Functional Design

Ballarat North PSP – Stormwater Drainage

Prepared for: Department of Transport and Planning
22 September 2026
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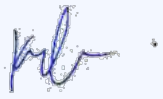
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Executive Summary

SMEC has been engaged by the Department of Transport and Planning (DTP) to refine the stormwater drainage strategy based on the Integrated Water Management (IWM) Plan and prepare the functional designs for the Ballarat North Precinct Structure Plan (PSP). This phase of the project incorporates the functional design of the proposed assets including the constructed waterway, wetlands and retarding basins. The outcomes of the stormwater drainage strategy will be used to inform the PSP land budget and the associated costing to deliver the drainage infrastructure works in the form of a Development Contributions Plan (DCP).

A literature review and contextual analysis (Stage 1) were conducted to understand the background work undertaken by the DTP and various consultants. The findings from this review helped inform the design basis. Subsequently, a preliminary drainage concept was developed and presented to the key stakeholders for initial feedback and support.

As part of the proof of concept (Stage 2) outlined in this report, SMEC has undertaken additional technical analysis (including hydrological, water balance, and hydraulic modelling) to corroborate the preliminary drainage strategy and provide confidence in the land budget allocated for stormwater drainage assets. The stormwater drainage strategy has been further refined with input from the DTP, and the required stormwater infrastructure has been identified and conceptually sized.

Site Context

Ballarat North PSP is located within the major river catchment of Hopkins River and within the sub catchment of Burrumbeet Creek. The PSP area is located within the City of Ballarat on the northern boundary of the existing urban extent of Ballarat. The PSP area is predominantly bounded by farming areas, and residential areas. The total site area is approximately 832 ha with a ‘Core Area’ of 567 ha and an ‘Expanded Area’ of 265 ha. The ‘Core Area’ was recognised by Ballarat City Council as the preferred next residential growth area and has been the subject of strategic technical assessments and engagement with landowners and relevant agencies over several years by Council. The ‘Core Area’ is the subject of this report.

The Ballarat North PSP area is generally split into five major catchments. The south east (SE) catchment is approximately 160 ha. This catchment is split into two sub catchments identified as SEN (98 ha) and SES (62 ha). The central (C) catchment is approximately 167 ha of which 48 ha is external catchment outside of the PSP boundary. The largest catchment is north west (NW) catchment and is approximately 235 ha of which 42 ha is external catchment outside of the PSP boundary. This catchment generally slopes towards western boundary of the site where it drains into the Burrumbeet Creek. The south west catchment (SW) is approximately 64 ha which drains north into the Burrumbeet Creek. This catchment constitutes large open paddocks which runs through the North Common Wetland Reserve. This area is designated as Crown Land and is likely to remain undeveloped.

Some of the key features of the PSP area include Ballarat Town Commons, Mount Rowan, Ballarat Grammar Mount Rowan campus, Miners Rest wetland and former Wendouree tip site. Burrumbeet Creek and its tributary to the east are a prominent feature within the PSP area and is subject to a range of planning, engineering and environmental considerations. The site constraints, including existing flooding conditions and biodiversity considerations, have been identified and considered in the development of the strategy.

Stormwater Drainage Strategy

A stormwater drainage strategy has been developed to address stormwater management requirements, including flood protection, IWM objectives where possible, compliance with relevant drainage authority design standards, and stormwater quality management. The strategy incorporates drainage assets and centralised stormwater treatment systems aligned with the IWM plan and the ‘Vision and Purpose’ of the PSP. Identified assets include a constructed waterway, retarding basins, wetlands and sediment ponds, along with provisions for supporting stormwater infrastructure such as pipelines, culverts and overland flow paths to manage and control runoff before it is discharged into Burrumbeet Creek. Retarding basins have been designed based on the climate change scenario (SSP 2-4.5) as per Department of Transport and Planning guidance while Burrumbeet Creek has been assessed and designed for climate change (SSP 5-8.5) as per Department of Transport and Planning guidance.

The proposed locations of the stormwater infrastructure, waterways and outlet points are shown in the figure below.

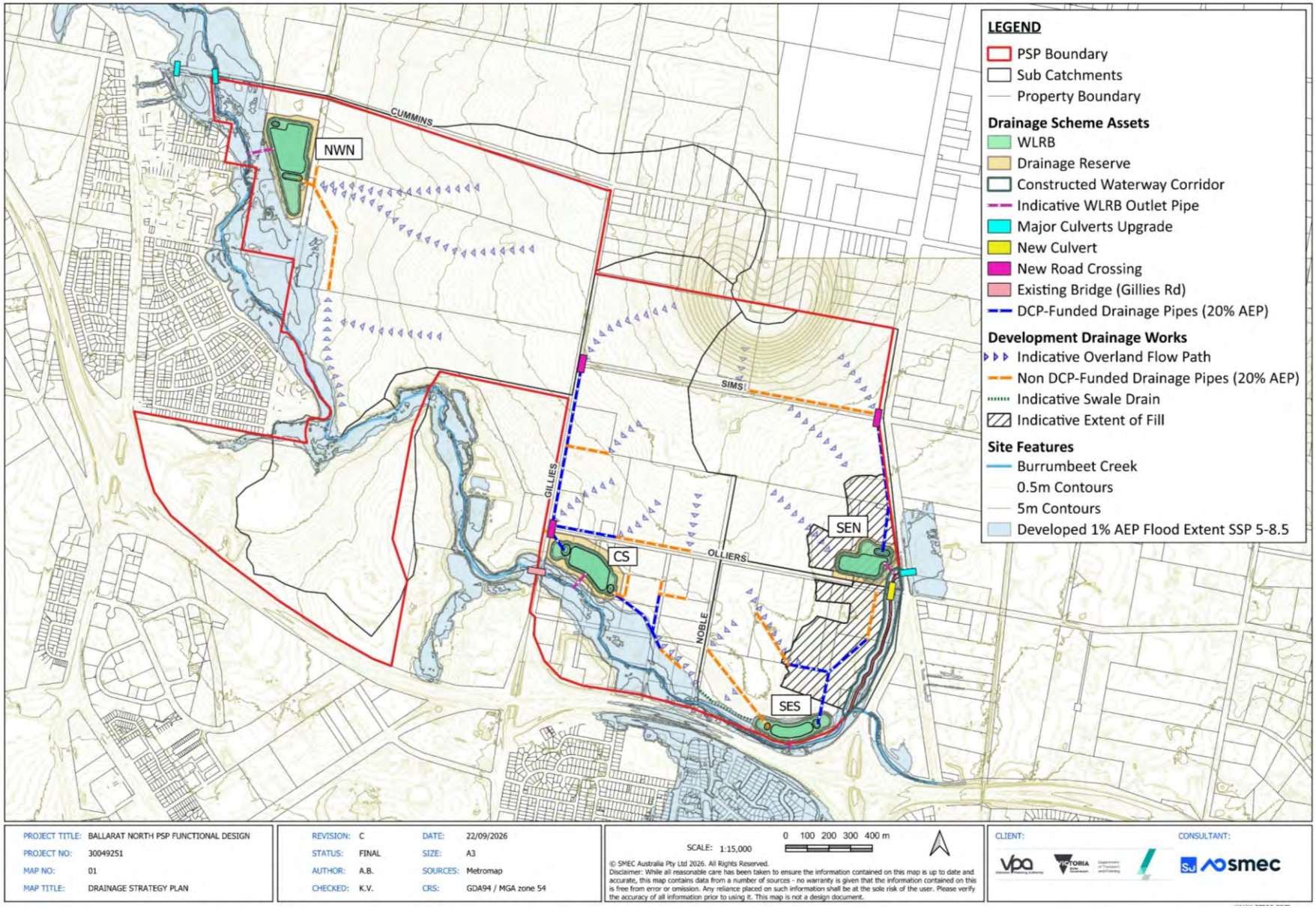


Figure 0-1-1 Ballarat North PSP functional drainage strategy

Integrated Water Management Strategy

The IWM Plan (Arup, 2024) recommends an alternative approach known as the 'Adaptive Plan.' This approach involves the provision of lot-scale rainwater tanks and precinct-scale WSUD wetlands, with the objective of harvesting stormwater for reuse in the irrigation of local open spaces.

Modelling shows that 22% of the non-potable water demand is supplied by a 2kL rainwater tank installed in every household within the PSP area, operating with approximately 67% reliability.

The water balance modelling conducted to date indicates that approximately 43% of the total runoff volume could potentially be harvested from the wetland systems for stormwater reuse when rainwater tanks are included. In the absence of rainwater tanks, this increases to approximately 53% of the total runoff volume, as a greater proportion of runoff is available for harvesting from the wetlands. However, this outcome is contingent upon the availability of an equivalent water demand within the area.

The results confirm that the harvested water can be appropriately stored for reuse and that the necessary infrastructure for transporting the water to support irrigation in the designated active open space, as outlined in the IWM plan, is properly planned.

Burrumbeet Creek Waterway Corridor Rehabilitation

It is recommended that the Burrumbeet Creek waterway corridor is revitalised through stabilisation of the existing creek form, and the reintroduction of native vegetation and trees along the riparian zones. Further studies such as hydro-ecological, geomorphological assessments, targeted flora and fauna survey will help identify areas of the creek that may require protection or further consideration as part of future development. The proposed PSP WLRBs have been designed to manage development-related impacts and avoid increasing detriment to the existing creek system. No specific creek enhancement works, or associated costs have been identified as part of the DCP-funded works at this stage. Any requirements for future in-stream works would be subject to further assessment and consultation with GHCMA as the relevant waterway authority.

Flood Impact Assessment

Ballarat North PSP is situated within the Glenelg Hopkins Catchment Management Authority (GHCMA) regions. Ballarat North is subject to flooding along the Burrumbeet Creek floodplain in the 1% Annual Exceedance Probability (AEP). A hydrologic and hydraulic assessment have been completed in accordance with Australian Rainfall and Runoff (AR&R) (AR&R, 2019) and GHCMA Guidelines. Specifically, climate change scenario modelling has been undertaken to define the 1% AEP flood extent. This has been used as the basis for the flood impact assessment.

The hydraulic modelling assessment has incorporated the proposed retarding basins, constructed waterway diversion and associated filling to assess the impacts on the floodplain under the developed conditions. The outcomes demonstrate that the PSP development with the proposed infrastructure does not result in any worsening of flood conditions in the 1% AEP event under climate change scenario.

Conclusion and Recommendation

The functional design outcomes have demonstrated that the proposed drainage infrastructure and mitigation works are technically feasible and meet the relevant requirements. Key recommendations include:

- Continue collaboration with stakeholders, including Ballarat City Council, Glenelg Hopkins CMA and Central Highlands Water, to ensure agreed understanding of flooding requirements in particular impacts of climate change and explore integrated water management opportunities beyond the PSP framework.
- Investigate the opportunity for a comprehensive rehabilitation program for Burrumbeet Creek, including geomorphological and eco-hydrological assessments to restore geomorphology, riparian vegetation, creek form and ecological health.
- As part of the development process complete detailed site investigations to refine overland flow paths, pipe alignments, and confirm conveyance needs, especially near Burrumbeet Creek.

1. Introduction

SMEC has been engaged by the Department of Transport and Planning (DTP) to refine the stormwater drainage strategy prepared by Arup in 2024 and prepare the functional designs for the Ballarat North Precinct Structure Plan (PSP). The outcomes of the stormwater drainage strategy will be used to inform the PSP and the associated costing to deliver the drainage infrastructure works in the form of a Development Contributions Plan (DCP).

Ballarat North PSP is divided into core and expanded areas, as shown in the Figure 1-1 below. The study focuses primarily on the core area, with future-proofing considerations made for the expanded area.

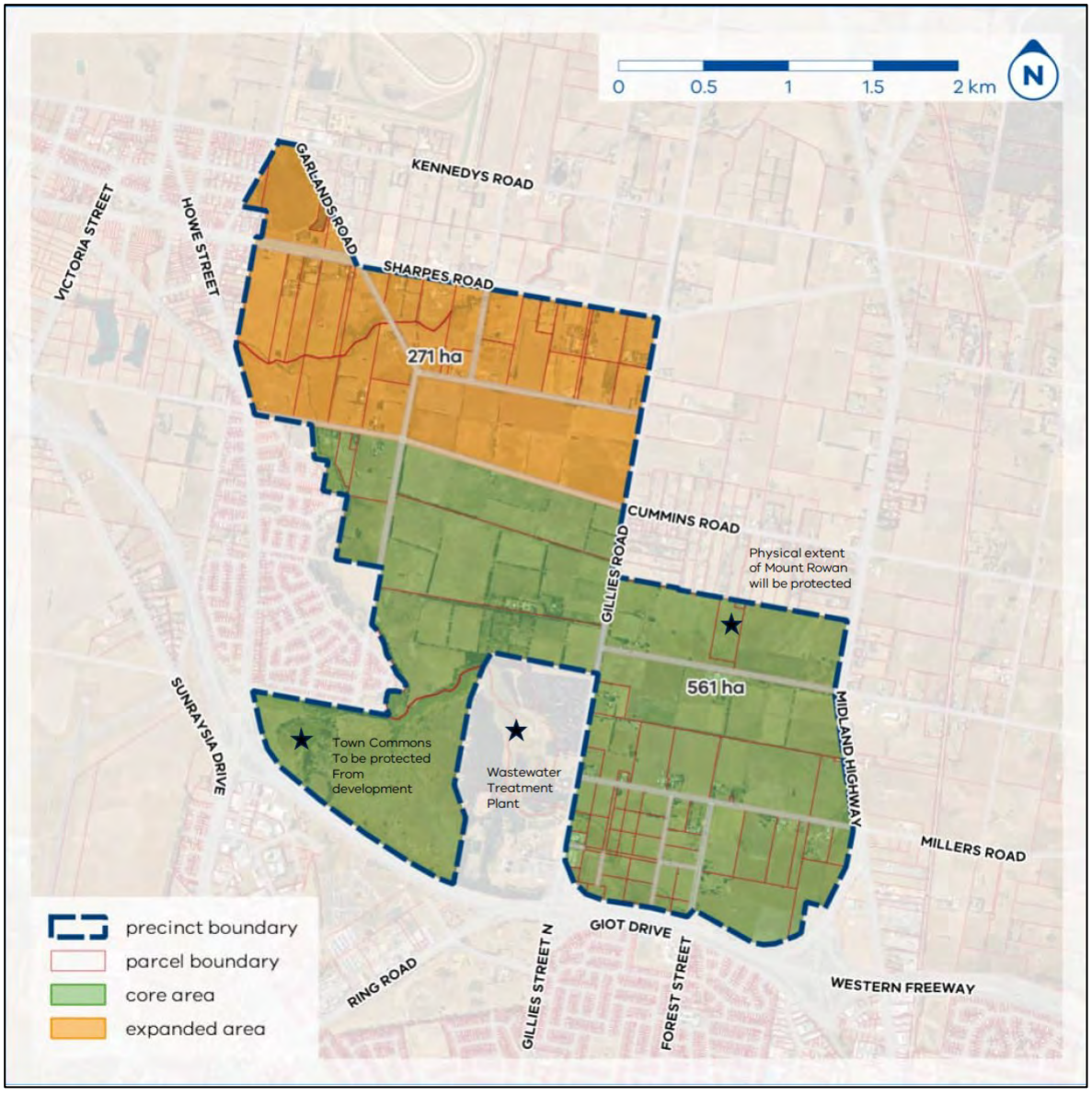


Figure 1-1 Ballarat North PSP boundary

The PSP core area is approximately bounded by Cummins Road in the north, Midland Highway in the east, Burrumbeet Creek in the west, and Western Freeway in the south.

The scope of works encompasses a number of stages:

- Stage 1 - Literature Review and Contextual Analysis, Preliminary Drainage Concept
- Stage 2 – Stormwater Proof of Concept

- Stage 3 – Functional Design and Costing

A literature review was conducted to understand the background works undertaken by the DTP and various consultants. The findings from this review helped inform the design basis. Subsequently, a preliminary drainage concept was developed and presented to the key stakeholders for initial feedback and support.

This report describes the key outcomes and methodology related to various aspects of the drainage strategy development. The following report sections detail the key components:

- Key outcomes of the contextual analysis (Sections 3 and 4)
- Waterway health (Section 3.7)
- Stormwater management objectives (Section 5)
- Existing conditions hydrology (Section 6)
- Outcomes of the stormwater proof of concept design for the developed conditions – infrastructure sizing (Section 7)
- Stormwater quality analysis and Integrated water management (Sections 8 & 9)
- Flood impact assessment (Section 10)
- The detailed modelling methodology and results of the RORB and MUSIC modelling are provided in the Appendices.

The outcomes of Stage 2 (proof of concept report) include verification of drainage asset sizing and land allocation at a conceptual level. Further assessments, hydraulic modelling and 3d surface design have been completed in the functional design (Stage 3, this report) to ultimately inform the costing of the Ballarat North PSP and Development Contributions Plan.

2. Available Data

The following reports and digital data have been supplied by the DTP.

2.1 Reports

List of reports is presented in Table 2-1.

Table 2-1 Key reference documents and input reports

Author	Year	Document Title
Arup	2024	Ballarat North PSP IWM & Drainage Assessment, Ballarat North PSP IWM Plan, Rev 03, 2 July 2024
Central Highlands Water, City of Ballarat, Corangamite CMA	2018	Ballarat City Integrated Water Management Plan, Final Report
Central Highlands Water	2018	Ballarat Potable Water Demand Target
Department of Environment, Land, Water and Planning	2017	Growling Grass Frog Habitat Design Standards
Ecology and Heritage Partners	2024	Ballarat North Precinct Structure Plan: Strategic Bushfire Development Report and Risk Assessment, Final, July 2024
GHD	2024	Adverse Amenity Impact Assessment, Ballarat North, Rev 0, 28 May 2024
Jacobs	2024	Land Capability Statement, Ballarat North Precinct Structure Plan 10 July 2024
Mesh	2024	Final Landscape and Visual Assessment, Ballarat North PSP, Version 1, May 2024
Spiire	2024	Memo - Drainage Strategy Asset Locations 10 July 2024
Stantec	2024a	Ballarat North Precinct Structure Plan, Situational Analysis Report and Utility Servicing Assessment, Revision 03, 3 July 2024
Stantec	2024b	Design Brief Report – Miners Rest Flood Mitigation Rev 02 31 January 2024
RBA	2024	Ballarat North PSP Historical (Post-Contact) Heritage Assessment, July 2024
State Government of Victoria	2014	Central Highlands Regional Growth Plan
Tree Logic	2024	Arboricultural Assessment and Report, Ballarat North – PSP, 6 August 2024
Urbis	2024	Ballarat North Precinct Structure Plan, Economic & Retail Assessment, Final Report, June 2024
Victorian Planning Authority	2023	Ballarat North Precinct Structure Plan, Vision & Purpose Survey Summary
Victorian Planning Authority	2024	Community Infrastructure and Open Space Needs Assessment, Ballarat North Precinct Structure Plan, June 2024
Victorian Planning Authority	2024	Draft Ballarat North Place Based Plan for future urban structure
Victorian Planning Authority	2024	Ballarat North Precinct Structure Plan - Co -Design Summary

Table 2-1 Continued

Author	Year	Document Title
Wadawurrung Traditional Owners	2024	Wadawurrung IWM Statement
Wadawurrung Traditional Owners	2024	Healthy Country Plan
Water Technology	2013	Burrumbeet Flood Investigation, Summary Study Report
Water Technology	2013	Burrumbeet Flood Investigation, Hydrologic and Hydraulic
WSP	2024	Ballarat North Precinct Structure Plan, Biodiversity Assessment Report, Rev C, 9 August 2024

2.2 Digital Data

List of available digital data is presented in Table 2-2.

Table 2-2 Summary of digital data sources

Source	Year	Description
Department of Energy, Environment, and Climate Action	2024	3D Regional Towns LiDAR, 1m DEM, Provided by DTP, Accessed 10 September 2024. Elevation Data acquired between 2019-2020.
Arup	2024	MUSICX - Ballarat North PSP IWM and Drainage Assessment
Arup	2024	RORB Model - Ballarat North PSP
Water Technology	2013	TUFLOW Model of Burrumbeet Creek
DTP	2025	GIS Shapefiles, Locality, Precinct Boundary, Existing Utilities, Landfill Site Shapefiles from Datashare
DTP	2025	Place-based plan (PBP) 23/06/2025
DTP	2026	Place-based plan (PBP) 17/06/2026

3. Contextual Analysis

3.1 Site Context

Ballarat North PSP area is located within the City of Ballarat on the northern boundary of the existing urban extent of Ballarat and south of the locality of Miners Rest as shown in Figure 3-1. The PSP area is predominantly surrounded by farming area to the north and east, and existing residential area to the west and south. It is bounded by Cummins Road to the north, Midland Hwy to the east, Western Fwy to the south, and Miners Rest residential area to the west. A key feature of the PSP is Burrumbeet Creek traversing along the southern portion of the PSP.

The total site area is approximately 567 ha and identified by Ballarat City Council as the preferred next residential growth area and has been the subject of appropriate strategic technical assessments and engagement with landowners and relevant agencies over several years by Council.

Ballarat North PSP has an average slope of approximately 3% and drains from north to south towards Burrumbeet Creek. Along the low point of the Creek, the terrain becomes relatively flat as it drains towards northwest of the PSP boundary. The site has an elevation varying from 516 to 420 m AHD. The highest point of the PSP site is north of Sims Road, and the lowest point is Burrumbeet Creek.

Ballarat Town Commons is located in the southwest corner of the PSP which is identified as 'Crown Land' and is supposed to likely remain undeveloped. This catchment drains naturally towards north into Burrumbeet Creek.

The site is currently zoned as Urban Growth Zone. A number of planning overlays cover the PSP area including and not limited to Land Subject to Inundation (LSIO), Floodway Overlay, Environmental Significance Overlay (Schedule 2) and Erosion Management Overlay along the Burrumbeet Creek corridor.

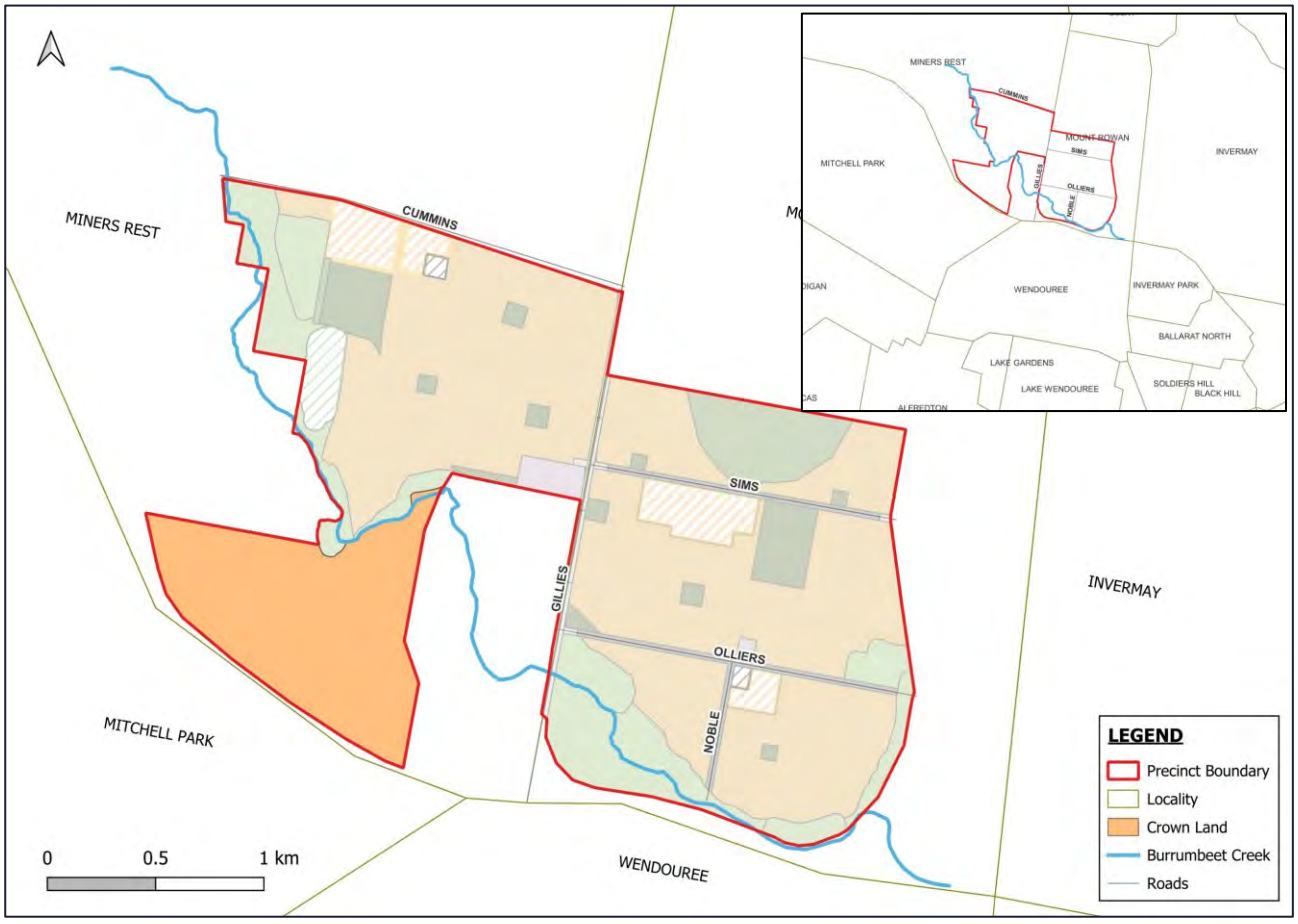


Figure 3-1 Ballarat North PSP site overview

3.2 Core Area Catchments

The Ballarat North PSP area is generally split into five major catchments. These catchments are described below and shown in Figure 3-2.

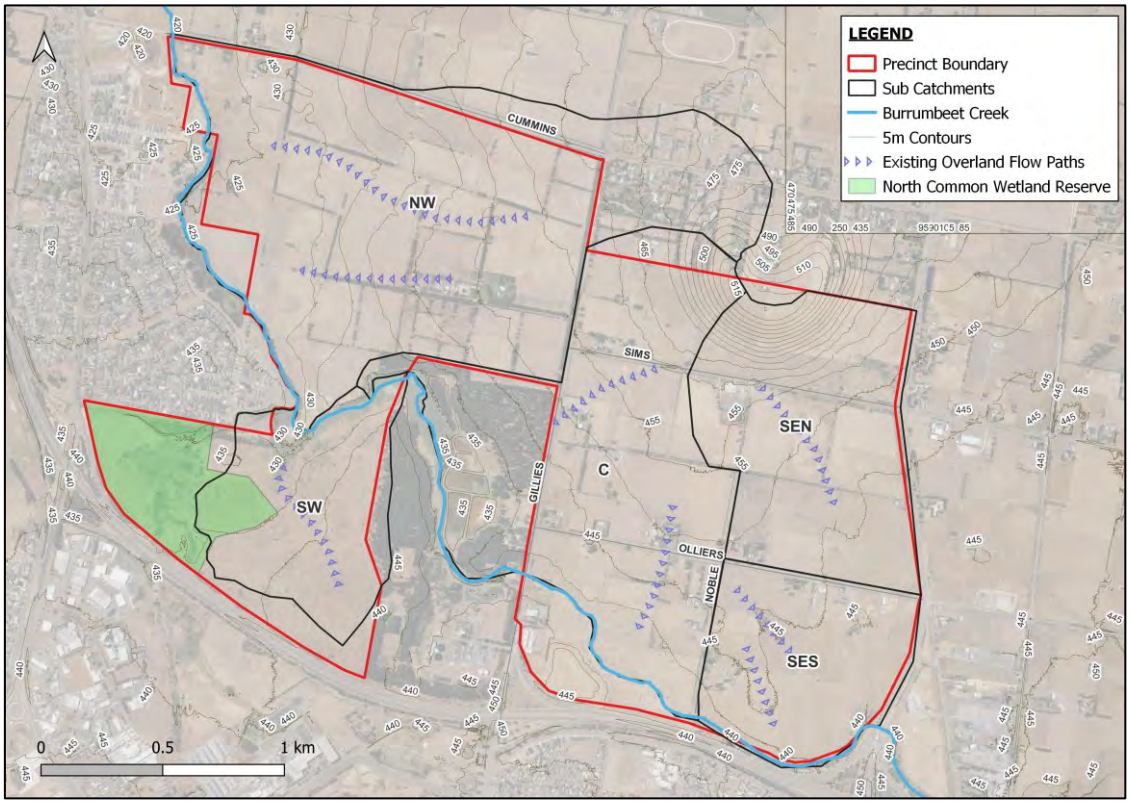


Figure 3-2 Catchment split based upon existing overland flow paths

3.2.1 South East Catchment

The south east (SE) catchment is approximately 160 ha. This catchment is further split into two sub catchments SE (north) and SE (south).

3.2.1.1 South East (north) Catchment

The SE (north) catchment is approximately 98 ha. The majority of the catchment is mainly large open paddocks which accommodates livestock grazing or otherwise underutilised rural land use. The direction of runoff is generally from north west to south east of the boundary. The highest point of SE (north) catchment is north of Sims Road with the runoff draining towards south east into the existing waterway. The SE (north) catchment elevation is varied from 520 m Australian Height Datum (AHD) to 442 m AHD.

3.2.1.2 South East (south) Catchment

The SE (south) catchment covers an area of approximately 62 ha. The catchment is predominantly characterised by large open paddocks currently used for livestock grazing or remaining as undeveloped rural land. Surface runoff generally follows a north to south drainage pattern across the site. The highest point of the catchment is located along Olliers Road, with flows draining southwards towards Burrumbeet Creek. Ground levels within the SE (south) catchment range from approximately 448 m AHD at the upstream extent to 440 m AHD at the downstream boundary.

3.2.2 Central Catchment

The central (C) catchment is approximately 167 ha of which 48 ha is external catchment outside of the PSP boundary. The majority of the external catchment is west of the Gillies Road with a small portion situated north of

the PSP boundary. The C catchment is mainly open rural lands and slopes from north east to south west and south of the boundary towards Burrumbeet Creek. It has an elevation ranging from 520 m AHD to 435 m AHD. This catchment has multiple outlet locations along the creek interface.

3.2.3 North West Catchment

The larger part of the PSP area is called north west (NW) catchment. The land use type is largely open space which is being used for livestock grazing and is approximately 235 ha in size. This catchment generally slopes towards western boundary of the site where it drains into the Burrumbeet Creek. The highest point elevation is 512 m AHD, and lowest point is at 420 m AHD at the Burrumbeet Creek outlet (considered as the outlet of the entire PSP area). A rural residential external catchment of approximately 50 ha enters the catchment boundary to the east and north east.

3.2.4 South West Catchment

The south west catchment is approximately 64 ha which drains north into the Burrumbeet Creek. This catchment constitutes large open paddocks and environmental land, including part of the alignment of Burrumbeet Creek which runs through the North Common Wetland Reserve (see Figure 3-2), located on the southwest corner of the catchment boundary. This area is designated as Crown Land and is likely to remain undeveloped. Since there are no proposed developments in this area, there are no requirements for assets sizing and thus this catchment is excluded from ongoing modelling.

3.2.5 External Catchment - Tributary of Burrumbeet Creek

There is a sizeable external catchment (990 ha) on the north and eastern side of the PSP boundary. Part of flows head east along Cummins Road and then turn south along the Midland Highway within the Mt Rowan locality. The remaining of the external catchment come from the Invermay locality to the east of the PSP boundary. Flows coming from this external catchment will not impact the WLRB sizing. However, this external catchment has been included in the RORB model for sizing of the realigned constructed waterway. Figure 3-3 below shows a snippet of the external catchment in the north and east of the PSP area.

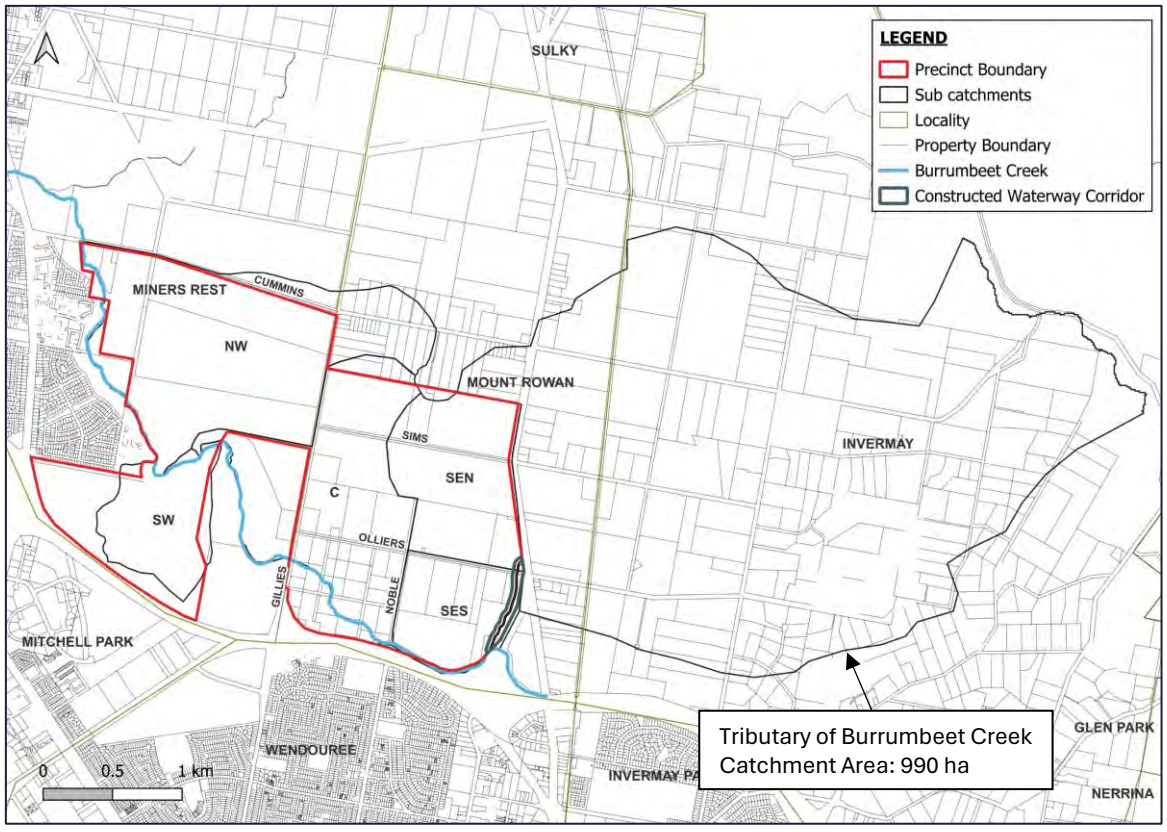


Figure 3-3 External catchment to the waterway

3.3 Expanded Area Catchment

The expanded area is bounded by Sharpes Road to the north, Howes Street to the west and Gillies Road to the east covering an area of 268 ha. This area generally drains towards north west into a separate tributary of Burrumbeet Creek and is considered independent of the core area catchments. The catchment topography and direction of flow allows for drainage partitioning. The core area of the PSP has been prepared cognisant of the PSP expanded area. As such, the future drainage works within the core area does not preclude the expanded area to be investigated in the future. Catchment modelling for the core area will exclude the expanded area so that there is a clear division of catchment flows. The expanded area is shown in Figure 3-4.

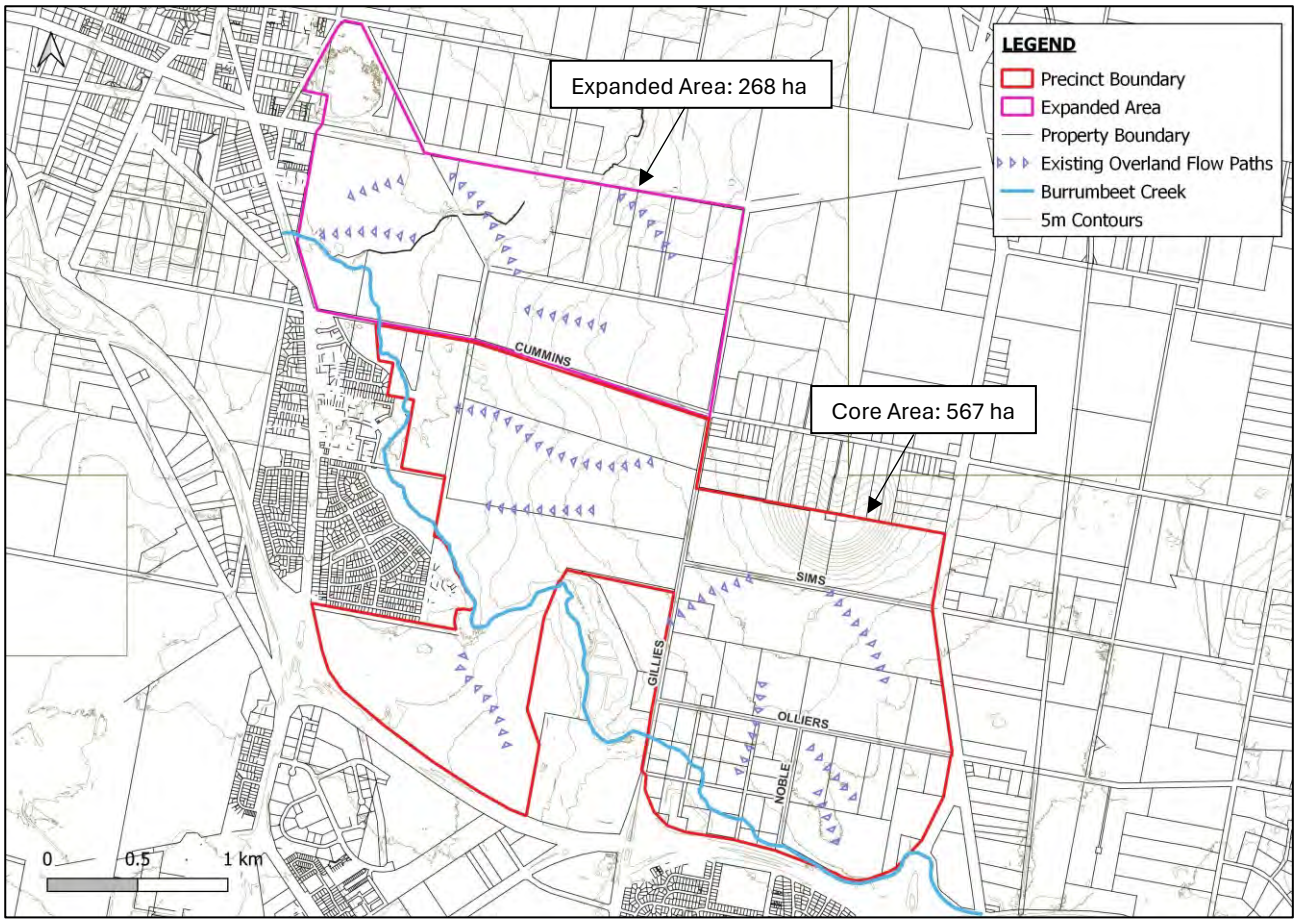


Figure 3-4 Ballarat North PSP expanded area

3.4 Planning Overlays

The following overlays as shown in Figure 3-5 impacting the Ballarat North PSP area:

- The portion of the PSP area north of Sims Road is affected by the Significant Landscape Overlay (SLO) and Erosion Management Overlay (EMO). Any construction work (building or carry out works such as roadworks) is restricted in this area and a permit is required.
- The portion of the PSP area south of Sims Road is affected by the Specific Controls Overlay (SCO). This area is to be used or developed for Ballarat Grammar School Mount Rowan Campus as documented on the planning scheme map. Use or development of this area beyond the controls is prohibited or restricted.
- Bushfire Management Overlay (BMO) and Environmental Significance Overlay (ESO) (Schedule 4) on water reclamation plant site along the centre of the PSP boundary. The C, SW and NW catchments are partly affected by these overlays. The development of land in this area is affected by environmental constraints to ensure development is compatible with environmental values. Development is also only permitted where the risk to life and property from bushfire can be reduced to an acceptable level.
- The PSP area along the Burrumbeet Creek corridor is affected by the Land Subject to Inundation (LSIO), and Floodway Overlay (FO). This area is flood prone which is affected by the 1 in 100-year flood and therefore a permit is required to construct a building or carry out works.
- The NW catchment is partly affected by the Design and Development Overlay (DDO) connected to Ballarat Airport, west of the Ballarat North PSP boundary.
- There is a conservation area called seasonal herbaceous wetland along the Burrumbeet Creek to the west boundary of the NW catchment. Retention of the wetland habitat is recommended. (VPA, 2024).

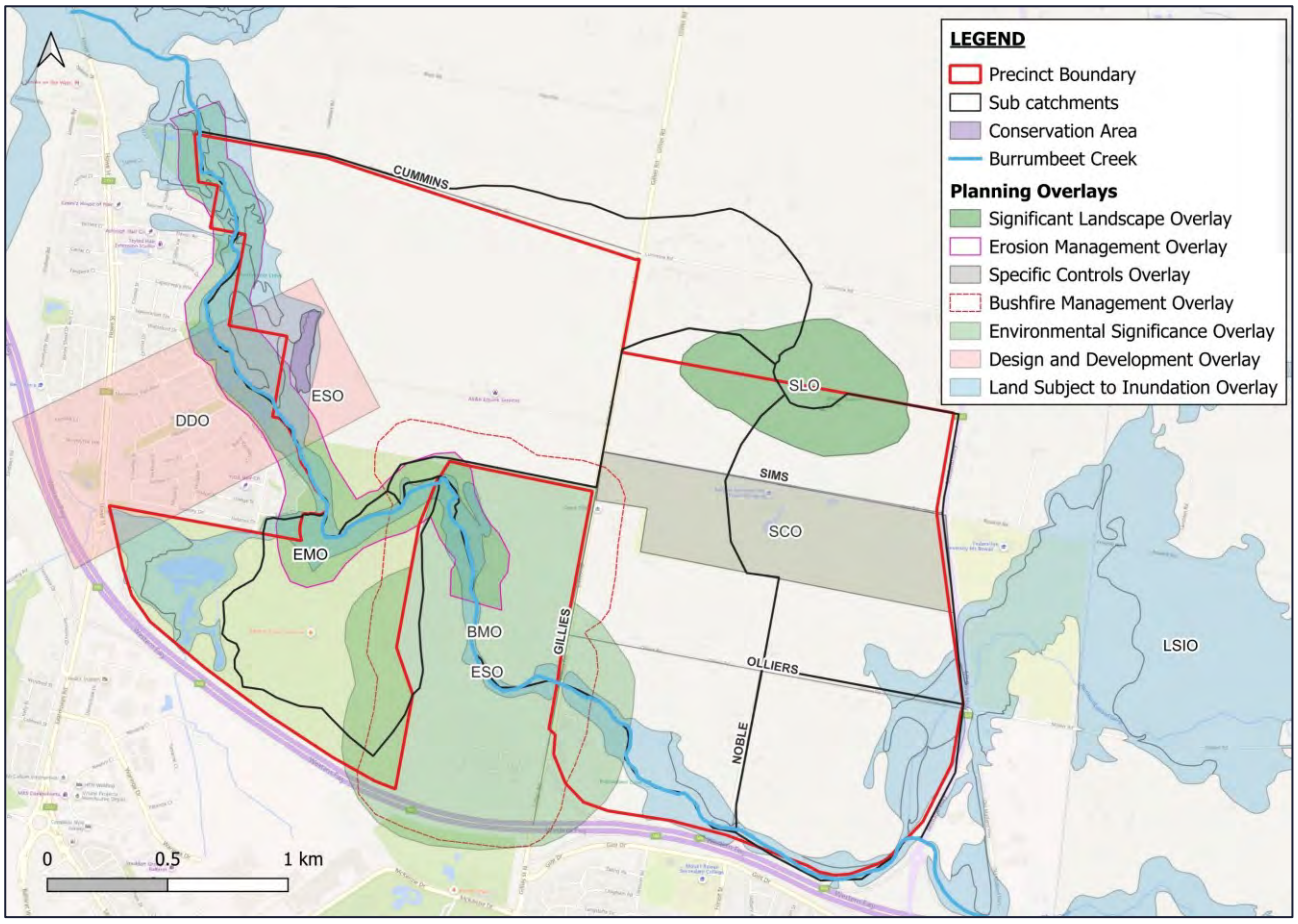


Figure 3-5 Planning overlays for Ballarat North PSP (source: mapshare.vic.gov.au)

3.5 Site Visit

SMEC attended the site on 24 September 2024. The primary objectives and expected outcomes of the visit were to:

- Comprehend the site condition and constraints.
- Inspect the location of the four detention basins within the Ballarat North PSP area, as proposed in the IWM Plan (Arup, 2024), to check the suitability of these areas for the proposed treatments.
- Inspect the Burrumbeet Creek condition to assess the waterway health and any geomorphological change.

Refer to Figure 3-6 for the inspected locations on the site visit day.

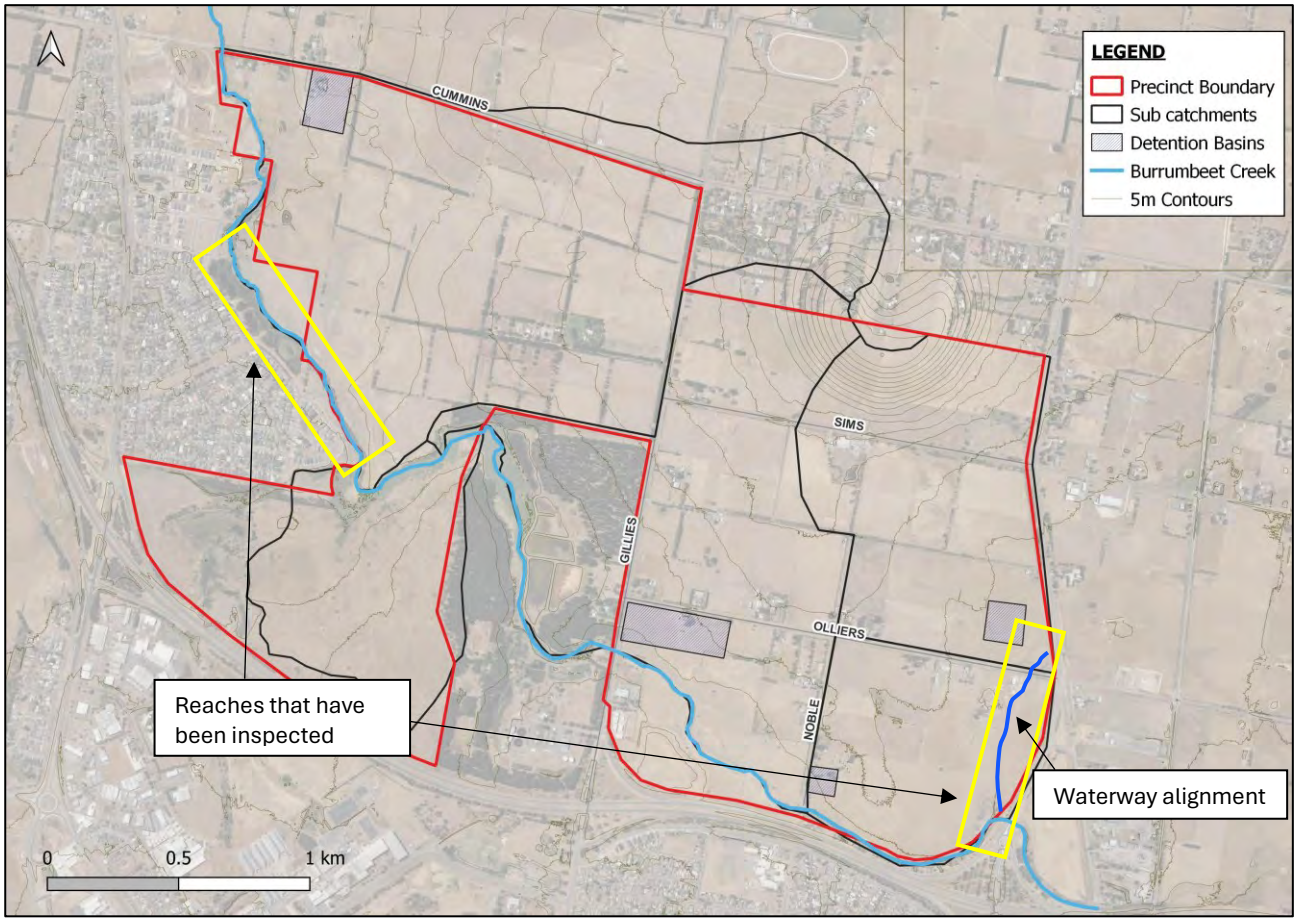


Figure 3-6 Site visit locations (24 September 2024)

The inspected locations of the detention basins proposed by Arup (2024) are shown in Figure 3-7 below.



Figure 3-7 (a) Location of detention basin 1 north of Olliers Road



(b) Location of detention basin 2 east of Noble Ct adjacent to the Burrumbeet Creek



(c) Location of detention basin 3 east of Gillies Road adjacent to the Burrumbeet Creek



(d) Location of detention basin 4 south of Cummins Road

The unnamed tributary of Burrumbeet Creek was inspected on site running along the eastern boundary of the PSP area near Midland Hwy from north to south. This drain flows under Olliers Road through four (4) box culverts (approx. 1200mm (W) × 450mm (H)) and joins Burrumbeet Creek in the south with an average longitudinal slope of 0.004 m/m. The location and extent of this drain is illustrated in Figure 3-8.

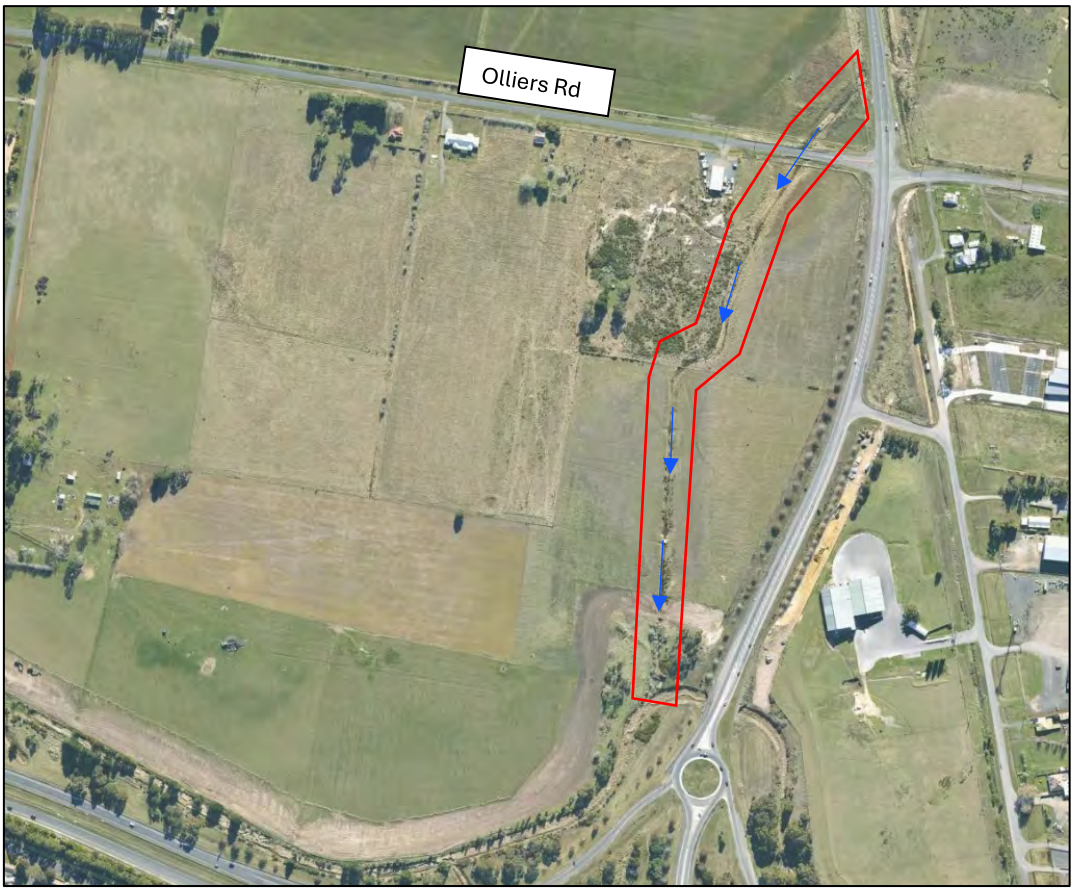


Figure 3-8 An unnamed drain (tributary of Burrumbeet Creek) near the eastern boundary of the PSP (source: Metromap)

The drain is in poor condition, with insufficient vegetation coverage on the banks to protect the channel from erosion. Although the channel has a relatively low longitudinal slope (average 0.004 m/m), there are clear signs of bank erosion. The primary cause of this active erosion is the lack of protective vegetation, likely compounded by an inadequate design that does not account for the channel's susceptibility to erosion.

Additionally, the drain contains patches of exotic vegetation, and there is little to no presence of native species such as trees, understory plants, or grasses, which are essential for stabilising the banks and supporting the ecosystem. Figure 3-9 illustrates two photos from the channel condition with clear signs of bank erosion and exotic vegetation on banks.

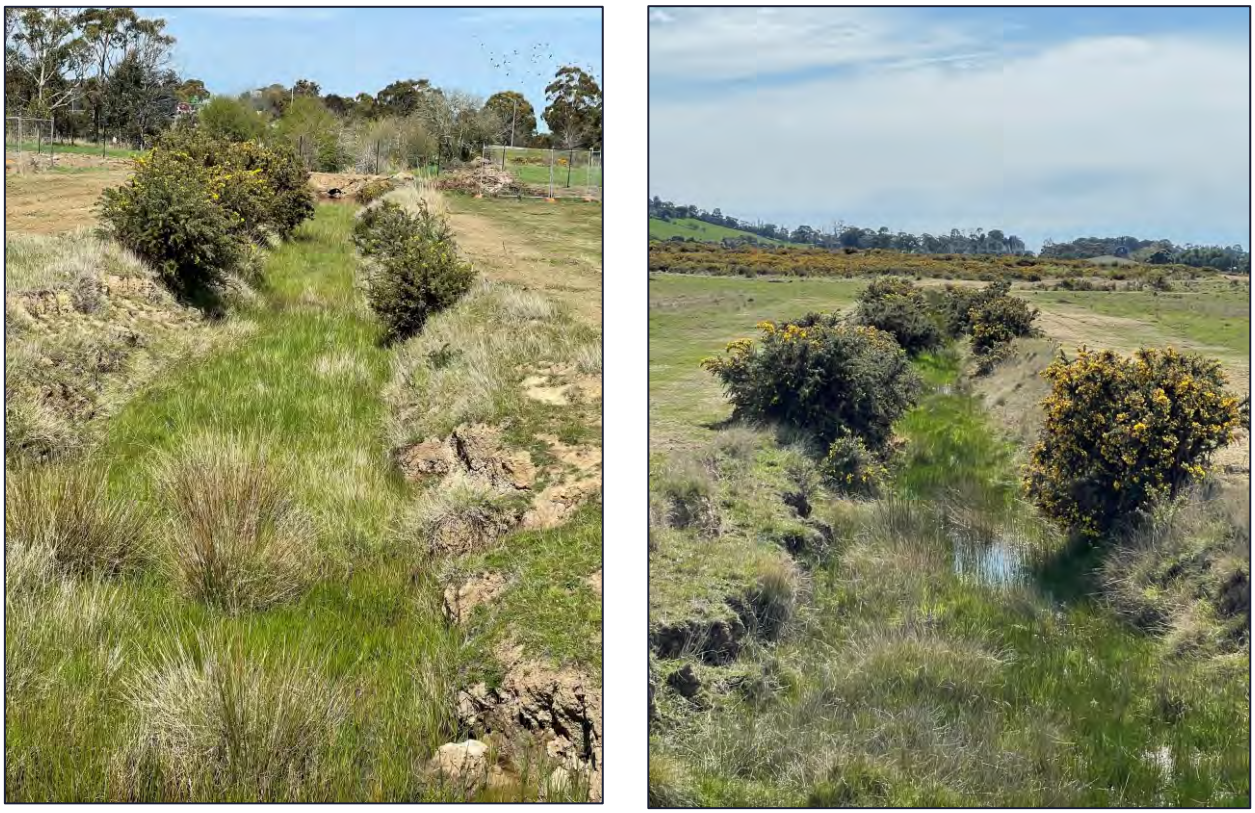


Figure 3-9 Current condition of the unnamed drain near the eastern boundary of the PSP (looking downstream on the left and upstream on the right)

Burrumbeet Creek suffers from a lack of dense native riparian vegetation and a well-defined geomorphological form between the confluence of the unnamed drain and Burrumbeet Creek in the southeast corner of the PSP and south of Noble Court. The creek runs in a straight alignment for a long distance up to 407 m with no meandering alignment or proper geomorphological channel section. Figure 3-10 and Figure 3-11 illustrate the river condition within this stretch.



Figure 3-10 Channel straight alignment (source: Metromap)



Figure 3-11 Lack of native riparian vegetation in the channel corridor

Burrumbeet Creek has similar condition and issues west of Noble Court. Lack of vegetation is obvious on river banks in the river reach between Noble Court and Gillies Road. The river condition within this stretch is susceptible to erosion due to lack of vegetation on the river banks as a protective layer.



Figure 3-12 Lack of vegetation on river bank (source: Metromap)

Burrumbeet Creek is also in poor condition west of Gillies Road. The creek suffers from vertical and undermined riverbanks, as well as the presence of exotic vegetation (see Figure 3-13). The unstable banks indicate ongoing channel widening, which represents the second stage in a river channel's geomorphological cycle, following channel deepening. This suggests active erosion within the channel, causing a significant threat to the health of the waterway in this area.



Figure 3-13 Undermined bank and exotic vegetations (left), vertical bank and exotic vegetations (right)

3.6 Integrated Water Management

A review of the Integrated Water Management (IWM), Water Sensitive Urban Design (WSUD) elements completed in the earlier study by Arup (2024), are discussed below.

3.6.1 Review of the Arup (2024) Design Basis

- The IWM Plan report proposed that all development and detention basin works should be located outside the 1% AEP flood extent (including climate change). This is consistent with the asset locations in the Arup drainage layout plan. Refer to Figure 3-14 below for the IWM plan by Arup.

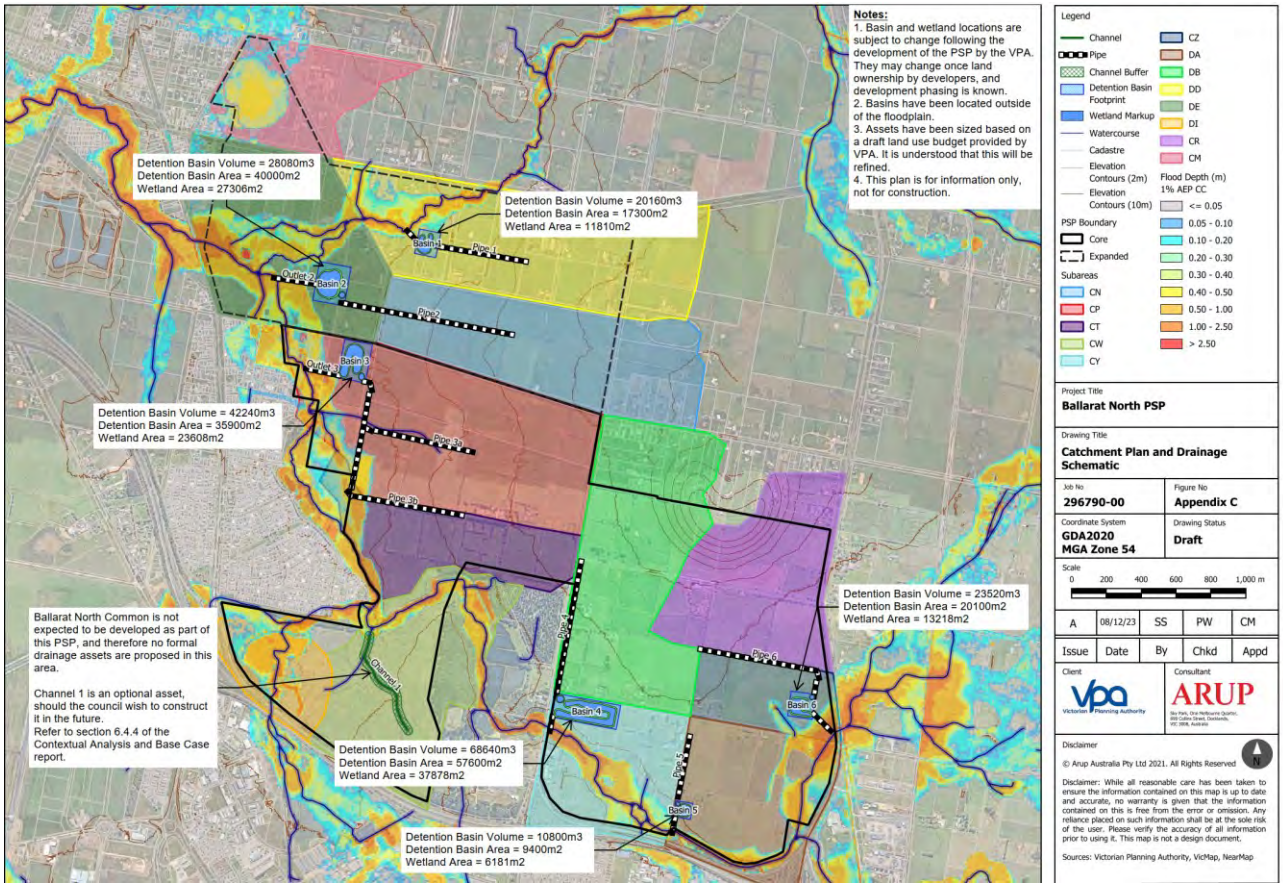


Figure 3-14 IWM Plan (Arup, 2024)

- A review of the initial drainage layout reveals challenges in design of RB and wetland infrastructure driven by elevation differentials between two and five meters. Such variation would result in significant excavation costs and land take to achieve appropriate batter slopes. It is preferable for retarding basins and wetlands to be located in flat terrain.
- It has been identified that the assets are not located at the most downstream point of the catchments. As a result, downstream catchment areas would be untreated and unattenuated unless additional infrastructure is included further downstream. Where possible it is best to locate centralised stormwater infrastructure close to the drainage outlet to minimise the number of assets required. Based on a review of the terrain and the site visit, there are opportunities to locate the future assets closer to the catchment outfalls.
- The landscape and visual amenity assessment (Mesh, 2024) is supportive of RBs, and wetlands located along the waterway corridor in flood prone land where possible to provide natural amenity, subject to floodplain requirements being met.

- Similar to the Water Technology (2013) modelling, a uniform climate change upscaling factor of 20% in the rainfall depth was adopted in the Arup model run. This factor was based on the climate scenario beyond the year 2100 and was consistent with practices at the time. The recent update to climate change guidance, as mentioned above, means that the hydrology was required to be updated.
- A RORB rainfall runoff model was used to represent the developed conditions based on the draft Place Based Plan at the time. Based on the review of the model a number of aspects can be refined in the proof-of-concept stage. Some of these are as follows:
    - The subarea delineation will need to be redone to ensure there is a sufficient number of subareas upstream to provide a reasonable representation of the inflow hydrograph suitable for retarding basin sizing.
    - Refinement of the fraction of impervious area to reflect the latest land zonings in the developed conditions.
    - Reach length and slopes are to be recalculated based on the revised drainage layout.
- Arup (2024) states that the gap flows along the future roads can convey flows up to 10 m^3/s. This assessment is subject to the road design width and vertical slope. The terrain has an average longitudinal grade between 2-3% and can potentially convey a flow of this magnitude. The allowable gap flow will also need to consider flood safety criteria in residential streets used as floodway. If the road cannot convey the gap flows safely, then a formal overland flow path (easement) or constructed waterway may need to be designed into the landscape.
- This functional design report has confirmed if provision for overland channel is required in the PSP land budget and are covered in Appendix C.

3.6.2 Innovation Pathway Pilot Project

Ballarat North PSP was chosen as a project for the DTP to trial the Innovation Pathway Pilot Program. This pilot project introduces a new Innovation Pathway for preparing structure plans. The five key areas of innovations are:

- Sustainable embedded energy networks
- Sustainable Subdivisions
- Biodiversity Corridors
- A new approach to waste management
- Social and affordable housing including diverse range of housing options.

3.6.3 Vision and Purpose Survey

- The Vision and Purpose Survey has been prepared by the DTP with input from survey responses and is described in VPA (2023). The document describes the aspirations for the future community and the environment. Some of the key aspirations that can be achieved through the stormwater strategy development are:
- To facilitate a more sustainable form of subdivision
- To encourage housing that incorporates Environmentally Sustainable Design principles
- To apply a holistic approach to water and drainage management in the precinct and the surrounding area
- To appropriately manage flooding and inundation risks in the precinct
- To identify and plan for the optimal location and sizes of waterway assets to manage flooding and drainage in the precinct
- To protect the Ballarat Town Commons from development
- To establish streetscapes characterised by an abundant presence of canopy trees

- To make sure people have access to and can enjoy the Burrumbeet Creek
- To maintain and improve the biodiversity of the precinct, particularly around the Burrumbeet Creek and Ballarat Town Commons
- To ensure public access and enjoyment of Burrumbeet Creek.

3.6.4 Water Balance and Treatment Modelling

Arup (2024) describes water balance and pollutant modelling using MUSICX. A review of the model setup and assumptions has identified a number of items that can be refined. Generally, the treatment and stormwater harvesting performance outcomes meet the relevant requirements of the IWM strategy at the time of the analysis.

1) Update of fraction of impervious area based on the latest draft Place Based Plan.
2) The wetland areas and volumes are to be updated to reflect the revised drainage layout.
3) MUSICX outputs are difficult to assess in terms of inundation frequency analysis which is critical in wetland functional design. The proof-of-concept modelling will recreate the catchment model using MUSIC 6 version and in accordance with Melbourne Water MUSIC Guidelines (Melbourne Water, 2018).
4) The MUSICX model indicates that runoff from the entire residential area is captured in rainwater tanks. This representation is unrealistic as only a portion of the roof area will be connected to rainwater tanks. There is opportunity to refine the area entering the tanks to ensure the stormwater harvesting portion is not overestimated.
5) Consideration of the impacts of trees on infiltration and evapotranspiration targets can be assessed in the proof-of-concept stage.
6) The IWM Plan has clearly highlighted the preference for constructed wetlands as the primary treatment measure to meet best practice targets. It aligns with the objectives of a blue green corridor for the Burrumbeet Creek, increased amenity, and open space for the precinct.
    - An analysis of a base case for water and pollutant balance modelling applicable for the PSP is described in Arup (2024). Water demands derived from CHW (2018) and Arup (2024) documents will be used in the concept proofing stage of the project.
        - Residential potable water – 126.8 kL/lot/yr
        - Residential non-potable water demand – 43.3 kL/lot/yr
        - Passive Open Space – 2,000 kL/ha/yr
        - Active Open Space – 5,000 kL/ha/yr

3.6.5 Stormwater Harvesting and Reuse

- A range of IWM portfolios were identified in Arup (2024) that could be implemented in the PSP to meet the wider catchment IWM objectives. Portfolio 1 is the base case scenario, Portfolio 2 aims to achieve the sustainability industry practice, Portfolio 3 aims to meet aspirational targets and Portfolio 4 as the Burrumbeet revitalisation. The recommendation was to attain Portfolio 4 which incorporates a centralised recycled water reuse scheme to service homes in the PSP area achieving a higher standard of service in terms of stormwater volume reduction targets. The same IWM opportunity was noted in the Ballarat City Integrated Water Management Plan (E2DesignLab, 2018) for the Northern Greenfield Investigation Area (Ballarat North PSP). Importantly, the feasibility of this option is subject to further investigation and development of a business case by CHW.
- The IWM report (Arup, 2024) provides a high-level direction for the PSP and is subject to stakeholder agreement prior to design and implementation (see Figure 3-15). The recommended Portfolio 4 and modelling completed to date does not include details of stormwater harvesting and reuse modelling to quantify the benefits (reduction in potable water demand) of the recycled water scheme option. Information on the recycled water scheme is currently insufficient to allow Portfolio 4 to progress into functional design. Additionally, the timing of the business case is unknown, resulting in critical knowledge gaps that hinder progress on the Portfolio 4 option.

Preferred portfolio of options	Base case (no IWM approach is taken)	Combined retarding basins and wetland to meet BPEM target and to control post development 1% AEP flows
		Stabilisation of Burrumbeet Creek
	Recommended IWM interventions	Recycled water to homes
		Precinct scale stormwater harvesting for open space irrigation
		Blue-green corridors in PSP
		Provide ecological refuge and resilience for flora and fauna residing within Burrumbeet Creek

Figure 3-15 IWM Portfolio 4

Until a decision is made, Arup (2024) recommends an alternative plan to be considered in the preparation of the PSP. The recommended Adaptive Plan portfolio is summarised as follows and shown in Figure 3-16. It is described as follows: "precinct scale wetlands connected to local stormwater harvesting to irrigate open spaces is delivered, and that blue-green corridors are incorporated into the land use plan for the PSP following key drainage pathways".

Alternative portfolio of options	Base case (no IWM approach is taken)	Combined retarding basins and wetland to meet BPEM target and to control post development 1% AEP flows
		Stabilisation of Burrumbeet Creek
		2kL rainwater tanks in homes
	Recommended IWM interventions	Precinct scale stormwater harvesting for open space irrigation
		Household raingardens
		Bioretention systems or passively irrigated trees in the streetscape
		Provide ecological refuge and resilience for flora and fauna residing within Burrumbeet Creek

Figure 3-16 Adaptive Plan

- The main differences between the two plans are stormwater harvesting using lot scale rainwater tanks for all developments or a centralised system to be controlled by CHW and the inclusion of a blue green corridor along Burrumbeet Creek.
- SMEC will be progressing the drainage strategy design and modelling based on the Adaptive Plan option noting that information on the recycled water scheme is currently insufficient to allow Portfolio 4 to progress into functional design. It is noted that confirmation from Central Highlands Water regarding proceeding with Adaptive Plan option in the agency validation phase is a key decision to provide certainty in the drainage strategy.
- SMEC will endeavour to develop an engineering solution that functionally serves both options in terms of location to allow for future proofing as best as possible noting the limited input available. Where possible the large, centralised assets (RB and wetland) will be co-located to allow for interchangeability in systems including rainwater tanks or excluding recycled water. The aim is to have a consistent drainage layout for the two options. However, the exact modelling and volume can only be quantified once there is certainty in the recycled water scheme.
- There is uncertainty regarding the asset ownership and management of the future stormwater drainage assets. It is assumed that all drainage assets will be owned and managed by City of Ballarat with the exception of Burrumbeet Creek and any constructed waterways. In the case of the Portfolio 4, asset ownership of recycled water facilities would involve Central Highlands Water. Constructed waterways will likely become the responsibility of GHCMA. Confirmation of future asset ownerships should be agreed with all relevant parties.
- It is anticipated that proposed drainage assets (including wetlands, retarding basins, sediment basins, culverts, pipes and constructed waterways will be owned and managed by the City of Ballarat in

consultation with relevant authorities such as CHW, GHCMA and stakeholders including the Traditional Owners of the Wadawurrung Country.

3.7 Waterway Health

Burrumbeet Creek and the unnamed drain near the eastern boundary of the PSP are in a poor condition from the waterway health perspective. The main issues observed during the site inspection are listed below:

- Lack of riparian vegetation in some reaches of the unnamed drain and Burrumbeet Creek (Section 3.7.1)
- Exotic and invasive vegetation on river banks (Section 3.7.1)
- Straightened channel alignment (Section 3.7.2)
- River water quality (Section 3.7.3)
- Active erosion (Section 3.7.4), and
- Growling Grass Frog habitat (Section 3.7.5).

Identified issues and potential solutions are discussed in the following sections.

3.7.1 Lack of Riparian Vegetation and Exotic Vegetation

Riparian vegetation is essential for maintaining a healthy waterway. A well-balanced mix of native trees, understory plants, and grasses along riverbanks helps prevent erosion by providing effective ground cover during floods and stabilising the soil through tree root systems.

Native riparian vegetation is highly adaptable to local environmental conditions, offering climate resilience and natural resistance to diseases and pests. Also, it supports a thriving habitat for aquatic and terrestrial flora and fauna, including invertebrates and amphibians.

In contrast, exotic vegetation can disrupt the ecosystem, introducing environmental challenges unfamiliar to local wildlife. Below are two key examples of issues that may arise due to the introduction of exotic vegetation:

- Native birds may not recognise exotic trees as suitable environments for nesting, leading to a decline in their use of shelter and feeding on insects that inhabit these non-native plants. In extreme conditions, this might lead to migration of native bird population or other native fauna.
- Exotic trees and shrubs may have different water requirements, often leading to excessive water uptake from waterways, which can disrupt the local hydrological balance.

Under existing conditions, the banks of Burrumbeet Creek and the unnamed drain near the eastern boundary are largely covered with exotic vegetation or remain bare for long stretches. This lack of appropriate vegetation increases the risk of erosion along the riverbanks.

Following urban development, the risk of erosion will increase due to hydrological changes in the catchment. Although current legislation mandates that peak flow rates under urbanised conditions match existing conditions, localised increases in flow rates between retardation points are still expected. In addition to flow rate, other factors contributing to the exacerbation of the risk of erosion include increased water volume and prolonged flow duration.

These factors highlight the critical role of in-channel and riparian vegetation in protecting the stability of the waterway and mitigating erosion.

3.7.2 Straightened Channel Alignment

Burrumbeet Creek follows a straight alignment from its confluence with an unnamed drain near the eastern boundary of the PSP and Noble Ct. While limited data is available on the channel bed, the site visit on 24 September 2024 confirmed the absence of pools and riffles. Naturally straight river alignments are extremely rare, typically occurring only in rocky channel beds. This rarity suggests that straight channels are inherently more susceptible to erosion. It is important to note that urban development can accelerate geomorphological changes, exacerbating erosion risks.

Beyond erosion concerns, a meandering channel form improves water quality and enhances aquatic habitats. Meanders promote better interaction between water and riparian vegetation at bends, as well as increased exchange between surface and groundwater through the hyporheic zone.

3.7.3 River Water Quality

Although there is no current data on the water quality of Burrumbeet Creek, it is likely to be poor due to high concentrations of nitrogen and phosphorus from agricultural fertiliser runoff. The presence of pathogen contamination and pesticides can be other potential issues under the current situation.

Urban development will alter the type and concentration of nutrients in the area. However, with proper planning and the implementation of stormwater treatment facilities, such as wetlands, surface water quality can be improved

3.7.4 Active Erosion

Active erosion was observed within Burrumbeet Creek during the site inspection. Vertical, collapsed embankment and undermined banks were observed frequently along the creek and drains discharging to the creek. There are multiple reasons as cause of erosion such as lack of proper vegetation coverage, lack of proper geomorphological alignment and channel and potentially hydraulic condition. See examples of active erosion in Figure 3-17 and Figure 3-18.



Figure 3-17 Local erosion on the right bank of the unnamed drain



Figure 3-18 Undermined river bank

From a geomorphological perspective, the site observations suggest that the river is unstable and in the second phase of geomorphological evolution. The geomorphological evolution cycle and the channel widening process are illustrated in Figure 3-19 and Figure 3-20.

As previously mentioned, in addition to peak flow, changes in surface water volume and event duration will further accelerate the geomorphological evolution of Burrumbeet Creek and its tributaries. Therefore, proper planning and design are essential to guide the creek toward an equilibrium state and mitigate future changes.

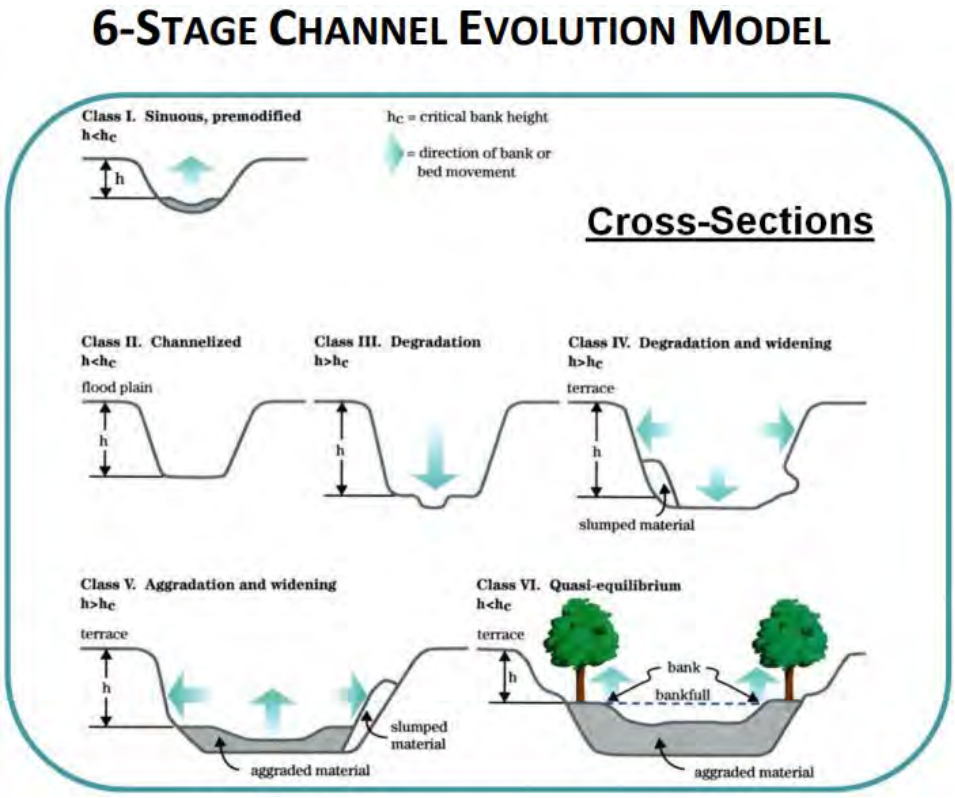


Figure 3-19 Six stages of channel geomorphological evolution model (source: NSCEP, 1998)

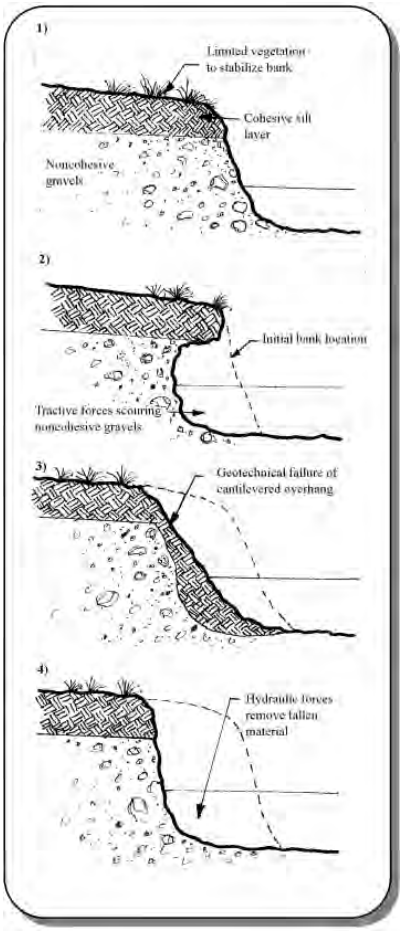


Figure 3-20 Channel widening and river bank failure process (source: NSCEP, 1998)

3.7.5 Growling Grass Frog habitat

Growling Grass Frog (GGF) is a threatened amphibian species with a declining population, which was once a common frog in south-eastern Australia. According to WSP (2024), no Growling Grass Frogs were recorded during the targeted survey in this area. However, they have suggested that under the right conditions, this species would be likely to utilise aquatic riparian habitat across the study area.

"No Golden Sun Moths, Growling Grass Frogs or Striped Legless Lizards were recorded during targeted survey. Based on the results of targeted surveys, Growling Grass Frog is considered unlikely to currently occur within the study area. However, the creeks and associated wetlands are connected with known habitat ~8.6 km upstream via the Burrumbeet Creek and Slattery Creek in Creswick State Forest. It is reasonable to assume that under the right conditions (e.g. high rainfall/flooding) this species would be likely to utilise aquatic riparian habitat across the study area whilst dispersing throughout the landscape."

Multiple factors have contributed to the reduction in the population of Growling Grass Frog, including loss of habitat, change in hydrological regime of waterways, poor water quality, disease including chytrid fungus, overshading of pools and dense terrestrial vegetation adjacent to their habitat.

The existing waterways, including drains, Burrumbeet Creek, and constructed wetlands do not provide suitable habitat for the GGF. The key factors preventing their migration to this area are listed below:

- Constructed wetlands designated to treat stormwater are not optimal as the high concentration of nutrients in stormwater entering these wetlands increases the risk of algal blooms and another disease that are fatal to the GGF.
- The design of conventional constructed wetlands designated to treat stormwater is not ideal for the GGF. For instance, GGF ponds require a specific water balance, shape and depth to guarantee water security for Growling Grass Frog and refuge areas for adult frogs as well as for eggs and tadpoles. Also, Growling Grass Frog wetlands require rocks around the minimum of 50% of the wetland perimeter.
- River channels with overgrown reeds and rushes are not suitable environments for GGF because of lack of areas with submerged vegetation, which is vital refuge areas for frog eggs and juveniles. Also, overgrown reeds and rushes reduce the water temperature, which increases the risk of disease such as chytrid fungus.
- A successful plan for GGF requires a cluster of wetlands with a preferred area of 7000 m^2 in size and the minimum size of 3000 m^2. The maximum distance between GGF should be 700 m.

GGF habitats have not been included in the designs and costings prepared by SMEC but that further investigations to establish GGF habitats may be considered in the future.

To encourage the migration of the Growling Grass Frogs to this area, multiple ponds should be designed on the floodplains, offline from Burrumbeet Creek. Given the specific geometric requirements of the ponds and their water demands, these should be separate from conventional constructed wetlands designed for stormwater treatment.

4. Site Constraints

4.1 Flooding

A high-level review has been completed of the available flood modelling information. Burrumbeet Creek is the main drainage outfall for the PSP area providing flood conveyance, amenity and a biodiversity corridor. It has also been identified as one of the main opportunities for enhancement and rehabilitation. It is understood that the current Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) are based on the 2013 flood modelling outcomes. Refer to Figure 4-1 below.

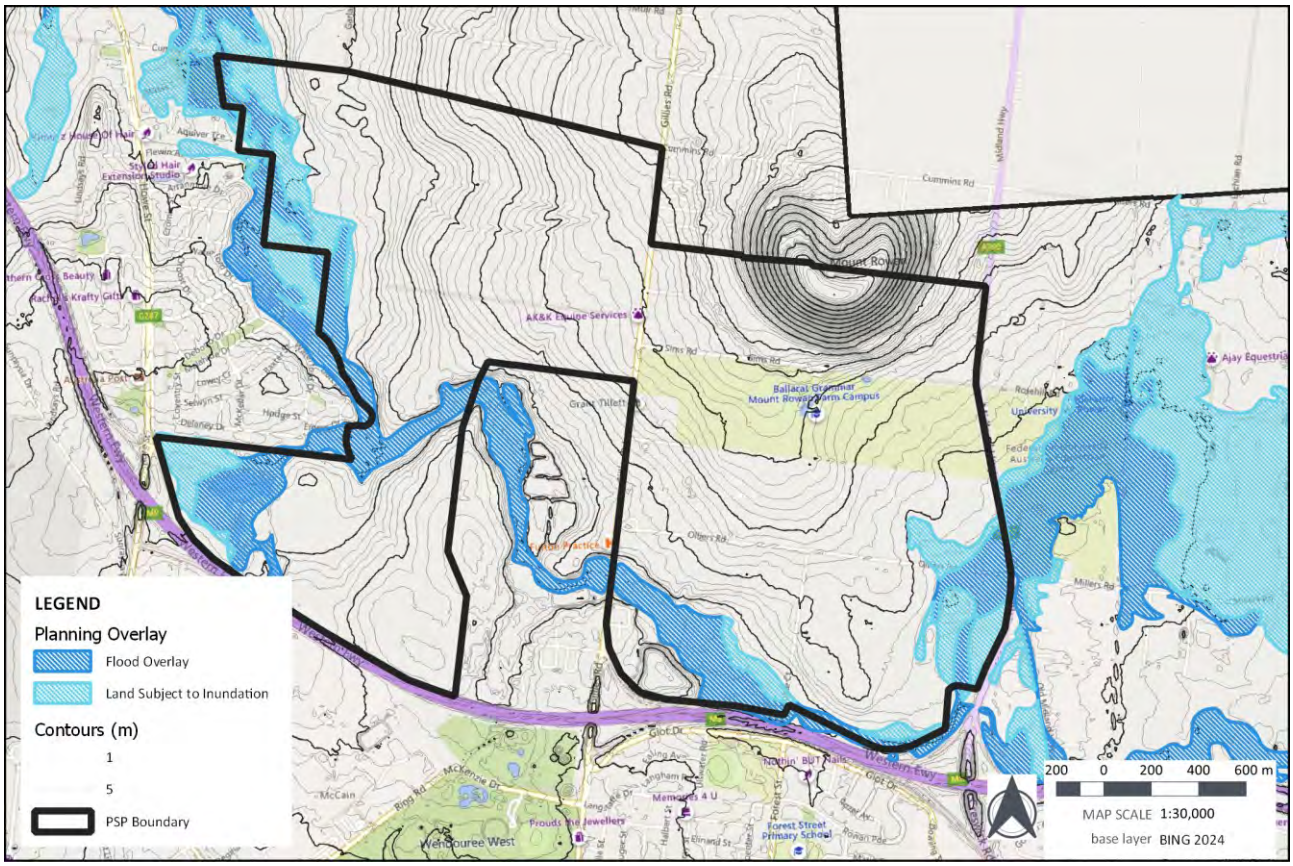


Figure 4-1 Flood Overlay and Land Subject to Inundation

Glenelg Hopkins Catchment Management Authority (GHCMA) has previously commissioned a flood study of the Burrumbeet Creek which is documented in Water Technology (2013). GHCMA has advised the DTP that the flood extents documented in the report are now out of date and are supportive of an update to be completed in collaboration with the City of Ballarat. The update will incorporate catchment alterations and guideline updates including:

- New major drainage infrastructure.
- Any increase in impervious areas that has occurred due to new developments.
- Updates to the technical practice in hydrological analysis including Design Rainfall Depth and Losses updates (Bureau of Meteorology, 2016) and DCCEEW climate change modelling guidance (https://www.dcceew.gov.au/climate-change/publications/national-climate-scenario-guidance)
- Validation of the model using historical major flood event data that may be available subsequent to the previous study.

The currency of the defined 1% Annual Exceedance Probability (AEP) flood extent impacts the Ballarat North PSP scope of works as it defines the development exclusion zone. The existing Burrumbeet Creek flood study was used to assist in providing recommendation relevant to the Ballarat North PSP as summarised below:

4.1.1 Implications of using the Existing Flood Extent

- The Burrumbeet Creek flood modelling described in Water Technology (2013) was grounded on a joint calibration of the hydrologic (RORB) and hydraulic model to a gauging station at Burrumbeet Lake. A TUFLOW model was utilised for the hydraulic modelling to produce the flood extents for various probability events. Four calibration events (1981, 2000, 2010 and 2011) were selected to calibrate the models. Model parameters were determined based on the outcomes of the calibration. Losses were derived using literature current at the time. The resulting design flows were reported to have a good match to the flood frequency curve derived from the gauging station.
- Since the model parameters have been derived using a calibration process, an update to the flood study is unlikely to change those parameters. However, the most recent 2016 design rainfall depths are lower relative to those applied in the study described in Water Technology (2013).
- A desktop assessment has been completed to identify any catchment changes subsequent to 2013 with the potential to impact hydrology modelling. No features were identified in aerial imagery or terrain data across the Ballarat North PSP core and catchments with the potential to result in substantial changes to 2013 flood extents.

4.1.2 2024 Climate Change Consideration Update

- The latest National Climate Change guidance (DCCEEW, 2026) will result in increased flood levels and extents relative to the previous modelling. According to Water Technology (2013), the previous climate change scenario modelling generally resulted in 0.5 m increase in flood depth along the Burrumbeet Creek above the 2013 existing conditions.
- The new climate change guidance (DCCEEW, 2026) recommends application of an upscaling factor for all design storms. Further, the scaling factor varies with the adopted planning time horizon and climate condition. The updated guidance was released in September 2024, and the updated flood modelling will not be completed in time for the PSP preparation. It is emphasised that this knowledge gap has an impact on the flood extent definition and ultimately the areas that can be developed.
- The recent update to climate change guidance means that the hydrology is required to be update as follows:
    - 2016 Intensity Frequency Duration (IFD) curves must be adjusted to represent the future climate conditions, recognising that global temperatures have increased subsequent to the period over which data used to derive the IFD was collected. The uplift factors are derived from the Datahub (AR&R, 2019).
    - Adopting a global temperature increase depending on the potential future development options and emissions pathways (from very low, to very high emissions), to assess the future climate change scenario. Based on GHCMA flood modelling guidelines (GHCMA, 2024), a worst-case scenario (4.5° Celsius increase in global temperature) should be adopted.
    - Selecting a future timeframe for which the climate change scenario is assessed. It is considered typical to adopt 100 years design life assessment for stormwater infrastructure. The 2100-year horizon has been adopted as per GHCMA guidelines.
- SMEC recommended that a preliminary estimate of the flood extent (with climate change) be prepared and adopted for the basis of design. Due to limited timeframes in the DTP program, a coarse but conservative approach has been adopted to produce a flood extent. The preliminary flood extent has buffer to allow for uncertainties and was grounded on conservative assumptions. The preliminary estimate was presented to GHCMA for in principle support prior to proceeding to the draft drainage layout phase. The intention was that the comprehensive flood study should be investigated in parallel to the preparation of the PSP and to be incorporated in the final stages of the PSP preparation.

- As part of the literature review, SMEC completed the above exercise and presented the methodology and outcomes to GHCMA in the form of Technical Memo. The results of the sensitivity analysis shows that there are minor variations to the 1%AEP flood extents in the Ballarat North PSP area. SMEC conservatively adopted the Scenario 3 flood extent (green line in Figure 4-2) as the basis of preliminary design which was considered a reasonable and conservative interim approach. Scenario 3 is the result of peak outflows from the climate change scenario (2100-year horizon and 4.5 degrees increase in global warming) multiplied by two.

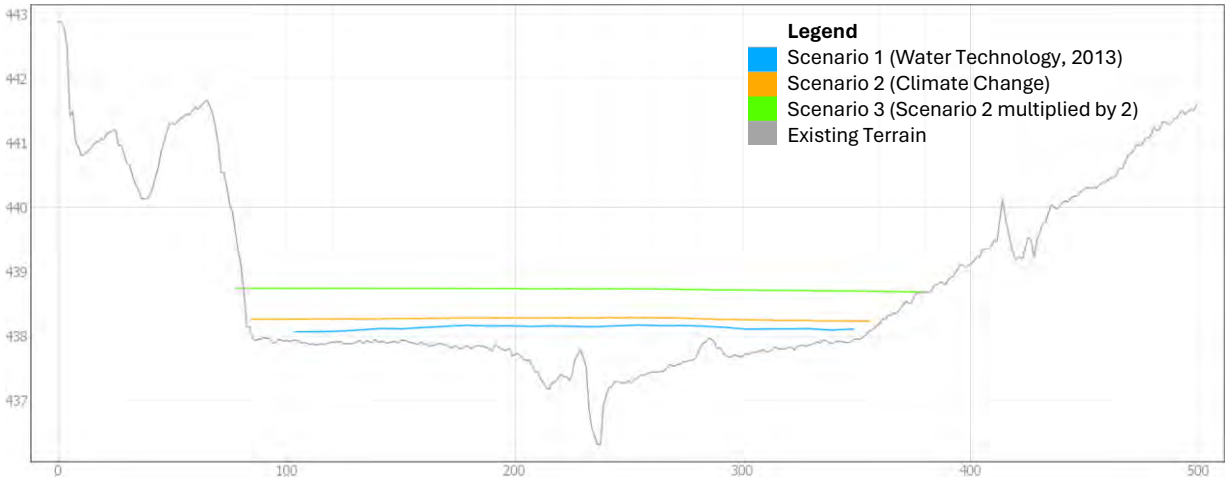


Figure 4-2 Cross section location 4

- GHCMA ultimately provided in principle support subject to further model refinement in later phase of the project. This allowed the PSP preparation to progress. A copy of the Technical Memorandum and in principle support from GHCMA are included as Appendix E.
- The subsequent proof-of-concept Stage 2 and functional design Stage 3 further refined the hydraulic modelling to reduce the uncertainties and therefore reduced the preliminary flood extents. The refinement of the hydraulic modelling is discussed in Section 10.

4.1.3 Flood Mitigation Option within the Catchment

- Water Technology (2013) investigated flood mitigation measures to reduce flood impacts to properties. One option worth noting was the proposed construction of a retarding basin for Burrumbeet Creek upstream of Gillies Road. During the stakeholder workshop held on the 27 November 2024, GHCMA confirmed that this option is no longer being considered. Instead, flood mitigation investigation in Miners Rest a few kilometres downstream were being explored. Refer to an extract of the Water Technology (2013) report presenting the mitigation option in Figure 4-3.

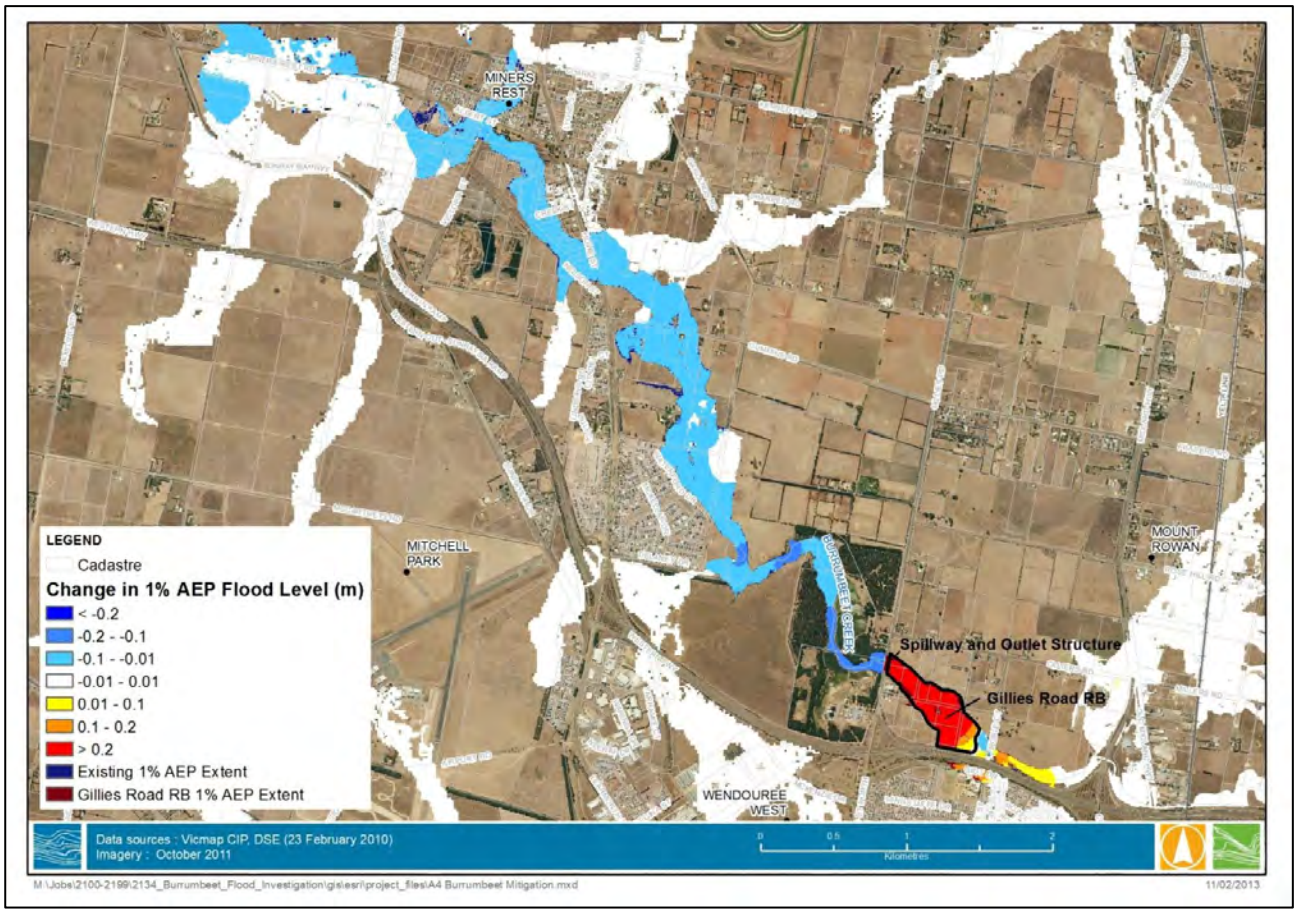


Figure 4-3 Potential Gillies Road RB from Water Technology (2013)

4.1.4 Miners Rest Flood Mitigation - Stantec (2024b)

- A report detailing the flood mitigation strategies for Miners Rest is described in Stantec (2024b). The report was prepared for the City of Ballarat. The investigation identified and assessed flood mitigation options to reduce the number of properties subject to flooding from Burrumbeet Creek. The study area is located approximately 700 metres downstream from the Ballarat North PSP core area boundary. The mitigation options include levees, channel widening and regrading of Burrumbeet Creek.
- A high-level review of the potential implications of the mitigation options for the PSP core area suggests little impact on the proposed drainage systems. Any changes to Burrumbeet Creek at Miners Rest will have hydraulic implications for the creek itself but the peak flood level is unlikely to be significantly different since there is at least two meters fall downstream to Miners Rest and that there are culvert structures at Cummins and Victoria Street that provide key hydraulic controls for Burrumbeet Creek and the PSP area upstream.
- The proposals suggest that engineering and widening the Creek cross sections are feasible options to increase flood conveyance and flood storage. Progression of these options is subject to additional investigations of the geology, feature levels and vegetation to define site constraints.
- The Ballarat North PSP drainage investigations must consider the downstream Miners Rest Flood Mitigation Project, which is currently progressing through the schematic design phase following completion of the concept design. The project includes proposed flood mitigation measures comprising new levees, upgraded culverts and a replacement bridge at Victoria Street, with ongoing hydraulic modelling, utility investigations and design development underway. Schematic design is expected to be completed in late 2026, with detailed design anticipated in early 2027 prior to tendering for construction. Both projects form part of the broader catchment flood management framework and appropriate coordination is required to ensure alignment of drainage and flood modelling assumptions, as well as to understand any cumulative impacts across the catchment.

4.2 Biodiversity

4.2.1 Burrumbeet Creek Rehabilitation

Various reports including the IWM report (Arup, 2024), Biodiversity assessment report (WSP, 2024) and Land capability statement (Jacobs, 2024) describe the flora and fauna within the PSP core area. Some of the key considerations are listed below.

- Burrumbeet Creek is understood to have a low strategic biodiversity score and is in 'Poor' condition. A targeted Growling Grass Frog survey did not record any sightings in the area of study (WSP, 2024). The report also states there is limited value in the retention of sporadic occurrences of low-quality remnant native vegetation. Nonetheless, it is recommended by the report to avoid and minimise works in the creek and natural wetlands.
- As summarised in Arup (2024), Burrumbeet Creek provides potential habitat for fauna species protected under the Environmental Protection and Biodiversity Conservation (EPBC) Act, namely Golden Sun Moth, Striped Legless Lizard and Growling Grass Frog.
- WSP (2024) recommends adopting the Melbourne Water Waterway Corridor Guidelines (Melbourne Water, 2013) in setting an appropriate setback from the Creek. The guidelines set a fixed minimum width to allow for core riparian zone and vegetated buffer on either side of the waterway hydraulic width.
- GHCMA is responsible for the adoption of the appropriate corridor setback for Burrumbeet Creek. There are opportunities to consider an alternative setback requirement specific to the area based on the floodplain form and the interface with the future stormwater assets proposed to service the development.
- Erosion is a pertinent risk that has been identified in a number of documents and overlays including the Erosion Management Overlays and Land Capability Statement (Jacobs, 2024).
- As an outcome of the DTP's pitching session in July 2023, various agencies have highlighted the opportunities to improve the state of the existing waterway.
- Arup (2024) which is informed by the strategic objectives, recommends that the Burrumbeet Creek corridor is enhanced to provide ecological refuge and resilience for flora and fauna, or to reintroduce lost species to the creek.
- A design response to address Burrumbeet Creek objectives will require consultation with the relevant agencies (City of Ballarat, GHCMA and Traditional Owners) and agreement on the appropriate interventions to be included in the stormwater drainage strategy and the PSP Development Contribution Plan.
- The Wadawurrung Traditional Owners have expressed their concerns about the water usage from the catchment. The Cultural flows have been highlighted as an important resource for the Traditional Owners in terms of spiritual, cultural, environmental, social and economic importance. Working together with the Wadawurrung will be important to achieve the goals of the Wadawurrung Healthy Country Plan.
- A statement by the Wadawurrung Traditional Owners has been made in relation to the Ballarat North PSP. "While treated storm water can be used to support environmental flows and systems, treated storm water must not to be used as Cultural Water - it should be used as the re-allocation source for systems in place, freeing up licenses and reducing extraction from natural systems, allowing passing flow management and future water entitlements to be handed back to Traditional Owners".

4.2.2 Growling Grass Frog

- Based on the information reviewed to date, there is no clarity in terms of a Growling Grass Frog (GGF) Corridor for this section of the Burrumbeet Creek. However, it has been identified as a potential location for enhancement to encourage GGF migration in the future.
- WSP (2024) reports, "No Golden Sun Moths, Growling Grass Frogs or Striped Legless Lizards were recorded during targeted survey. Based on the results of targeted surveys, Growling Grass Frog is considered unlikely to currently occur within the study area. However, the creeks and associated

wetlands are connected with known habitat ~8.6 km upstream via the Burrumbeet Creek and Slattery Creek in Creswick State Forest. It is reasonable to assume that under the right conditions (e.g. high rainfall/flooding) this species would be likely to utilise aquatic riparian habitat across the study area whilst dispersing throughout the landscape."

- Therefore, while GGF habitat is not a primary objective for this site rehabilitation of the waterway and improvement of the riparian zone provides an appropriate environment to facilitate GGF migration. SMEC believe this is a preferential objective dependent on the satisfaction of the following criteria:
- GGF is sensitive to the quality of water within their habitat. According to Growling Grass Frog Habitat Design Standard (DELWP, 2017), "Stormwater and other nutrient rich water sources are less optimal (for GGF habitat and water source) as they might increase the risk of algal blooming". As such, the constructed wetlands for stormwater quality are not recommended for GGF habitat.
- GGF require multiple wetlands as they need to move between these water bodies. Therefore, the limited space within this floodplain presents a challenge for to inclusion of GGF habitat which would be in addition to the WSUD wetlands.
- Water with good quality should be provided from different water sources including, portable, high-quality groundwater and treated stormwater. Whereas the primary goal of the PSP is treating stormwater runoff.
- Wetlands located within retarding basins provide a challenge for GGF migration between wetlands.
- Connectivity of suitable habitat for the GGF between their current habitat, located 8.6 km upstream, and this site is crucial for their migration. However, the presence of multiple road crossings that are not GGF-friendly makes migration to this site unlikely.
- Therefore, due to the absence of GGF at this location, the lack of suitable habitat between their current upstream habitat and this site, and the limited space for additional GGF-specific wetlands, SMEC has not included GGF ponds in this floodplain. Establishment of GGF habitat in this floodplain may be further investigated in the future.

4.3 Other Opportunities and Constraints

Further opportunities, constraints and gaps in the knowledge identified in the literature review are listed below.

- Existing underground infrastructure has been reviewed at a high level as described in Stantec (2024a). The review has not identified any critical services that could impact the viability of the drainage infrastructure.
- No geomorphologic studies have been undertaken within the core area. At this stage no allowance has been made for intrinsic geomorphologic values requiring protection along Burrumbeet Creek and its tributaries.
- The Ballarat Town Commons are within the PSP core area but do not contain any developable areas. As such no drainage works have been allowed for. The concept plan presented in Arup (2024) identifies a potential waterway channel alignment to mitigate the risk of erosion from overland runoff.
- The concept design presented in Arup (2024) excluded consideration of land ownership. The refined stormwater strategy will consider the land ownership in the arrangement of drainage assets. The implementation and delivery of the ultimate drainage works is an important consideration at the concept stage. Further input will be sought from key stakeholders and developers during the consultation period to ensure the final stormwater strategy has considered development staging and deliverability of the overall system.
- Potential for land contamination has been identified in the PSP area (Jacobs, 2024). Specifically, there is an old landfill located south of the creek line. The RBs and Wetland will be located outside of the old landfill.
- The hydrogeology has been considered at a high level (Jacobs, 2024). No specific details have been provided but shallow groundwater could be encountered in the low-lying parts of the catchment. The land capability assessment (Jacobs, 2024) has also identified the risk of dispersive and sodic soils within the

area of investigation. Site-specific assessments were recommended and will be further discussed with the City of Ballarat in a later project phase through allowances for site mitigation strategies or design interventions where possible. However, the functional design phase will be based on a standard design. At the time of writing, the information on these matters is limited.

- An arboricultural assessment is documented in Tree Logic (2024) and recommends avoiding highly rated trees as a priority where possible.
- The outcome of the proof of concept will identify the potential changes to the draft Place Based Plan. These will be discussed with the DTP regarding the risks and opportunities of the PSP layout and locations of proposed assets.
- The co-design workshop has considered the ideal locations for activity centres and businesses, and how infrastructure will be delivered for the precinct and their timeframes. This is just to name a few. The locations of active and passive open spaces will be an important consideration for the future placement of the constructed wetlands to meet the aspirations of stormwater harvesting for active space irrigation.
- Aboriginal Cultural Heritage Sensitivity layer applies to Burrumbeet Creek and that more detailed cultural heritage assessment may be required at permit stage.

5. Stormwater Management Objectives

5.1 Drainage Requirements

The Ballarat City Council requires that all new developments be designed to meet the standards and guidelines set forth in the Australian Rainfall and Runoff (AR&R) Guidelines (AR&R, 2019) and the Infrastructure Design Manual (IDM) (LGIDA, 2019). Additionally, the design outcomes must comply with the provisions of the *Planning and Environment Act 1987*.

The IDM requires new developments to:

- Provide drainage capacity equivalent to 20% AEP for minor drainage system in residential areas for Council drainage systems
- Be protected from major flooding equivalent to the 1% AEP event, where all new lots shall be above the 1% AEP flood level, and buildings are at least 300mm above the 1%AEP flood level.

In developing the precinct, it is a requirement to ensure there is no adverse change to the stormwater peak discharges from the site outfall boundaries for critical storms up to the 1% AEP event and ultimately prevent any adverse impacts to downstream properties. To meet this requirement, it is typical to manage the stormwater flows as follows:

- Collect and control stormwater flows via provisions of underground drainage systems, overland flow paths and drainage channels or waterways.
- Retain the peak flow from developed conditions to match the existing conditions within the catchment, before discharging to the catchment outlet, through the provision of retarding basin infrastructure.

5.2 Stormwater Quality

The minimum requirements for urban stormwater quality treatment are outlined in EPA Publication 1739.1 – *Urban Stormwater Management Guidance* (EPA Victoria, 2021), as referenced under Clause 56.07 Integrated Water Management. The guideline document sets a minimum target of stormwater pollutant reduction as follows:

- 80% Total Suspended Solids
- 45% Total Phosphorus
- 45% Total Nitrogen
- 70% Gross Pollutants or Litter

Water Sensitive Urban Design (WSUD) principles are applied to the development in order to meet these requirements which generally involves provision of sedimentation basins, bioretention systems and constructed urban wetlands.

5.3 Stormwater Volume Management

The EPA Publications - Urban Stormwater Management Guidance (1739.1) (EPA Victoria, 2021) provides the guidance on the management of urban stormwater which includes guidelines on volume reduction targets. The aim of the document is to set minimum and aspirational targets for stormwater runoff volume reduction by infiltration and stormwater harvesting and reuse where possible. It also provides guidance on the areas with higher priority to the rest of the urban catchments. For Ballarat North PSP, where the average annual rainfall is around 600 mm the target is 29% harvesting and evapotranspiration, and 7% infiltration.

5.3.1 Precinct Structure Plan 2.0 Guidance

- The DTP has prepared PSP guidance with the aim to 'lift the bar' by encouraging higher standards of design and development. With respect to IWM, the following targets were included.

  - T14– All streets containing canopy trees should use stormwater to service their watering needs.
  - T17– IWM solutions should meaningfully contribute towards the actions and targets of the relevant Catchment Scale Public Realm & Water Plans and any relevant water-related strategy, plan, or guideline.

- National Construction Code (NCC) 2022 in Schedule 2. There are no specific requirements for provision of rainwater tanks. However, there is a strong push by the State Government to improve the water efficiency of all buildings subject to regulatory impact statement and stakeholder and community consultation.
- Ballarat Potable Water Demand Target – Supplementary Guide describes the compulsory potable water use target of 124 litres per person per day for residential developments within the PSP area. Central Highlands Water (CHW) does not mandate specific solutions with the onus being on the developer to demonstrate the target is met. An example is provided which includes installing a 2-kL rainwater tank with water efficiency devices. Ballarat City Council accepts this as a minimum base case for residential developments.

6. Existing Condition

6.1 Hydrology

The catchment hydrologic model, RORB, was employed to estimate runoff hydrographs for the catchment. RORB (Laurenson et al., 2010) is a nonlinear rainfall runoff and stream flow routing model for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be subdivided into subareas, connected by conceptual flow reaches.

The latest RORB model (Water Technology, 2013) was adopted as a base case model and modified to represent the PSP catchment at a smaller scale. The RORB model k_c parameter was adjusted through a calibration process, and the calibration compared the peak flow of the combined model just downstream of the Ballarat North PSP against the peak flow at the same location of the base case Water Technology model. Appendix A-1 details the RORB model parameters and calibration methodology.

Figure 6-1 below shows the existing condition RORB model setup for the Ballarat North PSP. By definition the existing conditions represent the catchment as it currently is without any new developments. The PSP area has been subdivided into sub catchments SE (north and south), C, and NW, and SW. It is noted that SW catchment is a regional open space and most likely to remain undeveloped and thus is removed from modelling. The sub catchment characteristics such as areas and fraction imperviousness are presented in Appendix A-1.

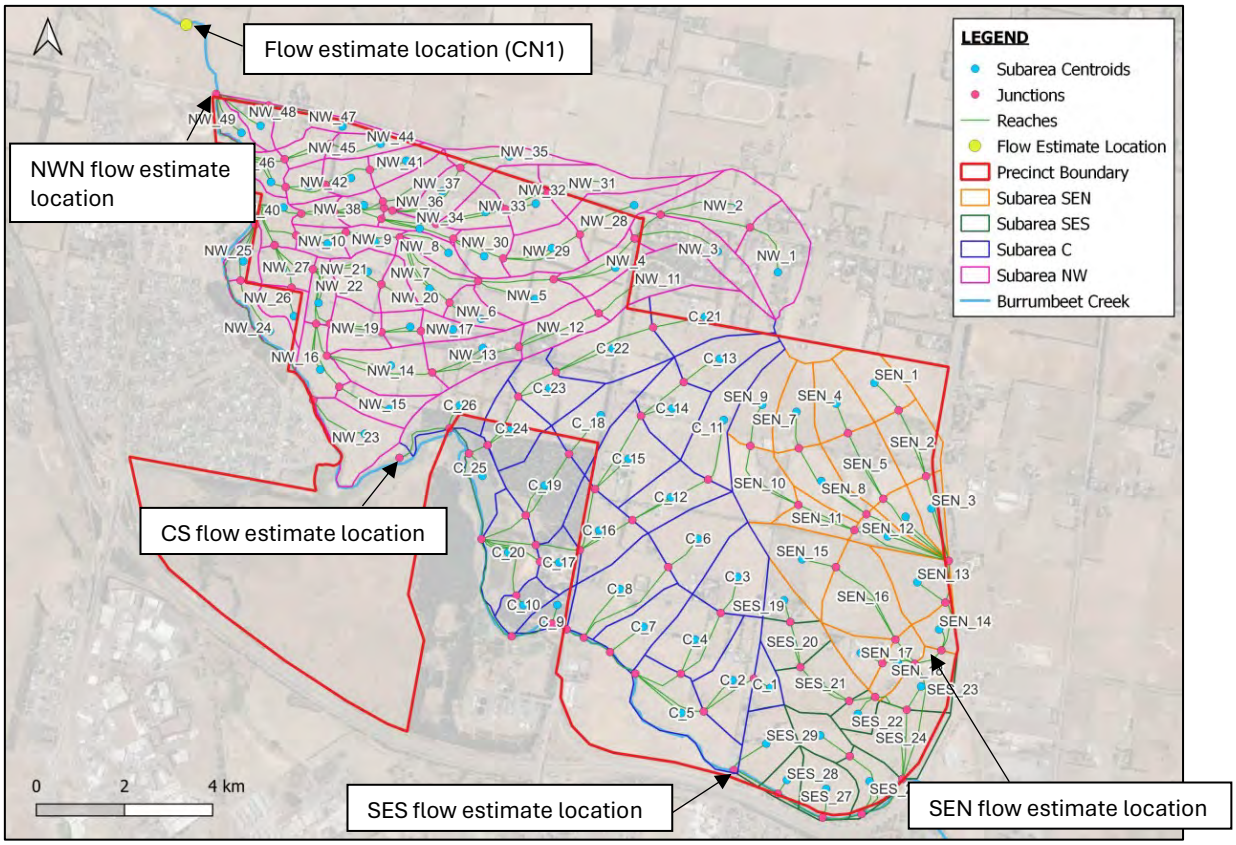


Figure 6-1 Ballarat North PSP existing condition RORB model setup

The RORB model was simulated for the 10% AEP and 1% AEP, and the peak flows are outlined in Table 6-1 and Table 6-2. The flow estimate locations are shown in Figure 6-1 above.

Table 6-1 Existing condition 10% AEP flow estimates

Flow Estimate Location	Peak Flow	Critical Duration
SEN	1.0 m^3/s	2.0 hrs
SES	1.3 m^3/s	1.5 hrs
CS	3.4 m^3/s	1.5 hrs
NWN	1.8 m^3/s	2.0 hrs
CN1	24.4 m^3/s	6.0 hrs

Table 6-2 Existing condition 1% AEP flow estimates

Flow Estimate Location	Peak Flow	Critical Duration
SEN	2.3 m^3/s	3.0 hrs
SES	2.6 m^3/s	45 mins
CS	6.8 m^3/s	1.5 hrs
NWN	4.0 m^3/s	3.0 hrs
CN1	58.2 m^3/s	9.0 hrs

6.1.1 Adopted Climate Change Scenario (SSP 2-4.5, Year 2100)

In accordance with GHCMA guidelines, the Burrumbeet Creek floodplain has been modelled and assessed using the SSP 5-8.5 climate change scenario. For the drainage design and assessment, SMEC evaluated a range of climate change scenarios, including SSP 2-4.5 and SSP 3-7.0, as part of the Standing Advisory Committee (SAC) hearing. Following consultation with the DTP and the City of Ballarat, the SSP 2-4.5 climate change scenario was adopted as the design basis for this functional design. The adopted SSP 2-4.5 climate change scenario represents an increase in global mean temperature of approximately 2.5°C by the 2100 planning horizon.

The climate change uplift factors for SSP 2-4.5 vary depending on the storm duration and AEP. A summary table of the uplift factors applicable to the site location is illustrated in Table 6-3. Detailed climate change factors are included in Appendix A-2.

Table 6-3 Data hub climate change consideration uplift factors – SSP 2-4.5 (AR&R v4.2, 2019)

SSP2-4.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	1.18	1.17	1.16	1.14	1.13	1.12	1.12	1.11	1.1	1.1
2040	1.22	1.2	1.19	1.17	1.16	1.15	1.14	1.13	1.12	1.12
2050	1.27	1.24	1.23	1.21	1.19	1.18	1.17	1.16	1.15	1.14
2060	1.3	1.27	1.25	1.23	1.21	1.2	1.19	1.18	1.16	1.16
2070	1.33	1.3	1.28	1.26	1.24	1.22	1.21	1.19	1.18	1.17
2080	1.37	1.33	1.31	1.28	1.26	1.24	1.22	1.21	1.2	1.19
2090	1.4	1.36	1.34	1.31	1.28	1.26	1.24	1.23	1.21	1.2
2100	1.41	1.37	1.35	1.32	1.29	1.27	1.25	1.24	1.22	1.21

A sensitivity analysis has also been undertaken for the SSP 3-7.0 (2100) climate change scenario. The resulting 1% AEP flood levels and retarding basin storage volumes are presented in Appendix A-1-3.

The outcome of this scenario for the 10% AEP and 1% AEP storm events is presented in Table 6-4 and Table 6-5.

Table 6-4 Existing condition 10% AEP flow estimates with SSP 2-4.5

Flow Estimate Location	Peak Flow	Critical Duration
SEN	1.6 m^3/s	2.0 hrs
SES	2.0 m^3/s	45 mins
CS	5.2 m^3/s	1.0 hr
NWN	2.8 m^3/s	1.5 hrs
CN1	35.6 m^3/s	4.5 hrs

Table 6-5 Existing condition 1% AEP flow estimates with SSP 2-4.5

Flow Estimate Location	Peak Flow	Critical Duration
SEN	3.4 m^3/s	2.0 hrs
SES	3.9 m^3/s	45 mins
CS	10.1 m^3/s	1.0 hr
NWN	5.8 m^3/s	2.0 hrs
CN1	78.2 m^3/s	4.5 hrs

The tabulated values above establish the allowable peak discharge rates for developed conditions, to mitigate the increase in catchment runoff generated by PSP development. This assessment will be covered in Sections 7 and 10 of the report where the retarding basin sizing and flood impacts are assessed for current climate conditions and the future climate change conditions.

7. Stormwater Drainage Strategy

7.1 General

The stormwater drainage strategy has been further refined, considering various constraints, site context analysis, IWM objectives, and the strategic vision for the Burrumbeet Creek waterway. The strategy maintains the concept of centralised assets positioned alongside the waterway corridor consistent with the blue green corridor concept in the IWM plan. A major/minor drainage system is proposed to manage the flow conveyance of the PSP which is consistent with the Infrastructure Design Manual (LGIDA, 2019).

It is noted that the future internal road network and subdivision layout is not yet known at the PSP level and will ultimately determine the direction of flows. However, the strategy as discussed below provides the overarching plan on how to direct the stormwater runoff into the proposed drainage infrastructure.

The Burrumbeet Creek waterway and its tributaries provide opportunity to interface the water sensitive urban design (WSUD) features together with active open spaces. Future developers of the new estates are encouraged to integrate the blue green corridor with the urban design. For example, the proposed tributary realignment Section 7.2.1.3 could be designed in parallel with a main boulevard and provide a high impact amenity feature for the new estate's main entrances. The proposed wetland/RBs have been located adjacent to the Burrumbeet Creek, and its tributary and Active Open Space reserves have been co-located to support integration between passive and active open spaces, as well as connectivity for shared paths through the precinct. It is expected that the shared paths would be integrated with the proposed WSUD assets.

Section 7.2 discusses the proposed strategy for each sub-catchment while the details of the retarding basin and wetland sizing are discussed in Section 7.4 and Section 8.1 respectively.

7.2 Strategy Basis

The PSP area is split into five sub catchments SE (north and south), C, NW, and SW. Each catchment outfalls separately on the northside of Burrumbeet Creek with exception to SW which drains from the south side of the Creek. A combined wetland/retarding basin system (WLRB) are proposed to capture flows up to and including the 1% AEP plus climate change (SSP 2-4.5) event prior to discharging to the Burrumbeet Creek. As mentioned, SW (Town Commons) is earmarked to remain as a nature reserve and as such, no hard drainage assets are required for this catchment.

The overall drainage strategy layout plan is illustrated in Figure 7-1. General notes in preparation of the drainage strategy are:

- Note that SW catchment is a regional open space and identified as a Crown Land and thus is less likely to develop. Therefore, there is no proposed infrastructure assets for this catchment.
- SMEC have provided the indicative drainage pipelines as part of the drainage strategy. Existing sewer invert levels and diameters in the southern part of the PSP along Burrumbeet Creek have been provided by CHW, however sewer main depths remain unknown. This prevents a detailed assessment of potential clashes between the proposed drainage infrastructure and existing or future sewer mains. Based on the indicative future sewer alignments, which are expected to be approximately 2–6 m deep, clashes between the proposed drainage infrastructure and existing/future sewer mains are considered unlikely. Notwithstanding this, any potential clashes should be confirmed during the functional design undertaken as part of future development, once more accurate sewer depth information is provided by CHW.

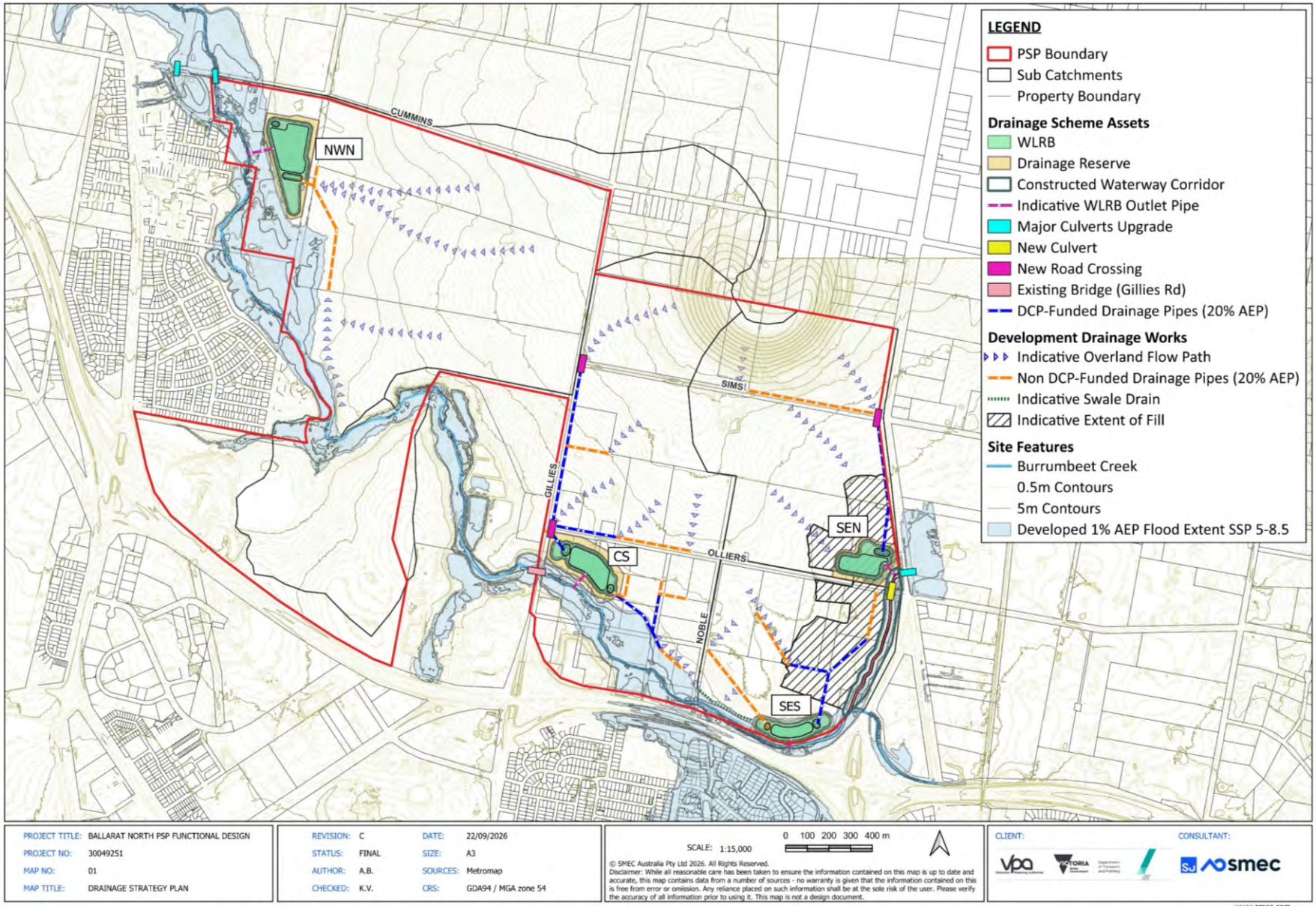


Figure 7-1 Proposed stormwater functional drainage strategy

The proposed drainage strategy for each of the sub catchments are explained below:

7.2.1 SE Catchment

7.2.1.1 SEN & SES WLRB

- Two WLRBs are proposed for sub-catchment SE. One located north of Olliers Rd, and adjacent to the proposed constructed waterway which is identified as SEN in the plan. SEN has been sized to receive flows from the eastern catchment of the future School (Ballarat Grammar Mount Rowan campus) and northern residential catchment of Olliers Road. The retarding basin is sized to attenuate no more than the existing conditions peak flow at the same location. Once the flows have been attenuated, it is intended to convey this flow via underground drainage pipe into the proposed constructed waterway.
- SEN will provide stormwater treatment via wetland and the treated water be discharged into the realigned constructed waterway (tributary of Burrumbeet Creek called CW1 in this report) and eventually to the Burrumbeet Creek.
- SEN WLRB will require the major culverts at Olliers Road (CU-04-1) to be constructed to provide a gravity outfall for the asset. If the ultimate CW1 waterway works are not delivered concurrently, temporary excavation of the outfall channel would also be required to facilitate discharge to the existing downstream system. Approval by GHCMA of any temporary works on the waterway would require an appropriate assessment, including a flood impact assessment demonstrating that the works do not adversely affect flood behaviour. Freeboard and other design requirements may also apply. In addition, landowner consent for the downstream temporary outfall works would need to be obtained by the upstream developer. While these matters can generally be managed during the development process, it would be preferable for the Olliers Road upgrade, including culverts CU-04-1 and the associated CW1 waterway works, to be delivered during the early stages of the PSP. This would provide the permanent gravity outfall for SEN WLRB and avoid the need for temporary infrastructure, approvals, and associated risks. It is understood that the Olliers Road upgrade has been identified as one of the critical pieces of infrastructure required during the early stages of the PSP.
- SES has been sized to treat the remaining areas south of the Olliers Rd and retard the flows back to existing conditions.
- A portion of the sub catchment draining towards Noble Court is proposed to be diverted east towards SES. This can be achieved through the provision of minor drainage pipe and major overland flow path (swale drain) to convey the flows through to WLRB SES.
- There is a minor encroachment of the 1% AEP flood extents (with climate change SSP 2-4.5) to the WLRB SES footprint. The impact of this has been assessed in the flood impact assessment section of this report.

7.2.1.2 Trunk Drainage Design

- A major culvert is required to cross Olliers Rd and provide connection for the realigned constructed waterway. A culvert upgrade is also required to provide connection between the external catchment east of the Midland Highway to the entrance of the realigned constructed waterway. These culverts have been sized for climate change SSP 5- 8.5 2100. More discussion of the sizing of the culverts is presented in Section 7.5.
- A road crossing culvert is required to cross Sims Rd. The sizing of this culvert is presented in Section 7.6.
- Localised filling is required adjacent to the SEN WLRB to achieve appropriate drainage grades and facilitate gravity discharge into the sediment basin. The finished surface level in this area has been set at approximately RL 445.5 m AHD to provide a suitable hydraulic connection. The final earthworks extent and finished levels will be confirmed during detailed design.
- Runoff from the remaining of catchment SE between Noble Court and Midland Highway is proposed to be conveyed towards southeast into a drainage pipe along the west side of the future waterway realignment all the way to SES.

- It is proposed that the drainage pipes will capture the 20% AEP flows for future climate (SSP 2-4.5) and any gap flows (flows between 1% AEP and 20% AEP with climate change) will be conveyed towards SES via overland flow path within the road reserves adjacent of the constructed waterway. No outfall connection into the proposed constructed waterway are proposed except for the pipe outlet from SEN. This concept provides a simple and consistent strategy where all runoff are treated and retarded at prior to discharging into the waterway.
- As an alternative, the trunk drainage can be designed to capture the 20% AEP flow with the gap flows allowed to overtop into the constructed waterway. This gap flow will be then conveyed by the waterway and discharged into Burrumbeet Creek without retardation. The future developer can investigate and confirm if this option is feasible since it depends on the subdivision design. Hydrological analysis (RORB modelling) will be required to ensure flows are adequately retarded back to the predevelopment levels.

  Figure 7-1 shows the indicative pipe and culvert infrastructure required for each parcel to connect into the centralised WLRB.

7.2.1.3 Waterway Diversion (CW1)

- An unnamed waterway (hereafter called CW1) near the eastern boundary of the PSP (see the current location and extent of this waterway in Figure 3-8) is proposed to be re-located along the eastern boundary of the PSP area as shown in Figure 7-2. Based upon the low value of the existing drain, there is an opportunity to reconstruct the waterway into an improved form and condition, whilst also providing floodplain containment into a narrower constructed waterway. The realignment allows for a better use of the land which would otherwise be difficult to develop, specifically the area in between the existing waterway and Midland Road.
- It is noted as a general principle that GHCMA do not support the realignment of waterways or floodplain topography changes for the purposes of large-scale development. However, GHCMA may consider proposals if it can be demonstrated that there is an unequivocal advantage for both waterway and floodplain health. GHCMA, has requested that the advantage of the proposed realignment is presented against the original alignment in relation to other benefits outside of lot development yield. Furthermore, the Biodiversity Assessment Report (WSP, 2024) states that there are high value vegetation are evident in the current alignment.

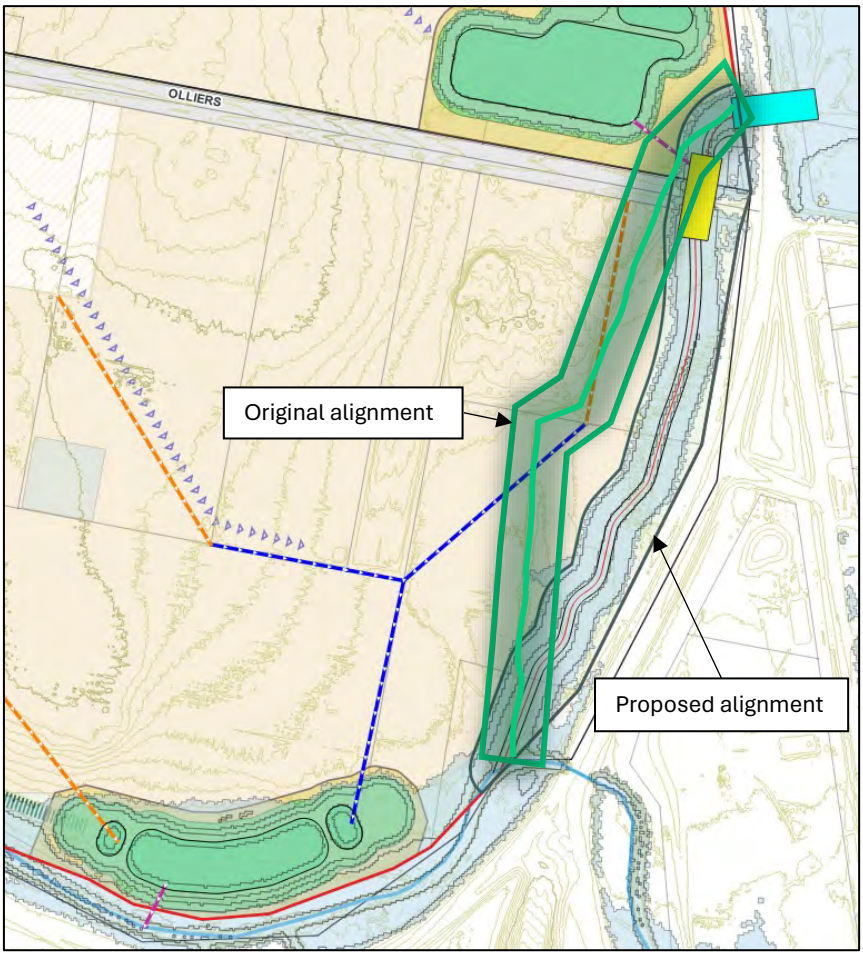


Figure 7-2 Waterway realignment option assessment

- In an attempt to address the above concerns from GHCMA at POC stage, commentary on the advantages of the proposed realignment (adjacent Midland Highway in blue line) (Refer to Figure 7-2) against the current waterway alignment (green line), and their likely outcomes are described below.
    - From a hydraulic perspective there is minimal difference between the two alignments in terms of length and typical cross-sectional width. Both options will need to meet a specific hydraulic capacity and will likely result in similar hydraulic width and ultimately corridor width. The waterway bend radius will be smaller at the upstream section of the reach in the alternative alignment.
    - The main difference between the two options will be the interface to either side of the waterway and connectivity over the waterway. In the original alignment, it is likely that there will be a road interface on both sides and potentially pedestrian or traffic crossing over the waterway. The alternative alignment abuts to Midland Highway and is unlikely to require a crossing over the waterway.
    - From a visual amenity standpoint, the alternative constructed waterway alignment would be visible from the main road (Midland Hwy) and provides an opportunity for a shared user path between the waterway corridor and Midland Highway contributing to the ‘blue green corridor’ vision for the PSP.
    - From a bulk earthworks perspective, the proposed realignment would require significant filling of the floodplain and excavation to offset the flood storage. It is expected that the cost of the filling would not be included in the DCP costs but would be borne by the developer benefiting from the additional developable land that would otherwise be floodplain storage.
- The external catchment entering the PSP at Midland Highway culverts is approximately 990 ha and will be conveyed by the proposed constructed channel.

- Filling is required to the west of the waterway and as a result flood storage is required to be offset in the design of the waterway. A functional design has been completed to show this is feasible and the modelling outcomes are discussed in Section 10 of the report. The final fill level is subject to design of the future development.
- Minor flows will be piped underground to the WLRB with proposed overland gap flows to be contained within the road reserves and directed to the retarding basins. An assessment of the typical capacity of the road reserve to carry the gap flows have been completed. The details are reported in Appendix C.
- Overland flows (gap flows between the 20% AEP and 1% AEP with climate change SSP 2-4.5) within and discharging from the site is required to be safely convey via the road reserves.
- The waterway has been designed for the 1% AEP (climate change SSP 5-8.5 2100) with the following hydraulic design parameters in Table 7-1 to Table 7-4.

Table 7-1 High flow compound channel

Parameter	Value
Drain depth	1 m
Base width	41 m
Slope	0.001429 m/m
Side slopes	1 in 5
Area	46 m^2
ss length	5.10 m
Wetted perimeter	51.20 m
R	0.90 m
Mannings n	0.035
Capacity	46.25 m^3/s
Velocity	1.01 m/s

Table 7-2 Low flow channel

Parameter	Value
Drain depth	0.5 m
Base width	8 m
Side slopes	1 in 3
Top width	11 m
Area	4.75 m^2
ss length	1.58 m
Wetted perimeter	11.16 m
R	0.43 m
Mannings n	0.050
Capacity	2.03 m^3/s
Velocity	0.43 m/s

Table 7-3 Combined channel

Parameter	Value
Depth	2.19 m
width	54 m
Area	50.75 m^2
Wetted perimeter	51.36 m
R	0.99 m
Mannings n	0.043
Capacity	48.28 m^3/s
Velocity	0.95 m/s

- The functional design has investigated the required waterway corridor width of the diverted waterway. Based on a hydraulic width of 50 m a waterway corridor width shall be a minimum of 60 m as per Table 4 of the *Waterway Corridor for Greenfield Development Guidelines* (Melbourne Water, 2013). It is proposed the waterway corridor varies between 60-75 m to match the PSP boundary to the east. The proposed corridor assumes a 30 m buffer from the waterway centreline towards the west, while the eastern extent of the corridor is constrained by the PSP boundary.

Summary of the drainage and WSUD details within the SE catchment is presented in Table 7-4Table 7-4.

Table 7-4 SE catchment drainage and WLRB details

Asset ID	Catchment Area	Asset Type	Drainage Reserve Area	Comment
SEN WLRB	98 ha	Retarding Basin/Wetland	4.9 ha	Located north of the Olliers Rd adjacent to the proposed constructed waterway
SES WLRB	62 ha	Retarding Basin/Wetland	3.7 ha	Located next to Burrumbeet Creek.
CW1	990 ha	Constructed Waterway	4.6 ha	704 m waterway length 60-75 m wide corridor
Midland Hwy Culvert	1,060 ha	Major Culvert (upgraded)	n/a	10 BC no. 1200mm H x 2400mm W
Olliers Rd Culvert	1,090 ha	Major Culvert	n/a	12 BC no. 1200mm H x 2400mm W
Sims Road Crossing	32 ha	Road Crossing	n/a	Dual 1050 mm pipes

7.2.2 C Catchment

7.2.2.1 CS WLRB

- One WLRB is proposed for sub-catchment C which is identified as CS WLRB. This asset is located along the Burrumbeet Creek floodplain on the east side of the Gillies Rd where the terrain is flatter and is best suited from engineering perspective. The drainage reserve sizing is provided in Table 7-5.
- Minor flows within this catchment will be piped underground to the WLRB with proposed overland gap flows to be contained within the road reserves and directed to the retarding basin. An assessment of the typical capacity of the road reserve is in Appendix C.
- There are two sediment basins, and a centralised wetland proposed for C catchment.
- Hydraulic modelling indicates that Gillies Rd is safe in existing conditions with climate change SSP 5-8.5 2030 and therefore no culvert upgrade is required. The size of the existing culvert is currently unknown.
- Two road crossing culverts are required to cross Sims Rd and Olliers Rd. The sizing of these culverts is presented in Section 7.6.
- Hydraulic modelling confirms that the existing Gillies Road bridge remains safe for 1% AEP events under existing conditions for the adopted 2030 climate change scenario (SSP 5-8.5). The SSP 5-8.5 scenario was adopted to meet GHCMA flood modelling guidance, as per discussion in Section 7.5
- There is a minor encroachment of the 1% AEP flood extents (with climate change SSP 2-4.5) to the WLRB CS footprint. The impact of this has been assessed in the flood impact assessment section of this report.
- The functional design has investigated the significant tree identified by Tree Logic (2024), and the retarding basin footprint has been refined to avoid the removal of the significant tree.

Summary of the WSUD details within the C catchment is presented in Table 7-5.

Table 7-5 C catchment WLRB detail

Asset ID	Catchment Area	Asset Type	Drainage Reserve Area	Comment
CS WLRB	107 ha	Retarding Basin/Wetland	6.5 ha	Located east of the Gillies Rd
Sims Road Crossing	31 ha	Road Crossing	n/a	Single 1350 mm pipe
Olliers Road Crossing	83 ha	Road Crossing	n/a	Upgraded dual 1500 mm pipes

7.2.3 NW Catchment

7.2.3.1 NWN WLRB

- One WLRB is proposed for sub-catchment NW which is identified as NWN. The NWN WLRB is located along the Burrumbeet Creek floodplain south of the Cummins Rd and northwest boundary of the PSP.
- Minor flows will be piped underground to the WLRB with proposed overland gap flows to be contained within the road reserves and directed to the retarding basins. An assessment of the typical capacity of the road reserve to carry the gap flows have been completed. The details are reported in Appendix C.
- There is a centralised wetland, and two sediment basins proposed for NW catchment.
- There is a minor encroachment of the 1% AEP flood extents (with climate change SSP 2-4.5) to the WLRB NWN footprint. The impact of this has been assessed in the flood impact assessment section of this report.
- Major culverts' upgrade / construction is required to provide connection at Cummins Rd / Burrumbeet Creek. These culverts have been sized for climate change SSP 5- 8.5 2100. More discussion of the sizing of these culverts are presented in Section 7.5.
- NWN WLRB is proposed to be located immediately west of the existing road reserve.
- Opportunities for irrigation of the Active Open Space (AOS) adjacent to the NWN have been considered and discussed in Section 9.2.4.
- CHW has indicated that a future sewer alignment may clash with the proposed stormwater assets. Refer to Figure 7-3. The concept design is largely determined by the terrain's low point and has limited opportunity to be relocated elsewhere. Therefore, it is important that consultation and negotiation with CHW are continued to potentially relocate the future sewer alignment to avoid the potential maintenance issue with the sewer, proposed wetland and retarding basin. It is noted that vertical clearance is likely to not be an issue since the sewer is expected to be deep enough below the wetland as per CHW comments. Although, the sewer cannot be too deep since it has to connect to the existing sewer pump station (SPS) at Cummins Road.

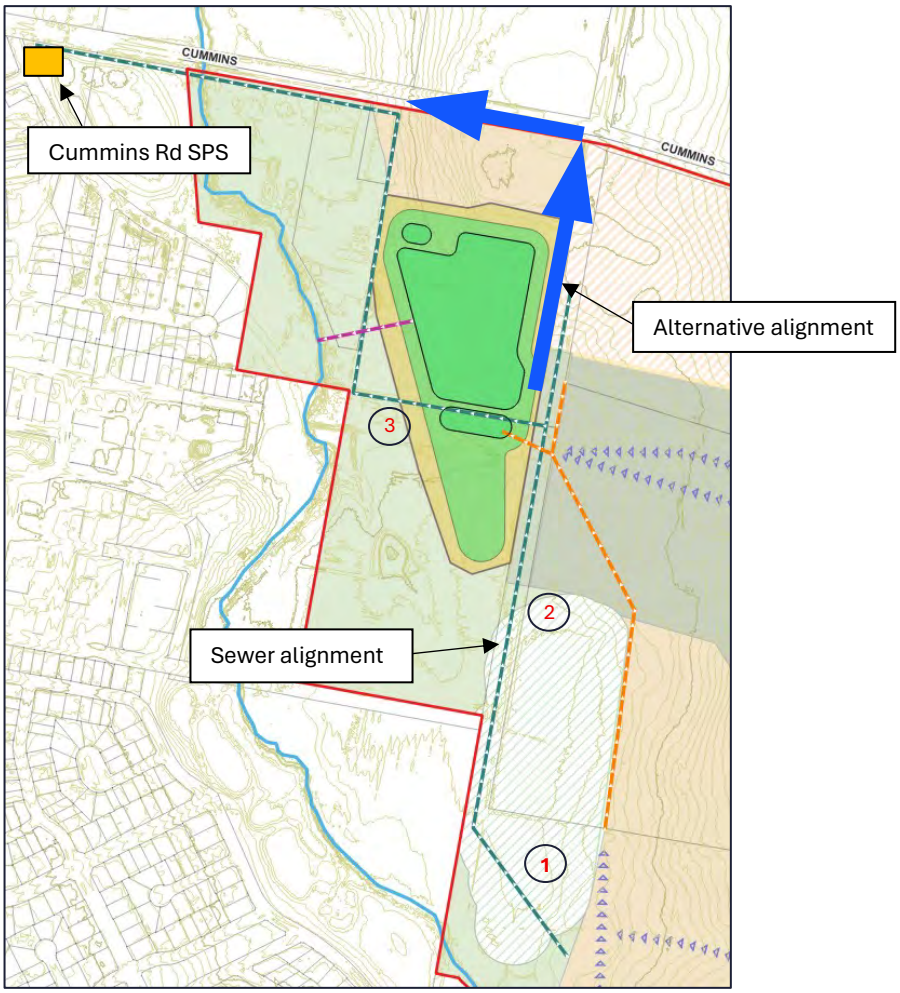


Figure 7-3 Potential alternative sewer alignment for NWN WLRB (indicative trunk sewer alignment provided by CHW).

Summary of the WSUD and major culvert details within the NW catchment is presented in Table 7-6.

Table 7-6 NW catchment drainage and WLRB details

Asset ID	Catchment Area	Asset Type	Drainage Reserve Area	Comment
NWN WLRB	190 ha	Retarding Basin/Wetland	8.6 ha	Located south of the Cumins Rd
Cummins Rd Culvert (primary)	1,680 ha	Major Culvert (upgraded)	n/a	10 BC no. 2100mm H x 2400mm W
Cummins Rd Culvert (secondary)	1,680 ha	Major Culvert (upgraded)	n/a	20 BC no. 900mm H x 1200mm W

7.2.3.2 Seasonal Herbaceous Wetland

- The water requirements of the SHW is currently unknown in terms of the hydrological regime that is required to maintain the conservation area. These are expected to be investigated once the development is underway. The construction of the drainage assets will likely modify the frequency of stormwater runoff entering the SHW. The impacts of this will need to be investigated. By locating the wetland near the SHW, there is opportunity to supply water into the SHW if it is deemed necessary.
- The PSP area along the Burrumbeet Creek corridor is affected by the Land Subject to Inundation (LSIO), and Floodway Overlay (FO). These areas are flood prone which is impacted by the 1% AEP flood. All new

lots will be set or filled to a minimum of 300 mm from overland flow paths and 600 mm above the 1% AEP flood level if adjacent the creek which is to be determined during the design stage.

- Overland flows (gap flows between the 20% AEP and 1% AEP storm events) within and discharging from the site is required to be safely conveyed via the road reserves.
- Any roads or access ways proposed to act as a stormwater overland flow path will be designed and constructed to comply with the floodway safety criteria of the Guidelines for Development in Flood Affected Areas (DELWP, 2019), or where appropriate to Council's requirements and standards.
- Catchment NW includes external catchment of approximately 42 ha extending east of Gillies Road and north Cummins Road. This area has been taken into consideration in the sizing of the assets, noting that some area north of Cummins Road may ultimately be managed and captured by the drainage strategy for the expanded area.

7.2.4 SW Catchment

- SW catchment is currently earmarked to remain as a nature reserve referred to as Ballarat Town Commons. No development is proposed in this catchment. As such, no drainage works are required to manage the existing runoff.
- The SW catchment is Crown Land and contains the existing North Common Wetland.
- The previous IWM study by Arup (2024) identified an optional channel works to manage overland flow path within the reserve that could be delivered by Council should they wish to do so. It is understood that these works would not be included in the DCP. The Proof-of-Concept design has not found any reason or justification to pursue this further.

7.3 Developed Condition

A developed conditions catchment RORB model has been created for the entire PSP area to represent the increase in peak runoff resulting in increased impervious areas from the development. Subsequently, the retarding basin size and storage were determined to ensure the resulting outflow is no more than the existing conditions under the future climate change. This model encapsulates all the four sub-catchments and the external catchment of the Burrumbeet Creek system. The extent of the developed conditions RORB model for the Ballarat North PSP area is shown in Figure 7-4.

Note that SW catchment is a Crown Land and is likely to remain undeveloped and therefore no infrastructure assets have been provisioned for this area. Hence, this catchment has not been further split up and has been excluded from the ongoing modelling.

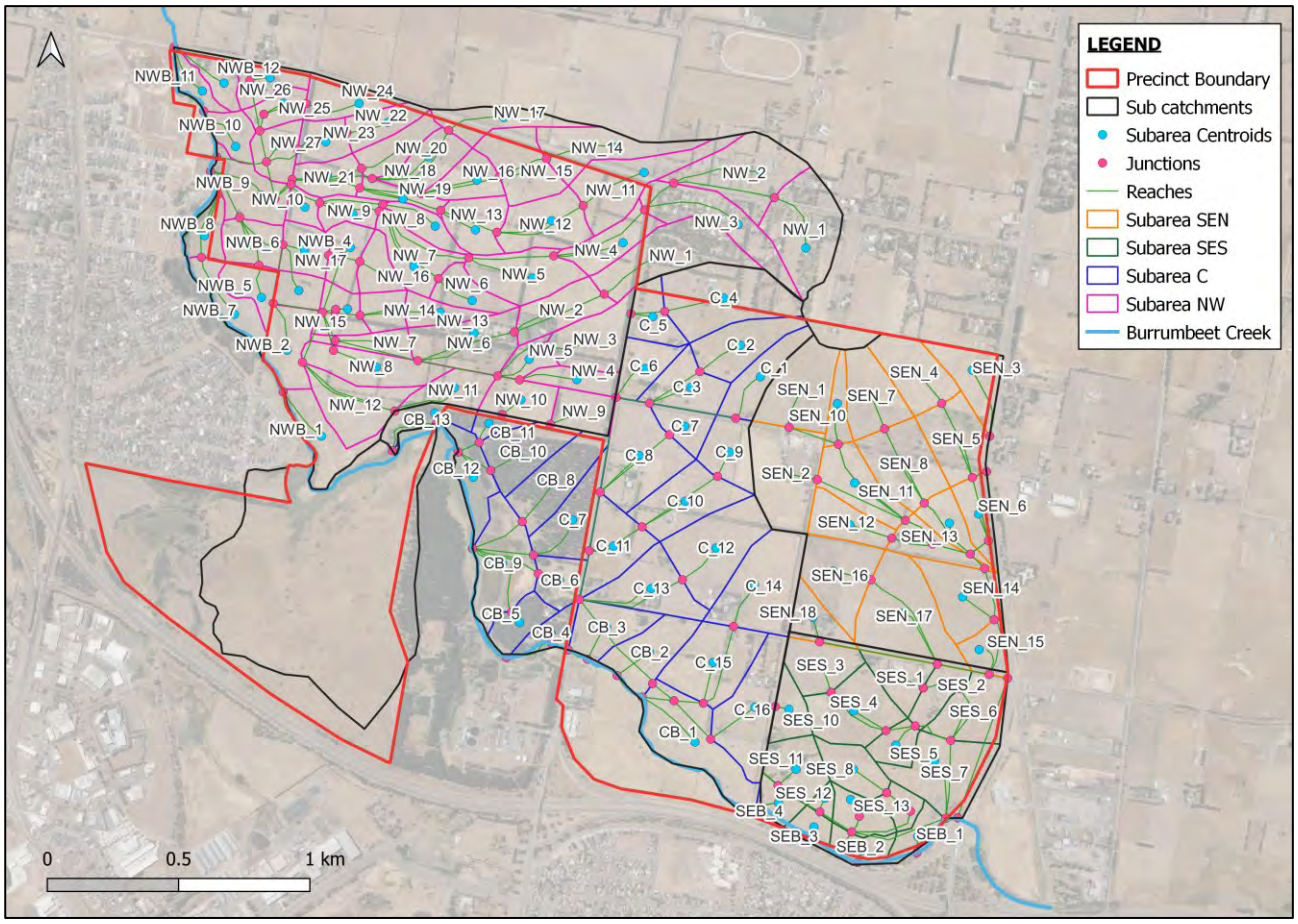


Figure 7-4 Ballarat North PSP developed condition RORB model setup

The RORB model was simulated for the 10% AEP and 1% AEP without climate change uplift factors and the peak inflows are outlined in Table 7-7and Table 7-8.

Table 7-7 Developed condition 10% AEP flow estimates

Flow Estimate Location	Peak Inflow	Critical Duration
SEN	3.6 m^3/s	2.0 hr
SES	2.7 m^3/s	45 min
CS	5.7 m^3/s	1.0 hr
NWN	6.8 m^3/s	1.0 hr
CN1	23.8 m^3/s	6.0 hr

Table 7-8 Developed condition 1% AEP flow estimates

Flow Estimate Location	Peak Inflow	Critical Duration
SEN	6.5 m^3/s	1.0 hr
SES	5.0 m^3/s	45 mins
CS	10.5 m^3/s	30 mins
NWN	12.4 m^3/s	1.0 hr
CN1	57.1 m^3/s	9.0 hrs

A scenario where climate change factors for SSP 2-4.5 are taken into consideration as per the AR&R guidelines (AR&R, 2019) has been modelled. The outcomes for the 10% AEP and 1% AEP events are shown in Table 7-9 and Table 7-10.

Table 7-9 Developed condition 10% AEP flow estimates with SSP 2-4.5

Flow Estimate Location	Peak Inflow	Critical Duration
SEN	5.4 m^3/s	1.0 hr
SES	4.0 m^3/s	45 mins
CS	8.4 m^3/s	1.0 hr
NWN	10.4 m^3/s	1.0 hr
CN1	34.5 m^3/s	4.5 hr

Table 7-10 Developed condition 1% AEP flow estimates with SSP 2-4.5

Flow Estimate Location	Peak Inflow	Critical Duration
SEN	9.8 m^3/s	1.0 hr
SES	7.1 m^3/s	45 min
CS	15.2 m^3/s	30 min
NWN	18.7 m^3/s	1.0 hr
CN1	76.8 m^3/s	9.0 hr

The details of the developed conditions RORB modelling methodology and parameters are provided in Appendix A. The storage and retardation modelling outcomes are discussed in the following section.

7.4 Retarding Basin Sizing

The footprint of the retarding basins (RBs) was initially established by adopting the area required for the wetland, sediment pond and drying areas, including maintenance access tracks, as the base footprint of the RB. The available depth above this base area was then utilised to provide the required detention storage volume.

The SSP 2-4.5 climate change scenario has been adopted as the primary design basis, with the retarding basins (RBs) sized to comply with the design requirements under this scenario and verified to also provide adequate performance under current climate conditions.

The locations of the WLRBs have subsequently been optimised based on site inspections and site topography constraints. A detailed three-dimensional surface design was developed using 12d software to optimise cut and fill balance and to account for batter slopes, enabling a more accurate definition of the RB footprints. A 1V:5H safety batter slope has been adopted for the RB side slopes to ensure safe access and maintenance requirements.

The basin height, storage volume and outlet configuration (including pipe outlets and spillways) were iteratively assessed using RORB until the critical peak outflows were reduced to below existing condition flows.

The outcomes of the retarding basin (RB) sizing for each sub-catchment is summarised in Table 7-11.

Table 7-11 1% AEP retarding basin outcomes

Asset ID	Existing Flow	Inflow	Outflow and Duration	Storage Volume	Outlet Configuration	Drainage Reserve Area
SEN	2.3 m^3/s	6.5 m^3/s	1.5 m^3/s (12.0 hr)	33,500 m^3	1 Ø1050 mm	4.9 ha
SES	2.6 m^3/s	5.0 m^3/s	0.6 m^3/s (9.0 hr)	19,700 m^3	1 Ø600 mm	3.7 ha
CS	6.8 m^3/s	10.5 m^3/s	1.5 m^3/s (9.0 hr)	39,100 m^3	1 Ø1050 mm	7.3 ha
NWN	4.0 m^3/s	12.4 m^3/s	2.1 m^3/s (9.0 hr)	71,000 m^3	1 Ø1200 mm	8.6 ha

The assessment was repeated for the climate change scenario SSP 2-4.5 as shown in Table 7-12.

Table 7-12 1% AEP retarding basin outcomes with SSP 2-4.5

Asset ID	Existing Flow	Inflow	Outflow and Duration	Storage Volume	Outlet Configuration	Drainage Reserve Area
SEN	3.4 m^3/s	9.8 m^3/s	2.0 m^3/s (4.5 hrs)	42,700 m^3	1 Ø1050 mm	4.9 ha
SES	3.9 m^3/s	7.1 m^3/s	0.8 m^3/s (4.5 hrs)	24,300 m^3	1 Ø600 mm	3.7 ha
CS	10.1 m^3/s	15.2 m^3/s	2.0 m^3/s (4.5 hrs)	49,100 m^3	1 Ø1050 mm	7.3 ha
NWN	5.8 m^3/s	18.7 m^3/s	3.2 m^3/s (4.5 hrs)	86,200 m^3	1 Ø1200 mm	8.6 ha

The outcome of the analysis confirms the requirements to retard the flows back to existing conditions can be met by the retarding basins proposed and the combination of these does not increase the peak flows along Burrumbeet Creek.

7.5 Major Culverts Sizing

A number of cross-drainage box culverts are required to convey design flows under future climate conditions. Culvert sizing has been undertaken using TUFLOW hydraulic modelling based on the adopted climate change scenario.

Culvert designs and costings at Burrumbeet Creek and its tributaries do not include specific enhancements for wildlife movements (such as GGF). Refinements to culverts for wildlife may be considered by the City of Ballarat at the detailed design stage.

Box culverts at Midland Highway and Olliers Road have been sized for the 1% AEP SSP 5-8.5 climate scenario for the year 2100 to meet GHCMA requirements, and the Cummins Road culverts have also been assessed under the 1% AEP SSP 5-8.5 scenario for the year 2100 to satisfy City of Ballarat requirements.

As per the requirements of the GHCMA, the Gillies Road existing bridge has been assessed under the 1% AEP SSP 5-8.5 climate scenario for the year 2030 and 2050 to determine if it can provide safe access to the PSP area until such time that the ultimate culverts for Olliers Road and Midland Hwy are built. The assessment indicates that the existing crossing at Gillies Road has sufficient capacity to safely pass the 1% AEP flows with some overtopping of the road but within safe limits as per GHCMA Guidelines Section 2.2 (GHCMA, 2024) and thus no culvert upgrade is proposed for Gillies Road at this stage. Once the Olliers Road and Midland Hwy box culverts are built in the medium term, these will provide the safe ingress/egress to the ultimate development conditions of the PSP area during the 1% AEP future flood event (SSP 5-8.5 2100).

The culvert sizing presented herein has been developed using TUFLOW hydraulic modelling and satisfies the adopted hydraulic design criteria.

The culvert sizes and associated contributing catchment areas are summarised in Table 7-13.

Table 7-13 Major culverts details

Asset ID	DCP Label	Location	Design Flow	Box Culvert Size	Notes
BC3-1	CU-03-1	Cummins Rd (primary)	74.1 m^3/s	10 no 2100H × 2400W mm	Primary culvert crossing upgrade for 1% AEP SSP 5-8.5
BC3-2	CU-03-2	Cummins Rd (secondary)	74.1 m^3/s	20 no 900H × 1200W mm	Additional culvert upgrade to mitigate afflux for 1% AEP SSP 5-8.5
BC4-1	CU-04-1	Olliers Rd	34.9 m^3/s	12 no 1200H × 2100W mm	Culvert crossing for 1% AEP SSP 5-8.5
BC4-2	CU-04-2	Midland Hwy	34.9 m^3/s	10 no 1200H × 2400W mm	Culvert crossing upgrade for 1% AEP SSP 5-8.5

At the Cummins Road crossing, additional box culverts (20 no 1200 mm (W) × 900 mm (H)) are required to mitigate afflux and improve conveyance under design flow conditions. TUFLOW hydraulic modelling confirms that supplementary secondary box culverts are necessary in addition to the primary culvert crossing.

The functional design also confirms a revised road profile to further manage afflux impacts. The road crest has been set at RL 422.2 m AHD on the western side of Burrumbeet Creek and transitions to approximately RL 422.4 m AHD on the eastern side of the creek. Hydraulic modelling indicates that the adopted culvert configuration and road profile achieve acceptable afflux and depth–velocity criteria.

The arrangement of the proposed additional box culverts at Cummins Road, including the secondary culvert crossing and indicative road profile adjustment, is illustrated in Figure 7-5.

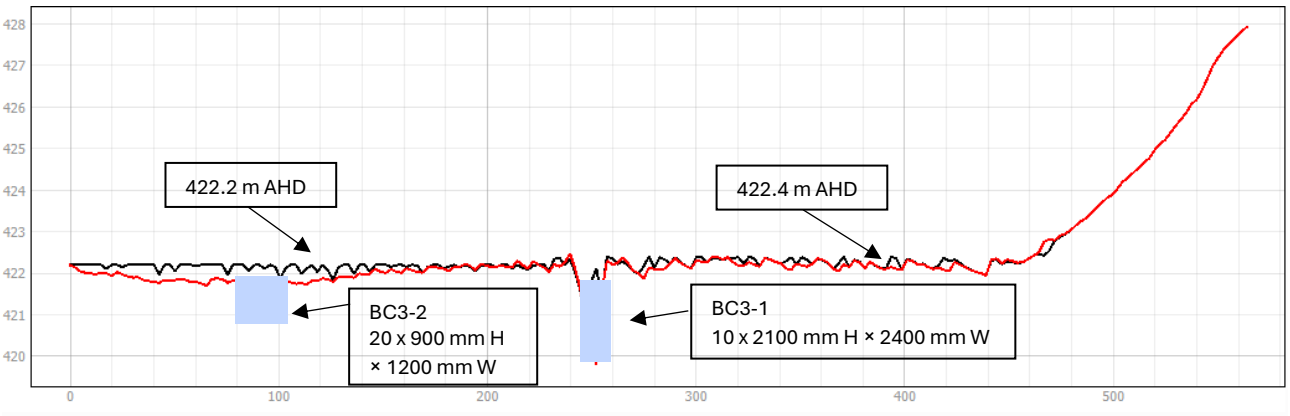


Figure 7-5 Indicative layout of additional culvert crossing at Cummins Road (red denotes existing profile and black denotes proposed profile)

The cost allocation for the box culverts will be undertaken by the SMEC Transport team and documented in a separate report.

The locations of the culverts are shown in Figure 7-6.

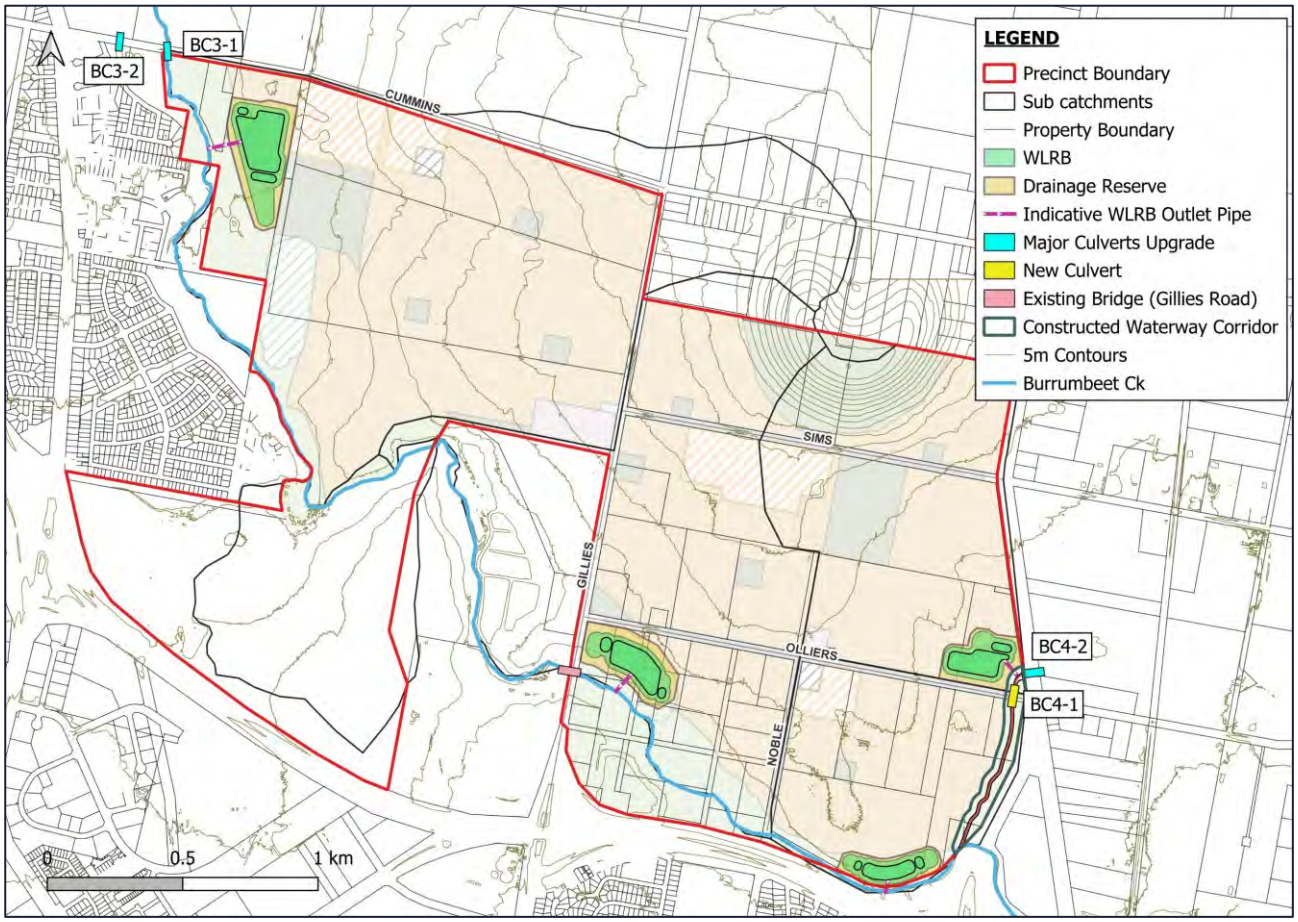


Figure 7-6 Locations of the major culverts

7.6 Minor Drainage and Road Crossing Sizing

Minor drainage infrastructure, including pipe networks and road crossings, has been sized using DRAINS modelling based on the Extended Rational Method. The adopted runoff coefficients include impervious and pervious C10 values of 0.90 and 0.37, respectively.

Both the pipe network and road crossings are intended to be designed to convey the 20% AEP design event under the adopted climate change scenario (SSP 2-4.5, year 2100), consistent with the current project design basis.

A total of three road crossings (pipe culverts) have been assessed as part of the drainage network, comprising two crossings along Sims Road, and one crossing at Olliers Road. The DRAINS model has been run for the 1% AEP event with climate change (SSP 2-4.5, year 2100) to identify gap flows. These flows have been compared against the available road overland flow capacity, as presented in Appendix C. Where the available road capacity is insufficient to safely convey gap flows, the corresponding pipe culverts have been upgraded to accommodate these flows. This only applies to the Olliers Road crossing (PC1). The sizing of pipe culverts (PC) is summarised in Table 7-14.

Table 7-14 Road crossing sizing summary

Asset ID	DCP Label	Location	Catchment Area	Design Flow	Crossing Size
PC1	CU-01	Olliers Rd	83 ha	11.8 m^3/s	2 × 1500 mm (upgraded)
PC2	CU-02	Sims Rd	31 ha	3.9 m^3/s	1350 mm
PC5	CU-05	Sims Rd	32 ha	4.0 m^3/s	2 × 1050 mm

The layout of the minor drainage network, including pipe alignments and road crossing locations, is shown in Figure 7-7. In accordance with DTP's advice, drainage pipes that perform a precinct-level function by servicing two or more PSP land parcels have been identified as DCP-funded assets. These pipes are shown in blue.

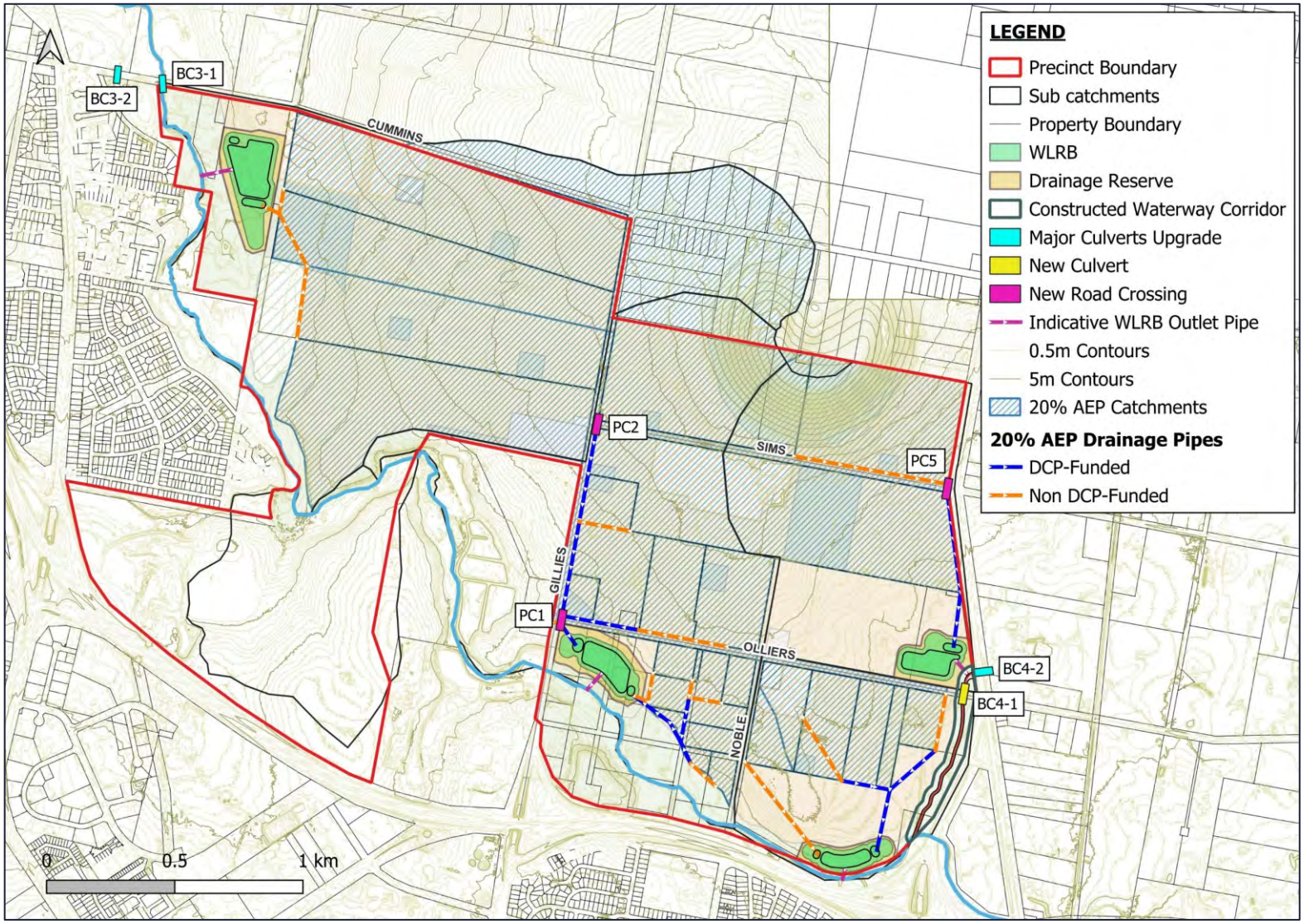


Figure 7-7 Layout of the minor drainage and road crossings

The proposed drainage pipe and pit alignment, including DCP-funded and non-DCP-funded drainage infrastructure, is presented in Figure 7-8.

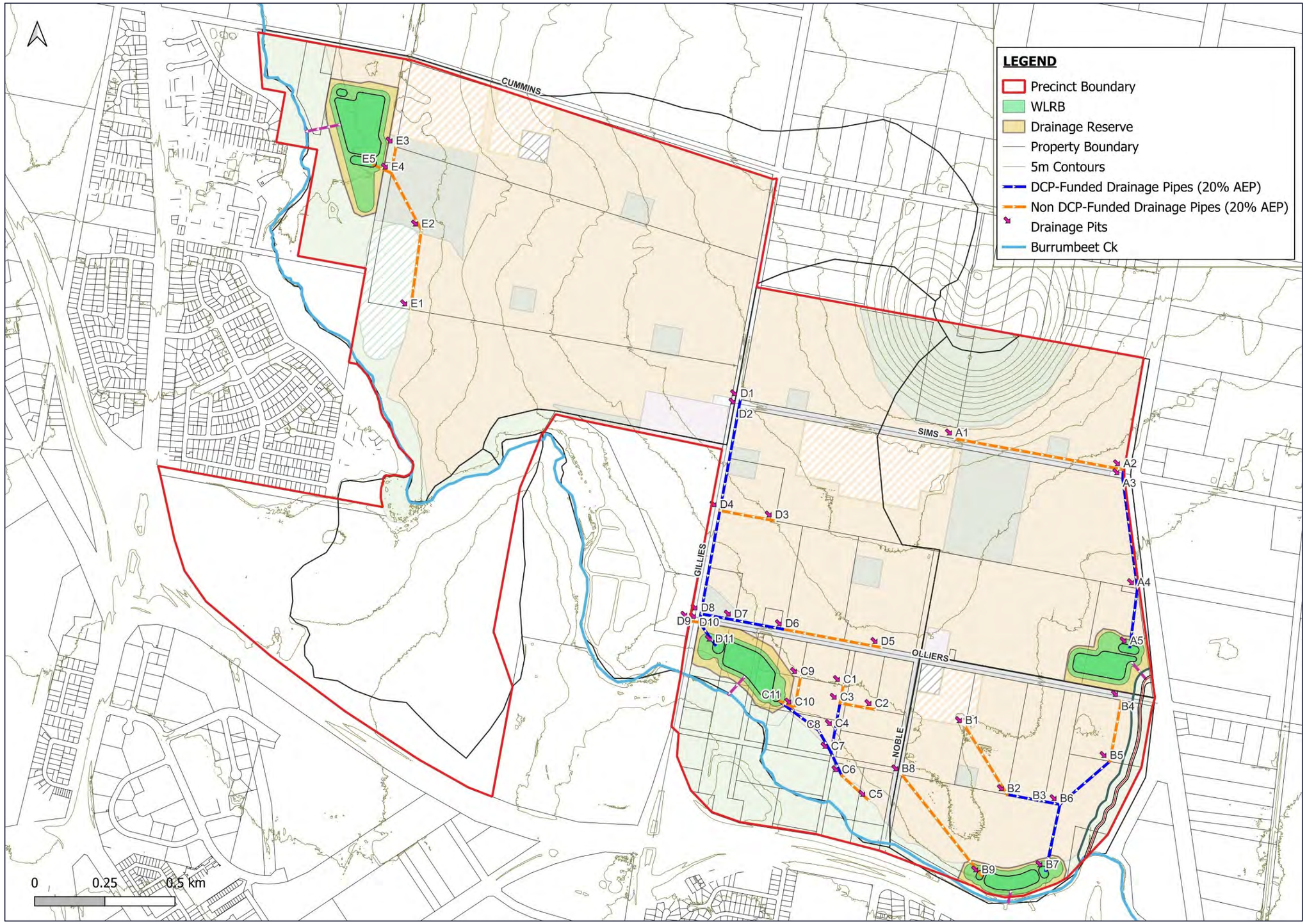


Figure 7-8 Proposed drainage pipe and pit alignment

Detailed pipe section itemisation, including asset segmentation is presented in Table 7-15. DCP-funded pipes are highlighted in blue in the table below. Associated cost allocation is provided in Appendix H.

Table 7-15 Drainage pipes details

Pipe Reference	Design Flow	Pipe Size	Pipe Grade	US Invert Level	DS Invert Level
A 1-2	0.6 m^3/s	600 mm	1 in 51	459.30 m AHD	447.30 m AHD
A 2-3 (PC5)*	4.0 m^3/s	2 × 1050 mm	1 in 64	447.30 m AHD	446.80 m AHD
A 3-4	3.9 m^3/s	2 × 1050 mm	1 in 113	446.80 m AHD	443.30 m AHD
A 4-5	7.7 m^3/s	3 × 1200 mm	1 in 296	443.30 m AHD	442.80 m AHD
B 1-2	1.0 m^3/s	825 mm	1 in 303	442.38 m AHD	441.44 m AHD
B 2-3	2.0 m^3/s	1050 mm	1 in 300	441.44 m AHD	440.99 m AHD
B 3-6	2.8 m^3/s	1200 mm	1 in 300	440.99 m AHD	440.80 m AHD
B 4-5	0.4 m^3/s	750 mm	1 in 303	442.31 m AHD	441.58 m AHD
B 5-6	0.8 m^3/s	825 mm	1 in 301	441.58 m AHD	440.80 m AHD
B 6-7	3.8 m^3/s	2 × 1050 mm	1 in 301	440.80 m AHD	440.00 m AHD
B 8-9	0.5 m^3/s	675 mm	1 in 230	442.00 m AHD	440.00 m AHD
C 1-3	0.1 m^3/s	300 mm	1 in 32	443.00 m AHD	441.00 m AHD
C 2-3	0.5 m^3/s	525 mm	1 in 126	442.00 m AHD	441.00 m AHD
C 3-4	1.0 m^3/s	825 mm	1 in 38	441.00 m AHD	438.50 m AHD
C 4-7	1.5 m^3/s	1050 mm	1 in 166	438.50 m AHD	438.00 m AHD
C 5-6	0.4 m^3/s	600 mm	1 in 130	439.50 m AHD	438.50 m AHD
C 6-7	0.5 m^3/s	750 mm	1 in 182	438.50 m AHD	438.00 m AHD
C 7-8	2.6 m^3/s	1200 mm	1 in 89	438.00 m AHD	437.00 m AHD
C 8-11	2.2 m^3/s	1200 mm	1 in 334	437.00 m AHD	436.50 m AHD
C 9-10	0.5 m^3/s	600 mm	1 in 25	442.50 m AHD	437.50 m AHD
C 10-11	0.9 m^3/s	600 mm	1 in 63	437.50 m AHD	436.50 m AHD
D 1-2 (PC2)*	3.9 m^3/s	1350 mm	1 in 60	452.20 m AHD	451.70 m AHD
D 2-4	4.0 m^3/s	1350 mm	1 in 53	451.70 m AHD	444.70 m AHD
D 3-4	2.9 m^3/s	1350 mm	1 in 57	448.20 m AHD	444.70 m AHD
D 4-8	7.2 m^3/s	1650 mm	1 in 98	444.70 m AHD	440.90 m AHD
D 5-6	1.7 m^3/s	1050 mm	1 in 138	446.20 m AHD	443.70 m AHD
D 6-7	3.2 m^3/s	1500 mm	1 in 74	443.70 m AHD	441.20 m AHD
D 7-8	4.6 m^3/s	1800 mm	1 in 303	441.20 m AHD	440.80 m AHD
D 8-10 (PC1)*	11.8 m^3/s	2 × 1500 mm	1 in 77	440.80 m AHD	440.40 m AHD
D 9-10	0.4 m^3/s	525 mm	1 in 77	440.80 m AHD	440.40 m AHD
D 10-11	12.6 m^3/s	2 × 1500 mm	1 in 29	440.40 m AHD	435.70 m AHD
E 1-2	4.3 m^3/s	1800 mm	1 in 286	426.50 m AHD	425.50 m AHD
E 2-4	7.3 m^3/s	1800 mm	1 in 230	425.50 m AHD	424.50 m AHD
E 3-4	6.6 m^3/s	1650 mm	1 in 188	425.00 m AHD	424.50 m AHD
E 4-5	17.2 m^3/s	3 × 1350 mm	1 in 46	424.50 m AHD	423.00 m AHD

*This pipe project is a component of a culvert project which has been designed and costed by SMEC in a separate report. For further details, please see *'Ballarat North PSP – Transport Infrastructure Designs and Costings – Functional Design Report (SMEC, September 2026)'*.

Drainage pits have been itemised in the drainage plan (refer to Figure 7-8). Each pit has been assigned a unique ID and details are presented in Table 7-16Table 7-16 below. DCP-funded pits are highlighted in blue in the table below.

Table 7-16 Drainage pits details

Pit Reference	Pit Type	Material	Length	Width	Depth
A1	GP / SEP	PRC	1100 mm	900 mm	1700 mm
A2	GP / SEP	PRC	2600 mm	1750 mm	1700 mm
A3	GP / SEP	PRC	2600 mm	1750 mm	1700 mm
A4	GP	PRC	4000 mm	1900 mm	1700 mm
B1	GP	PRC	1200 mm	750 mm	2100 mm
B2	GP	PRC	1500 mm	1100 mm	2600 mm
B3	GP	PRC	1600 mm	1500 mm	2900 mm
B4	GP / SEP	PRC	1100 mm	450 mm	1200 mm
B5	GP	PRC	1200 mm	600 mm	1400 mm
B6	GP	PRC	2400 mm	1500 mm	1400 mm
B8	GP	PRC	1100 mm	750 mm	1500 mm
C1	GP	PRC	600 mm	450 mm	2000 mm
C2	GP	PRC	900 mm	600 mm	2000 mm
C3	GP	PRC	1350 mm	1100 mm	2000 mm
C4	GP	PRC	1500 mm	1200 mm	2000 mm
C5	GP	PRC	900 mm	750 mm	2000 mm
C6	GP	PRC	1100 mm	600 mm	2000 mm
C7	GP	PRC	1750 mm	1750 mm	2000 mm
C8	GP	PRC	1600 mm	1600 mm	2000 mm
C9	GP	PRC	900 mm	900 mm	2000 mm
C10	GP	PRC	900 mm	900 mm	2000 mm
D1	GP / SEP	PRC	2000 mm	2000 mm	2300 mm
D2	GP / SEP	PRC	2000 mm	2000 mm	2300 mm
D3	GP	PRC	1800 mm	1800 mm	2300 mm
D4	GP / SEP	PRC	2500 mm	2500 mm	2300 mm
D5	GP / SEP	PRC	1500 mm	1500 mm	2300 mm
D6	GP / SEP	PRC	1900 mm	1800 mm	2300 mm
D7	GP / SEP	PRC	2100 mm	1600 mm	2300 mm
D8	GP / SEP	PRC	3500 mm	2600 mm	2400 mm
D9	GP	PRC	900 mm	450 mm	2300 mm
D10	GP / SEP	PRC	3500 mm	3500 mm	2600 mm
E1	GP	PRC	2100 mm	1800 mm	2500 mm
E2	GP	PRC	2400 mm	2400 mm	2500 mm
E3	GP	PRC	2300 mm	2300 mm	2500 mm
E4	GP	PRC	5000 mm	3500 mm	2500 mm

8. Stormwater Quality Analysis

The combined WLRB was designed in accordance with Melbourne Water (2020) including sediment basins, wetlands, and dewatering areas components. Refer to Appendix A-2 for Water Quality Analysis and MUSIC modelling details and following section about sediment basins and wetlands sizing.

Figure 8-1 below shows the locations and names of the sediment basins and wetlands and the internal catchment that are flowing into these assets. These catchment areas have been used for water quality modelling.

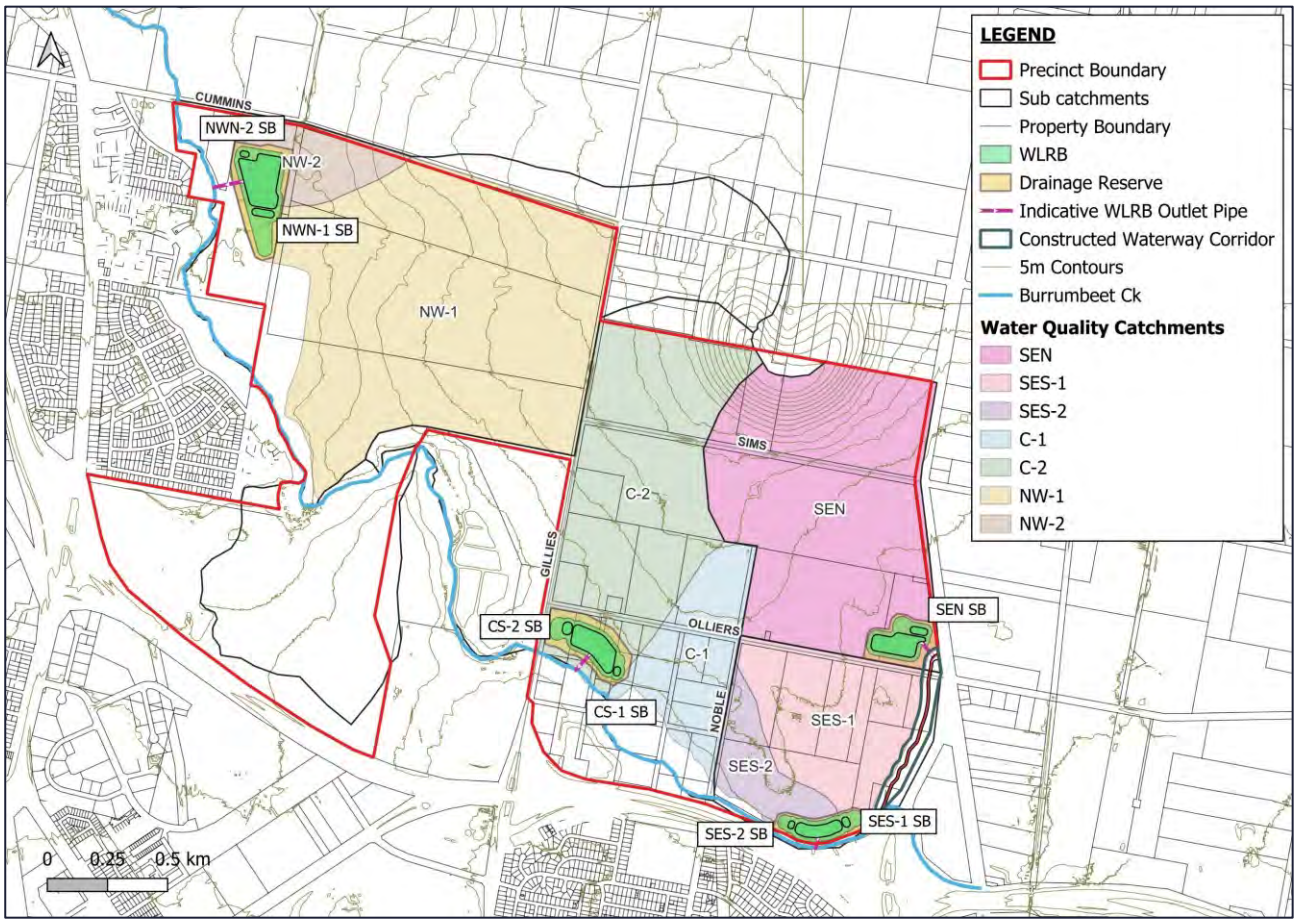


Figure 8-1 Layouts of the wetlands and sediment basins

8.1 Treatment Efficiency

Tables below show the treatment train effectiveness for each WSUD asset.

Table 8-1 SEN treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	60,600	11,000	81.9
Total Phosphorus (TP)	129	39.5	69.4
Total Nitrogen (TN)	947	518	45.3
Gross Pollutants	13,700	0	100

Table 8-2 SES treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	39,400	6,350	83.9
Total Phosphorus (TP)	82.2	24	70.9
Total Nitrogen (TN)	592	319	46.1
Gross Pollutants	8,540	0	100

Table 8-3 CS treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	76,100	12,400	83.8
Total Phosphorus (TP)	160	46.8	70.8
Total Nitrogen (TN)	1,160	628	45.7
Gross Pollutants	16,800	0	100

Table 8-4 NWN treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	113,000	19,600	82.6
Total Phosphorus (TP)	237	71	70.1
Total Nitrogen (TN)	1,720	932	45.8
Gross Pollutants	24,900	0	100

8.1.1 Overall Treatment Train Effectiveness

As per the MUSIC modelling results, the removal efficiency of proposed treatment nodes in the PSP area is shown in Table 8-5. The results demonstrates that BPEMG can be achieved by the proposed wetland and sediment basin assets.

Table 8-5 Reduction in pollutant loads

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	290,000	49,900	82.8
Total Phosphorus (TP)	610	182	70.1
Total Nitrogen (TN)	4,420	2,400	45.6
Gross Pollutants	64,100	0	100

8.2 Functional Design

The design refinement of the wetland and sediment basins is described below. The detailed modelling inputs, assumptions and results are further described in Appendix B.

8.2.1 Sediment Basins Design

The initial size of the sediment basins was estimated based on the Fair and Geyer equation to meet the guideline requirements of adequate sediment storage volume to store 5 years of sediment. The following sections outline the design principles and adopted parameters for functional design. Refer to Appendix G for design drawings. Assets ‘NW’ and ‘C’ in the design drawings are referred to as ‘NWN’ and ‘CS’ in the report.

8.2.1.1 Sediment Basins Geometry

According to Melbourne Water (2020), a batter slope of 1:5 should be adopted for the area between Normal Water Level (NWL) to Top of Extended Detention Depth (TEDD) and to the base of the retarding basin. A safety bench was designed with a batter slope of 1:8 to 350 mm below NWL. The batter of the sediment basins was extended with a 1:3 slope to the base of the sediment basins, 1.5 m below NWL.

8.2.1.2 Sediment Basins Sizing

The sediment basins were sized to ensure a minimum 95% capture efficiency for suspended solids is achieved at the design flow. The design flow was estimated using rational calculations. Two scenarios of the sediment basins being empty and full were considered and the minimum areas of the sediment basins at NWL that satisfy this requirement were adopted.

The procedure involves the use of the Fair and Geyer equation to size the sediment basins. The design sediment loading of 1.6 m^3/ha/year and gross pollutant loading rate of 0.4 m^3/ha/year were applied for developed conditions. Table 8-6 details input parameters used for sizing the basins.

Table 8-6 Sediment basins design parameters

Parameters	SEN	SES-1	SES-2	CS-1	CS-2	NWN-1	NWN-2
4EY Design Flow (m^3/s)	0.4	0.3	0.2	0.5	0.8	1.0	0.3
Surface Area at NWL (m^2)	2,015	1,120	710	920	1,800	2,620	810
Extended Detention Depth (m)	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Permanent Pool Volume (m^3)	2,015	1,120	710	920	1,800	2,620	810
Portion of Solids Removed (%)	99	99	99	98	98	99	99
Minimum Storage Volume (m^3)	1,110	475	225	350	960	1,570	280
Minimum Drying Area (m^2)	1,990	830	400	560	1,780	2,870	480
Notional detention Time (hrs)	12	12	12	12	13	12	12

8.2.1.3 Sediment Basin Flow Velocity

The maximum flow velocity was checked for the 1% AEP flow rate directly entering the sediment basins from the upstream development. A flow depth was adopted based on the 10% AEP water level determined using RORB modelling. The method described in the Wetland Design Manual (Melbourne Water, 2020) was followed to calculate the flow velocity. Velocities were calculated for 1% AEP to be below the maximum value of 0.5 m/s. See Table 8-7 below for detailed calculations.

Table 8-7 Sediment basins 1% AEP flow velocity check

Parameters	SEN	SES-1	SES-2	CS-1	CS-2	NWN-1	NWN-2
10% AEP WSE (m AHD)	442.23	439.40	439.40	438.68	438.68	424.53	424.53
NWL (m AHD)	441.55	438.75	438.75	437.95	437.95	423.75	423.75
Flow Depth (m)	0.68	0.65	0.65	0.73	0.73	0.78	0.78
Min Width at NWL (m)	30	30	25	40	30	30	25
Min Width at 10% AEP (m)	200	350	350	350	350	460	460
Average Flow Width (m)	115	190	187	195	190	245	242.5
Flow Area (m^2)	78.2	123.5	121.5	142.3	138.7	191.1	189.2
1% AEP Flow (m^3/s)	6.5	4.9	4.9	10.3	10.3	12.4	12.4
1% AEP Flow Velocity (m/s)	0.08	0.04	0.04	0.07	0.08	0.07	0.07

Sediment Basins Maintenance

A 4 m minimum base width has been adopted to provide access to the sediment basins during the clean out maintenance period. The actual storage volumes of sediment basins were calculated using 12d from the base of the sediment ponds to 0.5 m below NWL, including the reduction in volume due to the access ramp. The storage volumes of the sediment basins are greater than the minimum required storages for a 5-year maintenance period, however the basins must, nevertheless be cleaned out at a minimum frequency of 5 years.

Sediment dewatering areas have been sized for a placed depth of 500 mm. The sediment basins are to be hydraulically separated from the wetlands by a grated outlet set at NWL. This will allow for dewatering of the sediment basin without affecting the wetland macrophyte zones.

8.2.1.5 Sediment Basins Transfer Pipes to Wetlands

Flows are transferred from the sediment basins to wetlands via a pit and pipe connection. The top of the outlet pit will be located at sediment basin NWLs. A transfer pipe at the bottom of the pit will convey 4EY flows to the wetlands. This occurs when the water levels in the sediment basins are at TEDD and in the wetlands are at NWL. The sizes of transfer pipes between the sediment basins and wetlands are shown in Table 8-8. Calculations detailing pit and pipe connection sizing are presented in Appendix B-2.

Table 8-8 Sediment basins transfer pipe sizing

Transfer Pipe Name	RCP Pipe Diameter
SEN	600 mm
SES-1	525 mm
SES-2	450 mm
CS-1	600 mm
CS-2	750 mm
NWN-1	900 mm
NWN-2	450 mm

8.2.2 Wetland Design

The initial size of the wetlands was estimated using the MUSIC model to meet best practice standards. The following sections outline the design principles and adopted parameters for functional design. Refer to Appendix G for design drawings. Assets ‘NW’ and ‘C’ in the design drawings are referred to as ‘NWN’ and ‘CS’ in the report.

8.2.2.1 Wetlands Geometry

A batter slope of 1V:5H should be adopted for the area between NWL to EDD and to the base of the retarding basin. The geometry of wetlands below NWL is similar to the sediment basins in inlet, intermediate and outlet pools.

The detailed wetland bathymetry, including the inlet, outlet and intermediate pools, has not been developed at this stage and will be finalised during the detailed design phase. The detailed design will confirm the location, dimensions and depths of the pools, as well as the overall wetland bathymetry, to achieve the required hydraulic performance, flow distribution and treatment objectives.

8.2.2.2 Wetlands Sizing

The sizes of the wetlands were initially obtained from MUSIC model to ensure best practice water quality objectives have been met. Appendix B-1 shows the snippet of the MUSIC model layout for the developed condition. Details of the wetlands modelled in MUSIC are provided in Table 8-9.

Table 8-9 Wetlands design parameters

Parameters	SEN	SES	CS	NWN
Surface Area (m^2)	15,520	9,570	19,300	29,600
Extended Detention Depth (m)	0.35	0.35	0.35	0.35
Average Depth (m)	0.35	0.35	0.35	0.35
Permanent Pool Volume (m^3)	5,425	3,325	6,650	10,150
Notional Detention Time (hr)	72	72	72	72

8.2.2.3 Wetland Flow Velocity

The flow velocity during major events (1% AEP) is generally very low in the retarding basin as the basin is fully submerged in these events. Therefore, the maximum flow velocity was checked for the 1% AEP flow rate and the 4EY (3-month) flow rate directly entering the macrophyte zone from the upstream development.

A flow depth was adopted based on the 10% AEP water level determined using RORB modelling for the 1% AEP calculation and the EDD was adopted for the 4EY flow depth. The method described in Melbourne Water (2020) was followed to calculate the flow velocity.

The calculated 1% AEP and 4EY flow velocities for all wetlands are well below the target criterion of 0.5 m/s and 0.05 m/s specified in the Melbourne Water (2020). The wetland bathymetry will be further refined during the detailed design phase, and consequently the calculated flow velocities presented herein will subject to change following refinement of the detailed bathymetric design. See Table 8-10 and Table 8-11 for detailed calculations of the 1% AEP and 4EY flow velocity checks.

Table 8-10 Wetlands 1% AEP flow velocity check

Parameters	SEN	SES	CS	NWN
10% AEP WSE (m AHD)	442.23	439.40	438.68	424.53
NWL (m AHD)	441.45	438.65	437.85	423.65
Flow Depth (m)	0.78	0.75	0.83	0.88
Min Width at NWL (m)	66	40	80	120
Min Width at 10% AEP (m)	150	62	100	150
Average Flow Width (m)	108	51	90	135
Flow Area (m^2)	84.2	38.3	74.7	118.8
1% AEP Flow (m^3/s)	6.5	4.9	10.3	12.4
1% AEP Flow Velocity (m/s)	0.08	0.13	0.14	0.10

Table 8-11 Wetlands 4EY flow velocity check

Parameters	SEN	SES	CS	NWN
EDD (m AHD)	441.80	439.00	438.15	424.00
NWL (m AHD)	441.45	438.65	437.85	423.65
Flow Depth (m)	0.35	0.35	0.35	0.35
Min Width at NWL (m)	66	40	80	120
Min Width at EDD (m)	75	45	86	125
Average Flow Width (m)	70.5	42.5	83	122.5
Flow Area (m^2)	24.7	14.9	29.1	42.9
4EY Flow (m^3/s)	0.6	0.5	1.0	1.0
4EY Flow Velocity (m/s)	0.02	0.03	0.03	0.02

8.2.2.4 Wetlands Detention Time and Inundation Frequency Analysis

An inundation frequency analysis was undertaken using the Melbourne Water Wetland Analysis Tool, incorporating daily flux data generated from the MUSIC model. The results indicate that for most plant species recommended by Melbourne Water, the frequency of inundation is below 20%. This suggests that the risk of plant drowning is minimal and within acceptable thresholds.

The average water depths were found to be within the 50th percentile, and acceptable. Wetlands are typically designed to achieve a 90th percentile detention time of 72 hours. Based on the current functional design modelling, this criterion can be achieved across all wetlands.

It should be noted that the custom storage–discharge relationships for the wetlands have not yet been defined to a level consistent with detailed design. Accordingly, the residence time should be re-confirmed as part of detailed design when the wetland bathymetry and outlet configurations are further refined.

Refer Appendix B-3 for the details.

9. Integrated Water Management Strategy

9.1 General

This section of the report describes the Integrated Water Management (IWM) water balance modelling completed for Ballarat North PSP. The intent of this IWM plan is to quantify the potential stormwater runoff volume that can be harvested from the PSP development.

IWM is a holistic plan that encompasses various components of the water cycle. The WSUD component has been addressed in Section 8 of this report. This section focuses on the water balance modelling, with an emphasis on the potential for rainwater and stormwater harvesting from the PSP catchment.

9.2 Adaptive Plan

The development of the PSP is expected to span several years, during which time opportunities for the implementation of IWM will continue to evolve. One major opportunity, which is yet to be confirmed, is the potential stormwater harvesting scheme by CHW.

The IWM study conducted by Arup (2024) to inform the PSP recommends an alternative approach known as the 'Adaptive Plan' which involves installation of 2kL rainwater tanks in all residential dwellings as well as the provision of precinct-scale wetlands for stormwater harvesting for open space irrigation.

The supplementary lot scale IWM recommendations include implementation of household raingardens, and passively irrigated trees. The modelling of these features have not been quantified at this point.

Additionally, Burrumbeet Creek corridor enhancement was identified to be a key recommendation of the IWM initiatives.

9.2.1 Water Demands

SMEC has adopted the land use budget provided by DTP dated 23/06/2025 to estimate water demands for the PSP area. The demand calculations are subject to change should an updated land use budget be provided; however, any revisions are expected to have a minimal impact on the overall results. To estimate the expected water demands for the PSP, the assumptions are outlined in Table 9-1.

Table 9-1 Water demand assumptions

Type	Water Demand	Unit	Reference
Residential Potable Water Demand	126.9	kL/lot/yr	CHW,2018
Residential Non-Potable Water Demand (includes toilet flushing and garden irrigation)	43.3	kL/lot/yr	CHW,2018
Active Open Space (sports fields)	5,000	kL/ha/yr	Arup, 2024
Passive Open Space (local parks and landscaped areas)	2,000	kL/ha/yr	Arup, 2024

The total water demand for residential lots and open spaces within PSP area has been estimated and is illustrated in Figure 9-1. The total water demand within the PSP area is estimated to be 3,834 kL/day (1,400 ML/year). The full list of analysis assumptions is provided in Appendix D.

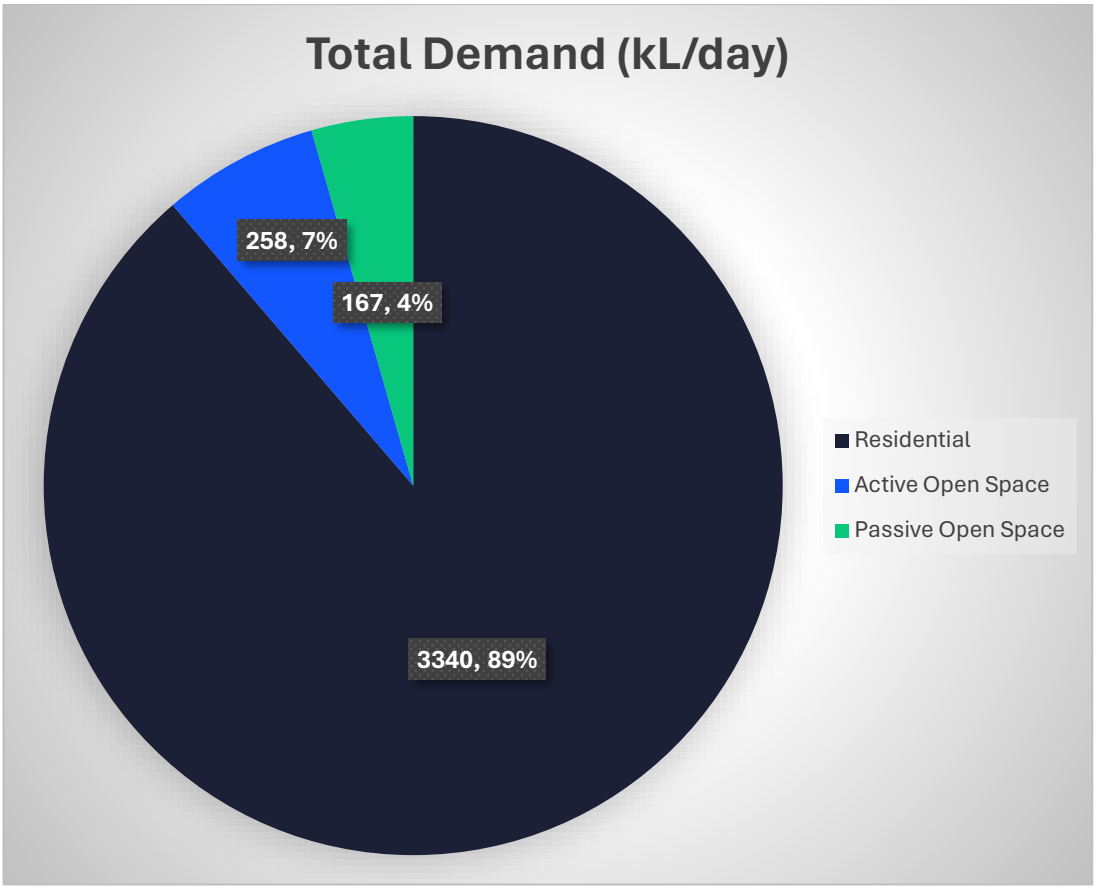


Figure 9-1 Ballarat North PSP water demand distribution

9.2.2 Rainwater Harvesting

Rainwater can be collected from rooftops and directed into tanks for household use in meeting non-potable needs, such as toilet flushing, and outdoor irrigation. According to the Supplementary Guide (CHW, 2018), all new residential dwellings are required to install a minimum 2kL rainwater tank to help reduce dependence on potable water. A MUSIC model was developed to determine the magnitude of stormwater able to be generated and captured from residential roof areas within the PSP area. The snippet of the MUSIC model is shown in Appendix D. Additional information regarding assumptions and water demands are provided in the following sections.

9.2.2.1 Model Assumptions

The following assumptions have been made in setting up the MUSIC model.

- Impervious fraction values are taken from MW MUSIC Guidelines and estimated based on land use budget shapefile provided by DTP for the Ballarat North PSP.
- Rainwater is to be harvested only from residential roofs within Ballarat North PSP area.
- 80% of roof areas is assumed to be drained to a rainwater tank, and 20% would bypass.
- 2kL rainwater tanks are installed in every household, and that it will be reused for toilet flushing, and garden irrigation.
- Average number of people per household in Ballarat North area is 2.2 (ABS, 2021). This figure has been used for toilet flushing reuse demand calculations.
- Toilet flushing demand is assumed to be 20 L/person/day for residential lots.
- Irrigation reuse demand for residential gardens is assumed to be 2 ML/ha/yr, consistent with the rate adopted for passive open spaces.

9.2.2.2 Reliance on Rainwater Harvesting

The Ballarat Potable Water Demand Target Supplementary Guidelines (CHW, 2018) specify a mandatory potable water target of 124 L/person/day within the PSP area and recommend the implementation of WSUD measures to achieve this goal. In line with these guidelines, 22% of the non-potable water demand is supplied by a 2kL rainwater tank, operating with approximately 67% reliability.

9.2.3 Stormwater Harvesting from Wetlands

The objective of this approach is to harvest stormwater from wetlands for local open space irrigation purposes. The effectiveness of this measure to the volume reduction and infiltration targets is known to be much larger in comparison to smaller lot scale initiatives. The estimation of the stormwater runoff volume available from wetlands within the PSP area has been assessed in two scenarios:

- Scenario A – Rainwater tanks installed
- Scenario B – Rainwater tanks not installed

The water balance model (MUSIC) created to assist with sizing of the WSUD wetland treatment areas was utilised to estimate the stormwater runoff volume available from wetlands within the PSP area in the developed conditions.

9.2.3.1 Model assumptions

The following assumptions have been made in setting up the MUSIC model.

- The volume available for harvesting from wetlands is sensitive to the wetlands' configuration. It is assumed that only *excess flows* (bypass and weir overflow) can be harvested to ensure wetland planting is not compromised.
- Model calibration has not been employed in this assessment to validate the runoff volumes outcomes. It is judged likely that the runoff volumes produced by the model may not be accurate and further validation may be warranted should these proceed to design or cost benefit analysis study. For the purposes of this high-level assessment the model outcomes are considered appropriate.
- No storage has been included in the model. This would potentially overestimate the volumes being harvested.
- Water demand for each wetland systems has not been determined at this stage.

9.2.3.2 Scenario A - Rainwater Tanks Installed

The stormwater runoff volume generated from the existing catchment and the increased runoff volume from the full development of the PSP area are shown in Table 9-2. This is a 125% increase from existing condition. The total volume of runoff that can be harvested from wetlands is estimated to be approximately 374 ML/yr which is 43% of the total runoff volume increase. This is above the target of 29% as per EPA (2021).

Table 9-2 Water balance model results – Scenario A

Water Balance Metrics	Value
Existing Condition	697 ML/yr
Developed Condition	1,570 ML/yr
Increase in Runoff Volume	873 ML/yr
% increase	125%
Stormwater Runoff available for Harvesting from Wetlands	374 ML/yr

The breakdown of the mean annual volume that can be extracted from each wetland is shown in Table 9-3 below.

Table 9-3 Breakdown of potential harvested runoff volume from wetlands – Scenario A

Wetlands	Mean Annual Volume Harvested
SEN	81.7 ML/yr
SES	48.5 ML/yr
CS	99.8 ML/yr
NWN	144.0 ML/yr
TOTAL	374 ML/yr

9.2.3.3 Scenario B - Rainwater Tanks Not Installed

The total volume of runoff that can be harvested from wetlands is estimated to be approximately 466 ML/yr which is 53% of the total runoff volume increase in the absence of rainwater tanks. This is above the target of 29% as per EPA (2021). The breakdown of the mean annual volume that can be harvested from each wetland is shown in Table 9-4.

Table 9-4 Breakdown of potential harvested runoff volume from wetlands – Scenario B

Wetlands	Mean Annual Volume Harvested
SEN	101.2 ML/yr
SES	65.8 ML/yr
CS	119.6 ML/yr
NWN	179.4 ML/yr
TOTAL	466 ML/yr

9.2.4 Potential for Active Open Space Irrigation

A sports field is proposed to be located in the north-western corner of the PSP (refer to Figure 9-2) and can be irrigated using runoff harvested from the adjacent NWN wetland. The results indicate that there is an adequate amount of volume available from this wetland to irrigate the adjacent active open space. Following assumptions have been made:

- The assessment has only been carried out for Scenario A with inclusion of rainwater harvesting tanks.
- Irrigation reuse demand is assumed to be 5 ML/ha/yr for the active open space.

To irrigate the proposed active open space (SR-01) from NWN wetland, the required stormwater harvesting transfer pipe can be aligned along the shortest practical route between the wetland and the active open space. Given that the active open space is located immediately east of the wetland, consideration should be given to locating the extraction point and associated pump infrastructure on the eastern side of the wetland to minimise the length and complexity of the transfer infrastructure. The extraction point does not necessarily need to coincide with the wetland outlet, subject to suitable permanent water depth, access and operational requirements. The final extraction point, pump arrangement, electrical servicing and transfer pipe alignment are subject to detailed design.

Percentage of harvested stormwater required for irrigation of the active open space is estimated in Table 9-5. The results confirm that the harvested water can be appropriately stored for reuse and that the necessary infrastructure for transporting the water to support irrigation in the designated active open space, as outlined in the IWM plan, is properly planned.

Table 9-5 Harvested stormwater required for active open space irrigation

Parameter	Value
Active Open Space Area	9.5 ha
Total Irrigation Demand	47.5 ML/yr
Available Harvested Stormwater from NWN Wetland	144.0 ML/yr
% of Harvested Stormwater Required for Irrigation	33%

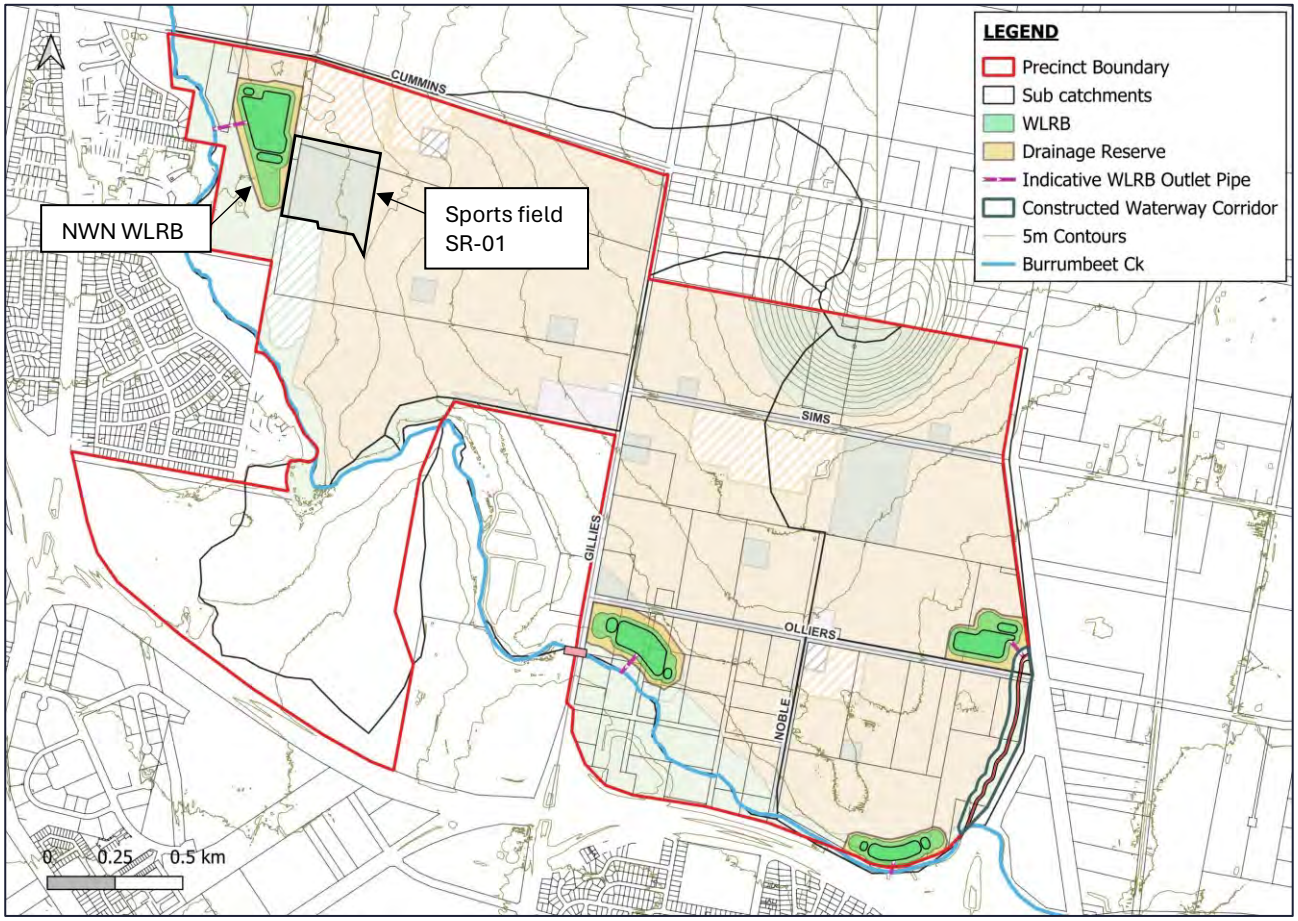


Figure 9-2 Location of the active open spaces within the PSP area

9.2.5 Burrumbeet Creek corridor improvements

This report (Section 3.7), along with the previous IWM study has identified the risks of further erosion of Burrumbeet Creek under current conditions, a risk likely to be exacerbated by future conditions due to increased runoff volume, and increased frequency and duration from urban runoff despite a reduction in peak runoff rate during the 10% and 1% AEP flood event.

To address this, it is recommended that this section of the Burrumbeet Creek waterway corridor is revitalise through stabilisation of the existing creek form, and the reintroduction of native vegetation and trees along the riparian zones.

Further studies such as hydro-ecological, geomorphological assessments, targeted flora and fauna survey will help identify and prioritise specific sections for enhancement. These items can be included in the DCP costs, as there is a clear nexus between the increased risk of creek deformation and future development within the PSP area, even though existing creek instabilities have already been caused by current land uses. The responsibility of setting the requirements and acceptance of the proposed in stream works ultimately lies with GHCMA as the waterway authority. Consultation with the traditional owners are also recommended to achieve the best outcome.

9.3 Summary and Recommendations

Modelling shows that 22% of the non-potable water demand is supplied by a 2kL rainwater tank installed in every household within the PSP area, operating with approximately 67% reliability. The water balance modelling conducted to date also suggests that 43% and 53% of the total runoff volume can potentially be harvested from wetland system for stormwater reuse with and without rainwater tanks in place. However, this outcome is contingent upon the availability of an equivalent water demand within the area. There is an opportunity to reuse the water for irrigation purposes for the active open space near NWN WLRB. The results confirm that the harvested water can be appropriately stored for reuse and that the necessary infrastructure for transporting the water to support irrigation in the designated active open space, as outlined in the IWM plan, is properly planned.

For Burrumbeet Creek, further assessments such as geomorphological, and flora and fauna assessments are recommended to be undertaken to better understand the interventions possible for the creek to ultimately meet one of the key IWM initiatives identified for the PSP.

10. Flood Impact Assessment

10.1 Defining the Existing Conditions Extent

Correspondence from Glenelg Hopkins Catchment Management Authority (GHCMA) to the DTP has flagged that the available 1% Annual Exceedance Probability (AEP) flood extents of Burrumbeet Creek are out of date. The current flood study upon which the flood mapping is based is described in Water Technology (2013). The current flood mapping does not accurately represent the recent changes in the catchment including new major drainage infrastructure and increases in development area.

The Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) based on the current flood study are overlaid on the Ballarat North PSP in Figure 10-1. The changes in modelling practice subsequent to the current flood study include revised design rainfall depths and climate change impact estimation techniques.

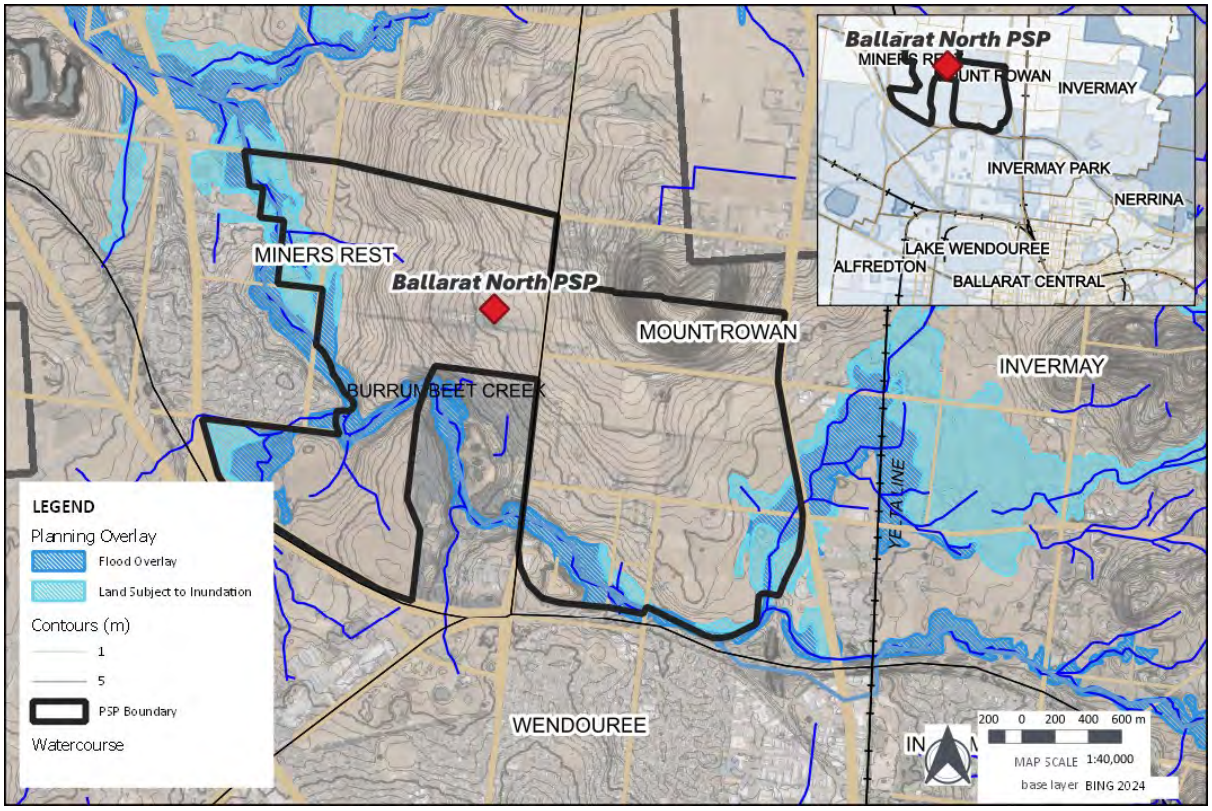


Figure 10-1 Ballarat North PSP and Burrumbeet Creek flood overlays

The flood extent defines the development exclusion zone, and an estimate of the updated zone is required to provide certainty for development planning purposes. Furthermore, defining the existing conditions base case is also necessary in order to assess the impact of the development conditions.

10.1.1 Interim Flood Extent

SMEC was tasked with preparing a methodology to delineate an interim flood inundation extent in advance of a more detailed future flood study to be completed at a later time. The methodology and outcomes was presented for in principle agreement to GHCMA. The intent of the interim methodology is to define the 1% AEP flood extent inclusive of climate change applying a simple, conservative analysis. The detail of this assessment is documented in a Technical Memo (30049251-181-TM-001) provided in Appendix E.

Subsequent to the interim flood outcomes and development of the RORB models, the TUFLOW model was refined to be more accurate, and the methodology and outcomes are presented below.

10.1.2 Methodology

10.1.2.1 Inputs

The models supplied by DTP were modified by SMEC. More recent terrain data were sourced from publicly available sources. These includes:

- Burrumbeet Creek – rainfall runoff model – RORB (Refer to Section 6)
- RORB sub catchment and reaches in GIS format (shapefiles)
- Burrumbeet Creek - 2d hydraulic model - TUFLOW
- Terrain (LiDAR) data 2019 (Geoscience Australia, 2024)

10.1.2.2 2024 Climate Change Consideration Update

AR&R (2019) defines the industry standard for completing design event rainfall runoff estimation and associated flood modelling. Subsequent to completion of the current flood study in 2013, AR&R (2019) has been updated in 2019 (Version 4.1) and more recently in September 2024 (Version 4.2). The updates incorporate changes to design rainfall and then, in 2024, changes to climate change impact estimation procedures.

For the purpose of the flood impact assessment, the existing conditions including climate change was simulated as it produces the critical and higher flood levels.

10.1.2.3 Limitations

- The model does not include all the underground drainage information on the south side of the Western Freeway. The existing residential area is indicated as flood prone. It is likely that the severity of the flood in this area may be overstated in the SMEC model since the culvert size under the freeway were based on site observations. Therefore, the size and capacity have not been verified.
- Similarly for the downstream areas in Miners Rest, the Council drainage system have not been included in the hydraulic modelling. However, since this area is downstream of the PSP site, the flood impact assessment should not be significantly influenced by the lack of drainage data.

10.1.3 Hydrology

The design rainfall and climate change conditions adopted for this assessment is consistent with the requirements of AR&R and GHCMA Flood Modelling Guidelines and Specifications (GHCMA, 2024). These are summarised in Table 10-1.

Table 10-1 Rainfall depth and climate change uplift factor

Scenario	Scenario Description	Design Rainfall Depth Source	Adopted Time Horizon	Global Climate Condition	Design Rainfall Depth Uplift Factor
Existing Condition	Latest Climate Change Consideration	BoM IFD 2016 w/ uplift as per AR&R (2019)	2100	SSP 5-8.5 4.5 degrees °C increase	1.47[1]

1. For critical duration of 12 hours

The future climate change scenario is based on an increase in global temperature of 4.5 °C in the year 2100 horizon. The climate change uplift factors vary depending on the storm duration and AEP. A summary table of the uplift factors applicable to the site location is illustrated in Table 10-2. Detailed climate change factors are included in Appendix A-2.

Table 10-2 Data hub climate change consideration uplift factors (AR&R v4.2, 2019)

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

The RORB (Laurenson et al., 2010) mo8el sub area and reaches and parameters (delay and losses) are described Appendix A of this report. A summary of the model parameters is shown in Table 10-3. For the 12-hour storm duration, the adopted initial loss is 10.2 mm (refer to Table A-1-3), which has been factored by 1.19 under the SSP 5-8.5 climate change scenario. The continuing loss of 3.7 mm/h has also been adjusted by a factor of 1.44.

Table 10-3 RORB model input parameters

Parameter	Value
Delay - kc[1] adopted for the Catchment Outlet	46
Non-linearity - m	0.8
Initial Loss IL (mm)	12.1
Continuing Loss CL (mm/hr)	5.33

Note 1: The primary delay adopted. k_c was adjusted for smaller sub catchment using interstations.

10.1.3.1 Outcomes

The 1% AEP peak flow with the climate change SSP 5-8.5 estimated at the PSP outlet (CN1) and at the catchment outlet are summarised in Table 10-4.

Table 10-4 1% AEP design flow (SSP 5-8.5)

Scenario	Miners Rest (CN1) 1% AEP Peak Flow (Duration)	Lake Burrumbeet Gauge – Outlet 1% AEP Peak Flow (Duration)
Existing Condition	102.8 m^3/s (4.5 hr)	145.8 m^3/s (12.0 hr)

The RORB catchment model setup and locations of the reported peak flows are shown in Figure 10-2.

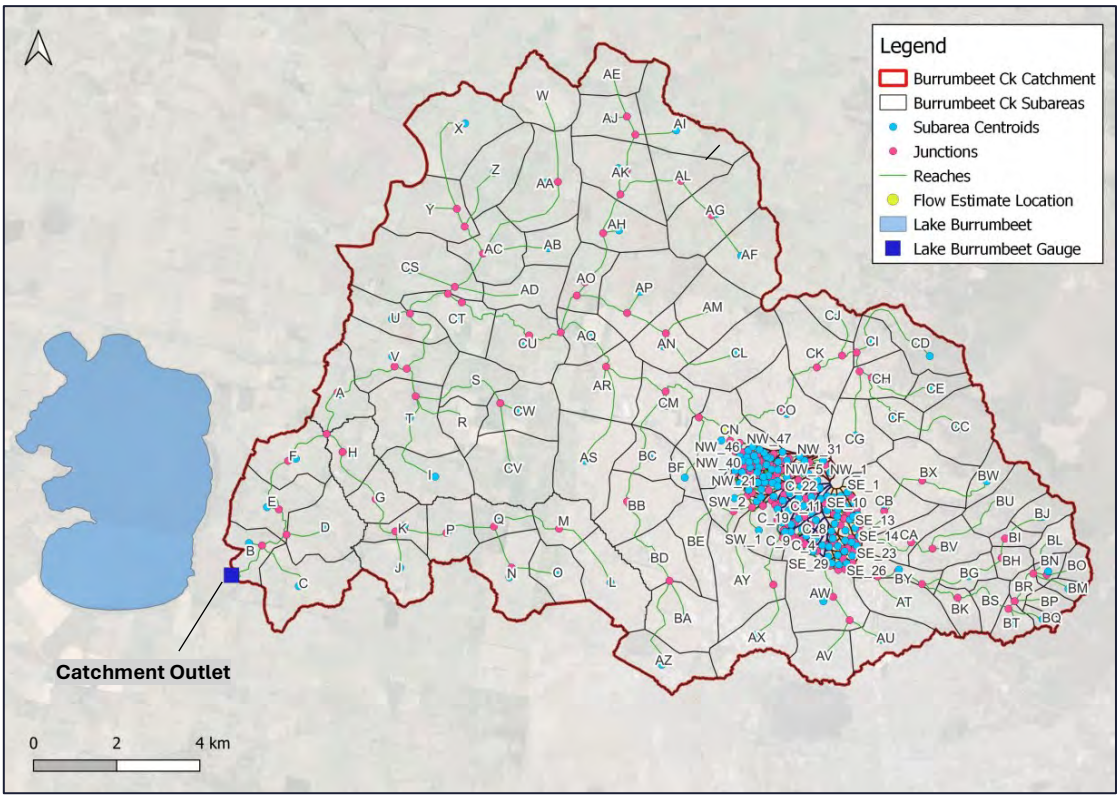


Figure 10-2 RORB catchment model

A range of storm durations and corresponding critical temporal pattern were selected for hydraulic simulation based on the peak flows at key locations (road crossings, along Burrumbeet Creek and proposed RB outlet) within the PSP. In particular at Miners Rest (CN1) and external catchment inflow location at Midland Road.

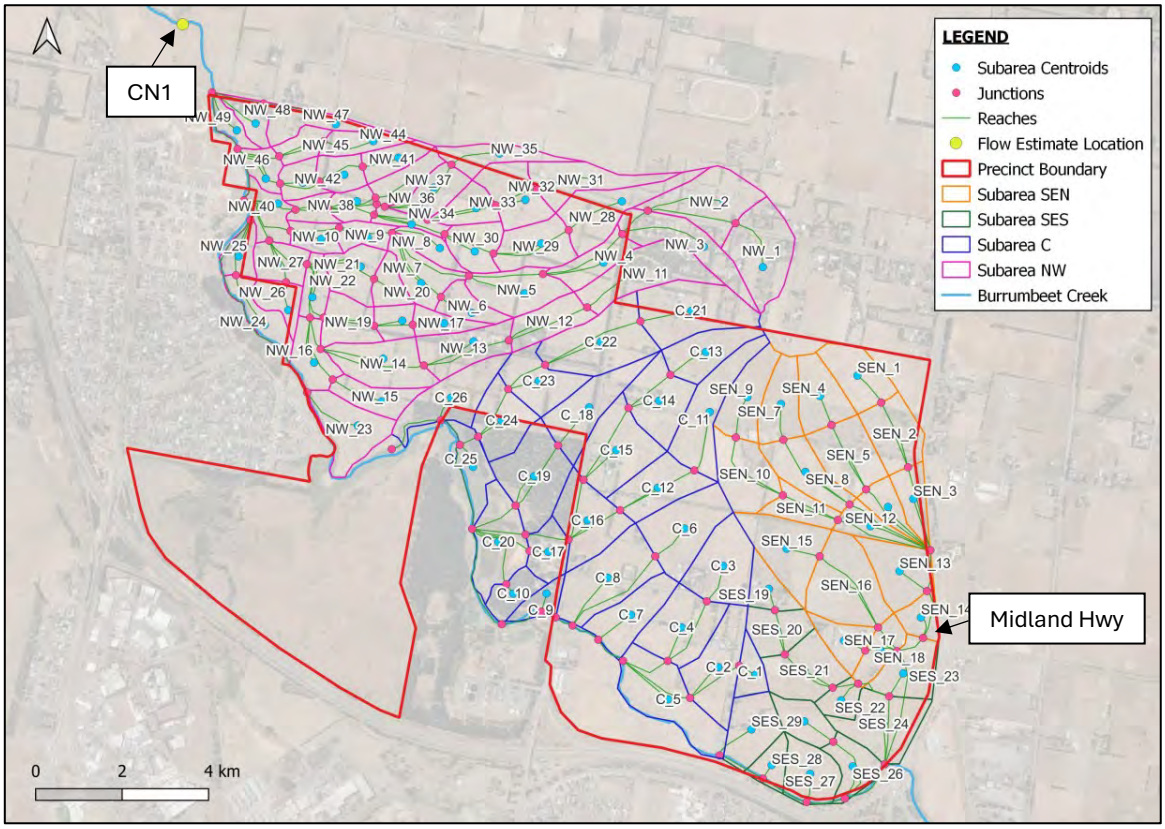


Figure 10-3 Peak flows at Key locations – existing condition

Table 10-5 outlines the storm events selected for the hydraulic simulation.

Table 10-5 Hydraulic simulation storm events

Storm Duration	Temporal Pattern
1.0 hr	TP27
2.0 hr	TP28
4.5 hr	TP28
9.0 hr	TP26
12.0 hr	TP21
24.0 hr	TP21

10.1.4 Hydraulic Modelling

A 2d hydraulic model (TUFLOW) was setup to determine the maximum flood extents from various storm events for the 1% AEP. The TUFLOW model was setup and ran as follows:

- Inflow hydrograph at the upstream end of the model domain and for individual reach and tributary entering the Creek.
- Outflow boundary condition based on longitudinal slope.
- 5 m grid size based on 2019 LiDAR of 1m resolution.
- HPC computation scheme with sub-grid-sampling (SGS) enabled.
- Roughness definition (materials file) were modified to refine the area covering the PSP.
- Model extent is limited to the Burrumbeet Creek reach covering the PSP area and 2 km downstream into Miners Rest.
- The inflow hydrograph to the hydraulic model was extracted from the hydrologic model at a location shown in Figure 10-4. This represents more accurate representation of inflows for each sub catchment and tributaries.
- Major culvert structures at road crossings have been included in the TUFLOW model as detailed in Section 7.5.
- Raise the road elevations at Cummins Road Crossing to 422.2 m AHD and 422.4 m AHD from west to east.
- Reinforce the road elevation at Midland Highway Crossing due to poor LiDAR horizontal resolution data.

The TUFLOW model domain is shown in Figure 10-4.

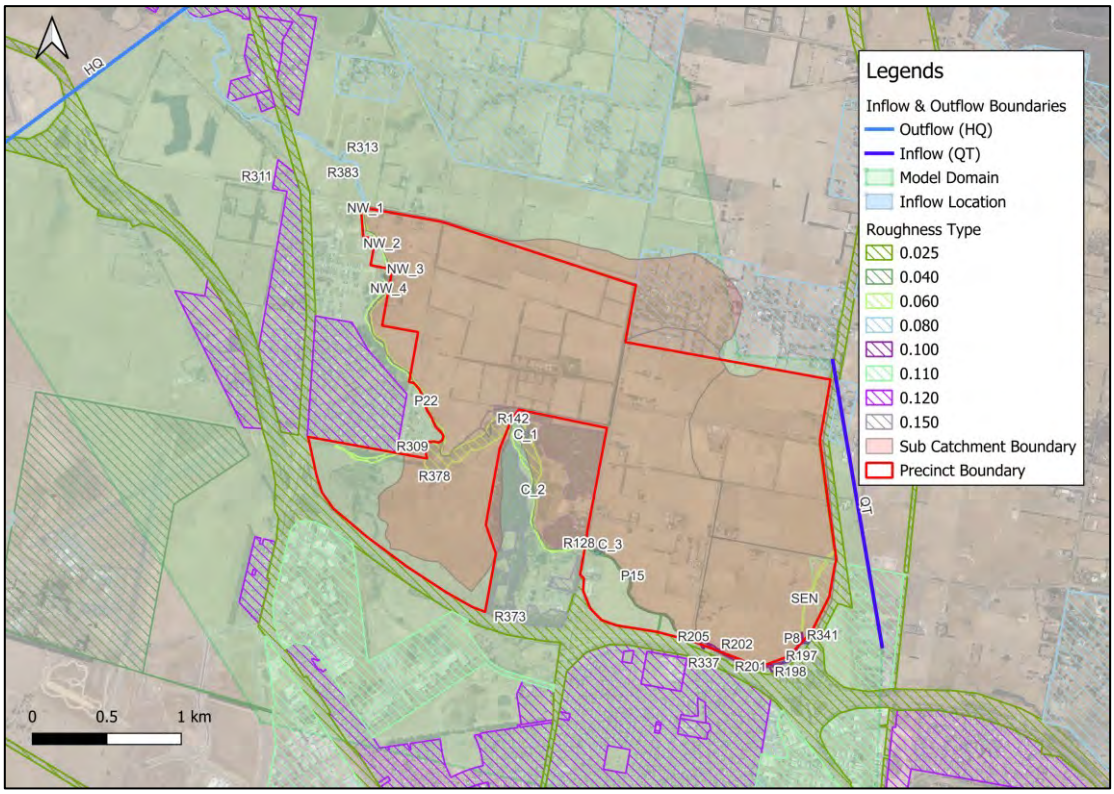


Figure 10-4 TUFLOW model setup existing conditions

10.1.5 Existing Conditions Extent Results

The results of the various storm events were combined to create the maximum flood extent. The 1% AEP flood extent of the existing conditions scenarios are provided in Figure 10-5 and Appendix F.

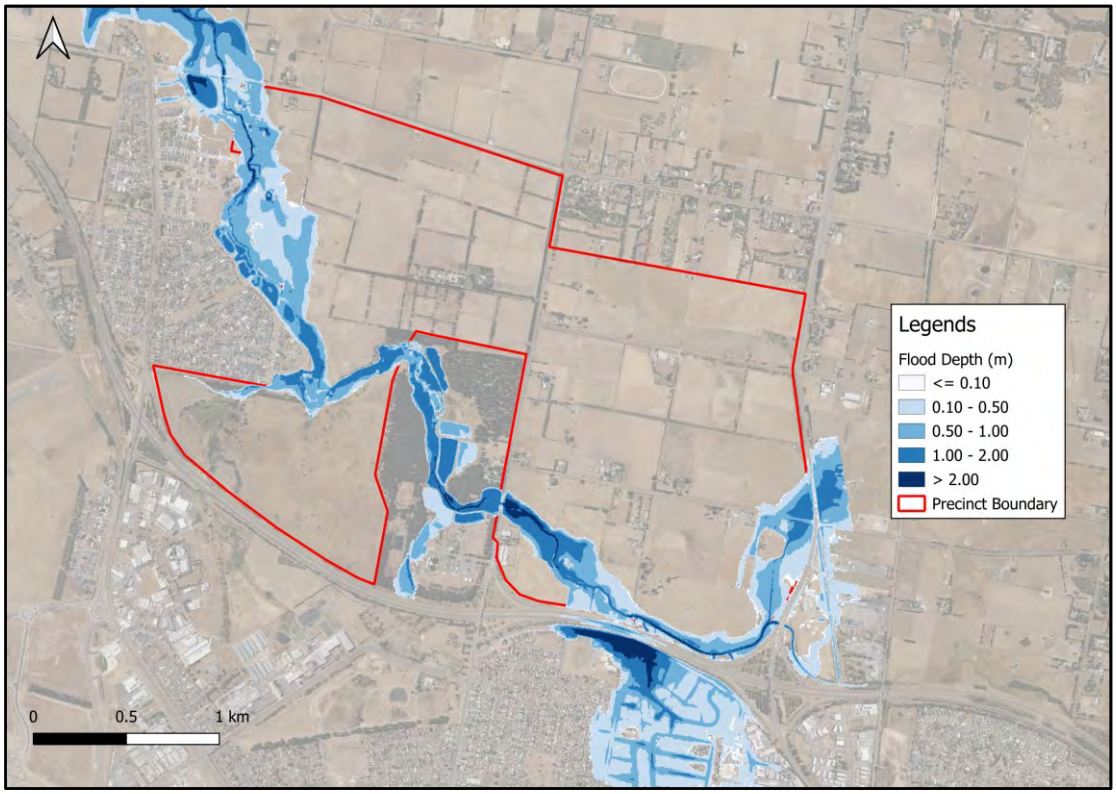


Figure 10-5 Existing condition flood impact assessment – 1% AEP

10.2 Developed Condition

10.2.1 Waterway Diversion

A waterway diversion is proposed on the eastern boundary of the PSP. The design intent is to fill the adjacent flood prone land to the west as described in Section 7.2.1. A design tin of the proposed waterway realignment has been created based on a typical constructed waterway with a pilot channel and benching. Refer to Figure 10-6 for the typical cross section of the proposed waterway diversion.

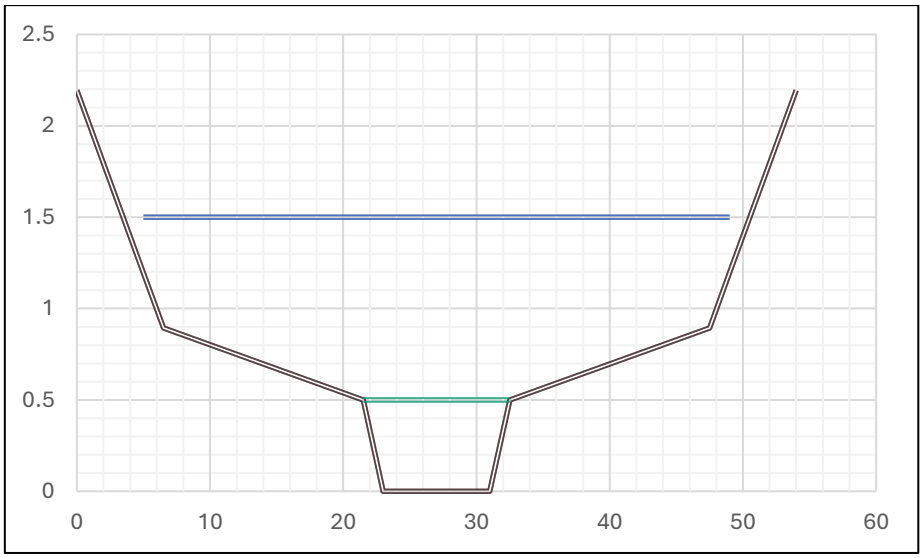


Figure 10-6 Typical constructed waterway

For the proof-of-concept stage, the waterway profile has been determined to meet the hydraulic capacity requirements initially. In this functional design phase, the waterway profile has been further refined to contain the 1% AEP flood (SSP5-8.5 2100) in the new constructed waterway consistent with the Constructed Waterway Design Guidelines (Melbourne Water, 2019). Additional refinement was made to ensure there was no afflux upstream of Midland Hwy culvert crossing. A typical waterway profile and fill levels compared to the existing terrain is shown in Figure 10-7.

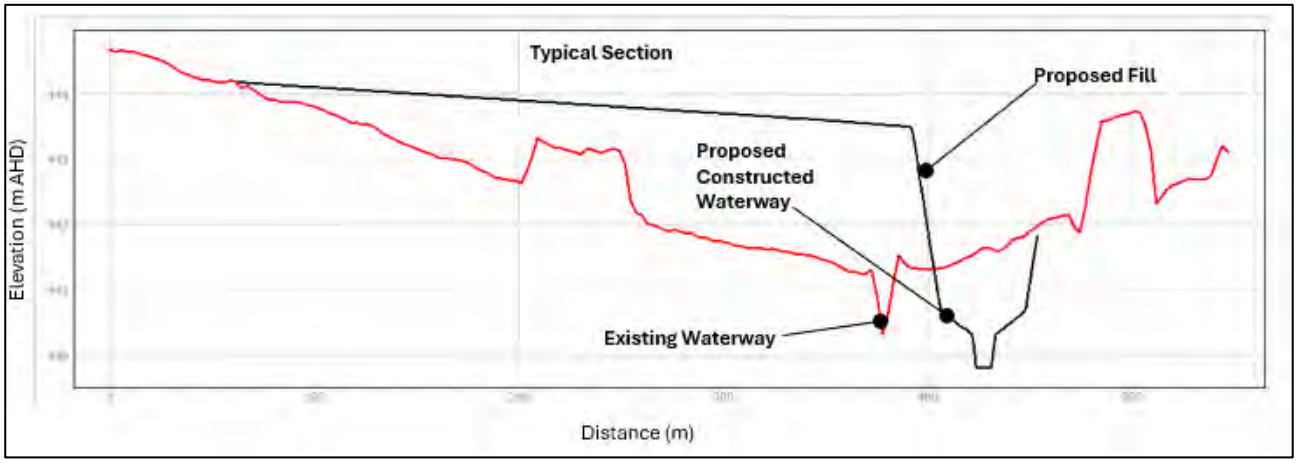


Figure 10-7 Typical waterway profile

The alignment of the waterway diversion is shown in Figure 10-8. It is noted that the waterway diversion begins at Midland Hwy and is proposed to extend into the confluence of Burrumbeet Creek. The western side of the Creek is expected to be filled to meet the freeboard requirements. The fill levels and freeboard requirement are subject to the detailed design and further consultation with GHCMA. SMEC has adopted that if 600mm freeboard is

required then this will need to be achieved by filling of the adjacent land rather than deepening or widening of the channel as the invert levels of the waterway are fixed on the upstream and downstream points.

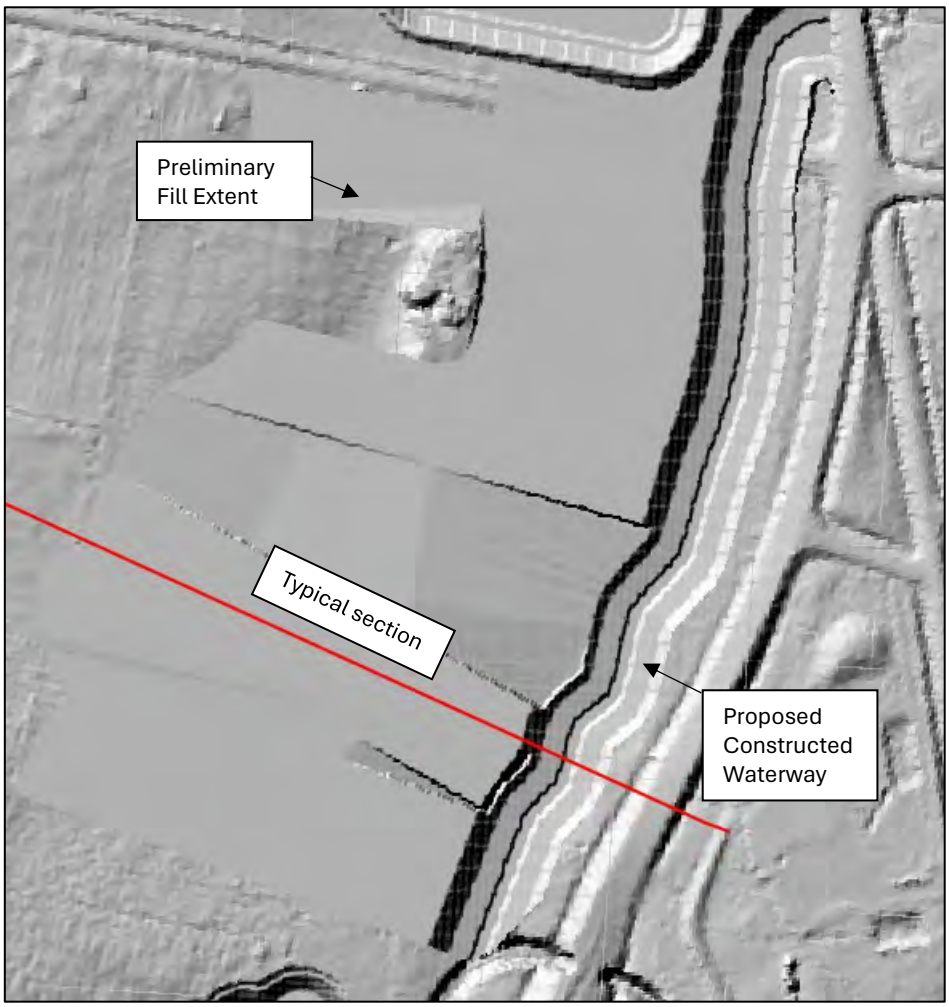


Figure 10-8 Alignment of the waterway diversion

10.2.2 Wetland and RB Design

The design surface of the retarding basins and outlet pipes have been incorporated into the developed conditions model. The locations of the proposed assets are within the existing conditions flood extent which would result in loss of flood storage and impede flow paths. The aim of the hydraulic modelling is to ensure that afflux caused by the retarding basin positions is minimised as much as possible and limited to the PSP boundary.

10.2.3 Inflow Conditions

The developed conditions model was simulated with the inflow locations representing the inflow hydrographs at each of the retarding basins. This is in addition to the external and adjacent subarea flows into Burrumbeet Creek. Figure 10-9 shows the inflow locations matching the developed conditions RORB model.

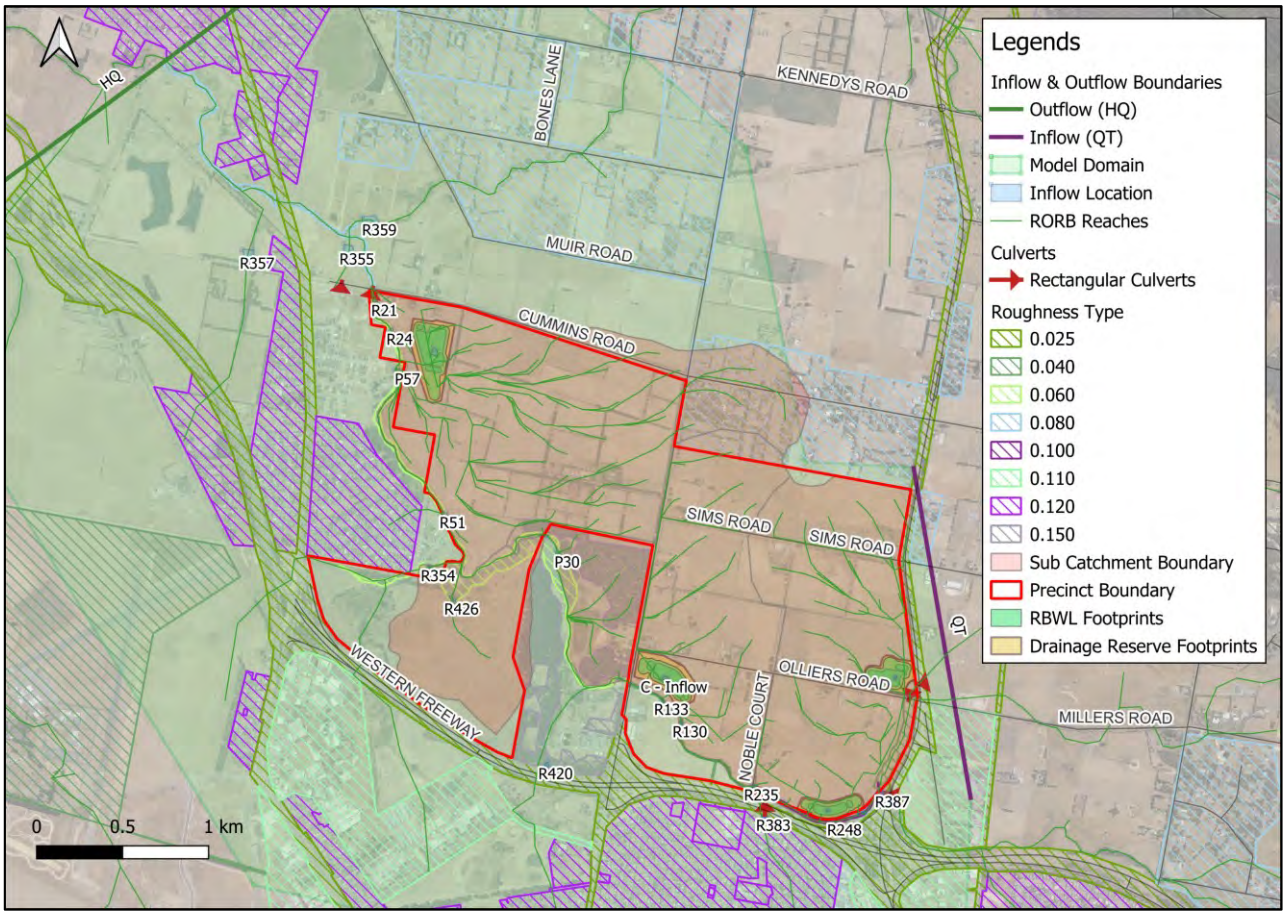


Figure 10-9 TUFLOW model inflow locations - developed conditions

10.2.4 Results

The results of the same storm events modelled in the existing conditions were combined to create the maximum flood extent. The 1% AEP flood extent of the developed conditions scenarios are provided in Figure 10-10 and Appendix F.

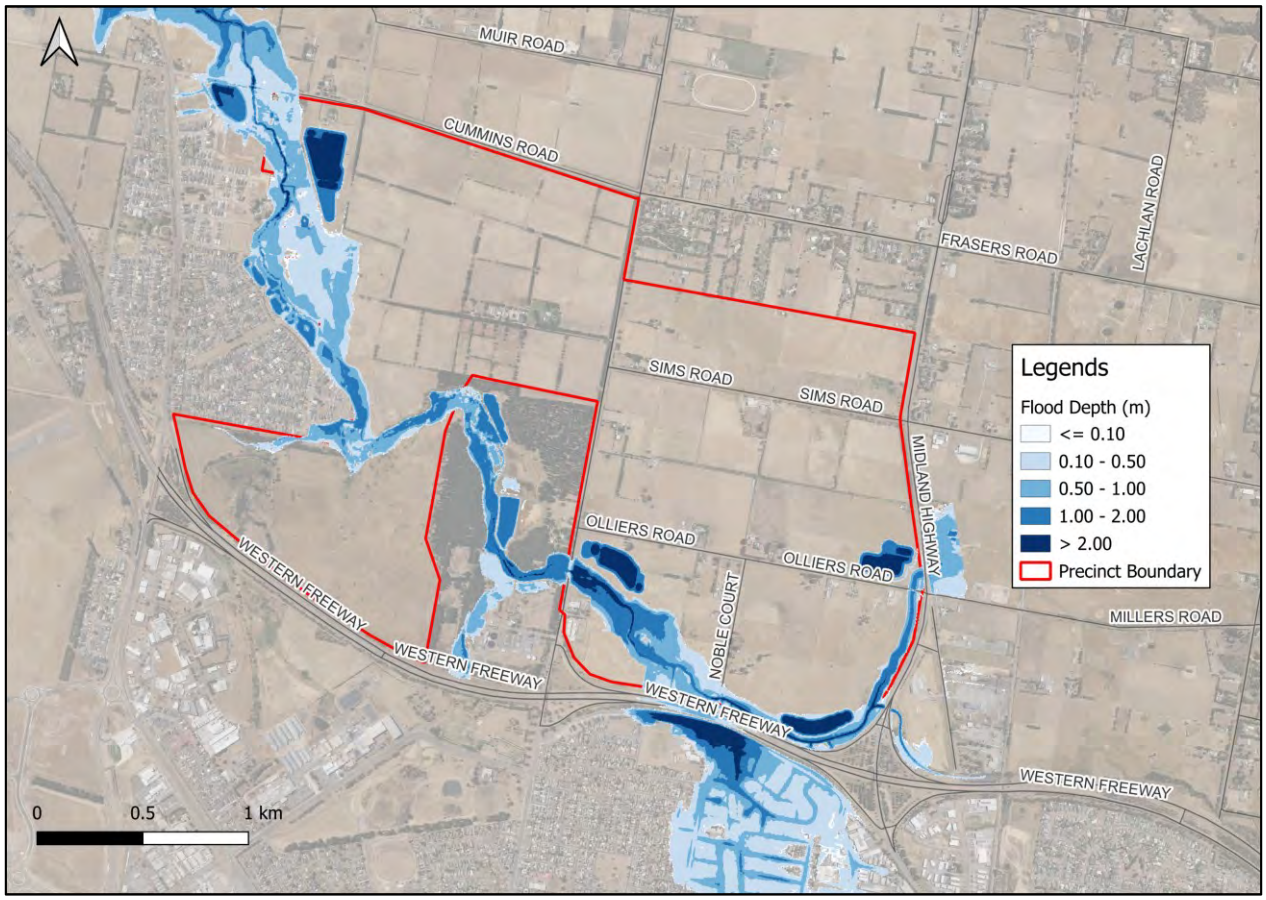


Figure 10-10 Developed condition flood impact assessment – 1% AEP

10.2.5 Impacts Assessment Result

The difference in flood levels were compared between the existing and developed conditions which is presented in an afflux map. The results are provided in Figure 10-11 and Appendix F.

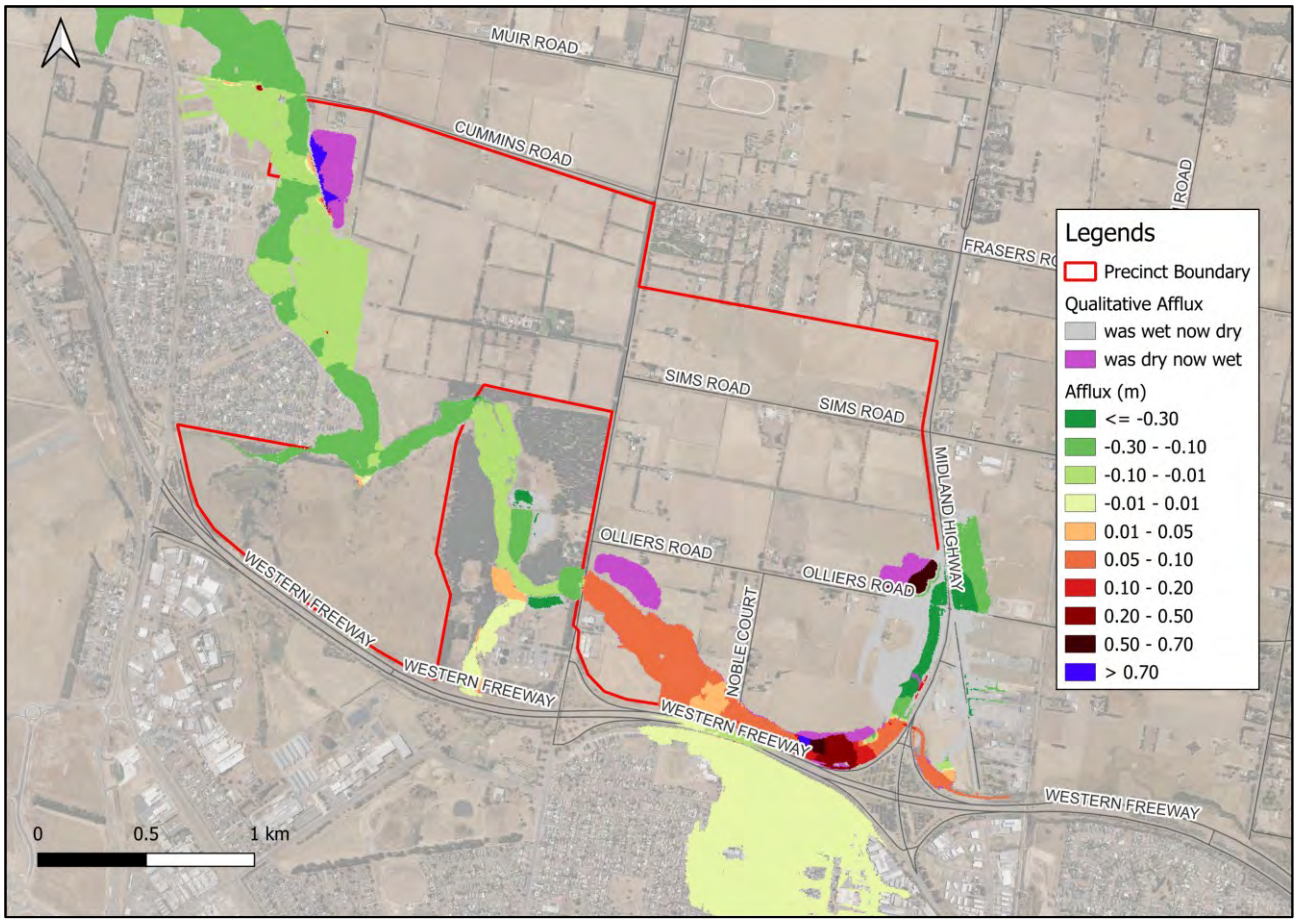


Figure 10-11 Flood impact assessment - Afflux

The afflux map shows the developed conditions flood level within Burrumbeet Creek is generally lower by up to 300mm on the downstream section from Gillies Road. Upstream of this point, the model suggests an increase of approximately 50mm and increasing to 500mm towards upstream along Burrumbeet Creek. The increase in flood level is likely due to the flood storage loss and flow conveyance reduction caused by the retarding basins C and SES and the flood conveyance improvement as a result of the waterway realignment upstream. A small area of localised increase in flood levels around the proposed retarding basin NWN is also evident. The positive affluxes are generally contained within the PSP boundary.

The assessment also indicates minor afflux, approximately 50mm, upstream of the confluence along Burrumbeet Creek waterway and outside of the PSP boundary. The minor afflux is likely due to the back water effects at the confluence of the proposed waterway and Burrumbeet Creek which should be resolved in detailed design phase with GHCMA.

The outcomes demonstrates there is no worsening of flood conditions in the 1% AEP with climate change as a result of the PSP development. The results provide evidence that the provisions of flood mitigation measures (retarding basins, waterway realignment and specified culvert crossings) can appropriately mitigate the impacts of the increased peak runoff from the PSP development.

11. Conclusion

This phase of the project involves the functional design of proposed assets, including constructed waterway, outfall drains, major culverts, wetlands and retarding basins. A 3D modelling exercise has been undertaken to validate and refine the proposed wetlands/retarding basins in the functional design, ultimately informing costs estimates for inclusion in the Development Contributions Plan.

The proposed drainage infrastructure including waterway, culverts and drainage network has also been developed and assessed using hydraulic modelling, demonstrating that the adopted design achieves the required performance objectives. Accordingly, the functional design provides a suitable basis for implementation of the drainage infrastructure within the precinct.

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Appendix A

Hydrology

A-1 RORB Modelling

A-1-1 General

In order to mitigate the impacts of increased runoff from the development, an existing condition design flow estimate is required to set the base case hydrology for the Ballarat North PSP area. As there are no local flow gauges near the site, there are uncertainties in the existing peak runoff that would be expected from the site. The nearest flow gauge available is located 21 km downstream from the PSP area at Bo Peep Gauge near Lake Burrumbeet.

In the absence of local data, the procedures set out in Australian Rainfall & Runoff (AR&R) guidelines (AR&R, 2019) have been adopted to quantify a target peak flow. Water Technology (2013) describes the flood study for the larger Burrumbeet Creek catchment and has been considered in setting the model parameters. The 2013 flood study is comprehensive and includes hydrologic and hydraulic calibration to actual flood events. The snippet of the Water Technology (2013) existing conditions hydrologic model (RORB) model setup is illustrated in Figure A-1-1 below. This model was adapted as a reference to represent the PSP area at a smaller scale.

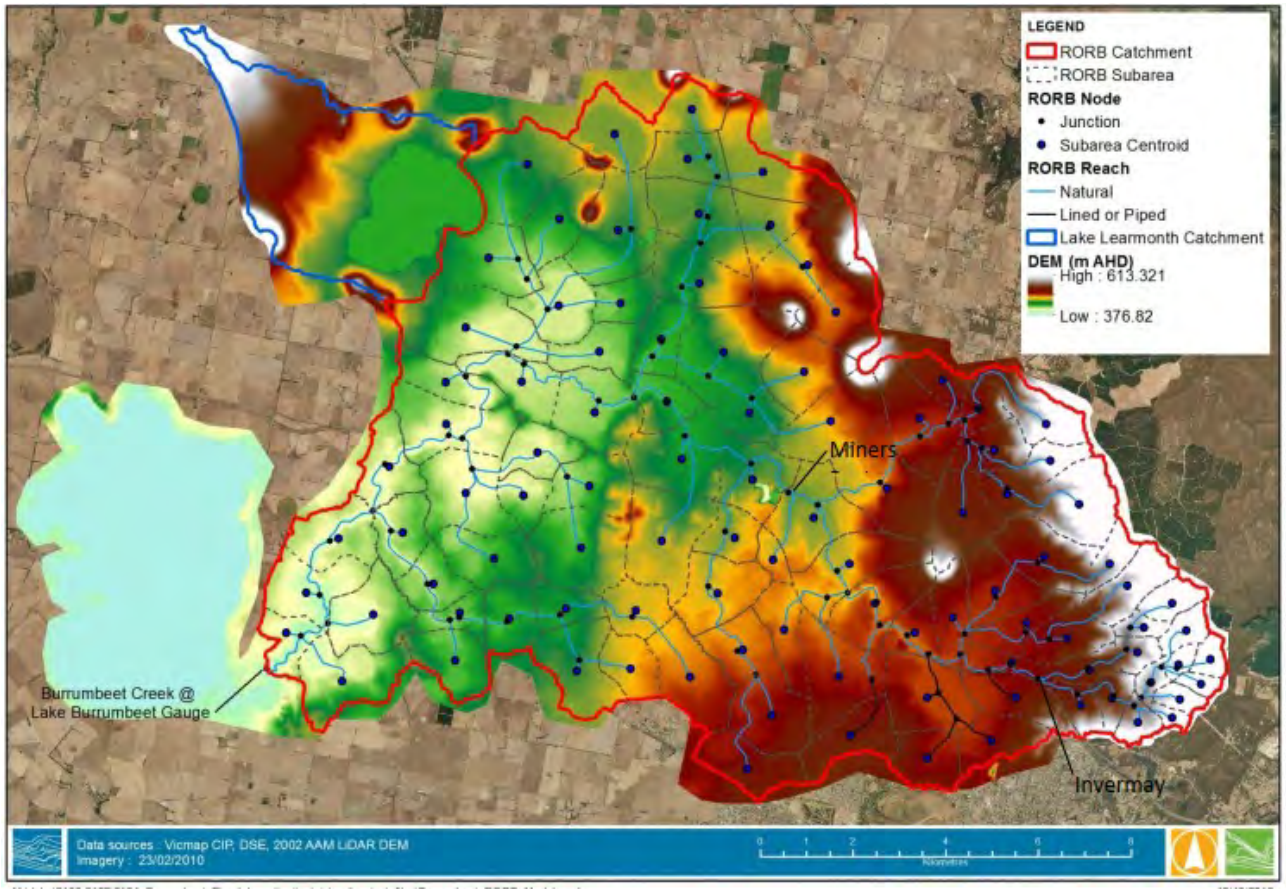


Figure A-1-1 Water Technology RORB model setup (Water Technology, 2013)

A-1-2 Existing Condition

The runoff-routing model, RORB (Version 6.45) was used to determine the magnitude of design flows in accordance with the latest version of AR&R (AR&R, 2019). The larger model created by Water Technology (2013) was subdivided to smaller subareas representing the Ballarat North PSP area at a scale appropriate for the PSP. The PSP area has been subdivided into subareas SE, C, and NW. The graphical representation of the modified existing condition RORB model setup is shown in Figure A-1-2.

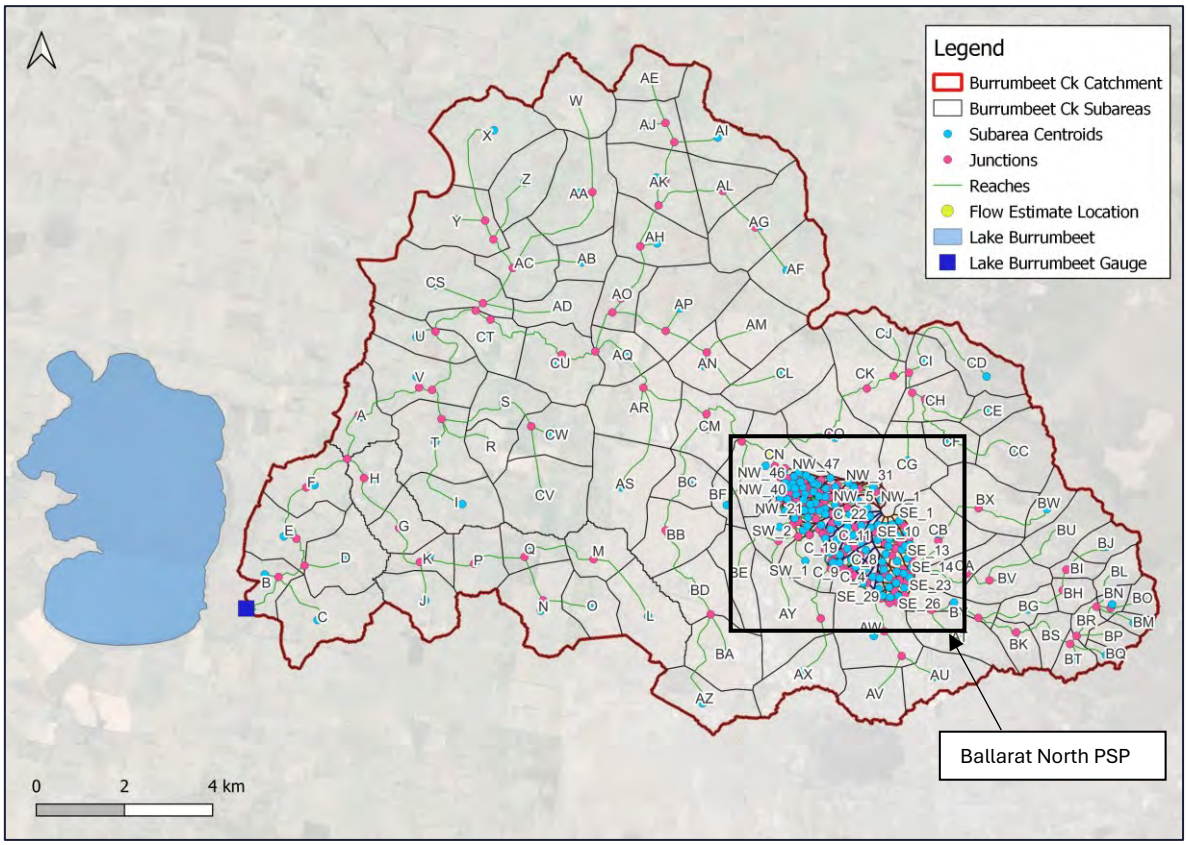


Figure A-1-2 Existing condition RORB model setup

The magnified view of the Ballarat North PSP is shown in Figure A-1-3.

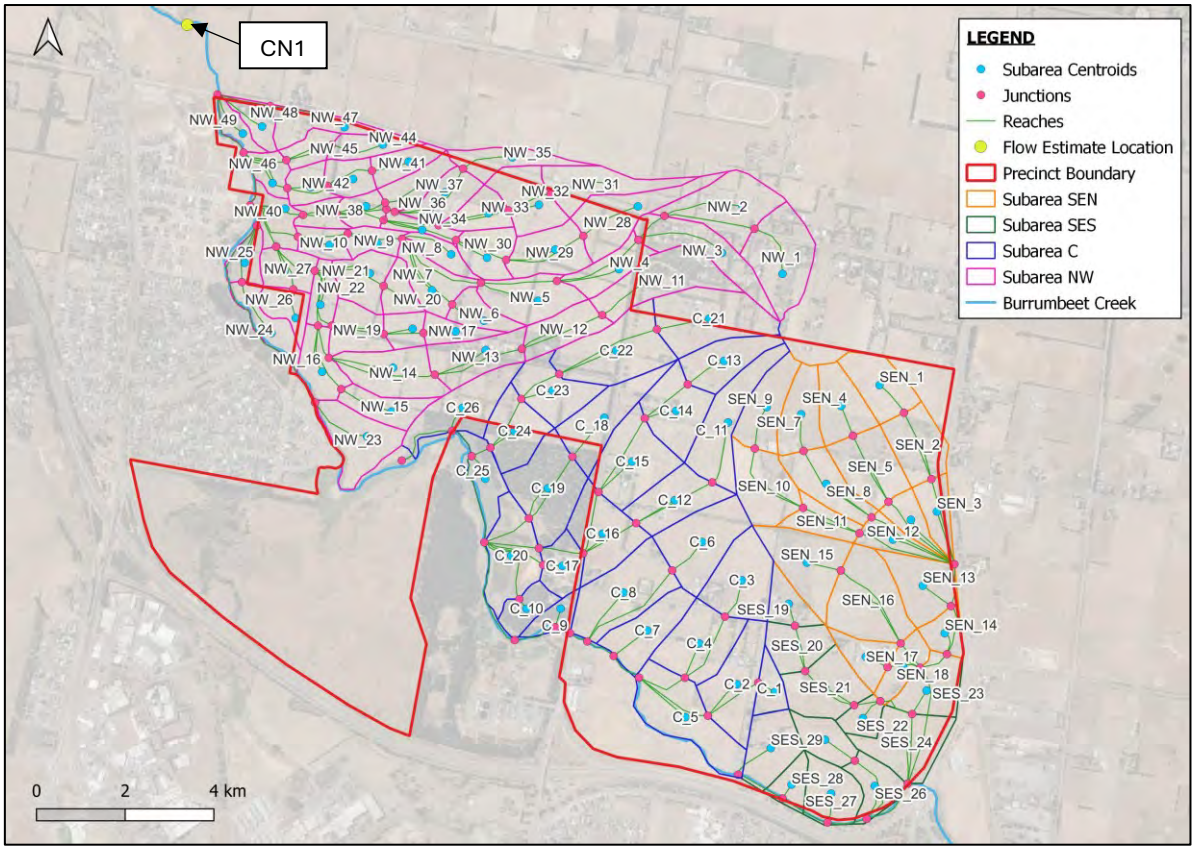


Figure A-1-3 Ballarat North PSP existing condition RORB model setup in QGIS

The sub catchment characteristics within the Ballarat North PSP area for the existing condition are presented in Table A-1-1 below.

Table A-1-1 Existing condition Ballarat North PSP sub catchment characteristics

Sub catchment	Sub catchment Area	Fraction Imperviousness
SEN	1.0 km^2	10%
SES	0.5 km^2	10%
C	1.9 km^2	10%
NW	2.1 km^2	10%

A-1-3 Model Parameter Calibration

Design Rainfall Depth

Rainfall depths were obtained from the Australian Bureau of Meteorology (BoM) 2016 Rainfall IFD Data System. Areal reduction factors, and temporal patterns were adopted from the ARR Datahub. Given that the combined RORB model exceeds 75 km^2, areal temporal patterns must be applied. However, areal temporal patterns for durations less than 9 hours were not available, and thus temporal patterns have been applied for durations up to and including 9 hours with areal temporal patterns have been applied for duration of 12 hours and above.

Pre-burst rainfalls have been applied using the in-built functionality of RORB. Median pre-burst data downloaded from the ARR 2016 Datahub was read into RORB and applied in a single increment prior to the design storm.

Delay Parameter (k_c)

Due to the modification of the model setup which results in smaller subareas for the three sub catchments, it is required to adjust the delay parameter (k_c) to ensure the delay response is consistent with the larger catchment model. Four interstations (outlets of the catchments) were included to allow the adjustment of the k_c parameter to match the existing conditions outcome of the Water Technology (2013) flood study. Once this has been achieved, this model would be used as the base case model.

To determine an appropriate k_c value for the PSP area, k_c/d_{ave} for the larger Burrumbeet Creek RORB model was calculated and k_c values for each of the subareas NW, C, and SE within the Ballarat North PSP were estimated based on the known d_{ave} values. The following k_c values were adopted as presented in Table A-1-2.

Table A-1-2 Adopted k_c values

Catchment	Average Flow Distance (d_{ave})	Delay Parameter (k_c)
SEN	0.97 km	2.28
SES	0.47 km	1.10
C	0.61 km	1.43
NW	1.19 km	2.80
Burrumbeet Ck Outlet	19.60 km	46.00

Loss Parameter

The initial loss (IL) of 1 mm and continuing loss (CL) of 3.7 mm/hr were adopted from Water Technology (2013) and verified at the downstream node of the Ballarat North PSP to provide a similar flow as to Burrumbeet Creek existing conditions peak flow. Water Technology has adopted a variable initial loss factor for various storm durations. The loss values are based on (Hill et al, 1998) Loss parameters adopted for RORB modelling is presented in Table A-1-3. 'm' value is also assumed to be 0.8.

Table A-1-3 Loss parameters

Parameter	Duration	Value
IL (mm)	10 min	1.9
	15 min	2.3
	20 min	2.6
	25 min	2.9
	30 min	3.1
	45 min	3.7
	1 hour	4.2
	1.5 hours	4.9
	2 hours	5.5
	3 hours	6.4
	4.5 hours	7.5
	6 hours	8.2
	9 hours	9.4
	12 hours	10.2
	18 hours	11.5
	24 hours	12.4
	30 hours	13.1
	36 hours	13.7
	48 hours	14.5
	72 hours	15.7
CL (mm/hr)		3.7

A-1-4 Outcomes

Critical durations were determined using ensemble analysis for the different storm events. The temporal patterns that generate the closest peak flow to the median of all temporal patterns were adopted as the critical temporal pattern.

The RORB modelling results for the 10% AEP and 1% AEP storm events for the existing condition are outlined in Table A-1-4 and Table A-1-5. The validation point was selected to be at CN1 just downstream of the PSP boundary as shown in Figure A-1-3. Utilising the Water Technology (2013) loss parameters with the adjusted k_c values for each of the sub catchments within the PSP area provides a similar peak flow for the combined model.

Table A-1-4 Existing condition 10% AEP flow estimates

Flow Estimate Location	Peak Flow	Critical Duration
SEN	1.0 m^3/s	2.0 hr
SES	1.3 m^3/s	1.5 hr
CS	3.4 m^3/s	1.5 hr
NWN	1.8 m^3/s	2.0 hr
PSP Outlet (CN1)	24.4 m^3/s	6.0 hr

Table A-1-5 Existing condition 1% AEP flow estimates

Flow Estimate Location	Peak Flow	Critical Duration
SEN	2.3 m^3/s	3.0 hr
SES	2.6 m^3/s	45 min
CS	6.8 m^3/s	1.5 hr
NWN	4.0 m^3/s	3.0 hr
PSP Outlet (CN1)	58.2 m^3/s	9.0 hr

A-1-5 Comparison to Regional Flood Estimates

A summary of the Regional Flood Frequency Estimation (RFFE) results are provided in Table A-1-6. A comparison between the modelled 1% AEP flows and RFFE estimates indicates generally good agreement across the SEN, SES and C sub-catchments, with modelled flows within approximately ±25% of the RFFE expected values.

For the NW sub-catchment the modelled flow (4.0 m^3/s) is notably lower than the RFFE expected flow (6.6 m^3/s). However, the modelled flow remains within the RFFE confidence interval, indicating that the result is still within the range of regional hydrological uncertainty. The discrepancy at NWN flow estimate location may reflect local catchment characteristics not fully captured by regional methods.

Table A-1-6 Existing condition 1% AEP flow estimates comparison - Ballarat North PSP

Flow Estimate Location	RFFE Method		
	Expected Flow	5% CL Flow	95% CL Flow
SEN	3.1 m^3/s	1.0 m^3/s	10.3 m^3/s
SES	2.3 m^3/s	0.7 m^3/s	7.3 m^3/s
CS	6.0 m^3/s	1.9 m^3/s	19.3 m^3/s
NWN	6.6 m^3/s	2.1 m^3/s	21.3 m^3/s

A-1-6 Developed Condition

RORB model was setup using a plug-in for the Ballarat North PSP under developed conditions. Similar to the existing condition RORB model, this model was combined with the larger Burrumbeet CK RORB model provided by Water Technology (2013) and run for the 1% AEP storm event with the adjusted Kc values to determine the 1% AEP peak flow at the downstream node (CN1) of the Ballarat North PSP outlet. Details of sub catchment characteristics within the Ballarat North PSP area for the developed condition are presented in Table A-1-7.

Table A-1-7 Developed condition Ballarat North PSP sub catchment characteristics

Sub catchment	Sub catchment Area	Fraction Imperviousness
SEN	1.0 km^2	59%
SES	0.5 km^2	45%
C	1.7 km^2	41%
NW	2.3 km^2	48%

The updated place-based plan (PBP) was provided by DTP on 17/06/2026; however, SMEC believe that there are only minor alterations to the PBP which result in a minor impact to the flow estimates. These changes do not affect the sizing of the proposed WSUD assets and RB footprints. The changes on this version of the PBP are listed below:

- The passive open space north of Sims Road has been slightly reduced, resulting in a corresponding increase in the Net Developable Area (NDA).
- The seasonal herbaceous wetland has been slightly reshaped.
- The AOS adjacent to the NWN wetland has been slightly enlarged and shifted.
- The school site adjacent to the NWN wetland has been reduced in size, with the surrounding residential areas correspondingly increased.
- Minor adjustments to the AOS boundaries around the Noble/Gillies intersection.

It must be noted that the previous PBP layout plan supplied by DTP on 23/06/2025 has been used to estimate the overall fraction imperviousness for each of the sub catchments. Figure A-1-4 below shows the fraction imperviousness map for the PSP area.

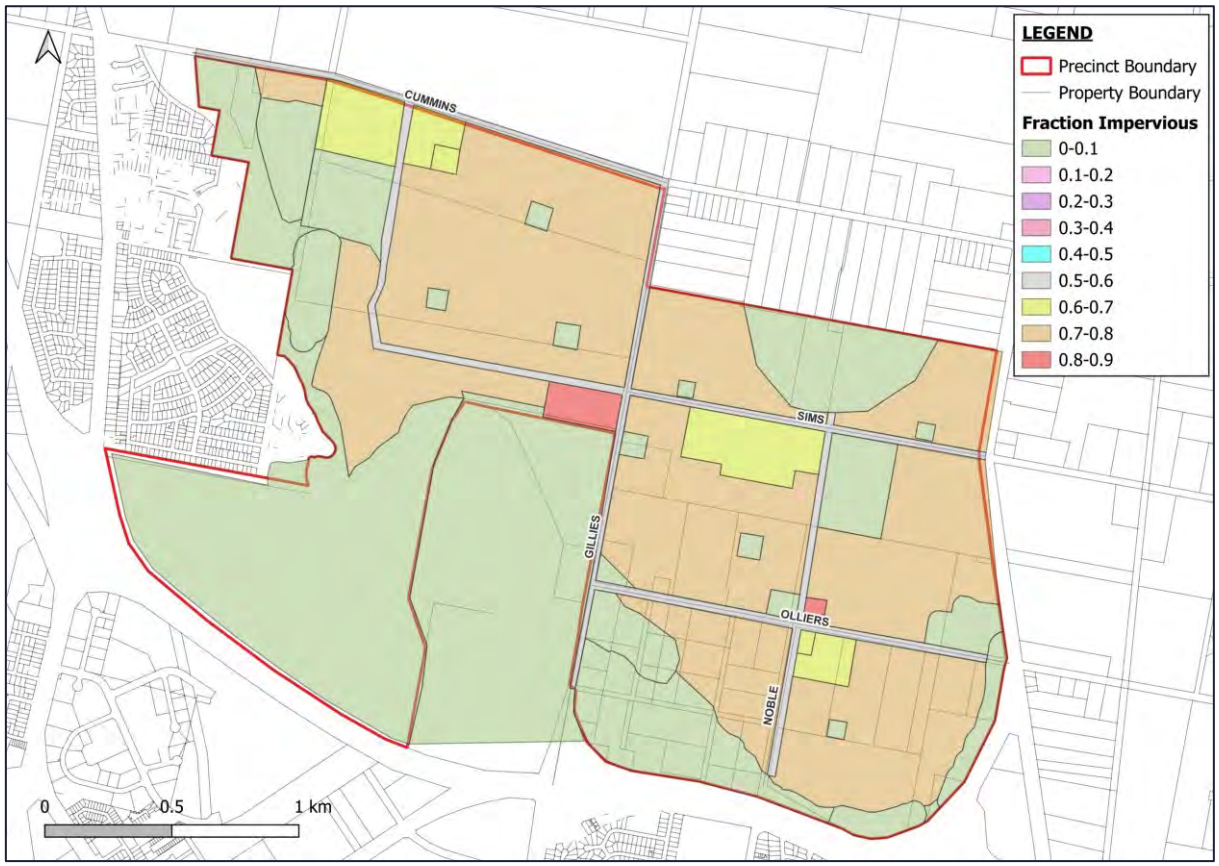


Figure A-1-4 Ballarat North PSP fraction impervious map based on PBP 23/06/2025

Figure A-1-5 shows the snippet of the developed condition RORB model. RORB catg and par files for the developed condition are provided in conjunction with this report.

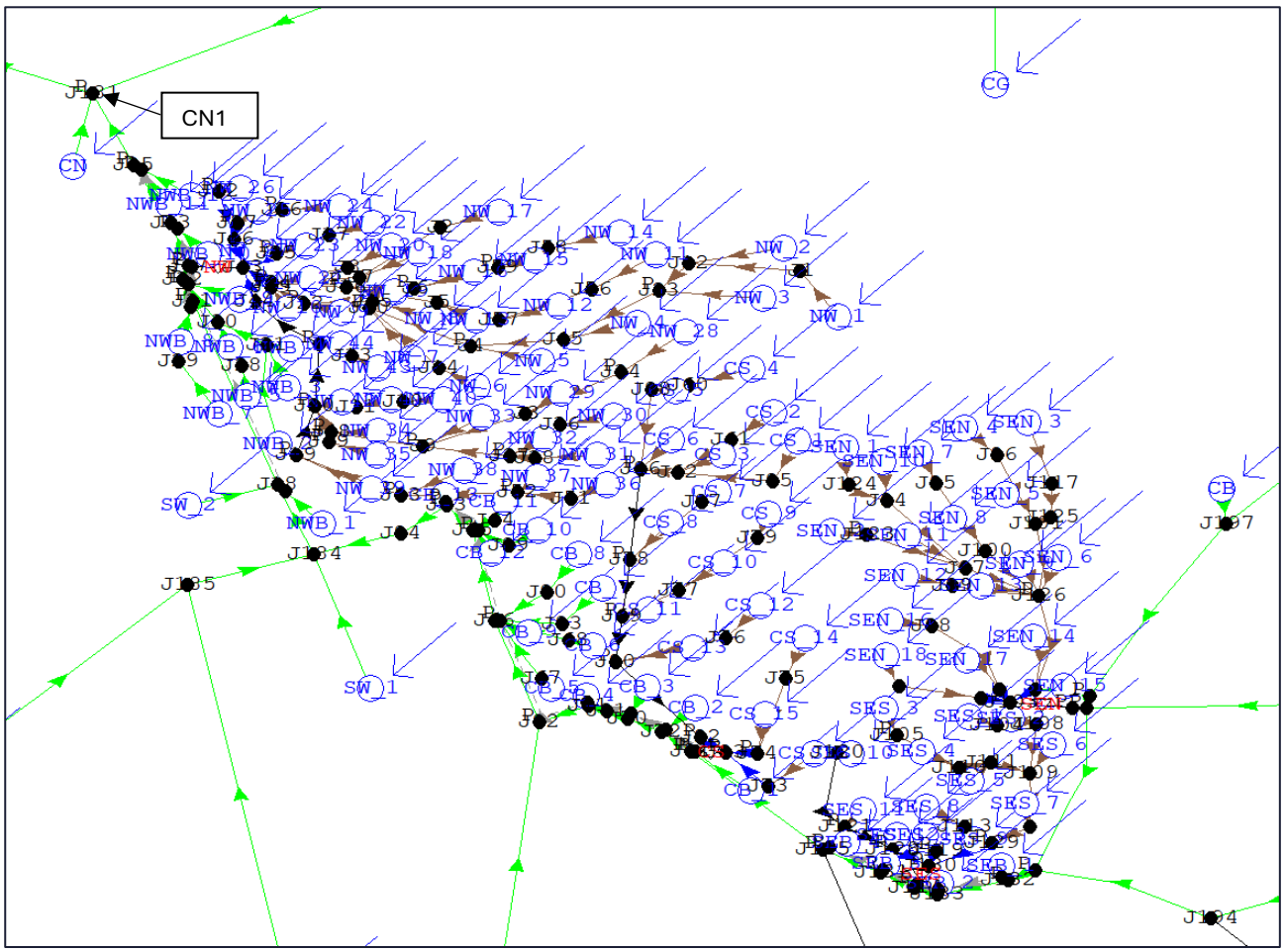


Figure A-1-5 Developed condition RORB model setup – Ballarat North PSP

The developed condition RORB modelling results at the downstream node (CN1) of the Ballarat North PSP for the 10% AEP and 1% AEP events are outlined in Table A-1-8.

Table A-1-8 Developed condition flow estimates at PSP outlet (CN1)

Flow Estimate Location	10% AEP Peak Flow	Critical Duration	1% AEP Peak Flow	Critical Duration
PSP Outlet (CN1)	23.8 m^3/s	6.0 hrs	57.1 m^3/s	9.0 hrs

A-1-7 Retarding Basin Sizing

Multiple retarding basins for the subareas SEN, SES, C, and NW have been designed for future climate SSP 2-4.5 to retard developed flows back to the existing flows under the 1% AEP storm event (see Figure A-1-6).

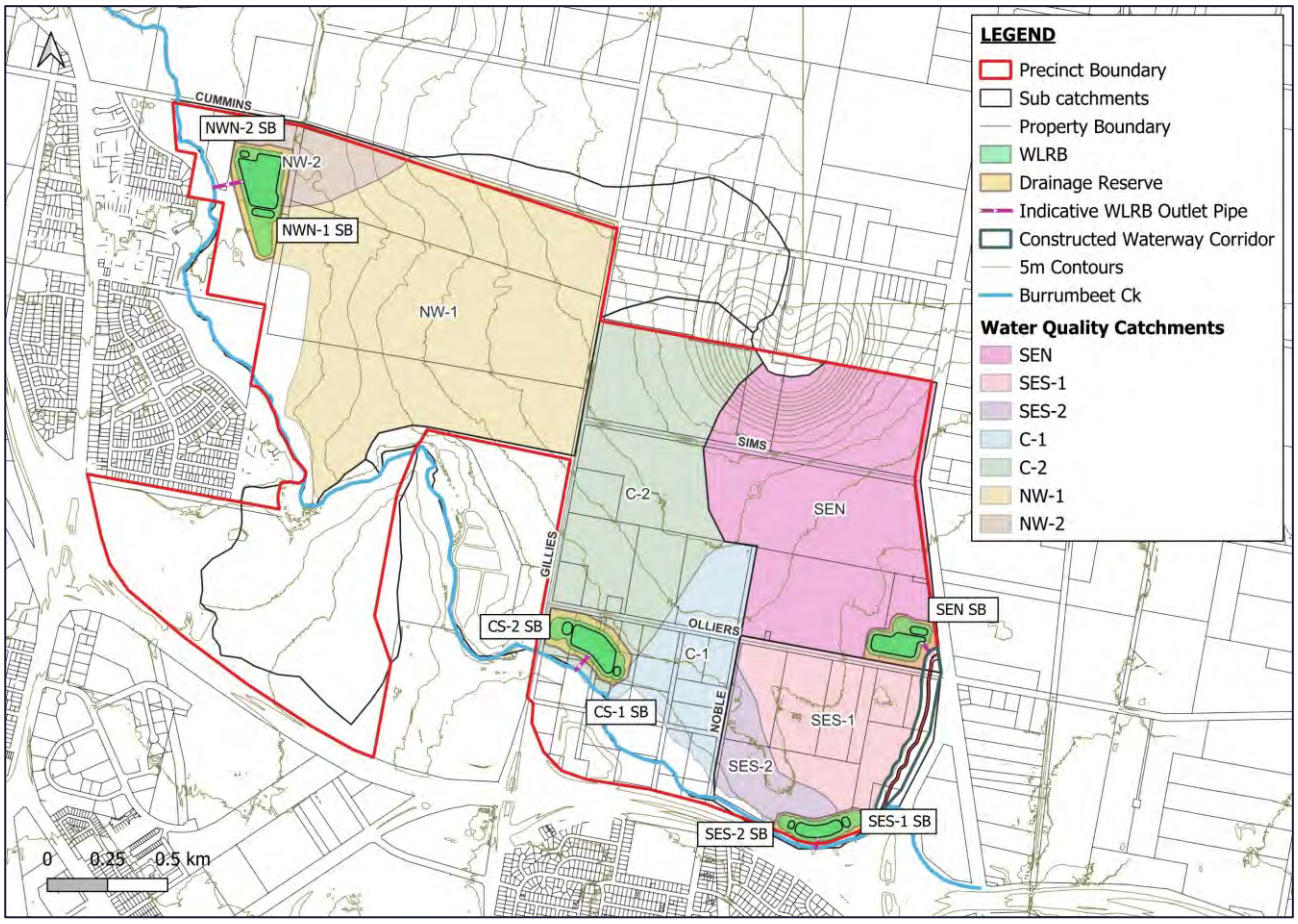


Figure A-1-6 Layout of the retarding basins

Summary of retarding basin levels and storage volumes is presented in Table A-1-9.

Table A-1-9 1% AEP retarding basins' levels and storage volumes

RB Name	1% AEP Flood Level	Spillway Level	Storage
SEN	443.00 m AHD	443.30 m AHD	33,500 m^3
SES	439.93 m AHD	440.50 m AHD	19,700 m^3
CS	439.32 m AHD	439.70 m AHD	39,100 m^3
NWN	425.32 m AHD	425.50 m AHD	71,000 m^3

A-1-8 RORB Results

10% AEP Design Flows

The RORB model 10% AEP flow estimates downstream of the retarding basins are presented in Table A-1-10 and compared with those of existing condition.

Table A-1-10 10% AEP flow estimates comparison

Flow Estimate Location	Existing 10% AEP Flow & Critical Duration	Developed 10% AEP Flow & Critical Duration
SEN	1.0 m^3/s (2.0 hr)	0.8 m^3/s (9.0 hr)
SES	1.3 m^3/s (1.5 hr)	0.3 m^3/s (9.0 hr)
CS	3.4 m^3/s (1.5 hr)	0.8 m^3/s (9.0 hr)
NWN	1.8 m^3/s (2.0 hr)	1.1 m^3/s (9.0 hr)
PSP Outlet (CN1)	24.4 m^3/s (6.0 hr)	23.8 m^3/s (6.0 hr)

1% AEP Design Flows

The RORB model 1% AEP flow estimates downstream of the retarding basins are presented in Table A-1-11 and compared with those of existing condition.

Table A-1-11 1% AEP flow estimates comparison

Flow Estimate Location	Existing 1% AEP Flow & Critical Duration	Developed 1% AEP Flow & Critical Duration
SEN	2.3 m^3/s (3.0 hr)	1.5 m^3/s (12.0 hr)
SES	2.6 m^3/s (45 min)	0.6 m^3/s (9.0 hr)
CS	6.8 m^3/s (1.5 hr)	1.5 m^3/s (9.0 hr)
NWN	4.0 m^3/s (3.0 hr)	2.1 m^3/s (9.0 hr)
PSP Outlet (CN1)	58.2 m^3/s (9.0 hr)	57.1 m^3/s (9.0 hr)

A-1-9 Climate Change Design Basis (SSP 2-4.5 , Year 2100)

The design of the drainage system and retarding basins has been undertaken considering projected climate change conditions based on the SSP 2-4.5 scenario for the year 2100. Rainfall intensities were adjusted within the RORB model using climate change factors of 1.10 and 1.22 applied to the initial loss and continuing loss parameters, respectively.

The resulting 10% and 1% AEP flow estimates under climate change conditions for both existing and developed scenarios are presented in Table A-1-12 and Table A-1-13.

Table A-1-12 10% AEP flow estimates comparison with SSP 2-4.5

Flow Estimate Location	Existing 10% AEP Flow & Critical Duration	Developed 10% AEP Flow & Critical Duration
SEN	1.6 m^3/s (2.0 hr)	1.1 m^3/s (9.0 hr)
SES	2.0 m^3/s (45 min)	0.4 m^3/s (9.0 hr)
CS	5.2 m^3/s (1.0 hr)	1.0 m^3/s (9.0 hr)
NWN	2.8 m^3/s (1.5 hr)	1.5 m^3/s (9.0 hr)
PSP Outlet (CN1)	35.6 m^3/s (4.5 hr)	34.5 m^3/s (4.5 hr)

Table A-1-13 1% AEP flow estimates comparison with SSP 2-4.5

Flow Estimate Location	Existing 1% AEP Flow & Critical Duration	Developed 1% AEP Flow & Critical Duration
SEN	3.4 m^3/s (2.0 hr)	2.0 m^3/s (4.5 hr)
SES	3.9 m^3/s (45 min)	0.8 m^3/s (4.5 hr)
CS	10.1 m^3/s (1.0 hr)	2.0 m^3/s (4.5 hr)
NWN	5.8 m^3/s (2.0 hr)	3.2 m^3/s (4.5 hr)
PSP Outlet (CN1)	78.2 m^3/s (4.5 hr)	76.6 m^3/s (9.0 hr)

Table A-1-14 below presents the peak elevation, and the storage required for each of the retarding basins under 1% AEP storm event as opposed to the base design event.

Table A-1-14 1% AEP retarding basins' levels and storage volumes with SSP 2-4.5

RB Location	1% AEP Flood Level	Spillway Level	Storage
SEN	443.29 m AHD	443.30 m AHD	42,700 m^3
SES	440.12 m AHD	440.50 m AHD	24,300 m^3
CS	439.58 m AHD	439.70 m AHD	49,100 m^3
NWN	425.50 m AHD	425.50 m AHD	86,200 m^3

A-1-10 Climate Change Sensitivity Analysis (SSP 3-7.0, Year 2100)

The sensitivity of flood behaviour to projected Climate Change was tested for the SSP 3-7.0 for the year 2100. The increased rainfall intensity was simulated in the RORB model. The adjustment factors of 1.15 and 1.34 have been applied for the initial loss and continuous loss, respectively.

Table A-1-15 presents the peak elevation, and the storage required for each of the retarding basins under 1% AEP storm with climate change SSP 3-7.0 adoption.

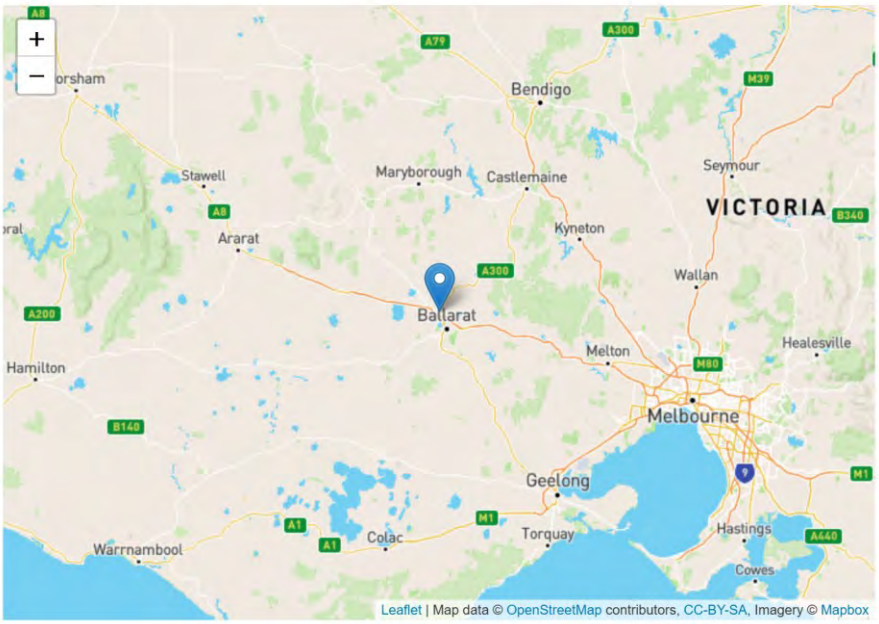
Table A-1-15 1% AEP retarding basins' levels and storage volumes with SSP 3-7.0

RB Location	1% AEP Flood Level	Spillway Level	Storage
SEN	443.42 m AHD	443.30 m AHD	46,900 m^3
SES	440.25 m AHD	440.50 m AHD	27,400 m^3
CS	439.73 m AHD	439.70 m AHD	54,800 m^3
NWN	425.71 m AHD	425.50 m AHD	94,000 m^3

A-2 Data Hub Climate Change Factors

Input Data

Longitude	143.828
Latitude	-37.506
Selected Regions (clear)	
Climate Change Factors	show



Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.05**	**1.05**	**1.05**	**1.05**
2040	1.05	1.06	1.06	1.07
2050	**1.06**	**1.07**	**1.07**	**1.08**
2060	1.06	1.07	1.09	1.1
2070	1.06	1.08	1.1	1.12
2080	1.06	1.09	1.12	1.14
2090	**1.06**	**1.09**	**1.13**	**1.17**
2100	1.06	1.1	1.15	1.19

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.1**	**1.1**	**1.1**	**1.11**
2040	1.12	1.12	1.13	1.14
2050	**1.12**	**1.15**	**1.16**	**1.18**
2060	1.13	1.17	1.19	1.23
2070	1.13	1.18	1.23	1.28
2080	1.13	1.2	1.27	1.33
2090	**1.13**	**1.21**	**1.31**	**1.39**
2100	1.12	1.22	1.34	1.44

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

Time Accessed	27 October 2024 11:03PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

Appendix B

Stormwater Quality

B-1 MUSIC Modelling

B-1-1 General

The minimum requirements urban stormwater quality treatment are outlined in EPA Publication 1739.1 – Urban Stormwater Management Guidance (EPA Victoria, 2021). The best practice water quality targets are detailed in Table B-1-1.

Table B-1-1 Best Practice water quality targets

Pollutant	% Target Reduction
Total Suspended Solids	80
Total Phosphorus	45
Total Nitrogen	45
Gross Pollutants	70

B-1-2 Proposed Works

SMEC has identified the following works for provision of stormwater quality treatment:

- Sediment basins to treat up to and including 4EY (3-month ARI) flows for each of the sub catchments.
- Wetlands to treat up to and including 4EY (3-month ARI) flows for each of the sub catchments.

B-1-3 MUSIC Model Setup

The proposed stormwater treatment devices to meet these objectives have been modelled using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) Version 6 and the Melbourne Water MUSIC Guidelines (Melbourne Water, 2023).

The MUSIC model requires the specification of subarea parameters, and meteorological data (rainfall and evaporation). The parameters for the MUSIC model were adopted in accordance with the Melbourne Water MUSIC Modelling Guidelines (2023).

Subarea Parameters

Suitable source nodes and effective impervious areas (EIA) were assigned to the land uses. EIA calculation is based on the PBP provided by DTP on 23/06/2025. A revised PBP was provided by DTP on 17/06/2026. A review of the updated PBP indicated that the changes are limited to minor refinements to the land use plan and do not affect the sizing of the proposed WSUD assets. Accordingly, the current MUSIC modelling has been undertaken based on the previous PBP dated 23/06/2025. Table B-1-2 provides a breakdown of the subareas and their %EIA adopted in the MUSIC model for the Ballarat North PSP area.

Table B-1-2 Subarea parameters

Subarea ID	Catchment Area	EIA
SEN	98 ha	55%
SES-1	38 ha	71%
SES-2	15 ha	56%
C-1	27 ha	71%
C-2	80 ha	61%
NW-1	139 ha	67%
NW-2	19 ha	47%

Climate Data

Rainfall data for the project area has been adopted from Bureau of Meteorology station 089002 (Ballarat). Key climate data parameters are summarised in Table B-1-3.

Table B-1-3 Meteorological data

Station Name – Ballarat	
Station ID	089002
Long Term Data Period	20/08/1954 – 31/07/1999
Number of Years	45 yr
Average Annual Rainfall	664 mm
Average Annual Evapotranspiration	1032 mm
Time Step	6 min

B-1-4 Proposed Treatment Train

A combined treatment train of the sediment basins and wetlands has been proposed for the PSP area to meet best practice water quality objectives.

To ensure consistency between the hydrologic and water quality analysis, the MUSIC model was schematised with the same subarea configuration as the RORB model. A layout of the MUSIC model for the developed condition is shown in Figure B-1-4. Treatment feature parameters are detailed in Section 8.2. The layouts of the water quality catchments is shown in Figure 8-1.

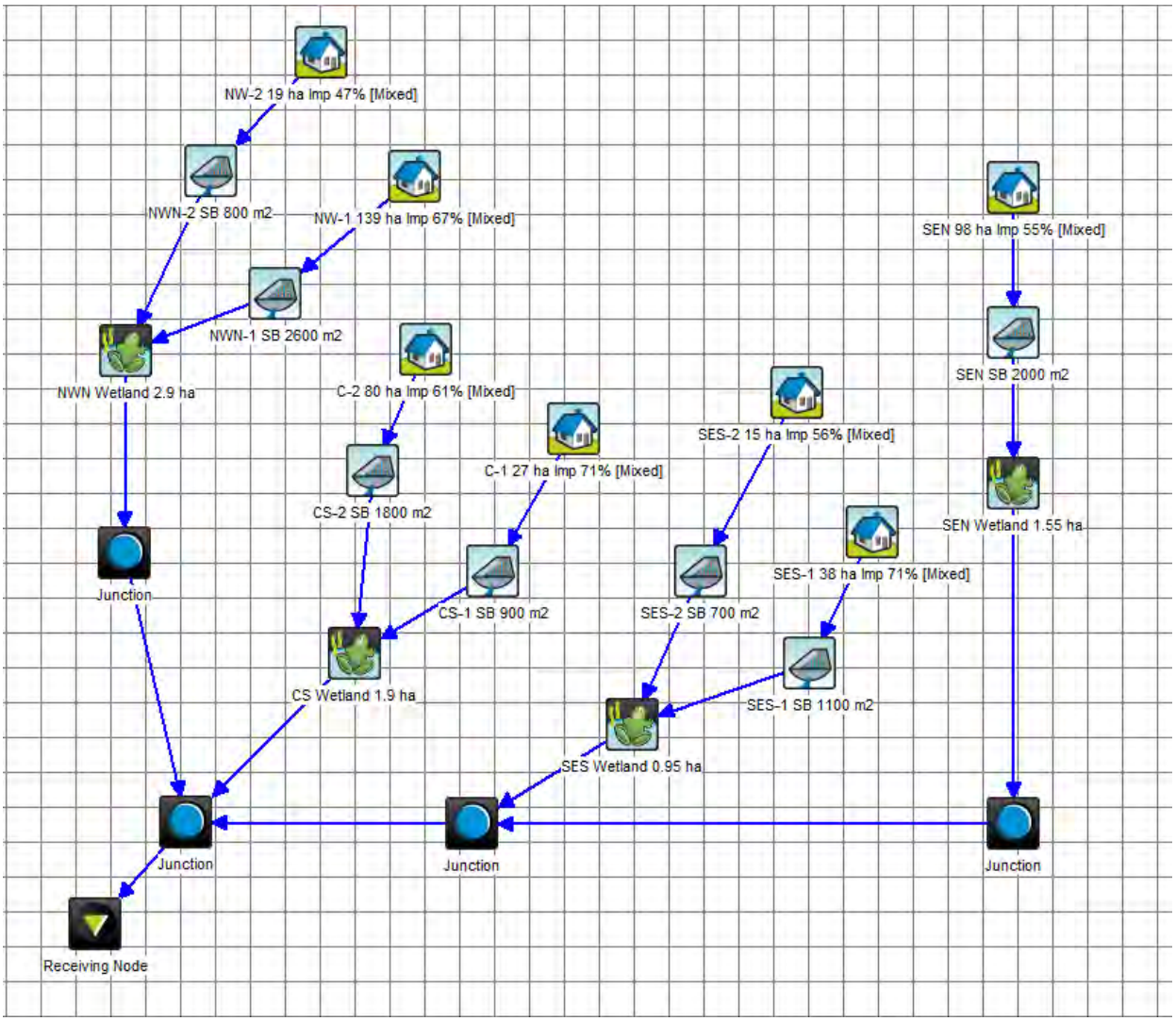


Figure B-1-4 MUSIC model schematic layout

B-1-5 Stage Storage Inputs

Custom stage-storage relationships have not been used for this version of the MUSIC modelling, as the detailed wetland bathymetry has not yet been developed. The wetland bathymetry, including the stage-storage relationship, will be finalised during the detailed design phase and subsequently incorporated into the MUSIC model to accurately represent storage volumes, pipe flows and weir flows.

B-1-6 Treatment Areas

Table B-1-4 below shows the sediment basins and wetlands treatment areas for each asset proposed within the PSP.

Table B-1-4 Sediment basins and wetland treatment areas

Parameter							
Sediment Basin Name	SEN	SES-1	SES-2	CS-1	CS-2	NWN-1	NWN-2
Surface Area at NWL (m^2)	2,015	1,120	710	920	1,800	2,620	810
Wetland Name	SEN		SES		CS		NWN
Surface Area at NWL (m^2)	15,520		9,570		19,300		29,600

B-1-7 Treatment Effectiveness

Tables below show the treatment train effectiveness for each WSUD asset.

Table B-1-5 SEN treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	60,600	11,000	81.9
Total Phosphorus (TP)	129	39.5	69.4
Total Nitrogen (TN)	947	518	45.3
Gross Pollutants	13,700	0	100

Table B-1-6 SES treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	39,400	6,350	83.9
Total Phosphorus (TP)	82.2	24	70.9
Total Nitrogen (TN)	592	319	46.1
Gross Pollutants	8,540	0	100

Table B-1-7 CS treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	76,100	12,400	83.8
Total Phosphorus (TP)	160	46.8	70.8
Total Nitrogen (TN)	1,160	628	45.7
Gross Pollutants	16,800	0	100

Table B-1-8 NWN treatment efficiency

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	113,000	19,600	82.6
Total Phosphorus (TP)	237	71	70.1
Total Nitrogen (TN)	1,720	932	45.8
Gross Pollutants	24,900	0	100

B-1-8 Overall Treatment Train Effectiveness (PSP-scale)

The removal efficiency of the proposed treatment trains within the PSP area is shown in Table B-1-9.

Table B-1-9 Reduction in pollutant loads

Pollutant	Source Loads (kg/yr)	Residual Loads (kg/yr)	% Reduction
Total Suspended Solids (TSS)	290,000	49,900	82.8
Total Phosphorus (TP)	610	182	70.1
Total Nitrogen (TN)	4,420	2,400	45.6
Gross Pollutants	64,100	0	100

B-2 Connection Sizing between Sediment Basins and Wetlands

SEN SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.42
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	600
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.28
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	0.50
Pit dimensions	
Pit length (m)	0.9
Pit width (m)	0.9
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.52
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.43
Check if connection between SB & MZ has minimum capacity to cnovey 4EY flow	
Qdes - design flow rate (m3/s)	0.43
Capacity check "Target ≥ 4EY flow"	OK

SES – 1 SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.38
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	525
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.22
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	0.39
Pit dimensions	
Pit length (m)	0.9
Pit width (m)	0.9
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.52
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.43
Check if connection between SB & MZ has minimum capacity to cnovey 4EY flow	
Qdes - design flow rate (m3/s)	0.39
Capacity check "Target ≥ 4EY flow"	OK

SES – 2 SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.21
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	450
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.16
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	0.28
Pit dimensions	
Pit length (m)	0.75
Pit width (m)	0.75
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.43
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.30
Check if connection between SB & MZ has minimum capacity to cnovey 4EY flow	
Qdes - design flow rate (m3/s)	0.28
Capacity check "Target ≥ 4EY flow"	OK

CS – 1 SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.45
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	600
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.28
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	0.50
Pit dimensions	
Pit length (m)	1.1
Pit width (m)	0.9
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.58
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.53
Check if connection between SB & MZ has minimum capacity to cnovey 4EY flow	
Qdes - design flow rate (m3/s)	0.50
Capacity check "Target ≥ 4EY flow"	OK

CS – 2 SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.75
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	750
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.44
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	0.79
Pit dimensions	
Pit length (m)	1.35
Pit width (m)	1.35
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.78
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.97
Check if connection between SB & MZ has minimum capacity to cnovey 4EY flow	
Qdes - design flow rate (m3/s)	0.78
Capacity check "Target ≥ 4EY flow"	OK

NWN– 1 SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.96
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	900
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.64
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	1.13
Pit dimensions	
Pit length (m)	1.75
Pit width (m)	1.6
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.97
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	1.49
Check if connection between SB & MZ has minimum capacity to cnovey 4EY flow	
Qdes - design flow rate (m3/s)	0.97
Capacity check "Target ≥ 4EY flow"	OK

NWN– 2 SB

Sizing connection between SB and MZ	
4EY flow (m3/s)	0.25
Pipe number and diamater	
Number of pipes	1
Pipe diameter (mm)	450
Flow rate controlled by pipe (flowing full)	
Cp - pipe discharge coefficient	0.60
H - head level difference between NWLs at SB and MZ (m)	0.10
h - head level driving flow through the pipe (m) given that SB is at TEDD and MZ at NWL	0.45
A - pipe cross section area (m2)	0.16
V - pipe flow velocity (m/s)	2.97
Q - pipe capacity (m3/s)	0.28
Pit dimensions	
Pit length (m)	0.75
Pit width (m)	0.75
Flow rate controlled by pit acting as a weir	
B - blockage factor	0.50
C_w - weir coefficient	1.40
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.43
Flow rate controlled by pit acting as an orifice	
B - blockage factor	0.50
e- portion of pit area not taken up by bars	0.90
Cd - orifice discharge coefficient	0.45
h - height of water above the crest of the outlet pit (m)	0.35
Q - pit capacity (m3/s)	0.30
Check if connection between SB & MZ has minimum capacity to convey 4EY flow	
Qdes - design flow rate (m3/s)	0.28
Capacity check "Target ≥ 4EY flow"	OK

B-3 Inundation Frequency Analysis



Wetland Analysis Tool

Welcome to the Wetland Analysis Tool for checking compliance with the Melbourne Water Constructed Wetland Manual. This tool assesses the wetland depths relative to plant heights and the wetland residence time and advises whether the Deemed to Comply requirements are satisfied.

Please enter the 'Shallow marsh zone planting depth' and 'Deep marsh zone plating depth'.

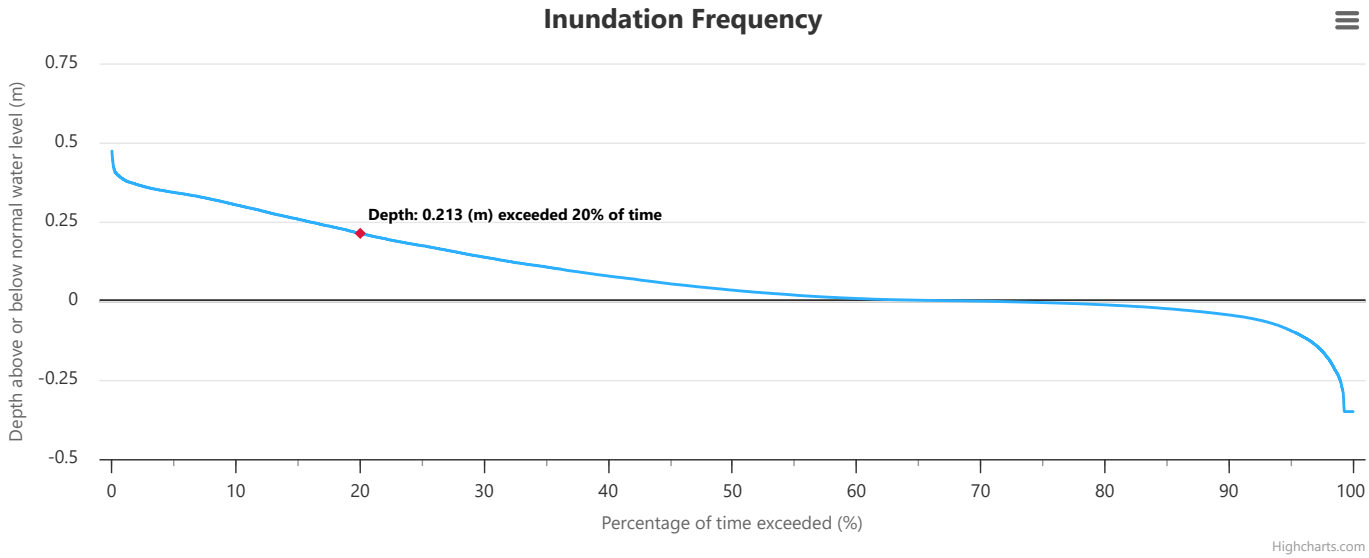
Shallow Planting Depth 0.15 m
Deep Planting Depth 0.35 m

Please enter the permanent pool volume.

Permanent Pool Volume 5425 m

Please select the daily flux file generated in MUSIC for a wetland.
The file must be generated with MUSIC Version 6 and be a DAILY flux file.

Choose File WL SEN_Flux.csv
FILE IS UPLOADED



Please select at least 3 plants for each of the shallow and deep marsh zones.

Clear Selection

Name	Average plant height (m)	Shallow marsh plants	Deep marsh plants	Suitability
Sea Club-rush *Bolboschoenus caldwellii*	1	☑		Shallow Only
Water Ribbons *Triglochin procerum*	1	☑	☐	

Jointed Club-rush *Baumea articulata*	1.8	☑	☑	
Tall Club-rush *Bolboschoenus fluviatilis*	1.8	☑	☑	
Marsh Club-rush *Bolboschoenus medianus*	1.5	☑	☑	Shallow and Deep
Leafy Twig-rush *Cladium procerum*	2	☑	☑	
River Club-rush *Schoenoplectus tabernaemontani*	1.8	☑	☑	
Tall Spike-rush *Eleocharis sphacelata*	1.5		☑	Deep Only
Common reed *Phragmites australis*	2.5		☑	
Common Spike-rush *Eleocharis acuta*	0.5	☐		Unsuitable

+ Add user defined plant

Report

File: WL SEN_Flux.csv
Shallow marsh zone meets deemed to comply criteria

Deep marsh zone meets deemed to comply criteria

Water level exceeded for 20% of time: 0.213 m

Water level exceeded for 50% of time: 0.0336 m
·Effective water level is within 50 mm of normal water level and is acceptable.

90th Percentile Residence Time: 3 days

☐ Spells Analysis?



Wetland Analysis Tool

Welcome to the Wetland Analysis Tool for checking compliance with the Melbourne Water Constructed Wetland Manual. This tool assesses the wetland depths relative to plant heights and the wetland residence time and advises whether the Deemed to Comply requirements are satisfied.

Please enter the 'Shallow marsh zone planting depth' and 'Deep marsh zone plating depth'.

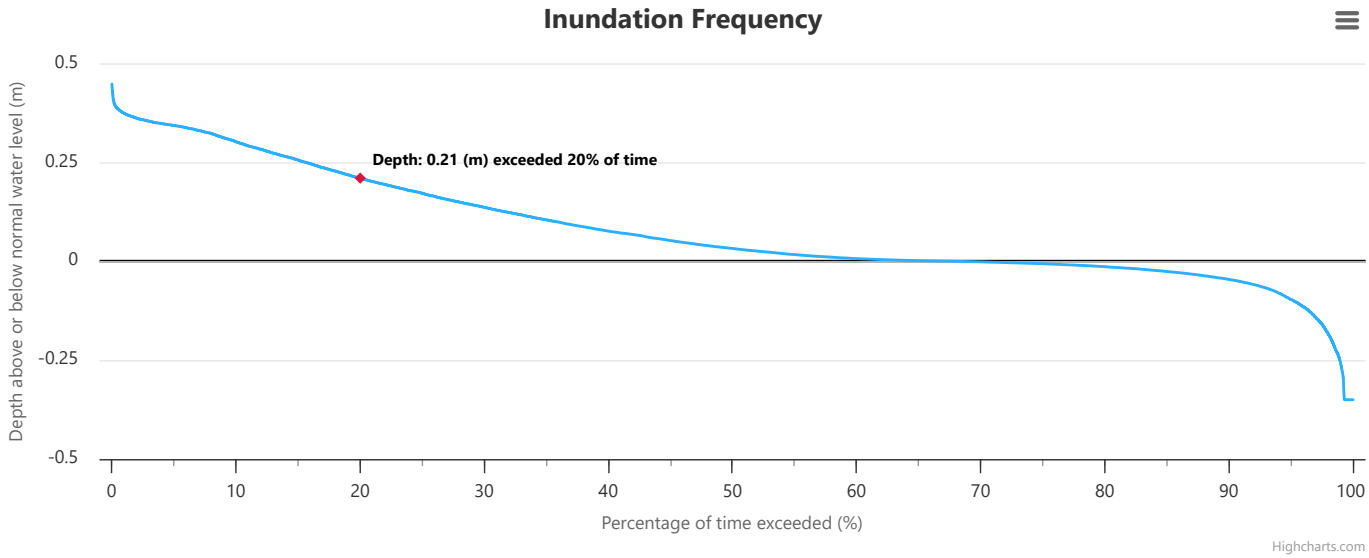
Shallow Planting Depth 0.15 m
Deep Planting Depth 0.35 m

Please enter the permanent pool volume.

Permanent Pool Volume 3325 m

Please select the daily flux file generated in MUSIC for a wetland.
The file must be generated with MUSIC Version 6 and be a DAILY flux file.

Choose File WL SES_Flux.csv
FILE IS UPLOADED



Please select at least 3 plants for each of the shallow and deep marsh zones.

Clear Selection

Name	Average plant height (m)	Shallow marsh plants	Deep marsh plants	Suitability
Sea Club-rush *Bolboschoenus caldwellii*	1	☑		Shallow Only
Water Ribbons *Triglochin procerum*	1	☑	☐	

Jointed Club-rush *Baumea articulata*	1.8	☑	☑	
Tall Club-rush *Bolboschoenus fluviatilis*	1.8	☑	☑	
Marsh Club-rush *Bolboschoenus medianus*	1.5	☑	☑	Shallow and Deep
Leafy Twig-rush *Cladium procerum*	2	☑	☑	
River Club-rush *Schoenoplectus tabernaemontani*	1.8	☑	☑	
Tall Spike-rush *Eleocharis sphacelata*	1.5		☑	Deep Only
Common reed *Phragmites australis*	2.5		☑	
Common Spike-rush *Eleocharis acuta*	0.5	☐		Unsuitable

+ Add user defined plant

Report

File: WL SES_Flux.csv
Shallow marsh zone meets deemed to comply criteria

Deep marsh zone meets deemed to comply criteria

Water level exceeded for 20% of time: 0.21 m

Water level exceeded for 50% of time: 0.03215 m
·Effective water level is within 50 mm of normal water level and is acceptable.

90th Percentile Residence Time: 3 days

☐ Spells Analysis?



Wetland Analysis Tool

Welcome to the Wetland Analysis Tool for checking compliance with the Melbourne Water Constructed Wetland Manual. This tool assesses the wetland depths relative to plant heights and the wetland residence time and advises whether the Deemed to Comply requirements are satisfied.

Please enter the 'Shallow marsh zone planting depth' and 'Deep marsh zone plating depth'.

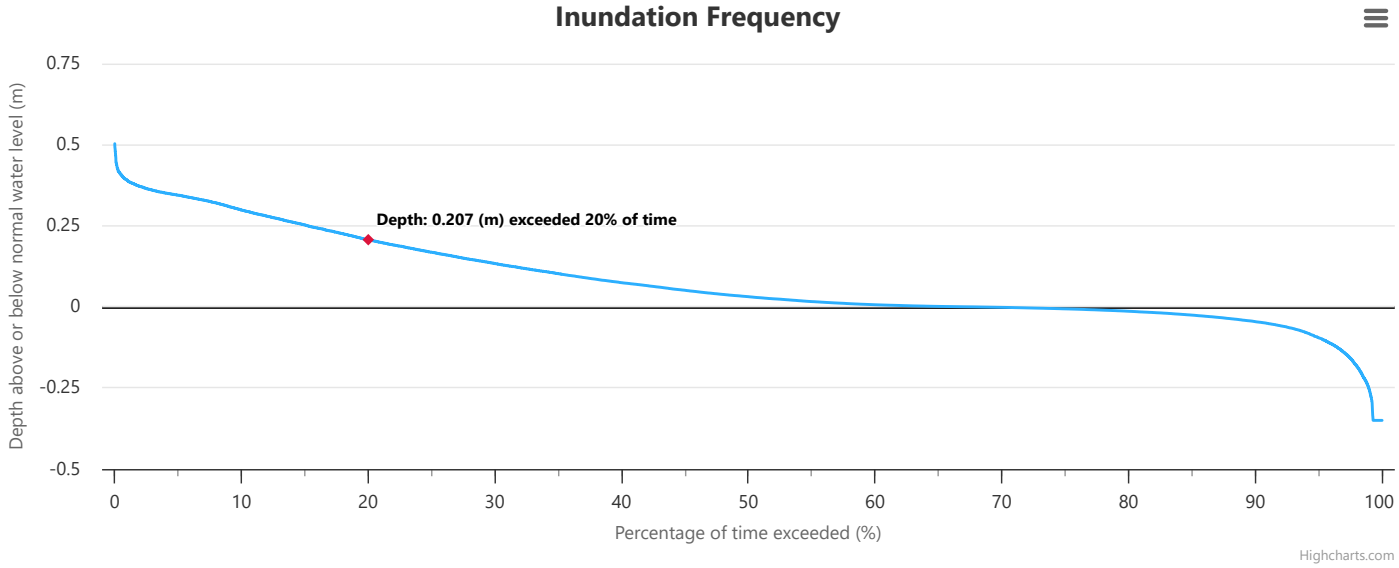
Shallow Planting Depth 0.15 m
Deep Planting Depth 0.35 m

Please enter the permanent pool volume.

Permanent Pool Volume 6650 m

Please select the daily flux file generated in MUSIC for a wetland.
The file must be generated with MUSIC Version 6 and be a DAILY flux file.

Choose File WL CS_Flux.csv
FILE IS UPLOADED



Please select at least 3 plants for each of the shallow and deep marsh zones.

Clear Selection

Name	Average plant height (m)	Shallow marsh plants	Deep marsh plants	Suitability
Sea Club-rush *Bolboschoenus caldwellii*	1	☑		Shallow Only

Water Ribbons *Triglochin procerum*	1	☑	☐	
Jointed Club-rush *Baumea articulata*	1.8	☑	☑	
Tall Club-rush *Bolboschoenus fluviatilis*	1.8	☑	☑	
Marsh Club-rush *Bolboschoenus medianus*	1.5	☑	☑	Shallow and Deep
Leafy Twig-rush *Cladium procerum*	2	☑	☑	
River Club-rush *Schoenoplectus tabernaemontani*	1.8	☑	☑	
Tall Spike-rush *Eleocharis sphacelata*	1.5		☑	Deep Only
Common reed *Phragmites australis*	2.5		☑	
Common Spike-rush *Eleocharis acuta*	0.5	☐		Unsuitable

+ Add user defined plant

Report

File: WL CS_Flux.csv
Shallow marsh zone meets deemed to comply criteria

Deep marsh zone meets deemed to comply criteria

Water level exceeded for 20% of time: 0.207 m

Water level exceeded for 50% of time: 0.03135 m
·Effective water level is within 50 mm of normal water level and is acceptable.

90th Percentile Residence Time: 3 days

☐ Spells Analysis?



Wetland Analysis Tool

Welcome to the Wetland Analysis Tool for checking compliance with the Melbourne Water Constructed Wetland Manual. This tool assesses the wetland depths relative to plant heights and the wetland residence time and advises whether the Deemed to Comply requirements are satisfied.

Please enter the 'Shallow marsh zone planting depth' and 'Deep marsh zone plating depth'.

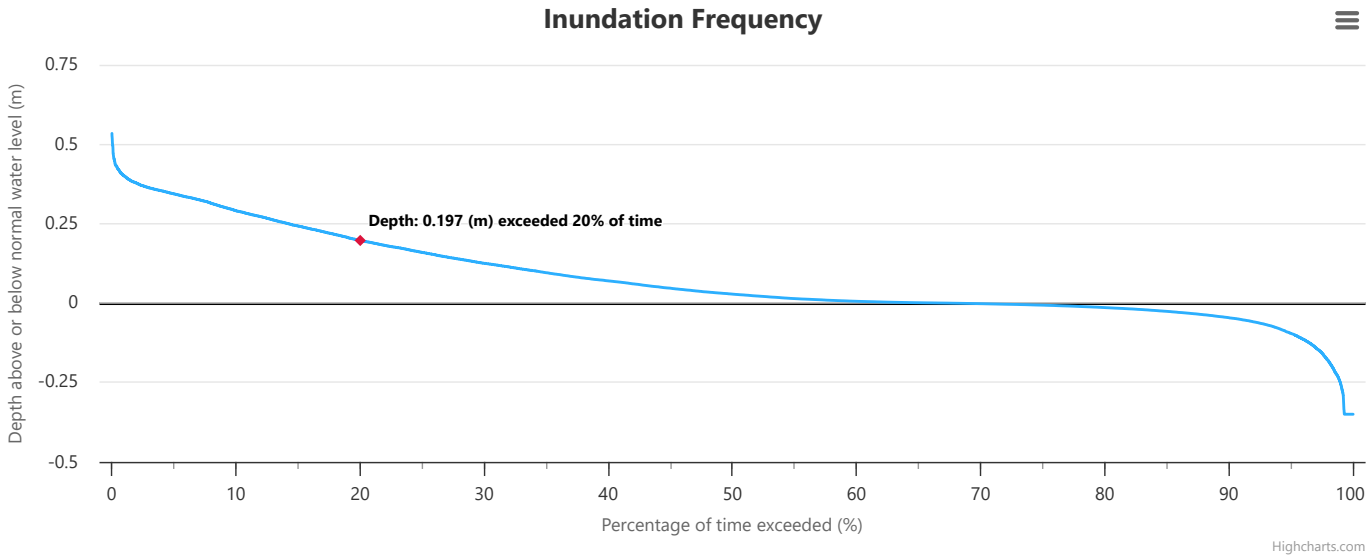
Shallow Planting Depth 0.15 m
Deep Planting Depth 0.35 m

Please enter the permanent pool volume.

Permanent Pool Volume 10150 m

Please select the daily flux file generated in MUSIC for a wetland.
The file must be generated with MUSIC Version 6 and be a DAILY flux file.

Choose File WL NWN_Flux.csv
FILE IS UPLOADED



Please select at least 3 plants for each of the shallow and deep marsh zones.

Clear Selection

Name	Average plant height (m)	Shallow marsh plants	Deep marsh plants	Suitability
Sea Club-rush *Bolboschoenus caldwellii*	1	☑		Shallow Only
Water Ribbons *Triglochin procerum*	1	☑	☐	

Jointed Club-rush *Baumea articulata*	1.8	☑	☑	
Tall Club-rush *Bolboschoenus fluviatilis*	1.8	☑	☑	
Marsh Club-rush *Bolboschoenus medianus*	1.5	☑	☑	Shallow and Deep
Leafy Twig-rush *Cladium procerum*	2	☑	☑	
River Club-rush *Schoenoplectus tabernaemontani*	1.8	☑	☑	
Tall Spike-rush *Eleocharis sphacelata*	1.5		☑	Deep Only
Common reed *Phragmites australis*	2.5		☑	
Common Spike-rush *Eleocharis acuta*	0.5	☐		Unsuitable

+ Add user defined plant

Report

File: WL NWN_Flux.csv
Shallow marsh zone meets deemed to comply criteria

Deep marsh zone meets deemed to comply criteria

Water level exceeded for 20% of time: 0.197 m

Water level exceeded for 50% of time: 0.02805 m
·Effective water level is within 50 mm of normal water level and is acceptable.

90th Percentile Residence Time: 3 days

☐ Spells Analysis?

Appendix C

Overland Flow Assessment

C-1 Overland Flow Capacity within Road Reserve

An assessment has been completed whether any additional channel or waterway is required to safely convey the major flow path shown in the preliminary drainage concept plan. In doing so, the road overland flow capacity has been estimated using the PC Convey software tool. Figure C-1-1 below shows the locations of the roads for which the overland flow capacity has been estimated.



Figure C-1-1 Locations of the roads

Sims Rd (Section 1) has a longitudinal grade of 1.4%, Gillies Rd has a grade of 1.8%, and Sims Rd (Section 2) and UNNAMED Rd have a grade of 2.2%.

A typical road profile for a 24 m (without median) and 34 m (with median) reserve widths as proposed in IDM (LGIDA, 2019) was used to estimate the maximum overland flow capacity that can be contained within the road reserve (see Figure C-1-2).

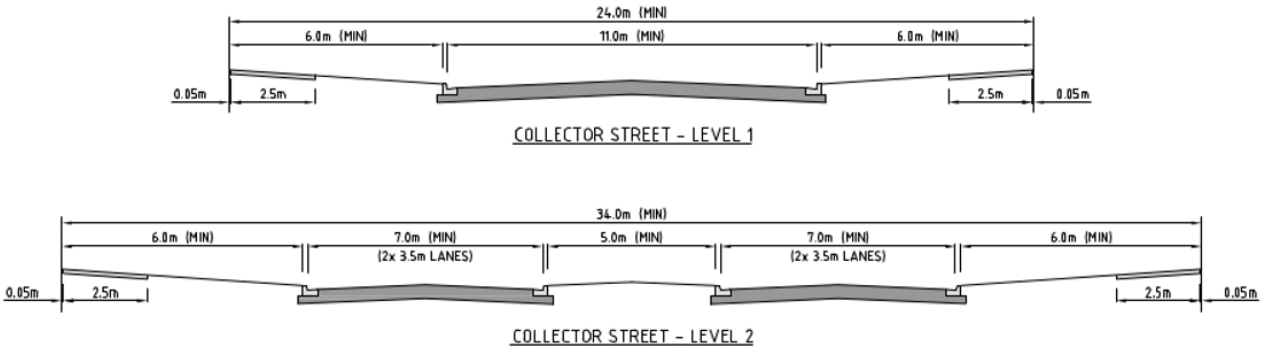


Figure C-1-2 Road profiles access place and Street/Collector Level 1 (top image) and Level 2 (bottom image) (IDM,2020)

There are two types of road cross section that are 'with and without median strip' that can be assessed. When a median strip is present, as long as the average depth and velocity parameters are met, the overland flow can increase to the footpath with the freeboard requirement met within the lot. This means that the entire road reserve can take overland flows. This is while a road profile without a median strip can significantly take less overland flow because the freeboard must be catered for in the road itself. For this assessment, it is assumed that the roads have median strips and thus the reserves can also take overland flows.

The PC Convey results for the road profiles Level 1 and Level 2 with median strip are presented below. The road grades are assumed to be 1%, 2% and 3% in the software tool.

Table C-1-1 PC Convey results for the Level 1 Collector Street (without median)

Road Grade	Maximum Flow	Average Depth (D_{ave})	Average Velocity (V_{ave})	$D_{ave} \times V_{ave}$
1%	5.3 m^3/s	0.16 m	1.47 m/s	0.23 m^2/s
2%	7.5 m^3/s	0.16 m	2.08 m/s	0.33 m^2/s
3%	9.2 m^3/s	0.16 m	2.55 m/s	0.41 m^2/s

Table C-1-2 PC Convey results for the Level 2 Collector Street (with median)

Road Grade	Maximum Flow	Average Depth (D_{ave})	Average Velocity (V_{ave})	$D_{ave} \times V_{ave}$
1%	8.9 m^3/s	0.18 m	1.56 m/s	0.27 m^2/s
2%	12.5 m^3/s	0.18 m	2.21 m/s	0.39 m^2/s
3%	15.4 m^3/s	0.18 m	2.71 m/s	0.47 m^2/s

The gap flows between the 1% and 20% AEP storm events generated within each of the roads shown in Figure C-1-1 have been calculated using RORB and compared with the PC Convey results to ensure the aforementioned roads have enough capacity to contain gap flows safely. All roads are assumed to be Level 2 (with median) except for the UNNAMED Rd. The summary of the calculations is presented below. As shown, the overland flow capacity of the roads are well beyond the gap flows and thus the roads can contain the gap flows safely.

Table C-1-3 Road overland flow capacity

Road Name	Road Grade	1% AEP Flow	20% AEP Flow	Gap Flow	Capacity Range*
Sims Rd (Sec. 1)	1.4%	2.2 m^3/s	0.9 m^3/s	1.3 m^3/s	8.9-12.6 m^3/s
Gillies Rd	1.8%	5.0 m^3/s	2.3 m^3/s	2.7 m^3/s	8.9-12.6 m^3/s
Sims Rd (Sec. 2)	2.2%	5.6 m^3/s	2.4 m^3/s	3.2 m^3/s	12.6-15.4 m^3/s
UNNAMED Rd	2.2%	5.7 m^3/s	2.3 m^3/s	3.4 m^3/s	7.6-9.3 m^3/s

*Capacity range has been adopted from PC Convey results for the Level 2 Collector Street based upon varying road grades. The exception is UNNAMED Rd which is assumed to be Level 1 Collector Street.

The road overland flow capacity has been estimated based on the climate change SSP 2-4.5 design scenario. Results presented in Table C-1-4 indicate that all roads have sufficient capacity to convey the 1% and 20% AEP storm events, including associated gap flows, within the assumed road reserves.

It is noted that this assessment is based on concept-level design assumptions, including indicative road classifications and reserve widths. The capacity assessment should be reviewed and confirmed once road typologies and reserve widths are finalised.

Table C-1-4 Road overland flow capacity with SSP 2-4.5

Road Name	Road Grade	1% AEP Flow	20% AEP Flow	Gap Flow	Capacity Range
Sims Rd (Sec. 1)	1.4%	3.2 m^3/s	1.4 m^3/s	1.8 m^3/s	8.9-12.6 m^3/s
Gillies Rd	1.8%	7.3 m^3/s	3.3 m^3/s	4.0 m^3/s	8.9-12.6 m^3/s
Sims Rd (Sec. 2)	2.2%	8.5 m^3/s	3.6 m^3/s	4.9 m^3/s	12.6-15.4 m^3/s
UNNAMED Rd	2.2%	8.7 m^3/s	3.6 m^3/s	5.1 m^3/s	7.6-9.3 m^3/s

Appendix D

Integrated Water Management Strategy

D-1 IWMS Summary Tables

Site Information

Table D-1-1 Lot size distribution and occupancy

Lot Size	Number of lots	Occupancy
0-300 m^2	0	
300-500 m^2	7,151	2.2
>500 m^2	0	
Total	7,151	

Table D-1-2 Land use distribution

Parameter	Unit	Value	Percentage
Residential	ha	286.1	68.8%
Active Open Space	ha	27.3	6.6%
Passive Open Space	ha	22.0	5.3%
Commercial	ha	6.1	1.5%
Education	ha	28.5	6.8%
Transport	ha	20.7	5.0%
Drainage Reserve	ha	25.4	6.1%
Total	ha	416	100%

MUSIC Climate Data Inputs

Table D-1-3 Rainfall station and data period

Parameter	Unit	Value
Rainfall station	Station # and location	089002 - Ballarat
Date period	Year starting to year ending	1954 - 1999
Time step	Minutes	6

Water Demand Assumptions and Calculations

Table D-1-4 Water demand assumptions

Parameter	Unit	Value
Residential		
Potable water demand (per lot)	L/day	348
Non-potable water demand incl irrigation (per lot)	L/day	119
Active Open Space		
Irrigation rate for sports fields	ML/ha/year	5
Passive Open Space		
Irrigation rate for local parks and landscaped areas	ML/ha/year	2

Table D-1-5 Residential reuse demand calculations

Parameter	Unit	Value
Residential		
Toilet reuse demand (per lot)	L/day	44
Irrigation reuse demand (per lot)	L/day	75
Rainwater tank volume (per lot)	kL	2
Uptake rate of rainwater tank installed for residential lots	%	100
Total reuse supplied	KL/day	626
Total reuse supplied	ML/year	228.3

Table D-1-6 Residential total water demand calculations

Parameter	Unit	Value
Residential		
Total potable water demand	ML/year	908.4
Total non-potable water demand	ML/year	310.6
Total water demand	ML/year	1,219
Total rainwater tanks installed	no.	7,151
Total rainwater supplied	ML/year	228.3
Total stormwater supplied	ML/year	0
Total alternative water supplied	ML/year	82.3
Total potable water reduction from alternative water supplied	%	25

D-2 MUSIC Modelling Layout

The snippets of the MUSIC model incorporating rainwater harvesting tanks are shown in the figures below.

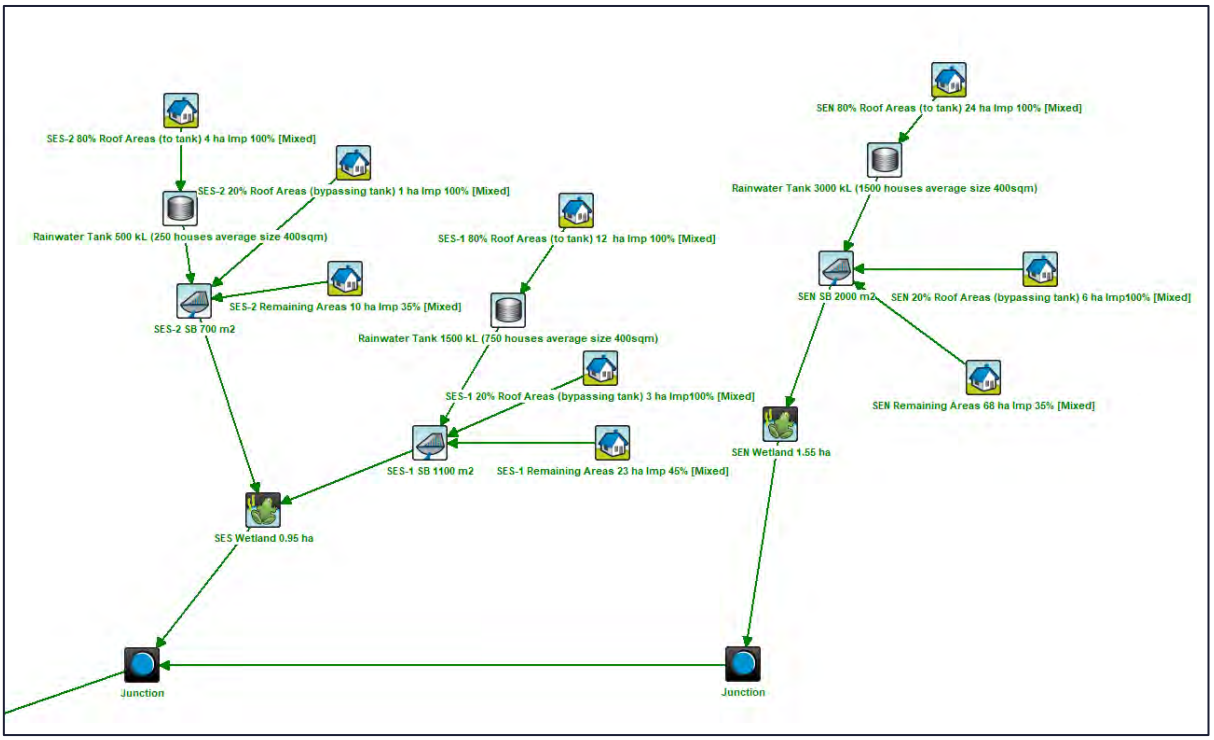


Figure D-2-1 MUSIC model layout – nodes for SE north and south catchments

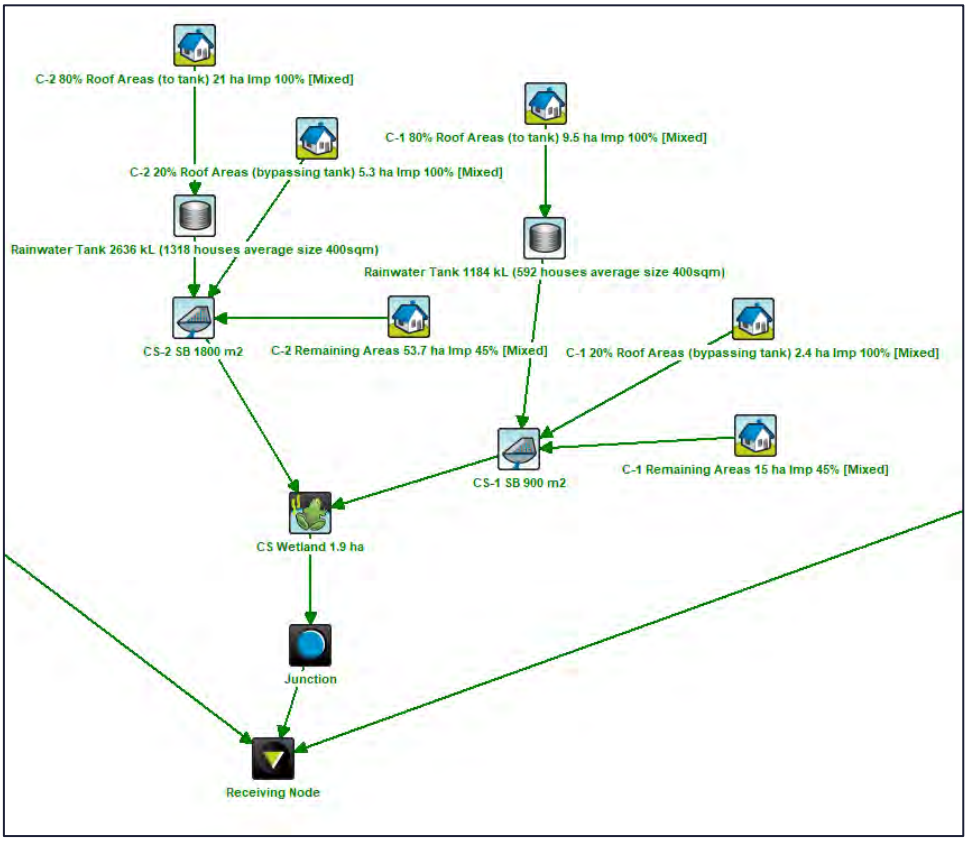


Figure D-2-2 MUSIC model layout – nodes for C catchment

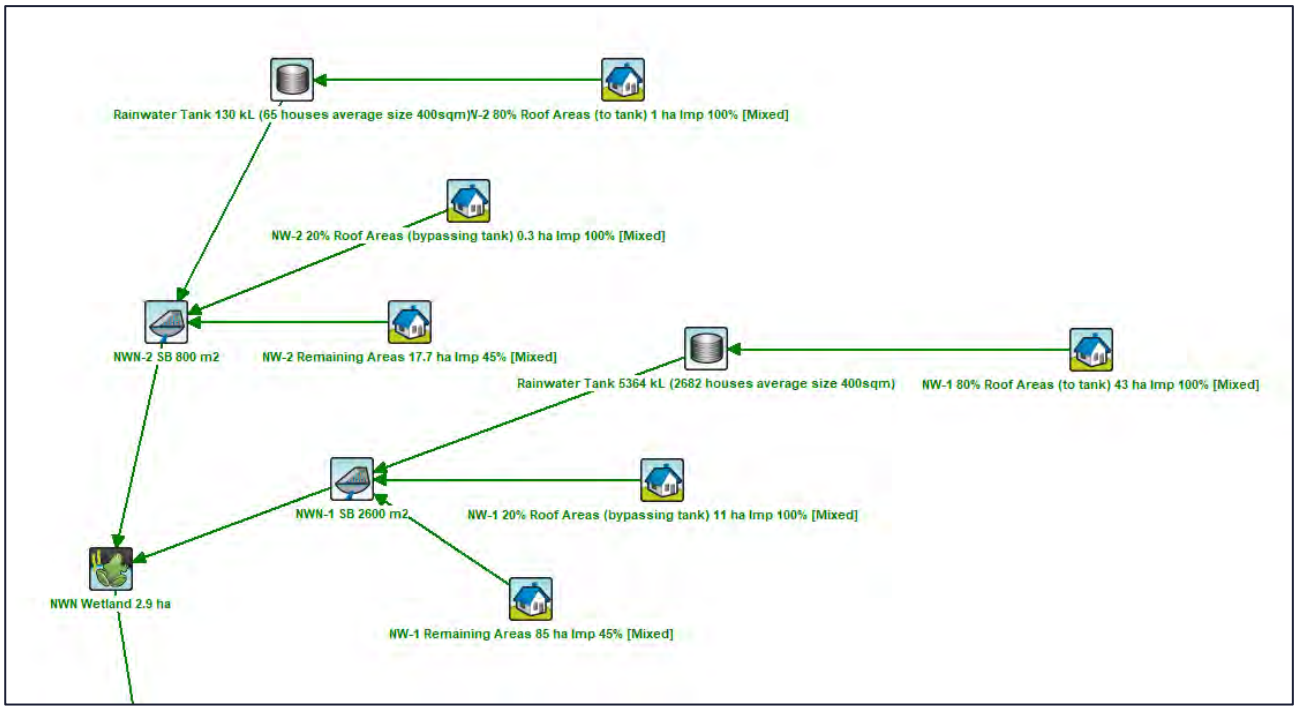


Figure D-2-3 MUSIC model layout – nodes for NW catchment

Appendix E

Technical Memo - GHCMA

Technical Memorandum

Memo No.	181-TM-001	**Date of Issue**	30 October 2024
Subject	Burrumbeet Creek Interim Flood Extent	**Discipline**	Flood Modelling
Project Title	Ballarat North PSP Stormwater Functional Design	**Project No.**	30049251
Document No.	30049251-181-TM-001	**Revision**	0
Author	Karl Velasco – Associate Engineer Water Resources / Project Manager		
Reviewed by	Tim Rhodes – Technical Principal Water Resources	**Approved by**	Sander van Hall – Project Director
Prepared for	Robert Marks - Victorian Planning Authority	**Attention to**	Glenelg Hopkins Catchment Management Authority
Attachments	• Appendix B - Depth Maps • Appendix C - Meeting File Note – VPA/SMEC/GHCMA/CoB – Brief to GHCMA on SMEC's approach to address limitations in 2013 Burrumbeet Creek flood mapping in assumptions for Ballarat North PSP drainage strategy		

1. Introduction

SMEC has been engaged by the Victorian Planning Authority (VPA) to prepare a stormwater drainage strategy for the Ballarat North Precinct Structure Plan (PSP). The subject site is located approximately 7 km north of Ballarat as shown in **Figure 1-1**.

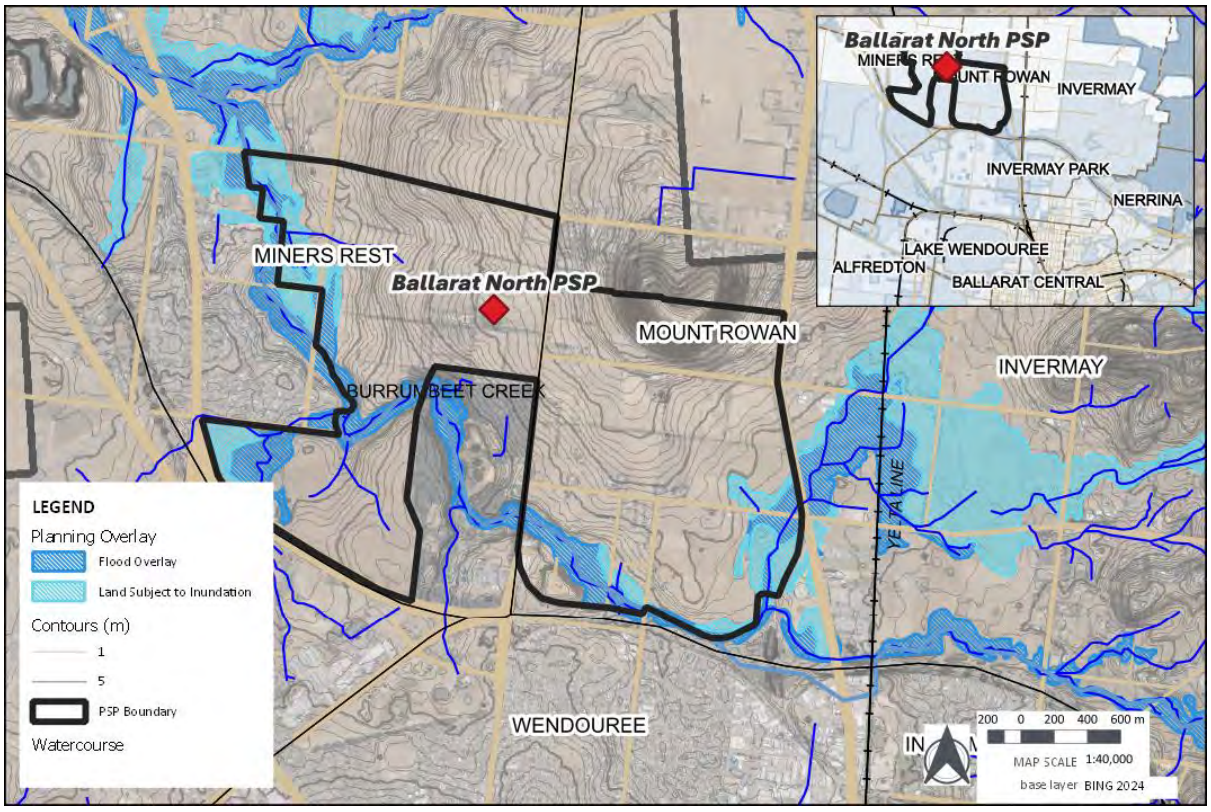


Figure 1-1 Ballarat North PSP and Burrumbeet Creek Flood Overlays

Correspondence from Glenelg Hopkins Catchment Management Authority (GHCMA) to the VPA has flagged that the available 1% Annual Exceedance Probability (AEP) flood extents of Burrumbeet Creek are out of date. The current flood study upon which the flood mapping is based is described in Water Technology (2013). The current flood mapping does not accurately represent the recent changes in the catchment including new major drainage infrastructure and increases in development area. The Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO) based on the current flood study are overlaid on the Ballarat North PSP in **Figure 1-1**. The changes in modelling practice subsequent to the current flood study include revised design rainfall depths and climate change impact estimation techniques.

The flood extent defines the development exclusion zone and an estimate of the updated zone is required to provide certainty for development planning purposes.

1.1 Consultation with GHCMA

SMEC was tasked with preparing a methodology to delineate an interim flood inundation extent in advance of a more detailed future flood study to be completed by others. The methodology requires input and in principal agreement from GHCMA.

The intent of the interim methodology is to define the 1% AEP flood extent inclusive of climate change applying a simple, conservative analysis. The method is to incorporate the latest modelling guidance with a buffer to allow for uncertainties. The interim flood extent is to be updated at the time when outputs from a revised Burrumbeet Creek flood study become available. GHCMA has indicated that they are currently planning to commission a new flood study in collaboration with the City of Ballarat (CoB).

A meeting involving SMEC, VPA, GHCMA, and CoB was held on 13th September 2024, where the proposed approach and modelling outcomes were discussed and generally supported by GHCMA (Refer to Meeting File Note in **Appendix C**).

2. Methodology

2.1 Inputs

The current flood study (Water Technology, 2013) was supplied by VPA inclusive of the associated models and data as follows:

- Burrumbeet Creek – rainfall runoff model – RORB
- RORB sub catchment and reaches in GIS format (shapefiles)
- Burrumbeet Creek - 2d hydraulic model - TUFLOW
- Terrain (LiDAR) data used in the 2013 TUFLOW model

2.2 2024 Climate Change Consideration Update

Ball et al. (2019) defines the industry standard for completing design event rainfall runoff estimation and associated flood modelling. Subsequent to completion of the current flood study in 2013, Ball et al. (2019) has been updated in 2019 (Version 4.1) and more recently in September 2024 (Version 4.2). The updates incorporate changes to design rainfall and then, in 2024, changes to climate change impact estimation procedures.

2.3 Hydrology

The interim modelling methodology assesses the sensitivity of the flood extent to the hydrological inputs. Three scenarios were evaluated as follows.

1. Older (current) assessment – based on outcomes presented in Water Technology (2013) procedures, inclusive of climate change factors at the time.
2. Future conditions – based on Ball et al. (2019) procedures, inclusive of climate change.
3. Sensitivity - Hydrograph from Scenario 2 increased by a factor of 100%.

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The results were compared with the climate change scenario outcomes presented in Water Technology (2013). The design rainfall depths and uplifts adopted for each scenario are summarised in **Table 2-1**.

Table 2-1 Hydrological Sensitivity Scenarios

Scenario Number	Scenario Description	Design Rainfall Depth Source	Adopted Time Horizon	Global Climate Condition	Design Rainfall Depth Uplift Factor
1	Previous 2013 Climate Change Consideration	BoM IFD 1987	n/a	n/a	1.2
2	Latest Climate Change Consideration	BoM IFD 2016 w/ uplift as per Ball et al. (2019)	2100	SSP8.5 4.5 degrees °C increase	1.47[1]
3	Scenario 2 hydrograph increased by 100%	n/a	n/a	n/a	n/a

1. For critical duration of 12 hours

Scenario 2 is the future climate change scenario based on an increase in global temperature of 4.5 °C in the year 2100 horizon. The climate change uplift factors vary depending on the storm duration and AEP. A summary table of the uplift factors applicable to the site location is illustrated in **Table 2-2**. Detailed climate change factors are included in **Appendix A**. Scenario 3 is a sensitivity run where the flow rate from Scenario 2 is doubled to assess the sensitivity of the outcomes to input variability.

Table 2-2 Data hub Climate Change Consideration Uplift Factors (AR&R v4.2, 2019)

SSP5-8.5

Year	<1 hour	1.5 Hours	2 Hours	3 Hours	4.5 Hours	6 Hours	9 Hours	12 Hours	18 Hours	>24 Hours
2030	**1.2**	**1.18**	**1.17**	**1.16**	**1.14**	**1.13**	**1.13**	**1.12**	**1.11**	**1.11**
2040	1.26	1.24	1.22	1.2	1.18	1.17	1.16	1.15	1.14	1.14
2050	**1.34**	**1.31**	**1.29**	**1.26**	**1.24**	**1.23**	**1.21**	**1.2**	**1.18**	**1.18**
2060	1.42	1.38	1.35	1.32	1.29	1.28	1.26	1.24	1.22	1.21
2070	1.52	1.47	1.43	1.4	1.36	1.34	1.31	1.29	1.27	1.26
2080	1.63	1.57	1.52	1.48	1.43	1.4	1.37	1.35	1.33	1.31
2090	**1.77**	**1.69**	**1.64**	**1.58**	**1.52**	**1.49**	**1.45**	**1.42**	**1.39**	**1.37**
2100	1.86	1.77	1.71	1.64	1.58	1.54	1.5	1.47	1.43	1.41

The RORB (Laurenson et al., 2010) model sub area and reaches were maintained from the original Burrumbeet Creek model. The routing parameters were maintained, and losses were updated from the Bureau of Meteorology (2016). A summary of the model parameters is shown in **Table 2-3**.

Table 2-3 RORB model parameters

Parameter	Value	Source
Delay (k_c)	46	Water Technology (2013)
Non-linearity (m)	0.8	Water Technology (2013)
Initial Loss (mm)	17.25	BoM Data hub (Ball et al., 2019)
Continuing Loss (mm/hr)	5.33	BoM Data hub (Ball et al.,2019)

For Scenario 2 the initial and continuing losses were adjusted according to the latest Climate Change guidance. Refer to **Appendix A** for the loss adjustment factors adopting 4.5 °C increase and year 2100.

The 1% AEP peak flow estimated at Burrumbeet Creek within the PSP area (Node 156) and at the catchment outlet are summarised in **Table 2-4.** The critical storm duration at the site is the 12-hour storm event.

Table 2-4: Design Flow 1%AEP

Scenario	1% AEP Peak Flow (m^3/s)	
	Node 156	Lake Burrumbeet Gauge-Outlet
1	Not reported	93
2	53	131
3	106	262

The RORB catchment model setup and locations of the reported peak flows are shown in **Figure 2-1**.

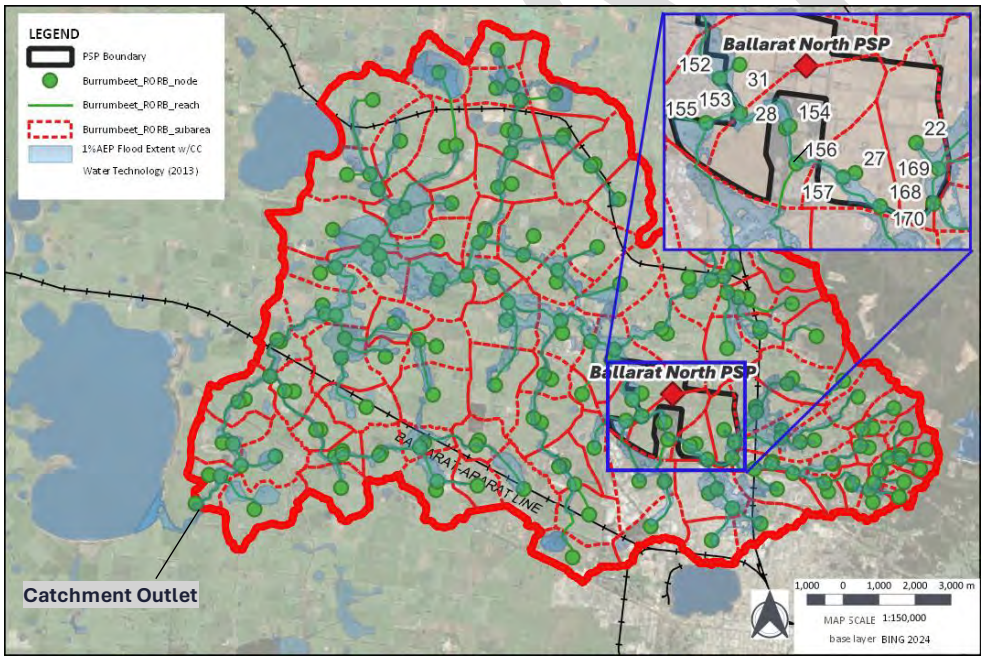


Figure 2-1 RORB catchment model

2.4 Hydraulic Modelling

A simple 2d hydraulic model was setup to determine the sensitivity of the flood extents from various hydrologic scenarios mentioned above. The TUFLOW model was setup and ran as follows:

- Inflow hydrograph at the upstream end of the model domain.
- Outflow boundary condition based on longitudinal slope.
- 5 m grid size based on 2019 LiDAR of 1m resolution.

- HPC computation scheme with sub-grid-sampling (SGS) enabled.
- Roughness definition (materials file) were maintained as per the original model.
- Model extent is limited to the Burrumbeet Creek reach covering the PSP area.

The TUFLOW model domain is shown in **Figure 2-2**.

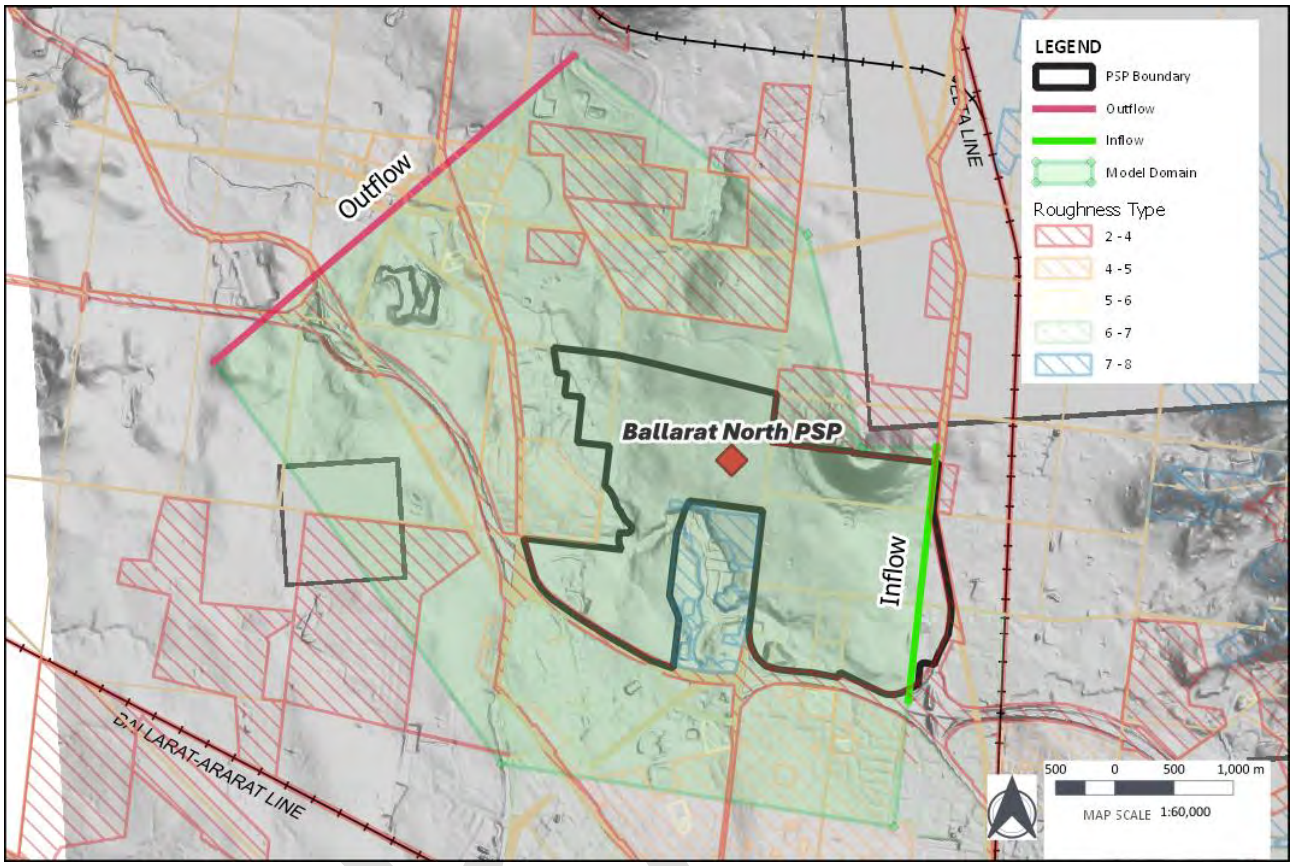


Figure 2-2 TUFLOW Model Setup

Limitations

The following limitations are noted:

- The model does not include the inflows from minor tributaries along Burrumbeet Creek. This has the potential to result in less inflow downstream of the model domain and therefore lower flood levels.
- The inflow hydrograph to the hydraulic model was extracted from the hydrologic model at a location halfway between the PSP upstream and downstream reaches. This represents an average flow along Burrumbeet Creek. A more accurate representation would be to include a series of inflows at the location of each tributary.
- Major culvert structures at road crossings were not included in the TUFLOW model. This can influence the flood extents considerably in the local area.
- One storm duration (12hr) was simulated based on the critical storm duration from Burrumbeet Creek. There is a potential for the flood extent from the northern tributary to be larger if the shorter durations were simulated.
-

3. Results

3.1 1%AEP Flood Extent with Climate Change

The 1% AEP flood extent from the three scenarios are shown in **Appendix B – Map 1**.

Comparison

- The outcomes indicate that the flood extent area does not vary substantially between scenarios 1 and 2. The flood depth of the 2013 flood study (Scenario 1) and Scenario 2 does not vary greater than 1 m across the model domain. Largest deviation can be seen in the areas where there are road culverts.
- The areas where the flood line are closer together indicates the waterway banks are relatively steeper. The areas where the extents are notably wider the flooding extends in the floodplains.
- The sensitivity run of scenario 3 gives the largest flood extent from all scenarios. It is recommended to adopt this flood extent as the basis of design for the preparation of the Ballarat North PSP drainage strategy. Adopting this scenario allows for the simplifications and uncertainties that has not been accounted for in the assessment. This is considered a conservative approach in the interim as the updates to the flood study is expected to be less than scenario 3.

Cross sections

A number of cross sections are provided in **Figure 3-1** to **Figure 3-4** illustrating the maximum flood depth relative to the topography of Burrumbeet Creek and the floodplain. The right-hand side interfaces to the Ballarat North PSP development area. The approximate distance of Scenario 2 (orange) to Scenario 3 (green) extent is 30 m at one of the critical cross sections in location 7. Refer to **Figure 3-4.**

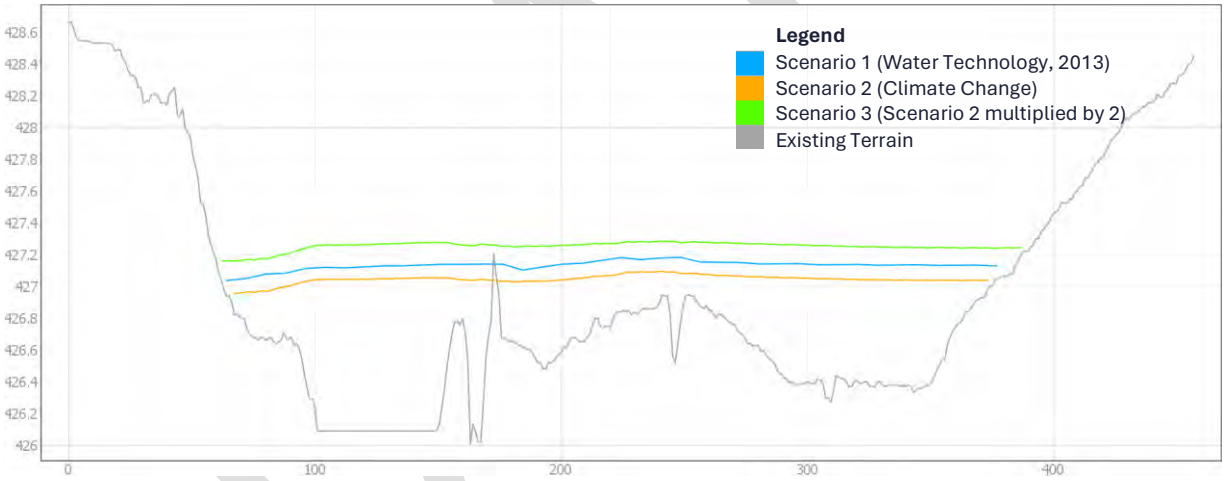


Figure 3-1 Cross section location 2

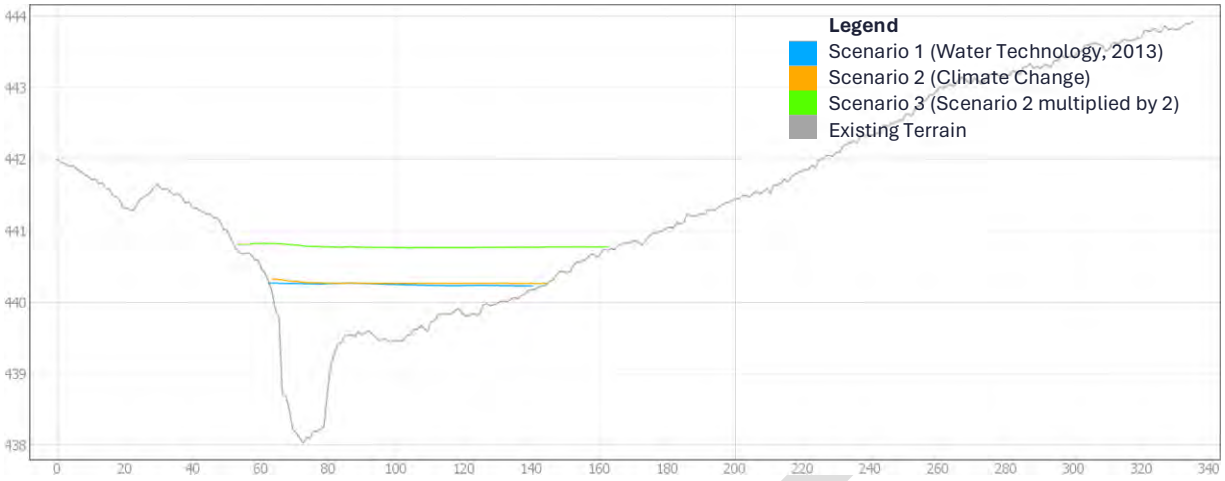


Figure 3-2 Cross section location 3

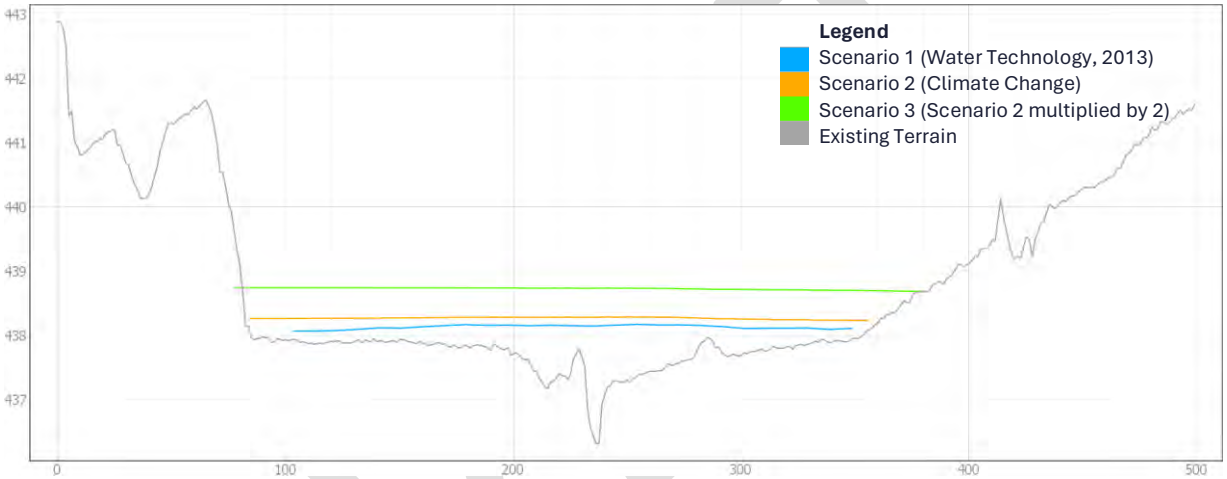


Figure 3-3 Cross section location 4

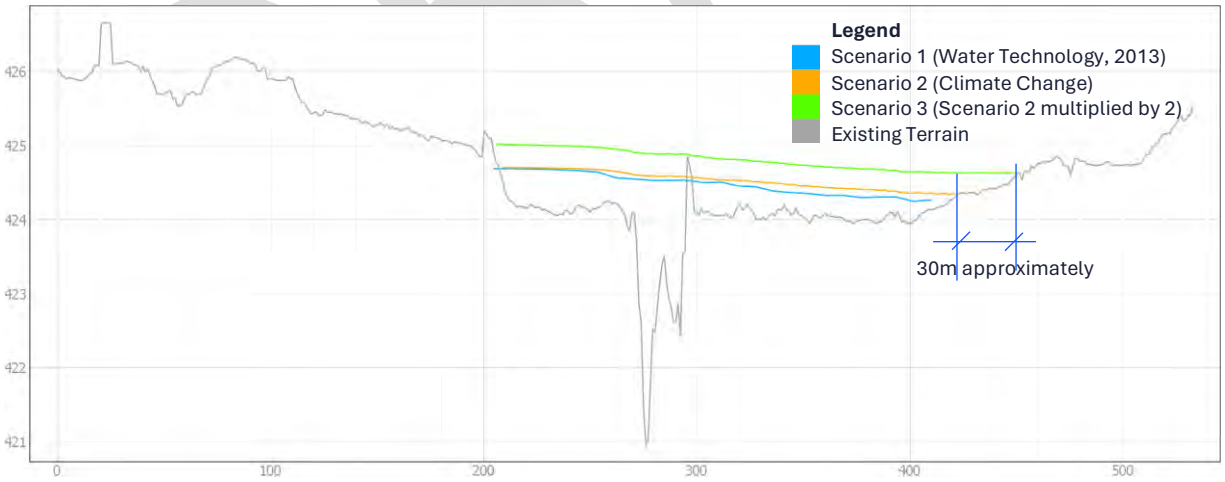


Figure 3-4 Cross section location 7

4. Conclusion

A coarse hydrologic and hydraulic analyses have been completed to understand the sensitivity of climate change impacts and recent updates to AR&R on the flood inundation extent. The results shows there are minor variations to the 1%AEP flood extents in the Ballarat North PSP area. SMEC proposes to adopt the Scenario 3 flood extent to be used as the basis of design which is considered a reasonable and conservative interim

approach. It is recommended that the impending flood study be progressed in parallel with the PSP development and be incorporated in the Ballarat North PSP. Glenelg Hopkins CMA's in-principle support to the above methodology and outcomes are required to provide confidence in the next phase of the project.

5. References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), (AR&R) Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia), Version 4.2, 2019.

Laurenson,E.M, Mein,R.G. and Nathan,R.J (2010), RORB – Version 6.15, Runoff Routing Program, User Manual, Department of Civil Engineering, Monash University, Clayton, Australia.

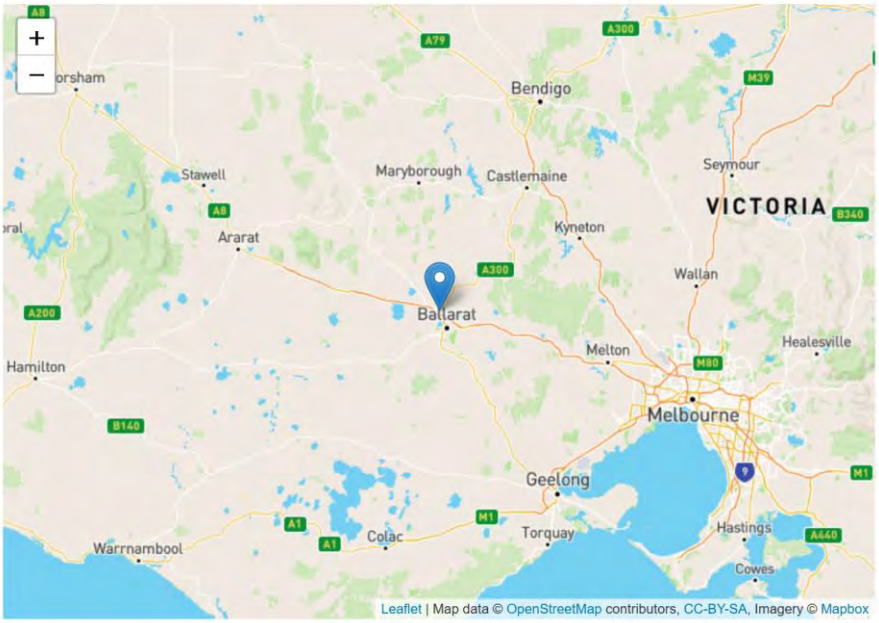
Water Technology (2013), Burrumbeet Flood Investigation, Summary Study Report.

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Appendix A – Data Hub Climate Change Factors

Input Data

Longitude	143.828
Latitude	-37.506
Selected Regions (clear)	
Climate Change Factors	show



Loss Factors

Initial Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.05**	**1.05**	**1.05**	**1.05**
2040	1.05	1.06	1.06	1.07
2050	**1.06**	**1.07**	**1.07**	**1.08**
2060	1.06	1.07	1.09	1.1
2070	1.06	1.08	1.1	1.12
2080	1.06	1.09	1.12	1.14
2090	**1.06**	**1.09**	**1.13**	**1.17**
2100	1.06	1.1	1.15	1.19

Continuing Loss (Adjustment Factors)

	Losses SSP1-2.6	Losses SSP2-4.5	Losses SSP3-7.0	Losses SSP5-8.5
2030	**1.1**	**1.1**	**1.1**	**1.11**
2040	1.12	1.12	1.13	1.14
2050	**1.12**	**1.15**	**1.16**	**1.18**
2060	1.13	1.17	1.19	1.23
2070	1.13	1.18	1.23	1.28
2080	1.13	1.2	1.27	1.33
2090	**1.13**	**1.21**	**1.31**	**1.39**
2100	1.12	1.22	1.34	1.44

Temperature Changes (Degrees, Relative to 1961-1990 Baseline)

Year	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2030	**1.2**	**1.2**	**1.2**	**1.3**
2040	1.3	1.4	1.5	1.6
2050	**1.4**	**1.7**	**1.8**	**2.1**
2060	1.5	1.9	2.2	2.5
2070	1.5	2.1	2.5	3
2080	1.5	2.2	2.9	3.5
2090	**1.5**	**2.4**	**3.3**	**4.1**
2100	1.4	2.5	3.6	4.5

Layer Info

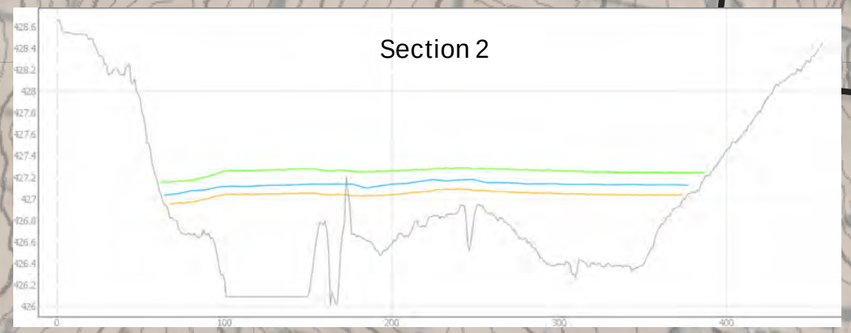
Time Accessed	27 October 2024 11:03PM
Version	2024_v1
Note	Updated climate change factors for IFD Initial loss and continuing loss based on IPCC AR6 temperature increases from the updated Climate Change Considerations (Book 1: Chapter 6) in ARR (Version 4.2). ARR recomends the use of Current and near-term (2030 midpoint). Medium-term (2050 midpoint) and Long-term (2090 midpoint)

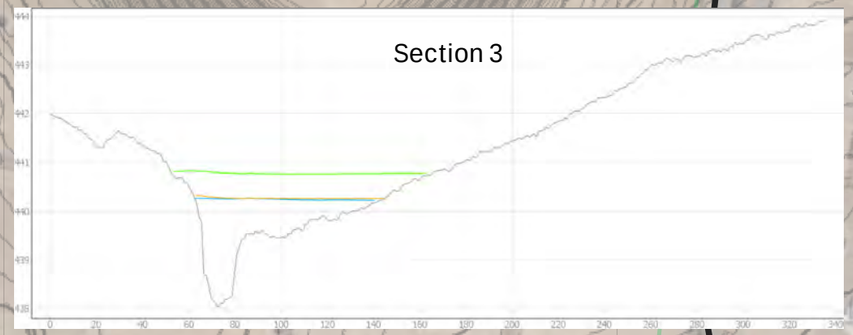
Appendix B – Flood Extent Map

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218000 219000 220000 221000

5845000 5844000 5843000





10
2
6
5
4
3
1
Gillies Rd
Burrumbeet Creek

Flood Extent Estimate Only
Subject to Confirmation

North West Tributary

Start of Model Extent

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LEGEND

- Scearion 1 - Previous Climate Change (Water Tech 2013)
- Scenario 2 - Latest Climate Change Conditions
- Scenario 3 - Sensitivity (Scenario 2 Multiplied by 2)
- Scenario 3 - Extended

Contours

- 1
- 5
- Cross Section Location
- Model Domain
- PSP Boundary

MAP 1A

1% AEP FLOOD EXTENT

BURRUMBEET CREEK SENSITIVITY ASSESSMENT

BALLARAT NORTH PSP STORMWATER AND DRAINAGE

client: Victorian Planning Authority

consultant: smec

PROJECT NO	30049251
DATE	30 Oct 2024
REVISION	Draft
CREATED BY	KV
aerial imagery	BING MAPS

100 0 100 200 300 m

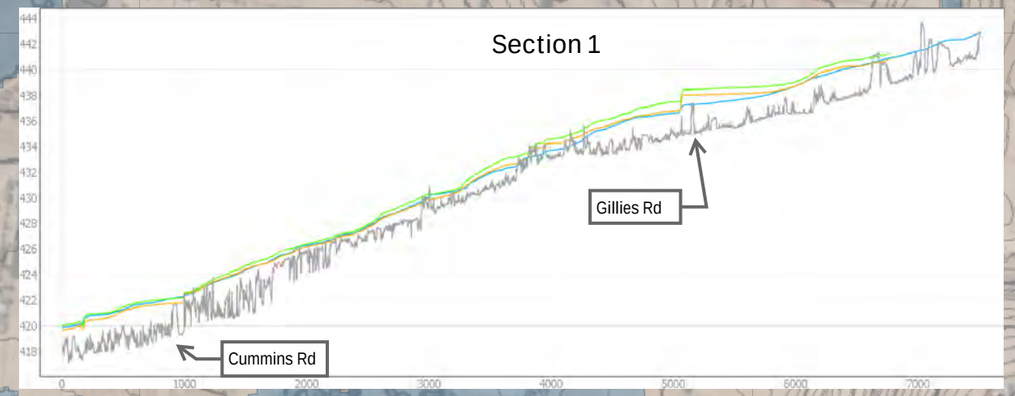
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PROJECTION	MGA Zone 55

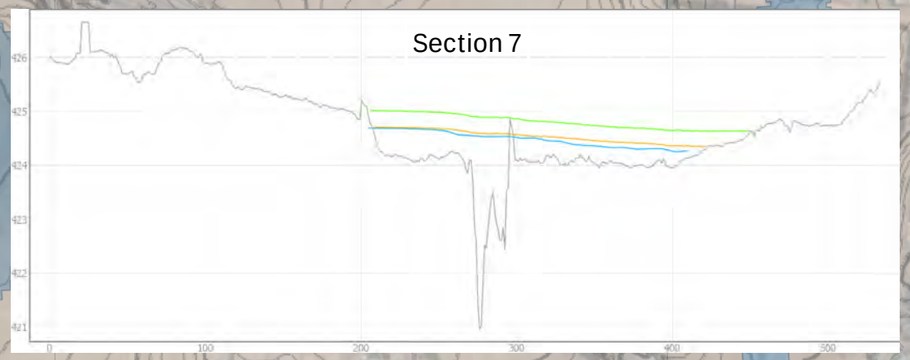
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216000 217000 218000 219000

5847000 5846000 5845000

End of Model Extent





9 8 7 10 1 2

Cummins Rd

LEGEND

- Scearion 1 - Previous Climate Change (Water Tech 2013)
- Scenario 2 - Latest Climate Change Conditions
- Scenario 3 - Sensitivity (Scenario 2 Multiplied by 2)
- Scenario 3 - Extended

Contours

- 1
- 5
- Cross Section Location
- Model Domain
- PSP Boundary

DRAFT

MAP 1B **1% AEP FLOOD EXTENT**

BURRUMBEET CREEK SENSITIVITY ASSESSMENT

BALLARAT NORTH PSP STORMWATER AND DRAINAGE

client Victorian Planning Authority

consultant smec

PROJECT NO 30049251
DATE 30 Oct 2024
REVISION Draft
CREATED BY KV

aerial imagery BING MAPS

100 0 100 200 300 m

MAP SCALE 1:10,000
PAGE SIZE A3
DATUM GDA94
PROJECTION MGA Zone 55

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Appendix C – Meeting File Note

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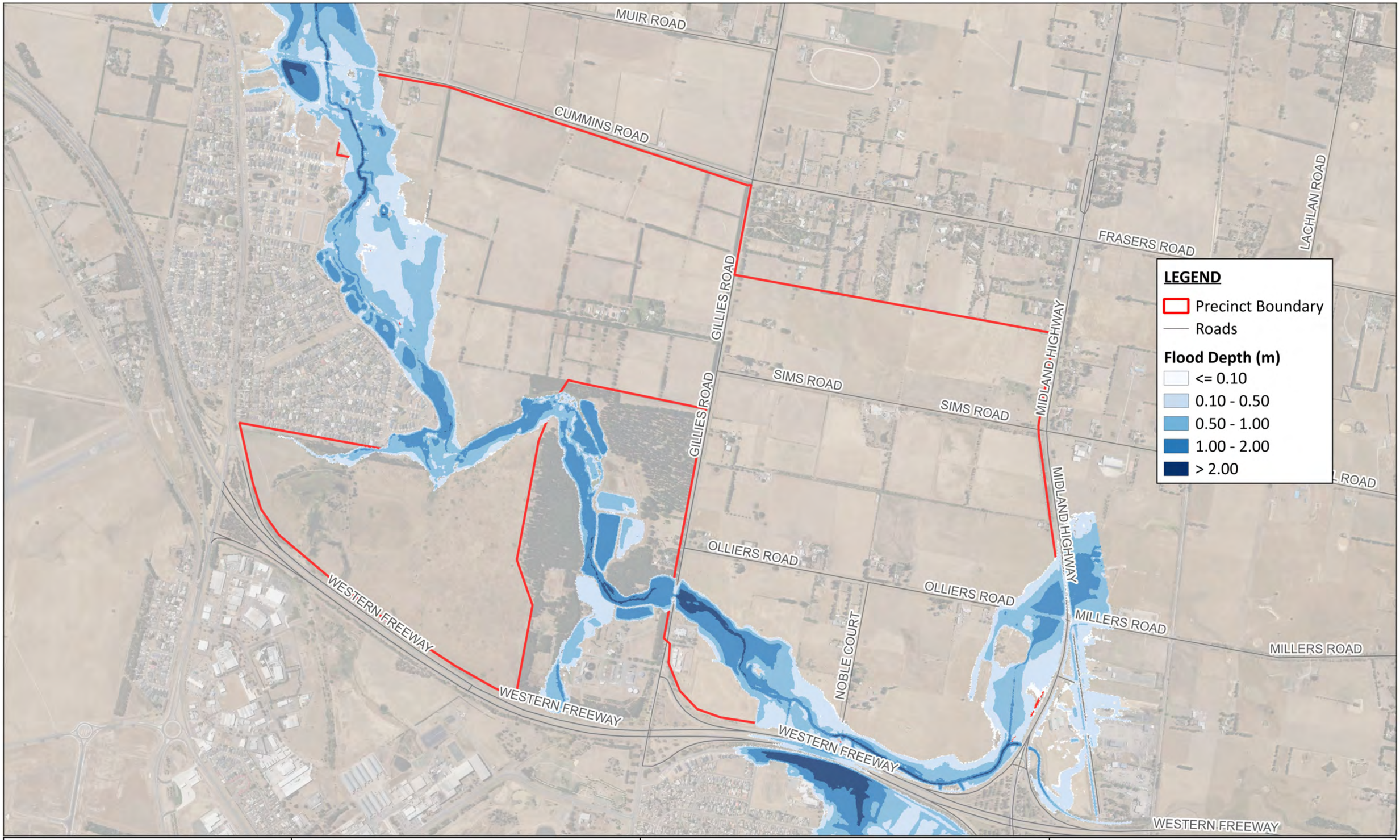
VPA/SMEC/GHCMA/CoB – Brief to GHCMA on SMEC's approach to address limitations in 2013 Burrumbeet Creek flood mapping in assumptions for Ballarat North PSP drainage strategy

Date:	*13 September 2024*	**Time:**	*11:00am – 12:00pm*
Meeting Location:	MS Teams		
Attendees:	Peter Robertson (Glenelg Hopkins CMA) Karl Velasco (SMEC) Tim Rhodes (SMEC) Hamid Ghajarnia (SMEC) Sam Brown (CoB) Mario De La Pena (CoB) Derylle Hastings (CoB)		
VPA Attendees:	Noor Syuhada Shamsul, Andrew Nguyen, Rob Marks, April Chan		
Aspects Discussed	1. Welcome and introductions		
	2. Rob provided history of discussions between VPA and GHCMA then introduced SMEC to present their approach to limitations with the 2013 Burrumbeet Creek flood mapping data.		
	3. SMEC shared GIS mapping of the results of a preliminary model that has new assumptions applied to bring the flood mapping up to date (as best as possible). SMEC noted: a. They have considered hydrology and hydraulics b. The purpose of this model was to get a sense of the variables they would get compared to the 2013 data c. This model is not a detailed product, further detail and refinement will occur to inform the PSP d. SMEC adopted 2100 timeframe and SSP8.5 climate change scenario e. Rainfall has been increase to 47% with flows up to 55% greater than 2013 data i. This was applied to a basic TUFLOW model ii. The result is less than +500mm to the water level compared to the 2013 flood mapping. f. Model is updated to recent ARR guidelines and takes climate change into consideration. g. The model is a rough indication of future flood levels and will be refined as the project progresses. i. Red outline in SMEC model shows the existing data ii. Green outline in SMEC model shows SMEC's proposed flood extents. 1. SMEC noted green outline is beyond what could be expected from climate change and is a suitable		

	'development line' to apply a buffer to account for the 2013 data limitations. h. Limited extent as they do not have data for flows from the east as Midland Hwy i. Minor tributaries and culverts not considered at this stage
	4. GHCMA supported the principles of SMEC's approached and supported these as an appropriate means to progress the PSP, subject to a document outlining SMEC's approach being provided to GHCAM for review.
	5. GHCMA noted that work is underway by CoB in Miners Rest (West of Howe St) that is also relevant, led by Vaughan Notting (CoB). Mario (CoB) noted he will follow up with Vaughan on the scope of this work and the timing.
	6. SMEC sought GHCMA advice on waterway corridor widths and noted if there's no guidance, they would adopt the MW guidelines. GHCMA emphasised the main objective of the CMA in this regard is to ensure no development in any flood prone areas. SMEC noted that if any development is proposed in these areas, SMEC will provide options and mitigations for consideration by the CMA (such as waterway manipulation, cut & fill)
Next Steps and Actions	**1. SMEC to prepare summary document outlining:** • Brief description of the limitations of the 2013 flood mapping for application in the Ballarat North PSP • Summary of the assumptions applied to SMEC's model, including: o Aspects yet to be considered in the model such as minor tributaries and culverts o Timeframes o Climate change scenario o Rainfall and flow increases o Resulting water level o ARR guidelines • SMEC's recommendation for how the approach can/should be applied for the PSP **2. GHCMA to review SMEC's document and advise VPA/SMEC whether the approach is supported by GHCMA and if suitable to progress the PSP.**
Prepared by	Robert Marks

Appendix F

Flood Impact Assessment Maps



PROJECT TITLE:	Ballarat North PSP - Functional Design	REVISION:	B	DATE:	21/07/2026
PROJECT NO:	30049251	STATUS:	FINAL	SIZE:	A3
MAP NO:	01	AUTHOR:	W.W	SOURCES:	BING
MAP TITLE:	EXISTING CONDITION FLOOD DEPTH 1% AEP (WITH CLIMATE CHANGE)	CHECKED:	K.V.	CRS:	GDA94 / MGA zone 54

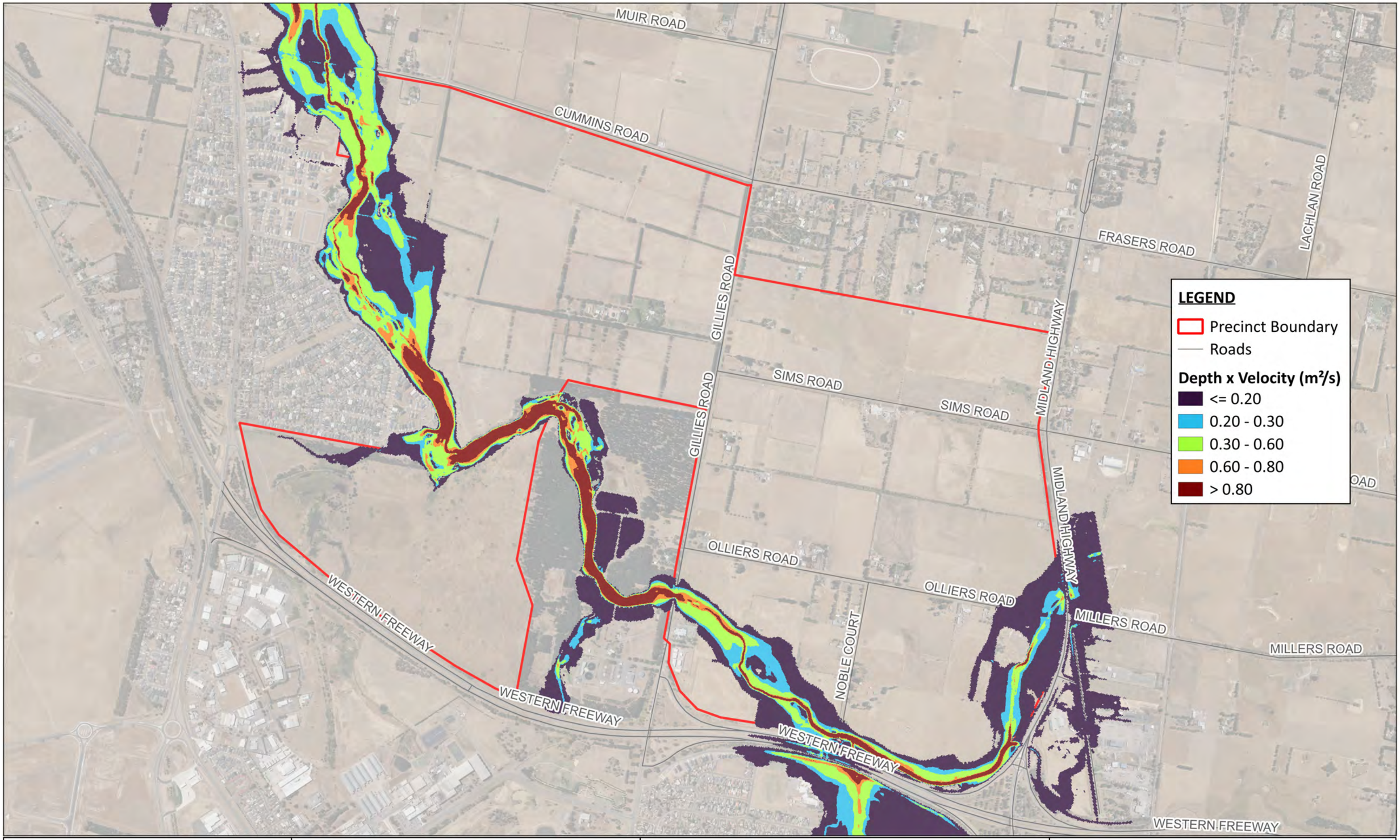
0 300 600 900 1,200 m

SCALE: 1:15,000

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Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains data from a number of sources - no warranty is given that the information contained on this is free from error or omission. Any reliance placed on such information shall be at the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.

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CONSULTANT:



PROJECT TITLE:	Ballarat North PSP - Functional Design	REVISION:	B	DATE:	21/07/2026
PROJECT NO:	30049251	STATUS:	FINAL	SIZE:	A3
MAP NO:	02	AUTHOR:	W.W	SOURCES:	BING
MAP TITLE:	EXISTING CONDITION FLOOD HAZARD 1% AEP (WITH CLIMATE CHANGE)	CHECKED:	K.V.	CRS:	GDA94 / MGA zone 54

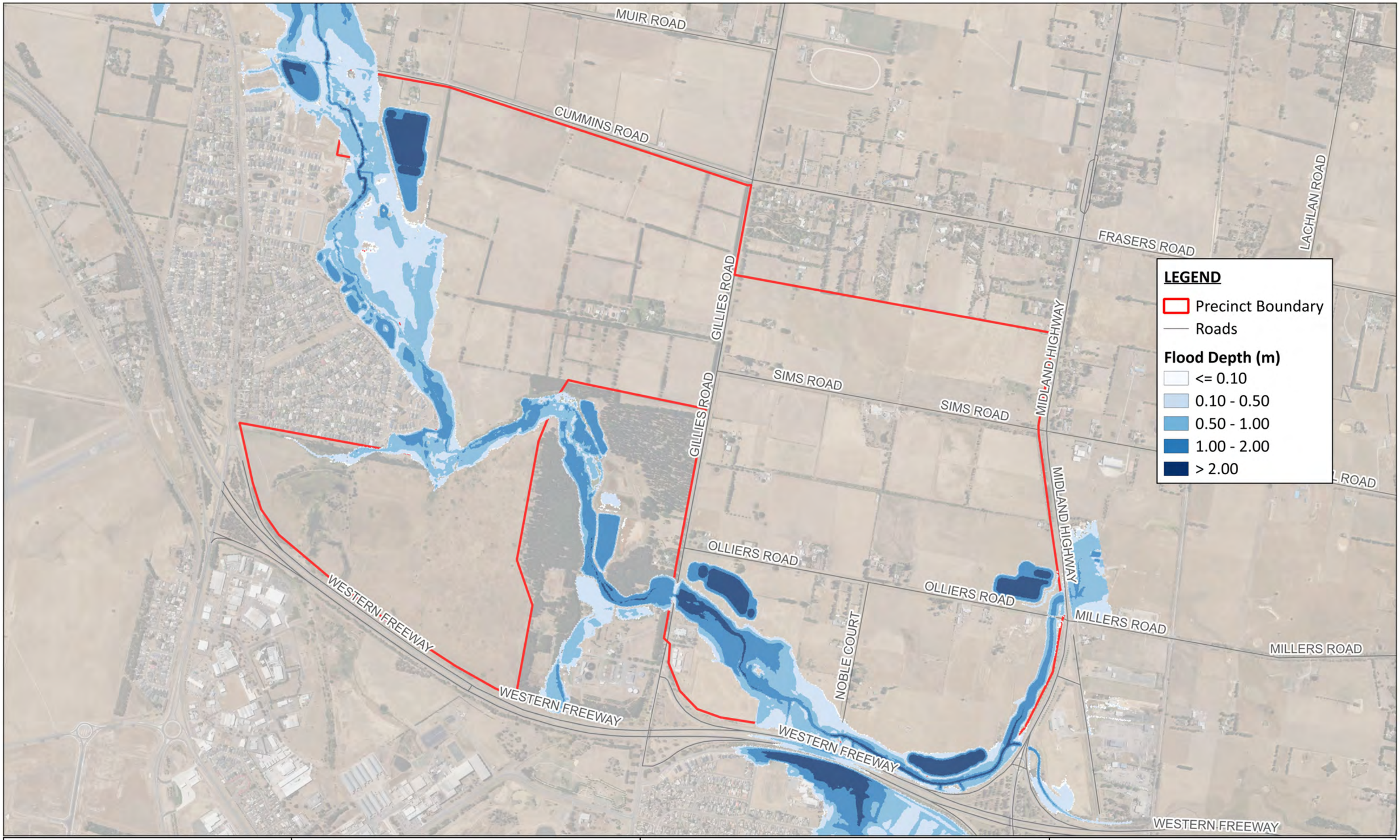
0 300 600 900 1,200 m

SCALE: 1:15,000

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CONSULTANT:



PROJECT TITLE:	Ballarat North PSP - Functional Design	REVISION:	C	DATE:	31/08/2026
PROJECT NO:	30049251	STATUS:	FINAL	SIZE:	A3
MAP NO:	03	AUTHOR:	W.W	SOURCES:	BING
MAP TITLE:	DEV. CONDITION FLOOD DEPTH 1% AEP (WITH CLIMATE CHANGE)	CHECKED:	K.V.	CRS:	GDA94 / MGA zone 54

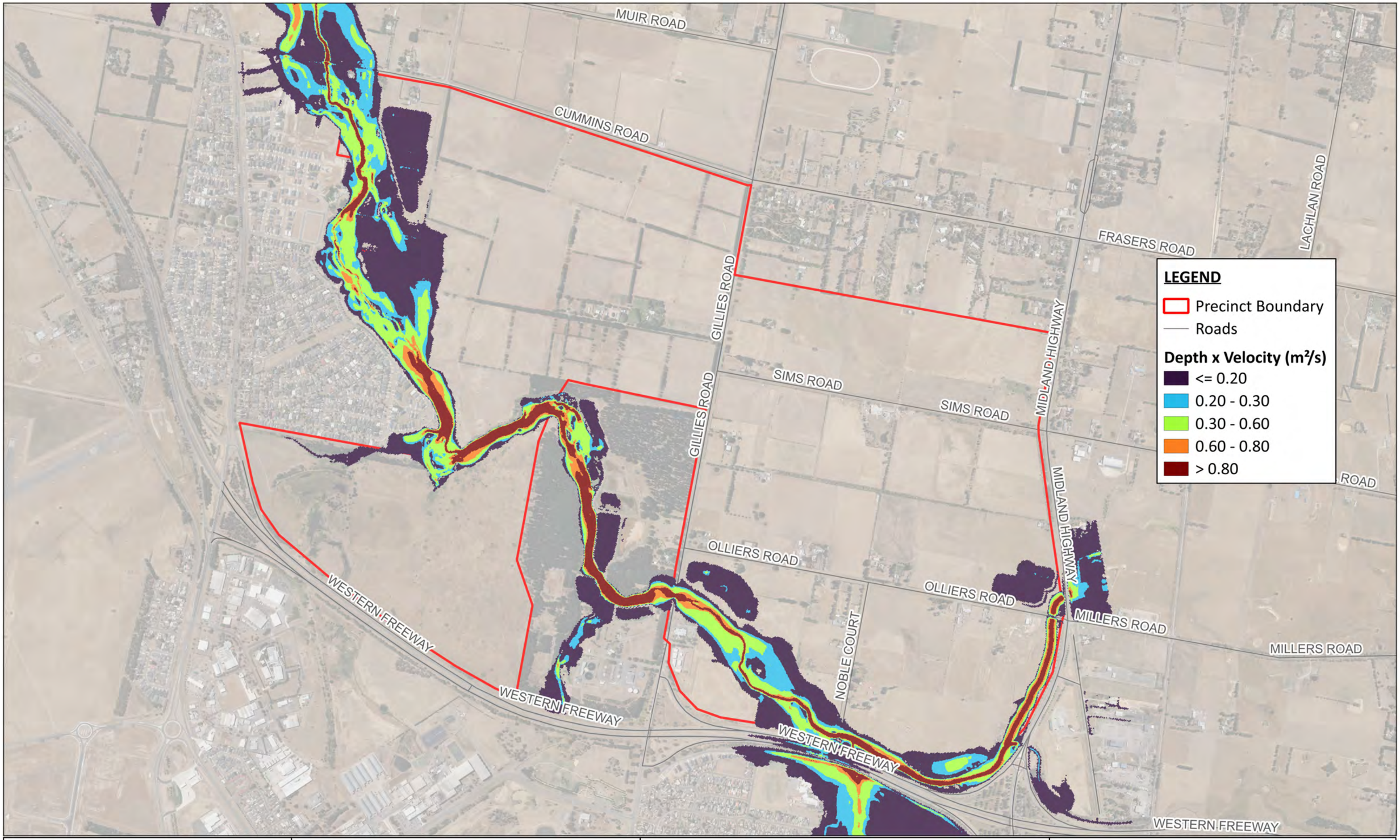
0 300 600 900 1,200 m

SCALE: 1:15,000

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PROJECT TITLE:	Ballarat North PSP - Functional Design	REVISION:	B	DATE:	31/08/2026
PROJECT NO:	30049251	STATUS:	FINAL	SIZE:	A3
MAP NO:	04	AUTHOR:	W.W	SOURCES:	BING
MAP TITLE:	DEV. CONDITION FLOOD HAZARD 1% AEP (WITH CLIMATE CHANGE)	CHECKED:	K.V.	CRS:	GDA94 / MGA zone 54

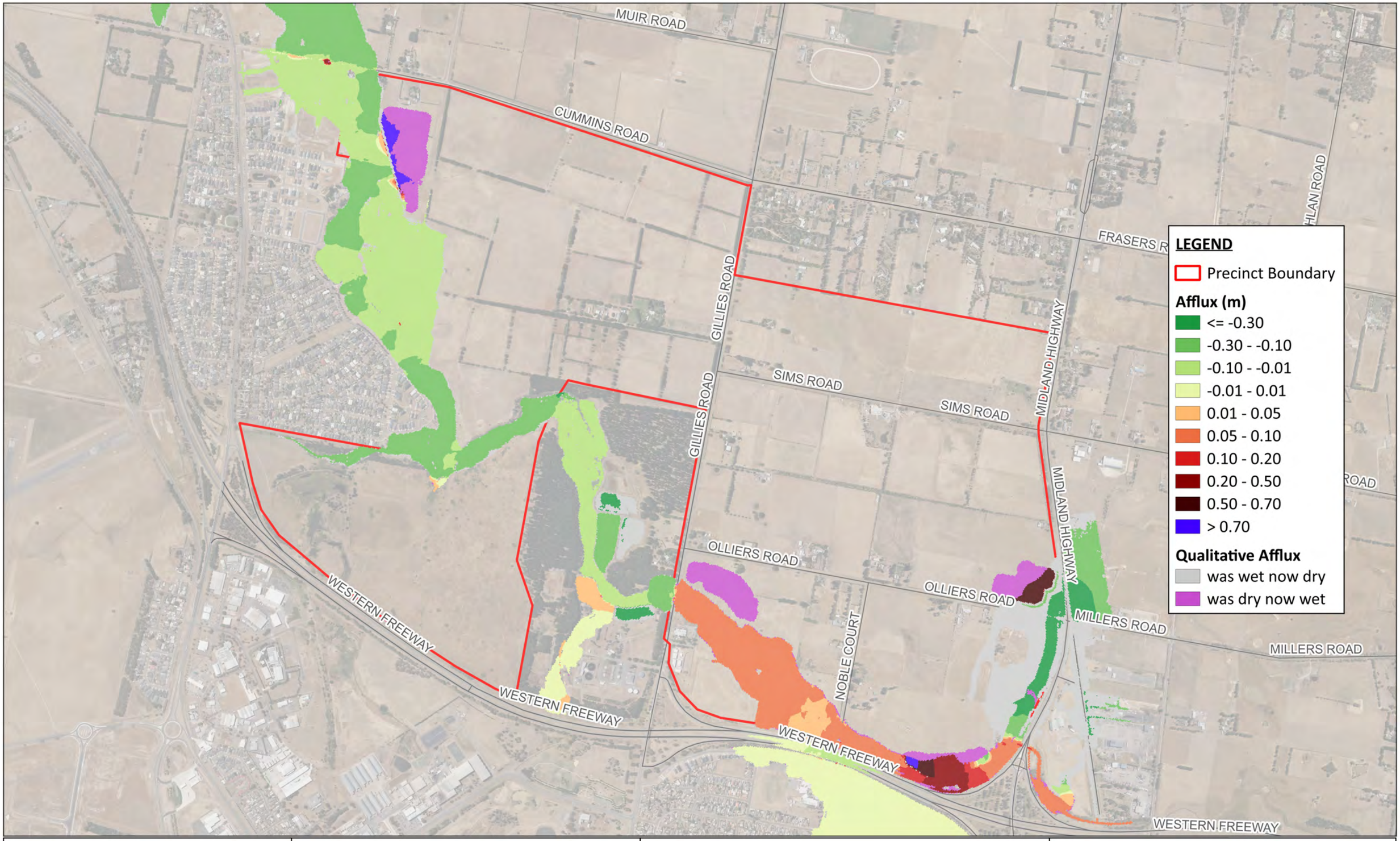
0 300 600 900 1,200 m

SCALE: 1:15,000

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PROJECT TITLE:	Ballarat North PSP - Functional Design	REVISION:	C	DATE:	31/08/2026
PROJECT NO:	30049251	STATUS:	FINAL	SIZE:	A3
MAP NO:	05	AUTHOR:	W.W	SOURCES:	BING
MAP TITLE:	FLOOD IMPACT ASSESSMENT - AFFLUX 1% AEP (WITH CLIMATE CHANGE)	CHECKED:	K.V.	CRS:	GDA94 / MGA zone 54

0 300 600 900 1,200 m

SCALE: 1:15,000

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Appendix G

Design Drawings