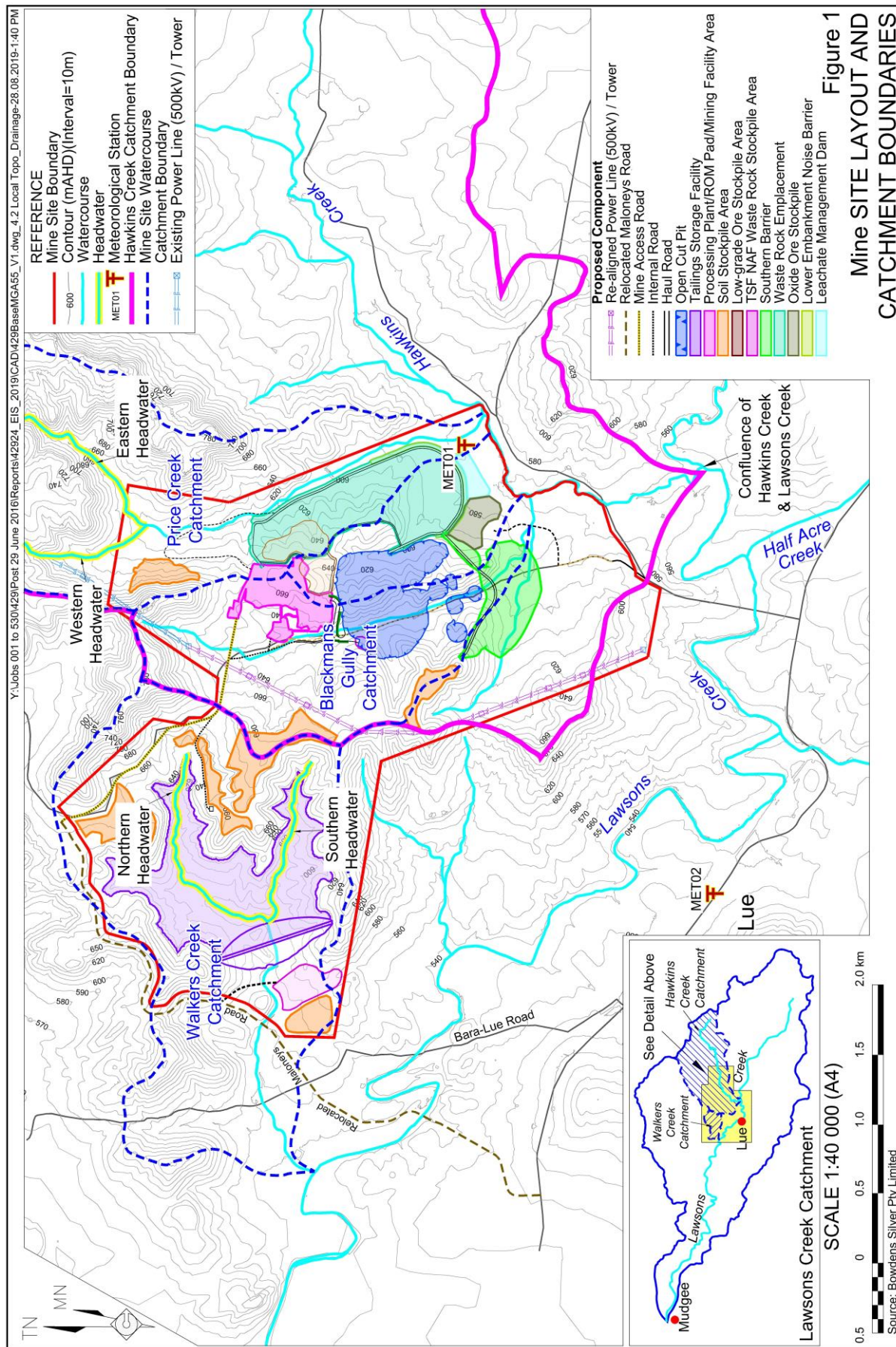
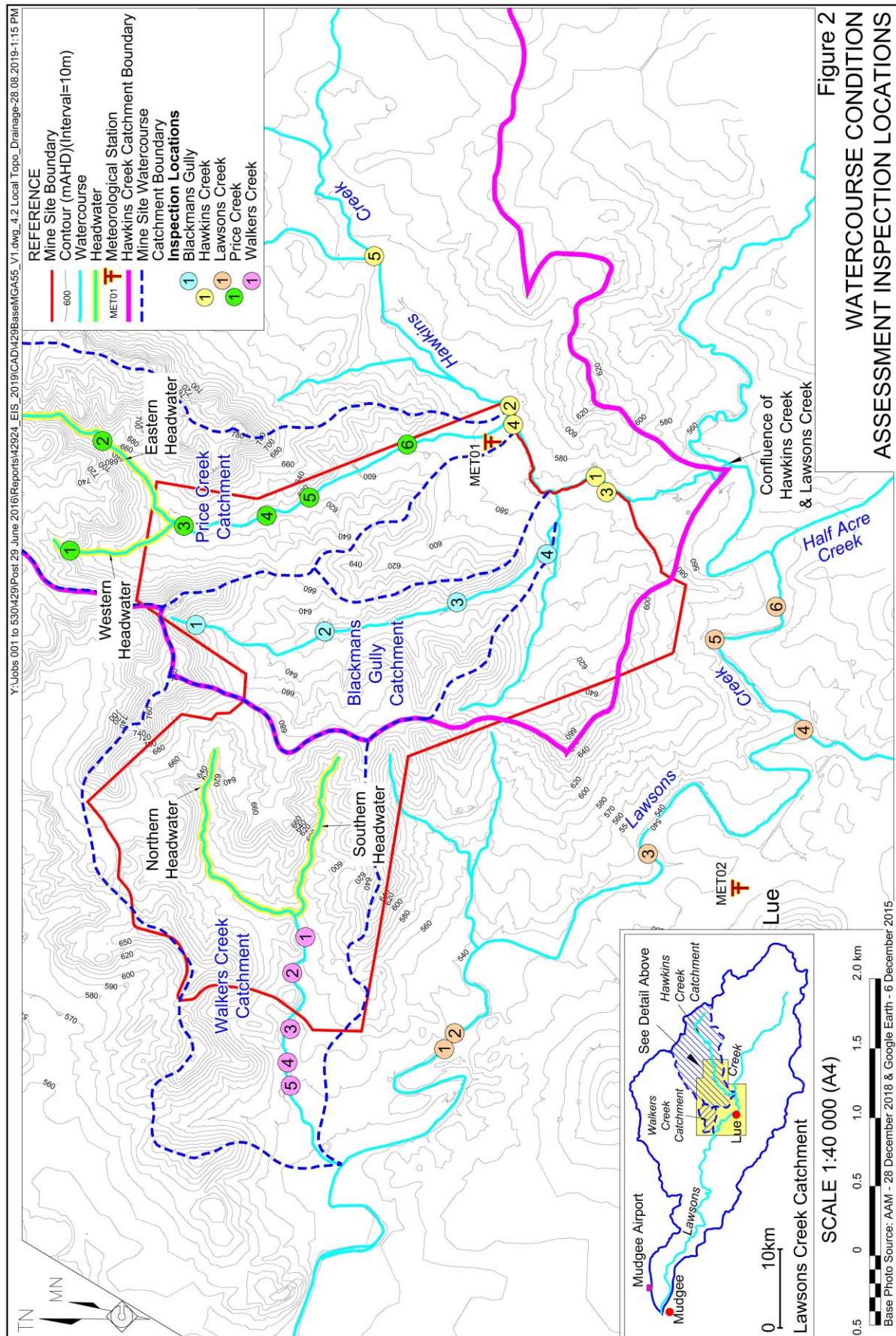


Figure 2 Watercourse Condition Assessment Inspection Locations



Photographs were also taken to assist with this assessment (see **Figure 3**). This geomorphic characterisation was used as a means of quantifying the prevailing hydrologic regime (discharge environment) of the contributing catchment and note any historic changes over time.

The prevailing hydrologic regime is typically influenced principally by a combination of factors such as:

- catchment topography which influences the timing of peak discharge events, flow velocity and watercourse planform;
- catchment geology which influences the nature and type of sediment transported by a watercourse and water chemistry;
- catchment land use and vegetation cover which influences the nature and timing of discharge, sediment loads and water chemistry; and
- climate influences the type of climatic environment which influences the weathering regime of the host geology and consequently the sediment type whilst the frequency and duration of rainfall events influences peak discharge in a given watercourse that subsequently influences its geomorphology.

The interactions of the factors described above effectively place direct controls on the distribution of flow energy within a given watercourse that, as a consequence, influences the erosional and depositional environment within the watercourse itself. Subsequently, the erosional and/or depositional environment influences the physical features (geomorphic units) of the watercourse which may then be used to characterise the nature of the prevailing hydrologic regime of the contributing catchment.

The geomorphic units observed and other geomorphic features such as channel planform and the position of the channel within the valley were then used to place each watercourse into a valley setting to geomorphologically characterise the watercourse in a manner that is in general agreement with the “River Styles” methodology (Brierley et al, 2002).

The physical condition of the subject watercourse at a given location was also assessed in order to place current and historic land uses in context with the current and past hydrologic regime that are expressed as the geomorphologic features described above.

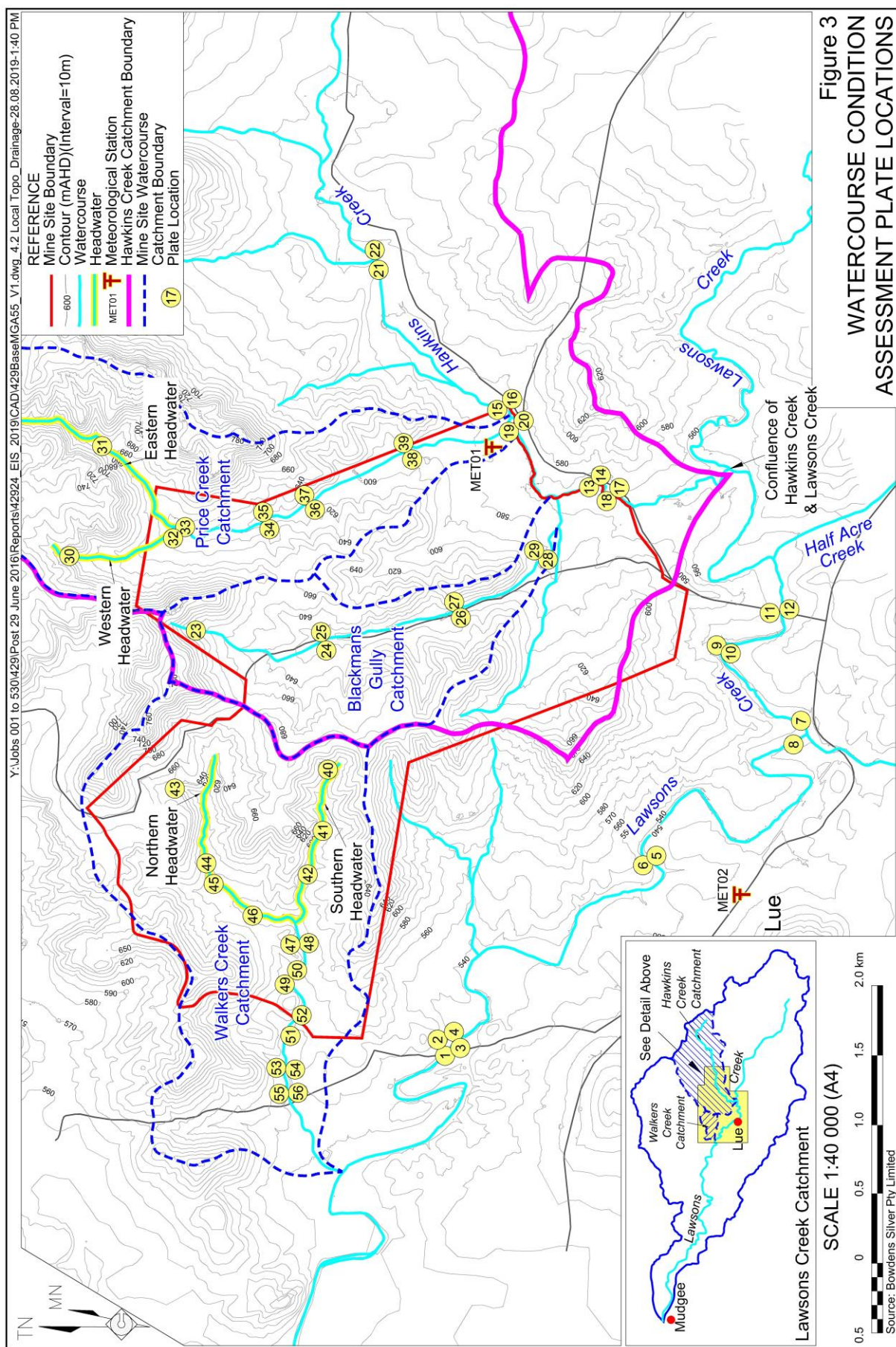
Physical condition was also generally assessed through the observation of evidence of degradation, typically as a result of factors such as:

- animal disturbance (burrows, stock paths);
- loss of riparian vegetation; and
- increased discharge or velocity.

1.3 SUBJECT WATERCOURSES

The subject watercourses inspected were the regional (Lawsons Creek), sub-regional (Hawkins Creek) and Mine Site (Blackmans Gully, Price Creek and Walkers Creek).

Figure 3
WATERCOURSE CONDITION
ASSESSMENT PLATE LOCATIONS



Whilst not directly impacted by the Bowdens Silver Project, the sub-regional Hawkins Creek was inspected at locations upstream and downstream of the Mine Site as Blackmans Gully and Price Creek presently discharge into this system. Similarly, the regional watercourse, Lawsons Creek was inspected downstream of its confluence with Hawkins Creek so as to characterise the receiving system downstream of the Mine Site. Walkers Creek discharges into Lawsons Creek approximately 4km west of the Mine Site.

Whilst a number of watercourses occur within the Mine Site boundary, the inspection was conducted on those watercourses (and catchments) within which the principal components of the Bowdens Silver Project (see **Figure 1**) would be situated, namely:

- i) an open cut pit situated largely within the Blackmans Gully catchment;
- ii) a processing plant and related infrastructure situated within the upper reaches of the Blackmans Gully catchment;
- iii) low grade ore and non-acid forming construction material stockpiles within the Blackmans Gully, Price Creek and Walkers Creek catchments;
- iv) waste rock emplacement (WRE) within the Price Creek catchment (i.e. WRE); and
- v) a tailings storage facility (TSF) within the Walkers Creek catchment.

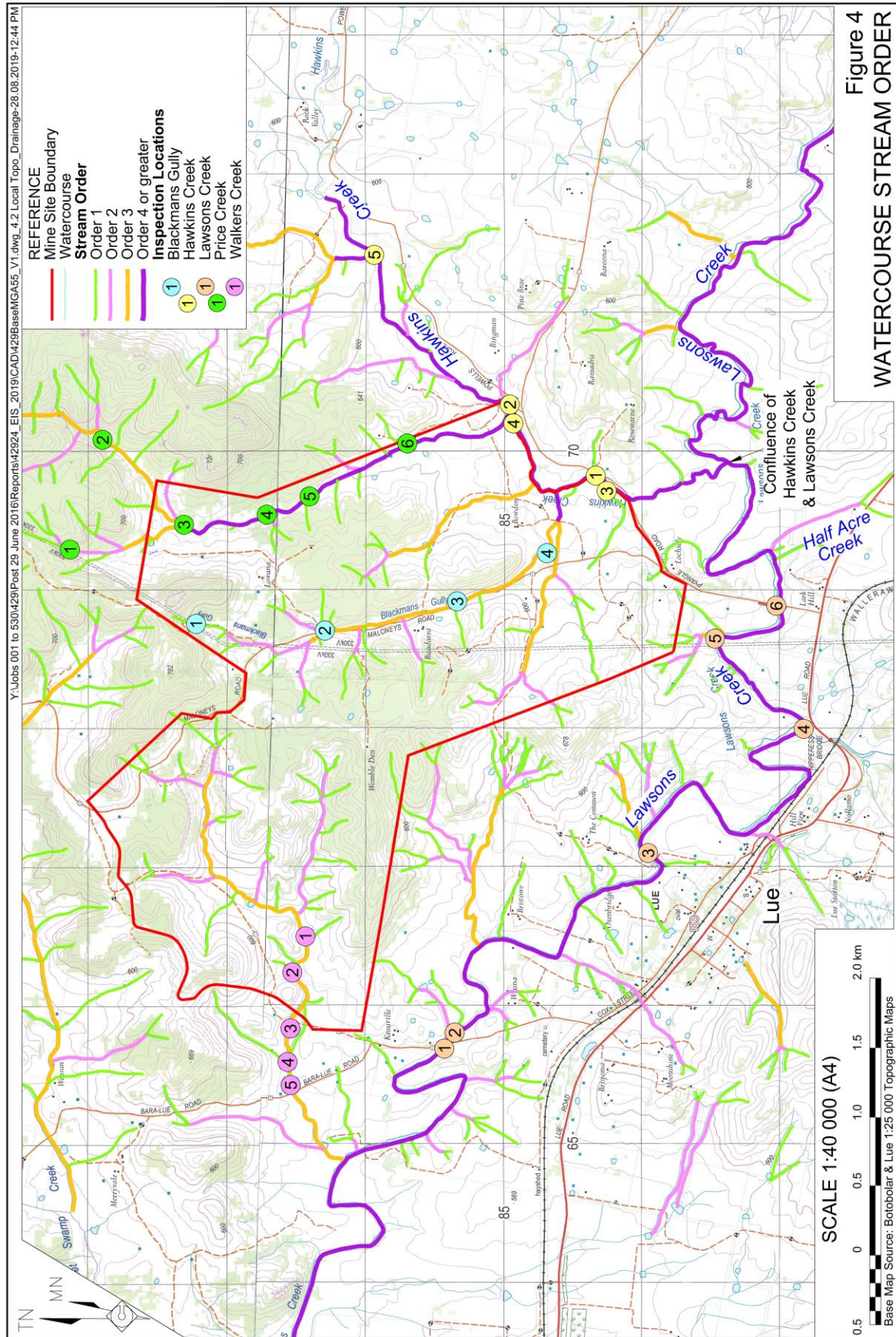
1.4 STREAM ORDER

In accordance with Schedule 2 of the *NSW Water Management (General) Regulation 2018* the stream order classifications for the subject watercourses was undertaken using the Strahler system (Strahler, 1952), utilising the NSW hydroline spatial data that is based on topographic mapping (Lue 1:25 000 and Botobolar 1:25 000) (refer **Figure 4**).

Review of the available spatial data for the Blackmans Gully and Walkers Creek catchments, identified each of these systems as being a 3rd order stream under the Strahler system. However, upon undertaking the physical inspection of the watercourses, it was identified that many of the lower order (i.e. 1st or 2nd) intermittent watercourses, identified on the topographic mapping, were either absent or lacking some or all of those features that would normally be used to characterise a watercourse or stream that would generate physical evidence of its presence (Taylor and Stokes, 2005), such as having a:

- definable bed;
- definable banks;
- surface flow present or evidence of prolonged wetness within the drainage feature;
- fluvial bedforms (e.g. pools, riffles, zones of sediment accumulation etc);
- visible habitats that may sustain aquatic fauna; and
- presence of aquatic flora that would require periods of uninterrupted moisture.

Figure 4 Watercourse Stream Order



Whilst some of the features listed above were observed in some of the lower order watercourses identified from the mapping, not all were present. This would suggest that these “watercourses” are in fact preferential flow paths that only briefly experience discharge during and after a rainfall event. Therefore, these watercourses are better considered as being “ephemeral” (not intermittent or perennial), and as such may be excluded from the stream ordering process in accordance with Strahler (1964), which states:

“Assuming that one has available a channel-network map including all intermittent and permanent flow lines located in clearly defined valleys, the smallest fingertip tributaries are designated order 1”.

Subsequently, whilst this report assigns lower order drainage features in the Blackmans Gully and Walker Creek catchments with a stream order in accordance with the available spatial data, based on the physical inspection of these watercourses documented in this report, the ephemeral nature of many lower order drainage features indicate that, rather than being 3rd order watercourses, in actuality Blackmans Gully is instead a 1st order watercourse and Walkers Creek a 2nd order watercourse. This would suggest that the watercourses shown on the hydroline spatial dataset, that is drawn from the Lue 1:25 000 and Botobolar 1:25 000 mapping, have never been “ground-truthed” or subjected to site investigation to verify the accuracy of the original mapped interpretation.

1.5 METEOROLOGY

1.5.1 Climate Data

The closest Bureau of Meteorology (BoM) weather station that provides long term climatic information suitable for use in describing the local climate is located at Mudgee Airport AWS (Station No. 062101), 26km west-northwest of the Mine Site.

Additional climate information was sourced from the two Bowdens weather stations, Lue Met 01 in the eastern section of the Mine Site and Lue Met 02 in Lue, between March 2013 and November 2018 to provide Site-based weather data and conditions. **Figure 2** shows the locations of both Met stations and Mudgee Airport.

Table 1 provides the historical climate data from the BoM, Met 01 and Met 02.

1.5.2 Temperature and Humidity

Temperature and humidity data were sourced from the Mudgee Airport BoM station and show that January is the warmest month with a mean maximum temperature of 31.0°C and mean minimum temperature of 16.1°C. July is the coldest month with a mean maximum temperature of 14.4°C and a mean minimum temperature of 1.1°C.

The lowest average relative humidity generally occurs in the summer months, with January and December sharing the lowest relatively humidity values throughout the year. The highest average relative humidity occurs in June.

Table 1
Historic Climatic Data (Measured)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature (°C) Mudgee Airport Station (Station # 062101) Period of Record 27 Years													
Mean maximum temperature	31.0	29.5	26.8	23.0	18.6	15.0	14.4	16.3	19.6	23.1	26.4	28.8	22.7
Mean minimum temperature	16.1	15.6	12.8	8.0	4.0	2.4	1.1	1.5	4.3	7.7	11.3	13.8	8.2
Relative Humidity (%) Mudgee Airport Station (Station # 062101) Period of Record 19 Years													
Mean 9:00am relative humidity	63	70	72	71	80	87	87	78	70	61	63	62	72
Mean 3:00pm relative humidity	37	42	42	41	49	57	55	47	44	41	40	37	44
Rainfall (mm) Mudgee Airport Station (Station # 062101) Period of Record 24 Years													
Mean monthly rainfall	67.6	63.1	58.9	33.2	37.9	45.0	43.4	35.2	54.6	51.1	75.4	80.7	663.2
Highest monthly rainfall	195.6	233.0	187.0	108.4	124.0	127.2	143.8	112.2	197.4	135.8	162.8	241.6	1152.4
Lowest monthly rainfall	10.0	2.2	0.0	0.0	0.4	1.4	2.6	1.0	0.8	0.2	9.4	15.0	349.6
Highest daily rainfall	65.0	174.2	72.0	46.2	44.4	37.0	51.2	51.2	61.0	51.0	57.2	100.8	-
Average Rain Days (>1mm)	7.3	6.9	6.9	4.8	6.3	10.1	9.9	7.6	7.4	8.0	9.3	8.6	93.1
Rainfall (mm) Lue Met01 - Period of Record 5 Years													
Mean monthly rainfall	41.2	57.2	65.2	38.6	36.4	58.2	36.6	29.1	53.4	39.6	53.0	61.5	635.3
Highest daily rainfall	45.2	81	50.6	31.4	26.8	29.2	41.6	19	50	24.6	49.2	51.6	-
Rainfall (mm) Lue Met02 - Period of Record 5 Years													
Mean monthly rainfall	34.3	56.2	58.0	31.6	31.1	59.2	44.4	32.4	57.8	45.0	56.6	71.5	632.2
Highest daily rainfall	41.8	125.6	52	32.4	25.8	29.8	41.2	20.8	60.8	30.6	56	58.2	-
Rainfall (mm) SILO Climate Data - Period of Record 129 Years													
Mean monthly rainfall	71.2	63.1	54.2	44.7	44.2	52.9	51.9	50.8	51.9	57.1	64.3	64.7	672.1

1.5.2.1 Rainfall

Rainfall data were sourced from Mudgee Airport BoM, the two on-site Met Stations (**Table 1**) and the Scientific Information for Land Owners (SILO) Climate Database (**Table 2**) which provides data of historical climate records by accessing grids of data (grid reference -32.60, 149.85) that were interpolated from point observations by the Bureau of Meteorology. Whilst the on-site Met Stations have a limited dataset (2013-2018), the rainfall generally reflects rainfall trends displayed in the SILO dataset, albeit at slightly lesser amounts. Average annual rainfall at Mudgee Airport BoM is 663.2mm. The average annual rainfall generated for the two on-site stations is considered less reliable due to the short timeframe covered in the dataset.

Rainfall can be variable, with infrequent, high intensity rainfall events occurring. This is evidenced by the highest daily rainfall values shown in **Table 1** and the fact that the maximum daily rainfall values can be as high as 2 times the average monthly rainfall values (e.g. 125.6mm, Met 02, 25 February 2018). An example of this rainfall variability is the high intensity rainfall event recorded at Met 01 (81mm) and Met 02 (125.6mm) on 25 February 2018 whilst no rainfall was recorded at Mudgee Airport on the same date.

Climatic conditions during the inspection period were mild and clear with the total rainfall recorded at the two Bowdens Silver meteorological stations (Met 01 and Met 02) in the period preceding the inspection as follows.

- Met 01: 3-day rainfall 1.4mm; 7-day rainfall 1.4mm.
- Met 02: 3-day rainfall 2.2mm; 7-day rainfall 2.4mm.

1.5.2.2 Evaporation

Evaporation data have been sourced from SILO with the averages being calculated using Class A Evaporation (post 1970) and synthetic pan evaporation (pre 1970).

Mean monthly evaporation for the Mine Site varies throughout the year, from approximately 222 mm in January and December to 42 mm in June, typically following the seasons throughout the year (**Table 2**). The annual SILO evaporation rate of 1 517 mm exceeds the average annual rainfall averaged calculated from SILO data by a factor of approximately 2.3.

Table 2
Historic Evaporation Data (SILO)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Class A Evaporation (mm) SILO Climate Data - Period of Record 129 Years (pre 1970: synthetic pan evaporation)													
Mean monthly evaporation	222.4	176.7	155.3	101.5	62.6	42.2	46.9	69.7	99.3	142.9	178.0	220.3	1517.0
Mean daily evaporation	7.2	6.3	5.0	3.4	2.0	1.4	1.5	2.2	3.3	4.6	5.9	7.1	-

1.6 LAWSON'S CREEK

1.6.1 Catchment Description

Catchment area: 507km²

Stream order: 4th (in the vicinity of the Mine Site)

AMTD: 64.3km

Elevation: Headwaters 910m AHD; Outlet 560m AHD

Average grade: 0.54%

Land-use: Cleared agricultural land (pastoral) on lowlands with forested (native vegetation) on uplands.

Lawsons Creek is an unregulated watercourse that drains the regional catchment in which the Mine Site is situated.

The headwaters of the Lawsons Creek system are situated on Mount Graham (elevation approximately 910m AHD) which is approximately 20km east of the Mine Site. The northern and eastern extents of the Lawsons Creek catchment are heavily vegetated and underlain by Permian sediments of the Sydney Basin. The southwestern extent of this catchment is also heavily vegetated but underlain by metasediments and volcanics associated with the Lachlan Orogen.

A review of aerial photography indicates that the bulk of the Lawsons Creek catchment has been altered (cleared) to support agricultural activities. The aerial photography also suggests that, historically, Lawsons Creek was likely to have been an intermittent to perennially discharging watercourse however, subsequent land use changes and the construction of water capture and storage structures to support agriculture have altered the hydrologic regime such that Lawsons Creek may now be described as an intermittent to ephemeral watercourse.

Lawsons Creek in the vicinity of the Mine Site and a subordinate watercourse Half Acre Creek, were inspected on 17 July 2017 at locations from the Bara-Lue Road crossing, approximately 3km west (downstream) of the Mine Site (Adopted Middle Thread Distance (AMTD) 37.8km) and the Pyangle Road crossing, approximately 2.5km south (downstream) of the Mine Site (AMTD 45.2km) which is 1.1km west of the Hawkins and Lawsons Creeks confluence. Property access limited the watercourse inspection at a number of locations along this reach of the watercourse.

1.6.2 Watercourse Inspection Summary

The watercourse inspection identified that Lawsons Creek has historically experienced a discharge regime which triggered channel mobility, as evidenced by the observed presence of reworked alluvial sediments in exposed banks. As a consequence, of this historic discharge environment, the section of Lawsons Creek in the vicinity of the Mine Site displays relatively high channel sinuosity. However, the frequency and magnitude of discharge events has diminished over time as a consequence of reduced runoff volumes due to the capture and storage of overland flow and subordinate watercourse discharge in farm dams.

The channel in the section inspected abuts the valley margin between approximately 10% and 50% of its length and contains a number of pool and riffle sequences with meander curves invariably controlled by rock outcrop. Subsequently, Lawsons Creek in the section inspected may be described as being a meandering, planform controlled discontinuous floodplain watercourse in a partly confined valley setting.

1.6.3 Catchment Inspection Results: Lawsons Creek

Location: Lawsons Creek 1	Date: 17 July 2017
Easting: 765696 Northing: 6385447	AMTD: 37.8km
Flow condition: Low flow	Time: 10:00am
	
Plate 1: Lawsons Creek: View downstream. Note flood debris on fence	
Plate 2: Lawsons Creek: View upstream. Note causeway (culverts out of view to right)	
Channel Geometry: • High flow: Approximately 25m wide; Left bank 5m high, 1:1.5; Right bank 2m high, 1:2 (V:H) • Low flow: Approximately 10m wide, Left bank 1m high, 1:1; Right bank 1m high, 1:1 (V:H)	
Planform Geometry: Straight reach, confined section of single channel displaying low to moderate sinuosity.	
Geomorphic Units • Channel: Low flow channel: Approximately 1.5m deep pool downstream of riffle. Stable with little evidence of recent mobility • Floodplain: Developed on right bank with evidence of past engagement; poorly developed on left bank due to confined flow.	
Bed Condition: Stable, minor evidence of bed aggradation. Algae present.	
Bank Condition: Minor erosion on vegetated (trees, grass) right bank, historic slumping on vegetated (grass) left bank.	
Sediment • Channel: Gravel / cobbles with interstitial coarse sand and silts. No imbrication evident. • Floodplain: Overbank deposits of silts and clays	
Comment: Hydraulic control (Bara-Lue Road crossing) upstream that appears to attenuate moderate to low flow conditions. Some evidence of cobbles and boulders in bank profile suggesting historic channel mobility that is no longer occurring.	

Location: Lawsons Creek 2	Date: 17 July 2017
Easting: 765796 Northing: 6385359	AMTD: 38.0km
Flow condition: Low flow, standing water	Time: 10:20am
	
Plate 3: Lawsons Creek: View downstream. Note causeway downstream Plate 4: Lawsons Creek: View upstream. Note pooling due to flow attenuation downstream	
Channel Geometry: • High flow: Approximately 20m wide; Left bank (extension of low flow) 4m high, 1:1.5 (V:H); Right bank 2m high, 1:1.5 (V:H) • Low flow: Approximately 10m wide, Left bank as above; Right bank 2m high, 1:1 (V:H)	
Planform Geometry: Straight reach, confined section of single channel displaying low to moderate sinuosity.	
Geomorphic Units • Channel: Low flow channel: Approximately 2m deep pool upstream of hydraulic control. • Floodplain: Developed on both banks with limited evidence of recent engagement.	
Bed Condition: Not visible at time of inspection	
Bank Condition: Minor slumping evident (vegetated blocks) on vegetated (trees, grass) right bank, historic undercutting on vegetated (grass) left bank.	
Sediment • Channel: Not visible at time of inspection • Floodplain: Overbank deposits of silts and clays	
Comment: High capacity low flow channel with hydraulic control (Bara-Lue Road crossing) downstream which appears to attenuate moderate to low flow conditions and artificially influence the water level. Head cut erosion adjacent to right bank due to animal activities (wombat burrows). No evidence of recent channel mobility observed.	

Location: Lawsons Creek 3	Date: 18 July 2017
Easting: 767095 Northing: 6383969	AMTD: 40.7km
Flow condition: Low flow	Time: 9:30am
	
Plate 5: Lawsons Creek: View downstream. Note flood debris in tree	Plate 6: Lawsons Creek: View upstream. Note bedrock controls influencing low flow channel
Channel Geometry: High flow: Approximately 20m wide; Left bank (extension of low flow) 2m high, 1:1.5 (V:H); Right bank 6m high, 1:2 (V:H) Low flow: Approximately 4m wide, Left bank as above; Right bank 1m high, 1:1 (V:H)	
Planform Geometry: Straight reach downstream of bedrock / topography-controlled curve.	
Geomorphic Units Channel: Low flow channel: Broad, 4m wide low flow channel deep pool (thalweg) at outer bank downstream of Half Acre Creek confluence. High flow channel displays minor floodplain development, vegetated depositional bar (cobbles and boulders) and minor channel development on inner bank. Floodplain: Developed on both banks with limited evidence of recent engagement.	
Bed Condition: Stable, algae observed in low flow channel bed, high flow channel well vegetated (grass and tress)	
Bank Condition: High flow channel left hand bank bare, evidence of historic slumping or stock impacts. Right bank well vegetated (grass) and stable.	
Sediment Channel: Low flow: silts and clay. High flow: sand, gravel, cobbles and boulders. Floodplain: Overbank deposits of silts and clays	
Comment: High capacity channel receiving Half Acre Creek discharge. Outer bank of meander curve (Lawsons Creek) displays evidence of historic mobility and terracing whilst inner bank (Lawsons Creek) also displays evidence of historic mobility as a result of Half Acre Creek discharge. No current evidence of recent channel mobility was apparent. Flood debris was observed in trees located in high flow channel but not at the level of the high flow channel bank.	

Location: Lawsons Creek 4	Date: 17 July 2017
Easting: 768002 Northing: 6382846	AMTD: 43.6km
Flow condition: Low flow, standing water	Time: 11:10am
	
Plate 7: Lawsons Creek: View downstream. Note flood debris in trees, low flow channel at outer bank	Plate 8: Lawsons Creek: View upstream. Note pooling at confluence with Half Acre Creek (out of view, lower right)
Channel Geometry: High flow: Approximately 50m wide; Left bank (extension of low flow) 5m high, 1:1 (V:H); Right bank 2m high, 1:2 (V:H) Low flow: Approximately 2m wide, Left bank as above; Right bank 2m high, 1:3 (V:H)	
Planform Geometry: Meander curve.	
Geomorphic Units Channel: Low flow channel: Approximately 2m deep pool (thalweg) at outer bank downstream of Half Acre Creek confluence. High flow channel displays minor floodplain development, vegetated depositional bar (cobbles and boulders) and minor channel development on inner bank. Floodplain: Developed on both banks with limited evidence of recent engagement.	
Bed Condition: Stable, algae observed in low flow channel bed, high flow channel well vegetated (grass and tress)	
Bank Condition: High flow channel left hand bank bare, evidence of historic slumping or stock impacts. Right bank well vegetated (grass) and stable.	
Sediment Channel: Low flow: silts and clay. High flow: sand, gravel, cobbles and boulders. Floodplain: Overbank deposits of silts and clays	
Comment: High capacity channel receiving Half Acre Creek discharge. Outer bank of meander curve (Lawsons Creek) displays evidence of historic mobility and terracing whilst inner bank (Lawsons Creek) also displays evidence of historic mobility as a result of Half Acre Creek discharge. No current evidence of recent channel mobility was apparent. Flood debris was observed in trees located in high flow channel but not at the level of the high flow channel bank (i.e. bankfull discharge not achieved).	

Location: Lawsons Creek 5	Date: 17 July 2017
Easting: 768637 Northing: 6383461	AMTD: 44.5km
Flow condition: Low flow, standing water	Time: 12:10pm
	
Plate 9: Lawsons Creek: View downstream. Note evidence of past lateral channel mobility now inactive and vegetated (right of frame).	Plate 10: Lawsons Creek: View upstream. Note stock paths and vertical banks.
Channel Geometry: High flow: Approximately 20m wide; Left bank 2m high, 1:4 (V:H); Right bank 4m high, 1:2 (V:H) Low flow: Approximately 2m wide, Left bank 0.5m high 1:3 (V:H); Right bank 0.5m high 1:3 (V:H).	
Planform Geometry: Curved reach (meander?) downstream of hydraulic control (road crossing).	
Geomorphic Units Channel: Low flow channel: Evidence of historic point bar deposition on inner bank of meander curve. Vegetated high flow channel displays minor floodplain development. Floodplain: Developed on both banks with limited evidence of recent engagement.	
Bed Condition: Stable and vegetated (grass, some woody shrubs)	
Bank Condition: Left and right bank well vegetated (grass) and stable, evidence of historic cut and slumping that appears in situ and vegetated.	
Sediment Channel: Silts and clay, minor boulders. Floodplain: Overbank deposits of silts and clays	
Comment: High capacity channel displaying capacity to convey discharge within banks. Evidence of historic lateral mobility apparent. Engagement of floodplain likely on inner bank, however no recent evidence of bankfull discharge apparent. Presence of grass in channel bed, floodplain and bank sections indicate lower magnitude and frequency of discharge in the system (bed aggradation).	

Location: Lawsons Creek 6	Date: 17 July 2017
Easting: 768886 Northing: 6383017	AMTD: 45.2km
Flow condition: Low flow, standing water	Time: 12:00pm
	
Plate 11: Lawsons Creek: View downstream. Note reed establishment in channel	Plate 12: Lawsons Creek: View upstream. Note water level below culvert invert
Channel Geometry: Single channel with pooling potentially concealed low flow channel, 20m wide, right bank 2m 1:3 (V:H), left bank 2m 1:2 (V:H).	
Planform Geometry: Straight reach downstream of hydraulic control (road crossing)	
Geomorphic Units Channel: Single channel: Pooling and significantly vegetated (reeds) both downstream and upstream of hydraulic control Floodplain: Developed on both banks with limited evidence of recent engagement.	
Bed Condition: Not observed however considered to be stable as a consequence of the hydraulic control and evidenced by the presence of reed beds.	
Bank Condition: Left and right bank well vegetated (grass) and stable, with the exception of a section on the left bank that has been treated with rock to prevent piping from road runoff.	
Sediment Channel: Not visible at time of inspection Floodplain: Overbank deposits of silts and clays with some gravel and coarse sand.	
Comment: High capacity channel with hydraulic control (Pyangle Road crossing) downstream which appears to attenuate flow conditions, artificially influence the water levels present and potentially lead to bed aggradation.	

1.7 HAWKINS CREEK

1.7.1 Catchment Description

Catchment area: 61km²

Stream order: 4th

AMTD: 17.1km

Elevation: **Headwaters** 910m AHD; **Outlet** 560m AHD

Average grade: 2%

Land-use: Cleared agricultural land (pastoral) on lowlands with forested (native vegetation) on uplands.

Hawkins Creek is an unregulated watercourse that drains the sub-regional catchment in which the Mine Site is situated. The headwaters of the Hawkins Creek system are located in the Upper Growee area at an elevation of approximately 920m AHD, approximately 11km east of the Mine Site. Similar to the Lawsons Creek catchment, the northern and eastern extents of the Hawkins Creek catchment are heavily vegetated and underlain by Permian sediments of the Sydney Basin, however, the southern extents of the catchment display less relief and are generally cleared pasture.

A review of aerial photography indicates that the approximately half of the Hawkins Creek catchment has been altered (cleared) to support agricultural activities. The aerial photography also indicates that Hawkins Creek historically displayed some channel mobility however this mobility is no longer apparent. However, similar to Lawsons Creek, land use change and the construction of water capture and storage structures to support agriculture have altered the hydrologic regime such that Hawkins Creek.

Hawkins Creek was inspected on 17 and 18 July 2017 at locations commencing adjacent to Battens (Powells) Road, approximately 0.8km south of the Mine Site (AMTD 1.1km) and traversing upstream, approximately 2.5km east (upstream) of the Mine Site (AMTD 4.1km). Property access limited the watercourse inspection along the full extent of the watercourse.

1.7.2 Watercourse Inspection Summary

Similar to Lawsons Creek, the watercourse inspection identified that Hawkins Creek would have historically experienced higher discharge regime which has diminished over time as a consequence of reduced runoff volumes due to the capture and storage of overland flow and subordinate watercourse discharge in farm dams.

The channel displays evidence of bed aggradation and the subsequent establishment of reedy vegetation has led to a discontinuous low flow channel within an historic high flow channel. This would imply that historically, with a continuous channel, Hawkins Creek could have been characterised as a low/moderate sinuosity, sand bed watercourse in an alluvial valley setting however, subsequent bed aggradation has led to channel discontinuity suggesting that Hawkins Creek is transitioning into an intact valley fill chain of ponds watercourse.

1.7.3 Catchment Inspection Results

Location: Hawkins Creek 1	Date: 17 July 2017
Easting: 769822 Northing: 6384347	AMTD: 1.3km
Flow condition: Low flow, standing water	Time: 12:35pm
	
Plate 13: Hawkins Creek: View downstream. Note vegetation obscuring channel and bedrock on right bank.	Plate 14: Hawkins Creek: View upstream. Note pool with no apparent low flow channel acting as an outlet.
Channel Geometry: Discontinuous, poorly defined low and high flow channels. 8m wide, Left bank 2m 1:3 (V:H), Right bank 2m 1:2 (V:H).	
Planform Geometry: Straight reach with some minor meanders	
Geomorphic Units Channel: Single, flat broad channel: Discontinuous with pooling and significantly vegetated (reeds) Floodplain: In the absence of a high flow channel, assumed to be extensively developed as valley fill and overbank deposits.	
Bed Condition: Not observed however considered to be stable as a consequence of the vegetation and pooling.	
Bank Condition: Left and right bank well vegetated (reeds and grass) and stable. Some bedrock controls	
Sediment Channel: Fine, organic rich (observed in section separating pools) Floodplain: Overbank deposits consisted of fine material.	
Comment: Poorly developed low and high flow channel with no recent evidence that discharge exceeded channel capacity although this is assumed to have historically occurred during frequent rainfall events. Discontinuous low flow channel likely due to a reduction in the frequency and magnitude of peak discharge events.	

Location: Hawkins Creek 2	Date: 17 July 2017
Easting: Northing	AMTD:
Flow condition: Low flow, standing water	Time: 1:00pm
	
Plate 15: Hawkins Creek: View north. Note standing water in low capacity, low flow channel and absence of high flow bank.	Plate 16: Hawkins Creek: View upstream. Note pool with rock control on right bank.
Channel Geometry: Discontinuous single low flow channel with pool and no evidence of high flow channel. 2m wide, Left bank 0.5m 1:1 (V:H), Right bank 0.5m 1:1 (V:H).	
Planform Geometry: Straight reach with pools and meanders (likely rock controlled)	
Geomorphic Units • Pool: 25m length, 8m wide, Left bank 1m 1:3, Right bank 1m 1:1 (V:H) • Channel: Single, flat, broad, discontinuous low flow channel with vegetated bed and banks. Channel is low capacity and readily engages with floodplain. • Floodplain: In the absence of a high flow channel, assumed to be extensively developed as valley fill and overbank deposits.	
Bed Condition: Stable, vegetated (grass).	
Bank Condition: • Pool: Stable, vegetated. Left bank (long grass), Right bank (grass) with some rock control. • Channel: Stable, vegetated (grass).	
Sediment • Channel: Fine, silts and sands. • Floodplain: Fine, silts and sands.	
Comment: Discontinuous low capacity low flow channel interspersed by pools. Active engagement with floodplain apparent, whilst no terracing evident, apparent valley fill nature of floodplain suggests historic lateral mobility of channel and reworking of sediments.	

Location: Hawkins Creek 3	Date: 18 July 2017
Easting: 769730 Northing: 6384265	AMTD: 1.1km
Flow condition: No flow	Time: 11:25am
	
Plate 17: Hawkins Creek: View downstream. Note bank undercutting, bare banks and sand.	Plate 18: Hawkins Creek: View upstream. Note heavily vegetated low flow channel (reeds) and vegetated high flow channel (grass).
Channel Geometry: Continuous low flow channel (assumed by reeds) 3 wide, unable to discern banks due to vegetation. High flow channel. 12m wide, Left bank 2m 3:1 (V:H), Right bank 2m 1:1 (V:H).	
Planform Geometry: Meander curve	
Geomorphic Units • Scour Pool: Adjacent to outer bank of high flow channel (downstream) in thalweg • Channel: Single, flat, broad, likely continuous low flow channel with heavily vegetated bed and banks (reeds). Channel is low capacity and readily achieves bankfull discharge as evidenced by active erosion in of high flow banks. High flow channel is high capacity with limited engagement of floodplain. • Floodplain: Not laterally extensive due to terrain (limited to valley fill). Evidence of cut-off channel and point bar development on inner bank of meander curve.	
Bed Condition: Stable, vegetated (grass and reeds).	
Bank Condition: Stable, vegetated (grass). Undercutting and slumping observed on outer bank (right) of high flow channel suggesting lateral mobility. Historic piping of left bank observed at point where cut-off re-enters channel.	
Sediment • Channel: Fine, silts with sand and gravel observed in high flow channel bed. • Floodplain: Fine, silts, sands and gravel (observed in bank profile).	
Comment: Location where discharge from Blackmans Gully enters Hawkins Creek via overland flow after redirection by contour bank. Some gully erosion apparent in Blackmans Gully flow path. Sediment in this location distinctly coarser and dominated by sand with minor gravel.	

Location: Hawkins Creek 4	Date: 18 July 2017
Easting: 770204 Northing: 6384925	AMTD: 2.2km
Flow condition: Low flow	Time: 11:45am
	
Plate 19: Hawkins Creek: View downstream. Note standing water, rock on banks. Discharge from Price Creek enters Hawkins Creek in centre of frame	Plate 20: Hawkins Creek: View upstream. Note historically eroded, vegetated high flow bank with evidence of gully erosion (far left).
Channel Geometry: Continuous low flow channel between pools of varying geometry up to 2m wide, Left bank 3m 1:2, Right bank 1m 1:1 (V:H). High flow channel. 12m wide, Left bank 2m 3:1 (V:H), Right bank 2m 1:1 (V:H).	
Planform Geometry: Meanders connected by straight reaches (some rock controls), intersected by pools	
Geomorphic Units • Channel: Single, flat, broad, discontinuous low flow channel between pools. Channel is low capacity and readily achieves bankfull discharge as evidenced by active erosion in the high flow banks. High flow channel is high capacity with limited engagement of floodplain. • Floodplain: Not laterally extensive due to terrain (limited to valley fill). Evidence of cut-off channel and point bar development on inner bank of meander curve.	
Bed Condition: Stable, vegetated (grass and reeds).	
Bank Condition: Stable, vegetated (grass). Undercutting and slumping observed on outer bank (right) of high flow channel suggesting lateral mobility. Historic piping of right bank observed at point where Price Creek discharge enters channel.	
Sediment • Channel: Fine, silts with sand and gravel observed in high flow channel bed. • Floodplain: Fine, silts, sands and gravel (observed in bank profile).	
Comment: Location where discharge from Price Creek enters Hawkins Creek via overland flow after redirection by contour banks. Some gully erosion apparent in the Price Creek flow path. Sediment in this location distinctly coarser and dominated by sand with minor gravel.	

Location: Hawkins Creek 5	Date: 17 July 2017
Easting: 771430 Northing: 6385932	AMTD: 4.1km
Flow condition: Low flow, standing water	Time: 1:15pm
	
Plate 21: Hawkins Creek: View downstream. Note standing water in pool, steep outer bank with animal disturbance and coarse material in profile.	Plate 22: Hawkins Creek: View upstream. Note pool and low flow channel, steep sided banks and evidence of bed and bank degradation from stock access.
Channel Geometry: Continuous low flow channel, 0.5m wide, 0.2m 1:1 (V:H) banks and high flow channel. 3m wide, Left bank 1.5m 1:1 (V:H), Right bank 1.5m 1:1 (V:H).	
Planform Geometry: Straight reach with small pool upstream and large scour pool downstream. Evidence of lateral mobility (undercutting) and scour in both bed and banks.	
Geomorphic Units • Pools: – Upstream: 3m length, 3m wide, Left bank 1.5m 1:1, Right bank 1.5m 1:1 (V:H) – Downstream: 6m length, 5m wide, Left bank 2m 1:1, Right bank 1.5m 1:1 (V:H) • Channel: – Low flow: Continuous, low capacity channel. – High flow: Steep sided, moderate capacity channel. Bare banks. • Floodplain: In the absence of a high flow channel, assumed to be extensively developed as valley fill and overbank deposits. Poorer vegetation condition lower than previous sites inspected.	
Bed Condition: Unstable, poorly vegetated (short grass and reeds), degraded by stock access with evidence of channel incision and mobility (scour).	
Bank Condition: • Pools: Unstable, poorly vegetated (grass) (right bank, downstream pool only). Bare banks with evidence of undercutting, slumping and animal burrows (downstream pool). • Channel: Unstable, poorly vegetated (grass), degraded by stock access.	
Sediment • Channel: Fine, silts. • Floodplain: Fine, silts, sands and gravel (observed in bank profile).	
Comment: Location is more degraded than previous sites due to stock access and scour. Scour at this location likely due to grade as bed elevation drops approximately 1.5m from 30m upstream to channel invert at pool inlet. Further degradation attributed to animal disturbance and lack of vegetation cover. Inspection of exposed profile in banks indicates valley fill being reworked.	

1.8 BLACKMANS GULLY

1.8.1 Catchment Description

Catchment area: 2.3km²

Stream order: 4th (mapping), 1st (inspection)

AMTD: 3.5km

Elevation: Headwaters 750m AHD; Outlet 565m AHD

Average grade: 5.3%

Land-use: Minor areas of cleared agricultural land (pastoral) on lowlands with forested (native vegetation) on uplands and slopes.

Blackmans Gully is an unregulated watercourse that drains a catchment in the central section of the Mine Site. The headwaters of the Blackmans Gully system are located at an elevation of approximately 750m AHD, approximately 2.1km north of the proposed open cut pit. The northern, eastern and western extents of the catchment are heavily vegetated and underlain by Triassic and Permian sediments whilst the southern section of the catchment is underlain by Permian volcanics. As a consequence of activities to facilitate agricultural activity, the Blackmans Gully catchment discharges via overland flow that is redirected via a contour bank. This discharge enters Hawkins Creek in the vicinity of Hawkins Creek Location 3 (Section 1.1.6)

The watercourse inspection was conducted on 18 July 2017 along the entire reach of the watercourse.

1.8.2 Watercourse Inspection Summary

In summation, Blackmans Gully transitions from a topographically controlled, low capacity preferential flow path (Blackmans Gully Location 1) to a 1st order watercourse with a moderate capacity channel as the contributing catchment increases and where historic modifications to facilitate drainage along Maloneys Road has occurred (Blackmans Gully Location 2). Downstream of Blackmans Gully Location 2, this stream order is maintained, however the continued increase in contributing catchment has led to a coincident increase in channel capacity.

Subsequently, Blackmans Gully is characterised as a 1st order watercourse in a confined valley setting with occasional floodplain pockets, principally in the lower reaches.

1.8.3 Catchment Inspection Results: Blackmans Gully

Location: Blackmans Gully 1	Date: 18 July 2017
Easting: 768767 Northing: 6387234	AMTD: 3.3km
Flow condition: No flow	Time: 10:05am
	
Plate 23: Blackmans Gully: View across minor capacity channel at this location. Note vegetation cover and absence of geomorphic units.	
Channel Geometry: Relatively indistinct, minor low capacity channel. Consistent geometry approximately 0.2m wide, Left bank 0.5m 1:4 (V:H), Right bank 0.5m 1:4 (V:H).	
Planform Geometry: Straight. Topographically controlled	
Geomorphic Units • Channel: Single, incised low capacity channel. • Floodplain: None developed.	
Bed Condition: Stable, vegetated (grass).	
Bank Condition: Stable, vegetated (grass).	
Sediment • Channel: Fine, silts with cobbles observed in channel bed. • Floodplain: None developed however fine, silts and sands on adjacent slope.	
Comment: Location is a minor drainage feature in the headwaters of Blackmans Gully catchment. The watercourse in this location does not display evidence of the development of geomorphic units such as a low flow and high flow channel. The watercourse in this location appears to be a preferential flow path from the local topography concentrating and directing runoff.	

Location: Blackmans Gully 2	Date: 18 July 2017
Easting: 768697 Northing: 6386302	AMTD: 2.3km
Flow condition: No flow	Time: 10:20am
	
Plate 24: Blackmans Gully: View looking upstream. Note farm dam embankment right of frame.	Plate 25: Blackmans Gully: View across top of right bank to top of left bank. Note Maloneys Road adjacent to top of left bank and placement of material in right (centre) of frame.
Channel Geometry: Continuous low flow channel. Vertical banks approximately 1m high, flat channel bed approximately 1m wide.	
Planform Geometry: Straight, follows Maloneys Road alignment.	
Geomorphic Units • Channel: Single, flat, broad, low flow channel. Channel is of moderate capacity and has likely been altered to facilitate drainage of Maloneys Road. • Floodplain: Not laterally extensive due to topography and Maloneys Road.	
Bed Condition: Stable, vegetated.	
Bank Condition: Stable, vegetated (grass). Historic placement of material from grading of Maloneys Road apparent.	
Sediment • Channel: Sand, gravel and minor cobbles observed in channel. • Floodplain: Sand, gravel and minor cobbles.	
Comment: Location where, similar to the Blackmans Gully Location 1, the watercourse has not developed geomorphic features due to a limited contributing catchment. Two farm dams have been constructed east and west of the watercourse and each of these hydraulic controls intercepts runoff from two sub-catchments, thus reducing discharge volumes in the watercourse at this location. In addition, it is likely that excavation and watercourse re-alignment has historically been undertaken to facilitate road drainage in this location.	

Location: Blackmans Gully 3	Date: 18 July 2017
Easting: 768913 Northing: 6385346	AMTD: 1.3km
Flow condition: No flow in channel, minor pooling	Time: 10:30am
	
Plate 26: Blackmans Gully: View looking upstream. Note bed cut / drop and pool formed at base. Stock / wildlife track at lower right of frame.	Plate 27: Blackmans Gully: View downstream. Note vegetated low capacity, low flow channel and absence of high flow channel.
Channel Geometry: Continuous flat bed, low flow channel. Vertical banks approximately 0.8m high, flat channel bed approximately 1.5m wide.	
Planform Geometry: Straight.	
Geomorphic Units Channel: Single, flat, broad, low flow channel. Floodplain: Not laterally extensive due to topography.	
Bed Condition: Stable, vegetated (sedge grass).	
Bank Condition: Stable, vegetated (reeds) at top of bank but bare vertical banks. Evidence of stock / wildlife crossing leading to minor degradation of bank.	
Sediment Channel: Fine silt, clay, sand, gravel and minor cobbles observed in channel. Floodplain: Fine silt, clay, sand, gravel and minor cobbles.	
Comment: Location where the watercourse has not developed geomorphic features due to topographic controls. Notable change in type of vegetation and minor pooling of standing water suggests potential minor, periodic, groundwater discharge occurs at this location.	

Location: Blackmans Gully 4	Date: 18 July 2017
Easting: 769262 Northing: 6384699	AMTD: 0.5km*
Flow condition: No flow.	Time: 11:00am
	
Plate 28: Blackmans Gully: View looking upstream. Note steep left hand (outer) bank and vegetated right hand (inner) bank.	Plate 29: Blackmans Gully: View downstream. Note angular, sub-rounded cobbles in bed and bank.
Channel Geometry: High capacity, continuous flat bed channel of varying width (1m – 2m). • Low Flow Channel: Low flow channel: vertical Right (outer) bank Approx.' 1.5m high, vertical Left (inner) bank Approx.' 0.5m high. • High Flow Channel: Channel development evident with vertical Right (outer) bank (as for low flow channel), 1.5m, 1:3 (V:H) Left (inner) bank, width (top of banks) Approx.' 6m	
Planform Geometry: Curve.	
Geomorphic Units • Channel: Mobile, single, flat, broad, channel. • Floodplain: Extensive from top of right hand (outer) bank however no evidence of recent engagement.	
Bed Condition: Incised, bare low flow, vegetated (grass) high flow.	
Bank Condition: Unstable, bare Right (outer) bank with active erosion evidence of channel mobility. Stable Left (inner) bank (grass, reeds and small trees).	
Sediment • Channel: Fine silt, clay, sand, gravel, cobbles and boulders observed in channel. • Floodplain: Fine silt, clay, sand, gravel and minor cobbles.	
Comment: High capacity channel displaying evidence of historic mobility and lateral movement in right hand (outer) bank profile.	
* AMTD from clearly defined channel, pastoral modifications overprint relict channel geometry.	

1.9 PRICE CREEK

1.9.1 Catchment Description

Catchment area: 5.2km²

Stream order: 4th (mapping), 2nd (inspection)

AMTD: 5.8km (including eastern headwater); western headwater 0.99km

Elevation: **Headwaters** 840m Australian Height Datum (AHD) (eastern headwater);
Outlet 570m AHD

Average grade: 7.7%

Land-use: Minor areas of cleared agricultural land (pastoral) in the lower valley fill sections with forested (native vegetation) on uplands and slopes.

Price Creek is an unregulated watercourse that drains a catchment in the eastern section of the Mine Site. The twin headwaters (eastern and western) of the Price Creek system are respectively situated at elevations of approximately 840m AHD and 740m AHD, approximately 4.8km (eastern headwater) northeast of the proposed open cut pit. The extents of the catchment are heavily vegetated and underlain by Triassic and Permian sediments whilst the cleared southern section of the catchment is underlain by Permian volcanics. The confluence of the eastern and western headwaters is located in the main Price Creek valley at 2.8km AMTD. Similar to Blackmans Gully, the Price Creek catchment discharges via overland flow after interception and redirection by a series of contour banks. Discharge from Price Creek enters Hawkins Creek in the vicinity of Hawkins Creek Location 4.

The watercourse inspection was conducted on 18 July 2017 along the entire reach of the western headwater, a section of the eastern headwater and the entire section of the main Price Creek watercourse.

1.9.2 Watercourse Inspection Summary

The watercourse inspection identified that the eastern and western headwaters are topographically controlled, incised flow paths that merge to form a moderate capacity channel as the contributing catchment increases. Substantial historic modifications such as earthworks, contour banks and shallow drains in the downstream reach of the watercourse to facilitate agricultural activity have effectively removed the watercourse in this area with the former channel overprinted by pasture and only visible from aerial imagery.

Subsequently, Price Creek is characterised as a watercourse in a confined valley setting with occasional floodplain pockets.

1.9.3 Catchment Inspection Results

Location: Price Creek 1 (western headwater)	Date: 18 July 2017
Easting: 769284 Northing: 6388144	AMTD: 0.8km*
Flow condition: No flow	Time: 12:15pm
	
Plate 30: Price Creek: View downstream. Note steep terrain, vegetation cover, colluvial boulders and felled trees as a result of powerline easement management.	
Channel Geometry: Flat bottomed, continuous, low capacity channel. 0.5m, 1: 1 (V:H) banks and 1m wide channel.	
Planform Geometry: Straight. Topographically controlled	
Geomorphic Units • Channel: Single, incised low capacity channel. • Floodplain: None developed.	
Bed Condition: Stable, vegetated (bracken, grass).	
Bank Condition: Stable, vegetated (bracken, grass).	
Sediment • Channel: Coarse sand and gravel. • Floodplain: Coarse sand and gravel.	
Comment: Location is a minor, incised drainage feature in the western headwaters of Price Creek catchment which does not display evidence of the development of geomorphic units such as a low flow and high flow channel. The watercourse in this location is a topographically controlled preferential flow path at the base of a sandstone scarp.	
* AMTD measured from confluence with eastern headwater	

Location: Price Creek 2 (eastern headwater)	Date: 18 July 2017
Easting: 770088 Northing: 6387900	AMTD: 0.8km*
Flow condition: No flow	Time: 12:40pm
	
Plate 31: Price Creek: View upstream. Note vegetated, steeply sloping banks and broad, shallow, low capacity channel devoid of vegetation.	
Channel Geometry: Shallow, flat bottomed and continuous 1m wide low capacity channel with 10m, 1:2 (V:H) banks.	
Planform Geometry: Straight, topographically controlled (minor outcrop controls).	
Geomorphic Units • Channel: Single, incised low capacity channel. • Floodplain: Minor development in downstream sections.	
Bed Condition: Unvegetated however appears stable with no evidence of active erosion.	
Bank Condition: Stable, vegetated (trees, woody shrubs and grass).	
Sediment • Channel: Silts, clays, coarse sand, gravel and boulders. • Floodplain: Where developed, fine silts and clays.	
Comment: Incised drainage feature in this location is a second order watercourse in the eastern headwaters of Price Creek catchment. The watercourse in this location is topographically controlled with minor floodplain development evident, particularly in the downstream sections.	
* AMTD measured from confluence with western headwater	

Location: Price Creek 3	Date: 18 July 2017
Easting: 769487 Northing: 6387313	AMTD: 2.7km
Flow condition: No flow.	Time: 12:55pm
	
Plate 32: Price Creek: View looking to left hand bank. Note bare bank and outcrop (rock) control.	Plate 33: Price Creek: View upstream from right hand bank (channel at right). Note grassed floodplain with animal burrow.
Channel Geometry: Broad, continuous, single channel with 2m high, 1:2 (V:H) banks and 1m wide low flow channel at base (0.1m banks with 1:1 (V:H) slope).	
Planform Geometry: Straight. Topographically controlled with minor outcrop control.	
Geomorphic Units • Channel: Incised, single, flat, broad, channel with minor low flow channel. • Floodplain: Well developed and extensive, no evidence of recent engagement.	
Bed Condition: Stable, bare low flow, vegetated (grass and blackberry) high flow.	
Bank Condition: Stable, some sections inspected were relatively bare, with the exception of minor grass and small trees (see Plate 32). Blackberry vines were also prevalent in sections (see Plate 33).	
Sediment • Channel: Fine silt and clay. • Floodplain: Fine silt and clay with sand, gravel evident in bank profile.	
Comment: High capacity channel receiving discharge from eastern and western headwaters of the catchment. Evidence of relict channel identified upstream however abandonment of this watercourse more attributable to construction of farm dam upstream than evidence of historic mobility. Well-developed floodplain at this location is a consequence of partially confined flow leading to valley filling.	

Location: Price Creek 4	Date: 18 July 2017
Easting: 769560 Northing: 6386729	AMTD: 2.0km
Flow condition: No flow.	Time: 1:20pm
	
Plate 34: Price Creek: View looking upstream. Note bare right hand bank with outcrop (rock) control, vegetated left hand bank (blackberry vines).	Plate 35: Price Creek: View towards left hand bank. Note bare bank with erosion.
Channel Geometry: Broad, continuous, single channel with 2m high, 1:2 (V:H) banks and 1m wide low flow channel at base (0.1m banks with 1:1 (V:H) slope).	
Planform Geometry: Straight. Topographically controlled with minor outcrop control.	
Geomorphic Units Channel: Incised, single, flat, broad, channel with minor low flow channel. Floodplain: Developed and apparent, no evidence of recent engagement.	
Bed Condition: Stable, bare low flow, vegetated (grass and blackberry) high flow.	
Bank Condition: Sections of the bank inspected were relatively bare, with the exception of minor grass and small trees and unstable showing evidence of erosion and animal tracks (see Plate 35). Blackberry vines were also prevalent in sections (see Plate 34).	
Sediment Channel: Fine silt and clay. Floodplain: Fine silt and clay with sand, gravel evident in bank profile.	
Comment: Incised channel abutting western slope of narrow valley in this section of Price Creek. Valley fill material likely to be a mix of alluvial and colluvial material, as evidenced by large, angular boulders observed in the banks (see Plate 34 , lower left of frame).	

Location: Price Creek 5	Date: 18 July 2017
Easting: 769680 Northing: 6386415	AMTD: 1.7km
Flow condition: No flow.	Time: 1:35pm
	
Plate 36: Price Creek: View looking upstream. Note well vegetated, stable banks and bed with stock track.	Plate 37: Price Creek: Catchment view downstream (watercourse at left) towards Hawkins Creek. Note change in slope with valley becoming less confined.
Channel Geometry: Flat bottomed, continuous, single channel (0.5m wide) with 1.5m high, 1:1.5 (V:H) banks.	
Planform Geometry: Straight, meanders apparent downstream.	
Geomorphic Units • Channel: Incised, single, flat bottomed channel of lower capacity than observed at upstream locations (Price Creek 3 and 4). • Floodplain: Developed and apparent, no evidence of recent engagement however likely to occur regularly due to lower capacity channel.	
Bed Condition: Stable, mostly vegetated (grass) though observed to be bare in some sections (exposed gravel).	
Bank Condition: Stable, vegetated (grass) with established trees at top of bank.	
Sediment • Channel: Fine silt, clay, sand and gravel. • Floodplain: Fine silt and clay.	
Comment: Stable channel with lower capacity, likely due to decrease in topographic grade and engagement with the floodplain. No evidence of erosion or channel mobility observed.	

Location: Price Creek 6	Date: 18 July 2017
Easting: 770057 Northing: 6385707	AMTD: 0.9km*
Flow condition: No flow.	Time: 1:55pm
	
Plate 38: Price Creek: View looking upstream. Note consistent bank slope suggesting historic mechanical re-alignment to facilitate and direct drainage downstream of contour banks.	Plate 39: Price Creek: Catchment view upstream (watercourse at left) towards contour banks. Note cleared paddock and low slope.
Channel Geometry: Single channel "V" drain, (0.5m wide) with 1m high, 1:2 (V:H) banks.	
Planform Geometry: Straight, engineered drainage feature.	
Geomorphic Units • Channel: Incised, low capacity "V" drain. • Floodplain: Developed and apparent.	
Bed Condition: Stable, vegetated (grass).	
Bank Condition: Stable, vegetated (grass).	
Sediment • Channel: Fine silt, clay and sand. • Floodplain: Fine silt and clay.	
Comment: Natural Price Creek watercourse not apparent in this location due to historic clearing and earthworks to facilitate agricultural production. A series of four contour banks have been formed 35 approx.' 600m upstream from this location and these have significantly disrupted natural discharge from this catchment. The watercourse at this location is an engineered drainage feature which gradually merges with the surrounding pasture to discharge via overland flow.	
* AMTD measured from assumed point of discharge in Hawkins Creek, pastoral activities have overprinted relict watercourse features.	

1.10 WALKERS CREEK

1.10.1 Catchment Description

Catchment area: 4.9km²

Stream order: 3rd (mapping), 2nd (inspection)

AMTD: 2.1km (headwater confluence); northern headwater 1.7km; southern headwater 1.3km.

Elevation: **Headwaters** 750m AHD (northern headwater); **Outlet** 525m AHD

Average grade: 6.5%

Land-use: Predominantly cleared agricultural land (pastoral) with minor forested (native vegetation) on uplands and slopes.

Walkers Creek is an unregulated watercourse that drains a catchment in the western section of the Mine Site in which the proposed Tailings Storage Facility would be situated. Based on the results of the physical inspection the stream order for Walkers Creek (refer Section 1.4), the northern headwater is classified as a 2nd order watercourse, whilst the southern headwater is classified as a 1st order watercourse and subsequently within the Mine Site boundary, Walkers Creek is considered a 2nd order watercourse. The upper reaches of the catchment are generally vegetated and underlain by Permian sediments which are notably scarped whilst the cleared central section of the catchment is, intruded by Permian volcanics. The confluence of the southern and northern headwaters is located at 2.1km AMTD.

The watercourse inspection was conducted on 20 July 2017 along the entire reach of the southern and a section of the northern headwaters, west of Maloneys Road was traversed.

1.10.2 Watercourse Inspection Summary

The watercourse inspection identified that the southern and northern headwaters of Walkers Creek are topographically controlled watercourses which collect runoff from erosional drainage features (i.e. nick points, rock falls and ephemeral, preferential flow paths) formed on the scarped Permian sediments. These northern and southern headwaters only develop typical watercourse features as they traverse the toe of the colluvial fans which have formed at the base of the scarps. These headwaters subsequently merge to form a 2nd order watercourse with a moderate to high capacity incised channel. Historic modifications such as contour banks or shallow drains are notably absent in this catchment with the exceptions being a farm dam situated across the northern headwater approximately 300m north of its confluence with the southern headwater, a 1500mm Reinforced Concrete Pipe (RCP) culvert and another farm dam across a 1st order watercourse below the confluence. This relative absence of hydraulic controls allows for unrestricted catchment discharge which, coupled with land clearing, has led to increased flow velocities and erosion of the valley fill. Whilst the channel of the 2nd order Walkers Creek displays a low sinuosity in the main section of the watercourse, which is likely attributable to an increased bed grade, lateral channel mobility in this section was observed and this was attributed to increased sediment loads from the colluvial uplands.

Subsequently, the southern headwater of the Walkers Creek system is characterised as being a 1st order watercourse in a confined valley setting with occasional floodplain pockets. Whilst the 2nd order northern headwater transitions from a confined valley setting to a partially confined, low sinuosity, planform-controlled system. Below the confluence of the headwaters, the 2nd order Walkers Creek system transitions again into a low sinuosity, gravel bed watercourse in an alluvial valley setting.

1.10.3 Catchment Inspection Results: Walkers Creek

Location: Walkers Creek (southern headwater)	Date: 19 July 2017
Flow condition: No flow.	Time: 10:45am
	
Plate 40: Walkers Creek: View looking upstream at head of 1st order watercourse. Note topographic control and exposed rock.	Plate 41: Walkers Creek: View looking upstream, mid-chainage of (now) 2nd order watercourse. Note channel is essentially a low capacity, preferential flow path at this location.
Channel Geometry: Single continuous channel, 0.2m – 0.8m wide bed.0.1m – 0.5m 1:2 (V:H) to 1:1 (V:H) banks.	
Planform Geometry: Straight, topographically controlled with some outcrop (rock) controls.	
Geomorphic Units • Channel: Incised, low capacity channel, no high flow channel developed.	
Bed Condition: Stable, vegetated (grass).	
Bank Condition: Stable, vegetated (grass).	
Sediment: Fine silt, clay, sand, gravel, cobbles and boulders.	
	Comment: Watercourse progressively increases channel capacity in response to increased discharge volume as a consequence of an increase in the contributing catchment. The watercourse in this location is predominantly topographically controlled although some sections are outcrop controlled. Valley fill likely alluvial and colluvial material.
Plate 42: Walkers Creek: View looking upstream mid-chainage. Note increased channel capacity and incised bed.	

Location: Walkers Creek (northern headwater)	Date: 19 July 2017
Flow condition: No flow.	Time: 10:45am
	
Plate 43: Walkers Creek: View looking downstream, northern headwater. Note Nick point at head of 1 st order watercourse.	Plate 44: Walkers Creek: View looking upstream, mid-chainage. Note steep sided banks and bare bed.
Channel Geometry: Single continuous channel, 0.2m – 0.8m wide bed. 0.1m – 0.5m 1V:2H to 1:1 (V:H) banks.	
Planform Geometry: Straight, topographically controlled with some outcrop (rock) controls.	
Geomorphic Units	
• Channel: Incised, low capacity channel, no high flow channel developed.	
Bed Condition: Stable, vegetated (grass) in most sections however some bare sections noted.	
Bank Condition: Stable, vegetated (grass).	
Sediment: Fine silt, clay, sand, gravel, cobbles and boulders.	
	
Plate 45: Walkers Creek: View looking upstream mid-chainage Note shallow low flow channel and evidence of erosion.	Plate 46: Walkers Creek: View looking downstream towards confluence with southern headwater. Note lack of channel definition.
Comment: Similar to the southern headwater, this watercourse also progressively increases channel capacity in response to increased discharge volume however, due to the construction of a farm dam at the catchment outlet, the channel loses definition (see Plate 48) as a result of reduced discharge. Vegetation changes were noted downstream of the farm dam suggesting possible discharge of shallow groundwater however no flow or pooling was observed.	

Location: Walkers Creek 1	Date: 19 July 2017
Easting: 766488 Northing: 6386465	AMTD: 2.0km
Flow condition: No flow.	Time: 10:05am
	
Plate 47: Walkers Creek: View looking upstream towards confluence of northern and southern headwaters. Note vertical banks (top centre) and cobbles and boulders in bed (centre).	Plate 48: Walkers Creek: View downstream. Note change in vegetation, absence of defined channel.
Channel Geometry: Low Flow Channel: Discontinuous 1.5m wide shallow channel with 0.5m high, 1:1 (V:H) banks. High Flow Channel: Discontinuous, broad 10m wide channel with 0.5m high, 1:1 (V:H) banks.	
Planform Geometry: Straight, topographically controlled with some outcrop (rock) controls	
Geomorphic Units Channel: Incised, minor development of high flow channel. Riffle: Approximately 10m long, 1.5m wide. Bed material size suggests high velocity flow. Floodplain: Developed and apparent.	
Bed Condition: Stable, some vegetation, no active erosion apparent.	
Bank Condition: Predominantly bare, some minor slumping and blocking observed however not recent.	
Sediment Channel: Sand, gravel, cobbles and boulders. Floodplain: Fine silt, clay, sand and gravel.	
Comment: Combined discharge of both northern and southern 2 nd order watercourses and apparent high velocity flow (from bed material) in riffle has led to the formation of a number of geomorphic features at this location. The features lose definition downstream. Whilst vegetation changes are apparent downstream and pooling of standing water was observed, it is unclear as to whether this is attributable to shallow groundwater discharge or hyporheic flow through the unconsolidated alluvial material deposited as valley fill.	

Location: Walkers Creek 2	Date: 19 July 2017
Easting: 766239 Northing: 6386543	AMTD: 1.7km
Flow condition: No flow.	Time: 9:50am
	
Plate 49: Walkers Creek: View looking upstream. Note bare low flow channel with cobbles and boulders in bed.	Plate 50: Walkers Creek: Standing pool upstream of inspection location.
Channel Geometry: Low Flow Channel: Continuous 1m wide shallow channel with 0.4m high, 1:2 (V:H) banks. High Flow Channel: Continuous, broad 7m wide channel with 1.5m high, 1:2 (V:H) banks.	
Planform Geometry: Curved, outcrop (rock) controlled.	
Geomorphic Units Channel: Incised, well developed high flow channel. Floodplain: Developed and apparent.	
Bed Condition: Stable, some vegetation in low flow which is armoured by angular, sub-angular cobbles and boulders although no imbrication apparent. High flow channel is well vegetated (grass), no active erosion apparent.	
Bank Condition: Vegetated (grass), some minor slumping and blocking observed however not recent.	
Sediment Channel: Sand, gravel, cobbles and boulders. Floodplain: Fine silt and clay (overbank deposits).	
Comment: Presence of angular / sub-angular cobbles and boulders in bed suggests relatively high flow velocity although no active erosion was observed, suggesting limited channel migration and hence outcrop (rock) controls	

Location: Walkers Creek 3	Date: 19 July 2017
Easting: 765841 Northing: 6386579	AMTD: 1.2km
Flow condition: No flow.	Time: 1:55pm
	
Plate 51: Walkers Creek: View looking upstream towards 1500/RCP culvert. Note vegetation in bed and absence of erosion.	Plate 52: Walkers Creek: Active undercutting, incision and erosion upstream of culvert. Note bank material, suggesting some reworking of deposited sediment.
Channel Geometry: Low Flow Channel: Continuous 0.8m wide shallow channel with 0.2m high, 1:2 (V:H) banks. High Flow Channel: Continuous, high capacity, broad 10m wide channel with 2m high, 1:1 (V:H) Left bank and 1:1.5 (V:H) Right bank.	
Planform Geometry: Low sinuosity curves, outcrop (rock) controlled.	
Geomorphic Units Channel: Incised, well developed high flow channel. Floodplain: Developed and apparent.	
Bed Condition: Downstream of culvert bed is stable and vegetated (grass) due to the hydraulic control of the culvert. Upstream of the culvert, active erosion occurring, leading to bed incision.	
Bank Condition: Downstream of culvert, inner (right) bank well vegetated (grass), whilst outer (left) bank is vertical and bare, with minor slumping and blocking observed. Upstream of culvert, active bank undercutting is occurring leading to lateral mobility of channel.	
Sediment Channel: Sand, gravel, cobbles and boulders. Floodplain: Fine silt, clay, sand, gravel, cobbles and boulders.	
Comment: High capacity and velocity discharge watercourse with active erosion and channel mobility apparent upstream of culvert and road which act as a hydraulic control which attenuates peak discharge downstream, leading to a more stable section of the watercourse. Upstream, it is apparent that the labile sediment material, predominantly derived from sandstone uplands, is being reworked via lateral mobility of the channel.	

Location: Walkers Creek 4	Date: 19 July 2017
Easting: 765595 Northing: 6386593	AMTD: 0.9km
Flow condition: No flow.	Time: 8:50am
	
Plate 53: Walkers Creek: View towards right hand bank. Note material in exposed bank profile indicating reworking of deposited sediment.	Plate 54: Walkers Creek: View upstream. Note riffle in foreground, pool in background and wide high flow channel
Channel Geometry: • Low Flow Channel: Continuous 1.5m wide shallow channel with pool and riffles with 1m high, 1:1 (V:H) Left bank and 3m high 1:1 (V:H) Right bank (high flow channel bank). • High Flow Channel: Continuous, high capacity, 7m wide channel with 3m high, 1:2 (V:H) Left bank and 1:1 (V:H) Right bank.	
Planform Geometry: Low sinuosity curves, sediment controlled.	
Geomorphic Units • Channel: Incised, well developed low and high flow channels. • Pool: Approximately 20m long, 3m – 5m wide developed in low flow channel (thalweg) adjacent to Right (outer) bank. • Riffle: Approximately 20m long, 1.5m wide. • Floodplain: Developed and apparent.	
Bed Condition: Varying conditions with minor vegetation (grass, reeds) on bar at pool outlet and the remaining sections bare.	
Bank Condition: Right hand bank was bare, with angular or sub-angular cobbles and boulders observed, animal burrows (wombat) were also noted. Right hand bank was vegetated (grass) and appeared stable.	
Sediment • Channel: Sand, gravel, cobbles and boulders. • Floodplain: Fine silt, clay, sand, gravel, cobbles and boulders.	
Comment: High capacity, single continuous channel. Exposed bank material indicates historic mobility however established grass cover on some banks suggests that this is no longer occurring. A number areas of historic bank erosion were observed however the establishment of vegetation precluded the identification of the cause of the erosion which could be attributed to animal disturbance (wombat burrows) or piping failure from the entry of discharge from the 1 st order drainage feature situated to the north of this location. Discharge from this 1 st order drainage feature is presently intercepted by a farm dam with a 2m embankment.	

Location: Walkers Creek 5	Date: 19 July 2017
Easting: 765421 Northing: 6386569	AMTD: 0.8km
Flow condition: No flow.	Time: 8:30am
	
Plate 55: Walkers Creek: View downstream. Note cobbles and boulders in channel bed and vegetated high flow channel.	Plate 56: Walkers Creek: View towards right hand bank. Note exposed bank material, evidence of undercutting and stock paths.
Channel Geometry: Low Flow Channel: Continuous, broad, shallow 1.5m wide channel with 0.5m -0.8m high, 1:1 (V:H) banks. High Flow Channel: Continuous, high capacity, 8m – 9m wide channel with 2.5m high, 1:1.5 (V:H) Right bank and Left bank which transitions from 1:2 (V:H) to 1:1 (V:H).	
Planform Geometry: Straight, incised.	
Geomorphic Units Channel: Incised, well developed low and high flow channels. Floodplain: Developed and apparent.	
Bed Condition: Varying with some sections bare (potentially a poorly developed pool and riffle sequence) with other sections vegetated (grass).	
Bank Condition: Right hand bank was vegetated (grass) in places although some rill erosion was observed. Left hand bank was vegetated (grass) although top (vertical) section was bare and evidence of undercutting was observed.	
Sediment Channel: Fine silts, sands, gravel, cobbles and boulders. Floodplain: Fine silt, clay, sand, gravel, cobbles and boulders.	
Comment: High capacity, single continuous channel that presents as deep erosional feature. Exposed bank angular and sub-angular material indicates historic deposition and subsequent reworking as a result of historic channel mobility. Banks are further degraded at this location as a result of stock paths and animal (wombat) disturbance.	

2. BASELINE WATER QUALITY ASSESSMENT

2.1 INTRODUCTION

Similar to geomorphology, the constituent concentrations of the range of physico-chemical parameters present in the discharge of a particular catchment is typically influenced by a combination of factors such as:

- catchment geology which influences the nature and type interactions between rock (e.g. groundwater discharge, weathering), rainfall and runoff and subsequently water chemistry;
- catchment land use and vegetation cover which influences the water chemistry; and
- climate influences the type of climatic environment influences the weathering regime of the host geology and consequently the sediment type, particularly the clay fraction whilst the frequency and duration of rainfall events influences the timing of peak discharge in a catchment that subsequently influences the transport of material either to or within a given watercourse which also influences the water chemistry (e.g. “first flush events”).

Monitoring and sampling for ambient surface water quality in Hawkins and Lawsons Creeks and their tributaries has been undertaken since 2012 to enable the characterisation of the upstream, downstream and mid-chainage water quality in the vicinity of the Mine Site. The reporting of sampled results to characterise the water quality is undertaken with reference to 20th, 50th and 80th percentile bands and box and whisker plots have been compiled and used to present the results. This type of plot is extremely useful in providing a visual representation of the statistical interpretations recommended in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) for checking data distribution to inform this condition assessment. All plots present data as maximum, minimum, median, 20th and 80th percentiles. The median has been chosen for comparison to trigger values as a means of characterising the water quality. This is the approach recommended in ANZG (2018) and intended as a mechanism to characterise the subject watercourses in recognition of historic catchment alteration to facilitate agricultural land use and the geology of the contributing catchment.

In August 2019, Bowdens Silver conducted a round of stream sediment sampling in Hawkins and Lawsons Creeks in the vicinity of Bowdens Silver’s surface water monitoring locations to identify the baseline chemical composition of these sediments within these creeks. In addition, leachate testing was undertaken on the sampled sediments to understand the readily mobilised solutes from the sediment. This section presents the results of the leachate tests conducted on sediment samples:

- within Hawkins Creek, upstream and downstream of the Mine Site; and
- within Lawsons Creek, upstream of Hawkins Creek and downstream of Lue.

2.2 WATER QUALITY OBJECTIVES

The principal guideline for water quality in Australia is ANZG (2018). Much of ANZG (2018) relies upon guidance developed by the Australian and New Zealand Environment and Conservation Council (ANZECC) in collaboration with the Agriculture and Resources Management Ministerial Council of Australia and New Zealand (ARMCANZ) and which was published in the (then) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000). ANZG (2018) sets quantitative and qualitative values for a range of water quality parameters for the protection of aquatic ecosystems, aquaculture, recreation, drinking and agricultural values.

The receiving environment in the vicinity of the Mine Site and downstream holds a range of water quality objectives reflecting the ecological, social and economic attributes and ecosystem function of the catchment in which they are situated. The identification of the water quality objectives helps determine the specific water quality trigger values which need to be maintained.

A description of the water quality objectives for the Macquarie Bogan River catchment, as identified by the NSW Environment, Energy and Science (EES) Group (formerly Office of Environment and Energy) for the receiving environment downstream from the Mine Site is summarised below.

Aquatic Ecosystem

- Maintaining or improving the ecological condition of waterbodies and their riparian zones over the longer term.

Visual Amenity

- Aesthetic quality of waters.

Primary Contact Recreation

- Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.

Secondary Contact Recreation

- Maintaining or improving water quality for activities such as boating and wading in which there is a low probability of water being swallowed.

Livestock Water Supply

- Protecting water quality to maximise the production of healthy livestock.

Irrigation Water Supply

- Protecting the quality of waters applied to crops and pasture.

Homestead Water Supply

- Protecting water quality for domestic use in homesteads including drinking, cooking and bathing.

Drinking Water (disinfection only or clarification and disinfection)

- Protecting the quality water at, and upstream of, offtake points for town water supply and specific sections of rivers that contribute to drinking water storages.

Aquatic Foods (cooked)

- Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.

Where more than one water quality objective is identified for a specific water resource, the more conservative water quality objective has been adopted as the appropriate trigger value in order to assess the water quality. Consequently, water quality trigger values for the assessment of the waters are based primarily on the relevant guideline values that have been developed for the aquatic ecosystem water quality objective. **Table 3** contains the adopted trigger values for the water quality objectives relevant to upland streams in the Macquarie Bogan River catchment.

Table 3
Guideline Trigger Values for Surface Water

Parameters	Unit	Trigger Value
Nutrients		
Ammonia as N*	mg/L	0.013 ¹
Nitrate*	mg/L	0.015 ¹
Total N*	mg/L	0.250 ¹
Total P*	mg/L	0.020 ¹
Physico-chemical		
pH	-	6.5-8.0 ²
Sulphate*	mg/L	1 000 ³
Electrical Conductivity	µS/cm	30-350 ¹
Dissolved Metals		
Arsenic*	mg/L	0.013 ¹
Cadmium*	mg/L	0.0002 ¹
Cobalt*	mg/L	Insufficient Data ¹
Copper*	mg/L	0.0014 ¹
Iron*	mg/L	Insufficient Data ¹
Lead*	mg/L	0.0034 ¹
Manganese*	mg/L	1.9 ¹
Nickel*	mg/L	0.011 ¹
Zinc*	mg/L	0.008 ¹ and 0.005 ⁴
* Guideline values relate to comparison with the 50 th percentile or median value of the results 1 ANZG Aquatic ecosystem protection 2 OEH NSW Aquatic ecosystem protection (Macquarie-Bogan Water Quality Objectives) 3 ANZG Livestock drinking water quality 4 OEH NSW Aquatic Foods (cooked) protection (Macquarie-Bogan Water Quality Objectives)		

2.3 SURFACE WATER SAMPLING LOCATIONS

A total of 10 locations along the subject watercourses were sampled by Kingsgate Bowdens Pty Ltd or Bowdens Silver between June 2012 and November 2018 with the data utilised for the purposes of this assessment. The sampling locations are listed in **Table 4** and presented on **Figure 5**.

Table 4
Surface Water Monitoring Locations

Location Ref	Watercourse / Catchment	Position
BSW 13	Hawkins Creek	Upstream of Mine Site Boundary
BSW 11*	Hawkins Creek	Adjacent to Mine Site Boundary
BSW 7	Hawkins Creek	Adjacent to Mine Site Boundary
BSW 12	Hawkins Creek	Downstream of Mine Site Boundary
BSW 19*	Hawkins Creek	Downstream of Mine Site Boundary
BSW 20*	Lawsons Creek	Upstream of Hawkins Creek confluence
BSW 21	Lawsons Creek	Downstream of Hawkins Creek confluence
BSW 22	Lawsons Creek	Downstream of Lue
BSW 28*	Lawsons Creek	Downstream of Lue
BSW 25	Tributary (Lawsons Creek)	West of Mine Site
BSW = Bowdens Surface Water		* Stream sediment sample also collected at this location

2.4 ANALYTES

The sampling locations listed in **Table 4** were generally sampled on a monthly basis and submitted to a NATA accredited laboratory for analysis of the physico-chemical parameters shown in **Table 3**. In total, the dataset comprises 11,904 individual analytical results from a suite of 29 analytes.

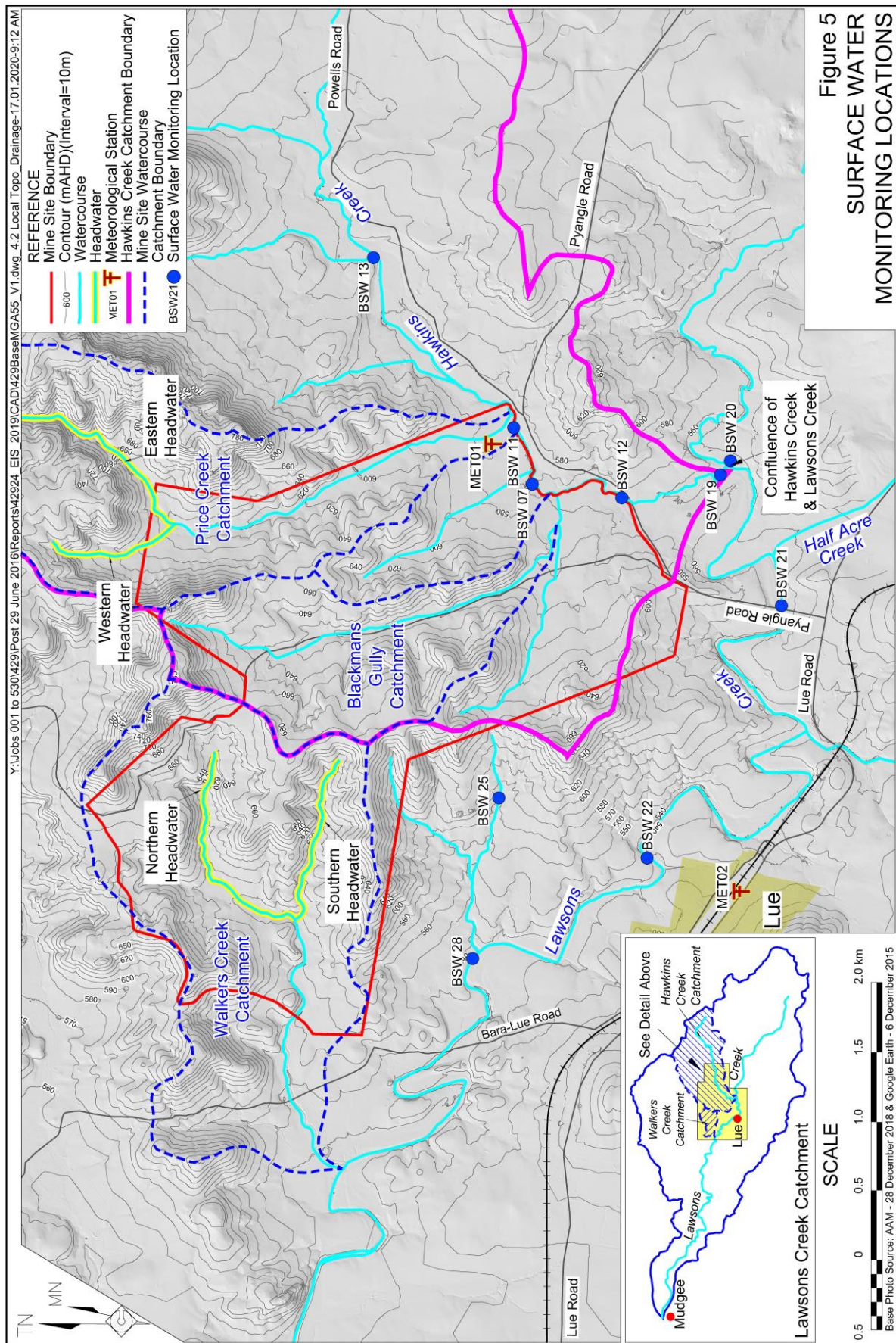
2.5 RESULTS AND INTERPRETATION

2.5.1 Data Presentation

2.5.1.1 Surface Water Quality

Box and whisker plots have been compiled and used to present the results of water quality monitoring for this assessment. This type of plot is extremely useful in providing a visual representation of the statistical distribution of a sample population. With the exception of electrical conductivity, which reports the 75th percentile value, all plots present data as maximum, minimum, median, 20th and 80th percentiles. With regard to electrical conductivity, the use of the 75th percentile, rather than the 80th percentile has been adopted as with this indicator the 80th percentile is usually significantly higher than the median and allows for too much change when compared to the median (EHP, 2009). The median has been chosen for comparison to trigger values. This is the approach recommended in ANZG. This approach is not intended as being an instrument to assess compliance but as an early warning mechanism for the management of potential impacts.

Figure 5 Surface Water Monitoring Locations



With the exception of Bowdens Surface Water (BSW) 25, which is the lone sampling location on a minor 1st order watercourse that discharges into Lawsons Creek west of the Mine Site, the data presented in Section 2.6.2 is organised so that monitoring locations are grouped by watercourse (Hawkins Creek or Lawsons Creek) with the most downstream sampling location positioned nearest to the left of the x-axis (Hawkins Creek = BSW 19; Lawsons Creek = BSW 28) with increasing distance from that sampling location reflected along the right of the x-axis. A discussion of the results follows the presentation of all data sets.

The sites referred to in the plots are those shown in **Figure 5** and listed in **Table 4**.

The results of the statistical analyses and a table listing the sample populations and number of samples that were below the limit of laboratory detection (limit of reporting [LOR]) for each sampling location is also provided. The LOR for each analyte is presented in the statistical summaries in Appendix 1. Statistical analyses were not performed where sampled populations did not record more than ten results were above the LOR and are left blank on the plots. As this is a baseline assessment and due to the catchment size and potential to influence water quality from multiple diffuse points within the catchment, the discussion accompanying the presentation of monitoring data is kept brief. Section 2.5.2 presents the results for each of the following analytes;

- ammonia
- total nitrogen
- pH
- electrical conductivity
- nitrate
- total phosphorous
- sulphate
- dissolved metals (arsenic, cadmium, cobalt, copper, iron, lead manganese, nickel and zinc)

Full statistical analyses of all monitoring data are presented in **Attachment 1**.

2.5.2 Results

2.5.2.1 Surface Water

Nutrients

The elevated concentrations of nitrogenous and phosphorous compounds described below may be attributable to the following aspects which relate to the principal land use of the contributing catchment being pastoral, namely:

- the application of nitrogenous and / or phosphatic fertilisers to facilitate pasture growth to sustain livestock production; and
- transport of nutrients adsorbed onto mineral surfaces.

However, two other potential contributions to the recorded nutrients concentrations may also be factors and are:

- the decay of organic materials, notably as the result of the vegetation becoming established in the channel of both Hawkins and Lawsons Creeks; and
- septic systems.

Ammonia

Figure 6 identifies that the median values (50th percentile) for ammonia exceed the trigger value range at all monitoring locations. The variance in samples above the LOR (**Table 5**) may be attributable to variation in flow events.

Figure 6 Monitoring Results: Ammonia

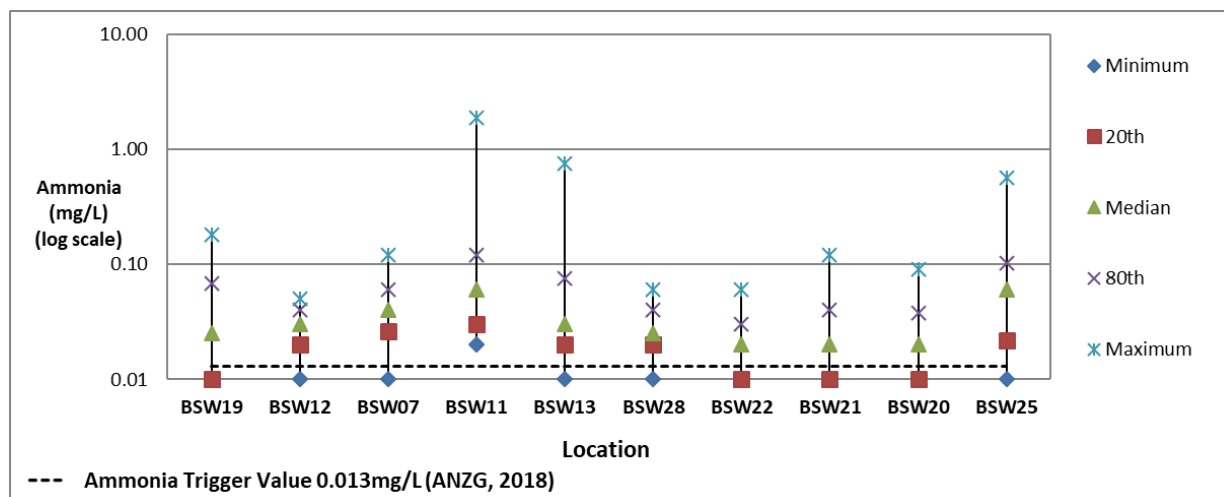


Table 5
Sample Population and Samples Below LOR: Ammonia

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	24	44	47	39	43	29	38	45	39	25
Above LOR	12	21	32	29	23	16	26	31	27	20
Below LOR	12	23	15	10	20	13	12	14	12	5
% Below LOR	50%	52%	32%	26%	47%	45%	32%	31%	31%	20%

Nitrate

Similar to ammonia, the median values (50th percentile) for nitrate exceed the trigger value at all monitoring locations (**Figure 7**). The variation in the results above LOR (**Table 6**) of nitrate are also likely attributable to the factors outlined for ammonia.

Figure 7 Monitoring Results: Nitrate

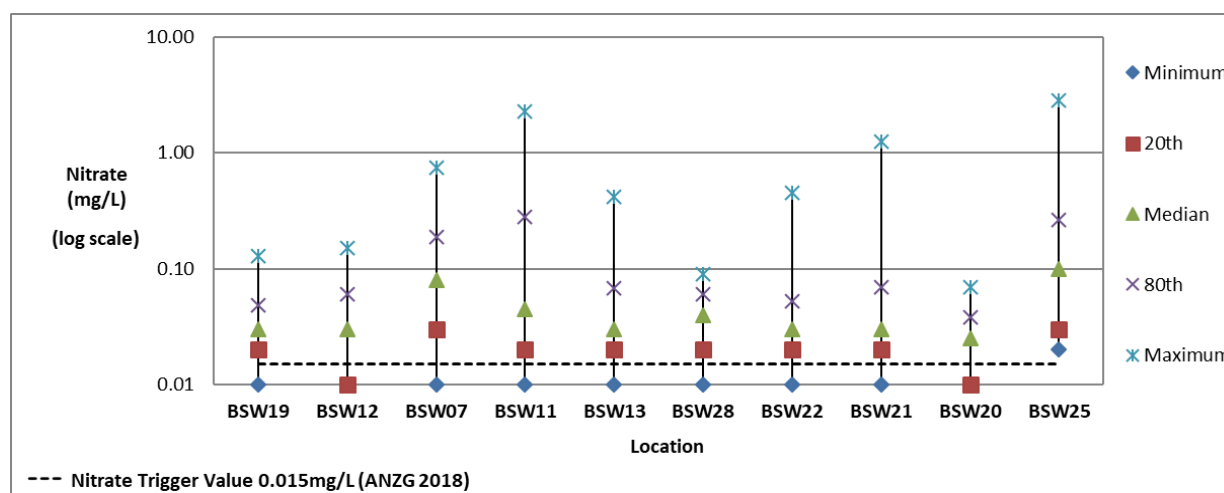


Table 6
Sample Population and Samples Below LOR: Nitrate

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	24	44	47	39	43	29	38	45	39	25
Above LOR	14	21	44	30	19	16	18	26	22	19
Below LOR	10	23	3	9	24	13	20	19	17	6
% Below LOR	42%	52%	6%	23%	56%	45%	53%	42%	44%	24%

Total Nitrogen

The median values (50th percentile) for total nitrogen are above the trigger value at all monitoring locations. Review of sampled results for total nitrogen and total Kjeldahl nitrogen, an analytical method for measuring organic nitrogen, identified that the increased number of sampled results for total nitrogen that were above LOR (**Table 7**) could be attributed to organic nitrogen (**Figure 9**) that was present at concentrations above the LOR in 97% of samples (**Table 8**).

Figure 8 **Monitoring Results: Total Nitrogen**

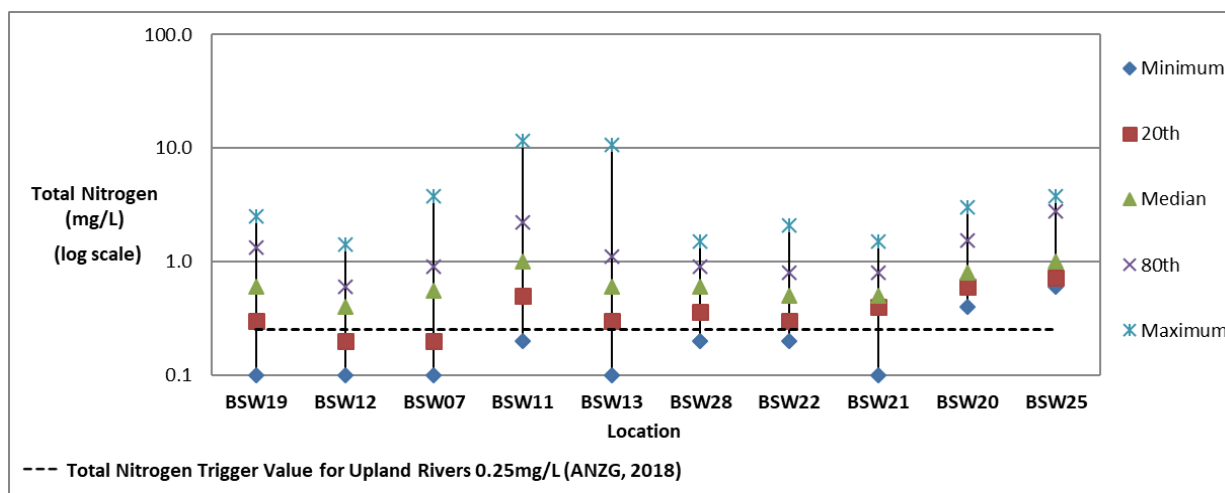


Table 7
Sample Population and Samples Below LOR: Total Nitrogen

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	24	44	47	39	43	29	38	45	39	25
Above LOR	24	39	44	38	43	29	38	45	39	25
Below LOR	0	5	3	1	0	0	0	0	0	0
% Below LOR	0%	11%	6%	3%	0%	0%	0%	0%	0%	0%

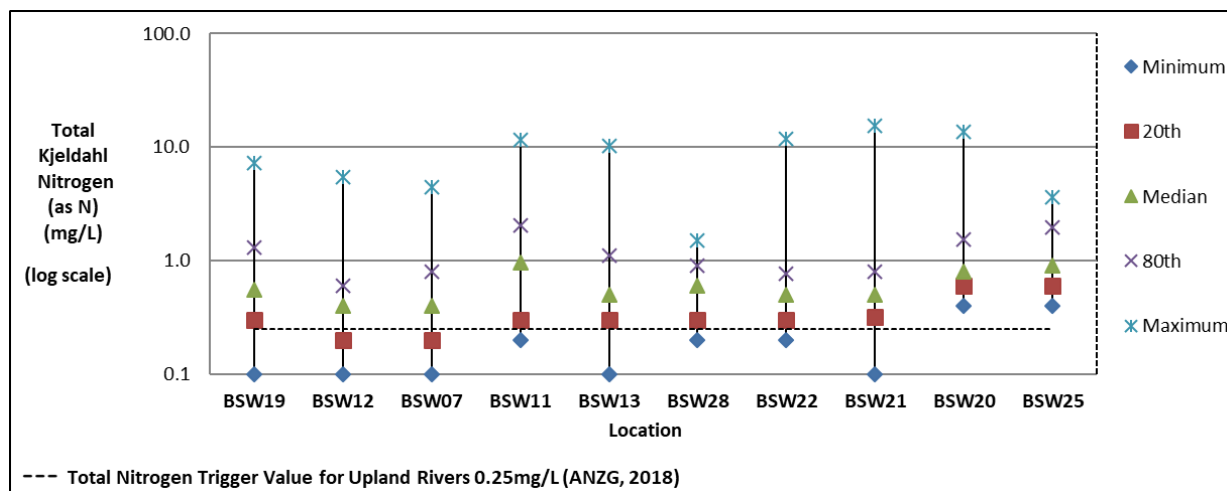
Figure 9 Monitoring Results: Total Kjeldahl Nitrogen

Table 8
Sample Population and Samples Below LOR: Total Kjeldahl Nitrogen

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	24	44	47	39	43	29	38	45	39	25
Above LOR	24	39	43	38	43	29	38	45	39	25
Below LOR	0	5	4	1	0	0	0	0	0	0
% Below LOR	0%	11%	9%	3%	0%	0%	0%	0%	0%	0%

Total Phosphorous

The median values (50th percentile) for total phosphorous exceed the trigger value at all sampling locations (**Figure 10**). Similar to total nitrogen, compared to ammonia and nitrate, an increased number of sampled results are above LOR (**Table 9**) suggesting a consistent contribution to catchment watercourses is occurring.

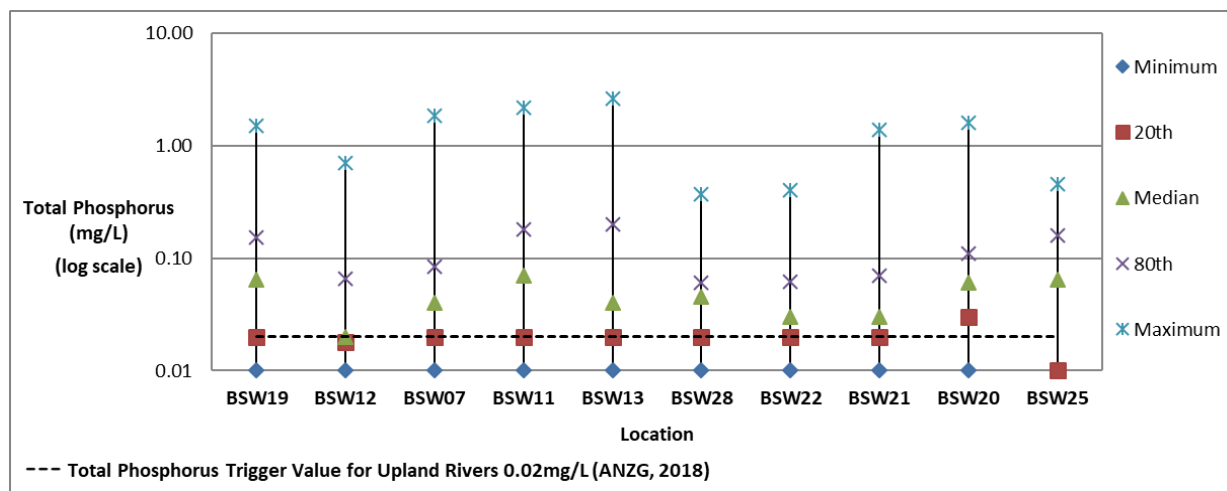
Figure 10 Monitoring Results: Total Phosphorous

Table 9
Sample Population and Samples Below LOR: Total Phosphorous

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	24	44	47	39	43	29	38	45	39	25
Above LOR	22	28	40	34	36	28	35	39	36	22
Below LOR	2	16	7	5	7	1	3	6	3	3
% Below LOR	8%	36%	15%	13%	16%	3%	8%	13%	8%	12%

With respect to Lawsons Creek, the highest median nitrate and ammonia concentrations are observed at the same monitoring location (BSW 21), which is downstream of the Lawsons Creek confluence with Hawkins Creek as well as another, unnamed watercourse which conveys discharge from a catchment to the southeast. The highest median nitrate concentrations for those monitoring locations on Hawkins Creek was recorded at BSW 7, which is downstream of BSW 11 (highest median ammonia) although both BSW 7 and BSW 11 have returned the highest nitrate concentrations. The land use of the catchment in the vicinity of both BSW 7 and BSW 11 is predominantly pastoral and both BSW 7 and BSW 11 are downstream of Price Creek with discharge from this catchment potentially influencing nitrate concentrations.

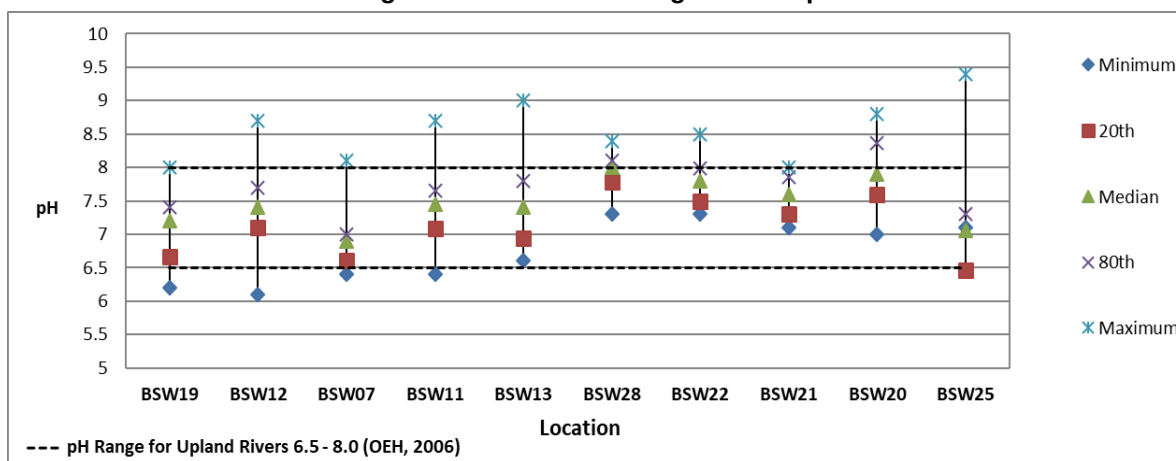
It should be noted however, that the general trend of a decrease in the concentration of nitrogenous compounds with increasing distance from the Mine Site is a situation not matched by the concentrations of total phosphorous. Conversely, the concentration of total phosphorous to those observed at BSW 20 (Lawsons Creek) and BSW 11 (Hawkins Creek) return to similar values at the furthestmost monitoring locations, BSW 28 and BSW 19 respectively downstream from the Mine Site.

Physico-chemical

pH

The range of calculated medians for the results of sampling at all monitoring locations indicates that pH is within the required range for upland rivers (**Figure 11**). The results for monitoring locations on Lawsons Creek are generally at the upper end of this range. It is notable that the maxima recorded at BSW 22, BSW 13 and BSW 12 all occurred during the sampling event conducted on 3 February 2016, however, a similar pH value was not recorded at BSW 21 on the same date, suggesting that the values recorded are not the result of equipment malfunction or sampling error.

Figure 11 Monitoring Results: pH

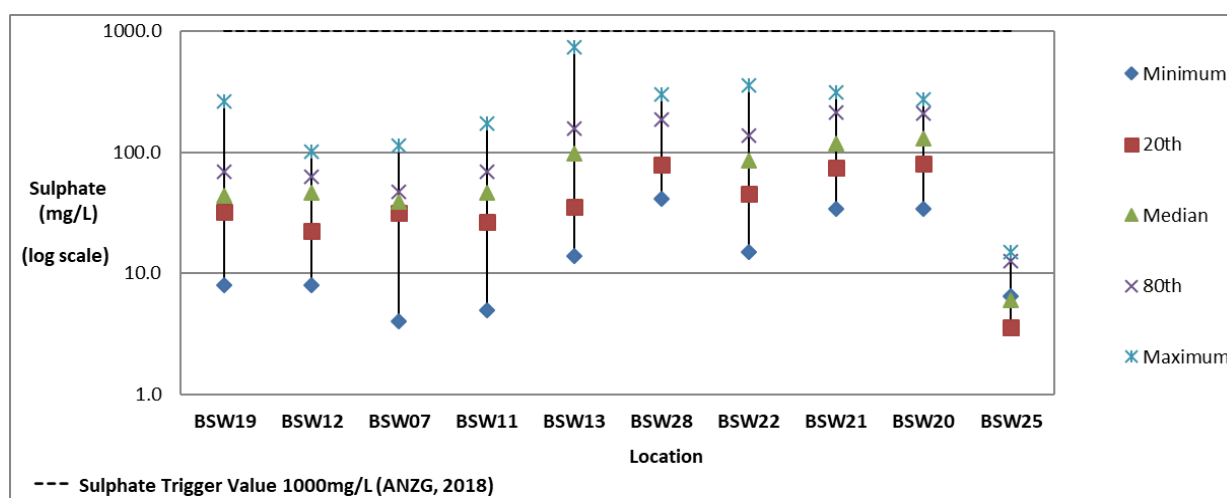


Given that pH is a measure of hydrogen activity, it is unsurprising that pH was recorded for all samples collected and subsequently no tabulation of sample populations is provided for pH.

Sulphate

The results of sampling for sulphate at all monitoring locations identifies that sulphate concentrations are below the trigger value (**Figure 12**). Sulphate was invariably reported above the LOR for almost all sampling rounds at all locations (**Table 10**). It is notable that the calculated median values for those monitoring locations on Hawkins Creek, in the vicinity, and downstream of, the ore body (i.e. BSW 19, BSW 12 and BSW 7) and therefore the area of sulphide mineralisation (and potential oxidation of sulphide to sulphate) are lower than those recorded at monitoring locations within Lawsons Creek.

Figure 12 Monitoring Results: Sulphate



**Table 10
Sample Population and Samples Below LOR: Sulphate**

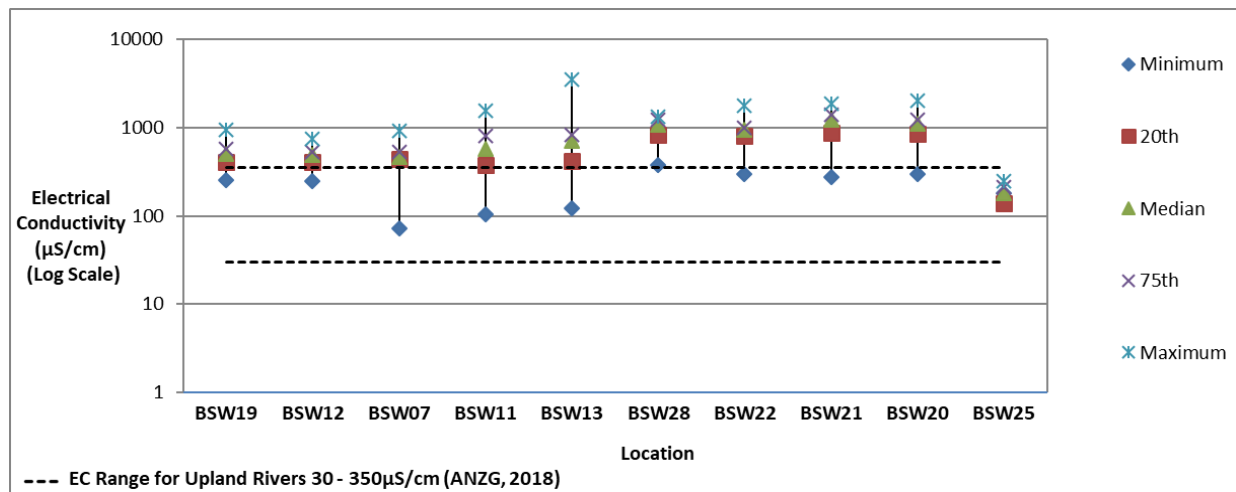
Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	30	51	54	46	50	29	45	52	45	15
Below LOR	0	0	0	0	0	0	0	0	0	10
% Below LOR	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%

Electrical Conductivity

The range of the results of sampling for electrical conductivity at all monitoring locations indicates that the values for this parameter are above the range for upland rivers (**Figure 13**).

This may be attributable to factors such as the land use of the contributing catchment leading to increase solutes and sediment in the surface water, changes to the prevailing hydrological regime leading to the formation of discontinuous pools and the establishment of vegetation in the channels of the watercourses (leading to increased biological activity) or natural causes related to the underlying geology and vegetation on the uplands.

Figure 13 Monitoring Results: Electrical Conductivity



Given that electrical conductivity is a measure of dissolved solutes, it is unsurprising that electrical conductivity was recorded in natural waters and for all samples collected. Subsequently, no tabulation of sample populations is provided for electrical conductivity.

Dissolved Metals

Arsenic

The results of sampling for arsenic and the results of the statistical analyses shown on **Figure 14** indicate that the concentration of arsenic is well below the trigger value at all monitoring locations. It is notable that of those monitoring locations located in Hawkins Creek, only BSW 11 returned results above LOR on ten occasions (**Table 11**) with all other Hawkins Creek monitoring locations recording result below LOR for >85% of samples (**Table 11**). Monitoring locations in Lawsons Creek returned a higher number of samples above LOR, allowing for the calculations of statistics. This notwithstanding, the median arsenic concentrations are all within a very narrow range between 0.003mg/L and 0.006mg/L.

Figure 14 Monitoring Results: Dissolved Arsenic

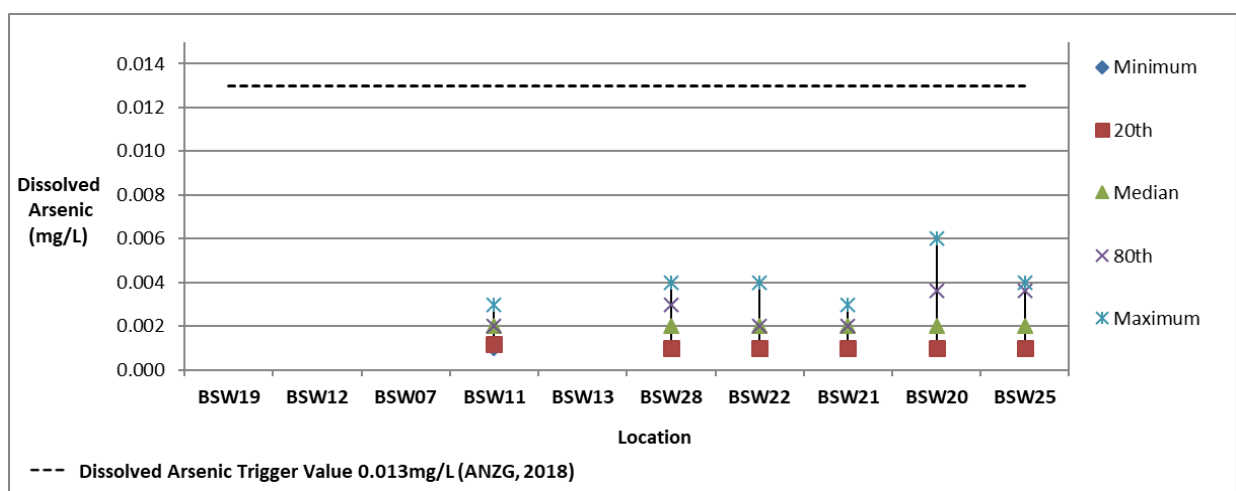


Table 11
Sample Population and Samples Below LOR: Dissolved Arsenic

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	4	4	4	10	3	18	22	21	23	13
Below LOR	26	47	50	36	47	11	23	31	22	12
% Below LOR	87%	92%	93%	78%	94%	38%	51%	60%	49%	48%

Cadmium

In the absence of any monitoring location returning more than ten results for dissolved cadmium that are above the LOR (**Table 12**), **Figure 15** presents the maximum value recorded. With the exception of BSW 11, no monitoring location returned a result above LOR on more than one sampling round (**Table 12**). With regards to BSW 21, the values shown are considered anomalous and are based on the results of one sampling round (20 June 2013) where the limit of reporting is recorded by the laboratory as being 0.001mg/L whereas all other results for cadmium for this round state the limit of reporting as being 0.0001mg/L. With the exception of BSW 21, the results of sampling for cadmium and the maximum results of the statistical analyses indicate that the concentration of cadmium is at or below the trigger value which is just above the limit of reporting (0.0001mg/L).

Figure 15 Monitoring Results: Dissolved Cadmium (maximum values)

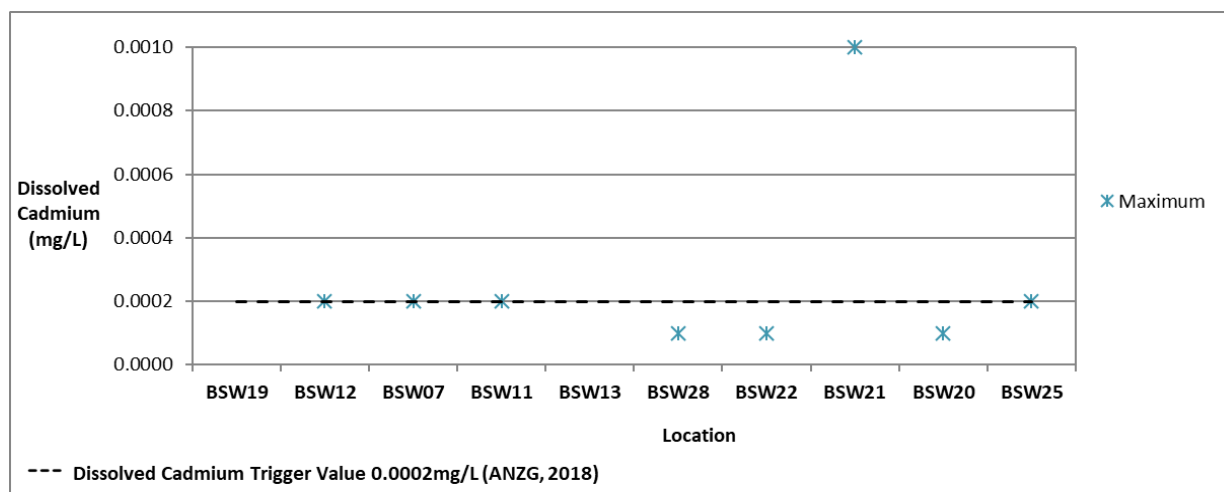


Table 12
Sample Population and Samples Below LOR: Dissolved Cadmium

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	0	1	1	3	0	1	1	1	1	1
Below LOR	30	50	53	43	50	28	44	51	44	24
% Below LOR	100%	98%	98%	93%	100%	97%	98%	98%	98%	96%

Cobalt

With the exception of monitoring locations BSW 7, BSW 11, BSW 13 and BSW 25, all of which are situated on Hawkins Creek, no monitoring locations recorded more than ten results that were above the LOR (**Figure 16, Table 13**). The results of the statistical analyses indicate that the median concentration of cobalt for all monitoring locations is within a relatively narrow range (0.001mg/L to 0.003mg/L).

Figure 16 Monitoring Results: Dissolved Cobalt

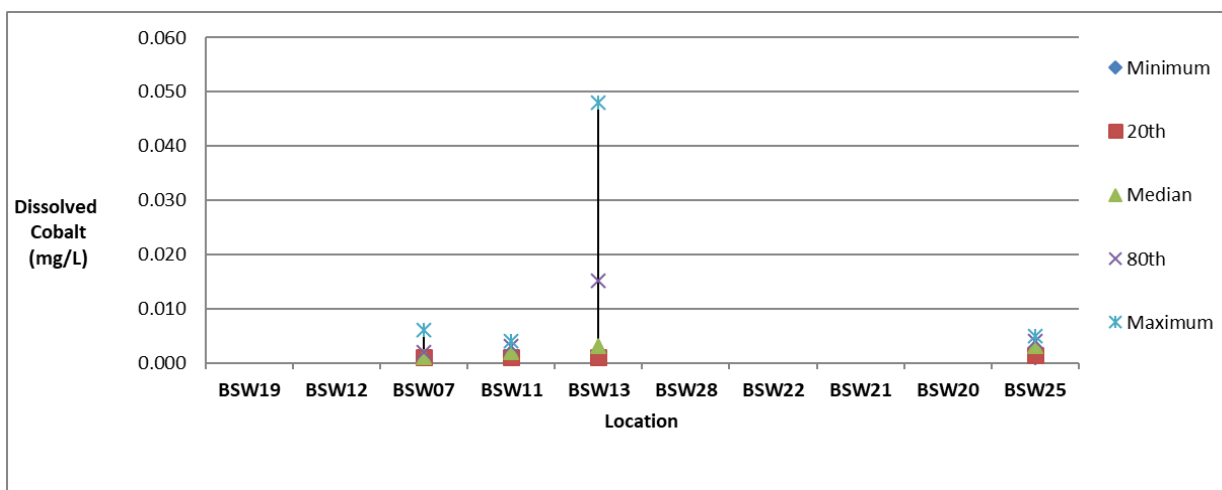


Table 13
Sample Population and Samples Below LOR: Dissolved Cobalt

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	24	44	47	39	43	29	38	45	39	25
Above LOR	9	3	10	12	33	1	1	1	5	11
Below LOR	15	41	37	27	10	28	37	44	34	14
% Below LOR	63%	93%	79%	69%	23%	97%	97%	98%	87%	56%

The maxima recorded at BSW 7 (19 March 2013), BSW 11 (15 November 2017) and BSW 13 (17 May 2017) were the result of different rounds of sampling and are considered as being representative of a temporal variation in cobalt concentrations although, based on the sample populations and monitoring locations, the spatial variation is limited. It is notable that elevated cobalt concentrations are not recorded during the same sampling round at the subsequent monitoring location either upstream or downstream.

Copper

The results at monitoring locations BSW 19, BSW 28 and BSW 25 did not return more than ten values above LOR (**Table 14**) however, as shown on **Figure 17**, with the exception of BSW 12 and BSW 21, the median concentration of copper at all monitoring locations is above the trigger value. This notwithstanding, the median copper concentrations at all monitoring locations are within a relatively narrow range (0.001mg/L to 0.002mg/L).

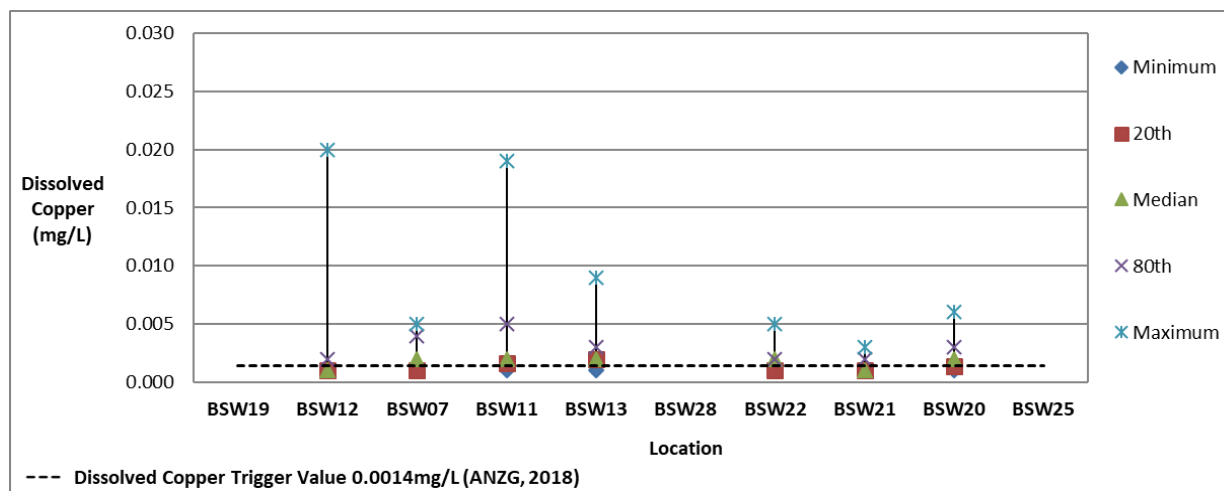
Figure 17 Monitoring Results: Dissolved Copper

Table 14
Sample Population and Samples Below LOR: Dissolved Copper

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	8	13	14	27	23	6	14	16	26	7
Below LOR	22	38	40	19	27	23	31	36	19	18
% Below LOR	73%	75%	74%	41%	54%	79%	69%	69%	42%	72%

The maxima recorded at BSW 13 and BSW 11 (4 February 2015), were recorded during the same round of sampling whilst that maximum recorded at BSW 12, downstream of BSW 13 and BSW 11, occurred on 18 October 2012. Again, it is notable that an elevated copper concentration was not recorded during the same sampling round at the downstream monitoring location on 4 February 2015 however, despite temporal variation, the spatial distribution of these results are restricted to Hawkins Creek.

Lead

Similar to cadmium, in the absence of any monitoring location returning more than ten results for dissolved lead that are above the LOR (**Table 15**), **Figure 18** presents the maximum value recorded. As shown on **Table 15**, Hawkins Creek monitoring locations BSW 19, BSW 12 and BSW 7 did not return any samples above LOR, with Lawsons Creek monitoring locations BSW 22 and BSW 21 also not returning results above LOR. Of those monitoring locations that did return samples above LOR, none returned more than two samples above the LOR. With the exception of monitoring locations BSW 11 (Hawkins Creek) and BSW 20 (Lawsons Creek), the maximum result for lead at each monitoring location were below the trigger value. However, carbonate complexation can influence lead toxicity and calculation of the hardness modified trigger values for BSW 11 (HMTV 0.0189mg/L) and BSW 20 (0.074mg/L) identify that the maxima recorded at BSW 11 (0.007mg/L) and BSW 20 (0.005mg/L) were below these modified trigger values. These two maxima were recorded at monitoring locations with no hydraulic connection (BSW 11 is situated on Hawkins Creek whilst BSW 20 is situated on Lawsons Creek, upstream of the confluence with Hawkins Creek), suggesting there is spatial variability on sources that may contribute to the presence of lead in these watercourses.

Figure 18 Monitoring Results: Dissolved Lead

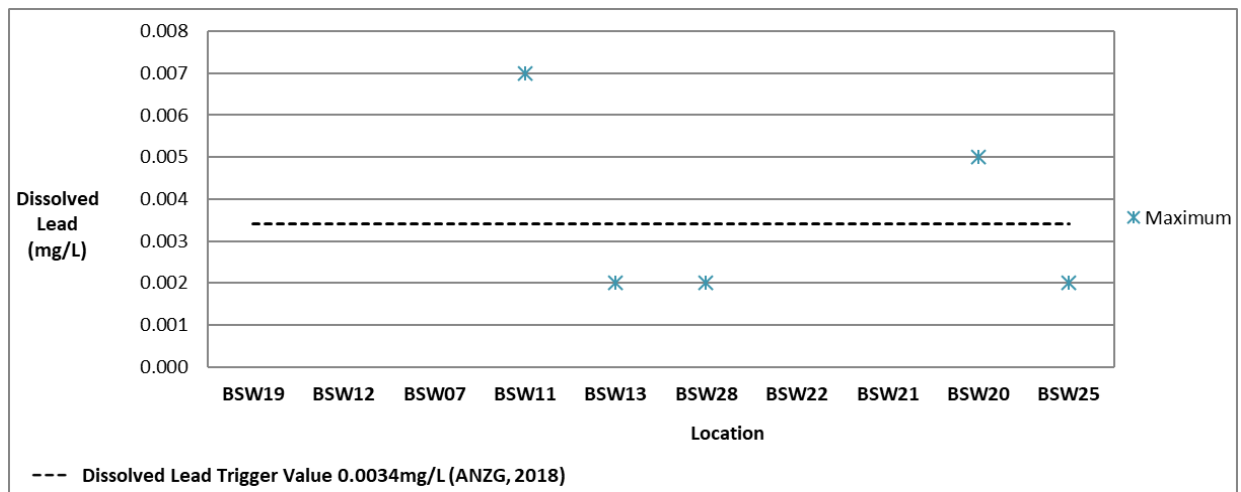


Table 15
Sample Population and Samples Below LOR: Dissolved Lead

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	0	0	0	1	2	1	0	0	2	2
Below LOR	30	51	54	45	48	28	45	52	43	23
% Below LOR	100%	100%	100%	98%	96%	97%	100%	100%	96%	92%

Manganese

Like iron, manganese is an essential element for organisms which can be bioconcentrated up to four orders of magnitude (ANZG, 2018) and compared to other trace metals its toxicity is low (ANZG, 2018). Dissolved manganese was recorded above LOR at all monitoring locations for almost all sampling rounds (**Table 16**)

Figure 19 Monitoring Results: Dissolved Manganese

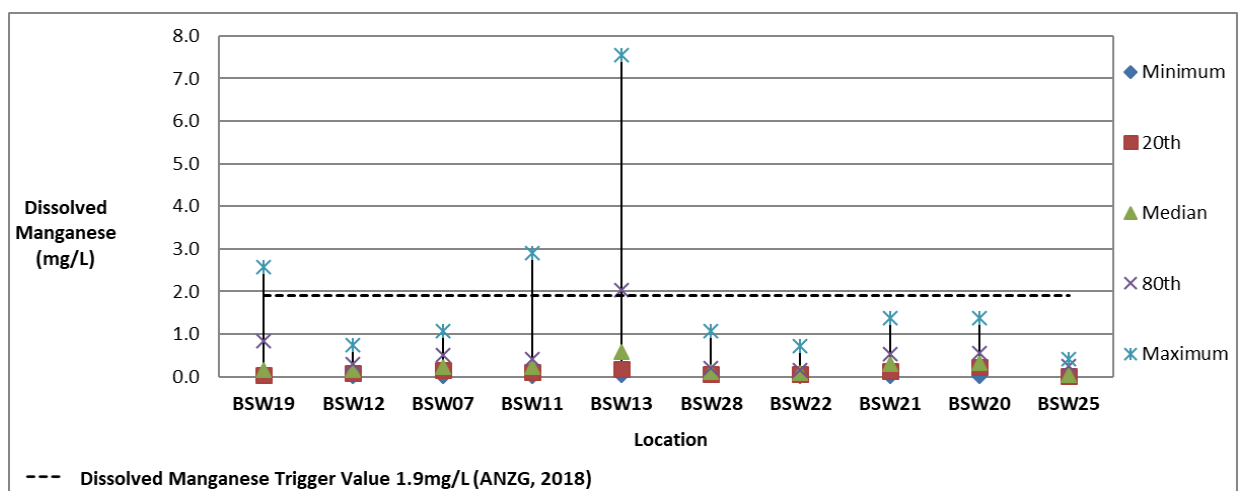


Table 16
Sample Population and Samples Below LOR: Dissolved Manganese

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	30	50	53	46	50	29	44	51	44	25
Below LOR	0	1	1	0	0	0	1	1	1	0
% Below LOR	0%	2%	2%	0%	0%	0%	2%	2%	2%	0%

However, it is noted that with the exception of the maximum values recorded at the monitoring locations BSW 19, BSW 13 and BSW 11, all of which are situated on Hawkins Creek, the results for all monitoring locations were all below the trigger value (**Figure 19**).

Of those three locations (BSW 19, BSW 13 and BSW 11) that recorded maximum manganese concentrations above the trigger value, these values were recorded during different sampling rounds (20 January 2017, 19 November 2014 and 15 May 2013 respectively) which suggests that there is temporal and spatial variation in manganese concentrations in Hawkins Creek. It is notable that the sampling event that recorded the highest manganese concentration, 3.0 mg/L (BSW 13) did not record elevated manganese concentrations at the downstream monitoring location (BSW 11, 0.23mg/L).

Nickel

With the exception of BSW 25, all monitoring locations returned sufficient sample populations above LOR to allow for statistical analysis (**Table 17, Figure 20**). Review of the analyses for total alkalinity (as CaCO₃) and adjustment for complexation of nickel with carbonate ions, in accordance with the algorithms presented in ANZG, indicate that the maximum recorded nickel concentration for BSW 12 (HMTV 0.028mg/L, maxima 0.043mg/L) is above the adjusted trigger value whilst all other maxima were below their respective modified trigger values. This notwithstanding, the median nickel concentrations at all monitoring locations are below the non-adjusted trigger value (0.011mg/L) and display a relatively narrow range (0.001mg/L to 0.002mg/L).

Figure 20 Monitoring Results: Dissolved Nickel

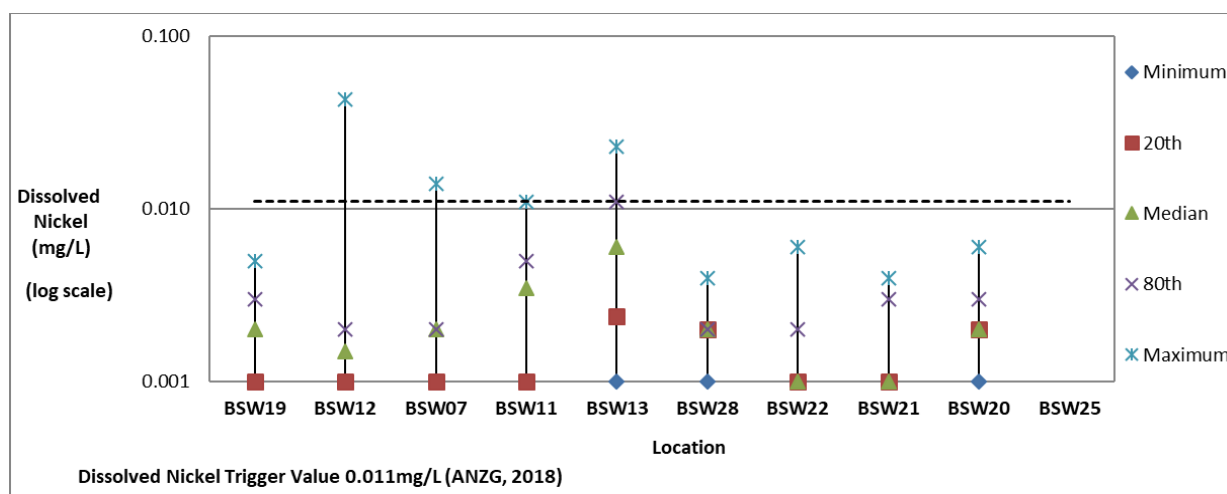


Table 17
Sample Population and Samples Below LOR: Dissolved Nickel

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	21	24	18	36	46	29	17	31	44	2
Below LOR	9	27	36	10	4	0	28	21	1	23
% Below LOR	30%	53%	67%	22%	8%	0%	62%	40%	2%	92%

The instances of maximum dissolved nickel concentrations were not recorded during the same sampling round however, despite this temporal variation, the spatial distribution of these results is restricted to Hawkins Creek.

Zinc

Zinc is an essential trace element for organisms and found in most natural waters in low concentrations (ANZG, 2018).

With the exception of BSW 28, all monitoring locations returned sufficient sample populations above LOR to allow for statistical analysis (**Table 18, Figure 21**). Review of **Figure 21** identifies that the median dissolved zinc concentration in all Hawkins Creek monitoring locations exceed the trigger value whilst only one monitoring location in Lawsons Creek (BSW 20) has a median above the trigger value. However, similar to copper, cadmium and nickel, zinc toxicity is hardness dependent, with toxicity decreasing with increasing hardness and alkalinity. Calculation of hardness modified trigger values for each monitoring location (**Figure 22**) identifies that once hardness is accounted for, the median dissolved concentrations at all monitoring locations, with the exception of BSW 19, are below the adjusted trigger values.

Figure 21 Monitoring Results: Dissolved Zinc

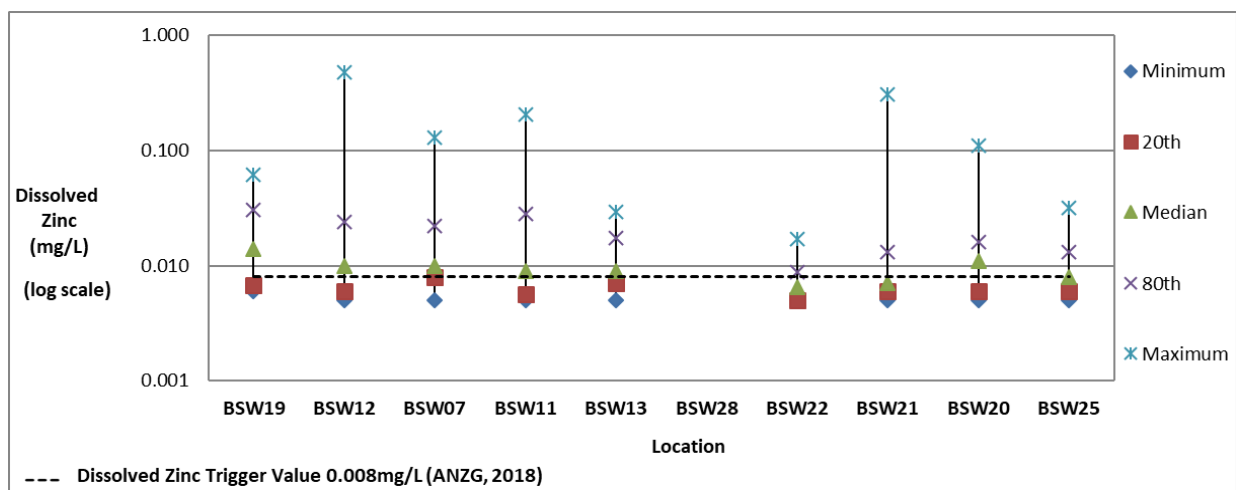


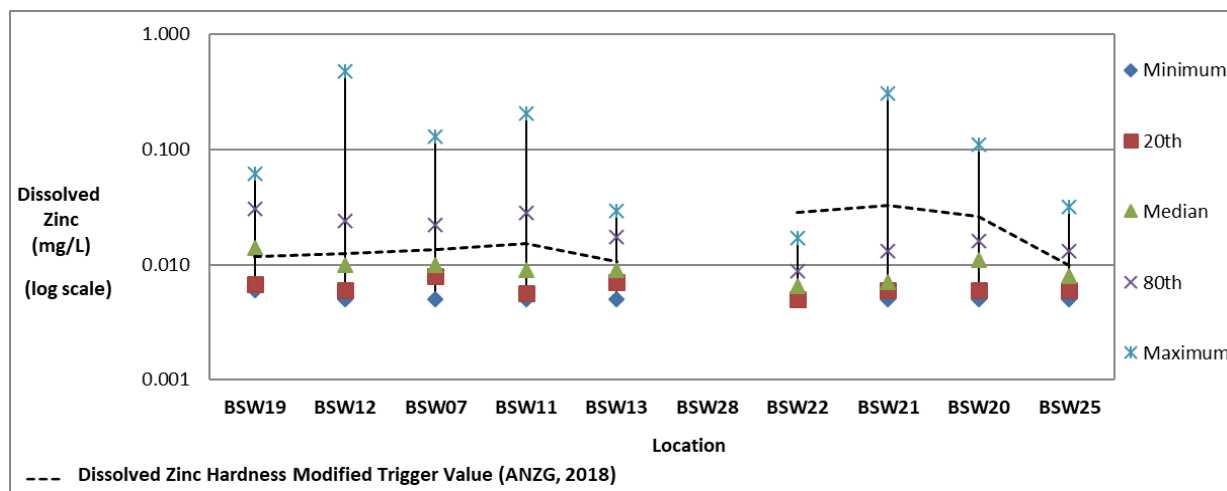
Figure 22 Monitoring Results: Dissolved Zinc (hardness modified trigger values)

Table 18
Sample Population and Samples Below LOR: Dissolved Zinc

Location	BSW19	BSW12	BSW07	BSW11	BSW13	BSW28	BSW22	BSW21	BSW20	BSW25
Sample population	30	51	54	46	50	29	45	52	45	25
Above LOR	13	24	23	17	29	5	12	15	11	11
Below LOR	17	27	31	29	21	24	33	37	34	14
% Below LOR	57%	53%	57%	63%	42%	83%	73%	71%	76%	56%

2.5.3 Stream Sediments

The principal rationale for the leachate analyses of the collected stream sediment samples was to compare the results with the results of leachate analysis of NAF waste rock material. This was to assess the suitability of Bowdens Silver's proposed water management system whereby runoff collected from certain catchments of the Mine Site which contained landforms and stockpiles comprised of NAF waste rock material could potentially be released into downstream watercourses, provided the collected runoff met criteria identified in an environmental protection licence for the Project. **Table 19** presents the results of the leachate analyses together with the default guideline water quality trigger values for the receiving watercourses as established by either NSW (pH and electrical conductivity) or Commonwealth (all others) regulatory authorities.

Table 19
Leachate Analyses of Selected Stream Sediment Samples

Material Analysed			Stream Sediment			
Sample Ref			BSW11	BSW19	BSW20	BSW28
Location [#]			Hawkins Ck (upstream of Mine Site)	Hawkins Ck (downstream of Mine Site)	Lawsons Ck (upstream of Hawkins Creek)	Lawsons Ck (downstream of Lue)
Parameter (µg/L)	Unit	Default Trigger Value				
pH	pH unit	6.5-8.0	6.5	5.7	7.3	7.2
Electrical conductivity	µS/cm	30-350	45	92	218	79
Aluminium	µg/L	55	310	130	40	80
Arsenic		13	2	5	2	7
Cadmium		0.2	<0.0001	0.2	<0.0001	<0.0001
Chromium		ID	<0.001	<0.001	12	<0.001
Cobalt		ID	2	6	<0.001	<0.001
Copper		1.4	<0.001	2	1	3
Iron		ID	530	50	700	60
Lead		3.4	<0.001	<0.001	<0.001	<0.001
Manganese		1900	392	158	329	<0.001
Nickel		11	1	4	2	<0.001
Zinc		8	109	431	49	55
ID = Insufficient Data			# See Figure 5			

3. NAF WASTE ROCK RUNOFF QUALITY

3.1 INTRODUCTION

The results of the testing program for NAF waste rock (WZ1, PZ1 and PZ2) undertaken by GCA (2019) indicate that these materials would be suitable for use in the construction, cover and rehabilitation activities over the Project life. As NAF waste rock would be utilised for the progressive development/construction of the southern barrier, WRE and TSF, consideration of runoff from these structures is considered important in the assessment of water quality downstream of the Mine Site both during and beyond the Project life. The WRE and TSF would be retained in the final landform whilst the NAF waste rock material stored in the southern barrier would be removed and used for rehabilitation of the Mine Site.

As runoff from sections of the southern barrier, WRE and TSF would enter the tributaries of Lawsons Creek during their construction and progressive development and prior to the establishment of cover vegetation (where required), appropriate measures for the capture of potentially sediment-laden runoff would be implemented. Once this runoff has been treated (i.e. after the removal/settlement of suspended sediment) to meet the relevant limit conditions of the Mine's environment protection licence, it would be discharged to assist maintaining flows in receiving watercourses.

Once extracted during mining operations and placed as part of construction, cover and rehabilitation activities, the NAF waste rock material would be exposed to atmospheric conditions and subjected to weathering processes including rainfall that could generate runoff. In order to provide an indication of the likely runoff quality, reliance has been placed upon the results of the leaching tests.

3.2 LEACHATE ANALYSES OF WEATHER NAF WASTE ROCK

Table 20 presents the results of the final round of kinetic testing and leachate analyses (i.e. representative of runoff from weathered NAF waste rock material) drawn from an analysis of the data assembled by GCA (2019). It should be noted that the results presented do not consider mixing and dilution with rainfall or runoff generated on undisturbed catchments and are therefore conservative with respect to the constituent chemistry being presented.

3.3 DISCUSSION

3.3.1 Water Quality

With regard to nutrients and electrical conductivity, the individual results of the water quality monitoring program at the Bowdens Silver Project and statistical analyses of the sample population indicate that there are influences upon water quality as a result of the agricultural activities in the contributing catchments. These influences may either be direct, as the result of runoff from pastoral lands, or indirectly as a consequence of alterations to the prevailing hydrologic regime which have subsequently influenced the geomorphic function of the watercourses.

Table 20
Results of Final Leachate Analysis of Weathered NAF Waste Rock Material

Sample ID (GCA10)		651	663	668	674	678	687	682
Total-S (%)		<0.01	<0.01	<0.01	0.2	0.1	0.1	0.1
Depth (m)		4.5	12.6	25.5	27.3	22.9	22.5	37.7
Class		WZ1	WZ1	PZ1	PZ2	PZ2	PZ2	PZ2
Weathering Period (weeks)		8	10	10	10	10	8	10
Parameter	Unit							
pH	pH	6.2	6.3	5.6	5.7	5.1	7.8	7.3
Electrical conductivity	µS/cm	49	60	68	93	150	140	64
Major ions								
Na	mg/L	8.3	0.7	1	2.1	1	13	3.5
K		0.4	8.2	10	11	12	8.5	8.7
Mg		0.15	1.6	1.7	3.8	6.6	4.7	5.4
Ca		1.3	4.3	1.5	2.9	11	7.5	11
SO4		10	21	23	38	72	12	26
Cl		<2	16	17	26	45	<2	<2
Dissolved metals								
Fe	µg/L	<0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01
Al		<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01
Mn		20	760	380	1400	5200	50	1000
Zn		20	50	70	40	190	20	10
Cd		0.04	0.3	0.5	0.04	0.71	<0.02	0.03
Pb		<0.5	<0.5	<0.5	0.6	1.1	1.3	<0.5
Co		0.2	13	6.9	11	42	0.2	2.5
As		42	0.7	0.6	0.5	0.5	8.9	0.3
Cu		<10	<10	<10	<10	<10	<10	<10
Ni		<10	20	10	10	60	<10	<10
Cr		<10	<10	<10	<10	<10	<10	<10
Hg		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sb		0.48	0.09	0.06	0.03	0.09	1.1	0.09
Bi		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Se		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
B		<10	<10	<10	<10	<10	<10	<10
Mo		0.32	<0.05	<0.05	<0.05	<0.05	5.5	<0.05
P		<100	<100	<100	<100	<100	<100	<100
Ag		0.04	<0.01	<0.01	0.09	0.01	<0.01	<0.01
Ba		0.9	15	20	9.9	8.5	63	2.8
Sr		5.9	19	11	24	32	74	76
Tl		0.02	4.7	2.2	0.87	2.6	0.12	0.16
V		<10	<10	<10	<10	<10	0.13	<10
Sn		0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
U		0.011	0.25	0.095	0.12	0.15	19	0.085
Th		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

With regard to dissolved metals, where sufficient sample populations above LOR permit statistical analysis, the calculated medians indicate that concentrations for arsenic, manganese and nickel are below the default trigger values presented in ANZG (2018). Where calculated medians or individual results (in the case of cadmium and lead) exceed trigger values, adjustment of the trigger value to account for complexation with carbonate ions invariably identifies that trigger values are not exceeded. However, the one instance where an exceedance is clearly identified (i.e. BSW 19, median zinc), indicates that this exceedance is isolated with little connection, either temporal or spatial with other monitoring locations to identify a clear source of the recorded exceedance.

3.3.2 NAF Waste Rock and Stream Sediments

As shown in **Tables 19** and **20**, leachate derived from both stream sediment and weathered NAF waste rock material generally exhibits similar characteristics although there are outliers such as:

- Hawkins Creek (upstream and downstream of the Mine Site): aluminium and zinc;
- Lawsons Creek (upstream of the confluence with Hawkins Creek): electrical conductivity;
- GCA10651: arsenic; and
- GCA10678: cadmium, manganese, nickel and zinc.

In addition to the outliers identified, the leachate analysis results for both stream sediment samples and NAF waste rock material identified exceedances of default water quality guidelines for a variety of parameters including:

- Aluminium: Hawkins and Lawsons Creeks;
- Cadmium: GCA10663 and GCA10668
- Copper: Hawkins and Lawsons Creeks;
- Zinc: all samples.

This notwithstanding and with the exception of outliers, the results of all leachate analyses of both the stream sediments and NAF waste rock are generally within a similar range, suggesting that any runoff from NAF waste rock material which would be utilised for the progressive development/construction of the southern barrier, WRE and TSF would be of similar quality to that of the runoff presently entering Hawkins and Lawsons Creeks, as shown in the results of leachate analyses.

4. REFERENCES

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Attachments

(Total No. of pages including blank pages = 40)

- | | |
|---------------|--|
| Attachment 1* | Statistical Analysis (6 pages) |
| Attachment 2* | Analytical Results by Monitoring Location (32 pages) |

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Attachment 1

Statistical Analysis

(Total No. of pages including blank pages = 6)

Table A1.1 Monitoring Results Statistical Summary:
Hawkins Creek

Table A1.2 Monitoring Results Statistical Summary:
Lawsons Creek

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Table A1.1
Monitoring Results Statistical Summary: Hawkins Creek

Watercourse																							
Location in Watercourse																							
Sample ID				BSW13 (Upstream)					BSW11 (Mid-chainage)					BSW07 (Mid-chainage)					BSW12 (Downstream)				
Parameter	Unit	LOR	Trigger	Min	20th	Median	80th	Max	Min	20th	Median	80th	Max	Min	20th	Median	80th	Max	Min	20th	Median	80th	Max
pH	pH Unit	0.01	6.5-8.0	6.6	6.9	7.4	7.8	9.0	6.4	7.1	7.45	7.7	8.7	6.4	6.6	6.9	7.0	8.1	6.1	7.1	7.4	7.7	8.7
Electrical Conductivity (µS/cm)	µS/cm	1	30-350	123	329.6	645	819.8	3550	105	378.4	569.5	810.0	1570	73.0	437.8	463.0	525.5	925	249	386	491	550.0	755
Total Suspended Solids (mg/L)	mg/L	1		0	3.0	9	99.2	2195	0	7.6	13.5	48.2	544	0.1	4	10.0	16.0	57	1	2	5	11.6	56
Bicarbonate Alkalinity as CaCO3	mg/L	1		10	46.0	83	137.8	178	10	76.2	117	159.0	253	4.0	84	100.0	114.0	213	30	72.6	90.5	129.4	199
Carbonate Alkalinity as CaCO3	mg/L	1		Below LOR	Below LOR	Below LOR	Below LOR	0	3	1.0	15	Below LOR	27	9.0	Below LOR	9.0	Below LOR	9	11	1	11.5	Below LOR	12
Hydroxide Alkalinity as CaCO3	mg/L	1		Below LOR	Below LOR	Below LOR	Below LOR	0	Below LOR	Below LOR	Below LOR	Below LOR	0	Below LOR	Below LOR	Below LOR	Below LOR	0	Below LOR	Below LOR	Below LOR	Below LOR	0
Total Alkalinity as CaCO3	mg/L	1		10	46.0	83	137.8	178	10	73.8	116	152.0	253	4.0	80	100.0	114.0	222	6	73	89.5	129.4	199
Sulphate (mg/L)	mg/L	1		14	32.0	48	135.0	735	5	26.4	46	69.2	171	4.0	33.4	41.0	47.0	113	10	27	47	64.8	102
Chloride	mg/L	1		7	28.8	86	136.0	704	8	37.6	66.5	150.4	360	12.0	45.4	52.0	69.0	165	24	44	53	67.4	118
Calcium	mg/L	1	1000	3	11.2	19.5	24.0	170	5	14.8	22.5	29.6	43	1.0	22.4	26.0	29.0	41	10	17	22	27.0	42
Magnesium	mg/L	1		3	11.2	19.5	26.0	136	3	11.6	18	28.4	41	1.0	13	15.0	18.0	36	8	14	17	19.4	29
Potassium	mg/L	1		2	2.0	3	4.0	25	2	3.0	5	11.2	28	3.0	4	4.0	5.0	8	2	4	5	7	14
Sodium	mg/L	1		12	38.6	86	100.6	365	9	45.0	65	104.0	204	5.0	38	44.0	54.4	118	22	37.6	46	60.4	88
Dissolved Arsenic (mg/L)	mg/L	1	0.013	0.001	0.0	0.001	0.003	0.004	0.001	0.0	0.002	0.002	0.003	0.0	0.001	0.0	0.0	0.002	0.001	0.001	0.001	0.001	0.002
Dissolved Cadmium (mg/L)	mg/L	0.1	0.0002	0	0.0	Below LOR	Below LOR	0.0000	0.0001	0.0	0.0001	0.0002	0.0002	0.0	0.00014	0.0	0.0	0.0002	0.0002	0.00014	0.0002	0.0002	0.0002
Dissolved Cobalt (mg/L)	mg/L	1	ID	0.001	0.0	0.002	0.005	0.017	0.001	0.0	0.002	0.003	0.004	0.0	0.001	0.0	0.0	0.006	0.001	0.001	0.002	0.002	0.002
Dissolved Copper (mg/L)	mg/L	1	0.0014	0.001	0.0	0.002	0.004	0.009	0.001	0.0	0.002	0.005	0.019	0.0	0.001	0.0	0.0	0.005	0.001	0.001	0.001	0.0020	0.02
Dissolved Iron (mg/L)	mg/L	50	ID	0.06	0.1	0.19	0.528	1.230	0.06	0.1	0.225	0.520	1.15	0.1	0.14	0.2	0.5	2.93	0.05	0.08	0.15	0.284	0.84
Dissolved Lead (mg/L)	mg/L	1	0.0034	0.001	0.0	0.0015	0.002	0.002	0.007	0.0034	0.007	0.007	0.007	Below LOR	Below LOR	Below LOR	Below LOR	0	Below LOR	Below LOR	Below LOR	Below LOR	0
Dissolved Manganese (mg/L)	mg/L	1	1.9	0.042	0.1	0.293	0.838	3.070	0.005	0.1	0.2185	0.419	2.91	0.0	0.1378	0.2	0.4	1.08	0.008	0.0704	0.1385	0.286	0.751
Dissolved Nickel (mg/L)	mg/L	1	0.011	0.001	0.0	0.004	0.006	0.011	0.001	0.0	0.0035	0.005	0.011	0.0	0.001	0.0	0.0	0.014	0.001	0.001	0.002	0.002	0.043
Dissolved Zinc (mg/L)	mg/L	5	0.008	0.006	0.0	0.008	0.017	0.029	0.005	0.0	0.009	0.028	0.206	0.0	0.008	0.0	0.0	0.13	0.005	0.006	0.01	0.024	0.478
Ammonia (mg/L)	mg/L	0.01	0.9	0.02	0.0	0.03	0.1	0.75	0.02	0.0	0.06	0.1	1.87	0.0	0.03	0.0	0.1	0.12	0.01	0.02	0.03	0.0	0.05
Nitrite as N	mg/L	0.01	30	0.03	0.0	0.035	0.0	0.04	0.02	0.0	0.045	0.1	0.06	0.0	0.01	0.0	0.0	0.05	Below LOR	Below LOR	Below LOR	Below LOR	0
Nitrate (mg/L)	mg/L	0.01	0.4	0.02	0.0	0.05	0.1	0.4	0.01	0.0	0.045	0.3	2.26	0.0	0.03	0.1	0.2	0.74	0.01	0.012	0.03	0.1	0.15
Nitrite + Nitrate as N	mg/L	0.01	430	0.02	0.0	0.05	0.1	0.46	0.01	0.0	0.06	0.3	2.32	0.0	0.03	0.1	0.2	0.74	0.01	0.012	0.03	0.1	0.15
Total Kjeldahl Nitrogen (as N)	mg/L	0.1		0.2	0.4	0.8	1.4	10.3	0.2	0.3	0.95	2.1	11.6	0.1	0.2	0.4	0.9	4.39	0.1	0.2	0.4	0.6	5.49
Total Nitrogen (mg/L)	mg/L	0.1	0.25	0.2	0.4	0.7	1.2	10.7	0.2	0.5	1	2.2	11.6	0.1	0.3	0.6	0.9	3.8	0.1	0.2	0.4	0.6	1.4
Total Phosphorus (mg/L)	mg/L	0.01	0.02	0.01	0.0	0.045	0.2	2.62	0.01	0.0	0.07	0.2	2.2	0.0	0.02	0.0	0.1	1.85	0.01	0.012	0.03	0.1	0.7
Ionic Balance	%	0.01		0.13	0.6	1.52	3.6	25.90	0.15	0.9	1.74	3.8	30.8	0.2	0.724	1.4	3.0	7.74	0.24	0.938	1.94	4.13	6.16
Total Anions	meq/L	0.01		1	3.0	6.805	14.5	163.00	2.36	3.6	5.355	8.8	199	2.5	4.064	4.4	4.7	98	2.20	3.926	4.515	5.284	125
Total Cations	meq/L	0.01		1.8	4.1	6.82	12.2	35.60	2.58	4.2	5.54	8.6	14.8	2.8	4.084	4.4	4.8	5.7	2.43	3.728	4.59	5.44	7.84

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Table A1.2
Monitoring Results Statistical Summary: Lawsons Creek

Watercourse																																																																																																																																																																																																																																																																																																																																																																																							
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Attachment 2

Analytical Results by Monitoring Location

(Total No. of pages including blank pages = 32)

Table A2.1	Monitoring Results: Hawkins Creek (Upstream)	BSW 13
Table A2.2	Monitoring Results: Hawkins Creek (Mid 1)	BSW 11
Table A2.3	Monitoring Results: Hawkins Creek (Mid 2)	BSW 07
Table A2.4	Monitoring Results: Hawkins Creek (Downstream 1)	BSW 12
Table A2.5	Monitoring Results: Hawkins Creek (Downstream 2)	BSW 19
Table A2.6	Monitoring Results: Lawsons Creek (Upstream 1)	BSW 28
Table A2.7	Monitoring Results: Lawsons Creek (Upstream 2)	BSW 22
Table A2.8	Monitoring Results: Lawsons Creek (Upstream 3)	BSW 21
Table A2.9	Monitoring Results: Lawsons Creek (Downstream 1)	BSW 20

Note: This Attachment is only available on the digital version of this document



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Table A2.1
Monitoring Results: Hawkins Creek (Upstream) BSW 13

Page 1 of 2

Sampling Date																										
Parameter	Unit	LOR	Mean	28/06/12	18/07/12	16/08/12	13/09/12	18/10/12	21/11/12	20/12/12	19/02/13	20/03/13	15/04/13	15/05/13	20/06/13	20/08/13	19/11/13	20/02/14	19/05/14	19/08/14	19/11/14	04/02/15	01/05/15	07/08/15	03/02/16	
pH Value	pH Unit	0.01	7.4	7.8	7.8	7.8	7.9	7.7	8.5	7.4	7.9	7.3	7.4	7.3	7.1	7.5	7.4	7	6.8	7	7.8	7.3	6.6	6.9	9	
Electrical Conductivity @ 25°C	µS/cm	1	768	690	535	635	750	765	525	840	725	610	655	605	825	835	664	209	572	1210	1380	356	259	312	211	
Suspended Solids (SS)	mg/L	1	125							<5	4	6	5	4	13	4	0.07	376	9	13	71	2195	140	190	175	
Bicarbonate Alkalinity as CaCO3	mg/L	1	92								142	143	133	173	93	127	163	12	57	78	178	75	30	31	83	
Carbonate Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Hydroxide Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Total Alkalinity as CaCO3	mg/L	1	91								142	143	133	173	93	127	146	12	57	78	178	75	30	31	83	
Sulfate as SO4 - Turbidimetric	mg/L	1	103	48	41	37	39	35	34	72	66	43	38	32	107	97	48	50	74	192	234	98	55	14	14	
Chloride	mg/L	1	119	110	87	115	145	122	53	136	101	85	91	68	122	133	82	23	84	213	230	28	23	7	12	
Calcium	mg/L	1	26	17	14	16	21	20	17	24	18	19	20	20	20	22	14	6	13	36	47	24	10	10	7	
Magnesium	mg/L	1	25	22	18	20	25	21	17	22	21	20	19	18	26	26	15	5	13	35	39	20	9	10	7	
Potassium	mg/L	1	4	2	3	2	2	2	3	3	3	2	4	4	4	4	2	4	2	7	11	25	6	4	2	
Sodium	mg/L	1	95	79	64	81	99	96	69	<0.001	98	85	92	78	98	107	98	29	86	157	193	89	31	38	19	
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.004	0.001	<0.001	<0.001	
Cadmium	mg/L	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Cobalt	mg/L	0.001	0.004								0.002	0.003	0.001	0.006	<0.001	0.002	<0.001	0.002	<0.001	0.002	0.001	0.003	0.001	0.001	<0.001	
Copper	mg/L	0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	0.004	0.005	0.002	0.001	0.003	0.009	0.007	0.002	0.002	
Iron	mg/L	0.05	0.310	0.08	0.25	0.17	0.22	0.13	0.1	<0.05	<0.05	0.11	0.11	0.6	0.27	0.1	<0.05	0.08	<0.05	0.35	<0.05	0.1	1.23	0.09	0.06	
Lead	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	<0.001	<0.001	
Manganese	mg/L	0.001	0.561	0.068	0.054	0.046	0.214	0.263	0.065	0.216	0.455	0.795	0.348	3.07	0.227	0.668	0.197	0.59	0.042	0.903	0.581	0.286	0.291	0.546	0.113	
Nickel	mg/L	0.001	0.005	<0.001	<0.001	0.002	0.002	0.003	0.004	0.001	0.004	0.006	0.005	0.006	0.002	0.002	0.006	0.005	0.002	0.004	0.006	0.01	0.008	0.004	0.003	
Zinc	mg/L	0.005	0.011	<0.005	<0.005	0.008	<0.005	0.006	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	0.013	0.006	0.017	0.018	0.029	<0.005	<0.005	
Ammonia as N	mg/L	0.01	0.12								0.02	<0.01	<0.01	<0.01	0.03	0.04	0.02	0.75	0.04	<0.01	0.18	0.66	0.02	<0.01	0.02	
Nitrite as N	mg/L	0.01	0.04								<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	
Nitrate as N	mg/L	0.01	0.10								0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.42	<0.01	<0.01	0.05	0.36	<0.01	0.02	0.18	
Nitrite + Nitrate as N	mg/L	0.01	0.11								0.06	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.46	<0.01	<0.01	0.05	0.39	<0.01	0.02	0.18	
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.4								0.6	1	0.4	0.5	0.6	1.1	6.25	3.3	0.6	1.1	1.9	10.3	1.4	0.2	0.8	
Total Nitrogen as N	mg/L	0.1	1.3								0.7	1	0.4	0.5	0.6	1.1	0.6	3.8	0.6	1.1	2	10.7	1.4	0.2	1	
Total Phosphorus as P	mg/L	0.01	0.25								0.02	0.44	0.02	0.04	0.02	0.04	0.6	1.01	0.05	0.08	0.07	2.62	0.29	0.03	0.1	
Ionic Balance	%	0.01	3.13								0.7	1.52	0.81	0.58	0.18	1.95	2.55		1.39	0.51	2.36	25.9				
Total Anions	meq/L	0.01	14.95								7.06	6.15	6.55	6.04	7.53	8.31	163	1.93	5.34	11.6	14.9	4.33	2.39		2.29	
Total Cations	meq/L	0.01	9.21								6.97	6.34	6.67	5.97	7.5	7.99	6.57	2.07	5.49	11.7	14.2	7.35	2.74		1.8	

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Table A2.1 (Cont'd)
Monitoring Results: Hawkins Creek (Upstream) BSW 13

Sampling Date																															
Parameter	Unit	LOR	Mean	11/05/16	31/08/16	26/09/16	24/10/16	21/11/16	12/12/16	19/01/17	16/02/17	14/03/17	28/04/17	17/05/17	14/06/17	13/07/17	22/08/17	19/09/17	17/10/17	14/11/17	12/12/17	16/01/18	15/02/18	14/03/18	17/04/18	18/05/18	18/06/18	16/08/18	20/09/18	22/10/18	14/11/18
pH Value	pH Unit	0.01	7.4	6.9	7.4	7.4	7.5	7.1	7.3	7.4	7.8	8	7	6.6	6.8	6.9	6.8	7.0	7.2	7.70	7.0	7.2	7.4	6.8	7.0	6.5	6.7	6.6	6.8	7.3	7.3
Electrical Conductivity @ 25°C	µS/cm	1	768	123	1230	249	420	422	450	565	2600	3550	818	811	714	702	689	681	766	413	801	1080	1640	865	972	950	887	729	702	663	761
Suspended Solids (SS)	mg/L	1	125	72	5	6	7	3	3	12	22	14	2	3	18	8	16	6	11	59	4	7	20	3	3	2	12	13	5	2	16
Bicarbonate Alkalinity as CaCO3	mg/L	1	92	10	126	46	80	89	107	135	109	80	67	46	61	62	64	69	92	106	87	32	46	23	48	38	87	55	58	58	66
Carbonate Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	91	10	126	46	80	89	107	135	109	80	67	46	61	62	64	69	92	106	87	32	46	23	48	38	87	55	58	58	66
Sulfate as SO4 - Turbidimetric	mg/L	1	103	21	135	21	22	32	41	43	574	735	143	151	115	104	113	109	118	36	122	240	332	176	186	213	158	153	125	114	142
Chloride	mg/L	1	119	13	238	30	59	48	51	61	449	704	126	116	84	86	78	78	107	34	133	188	278	148	168	163	148	114	106	104	124
Calcium	mg/L	1	26	3	34	10	13	18	20	23	120	170	24	24	19	16	21	20	22	9	24	36	64	26	29	30	27	20	19	17	23
Magnesium	mg/L	1	25	3	40	8	14	15	18	19	93	136	22	24	19	18	14	22	20	10	22	32	51	22	25	27	24	19	14	14	19
Potassium	mg/L	1	4	7	6	4	3	3	3	3	4	4	3	2	2	2	6	1	4	17	3	2	4	3	2	2	2	1	<1	1	1
Sodium	mg/L	1	95	12	158	27	50	41	44	60	315	365	98	98	89	99	63	81	98	44	94	132	203	100	110	117	103	99	88	88	107
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.004	<0.001	0.003	<0.001	0.001	<0.001	<0.001	<0.001	0.001	0.002	0.009	0.017	0.01	0.011	<0.001	0.013	0.016	0.001	0.014	0.007	0.002	0.011	0.016	0.034	0.048	0.025	0.017	0.008	0.003
Copper	mg/L	0.001	0.003	0.003	<0.001	0.002	0.002	<0.001	0.002	<0.001	0.003	0.002	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	0.003	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	0.310	0.57	0.64	0.56	1.05	0.4	0.19	0.22	<0.05	<0.05	0.19	0.17	0.32	0.33	<0.05	0.40	0.42	0.32	0.66	<0.05	<0.05	0.11	0.08	0.21	0.50	0.05	<0.05	<0.05	<0.05
Lead	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.561	0.061	1.01	0.05	0.275	0.563	0.295	0.171	0.458	0.95	1.15	2.29	1.76	1.61	0.049	1.96	3.52	0.620	2.65	1.79	1.46	1.48	2.70	4.40	7.56	3.06	2.46	2.26	1.65
Nickel	mg/L	0.001	0.005	0.004	0.003	0.003	0.003	0.002	<0.001	<0.001	0.006	0.008	0.009	0.011	0.008	0.006	0.002	0.011	0.012	0.002	0.011	0.014	0.008	0.013	0.019	0.023	0.022	0.016	0.014	0.009	0.008
Zinc	mg/L	0.005	0.011	0.009	<0.005	0.02	0.006	0.016	0.007	<0.005	<0.005	0.006	0.007	0.011	0.007	0.007	<0.005	<0.005	0.009	<0.005	0.021	0.007	0.005	0.012	0.012	0.023	0.018	0.016	0.010	<0.005	<0.005
Ammonia as N	mg/L	0.01	0.12	<0.01	0.03	<0.01	0.1	<0.01	<0.01	<0.01	0.02	0.03	0.03	0.02	0.04	<0.01	<0.01	<0.01	0.01	0.10	0.01	<0.01	0.04	<0.01	0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01
Nitrite as N	mg/L	0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.02
Nitrate as N	mg/L	0.01	0.10	<0.01	0.03	0.02	0.03	0.06	<0.01	0.08	<0.01	0.02	<0.01	0.03	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	0.03	0.03	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.11	<0.01	0.03	0.02	0.03	0.06	<0.01	0.08	<0.01	0.02	<0.01	0.03	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	0.03	0.03	<0.01	0.03	<0.01	0.02	<0.01	<0.01	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.4	0.7	1.1	0.8	0.8	0.5	0.2	0.5	1.6	1.2	0.4	0.2	0.4	0.3	0.3	0.3	0.4	1.6	0.6	0.3	0.9	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.4
Total Nitrogen as N	mg/L	0.1	1.3	0.7	1.1	0.8	0.8	0.6	0.2	0.6	1.6	1.2	0.4	0.2	0.4	0.3	0.3	0.3	0.4	1.6	0.6	0.3	0.9	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.4
Total Phosphorus as P	mg/L	0.01	0.25	0.2	0.05	0.03	0.04	<0.01	<0.01	0.02	0.1	0.03	0.01	<0.01	0.02	0.05	0.25	0.02	0.04	0.27	0.04	<0.01	0.08	0.02	0.03	<0.01	0.01	0.01	<0.01	<0.01	0.02
Ionic Balance	%	0.01	3.13		0.13		4.27	5.42	5.64	0.94	1.2	1.53	3.43	1.02	3.64	6.47	6.75	4.17	1.42	2.76	5.63	3.38	2.03	4.83	6.87	5.00	7.91	4.21	6.49	4.97	2.52
Total Anions	meq/L	0.01	14.95	1	12	2.51	3.72	4.99	14.5	17.7	26.8	36.8	7.87	7.34	5.98	5.83	5.83	5.85	7.31	3.83	8.03	10.9	15.7	8.30	9.57	9.79	9.20	7.50	6.75	6.47	7.77
Total Cations	meq/L	0.01	9.21	2.8	4.05	5.56	13	18	27.4	35.6	7.35			7.49	6.43	6.64	5.09	6.36	7.11	3.62	7.17	10.2	16.3	7.53	8.34	8.86	7.85	6.89	5.93	5.85	7.39

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Table A2.2
Monitoring Results: Hawkins Creek (Mid 1) BSW 11

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Sampling Date																								
Parameter	Unit	LOR	Mean	28/06/2012	18/07/2012	16/08/2012	13/09/2012	17/10/2012	21/11/2012	20/12/2012	19/02/2013	19/03/2013	15/04/2013	15/05/2013	4/02/2015	19/06/2013	21/08/2013	19/11/2013	20/02/2014	21/05/2014	19/08/2014	19/11/2014	28/04/2015	4/08/2015
pH Value	pH Unit	0.01	7.4	7.5	7.5	7.7	7.6	7.5	7.2	7.2	6.8	6.9	7	7.1	7.6	6.9	7.7	7.8	6.5	6.8	7.1	7.3	6.70	6.4
Electrical Conductivity @ 25°C	µS/cm	1	670	730	540	680	800	750	520	500	475	565	550	520	873	640	1290	1110	370	372	380	640	544.00	105
Suspended Solids (SS)	mg/L	1	47							57	5	3	3	5	544	5	12	0.07	271	7	13	266	139	18
Bicarbonate Alkalinity as CaCO3	mg/L	1	122								114	123	107	133	249	78	152	199	10	108	94	253	15	18
Carbonate Alkalinity as CaCO3	mg/L	1	15								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	119								114	123	107	133	249	78	152	32	10	108	94	253	15.00	18
Sulfate as SO4 - Turbidimetric	mg/L	1	52	61	49	48	57	40	44	45	42	61	44	46	22	74	140	76	75	24	32	18	171.00	12
Chloride	mg/L	1	103	117	81	115	145	132	52	45	50	68	68	56	117	92	237	195	53	33	30	58	38	8
Calcium	mg/L	1	23	19	16	18	22	24	27	26	20	26	26	26	19	16	32	29	15	17	14	38	30	5
Magnesium	mg/L	1	20	24	19	20	26	23	17	16	14	18	17	17	16	16	38	31	10	12	10	22	20	3
Potassium	mg/L	1	7	3	4	2	3	3	3	3	4	3	4	4	9	5	5	6	8	8	5	14	12.00	5
Sodium	mg/L	1	79	89	68	88	104	104	55	<0.001	54	69	65	58	49	79	175	147	47	45	42	68	46.00	9
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001
Cadmium	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00	<0.0001
Cobalt	mg/L	0.001	0.002								<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.003	<0.001	0.002
Copper	mg/L	0.001	0.004	<0.001	<0.001	<0.001	<0.001	0.008	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.019	0.002	<0.001	0.003	0.013	0.003	0.005	0.003	0.005	0.002
Iron	mg/L	0.05	0.336	0.15	0.33	0.21	0.14	0.3	<0.05	<0.05	0.2	0.07	0.08	0.13	0.37	0.42	<0.05	<0.05	0.12	1.15	0.2	<0.05	0.09	0.45
Lead	mg/L	0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.391	0.06	0.073	0.097	0.233	0.258	0.348	0.244	0.241	0.105	0.126	0.231	0.419	0.093	0.179	0.005	0.629	0.354	0.216	2.91	0.69	0.257
Nickel	mg/L	0.001	0.003	<0.001	0.001	0.001	0.001	0.005	<0.001	<0.001	0.001	0.001	<0.001	<0.001	0.011	0.002	0.001	0.003	0.006	0.005	0.004	0.007	0.004	0.004
Zinc	mg/L	0.005	0.025	<0.005	<0.005	<0.005	<0.005	0.029	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.206	0.011	<0.005	<0.005	<0.005	0.025	0.032	0.008	0.03	0.007
Ammonia as N	mg/L	0.01	0.19								<0.01	0.02	<0.01	<0.01	0.52	0.03	<0.01	0.07	0.28	0.08	<0.01	1.23	0.29	0.1
Nitrite as N	mg/L	0.01	0.04								<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.06	0.06	<0.01
Nitrate as N	mg/L	0.01	0.19								0.07	0.02	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.93	0.08	0.08	0.02	2.26	0.02
Nitrite + Nitrate as N	mg/L	0.01	0.20								0.07	0.02	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.96	0.08	0.08	0.08	2.32	0.02
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.8								0.3	0.3	<0.1	0.2	11.6	0.7	0.6	10.6	2.1	2	1.3	5.6	2	0.5
Total Nitrogen as N	mg/L	0.1	1.7								0.4	0.3	<0.1	0.2	11.6	0.7	0.6	2.2	3.1	2.1	1.4	5.7	4.3	0.5
Total Phosphorus as P	mg/L	0.01	0.19								0.03	<0.01	<0.01	<0.01	0.87	0.04	0.01	2.2	0.36	0.16	0.08	0.3	0.22	0.05
Ionic Balance	%	0.01	2.97								0.4	1.82	1.74	1.19	30.8	0.15	0.71	2.39	2.11	1.15	1.23	0.32	5.00	1.62
Total Anions	meq/L	0.01	11.59								4.56	5.65	5.43	5.19	8.73	5.69	12.6	199	3.66	4.09	3.39	7.07	4.93	2.36
Total Cations	meq/L	0.01	6.78								4.6	5.86	5.63	5.32	4.63	5.68	12.5	11.1	3.82	4	3.48	7.02	5.45	8.11

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Table A2.2 (Cont'd)
Monitoring Results: Hawkins Creek (Mid 1) BSW 11

Sampling Date																												
Parameter	Unit	LOR	Mean	2/02/2016	11/05/2016	1/09/2016	26/09/2016	24/10/16	21/11/2016	12/12/2016	19/01/217	16/02/2017	14/03/2017	28/04/2017	17/05/2017	01/09/2016	14/06/2017	13/07/2017	22/08/2017	19/09/2017	17/10/2017	15/11/2017	15/11/2017	12/12/2017	16/01/2018	15/02/2018	15/03/2018	17/04/2018
pH Value	pH Unit	0.01	7.4	7.1	7.1	7.5	7.4	7.5	7.6	7.2	7.4	7.2	7.6	7.2	7.1	7.5	7.2	7.2	7.6	7.9	8.7	8.2	8.2	7.5	8.3	8.4	7.5	7.6
Electrical Conductivity @ 25°C	µS/cm	1	670	265	267	810	273	381	570	556	565	535	530	576	569	810	587	704	980	991	1450	1560	1570	592	857	1260	332	289
Suspended Solids (SS)	mg/L	1	47	54	110	8	8	10	8	16	12	13	16	18	20	8	14	10	16	72	11	25	23	11	12	25	15	16
Bicarbonate Alkalinity as CaCO3	mg/L	1	122	55	85	107	50	78	116	120	135	120	118	116	117	107	120	125	122	146	188	222	217	75	159	242	73	94
Carbonate Alkalinity as CaCO3	mg/L	1	15	3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	27	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	119	59	85	107	50	78	116	120	135	120	118	116	117	107	120	125	122	146	215	222	217	75	159	242	73	94
Sulfate as SO4 - Turbidimetric	mg/L	1	52	43	5	95	18	22	31	47	43	46	42	60	50	95	53	60	74	62	76	45	44	54	62	44	27	9
Chloride	mg/L	1	103	13	24	132	35	48	72	62	61	54	64	65	54	132	62	84	181	162	339	359	360	102	154	242	36	31
Calcium	mg/L	1	23	8	10	20	10	12	19	21	23	25	22	26	25	20	28	25	30	37	41	43	42	19	29	34	12	13
Magnesium	mg/L	1	20	6	8	30	8	13	18	19	19	15	15	17	17	30	18	18	26	30	40	41	41	17	25	35	9	10
Potassium	mg/L	1	7	8	20	8	3	3	2	3	3	3	3	4	3	8	4	5	6	4	15	15	14	10	15	28	9	12
Sodium	mg/L	1	79	12	16	102	31	45	68	59	60	57	56	59	59	102	61	87	110	116	184	204	201	70	101	166	32	26
Arsenic	mg/L	0.001	0.002	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.002	<0.001	<0.001	0.003	<0.001	0.001
Cadmium	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.002	<0.001	0.003	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.003	0.002	0.004	<0.001	<0.001	0.001	<0.001	0.001
Copper	mg/L	0.001	0.004	0.001	0.002	0.005	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.001	0.002	0.001	0.002	0.001	<0.001	0.003	0.002	0.002	0.003	0.003
Iron	mg/L	0.05	0.336	0.07	0.44	0.52	0.62	0.82	0.55	0.06	0.22	0.08	0.06	0.07	<0.05	0.52	<0.05	0.08	0.23	<0.05	1.13	0.33	0.44	0.9	0.07	0.3	0.16	0.69
Lead	mg/L	0.001	0.007	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.391	0.119	1.1	0.089	0.076	0.19	0.223	0.221	0.171	0.122	0.118	0.203	0.165	0.089	0.18	0.216	0.312	0.366	1.76	1.54	1.53	0.431	0.088	0.658	0.016	0.237
Nickel	mg/L	0.001	0.003	0.001	0.007	0.004	0.003	0.003	0.004	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.004	0.001	0.002	0.002	0.002	0.004	0.005	0.004	0.005	0.003	0.004	0.003	0.004
Zinc	mg/L	0.005	0.025	0.012	0.006	0.009	<0.005	<0.005	0.006	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.009	<0.005	0.018	<0.005	<0.005	<0.005	<0.005	0.005	0.005	<0.005	<0.005	<0.005	<0.005
Ammonia as N	mg/L	0.01	0.19	0.03	1.87	0.06	0.05	0.05	<0.01	<0.01	<0.01	0.02	0.02	0.03	0.03	0.06	0.05	0.02	0.04	0.04	0.09	0.06	0.07	0.03	<0.01	0.09	<0.01	0.15
Nitrite as N	mg/L	0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Nitrate as N	mg/L	0.01	0.19	0.05	0.02	0.01	<0.01	0.08	0.04	0.17	0.08	0.13	0.28	0.32	0.37	0.01	0.31	0.29	0.02	0.02	<0.01	0.03	<0.01	<0.01	0.02	0.04	0.01	0.03
Nitrite + Nitrate as N	mg/L	0.01	0.20	0.05	0.02	0.01	<0.01	0.08	0.04	0.17	0.08	0.13	0.28	0.32	0.37	0.01	0.31	0.29	0.02	0.02	<0.01	0.03	<0.01	<0.01	0.02	0.04	0.01	0.05
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.8	0.8	4.6	0.2	1	0.9	0.9	0.3	0.5	0.3	0.4	0.5	0.4	0.2	0.3	0.5	1.1	1	1.8	2.2	2	1.7	1.2	3.6	1.6	2.1
Total Nitrogen as N	mg/L	0.1	1.7	0.8	4.6	0.2	1	1	0.9	0.5	0.6	0.4	0.7	0.8	0.8	0.2	0.6	0.8	1.1	1	1.8	2.2	2	1.7	1.2	3.6	1.6	2.2
Total Phosphorus as P	mg/L	0.01	0.19	0.09	0.53	0.01	0.05	0.04	<0.01	0.02	0.02	0.01	<0.01	0.03	0.02	0.01	0.02	0.06	0.1	0.07	0.07	0.13	0.11	0.11	0.04	0.21	0.11	0.13
Ionic Balance	%	0.01	2.97		1.67		4.7	4.26	1.25	0.79	1.61	1.95	0.33		3.8	1.67	3.53	4.11	2.88	3.76	5.88	2.38	2.79	1.32	3.1	0.25	1.24	
Total Anions	meq/L	0.01	11.59	2.48	7.84	2.36	3.37	4.99	5.12	5.31	4.88	5.04	5.4		4.9	7.84	5.25	6.12	9.08	8.78	15.4	15.5	15.4	5.5	8.81	12.6	3.04	2.94
Total Cations	meq/L	0.01	6.78	2.58	3.7	5.44	5.25	5.4	5.04	4.84	5.36				5.29	8.11	5.63	6.64	8.58	9.46	13.7	14.8	14.6	5.65	8.28	12.5	2.96	2.91

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Table A2.3
Monitoring Results: Hawkins Creek (Mid 2) BSW 07

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			Sampling Date																											
Parameter	Unit	LOR	Mean	28/06/2012	18/07/2012	15/08/2012	13/09/2012	17/10/2012	21/11/2012	20/12/2012	18/02/2013	19/03/2013	15/04/2013	15/05/2013	19/06/2013	21/08/2013	19/11/2013	17/02/2014	20/05/2014	19/08/2014	21/11/2014	5/02/2015	28/04/2015	4/08/2015	13/10/2015	2/02/2016	11/05/2016	30/08/2016		
pH Value	pH Unit	0.01	6.9	7	6.8	7.3	7.6	6.9	6.9	6.8	6.7	6.7	6.6	6.8	6.8	6.9	7	6.6	6.4	6.7	6.70	6.5	6.6	6.60	8.10	6.50	6.60	7.1		
Electrical Conductivity @ 25°C	µS/cm	1	492	740	525	635	645	575	500	460	430	460	435	450	535	600	460	456	446	452	478.00	507	495	526.00	525.00	523.00	618.00	925		
Suspended Solids (SS)	mg/L	1	13							16	3	3	3	<2	<2	2	0.05	57	12	10	15.00	12	44	10.00	23.00	55.00	14.00	7		
Bicarbonate Alkalinity as CaCO3	mg/L	1	100								100	97	97	100	79	95	98	95	84	79	109.00	96	80	68.00	111.00	98.00	113.00	114		
Carbonate Alkalinity as CaCO3	mg/L	1	9								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1			
Hydroxide Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1			
Total Alkalinity as CaCO3	mg/L	1	98								100	97	97	100	79	95	6	95	84	79	109.00	96	80	68.00	111.00	98.00	113.00	114		
Sulfate as SO4 - Turbidimetric	mg/L	1	43	56	47	47	48	37	42	45	40	44	38	44	57	67	43	38	46	43	44.00	46	57	50.00	38.00	46.00	41.00	113		
Chloride	mg/L	1	59	110	76	99	106	95	45	45	47	55	52	51	68	86	54	53	53	50	59.00	59	59	42.00	64.00	80.00	88.00	165		
Calcium	mg/L	1	26	22	16	20	23	23	27	27	19	24	24	25	19	25	24	29	26	23	36.00	32	33	33.00	37.00	37.00	41.00	29		
Magnesium	mg/L	1	16	25	18	20	21	17	15	15	13	15	13	14	14	18	14	15	15	13	16.00	17	18	17.00	20.00	20.00	20	33		
Potassium	mg/L	1	5	3	4	3	3	4	4	5	6	5	5	5	4	4	5	7	5	4	5.00	5	6	4.00	5.00	8.00	6	6		
Sodium	mg/L	1	47	92	62	77	75	70	44	<0.001	44	43	44	44	54	66	44	48	44	40	38.00	38	44	45.00	48.00	45.00	48.00	118		
Arsenic	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			
Cobalt	mg/L	0.001	0.002								<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Copper	mg/L	0.001	0.002	0.004	<0.001	0.001	<0.001	0.005	<0.001	<0.001	0.001	0.005	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	0.00	<0.001	0.004		
Iron	mg/L	0.05	0.388	0.2	0.31	0.23	0.14	0.28	0.19	0.17	0.16	2.93	0.32	0.17	0.5	0.25	0.06	0.22	0.15	0.56	0.14	0.92	0.2	0.47	0.21	0.12	0.27	0.44		
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Manganese	mg/L	0.001	0.309	0.072	0.082	0.107	0.149	0.233	0.213	0.231	0.18	0.102	0.155	0.16	0.146	0.208	<0.001	0.87	0.201	0.24	1.08	0.457	0.081	0.23	0.33	0.24	0.17	0.143		
Nickel	mg/L	0.001	0.003	0.001	0.001	0.001	0.002	0.011	<0.001	<0.001	0.001	0.014	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.004			
Zinc	mg/L	0.005	0.022	0.012	<0.005	<0.005	<0.005	0.103	0.009	<0.005	<0.005	0.021	<0.005	<0.005	0.008	<0.005	0.008	0.033	0.018	0.009	0.01	0.009	0.014	0.01	0.01	0.03	0.011	0.009		
Ammonia as N	mg/L	0.01	0.05								<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.04	0.06	0.02	<0.01	0.08	<0.01	0.04	0.05	0.03	0.03	<0.01	0.04		
Nitrite as N	mg/L	0.01	0.02								<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	<0.01			
Nitrate as N	mg/L	0.01	0.12								0.1	0.06	0.02	0.02	0.03	0.04	0.04	0.01	0.01	0.01	0.03	0.02	0.13	0.19	0.05	0.20	<0.01	0.06		
Nitrite + Nitrate as N	mg/L	0.01	0.12								0.1	0.06	0.02	0.02	0.03	0.04	0.04	0.01	0.01	0.01	0.03	0.02	0.13	0.19	0.05	0.20	<0.01	0.06		
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.7								0.3	0.3	<0.1	0.1	0.9	0.2	4.39	2	0.4	0.2	1.50	0.1	3.7	0.10	0.90	0.80	<0.1	1		
Total Nitrogen as N	mg/L	0.1	0.7								0.4	0.4	<0.1	0.1	0.9	0.2	0.8	2	0.4	0.2	1.50	0.1	3.8	0.30	1.00	1.00	<0.1	1.1		
Total Phosphorus as P	mg/L	0.01	0.14								0.02	<0.01	<0.01	<0.01	0.18	0.07	0.8	1.85	0.04	0.04	0.05	0.06	0.38	0.01	0.10	0.20	0.45	0.05		
Ionic Balance	%	0.01	2.01								0.88	0.27	1.32	1	1.44	0.16	0.16	3.07	0.76	2.21	1.41	2.54	7.74			4.46	2.95	0.86		
Total Anions	meq/L	0.01	6.83								4.16	4.41	4.2	4.35	4.68	5.72	98	4.65	4.5	3.88	4.76	4.54	4.45			5.17	5.59	9.28		
Total Cations	meq/L	0.01	4.46								4.09	4.43	4.31	4.44	4.55	5.7	4.38	4.95	4.57	4.06	4.89	4.78	5.2			5.65	2.76	3.62		

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Table A2.3 (Cont'd)
Monitoring Results: Hawkins Creek (Mid 2) BSW 07

			Sampling Date																													
Parameter	Unit	LOR	Mean	27/09/2016	24/10/2016	21/11/2016	12/12/2016	19/01/2017	16/02/2017	14/03/2017	28/04/2017	17/05/2017	14/06/2017	14/07/2017	22/08/2017	19/09/2017	17/10/2017	14/11/2017	12/12/2017	16/01/2018	15/02/2018	15/03/2018	17/04/2018	18/05/2018	18/06/2018	18/06/2018	18/07/2018	16/08/2018	20/09/2018	22/10/2018	22/10/2018	14/11/2018
pH Value	pH Unit	0.01	6.9	6.60	7.4	6.60	7.90	8.00	6.9	7	7	6.9	6.9	6.9	6.9	6.7	6.9	6.9	6.6	6.8	6.9	6.8	6.9	6.8	6.9	7	6.8	7.0	7.0	6.9	7.0	6.8
Electrical Conductivity @ 25°C	µS/cm	1	492	127.00	385	73.00	600.00	793.00	476	451	459	450	455	500	533	464	478	458	463	449	464	439	425	446	436	431	437	420	450	445	445	462
Suspended Solids (SS)	mg/L	1	13	4.00	8	18.00	21.00	12.00	8	6	14	6	8	9	10	16	12	16	6	9	20	16	10	6	4	4	4	4	6	11	12	15
Bicarbonate Alkalinity as CaCO3	mg/L	1	100	8.00	79	4.00	148.00	213.00	114	110	101	96	92	93	94	100	121	115	104	114	123	127	116	107	100	101	92	112	96	117	121	127
Carbonate Alkalinity as CaCO3	mg/L	1	9	<1	<1	<1	<1	9	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	98	8.00	79	4.00	148.00	222.00	114	110	101	96	92	93	94	100	121	115	104	114	123	127	116	107	100	101	92	112	96	117	121	127
Sulfate as SO4 - Turbidimetric	mg/L	1	43	25.00	22	4.00	77.00	81.00	39	35	39	38	39	44	43	36	36	33	44	28	29	26	27	33	34	34	36	35	31	27	26	32
Chloride	mg/L	1	59	13.00	46	12.00	44.00	69.00	48	53	50	43	47	55	65	44	49	46	54	46	48	42	51	56	48	48	48	51	62	53	53	53
Calcium	mg/L	1	26	5.00	13	1.00	32.00	40.00	26	22	24	25	25	23	25	24	27	26	27	28	29	27	27	29	26	26	25	27	26	26	28	
Magnesium	mg/L	1	16	4	13	1	24	36	14	14	13	14	14	14	15	12	18	14	17	14	15	12	12	14	12	12	12	13	12	13	14	
Potassium	mg/L	1	5	4	3	6	3	4	4	4	4	4	5	4	4	4	6	7	4	4	5	4	5	5	4	4	3	4	3	4	4	3
Sodium	mg/L	1	47	10.00	42	5.00	46.00	70.00	45	44	42	40	42	56	52	40	42	38	40	40	38	38	38	40	36	37	36	38	37	37	36	38
Arsenic	mg/L	0.001	0.001	0.00	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	0.0002	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.002	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	0.001	<0.001	<0.001	0.001	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	
Copper	mg/L	0.001	0.002	0.00	0.002	<0.001	0.00	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
Iron	mg/L	0.05	0.388	0.14	0.86	0.07	0.15	0.09	0.44	0.3	0.58	0.62	0.49	0.53	0.67	0.31	0.12	0.5	0.16	0.09	0.16	2.11	0.22	0.23	0.19	0.14	0.24	0.23	0.52	0.17	0.10	0.26
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.309	0.05	0.188	0.02	0.06	0.12	0.412	0.209	0.329	0.279	0.342	0.316	0.523	0.809	0.875	0.537	0.207	0.453	0.712	0.983	0.445	0.19	0.222	0.229	0.254	0.263	0.327	0.916	0.905	0.520
Nickel	mg/L	0.001	0.003	0.002	0.002	<0.001	0.002	0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	0.022	0.13	0.009	0.01	0.023	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.011	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ammonia as N	mg/L	0.01	0.05	<0.01	0.03	<0.01	<0.01	<0.01	0.04	0.04	0.04	0.08	0.09	0.05	0.11	0.06	0.03	0.12	<0.01	<0.01	0.03	<0.01	0.04	0.02	0.04	0.02	0.04	0.02	0.03	0.02	0.04	0.06
Nitrite as N	mg/L	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.12	<0.01	0.09	0.01	0.05	<0.01	0.06	0.08	0.14	0.25	0.2	0.29	0.25	0.3	0.18	0.17	0.74	0.04	0.29	0.05	0.04	0.08	0.12	0.11	0.19	0.09	0.03	0.08	0.09	0.02
Nitrite + Nitrate as N	mg/L	0.01	0.12	<0.01	0.09	0.01	0.05	<0.01	0.06	0.08	0.14	0.25	0.2	0.29	0.25	0.3	0.18	0.17	0.74	0.04	0.29	0.05	0.04	0.09	0.12	0.12	0.19	0.09	0.03	0.08	0.09	0.02
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.7	0.6	0.7	0.5	0.8	0.7	0.4	0.3	0.5	0.3	1.2	0.4	0.3	0.4	0.4	0.8	0.2	0.2	0.6	0.1	0.3	<0.1	0.2	<0.1	0.3	0.1	0.2	0.4	0.2	0.4
Total Nitrogen as N	mg/L	0.1	0.7	0.6	0.8	0.5	0.8	0.7	0.5	0.4	0.6	0.6	1.4	0.7	0.6	0.7	0.6	1	0.9	0.2	0.9	0.2	0.3	<0.1	0.3	0.1	0.5	0.2	0.5	0.3	0.4	0.4
Total Phosphorus as P	mg/L	0.01	0.14	0.02	0.04	0.03	0.01	0.05	0.04	<0.01	0.04	0.02	0.02	0.04	0.02	0.03	0.06	0.08	0.03	0.02	0.11	0.04	0.08	0.01	<0.01	0.02	<0.01	<0.01	0.02	0.05	0.03	0.05
Ionic Balance	%	0.01	2.01		4.14	4.24	0.74	0.87	0.73	1.79	0.52	3.92	4.54	5.59	2.53	0.48	2.78	<0.01	0.78	2.73	0.53	2.08	2.4	0.7	1.33	1.03	0.82	2.71	4.12	3.73	4.93	4.67
Total Anions	meq/L	0.01	6.83	2.46	3.33	4.84	4.71	4.62	4.44	4.42	4.24	3.92	3.98	4.32	4.61	3.99	4.55	4.28	4.52	4.16	4.42	4.26	4.32	4.4	4.06	4.08	3.94	4.40	4.31	4.39	4.45	4.70
Total Cations	meq/L	0.01	4.46	5.27	4.64	4.7	4.51	4.27	4.2		NG	4.24	4.35	4.84	4.85	4.03	4.81	4.28	4.59	4.39	4.46	4.09	4.12	4.47	3.95	4	3.88	4.17	3.97	4.08	4.04	4.28

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Table A2.4
Monitoring Results: Hawkins Creek (Downstream 1) BSW 12

			Sampling Date																											
Parameter	Unit	LOR	Mean	28/06/2012	18/07/2012	15/08/2012	13/09/2012	18/10/2012	21/11/2012	20/12/2012	19/02/2013	20/03/2013	15/04/2013	15/05/2013	20/06/2013	19/08/2013	19/11/2013	18/02/2014	21/05/2014	20/08/2014	19/11/2014	5/02/2015	29/04/2015	7/08/2015	14/10/2015	3/02/2016	11/05/2016	31/08/2016		
pH Value	pH Unit	0.01	7.4	7.7	7.7	7.7	7.9	7.6	7.7	7.5	7	7	7.3	7.2	7.2	7.7	7.7	7.5	6.9	6.7	7.40	7.6	6.90	6.7	8	8.7	6.1	7.1		
Electrical Conductivity @ 25°C	µS/cm	1	492	715	410	550	585	555	480	520	355	345	420	495	535	755	552	680	444	465	552.00	571	537.00	344	473	286	480	642		
Suspended Solids (SS)	mg/L	1	9							14	<2	<2	<2	<2	4	2	<0.01	13	6	5	37.00	11	9.00	2	6	35	14	4		
Bicarbonate Alkalinity as CaCO3	mg/L	1	98								79	68	91	100	76	101	125	199	73	72	144.00	127	82.00	53	74	60	30	84		
Carbonate Alkalinity as CaCO3	mg/L	1	12								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	11	12	<1	<1		
Hydroxide Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Total Alkalinity as CaCO3	mg/L	1	97								79	68	91	100	76	101	6	199	73	72	144.00	127	82.00	53	85	73	30	84		
Sulfate as SO4 - Turbidimetric	mg/L	1	47	49	43	46	47	38	62	51	41	44	48	54	69	90	60	21	58	69	49.00	44	74.00	60	44	13	102	78		
Chloride	mg/L	1	57	106	55	83	91	84	45	46	34	38	53	56	62	118	63	78	50	51	61.00	67	60.00	24	44	42	54	80		
Calcium	mg/L	1	22	18	13	18	20	22	27	30	15	16	22	25	18	27	27	42	21	23	35.00	27	27.00	11	26	20	25	19		
Magnesium	mg/L	1	17	20	14	17	19	18	17	19	11	12	14	16	14	23	20	29	16	17	21.00	20	21	8	19	14	15	19		
Potassium	mg/L	1	6	3	5	3	4	4	4	5	7	5	6	10	5	6	4	14	6	8	6.00	5	9.00	4	8	5	9	8		
Sodium	mg/L	1	48	72	48	64	64	67	46	<0.001	33	35	46	46	54	88	55	69	47	46	50.00	50	49.00	22	40	29	39	66		
Arsenic	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.00	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Cobalt	mg/L	0.001	0.002								<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001		
Copper	mg/L	0.001	0.003	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.002	0.001	0.007	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001		
Iron	mg/L	0.05	0.209	0.16	0.3	0.16	0.11	0.2	0.14	0.16	0.14	0.1	0.07	0.1	0.38	0.05	<0.05	0.12	0.1	0.07	<0.05	<0.05	0.07	0.06	0.24	0.31	0.08	0.16		
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Manganese	mg/L	0.001	0.203	0.053	0.089	0.122	0.079	0.286	0.083	0.104	0.143	0.1	0.068	0.111	0.082	0.074	<0.001	0.134	0.078	0.094	0.01	0.008	0.11	0.022	0.217	0.181	0.361	0.058		
Nickel	mg/L	0.001	0.004	<0.001	0.002	0.002	0.001	0.043	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001	<0.001	<0.001	0.00	0.001	0.002	<0.001	0.001	0.001	0.004	0.002		
Zinc	mg/L	0.005	0.037	<0.005	0.029	0.025	<0.005	0.478	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	0.018	0.006	0.006	0.012	0.01	0.018	0.01	<0.005	0.04	0.007	0.008	0.008	0.126	0.023		
Ammonia as N	mg/L	0.01	0.03								0.02	<0.01	<0.01	<0.01	<0.01	0.02	0.04	0.03	0.04	0.01	0.05	0.02	0.02	0.02	<0.01	0.03	<0.01	0.03		
Nitrite as N	mg/L	0.01									<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		
Nitrate as N	mg/L	0.01	0.04								0.04	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.15	0.01	<0.01	<0.01	0.06	0.02	0.07	<0.01	0.02		
Nitrite + Nitrate as N	mg/L	0.01	0.04								0.04	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.15	0.01	<0.01	<0.01	0.06	0.02	0.07	<0.01	0.02		
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.6								0.2	0.2	<0.1	0.2	0.4	0.5	5.49	0.7	0.5	0.3	1.40	0.8	0.40	<0.1	0.3	0.4	0.3	0.6		
Total Nitrogen as N	mg/L	0.1	0.5								0.2	0.2	<0.1	0.2	0.4	0.5	0.7	0.7	0.5	0.4	1.40	0.8	0.40	<0.1	0.3	0.5	0.3	0.6		
Total Phosphorus as P	mg/L	0.01	0.06								0.08	<0.01	0.08	<0.01	0.05	<0.01	0.7	0.09	0.02	0.02	0.04	0.07	0.02	<0.01	0.02	0.01	0.04	0.02		
Ionic Balance	%	0.01	2.48								1.86	1.31	1.04	1.24	1.93	<0.01	0.34	6.16	2.37	2.26	1.62	0.46	5.48		3.54	1.88	0.24			
Total Anions	meq/L	0.01	7.76								3.39	3.35	4.31	4.7	4.7	7.22	125	6.93	4.35	4.54	5.62	5.34	4.87		4.41	4.25	5.56	2.2		
Total Cations	meq/L	0.01	4.73								3.27	3.44	4.4	4.82	4.53	7.22	5.52	7.84	4.56	4.75	5.80	5.3	5.44		5.59	2.43	3.49	3.99		

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Table A2.4 (Cont'd)
Monitoring Results: Hawkins Creek (Downstream 1) BSW 12

Parameter	Unit	LOR	Sampling Date																											
			Mean	26/09/2016	24/10/2016	22/11/2016	12/12/2016	20/01/2017	16/02/2017	14/03/2017	28/04/2017	17/05/2017	14/06/2017	13/07/2017	22/08/2017	19/09/2017	17/10/2017	15/11/2017	12/12/2017	16/01/2018	15/02/2018	14/03/2018	17/04/2018	18/06/2018	18/07/2018	16/08/2018	20/09/2018	22/10/2018	14/11/2018	
pH Value	pH Unit	0.01	7.4	7.4	7.4	7.1	7.3	7.4	7.5	7.4	7.4	7.3	7.4	7.4	7.6	7.6	7.6	7.5	7.3	7.8	7.8	7	7.1	7.2	7.1	7.4	7.5	7.4	7.8	
Electrical Conductivity @ 25°C	µS/cm	1	492	249	355	422	450	507	506	492	433	491	468	496	665	525	530	455	369	517	684	380	386	489	489	488	459	414	466	
Suspended Solids (SS)	mg/L	1	9	6	5	3	3	3	3	2	4	3	2	1	4	3	8	56	6	9	12	8	9	2	2	2	9	38	11	
Bicarbonate Alkalinity as CaCO3	mg/L	1	98	46	74	89	107	141	132	115	58	90	85	87	93	99	144	130	95	168	145	125	110	80	80	87	124	124	183	
Carbonate Alkalinity as CaCO3	mg/L	1	12	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Total Alkalinity as CaCO3	mg/L	1	97	46	74	89	107	141	132	115	85	90	85	87	93	99	144	130	95	168	145	125	110	80	80	87	124	124	183	
Sulfate as SO4 - Turbidimetric	mg/L	1	47	21	23	32	41	27	28	35	44	62	50	56	64	49	37	30	16	10	73	16	14	66	68	60	33	16	8	
Chloride	mg/L	1	57	30	44	48	51	55	51	60	46	42	48	52	88	58	55	42	45	53	68	40	51	55	53	60	59	45	45	
Calcium	mg/L	1	22	10	13	18	20	22	27	22	21	26	24	21	25	26	25	24	15	27	37	17	16	21	22	22	21	28		
Magnesium	mg/L	1	17	8	13	15	18	20	17	17	14	17	16	15	19	19	19	16	11	19	24	12	13	16	16	17	14	19		
Potassium	mg/L	1	6	4	3	3	3	2	3	5	5	4	5	5	5	5	8	7	6	6	6	6	6	7	6	7	5	6	7	
Sodium	mg/L	1	48	27	39	41	44	48	46	44	38	42	42	52	69	47	45	40	31	50	65	36	34	42	42	43	37	35	41	
Arsenic	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Cadmium	mg/L	0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Cobalt	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001		
Copper	mg/L	0.001	0.003	0.002	0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Iron	mg/L	0.05	0.209	0.56	0.75	0.4	0.19	0.25	0.15	0.15	0.11	0.08	0.14	0.11	0.21	0.2	0.26	0.13	0.84	0.06	<0.05	0.54	0.38	0.11	0.08	0.08	0.11	0.18	0.09	
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Manganese	mg/L	0.001	0.203	0.05	0.081	0.563	0.295	0.3	0.255	0.227	0.283	0.249	0.211	0.216	0.268	0.256	0.554	0.418	0.641	0.029	0.021	0.669	0.751	0.164	0.15	0.095	0.168	0.387	0.231	
Nickel	mg/L	0.001	0.004	0.003	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	
Zinc	mg/L	0.005	0.037	0.02	0.009	0.016	0.007	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	0.01	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Ammonia as N	mg/L	0.01	0.03	<0.01	0.04	<0.01	<0.01	<0.01	0.04	0.04	0.02	0.02	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01		
Nitrite as N	mg/L	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02		
Nitrate as N	mg/L	0.01	0.04	0.02	0.07	0.06	<0.01	0.04	<0.01	0.01	<0.01	0.03	<0.01	0.02	<0.01	<0.01	<0.01	0.05	<0.01	0.01	0.03	0.03	<0.01	<0.01	0.11	0.01	<0.01	<0.01		
Nitrite + Nitrate as N	mg/L	0.01	0.04	0.02	0.07	0.06	<0.01	0.04	<0.01	0.01	<0.01	0.03	<0.01	0.02	<0.01	<0.01	<0.01	0.05	<0.01	0.01	0.03	0.03	<0.01	<0.01	0.11	0.01	<0.01	<0.01		
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.6	0.8	0.8	0.5	0.2	0.3	0.4	0.2	0.2	<0.1	0.2	0.4	0.2	0.2	0.2	0.5	0.6	0.6	0.9	0.4	0.3	0.1	0.2	<0.1	0.2	<0.1	0.4	
Total Nitrogen as N	mg/L	0.1	0.5	0.8	0.9	0.6	0.2	0.3	0.4	0.2	0.2	<0.1	0.2	0.4	0.2	0.2	0.2	0.6	0.6	0.6	0.9	0.4	0.3	0.1	0.3	<0.1	0.2	<0.1	0.4	
Total Phosphorus as P	mg/L	0.01	0.06	0.03	0.03	<0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.11	0.04	<0.01	0.06	0.02	0.02	<0.01	<0.01	<0.01	0.02	0.02	0.02	
Ionic Balance	%	0.01	2.48	4.38	2.49	0.45	0.49	1.74	1.95	0.87		3.95	4.39	3.33	2.3	4.13	2.22	0.3	5.18	1.74	3.56	5.37	5.75	1.72	1.28	1.45	9.54	2.56	1.69	
Total Anions	meq/L	0.01	7.76	3.2	3.8	4.43	4.93	4.66	4.72	3.91		4.27	4.09	4.37	5.67	4.63	5.2	4.41	3.5	5.06	6.34	3.96	3.93	4.52	4.51	4.68	4.83	4.08	5.09	
Total Cations	meq/L	0.01	4.73	4.47	4.88	4.82	4.54	3.98				4.62	4.47	4.67	5.94	5.03	4.97	4.43	3.16	5.24	6.8	3.56	3.5	4.37	4.4	4.55	3.99	3.88	4.92	

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Table A2.5
Monitoring Results: Hawkins Creek (Downstream 2) BSW 19

			Sampling Date																																	
Parameter	Unit	LOR	Mean	19/07/2012	16/08/2012	14/09/2012	18/10/2012	21/11/2012	20/12/2012	19/02/2013	19/03/2013	16/04/2013	15/05/2013	25/06/2013	21/11/2013	20/08/2014	14/08/2015	31/08/2016	26/09/2016	26/10/2016	21/11/2016	12/12/2016	20/01/2017	16/02/2017	14/03/2017	22/08/2017	20/09/2017	17/10/2017	14/11/2017	13/12/2017	16/01/2018	14/03/2018	18/04/2018			
pH Value	pH Unit	0.01	7.1	7.4	8	7.7	7.4	7.7	7.2	7.3	7	7.2	7.3	7.5	7.2	6.20	6.5	7.2	7.3	7.6	7.3	7	7.1	6.5	6.6	7.2	7.3	7	6.7	6.7	7.1	6.4	6.8			
Electrical Conductivity @ 25°C	µS/cm	1	506	430	545	570	530	455	420	365	350	415	445	495	753	526.00	445	652	254	380	416	402	567	508	540	499	546	587	939	592	650	497	408			
Suspended Solids (SS)	mg/L	1	22						11	3	3	6	2	46	0.07	26.00	8	43	6	5	5	4	74	12	47	9	26	28	68	14	21	52	30			
Bicarbonate Alkalinity as CaCO3	mg/L	1	87							84	74	92	100	70	119	33.00	23	75	51	80	87	89	181	94	112	87	100	102	32	91	144	74	83			
Carbonate Alkalinity as CaCO3	mg/L	1								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1			
Hydroxide Alkalinity as CaCO3	mg/L	1								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1			
Total Alkalinity as CaCO3	mg/L	1	82							84	74	92	100	70	13	33.00	23	75	51	80	87	89	181	94	112	87	100	102	32	91	144	74	83			
Sulfate as SO4 - Turbidimetric	mg/L	1	56	45	46	46	35	42	35	32	40	39	45	57	71	114.00	118	87	21	29	31	34	8	43	32	42	44	45	261	63	39	89	48			
Chloride	mg/L	1	63	58	77	87	85	47	43	38	36	52	49	60	123	59.00	30	102	30	46	48	50	64	58	80	60	62	79	110	80	78	49	46			
Calcium	mg/L	1	20	14	17	20	20	22	18	14	15	18	21	17	31	14.00	21	21	10	16	16	13	20	20	20	19	23	25	52	23	23	19	15			
Magnesium	mg/L	1	17	15	16	19	17	16	13	11	12	13	14	13	27	13.00	16	22	8	14	14	14	22	16	16	16	20	20	34	18	22	14	11			
Potassium	mg/L	1	6	4	4	4	4	5	6	6	5	9	8	5	10	11	6	5	3	4	3	5	8	5	7	5	5	7	10	4	7	5	6			
Sodium	mg/L	1	51	51	61	62	64	46	<0.001	36	35	44	47	48	73	60.00	42	73	26	44	40	40	58	52	53	47	51	59	63	51	71	52	42			
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001			
Cadmium	mg/L	0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001			
Cobalt	mg/L	0.001	0.004							<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.008	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.001	<0.001	<0.001	<0.001	0.003	0.005	0.002	<0.001	0.01	0.005			
Copper	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.00	0.001	<0.001	0.002	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001			
Iron	mg/L	0.05	0.675	0.32	0.21	0.28	0.34	0.16	0.2	0.23	0.3	0.13	0.11	0.51	0.16	0.20	0.09	0.32	0.64	0.84	0.64	0.39	0.79	1.1	4.89	0.5	0.53	0.5	0.21	1.06	0.44	3.33	0.84			
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001			
Manganese	mg/L	0.001	0.442	0.106	0.082	0.109	0.186	0.038	0.183	0.038	0.032	0.036	0.009	0.032	0.001	0.86	0.177	0.063	0.058	0.099	0.12	0.048	2.58	0.838	0.956	0.172	0.176	1.16	2.28	0.942	0.432	0.624	0.819			
Nickel	mg/L	0.001	0.002	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.00	0.004	0.003	0.003	0.003	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.004	0.001	0.001	0.005	0.002			
Zinc	mg/L	0.005	0.021	0.025	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	0.014	0.041	0.061	0.014	0.019	0.006	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.026	0.006	<0.005	0.033	<0.005			
Ammonia as N	mg/L	0.01	0.05							<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.03	0.02	<0.01	0.01	0.04	0.12	<0.01	0.02	<0.01	0.06	0.01	<0.01	<0.01	0.18	0.01	<0.01	<0.01	0.02			
Nitrite as N	mg/L	0.01								<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01			
Nitrate as N	mg/L	0.01	0.04							0.06	0.03	<0.01	<0.01	<0.01	0.02	0.13	0.03	0.02	0.02	0.03	0.04	<0.01	0.03	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.02	0.07	<0.01			
Nitrite + Nitrate as N	mg/L	0.01	0.04							0.06	0.03	<0.01	<0.01	<0.01	0.02	0.13	0.03	0.02	0.02	0.03	0.04	<0.01	0.03	<0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	0.02	0.07	<0.01			
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.1							0.3	0.3	0.2	0.2	0.4	7.2	1.3	0.3	1.5	1	1.3	0.5	0.5	2.5	0.5	1	0.1	0.7	0.6	2.4	0.2	0.8	0.5	1			
Total Nitrogen as N	mg/L	0.1	0.8							0.4	0.3	0.2	0.2	0.4	1.5	1.4	0.3	1.5	1	1.3	0.5	0.5	2.5	0.5	1	0.1	0.7	0.6	2.4	0.2	0.8	0.6	1			
Total Phosphorus as P	mg/L	0.01	0.16							0.02	0.01	0.02	0.03	0.03	1.5	0.1	<0.01	0.1	0.16	0.06	<0.01	0.02	0.32	0.07	0.25	0.02	0.06	0.07	0.3	0.02	0.05	0.08	0.13			
Ionic Balance	%	0.01	2.39							1.4	0.87	0.07	1.5	1.72	0.87	0.41				6.26	0.39	3.01	0.47	3.24	3.63	1.51	4.86	4.02	4.48	4.22	2.78	2.43	4.23			
Total Anions	meq/L	0.01	9.62							3.42	3.33	4.12	4.32	4.28	119	4.70			6.19	2.3	3.5	3.74	3.9	5.59	4.41	5.16	4.3	4.66	5.2	9.18	5.39	5.89	4.71	3.96		
Total Cations	meq/L	0.01	4.75							3.32	3.39	4.11	4.45	4.13	7.33	4.66			6.16	2.36	3.97	3.77	3.67	5.54	4.7	4.8	4.44	5.14	5.64	8.39	4.95	6.22	4.49	3.63		

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Table A2.6
Monitoring Results: Lawsons Creek (Upstream 1) BSW 28

Parameter	Unit	LOR	Mean	27/09/2016	26/10/2016	21/11/2016	12/12/2016	19/01/2017	16/02/2017	16/03/2017	28/04/2017	17/05/2017	15/06/2017	14/07/2017	23/08/2017	20/09/2017	18/10/2017	15/11/2017	12/12/2017	17/01/2018	15/02/2018	14/03/2018	18/04/2018	18/05/2018	18/06/2018	18/07/2018	16/08/2018	16/08/2018	20/09/2018	22/10/2018	14/11/2018	14/11/2018
pH Value	pH Unit	0.01	7.9	7.7	7.8	7.9	8	8	8.1	8.1	7.8	7.9	8	8	8.1	8.1	8	8	7.7	8	8.4	7.3	7.7	7.9	8	8.0	8.0	8.0	8.0	8.0	7.9	
Electrical Conductivity @ 25°C	µS/cm	1	980	379	522	600	791	1020	1160	1210	840	907	945	978	1030	1090	1200	1280	761	1040	1260	940	1000	1150	1180	1260	1340	1340	1200	1180	1270	1270
Suspended Solids (SS)	mg/L	1	16	7	8	21	10	14	11	17	8	8	7	9	8	18	16	16	34	32	39	10	16	30	13	12	19	20	18	38	46	46
Bicarbonate Alkalinity as CaCO3	mg/L	1	254	80	128	148	220	309	330	306	210	239	252	264	275	275	345	342	192	310	375	229	253	266	266	231	261	262	256	259	342	341
Carbonate Alkalinity as CaCO3	mg/L	1	12	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	8	5	<1	<1	24	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	
Total Alkalinity as CaCO3	mg/L	1	256	80	128	148	220	309	331	306	210	239	252	264	275	275	353	347	192	310	399	229	253	266	266	231	261	262	256	259	342	341
Sulfate as SO4 - Turbidimetric	mg/L	1	114	41	41	77	79	80	104	130	102	88	100	104	115	111	145	192	67	95	76	117	121	174	209	257	299	288	182	188	122	110
Chloride	mg/L	1	94	32	50	44	70	84	105	119	68	68	73	77	85	81	123	129	74	111	140	122	112	128	139	139	153	186	126	128	146	146
Calcium	mg/L	1	54	20	26	32	39	60	63	52	50	53	58	53	59	62	61	70	43	58	65	53	56	59	68	71	76	77	65	64	71	78
Magnesium	mg/L	1	40	14	22	24	37	43	51	53	34	37	40	35	42	46	47	54	29	42	50	38	42	43	51	54	56	57	48	47	55	59
Potassium	mg/L	1	5	3	3	3	4	6	8	9	4	3	4	4	4	3	5	5	5	6	9	7	6	5	6	5	6	6	4	5	5	6
Sodium	mg/L	1	90	33	49	46	71	84	103	120	70	80	84	103	93	97	103	124	72	100	138	88	95	94	107	110	116	117	106	103	121	132
Arsenic	mg/L	0.001	0.002	<0.001	0.001	0.001	0.002	0.003	0.003	0.003	<0.001	0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001	0.002	0.002	0.004	0.004	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.002
Cadmium	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	0.002	0.002	0.002	0.002	0.002	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	0.161	0.48	0.49	0.15	0.1	<0.05	0.06	0.08	0.05	0.06	<0.05	<0.05	0.06	0.07	0.06	<0.05	0.06	<0.05	0.07	0.53	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Lead	mg/L	0.001	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.139	0.056	0.088	0.06	0.118	0.177	0.118	0.123	0.059	0.058	0.055	0.043	0.027	0.053	0.093	0.051	0.245	0.06	0.145	1.06	0.232	0.105	0.107	0.055	0.113	0.118	0.067	0.262	0.242	0.263
Nickel	mg/L	0.001	0.002	0.003	0.004	0.002	0.001	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.003	0.002	0.002	0.003	0.002	0.002	0.002	0.001	0.003	0.002	0.002
Zinc	mg/L	0.005	0.011	0.007	<0.005	0.023	<0.005	0.006	0.012	<0.005	<0.005	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.003	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ammonia as N	mg/L	0.01	0.03	0.03	0.05	<0.01	<0.01	<0.01	0.04	0.02	0.02	0.02	0.06	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.03	0.04	0.04	<0.01	0.02	0.01	0.02	<0.01	0.05	<0.01	0.01	
Nitrite as N	mg/L	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
Nitrate as N	mg/L	0.01	0.03	0.05	0.04	0.05	<0.01	0.04	<0.01	0.01	0.06	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.03	0.02	<0.01	0.03	0.01	0.05	<0.01	<0.01	0.09	0.07	0.06	
Nitrite + Nitrate as N	mg/L	0.01	0.03	0.05	0.04	0.05	<0.01	0.04	<0.01	0.01	0.06	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.03	0.02	<0.01	0.03	0.01	0.05	<0.01	<0.01	0.09	0.07	0.06	
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.7	1	0.7	0.8	0.6	1	1	1.1	0.4	0.3	0.3	0.3	0.2	0.4	0.4	0.6	0.8	0.9	1.5	0.6	0.6	0.9	0.4	0.5	0.3	0.3	0.4	0.3	0.7	
Total Nitrogen as N	mg/L	0.1	0.7	1	0.7	0.8	0.6	1	1	1.1	0.5	0.3	0.3	0.3	0.2	0.4	0.4	0.6	0.8	0.9	1.5	0.6	0.6	0.9	0.4	0.6	0.3	0.3	0.4	0.4	0.8	
Total Phosphorus as P	mg/L	0.01	0.06	0.03	0.04	0.01	0.06	0.06	0.37	0.05	0.02	0.01	0.02	0.01	<0.01	0.02	0.02	0.05	0.07	0.06	0.15	0.06	0.05	0.07	0.08	0.02	0.01	0.02	0.03	0.02	0.05	
Ionic Balance	%	0.01	3.06	4.37	4.88	1.32	1.03	0.64	1.2	0.93	1.22	4.06	4.01	2.51	1.26	5.1	8.06	3.96	3.13	2.02	0.32	3.33	0.92	7.95	4.57	3.68	7.34	8.93	2.26	4.22	0.12	
Total Anions	meq/L	0.01	10.15	3.35	4.82	5.8	8.02	10.2	11.7	12.2	8.24	8.52	9.18	9.61	10.3	10.1	13.5	14.6	7.32	11.3	13.5	10.4	10.7	12.5	13.6	13.9	15.8	16.5	12.4	12.7	13.5	
Total Cations	meq/L	0.01	10.01	3.66	5.32	5.65	8.18	10.3	12	12.4	8.44	9.25	9.94	10.1	10.5	11.2	11.5	13.4	7.79	10.8	13.6	9.78	10.5	10.7	12.4	12.9	13.6	13.8	11.9	11.7	13.5	

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Table A2.7

Parameter		Unit	LOR	Sampling Date																																																																																																																																																																																																																																																																																																																			
				Mean	29/06/2012	18/07/2012	15/08/2012	14/09/2012	18/10/2012	21/11/2012	20/12/2012	19/03/2013	19/03/2013	15/04/2013	14/05/2013	20/06/2013	21/08/2013	19/11/2013	18/02/2014	22/05/2014	20/08/2014	20/11/2014	8/02/2015	1/05/2015	7/08/2015	14/10/2015	3/02/2016	12/05/2016	08/09/2016	27/09/2016	27/10/2016	21/11/2016	12/12/2016	19/01/2017	16/02/2017	14/03/2017	28/04/2017	18/05/2017	15/06/2017	14/07/2017	23/08/2017	20/09/2017	18/10/2017	15/11/2017	17/01/2018	16/02/2018	16/02/2018	14/03/2018	18/04/2018																																																																																																																																																																																																																																																																						
pH Value	pH Unit	0.01	7.8	7.9	7.8	8.1	7.8	8	7.8	7.8	8	7.9	7.6	7.8	7.7	7.6	7.9	8	7.9	7.4	7.5	7.40	7.7	7.7	7.90	7.70	7.70	8.50	7.8	7.5	7.4	7.6	7.4	7.6	8.4	7.9	8.1	7.6	7.7	7.8	7.8	7.8	7.9	7.9	7.90	7.9	8.2	8.1	7.5	7.6																																																																																																																																																																																																																																																																					
Electrical Conductivity @ 25°C	µS/cm	1	905	980	915	750	880	965	1040	1050	805	820	880	940	995	1040	1160	961	1040	1140	1200	945	1010	990	1060	648	992	389	300	549	565	960	1800	843	828	823	874	918	948	942	975	1000	963	896	962	964	906	911																																																																																																																																																																																																																																																																							
Suspended Solids (SS)	mg/L	1	14								73	13	3	6	6	<2	8	0.03	5	21	2	6.00	6	10	4.00	44.00	94.00	3	8	12	5	6	5	14	14	4	4	3	3	5	4	3	5	7	4	10	11	11	10																																																																																																																																																																																																																																																																						
Bicarbonate Alkalinity as CaCO3	mg/L	1	213								193	180	203	252	175	200	302	290	200	171	298.00	252	264	98.00	241.00	205.00	274	75	59	136	142	308	67	337	339	224	238	248	257	260	277	342	347	339	352	336	248	319																																																																																																																																																																																																																																																																							
Carbonate Alkalinity as CaCO3	mg/L	1	18								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	18	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1																																																																																																																																																																																																																																																																						
Hydroxide Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1																																																																																																																																																																																																																																																																					
Total Alkalinity as CaCO3	mg/L	1	211								193	180	203	252	175	200	<5	290	200	171	298.00	270	264	98.00	241.00	205.00	274	75	59	136	142	308	67	337	339	224	238	248	257	260	277	342	347	339	368	351	248	319																																																																																																																																																																																																																																																																							
Sulfate as SO4 -Turbidimetric	mg/L	1	106	173	73	122	110	111	124	74	108	121	104	90	137	138	134	51	171	195	180.00	72	99	180.00	166.00	24.00	72	49	34	45	45	45	73	359	20	15	88	80	86	88	83	77	75	67	20	16	18	115	71																																																																																																																																																																																																																																																																						
Chloride	mg/L	1	99	117	51	86	113	139	122	113	79	90	93	94	116	128	128	107	148	155.00	96	127	56.00	112.00	56.00	119	35	28	52	51	50	315	59	68	59	72	70	77	79	76	70	104	68	72	108	113	111	101																																																																																																																																																																																																																																																																							
Calcium	mg/L	1	50	40	23	36	42	51	59	54	43	67	63	63	60	63	62	63	60	63	60	63	60	63	60	63	60	63	60	63	60	63	51	51	51	56	63	59	60	55	45	45	52	53	40	41	39	36																																																																																																																																																																																																																																																																							
Magnesium	mg/L	1	38	45	24	36	39	42	45	46	42	48	46	46	46	46	48	46	46	44	48.00	48	46	44.00	48.00	26.00	42	15	12	24	23	40	63	35	37	34	3	3	3	3	3	3	3	3	3	3	3	3	3																																																																																																																																																																																																																																																																						
Potassium	mg/L	1	4	4	4	4	3	4	4	4	4	4	4	5	4	4	5	4	4	5	4.00	4	4	5.00	4.00	3.00	6	3	3	3	3	3	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3																																																																																																																																																																																																																																																																						
Sodium	mg/L	1	86	84	44	71	80	103	102	<0.001	72	80	92	86	89	98	107	105	95	114	116.00	83	101	98.00	97.00	52.00	99	36	28	51	53	106	217	74	72	68	77	78	96	84	88	90	86	84	103	105	80	82	82																																																																																																																																																																																																																																																																						
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.001	0.001	0.001	0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001	0.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<

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Table A2.8
Monitoring Results: Lawsons Creek (Updstream 3) BSW 21

		Sampling Date																											
Parameter	Unit	LOR	Mean	29/06/2012	18/07/2012	15/08/2012	14/09/2012	18/10/2012	21/11/2012	20/12/2012	19/02/2013	19/03/2013	15/04/2013	14/05/2013	20/06/2013	21/08/2013	19/11/2013	18/02/2014	22/05/2014	20/08/2014	20/11/2014	8/02/2015	1/05/2015	4/08/2015	14/10/2015	03/02/2016	12/05/2016	05/09/2016	28/09/2016
pH Value	pH Unit	0.01	7.6	7.3	7.6	8	7.9	7.7	7.7	8	7.6	7.4	7.7	7.7	7.3	7.7	8	7.8	7.3	7.2	7.40	7.5	7.50	7.10	7.6	7.4	7.7	7.2	7.5
Electrical Conductivity @ 25°C	µS/cm	1	1146	920	510	750	885	1030	1110	1380	800	805	945	1080	1280	1070	1440	1710	1260	1200	1560.00	1890	1420.00	1020.00	1380	1544	1410	272	376
Suspended Solids (SS)	mg/L	1	24							13	11	10	5	3	5	12	0.11	15	48	14	14.00	190	10.00	3.00	8	88	6	18	7
Bicarbonate Alkalinity as CaCO3	mg/L	1	257								168	155	213	316	161	195	503	390	192	133	446.00	361	289.00	72.00	149	373	281	46	72
Carbonate Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	5	<1	<1	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1									<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	222								168	155	213	316	161	195	16	390	192	133	446.00	361	289.00	72.00	154	373	281	46	72
Sulfate as SO4 - Turbidimetric	mg/L	1	157	156	75	120	112	143	133	77	118	126	101	93	248	139	114	229	236	202	201.00	314	248.00	114.00	232	214	225	38	41
Chloride	mg/L	1	132	120	57	92	124	157	132	115	87	88	97	104	159	139	129	192	152	184	195.00	236	173.00	38.00	152	159	170	30	35
Calcium	mg/L	1	58	31	20	30	37	48	59	75	36	37	52	64	50	50	74	93	70	51	95.00	104	97.00	37.00	85	101	98	11	17
Magnesium	mg/L	1	46	42	23	35	40	46	48	49	34	36	38	40	58	42	48	62	55	50	58.00	70	54	33	62	64	51	10	14
Potassium	mg/L	1	5	4	5	3	4	5	4	3	6	5	5	6	6	5	6	3	7	5	4.00	3	2.00	4.00	6	4	3	4	3
Sodium	mg/L	1	123	83	48	70	84	114	126	<0.001	79	82	107	113	123	109	177	228	128	129	192.00	225	167.00	74.00	154	190	159	26	36
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003	<0.001	<0.001	0.00	0.002	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	0.0010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.001								<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	<0.001	0.001	<0.001	0.001	0.00	0.00	<0.001	<0.001	<0.001	0.002	0.003
Iron	mg/L	0.05	0.120	0.17	0.36	0.2	0.08	0.07	<0.05	<0.05	0.13	0.09	0.07	0.06	0.09	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	0.06	0.10	<0.05	<0.05	0.61	0.55
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.285	0.125	0.129	0.146	0.419	0.575	0.61	0.117	0.452	0.29	0.317	0.31	0.458	0.245	<0.001	0.653	0.203	0.098	0.15	0.279	0.05	0.06	1.38	0.020	0.249	0.075	0.122
Nickel	mg/L	0.001	0.002	<0.001	0.002	0.001	0.002	0.001	0.001	<0.001	0.002	0.004	<0.001	<0.001	0.002	<0.001	0.001	0.001	0.001	0.001	0.00	<0.001	<0.001	0.002	0.002	<0.001	<0.001	0.003	0.004
Zinc	mg/L	0.005	0.050	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	0.304	<0.005	0.005	0.006	0.01	0.013	<0.005	<0.005	0.01	<0.005	0.006	0.008	<0.005	0.014	0.013
Ammonia as N	mg/L	0.01	0.03								<0.01	0.03	<0.01	<0.01	<0.01	0.02	0.06	0.01	0.04	0.03	0.04	0.02	0.02	<0.01	0.02	0.01	<0.01	0.12	0.04
Nitrite as N	mg/L	0.01									<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.07								0.05	0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.15	0.14	0.05	<0.01	<0.01	0.08	0.04	1.24	<0.01	0.09	<0.01
Nitrite + Nitrate as N	mg/L	0.01	0.07								0.05	0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01	0.15	0.14	0.05	<0.01	<0.01	0.08	0.04	1.24	<0.01	0.09	<0.01
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.7								0.8	1.2	0.3	0.1	0.5	0.5	15.5	0.6	0.7	0.8	1.00	0.5	0.40	0.60	0.4	0.3	0.1	1.0	1.0
Total Nitrogen as N	mg/L	0.1	0.7								0.8	1.2	0.3	0.1	0.5	0.5	1.4	0.6	0.8	0.9	1.00	0.5	0.40	0.70	0.4	1.5	0.1	1.1	1.0
Total Phosphorus as P	mg/L	0.01	0.20								0.07	0.32	<0.01	<0.01	0.02	0.03	1.4	0.08	0.04	0.04	0.04	0.1	0.02	<0.01	0.03	0.02	0.01	0.07	0.04
Ionic Balance	%	0.01	1.84								0.52	1.79	3.38	1.62	0.38	0.5	1.82	4.65	2.71	1.4	1.73	0.97	2.40		18.7	3.16		5.24	4.46
Total Anions	meq/L	0.01	50.91								8.27	8.2	9.81	11.2	12.9	10.7	503	18	13	12	18.60	20.4	15.80		16.1	15.1	2.56	3.28	4.03
Total Cations	meq/L	0.01	13.83								8.18	8.5	10.5	11.6	12.8	10.8	16.1	19.7	13.8	12.4	18.00	20.8	16.6		2.60	3.64	4.41	5.62	10.4

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Table A2.8 (Cont'd)
Monitoring Results: Lawsons Creek (Upstream 3) BSW 21

		Sampling Date																											
Parameter	Unit	LOR	Mean	24/10/2016	21/11/2016	12/12/2016	20/01/2017	14/03/2017	28/04/2017	17/05/2017	14/06/2017	14/07/2017	22/08/2017	20/09/2017	17/10/2017	15/11/2017	12/12/2017	17/01/2018	15/02/2018	14/03/2018	18/04/2018	18/05/2018	18/06/2018	18/07/2018	16/08/2018	20/09/2018	20/09/2018	22/10/2018	14/11/2018
pH Value	pH Unit	0.01	7.6	7.6	7.4	7.6	8.0	8.0	7.4	7.5	7.4	7.7	7.4	7.7	7.8	7.80	7.4	7.8	7.5	7.5	7.5	7.6	7.7	7.6	7.9	7.6	7.6	7.8	7.8
Electrical Conductivity @ 25°C	µS/cm	1	1146	450	565	990	1360	1390	1020	916	1140	920	1410	1160	1390	1400	718	1580	1780	1180	1050	1330	1410	1380	1430	1280	1290	1310	1750
Suspended Solids (SS)	mg/L	1	24	12	6	5	8	13	6	3	3	6	7	4	6	11	6	10	10	10	6	3	2	3	8	5	5	10	10
Bicarbonate Alkalinity as CaCO3	mg/L	1	257	93	142	308	475	518	257	250	288	247	353	336	478	501	172	406	427	235	297	419	440	399	444	331	333	415	490
Carbonate Alkalinity as CaCO3	mg/L	1		<1	<1	<1	18	<1	<1	<1	<1	<1	<1	<1	<1	10	<1	<1	9	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	222	93	142	308	493	518	257	250	288	247	353	336	478	511	172	406	436	235	297	419	440	399	444	331	333	415	490
Sulfate as SO4 - Turbidimetric	mg/L	1	157	34	45	73	75	75	110	69	121	73	170	96	75	115	58	215	252	232	109	117	123	134	150	114	116	85	204
Chloride	mg/L	1	132	52	51	90	122	117	106	73	110	81	144	108	150	139	76	187	198	154	120	148	168	157	162	146	148	148	223
Calcium	mg/L	1	58	18	27	48	66	67	57	46	70	44	82	64	76	77	35	93	97	60	55	75	80	77	81	68	67	68	108
Magnesium	mg/L	1	46	19	23	40	46	44	36	32	40	33	42	44	48	48	24	51	55	49	41	51	50	47	47	44	44	44	57
Potassium	mg/L	1	5	3	3	3	2	2	4	1	4	4	3	4	5	3	5	4	2	7	6	6	6	5	5	4	4	4	3
Sodium	mg/L	1	123	43	53	106	153	178	96	97	116	106	137	114	156	171	64	189	226	116	101	145	151	149	151	127	124	136	209
Arsenic	mg/L	0.001	0.002	<0.001	0.002	0.002	0.003	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	0.001	0.002	0.002	0.002	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Cadmium	mg/L	0.0001	0.0010	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	0.002	0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Iron	mg/L	0.05	0.120	0.65	0.55	0.10	<0.05	<0.05	0.10	0.08	0.06	0.05	<0.05	0.07	<0.05	<0.05	0.53	<0.05	<0.05	0.11	0.18	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	<0.05
Lead	mg/L	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.285	0.148	0.630	0.711	0.114	0.346	0.688	0.262	0.402	0.116	0.386	0.238	0.430	0.186	0.905	0.100	0.115	1.04	0.886	0.335	0.465	0.450	0.220	0.518	0.510	0.473	0.265
Nickel	mg/L	0.001	0.002	0.004	0.003	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.001	<0.001	0.001	<0.001	0.003	0.001	<0.001	0.004	0.002	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.001
Zinc	mg/L	0.005	0.050	<0.005	0.007	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ammonia as N	mg/L	0.01	0.03	0.03	0.01	0.01	0.04	0.02	0.03	0.02	0.03	0.03	<0.01	0.01	0.01	<0.01	0.06	<0.01	<0.01	0.01	0.01	<0.01	0.02	<0.01	<0.01	0.02	<0.01	0.06	0.03
Nitrite as N	mg/L	0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.07	0.03	0.04	<0.01	0.03	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.03	0.02	<0.01	0.02	0.01	0.02	<0.01	<0.01	0.02	0.03	0.07
Nitrite + Nitrate as N	mg/L	0.01	0.07	0.03	0.04	<0.01	0.03	0.02	<0.01	0.02	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.04	0.03	0.02	<0.01	0.02	0.01	0.02	<0.01	<0.01	0.02	0.03	0.07
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.7	0.8	0.7	0.5	0.7	0.6	0.5	0.3	0.3	0.8	0.2	0.4	0.5	0.5	0.8	0.4	0.4	0.8	0.6	0.4	0.4	0.2	0.3	0.4	0.4	0.4	0.4
Total Nitrogen as N	mg/L	0.1	0.7	0.8	0.7	0.5	0.7	0.6	0.5	0.3	0.3	0.8	0.2	0.4	0.5	0.5	0.8	0.4	0.4	0.8	0.6	0.4	0.4	0.2	0.3	0.4	0.4	0.4	0.5
Total Phosphorus as P	mg/L	0.01	0.20	0.07	0.02	0.05	0.13	0.03	0.03	0.01	0.02	0.05	0.02	0.03	0.02	0.06	0.07	0.03	0.05	0.03	0.04	0.01	<0.01	<0.01	<0.01	0.02	0.02	0.02	0.04
Ionic Balance	%	0.01	1.84	3.78	0.79	3.73	1.51	1.61		3.87	2.39	4.82	3.79	0.50	2.29	3.82	1.15	2.00	0.76	6.19	4.15	1.98	4.08	2.95	6.28	1.80	3.04	4.41	2.73
Total Anions	meq/L	0.01	50.91	5.21	10.2	14.8	15.2	10.4		8.49	11.4	8.74	14.6	11.8	15.3	16.5	6.79	17.9	19.5	13.9	11.6	15.0	16.1	15.2	16.6	13.1	13.2	14.2	20.3
Total Cations	meq/L	0.01	13.83	13.8	14.8	10.1				9.17	11.9	9.62	13.6	11.9	14.6	15.3	6.63	17.2	19.2	12.2	10.7	14.4	14.8	14.3	14.6	12.6	12.5	13.0	19.2

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Table A2.9
Monitoring Results: Lawsons Creek (Downstream 1) BSW 20

Sampling Date																										
Parameter	Unit	LOR	Mean	19/07/2012	16/08/2012	14/09/2012	18/10/2012	21/11/2012	20/12/2012	19/02/2013	19/03/2013	16/04/2013	15/05/2013	25/06/2013	21/11/2013	18/02/2014	22/05/2014	20/08/2014	20/11/2014	9/02/2015	1/05/2015	14/08/2015	14/10/2015	12/05/2016	31/08/2016	26/09/2016
pH Value	pH Unit	0.01	7.9	7.6	8	7.9	7.9	8	8	7.7	7.6	7.7	7.9	7.6	7.5	8.5	7	7.2	8.30	7.60	8.40	7	7.6	8.7	7.6	7.4
Electrical Conductivity @ 25°C	µS/cm	1	1117	550	780	940	1170	1250	1340	885	870	965	1050	1000	1400	2050	1200	1190	1540.00	1930	1900	1000	1350	1560	776	300
Suspended Solids (SS)	mg/L	1	28						15	17	6	5	13	24	0.08	92	79	11	72.00	71	103	6	34	14	10	12
Bicarbonate Alkalinity as CaCO3	mg/L	1	215							151	148	177	240	141	180	295	136	130	223.00	274.00	227.00	101	208	181	104	59
Carbonate Alkalinity as CaCO3	mg/L	1	25							<1	<1	<1	<1	<1	<1	21	<1	<1	<1	<1	<1	<1	<1	29	<1	<1
Hydroxide Alkalinity as CaCO3	mg/L	1								<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Alkalinity as CaCO3	mg/L	1	217							151	148	177	240	141	12	316	136	130	223.00	274.00	227.00	101	208	210	104	59
Sulfate as SO4 - Turbidimetric	mg/L	1	144	90	143	146	195	190	112	152	148	121	109	164	212	219	247	194	225.00	234	274	210	246	195	136	34
Chloride	mg/L	1	157	60	97	138	195	180	214	101	103	112	126	126	222	351	151	193	298.00	348	376	104	167	280	104	28
Calcium	mg/L	1	46	22	31	37	50	59	58	38	38	48	53	40	39	62	61	46	40.00	60.00	54.00	48	75	34	30	13
Magnesium	mg/L	1	50	26	39	48	58	65	59	42	42	44	47	44	61	93	57	50	74.00	85	92	45	63	76	37	12
Potassium	mg/L	1	6	4	3	4	5	5	6	6	5	5	8	5	8	10	8	5	5.00	9	15	5	6	11	5	3
Sodium	mg/L	1	115	45	66	84	120	133	<0.001	85	88	104	98	92	151	277	116	129	187.00	232.00	244.00	106	129	190	68	28
Arsenic	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.001	0.001	<0.001	<0.001	<0.001	0.001	0.006	<0.001	<0.001	0.00	0.005	0.003	<0.001	<0.001	0.002	<0.001	<0.001
Cadmium	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cobalt	mg/L	0.001	0.002							<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00	0.00	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	0.002	<0.001	0.001	<0.001	0.001	0.003	<0.001	0.002	0.002	<0.001	0.003	0.002	0.006	0.002	0.002	0.002	<0.001	0.005	0.004	0.002	<0.001	0.002	0.001	0.002
Iron	mg/L	0.05	0.159	0.33	0.17	0.06	0.07	<0.05	0.05	<0.05	0.08	<0.05	0.1	0.12	<0.05	<0.05	<0.05	<0.05	0.06	0.09	0.67	0.06	<0.05	0.06	0.16	0.55
Lead	mg/L	0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	mg/L	0.001	0.379	0.154	0.211	0.472	0.599	0.325	0.505	0.544	0.312	0.221	0.373	0.249	<0.001	0.082	0.545	0.348	0.35	0.99	0.61	0.244	1.38	0.016	0.167	0.088
Nickel	mg/L	0.001	0.003	0.002	0.002	0.002	0.003	0.002	<0.001	0.003	0.003	0.001	0.002	0.001	0.003	0.002	0.003	0.002	0.00	0.005	0.005	0.002	0.002	0.003	0.003	0.006
Zinc	mg/L	0.005	0.020	<0.005	<0.005	<0.005	0.013	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02	0.011	<0.005	0.008	0.016	<0.005	0.109	0.014	<0.005	<0.005	<0.005	<0.005	<0.005
Ammonia as N	mg/L	0.01	0.03							<0.01	<0.01	<0.01	<0.01	0.02	0.06	0.09	0.05	0.02	0.04	0.05	0.03	0.02	0.01	0.01	0.01	0.01
Nitrite as N	mg/L	0.01	0.01							<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.01	0.03							0.05	0.03	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.05	<0.01	<0.01	0.02	<0.01	0.03	<0.01	0.02	0.03
Nitrite + Nitrate as N	mg/L	0.01	0.03							0.05	0.03	<0.01	<0.01	<0.01	0.01	0.02	0.01	0.05	<0.01	<0.01	0.02	<0.01	0.03	<0.01	0.02	0.03
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.4							0.9	1.5	0.4	0.9	0.7	13.7	2	1	0.6	1.30	2.1	2.4	0.4	0.7	1.1	0.7	1.2
Total Nitrogen as N	mg/L	0.1	1.1							1	1.5	0.4	0.9	0.7	1.6	2	1	0.6	1.30	2.10	2.40	0.4	0.7	1.1	0.7	1.2
Total Phosphorus as P	mg/L	0.01	0.13							0.06	0.37	<0.01	0.06	0.03	1.6	0.12	0.06	0.04	0.06	0.11	0.16	0.01	0.06	0.06	0.03	0.11
Ionic Balance	%	0.01	3.47							0.93	1.98	4.05	1.66	0.21	1.92	5.18	3.44	0.27	3.55	0.35	0.97		16.5	1.4		5.01
Total Anions	meq/L	0.01	16.68							9.03	8.94	9.83	10.6	9.79	180	20.8	12.1	12.1	17.60	20.20	20.80		7.63	7.84	2.68	5.12
Total Cations	meq/L	0.01	11.69							9.2	9.31	10.7	11	9.75	14.3	23	13	12.2	16.40	20.30	21.30			2.93	5.66	5.11

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Table A2.9 (Cont'd)
Monitoring Results: Lawsons Creek (Downstream 1) BSW 20

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			Sampling Date																								
Parameter	Unit	LOR	Mean	26/10/2016	21/11/2016	12/12/2016	20/01/2017	16/02/2017	14/03/2017	22/08/2017	20/09/2017	17/10/2017	14/11/2017	13/12/2017	16/01/2018	16/02/2018	14/03/2018	18/04/2018	18/05/2018	18/06/2018	18/07/2018	16/08/2018	20/09/2018	22/10/2018	14/11/2018		
pH Value	pH Unit	0.01	7.9	7.7	7.6	7.9	8.4	8.8	8.4	8	7.9	7.9	8.3	7.8	8.7	8.7	7.5	7.6	7.7	7.7	7.9	7.9	7.9	7.9	8.1		
Electrical Conductivity @ 25°C	µS/cm	1	1117	533	531	716	1180	1230	1350	988	1080	1200	1230	845	1130	1320	1120	1010	1120	1150	1070	1130	1100	1100	1190		
Suspended Solids (SS)	mg/L	1	28	10	15	9	35	70	57	11	18	19	26	7	18	32	20	14	16	28	10	14	20	14	28		
Bicarbonate Alkalinity as CaCO3	mg/L	1	215	99	124	227	306	251	309	252	272	351	325	221	293	318	202	216	260	287	239	282	257	290	363		
Carbonate Alkalinity as CaCO3	mg/L	1	25	<1	<1	<1	21	32	4	<1	<1	4	31	<1	40	40	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Hydroxide Alkalinity as CaCO3	mg/L	1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Total Alkalinity as CaCO3	mg/L	1	217	99	124	227	326	283	313	252	272	355	356	221	333	358	202	216	260	287	239	282	257	290	363		
Sulfate as SO4 - Turbidimetric	mg/L	1	144	71	48	66	105	102	120	81	90	100	125	81	68	65	231	147	149	125	129	129	90	81	88		
Chloride	mg/L	1	157	59	48	78	140	167	189	106	111	156	149	104	152	188	160	128	142	156	141	161	142	149	169		
Calcium	mg/L	1	46	23	23	33	54	40	49	49	55	60	61	45	48	41	52	48	52	60	52	56	49	52	60		
Magnesium	mg/L	1	50	28	24	37	54	56	60	38	48	48	48	38	49	52	50	45	44	47	45	44	43	43	48		
Potassium	mg/L	1	6	3	3	4	5	5	6	6	7	7	5	5	5	6	8	7	5	8	5	5	5	4	4		
Sodium	mg/L	1	115	49	44	68	112	132	144	80	95	119	128	78	125	168	101	92	95	107	96	103	100	102	120		
Arsenic	mg/L	0.001	0.002	<0.001	0.001	0.002	0.003	0.004	0.002	<0.001	0.001	0.001	<0.001	<0.001	0.004	0.006	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.002		
Cadmium	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		
Cobalt	mg/L	0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001		
Copper	mg/L	0.001	0.002	0.002	0.002	0.005	<0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.003	0.002	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001		
Iron	mg/L	0.05	0.159	0.46	0.26	0.05	<0.05	<0.05	<0.05	0.08	<0.05	<0.05	<0.05	0.19	0.06	0.08	0.06	0.06	<0.05	0.16	0.05	<0.05	<0.05	<0.05	<0.05		
Lead	mg/L	0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Manganese	mg/L	0.001	0.379	0.256	0.449	0.167	0.309	0.286	0.224	0.332	0.442	0.452	0.013	0.806	0.308	0.309	0.246	0.402	0.296	0.77	0.315	0.741	0.336	0.491	0.560		
Nickel	mg/L	0.001	0.003	0.004	0.005	0.002	0.002	0.003	0.003	0.002	0.003	0.002	0.002	0.002	0.002	0.003	0.004	0.002	0.002	0.002	0.001	0.002	0.002	0.001	0.002		
Zinc	mg/L	0.005	0.020	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	0.006	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
Ammonia as N	mg/L	0.01	0.03	0.02	0.02	<0.01	0.02	<0.01	0.02	0.02	0.03	0.01	0.02	<0.01	<0.01	0.02	<0.01	0.03	<0.01	0.01	<0.01	<0.01	0.01	0.06	0.02		
Nitrite as N	mg/L	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02		
Nitrate as N	mg/L	0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	0.07	0.01	<0.01	<0.01	<0.01	0.02	0.07	0.04	<0.01	0.03	0.01	0.02	0.02	<0.01	<0.01	<0.01		
Nitrite + Nitrate as N	mg/L	0.01	0.03	<0.01	0.03	<0.01	0.03	<0.01	0.02	0.07	0.01	<0.01	<0.01	<0.01	0.02	0.07	0.04	<0.01	0.03	0.01	0.02	0.02	<0.01	<0.01	<0.01		
Total Kjeldahl Nitrogen as N	mg/L	0.1	1.4	2.3	1	0.8	1.3	3	1.6	0.6	0.8	0.6	0.8	0.6	1	1.6	0.6	0.8	0.6	0.4	0.6	0.4	0.6	0.4	0.7		
Total Nitrogen as N	mg/L	0.1	1.1	2.3	1	0.8	1.3	3	1.6	0.7	0.8	0.6	0.8	0.6	1	1.7	0.6	0.8	0.6	0.4	0.6	0.4	0.6	0.4	0.7		
Total Phosphorus as P	mg/L	0.01	0.13	0.05	0.05	0.03	0.11	0.2	0.11	0.03	0.22	0.03	0.08	0.03	0.08	0.17	0.05	0.05	0.02	<0.01	0.06	0.01	0.03	<0.01	0.03		
Ionic Balance	%	0.01	3.47	2.84	2.26	2.06	0.06	14.1	1.02	2.67	2.64	4.93	4.62	0.79	1.49	0.08	8.31	3.32	8.02	4.15	3.79	7.69	2.57	4.52	6.07		
Total Anions	meq/L	0.01	16.68	4.83	8.11	12.6	12.5	13.8		9.71	10.4	13.6	13.9	9.04	12.4	13.8	13.4	11	12.3	12.7	11.4	12.9	11.0	11.7	13.8		
Total Cations	meq/L	0.01	11.69	7.75	12.1	12.5				9.2	11	12.3	12.7	8.89	12	13.8	11.3	10.3	10.5	11.7	10.6	11.0	10.5	10.7	12.3		

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Annexure B

Flood Impact Assessment and Updated Lawsons Creek Crossing

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Bowdens Silver Project

Flood Impact Assessment

Bowdens Silver Pty Limited
1356-01-05, 31 January 2020

Report Title	Bowdens Silver Project Flood Impact Assessment
Client	Bowdens Silver Pty Ltd C/- R.W. Corkery and Co. Pty Limited
Report Number	1356-01-05

Revision Number	Report Date	Report Author	Reviewer
5	31 January 2020	AN	MB

For and on behalf of WRM Water & Environment Pty Ltd
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Michael Batchelor
Director

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1 Introduction

1.1 BACKGROUND

Bowdens Silver Pty Ltd (Bowdens Silver) is seeking approval to develop and operate an open cut silver mine near Lue, NSW (the Project). The Mine Site is located approximately 26 km east of Mudgee, NSW and is currently an undeveloped site. Figure 1.1 shows the location of the Mine Site.

Bowdens Silver requested WRM Water and Environment Pty Ltd (WRM) undertake a surface water assessment forming part of the Environmental Impact Statement for the Project. In accordance with the Secretary's Environmental Assessment Requirements, the impact assessment includes a detailed assessment of flooding on the Mine Site, and potential the impact of the proposed works on flooding in the adjacent reaches of Lawsons Creek, Hawkins Creek and their tributaries.

This report presents the methodology and results of hydrologic and hydraulic modelling undertaken for this assessment across.

1.2 PROJECT DESCRIPTION

Figure 1.2 shows the proposed Mine Site layout. The proposed operations would involve a conventional open cut mine including an out-of-pit waste rock emplacement (WRE), processing plant (with concentrate storage), tailings storage facility (TSF) and other ancillary infrastructure.

The Project would also involve construction of a new access road providing access to the Mine Site from a point west of Lue. The new access road would cross Lawsons Creek and effectively replace approximately 4.5km of Maloneys Road (Pyangle Road) that would be closed once the new road is constructed.

The study area for this assessment comprises the Mine Site and the adjacent reaches of Lawsons Creek, Hawkins Creek and their tributaries, including the reach of Lawsons Creek in the vicinity of the relocated Maloneys Road crossing.

1.3 REPORT STRUCTURE

This report is structured as follows.

- Section 2 - describes the existing drainage characteristics in the vicinity of the Mine Site;
- Section 3 - describes the infrastructure proposed for the Project which could potentially impact on flooding;
- Section 4 - describes the development of the hydrologic model used to estimate design peak discharges, including the model validation process;
- Section 5 - describes the methodology used to estimate the design discharges, and presents the design peak discharges at some key locations;
- Section 6 - describes the development of the hydraulic model used to estimate design peak flood levels and velocities in the vicinity of the Mine Site, and includes some flood mapping;
- Section 7 - describes the hydraulic modelling undertake used to estimate design flood conditions during Project operations and post-closure, including mapping of the impact of the proposed works on design flood levels and velocities;
- Section 8 - provides a summary of findings; and
- Section 9 - provides a list of references.

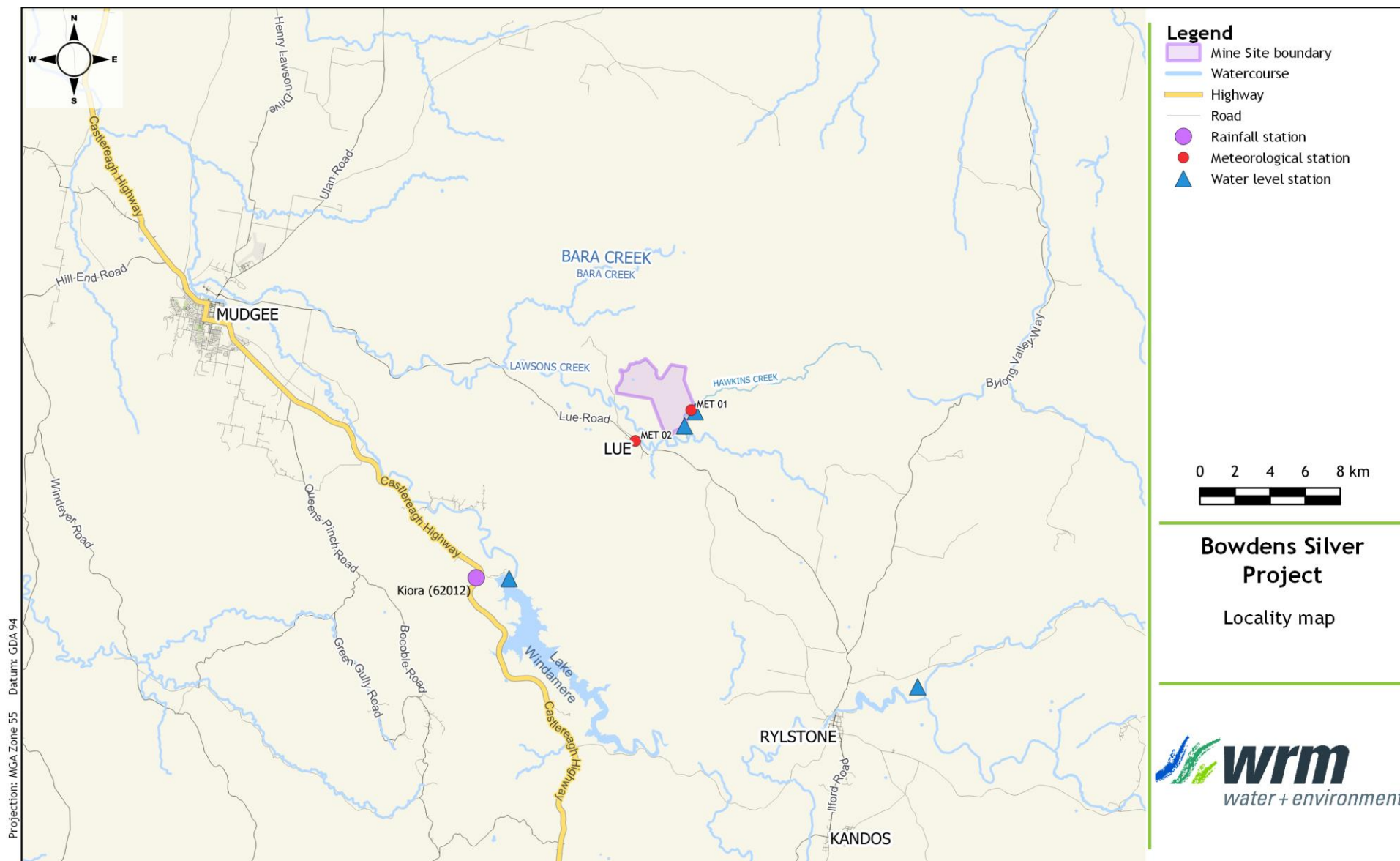


Figure 1.1 - Locality

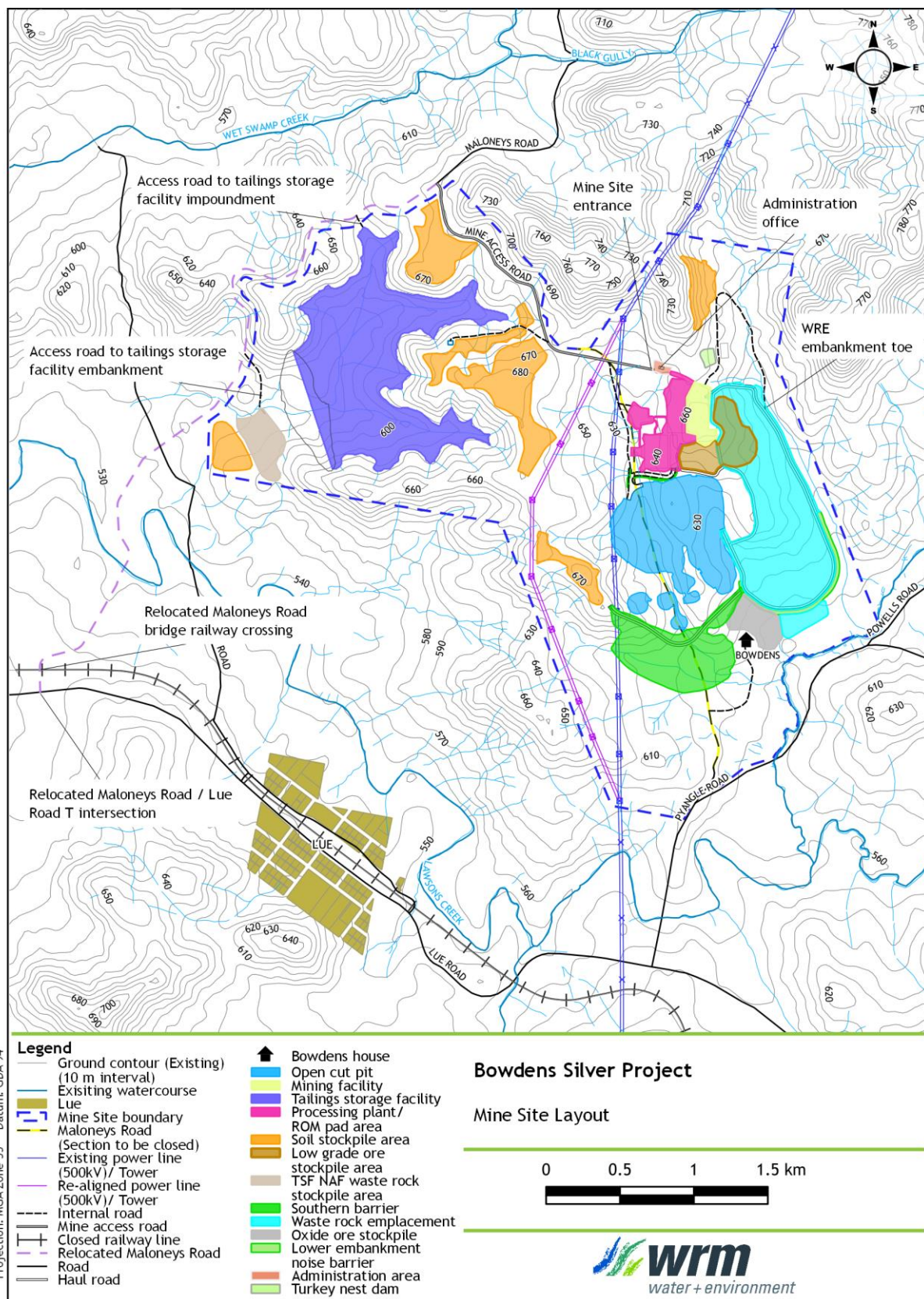


Figure 1.2 - Proposed layout of the Project

2 Existing drainage characteristics

2.1 REGIONAL DRAINAGE

Figure 2.1 shows the regional drainage features in the vicinity of the Mine Site which is located within the Lawsons Creek catchment, in the eastern headwaters of the Macquarie River basin. Lawsons Creek flows in a northwesterly direction and drains to the Cudgegong River near the township of Mudgee. The Cudgegong River flows in a northwesterly direction from Mudgee, before turning to the southwest and eventually draining to Burrendong Dam. Lawsons Creek has a catchment area of approximately 507 km² to the Cudgegong River confluence (near Mudgee). Burrendong Dam has catchment area of approximately 13,900 km².

2.2 LOCAL DRAINAGE

Figure 2.2 shows the Lawsons Creek catchment to just downstream of Lue. Figure 2.3 shows the local drainage characteristics within and in the immediate vicinity of the Mine Site boundary.

Hawkins Creek, a tributary of Lawsons Creek, flows in a southwesterly direction adjacent to but beyond the southeastern boundary of the Mine Site. Hawkins Creek has a catchment area of 61 km² upstream of the confluence with Lawsons Creek.

The Mine Site is traversed by the following tributaries of Hawkins and Lawsons Creeks (refer to Figure 2.3 for their locations):

- Price Creek (a south-flowing tributary of Hawkins Creek), which has a catchment area of 5.2 km² upstream of the Hawkins Creek confluence;
- Blackmans Gully (a south-flowing tributary of Hawkins Creek), which has a catchment area of 2.3 km² upstream of its confluence with an unnamed east-flowing tributary (referred to as the UN South tributary - catchment area of 1.1 km²). Its downstream reach (referred to as Blackmans Gully DS) has a catchment area of 3.6 km² to its confluence with Hawkins Creek.
- an unnamed south-flowing tributary of Hawkins Creek, referred to as the UN East tributary, which has a catchment area of 0.9 km² upstream of the Hawkins Creek confluence;
- an unnamed west-flowing tributary of Lawsons Creek, referred to as the UN West tributary, which has a catchment area of 1.6 km² upstream of the Lawsons Creek confluence; and
- Walkers Creek (a west-flowing tributary of Lawsons Creek) which has a catchment area of 4.8 km² upstream of the Lawsons Creek confluence. The Walkers Creek catchment is the site of the proposed tailings storage facility (TSF).

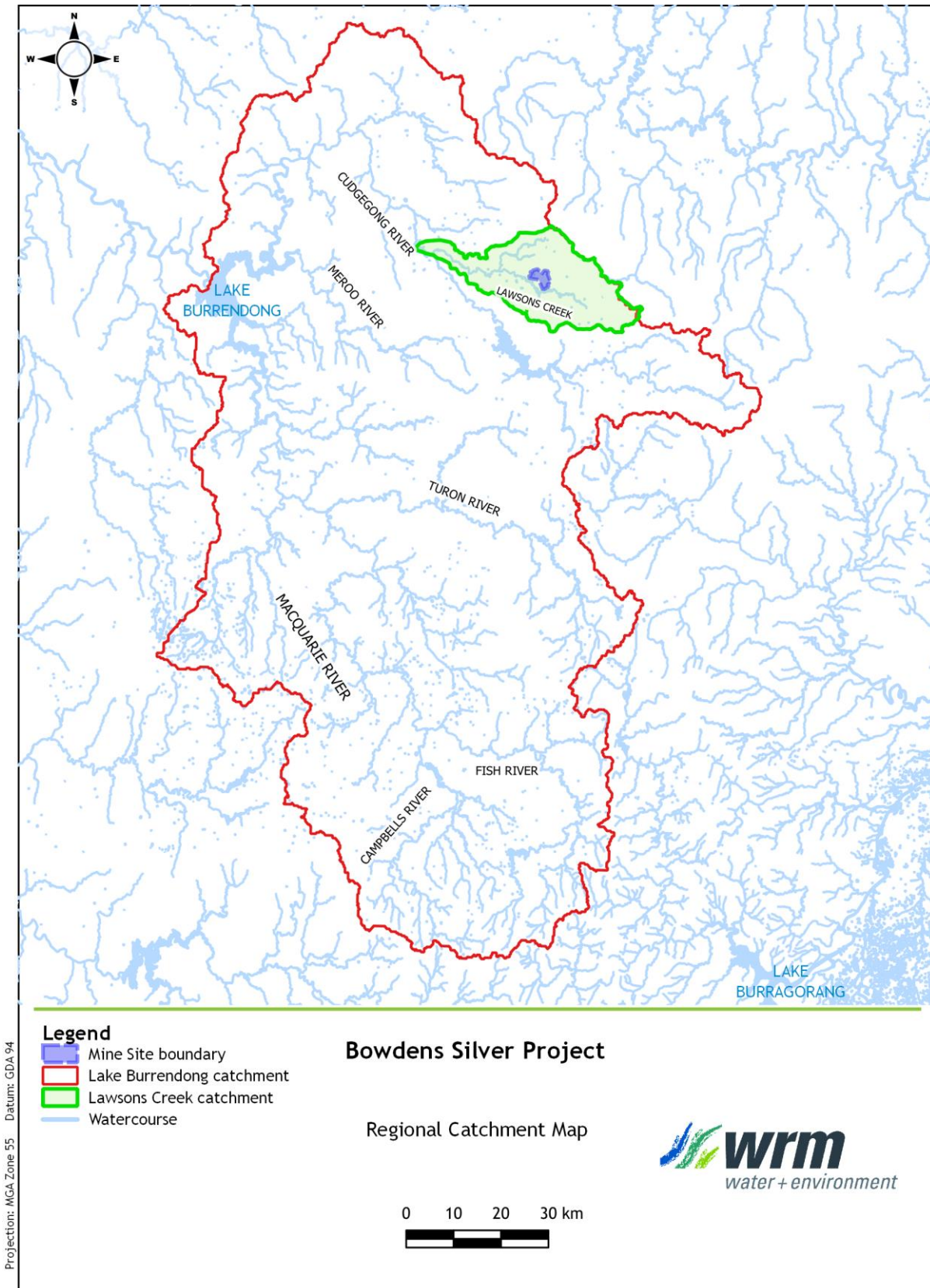


Figure 2.1 - Regional drainage features

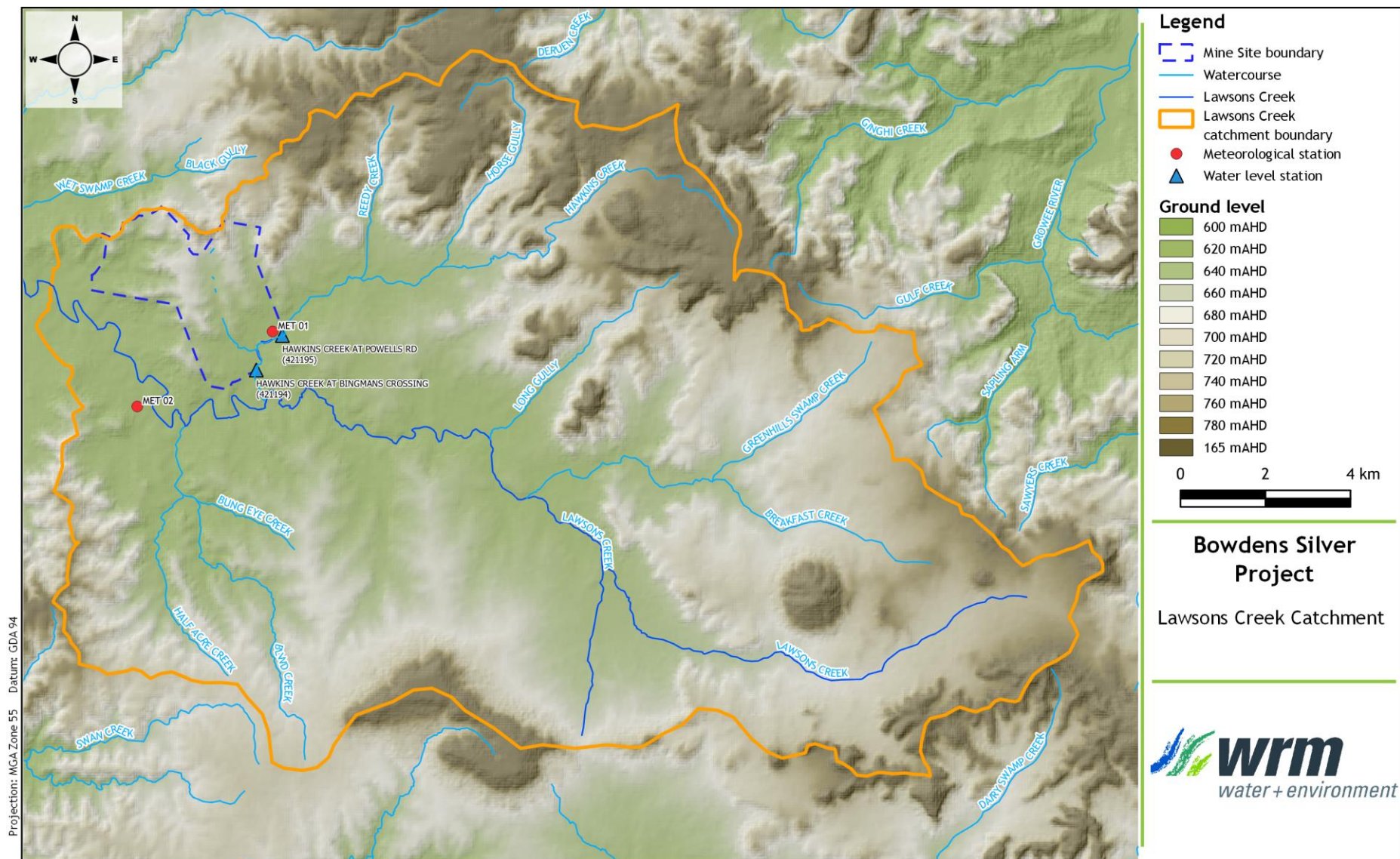


Figure 2.2 - Lawsons Creek catchment and the locations of rainfall and water level recording stations operated by Bowdens Silver

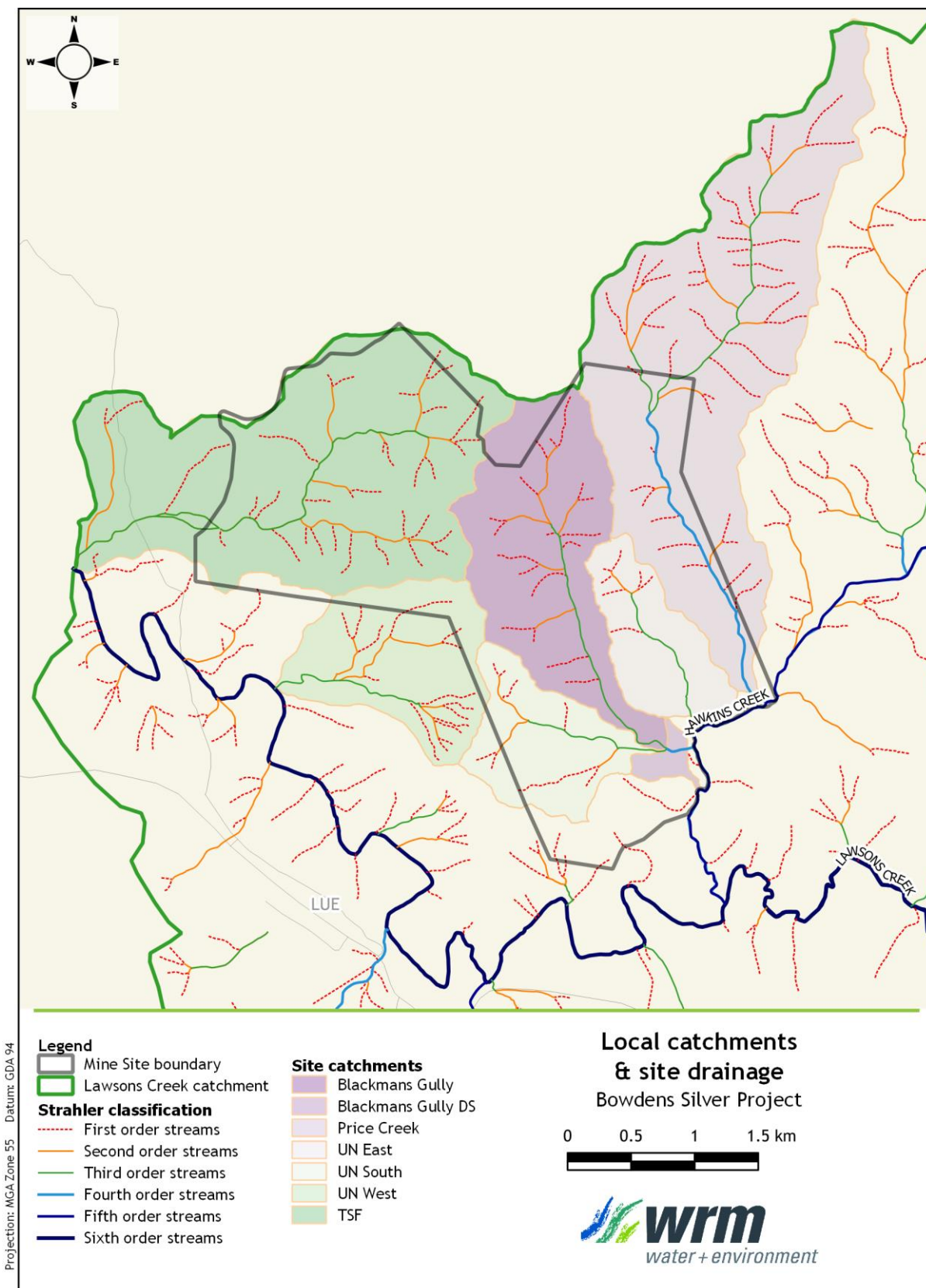


Figure 2.3 - Local drainage features

3 Description of proposed infrastructure

3.1 OVERVIEW

The proposed site layout is described in detail in the project description (EIS Section 2) as shown in Figure 1.2. Proposed infrastructure which could potentially interact with flood flow paths include the following:

- Waste rock emplacement (and associated haul roads and noise barriers);
- Leachate management dam;
- Southern barrier;
- Relocated Maloneys Road (Pyangle Road) crossing of Lawsons Creek;
- Clean water diversion system from Blackmans Gully to Price Creek.

The footprint of the proposed works would be largest during site operations. At the completion of mining and following rehabilitation of the Mine Site, some of these works would be decommissioned. As a result, the assessment has been based on two scenarios - maximum disturbance, and post-closure. Further details of how the works are incorporated into the flood model are provided in section 6.

3.2 WASTE ROCK EMPLACEMENT

The waste rock emplacement (WRE) is proposed to be constructed immediately to the east of the main open cut pit. The emplacement would be constructed in stages from north to south and includes a leachate collection system, lower haul road, and noise barrier along its eastern toe. The lower haul road and noise barrier would be decommissioned post-mining.

These works have the potential to impact flood conditions on the western margin of the Price Creek floodplain, and would interact with existing contour banks and other drainage structures within Price Creek. For the purpose of this assessment, the impacts of the proposed works in conjunction with existing structures has been assessed. During detailed design of the waste rock emplacement, consideration would be given to the mitigation of these impacts in conjunction with the decommissioning of existing drainage works.

3.3 SOUTHERN BARRIER

The southern barrier would be constructed across Blackmans Gully, and during operations would largely control flood flows entering Lawsons Creek downstream as flows would be directed through a culvert beneath the barrier. Runoff from nearby local stormwater catchments would be directed around the toe of the southern barrier. The Southern barrier would be decommissioned post-mining, and the pre-mine flow paths would be re-instated.

3.4 BLACKMANS GULLY CLEAN WATER DIVERSION DRAIN

The upper part of the Blackmans Gully catchment would be diverted east to Prices Creek, to reduce the potential for clean water to enter the active main open cut pits. The effect of this channel has been modelled by relocating the modelled upper sub-catchment inflows to Price Creek instead of Blackmans Gully.

3.5 LEACHATE MANAGEMENT DAM

The proposed leachate management dam would be located on the margin of the Lawsons Creek floodplain. The potential effect of this structure on the Lawsons Creek flooding and local runoff from Prices Creek has been assessed by incorporating the design surface into the hydraulic model.

3.6 LAWSONS CREEK CROSSING

The proposed Lawsons Creek crossing would be designed to be overtopped by flows in Lawsons Creek during a 10% (1 in 10) AEP event. Figure 3.1 shows the cross section of the proposed configuration used in the model. The following design characteristics have been adopted (however, the configuration would be refined further during detailed design):

- A road crest level of 528.8 mAHD (the existing 1 in 10 AEP flood level);
- A road width of 7 m;
- A two-way cross fall of 3%; and
- A road embankment (cut and fill) slope of 1V:3H;
- 10 barrels of 2.7 m (L) x 2.4 m RCBCs.

Based on the above assumptions, the road embankment would have a maximum height of 5 m above the creek bed, with the outer embankment slopes extending up to 17 m upstream and 15 m downstream of the road as shown in Figure 6.12.

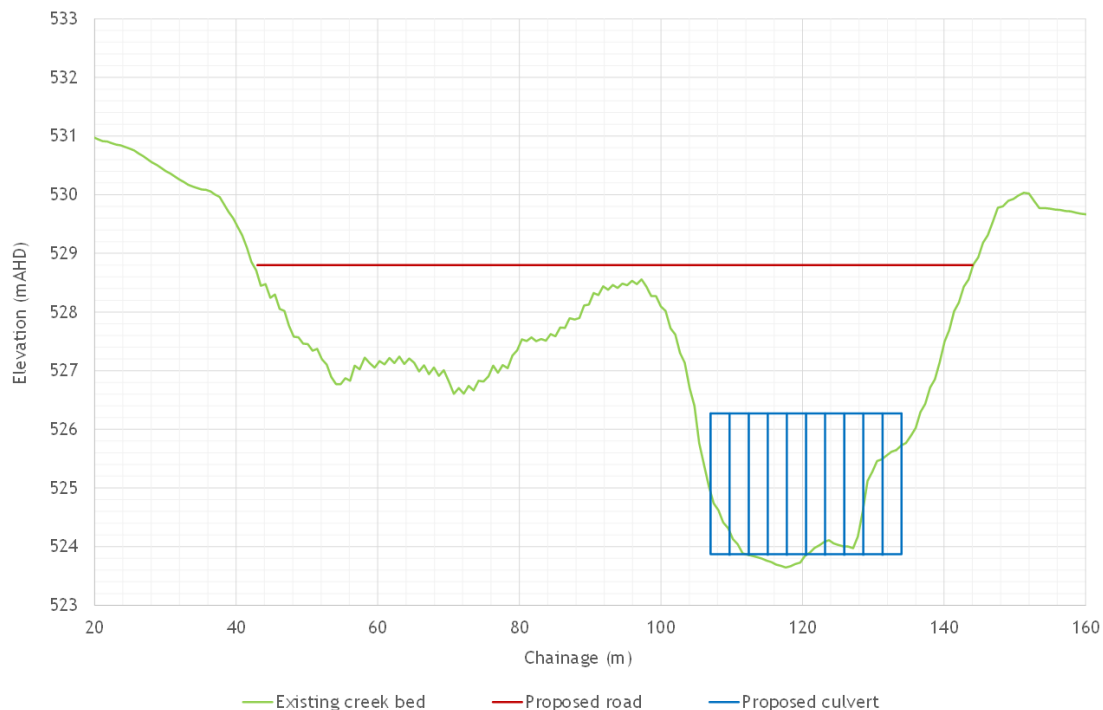


Figure 3.1 - Cross-section of proposed Lawsons Creek crossing (looking downstream)

4 Hydrologic model development and validation

4.1 METHODOLOGY

The XP-RAFTS runoff-routing model (Innovyze, 2018) was developed for the catchment of Lawsons Creek and its tributaries including Hawkins Creek and Price Creek.

The XP-RAFTS model was validated against Hawkins Creek water level data recorded by Bowdens Silver during three historical flow events (the validation events) peaking at the following dates:

- 20 July 2016 (July 2016 flow event);
- 9 September 2016 (September 2016 1st flow event); and
- 18 September 2016 (September 2016 2nd flow event).

None of these events were large floods in Hawkins Creek, with the largest having an AEP greater than 40%, and resulting in water just overtopping the banks. As a result, the data was unsuitable for calibration of the model, but was used to validate the adopted parameters.

4.2 AVAILABLE DATA

4.2.1 Rainfall data

There are no BOM-operated pluviometer stations located within Lawsons Creek catchment upstream of the Mine Site. Bowdens Silver operates the two meteorological stations adjacent to the Project, referred to as Stations MET01 and MET02. Figure 2.2 shows the locations of these meteorological stations.

Sub-hourly rainfall data recorded at MET01 and MET02 was available for the three validation events. However, given the large size of the Lawsons Creek catchment and the location of the rainfall station near the catchment outlet, it is possible that the rainfall data is not representative of rainfall over the entire catchment during these events.

Figure 4.1, Figure 4.2 and Figure 4.3 show the recorded rainfall intensities (mm/h) during the July 2016, September 2016 (1st flow event) and September 2016 (2nd flow event) respectively. Table 4.1 shows a summary of total rainfall depths recorded during the three validation events. For comparison, Table 4.1 also shows total rainfall depths recorded during three other smaller events which occurred between November 2016 and March 2017.

4.2.2 Streamflow data

There are no NSW Office of Water (NOW) or Bureau of Meteorology (BOM) streamflow recording stations in the vicinity of the Mine Site which would be suitable for model calibration.

Bowdens Silver provided streamflow records for Hawkins Creek at the following two recording stations it operates adjacent to the Project:

- Powells Road (Station No. 421195) - 3.2 year period from 26 March 2014 to 30 May 2017; and
- Bingmans Crossing (Station No. 421194) - 4 year period from 16 June 2013 to 30 May 2017.

Figure 2.2 shows the locations of these stations. These stations comprise a v-notch weir mounted on a concrete weir crossing the bottom of the channel. The invert level of the v-notch weir is at 0.5 m gauge height (GH) at both stations.

Figure 4.4 shows recorded water levels in Hawkins Creek at the Bingmans Crossing station (Station No. 421194) over the period of record. The period of record spans a period of very wet weather commencing in July 2016, preceded by a period of very dry weather. Figure 4.4 shows that baseflow generated depths of more than 100 mm over the v-notch weir between July and November 2016, and flow peaks exceeding 1 m gauge height (0.5 m above the v-notch weir crest) occurred several times over this period.

Figure 4.1, Figure 4.2 and Figure 4.3 show the recorded water level hydrographs during the July 2016, September 2016 (1st flow event) and September 2016 (2nd flow event) respectively. Table 4.1 shows a summary of recorded peak water levels at both stations during the three validation events, as well as the three smaller events between November 2016 and March 2017.

Figure 4.4 shows recorded water levels in Hawkins Creek at the Bingmans Crossing station (Station No. 421194) over the period of record. The period of record spans a period of very wet weather commencing in July 2016, preceded by a period of very dry weather. Figure 4.4 shows that baseflow generated depths of more than 100 mm over the v-notch weir between July and November 2016, and flow peaks exceeding 1 m gauge height (0.5 m above the v-notch weir crest) occurred several times during this period.

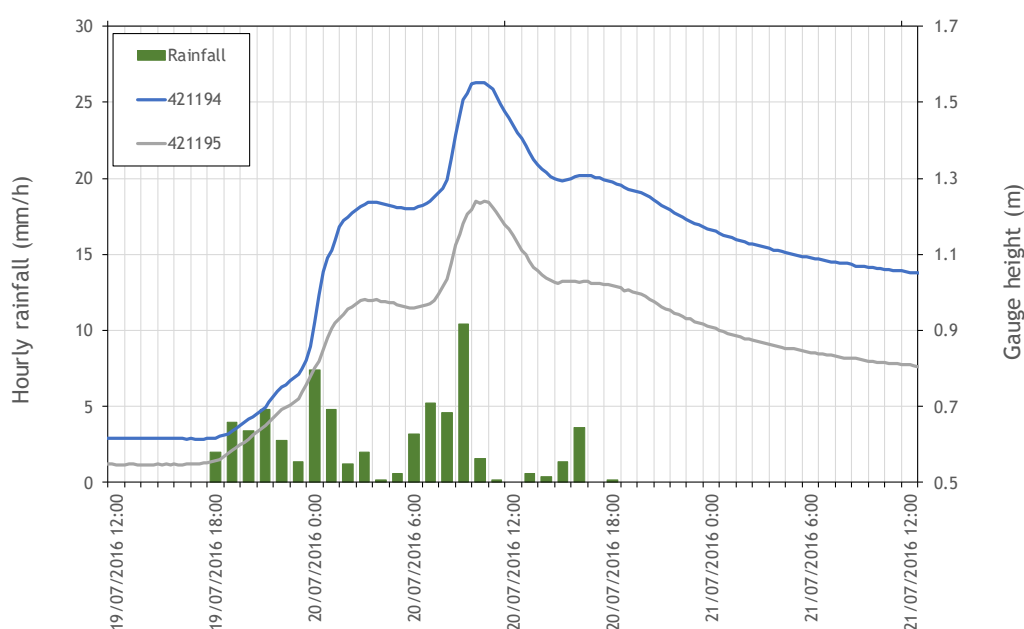


Figure 4.1 - Recorded water levels and rainfall intensities - July 2016 flow event

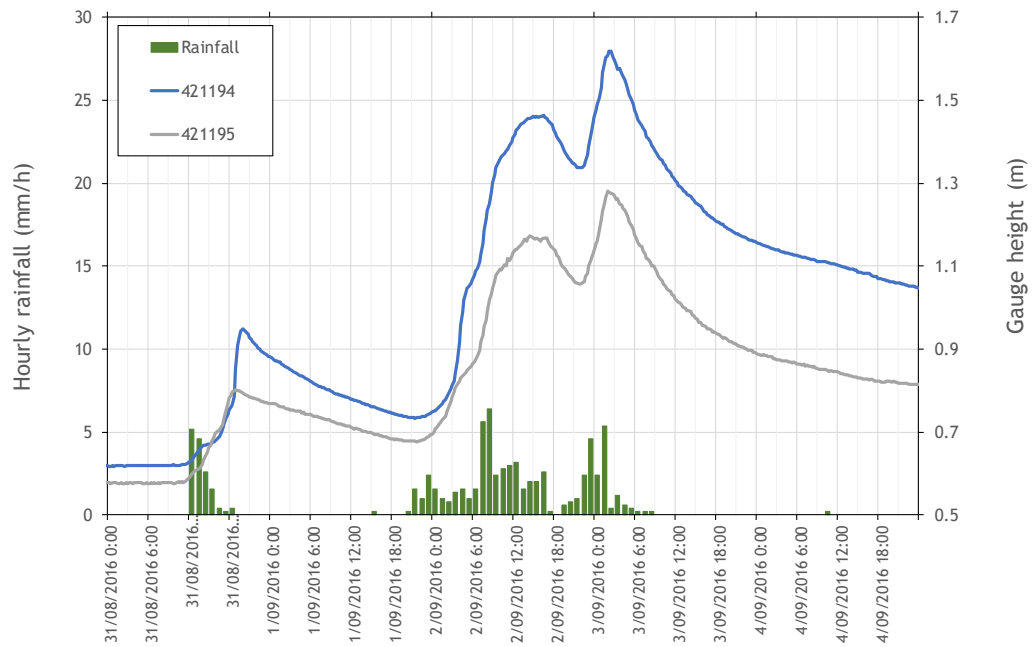


Figure 4.2 - Recorded water levels and rainfall - September 2016 1st flow event

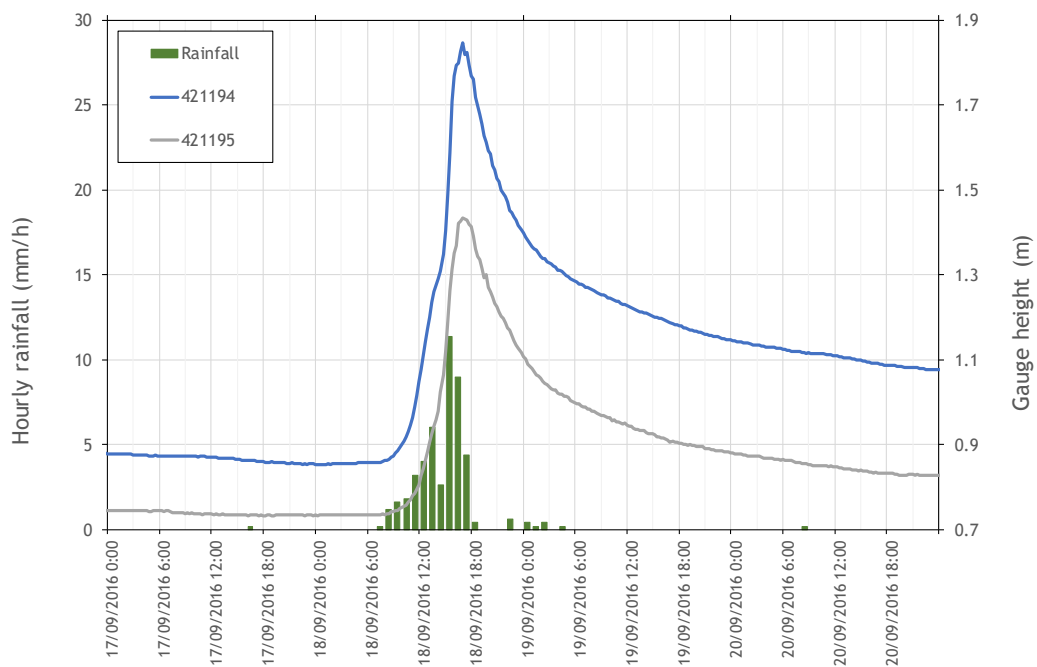


Figure 4.3 - Recorded water levels and rainfall - September 2016 2nd flow event

Table 4.1 - Summary of recorded rainfall depths and peak water levels at recording the stations operated by Bowdens Silver

Flow event	Event start date	Event finish date	Peak gauge height (m GH)		Total event rainfall depth (mm)	
			Bingmans Crossing (Stn. 421194)	Powells Road (Stn. 421195)	Station MET01	Station MET02
July 2016	19/07/2016	21/07/2016	1.55	1.24	66.0	64.6
September 2016 (1 st flow event)	31/08/2016	9/09/2016	1.62	1.28	82.0	89.8
September 2016 (2 nd flow event)	18/09/2016	20/09/2016	1.85	1.68	47.6	51.0
November 2016	12/11/2016	13/11/2016	1.22	0.96	49.2	56.0
March 2017 (1 st flow event)	23/03/2017	25/03/2017	1.09	0.86	44.6	41.8
March 2017 (2 nd flow event)	30/03/2017	1/04/2017	1.18	0.93	43.4	52.0

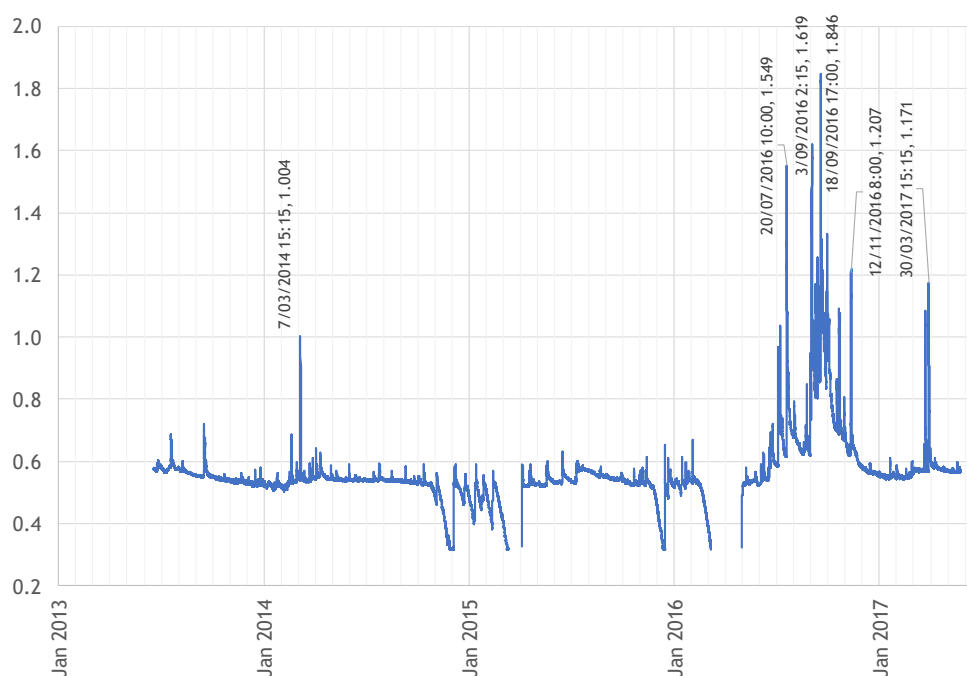


Figure 4.4 - Recorded water levels in Hawkins Creek at Bingmans Crossing (421194)

4.2.3 Rating curves

Bowdens Silver supplied rating curves (depth-vs-flow relationships) for the two Hawkins Creek recording stations. It is understood that these curves were developed from theoretical rating relationships and not from flow gaugings.

To validate the supplied rating curves, theoretical rating curves were developed by applying the theoretical relationships for v-notch weirs based on the dimensions measured during the site visit. The results showed that the theoretical rating curves closely matched the supplied rating curves.

The supplied rating curves do not extend to the range of flows occurring during high flow conditions. Therefore, the supplied rating curves were extrapolated by applying the following methodology:

- For flows up to 0.2 m³/s (200 L/s), the rating curve were extracted from the original (supplied) rating curves.
- For high flows (greater than approximately 20 m³/s), the rating curve was extracted from the TUFLOW hydraulic model results. The TUFLOW hydraulic model developed for this study is described in Section 6.
- For flows between approximately 0.2 m³/s and 20 m³/s, the rating curve was extracted from local HEC-RAS hydraulic models developed for each station. The HEC-RAS model for each station was developed using detailed ground survey of the creek and weir cross sections supplied by Bowdens Silver.

Figure 4.5 and Figure 4.6 show the rating curves described above for the Powells Road (421195) and Bingmans Crossing (421194) stations respectively. Figure 4.7 shows the adopted rating curves for both stations.

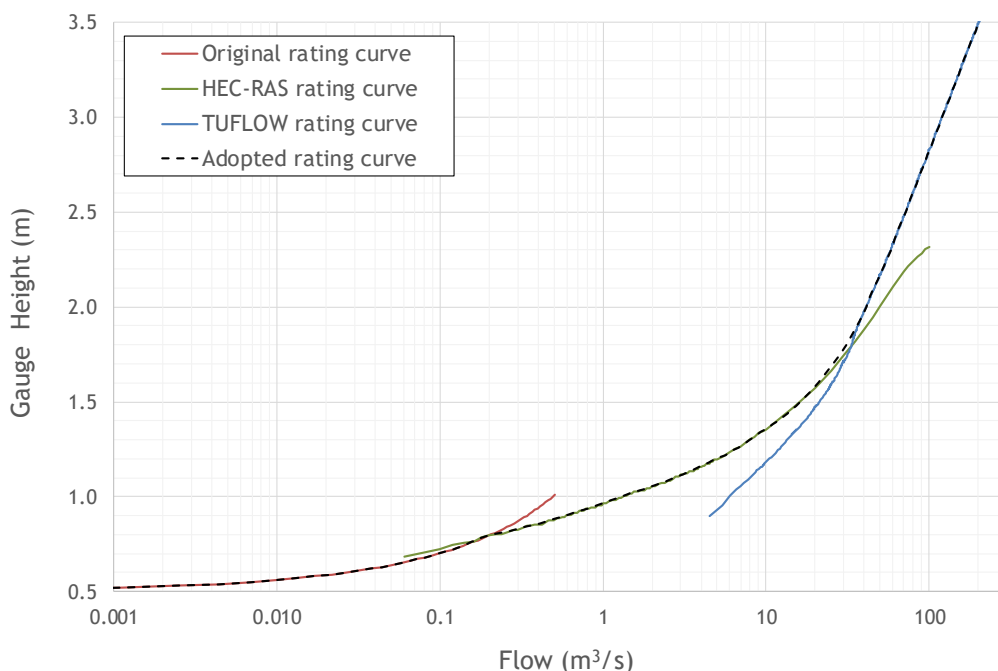


Figure 4.5 - Derivation of rating curve for Bowdens Silver recording station: Hawkins Creek at Powells Road (421195)

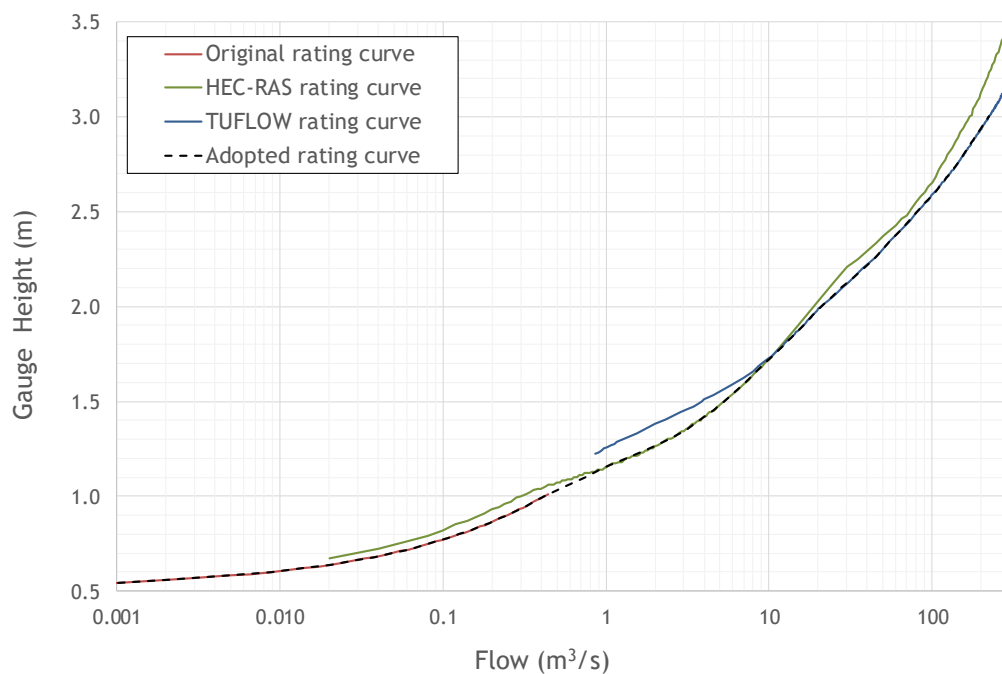


Figure 4.6 - Derivation of rating curve for Bowdens Silver recording station: Hawkins Creek at Bingmans Crossing (421194)

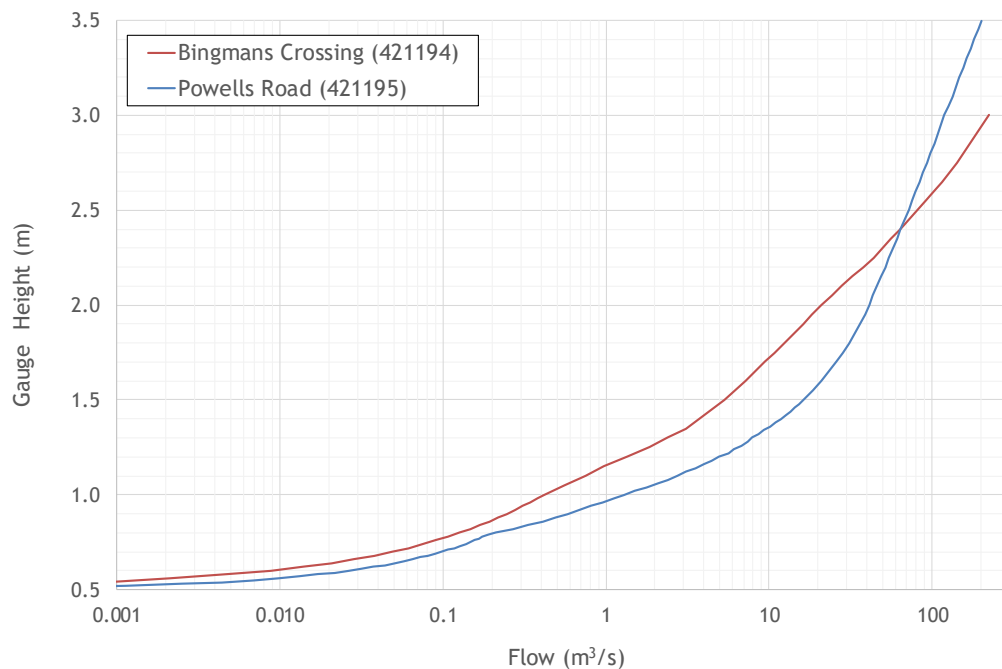


Figure 4.7 - Adopted rating curves for Bowdens Silver re-coding stations on Hawkins Creek

4.3 XP-RAFTS MODEL CONFIGURATION

4.3.1 Model extent

Figure 4.8 shows the entire XP-RAFTS model layout. Figure 4.9 shows the XP-RAFTS model subcatchments within the Project. The model extends to downstream of the confluence of Lawsons Creek and the TSF tributary. The total catchment of the XP-RAFTS model to the outlet is 272 km². The model has been subdivided into 84 subcatchments.

4.3.2 Subcatchment parameters

The adopted XP-RAFTS subcatchment parameters were configured based on the available topographic data and aerial photographs. Table A.1 in Appendix A shows the adopted subcatchment parameters including catchment area, percentage impervious, catchment slope and PERN 'n' catchment roughness coefficients. Model parameters for each subcatchment were determined as follows:

- A percentage impervious of zero was adopted for all subcatchments.
- Catchment slopes were determined based on the available topographic data.
- A default subcatchment storage coefficient multiplication factor 'Bx' of 1.0 was adopted for all events, and validated against the recorded catchment response.
- Subcatchment PERN 'n' values were determined based on the density of vegetation in each subcatchment. The adopted subcatchment PERN 'n' values are:
 - 0.035 for subcatchments with grassed areas;
 - 0.040 for subcatchments with a mixture of grassed and forested areas; and
 - 0.050 for subcatchments with largely forested areas.
- Initial (IL) and continuing (CL) losses for the validation events were determined based on the model validation results as described in Section 4.4. The selection of initial and continuing losses for design events is described in Section 5.

4.3.3 Routing parameters

Channel routing in the XP-RAFTS model was configured based on specifying a 'K' and 'X' value for each routing link. A default 'X' value of 0.2 was adopted for all routing links. The 'K' values represent estimated flow travel times (in hours) and were initially calculated based on the flow path lengths and the following assumed flow velocities:

- 2.0 m/s for stream slopes of up to 1%;
- 3.0 m/s for stream slopes of between 1% and 3%; and
- 3.5 m/s for stream slopes of steeper than 3%.

These parameters were validated against the hydraulic model results in the vicinity of the Mine Site and the timing of the recorded hydrographs.

4.4 XP-RAFTS MODEL VALIDATION

4.4.1 Overview

The rating curves developed for the two water level recording stations were used to convert recorded water level hydrographs into discharge hydrographs for the three validation events. The resulting flow hydrographs were then used to validate the XP-RAFTS model. The initial loss and continuing loss rates for the three validation events were varied to achieve the best possible match to the recorded discharge hydrographs.

Table 4.2 shows the recorded peak flows in Hawkins Creek at the two stations for the three validation events. Table 4.2 also shows the preceding baseflow and the adopted initial and continuing losses for each event.

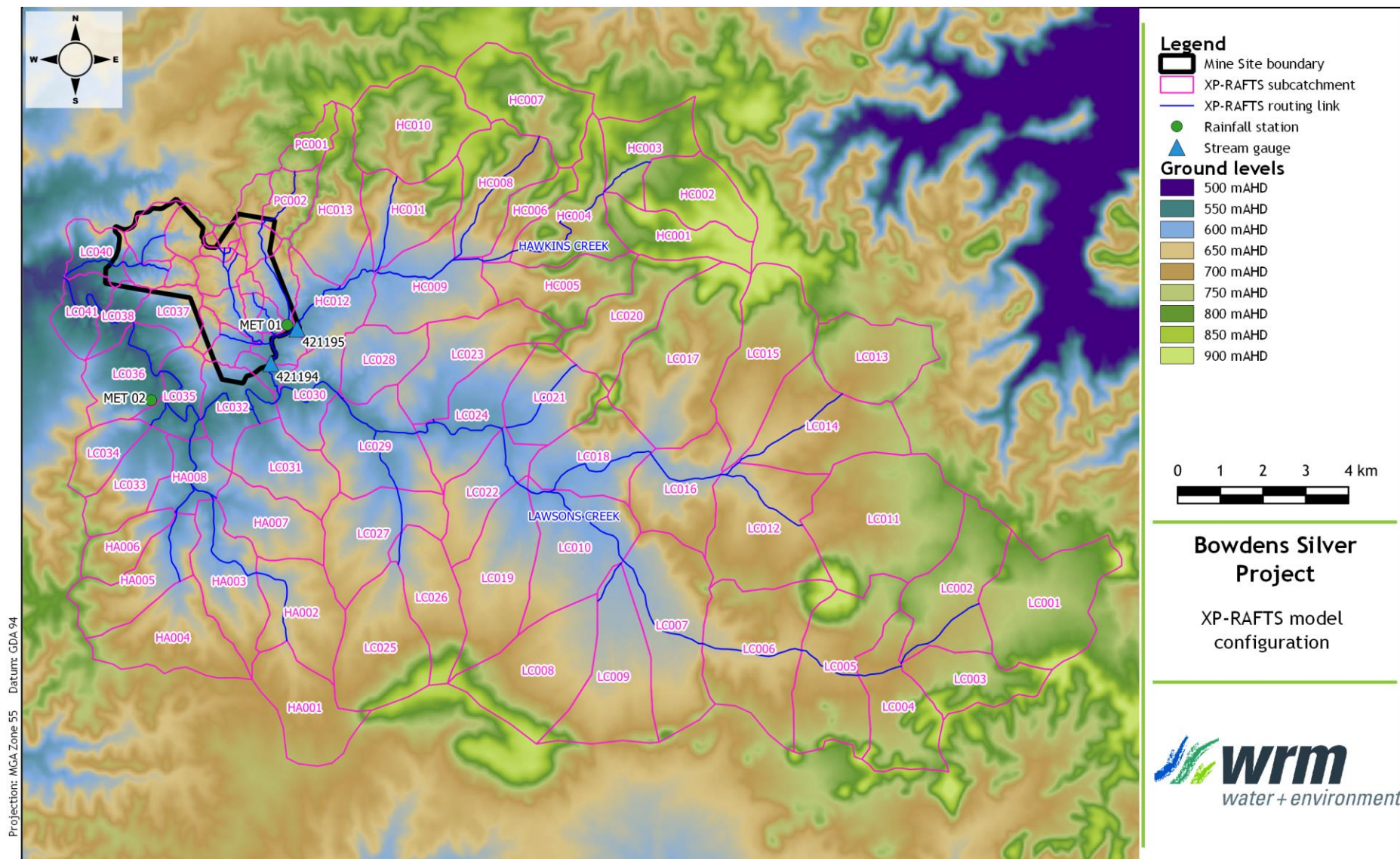


Figure 4.8 - XP-RAFTS model configuration

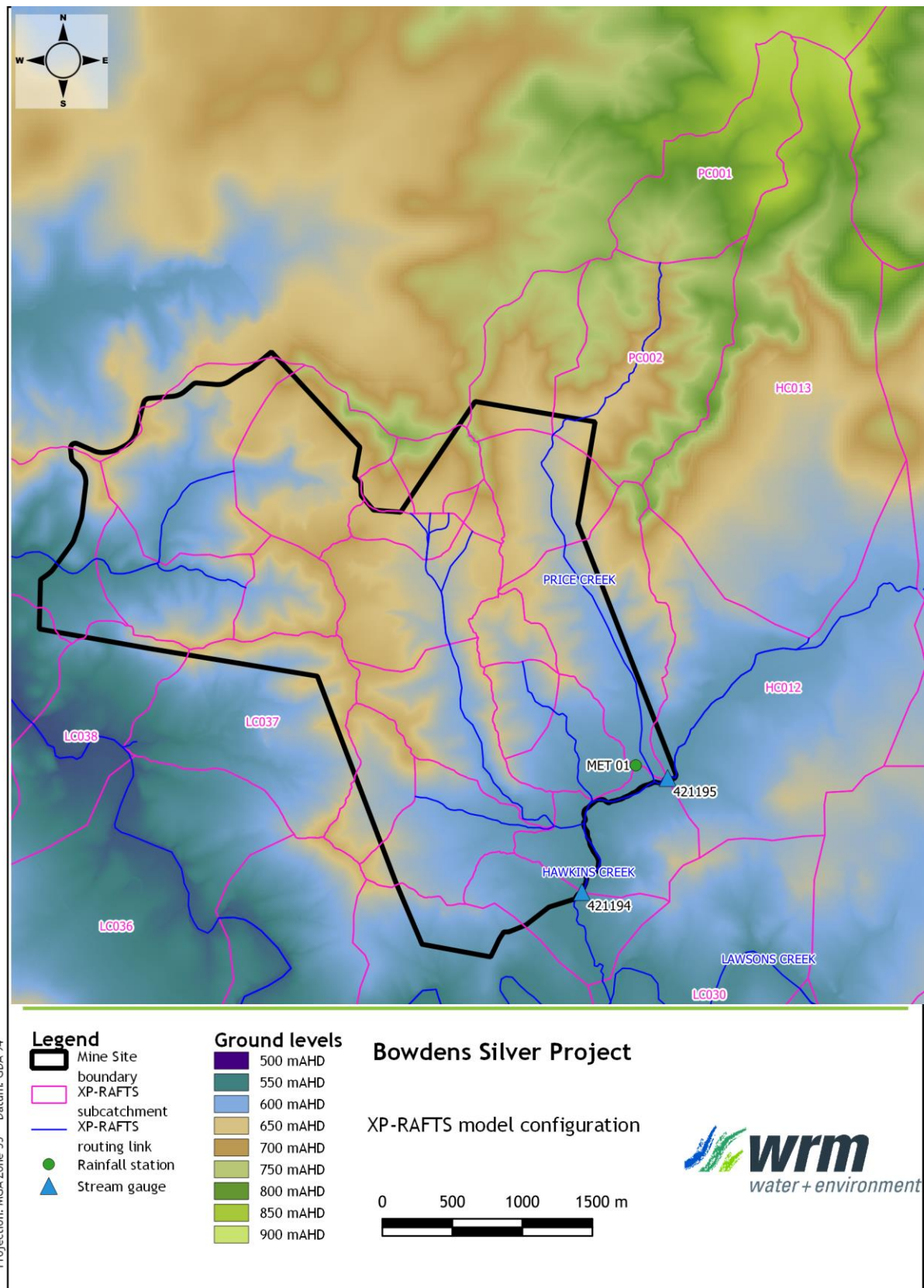


Figure 4.9 - XP-RAFTS model configuration within the Mine Site

Table 4.2 - Summary of recorded peak discharges at the water level recording stations operated by Bowdens Silver, with the XP-RAFTS adopted initial and continuing losses

Flow event	Event start date	Event finish date	Baseflow prior to event (m ³ /s)	Peak discharge (m ³ /s)		Adopted initial loss (mm)	Adopted continuing loss (mm/h)
				Bingmans Crossing (421194)	Powells Road (421195)		
July 2016	19/07/2016	21/07/2016	0.01	6.2	6.1	0.0	13.0
September 2016 (1 st flow event)	31/08/2016	9/09/2016	0.00	7.6	7.4	38.0	4.0
September 2016 (2 nd flow event)	18/09/2016	20/09/2016	0.19	14.2	24.8	0.0	11.0

4.4.2 Validation results

Comparisons between recorded and modelled peak discharge hydrographs for the three validation events are shown in the following figures:

- Figure 4.10 and Figure 4.11 for the July 2016 flow event at the Powells Road (421195) and Bingmans Crossing (421194) stations respectively;
- Figure 4.12 and Figure 4.13 for the September 2016 (1st flow event) at the Powells Road (421195) and Bingmans Crossing (421194) stations respectively; and
- Figure 4.14 and Figure 4.15 for the September 2016 (2nd flow event) at the Powells Road (421195) and Bingmans Crossing (421194) stations respectively.

The results show that very high continuing loss rates were required to achieve a good match to the peak discharges recorded during the July 2016 event and the September 2016 (2nd flow event). This is probably due at least in part, to the site rainfall recordings overestimating the catchment rainfall during the event. In contrast, the modelled peak discharge for the September 2016 (1st flow event) is within 15% to 20% of the recorded peak discharge with a continuing loss of 4.0 mm/h. The results show the model is able to reproduce the timing and shape of the hydrographs reasonably well.

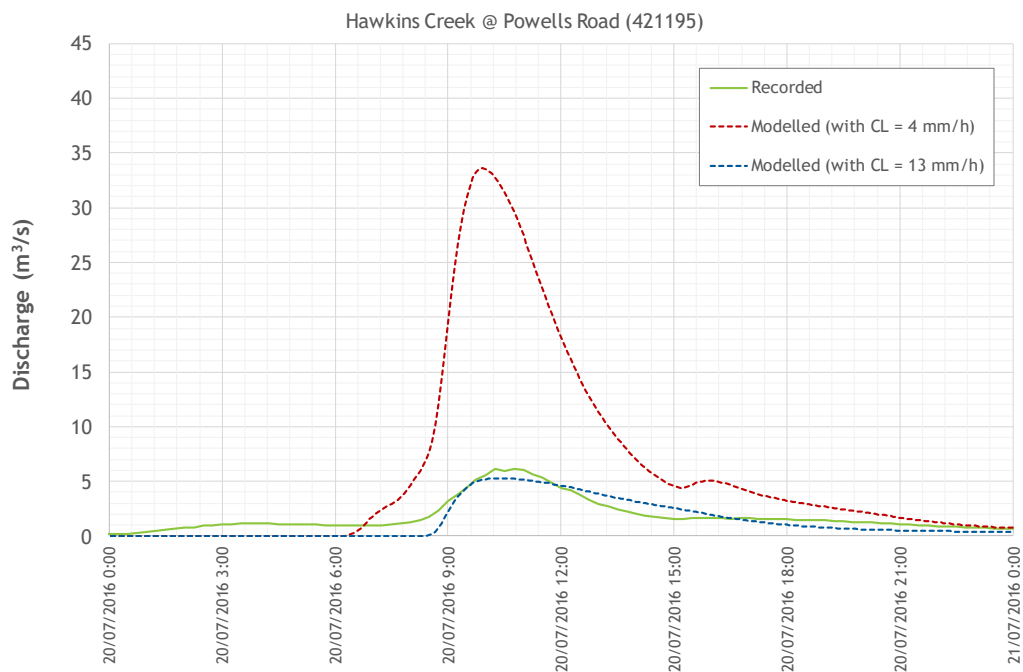


Figure 4.10 - Comparison of recorded and modelled discharge hydrographs for the July 2016 flow event - Hawkins Creek at Powells Road (421195)

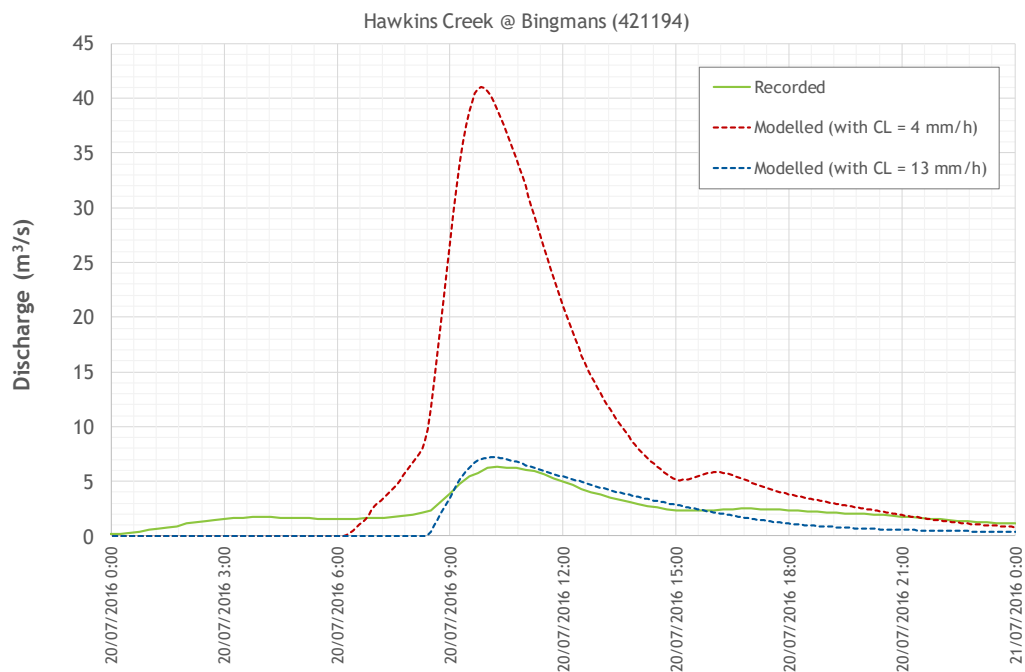


Figure 4.11 - Comparison of recorded and modelled discharge hydrographs for the July 2016 flow event - Hawkins Creek at Bingmans Crossing (421194)

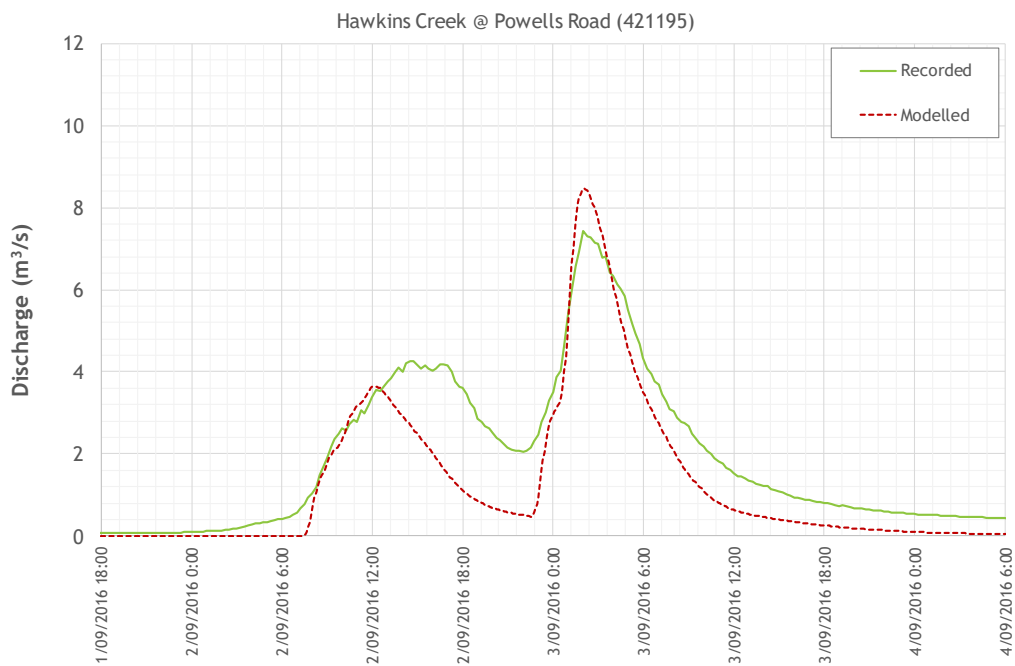


Figure 4.12 - Comparison of recorded and modelled discharge hydrographs for the September 2016 (1st flow event) - Hawkins Creek at Powells Road (421195)

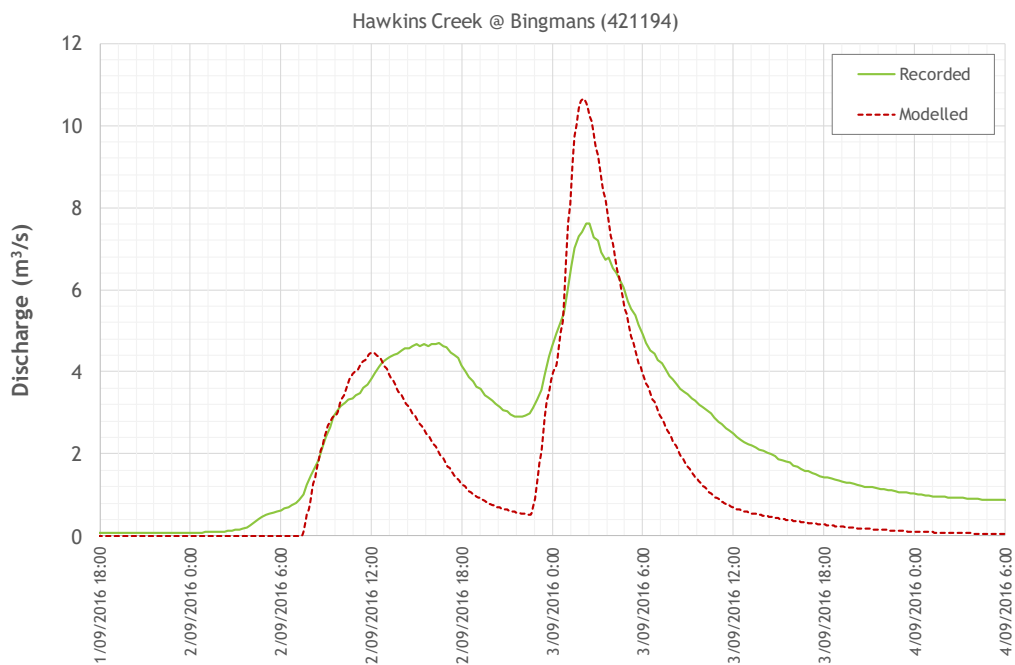


Figure 4.13 - Comparison of recorded and modelled discharge hydrographs for the September 2016 (1st flow event) - Hawkins Creek at Bingmans Crossing (421194)

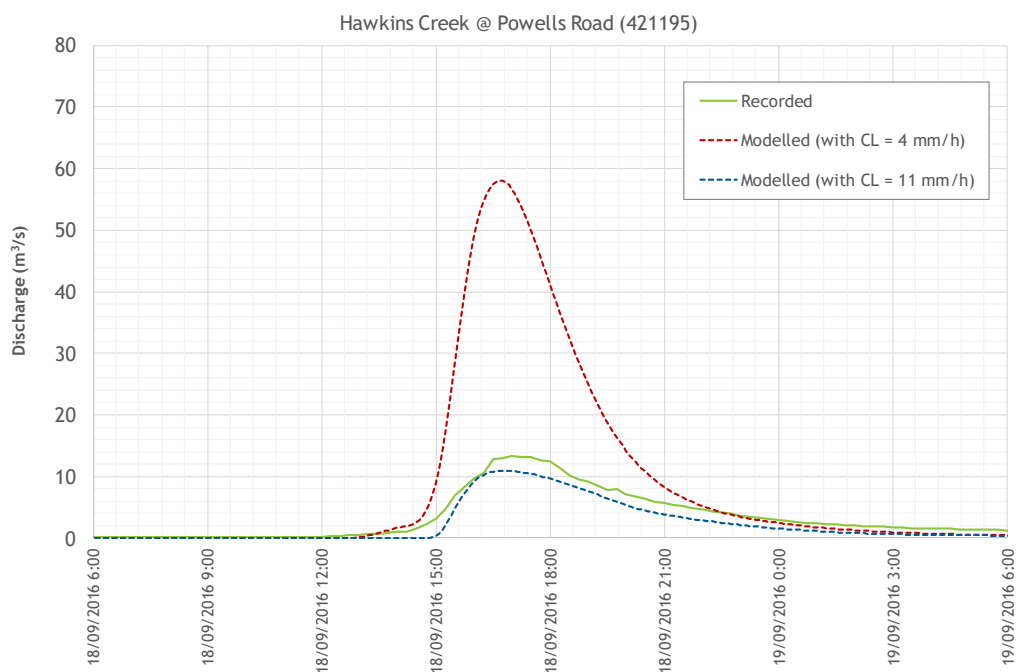


Figure 4.14 - Comparison of recorded and modelled discharge hydrographs for the September 2016 (2nd flow event) - Hawkins Creek at Powells Road (421195)

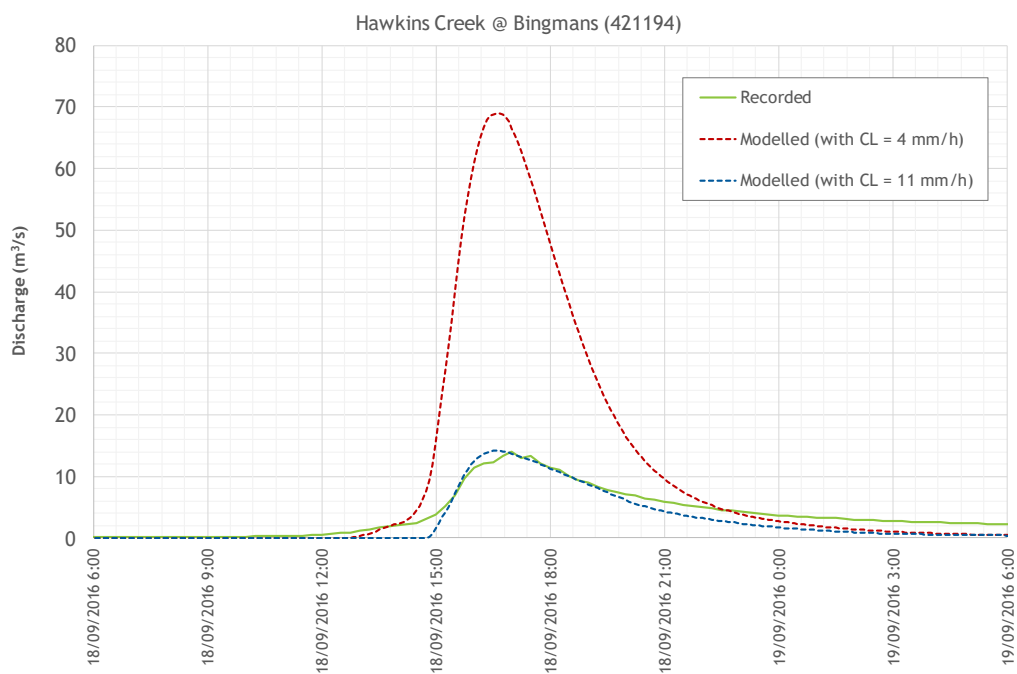


Figure 4.15 - Comparison of recorded and modelled discharge hydrographs for the September 2016 (2nd flow event) - Hawkins Creek at Bingmans Crossing (421194)

5 Estimation of design discharges

5.1 OVERVIEW

The XP-RAFTS model was used to derive flood discharge hydrographs for use in the hydraulic model. Design discharges were estimated based on the methodology described in the 2016 Australian Rainfall and Runoff (AR&R 2016) (Ball et al, 2019).

Design discharges were estimated for the 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200) and 0.2% (1 in 500) annual exceedance probability (AEP) events as well as the probable maximum precipitation (PMP) design event. Design flood discharge hydrographs were output for these seven design events and for a range of storm durations from 25 minutes up to 72 hours.

5.2 DESIGN RAINFALL DEPTH

5.2.1 10% to 0.2% AEP design events

Design rainfall depths and intensities were derived using intensity-frequency duration (IFD) data obtained from the Bureau of Meteorology's (BoM's) 2016 Rainfall IFD Data System. Design rainfall IFDs were obtained based on a point location at the centroid of the Lawsons Creek catchment to the XP-RAFTS model outlet.

For the 0.5% and 0.2% AEP design events, the BoM 2016 Rainfall IFD Data System does not provide design rainfall depth estimates for storm durations shorter than 24 hours. Therefore, rainfall depths for storm durations shorter than 24 hours for these events were derived by factoring the relevant 1% AEP design rainfall depths using 'growth curve factors' (Jordan et al, 2005) as recommended in Book 8 of AR&R 2016.

5.2.2 PMP design event

PMP rainfall depths for durations up to 6 hours were estimated using the methodology given in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (GSDM)* (BoM, 2003).

PMP rainfall depths for durations longer than 6 hours were estimated using the standard methodology given in *The Estimation of Probable Maximum Precipitation: Generalised Southeast Australia Method (GSAM)* (BoM, 2006) based on the catchment of Lawsons Creek upstream of the XP-RAFTS model outlet.

5.3 AREAL REDUCTION FACTORS

For design discharge estimation in Hawkins Creek and its minor tributaries that cross the Mine Site, an areal Reduction Factor (ARF) of 1.0 was adopted for all design events up to the 0.2% AEP. This would provide a conservative design discharge estimates in the minor tributaries across the Mine Site.

For design discharge estimation in Lawsons Creek (which has a much larger catchment compared to Hawkins Creek and its tributaries), ARFs derived using the methodology in Book 2 of AR&R 2016 were adopted for design events up to and including 0.2% AEP.

For the PMP design event, the BoM (2003) and BoM (2006) guidelines were used.

5.4 TEMPORAL PATTERNS

5.4.1 10% to 1% AEP design events

Temporal patterns were obtained from the AR&R 2016 data hub based on a point location at the centroid of the Lawsons Creek catchment to XP-RAFTS model outlet. The AR&R 2016 temporal pattern methodology involves the use of an 'ensemble' of 10 temporal patterns, which produces 10 design storms for each duration for each AEP. The temporal pattern which results in a peak flood discharge closest to the average of the 10 design storms for each storm duration is selected as the representative temporal pattern for that storm duration.

As the critical storm duration would vary significantly across the catchment, the ensemble method were used to determine the representative temporal pattern that gives a peak flood discharge closest to the average at each key locations for each critical duration. This representative temporal pattern for each storm duration was adopted for hydraulic modelling.

5.4.2 0.5% AEP to PMP design events

The temporal patterns for storm durations up to and including 12 hours were obtained from the GSDM methodology (BoM, 2003). Temporal patterns for durations longer than 12 hours were obtained for Inland Zone storms from the GSAM methodology (BoM, 2006).

5.5 SPATIAL DISTRIBUTION

5.5.1 10% to 0.2% AEP design events

An assessment on rainfall IFDs (obtained from AR&R 2016) across the Lawsons Creek catchment indicate that design rainfall intensities across the catchment generally increase from east to west and from south to north. However, when compared to the rainfall intensities near the centroid of the Lawsons Creek catchment to the XP-RAFTS model outlet, the variation in rainfall intensities within the catchment was not significant. For this study, rainfall IFDs generated at the centroid of the Lawsons Creek catchment to the XP-RAFTS model outlet were adopted for the entire catchment.

5.5.2 PMP design event

Spatial distribution of rainfall for storm durations between 1 hour and 6 hours is accounted for in the GSDM (BoM, 2003) rainfall depth estimation methodology. Spatial distribution of rainfall for storm durations longer than 6 hours is accounted for in the GSAM (BoM, 2006) rainfall depth estimation methodology.

5.6 DESIGN RAINFALL LOSSES

5.6.1 Overview

For each design event up to and including 1% AEP, the design initial loss and continuing loss rates were selected so that the peak design discharge averaged from the ensemble of design temporal patterns was consistent with peak discharges estimated using the Regional Flood Frequency Estimation (RFFE) technique.

The RFFE is an automated web-based tool developed as part of AR&R 2016 guideline to estimate peak discharges for ungauged catchments based on data from nearby gauged catchments. It is recalled that recorded water level data for Hawkins Creek is available for this study. However, the period of record is too short and does not include any large flood events. Hence the recorded water level data is not suitable for validation of the XP-RAFTS model for large events. Therefore, the RFFE peak discharge estimates were used to validate the XP-RAFTS model estimates for flood events up to and including 1% AEP.

Taking a conservative approach, zero losses were adopted for extreme events larger than 1% AEP.

5.6.2 Adopted design losses

The AR&R 2016 data hub recommends the following design loss parameters (after modification by application of the “NSW continuing loss adjustment factor” of 0.4 recommended in the NSW Floodplain Risk Management Guide) for the area of interest:

- Initial loss = 23.0 mm; and
- Continuing loss = 1.3 mm/h (3.3 mm/h before modification).

Design loss rates were selected for modelling based on reconciliation with the FFA derived using the RFFE at key locations within the study area (as described in the following section). Table 5.1 shows the adopted initial loss and continuing loss rates for all modelled events. The adopted 1% AEP continuing loss rate of 1.5 mm/h is similar to the modified AR&R 2016 data hub value of 1.3 mm/h. The adopted continuing loss rates are well below the values inferred from the recorded streamflow data described in section 4.

Table 5.1 - Adopted design initial loss and continuing loss rates

Event	Initial loss (mm)	Continuing loss (mm/h)
10% AEP	25.0	3.0
5% AEP	15.0	3.0
2% AEP	5.0	2.0
1% AEP	1.0	1.5
0.5% AEP	0.0	0.0
0.2% AEP	0.0	0.0
PMP	0.0	0.0

5.6.3 Validation of design losses using RFFE peak discharge estimates

The RFFE was used to estimate design peak discharges up to and including 1% AEP at the following three locations:

- Hawkins Creek at Powells Road;
- Price Creek upstream of the Hawkins Creek confluence; and
- Lawsons Creek at the XP-RAFTS model outlet.

Figure 5.1, Figure 5.2 and Figure 5.3 compare XP-RAFTS predicted design peak discharges (using the adopted design losses) against RFFE estimates at the above three locations. The results show that XP-RAFTS predicted peak discharges generally match well with the RFFE estimates. On this basis, the XP-RAFTS model would produce reasonable estimates of design peak discharges using the adopted design rainfall losses. Design Price Creek discharges derived from the XP-RAFTS model are generally less than the RFFE values, and during later design phases consideration should be given to adopting further reduced loss rates for events with AEPs greater than 1%.

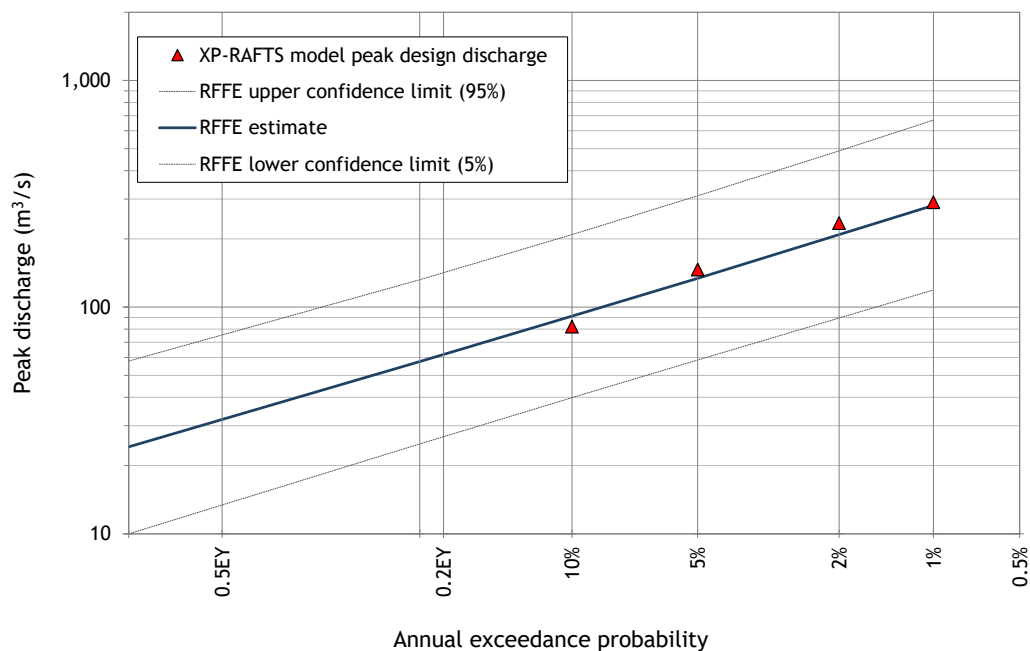


Figure 5.1 - Comparison of predicted XP-RAFTS design peak discharges against RFFE estimates, Hawkins Creek at Powells Road

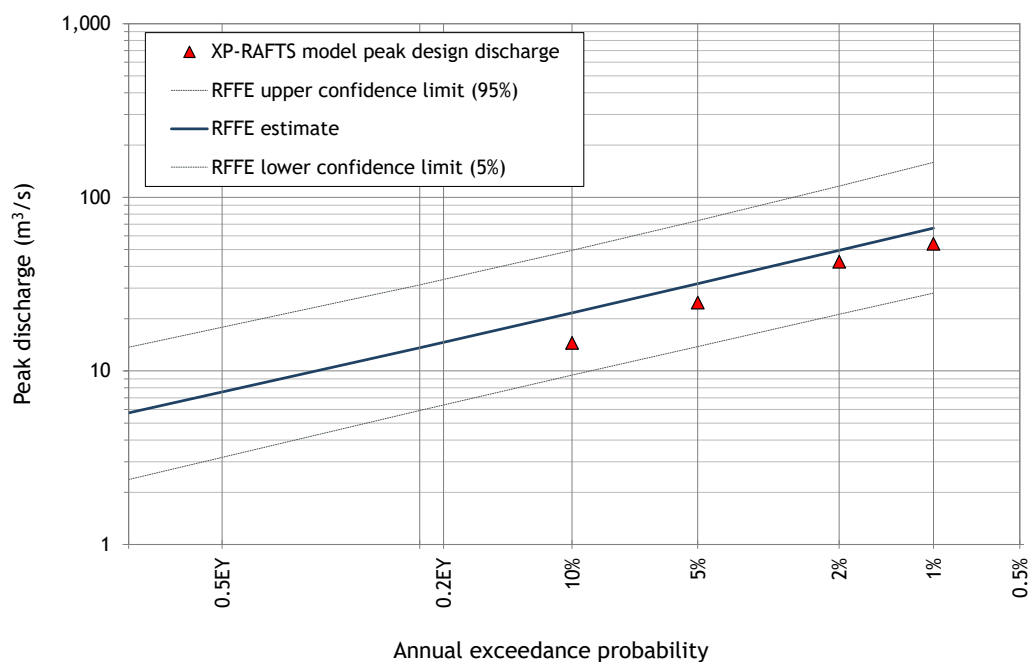


Figure 5.2 - Comparison of predicted XP-RAFTS design peak discharges against RFFE estimates, Price Creek upstream of Hawkins Creek confluence

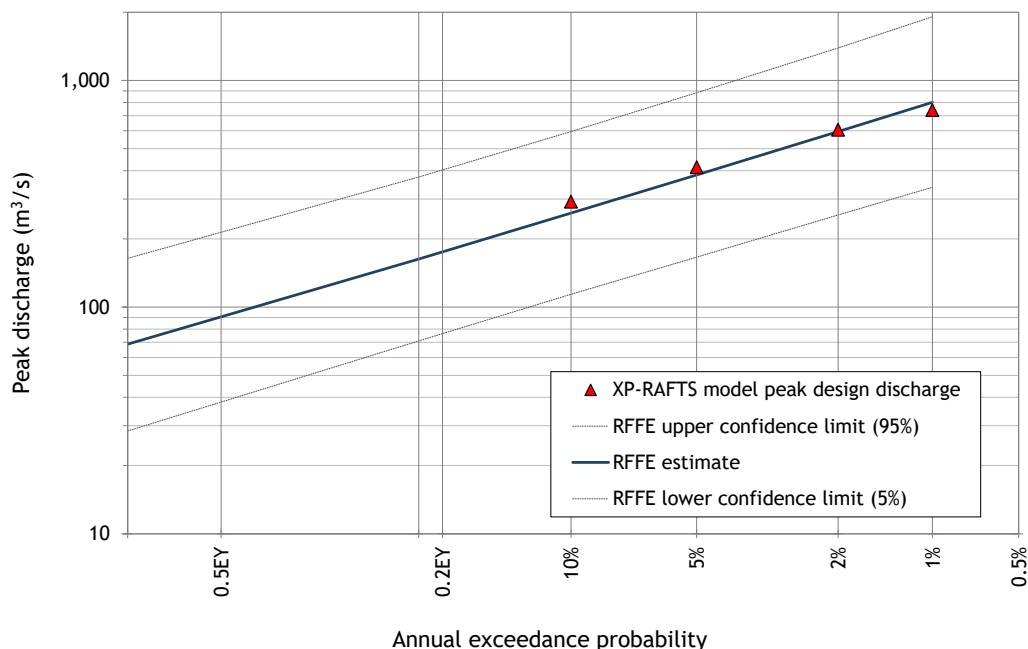


Figure 5.3 - Comparison of predicted XP-RAFTS design peak discharges against RFFE estimates, Lawsons Creek at XP-RAFTS model outlet

5.7 DESIGN DISCHARGES

Table 5.2 shows XP-RAFTS predicted design peak discharges and critical storm durations for all modelled design events at the following locations:

- Hawkins Creek at Powells Road;
- Price Creek upstream of the Hawkins Creek confluence; and
- Lawsons Creek at the XP-RAFTS model outlet.

The design peak discharges less than 0.5% were generated by one representative design storm which produced a peak discharge closest to the average of the 10 design storms for each storm duration at each location. For the PMP design storms, single temporal patterns were adopted for each duration in accordance with the GSDM methodologies.

To illustrate the range of peak discharges produced by the ensemble method of AR&R 2016, Appendix B provides box and whisker plots (box plots) to summarise the statistics of the XP-RAFTS model results for the 1% AEP design event at the above three locations. The box plots present the maximum, minimum, median, average, 25th and 75th percentile predicted peak discharges based on the model results for the 10 design storms for each storm duration. The XP-RAFTS model results indicate that the 10 design storms for each duration produced significantly different results. Notwithstanding this, design peak discharges were selected based on the average (mean) results from each ensemble (as suggested in AR&R 2016).

Table 5.2 - XP-RAFTS predicted design peak discharges and critical storm durations

AEP (%)	AEP (1 in X)	Peak discharge (m ³ /s)			Critical storm duration (hours)		
		Hawkins Creek at Powells Road	Price Creek u/s of Hawkins Creek confluence	Lawsons Creek at XP-RAFTS model outlet	Hawkins Creek at Powells Road	Price Creek u/s of Hawkins Creek confluence	Lawsons Creek at XP-RAFTS model outlet
10%	10	82	15	292	12	6	12
5%	20	146	25	414	6	2	6
2%	50	235	43	606	3	1	6
1%	100	290	54	740	2	1	6
0.5%	200	383	69	1,312	2	1	3
0.2%	500	466	84	1,571	2	1	3
PMP	PMP	2,384	337	8,070	2	1	3

6 Hydraulic modelling

6.1 OVERVIEW

The TUFLOW hydrodynamic model (BMT, 2019) was used to simulate existing conditions flood behaviour in Lawsons Creek, Hawkins Creek and their tributaries for a range of design events. TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically identifies breakout points and flow directions within the study area. All hydraulic modelling was undertaken using the TUFLOW Build 2017-09-AB HPC solver.

Flow paths within Lawsons and Hawkins Creeks are well defined for low flows. However, out-of-bank flows would occur in larger flood events such those modelled in this study. In addition, the channels of the various tributaries that cross the Mine Site are poorly defined with little capacity. Flows in the tributaries within the Mine Site would likely be conveyed by the floodplains of these tributaries as overland flow.

Out-of-bank flow conditions and the interaction between Hawkins and Lawsons Creeks and their much smaller tributaries would be poorly represented using simplistic one-dimensional modelling techniques. The TUFLOW modelling package is suited to simulation of dynamic hydraulic behaviour of complex overland flow in rural areas and was considered the most appropriate tool to determine the flood characteristics of Lawsons and Hawkins Creeks and their tributaries.

The discharges estimated using the XP-RAFTS runoff-routing model were adopted as inflows to the TUFLOW hydraulic model.

6.2 EXISTING CONDITIONS TUFLOW MODEL CONFIGURATION

6.2.1 Spatial configuration

Figure 6.1 shows the TUFLOW model configuration. The model covers an area of 11.5 km² and extends about 1.2 km upstream of the Mine Site along Hawkins Creek, and downstream to the XP-RAFTS model outlet (downstream of the confluence between Lawsons Creek and the TSF tributary).

The TUFLOW model was configured using a grid cell size of three metres. This provides a reasonable compromise between a coarse grid cell size sufficient for Lawsons and Hawkins Creeks, and a fine grid cell size required for the tributaries crossing the Mine Site.

6.2.2 Topography

Topographic LiDAR survey data for the area covered by the model was provided by Bowdens Silver in July 2017. The LiDAR data was converted into a digital terrain model (DTM) for use as the base TUFLOW model topography as well as mapping purposes.

6.2.3 Hydraulic roughness

Hydraulic roughness in the TUFLOW model is represented by Manning's 'n' roughness coefficients. Manning's 'n' values for the various land use types were selected based on typical published values (such as those in Chow (1959)). Land use types within the model were identified using aerial photography supplied by Bowdens Silver in August 2017.

The TUFLOW model was not calibrated to the recorded water level data at the Bowdens Silver recording stations (at Powells Road and Bingmans Crossing). Peak flows in Hawkins Creek recorded at these stations are too low (less than 20 m³/s) and considered unsuitable for model calibration.

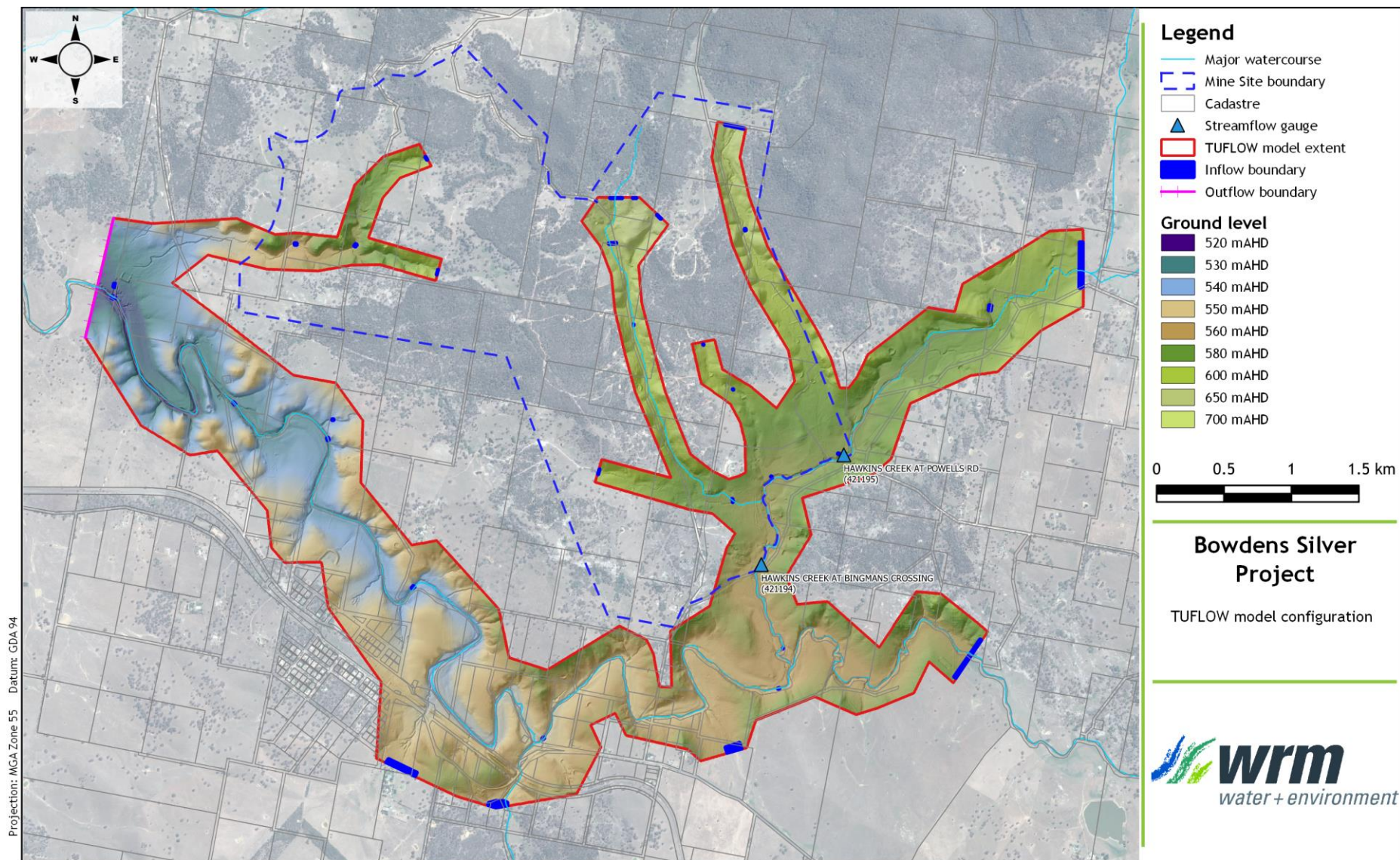


Figure 6.1 - TUFLOW model configuration

The adopted Manning's 'n' values in the TUFLOW model are as follows:

- River and creek channels - 'n' = 0.035;
- Floodplain (grassed open areas) - 'n' = 0.035;
- Moderate vegetation - 'n' = 0.05
- Dense vegetation - 'n' = 0.07; and
- Road - 'n' = 0.025.

6.2.4 Model inflow and outflow boundaries

Figure 6.1 shows the locations of inflow and outflow boundaries in the TUFLOW model. The model includes a total of 36 inflow boundaries. The model inflow boundaries were applied within the 2D model domain using surface-area "SA" polygons. Using this approach, flows are initially applied to the lowest point within each SA polygon. Design discharge hydrographs for these inflow boundaries were obtained from the XP-RAFTS hydrologic model.

As discussed in Section 5.4, the critical storm duration would vary significantly across the catchment. Therefore, the TUFLOW model was run using discharge hydrographs for various storm durations to ensure that the peak flood level is represented at all locations within the model. The TUFLOW model was run for one representative design storm for each storm duration.

A single rating curve outflow boundary was adopted based on a flood slope of 0.1%, which is the approximate bed slope at this location.

6.2.5 Hydraulic structures

Lawsons Creek is crossed by roads at the following locations within the model domain:

- 1 Bara-Lue Road;
- 2 Private access to property on Gunther Street, Lue;
- 3 Private access to property on Peel Street, Lue;
- 4 Pyangle Road - which comprises 5 reinforced box culverts, with the road crest at bank level and the approaches in cut.

As crossings 1 to 3 are low level crossings at the bed of the stream, they would have no perceptible impact on flood conditions. The Pyangle Road crossing would be drowned once flood levels significantly exceeded the road crest level. As the model results show that even during extreme events, inundation due to Lawsons Creek flooding would not extend within 250 m of the Mine Site the effect of these structures on flood levels has not been assessed in the hydraulic model.

6.3 EXISTING CONDITIONS FLOODING

6.3.1 Overview

Flood maps showing design peak flood levels, depths and velocities under existing conditions for the 1% (1 in 100) AEP event are shown in the following figures:

- Figure 6.2 and Figure 6.6 - for the entire hydraulic model extent;
- Figure 6.3 and Figure 6.7 - for the eastern extent (the locations of the proposed mining pit, processing plant and waste rock emplacements);
- Figure 6.4 and Figure 6.8 - for the western extent (the location of the proposed TSF); and
- Figure 6.5 and Figure 6.9 - for the Lawsons Creek extent (the location of the proposed mine access road).

Flood maps showing design peak flood levels, depths and velocities under existing conditions for the 10% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMP design events at the above locations are provided in Appendix C.

6.3.2 Peak flood levels and depths

Key points with regards to predicted peak flood levels and depths across the study area are summarised below:

- The Project disturbance area is located outside of the Lawsons Creek flood extent for all events up to the PMP design event.
- The area along the southeastern Mine Site boundary is affected by flooding from Hawkins Creek. However, the proposed open cut pits, WRE and leachate management dam are located outside of the predicted flood extent for Hawkins Creek for all events up to the PMP design event.
- Flooding along the Hawkins and Lawsons Creeks tributaries within the Mine Site is characterised by shallow overland flows. Flows in these tributaries are generally confined within the narrow floodplains, with no breakouts occurring except near the confluences of these tributaries with Hawkins and Lawsons Creeks. Due to the narrow floodplains, the difference in predicted flood extents along these tributaries between the 1% AEP and PMP design events are not significant.
- Predicted peak flood depths along the overbank areas of the Hawkins and Lawsons Creeks tributaries are generally below one metre for events up to and including 0.2% AEP. Peak flood depths of up to 1.5 m for the PMP design event are predicted in some sections along these tributaries.

6.3.3 Peak flood velocities

Key points with regards to predicted peak velocities across the study area are summarised below:

- Flows in the Lawsons and Hawkins Creeks tributaries are generally confined within narrow floodplains with relatively steep ground slopes. This results in relatively high predicted peak flood velocities of up to 2.5 m/s along the channel and overbank areas of these tributaries for events up to and including 0.2% AEP. For the PMP design event, peak flood velocities greater than 4 m/s are predicted in many sections along these tributaries.
- Predicted peak flood velocities in Hawkins Creek for events up to and including 0.2% AEP are generally less than 3 m/s, with peak velocities greater than 4 m/s predicted in some sections. For the PMP design event, peak flood velocities greater than 4 m/s are predicted throughout the Hawkins Creek main channel and in large areas of the floodplain.
- Predicted peak flood velocities in Lawsons Creek are relatively high for all modelled events. For events up to and including 0.2% AEP, peak flood velocities greater than 4 m/s are predicted in many sections along the Lawsons Creek channel and floodplain. For the PMP design event, peak velocities greater than 4 m/s are predicted throughout and Lawsons Creek main channel and large areas of the floodplain.

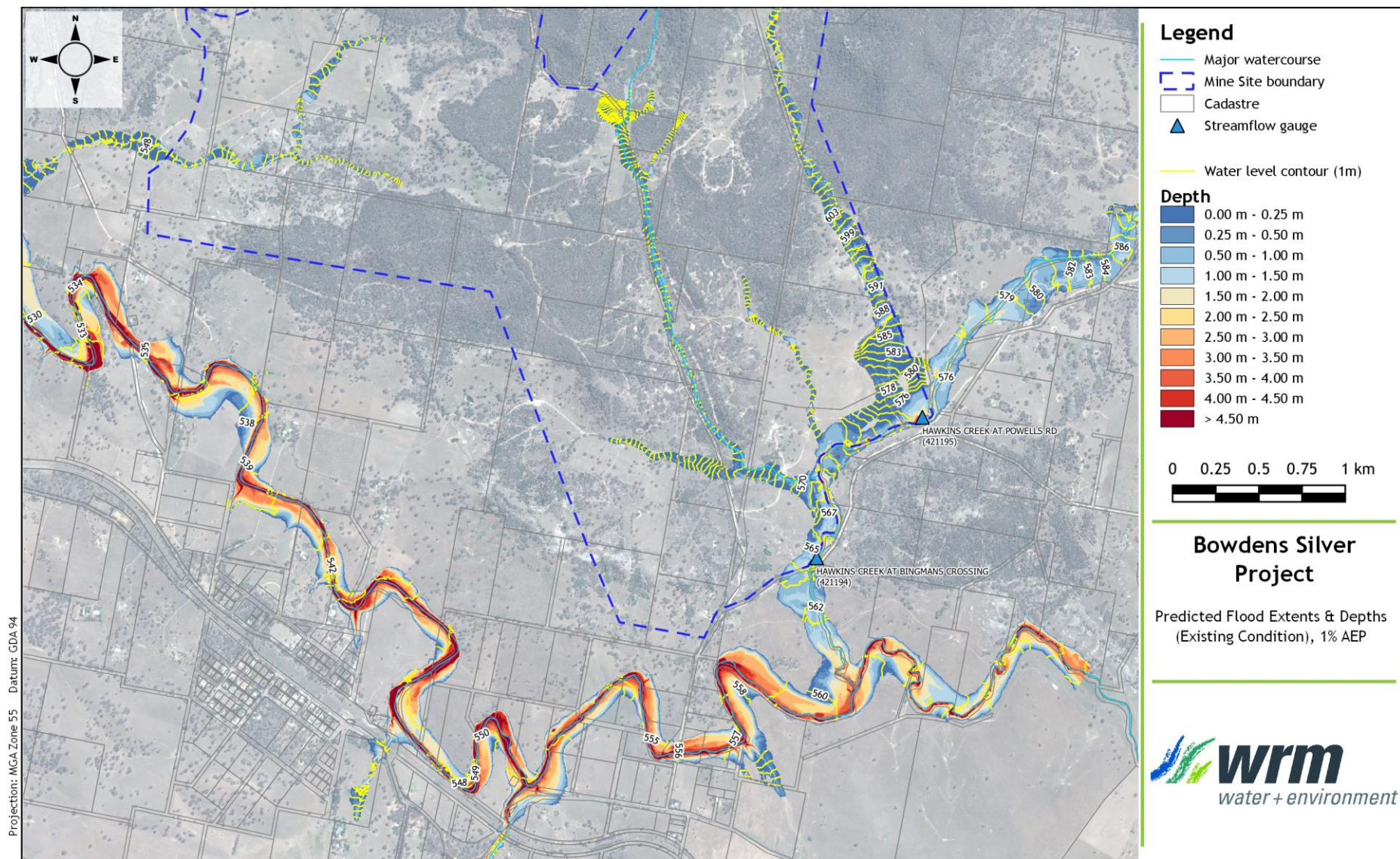


Figure 6.2 - 1% (1 in 100) AEP peak flood levels and depths - existing conditions - complete extent

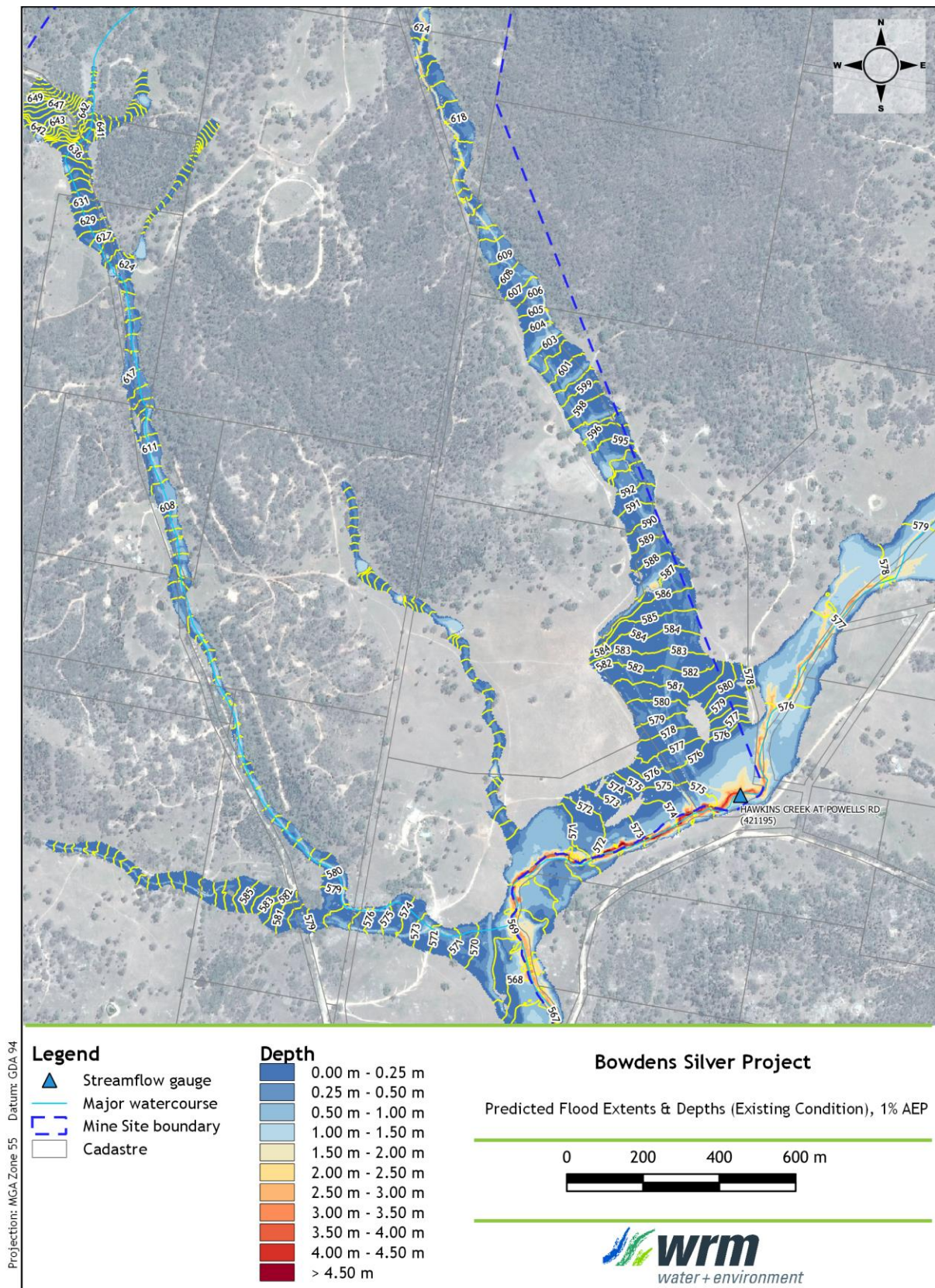


Figure 6.3 - 1% (1 in 100) AEP peak flood levels and depths - existing conditions - eastern extent



Figure 6.4 - 1% (1 in 100) AEP peak flood levels and depths - existing conditions - western extent

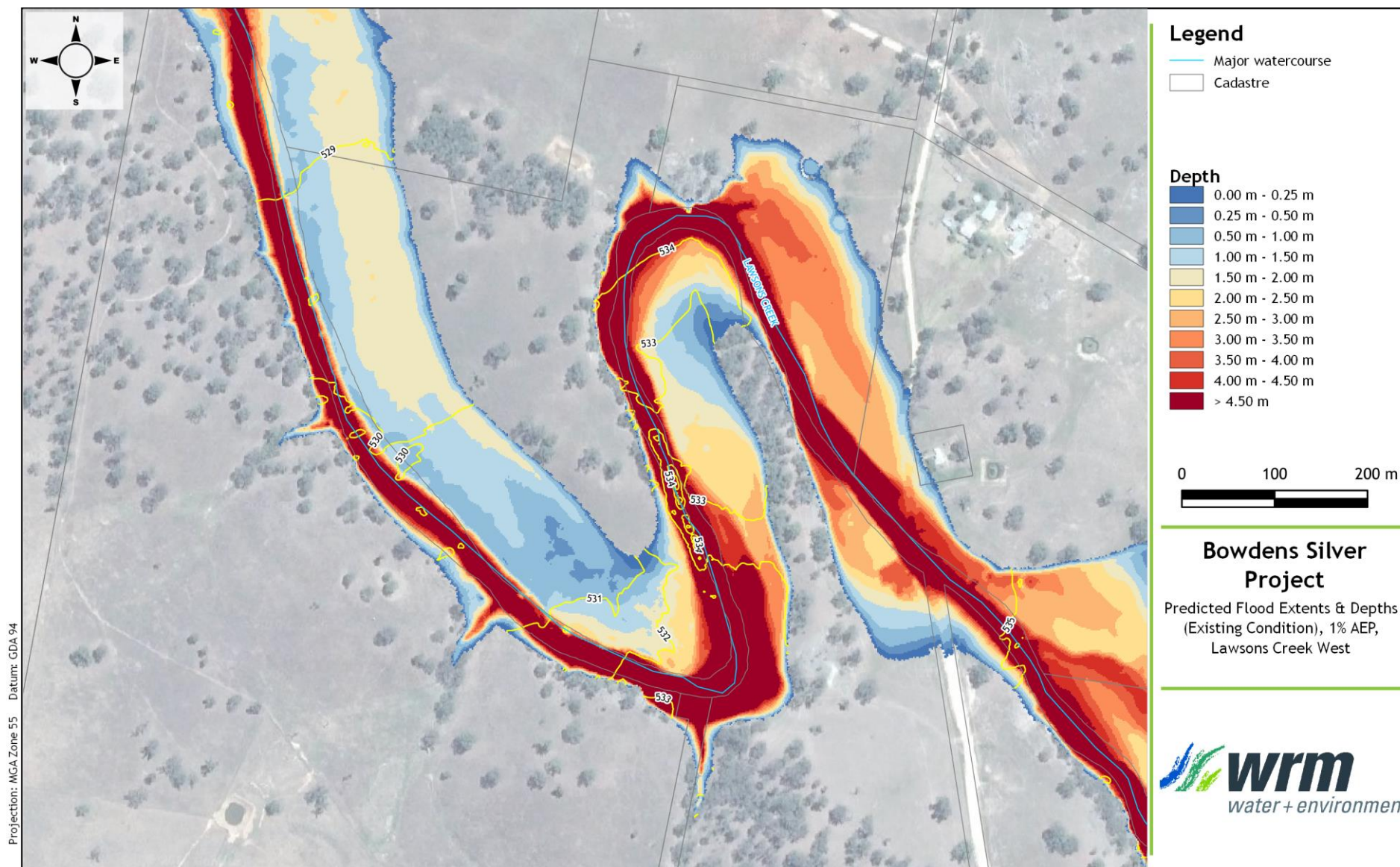


Figure 6.5 - 1% (1 in 100) AEP peak flood levels and depths - existing conditions - Lawsons Creek extent

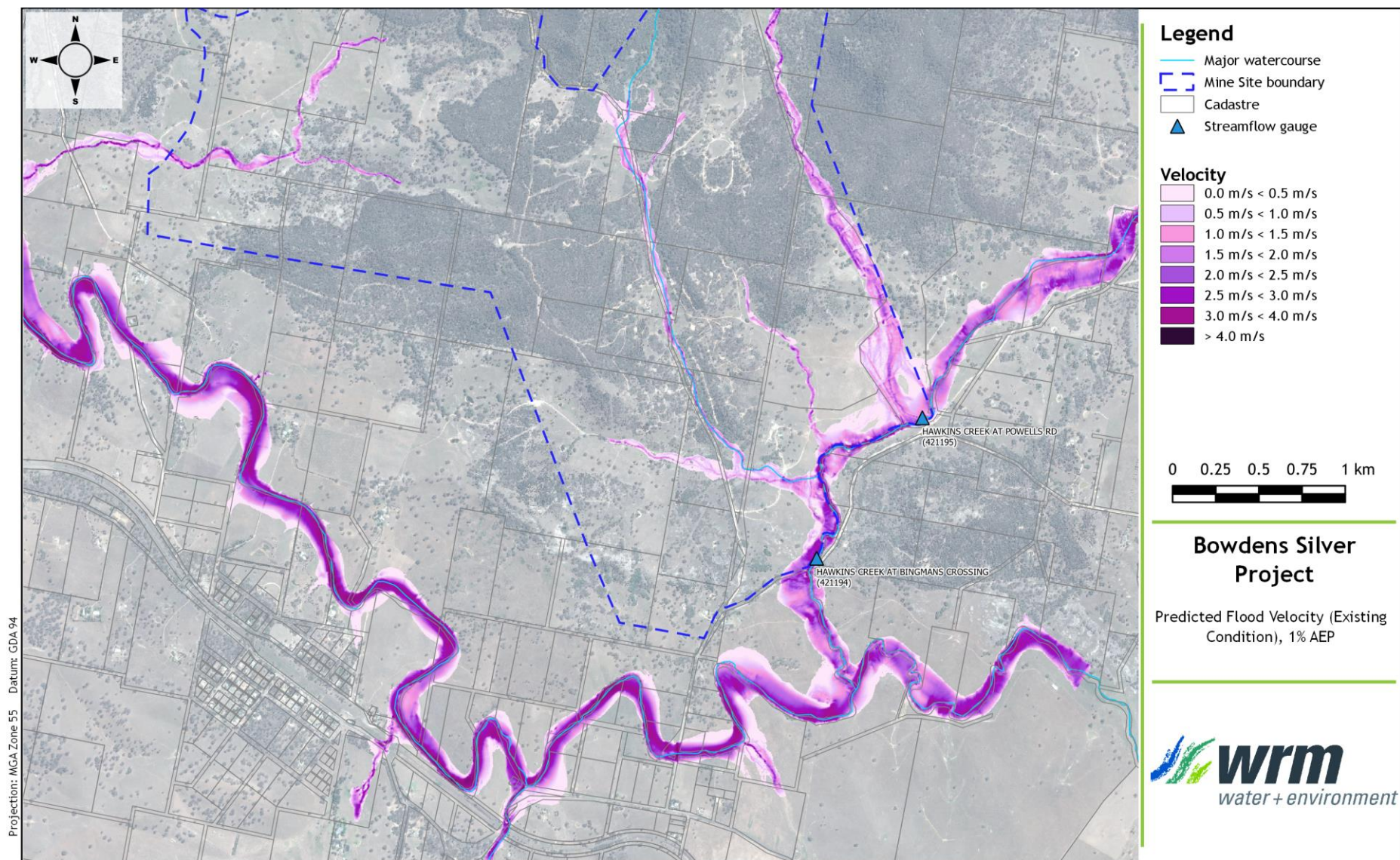


Figure 6.6 - 1% (1 in 100) AEP peak flood velocities - existing conditions - complete extent

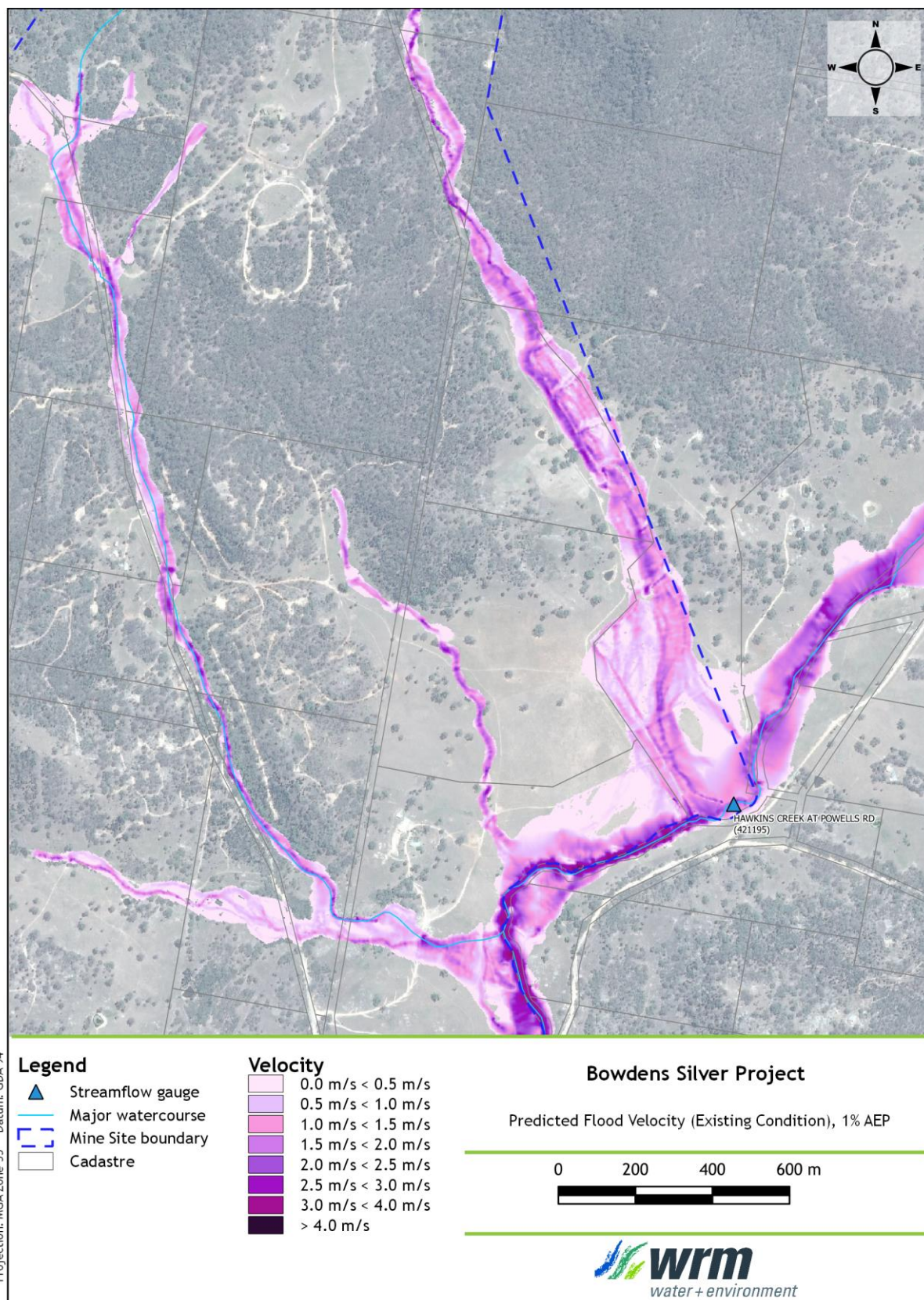


Figure 6.7 - 1% (1 in 100) AEP peak flood velocities - existing conditions - eastern extent



Figure 6.8 - 1% (1 in 100) AEP peak flood velocities - existing conditions - western extent

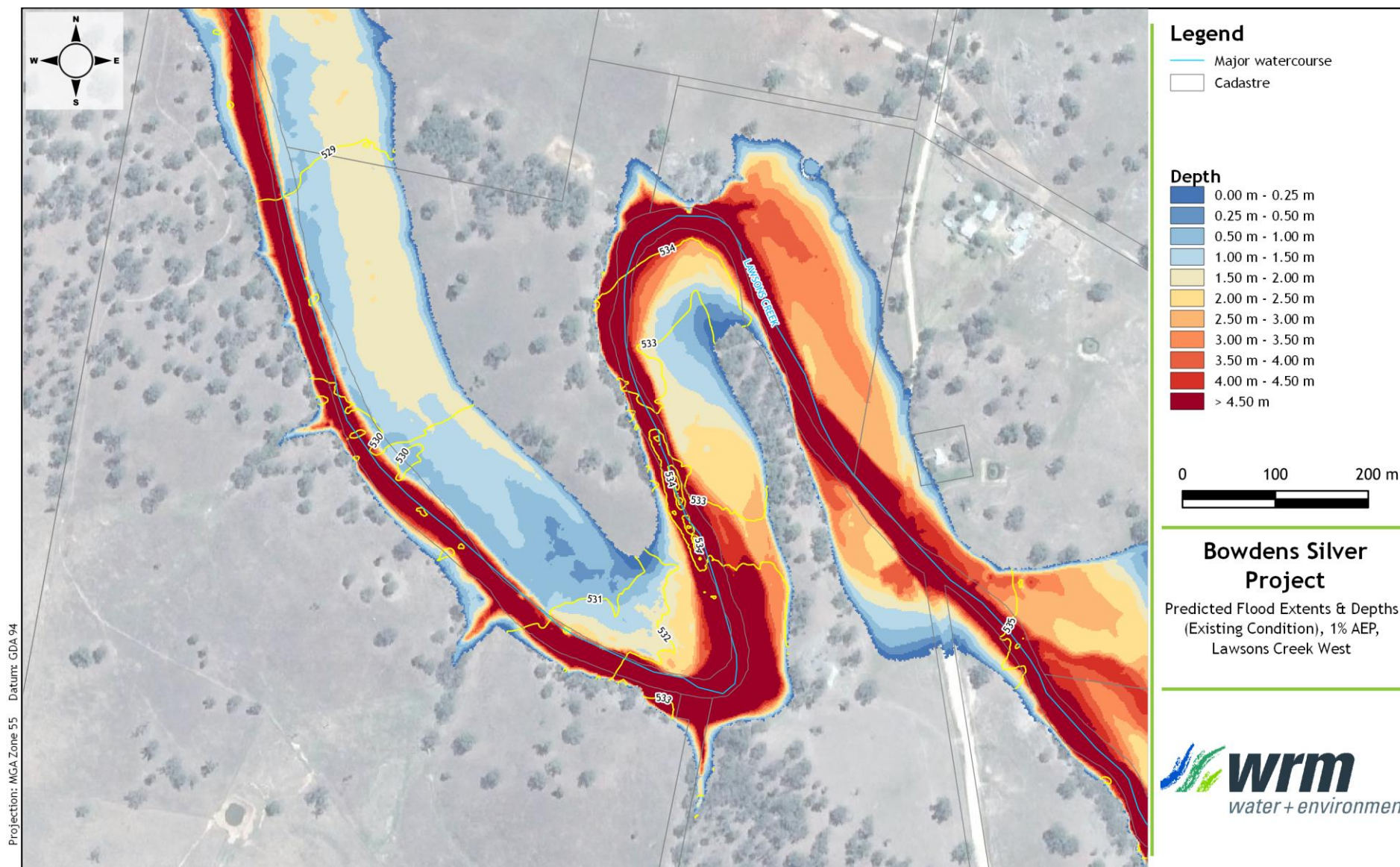


Figure 6.9 - 1% (1 in 100) AEP peak flood velocities - existing conditions - Lawsons Creek extent

6.4 DEVELOPED CONDITIONS TUFLOW MODEL CONFIGURATION

6.4.1 Overview

The existing conditions TUFLOW model was modified to include the proposed infrastructure, including the proposed WRE and associated haul roads and leachate management dam, southern barrier, oxide ore stockpile and Lawsons Creek crossing (relocated Maloneys Road (Pyangle Road)).

The developed conditions TUFLOW model was run for the following three scenarios:

- **‘Maximum disturbance’** - this scenario represents Year 16 of mining where the extent of mine disturbance is greatest.
- **‘Final landform’** - this scenario represents post-mining conditions.
- **‘Lawsons Creek crossing’** - this scenario incorporates the proposed Lawsons Creek crossing and associated culverts.

6.4.2 TUFLOW model modifications

6.4.2.1 Maximum disturbance and final landform scenarios

Figure 6.10 shows the modifications made to the TUFLOW model in the vicinity of Price Creek for the ‘Maximum Disturbance’ scenario. Figure 6.11 shows the modifications made to the TUFLOW model in the vicinity of Price Creek for the ‘Final Landform’ scenario.

Design surface tins of the WRE were provided by RW Corkery & Co for various stages of mining. The WRE adjacent to Price Creek was incorporated directly into the TUFLOW model topography.

It is also proposed to divert flows from the upper catchment of Blackmans Gully around the mine infrastructure area (via a drainage channel) and into Price Creek. To represent this, the base case TUFLOW inflow boundaries located in the upper catchment of Blackman Gully were relocated to the approximate location of the drainage channel’s outlet, which is just to the northeast of the WRE (as shown in Figure 6.10 and Figure 6.11).

For these two scenarios, water would be lost to the open cut pits, the WRE, the mine infrastructure area and the upstream diversion of the Blackmans Gully catchment. To account for this, TUFLOW inflows in Blackmans Gully were reduced in proportion to the reduction in catchment in the developed conditions.

The TUFLOW outflow boundary as well as the adopted hydraulic roughness distribution were unchanged from the existing conditions model.

6.4.2.2 Lawsons Creek crossing scenario

Figure 6.12 shows the modifications made to the TUFLOW model in the vicinity of the Lawsons Creek crossing for the ‘Lawsons Creek Crossing’ scenario.

The proposed crossing would be designed to be overtopped by flows in Lawsons Creek during a 10% AEP event. TUFLOW z-shapes were used to represent the proposed crossing embankment. The proposed culverts (10 barrels of 2.7 m (L) x 2.4 m RCBCs) were modelled as a 1d network linked to the 2D model domain.

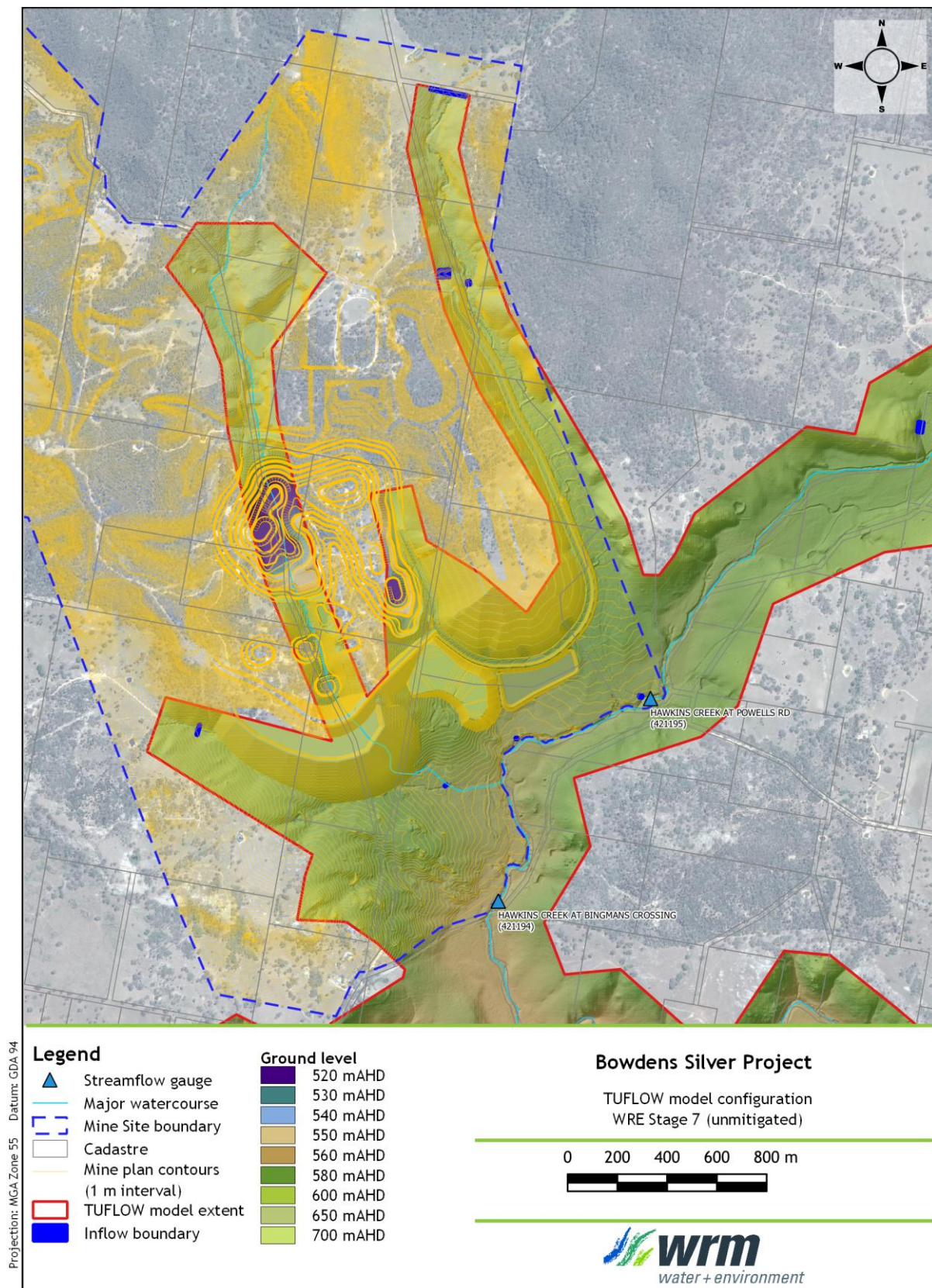


Figure 6.10 - Developed conditions TUFLOW model, 'Maximum Disturbance' scenario

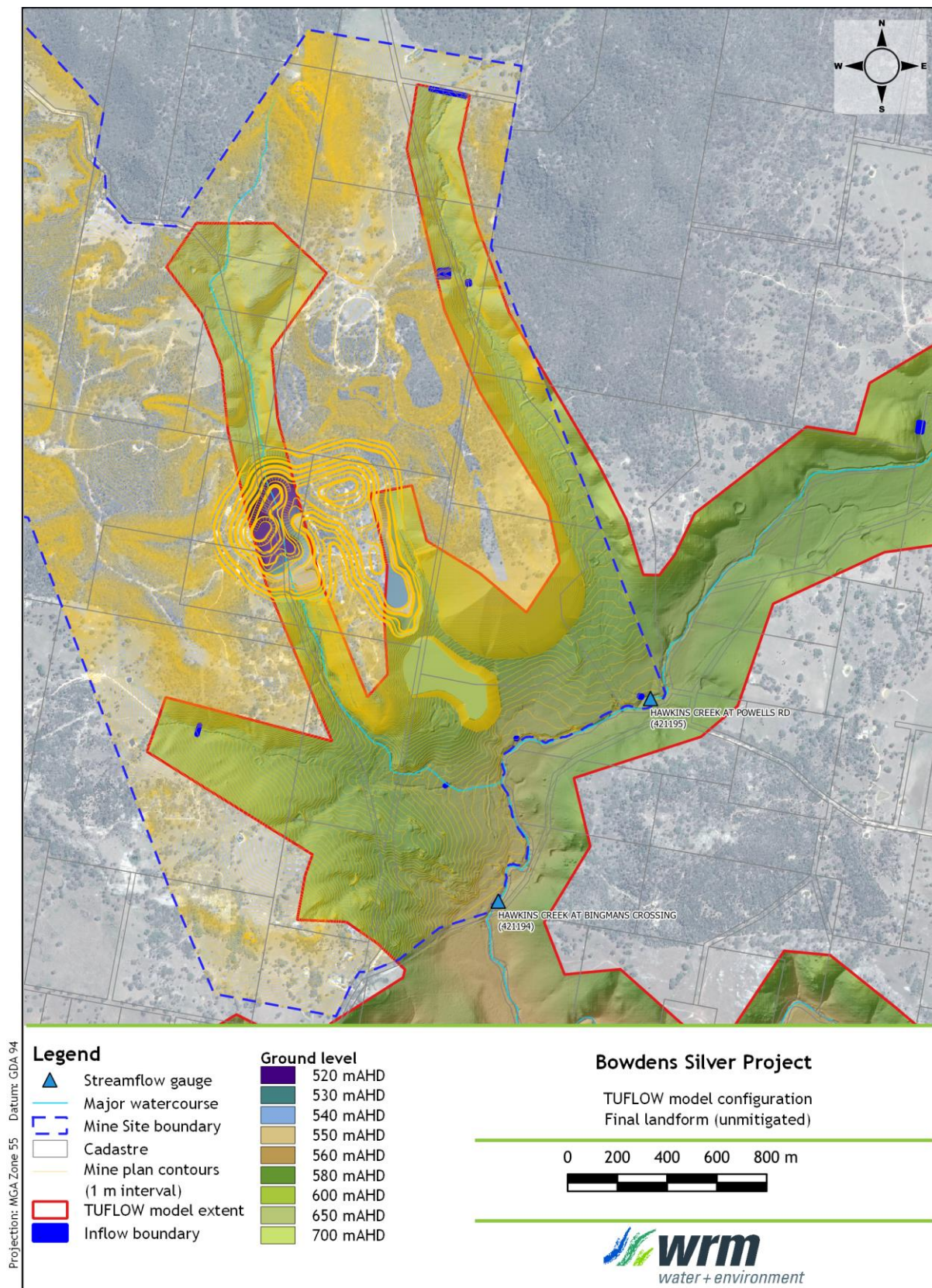


Figure 6.11 - Developed conditions TUFLOW model, 'Final Landform' scenario

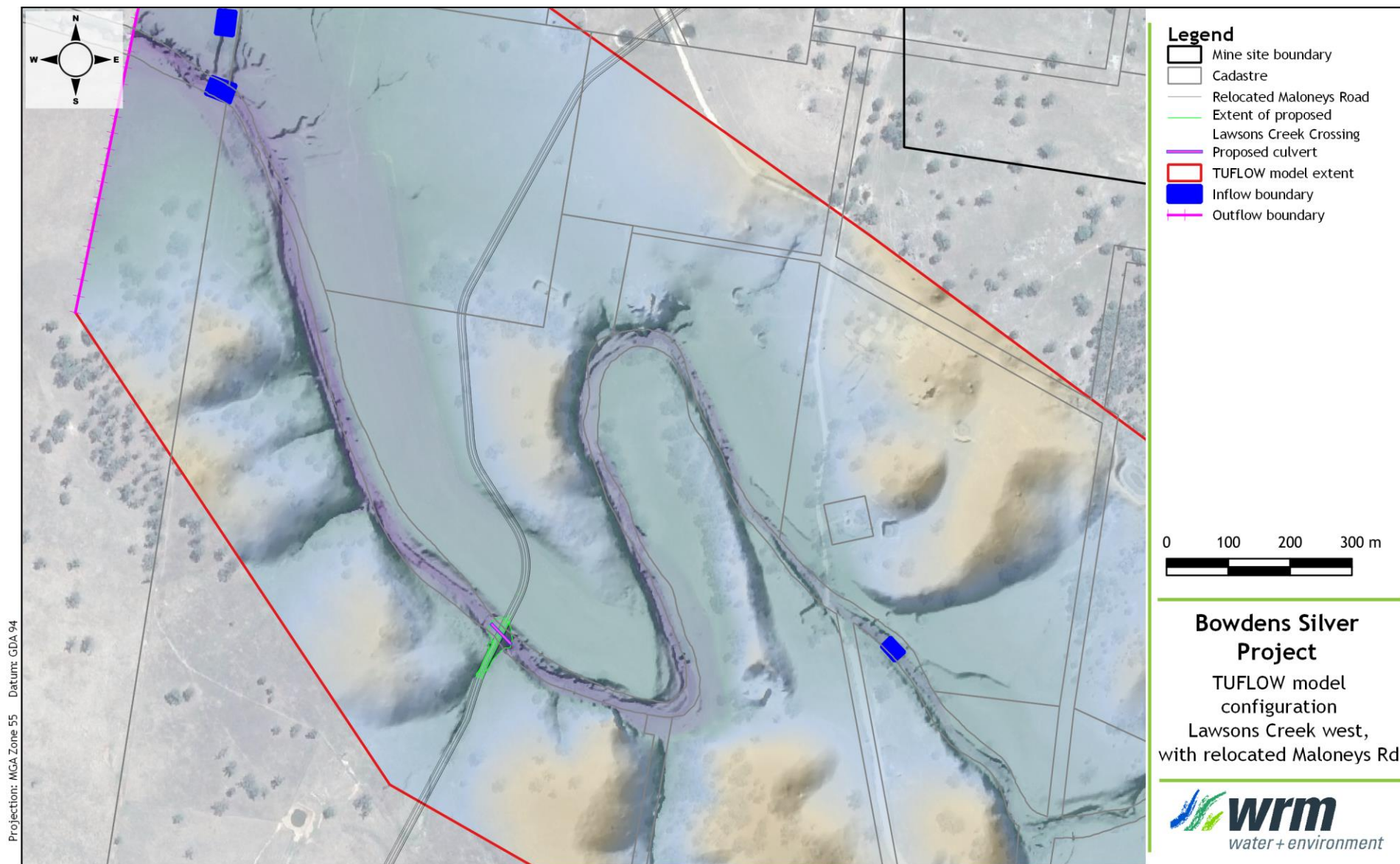


Figure 6.12 - Developed conditions TUFLOW model, 'Lawsons Creek Crossing' scenario'

7 Hydraulic impact assessment

7.1 OVERVIEW

The developed conditions TUFLOW model was used to estimate design peak flood levels, depths, extents and velocities for the 'Maximum Disturbance', 'Final Landform' and 'Lawsons Creek Crossing' scenarios for the 10% AEP, 1% AEP, 0.2% AEP and PMF events.

7.2 DEVELOPED CONDITIONS FLOODING

7.2.1 Maximum disturbance scenario

Figure 7.1 shows predicted peak flood levels and depths for the 1% (1 in 100) AEP event under the Maximum Disturbance Scenario in the vicinity of the proposed WRE. Figure 7.2 shows the corresponding 1% AEP peak velocities. Figure 7.3 shows (in greater detail) the predicted peak velocities along Price Creek adjacent to the proposed WRE for the Maximum Disturbance Scenario.

Flood maps showing design peak flood levels, depths and velocities under the Maximum Disturbance Scenario for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design events are provided in Appendix D.

The model results for this scenario indicate the following:

- The running surface of the proposed haul road at the toe of the proposed WRE would have immunity from flooding for all events up to the PMF.
- The leachate management dam would be located outside the extent of flooding in the 0.2% AEP flood.
- The northeastern section of the proposed haul road embankment would constrict flows in Price Creek. As a result, high peak velocities are predicted here. The predicted maximum velocities just downstream of this constriction range from 3.2 m/s for 10% AEP event to 4.9 m/s for the 1% AEP event. Mitigation measures for managing the short-term risk of erosion in these areas would be developed during detailed design.
- Some sections of the proposed haul road and WRE encroach into the Price Creek floodplain. As a result, the toe of the haul road located within the Price Creek flood extent would potentially be affected by high velocities. The predicted maximum velocities along the eastern edge of the proposed haul road range from 3.2 m/s for the 10% AEP event to 3.5 m/s for the 1% AEP event.

7.2.2 Final landform scenario

Figure 7.4 shows predicted peak flood levels and depths for the 1% (1 in 100) AEP event under the Final Landform Scenario in the vicinity of the proposed WRE. Figure 7.5 shows the corresponding 1% AEP peak velocities. Figure 7.6 shows (in greater detail) the predicted peak velocities along Price Creek adjacent to the proposed WRE for the Final Landform Scenario.

Flood maps showing design peak flood levels, depths and velocities under the Final Landform Scenario for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design events are provided in Appendix E.

The model results for this scenario indicate the following:

- The proposed haul road would be regraded from the toe of the WRE towards the existing ground level at the edge of the Price Creek floodplain as part of rehabilitation at mine closure. However, the predicted flood extent, depths and

velocities along Price Creek are very similar to those predicted for the Maximum Disturbance Scenario.

- The constriction at the northeastern corner of the WRE would still exist in the Final Landform. As a result, high peak velocities are also predicted here. The predicted maximum velocities just downstream of this constriction range from 3.2 m/s for 10% AEP event to 4.9 m/s for the 1% AEP event. Long-term measures for mitigating the consequent risk of erosion would be incorporated into the rehabilitation design.
- Some sections of the WRE would still encroach into the Price Creek floodplain. As a result, the toe of the WRE located within the Price Creek flood extent would potentially be affected by high velocities. The predicted maximum velocities along the eastern edge of the proposed haul road range from 2.5 m/s for the 10% AEP event to 3.4 m/s for the 1% AEP event. Long-term measures for mitigating the consequent risk of erosion would be incorporated into the rehabilitation design.

7.2.3 Lawsons Creek crossing

Figure 7.7 and Figure 7.8 show predicted peak flood levels and depths for the 10% (1 in 10) and 1% (1 in 100) AEP events respectively in Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing. Figure 7.9 and Figure 7.10 show the corresponding peak velocities for the 10% (1 in 10) and 1% (1 in 100) AEP events respectively.

Flood maps showing design peak flood levels, depths and velocities in Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMP design events at the above locations are provided in Appendix F.

The model results for this scenario indicate the following:

- The proposed road crossing would be overtopped during events equal to or greater than 10% AEP.
- For 10% AEP event, the predicted peak flood depths over the road are up to 0.5 m, while peak flood velocities over the road would be up to 4 m/s.
- For 1% AEP event, the predicted peak flood depths over the road are up to 1.2 m, while peak flood velocities over the road would be up to 6 m/s.
- For the PMF, the predicted peak flood depths over the road are up to 4 m.

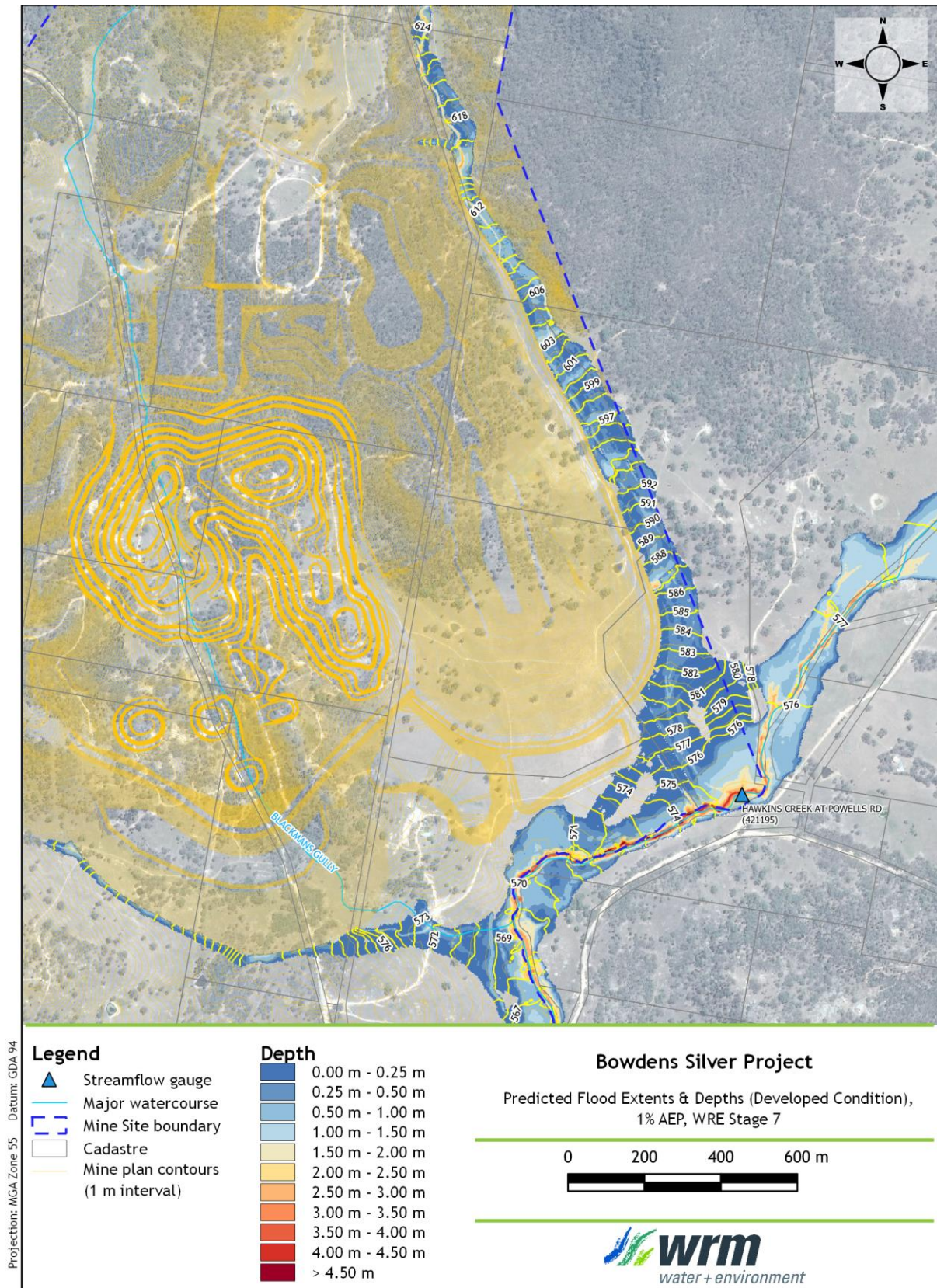


Figure 7.1 - 1% (1 in 100) AEP peak flood levels and depths in the vicinity of the proposed WRE - Maximum Disturbance Scenario

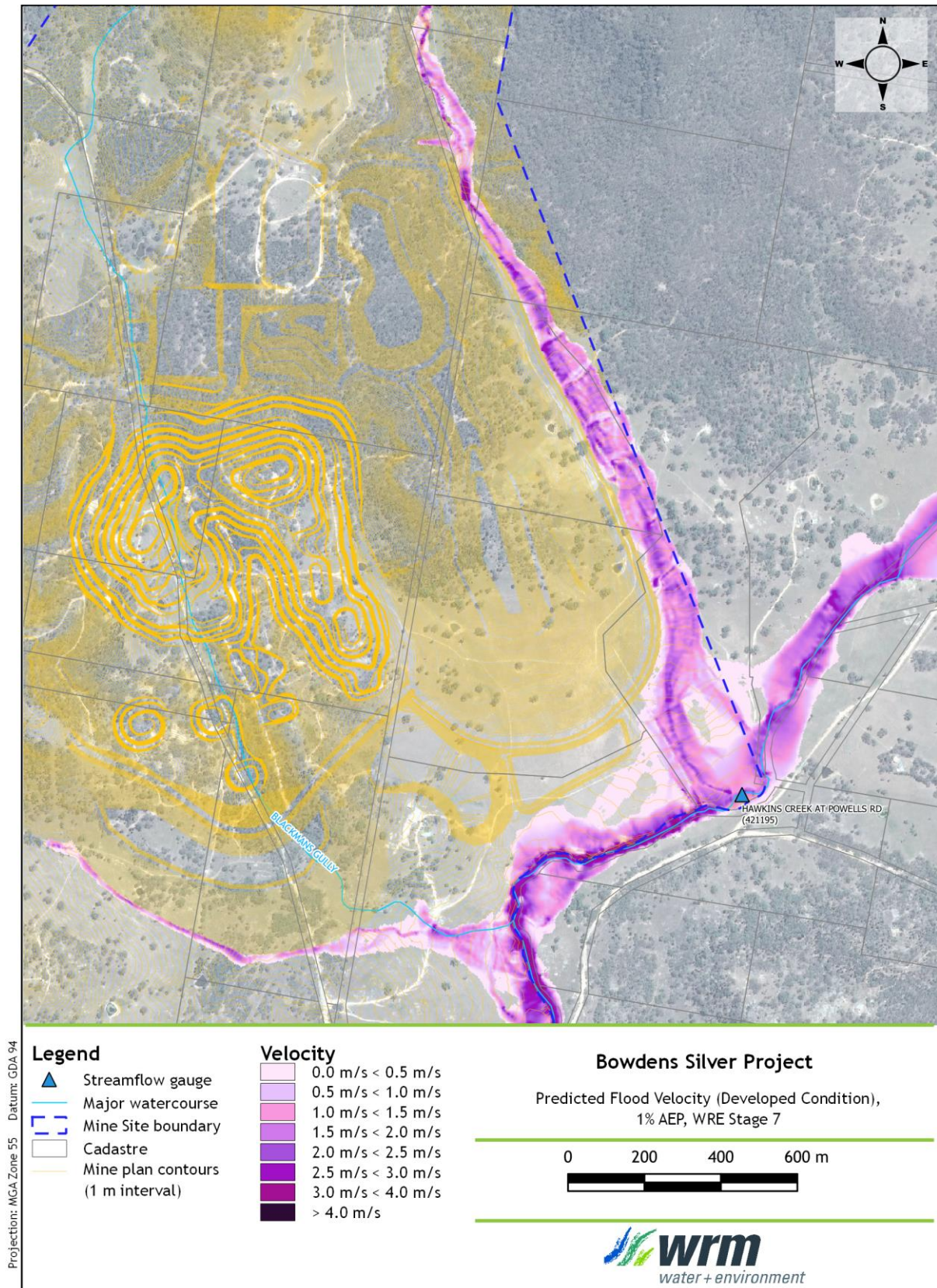


Figure 7.2 - 1% (1 in 100) AEP peak velocities in the vicinity of the proposed WRE - Maximum Disturbance Scenario

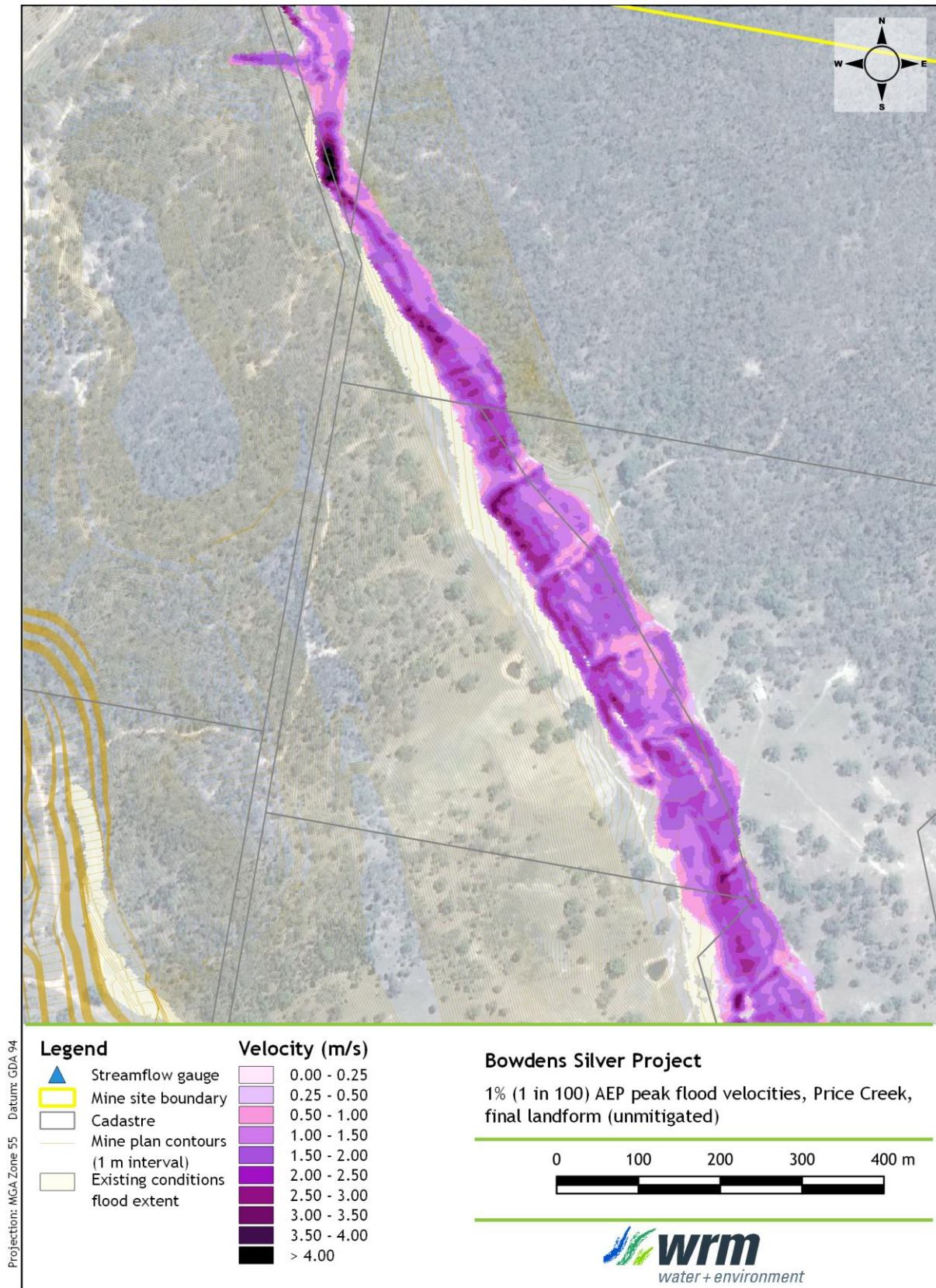


Figure 7.3 - 1% (1 in 100) AEP peak velocities along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

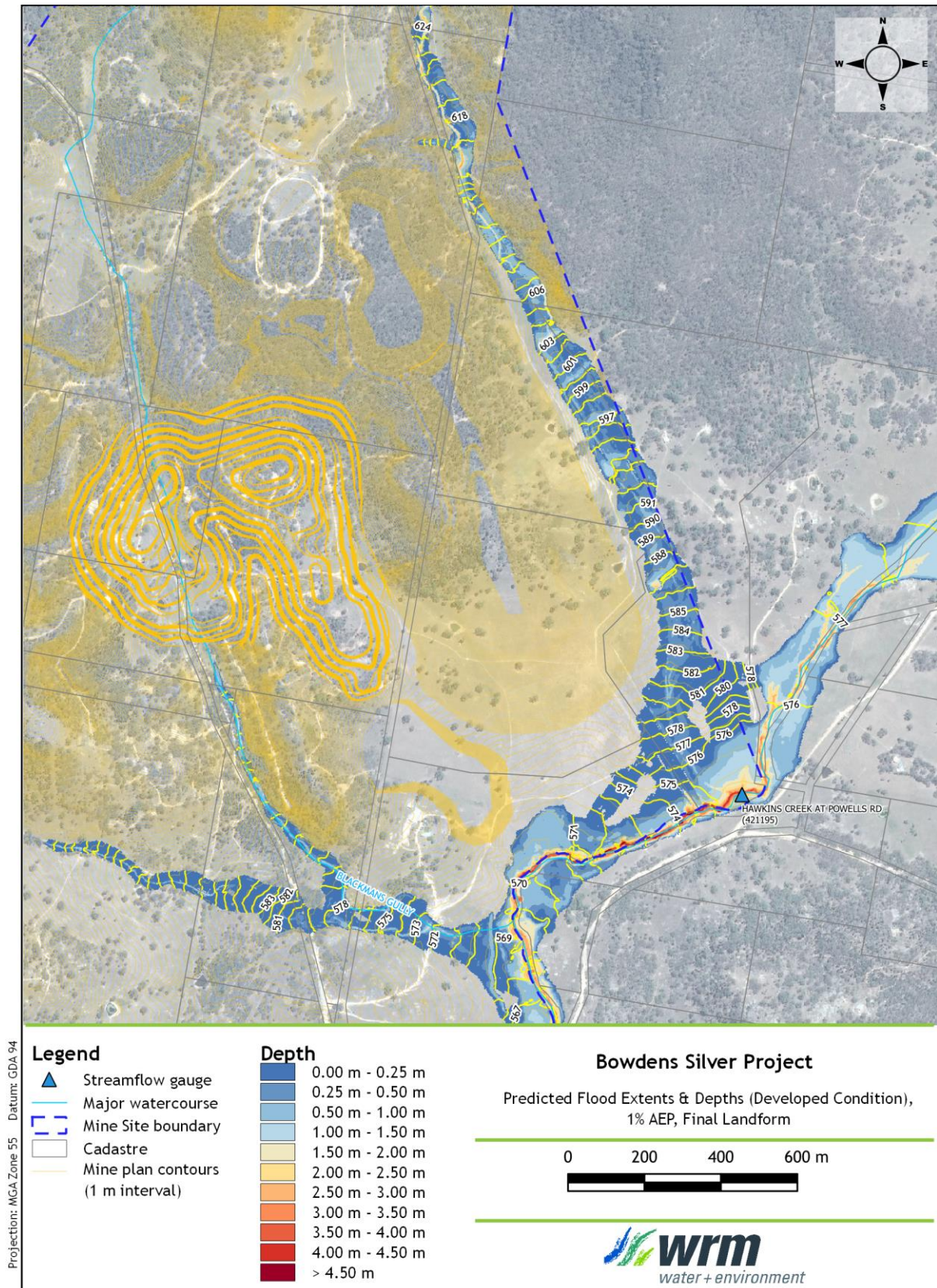


Figure 7.4 - 1% (1 in 100) AEP peak flood levels and depths in the vicinity of the proposed WRE - Final Landform Scenario

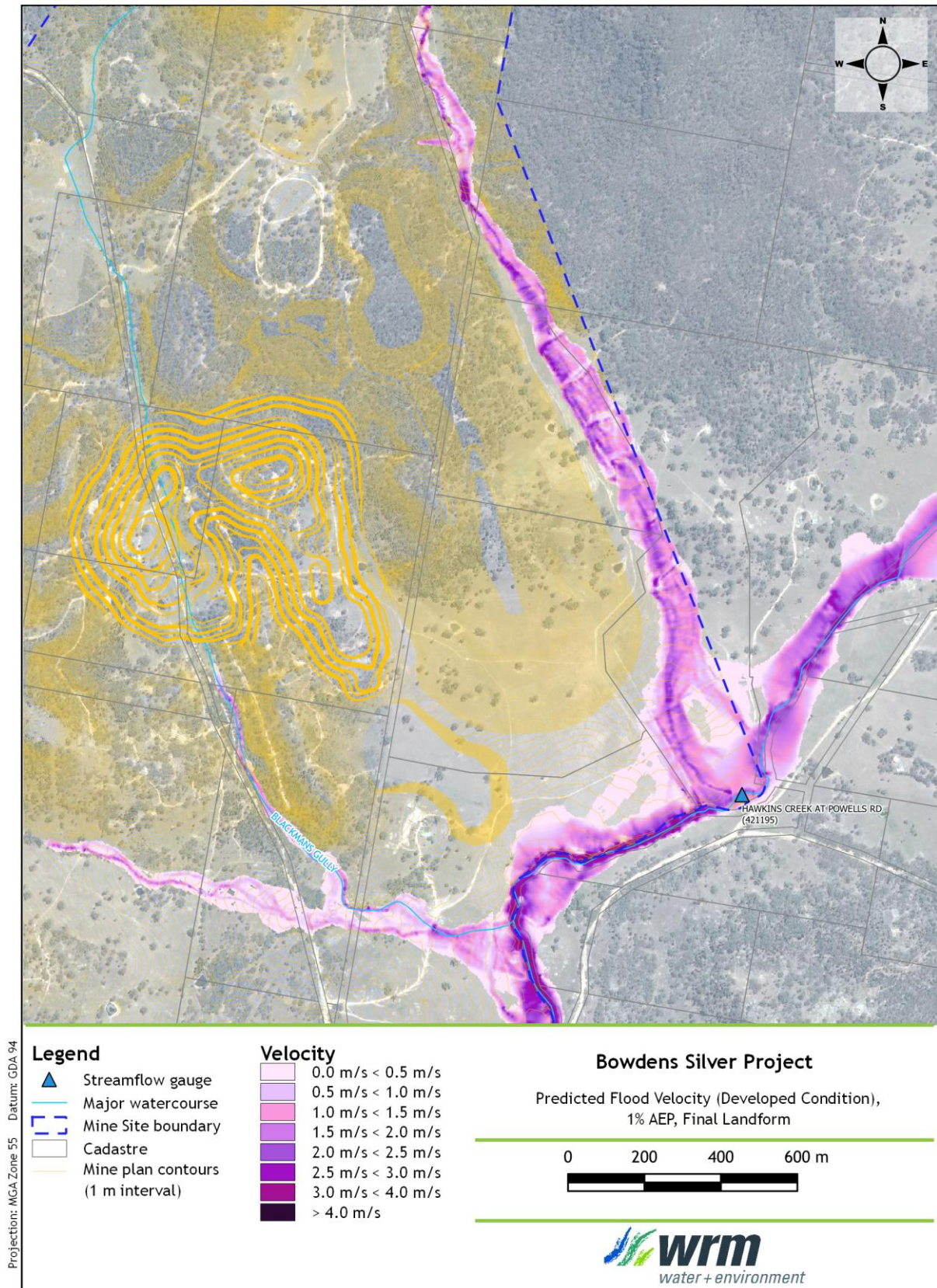


Figure 7.5 - 1% (1 in 100) AEP peak velocities in the vicinity of the proposed WRE - Final Landform Scenario

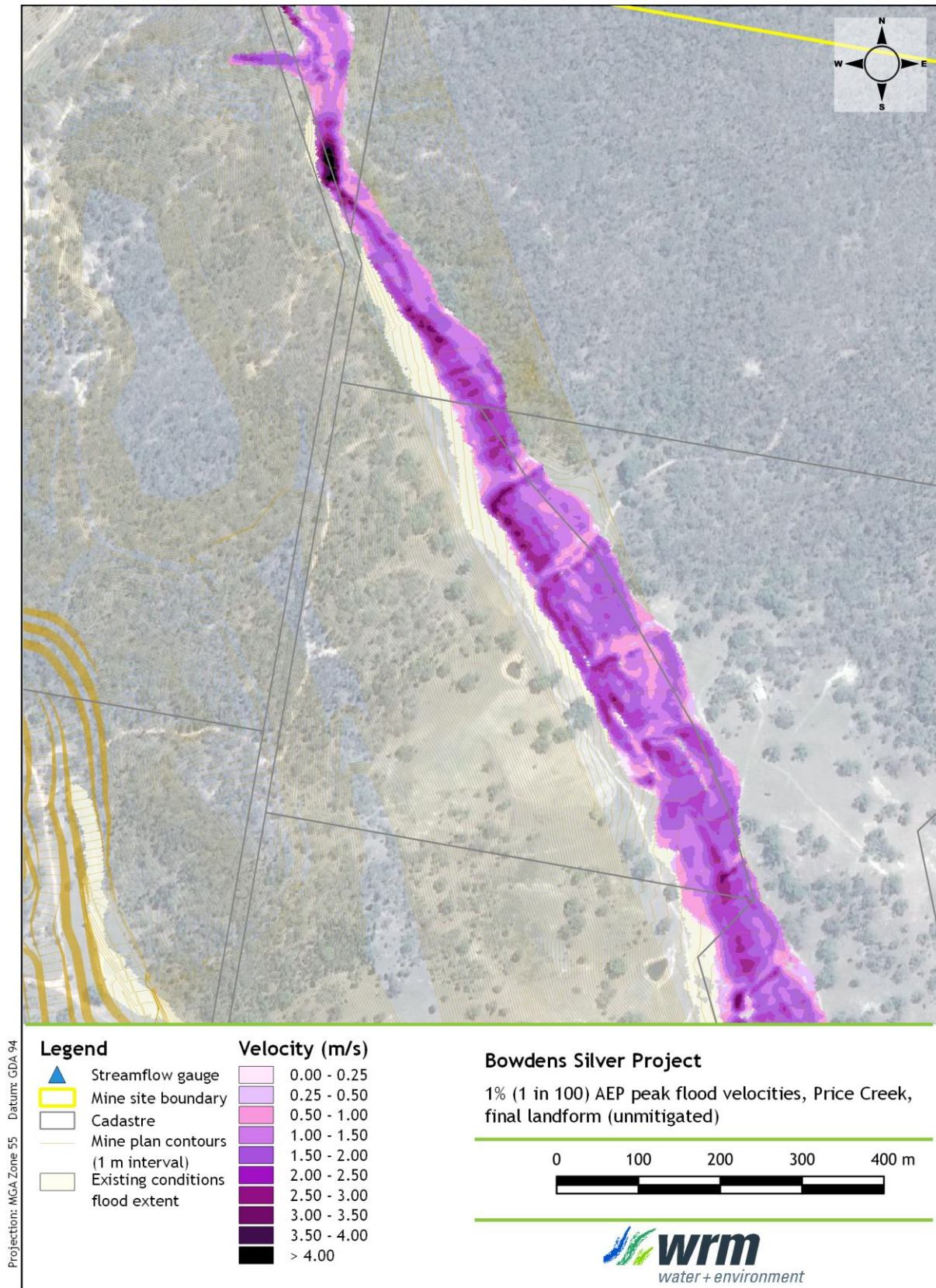


Figure 7.6 - 1% (1 in 100) AEP peak velocities along Price Creek adjacent to the proposed WRE - Final Landform Scenario

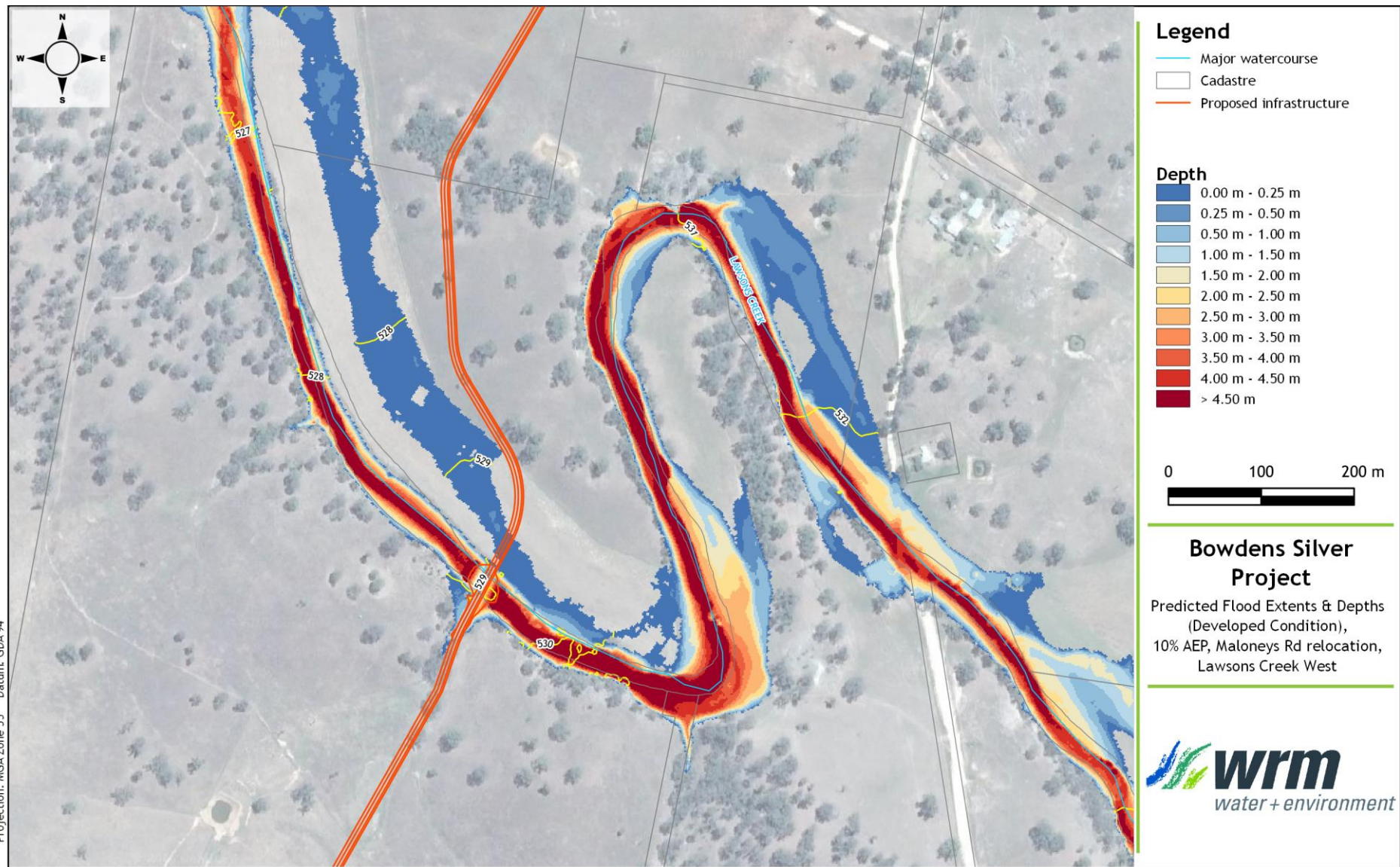


Figure 7.7 - 10% (1 in 10) AEP peak flood levels and depths along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

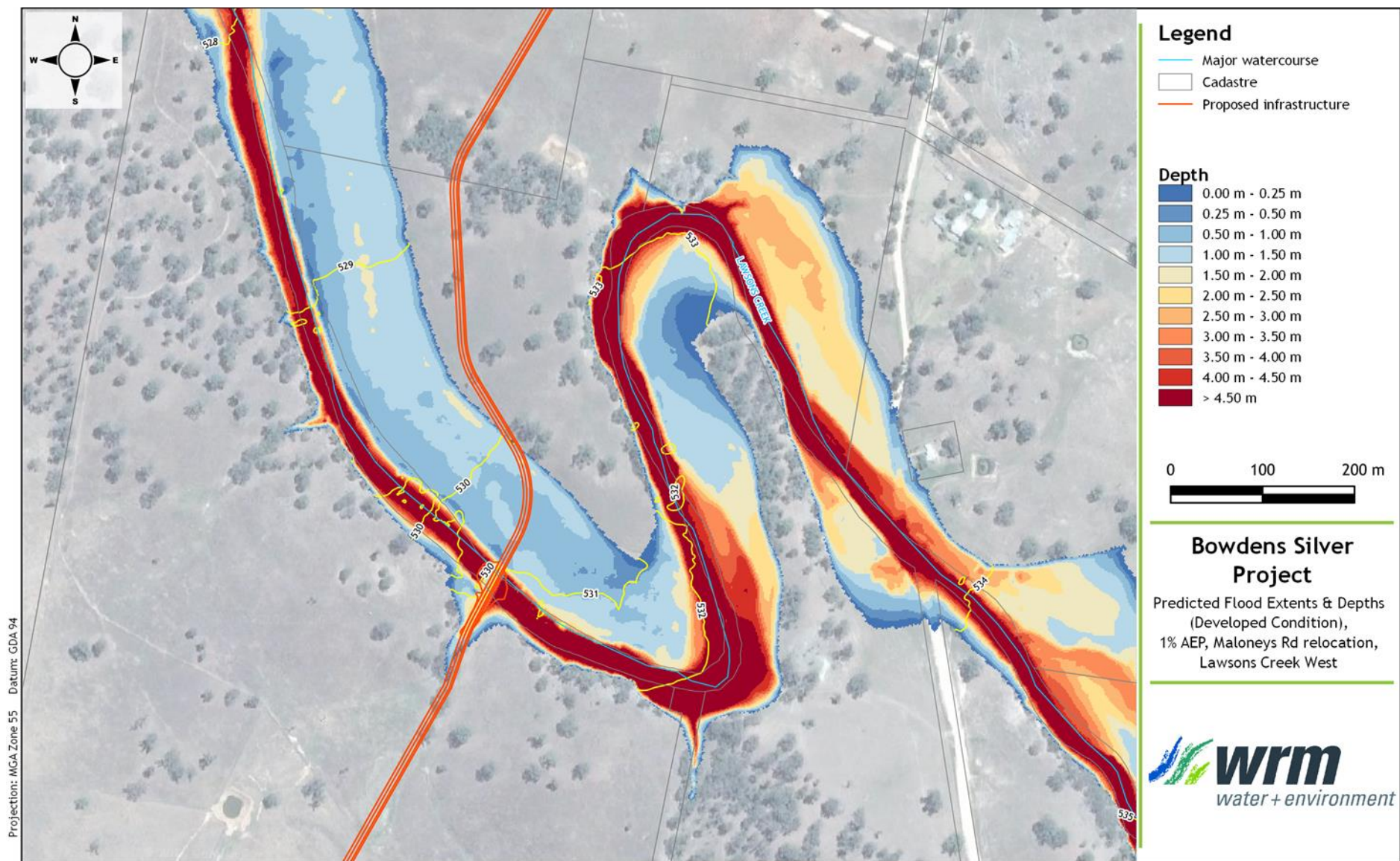


Figure 7.8 - 1% (1 in 100) AEP peak flood levels and depths along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

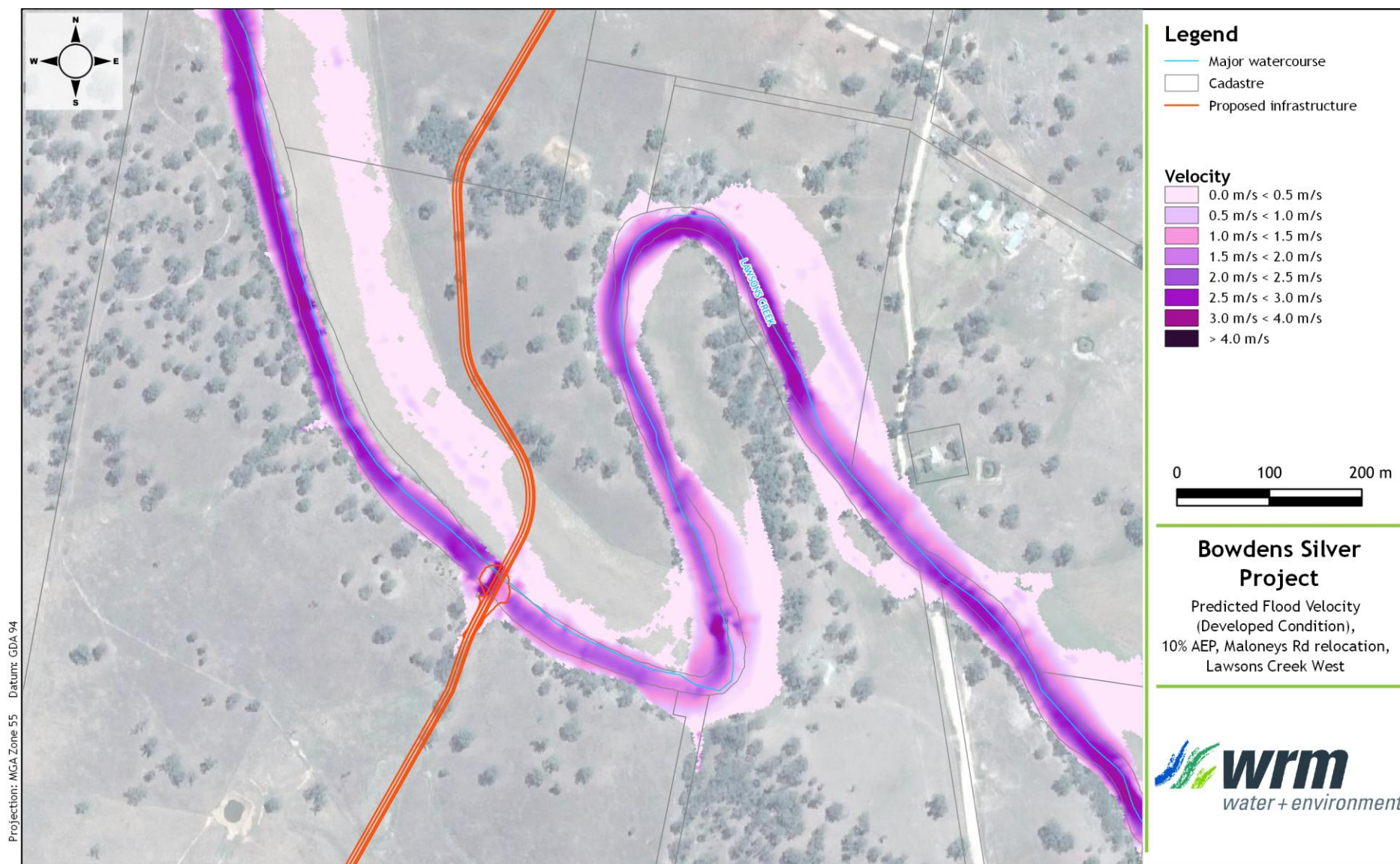


Figure 7.9 - 10% (1 in 10) AEP peak velocities along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario



Figure 7.10 - 1% (1 in 100) AEP peak velocities along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

7.3 HYDRAULIC IMPACTS

7.3.1 Maximum disturbance scenario

Flood maps showing the predicted impacts on peak flood levels and velocities in the vicinity of the proposed WRE for the Maximum Disturbance Scenario are shown in the following figures:

- Figure 7.11, Figure 7.12 and Figure 7.13 for the predicted impacts on peak flood levels for the 10% AEP, 1% AEP and 0.2% AEP events respectively; and
- Figure 7.14, Figure 7.15 and Figure 7.16 for the predicted impacts on peak velocities for the 10% AEP, 1% AEP and 0.2% AEP events respectively.

Additional flood maps showing the predicted impacts on peak flood levels and velocities under the Maximum Disturbance Scenario for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design events are provided in Appendix D.

The model results indicate the following:

- There are generally no increases in peak flood levels and velocities in Price Creek upstream of the proposed WRE for all modelled events.
- Flood levels would be increased at number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below:
 - Along the Price Creek floodplain adjacent to the WRE, there are predicted increases in peak flood levels of up to 0.3 m for the 10% AEP event, up to 0.4 m/s for the 1% AEP event and up to 0.5 m/s for the 0.2% AEP event. This is due to the proposed WRE forcing more water to flow along the eastern floodplain of Price Creek.
 - In Hawkins Creek, there would be minor increases in peak flood levels of up to 0.05 m for the 10% AEP event, up to 0.04 m for the 1% AEP event and up to 0.03 m for the 0.2% AEP event. These impacts dissipate to less than 0.01 m about 150 m upstream and downstream of the Bingmans Crossing stream gauge.
- Flood velocities would also be increased at number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below:
 - There would be increases in peak velocities along the Price Creek floodplain of up to 1.8 m/s for the 10% AEP event and up to 1.1 m/s for the 1% and 0.2% AEP events. This is due to the proposed WRE forcing more water to flow along the eastern floodplain of Price Creek.
 - Just downstream of the constriction at the northeastern corner of the proposed WRE and haul road, there would be localised increases in peak velocities of up to 3.1 m/s for the 10% AEP event, up to 3.5 m/s for the 1% AEP event and up to 3.7 m/s for the 0.2% AEP event.
 - Along the eastern toe of the WRE and haul (along the western side of the Price Creek floodplain), there would be localised increases in peak velocities of up to 1.4 m/s, 1.1 m/s and 1.1 m/s for the 10%, 1% and 0.2% AEP events respectively.
 - There would be increases in peak velocities of up to 0.9 m/s for the 10%, up to 0.6 m/s for the 1% AEP event and up to 0.5 m/s for the 0.2% AEP event near the southeastern corner of the proposed WRE.
 - In the Hawkins Creek, there would be minor increases in peak velocities of up to 0.14 m/s for the 10% AEP event, up to 0.08 m/s for the 1% AEP event and up to 0.07 m/s for the 0.2% AEP event. These impacts dissipate to less than 0.01 /s about 550 m downstream of the Bingmans Crossing stream gauge.

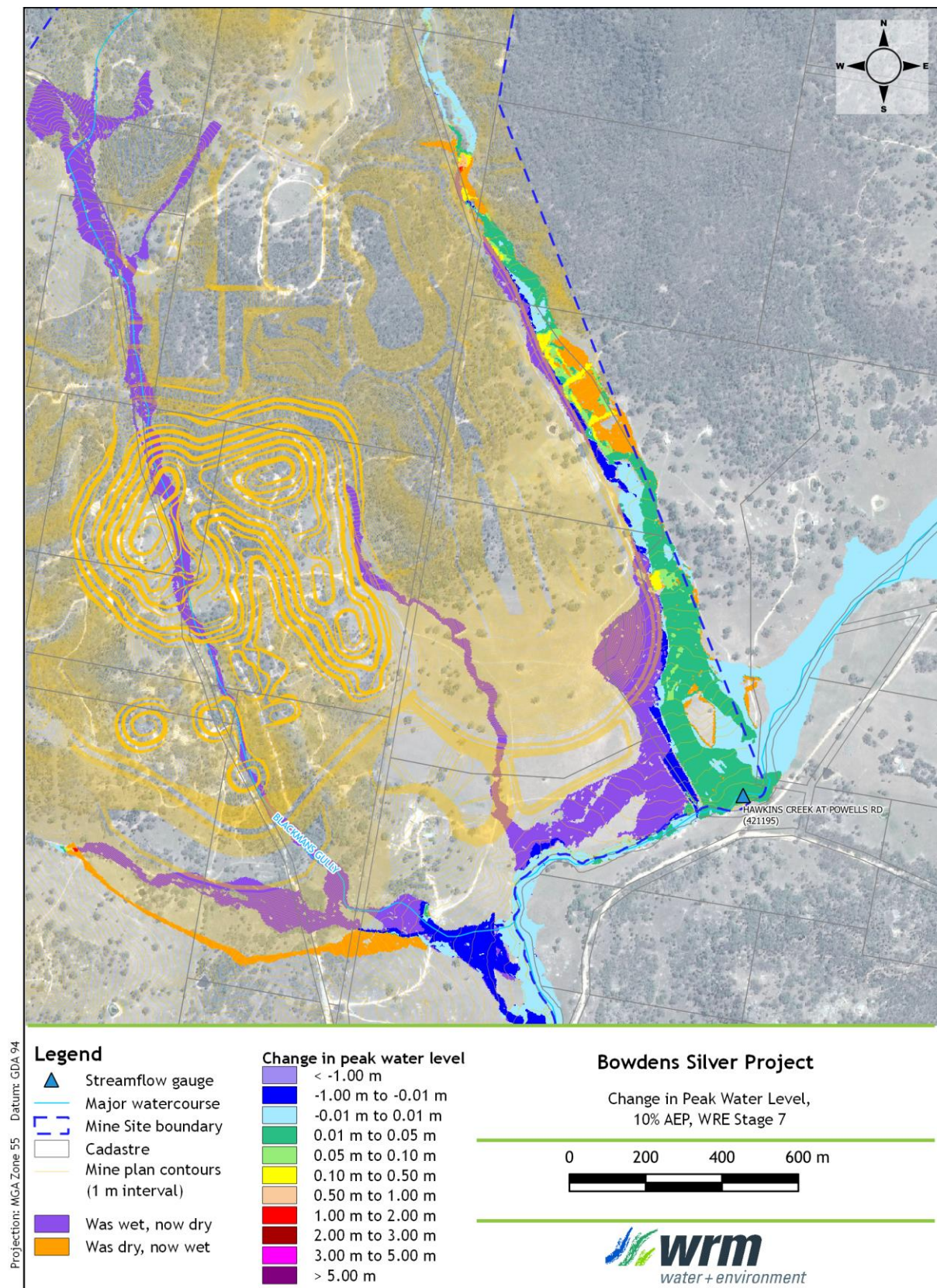


Figure 7.11 - 10% (1 in 10) AEP predicted impacts on peak flood levels along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

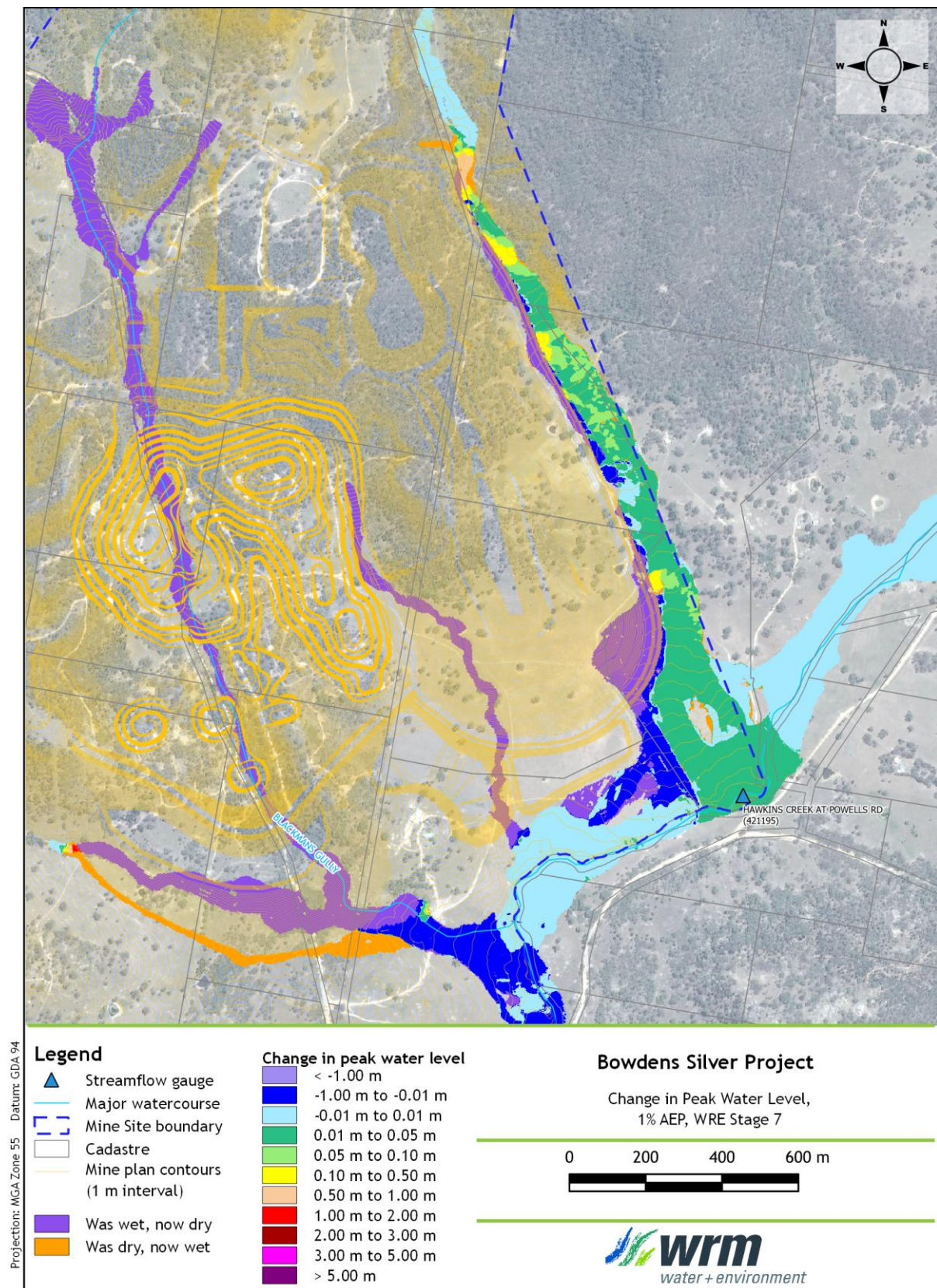


Figure 7.12 - 1% (1 in 100) AEP predicted impacts on peak flood levels along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

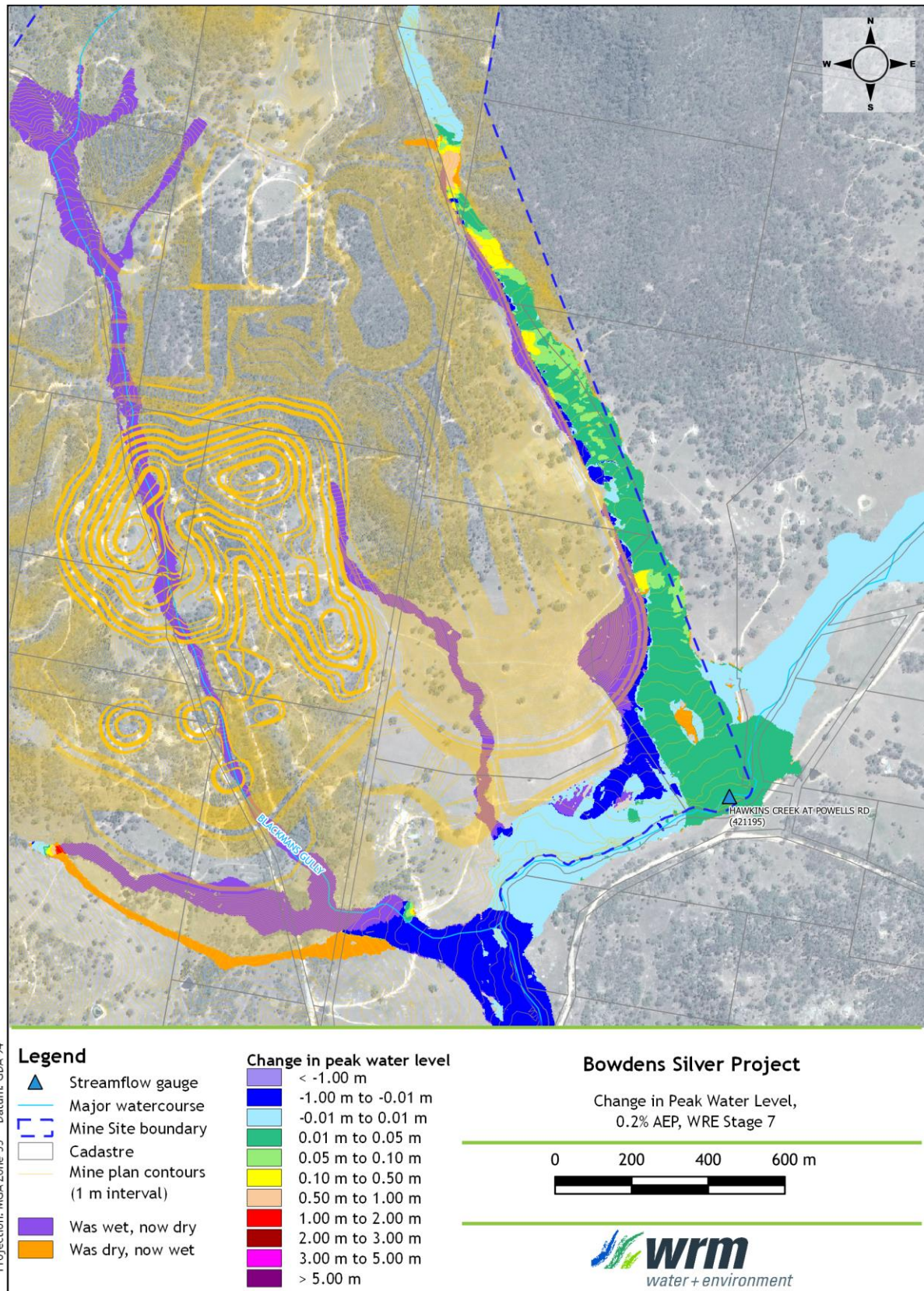


Figure 7.13 - 0.2% (1 in 500) AEP predicted impacts on peak flood levels along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

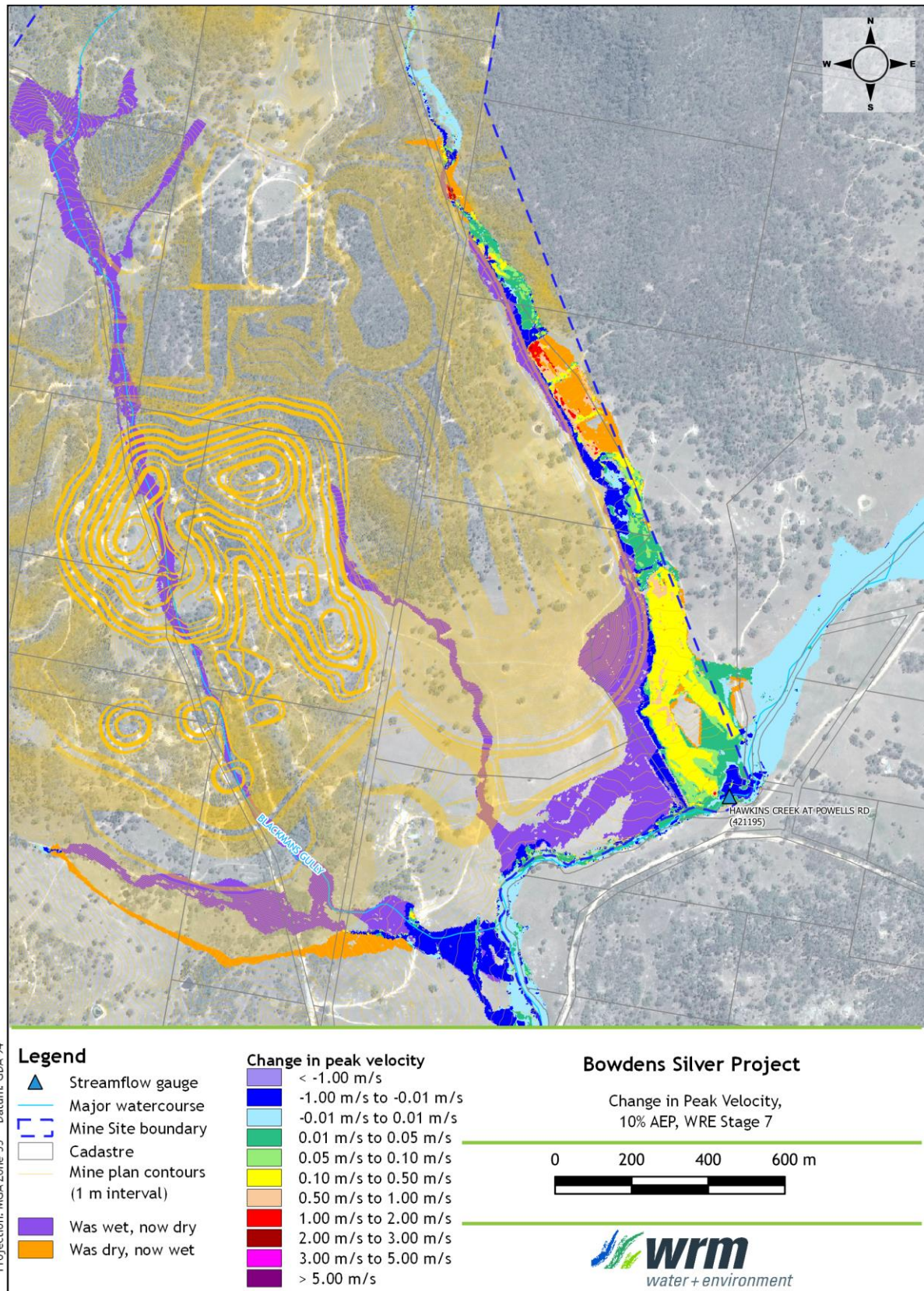


Figure 7.14 - 10% (1 in 10) AEP predicted impacts on peak velocities along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

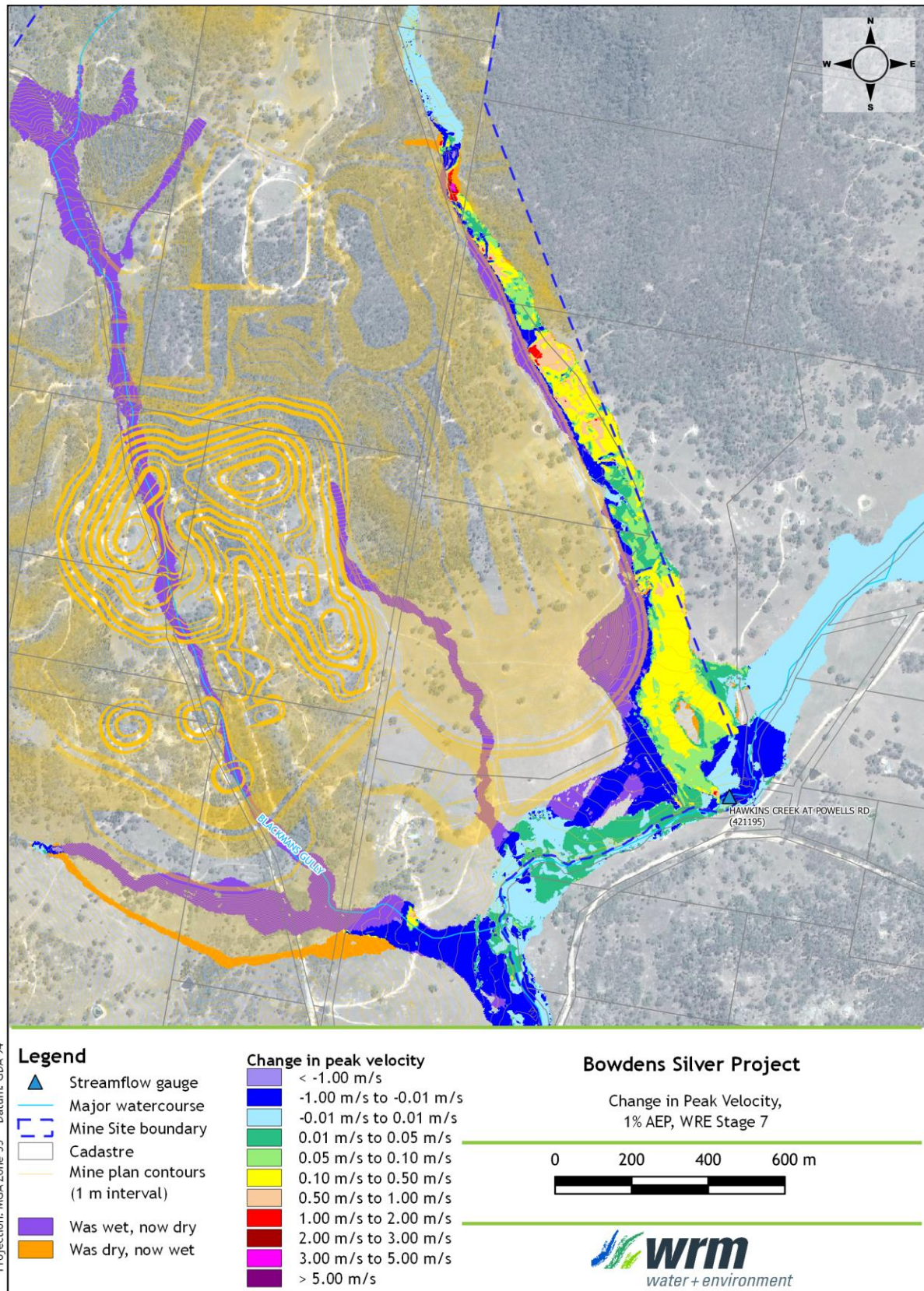


Figure 7.15 - 1% (1 in 100) AEP predicted impacts on peak velocities along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

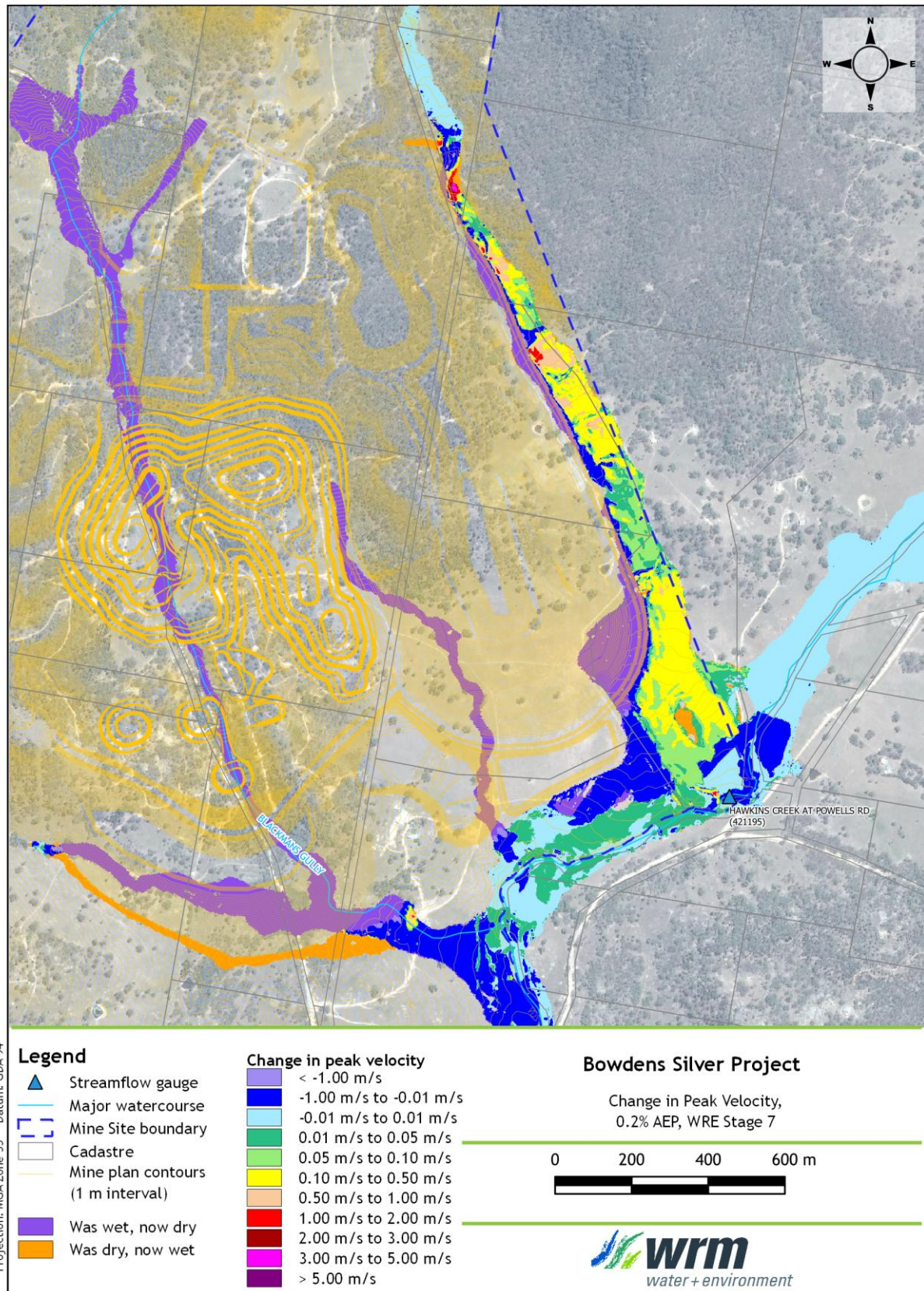


Figure 7.16 - 0.2% (1 in 500) AEP predicted impacts on peak velocities along Price Creek adjacent to the proposed WRE - Maximum Disturbance Scenario

7.3.2 Final landform scenario

Flood maps showing the predicted impacts on peak flood levels and velocities in the vicinity of the proposed WRE for the Final Landform Scenario are shown in the following figures:

- Figure 7.17, Figure 7.18 and Figure 7.19 for the predicted impacts on peak flood levels for the 10% AEP, 1% AEP and 0.2% AEP events respectively; and
- Figure 7.20, Figure 7.21 and Figure 7.22 for the predicted impacts on peak velocities for the 10% AEP, 1% AEP and 0.2% AEP events respectively.

Additional flood maps showing the predicted impacts on peak flood levels and velocities under the Final Landform Scenario for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design events are provided in Appendix E.

- The predicted impacts for the Final Landform Scenario are generally similar to those observed for the Maximum Disturbance Scenario.
- There are generally no increases in peak flood levels and velocities in Price Creek upstream of the proposed WRE for all modelled events.
- Flood levels would be increased at number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below:
 - Along the Price Creek floodplain adjacent to the WRE, there are predicted increases in peak flood levels of up to 0.3 m for the 10% AEP event, up to 0.4 m/s for the 1% AEP event and up to 0.5 m/s for the 0.2% AEP event. This is due to the proposed WRE forcing more water to flow along the eastern floodplain of Price Creek.
 - In Hawkins Creek, there would be minor increases in peak flood levels of up to 0.05 m for the 10% AEP event, up to 0.03 m for the 1% AEP event and up to 0.03 m for the 0.2% AEP event. These impacts dissipate to less than 0.01 m about 150 m upstream and downstream of the Bingmans Crossing stream gauge.
- Flood velocities would also be increased at number of locations in the Price Creek and Hawkins Creek channel and floodplain as described below:
 - There would be increases in peak velocities along the Price Creek floodplain of up to 1.8 m/s for the 10% AEP event and up to 3.2 m/s for the 1% and 0.2% AEP events. This is due to the WRE forcing more water to flow along the eastern floodplain of Price Creek.
 - Just downstream of the constriction at the northeastern corner of the proposed WRE and haul road, there would be localised increases in peak velocities of up to 2.7 m/s for the 10% AEP event, up to 4.5 m/s for the 1% AEP event and up to 5.2 m/s for the 0.2% AEP event.
 - Along the eastern toe of the WRE and haul (along the western side of the Price Creek floodplain), there would be localised increases in peak velocities of up to 1.7 m/s, 3.1 m/s and 3.6 m/s for the 10%, 1% and 0.2% AEP events respectively.
 - There would be increases in peak velocities of up to 0.8 m/s for the 10% AEP event, up to 2.4 m/s for the 1% AEP event and up to 2.7 m/s for the 0.2% AEP event near the southeastern corner of the proposed WRE.
 - In the Hawkins Creek, there would be minor increases in peak velocities of up to 0.2 m/s for the 10% AEP event and up to 0.08 m/s for the 1% AEP and up to 0.2% AEP events. These impacts dissipate to less than 0.01 /s about 550 m downstream of the Bingmans Crossing stream gauge.

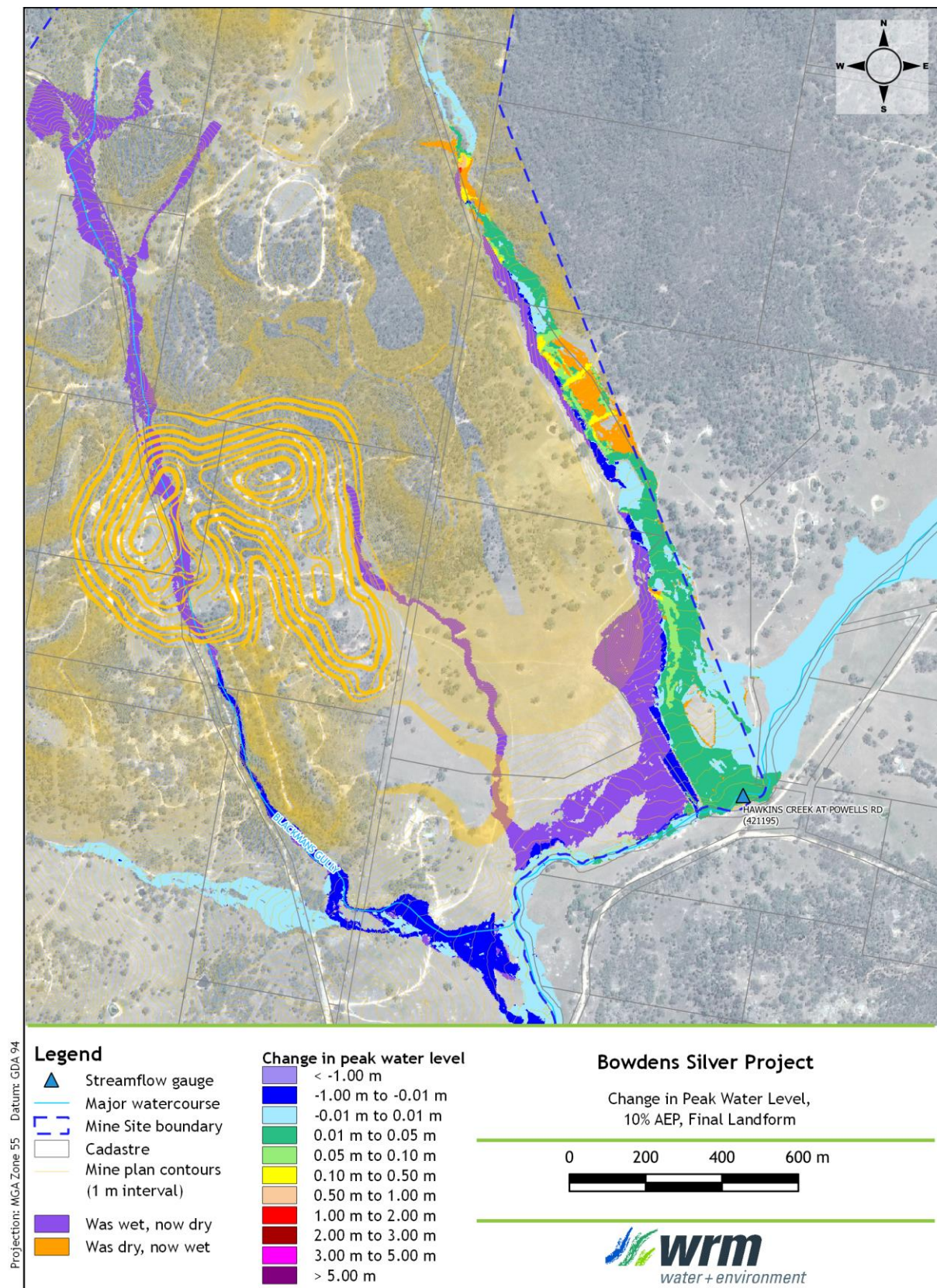


Figure 7.17 - 10% (1 in 10) AEP predicted impacts on peak flood levels along Price Creek adjacent to the proposed WRE - Final Landform Scenario

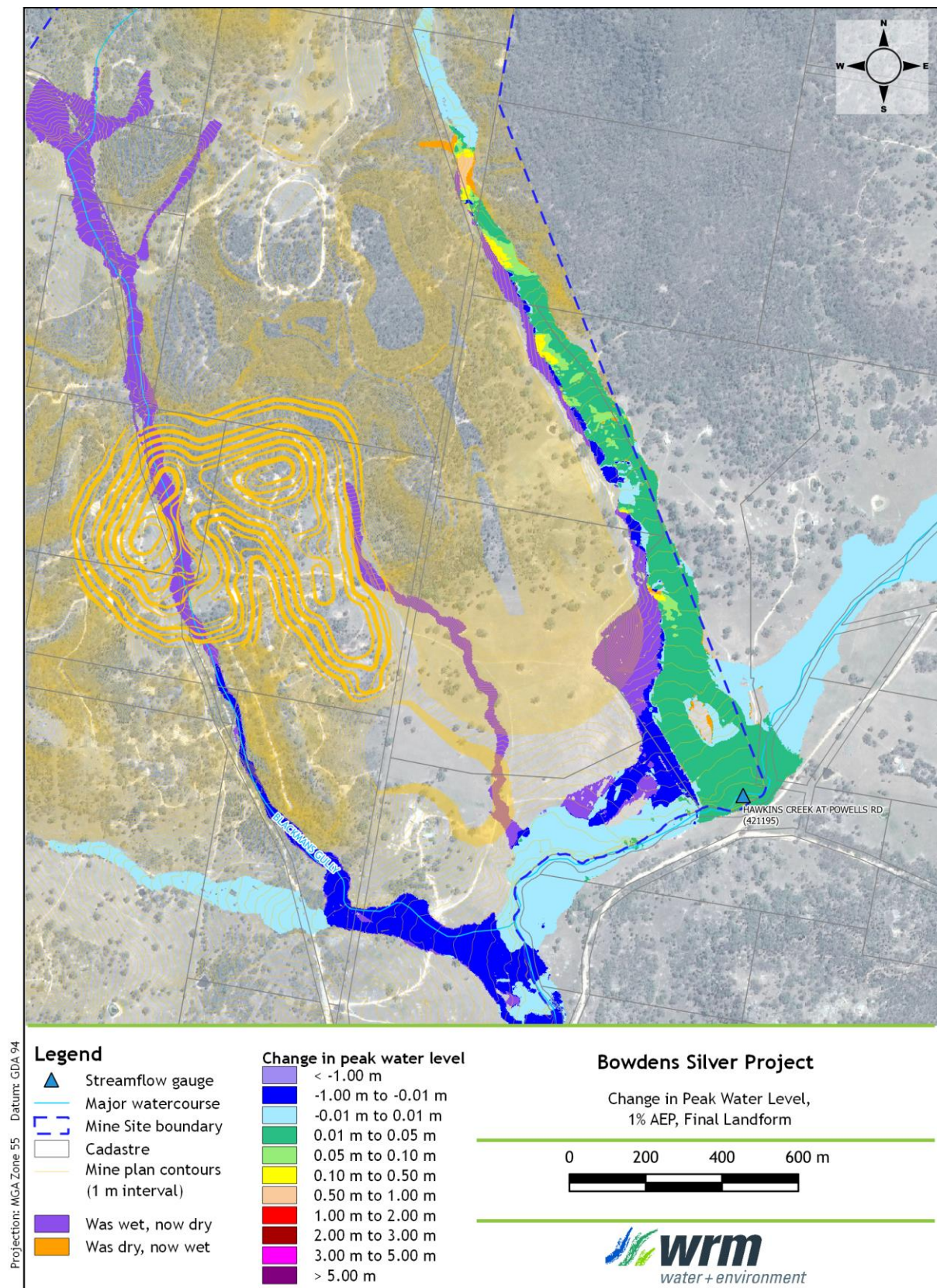


Figure 7.18 - 1% (1 in 100) AEP predicted impacts on peak flood levels along Price Creek adjacent to the proposed WRE - Final Landform Scenario

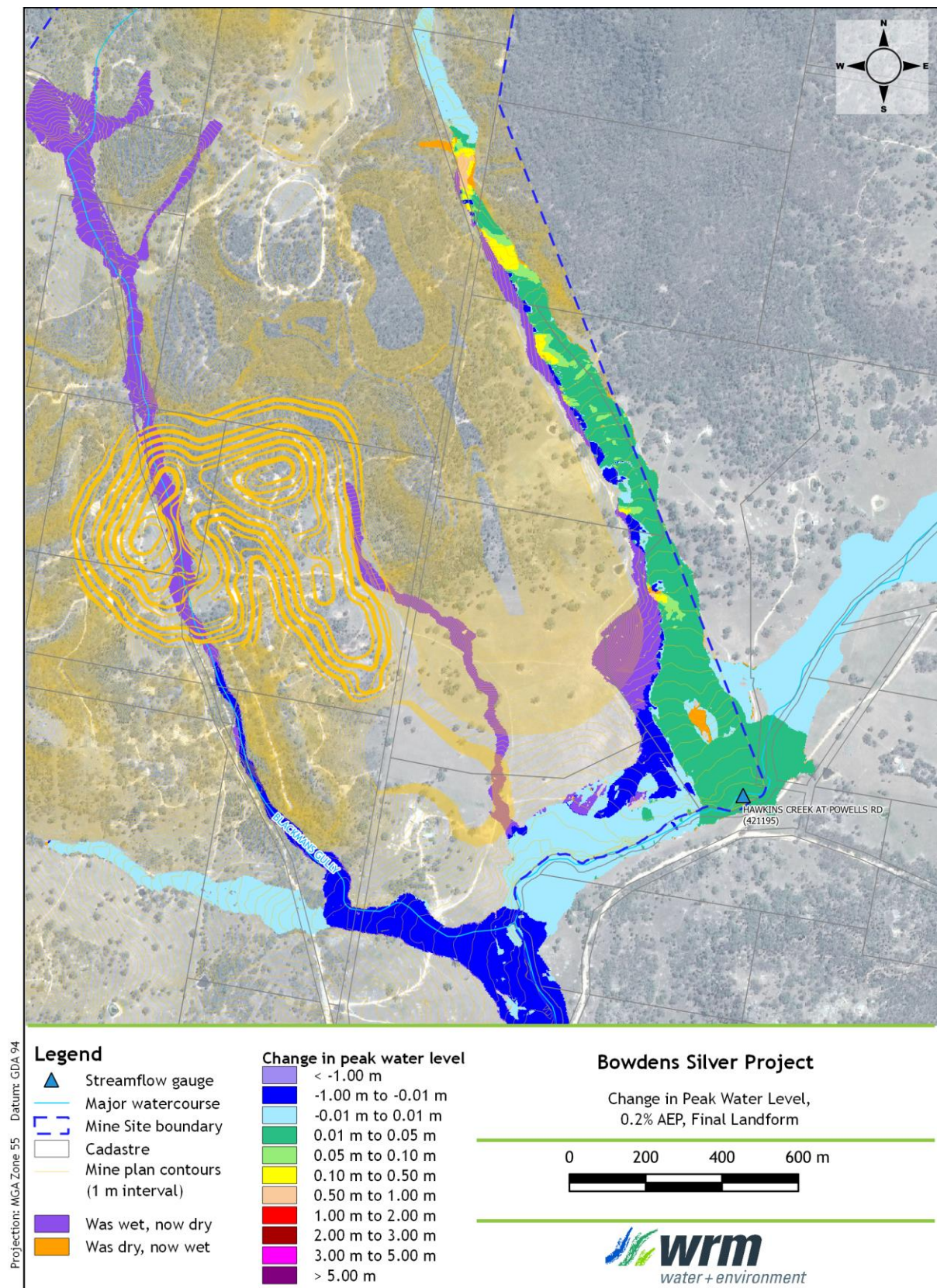


Figure 7.19 - 0.2% (1 in 500) AEP predicted impacts on peak flood levels along Price Creek adjacent to the proposed WRE - Final Landform Scenario

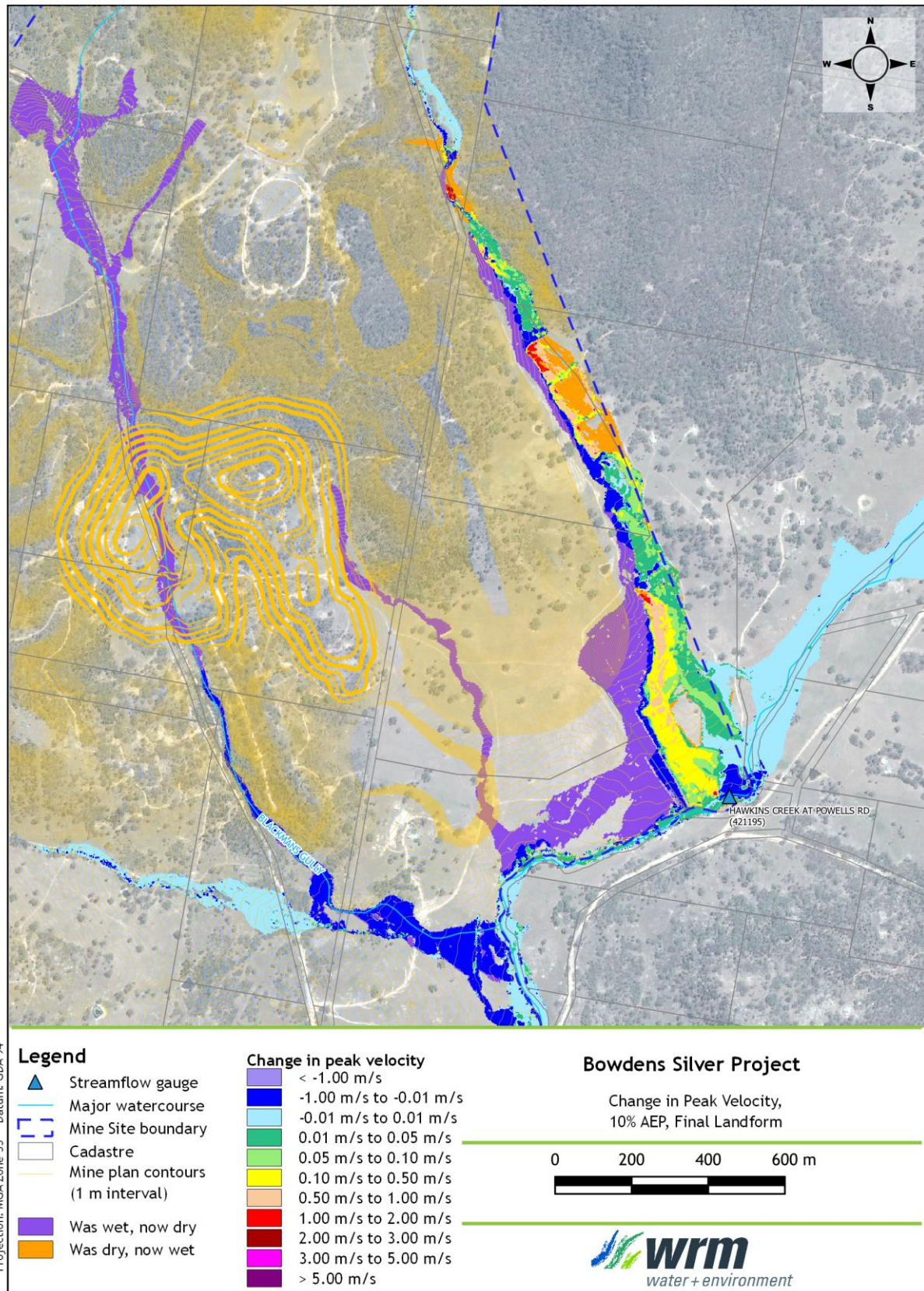


Figure 7.20 - 10% (1 in 10) AEP predicted impacts on peak velocities along Price Creek adjacent to the proposed WRE - Final Landform Scenario

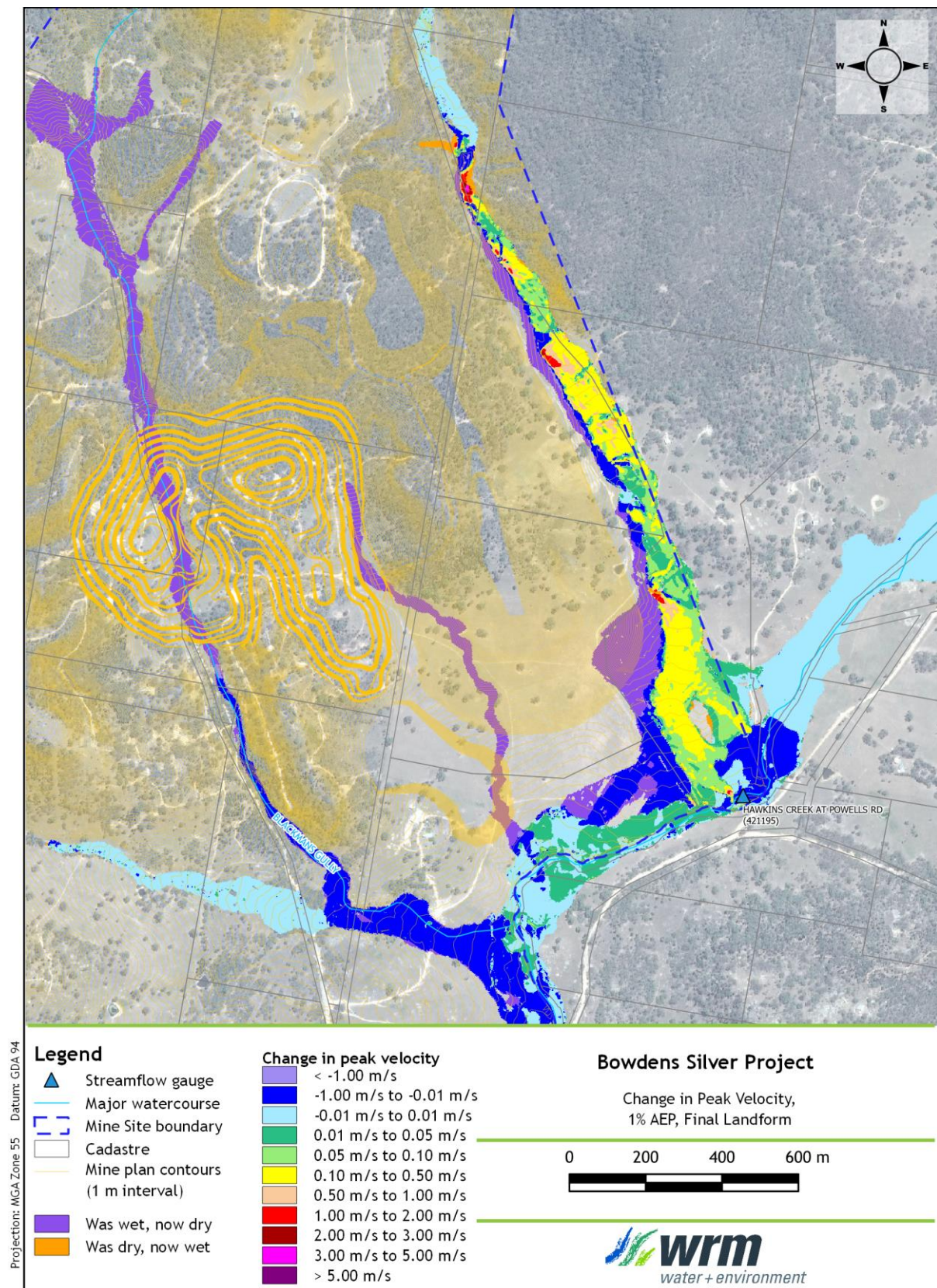


Figure 7.21 - 1% (1 in 100) AEP predicted impacts on peak velocities along Price Creek adjacent to the proposed WRE - Final Landform Scenario

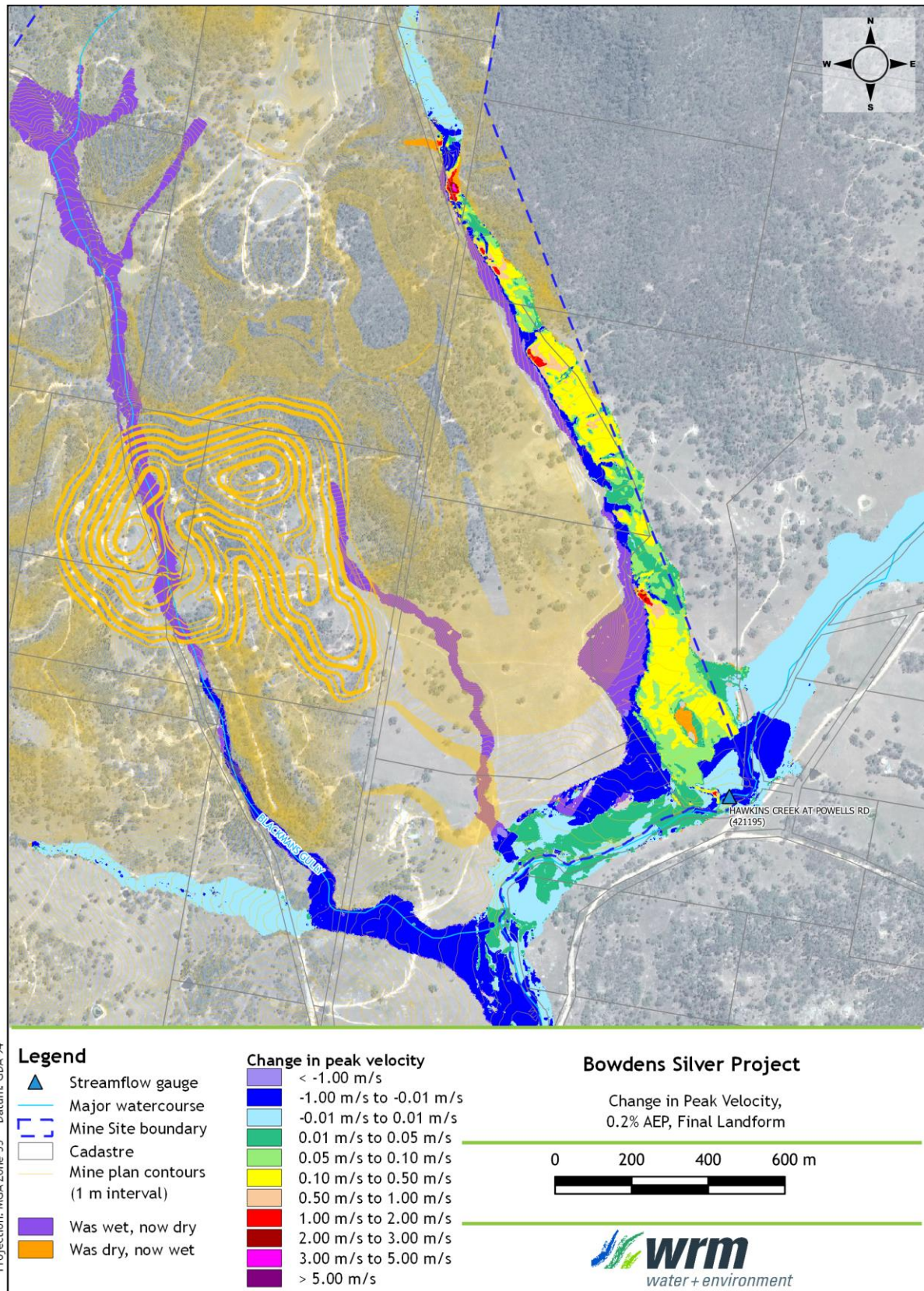


Figure 7.22 - 0.2% (1 in 500) AEP predicted impacts on peak velocities along Price Creek adjacent to the proposed WRE - Final Landform Scenario

7.3.3 Lawsons Creek crossing

Flood maps showing the predicted impacts on peak flood levels and velocities in the vicinity of the proposed Lawsons Creek Crossing for the Lawsons Creek Crossing scenario are shown in the following figures:

- Figure 7.23, Figure 7.24 and Figure 7.25 for the predicted impacts on peak flood levels for the 10% AEP, 1% AEP and 0.2% AEP events respectively; and
- Figure 7.26, Figure 7.27 and Figure 7.28 for the predicted impacts on peak velocities for the 10% AEP, 1% AEP and 0.2% AEP events respectively.

Additional flood maps showing the predicted impacts on peak flood levels and velocities for the Lawsons Creek Scenario for the 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF design events are provided in Appendix F.

The model results indicate the following:

- The proposed road crossing would increase peak flood levels upstream of the road:
 - For the 10% AEP event, peak flood levels would increase by up to 1.4 m. These impacts decrease in magnitude further away from the road crossing, dissipating to less than 0.01 m approximately 1.4 km upstream of the crossing.
 - The predicted increase in peak flood levels upstream of the crossing for the 10% AEP event would cause flows in Lawsons Creek to overtop the northern creek bank immediately upstream of the crossing. These overflows would drain to the northwest parallel to the Lawsons Creek before re-joining Lawsons Creek about 680 m downstream of the proposed crossing. These overflows would not occur under existing conditions for the 10% AEP event, but it would occur for larger events.
 - For the 1% AEP event, peak flood levels would increase by up to 1.4 m. These impacts decrease in magnitude further away from the road crossing, dissipating to less than 0.01 m approximately 700 m upstream of the crossing.
 - For the 0.2% AEP event, peak flood levels would increase by up to 1.8 m. These impacts decrease in magnitude further away from the road crossing, dissipating to less than 0.01 m approximately 700 m upstream of the crossing.
- There are predicted reductions in peak flood levels of up to 0.03 m downstream of the Lawsons Creek crossing for the 10% AEP event. However, peak flood levels would increase downstream of the crossing for the 1% and 0.2% AEP events:
 - For the 1% AEP event, peak flood levels would increase by up to 0.5 m. These impacts decrease in magnitude further away from the road crossing, dissipating to less than 0.01 m approximately 750 m downstream of the crossing.
 - For the 0.2% AEP event, peak flood levels would increase by up to 0.5 m. These impacts decrease in magnitude further away from the road crossing, dissipating to less than 0.01 m approximately 550 m downstream of the crossing.
- The proposed road crossing would reduce peak velocities in the Lawsons Creek channel. However, peak velocities would increase along the northern Lawsons Creek floodplain downstream of the crossing. This is due to the proposed crossing forcing water to flow to the northern bank of Lawsons Creek. For the 0.2% and 1% AEP events, velocities on the northern bank of Lawsons Creek would increase by up to 0.55 m/s, dissipating to less than 0.05 m/s approximately 800 m downstream of the crossing.
- The predicted increases in peak flood levels, extents and velocities do not appear to affect any existing dwellings for all events up to and including 0.2% (1 in 500) AEP. It is noted that all increases in flood levels, as the result of the relocated Maloneys Road (Pyangle Road) crossing of Lawsons Creek, would occur on land either owned or under an acquisition agreement with Bowdens Silver.

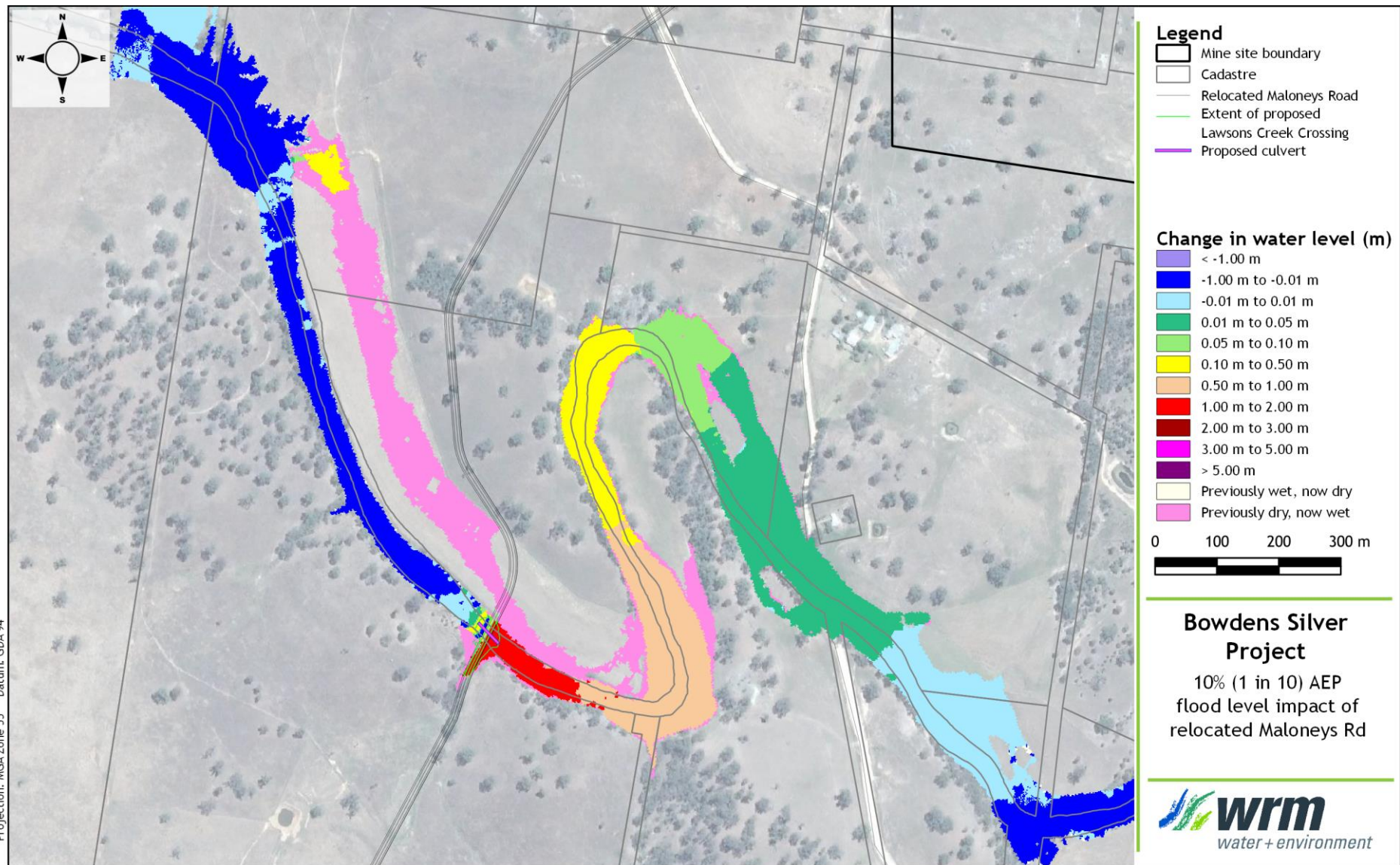


Figure 7.23 - 10% (1 in 10) AEP predicted impacts on peak flood levels along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

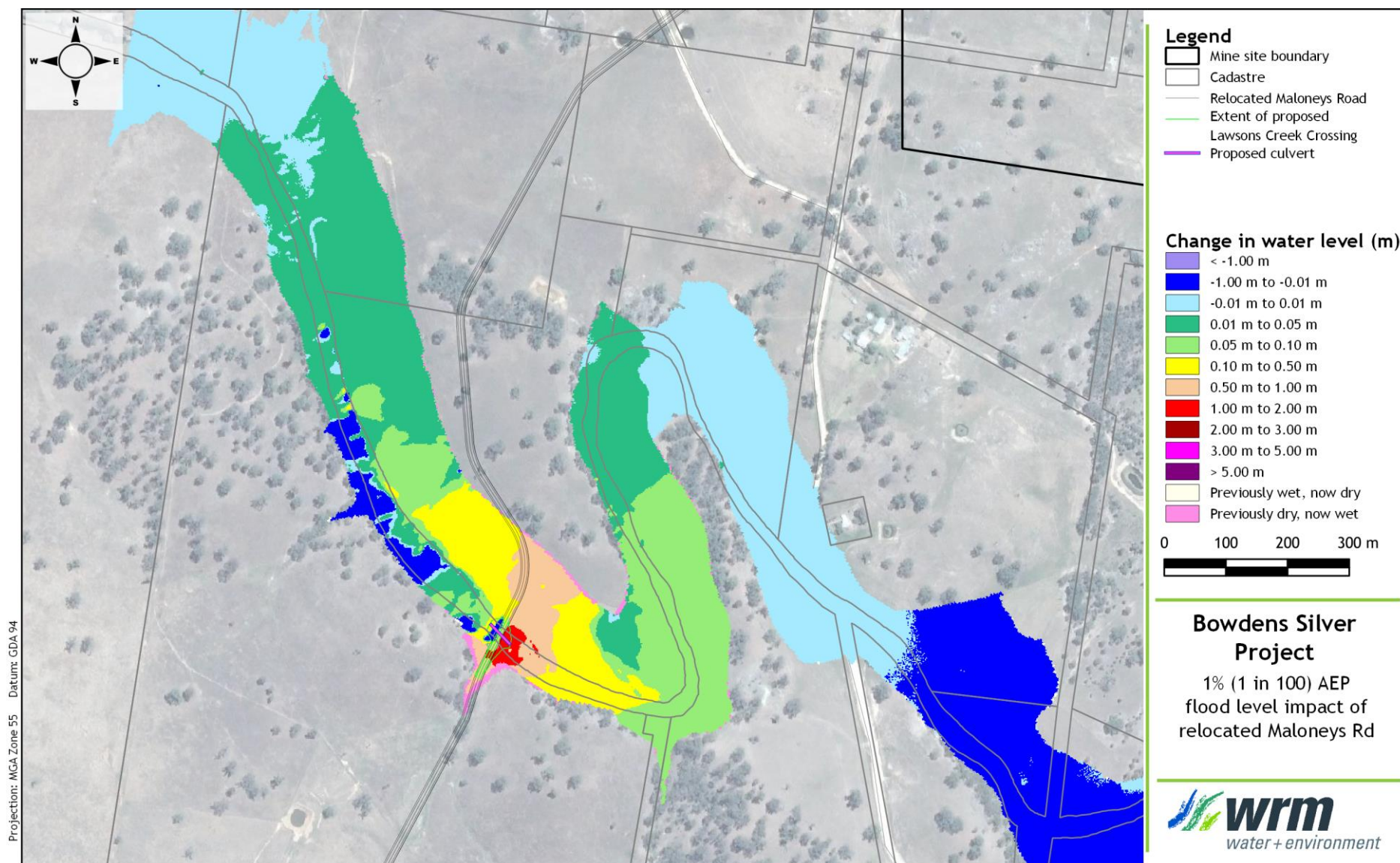


Figure 7.24 - 1% (1 in 100) AEP predicted impacts on peak flood levels along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

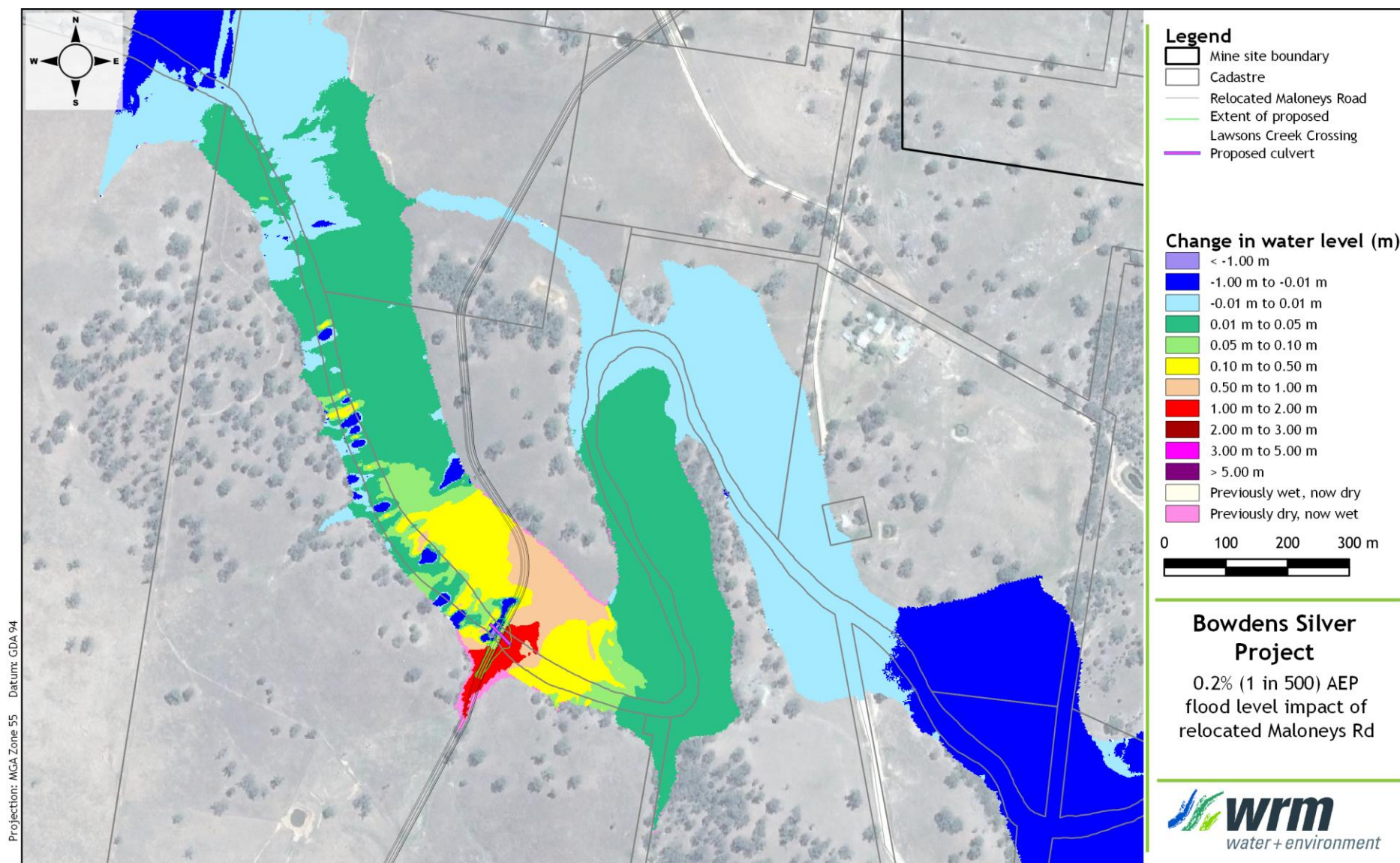


Figure 7.25 - 0.2% (1 in 500) AEP predicted impacts on peak flood levels along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

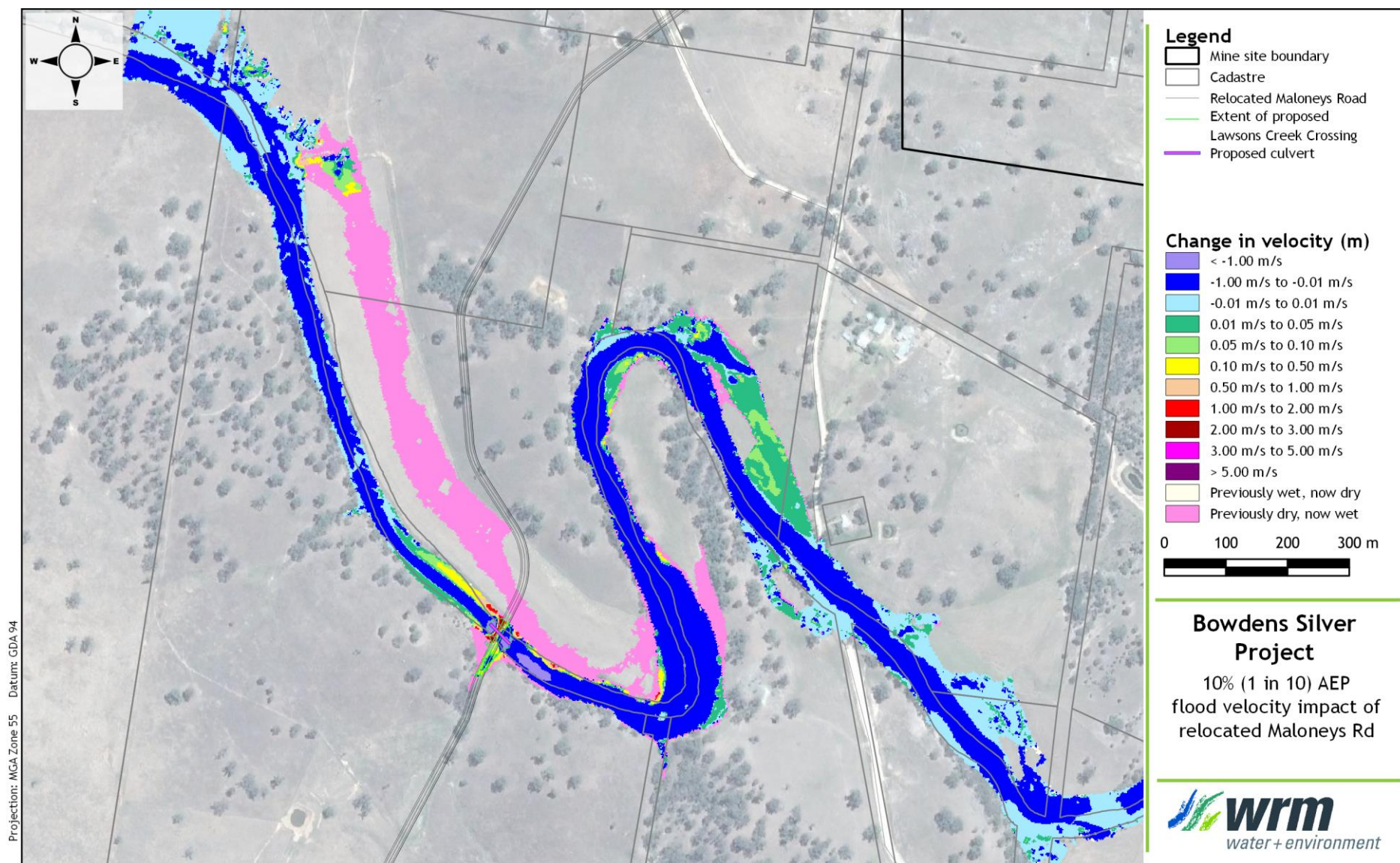


Figure 7.26 - 10% (1 in 10) AEP predicted impacts on peak velocities along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

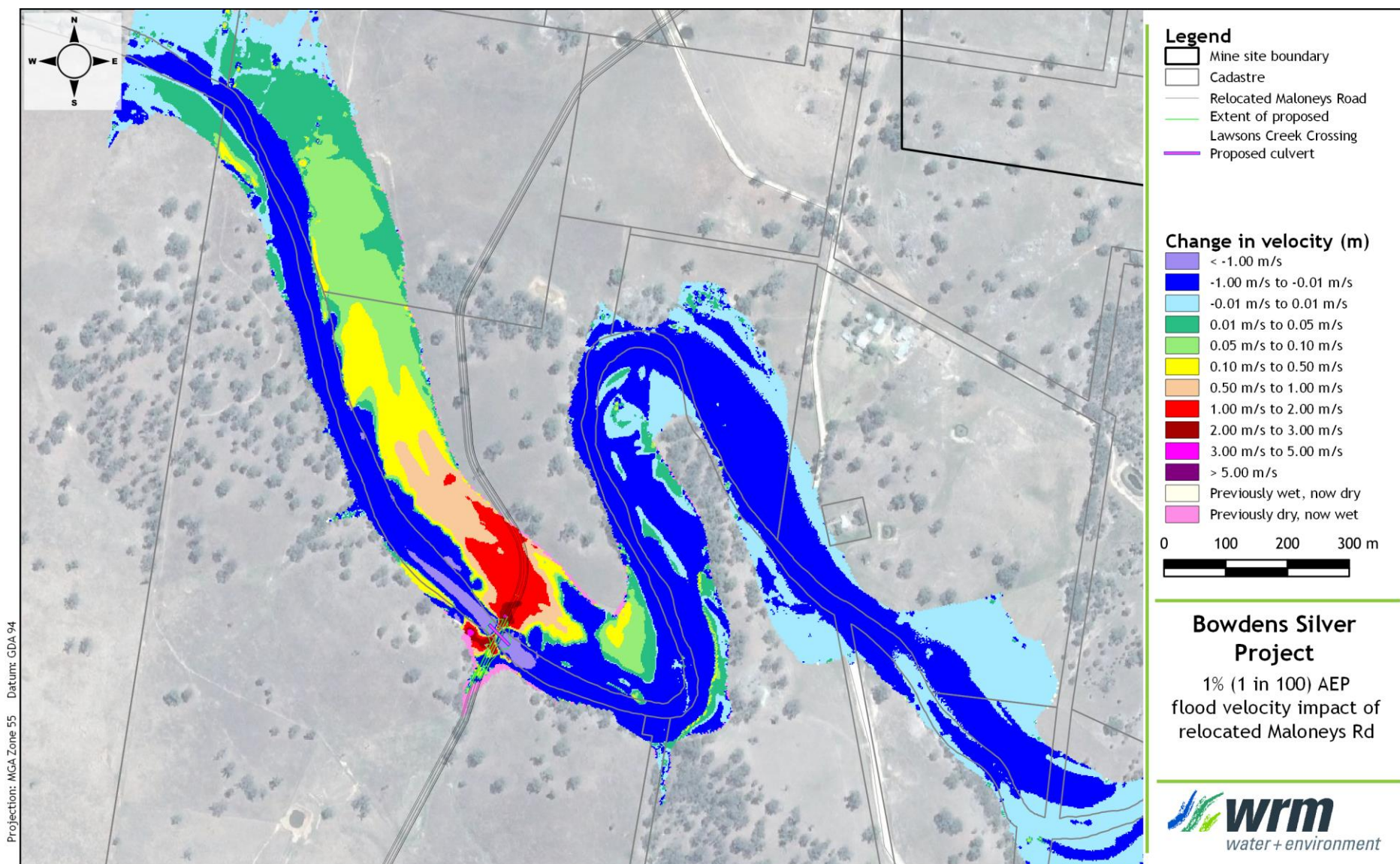


Figure 7.27 - 1% (1 in 100) AEP predicted impacts on peak velocities along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

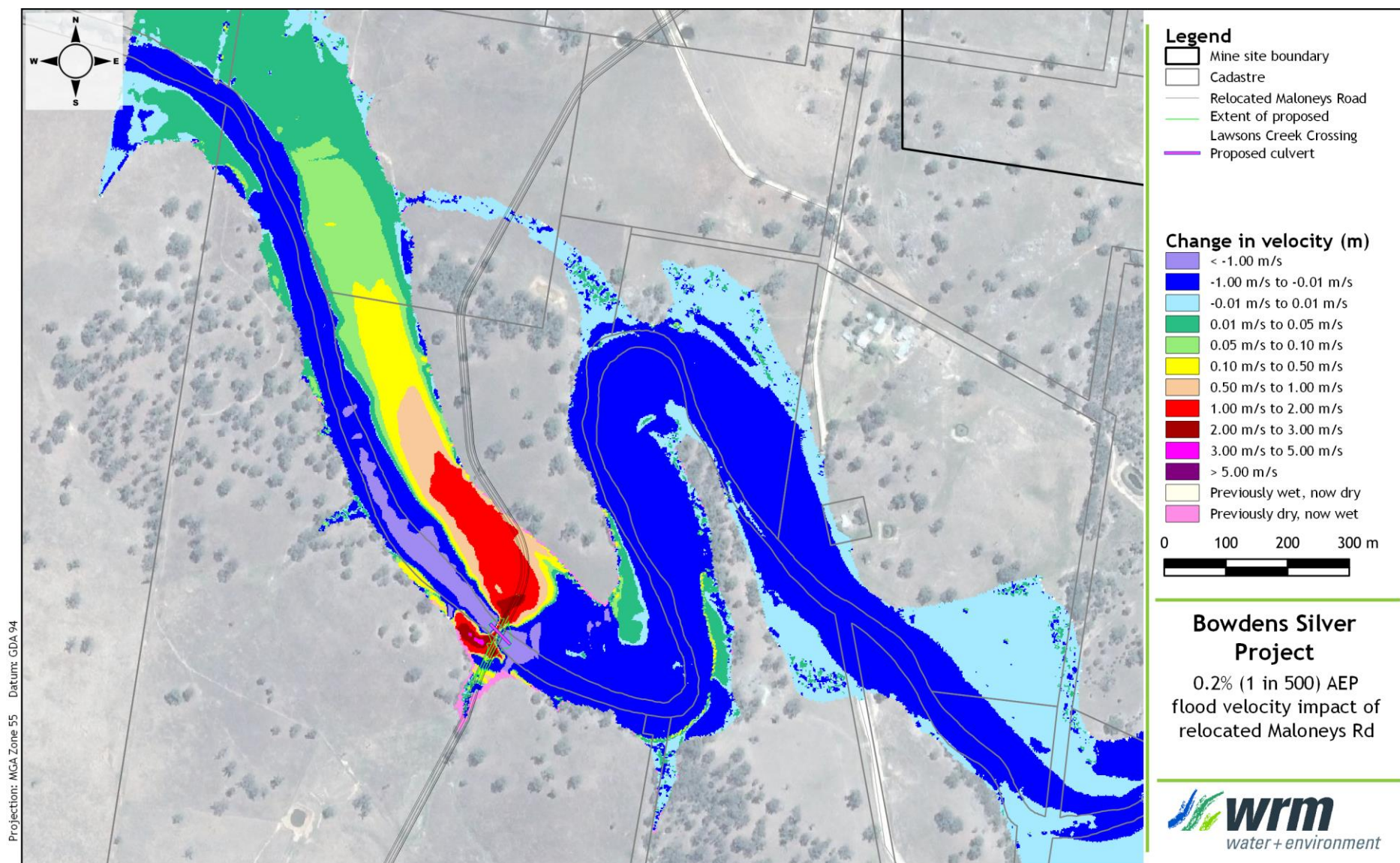


Figure 7.28 - 0.2% (1 in 500) AEP predicted impacts on peak velocities along Lawsons Creek in the vicinity of the proposed Lawsons Creek Crossing - Lawsons Creek Crossing Scenario

8 Summary of findings

8.1 OVERVIEW

An XP-RAFTS hydrologic model was developed for the catchments of Lawsons and Hawkins Creeks and their tributaries. A TUFLOW hydraulic model was also developed for these watercourses to determine existing conditions flood behaviour in the vicinity of the Project disturbance area.

8.2 HYDROLOGIC MODELLING

The XP-RAFTS model was validated recorded water level data at the Powells Road (Stn No. 421195) and Bingmans Crossing (Stn No. 421194) recording stations for one event in July 2016 and two events in September 2016. Rating (stage-discharge) curves for each of these recording stations were developed using a combination of theoretical rating curves and hydraulic modelling results. The rating curves were used to convert recorded water level data into discharges for model validation.

For the September 2016 (1st flow event), modelled peak discharges were within 15% to 20% of the recorded peak discharge (with a continuing loss rate of 4 mm/h). Very high continuing loss rates were required to achieve a good match to the peak discharges recorded during the July 2016 event and the September 2016 (2nd flow event), which may be partly caused by the site rainfall recordings overestimating the catchment rainfall during these events. However, the results show that the model is able to reproduce the timing and shape of the hydrographs reasonably well.

The XP-RAFTS model was used to estimate design discharges for the 10% (1 in 10), 5% (1 in 20), 2% (1 in 50), 1% (1 in 100), 0.5% (1 in 200) and 0.2% (1 in 500) AEP events as well as the PMP design event. Design discharges were estimated using the AR&R 2016 event ensemble methodology. The resulting peak discharges were validated against peak discharges estimated using the RFFE technique.

8.3 HYDRAULIC MODELLING

The TUFLOW hydraulic model was developed for the study area with a grid cell size of three metres. The discharges estimated using the XP-RAFTS runoff-routing model were adopted as inflows to the TUFLOW hydraulic model.

Key points with regards to predicted peak flood levels and depths across the study area are summarised below:

- The Project disturbance area is located outside of the predicted Lawsons Creek flood extent for all events up to the probable maximum precipitation (PMP) design event.
- The area along the southeastern Mine Site boundary is affected by flooding from Hawkins Creek. However, the proposed open cut pits, WRE and leachate management dam are located outside of the predicted flood extent for Hawkins Creek for all design events.
- Flooding along the Hawkins Creek and Lawsons Creek tributaries within the Mine Site is characterised by shallow overland flows. Flows in these tributaries are generally confined within narrow flood flow paths, with no breakouts occurring except near the confluences of these tributaries with Hawkins and Lawsons Creeks. Due to the narrow flood flow paths, the difference in predicted flood extents along these tributaries between the 1% Annual Exceedance Probability (AEP) and PMP design events is not significant.

- Predicted peak flood depths along the overbank areas of the Hawkins and Lawsons Creek tributaries are generally below one metre for events up to and including 0.2% (1 in 500) AEP. Peak flood depths of up to 1.5 m for the PMP design event are predicted in some sections along these tributaries.

Key points with regards to predicted peak velocities across the study area are summarised below:

- Flows in the Lawsons Creek and Hawkins Creek tributaries are generally confined within narrow flood flow paths with relatively steep ground slopes. This results in relatively high predicted peak flood velocities of up to 2.5 m/s along the channel and overbank areas of these tributaries for events up to and including 0.2% AEP. The proposed mine infrastructure would increase flood velocities in localised areas, and mitigation works would be required to manage erosion risks along the lower perimeter embankment of the WRE during operations and after mine closure.
- Existing peak flood velocities in Hawkins Creek for events up to and including 0.2% AEP are generally less than 3 m/s, with peak velocities greater than 4 m/s predicted in some sections. The Project results in some redistribution of tributary inflows to Hawkins Creek, and as a result there would be a minor increase (less than 0.1 m/s) in flood velocities immediately adjacent to the Mine Site.
- Existing peak flood velocities in Lawsons Creek are relatively high for all modelled events. For events up to and including 0.2% AEP, peak flood velocities greater than 4 m/s are predicted in many sections along the Lawsons Creek channel and floodplain. The proposed mine infrastructure would have minimal impact on Lawsons Creek flood velocities.

In summary, the works associated with the proposed WRE would result in localised minor flood level increases. The more significant flood level impacts are constrained to within the lease, and would not result in significant impacts to other properties, assets or infrastructure. The proposed WRE would also locally increase flood velocities in its immediate vicinity. Local scour protection measures would need to be developed during detailed design to mitigate the potential erosion impacts in this area. Any expected increases in flood velocities in Hawkins Creek and Lawsons Creek are negligible and would not adversely impact offsite property or infrastructure.

Key points with regards to flood conditions at the relocated Maloneys Road (Pyangle Road) crossing of Lawsons Creek are summarised below. The results indicate that:

- The upstream impacts of the proposed crossing decrease with increasing flood magnitude.
- The proposed road crossing would be overtopped during a 10% (1 in 10) AEP flood event. Peak flood depths over the road are up to 1.2 m, while peak flood velocities over the road are up to 3 m/s. Therefore, the proposed road crossing would be non trafficable by light or heavy vehicles during a 10% AEP event.
- Due to the predicted increase in peak flood levels upstream of the crossing, flows in Lawsons Creek would overtop the northern creek bank immediately upstream of the crossing. In the 10% AEP flood, these overflows would drain to the northwest parallel to the Lawsons Creek before re-joining Lawsons Creek about 680 m downstream of the proposed crossing. In larger flows, a greater proportion of flow would be directed along the northeast floodplain, resulting in increased floodplain velocities.
- The predicted increases in peak flood levels and flood extents for the 10% AEP event would not affect any existing dwellings. It is noted that Bowdens Silver either owns or holds the option to purchase all properties that are predicted to be affected by an increase in flood levels.

- The road crossing would be designed to manage the risk of scour induced by increased velocities, for example through the use of dumped rock or other erosion protection measures.

9 References

Ball et al, 2019	Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I (Editors), 2019, <i>Australian Rainfall and Runoff: A Guide to Flood Estimation</i> , Commonwealth of Australia
BMT, 2019	BMT Pty Ltd 2019, <i>TUFLOW User Manual - GIS Based 1D/2D Hydrodynamic Modelling</i> , Brisbane QLD
BoM, 2003	Commonwealth Bureau of Meteorology, June 2003, <i>Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Short-Duration Method</i> , Hydrometeorological Advisory Service
BoM, 2006	Commonwealth Bureau of Meteorology, October 2006, <i>Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Southeast Australia Method</i> , Hydrometeorological Advisory Service
BoM, 2016	Commonwealth Bureau of Meteorology, 2016, <i>Design rainfalls for Australia: data, methods and analyses</i> , Melbourne VIC.
Chow, 1959	V.T Chow, 1959, <i>Open Channel Hydraulics</i> , McGraw-Hill Book Company, NY
Jordan et al, 2005	Jordan P, Nathan R, Mittiga L and Taylor B, 2005, <i>Growth Curves and Temporal Patterns for Application to Short Duration Extreme Events</i> , Aust J Water Resour Volume 9(1), pp.69-80.
Innovyze, 2018	Innovyze Pty Ltd, XP-RAFTS User Manual, 2018



Appendix A - XP-RAFTS subcatchment parameters

Table A.1 - Adopted XP-RAFTS subcatchment parameters

Subcatchment ID	Area (km ²)	Percentage impervious (%)	Catchment slope (%)	Catchment PERN 'n'
BG001	0.10	0	10.9	0.050
BG002	0.77	0	2.6	0.040
BG003	0.27	0	11.2	0.050
BG004	0.04	0	21.2	0.050
BG005	0.20	0	5.6	0.040
BG006	0.07	0	16.8	0.040
BG007	0.89	0	3.9	0.040
HA001	4.09	0	2.4	0.035
HA002	4.15	0	1.9	0.035
HA003	4.05	0	2.3	0.035
HA004	4.73	0	4.6	0.050
HA005	3.76	0	3.3	0.050
HA006	1.95	0	5.5	0.040
HA007	3.24	0	2.8	0.035
HA008	2.14	0	1.8	0.035
HC001	3.13	0	4.0	0.050
HC002	3.39	0	4.5	0.050
HC003	3.11	0	2.9	0.050
HC004	4.10	0	3.2	0.050
HC005	3.76	0	3.0	0.050
HC006	1.61	0	5.2	0.050
HC007	4.89	0	3.2	0.050
HC008	4.55	0	3.5	0.050
HC009	4.70	0	1.5	0.035
HC010	5.87	0	7.0	0.050
HC011	3.80	0	4.8	0.050
HC012	3.07	0	0.9	0.035
HC013	4.08	0	5.0	0.050
HC014	0.78	0	2.0	0.035
HC016	0.42	0	5.9	0.050
HC017	0.62	0	1.6	0.035
HC018	0.43	0	4.0	0.035
HC019	0.67	0	2.8	0.035
HC020	0.22	0	6.2	0.040
HC021	0.26	0	6.1	0.040
LC001	6.92	0	2.3	0.050
LC002	5.35	0	1.9	0.050
LC003	3.36	0	3.2	0.050
LC004	4.63	0	2.5	0.050
LC005	6.55	0	3.5	0.040
LC006	7.38	0	2.1	0.040
LC007	6.80	0	1.3	0.035
LC008	6.19	0	3.5	0.035
LC009	5.62	0	2.2	0.035
LC010	5.61	0	1.7	0.035
LC011	9.12	0	2.8	0.050

Subcatchment ID	Area (km ²)	Percentage impervious (%)	Catchment slope (%)	Catchment PERN 'n'
LC012	6.65	0	3.2	0.040
LC013	4.42	0	2.4	0.040
LC014	6.01	0	2.4	0.040
LC015	6.12	0	3.1	0.050
LC016	4.42	0	2.4	0.040
LC017	8.51	0	3.2	0.050
LC018	4.11	0	4.6	0.040
LC019	5.54	0	2.9	0.035
LC020	4.22	0	3.7	0.050
LC021	3.83	0	3.8	0.035
LC022	3.19	0	1.9	0.035
LC023	4.68	0	2.7	0.035
LC024	3.97	0	1.4	0.035
LC025	5.43	0	2.4	0.035
LC026	3.70	0	4.1	0.035
LC027	4.61	0	2.5	0.035
LC028	2.69	0	2.4	0.035
LC029	4.88	0	1.4	0.035
LC030	2.49	0	0.8	0.035
LC031	3.39	0	2.9	0.035
LC032	2.76	0	2.3	0.035
LC033	2.77	0	4.1	0.035
LC034	1.90	0	4.7	0.035
LC035	2.18	0	0.7	0.035
LC036	3.45	0	1.9	0.035
LC037	1.56	0	4.7	0.040
LC038	1.14	0	3.3	0.035
LC039	0.98	0	8.3	0.040
LC040	1.62	0	3.4	0.035
LC041	1.87	0	1.4	0.035
LC042	1.16	0	4.1	0.035
LC043	0.41	0	7.7	0.040
LC044	0.64	0	3.9	0.040
PC001	1.06	0	8.6	0.050
PC002	1.55	0	4.7	0.050
PC003	0.69	0	7.3	0.050
PC004	0.67	0	4.1	0.040
PC005	1.21	0	3.4	0.035

Appendix B - Design discharges from AR&R 2016 event ensemble (1 in 100 AEP)

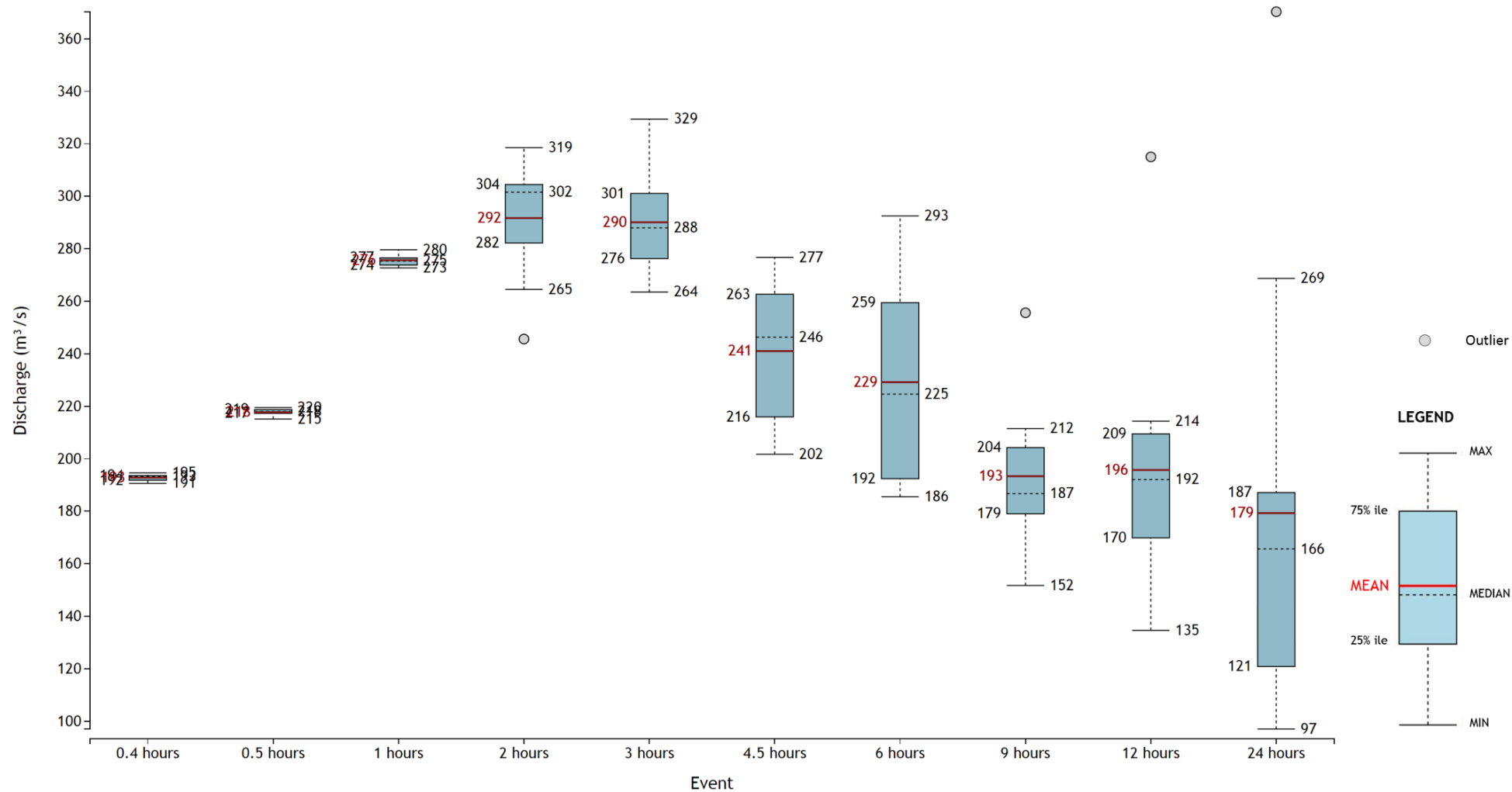


Figure B.1 - Ensemble of 1% (1 in 100) AEP predicted peak discharges in Hawkins Creek at Powells Road

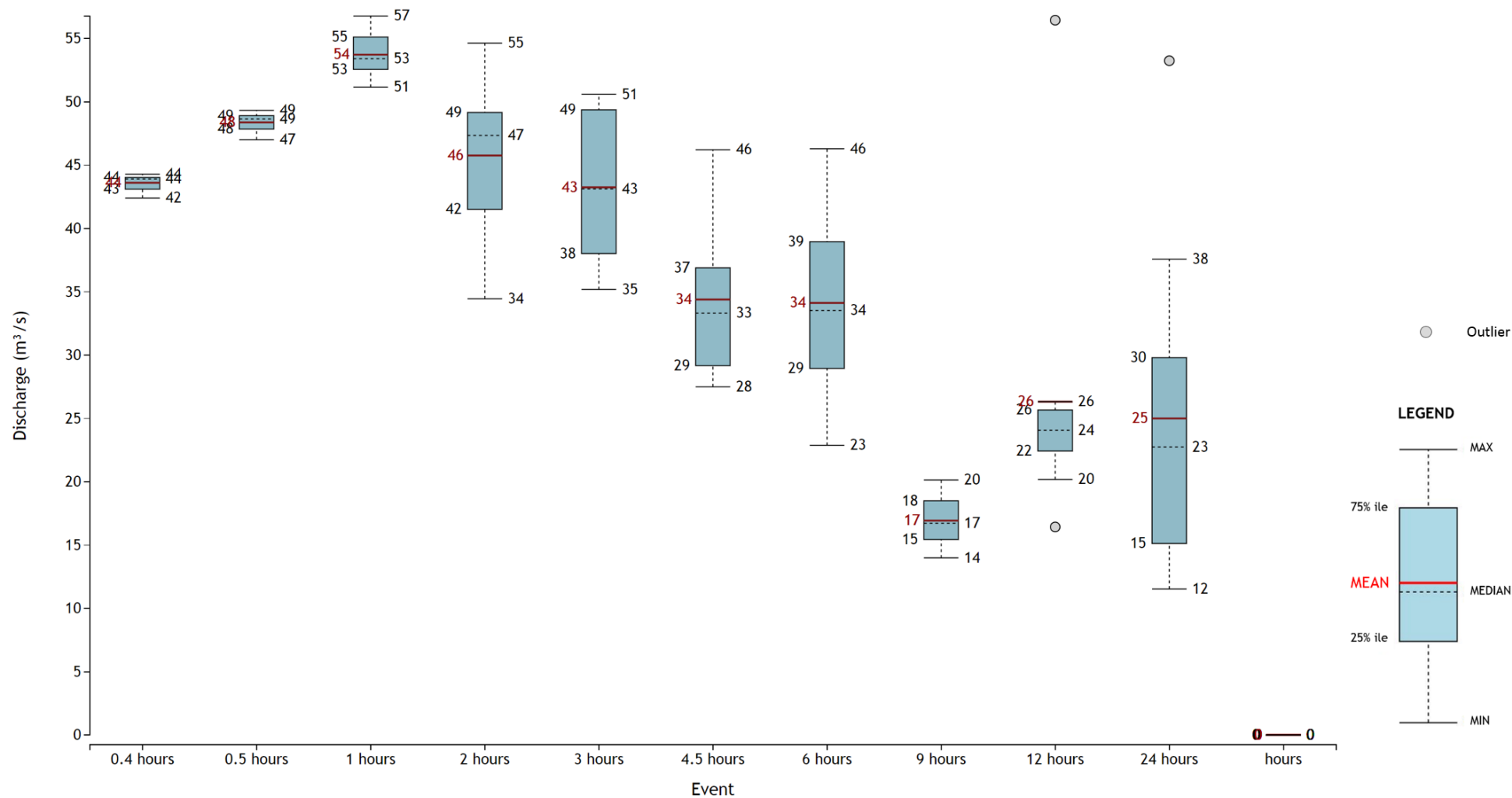


Figure B.2 - Ensemble of 1% (1 in 100) AEP predicted peak discharges in Price Creek upstream of Hawkins Creek confluence

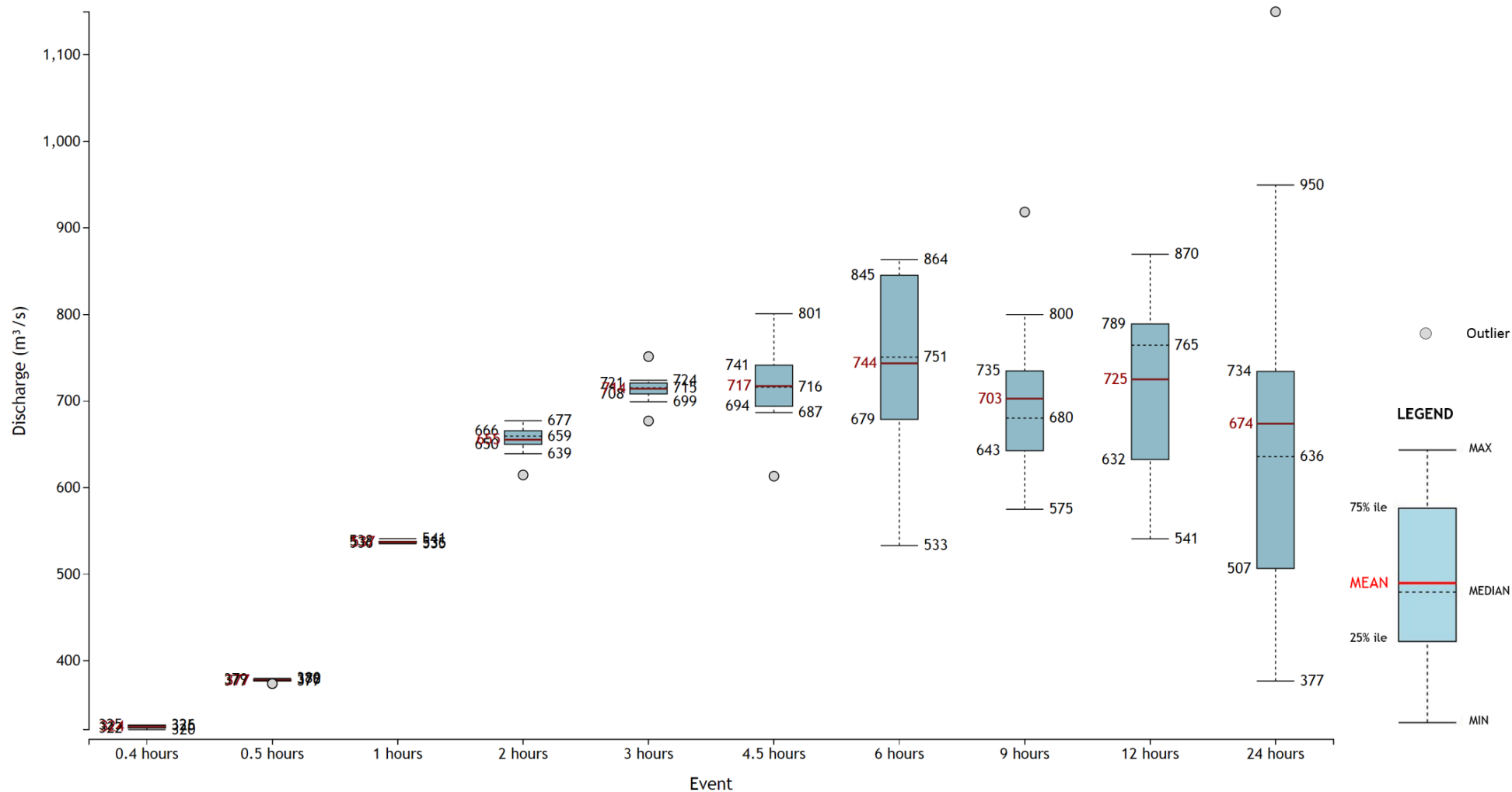
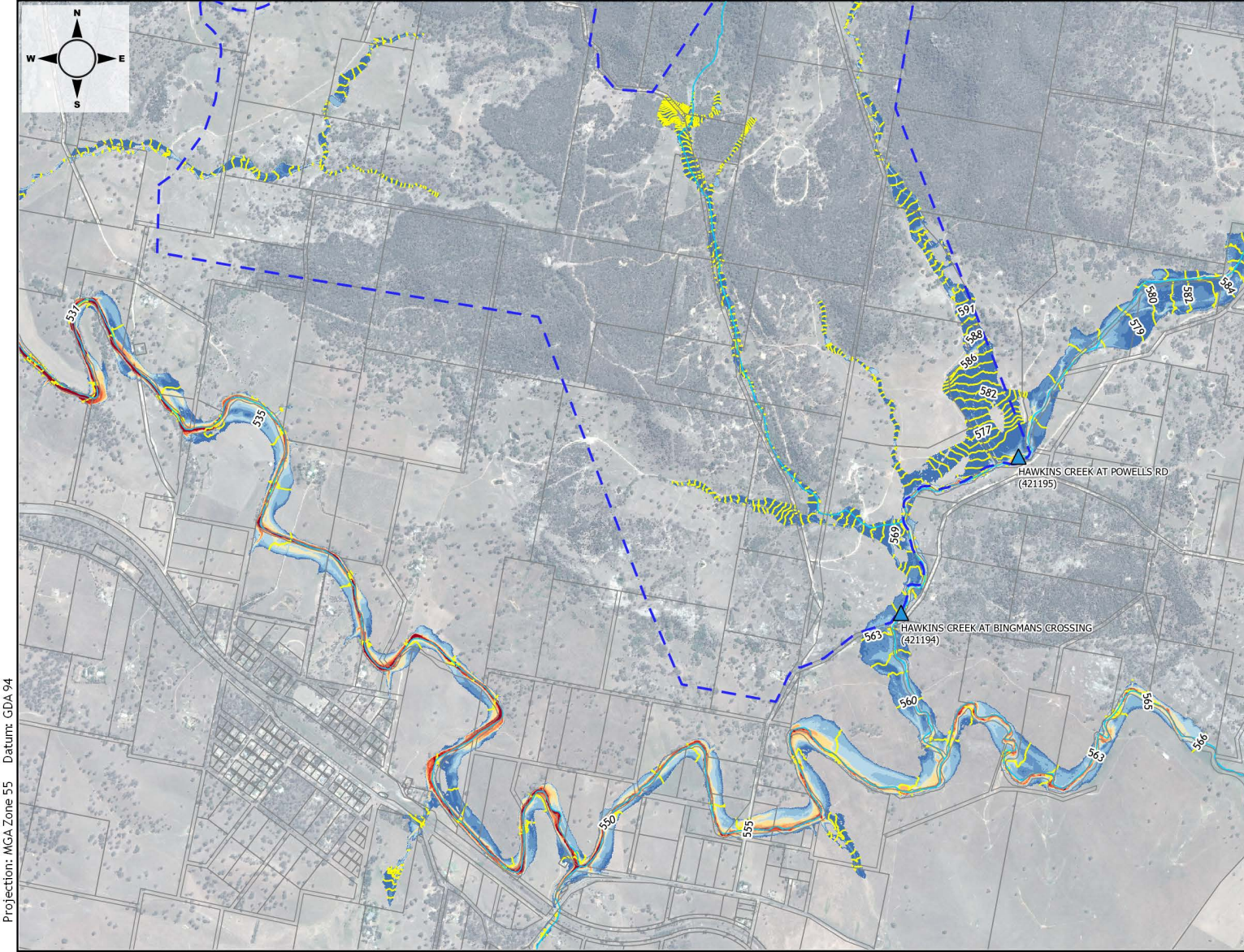


Figure B.3 - Ensemble of 1% (1 in 100) AEP predicted peak discharges in Lawsons Creek at the XP-RAFTS model outlet



Appendix C - Flood maps - Base case



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Water level contour (1m)

Depth

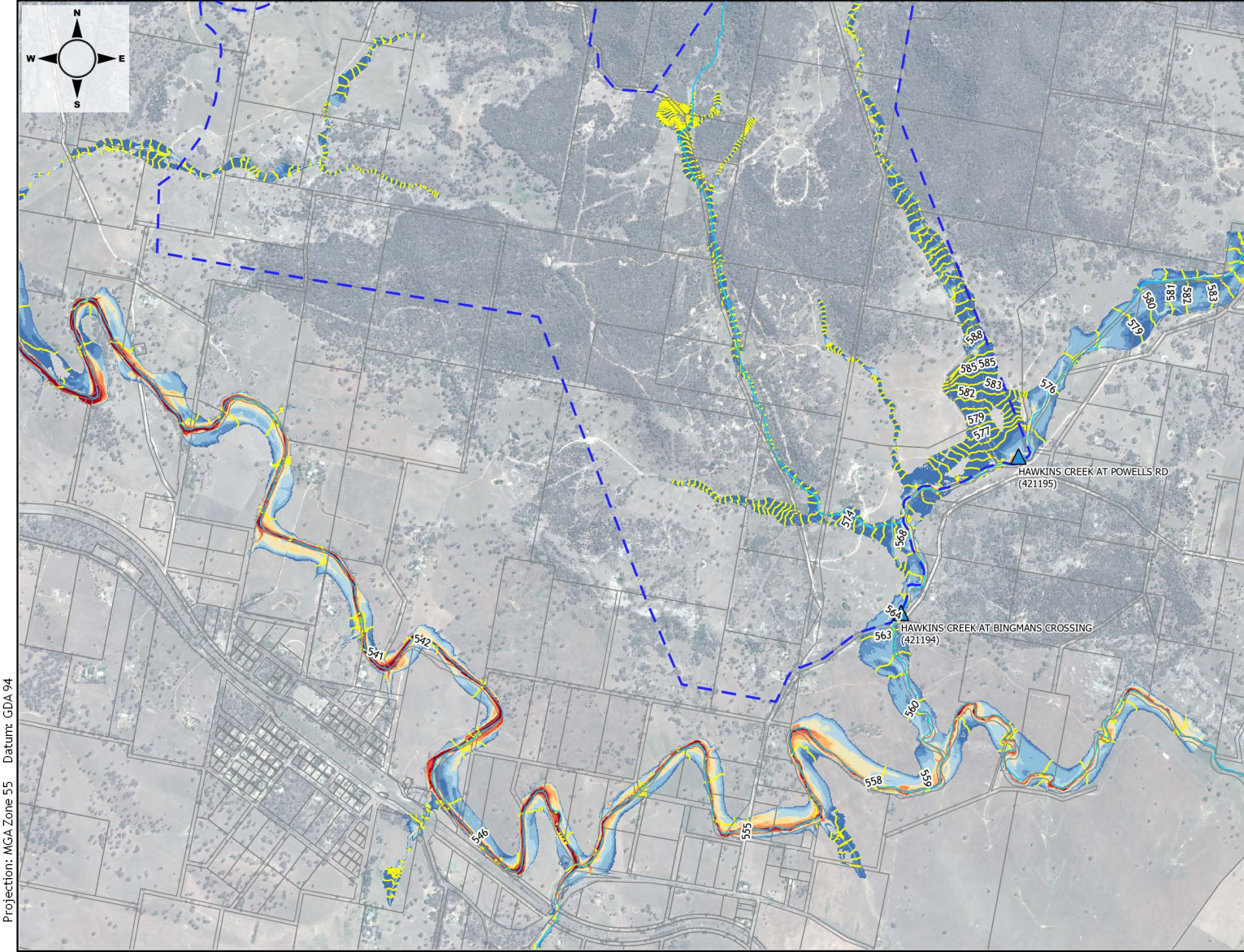
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 10% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Water level contour (1m)

Depth

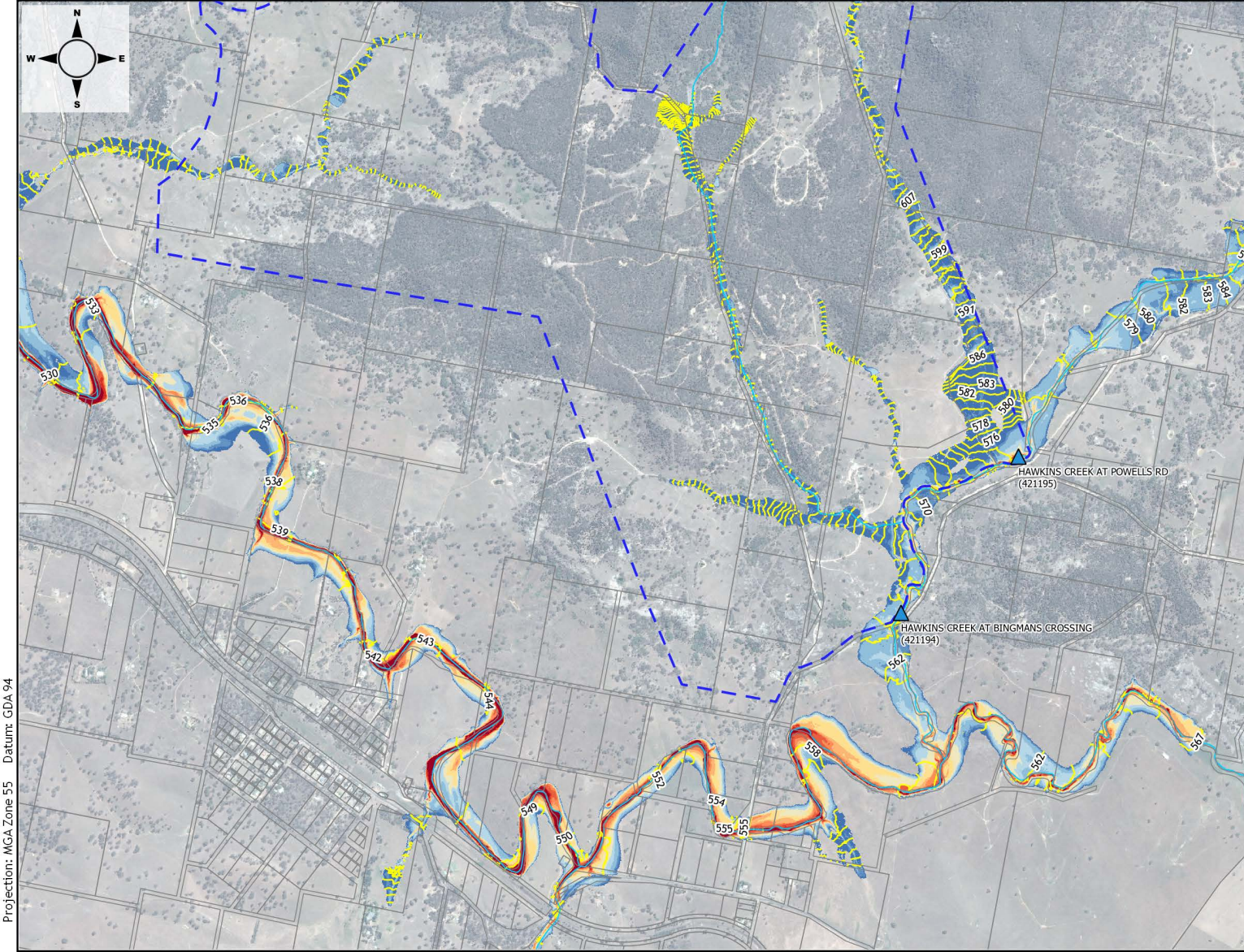
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 5% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Water level contour (1m)

Depth

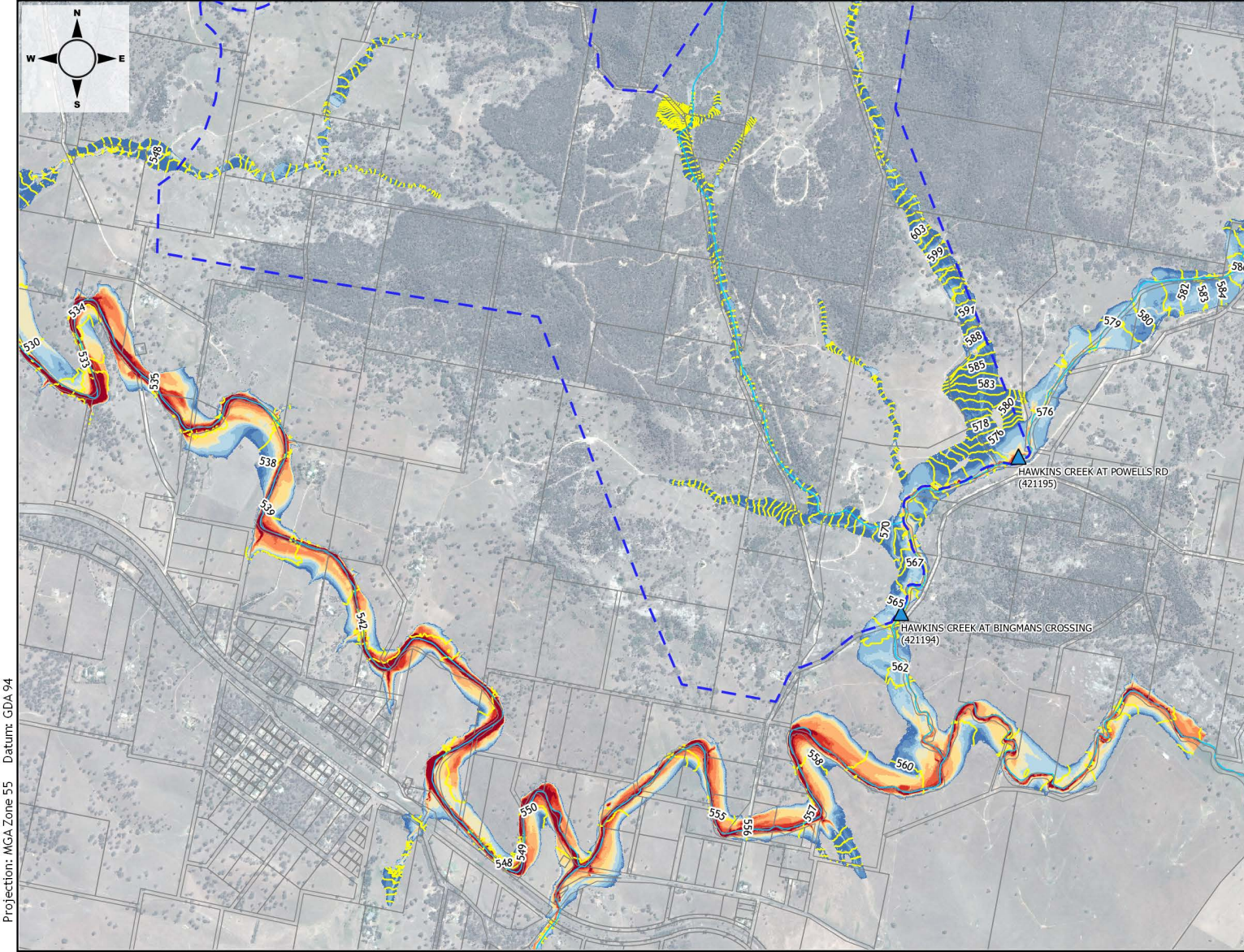
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 2% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastrate
- Streamflow gauge

Water level contour (1m)

Depth

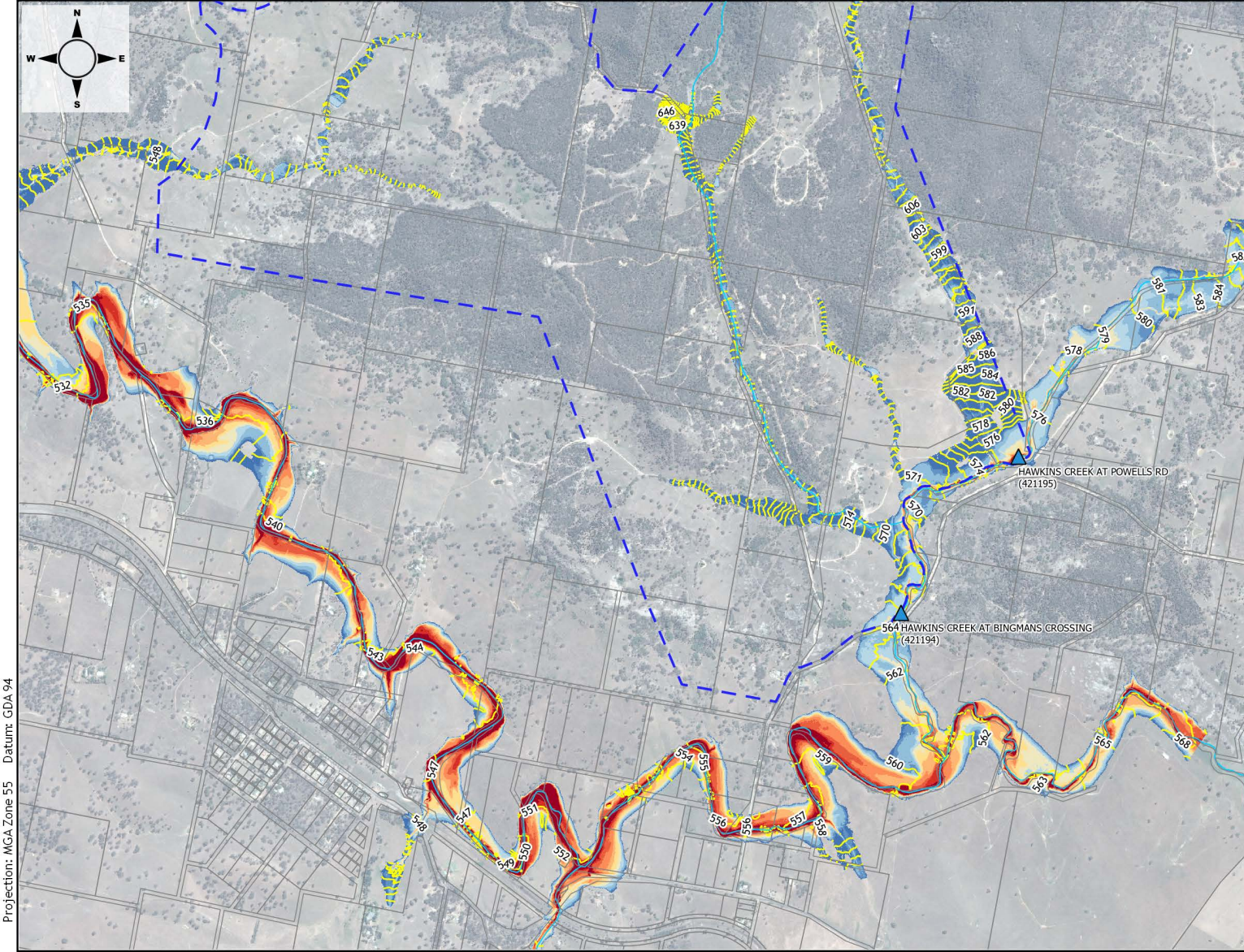
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 1% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastral
- Streamflow gauge

Water level contour (1m)

Depth

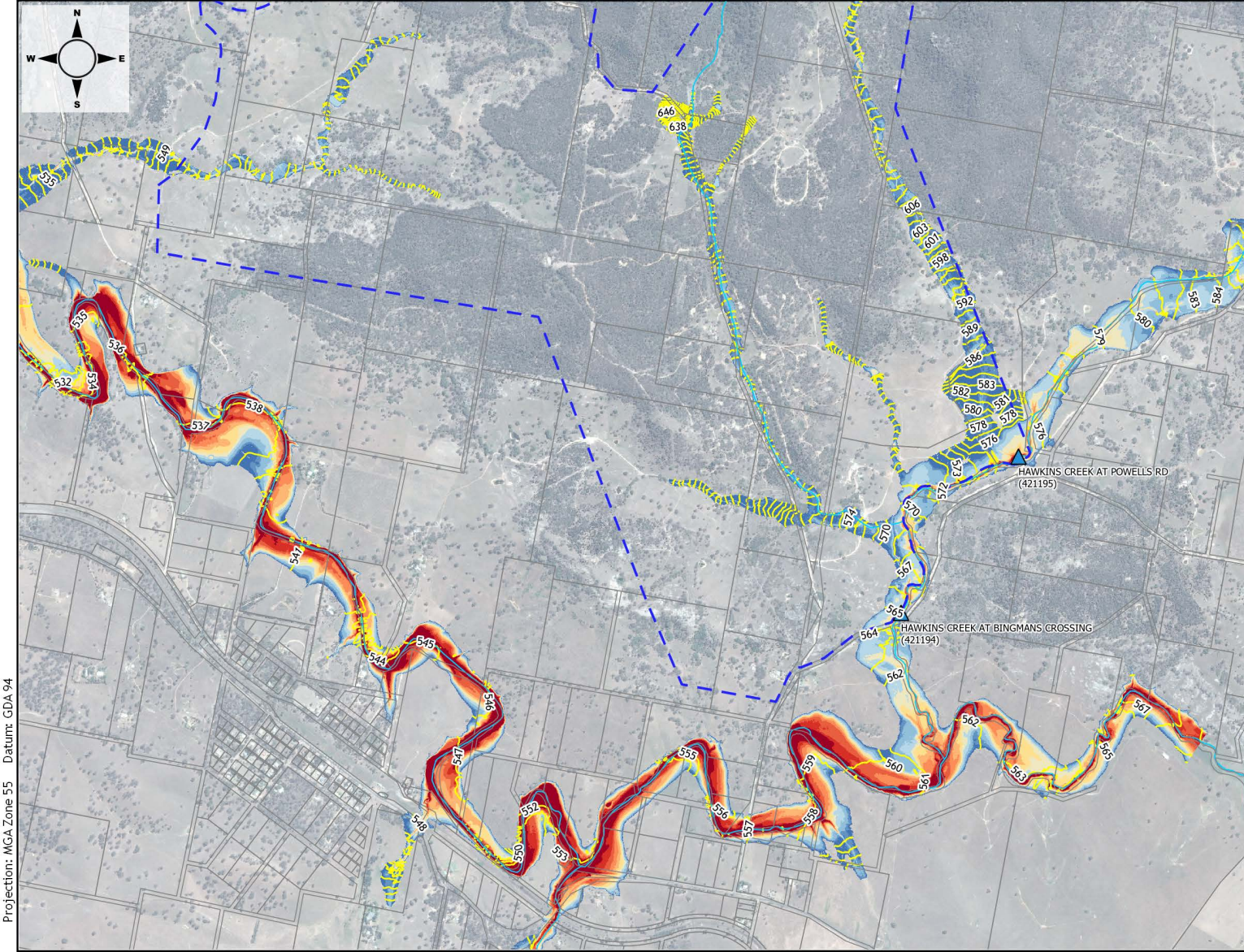
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 0.5% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Water level contour (1m)

Depth

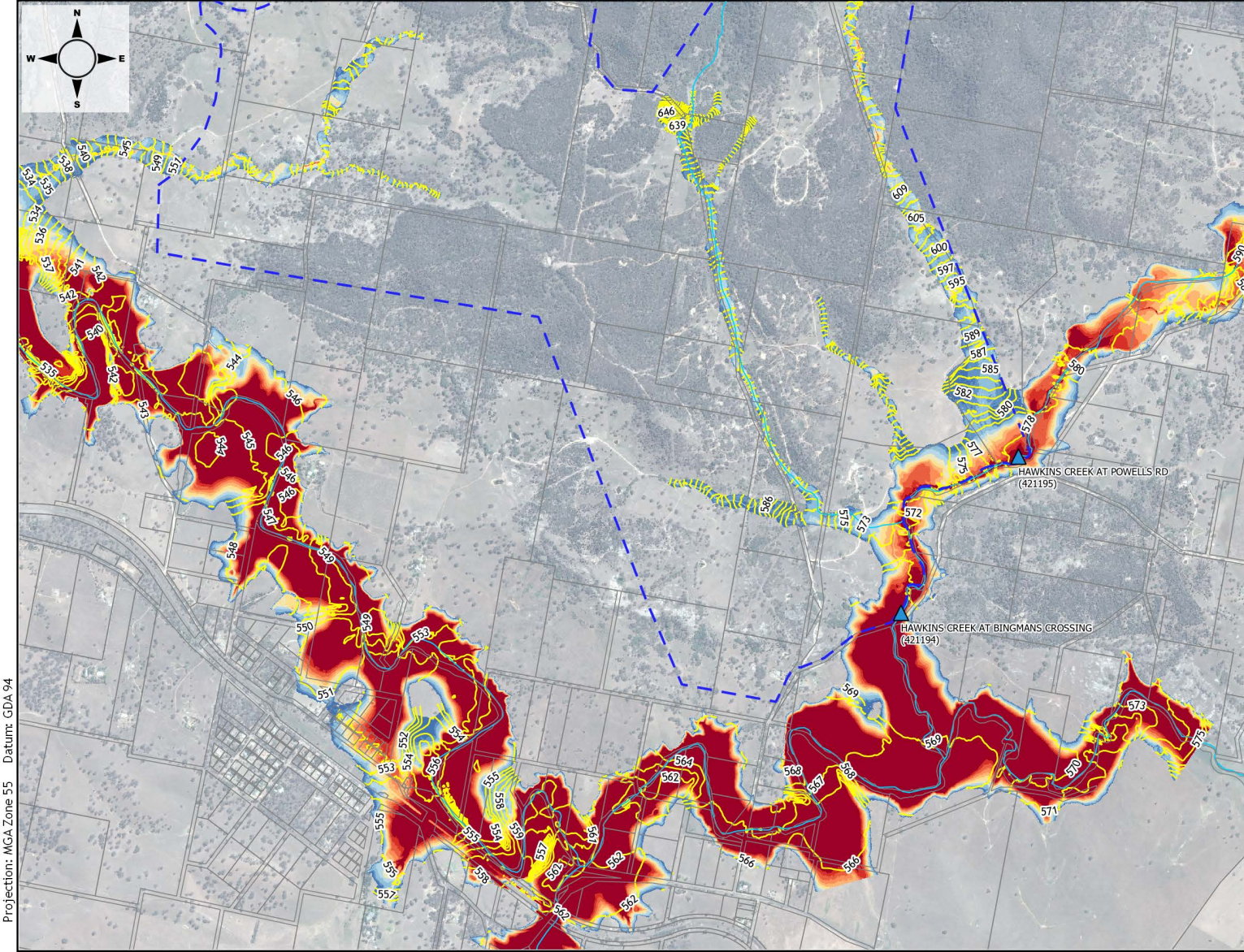
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- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 0.2% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastrate
- Streamflow gauge

Water level contour (1m)

Depth

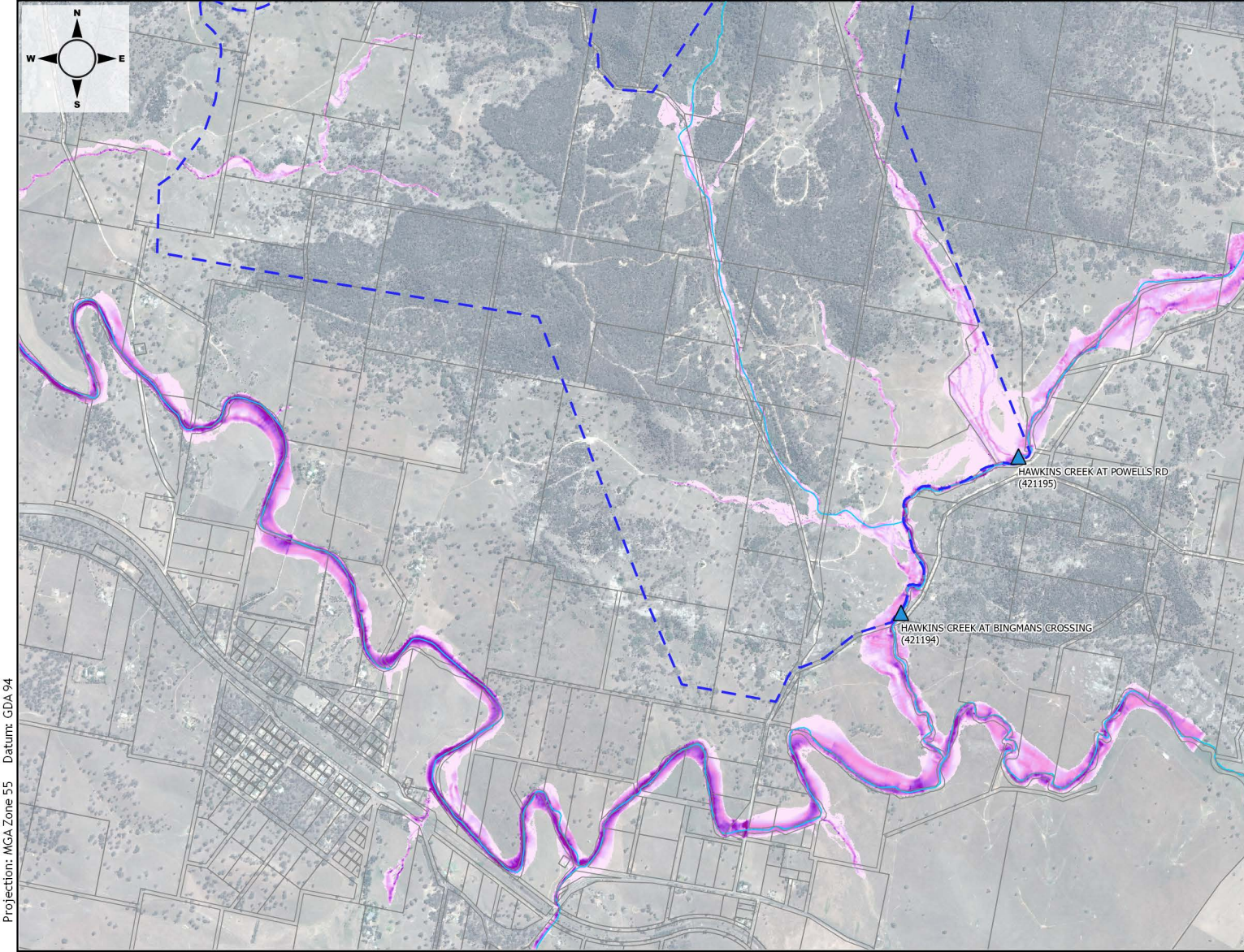
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- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), PMF



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

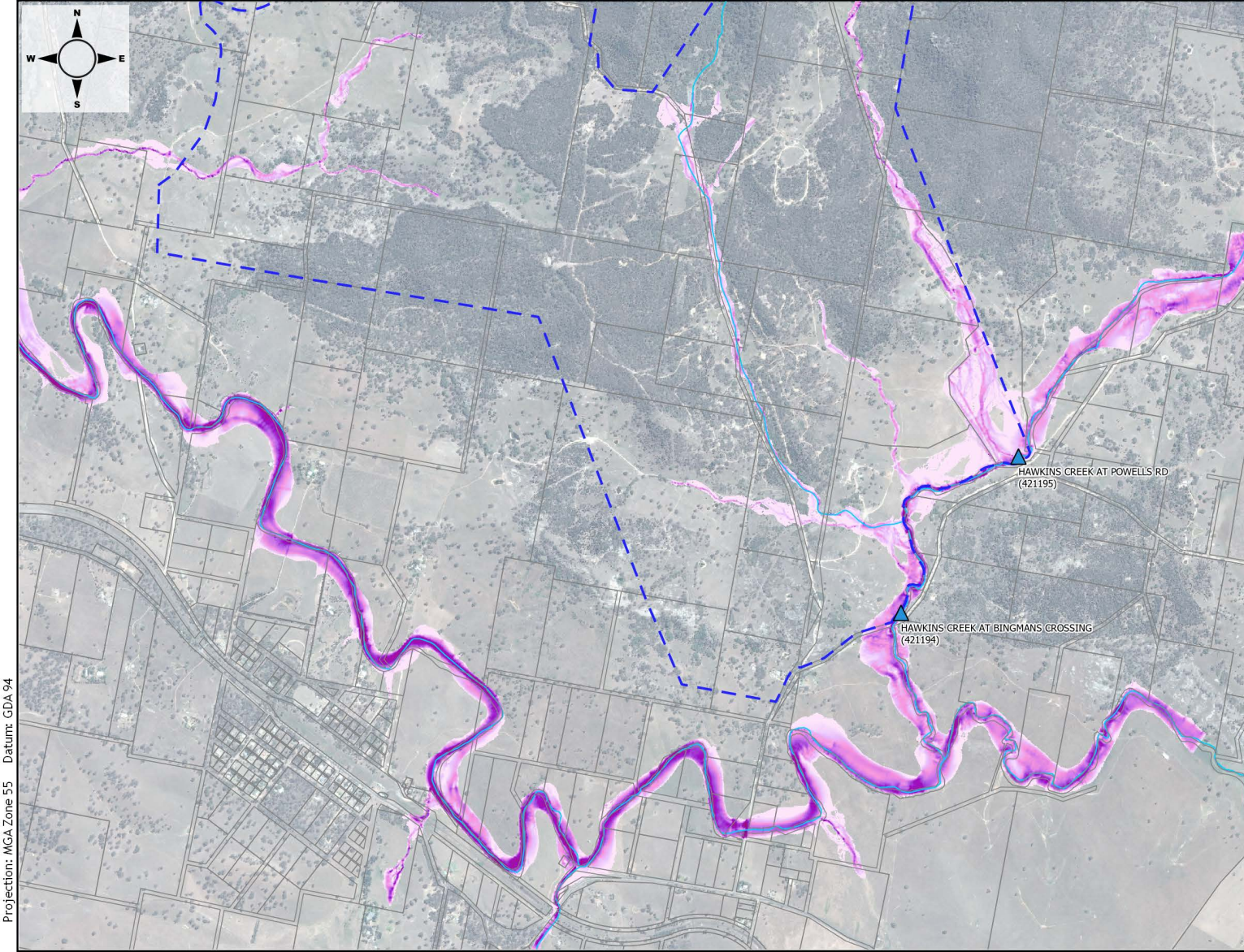
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- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 10% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

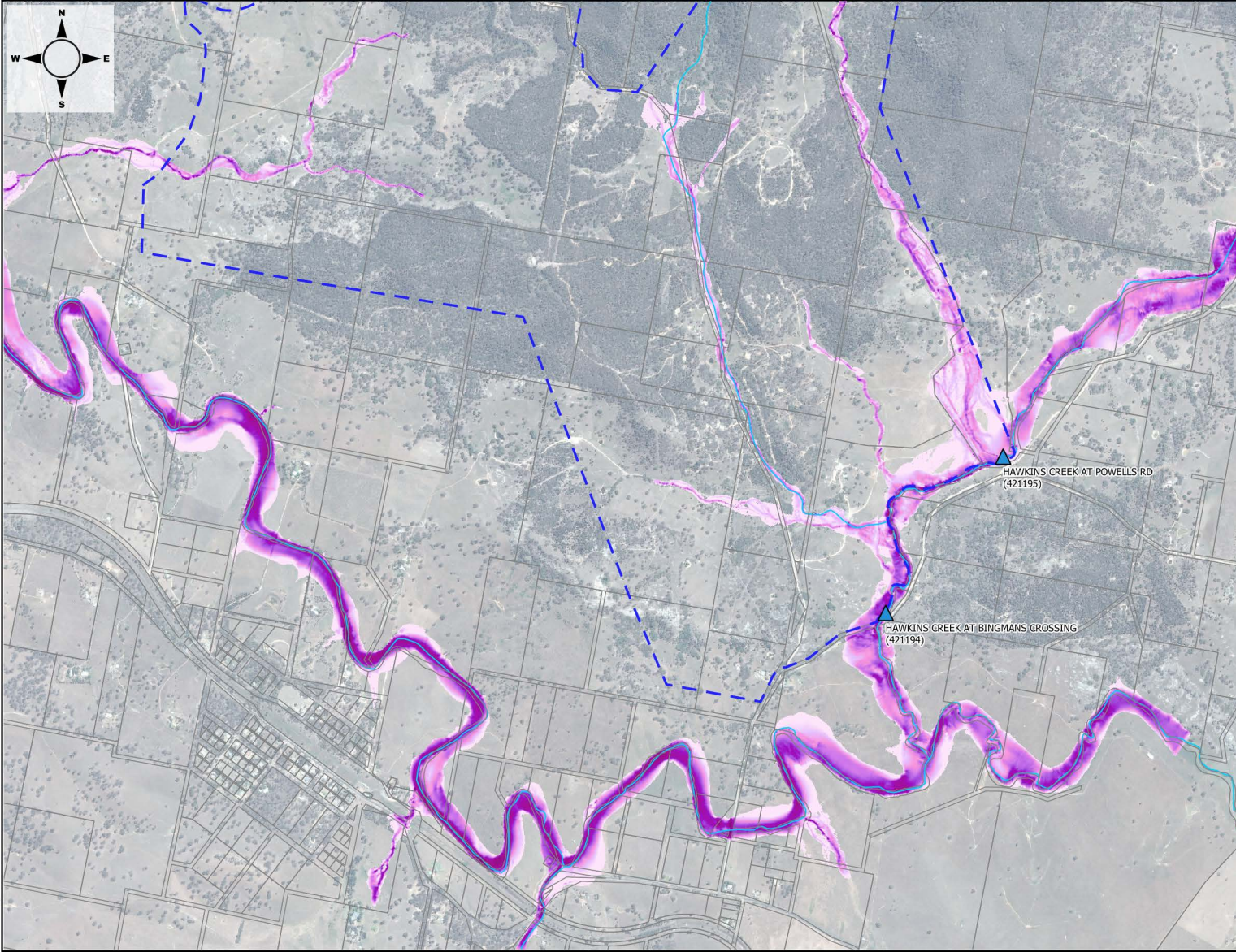
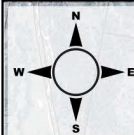
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 5% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

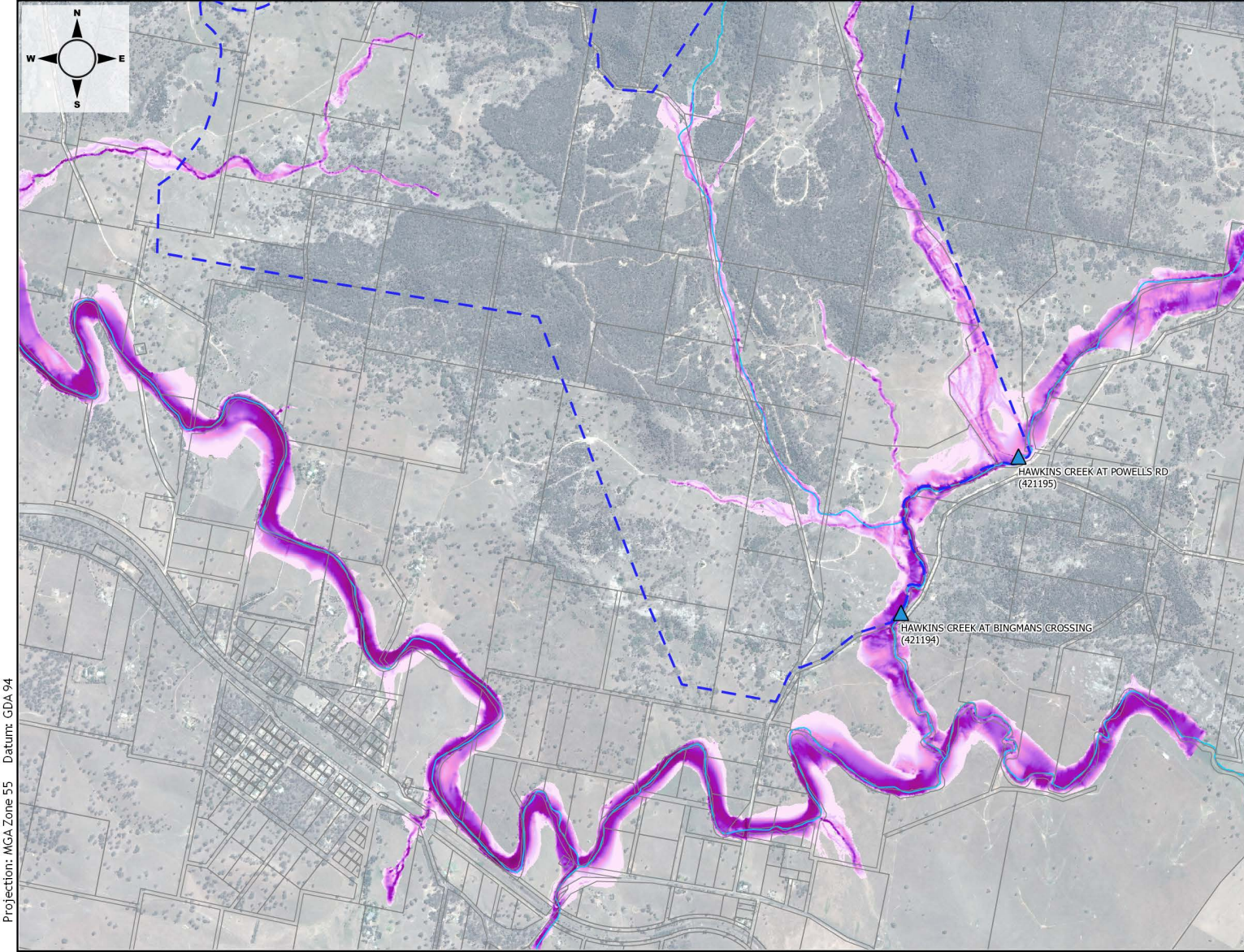
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 2% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

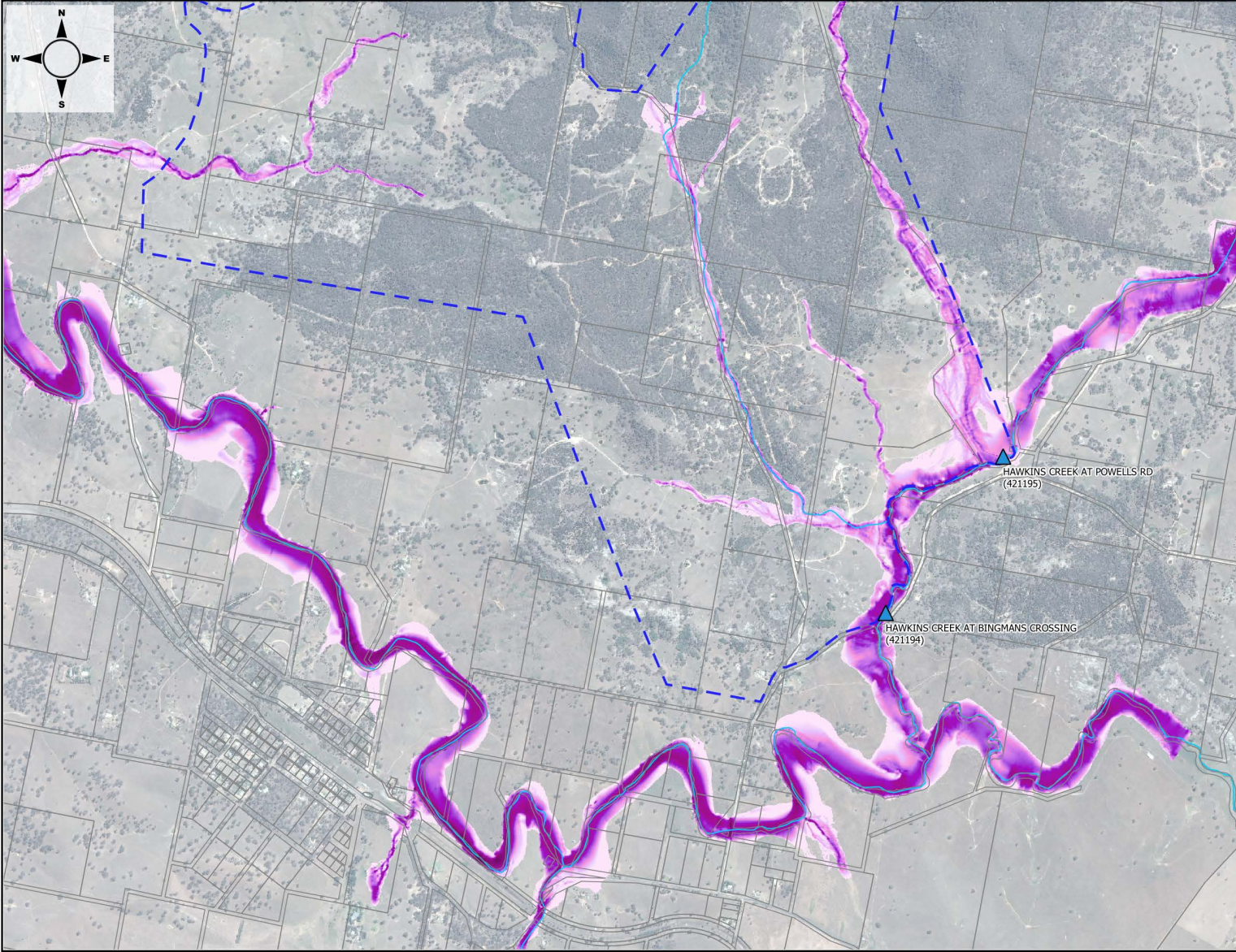
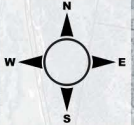
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 1% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

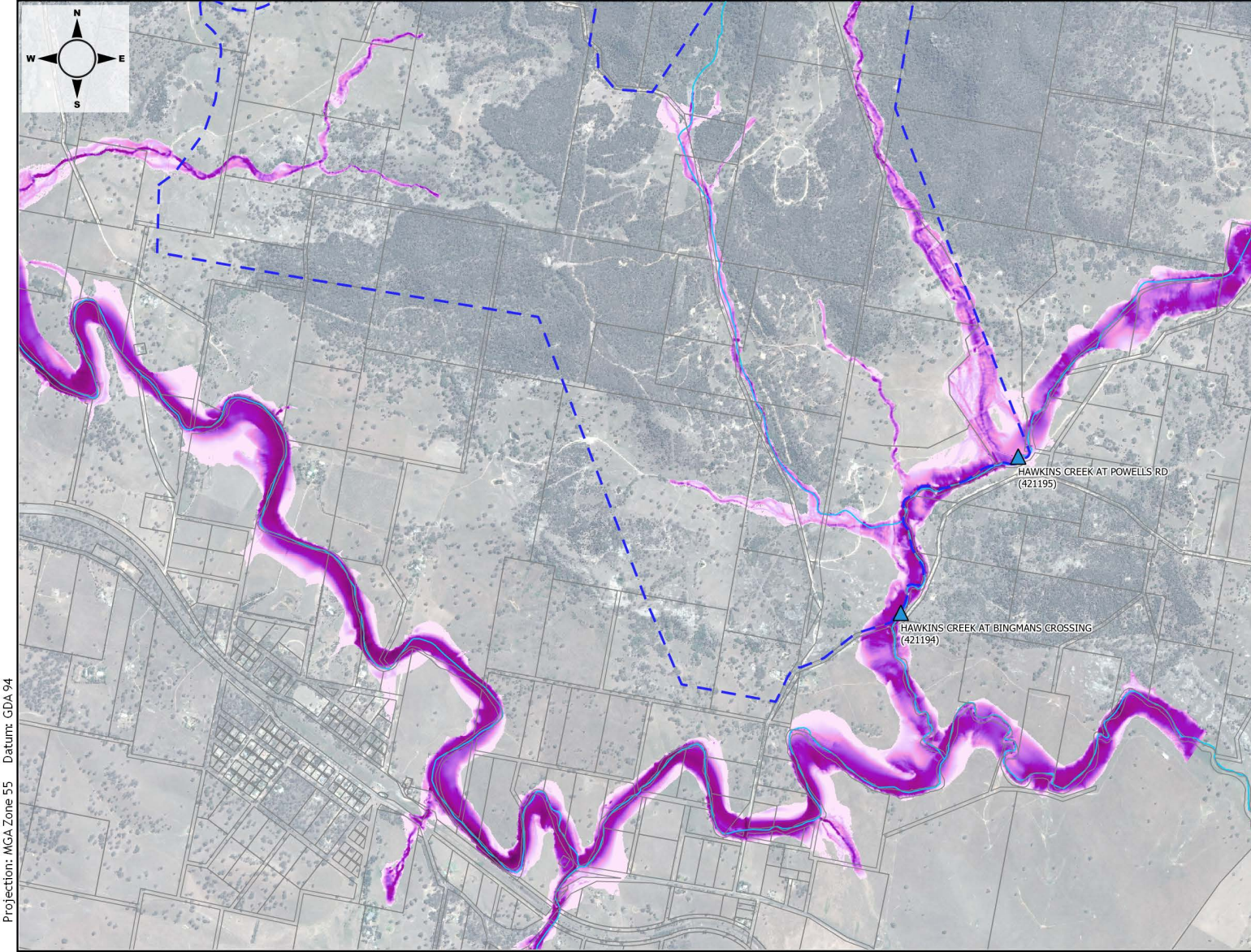
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 0.5% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

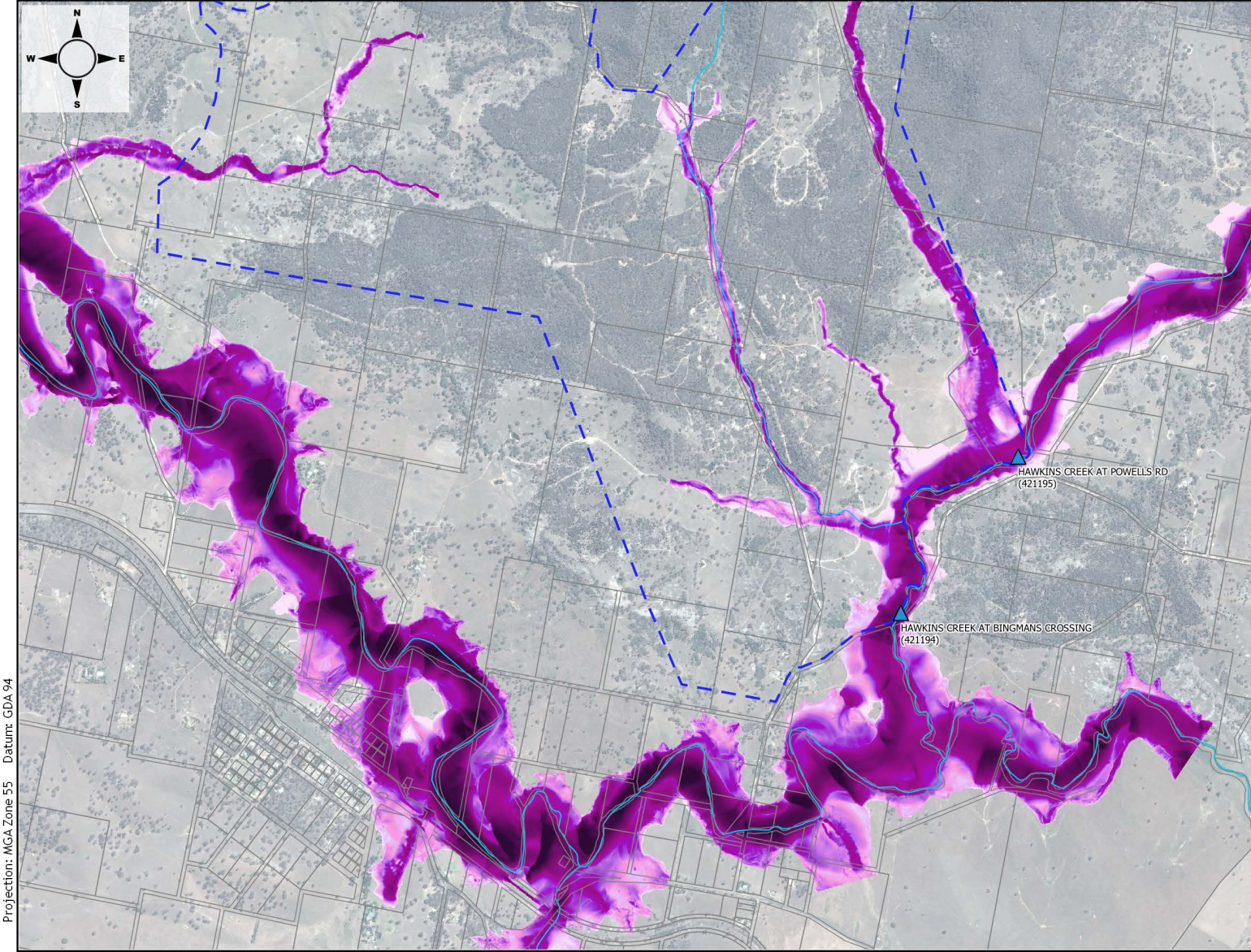
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 0.2% AEP



Legend

- Major watercourse
- Mine Site boundary
- Cadastre
- Streamflow gauge

Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

0 0.25 0.5 0.75 1 km



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), PMF



Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

Depth

-  0.00 m - 0.25 m
-  0.25 m - 0.50 m
-  0.50 m - 1.00 m
-  1.00 m - 1.50 m
-  1.50 m - 2.00 m
-  2.00 m - 2.50 m
-  2.50 m - 3.00 m
-  3.00 m - 3.50 m
-  3.50 m - 4.00 m
-  4.00 m - 4.50 m
-  > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), 10% AEP





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre

Depth

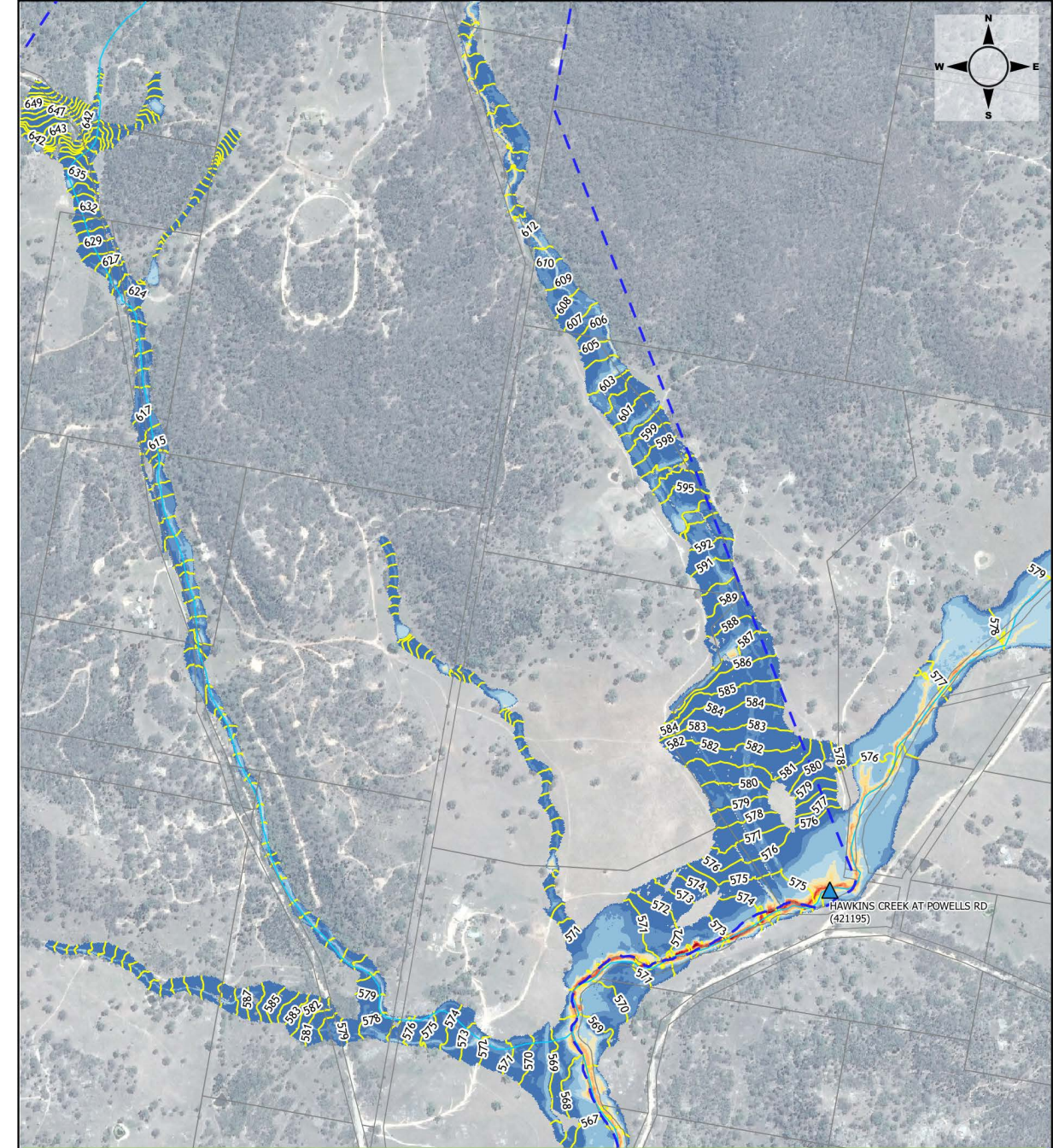
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), 5% AEP

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

Depth

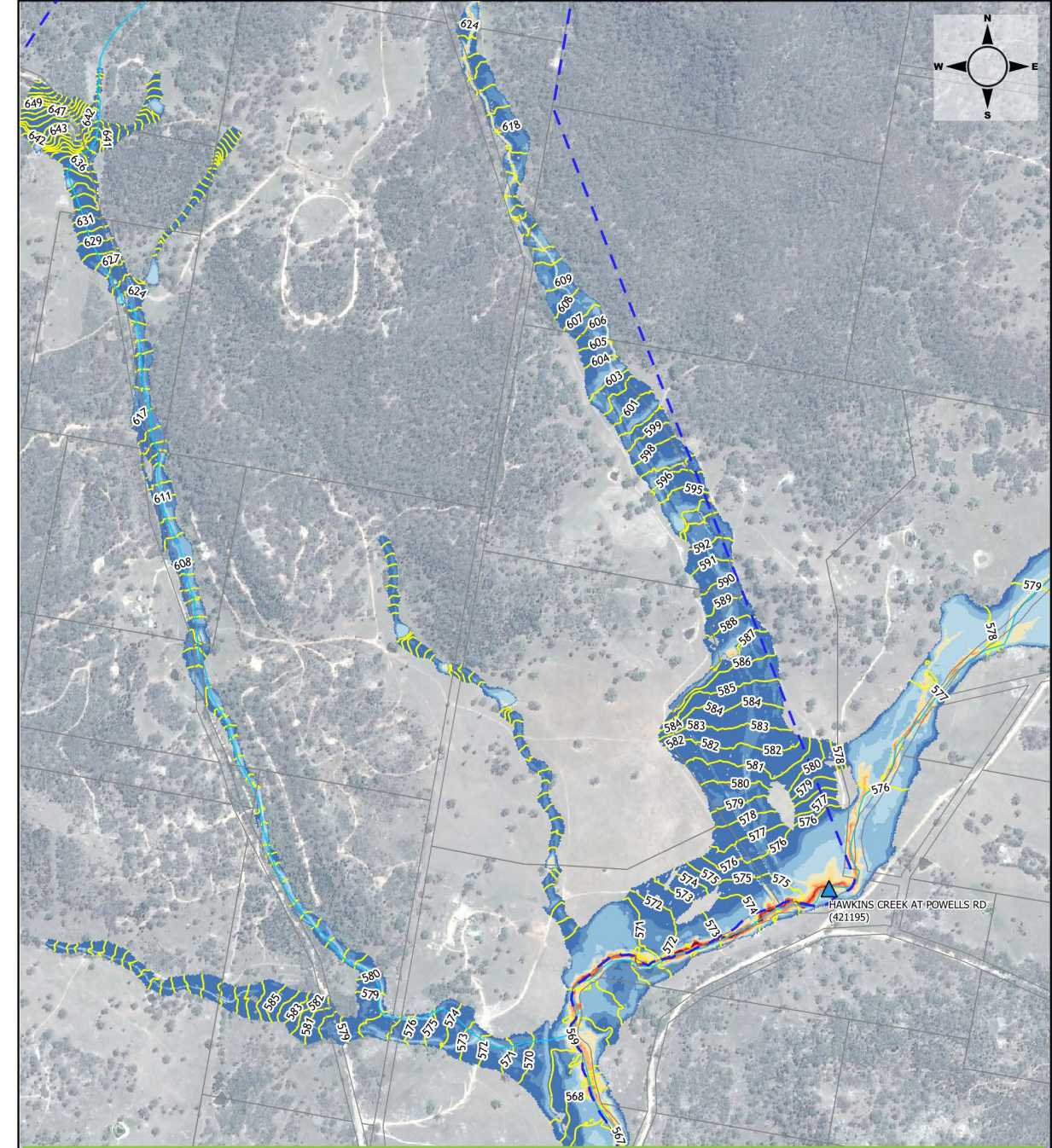
-  0.00 m - 0.25 m
-  0.25 m - 0.50 m
-  0.50 m - 1.00 m
-  1.00 m - 1.50 m
-  1.50 m - 2.00 m
-  2.00 m - 2.50 m
-  2.50 m - 3.00 m
-  3.00 m - 3.50 m
-  3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), 2% AEP

0 200 400 600 m





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

Depth

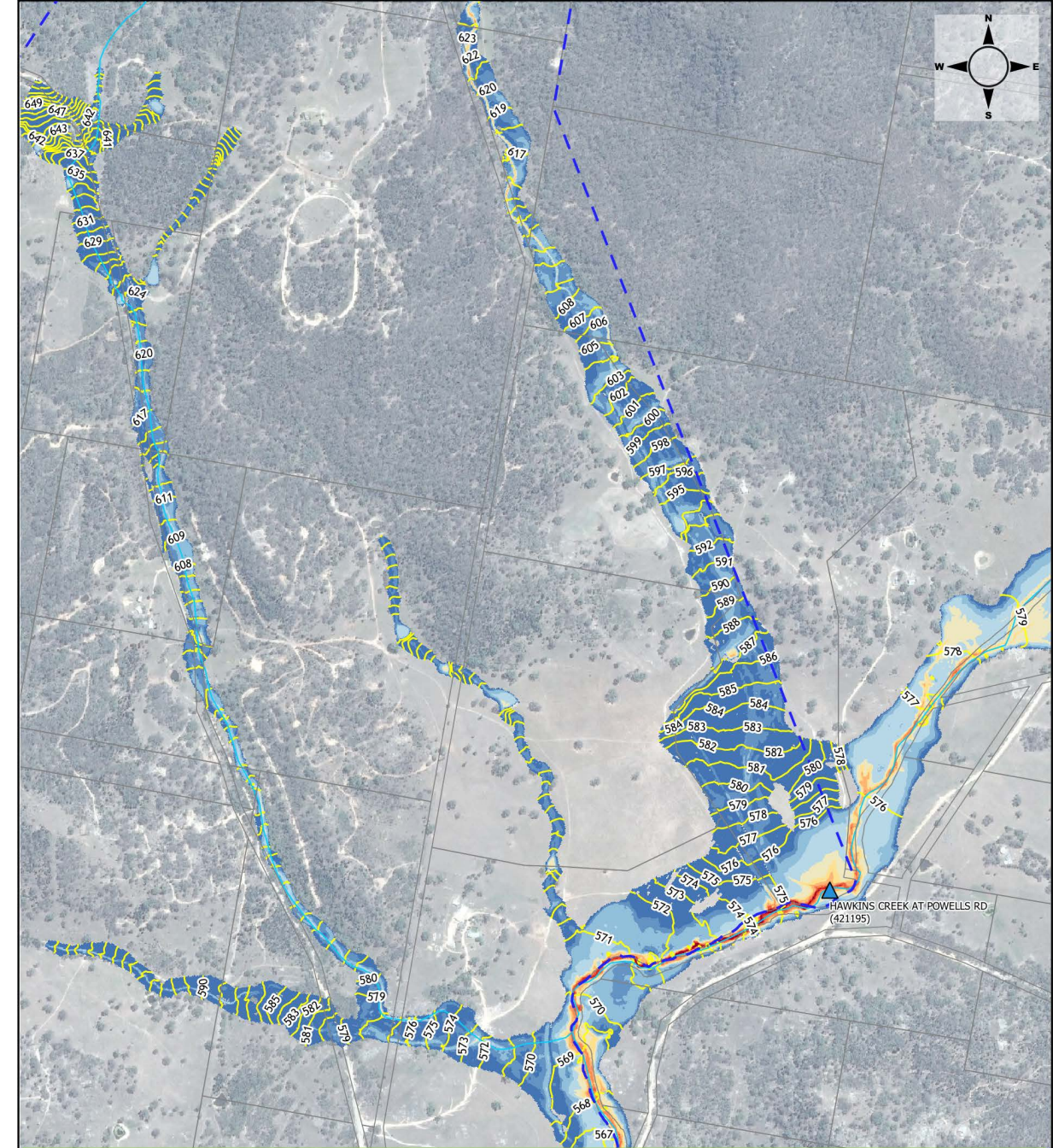
-  0.00 m - 0.25 m
-  0.25 m - 0.50 m
-  0.50 m - 1.00 m
-  1.00 m - 1.50 m
-  1.50 m - 2.00 m
-  2.00 m - 2.50 m
-  2.50 m - 3.00 m
-  3.00 m - 3.50 m
-  3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), 1% AEP

0 200 400 600 m





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

Depth

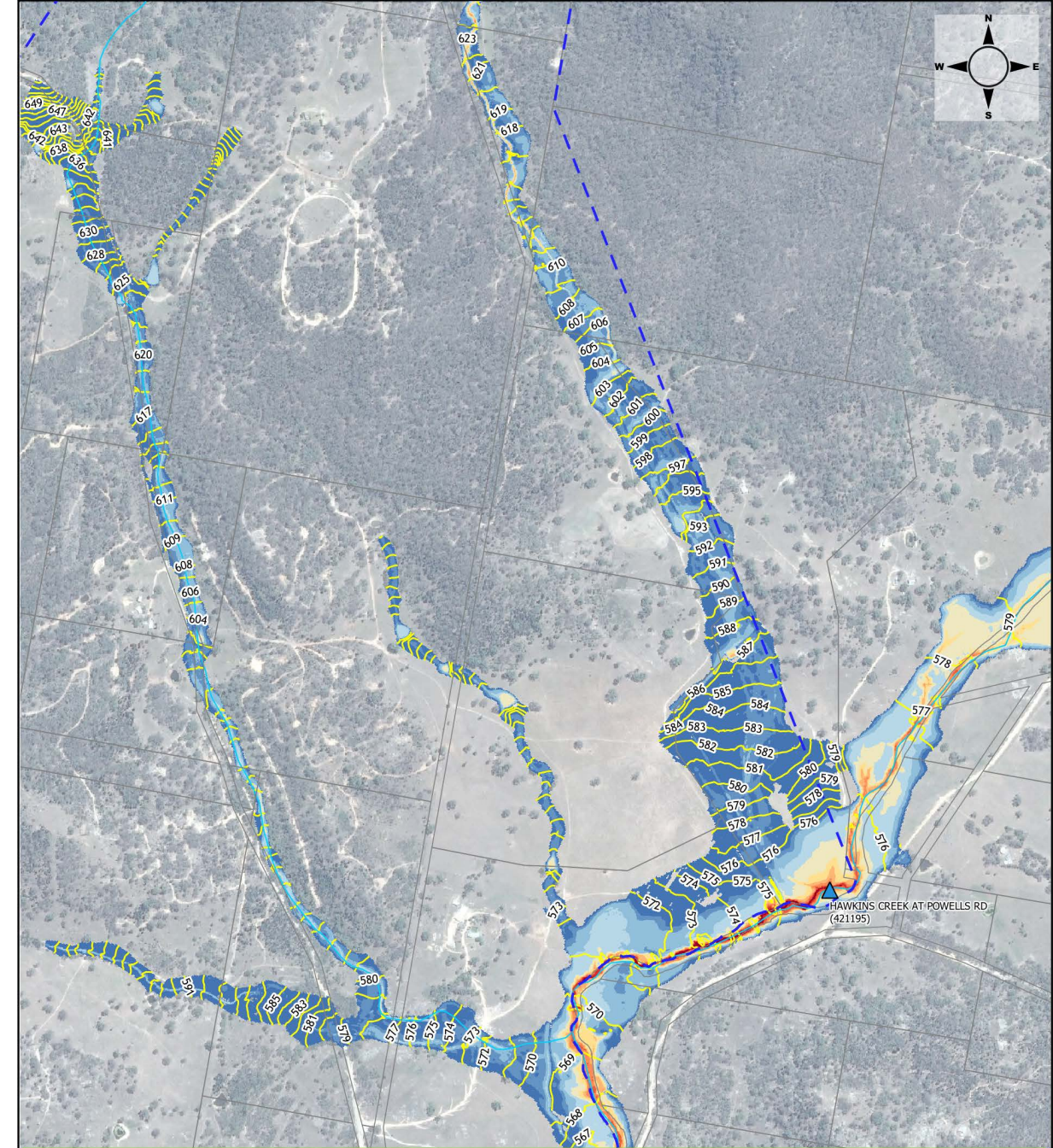
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), 0.5% AEP

0 200 400 600 m





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

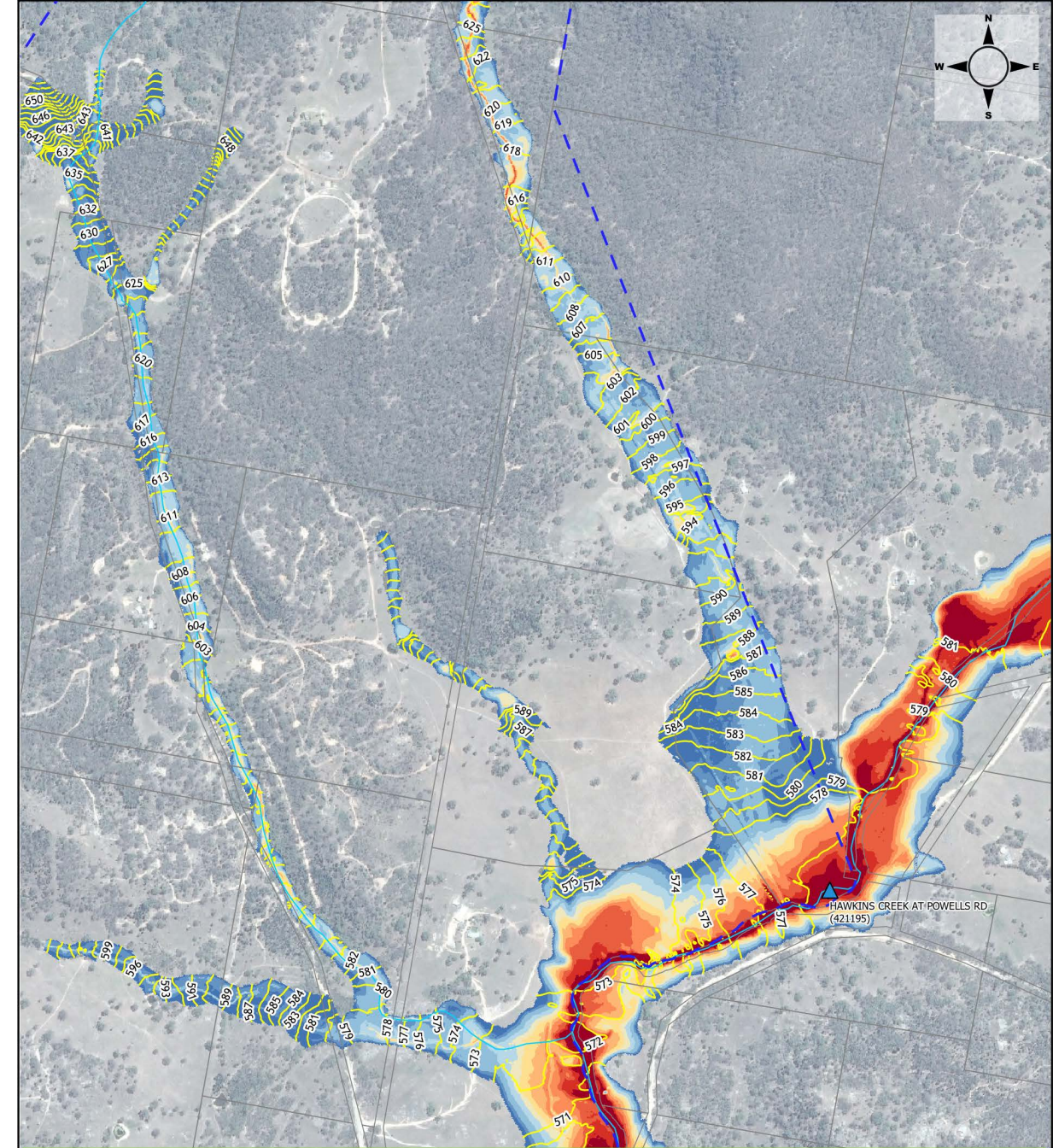
Depth

-  0.00 m - 0.25 m
-  0.25 m - 0.50 m
-  0.50 m - 1.00 m
-  1.00 m - 1.50 m
-  1.50 m - 2.00 m
-  2.00 m - 2.50 m
-  2.50 m - 3.00 m
-  3.00 m - 3.50 m
-  3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), 0.2% AEP





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

Depth

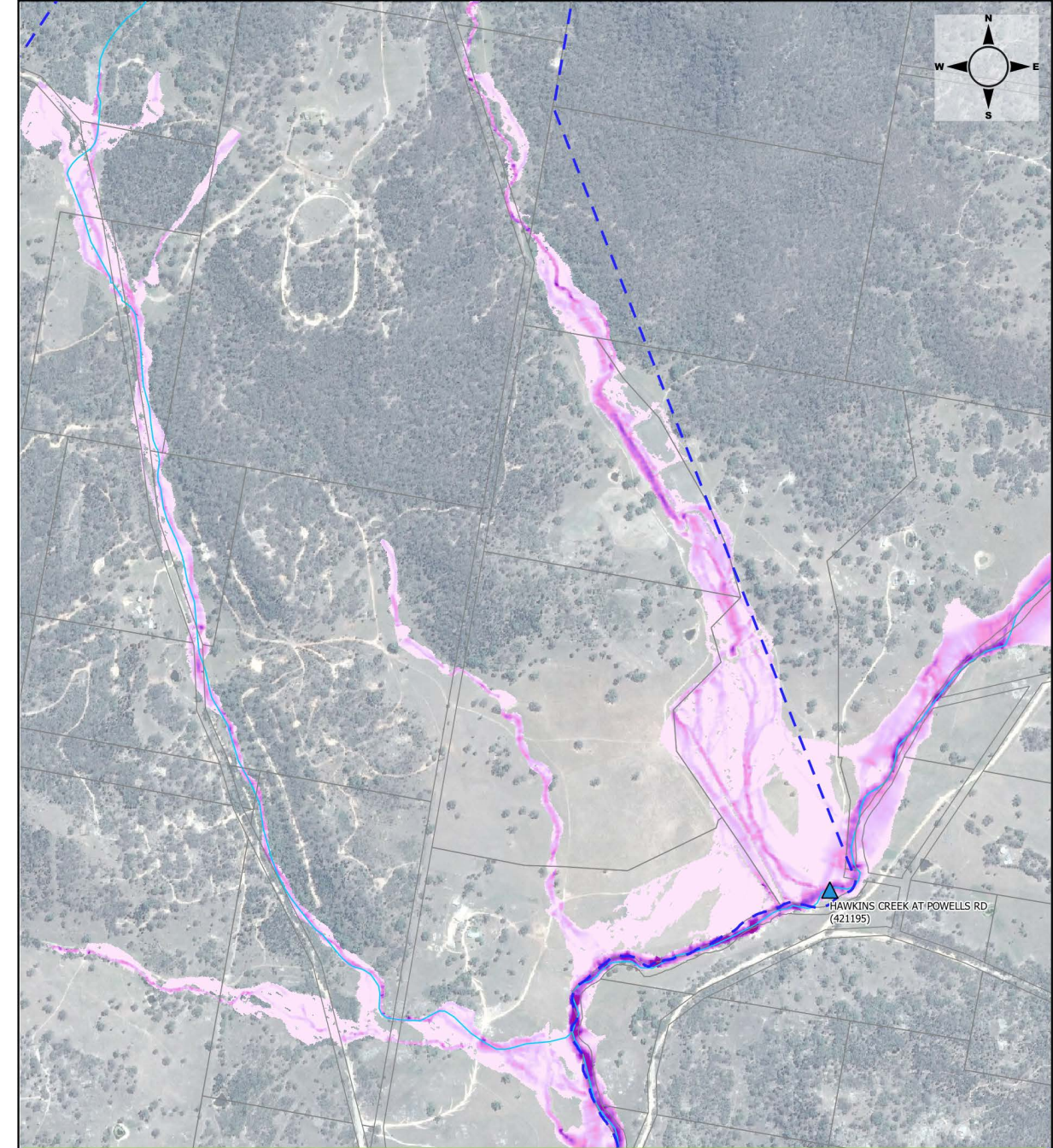
-  0.00 m - 0.25 m
-  0.25 m - 0.50 m
-  0.50 m - 1.00 m
-  1.00 m - 1.50 m
-  1.50 m - 2.00 m
-  2.00 m - 2.50 m
-  2.50 m - 3.00 m
-  3.00 m - 3.50 m
-  3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Existing Condition), PMF

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

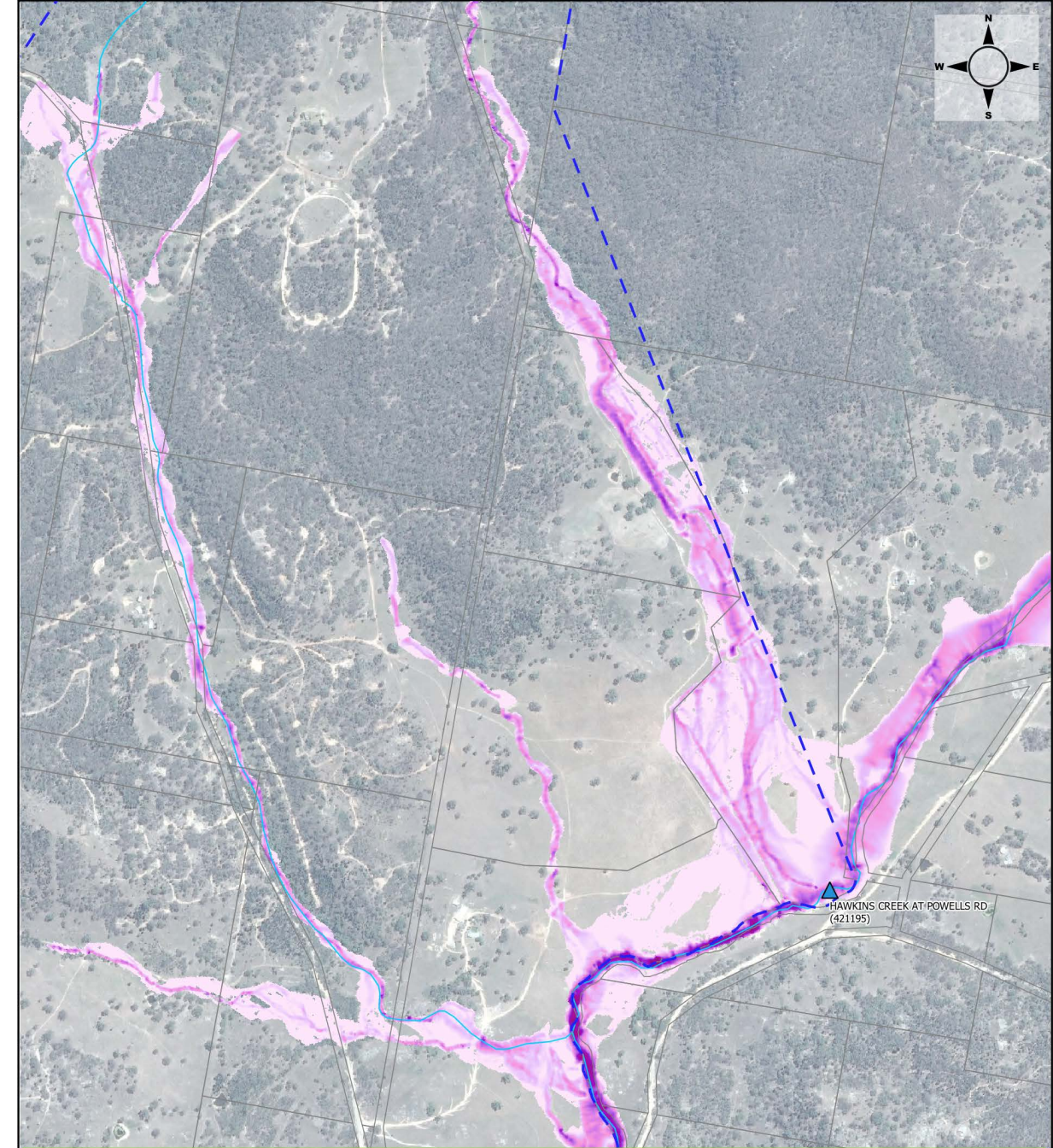
Velocity

-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 10% AEP





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

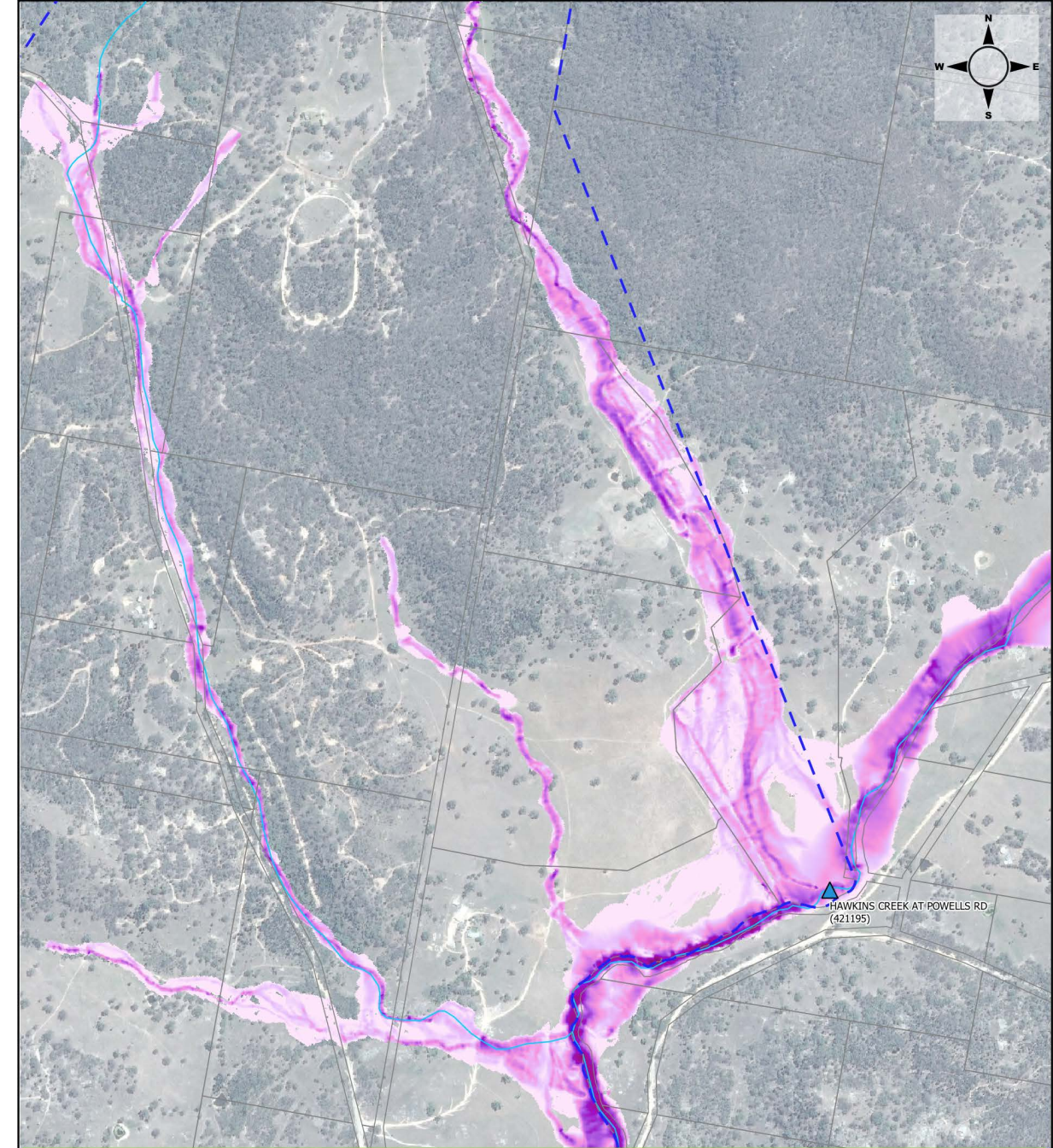
Velocity

-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 5% AEP





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

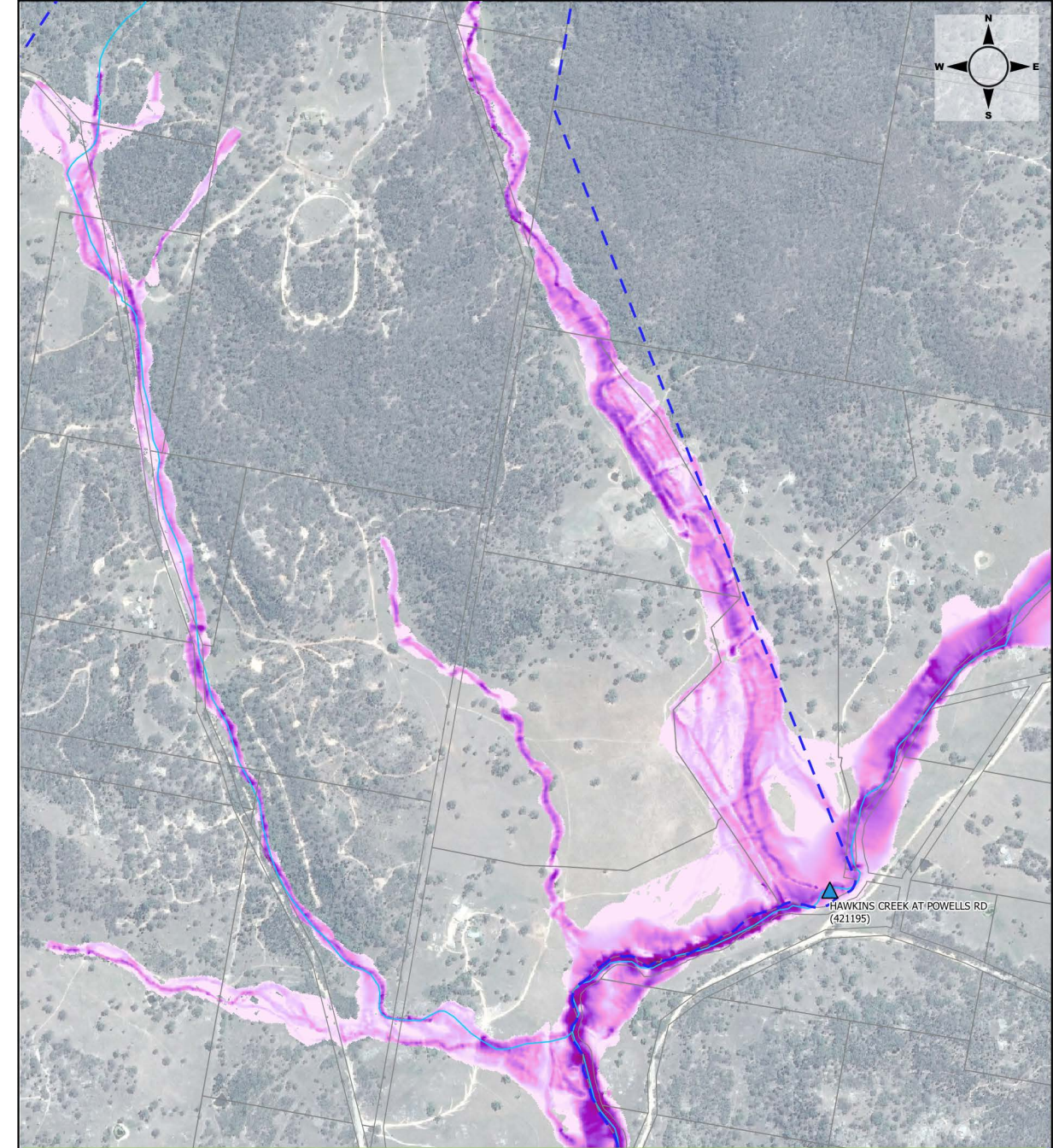
Velocity

-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 2% AEP





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

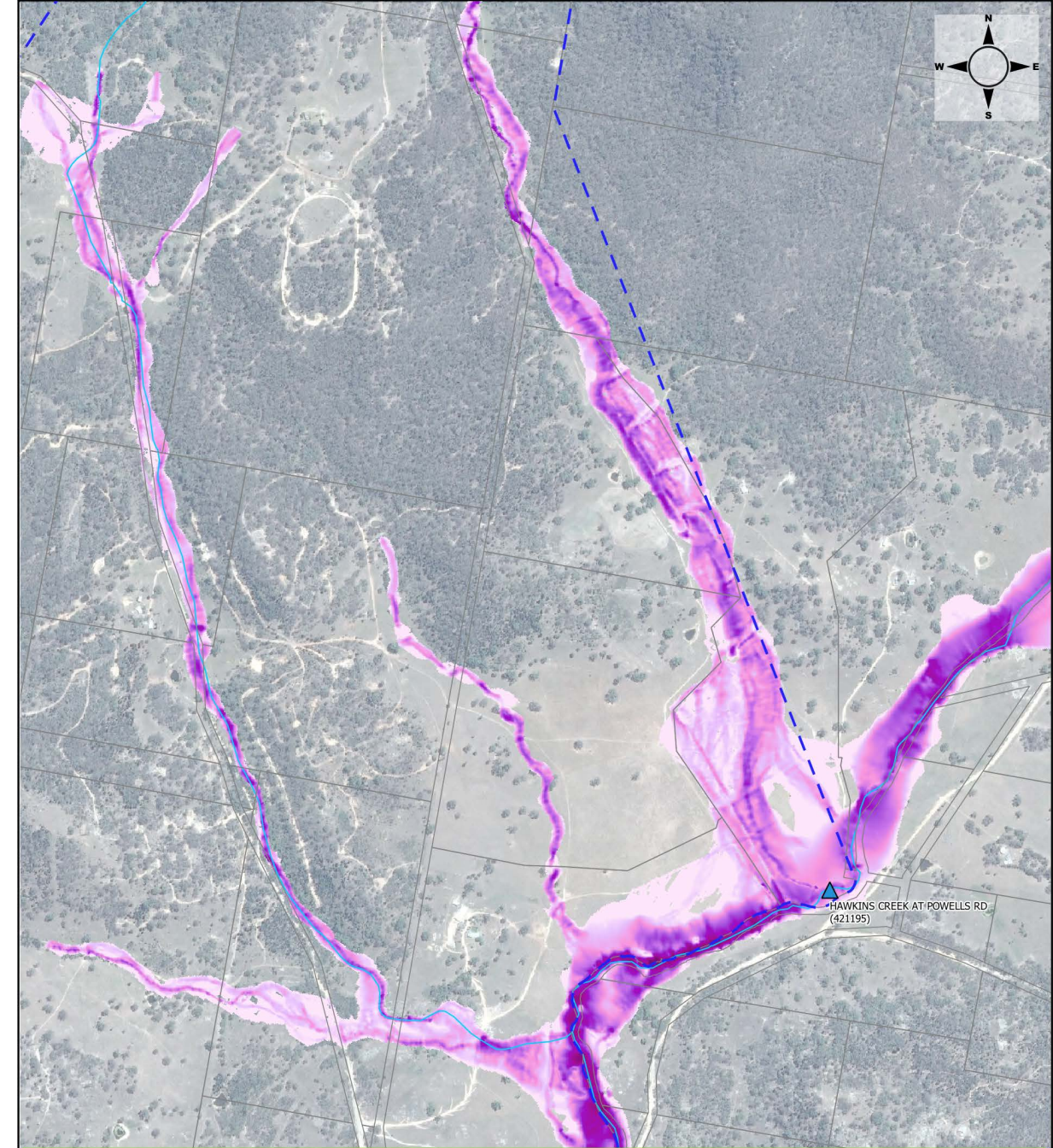
Velocity

-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 1% AEP





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre

Velocity

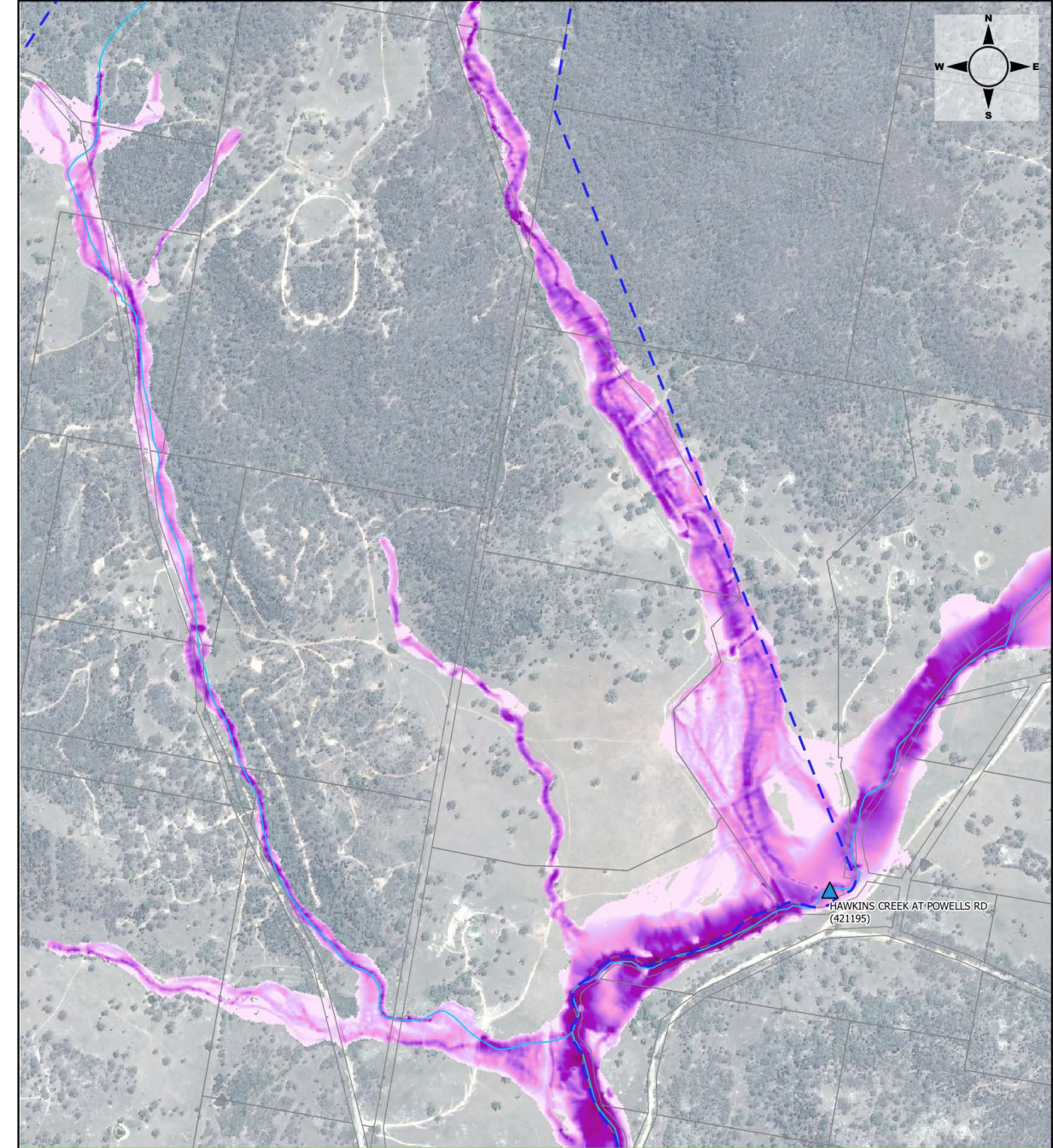
-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 0.5% AEP

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre

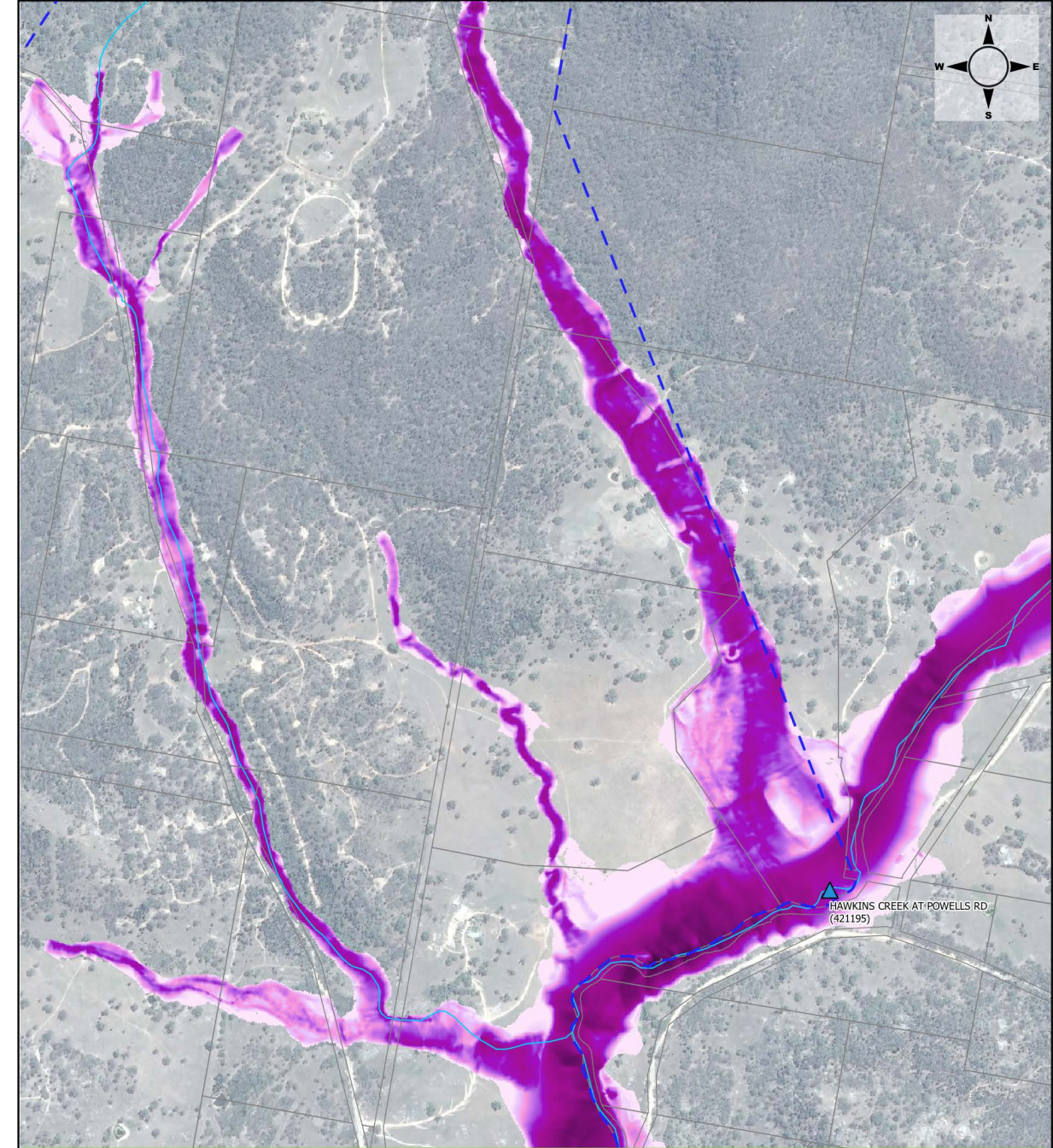
Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 0.2% AEP





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre

Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

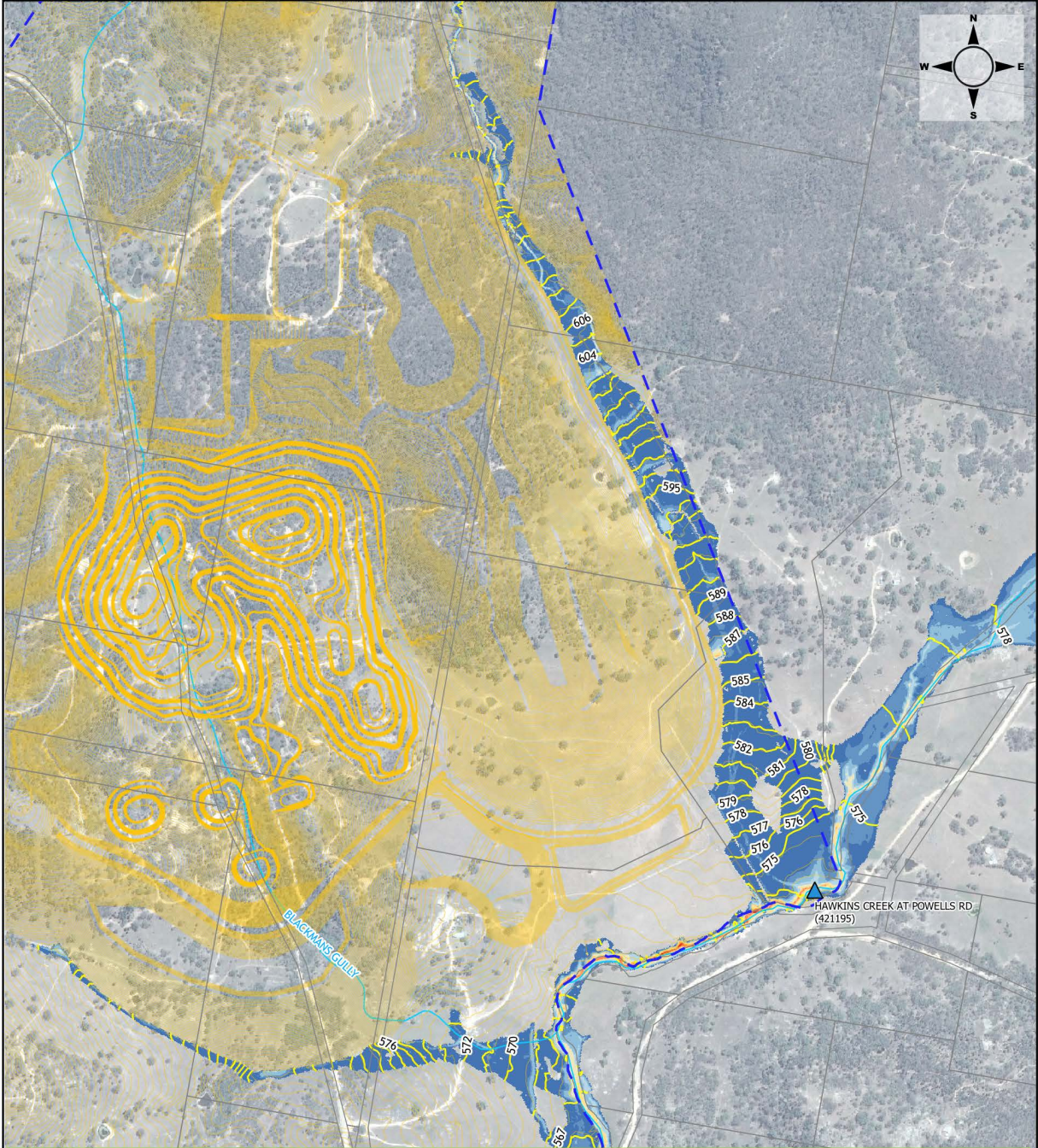
Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), PMF





Appendix D - Flood maps - Maximum disturbance scenario



Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

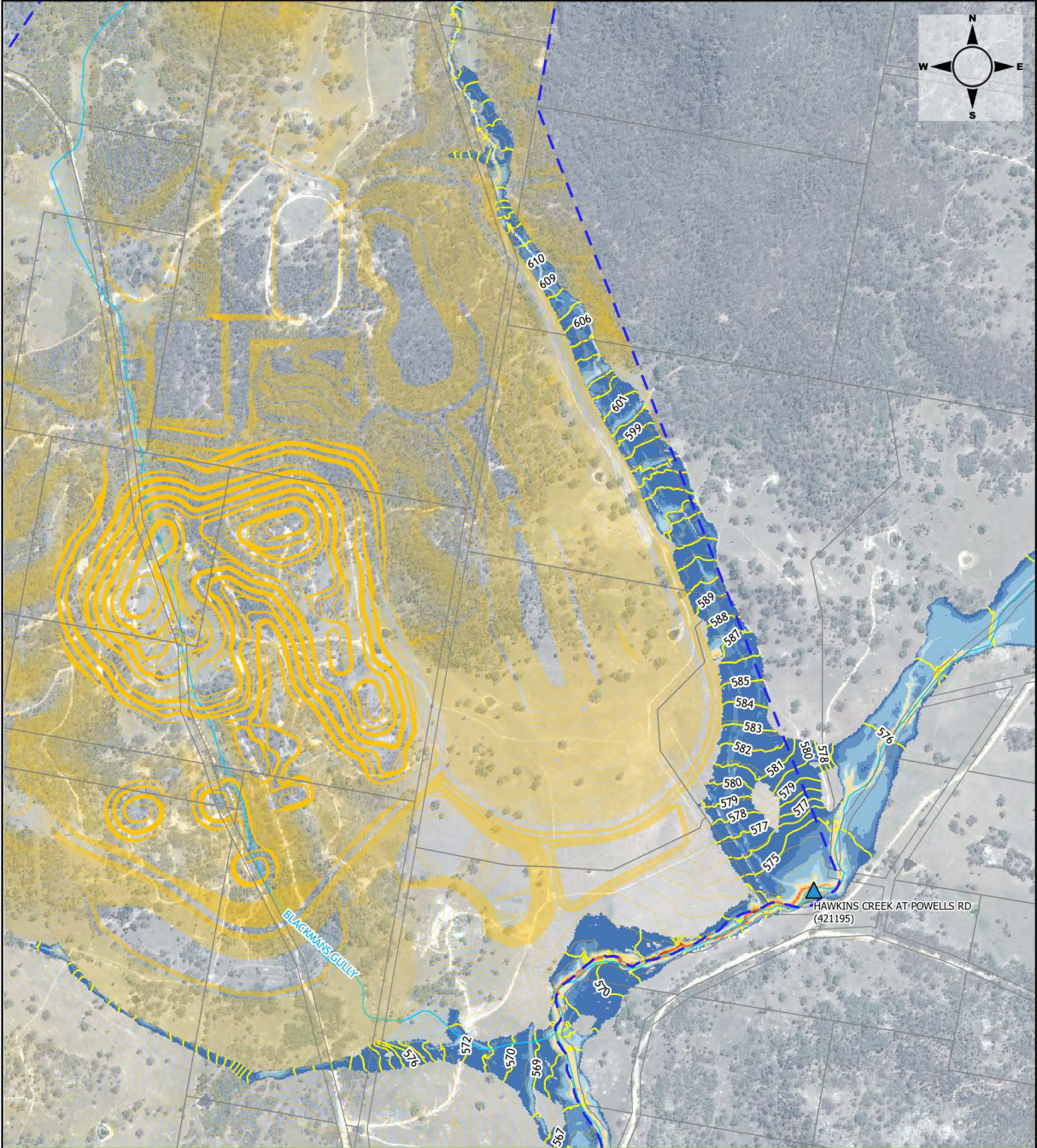
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
10% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

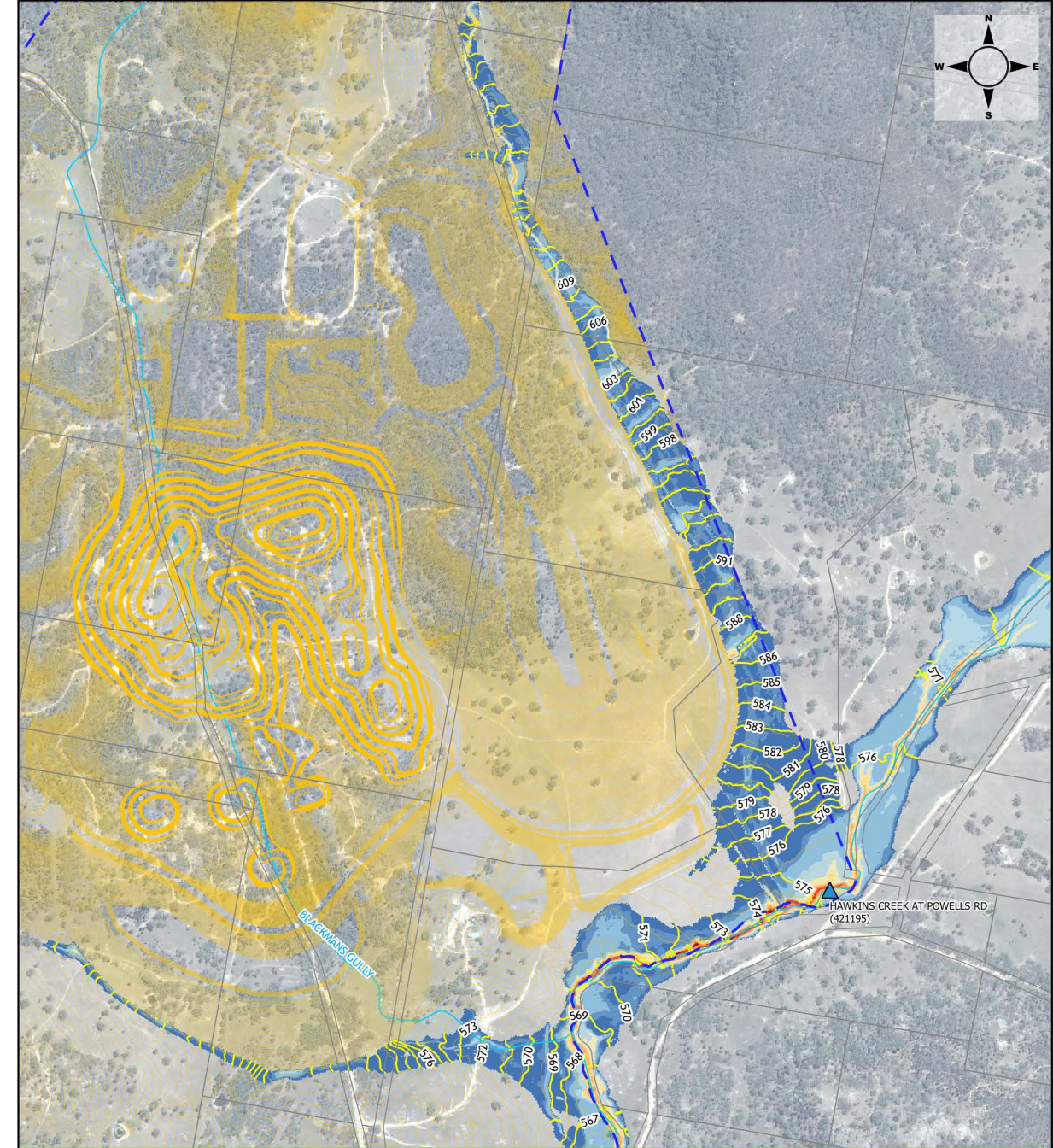
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
5% AEP, WRE Stage 7

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

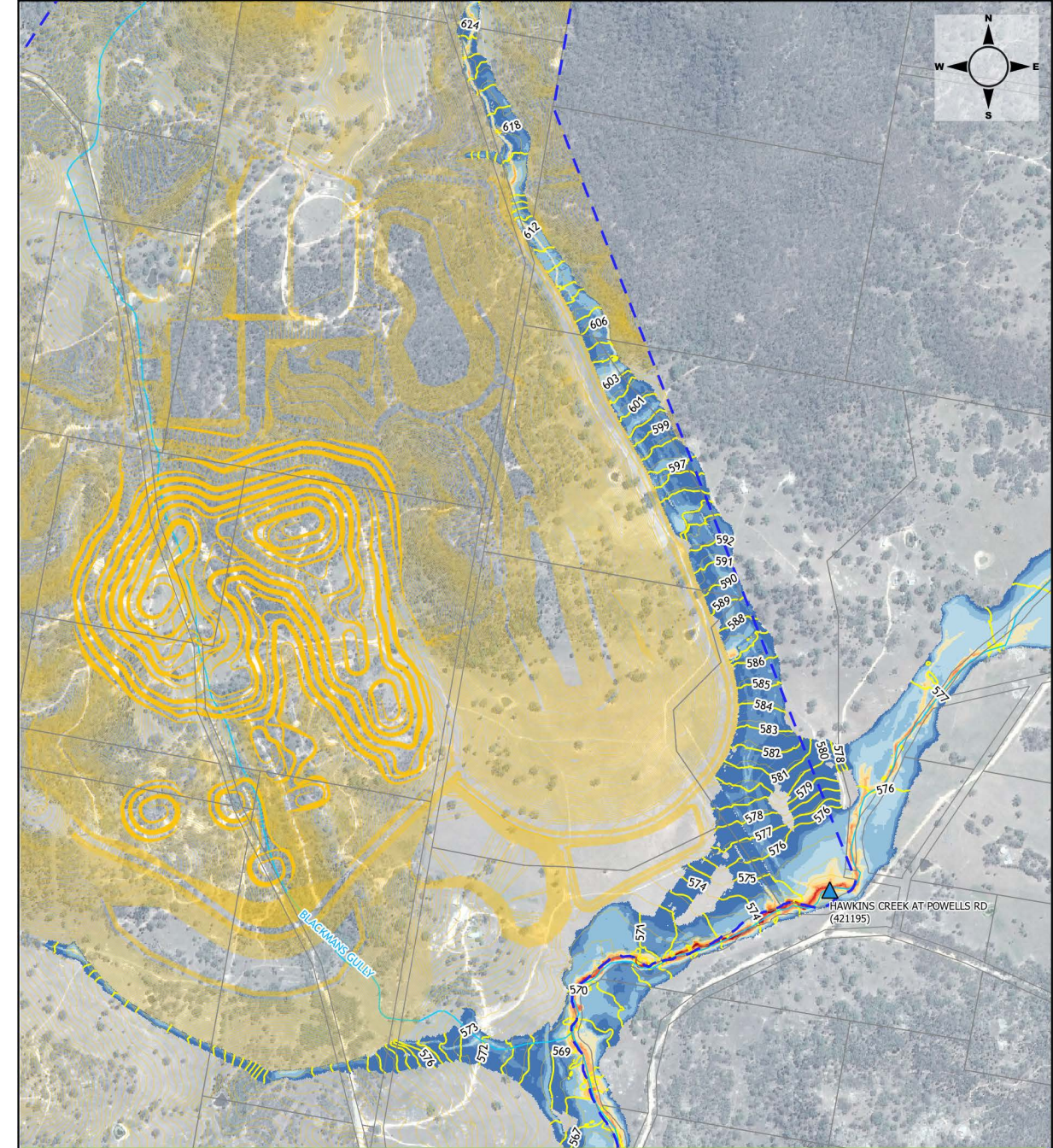
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
2% AEP, WRE Stage 7

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

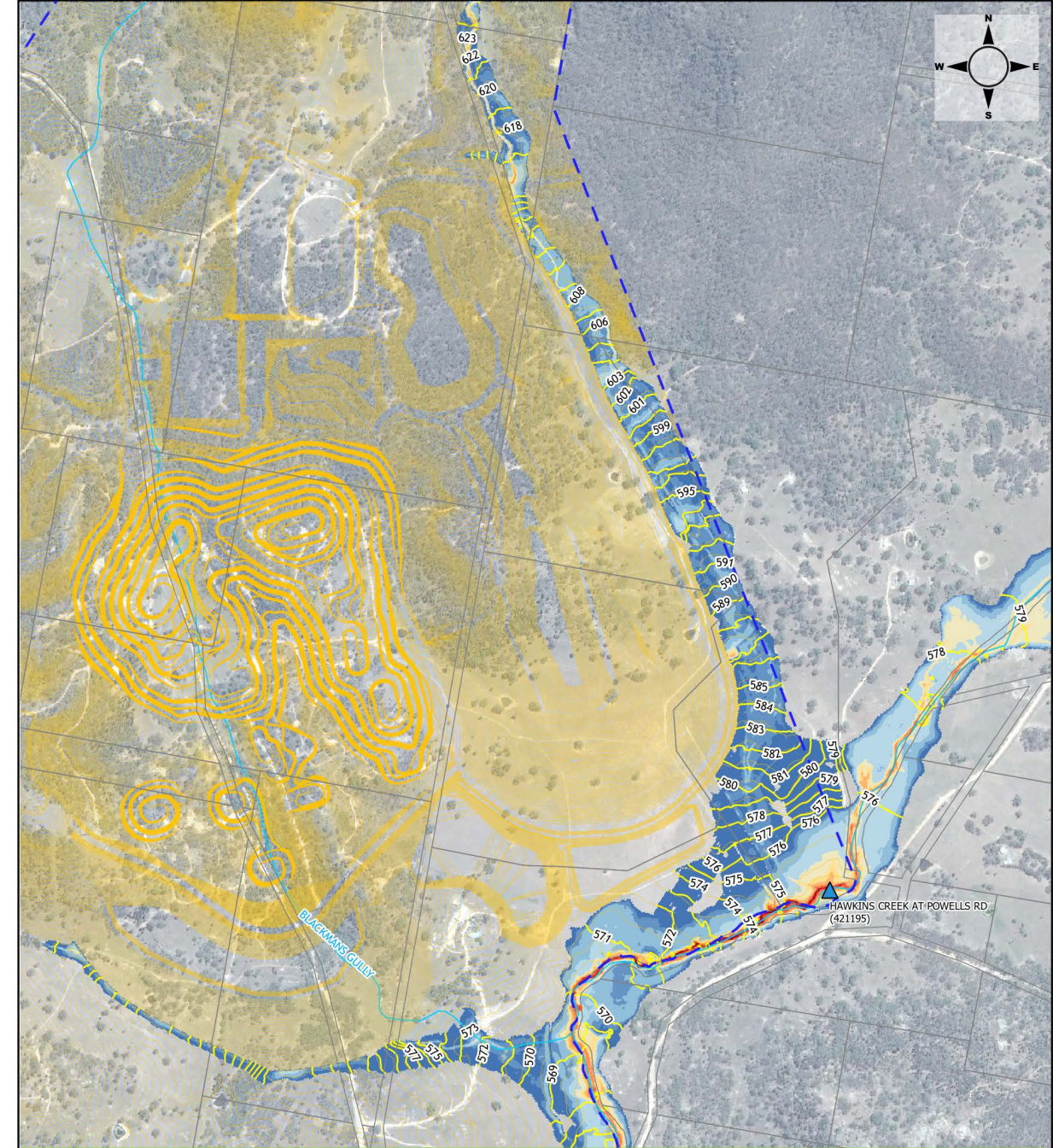
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
1% AEP, WRE Stage 7

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

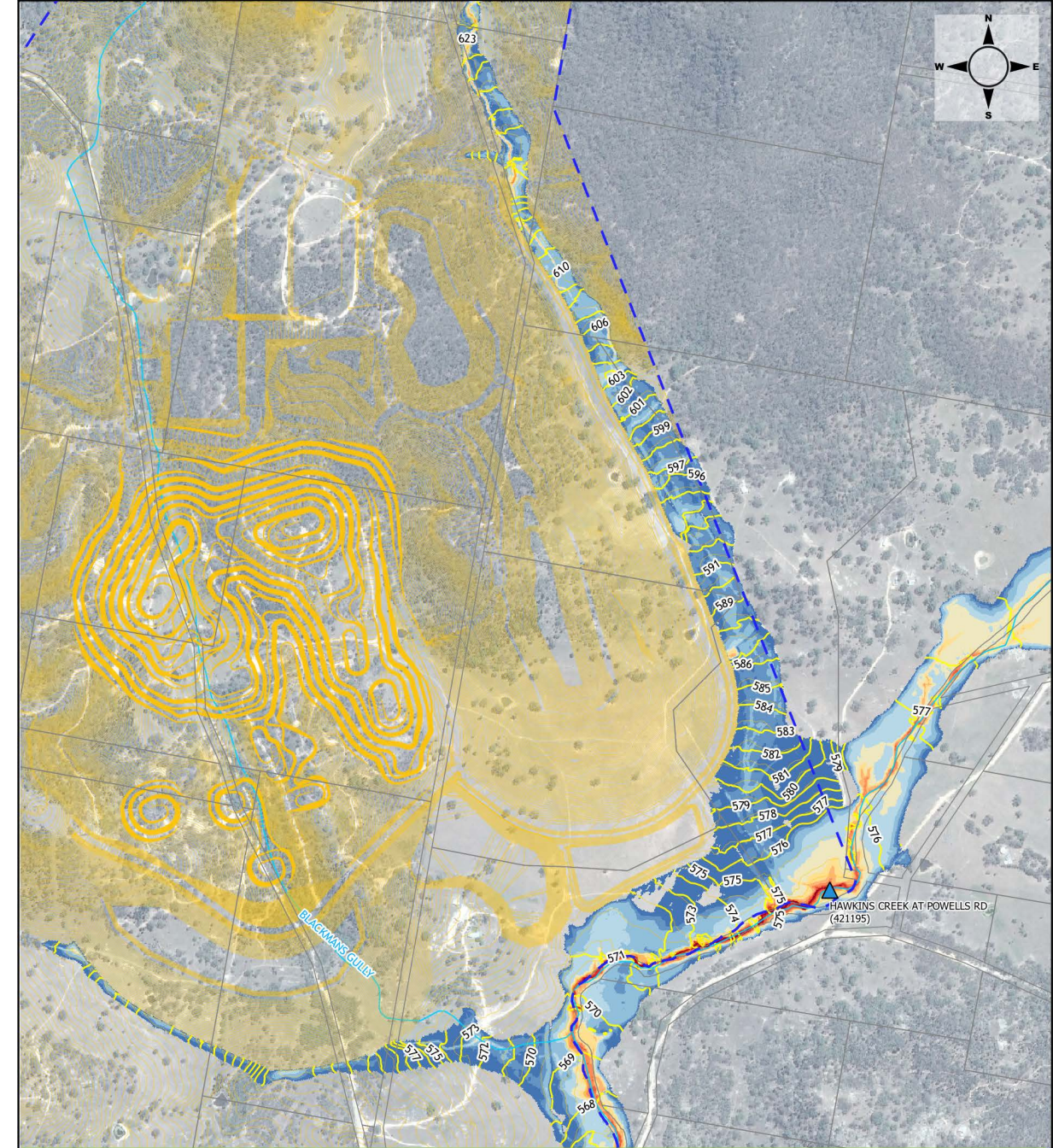
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
0.5% AEP, WRE Stage 7

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

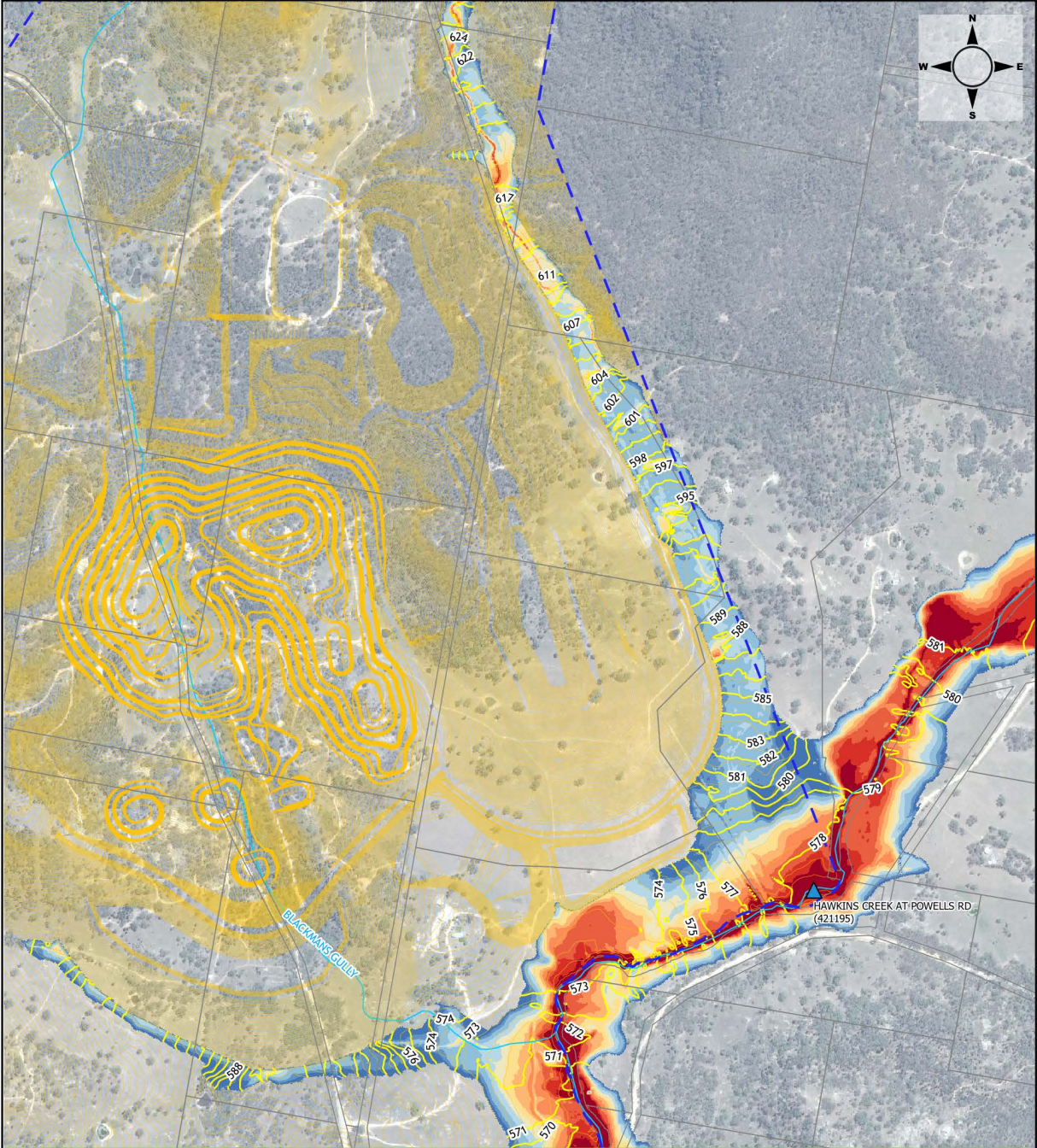
- | | |
|--|-----------------|
| | 0.00 m - 0.25 m |
| | 0.25 m - 0.50 m |
| | 0.50 m - 1.00 m |
| | 1.00 m - 1.50 m |
| | 1.50 m - 2.00 m |
| | 2.00 m - 2.50 m |
| | 2.50 m - 3.00 m |
| | 3.00 m - 3.50 m |
| | 3.50 m - 4.00 m |
| | 4.00 m - 4.50 m |
| | > 4.50 m |

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
0.2% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

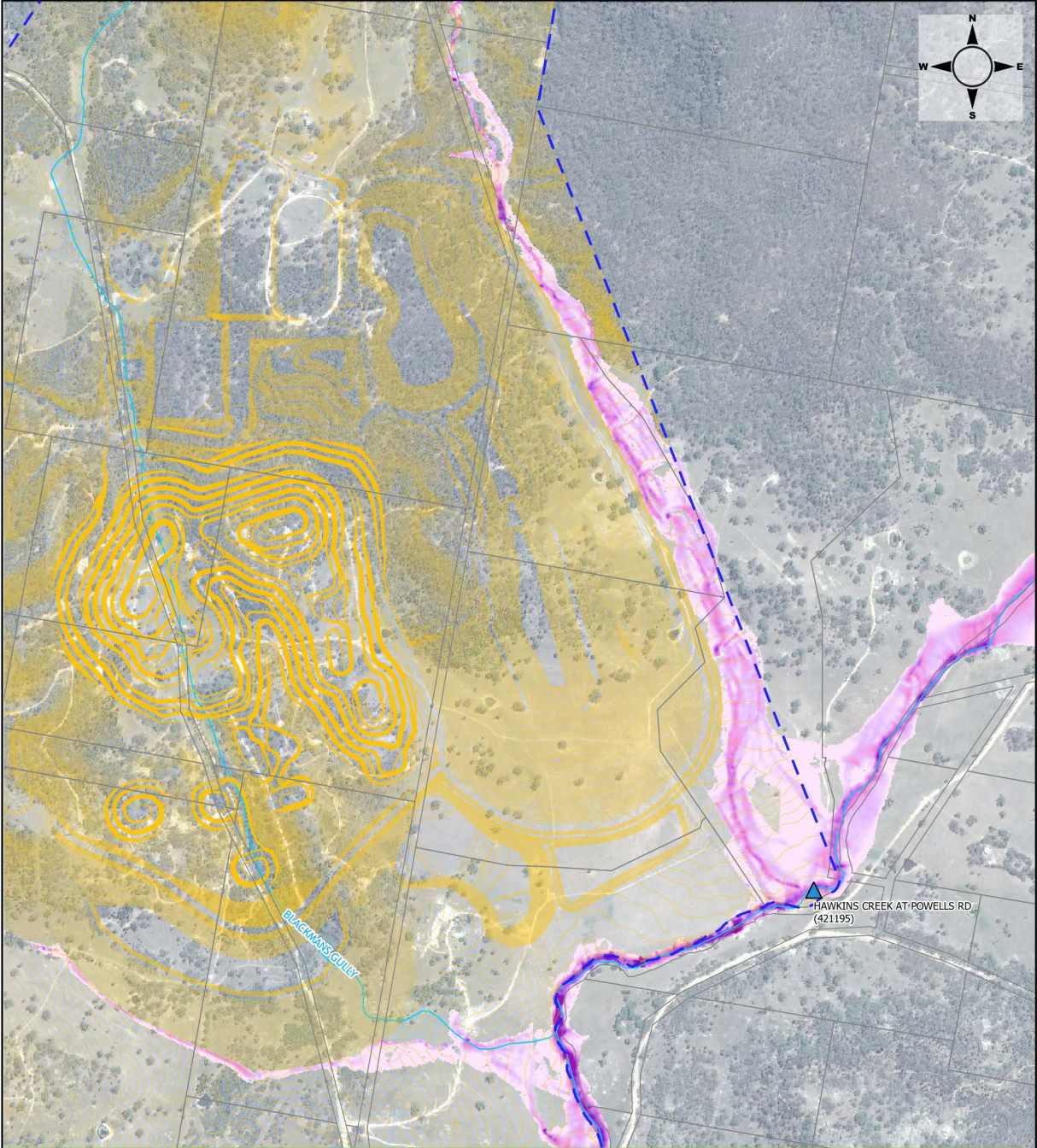
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
PMF, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

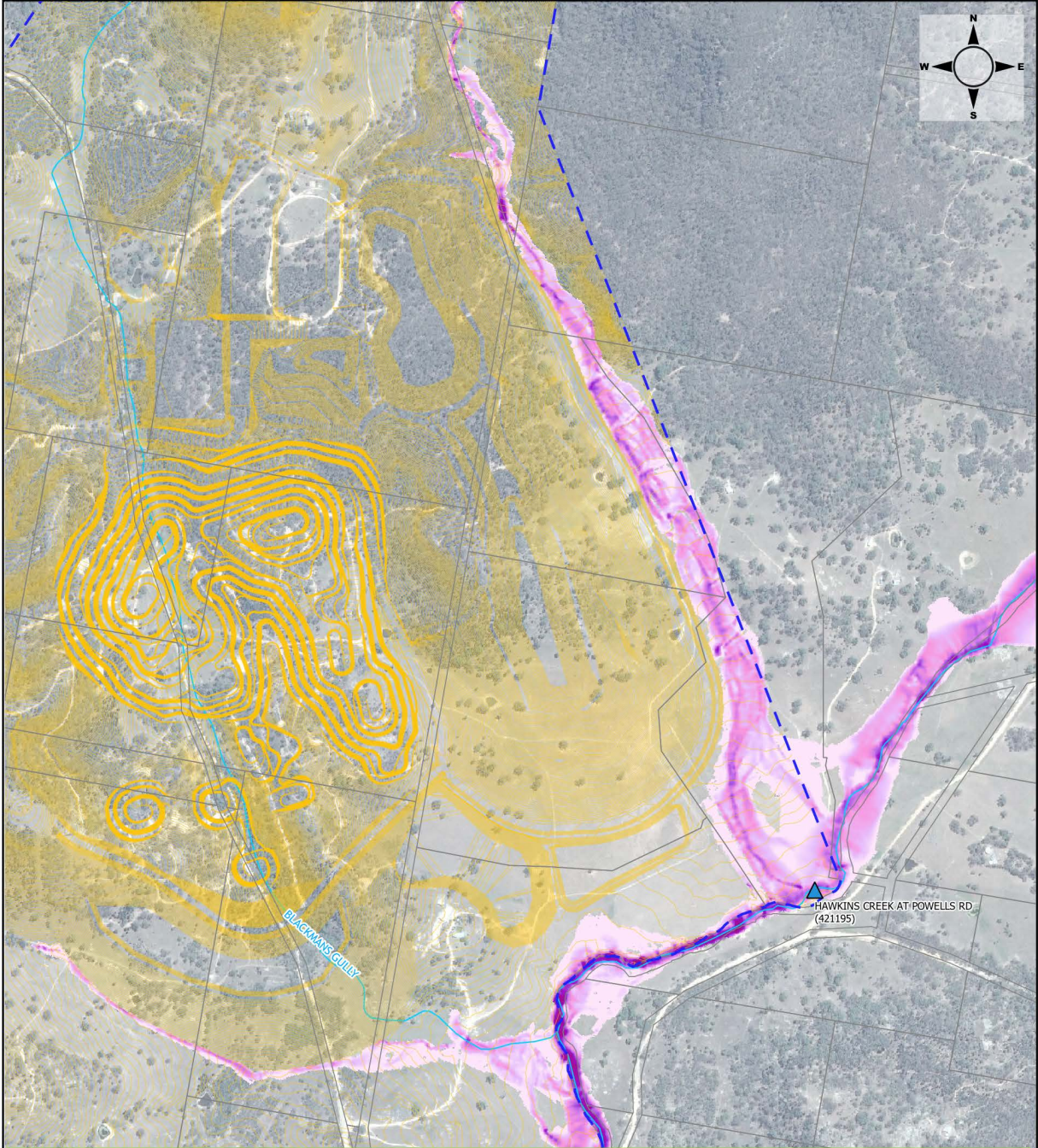
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
10% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

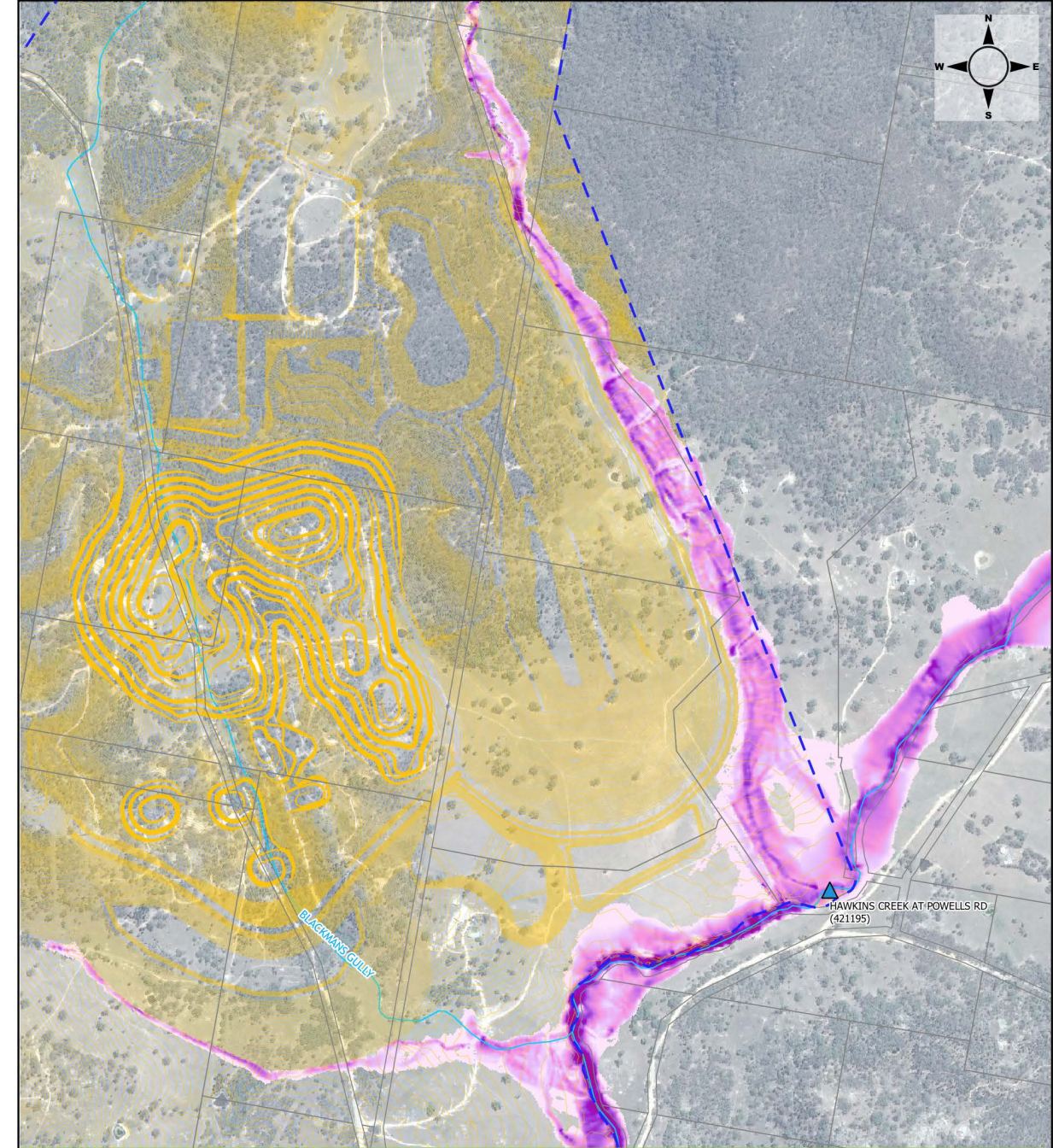
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
5% AEP, WRE Stage 7

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

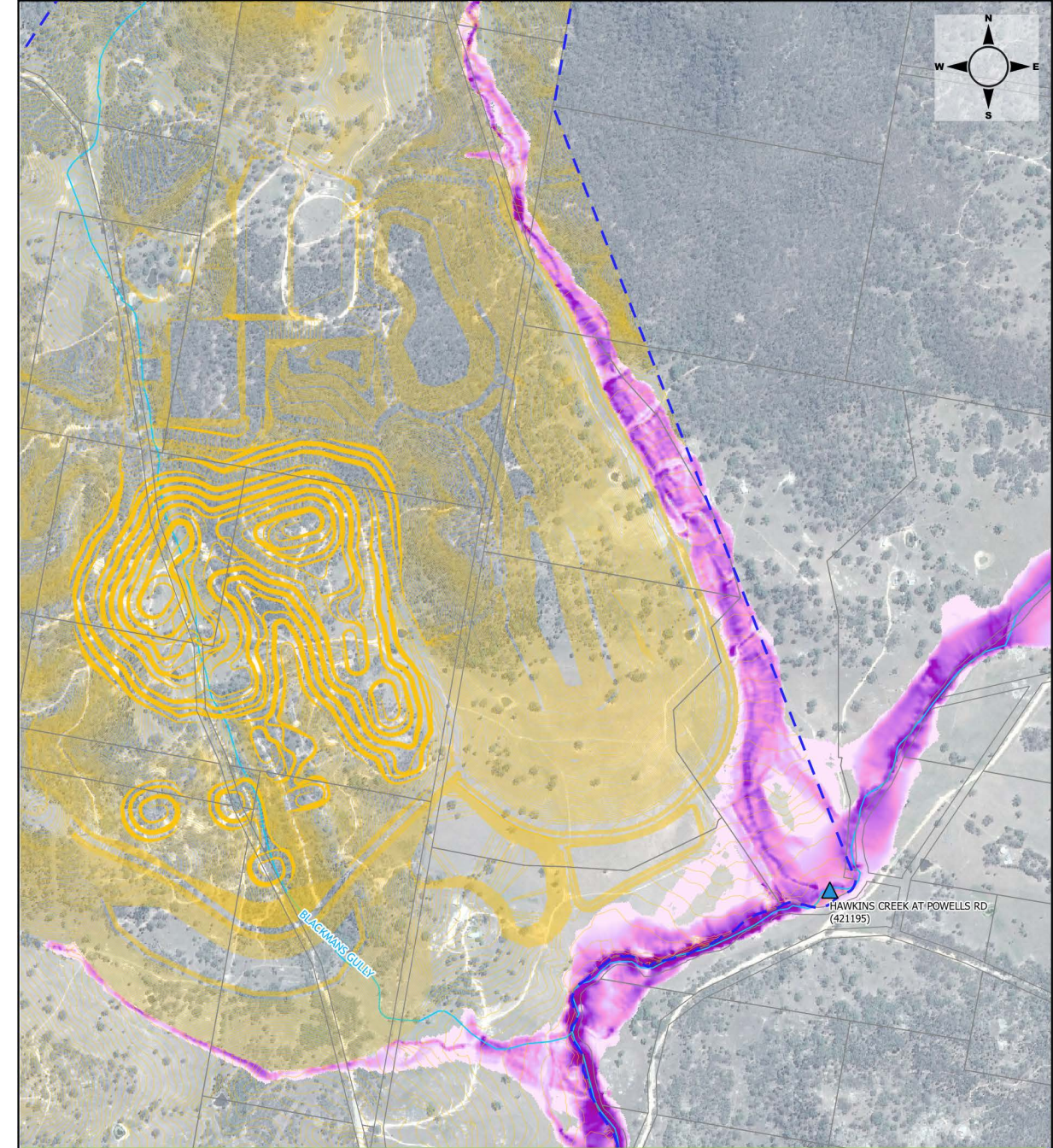
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
2% AEP, WRE Stage 7

0 200 400 600 m





Projection: MGA Zone 95 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

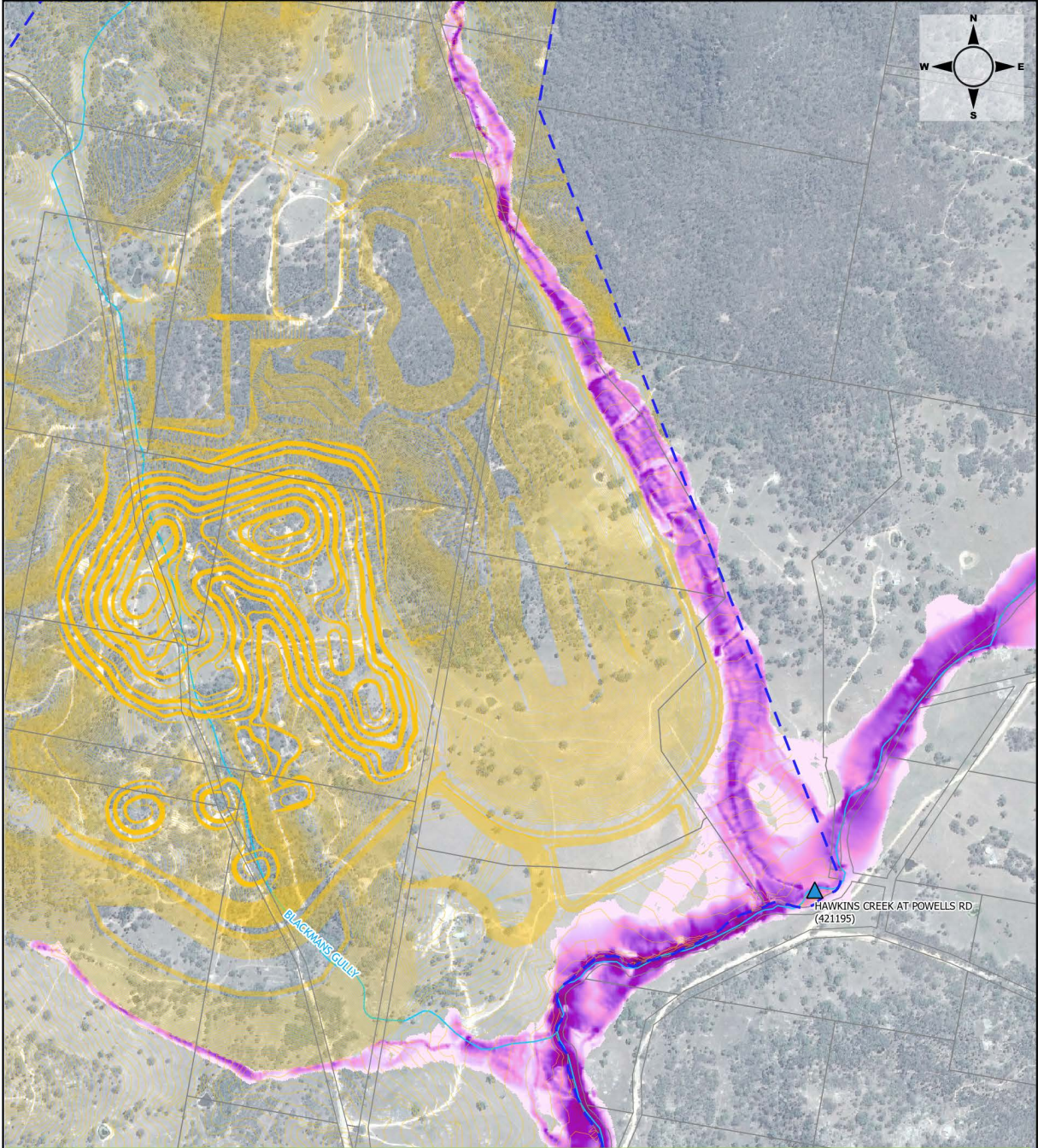
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
1% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

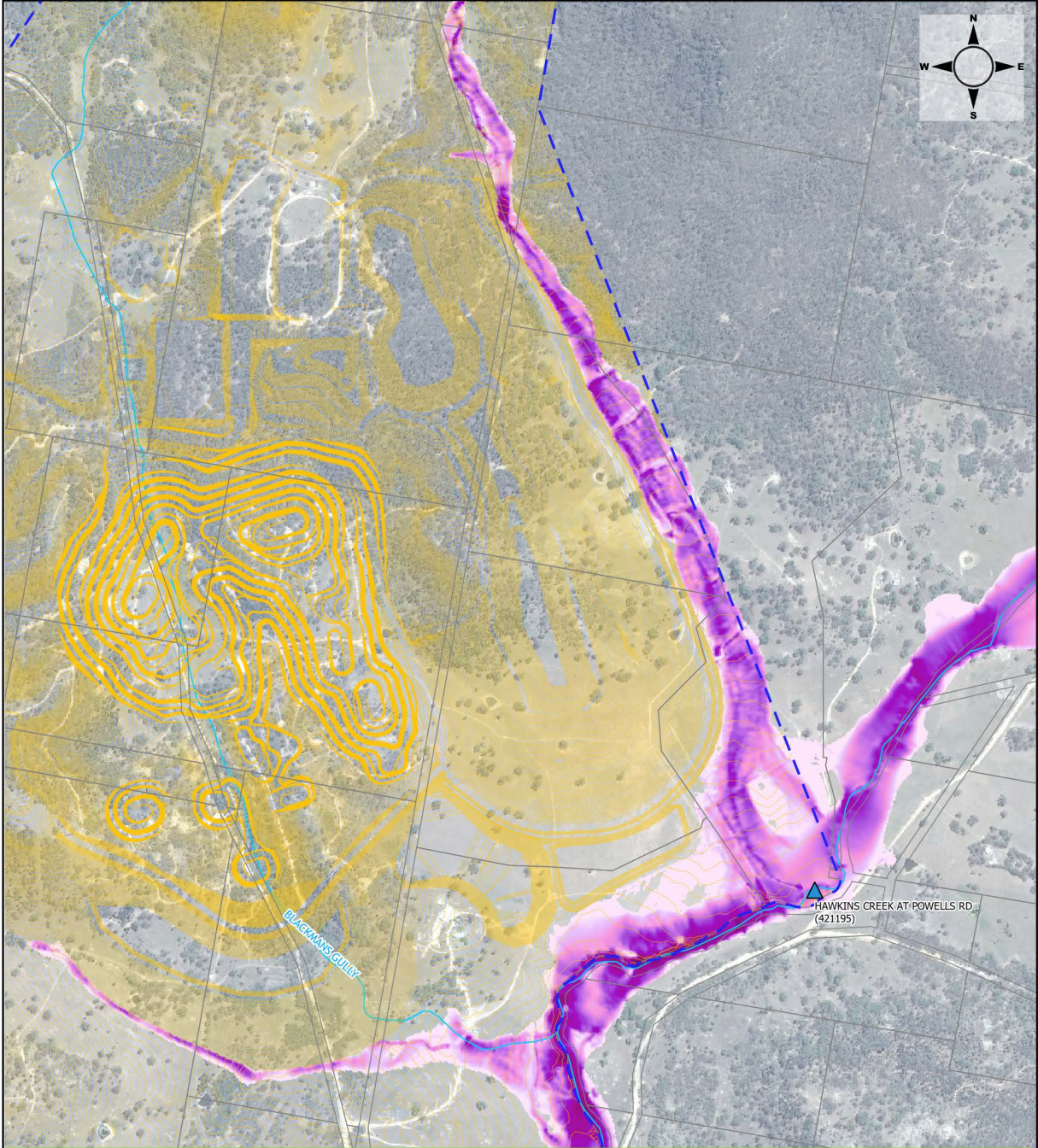
	0.0 m/s < 0.5 m/s
	0.5 m/s < 1.0 m/s
	1.0 m/s < 1.5 m/s
	1.5 m/s < 2.0 m/s
	2.0 m/s < 2.5 m/s
	2.5 m/s < 3.0 m/s
	3.0 m/s < 4.0 m/s
	> 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
0.5% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

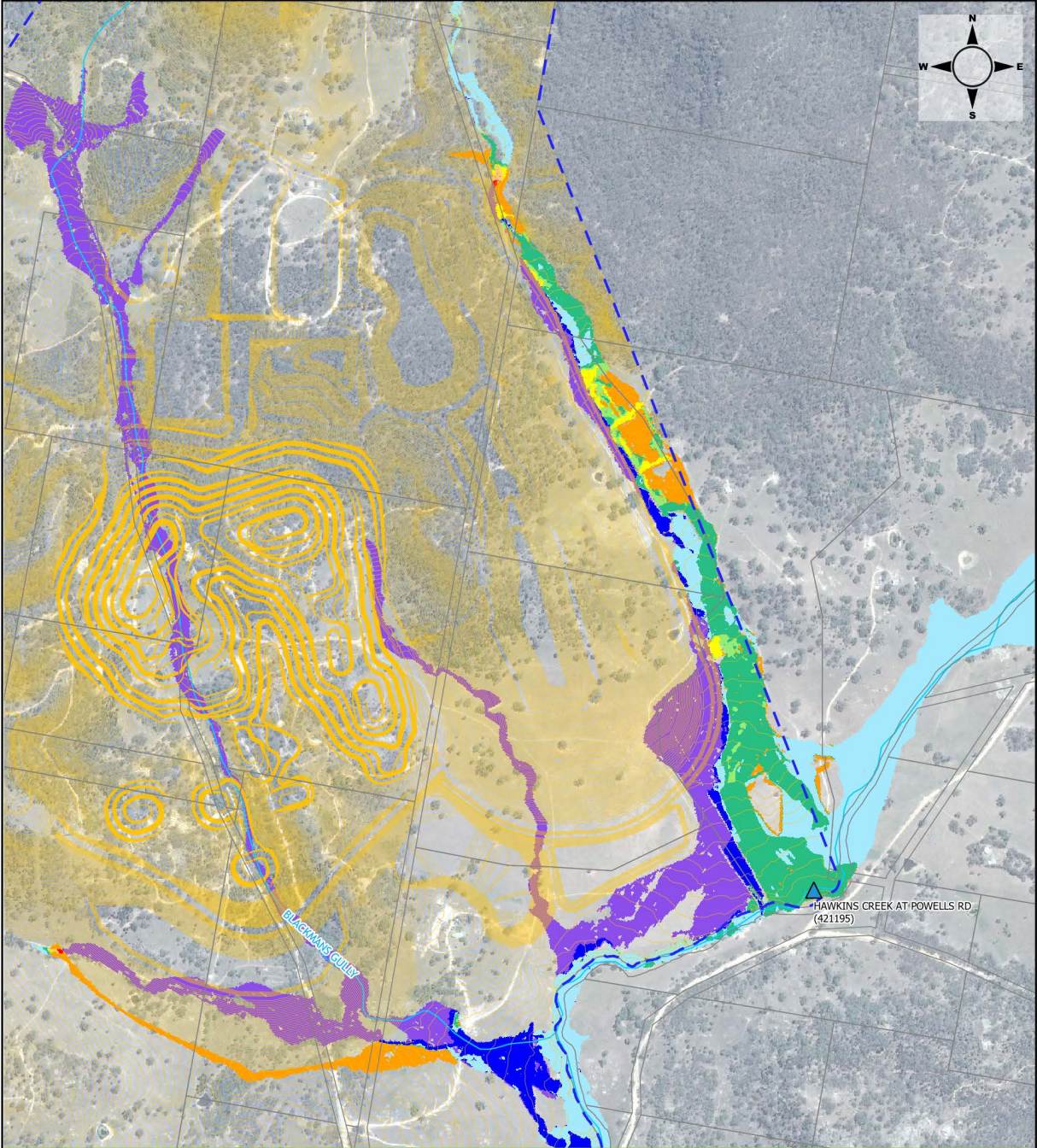
	0.0 m/s < 0.5 m/s
	0.5 m/s < 1.0 m/s
	1.0 m/s < 1.5 m/s
	1.5 m/s < 2.0 m/s
	2.0 m/s < 2.5 m/s
	2.5 m/s < 3.0 m/s
	3.0 m/s < 4.0 m/s
	> 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
0.2% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

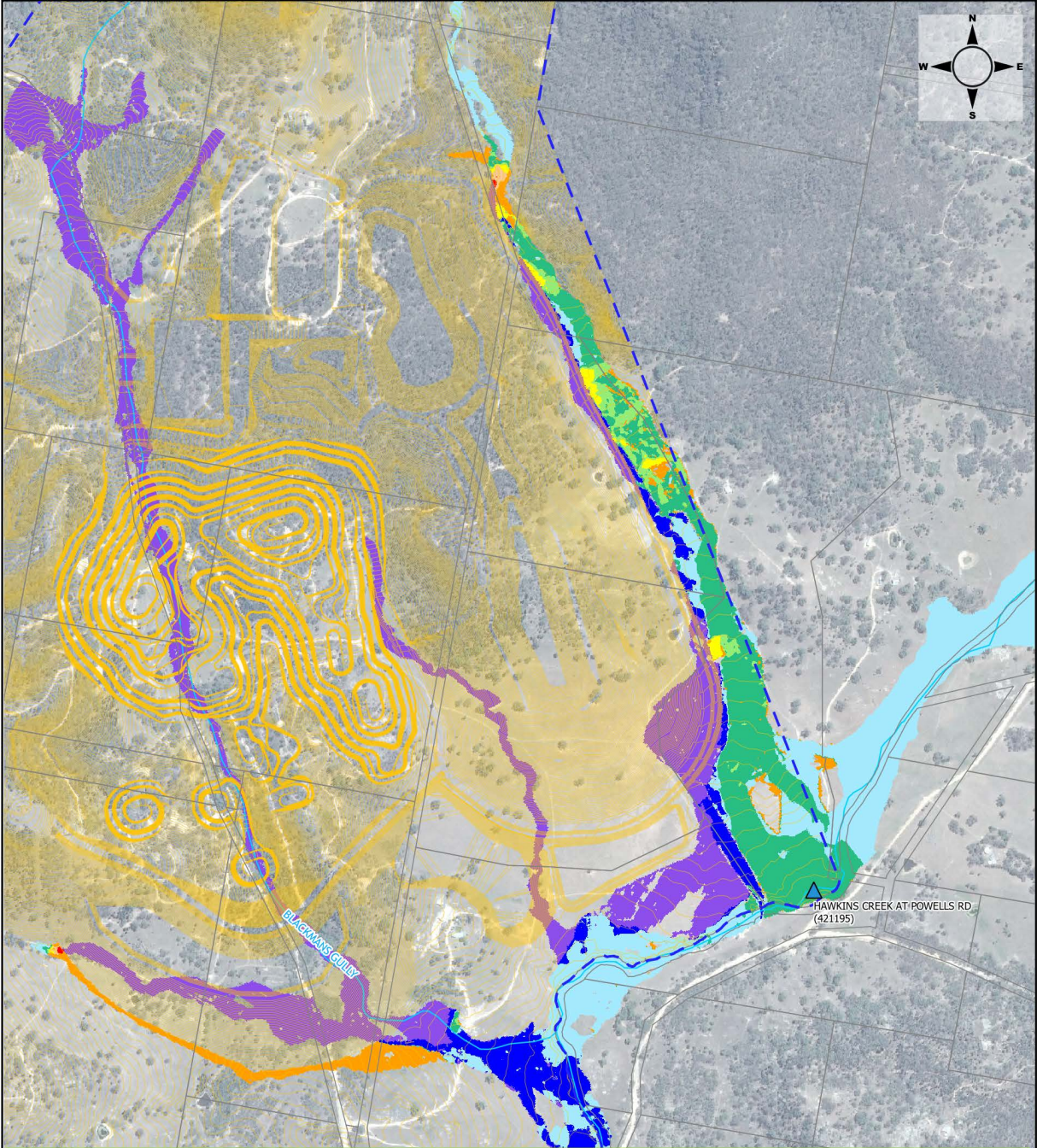
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
10% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

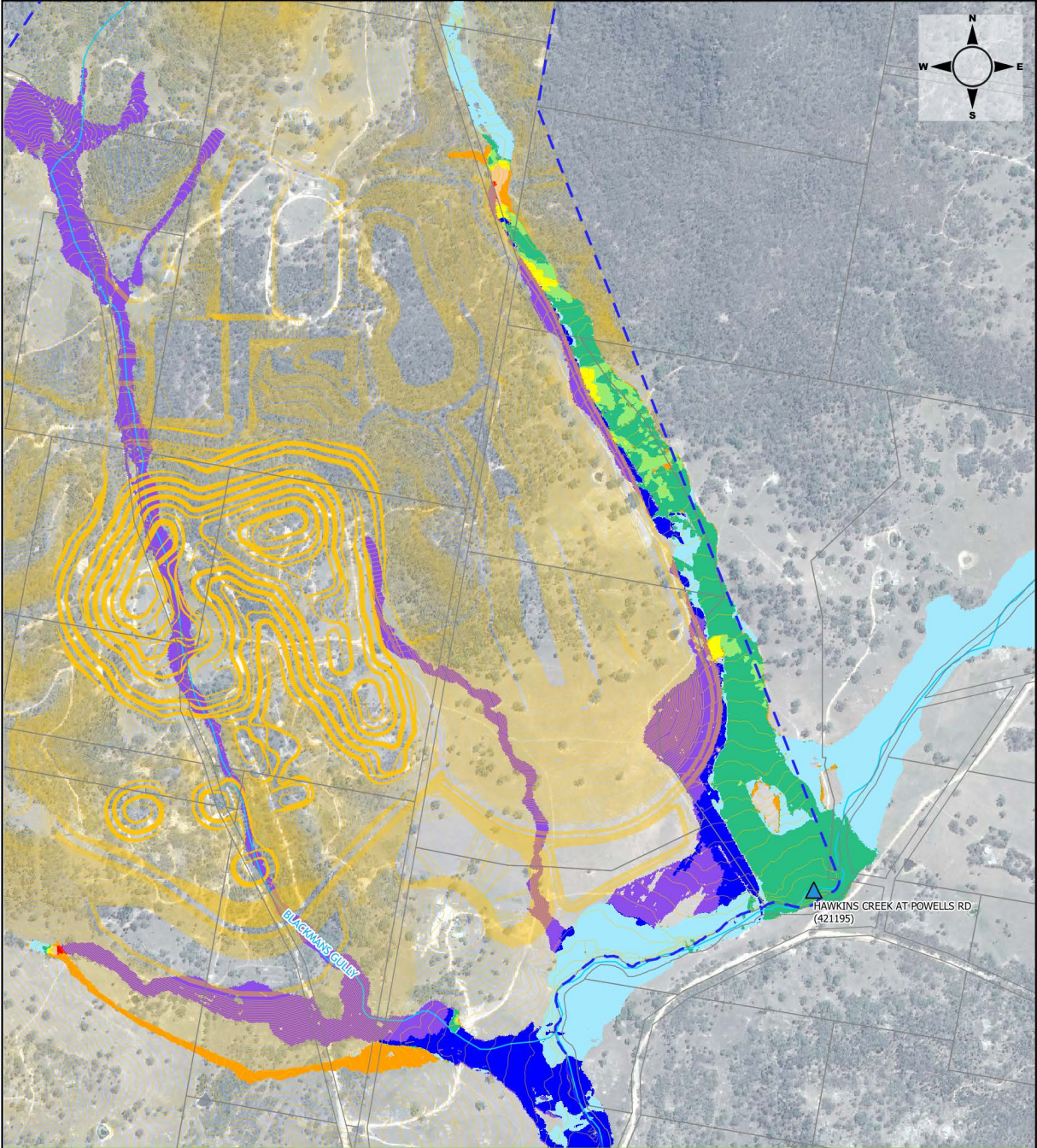
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
5% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

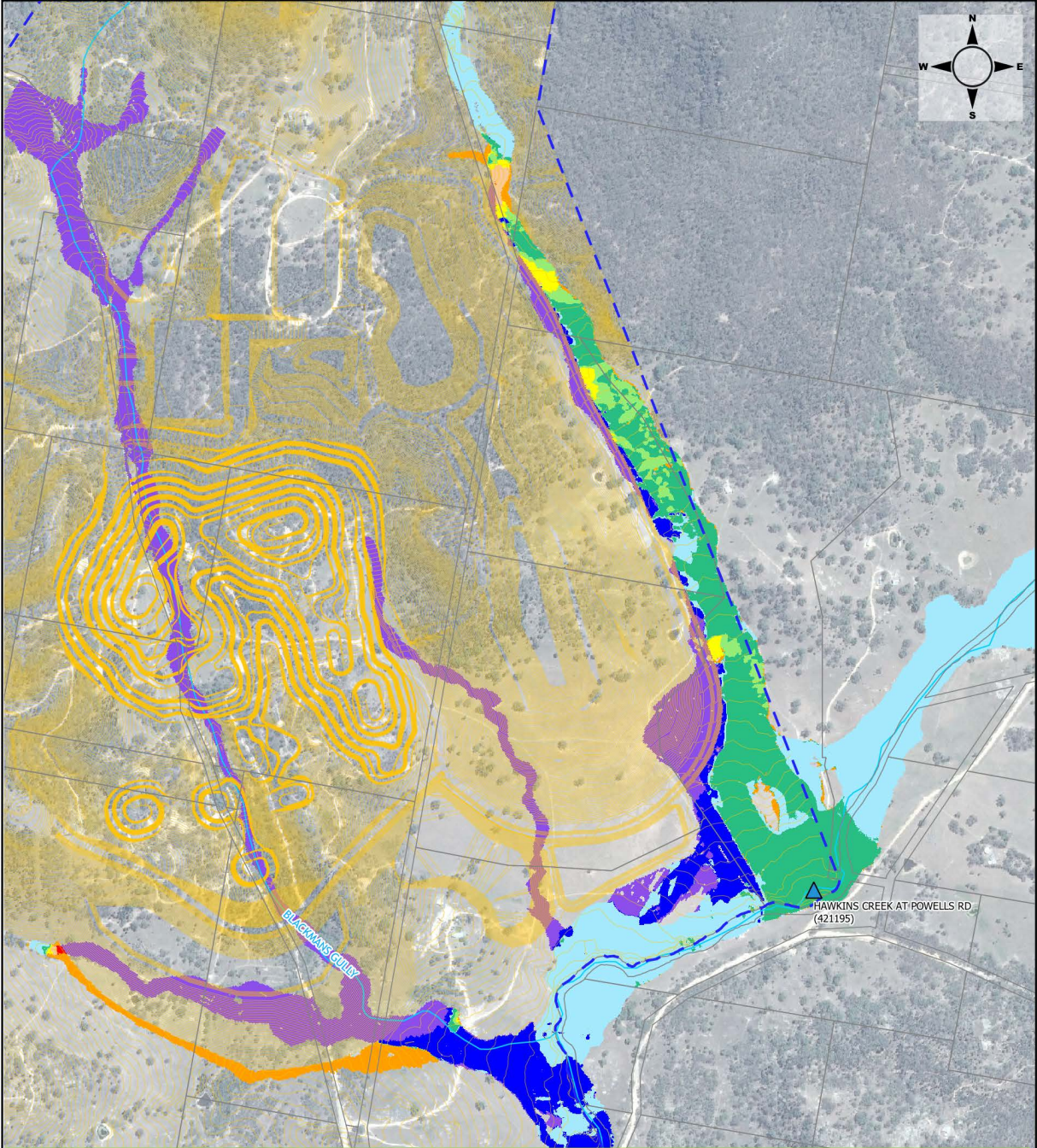
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
2% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

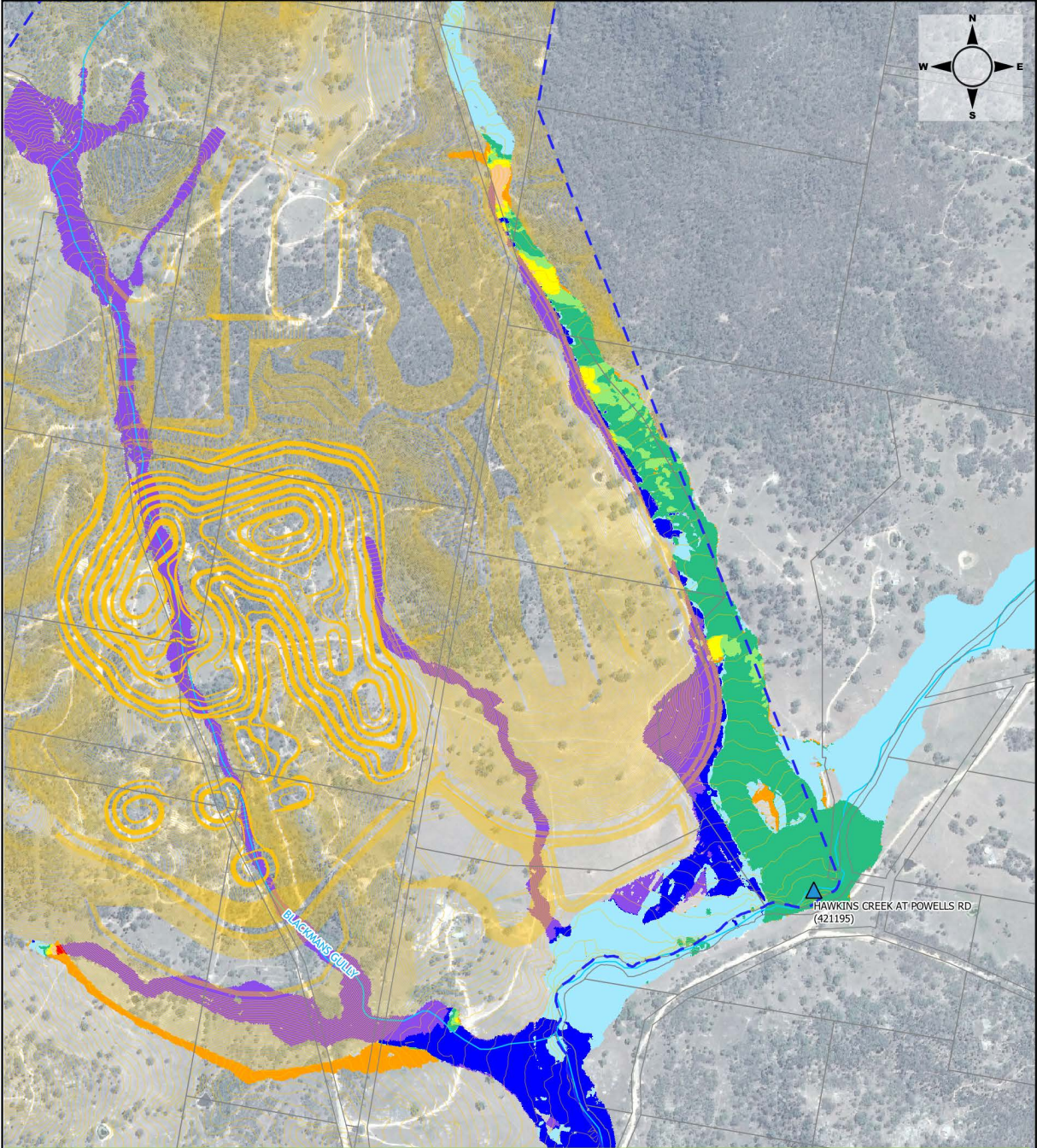
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
1% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

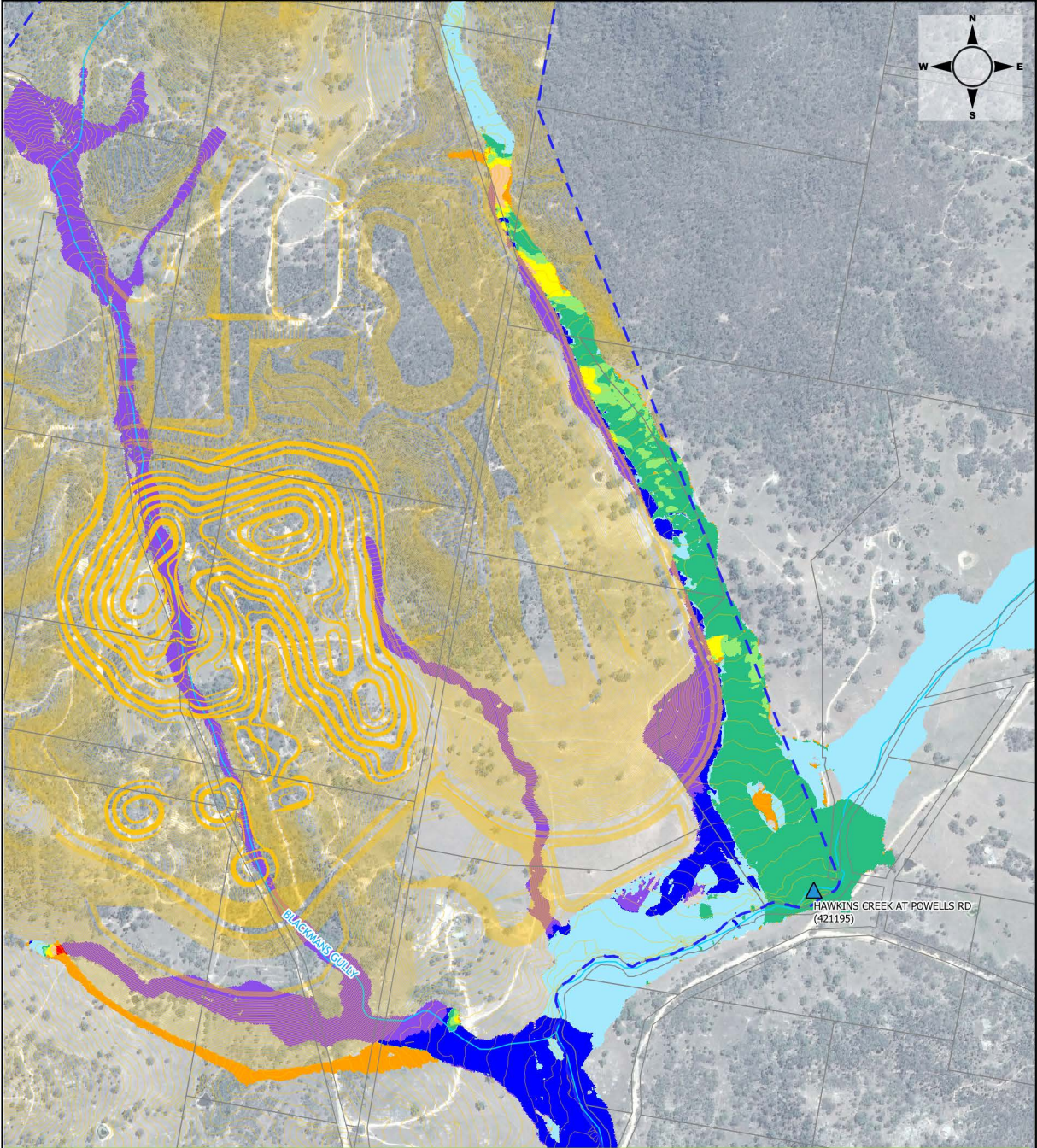
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
0.5% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

Change in peak water level

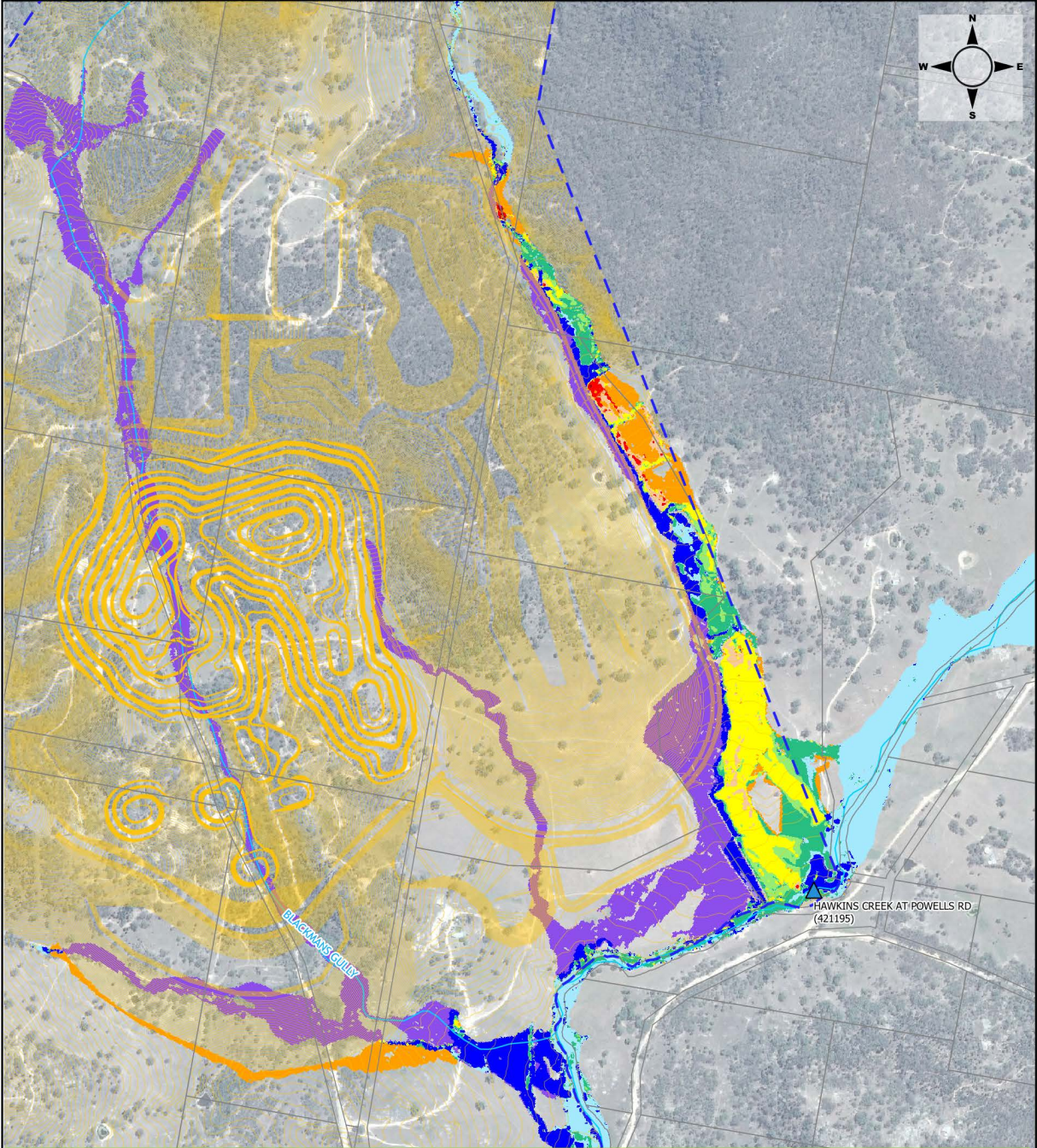
- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
0.2% AEP, WRE Stage 7

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

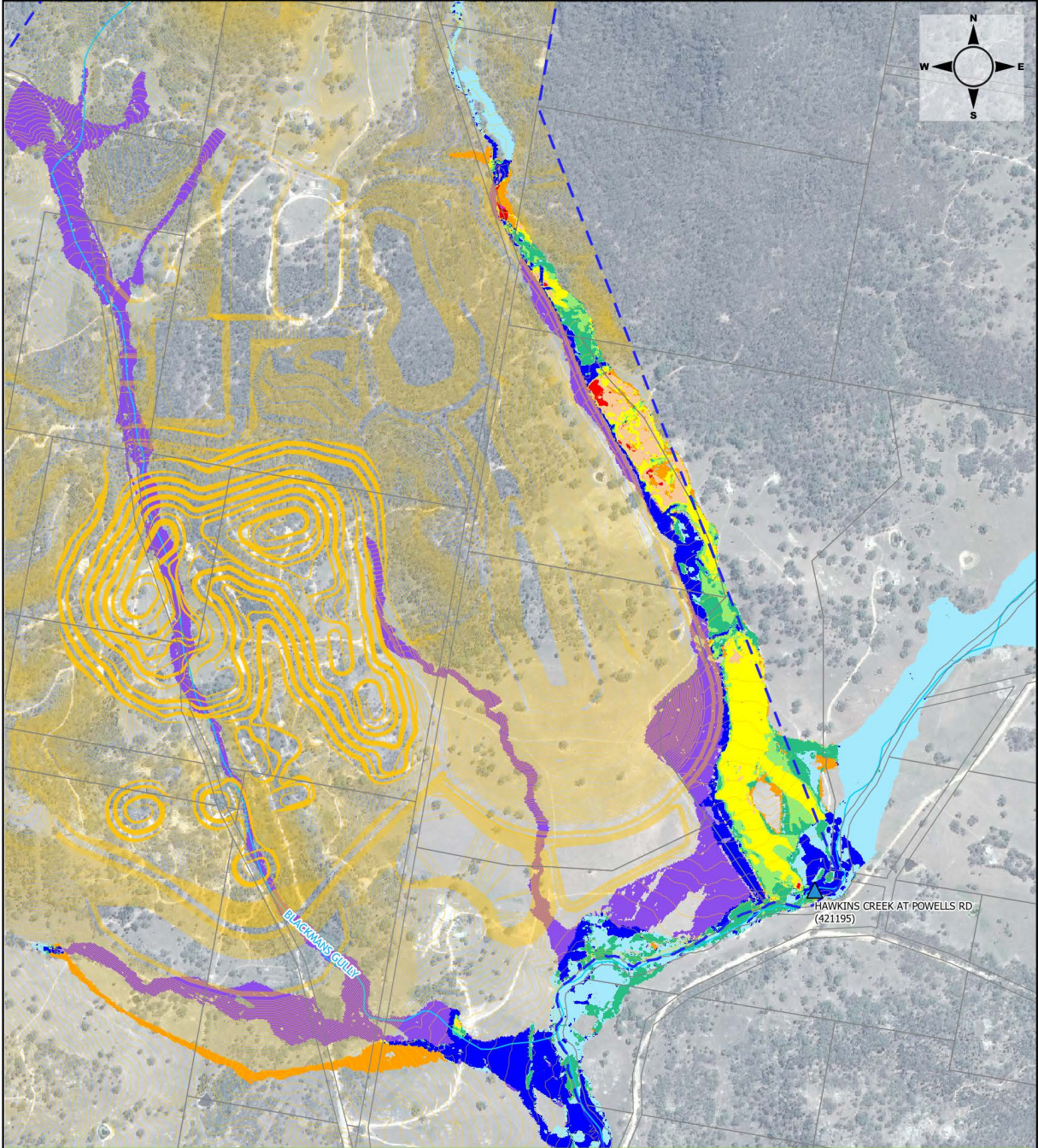
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
10% AEP, WRE Stage 7



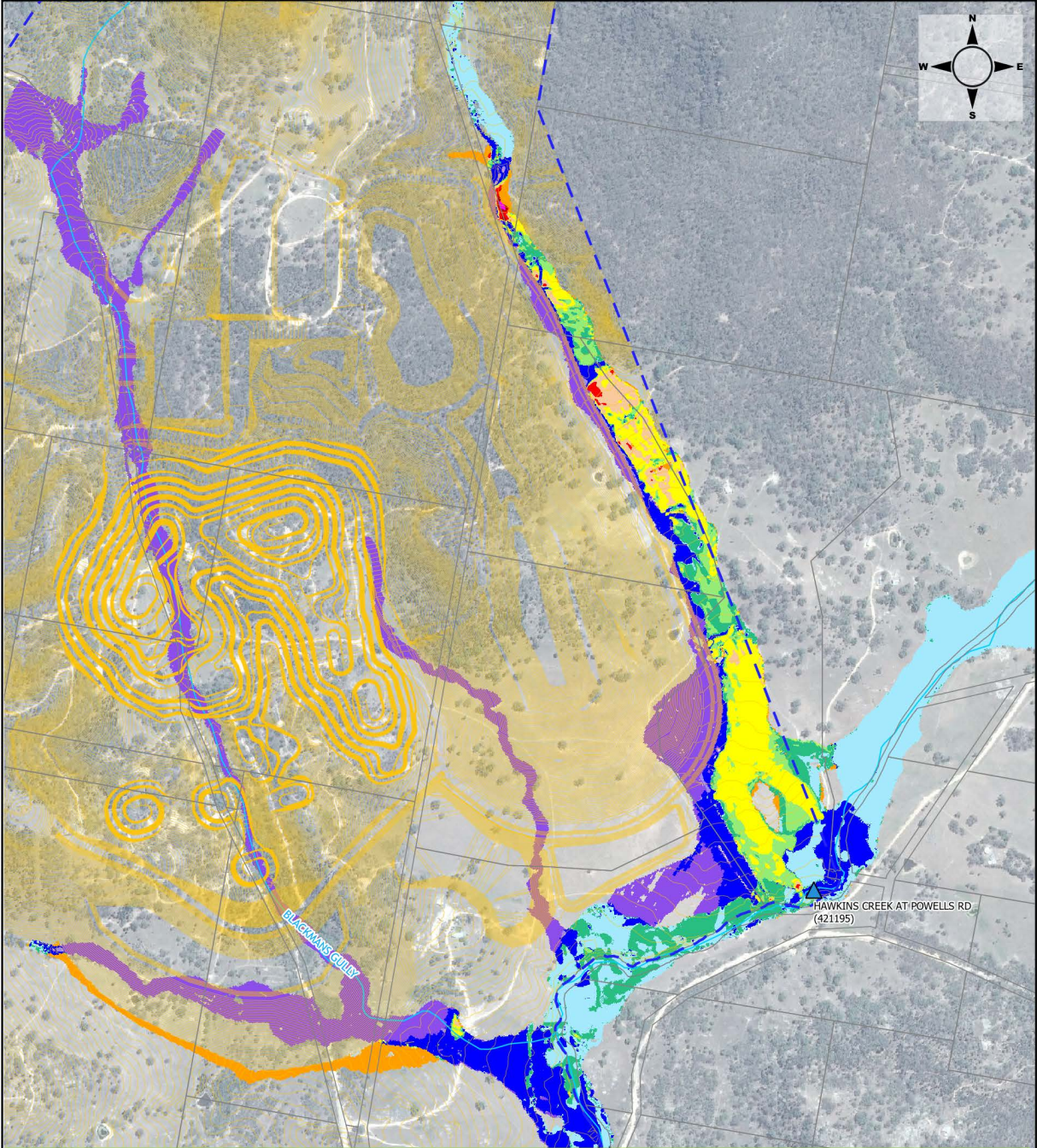


Legend

Change in peak velocity

Bowdens Silver Project





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

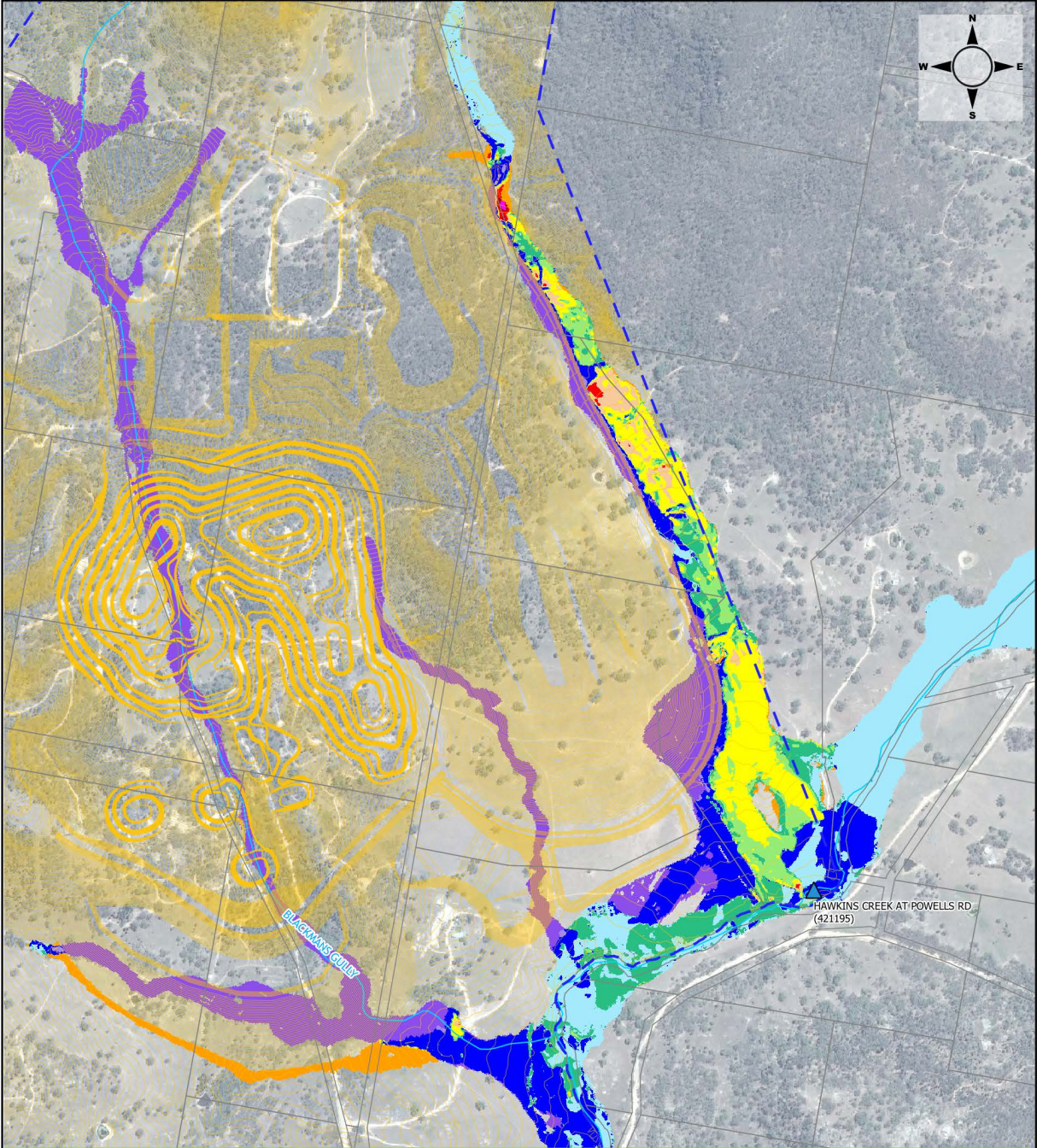
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
2% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

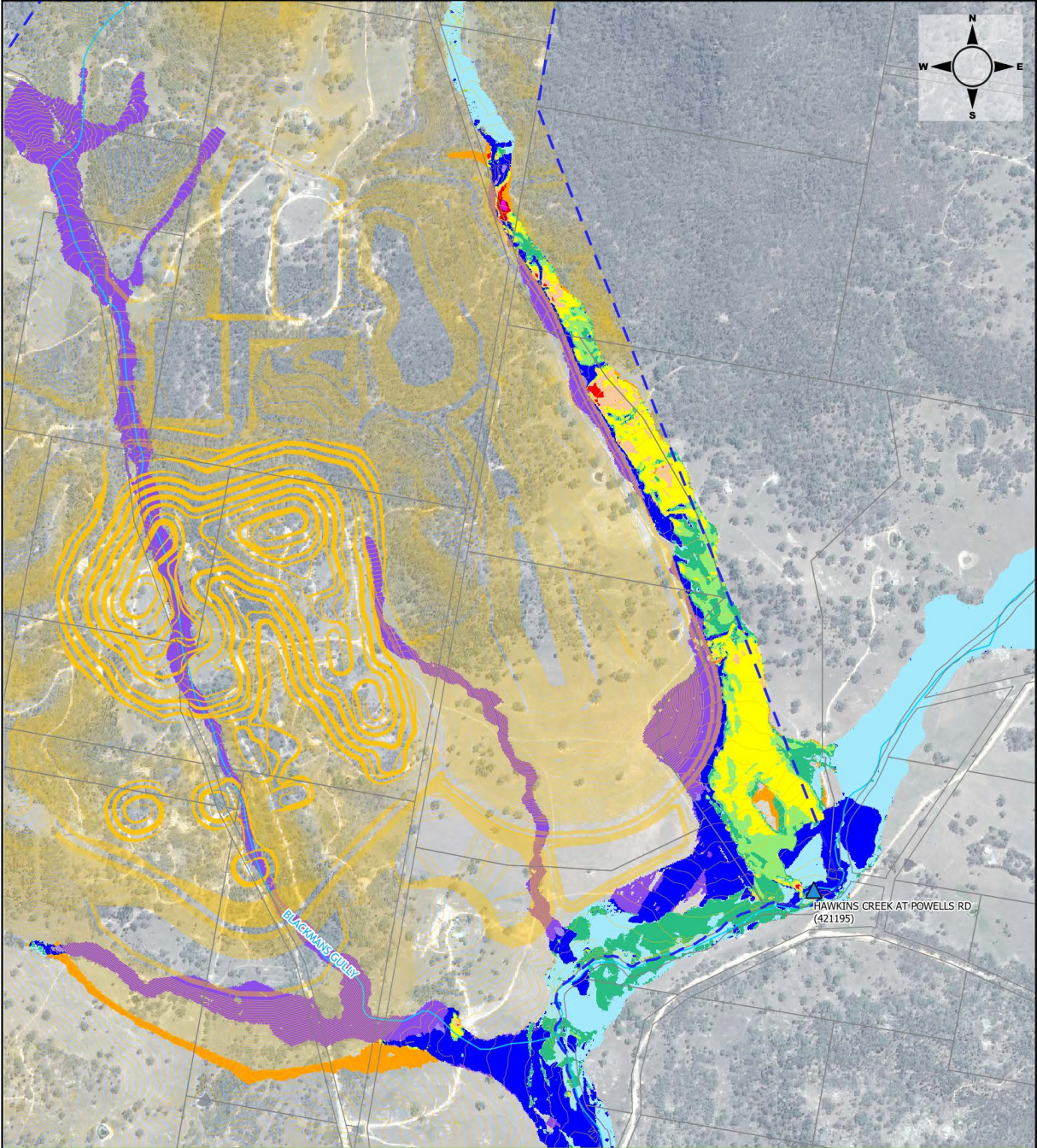
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
1% AEP, WRE Stage 7





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)
-  Was wet, now dry
-  Was dry, now wet

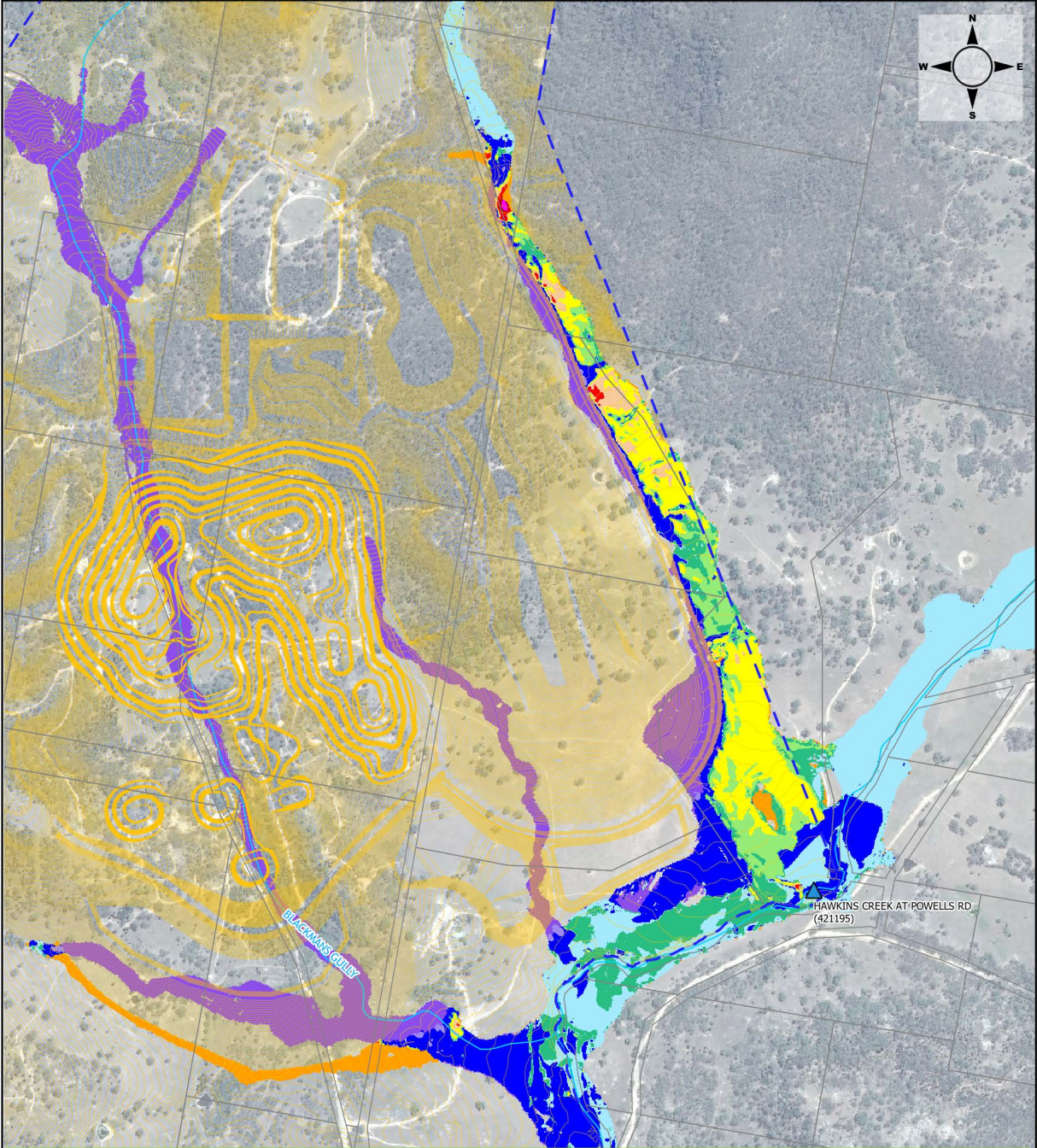
Change in peak velocity

-  < -1.00 m/s
-  -1.00 m/s to -0.01 m/s
-  -0.01 m/s to 0.01 m/s
-  0.01 m/s to 0.05 m/s
-  0.05 m/s to 0.10 m/s
-  0.10 m/s to 0.50 m/s
-  0.50 m/s to 1.00 m/s
-  1.00 m/s to 2.00 m/s
-  2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
0.5% AEP, WRE Stage 7





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

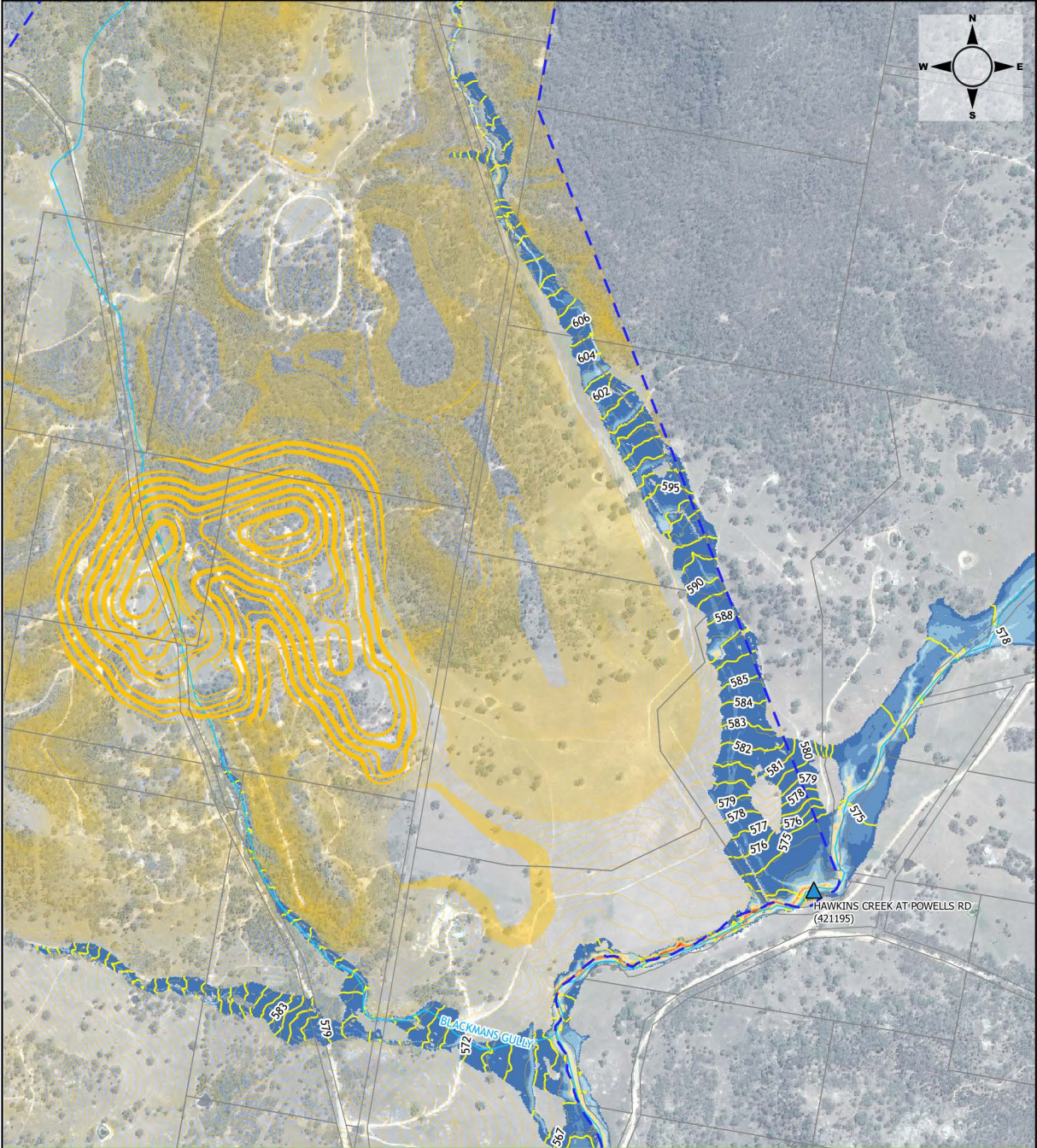
Bowdens Silver Project

Change in Peak Velocity,
0.2% AEP, WRE Stage 7





Appendix E - Flood maps - Final landform scenario



Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

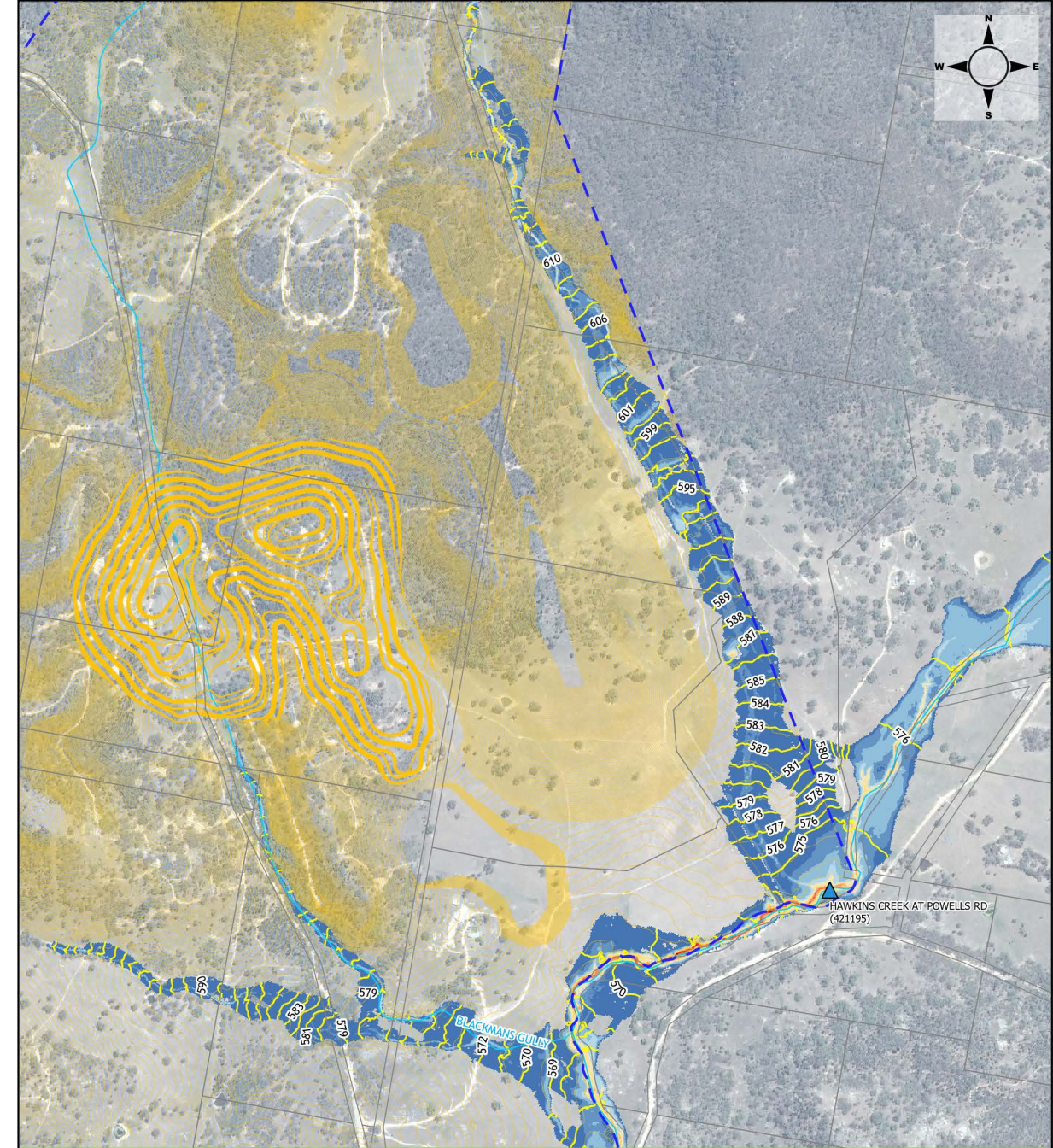
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
10% AEP, Final Landform

0 200 400 600 m





Projection: MGA Zone 55
Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

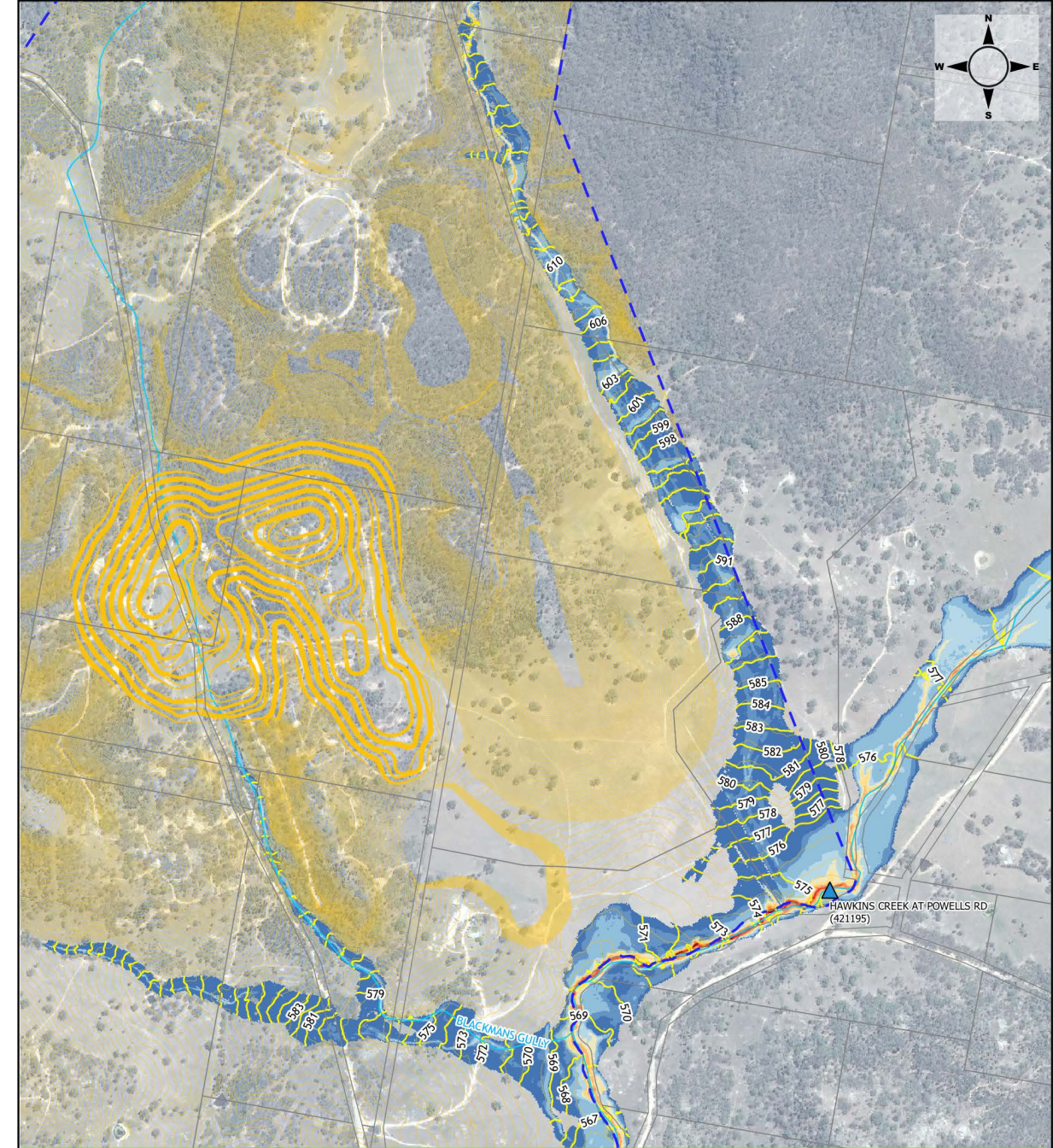
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
5% AEP, Final Landform

0 200 400 600 m





Projection: MGA Zone 55
Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

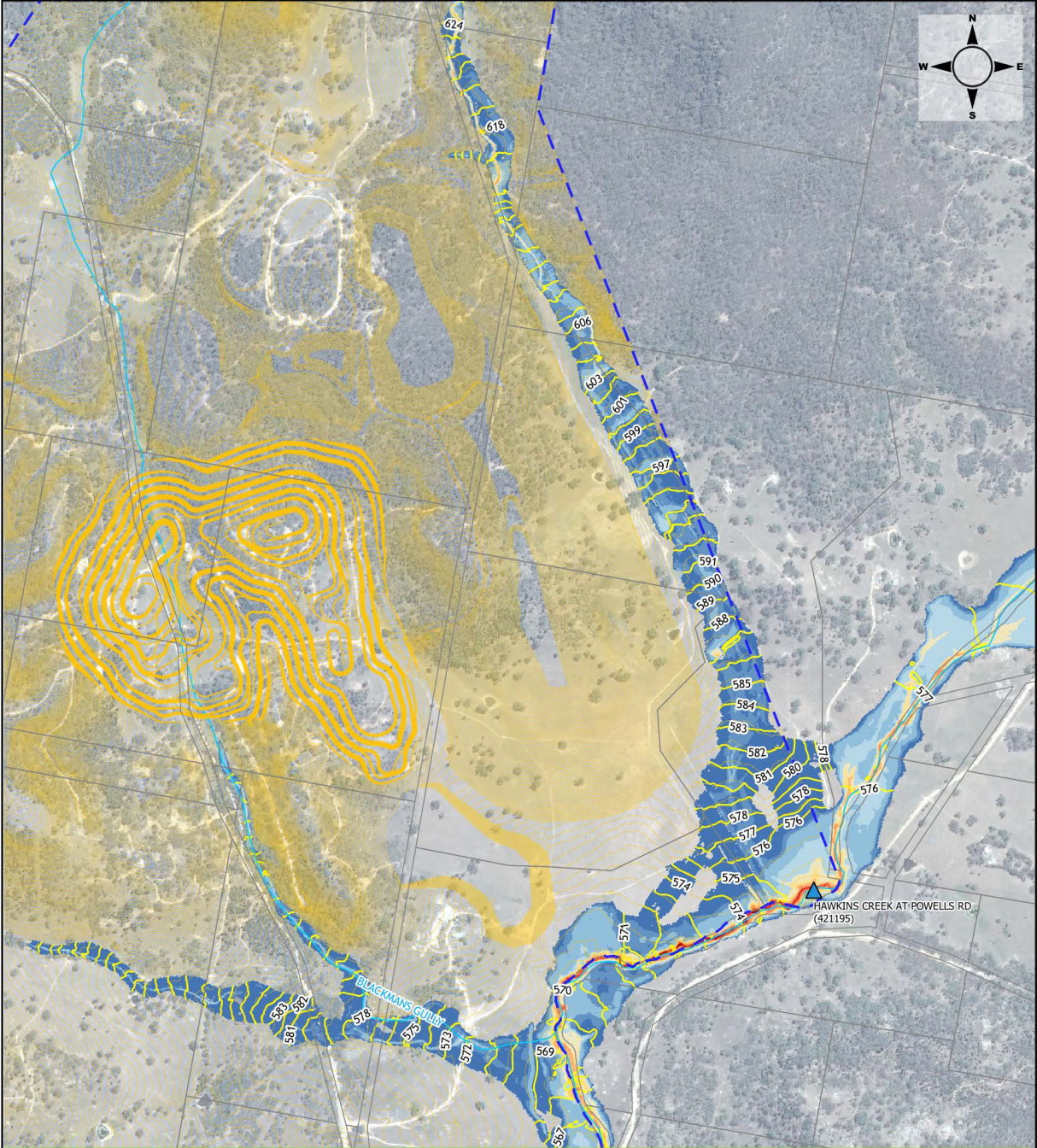
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
2% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

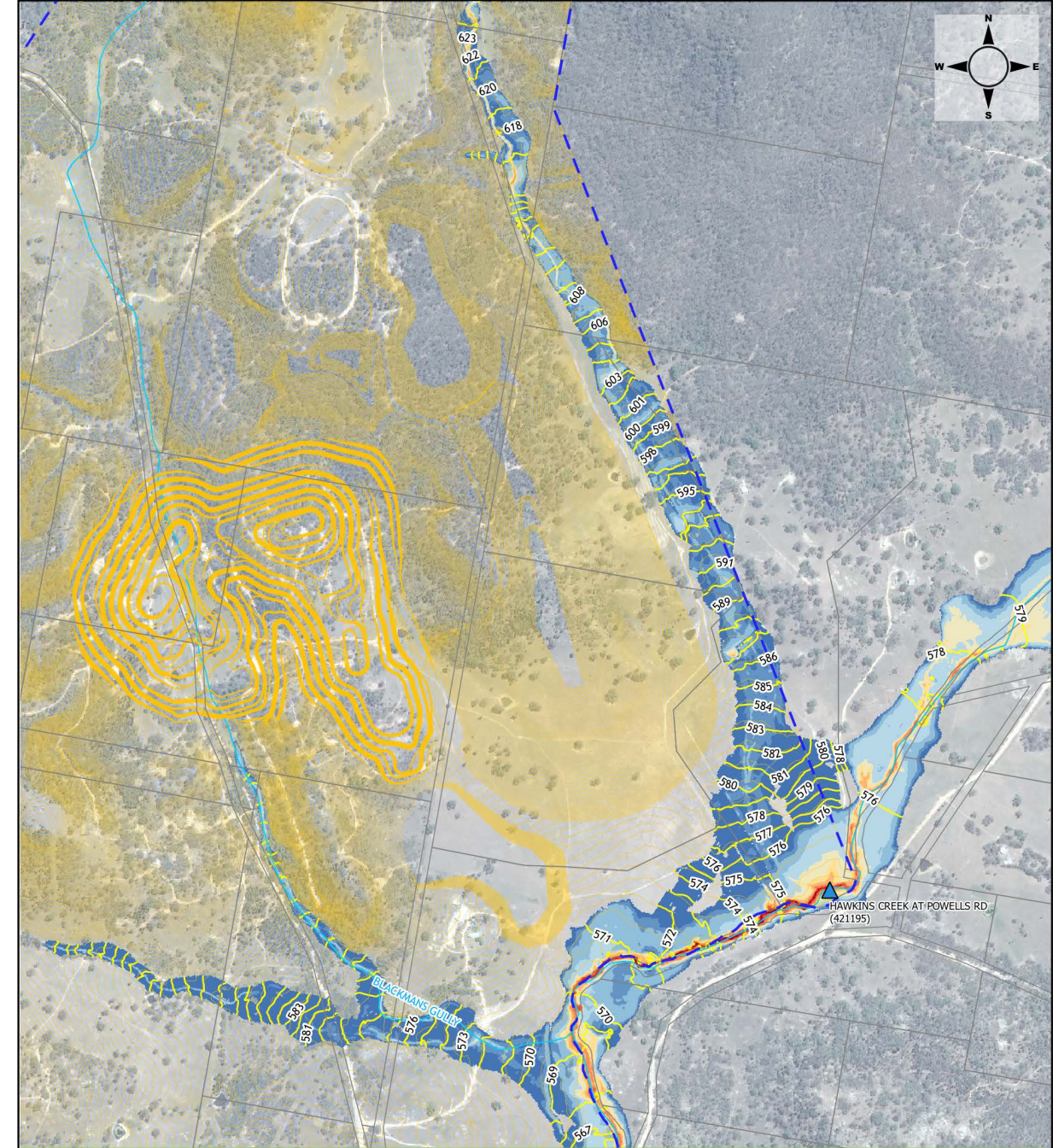
	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
1% AEP, Final Landform

0 200 400 600 m





Projection: MGA Zone 55 Datum: GDA 94

Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

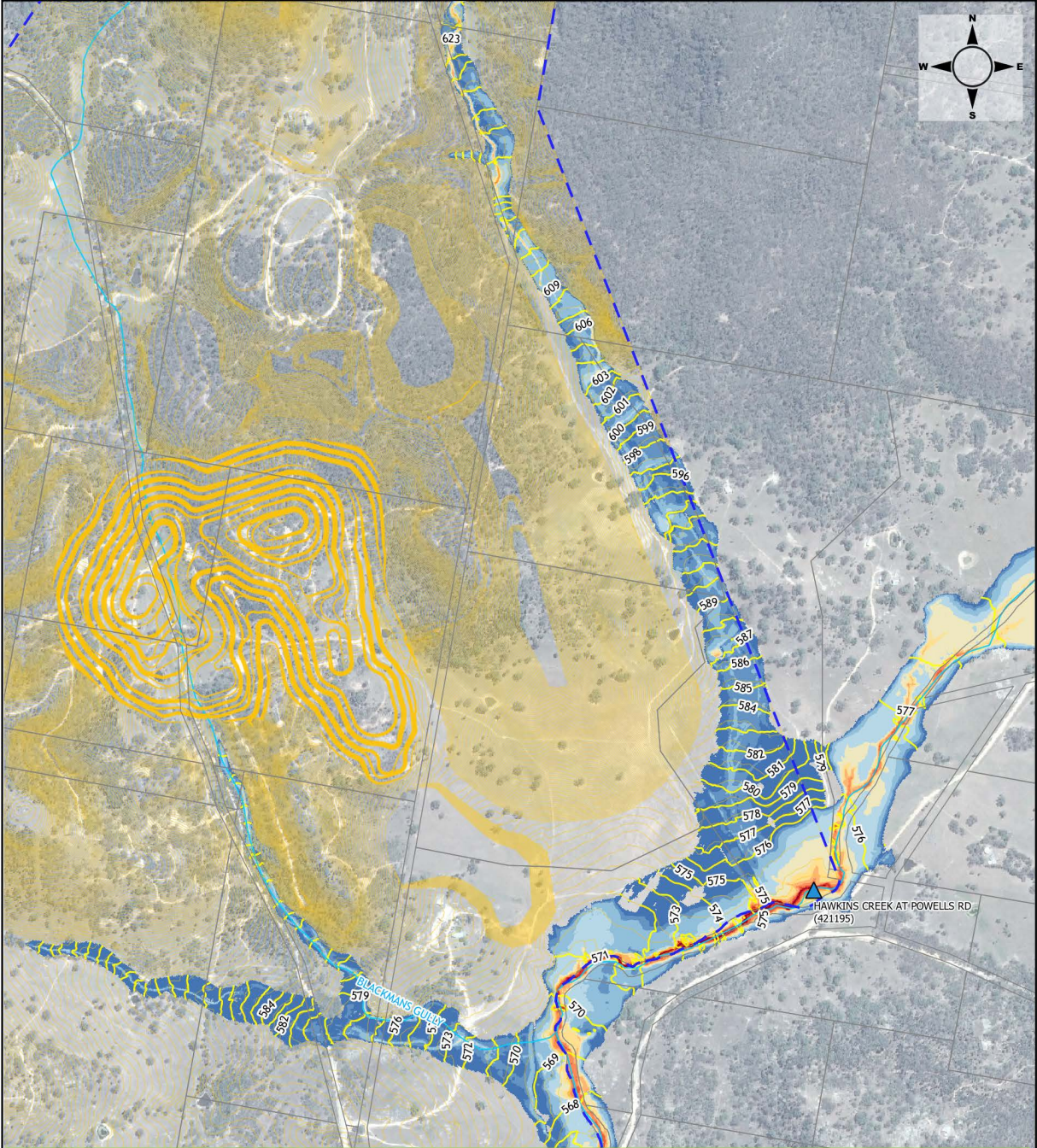
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
0.5% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Depth

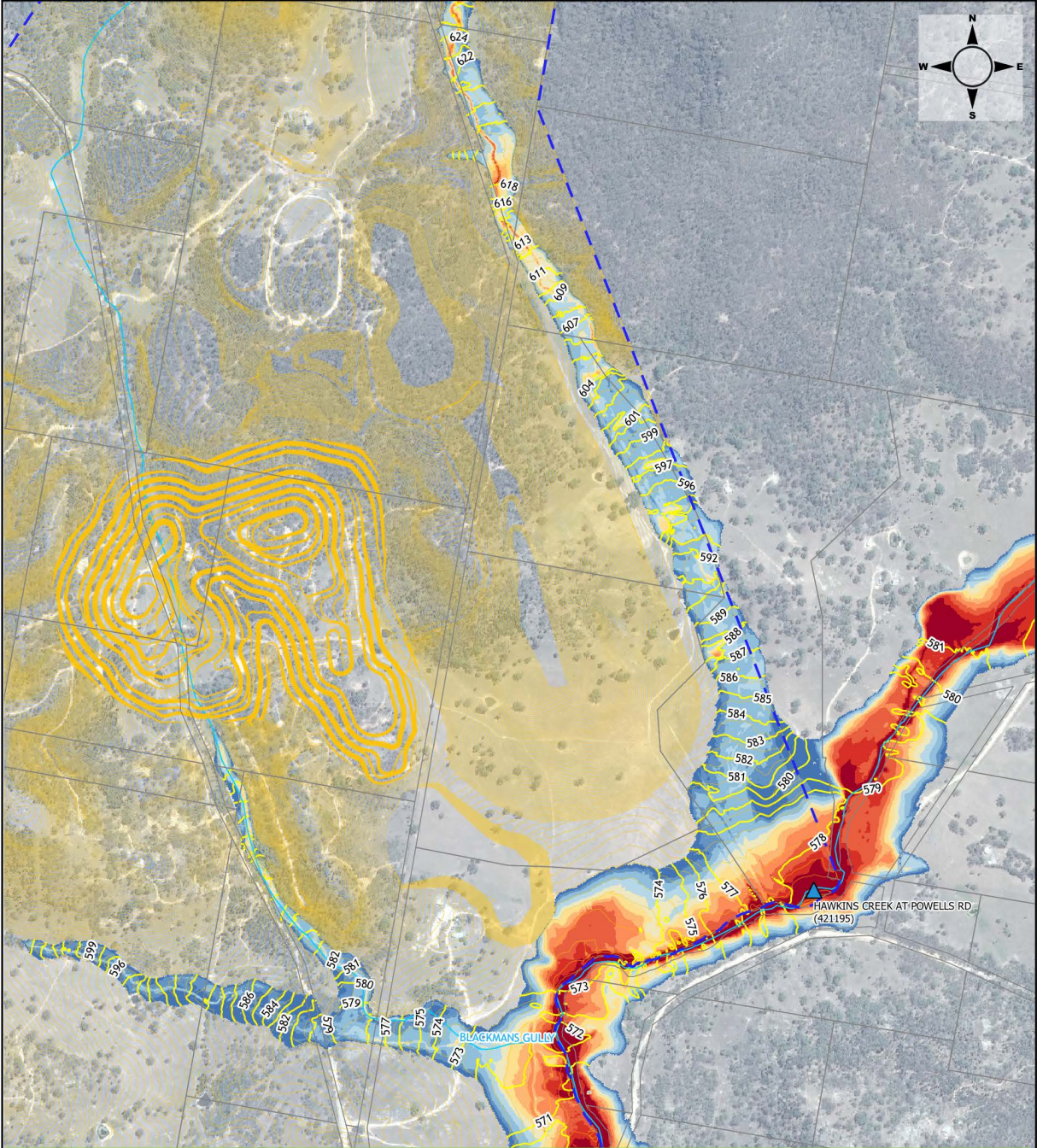
- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
0.2% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

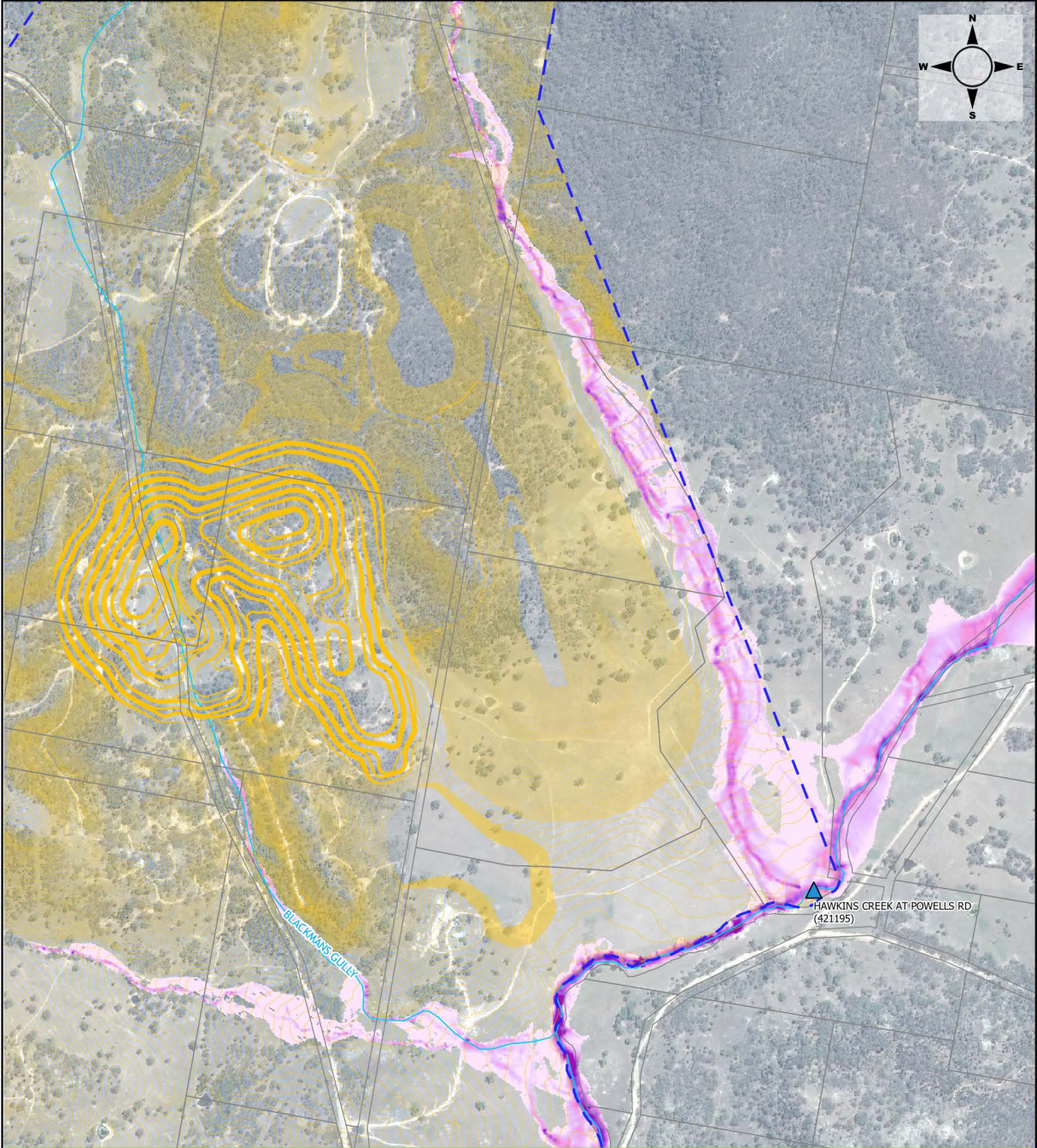
Depth

	0.00 m - 0.25 m
	0.25 m - 0.50 m
	0.50 m - 1.00 m
	1.00 m - 1.50 m
	1.50 m - 2.00 m
	2.00 m - 2.50 m
	2.50 m - 3.00 m
	3.00 m - 3.50 m
	3.50 m - 4.00 m
	4.00 m - 4.50 m
	> 4.50 m

Bowdens Silver Project

Predicted Flood Extents & Depths (Developed Condition),
PMF, Final Landform





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)

Velocity

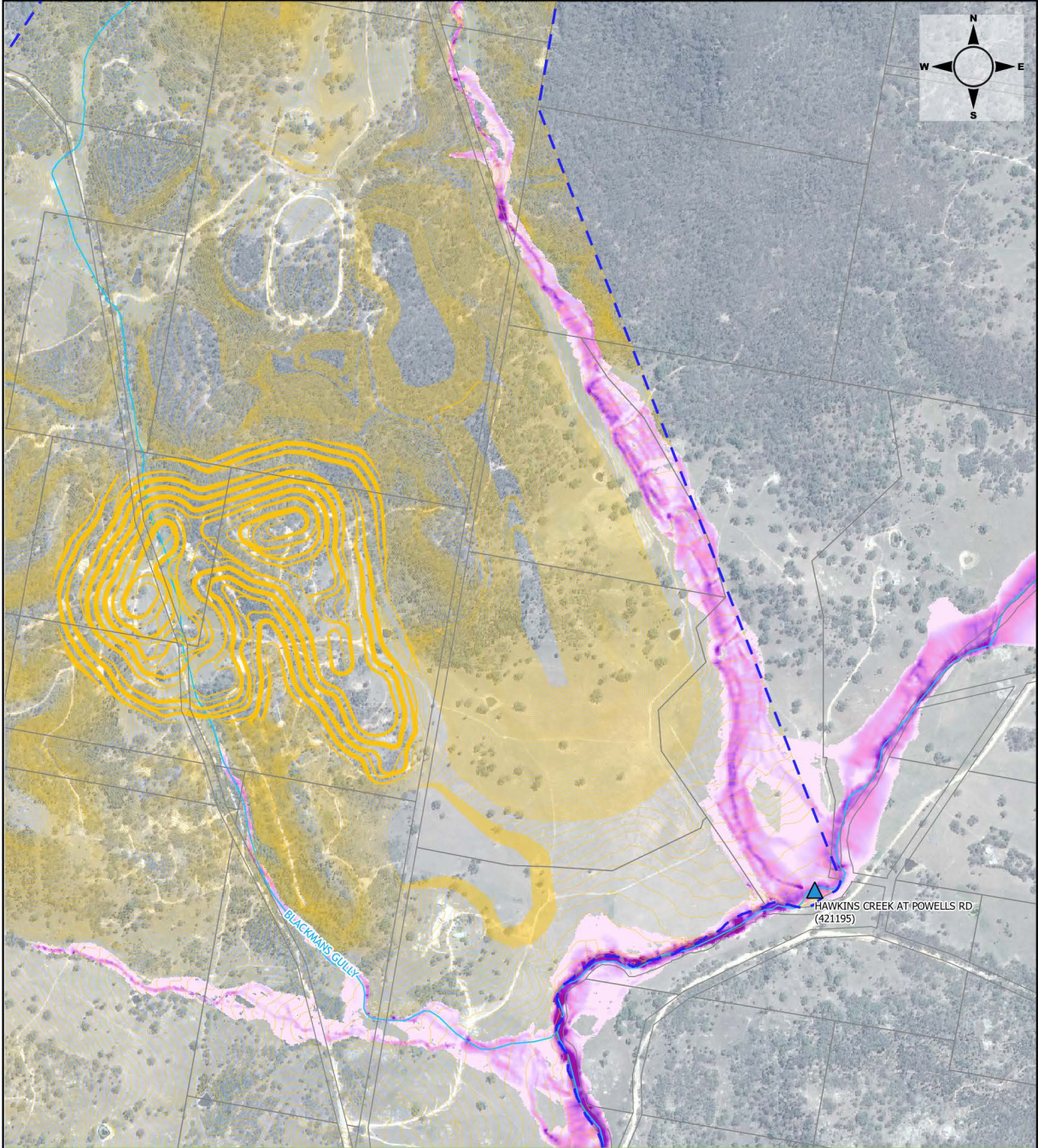
-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
10% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

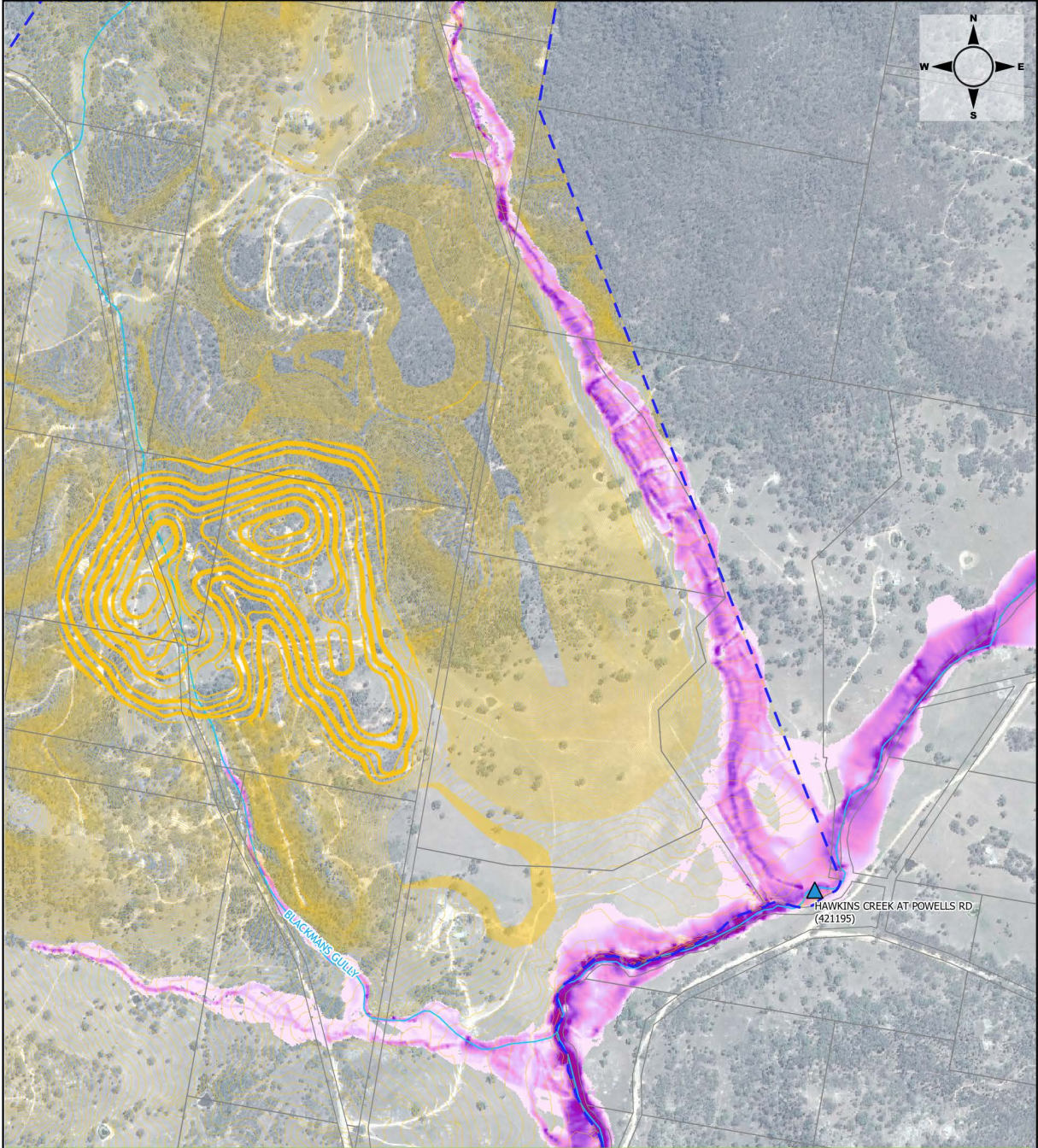
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
5% AEP, Final Landform

0 200 400 600 m





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)

Velocity

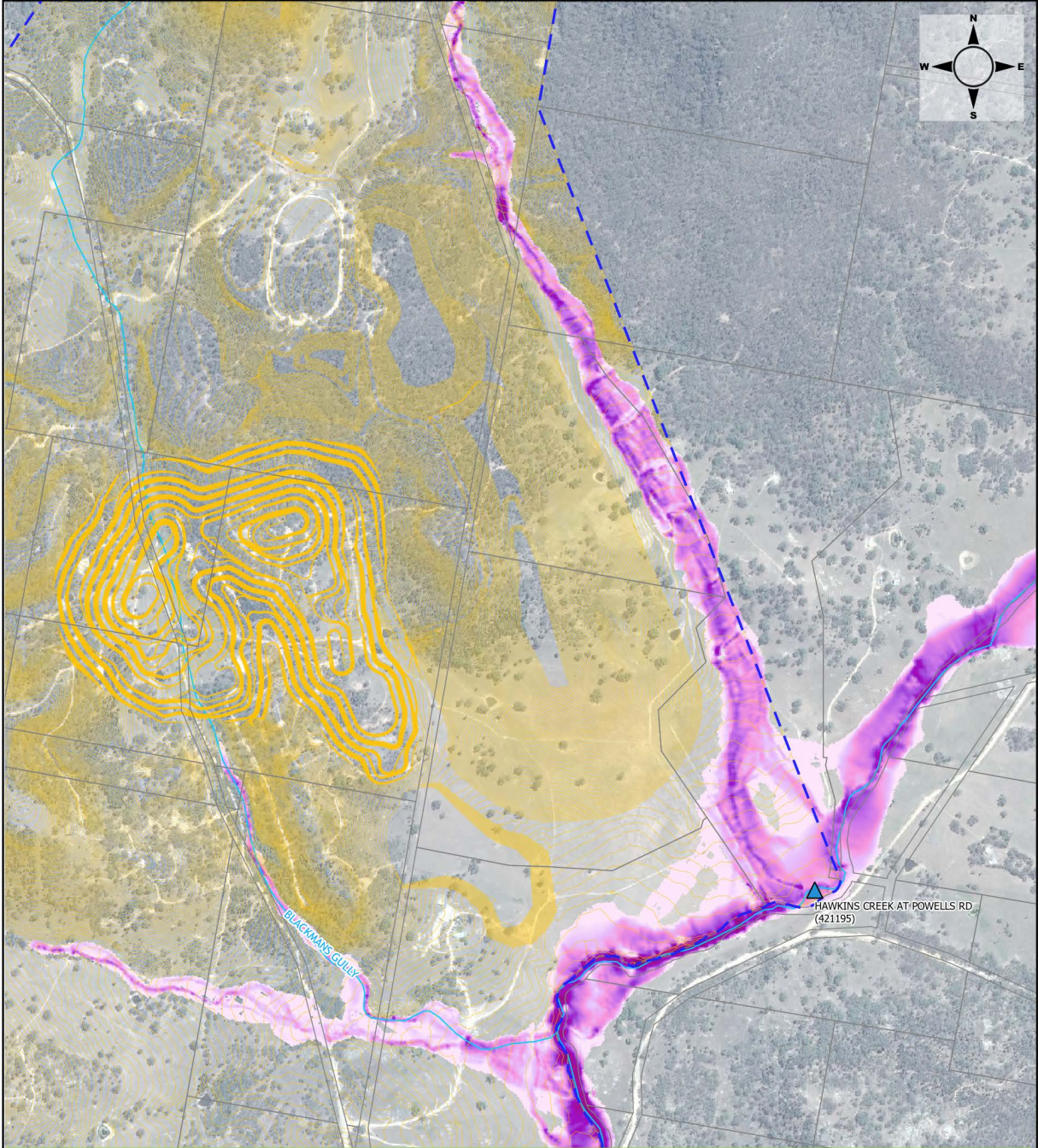
	0.0 m/s < 0.5 m/s
	0.5 m/s < 1.0 m/s
	1.0 m/s < 1.5 m/s
	1.5 m/s < 2.0 m/s
	2.0 m/s < 2.5 m/s
	2.5 m/s < 3.0 m/s
	3.0 m/s < 4.0 m/s
	> 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
2% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

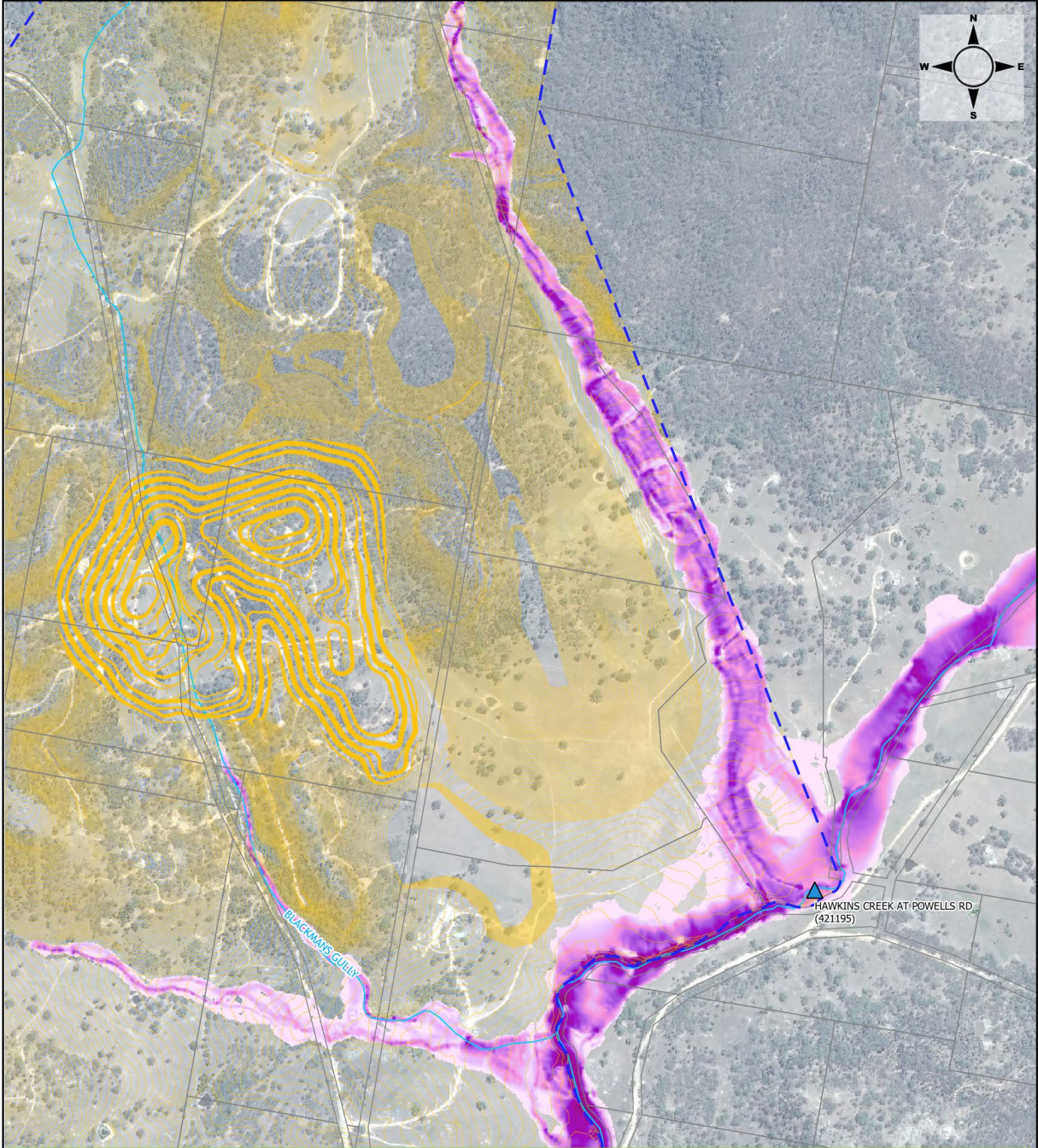
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
1% AEP, Final Landform

0 200 400 600 m





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)

Velocity

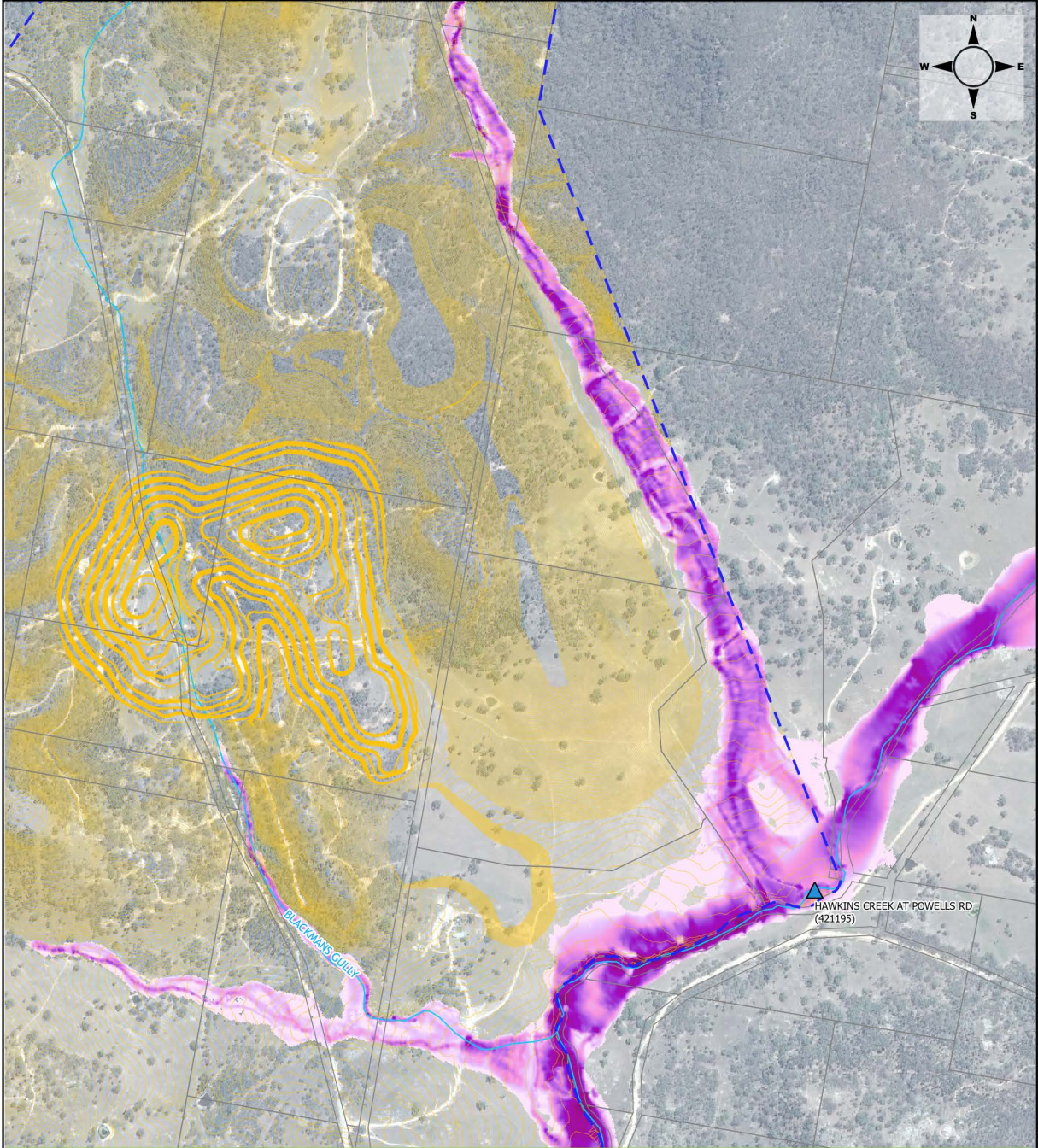
-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
0.5% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)

Velocity

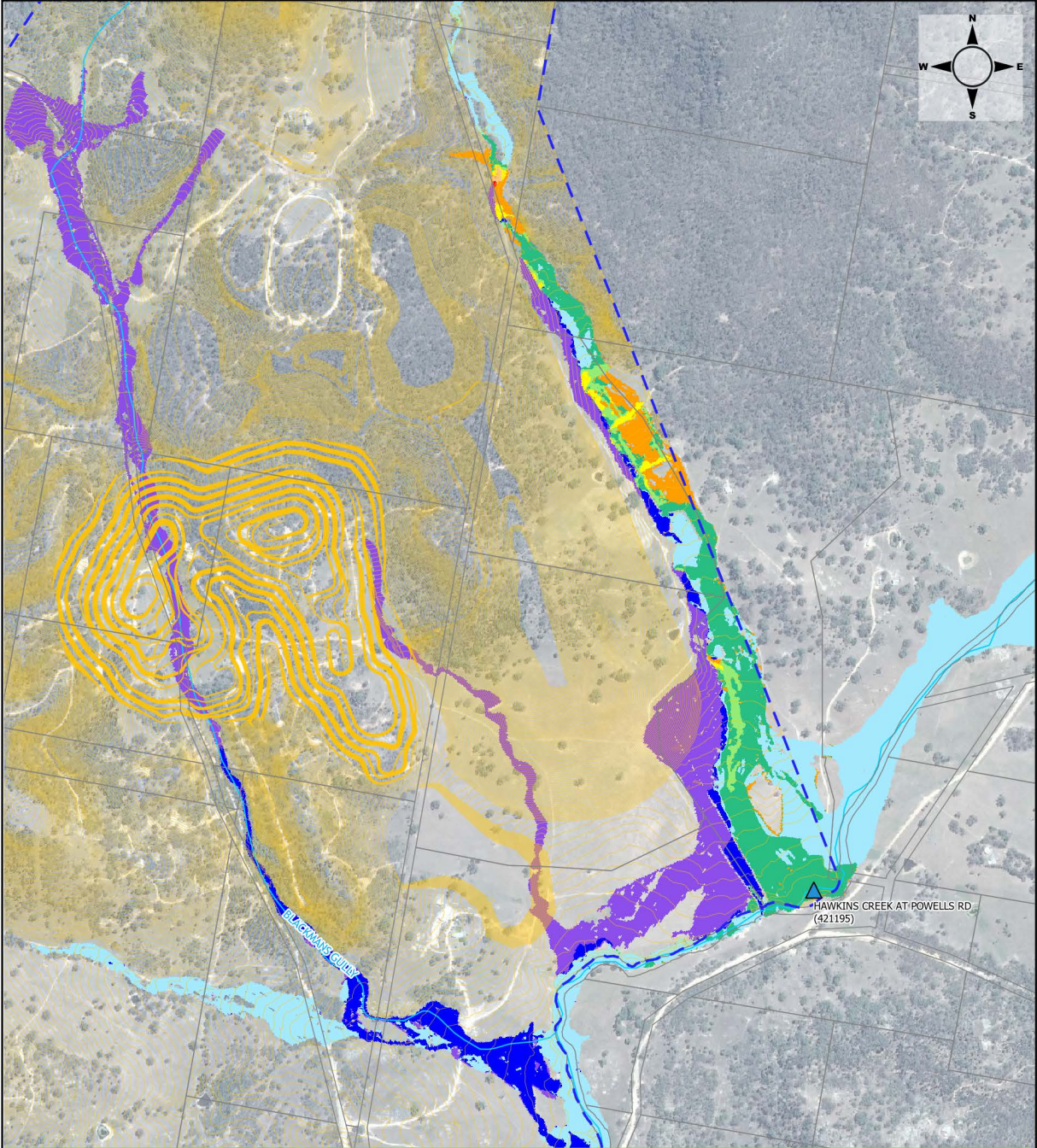
- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s

Bowdens Silver Project

Predicted Flood Velocity (Developed Condition),
0.2% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

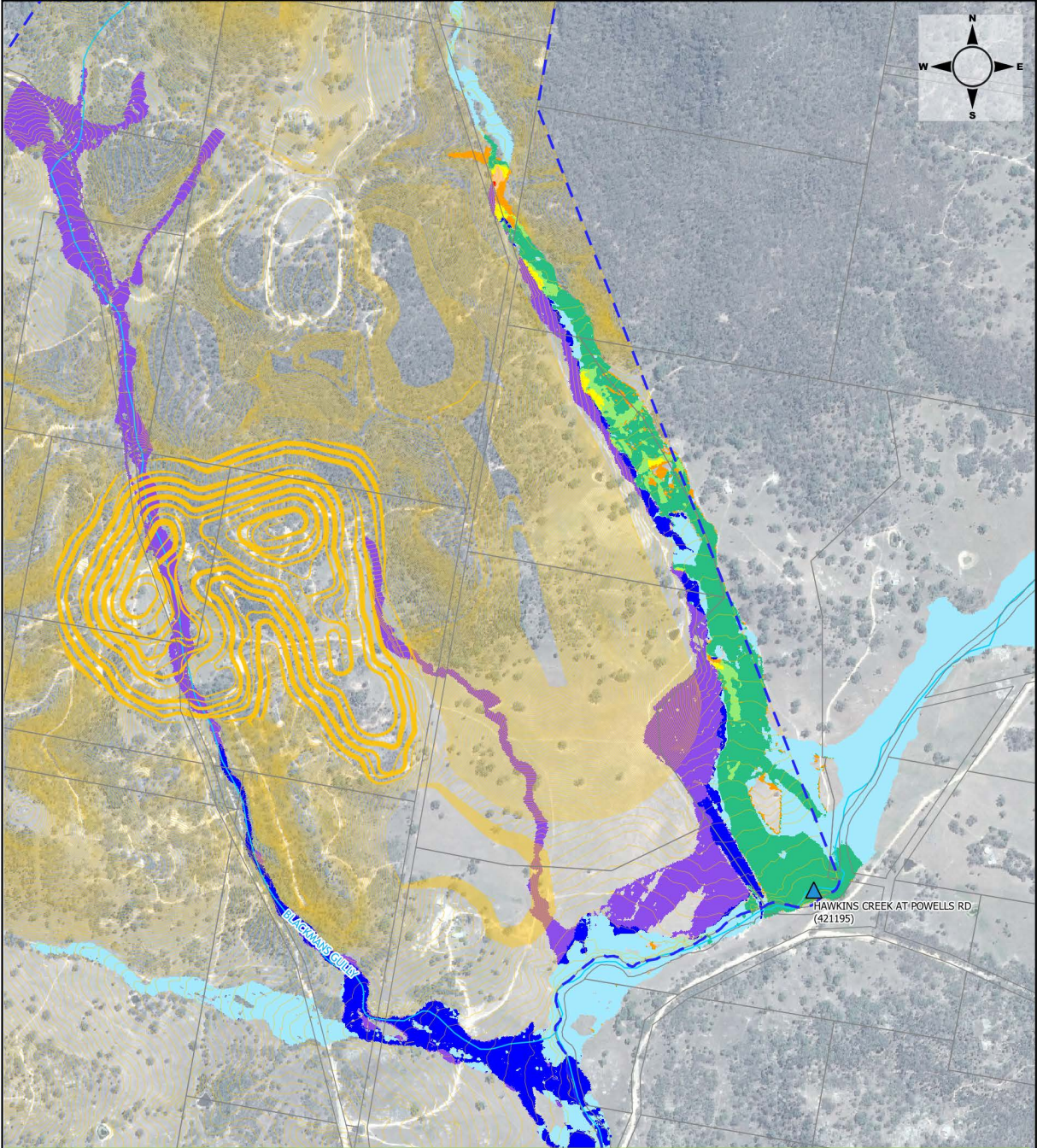
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
10% AEP, Final Landform





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

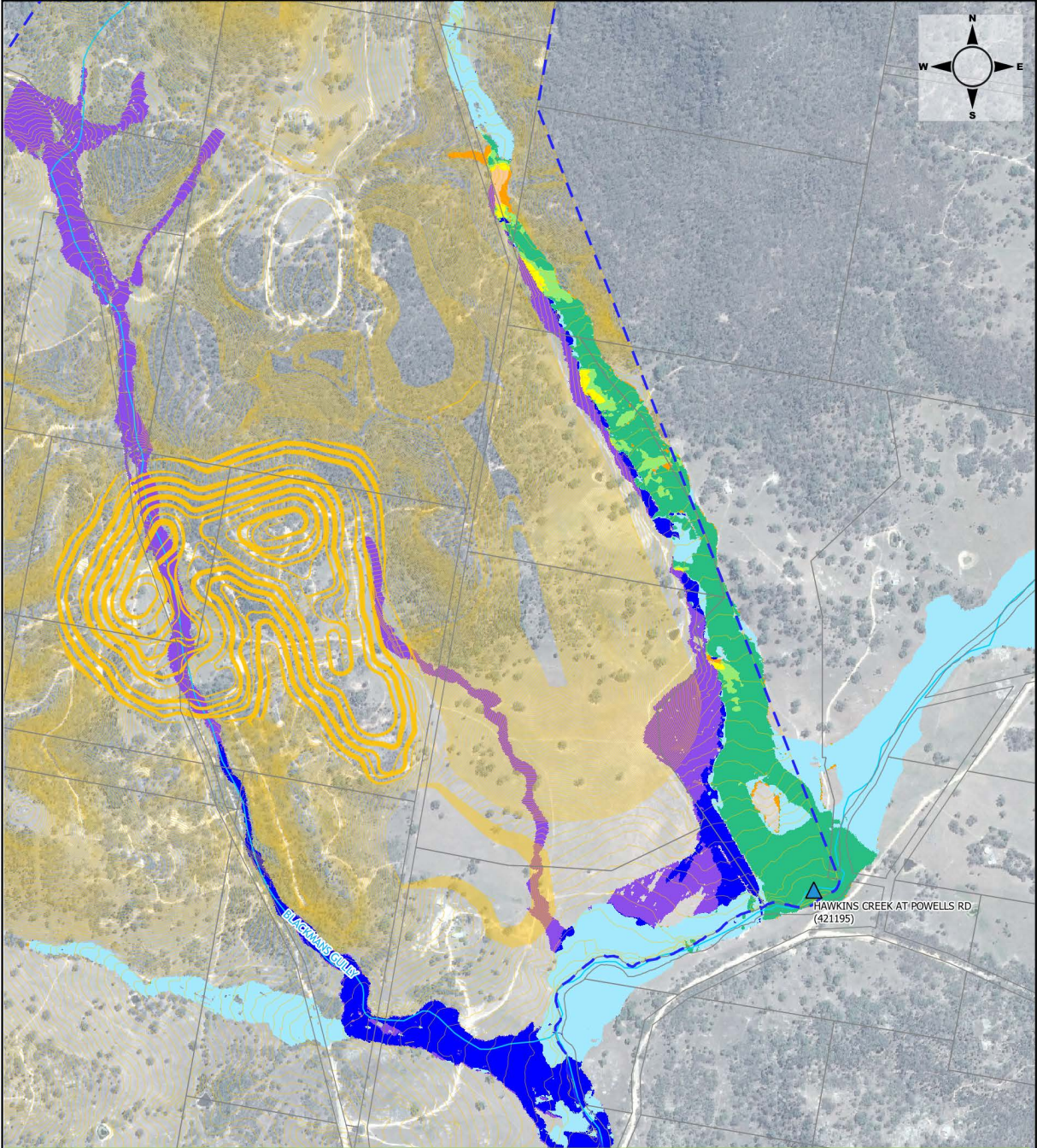
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
5% AEP, Final Landform





Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)
-  Was wet, now dry
-  Was dry, now wet

Change in peak water level

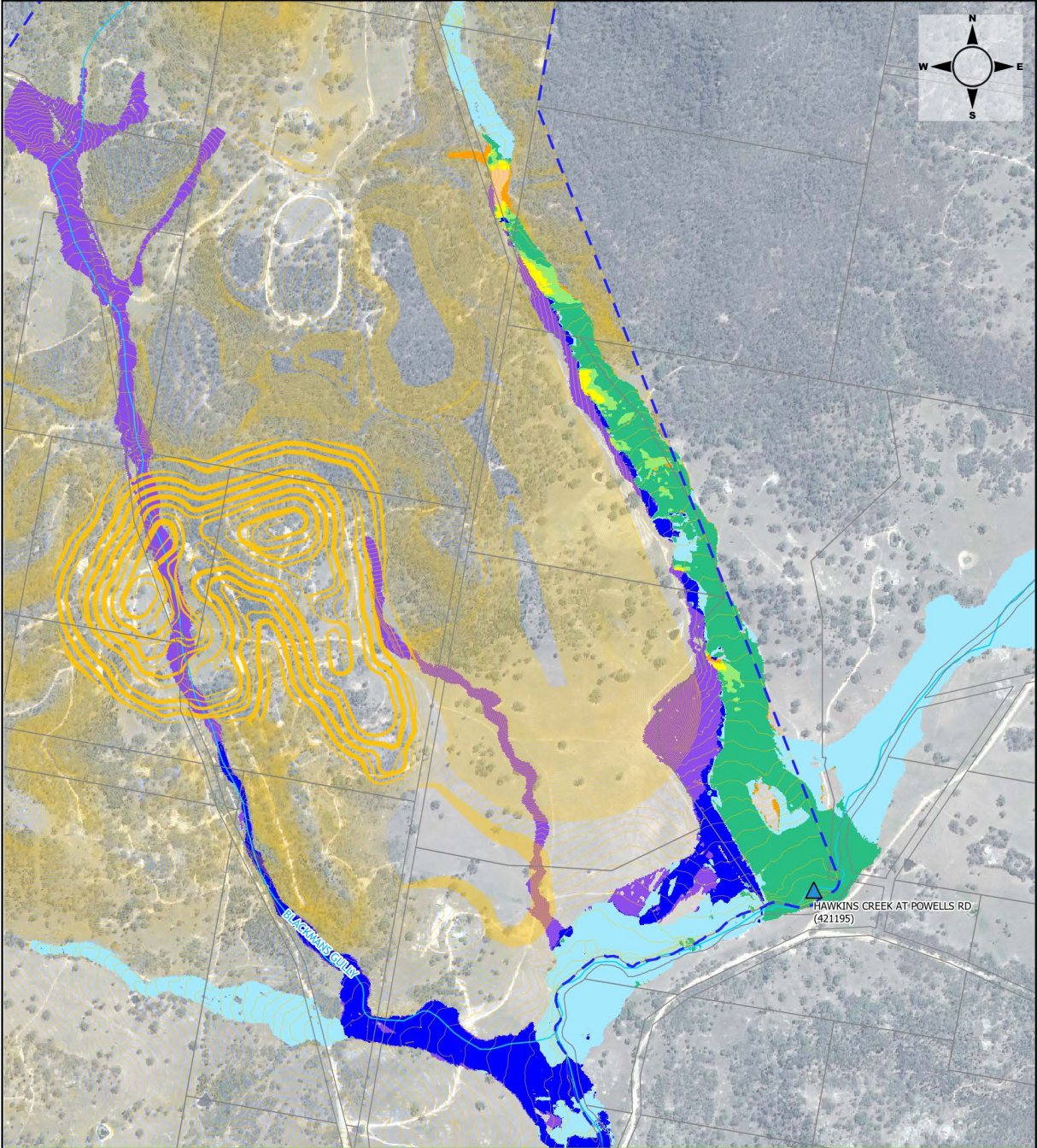
-  < -1.00 m
-  -1.00 m to -0.01 m
-  -0.01 m to 0.01 m
-  0.01 m to 0.05 m
-  0.05 m to 0.10 m
-  0.10 m to 0.50 m
-  0.50 m to 1.00 m
-  1.00 m to 2.00 m
-  2.00 m to 3.00 m
-  3.00 m to 5.00 m
-  > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
2% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

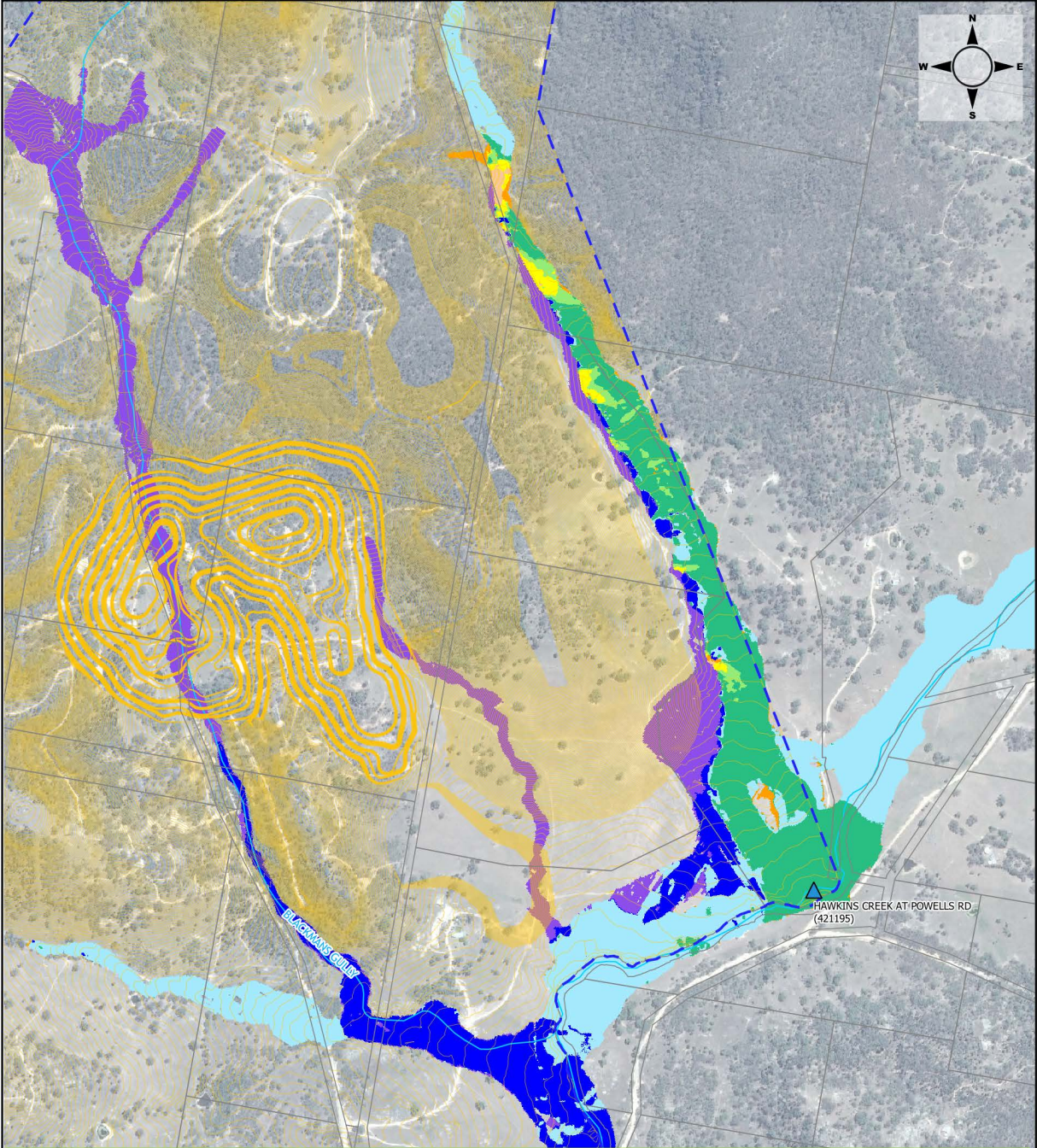
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
1% AEP, Final Landform





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

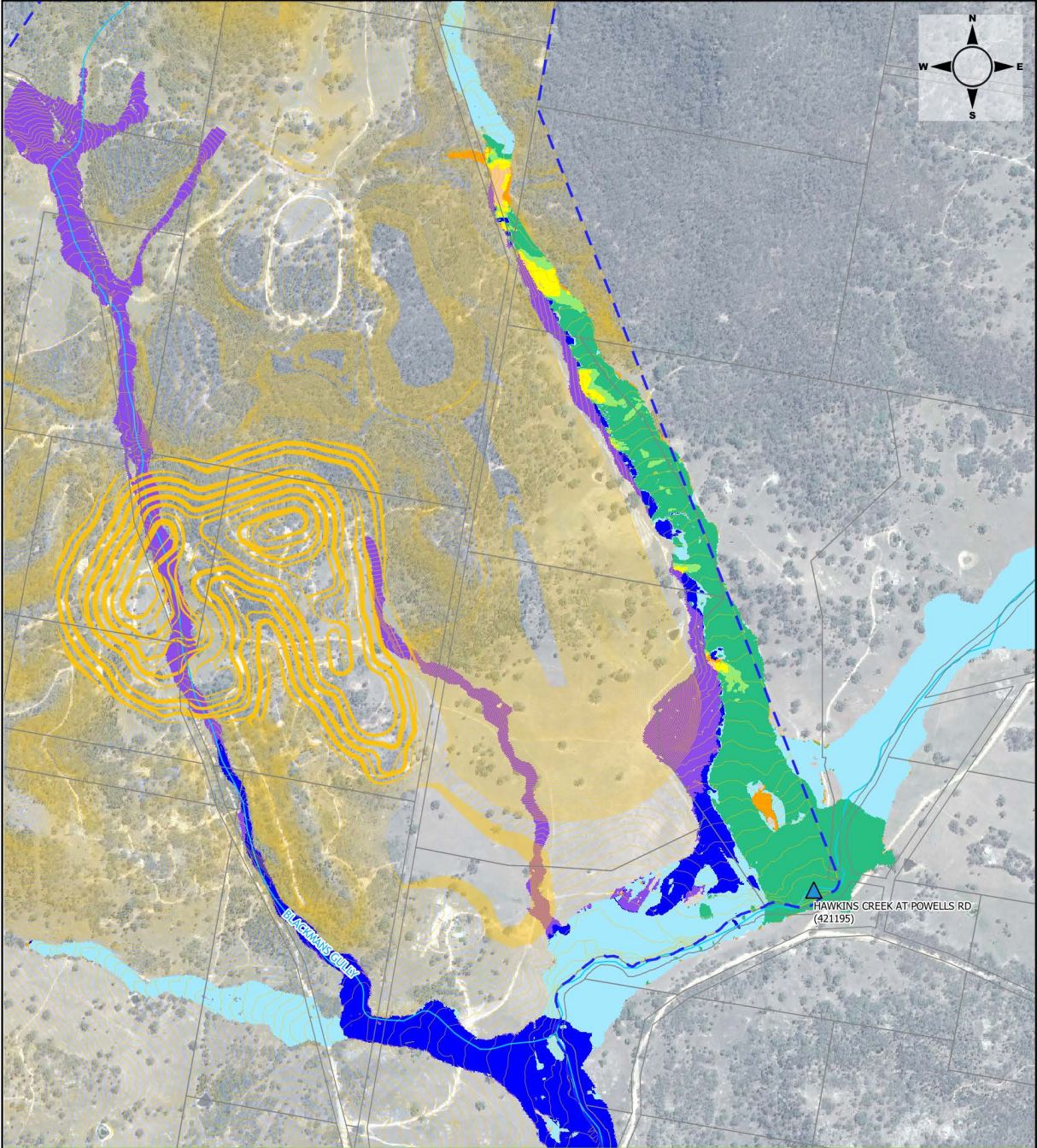
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
0.5% AEP, Final Landform





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

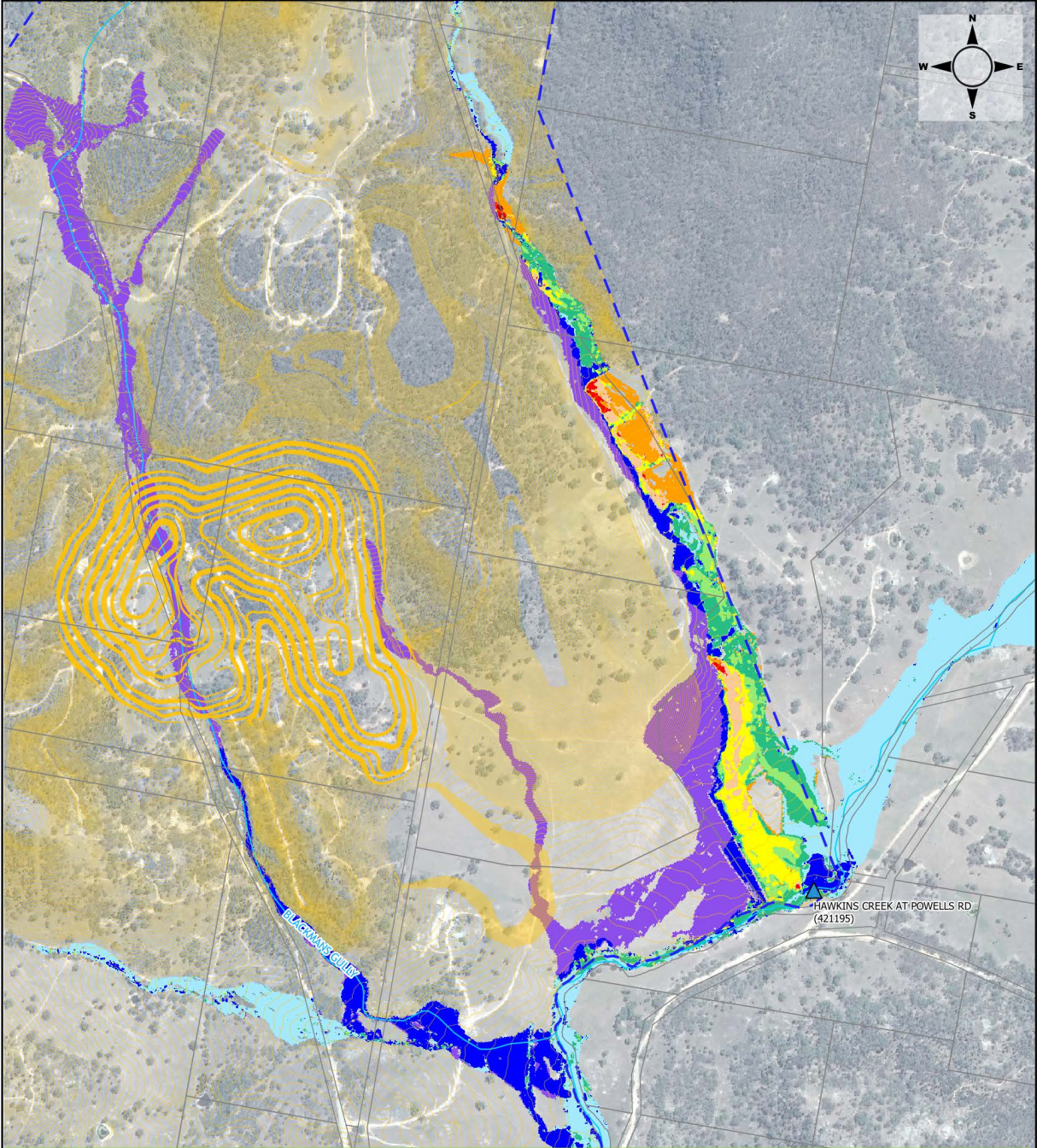
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m

Bowdens Silver Project

Change in Peak Water Level,
0.2% AEP, Final Landform





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

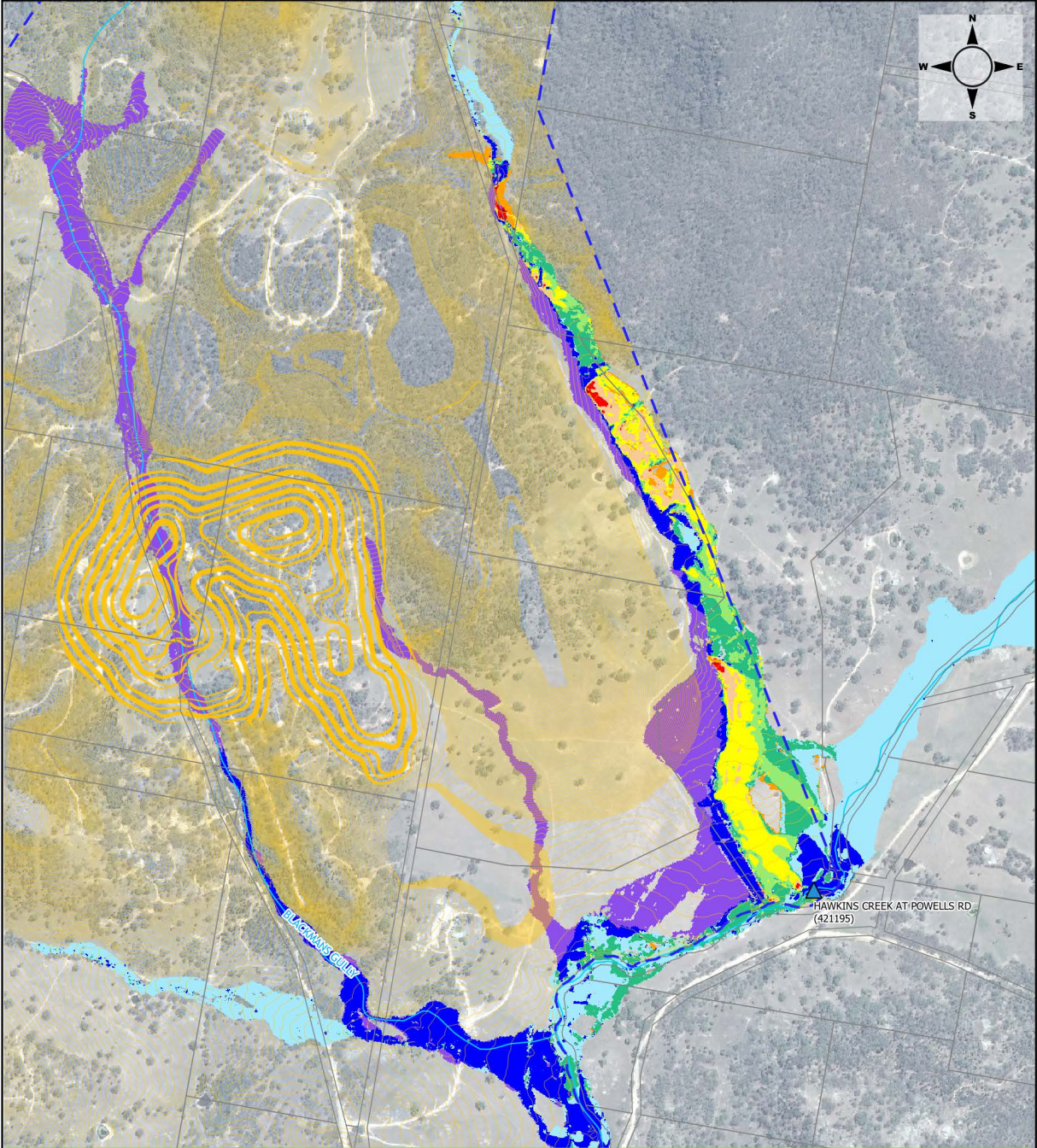
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
10% AEP, Final Landform





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

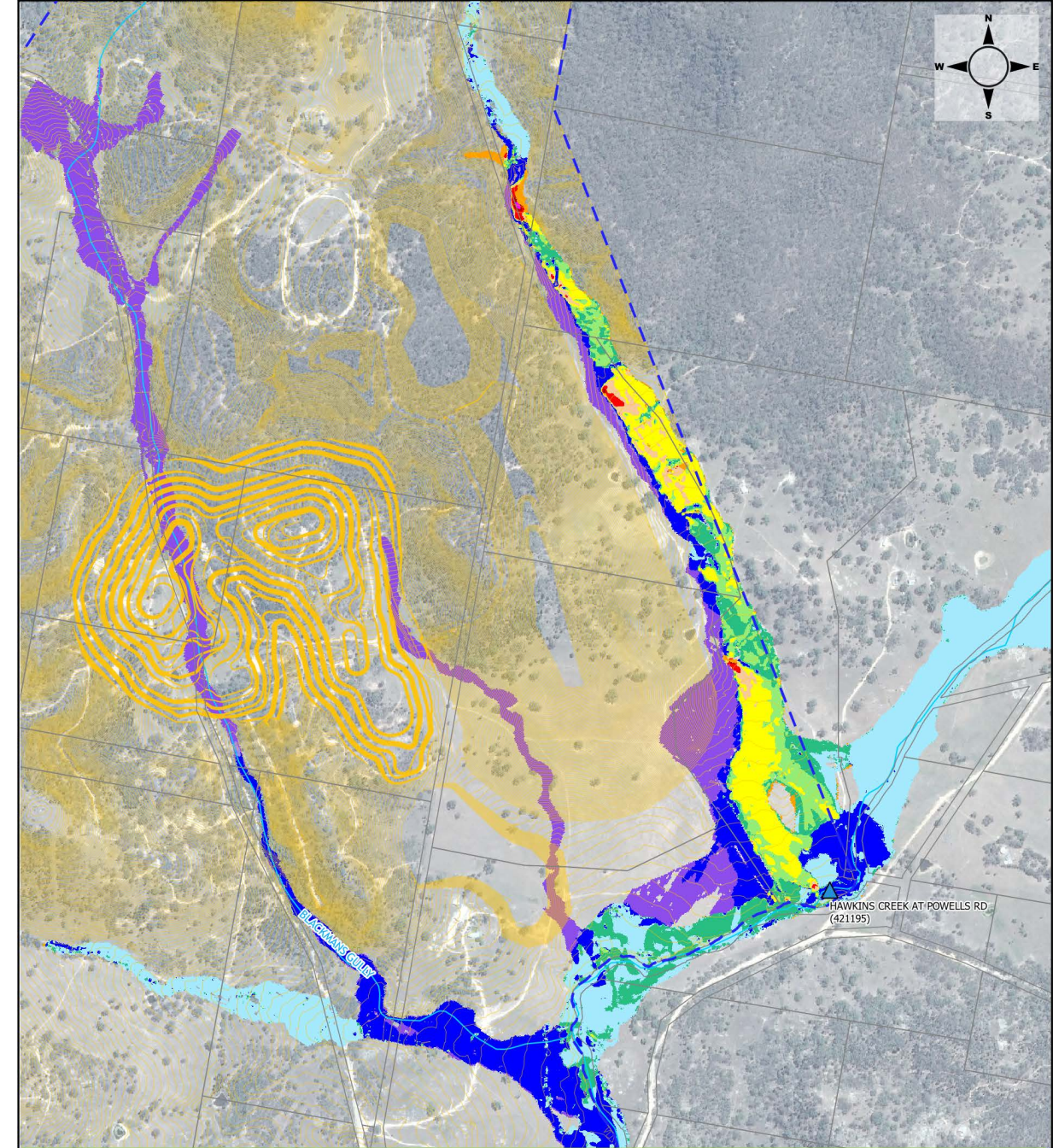
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
5% AEP, Final Landform





Projection: MGA Zone 55
Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)
-  Was wet, now dry
-  Was dry, now wet

Change in peak velocity

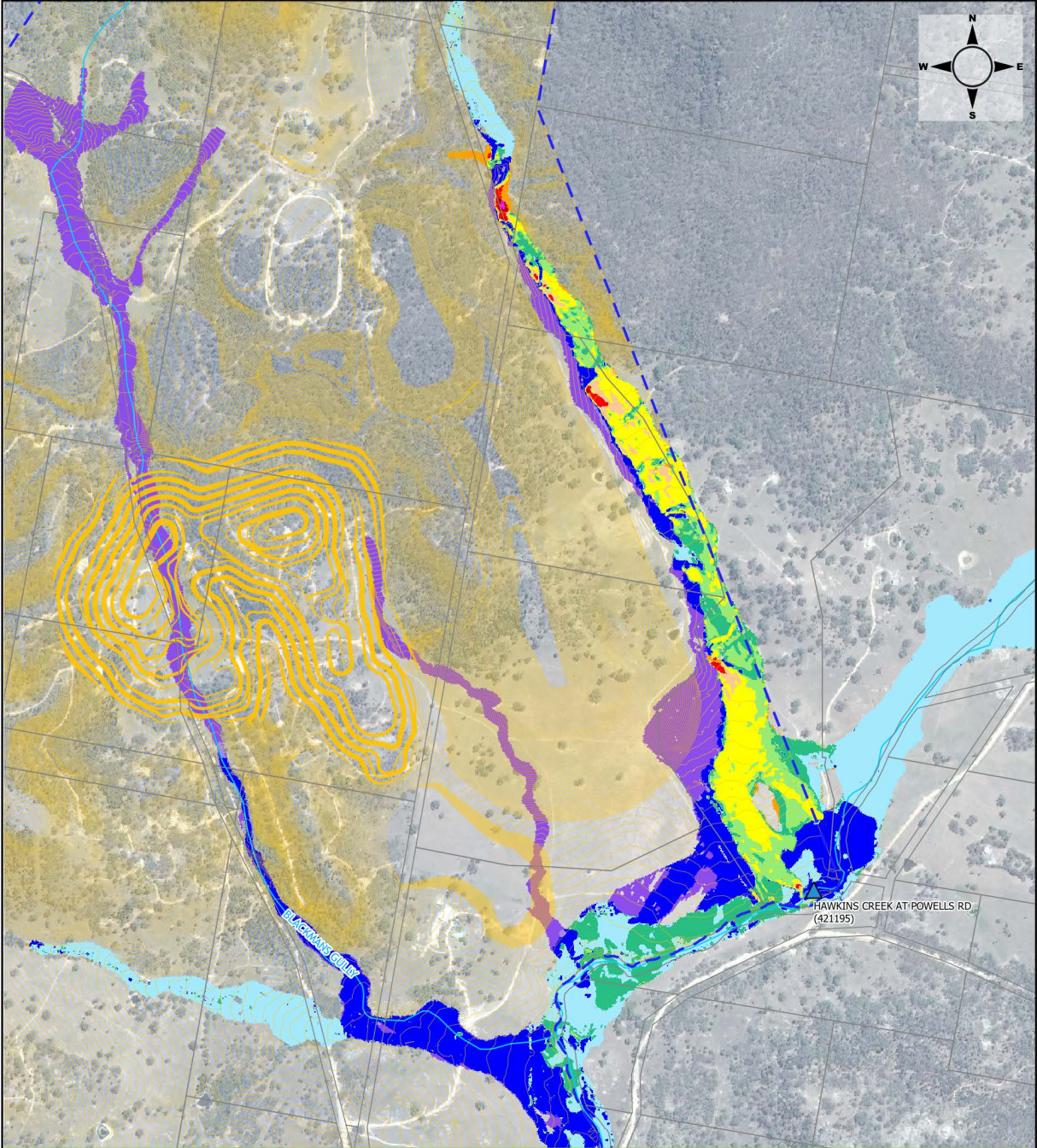
-  < -1.00 m/s
-  -1.00 m/s to -0.01 m/s
-  -0.01 m/s to 0.01 m/s
-  0.01 m/s to 0.05 m/s
-  0.05 m/s to 0.10 m/s
-  0.10 m/s to 0.50 m/s
-  0.50 m/s to 1.00 m/s
-  1.00 m/s to 2.00 m/s
-  2.00 m/s to 3.00 m/s
-  3.00 m/s to 5.00 m/s
-  > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
2% AEP, Final Landform

0 200 400 600 m





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

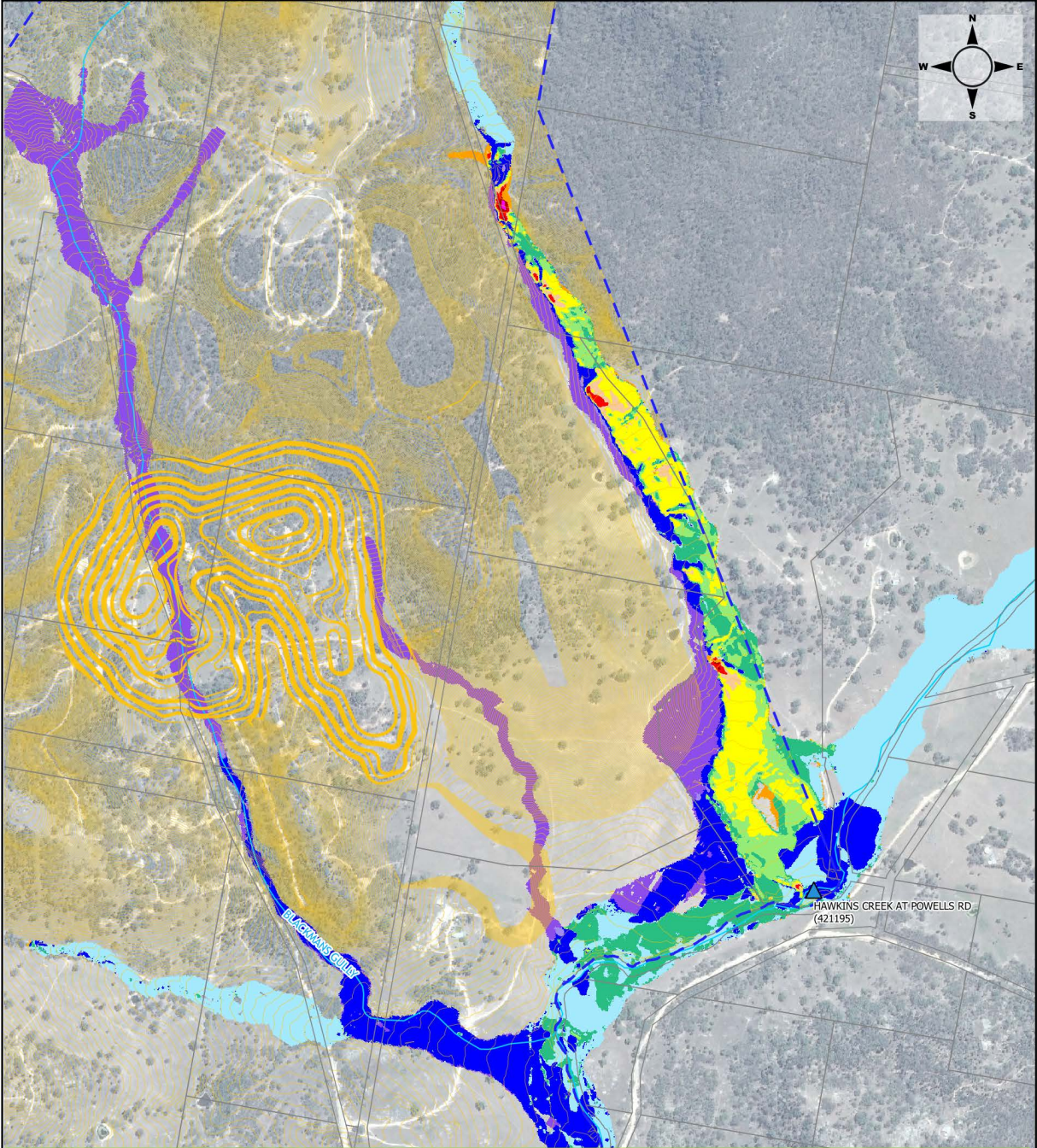
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
1% AEP, Final Landform





Legend

- Streamflow gauge
- Major watercourse
- Mine Site boundary
- Cadastre
- Mine plan contours (1 m interval)
- Was wet, now dry
- Was dry, now wet

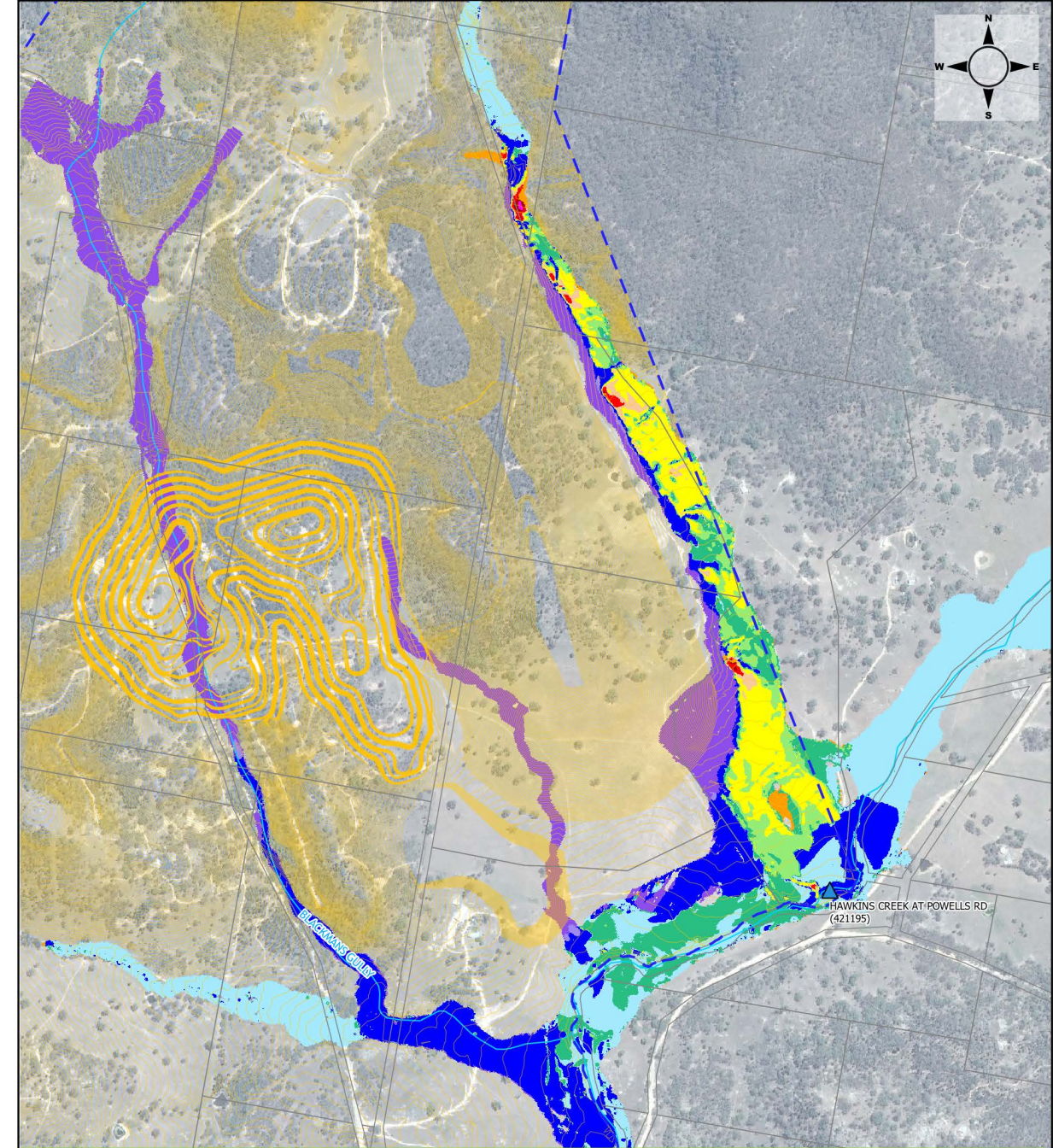
Change in peak velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

Bowdens Silver Project

Change in Peak Velocity,
0.5% AEP, Final Landform





Projection: MGA Zone 55 Datum: GDA 94

Legend

-  Streamflow gauge
-  Major watercourse
-  Mine Site boundary
-  Cadastre
-  Mine plan contours (1 m interval)
-  Was wet, now dry
-  Was dry, now wet

Change in peak velocity

-  < -1.00 m/s
-  -1.00 m/s to -0.01 m/s
-  -0.01 m/s to 0.01 m/s
-  0.01 m/s to 0.05 m/s
-  0.05 m/s to 0.10 m/s
-  0.10 m/s to 0.50 m/s
-  0.50 m/s to 1.00 m/s
-  1.00 m/s to 2.00 m/s
-  2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s

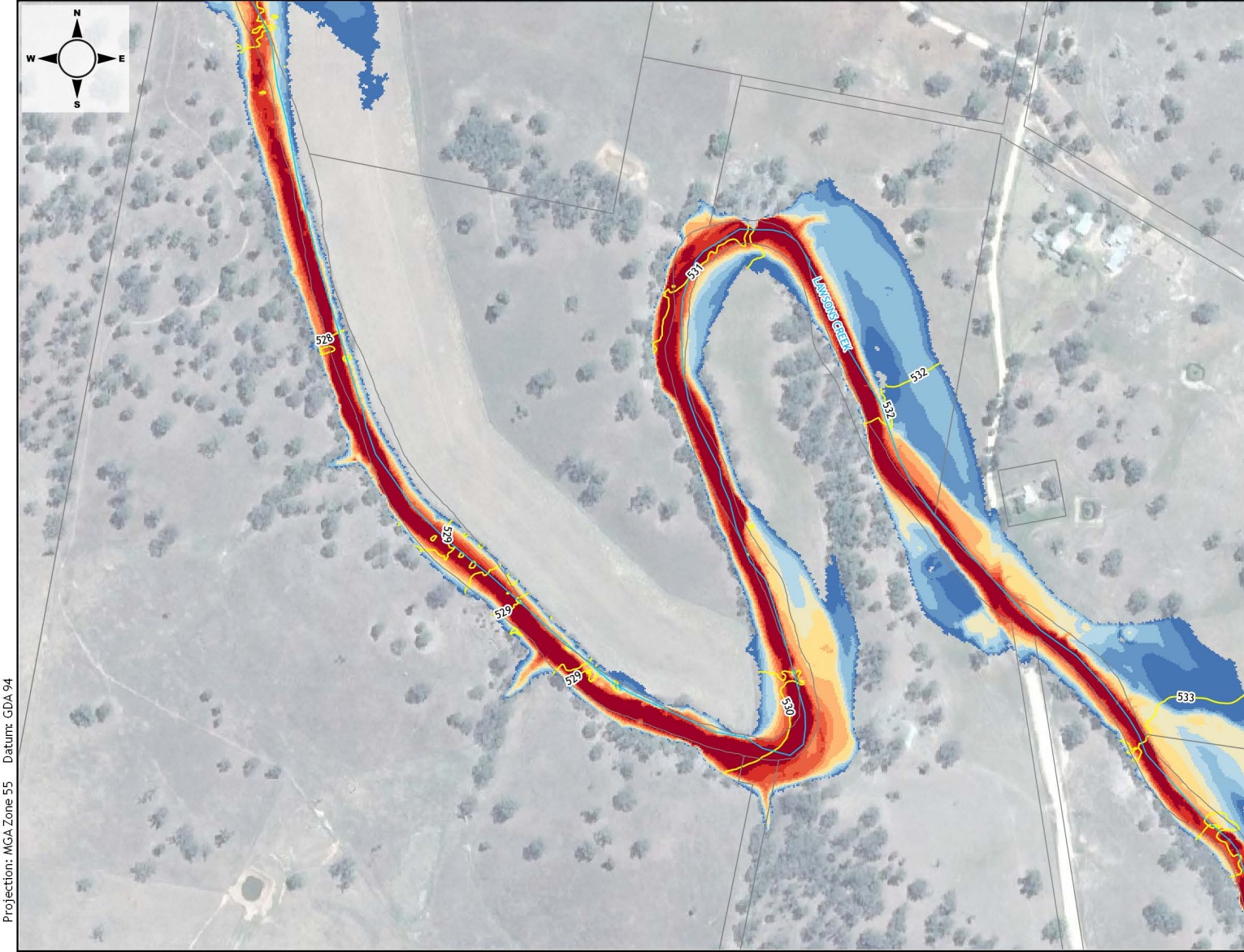
Bowdens Silver Project

Change in Peak Velocity,
0.2% AEP, Final Landform





Appendix F - Flood maps - Lawsons Creek crossing

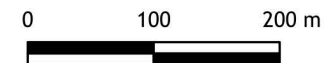


Legend

- Major watercourse
- Cadastre

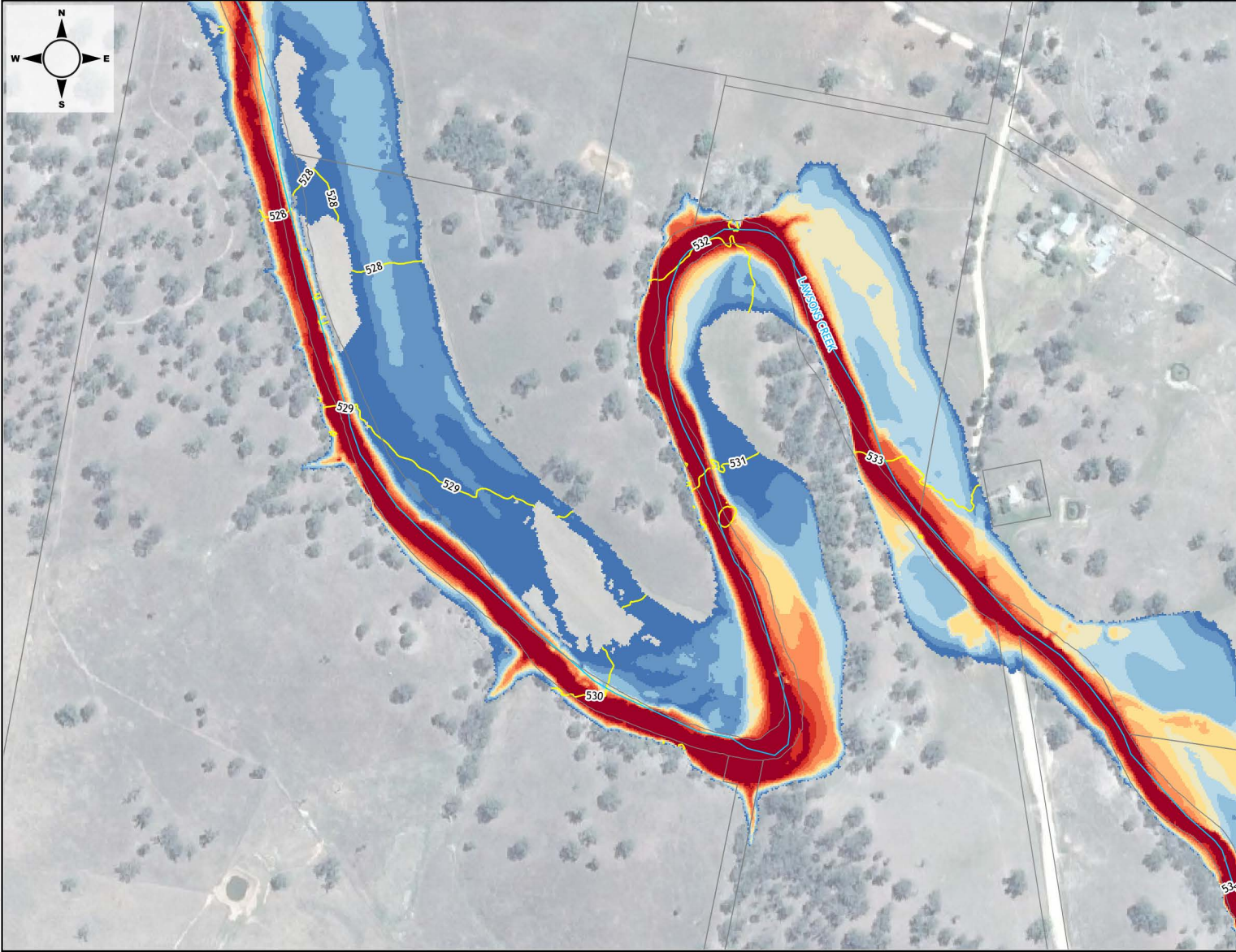
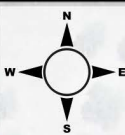
Depth

- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 10% AEP

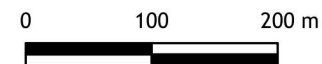


Legend

- Major watercourse
- Cadastre

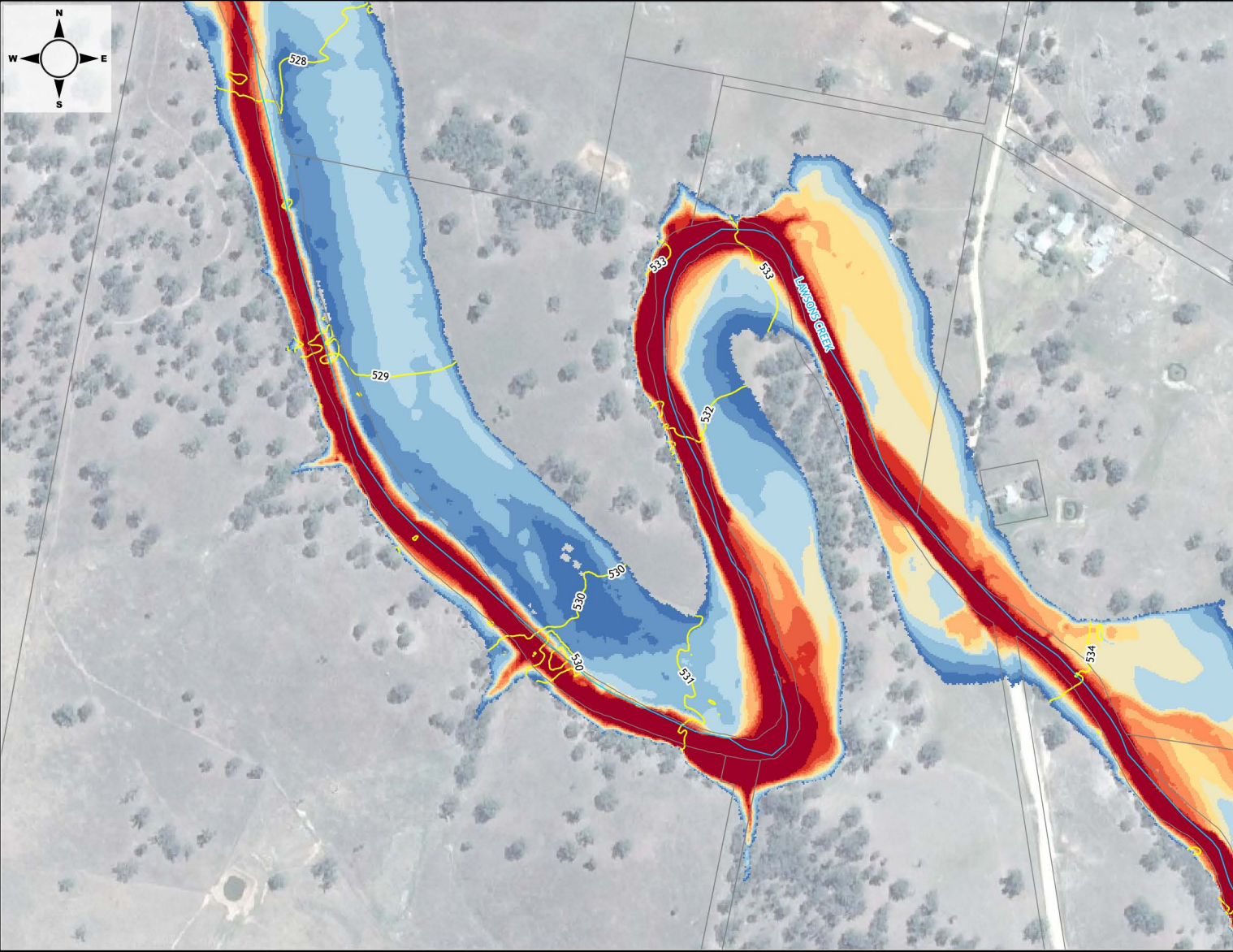
Depth

- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 5% AEP

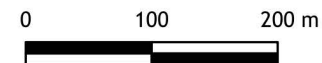


Legend

- Major watercourse
- Cadastre

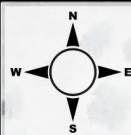
Depth

- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 2% AEP

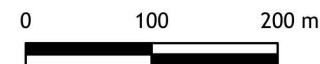


Legend

- Major watercourse
- Cadastre

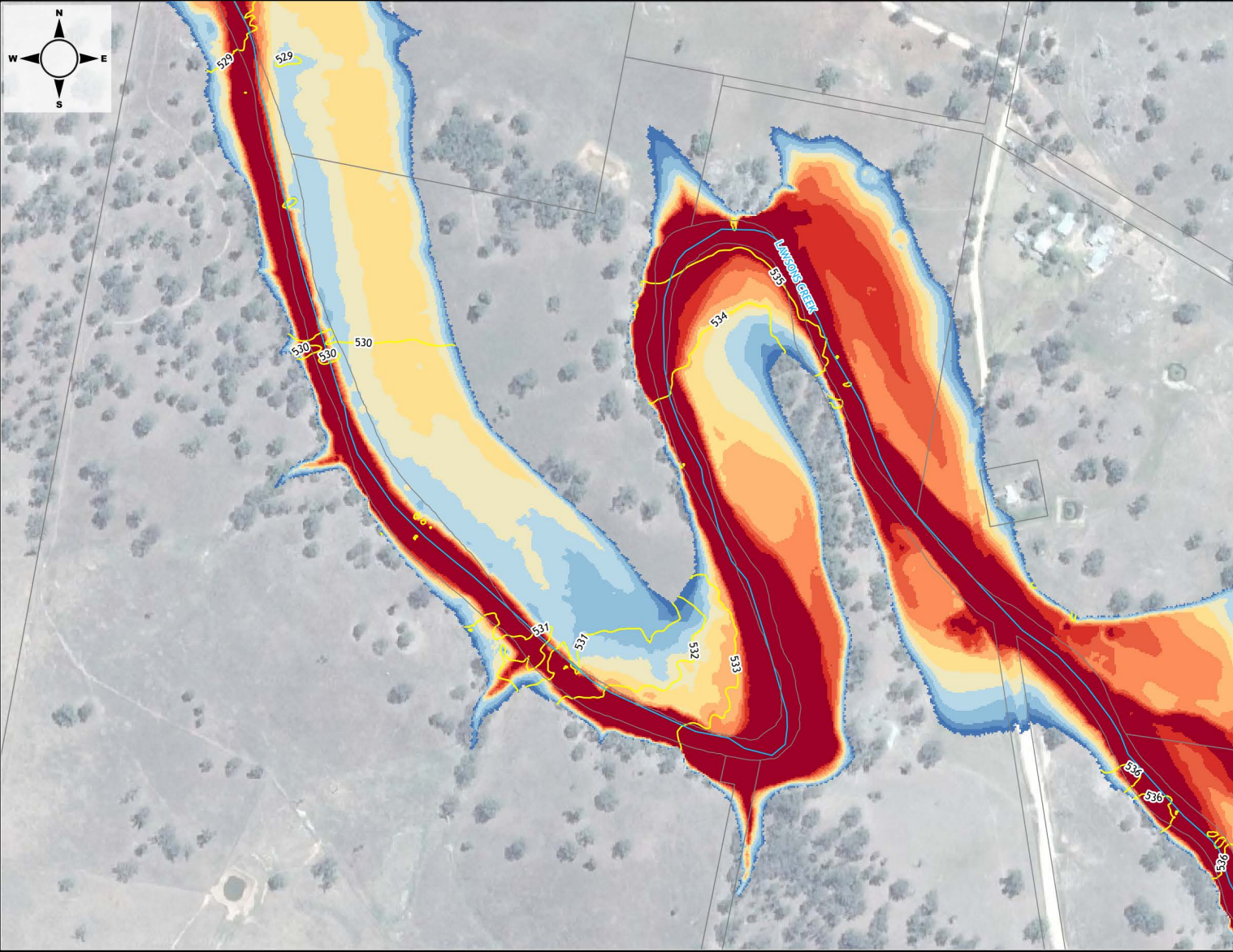
Depth

- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 1% AEP

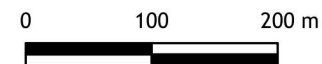


Legend

- Major watercourse
- Cadastre

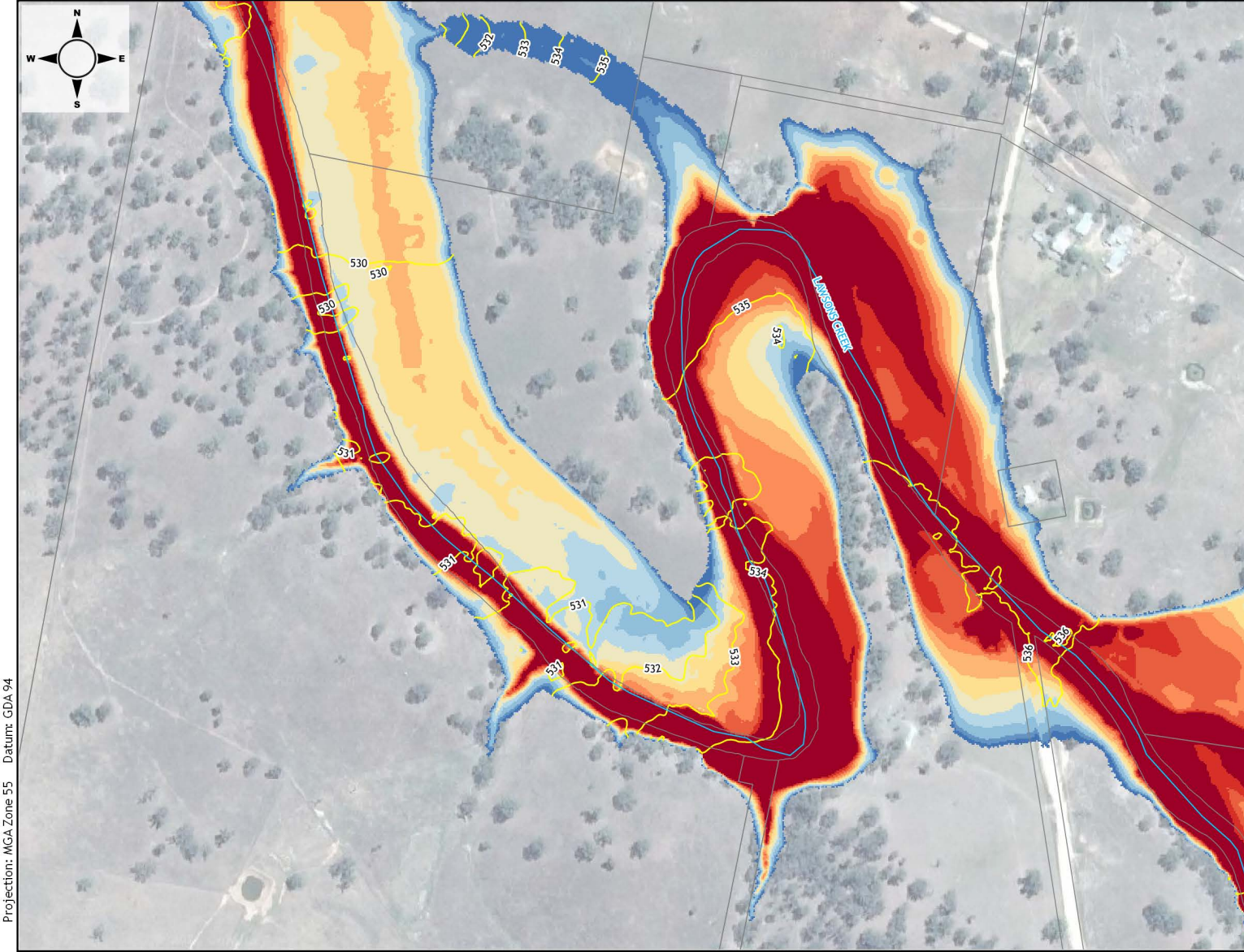
Depth

- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 0.5% AEP

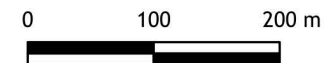


Legend

- Major watercourse
- Cadastre

Depth

- 0.00 m - 0.25 m
- 0.25 m - 0.50 m
- 0.50 m - 1.00 m
- 1.00 m - 1.50 m
- 1.50 m - 2.00 m
- 2.00 m - 2.50 m
- 2.50 m - 3.00 m
- 3.00 m - 3.50 m
- 3.50 m - 4.00 m
- 4.00 m - 4.50 m
- > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), 0.2% AEP

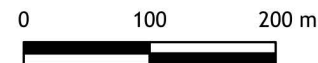


Legend

-  Major watercourse
-  Cadastre

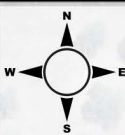
Depth

-  0.00 m - 0.25 m
-  0.25 m - 0.50 m
-  0.50 m - 1.00 m
-  1.00 m - 1.50 m
-  1.50 m - 2.00 m
-  2.00 m - 2.50 m
-  2.50 m - 3.00 m
-  3.00 m - 3.50 m
-  3.50 m - 4.00 m
-  4.00 m - 4.50 m
-  > 4.50 m



Bowdens Silver Project

Predicted Flood Extents & Depths
(Existing Condition), PMF

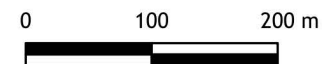


Legend

- Major watercourse
- Cadastral

Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 10% AEP

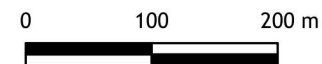


Legend

-  Major watercourse
-  Cadastre

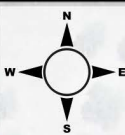
Velocity

-  0.0 m/s < 0.5 m/s
-  0.5 m/s < 1.0 m/s
-  1.0 m/s < 1.5 m/s
-  1.5 m/s < 2.0 m/s
-  2.0 m/s < 2.5 m/s
-  2.5 m/s < 3.0 m/s
-  3.0 m/s < 4.0 m/s
-  > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 5% AEP

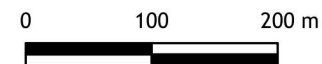


Legend

- Major watercourse
- Cadastre

Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 2% AEP

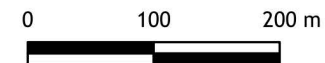


Legend

- Major watercourse
- Cadastre

Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 1% AEP

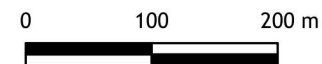


Legend

- Major watercourse
- Cadastre

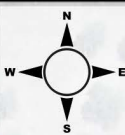
Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 0.5% AEP

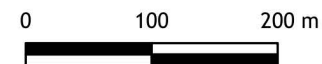


Legend

- Major watercourse
- Cadastre

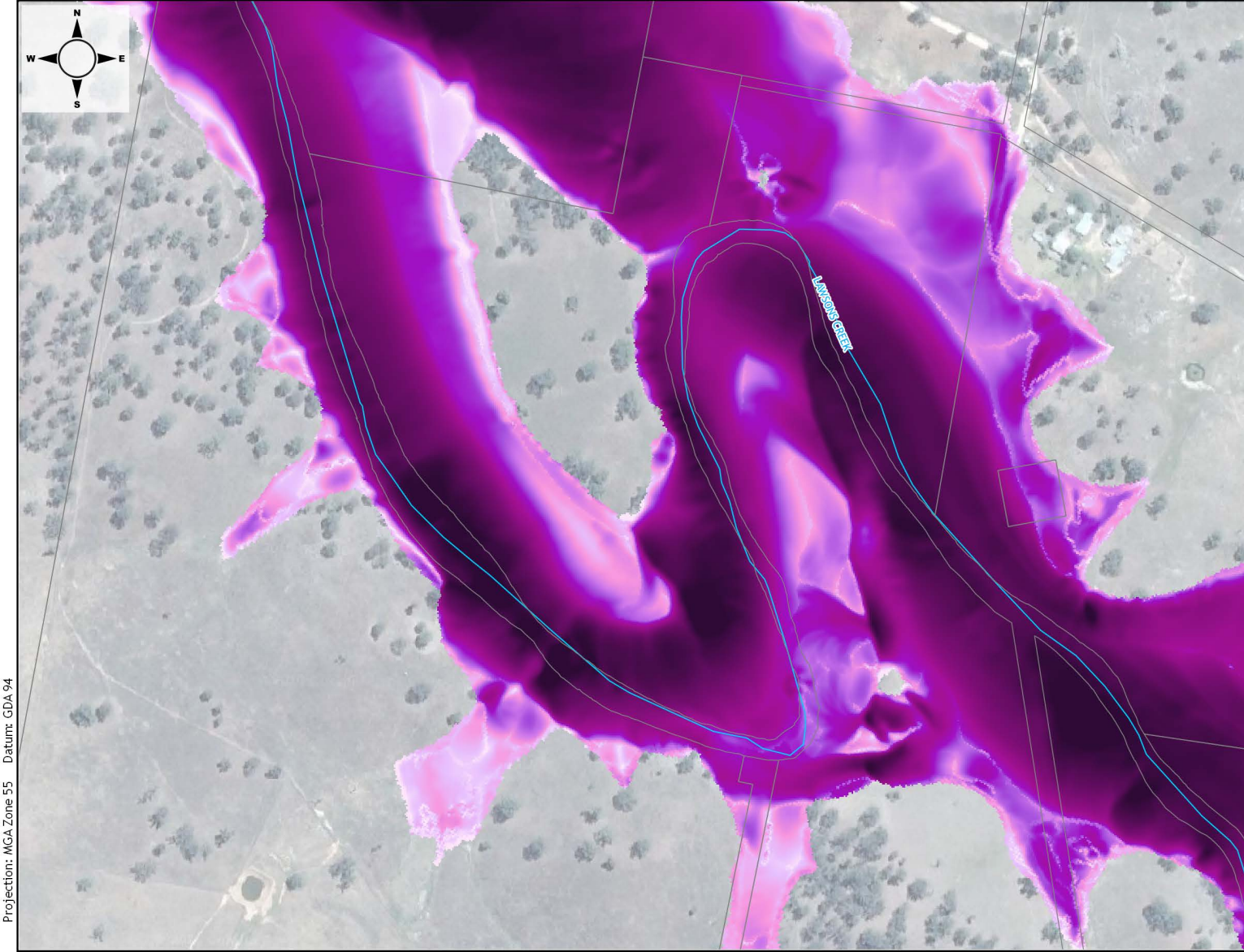
Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), 0.2% AEP

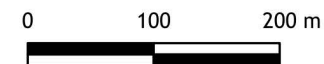


Legend

- Major watercourse
- Cadastre

Velocity

- 0.0 m/s < 0.5 m/s
- 0.5 m/s < 1.0 m/s
- 1.0 m/s < 1.5 m/s
- 1.5 m/s < 2.0 m/s
- 2.0 m/s < 2.5 m/s
- 2.5 m/s < 3.0 m/s
- 3.0 m/s < 4.0 m/s
- > 4.0 m/s



Bowdens Silver Project

Predicted Flood Velocity (Existing Condition), PMF



Legend

- Major watercourse
- Cadastral
- Proposed infrastructure

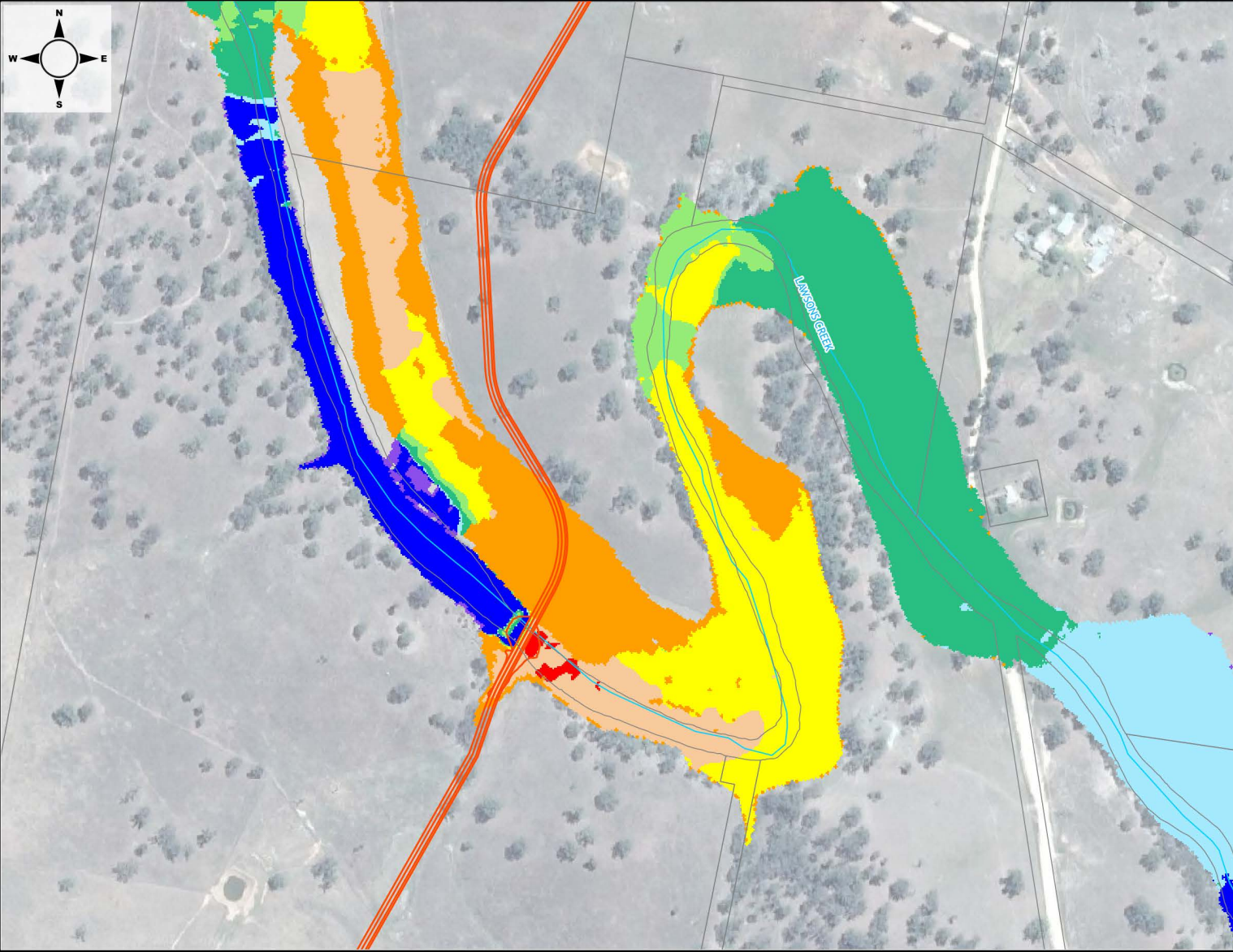
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m
- Was wet now dry
- Was dry now wet

0 100 200 m

Bowdens Silver Project

Change in Peak Water Level,
10% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

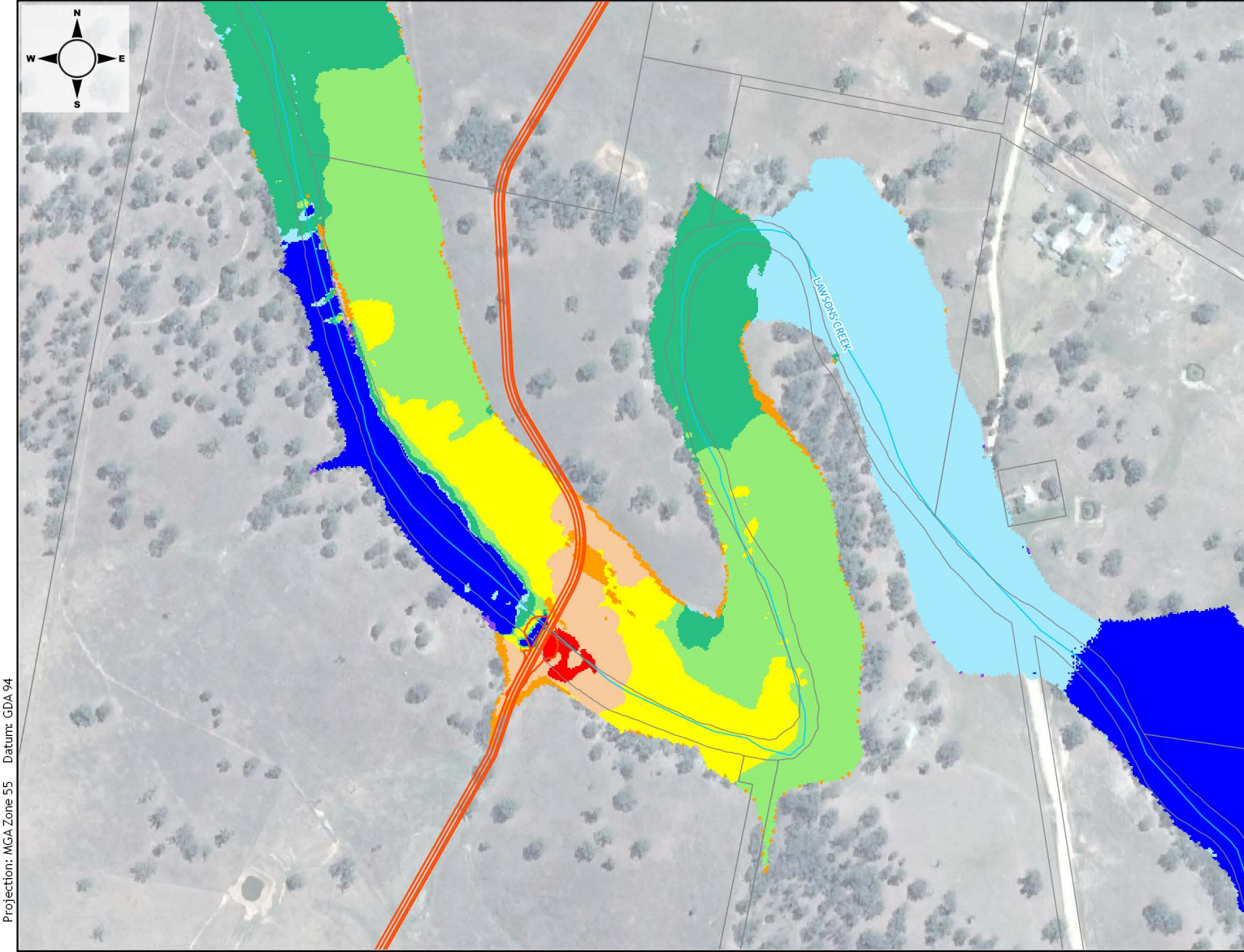
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m
- Was wet now dry
- Was dry now wet

0 100 200 m

Bowdens Silver Project

Change in Peak Water Level,
5% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

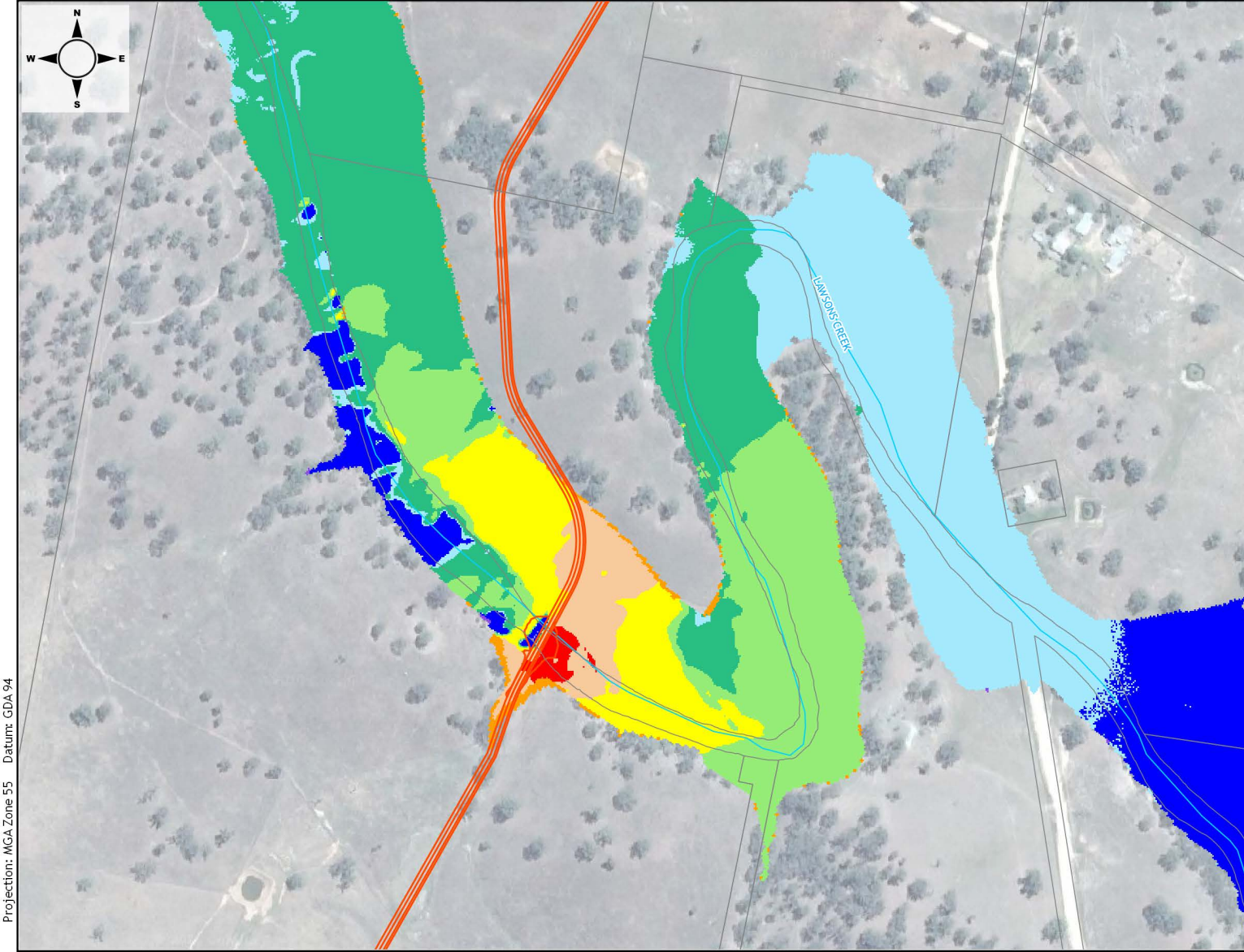
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m
- Was wet now dry
- Was dry now wet

0 100 200 m

Bowdens Silver Project

Change in Peak Water Level,
2% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastral
- Proposed infrastructure

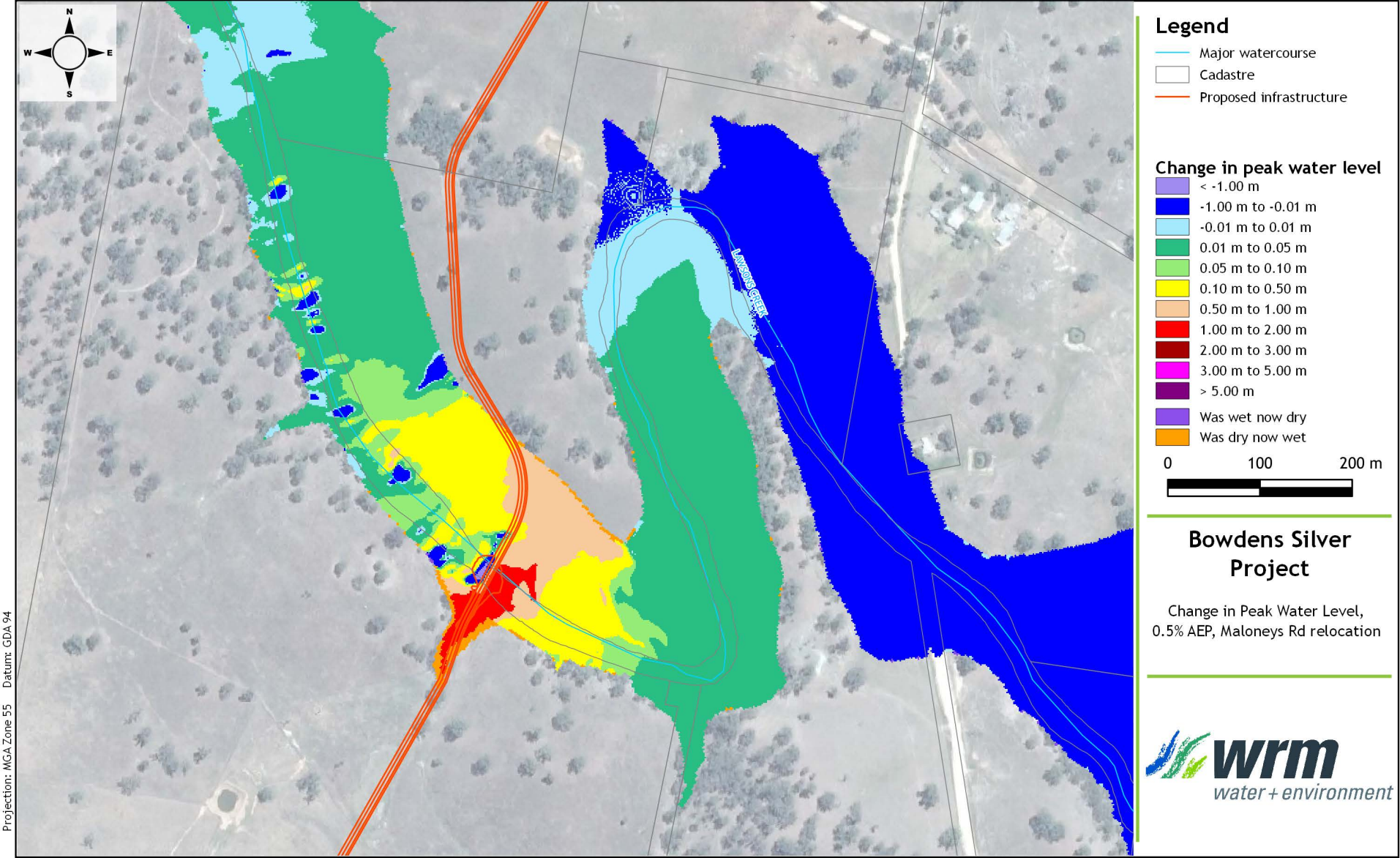
Change in peak water level

- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m
- Was wet now dry
- Was dry now wet

0 100 200 m

Bowdens Silver Project

Change in Peak Water Level,
1% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in peak water level

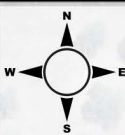
- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m
- Was wet now dry
- Was dry now wet

0 100 200 m

Bowdens Silver Project

Change in Peak Water Level,
0.5% AEP, Maloneys Rd relocation





Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in peak water level

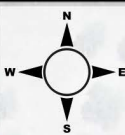
- < -1.00 m
- 1.00 m to -0.01 m
- 0.01 m to 0.01 m
- 0.01 m to 0.05 m
- 0.05 m to 0.10 m
- 0.10 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- 2.00 m to 3.00 m
- 3.00 m to 5.00 m
- > 5.00 m
- Was wet now dry
- Was dry now wet

0 100 200 m

Bowdens Silver Project

Change in Peak Water Level,
0.2% AEP, Maloneys Rd relocation





Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in velocity

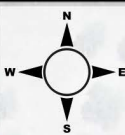
- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s
- Was wet now dry
- Was dry now wet

0 100 200 m



Bowdens Silver Project

Change in Peak Velocity,
10% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in velocity

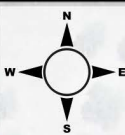
- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s
- Was wet now dry
- Was dry now wet

0 100 200 m



Bowdens Silver Project

Change in Peak Velocity,
5% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in velocity

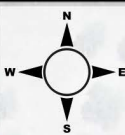
- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s
- Was wet now dry
- Was dry now wet

0 100 200 m



Bowdens Silver Project

Change in Peak Velocity,
2% AEP, Maloneys Rd relocation



Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in velocity

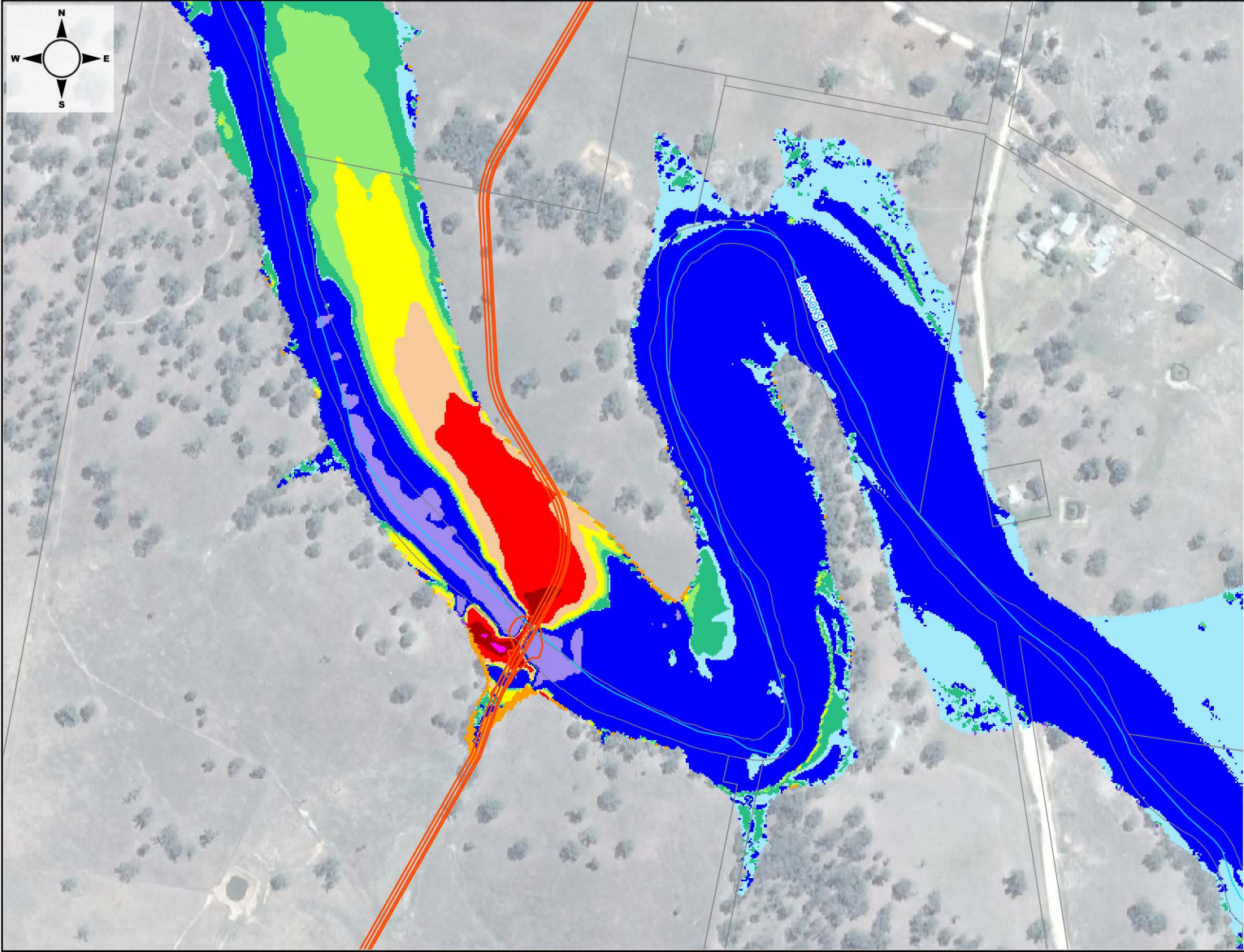
- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s
- Was wet now dry
- Was dry now wet

0 100 200 m



Bowdens Silver Project

Change in Peak Velocity,
1% AEP, Maloneys Rd relocation



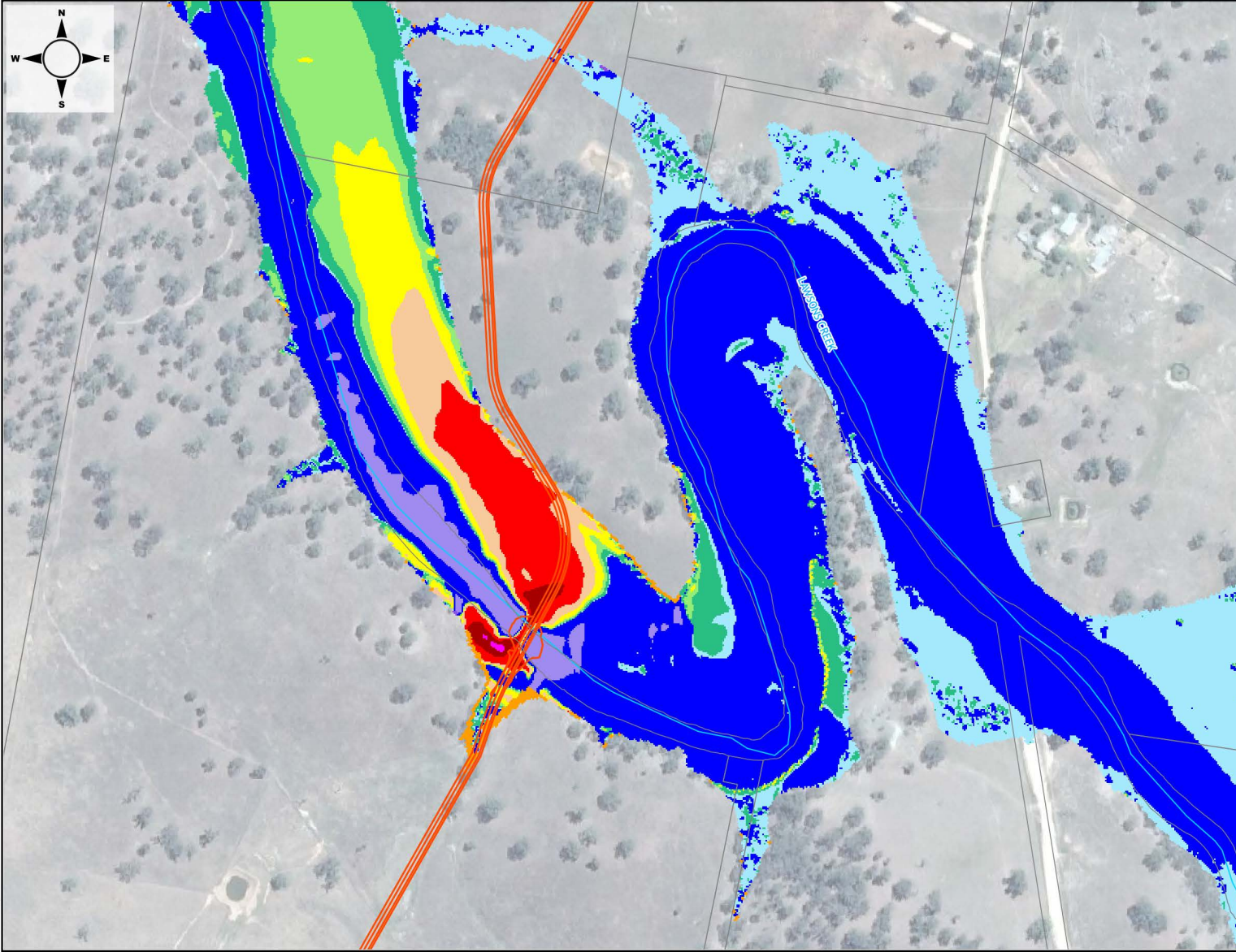
- Legend**
- Major watercourse
 - Cadastre
 - Proposed infrastructure

- Change in velocity**
- < -1.00 m/s
 - 1.00 m/s to -0.01 m/s
 - 0.01 m/s to 0.01 m/s
 - 0.01 m/s to 0.05 m/s
 - 0.05 m/s to 0.10 m/s
 - 0.10 m/s to 0.50 m/s
 - 0.50 m/s to 1.00 m/s
 - 1.00 m/s to 2.00 m/s
 - 2.00 m/s to 3.00 m/s
 - 3.00 m/s to 5.00 m/s
 - > 5.00 m/s
 - Was wet now dry
 - Was dry now wet
- 0 100 200 m

Bowdens Silver Project

Change in Peak Velocity,
0.5% AEP, Maloneys Rd relocation





Legend

- Major watercourse
- Cadastre
- Proposed infrastructure

Change in velocity

- < -1.00 m/s
- 1.00 m/s to -0.01 m/s
- 0.01 m/s to 0.01 m/s
- 0.01 m/s to 0.05 m/s
- 0.05 m/s to 0.10 m/s
- 0.10 m/s to 0.50 m/s
- 0.50 m/s to 1.00 m/s
- 1.00 m/s to 2.00 m/s
- 2.00 m/s to 3.00 m/s
- 3.00 m/s to 5.00 m/s
- > 5.00 m/s
- Was wet now dry
- Was dry now wet

0 100 200 m



Bowdens Silver Project

Change in Peak Velocity,
0.2% AEP, Maloneys Rd relocation

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Memorandum

Date	18 November 2021	Pages	29
Attention	Paul Ryall		
Company	R.W. Corkery & Co Pty Ltd		
Job No.	1356-05-J		
Subject	Bowdens Silver Project EIS - hydraulic modelling and options assessment for the Lawsons Creek crossing (Maloneys Road)		

1.0 Introduction

The Bowdens Silver Project (the Project) EIS (WRM, 2020a) included a flood impact assessment of the proposed new Maloneys Crossing of Lawsons Creek. The EIS design incorporated box culverts to convey Lawson Creek channel flows.

As part of the response to submissions for the Bowdens Silver Project EIS, Bowdens Silver commissioned WRM Water & Environment Pty Ltd (WRM) in November 2020 to prepare a flood impact assessment for a bridge crossing design which would pass bank-full flows below deck level. Hydraulic modelling was undertaken for a conceptual bridge crossing design. The results of this assessment was documented in a memorandum dated 2 November 2020 (WRM, 2020b). The results presented in the WRM (2020b) memo were used to inform discussions with NRAR and DPIE-Water.

Following discussions with NRAR and DPIE-Water, additional hydraulic modelling is required to refine the concept bridge design. This memo presents the results of hydraulic modelling undertaken for the following two bridge options:

- A dual span bridge option (two 30 m spans) with a 1 mid-span pier; and
- A single span bridge option (a single 60 m span) without a mid-span pier.

The flood level impact assessment was undertaken for the 10%, 5%, 2% and 1% annual exceedance probability (AEP) events.

2.0 Design criteria

The following sections summarise the adopted design criteria for the bridge crossing based on discussions with NRAR and DPIE-Water.

2.1 Bank-full flow criteria

The bridge design must provide conveyance of the Lawsons Creek main channel bank-full discharge, which defines the riparian corridor. The WRM (2020b) assessment estimated the Lawsons Creek bank-full discharge as 430 m³/s, which represents the peak discharge during a 5% AEP flood event in Lawsons Creek. This bank-full discharge corresponds to a maximum flood level of approximately 529.7 mAHD at the proposed bridge location.

2.2 Freeboard criteria

The bridge soffit is required to have 0.3 m (300 mm) freeboard above the 5% AEP water level (the bank-full flow) based on the Austroads (2008) guideline.

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2.3 Flood impacts

The flood impacts of both the single and dual-span bridge options were assessed based on the predicted changes in water levels, velocities, flow distribution (conveyance) and break-out flows.

DPIE-Water acknowledge that there are likely to be flood impacts resulting from construction of the bridge and embankment, particularly for flood events larger than the bank-full flow in Lawsons Creek. However, the impacts may be acceptable to DPIE-Water depending on the significance of these impacts.

3.0 Proposed crossing configuration

3.1 Dual-span bridge option

Figure 1 shows a plan view and the configuration of the proposed dual-span bridge option for the Maloneys Road crossing of Lawsons Creek. Figure 2 shows a cross section view of the proposed crossing including the predicted developed (with bridge) conditions water levels for the 10%, 5%, 2% and 1% AEP events.

The proposed bridge characteristics adopted in the TUFLOW model were:

- Bridge soffit level - 530 mAHD;
- Deck level - 531 mAHD;
- Deck thickness - 1 m;
- Deck width - 7 m;
- Guard rail height - 1 m;
- Total bridge length - 60 m (consisting of two 30 m spans);
- Pier width - 1.2 m diameter central pier (in-channel);
- Pier blockage factor - 2% blockage due to piers; and
- Rail blockage factor - 100% blockage due to guard rails.

Two sets of reinforced concrete box culverts (RCBCs) are proposed along the proposed road embankment within the northern overbank areas of Lawsons Creek. Details of these culverts are provided in Table 1.

Table 1 - Details of proposed overbank culverts

Culvert ID	Type	Width (m)	Height (m)	No. of barrels	Length (m)	US invert (mAHD)	DS invert (mAHD)
CH180	RCBC	1.2	0.9	2	11	529.4	529.2
CH265	RCBC	1.2	0.9	2	13	528.7	528.6

RCBC = Reinforced concrete box culvert

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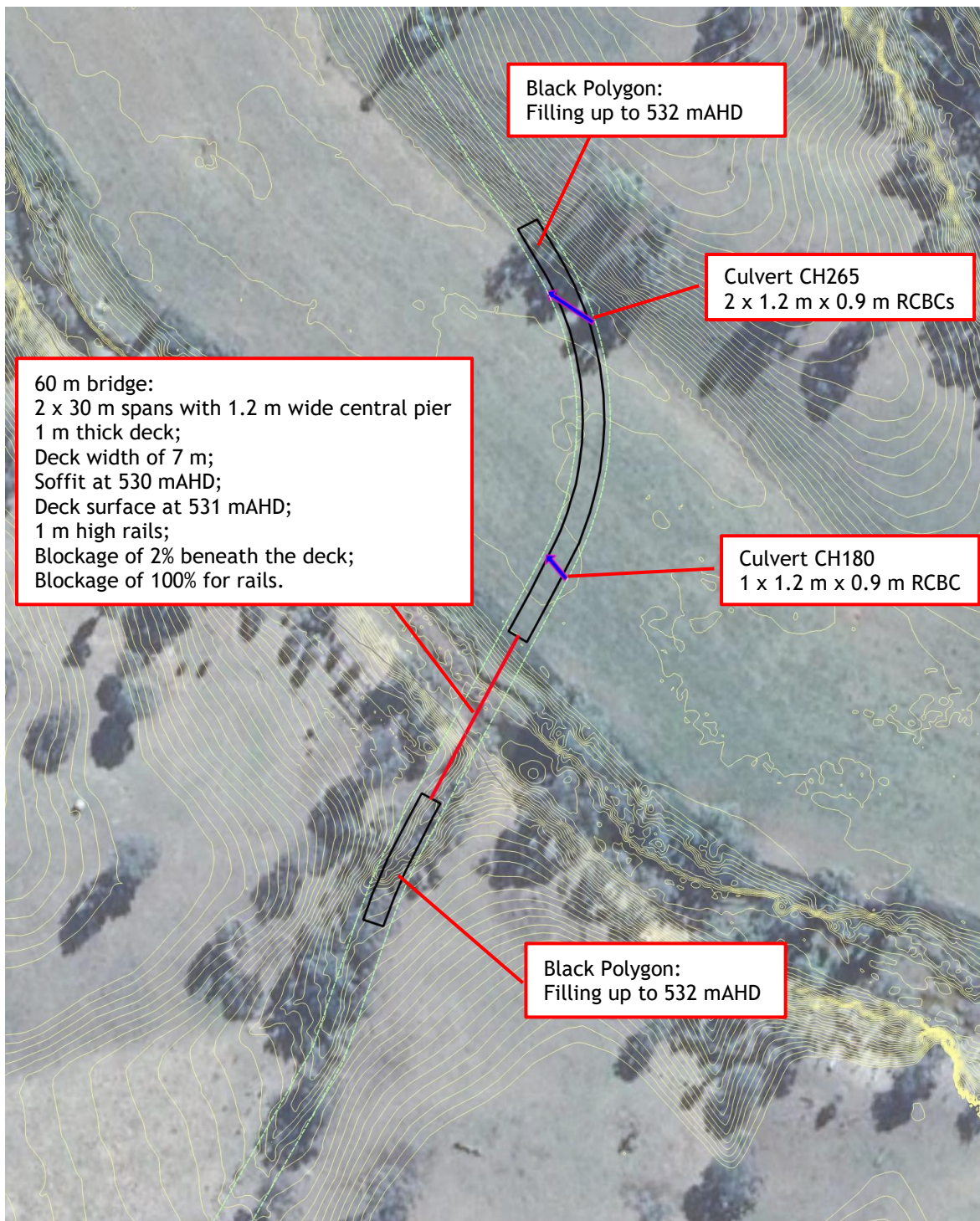


Figure 1 - Plan view of the proposed Maloneys Road crossing in Lawsons Creek, dual-span bridge option

Memorandum

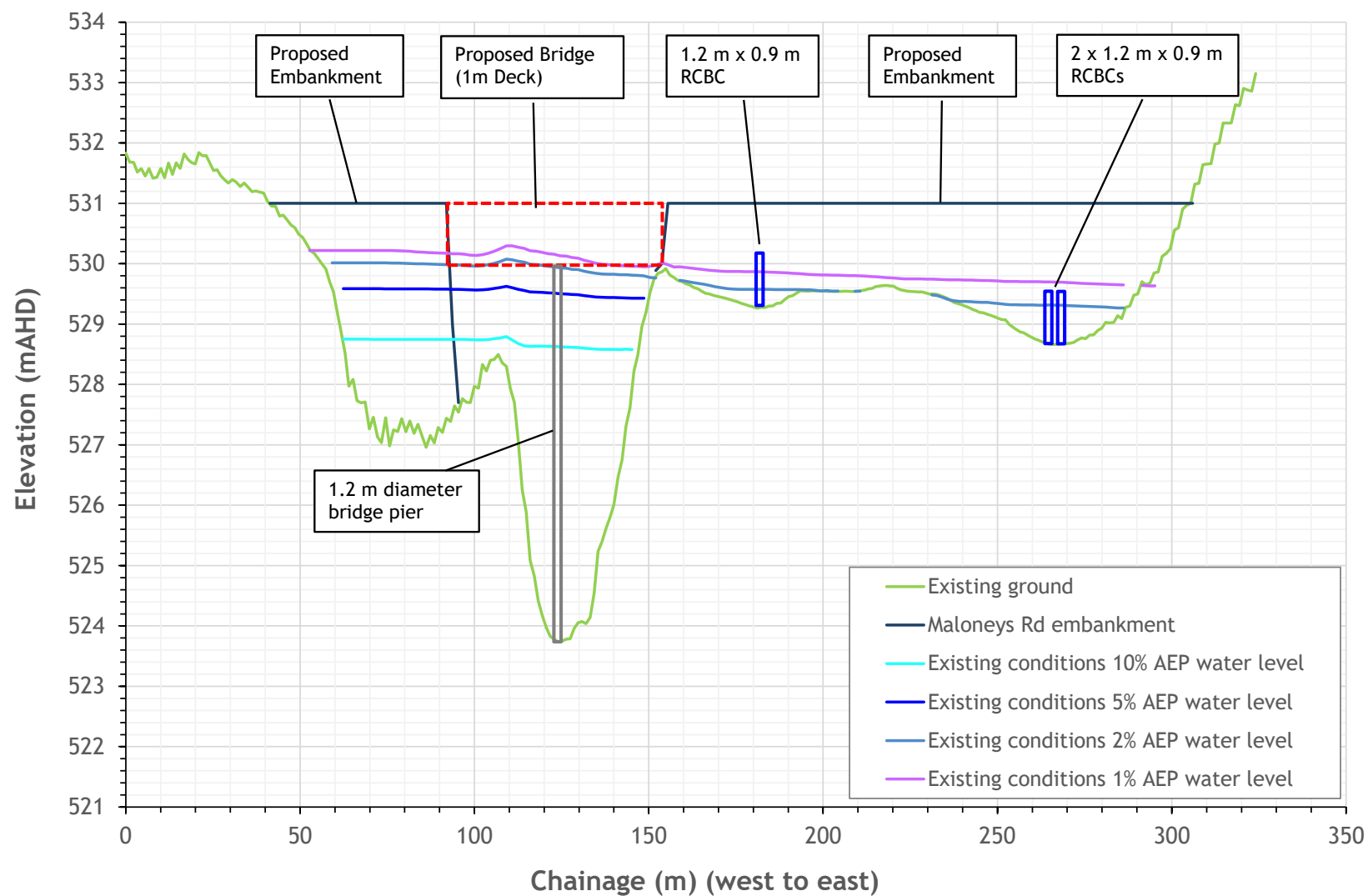


Figure 2 - Cross section view of proposed bridge and crossings for Maloneys Road at Lawsons Creek, dual-span bridge option

Memorandum

3.2 Single-span bridge option

Figure 3 shows a plan view and the configuration of the proposed single-span bridge option for the Maloneys Road crossing of Lawsons Creek. Figure 4 shows a cross section view of the proposed crossing including the predicted developed (with bridge) conditions water levels for the 10%, 5%, 2% and 1% AEP events.

The proposed bridge characteristics adopted in the TUFLOW model were:

- Bridge soffit level - 530 mAHD;
- Deck level - 532 mAHD;
- Deck thickness - 2 m;
- Deck width - 7 m;
- Guard rail height - 1 m;
- Total bridge length - 60 m (consisting of a single 60 m span);
- Rail blockage factor - 100% blockage due to guard rails.

Two sets of reinforced concrete box culverts (RCBCs) are proposed along the proposed road embankment within the northern overbank areas of Lawsons Creek as per the dual-span bridge option. The configuration of these culverts is the same as the dual-span bridge and are shown in Table 1.

Memorandum

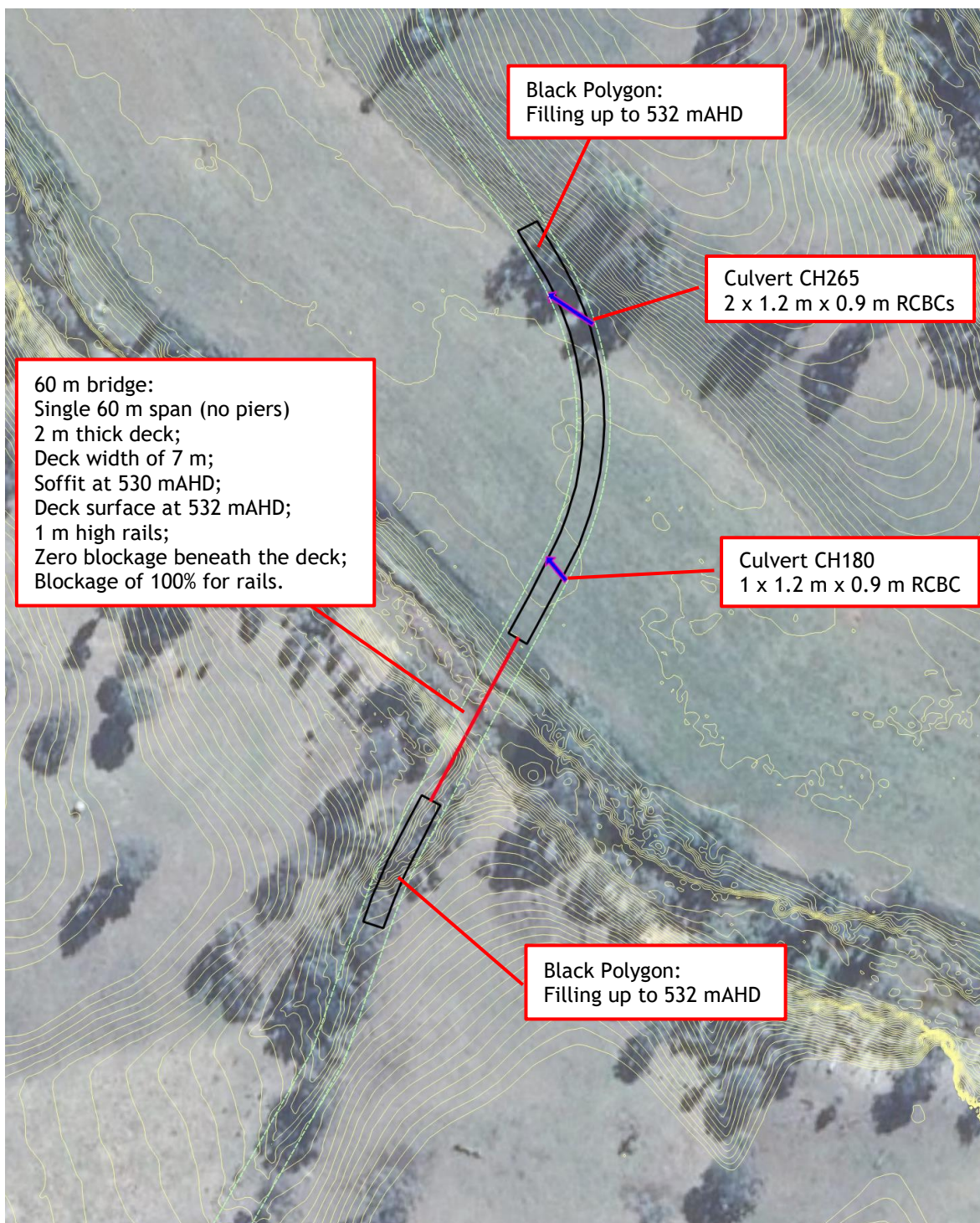


Figure 3 - Plan view of the proposed Maloneys Road crossing in Lawsons Creek, single-span bridge option

Memorandum

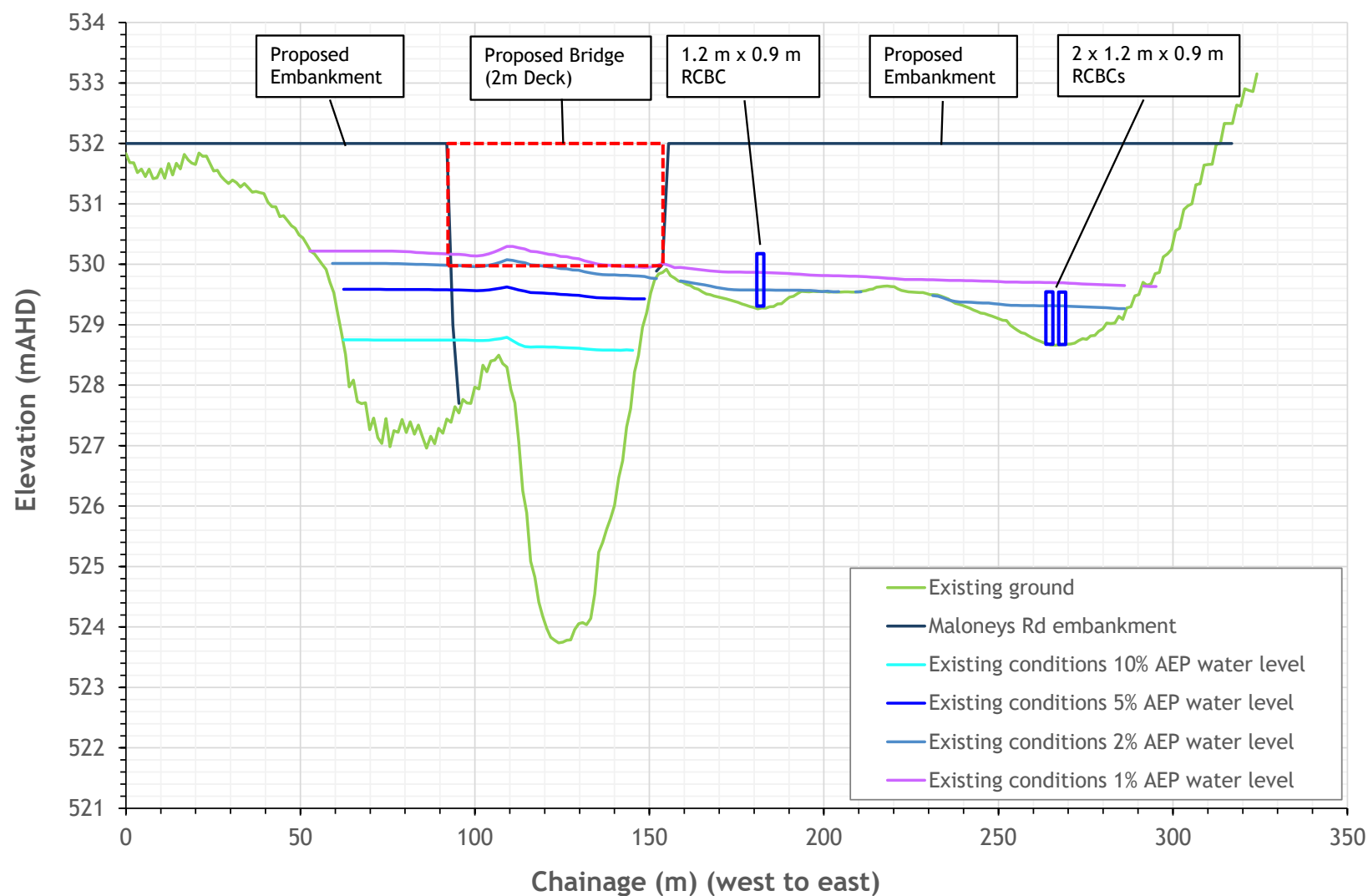


Figure 4 - Cross section view of proposed bridge and crossings for Maloneys Road at Lawsons Creek, single-span bridge option

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4.0 Design peak flood depths and velocities

Figure A.1 to Figure A.4 in Appendix A show the modelled peak flood depths in the vicinity of the crossing for developed (with bridge) conditions, for both the dual-span and single-span bridge options. Figure A.5 to Figure A.8 in Appendix A show the corresponding peak velocities.

5.0 Flood impact assessment

5.1 Lawsons Creek design flow assumption

Proposed mining operations as part of the Project would likely result in a small loss of catchment upstream of the Maloneys Road crossing, due to development of the mining pit and the proposed diversion of upslope catchments. As a result, design flows at Lawsons Creek under developed (with bridge) conditions would likely be lower compared to existing conditions.

For this assessment, the flood impact of the proposed crossing was assessed assuming that the design flows in Lawsons Creek would not be changed between existing conditions (pre-bridge) and developed conditions (with bridge). This approach is considered conservative and allows the impact of the crossing to be assessed in isolation from impacts of other components of the Project.

5.2 Impact on peak flood levels

Figure 5 to Figure 8 show the 10%, 5%, 2% and 1% peak water level impacts compared to existing conditions for both the dual-span and single-span bridge options.

For the dual-span bridge option:

- Peak flood levels in Lawsons Creek are predicted to increase upstream of the crossing for all modelled events (10% to 1% AEP). Peak flood levels downstream of the crossing are generally predicted to reduce.
- For all events up to 1% AEP, predicted increases in peak flood levels greater than 0.2 m are generally confined to within 200 m upstream of the crossing. These impacts generally dissipate to less than 0.1 m within 550 m upstream of the crossing.
- The predicted flood level impacts for the 10% to 1% AEP events do not appear to affect any existing dwellings along Lawsons Creek.

For the single-span bridge option:

- Peak flood levels in Lawsons Creek would not be increased for the 10% and 5% AEP events. This is due to the absence of an in-stream pier, in combination with flows being confined in-channel for these events.
- For the 2% and 1% AEP events, predicted increases in peak flood levels greater than 0.2 m are generally confined to within 150 m upstream of the crossing. These impacts generally dissipate to less than 0.1 m within 300 m upstream of the crossing.
- The predicted flood level impacts for the 2% and 1% AEP events do not appear to affect any existing dwellings along Lawsons Creek.

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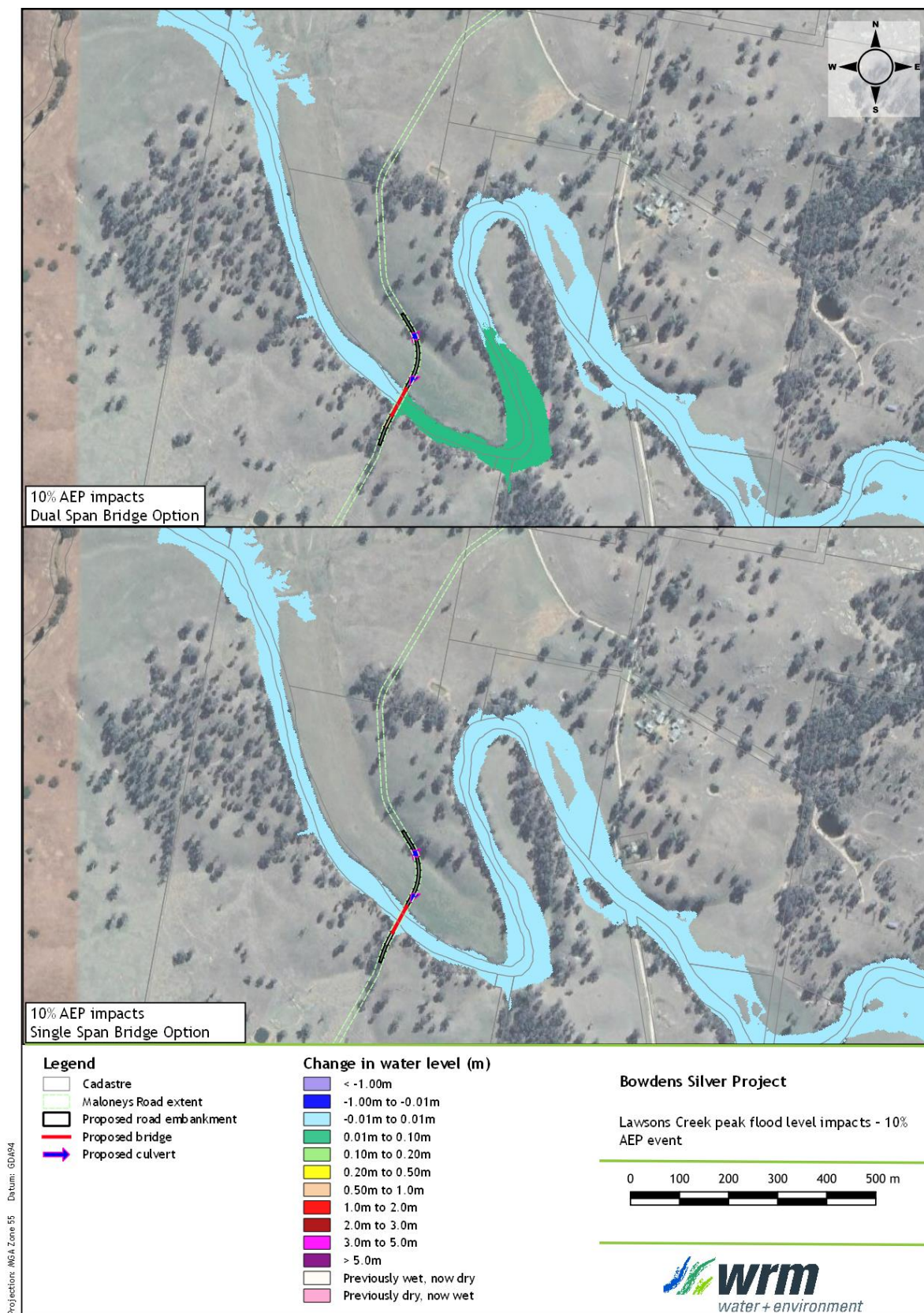


Figure 5 - Predicted changes in peak water levels - 10% AEP event

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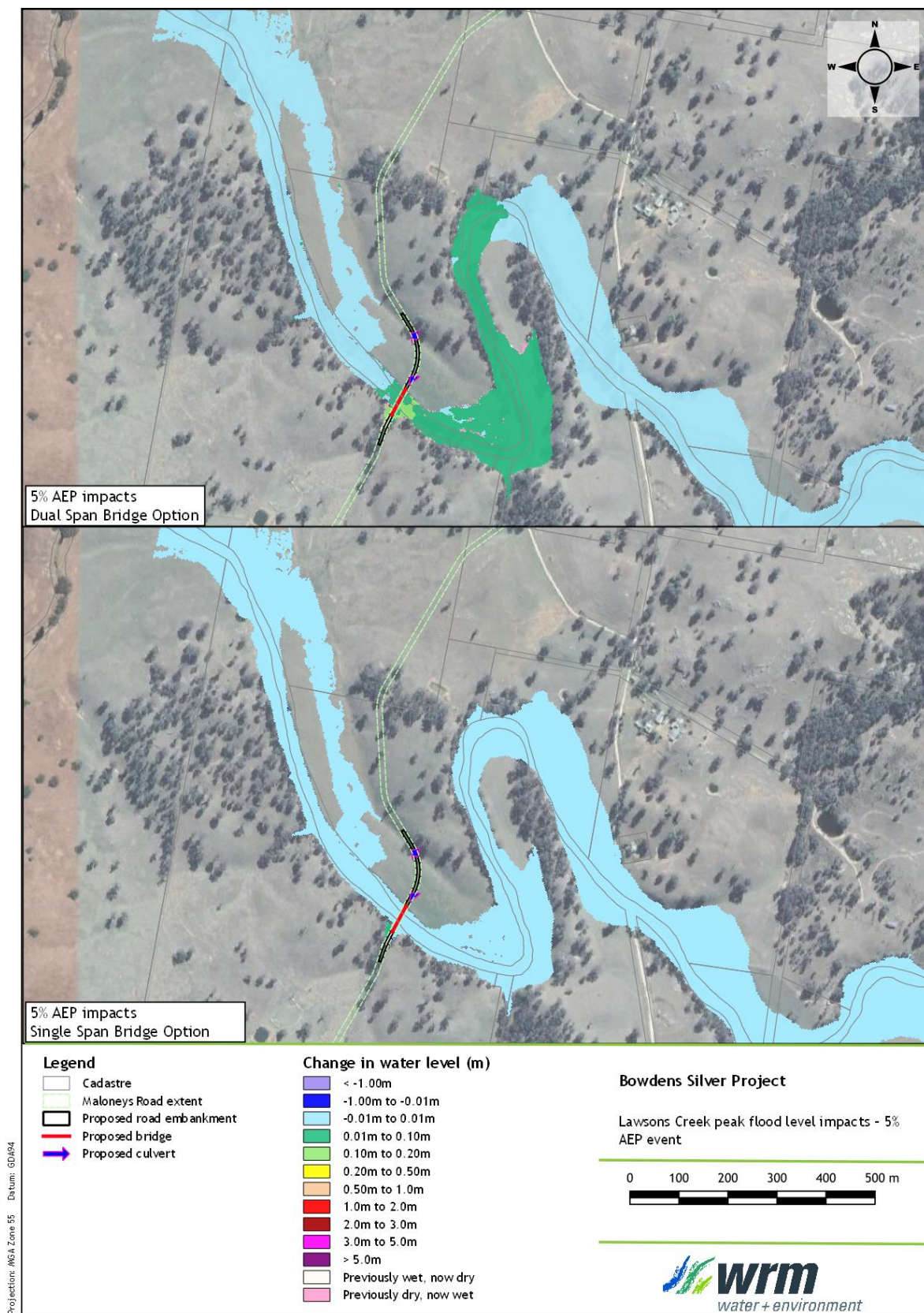


Figure 6 - Predicted changes in peak water levels - 5% AEP event

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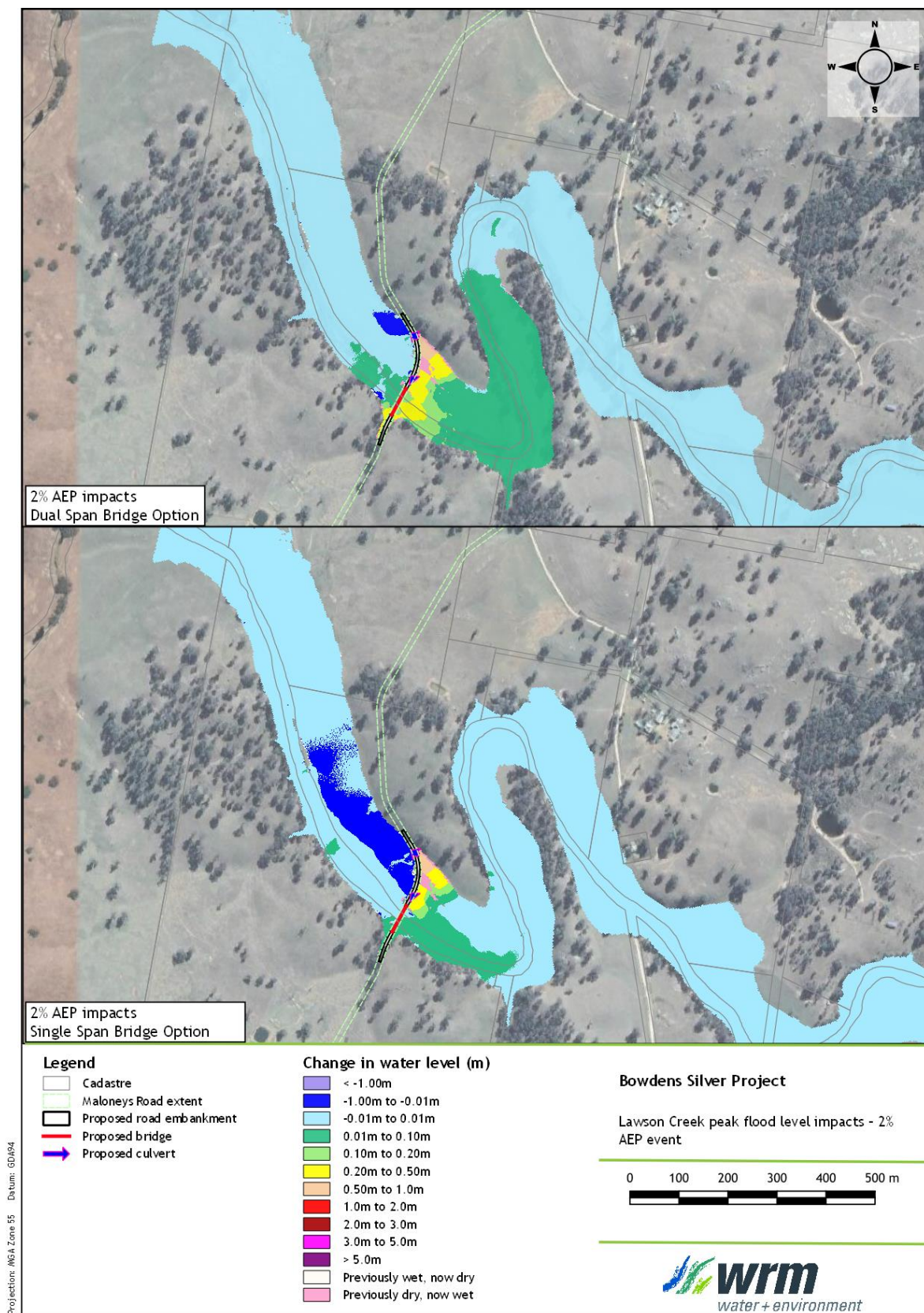


Figure 6 - Predicted changes in peak water levels - 2% AEP event

Memorandum

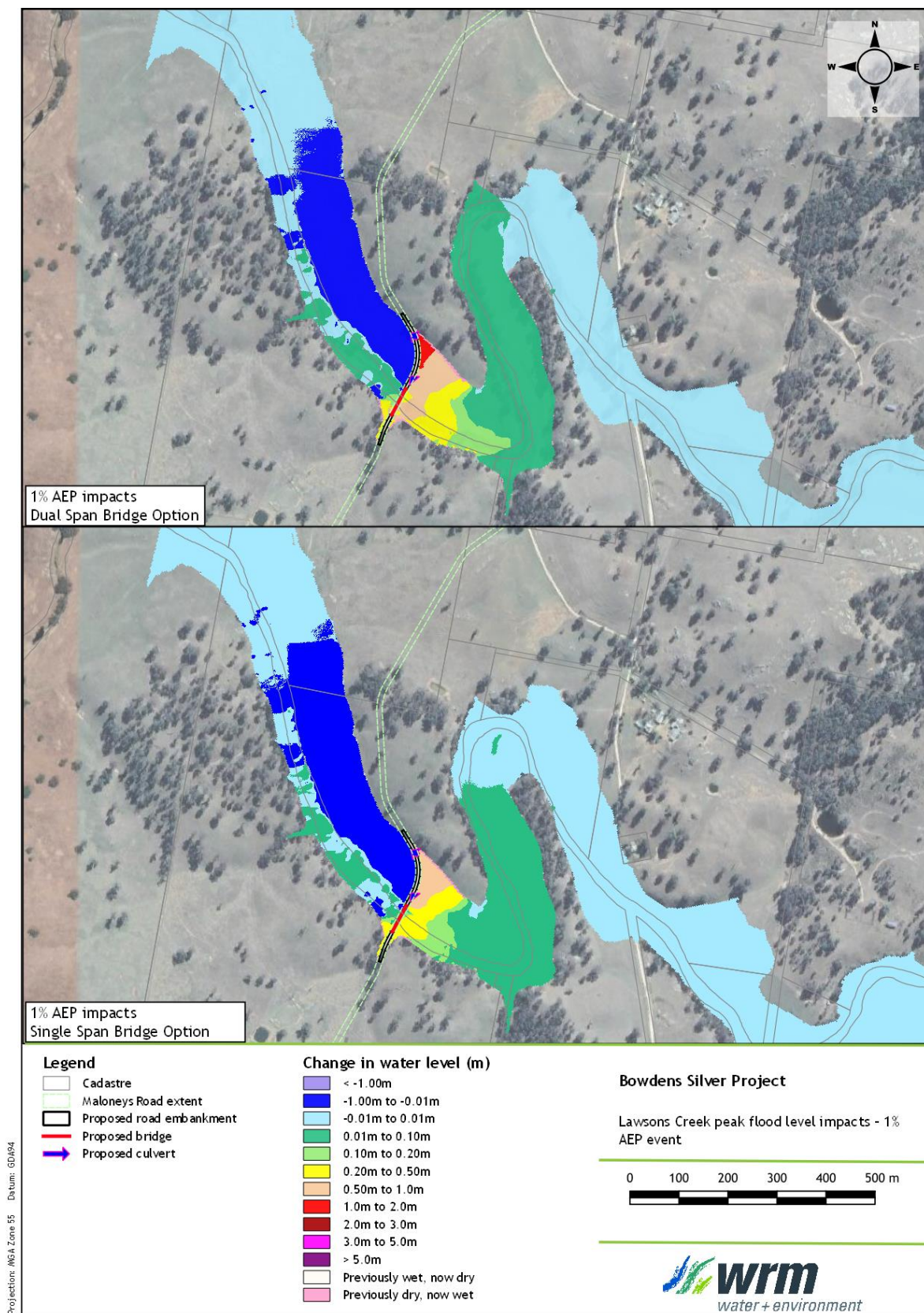


Figure 7 - Predicted changes in peak water levels - 1% AEP event

Memorandum

5.3 Impact on peak velocities

Figure 9 to Figure 12 show the 10%, 5%, 2% and 1% peak velocity impacts compared to existing conditions for both the dual-span and single-span bridge options.

For the dual-span bridge option:

- There is negligible impact on peak velocities for the 10% AEP event, and minor increases of up to 0.2 m/s near the bridge abutments for the 5% AEP event.
- For the 2% and 1% AEP events:
 - There are generally reductions in peak velocities predicted upstream of the proposed crossing due to the blockage caused by the proposed road embankment.
 - Peak velocities along the Lawsons Creek main channel downstream of the crossing would generally be increased by up to 0.2 m/s. Given that existing conditions velocities here are generally more than 4 m/s, the predicted increases in velocities are not considered significant.
 - There are localised increases in velocities of up to 2.8 m/s predicted at the Lawsons Creek channel banks near the proposed bridge abutments. The impact of these increases in velocity would need to be investigated further during detailed design. However, peak velocities in these areas under developed (with bridge) conditions are within the range of velocities predicted for existing conditions.

For the single-span bridge option:

- There is negligible impact on peak velocities for the 10% and 5% AEP events;
- For the 2% and 1% AEP events:
 - There are generally reductions in peak velocities predicted upstream of the proposed crossing due to the blockage caused by the proposed road embankment.
 - Peak velocities along the Lawsons Creek main channel downstream of the crossing would generally be increased by up to 0.2 m/s. Given that existing conditions velocities here are generally more than 4 m/s, the predicted increases in velocities are not considered significant.
 - There are localised increases in velocities of up to 2.8 m/s predicted at the Lawsons Creek channel banks near the proposed bridge abutments. The impact of these increases in velocity would need to be investigated further during detailed design. However, peak velocities in these areas under developed (with bridge) conditions are within the range of velocities predicted for existing conditions.

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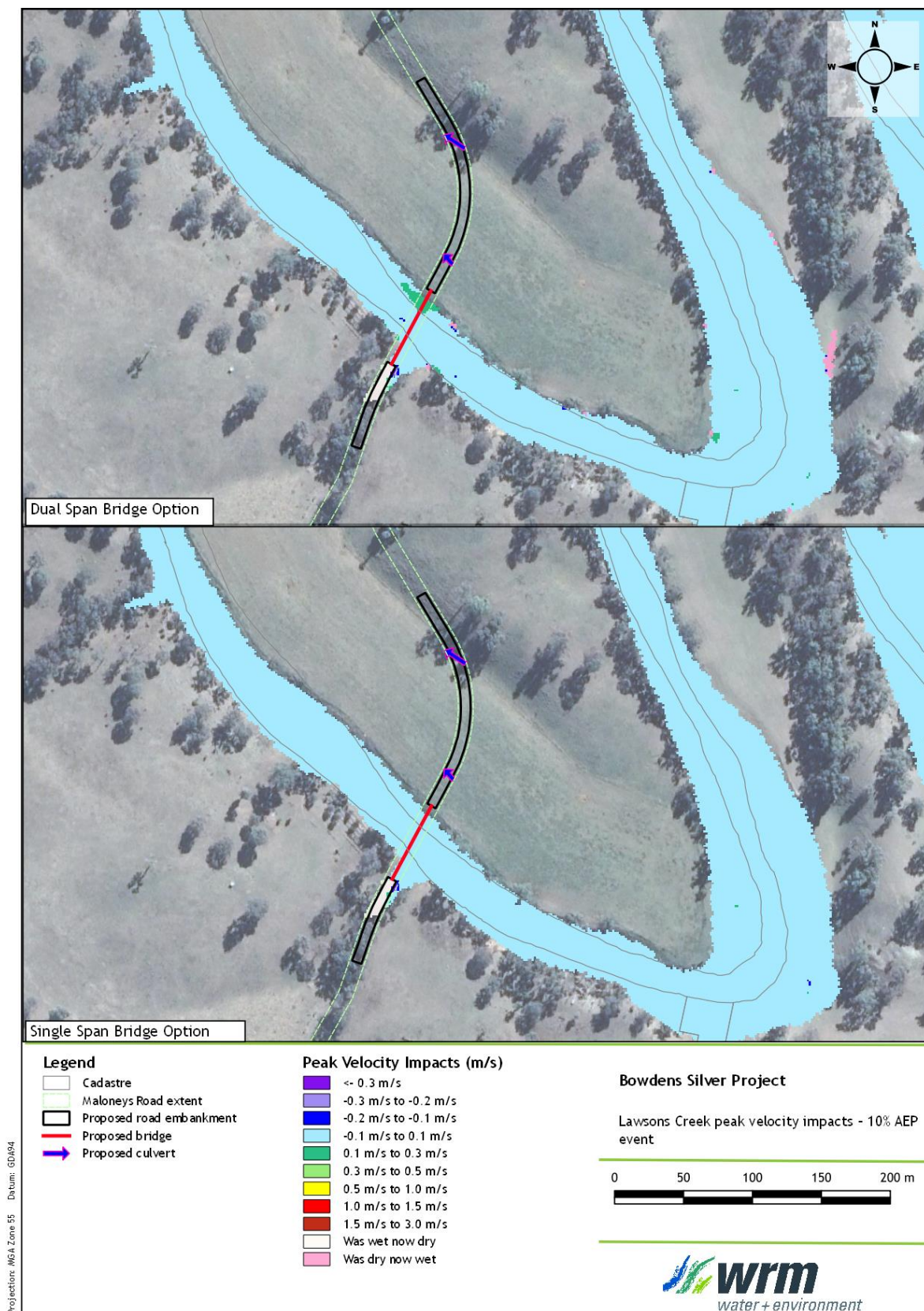


Figure 9 - Predicted changes in peak velocities - 10% AEP event

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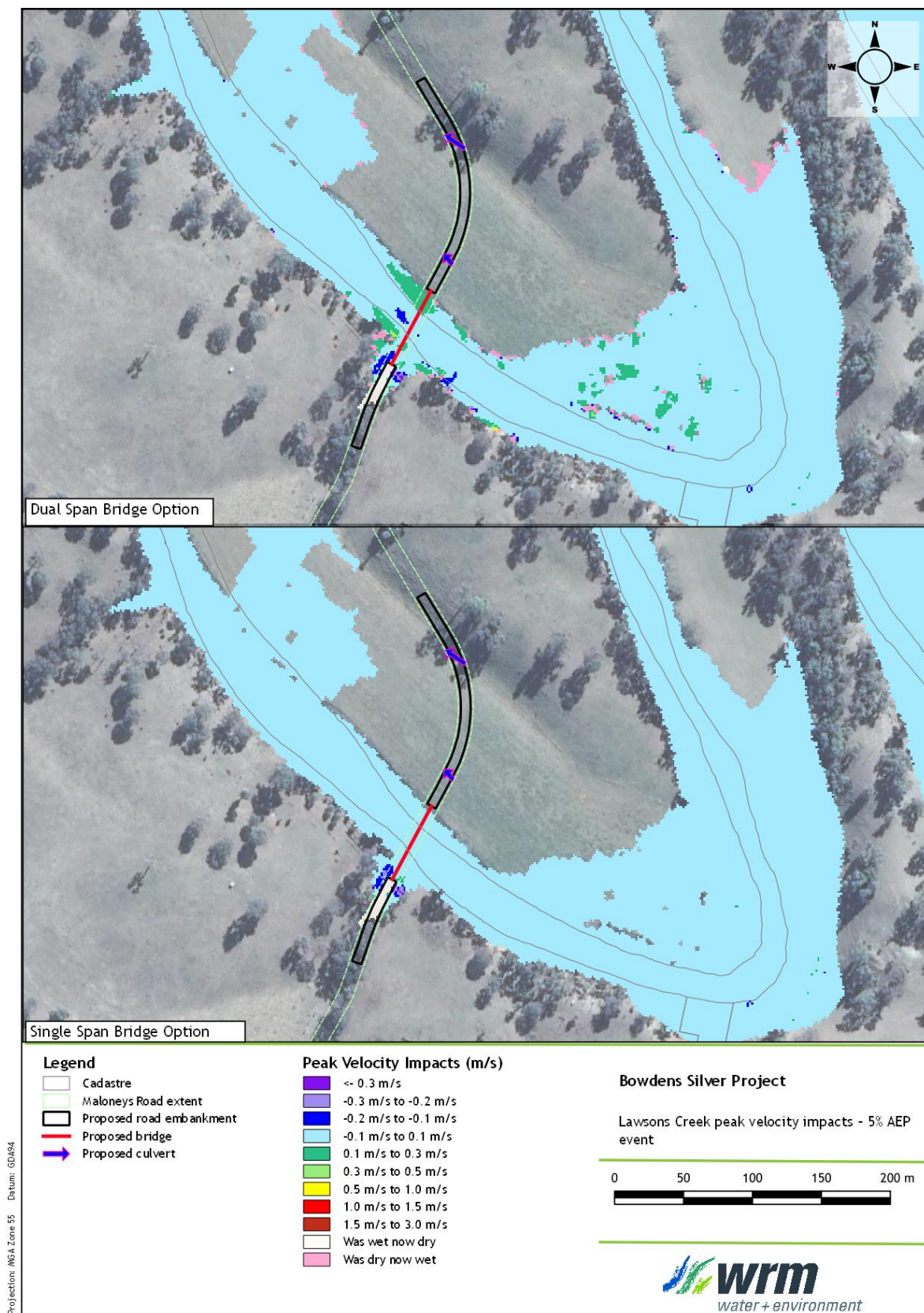


Figure 10 - Predicted changes in peak velocities - 5% AEP event

Memorandum

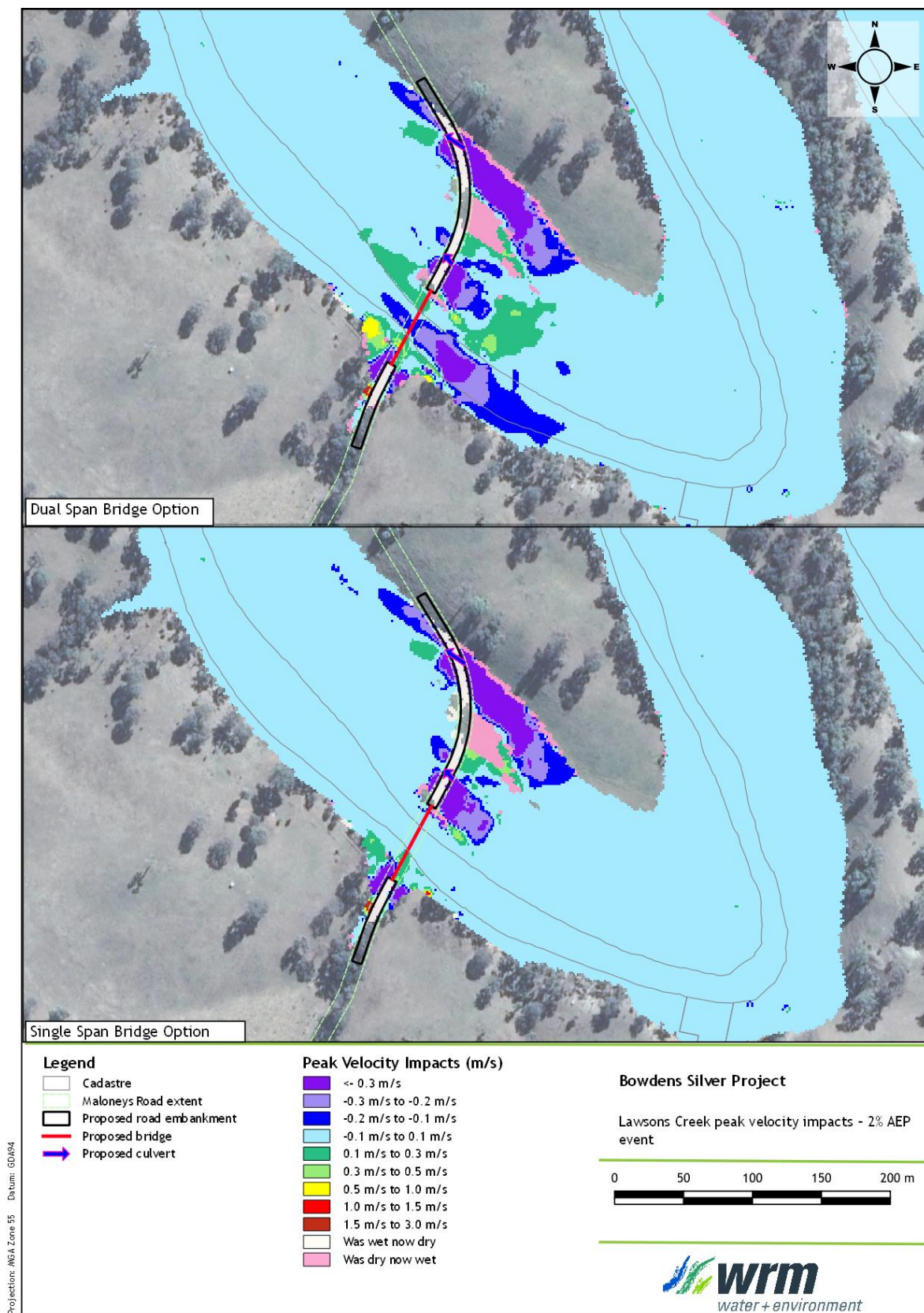


Figure 11 - Predicted changes in peak velocities - 2% AEP event

Memorandum

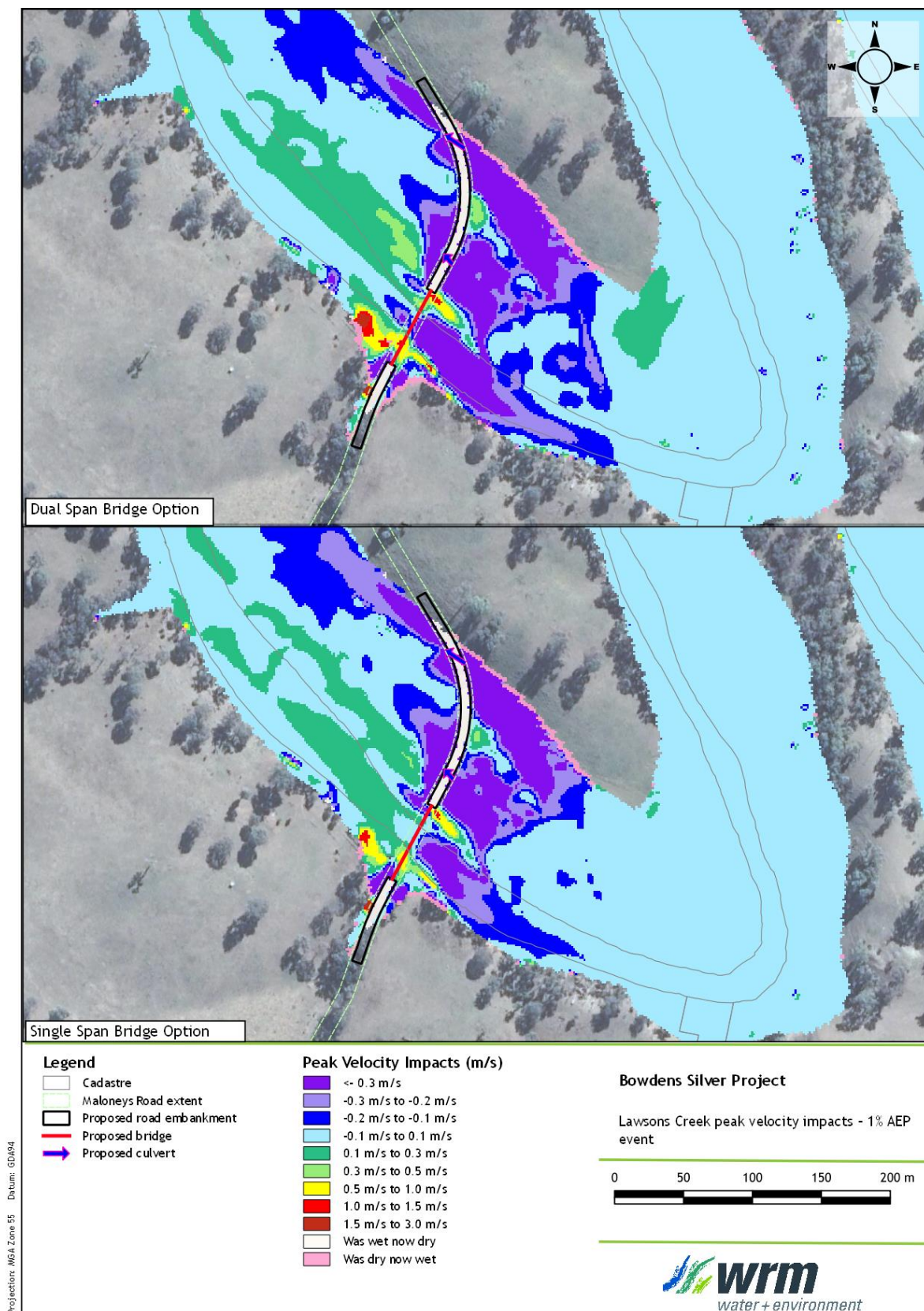


Figure 12 - Predicted changes in peak velocities - 1% AEP event

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5.4 Impact on flow distribution (conveyance)

Under existing conditions, Lawsons Creek flows are generally contained in-channel at the proposed crossing location for events up to and including 5% AEP. For the 2% and 1% AEP events, extensive overbank (out-of-channel) flows occur through the Lawsons Creek floodplain to the north of the main channel.

The proposed crossing for both the dual- and single-span bridge options would not change the flow distribution in Lawsons Creek, because the proposed bridge opening was designed to be wide enough to convey the bank-full flow in Lawsons Creek.

Table 2 compares the impact of the proposed crossing on the distribution of flow immediately downstream of the crossing for 2% and 1% AEP events at the following two locations:

- Lawsons Creek main channel (chainage 50 m to 150 m on Figure 2); and
- Northern overbank (chainage 150 m to 300 m on Figure 2).

The results show that the proposed crossing slightly increases the flow in the Lawsons Creek main channel and reduces the breakout flow through the northern overbank areas. This is likely due to the proposed road embankment diverting flows from the overbank areas to the main channel of Lawsons Creek. However, these predicted changes in flow distribution have no material impact on the land immediately upstream and downstream of the crossing.

Table 2 - Comparison of the distribution of flow just downstream of the proposed crossing between existing and developed (with bridge) conditions

Location	Peak discharge (m ³ /s)		
	Existing conditions	Dual-span bridge	Single-span bridge
2% AEP event			
Lawsons Creek main channel	594	596	597
Northern overbank	25	23	21
1% AEP event			
Lawsons Creek main channel	697	712	716
Northern overbank	63	48	44

5.5 Mitigation of flow breakouts

As described in Section 3.4, in the vicinity of the proposed crossing, Lawsons Creek flows are generally contained in-channel for events up to and including the 5% AEP event. For events equal to or greater than 1% AEP, flow in the Lawsons Creek main channel breaks out into the floodplain area north of the main channel.

The proposed crossing design includes box culverts along the proposed road embankment (north of the bridge) that will convey the breakout flows in northern overbank area across the road, hence maintaining the distribution of flow close to existing conditions. These culverts would also convey local catchment runoff from the local stormwater catchment upstream of the crossing.

Memorandum

The hydraulic model results indicate that the proposed box culvert configuration (refer to Table 2) in combination with the bridge, would provide the proposed Maloneys Road with immunity from flooding up to the 1% AEP event.

The impact assessment results also show that flood levels for the 2% and 1% AEP events are generally predicted to reduce within the overbank area immediately downstream of the crossing. This indicates that there is potential to improve the flow distribution further by adopting larger culverts.

6.0 Summary of findings

Two conceptual designs for the Maloneys Road crossing have been developed, including a dual-span bridge and single-span bridge option. Both options were configured to convey the Lawsons Creek bank-full flow of 430 m³/s beneath the bridge, with a freeboard of at least 0.3 m to the bridge soffit under bank-full flow conditions in the creek.

The flood level impacts for both bridge options are not significant, with the impacts generally localised near the bridge and dissipating to less than 0.01 m within 550 m upstream of the bridge. The predicted flood level impacts do not appear to affect any existing dwellings along Lawsons Creek.

The predicted impact of the proposed crossing on peak velocities are not significant for events up to and including 5% AEP. For events equal to or greater than 2% AEP, the impacts along the Lawsons Creek main channel are generally not significant. There are more significant (albeit localised) increases in peak velocities near the bridge abutments. The impact of these increases in velocity would need to be investigated further during detailed design. However, peak velocities in these areas under developed (with bridge) conditions are within the range of velocities predicted for existing conditions.

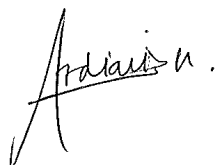
The proposed crossing (for both options) has no significant impact on flow distribution, with only a small increase in flow in the main channel and minor reductions in flow in the northern overbank areas. This has no material impact on the land immediately upstream and downstream of the crossing.

The proposed box culverts along the road embankment (north of the bridge) that will convey the breakout flows in northern overbank area across the road, hence maintaining the distribution of flow close to existing conditions.

The differences in predicted flood impacts between the dual-span and single-span bridge options are not significant, with the single-span bridge option resulting in causing slightly smaller impacts as expected.

For and on behalf of

WRM Water & Environment Pty Ltd



Ardianto Notodirdjo

Senior Engineer



Memorandum

References:

- WRM, 2020a *'Bowdens Silver Project - Part 6 Surface Water Assessment', prepared for R.W. Corkery & Co. Pty Limited by WRM Water & Environment Pty Ltd, report 42925_Vol 2_Part 6_Surface Water Assessment - May 2020.pdf, May 2020.*
- WRM, 2020b *'Bowdens Silver Project EIS - additional hydraulic modelling and options assessment for the Lawsons Creek crossing (Maloneys Road)', memorandum prepared for R.W. Corkery & Co. Pty Limited by WRM Water & Environment Pty Ltd, November 2020.*



Memorandum

Appendix A - Flood depth and velocity maps

Memorandum

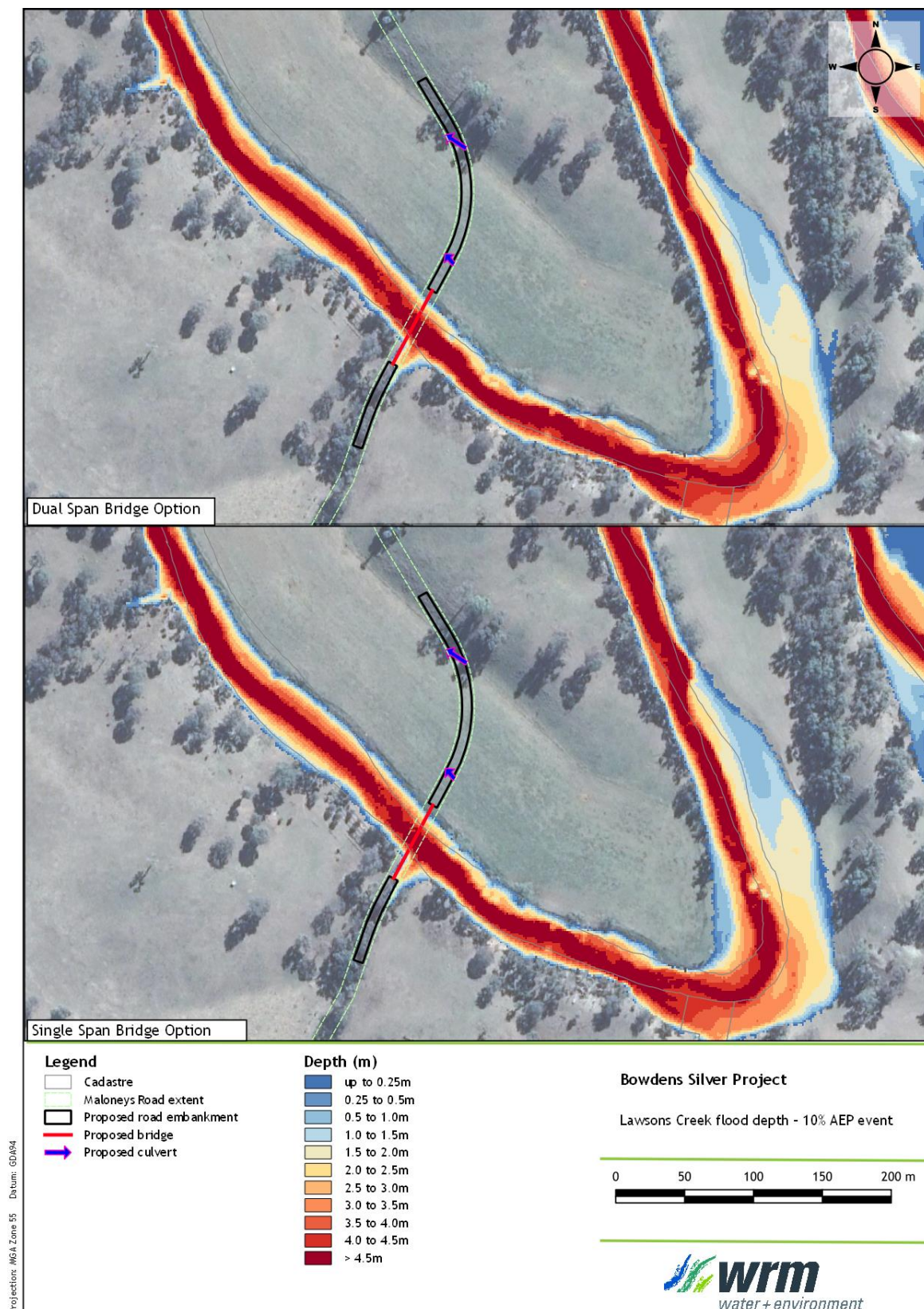


Figure A.1 - Developed (with bridge) conditions predicted peak flood depths - 10% AEP event

Memorandum

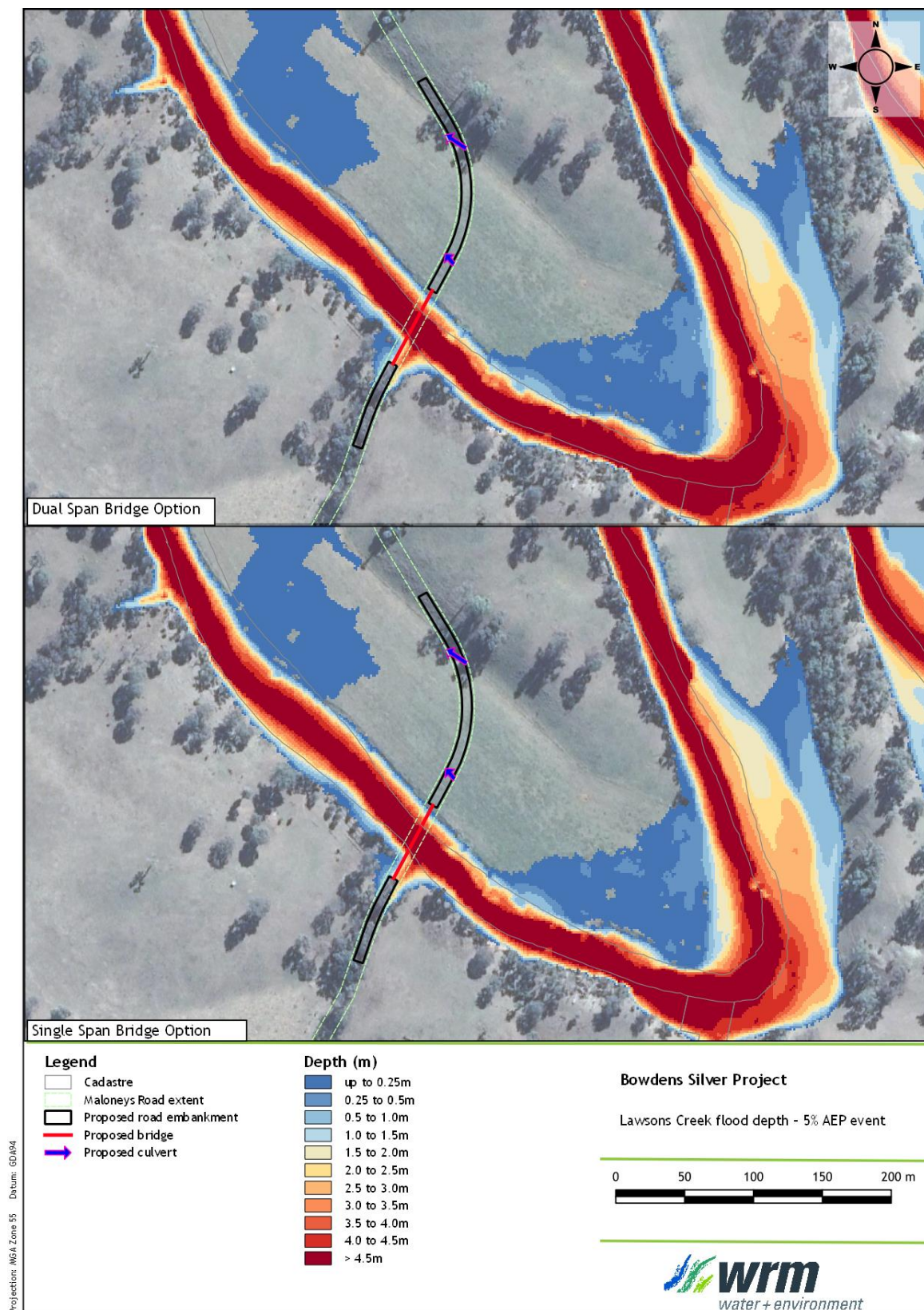


Figure A.2 - Developed (with bridge) conditions predicted peak flood depths - 5% AEP event

Memorandum

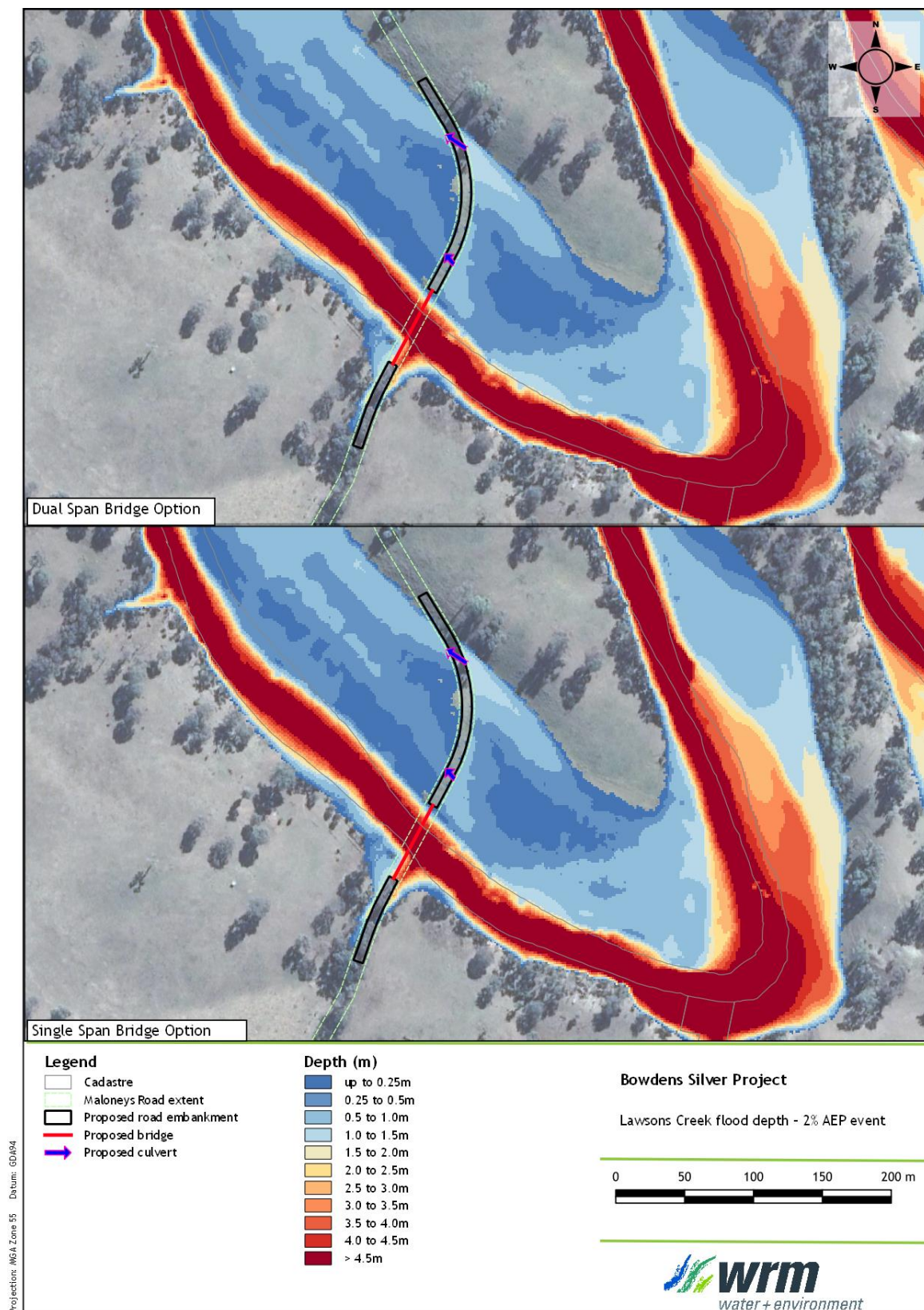


Figure A.3 - Developed (with bridge) conditions predicted peak flood depths - 2% AEP event

Memorandum

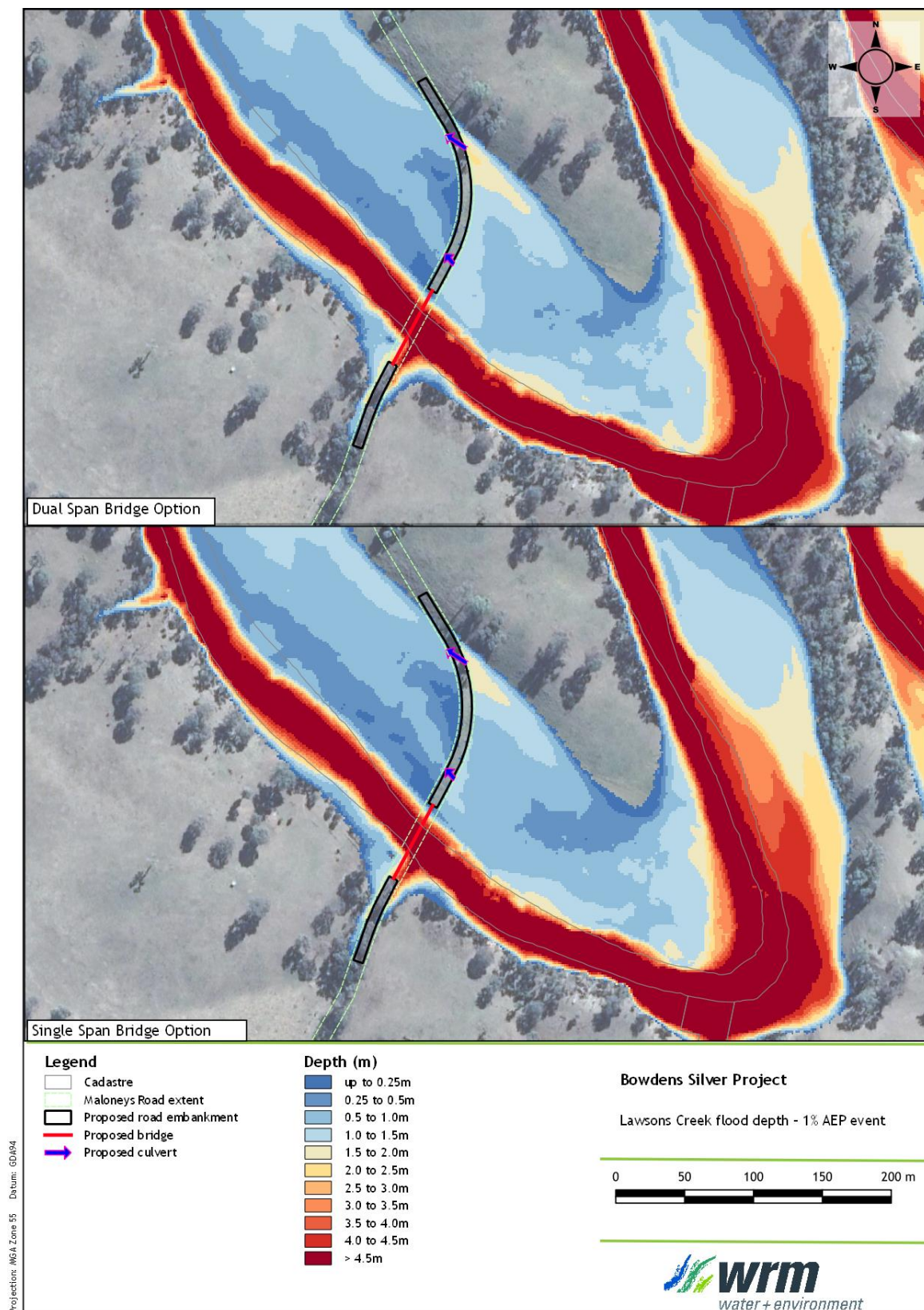


Figure A.4 - Developed (with bridge) conditions predicted peak flood depths - 1% AEP event

Memorandum

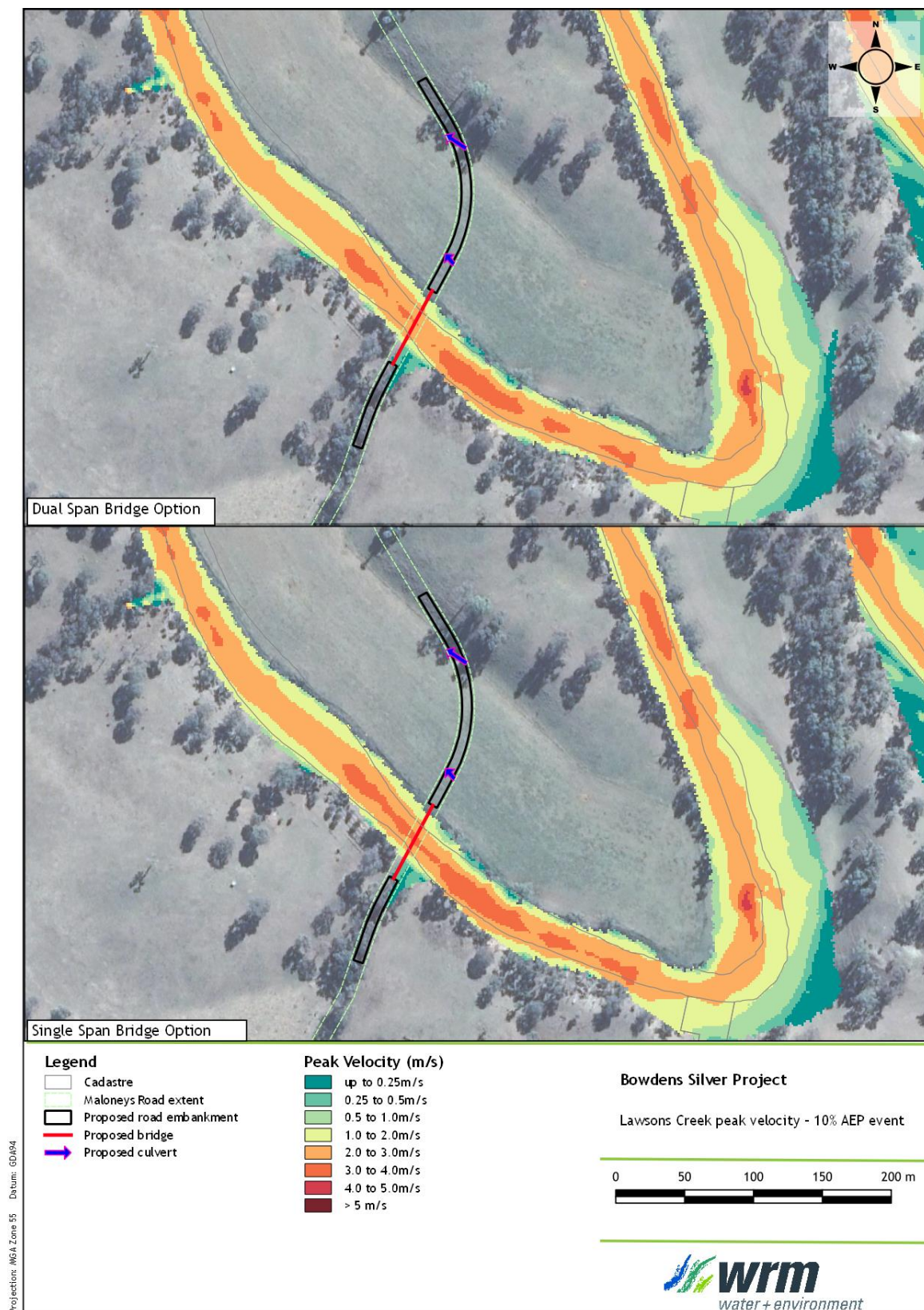


Figure A.5 - Developed (with bridge) conditions predicted peak flood velocities - 10% AEP event

Memorandum

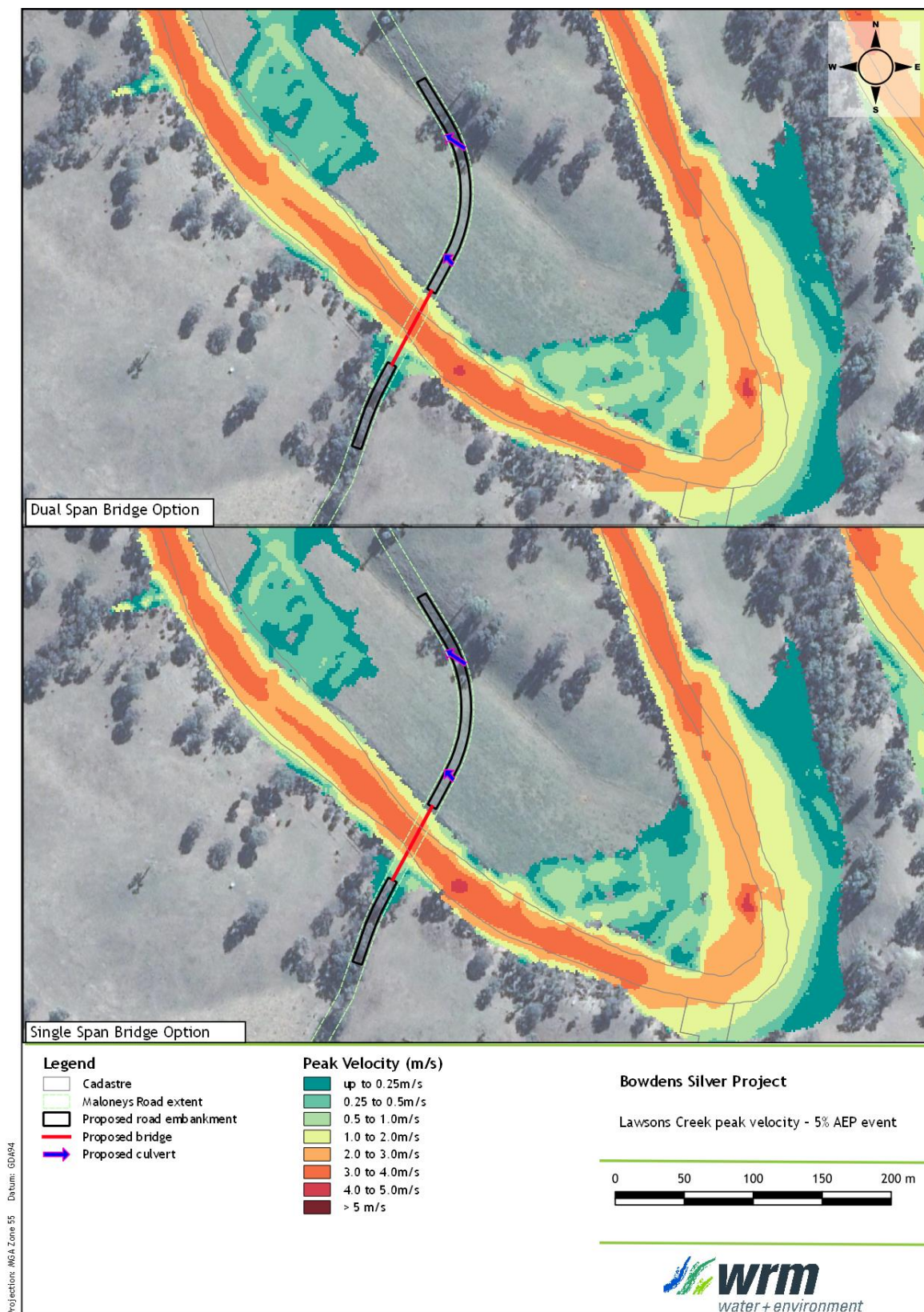


Figure A.6 - Developed (with bridge) conditions predicted peak flood velocities - 5% AEP event

Memorandum

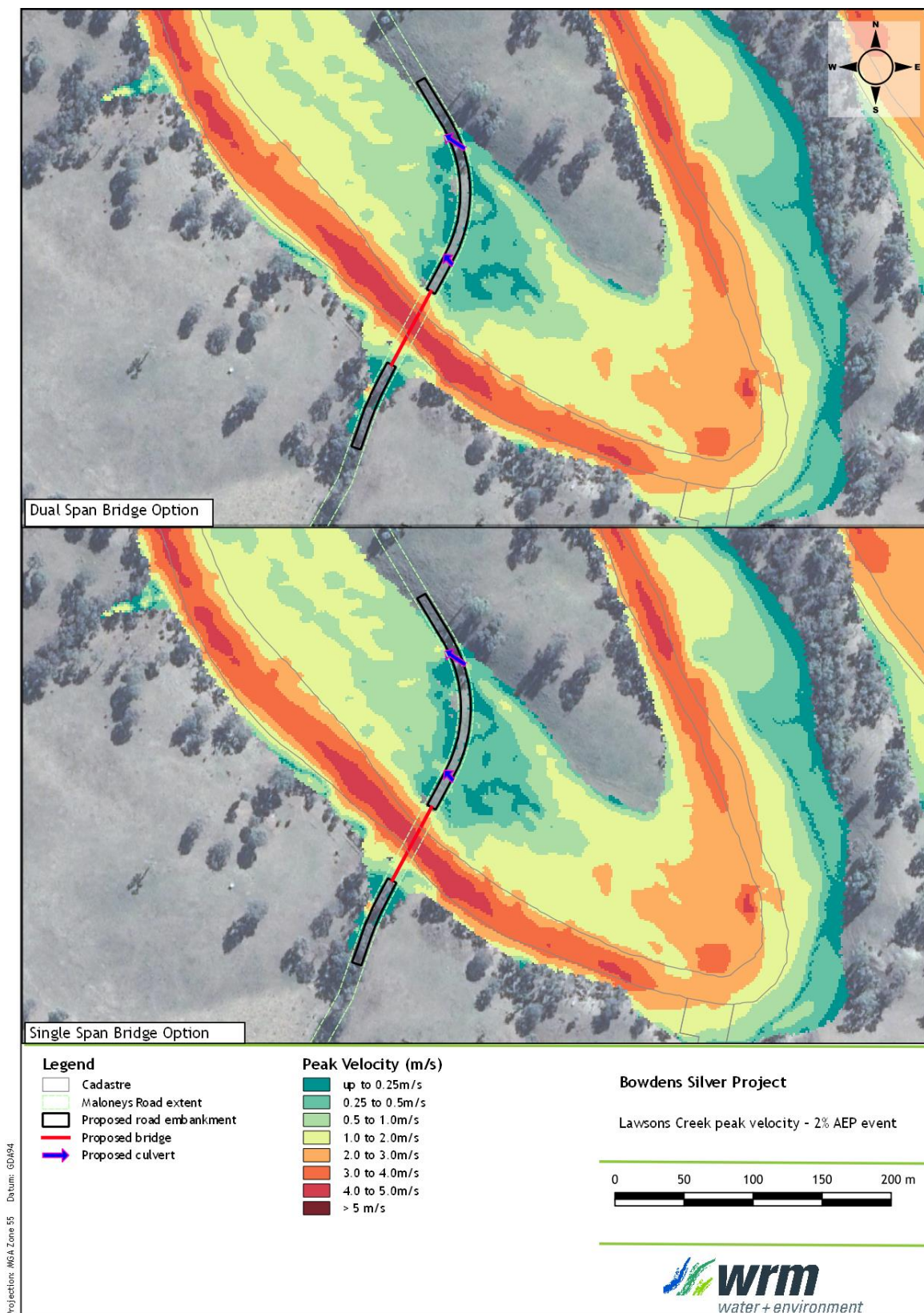


Figure A.7 - Developed (with bridge) conditions predicted peak flood velocities - 2% AEP event

Memorandum

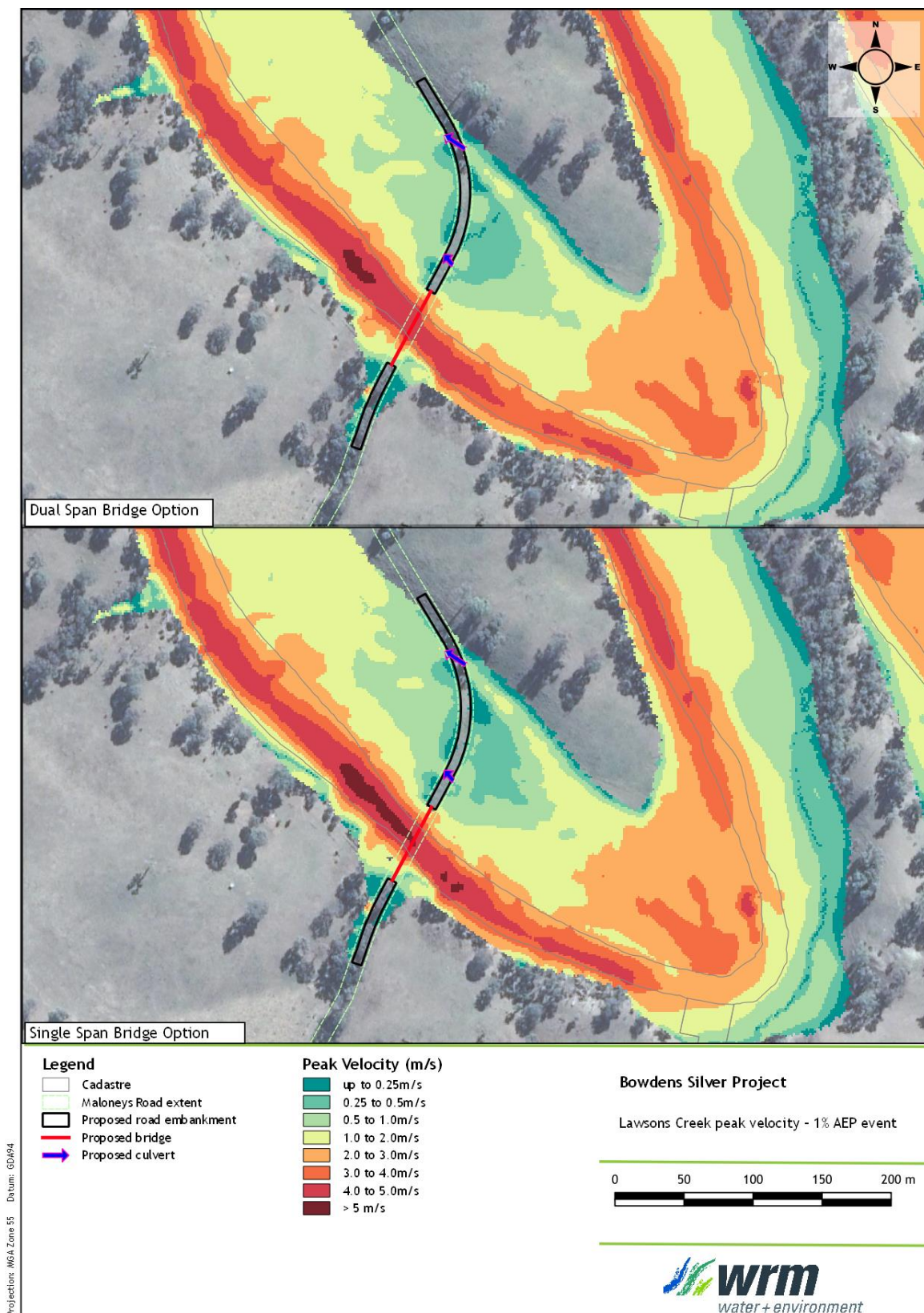


Figure A.8 - Developed (with bridge) conditions predicted peak flood velocities - 1% AEP event

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Annexure C

Peer Reviews – 2020 and 2022

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26 February 2020

Principal Environmental Consultant
RW Corkery & Co Pty Limited
PO Box 239
BROOKLYN NSW 2083
Attention: Nick Warren

Nick,

Re: Bowdens Silver Project EIS – Surface Water Assessment Peer Review

I have reviewed and commented on the Surface Water Assessment (SWA) for the Bowdens Silver Project (the Project) Environmental Impact Statement (EIS) prepared by WRM Water & Environment Pty Ltd (WRM) including the Annexure A Water Course Assessment by RW Corkery & Co Pty Limited and the Annexure B Flood Impact Assessment by WRM. This included multiple reviews of the SWA report. The review related mainly to the text and numerical content of the SWA and the two annexures, however a brief review was also undertaken of WRM's calibration of the catchment AWBM (rainfall-runoff model) for the Cudgegong River Upstream of Rylstone.

In undertaking the review I have checked that the SWA addresses the surface water resources related Secretary's Environmental Assessment Requirements (SEARs). These are summarised in Section 2 of the SWA report (although it was noted that multiple versions of the SEARs appear to exist).

Through the peer review process I have made a number of requests for clarification and suggestions for modifications to the methodology and reporting. The main suggestions related to the following issues.

- The veracity of calibration of the AWBM for the Cudgegong River Upstream of Rylstone and the appropriateness of AWBM parameter values for the Project water balance model.
- Revision of monitored baseline water quality statistics (Annexure A).
- Management of runoff and seepage from non-acid forming (NAF) waste rock emplacement areas, including enlarged sediment dam storage capacities and contingency pump-back measures, depending on the results of on-going testwork and monitoring.
- Increased detail on and verification of the feasibility of diversion of runoff around proposed satellite pits.

- Increased detail on management and modelling of runoff and seepage from potentially acid forming waste rock emplacement areas.
- Clarification of the quantity and salinity of water to be imported to the Project.
- Additional water balance model sensitivity analyses (relating to groundwater inflow rates).
- Revision of process plant makeup priority such that water collected from the waste rock emplacement leachate management dam is used as a first priority.
- Use of contemporary design loss rates for hydrologic modelling undertaken to estimate design flood flow rates (Annexure B).

The majority of these were resolved to my satisfaction. It is concluded that the assessment as it stands is sufficient and fit for purpose for the EIS, in terms of the assessment of surface water-related impacts as it has:

- adequately described the existing surface water environment in the vicinity of the Project and the relevant environmental values;
- developed and described a proposed comprehensive water management system and demonstrated through modelling that such a system is predicted to operate adequately under a range of climatic scenarios; and
- assessed the potential impacts on relevant environmental values due to the development of the Project.

During the review of the project water balance modelling it was noted that a number of assumptions and considerations were made (with justification), however it is recommended that further analysis be conducted during subsequent studies or detailed design to refine the design of the water management infrastructure. In summary, the recommendations for further analysis are as follows:

- continued geochemical testing and characterisation of runoff and seepage from NAF waste rock emplacement areas to guide determination of sediment dam sizing and the need for pump back to the water management system;
- consideration should be given to amending hydrologic (flood) modelling where justified using the most up to date recommended design loss parameters for NSW for higher annual exceedance probabilities (2% and higher) – as noted in Section 5.6.3 of Annexure A; and
- further refinement of modelled natural catchment AWBM parameters using site monitored flow data if possible.

Notwithstanding the above, this further analysis is considered unlikely to significantly affect the modelling outcomes/conclusions and therefore assessment of potential impacts already described in the Surface Water Assessment.

Please contact the undersigned if you require further information.

Yours faithfully,

A handwritten signature in blue ink, appearing to read 'Tony Marszalek', with a stylized, flowing script.

Tony Marszalek
Director

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4 March 2022

Senior Environmental Consultant
RW Corkery & Co Pty Limited
PO Box 239
BROOKLYN NSW 2083
Attention: Paul Ryall

Paul,

Re: Bowdens Silver Project EIS – Amended Surface Water Assessment Peer Review

I have previously reviewed and commented on the Surface Water Assessment (SWA) for the Bowdens Silver Project (the Project) Environmental Impact Statement (EIS) prepared by WRM Water & Environment Pty Ltd (WRM). My review letter was dated 26 February 2020 and addressed to Nick Warren of your office. It is understood that since that review, an alternative integrated water management and supply strategy has been developed for the Project, including changes to operational and processing strategies and increased on-site sourcing of water. This has resulted in the elimination of an off-site water supply from the Project – i.e. the previously proposed water supply pipeline. An amended SWA has now been prepared, incorporating these revisions.

I have reviewed and commented on the amended SWA for the Project EIS prepared by WRM, with the most recent report dated 25 February 2022 (“1356-06-B3_42925_Part 6_Surface Water Assessment.docx”). This included multiple reviews of the SWA report. The review focussed on Section 5 (Site Water Balance) as well as Section 7 (Final Void Pit Lake Behaviour) and where these changed from the original (2020) report. It is understood that the remainder of the SWA remains substantially unchanged from the original report.

Through the peer review process, I have made a number of requests for clarification and suggestions for modifications to reporting. These were communicated via comments to the supplied report text. I did not raise any significant issues regarding technical content or modelling methodology that were not raised in my review of the original (2020) report. The main suggestions regarding the Site Water Balance related to management of water late in the Project life, reporting of water supply reliability and stored water volumes, particularly on the tailings storage facility (TSF), as well as clarity around the location of “harvestable rights dams”. The main suggestions regarding Final Void Pit Lake Behaviour regarded clarity around changes resulting from the original report and the way in which results, such as final void water levels, were reported.

On the basis of the SWA sections reviewed, it is concluded that these are sufficient and fit for purpose for the EIS, in terms of the assessment of surface water-related impacts.

As part of the original SWA review, a number of recommendations were made for further analysis to be conducted during subsequent studies or detailed design to refine the design of the water management infrastructure. These recommendations remain unchanged.

Please contact the undersigned if you require further information.

Yours faithfully,



Tony Marszalek
Senior Principal Engineer