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Merrimu Precinct Structure Plan Water Balance and Development Options - Erosion Management | Pre-planning Advice and Risk Assessment Options for Managing Urban Stormwater

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Executive summary

This project used geomorphic, ecological, groundwater and water balance modelling to characterise the hydrology and ecology of the Merrimu plateau. Insights gained from field work and modelling were used to assess the impact of development on the geomorphology, ecology and hydrology of the plateau, to identify the risk profile of the four stormwater management options identified for the Merrimu PSP area.

The Merrimu plateau is capped by basalt soils which contain swelling clays. The plateau soils, which swell when wet, are the primary control on the volume of rainfall that infiltrates into groundwater. The basalt rock below the soils averages 10 m in depth, have high permeability and are unsaturated. Soils of the Werribee Formation underly the basalt rock. Tunnel erosion occurs adjacent incised drainage lines, and at the margin of the plateau where soils of the Werribee Formation are exposed. Drainage lines which have not exposed the underlying Werribee Formation soils are currently stable, but are highly sensitive to increases in runoff with the risk of incision (and exposure of sodic soils) increased by the steep gradient at the plateau margin. The sodic, dispersive soils and steep gradients of the Merrimu plateau mean that all stormwater management options should avoid increases in the volume of surface runoff entering waterways, compared to pre-development condition (based on average annual volumes).

Soil permeability testing and available groundwater information indicate that the contact between the basalt rock and the underlying Werribee Formation (the sodic soils) does not form a barrier to groundwater movement and infiltrating rainwater is able to percolate downwards towards the water table. The current elevation of the water table is unknown, but likely resides within the Werribee Formation.

Water balance modelling shows that under natural conditions the majority of the annual rainfall that falls on the plateau is lost to evaporation, with minor amounts contributing to runoff. The increase in impermeable surfaces associated with development will lead to increased annual runoff volumes. Increase runoff will increase the risk of erosion to soils of the Werribee Formation. The site characterisation and water balance modelling indicate that under a developed scenario, disposal of excess runoff via evaporation and infiltration would require between 10 and 16 % of the developed area to be set aside for associated stormwater management infrastructure. An estimated 1-1.5 m of additional storage depth would be required for a wet year. Off-site disposal of water via sealed pipes could be used to reduce the total volume of water to be stored on the plateau, and to mitigate the risk posed by rainwater infiltration.

The findings of this report lead to four recommendations for stormwater management on the Merrimu plateau:

1. A buffer is established to exclude stormwater infrastructure from the plateau margin and adjacent drainage lines
2. A distributed approach is adopted for the management of stormwater on the plateau
3. There is a strong focus on ecological management of Wetland A in the planning phase
4. Future stormwater management arrangements and designs are supported by appropriate evidence, including additional investigations where needed

1 Introduction

The Victorian Planning Authority (VPA) is preparing a Precinct Structure Plan (PSP) for the Merrimu precinct in consultation with the Moorabool Shire Council and other key stakeholders, including Melbourne Water. As part of the PSP process Melbourne Water require environmental investigations to inform future infrastructure, in particular the Development Services Scheme (DSS).

In 2019 Alluvium Consulting Australia (Alluvium) worked with Melbourne Water to characterise the ecology and geomorphology of the Merrimu PSP area¹. That study identified a set of unique hydrogeological issues related to highly erodible sodic soils, and the potential for severe erosion under a business-as-usual approach to stormwater management in the Merrimu PSP area.

The sensitivity of the study area to erosion, and the potential for development to impact Seasonal Herbaceous Wetlands mapped within the study area, meant that Melbourne Water required a more detailed understanding of the constraints the landscape imposes on stormwater management options. These constraints need to be identified before more detailed, spatially-explicit infrastructure planning commences.

Melbourne Water engaged the services of Alluvium to build on earlier investigations. The overarching aim of this study was to document the impacts of business-as-usual approach to stormwater management in the Merrimu PSP, to identify alternative stormwater management options to and to compare the alternative approaches to stormwater management using a risk based framework.

This report addresses the constraints identified in the Merrimu PSP area by integrating an ecological, geomorphic and groundwater assessment with an appraisal of stormwater control options. This investigation was undertaken in two parts: an impact assessment and an options assessment. The impact assessment characterises the vegetation, geomorphology and soil properties (as they relate to groundwater infiltration) to develop a conceptual model for the hydrology of the Merrimu plateau. The options assessment used the conceptual model to inform more detailed water balance modelling for the plateau, and to evaluate options for stormwater management using a risk-based framework.

Overall, this investigation consists of four complementary assessments:

1. An ecological field assessment focused on Seasonal Herbaceous Wetlands on the plateau
2. A geomorphic assessment focused on streams draining the plateau
3. A groundwater assessment that included field measurements and evaluation of Aquifer Recharge Suitability
4. A water balance model used to evaluate the impact of two development scenarios on the Merrimu Plateau

1.1 Merrimu PSP study area

The study area for this project is the part of the Merrimu precinct structure plan covered by the Merrimu plateau. The study area includes several waterways that drain the plateau, but does not include land adjacent the Werribee River, to the south (Figure 1).

The plateau is covered by the Merrimu North, O'Connell Road, Possumtail Run and Flanagans Drainage Schemes (which were interim schemes at the time of writing).²

¹ Alluvium (2019) Merrimu PSP Final Geomorphology & Vegetation Assessment, Report prepared for Melbourne Water

² <https://www.melbournewater.com.au/building-and-works/developer-guides-and-resources/drainage-schemes-and-contribution-rates/find-your#/>

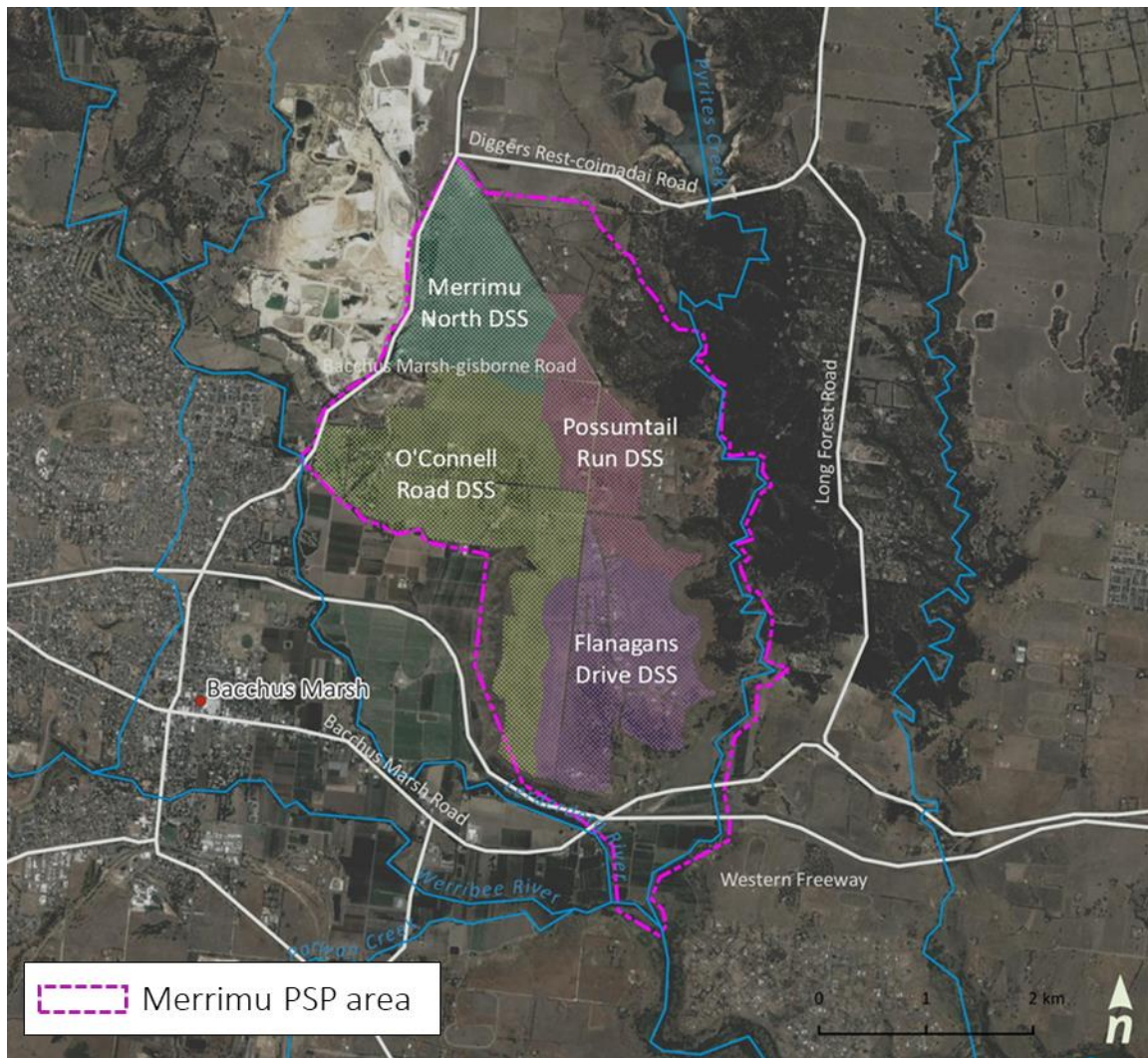


Figure 1 Study area

2 Impact assessment and option identification

2.1 Geology

Previous geomorphic assessments on the Merrimu Plateau (Alluvium, 2020), identified the potential for increased erosion in the steep headwater streams that drain the plateau, in response to the increased runoff generated by development. Soil type related to underlying geology (Figure 2) is a key driver of the potential for increased erosion in response to changes in hydrology.

The purpose of this project is to relate surface processes to the groundwater processes on the Merrimu plateau, and to assess the impact stormwater control measures may have on Seasonal Herbaceous Wetlands (SHW) on the plateau. The geomorphic assessment compliments the earlier assessments of waterways draining the plateau (Alluvium, 2020). The site visit for this project was undertaken with groundwater specialists from CDM Smith. Field observations were used to inform a conceptual model for the hydrology of the study area, which was then used to identify and evaluate stormwater management options for the Merrimu plateau.

The geomorphic assessment undertaken for the current study compliments that earlier work by:

- Assessing the upper extent of waterways that could not be accessed during the earlier investigations
- Assessing whether there was evidence for groundwater processes at the surface or within the waterways draining the plateau (such as tunnel erosion).

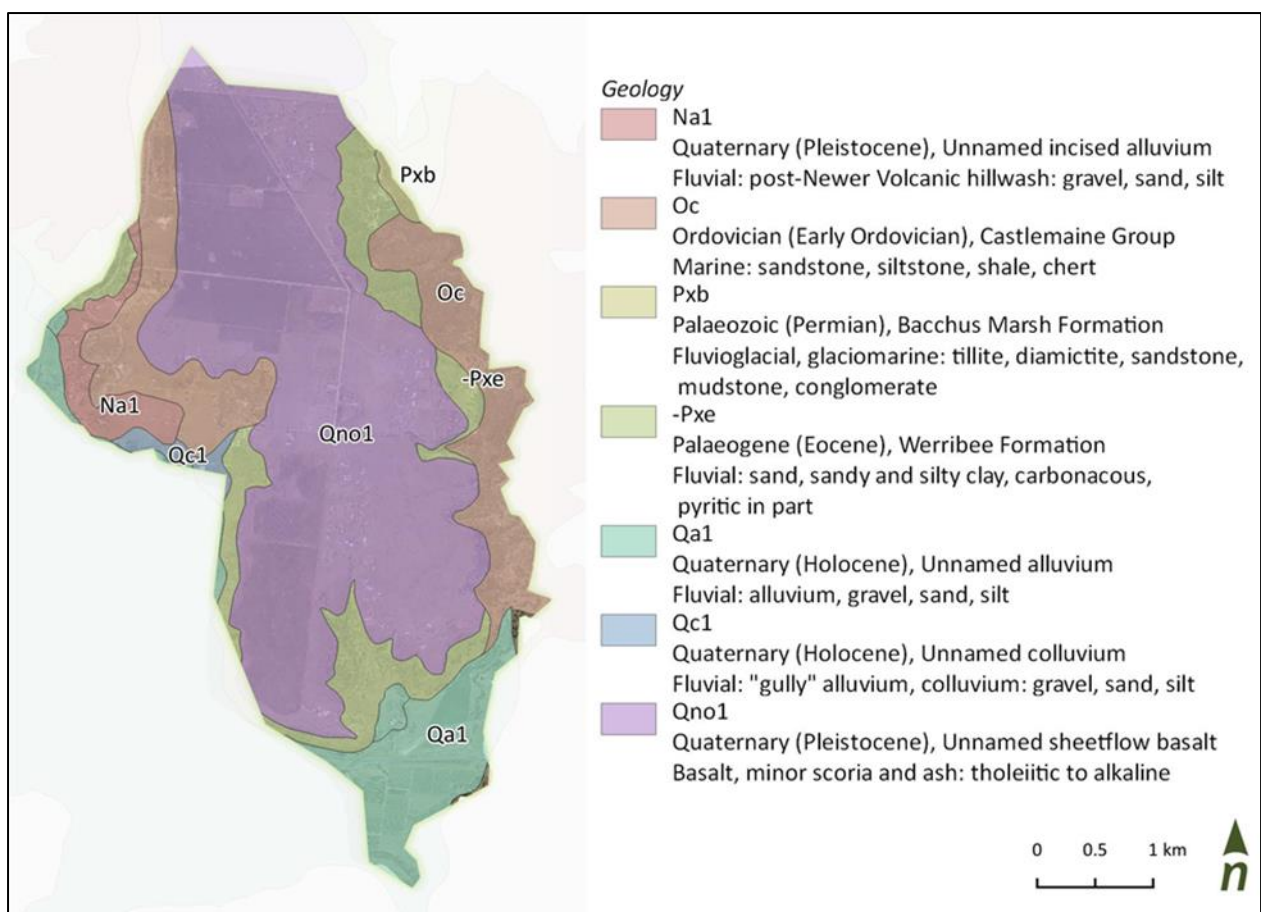


Figure 2. Geological units of the Merrimu PSP area

2.2 Topography

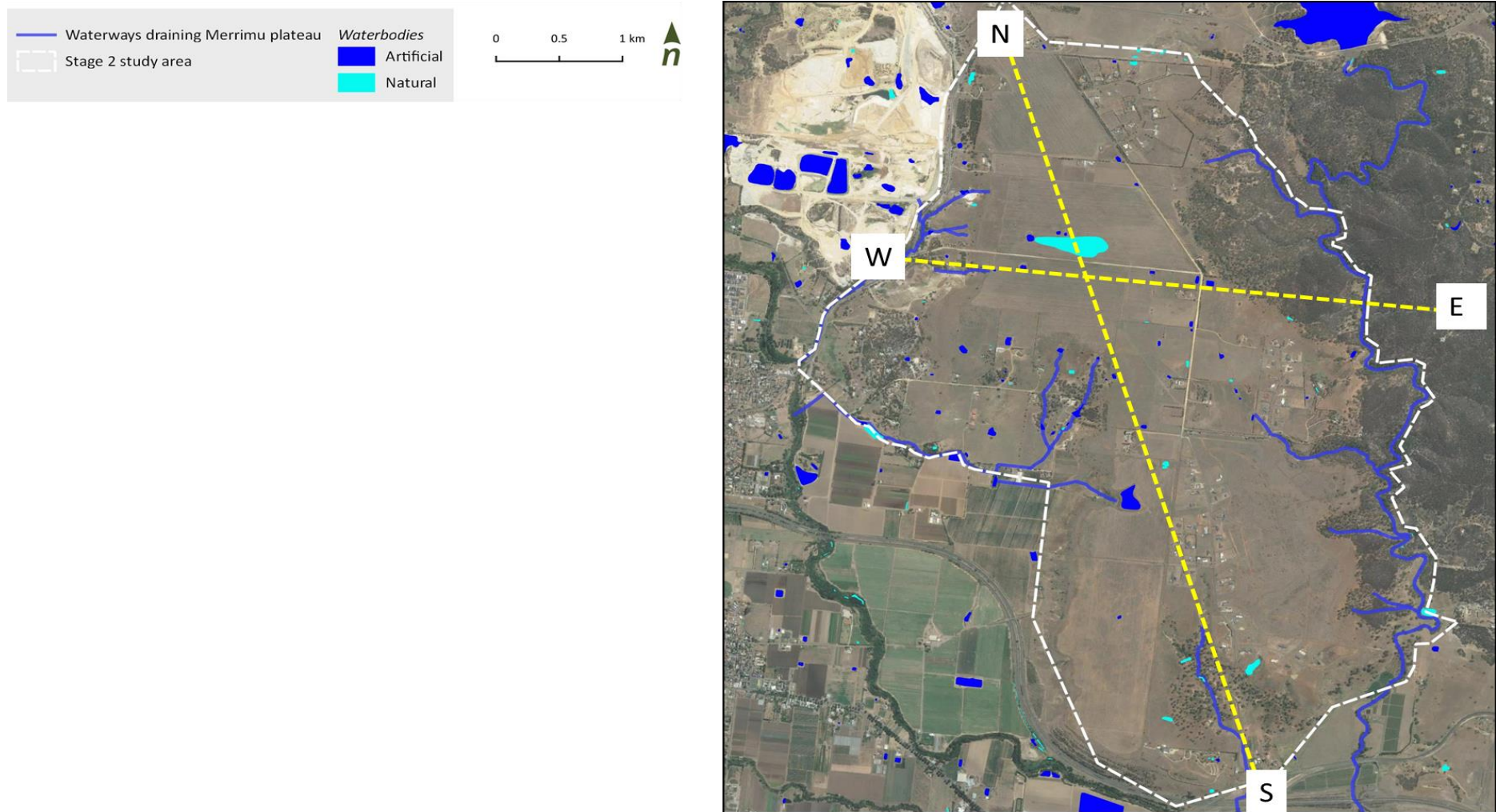


Figure 3 Map of the study area with water bodies (natural and artificial) and drainage lines shown. Dashed yellow lines are elevation profiles in Figure 4

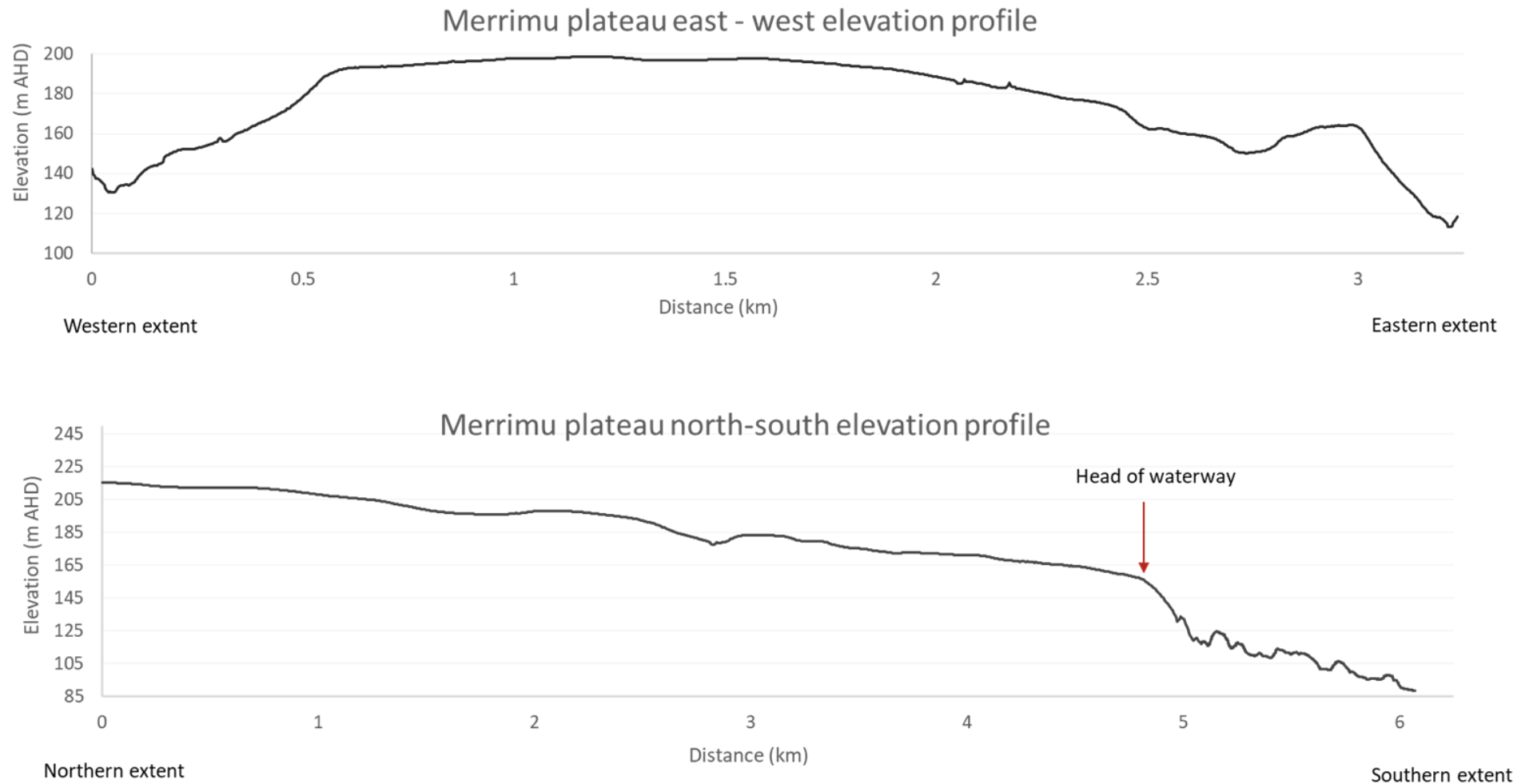


Figure 4 East-west and north-south elevation profiles of the Merrimu plateau

2.3 Geomorphology



Site characterised by gully erosion which has exposed the underlying Werribee formation (the sodic soil layer). Gully erosion is extensive along this waterway and is ongoing



The upstream parts of site two is characterised by a stable waterway with a good coverage of grasses – there are no signs of erosion. The downstream section of this waterway, is characterised by gully formation on the left bank (adjacent the former quarry) and tunnel erosion on the lower portion of the right bank



A large farm dam (that was dry at the time on the site visit) rests adjacent, and immediately up-slope from a large, terraced section of waterway. The date or purpose of the terraced works on the waterway is unknown, but is likely to have been completed as part of erosion control measures.



The upstream end of waterways at the south of the plateau are stable and well-vegetated. There were no signs of permanent, standing water in the streambed but localised sections of erosion, which have exposed Werribee formation soils, were visible in the downstream section.

2.4 Vegetation

Field assessments were undertaken with a focus EPBC listed Seasonal Herbaceous Wetlands. The objective of these assessments was to confirm locations where either SHWs occurred or had the potential to occur under the right conditions. SHWs are a form of wetland where filling of the wetland is usually supplied by local catchment rainfall. SHWs are usually not filled via regular input from an adjoining stream or waterway but are dependent on local rainfall and are intermittently filled. These wetlands have a dry and wet phase with the wet phase being visible for a relatively short period of time, i.e. often less than 9 months in any given year. They may also remain dry for several years and appear to be largely grass dominated with minimal other species diversity. These wetlands are often in a dormant phase with a combination of landscape form and sometimes sparsely distributed native vegetation being indicative of their presence in their dry phase.

The relatively wet summer of 2020/21 resulted in the identification of a number of SHW around Melbourne that had not been previously recorded. The expression of SHW at the subject site though is still dependant on local rainfall events and in this case, there was insufficient catchment rainfall for the wet phase of SHW to be expressed in the 2021 season.

It is important to identify these wetlands for a number of reasons, including:

1. Their high value biodiversity and conservation status. SHWs are federally listed and require additional approvals if any development is to impact their function.
2. Well managed stormwater can facilitate their improvement if critical elements of drying, duration of wetting and timing of wetting are carefully considered.
3. Identifying their presence early in the process of developments enables plans to progress with knowledge of their presence. This approach can reduce risk and potentially lengthy delays that can occur if they are identified some ways down the track of the development process.

Our assessment for SHW commenced with desktop analysis of suitable locations. We drew upon existing Melbourne Water data and our previous assessment of this landscape to identify potential sites (Figure 5). These areas were then visited in the field with a rapid assessment of their potential expression of SHW conducted.

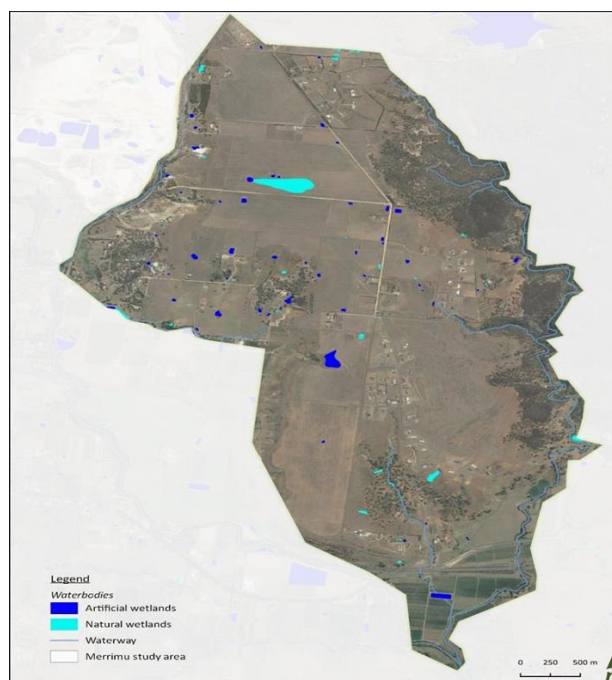


Figure 5. Sites investigated as potential Seasonal Herbaceous Wetlands

In total 7 sites were assessed in the field (Figure 6). One site was identified as having moderate potential for the expression of SHW values. All other sites where farm dams or did not have appropriate landscape attributes to comply within the definition of a SHW.

Site A. is a treeless grassy area with. Review of aerial imagery indicates that Wetland A has a history of cropping/pasture renovation and is currently grazed. The site may express vegetation characteristics consistent with Seasonal Herbaceous Wetland in wet years. Landscape characteristics and location are consistent with this vegetation type.

Site B The site is a treeless grassy area and is almost entirely dominated by Serrated Tussock. A wetland is not present, and it is assumed that this is a mapping/modelling anomaly has incorrectly designated this as a wetland.

Site C is not a natural wetland, our assessment sought to confirm if any indigenous species were present. The site has excavated edges, a clear dam wall and spoil mounds as well as a range of pipes and hoses suggesting that it formed a more permanent water body at some stage in the past.

Site D is not a natural wetland although modelling suggested it may hence our assessment to confirm features and vegetation values. The site has very steep excavated edges and spoil mounds.

Site E is not a natural wetland although modelling suggested it may hence our assessment. The site has excavated edges and functions as a temporary storage dam.

Site F is an excavated dam, it is not a natural wetland. It is at the edge of remnant woodland habitat dominated by indigenous species however this constructed dam does not have wetland vegetation or native terrestrial species.

Site G. Access was not available, so a detailed review was not conducted however review from the adjoining roadside and of aeriels indicates that this is most likely a constructed dam not a natural wetland

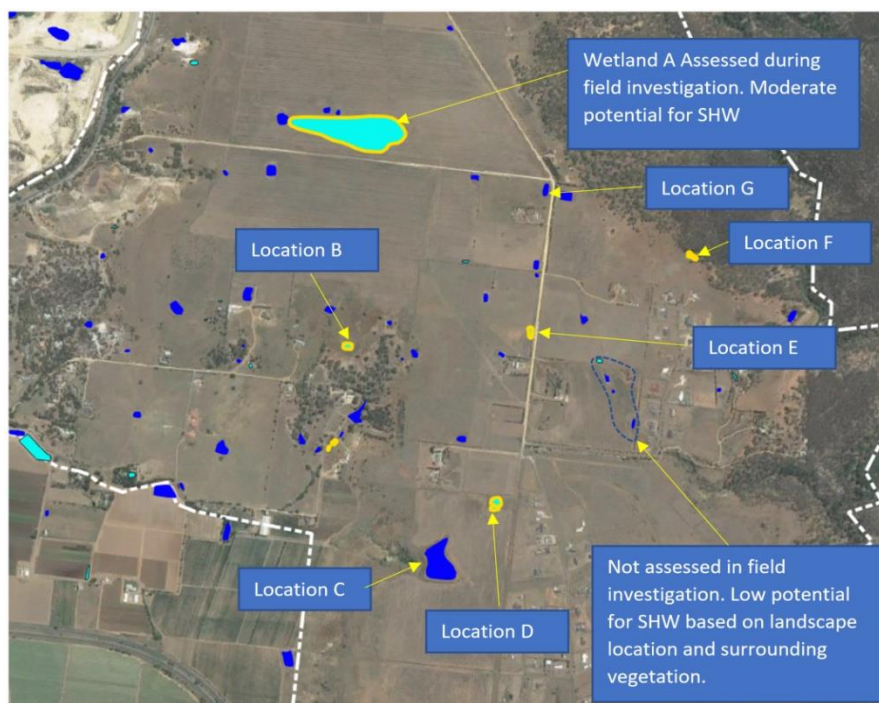


Figure 6. Location of wetlands assessed in this project.

Assessment of the plateau has identified that most wetland features are in poor condition and are generally farm dams that have been constructed over the past 10-30 years. The only potential wetland feature of interest

for its ecological attributes is Wetland A as described above. This wetland site is to be managed with appropriate consideration for its potential as a SHW. The implications of this are that it should not be planned to be developed solely as a stormwater treatment site.

A clear determination of whether Wetland A qualifies as a Seasonal Herbaceous Wetland could not be made at the time of assessment. This is because the conditions that would result in the expression of a seasonal herbaceous wetland (i.e. substantial winter rainfall) were not met prior to assessment. There was insufficient water in the landscape to trigger the development of SHW features, if indeed these values persist at the site.

A precautionary approach to the management of Wetland A would enable the sites potential for expression as a SHW while retaining the capacity for development to occur in the surrounds subject to the constraints of hydrology and groundwater identified in this assessment. Treating a portion of Wetland A as a site primarily for its ecological function does not rule out some form of stormwater harvesting and management in this area. However it constrains the duration and timing of water delivery and it presumes a sufficient level of pre-treatment will occur in order ensure that appropriate water quality requirements are met. SHW values could not be retained if typical stormwater volumes and event regimes were applied to this site. Degraded areas within Wetland A (which occur to the west) could serve as locations for primary treatment before allowing water to enter the parts of wetland A where there is potential for SHW values. The eastern portion of the site is more likely to retain some capacity for SHW expression.

Setting aside a portion of Wetland A for possible stormwater management and a portion for ecological management would be consistent with existing EPBC determination of SHW values and policy. Current determination identifies that areas of substantial disturbance may not retain SHW characteristics however areas of minimal disturbance such as cropping may still have SHW values. Partitioning the site in this way enables protection of potential values and offers some opportunity for stormwater management.

Segmenting this feature as proposed in Figure 7 will enable some design flexibility in future drainage scheme design. The east portion of Wetland A would be managed primarily for ecological purposes and become the responsibility of the appropriate local or state agency. Protection of this portion of Wetland A is consistent with broader objectives of the HWS that seeks to protect and retain a diverse range important ecological features in the landscape.

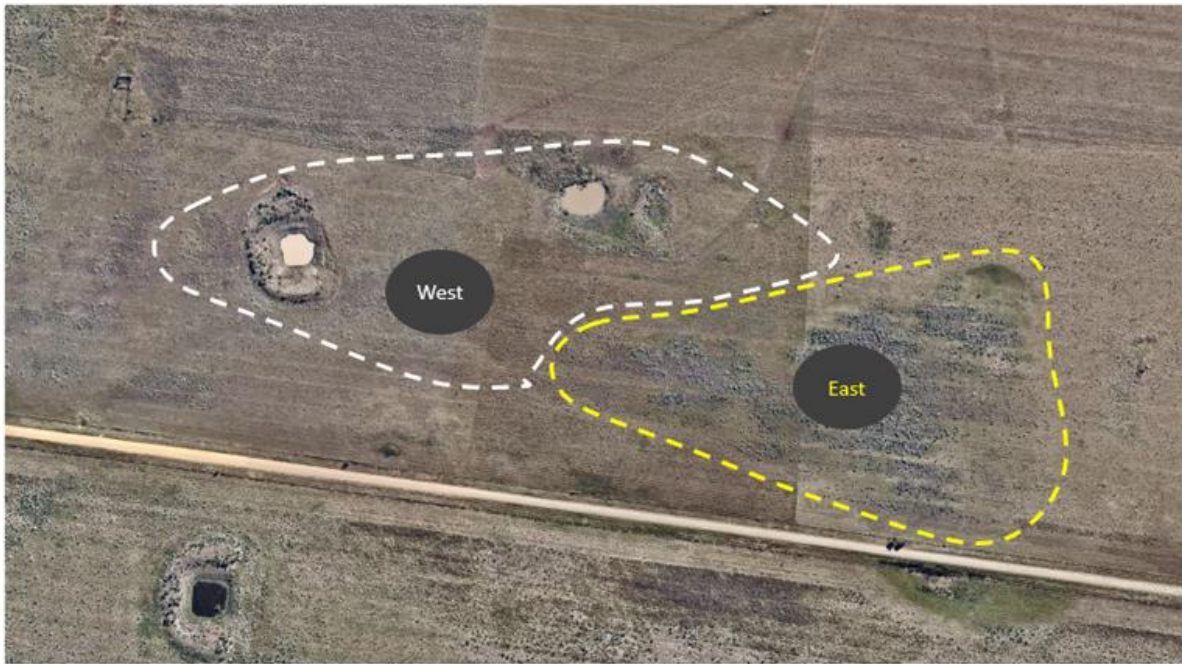


Figure 7. Indicative disturbance extent within Wetland A. All parts of this site have had soil disturbance to some degree. The western portion has been cropped and had substantial earthworks as a result of the construction of dams, while the eastern portion has been cropped but not had the extent of earthworks disturbance observed in the western portion.

It should be noted the segmentation of wetland A as indicative above will require further field verification to inform design. The extent of disturbance via extensive re-working of the soil profile by large machinery is a key driver.

2.5 Groundwater

In addition to background investigations and field observations, CDM Smith has undertaken a series of infiltration tests across the plateau and at the margins. The purpose of the tests was to:

- Quantify the permeability of the basalt soils that cap the plateau. The basalt soils are the overall control on the volume of rainfall that infiltrates to become groundwater.
- Quantify the permeability of the Werribee formation, which is exposed at the plateau margin and underlies the basalt. The permeability of these soils, which are sodic and prone to dispersion, is an important control on the tendency for water to percolate downwards into deeper aquifers or to accumulate at the basalt rock contact above.

Overall, the testing found that the dry and undisturbed basalt soils varied in permeability. In sections where shrinking clays in the soils had contracted (i.e. the soil was very dry) cracks formed and infiltration was very rapid. CDM Smith also note that the permeability of the basalt soils on top of the plateau decreases significantly when they are distributed, or when they become saturated (and the swelling clays expand) (Figure 8).

The testing also found that Werribee formation soils exposed on the eastern edge of the plateau varied in permeability but were overall highly permeable. No swelling clays are present within the Werribee formation. The geochemical properties of both soils are described in more detail in Attachment C.

The major implication of the soil testing is that once water infiltrates through the overlying basalt soils, it will likely continue to percolate downwards: the Werribee formation does not act as a barrier to groundwater movement.

The findings from the soil testing were used to inform the development of a conceptual model for the hydrology of the study area, and to guide the CDM Smith's assessment of the suitability of the Werribee formation for aquifer storage and recovery (ASR).

Background investigations, ASR evaluation, detailed soil testing results and a summary of aquifer properties beneath the plateau are available in the CDM Smith report (Attachment C)

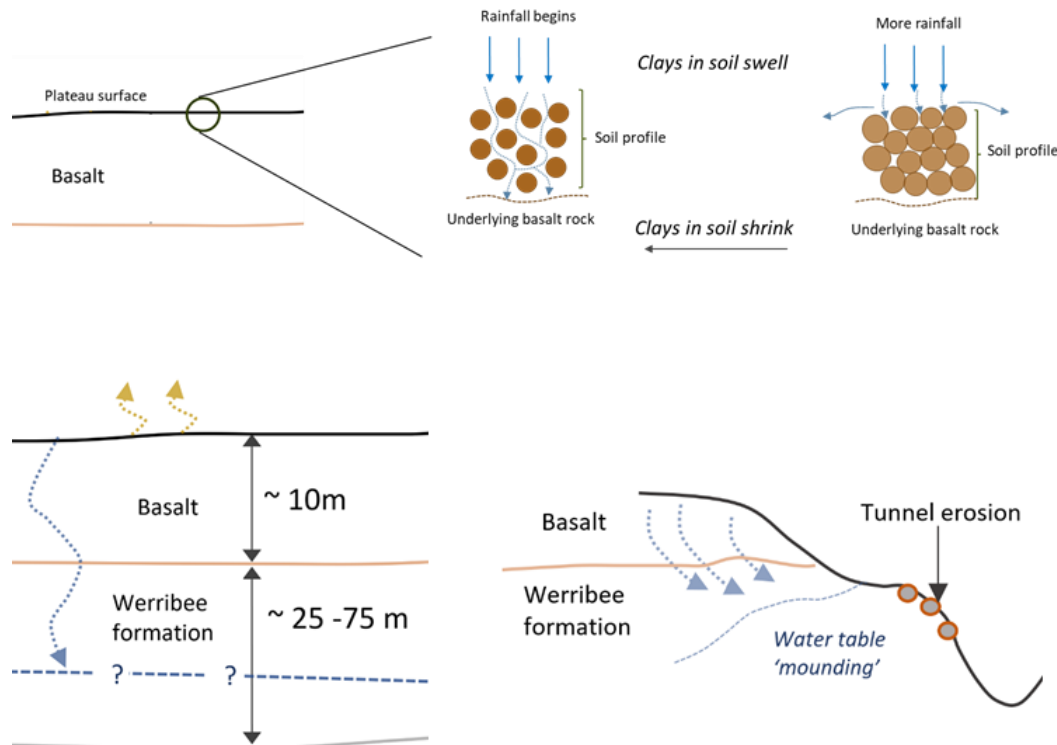


Figure 8. Soil and geological properties of the Merrimu Plateau and their influence on infiltration and groundwater movement

2.6 Water Balance modelling

The purpose of the water balance model was to establish the existing condition water balance and boundaries for stormwater runoff management at the study site. The assumptions behind the water balance model, the development scenarios that were modelled as well as the stormwater runoff mitigation approaches are outlined in Attachment D.

Unmitigated and BAU approaches

The results for a 1 ha catchment show that evapotranspiration is the dominant flux in the pre-developed condition (97%) with baseflow and surface runoff forming a small proportion of the water balance (Table 1). In the developed scenario 1 and 2 (unmitigated and BAU), evapotranspiration reduces significantly as does baseflow. The result is a significant increase in annual surface runoff – an increase of 2.6 ML/ha in the unmitigated developed scenario 1 and an increase of 1.5 ML/ha in the unmitigated developed scenario 2. The BAU scenario – which has been assumed to be an end-of-pipe approach to stormwater management in the form of a constructed wetland retarding basin system at the bottom of the catchment - has a small beneficial effect in reducing runoff volume compared to the unmitigated scenario (Table 1). It is recommended that a calibration of the model rainfall-runoff parameters is undertaken in the future to refine the estimation of pre-development surface runoff and baseflow.

Table 1 Water balance for pre-development and development scenarios (Little River MUSIC rainfall dataset)

	Pre-developed		Developed scenario 1 15 lots/ha Unmitigated		Developed scenario 1 15 lots/ha BAU		Developed scenario 2 8 lots/ha Unmitigated		Developed scenario 2 8 lots/ha BAU	
	ML/yr	%	(ML/yr)	%	(ML/yr)	%	(ML/yr)	%	(ML/yr)	%
Annual Evapo-transpiration	4.6	97	2.1	45	2.4	50	3.2	67	3.3	70
Annual baseflow	0.13	3	0.04	1	0.04	1	0.08	2	0.08	2
Annual surface runoff	0.0	0	2.6	55	2.3	49	1.5	31	1.3	28

2.7 Conceptual model of hydrology on the Merrimu Plateau

We have used previous studies on the plateau, observations and insights gained during field inspections and the groundwater expertise of CDM Smith to build a conceptual model for hydrology of the Merrimu plateau (Figure 9). The conceptual model shows the primary pathways of rainwater once it falls on the plateau and was used to guide the identification and appraisal of stormwater control options at the study site. The key elements to the conceptual model are:

Soils and rainwater infiltration

- The plateau is capped by basalt soils that are highly permeable (allow high infiltration rates) when dry but have very low permeability when disturbed or when wet (causing very low infiltration rates). This suggests that water is generally able to infiltrate through the surface soils and into the underlying basalt during shorter-duration rain events, but that surface runoff (which is also controlled by topography) is more likely during longer-duration rainfall events.
- Basalt rock beneath the soils is 8-10m thick across most of the plateau and is completely dry. Water infiltrating into the basalt continues downwards towards the Werribee formation aquifer below.
- The Werribee formation aquifer varies between in thickness between 25 m and 75 m across the plateau, being thicker at the southern end and thinning towards the north and east. The Werribee formation is highly permeable and does not prevent water from percolating downwards. The contact between the basalt rock and the Werribee formation does not act as a barrier to infiltration.

Water table elevation and erosion at the plateau margin

- There is little evidence for the water table intersecting the plateau margin. The exception is a permanently saturated wetland on the eastern margin, but this area is an anomaly and is likely a highly-localised issue.
- The presence of the single wetland, and instances of localised tunnel erosion within the Werribee formation soils adjacent incised waterways, suggests that the plateau margins are especially sensitive to erosion, and increases in infiltration in these areas is concentrated at towards the surface – which promotes erosion.
- The water table will fluctuate seasonally but likely rests within the Werribee formation. The exact depth of the water table is unknown (but can be determined by drilling a deeper borehole).
- Erosion at the plateau margin is generally restricted to areas where the sodic soils of the Werribee formation have been exposed. The permeable nature of these soils (which allows rapid infiltration) suggests that most of the gully erosion observed is a *surface process* driven by *runoff*, not a sub-surface process caused by tunnel erosion from groundwater. However, over the long term, tunnel erosion may make areas more susceptible to collapse, and therefore future surface runoff and erosion.
- Tunnel erosion that was observed is restricted to the area adjacent incised waterways, where the infiltration is concentrated as it runs along the steep gradient towards the stream.

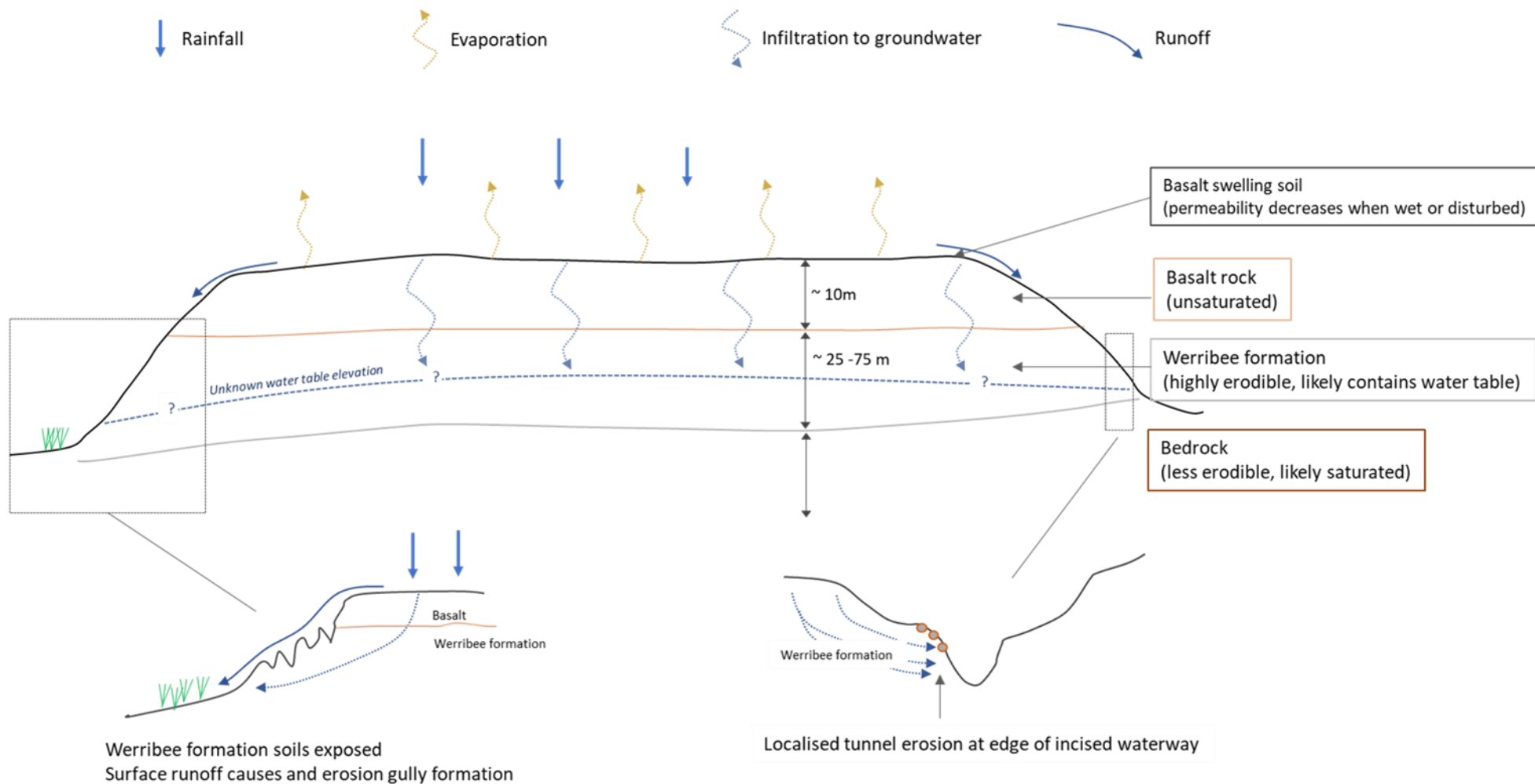


Figure 9. Conceptual model of hydrology on the Merrimu Plateau

2.8 Impact assessment conclusions

The impact assessment undertaken for this study has characterised the geomorphology, ecology, groundwater system and the natural water balance for the Merrimu plateau. The sensitivity of drainage lines, especially where those drainage lines have exposed the underlying Werribee formation soils (which are sodic and highly dispersive) means that no additional runoff should be delivered to tributaries draining the plateau.

This conclusion leads us to identify three options for stormwater management on the Merrimu plateau:

1. Infiltration
2. Evaporation
3. Piping and off-site disposal
4. Aquifer storage and recovery

We also note that at the time of reporting that the EPBC vegetation reporting process has determined that development of the Merrimu Plateau is to be a controlled action, with the assessment approach still to be advised. Further information has been requested of the applicant (at the time of writing it is unclear what information is being sought). The ecological assessment undertaken a part of this study may contribute to the information being sought, but was not undertaken with this specific purpose in mind.

3 Options assessment

3.1 Identified treatment options

The impact assessment has identified four stormwater treatment options for the Merrimu plateau:

1. Infiltration
2. Evaporation
3. Piping and off-site disposal
4. Aquifer storage and recovery

Each of the four potential stormwater treatment options have been assessed in more detail. The more detailed assessment quantifies the land take requirements (and likely costs) of infrastructure needed for the business as usual, infiltration, evaporation and piping and off-site disposal options. Aquifer storage and recovery has been identified as a possible option, but more detailed investigations are needed to assess the feasibility and costs of this option. The constraints imposed by the landscape on each of the stormwater treatment options are summarised below, and the risk posed by each management option is compared using a risk matrix.

3.2 Infiltration and evaporation/evapotranspiration assessment

The MUSIC modelling shows that an evaporation, evapotranspiration, or infiltration approach alone would generally require a storage footprint of between 2,550 to 3,100 m² (Table 2) – in other words 25.5 % to 31 % of the overall development area - to avoid increase in surface runoff volume entering waterway compared to pre-development condition (based on average annual volume). Combined approaches can reduce the footprint to 1,375 to 1,600 m² for developed scenario 1 (or between 10 and 16% of the overall development area). However, as the footprint reduces the additional storage depth required to manage excess runoff volume in a wet year increases. For developed scenario 2, the storage footprint requirement to manage excess runoff volume on a long-term basis is less than developed scenario 1. However, the additional storage depth required to manage excess runoff volume in a wet year is higher.

Table 2 Storage requirements for 1 ha development site to avoid increase in surface runoff volume entering waterway compared to pre-development condition

Approach	Development scenario 1	Development scenario 2	Development scenario 1	Development scenario 2
	15 lots/ha	8 lots/ha	15 lots/ha	8 lots/ha
	Storage footprint (m ²) required (assume 1.0 m deep)		Additional storage depth (m) required for wet year	
Evaporation approach (e.g. centralised evaporation basins)	2,550	1,500	0.75	0.97
Evapo-transpiration approach (e.g. stormwater harvesting for irrigation of land distributed through the catchment)	3,100	1,850	0.63	0.78
Infiltration approach (e.g. sub-surface infiltration systems distributed throughout the catchment)	2,950	1,750	0.66	0.84
Combined evapo-transpiration and infiltration approach (e.g. centralised vegetated infiltration basins and/or distributed measures for passive irrigation/infiltration)	1,600	950	1.13	1.45
Combined evapo-transpiration and infiltration approach with lot-scale indoor rainwater use.	1,375	825	1.19	1.53

3.3 Constraints on infiltration, evaporation and aquifer storage and recovery as stormwater management options

The approach to stormwater management adopted is likely to utilise some combination of the options identified above (e.g. centralised and distributed infiltration and evaporation/evapo-transpiration approaches) as well as aquifer storage and recovery) and possibly off-site disposal via a sealed pipe. With regards to infiltration and evaporation/evapotranspiration approaches, the layout and conceptual design of the assets should be undertaken once a preferred approach to managing excess runoff is determined. The preferred approach will need to factor risks, costs and benefits of a centralised versus distributed approach (or a combination of both) whilst also considering approach for meeting precinct scale stormwater quality requirements (e.g. to meet BPEM targets) and flow retardation requirements for major storm events (e.g. 1% AEP). However, this study has identified the constraints the landscape and vegetation communities of the Merrimu plateau place on the approach to stormwater management and has provided indicative asset footprint/storage requirements on a unit catchment basis and risks analysis to assist in the selection of a preferred approach. The constraints are:

- **High susceptibility to erosion at the escarpment margins and adjacent drainage lines.** Rainwater that infiltrates the surface moves down slope and towards the exposed edge of the steep escarpment or stream bank, where it concentrates and can triggers either tunnel erosion, or an increase in streamflow that may trigger or exacerbate erosion by surface flows.
- **Concentrated infiltration.** Development of the plateau decreases the total surface area available for stormwater infiltration. Concentrating infiltration at ponds, wetlands and in drains beside roadways has the potential to cause 'mounding' of the water table. Mounding occurs when the downward flow of groundwater from the surface out-paces the flow of water to deeper parts of the aquifer, generating a 'hump' in the water table. Mounding of the water table is of most concern near the plateau margins, where it may express at the surface and cause erosion (see above). Groundwater mounding can trigger tunnel erosion, expand and then trigger slumping and gully formation.
- **Potential SHW.** Wetland A is to be managed for its potential as a Seasonal Herbaceous Wetland. Design considerations are to place ecological values as a priority, stormwater design needs to put in place appropriate wetting and drying regimes that support the development of SHW values. Standard stormwater treatment wetlands can be located at any of the other sites assessed as long as they take into account other constraints listed here.
- **Waterway sensitivity to erosion by surface flows.** The sensitivity of waterways draining the plateau to erosion by surface flows (especially where Werribee formation soils are exposed) means that stormwater control measures should not lead to an increase in the volume of runoff entering those waterways compared to pre-development condition. More detailed, event-specific investigations are needed to determine the volume of runoff generated during events of different size, and the storage capacity or disposal capacity needed to prevent additional runoff entering waterways during such events.

In addition to the constraints outlined above, several elements of the hydrological system are unknown. This includes groundwater flow paths between the Plateau and the aquifers on the adjacent Werribee plains (which are used for food production) and the shear resistance that waterways that may receive from additional flows (delivered via a sealed pipe). An important unknown common to all stormwater management options is the willingness of local council to take on and then manage some of the associated infrastructure, especially when this infrastructure may be configured in novel ways (i.e. ASR, or a distributed infiltration system). Investigations needed to address these unknowns for each of the stormwater management options are outlined in Table 3.

Table 3 Further investigations needed to determine the most suitable stormwater management option (or combination of options) in the study area.

Stormwater management option	Unknowns
Storage requirements	The required volume of stormwater storage and its likely footprint on the plateau has been estimated based on annual rainfall volumes for rainfall events over a 10-year time series as well as for a wet year. The storage volume required during a major storm event (i.e. 1% AEP) to meet the same objective of no increase in runoff to the waterways needs to be estimated.
Infiltration	The potential for mounding of the water table is controlled by the initial elevation of the water table, which is unknown. Investigations (boreholes and groundwater modelling) are needed to establish the current elevation of the water table beneath the plateau.
Aquifer storage and recovery (ASR)	The likely elevation of the water table following injection of stormwater is controlled by the initial elevation of the water table, which is currently unknown. Investigations (boreholes and groundwater modelling) are needed to establish the current elevation of the water table beneath the plateau. This study has identified that the Werribee aquifer has the potential to store groundwater that can later be extracted. The feasibility of injecting, and then later extracting, groundwater from the Werribee aquifer needs to be assessed in more detail.

3.4 Off-site disposal options and constraints

Off-site disposal of stormwater avoids the potential for groundwater mounding and tunnel erosion that can arise from increased stormwater infiltration, prevents excess runoff being delivered to sensitive tributaries draining the plateau, and reduces the total volume of storage required on the plateau surface. The primary constraints on the use of off-site storage are:

- The need for off-site disposal pathways to be sealed pipes (which increases costs) to avoid disturbing sensitive soils on the plateau or its margin. A combination of sealed pipe across the escarpment edge, and an open cut trench/waterway between the toe of the escarpment and the nearest suitable waterway may be possible, and would likely reduce total costs compared to a sealed pipe for the entire distance between escarpment edge and the receiving waterway.
- The pipe draining stormwater from the plateau would need to be of sufficient capacity to convey the volume of water generated during a 100 year event (that is, the excess volume of water assuming no additional surface flows are delivered to the tributaries draining the plateau).
- Alternatively, the pipe could be of lower capacity but would need to be complemented by storage on the plateau surface (the extent and depth of which is identified as part of water balance modelling completed for this project) so that no additional water is delivered to the tributaries in events up to and including the 1% AEP.
- That the pipe outlet would need to discharge to a stable waterway. The capacity of receiving waterways to accommodate the discharge from the pipe without triggering erosion or adverse water quality or river health outcomes would need to be investigated.
- At the western edge of the plateau, larger, stable waterways that are better able to accommodate additional from the Merrimu plateau (the Lerderderg and Werribee Rivers) are 1 – 2 km from the toe of escarpment. At the east of the plateau, Pyrites Creek (which has been assessed as having a low sensitivity to geomorphic change) abuts the toe of the escarpment.

Given these constraints, infiltration and evaporation may be used in combination with disposal via a sealed pipe for some portion of the Plateaus four drainage schemes. Off-site disposal is not limited to stable waterways alone, and sealed pipes that avoid damaging the sensitive escarpment edge could discharge to infiltration/evaporation basins on the flat land between the plateau escarpment and the larger waterways to the south and west.



3.5 Stormwater options required interventions

Table 4 Land take requirements and indicative costs for infiltration, evaporation and piping with off-site disposal stormwater treatment options for the Merrimu Plateau³

Approach	Required investment - measures		Capital costs (assuming centralised assets)	
	Treatment area requirement			
	8 lots/Ha (m ²)	15 lots/Ha (m ²)	8 lots/Ha	15 lots/Ha
Wetland retarding basin (Business-As-Usual)	140 m ²	240 m ²	\$29,400	\$50,400
Centralised evaporation basins	1,500 m ²	2,550 m ²	\$180,000	\$306,000
Centralised (vegetated) infiltration basins	950 m ²	1,600 m ²	\$142,500	\$240,000
Development Piping and off-site disposal	Number and length of pipes used to deliver water from the plateau to suitable waterways will depend on how assets are configured on the plateau. Assume that escarpment face must be piped as a minimum, and that the slope face length varies between 150-400 m around the plateau.		\$12, 150/linear m \$1,825,000 – \$4,860,000 per pipe	
	Assumes a 900mm HDPE pipe, HDD			
Aquifer storage and recovery	Large – maximum of 10-16 % of developed area for runoff capture an temporary storage before injection		Not assessed – additional information required	

³ Costs should be considered indicative only. Wetland retarding basin cost rate is \$210/m² based on rate in Water sensitive urban design Life cycle costing data Melbourne Water (2013) allowing for cost adjustment to present day value (2021) with additional allowance of \$80/m² for land acquisition and \$40/m² for excavation for retarding basin storage requirements. An indicative cost rate of \$120/m² has been assumed for centralised evaporation basin and \$150/m² for centralised infiltration basin.

3.6 Stormwater options risk assessment

An assessment of the risk posed by each of the stormwater management options identified in this project was completed. The risk analysis assumes that no existing controls are in place (as the Merrimu Plateau is not yet developed).

The risk assessment implicitly considers how both groundwater and surface water processes, which may be altered by the different stormwater treatment options, contribute to risks to groundwater quality, surface water quality, geomorphic condition and riparian flora. The risk assessment uses Melbourne Water's risk management process, which follows the principles defined in the AS/NZS ISO31000:2009 Risk Management: Principles and Guidelines. We have extended the definition of environmental consequences to distinguish between local impacts (which are confined to the Merrimu Plateau) and off-site impacts. This spatial element to the consequences rating captures the changes in surface water or groundwater processes may have little impact on the Merrimu Plateau, but can have a much greater impact on values in downstream areas.

Each risk factor corresponds to an 'event' and the risk assessment considers the likelihood of the event occurring, and the consequences of that event occurring, for each of the stormwater treatment options. The events for each risk factor are:

- Surface water quality: Deterioration of surface water quality, in tributaries draining the Merrimu Plateau or in downstream waterways receiving flows from the Merrimu Plateau catchment, to the extent that the Healthy Waterway Strategy objectives for the Werribee catchment region are much less likely to be achieved.
- Groundwater quality: Deterioration in the quality of groundwater stored beneath the plateau or in surrounding aquifers recharged by the Merrimu plateau to the extent that groundwater either becomes unusable for current uses or requires significant additional treatment before use.
- Geomorphic condition: Severe and sustained erosion of waterways draining the plateau, on gullies on the escarpment edge that feed waterways, or on downstream waterways that receive flows from the Merrimu Plateau catchment. The visual amenity of waterways is decreased, habitat values are compromised, and waterway instabilities are ongoing.
- Riparian flora: Partial or complete loss of riparian vegetation adjacent waterways and wetlands so that habitat, amenity and geomorphic values are also undermined.

Outcomes of the risk assessment are presented in Table 5. Further detail describing the likelihood and consequence ratings assigned to each risk factor, for each treatment option are outlined in Attachment E.

The stormwater treatment options change the likelihood of adverse impacts eventuating (the various 'events') but do not alter the consequences of those impacts. Overall, the highest risk treatment options are a business as usual approach to stormwater management and aquifer storage and recovery. Infiltration, evaporation and off-site disposal via a sealed pipe have a low to medium risk rating.

Table 5 Risk matrix for stormwater management options identified for the Merrimu plateau

Stormwater treatment option	Groundwater quality	Waterways			Maximum risk category	Asset Management Planning Comments
		Surface water quality	Geomorphic condition	Riparian flora		
Existing (Inherent risk)	Medium	Low	Medium	Low	Groundwater and Geomorphic - Medium	N/A
Development-BAU (Current risk)	Medium	Medium	High	Medium	Geomorphic – High	High reliability in maintenance outcomes.
Development - Infiltration	Medium	Low	Medium	Low	Groundwater and Geomorphic - Medium	Not typically implemented by Melbourne Water- risk in using this approach in Merrimu PSP to be balanced against the risk erosion risk were development to proceed without appropriate mitigation.
Development - Evaporation	Medium	Low	Medium	Low	Groundwater and Geomorphic - Medium	Reasonable reliability, passive design.
Development - Piping and off-site disposal	Medium	Medium	Medium	Low	Groundwater, surface water & geomorphic - Medium	High reliability in maintenance outcomes, use of distributed storage an emerging technology, must be implemented at a range of scales.
Aquifer storage and recovery	Medium	Low	Low	Low	Groundwater- Medium	Approach not typically used by Melbourne Water- Maintenance implications poorly understood.

4 Recommendations

1. **Establish a buffer to exclude stormwater infrastructure.** Stormwater infrastructure includes infiltration galleries, unlined drains or ponds that may overflow. The buffer should be placed around the edge of the escarpment and adjacent drainage lines.
 - The width of the buffer will need to vary across the plateau in response to local topography.
 - The break in slope at the top of the escarpment edge or stream bank is one way that the reference line for buffer calculations can be identified.
 - A minimum width need to be determined, but was beyond the scope of this study. More detailed groundwater modelling to identify the likelihood of groundwater mounding at the escarpment edge and along drainage lines is needed to quantify the setback width. Overall, the setback width will need to be greater in areas with higher local relief (e.g. incised waterways), and above areas where sodic soils are exposed.
2. **Use a distributed approach to manage stormwater on the plateau.** Interventions should be located at every scale e.g. lot scale, street scale and end-of-pipe scale.
 - A distributed approach also addresses other objectives e.g. reduce potable water use by substituting a number of indoor water end uses with rainwater, and reduce urban heat stress by establishing high tree canopy target supported by passive irrigation using stormwater.
 - Passive infiltration at a distributed scale e.g. lot scale and street scale will also reduce risk of groundwater mounding. Adopting a distributed approach to stormwater runoff management as part of a development services scheme is a departure from the more traditional approach i.e. stormwater treatment systems at the bottom of the catchment. This distributed approach assumes local council is willing to adopt a greater number of stormwater management assets.
3. **Ensure that ecological values are a primary consideration in the future management of Wetland A** Avoid installing any future stormwater treatment options in the eastern portion of Wetland A and that future stormwater management in the west portion of Wetland A are consistent with maintaining potential SHW values in the east.
4. **Require that future stormwater management arrangements and designs are supported by appropriate evidence,** including detailed investigations of:
 - The elevation of the water table within the Werribee formation can be measured by installation of a borehole(s) that penetrates through the Werribee formation and intersects the water table. The number and location of these boreholes should be determined in partnership with an appropriately qualified hydrogeologist.
 - The impact of increased infiltration or direct injection and recovery of stormwater can be assessed using a combination of groundwater data from the borehole, and more detailed groundwater modelling investigations.
 - More detailed, event-based modelling of runoff volumes generated during storm events (including the 2,5,10,20,50 and 100 yr ARI events). This modelling should be spatially explicit and so that the excess flow delivered to each waterway, and the increase in erosive potential those flows cause, can be calculated.
 - A detailed feasibility assessment of ASR for the Werribee aquifer
 - Calibration of the rainfall-runoff model parameters is recommended in the future in order to refine the estimation of pre-development surface runoff and baseflow e.g. by utilising stream flow and rainfall data for the catchment or similar depending on data availability.

Attachment A Geomorphology

Site 1 – Exposed, eroding gullies on plateau margin

Site one is characterised by gully erosion which has exposed the underlying Werribee formation (the sodic soil layer). Gully erosion is extensive along this waterway and is ongoing (Figure 10). A small wetland has formed in the base of the waterway that the gullies feed, with the dense vegetation indicating that this depressions is permanently saturated.

The location of the wetland at site one may be due to localised groundwater patterns, where the water table intersects the surface and feeds the wetland. Alternatively, the wetland may have formed in a depression with low permeability soils that collects surface flows that are then unable to infiltrate into the ground below (i.e. the wetland is not the result of an elevated water table). While the exact mechanism controlling leading to the wetland is unknown, its location within the waterway, and the fact that similar wetlands *were* not observed at any other of the waterways along the plateau margin, suggests that this is a localised feature, rather than evidence for an elevated water table that extends across the plateau.



Figure 10. Exposed Werribee Formation soils that have eroded to form gullies (left), a small localised wetland immediately below the eroding gullies (right).

Site 2 – Eroding drainage line adjacent former quarry site

The upstream parts of site two is characterised by a stable waterway with a good coverage of grasses – there are no signs of erosion. However, in the downstream section of this waterway, is characterised by gully formation on the left bank (adjacent the former quarry) and trunnel erosion on the lower portion of the right bank (Figure 11). The key insights from this site are that tunnel erosion is promoted adjacent eroding (and more incised) waterways, where the local groundwater gradient is very steep. We found no evidence for tunnel erosion on the surface further upstream or at higher elevations on the right bank. The erosion on the left bank is due to the unconsolidated nature of the soils, which were likely material excavated from the quarry that was then tipped into the adjacent gully.



Figure 11 Tunnel erosion on the northern side of the drainage line at the base of the slope, immediately beside the waterway (left), looking downstream and across the waterway at the eroding cliffs on the southern side – beside the former quarry (right).

site 4 – Head of terraced waterway on plateau margin

A large farm dam (that was dry at the time on the site visit) rests adjacent, and immediately up-slope from a large, terraced section of waterway (Figure 12). The date or purpose of the terraced works on the waterway is unknown, but is likely to have been completed as part of erosion control measures. We speculate that water infiltrating through the dam may have contributed, via tunnel erosion and collapse, to erosion at the head of the adjacent waterway.



Figure 12. Looking south at the edge of the plateau, showing the proximity between a (currently empty) farm dam on the left of the photo and a terraced hillslope, likely to control past erosion issues, on the right of the photo.

Site 5 – Stable head of waterway at southern edge of plateau

The upstream end of waterways at the south of the plateau are stable and well-vegetated. There were no signs of permanent, standing water in the streambed but localised sections of erosion, which have exposed Werribee formation soils, were visible in the downstream section. The key insight from this site is that under current conditions the waterway is stable and not incising, but that the waterway is highly sensitive. Once erosion scours the cap of basalt soils to expose the underlying Werribee formation soils, gully erosion initiates and migrate up-slope (Figure 13).



Figure 13. The upstream extent of the waterways which is stable and has no signs of erosion – sodic soils are not present (left), a localised section of erosion that has exposed sodic soils at the base of the gully, downstream from the photo (right).

Attachment B Vegetation

Wetland A

This site is approximately 5.69 hectares in area. The site is a treeless grassy area dominated by exotic species at the time of assessment. Review of aerial imagery indicates that Wetland A has a history of cropping/pasture renovation and is currently grazed. Two constructed dams occur at the west end of the natural wetland depression. These are highly degraded and are not considered part of the natural wetland feature. The site may express vegetation characteristics consistent with Seasonal Herbaceous Wetland in wet years. Landscape characteristics and location are consistent with this vegetation type. State-wide flora mapping indicates the eastern edge of the site is mapped as Plains Grassland.

Note that this is the only site assessed within the study area where there should be future consideration of potential SHW values. Any future stormwater management proposals should avoid designating this location for primary stormwater or evapotranspiration purposes. The primary management concern for this location is its potential ecological value. It could be a candidate for receiving water if the quality and regime of receiving water was in keeping with the intermittent needs of a SHW. Permanent water or low quality water would degraded the potential of this site. Many other options and locations for stormwater treatment occur within the study area.



Figure 14. Typical cover of exotic vegetation in Wetland A – image taken facing west (left), degraded dam at the west edge of the natural wetland area of Wetland A (right).

Table 6 Wetland A characteristics

Approximate size	5.69 hectares
Percentage cover of exotic species	95%
Percentage cover indigenous species	>5%
Dominant exotic species	<i>Cirsium vulgare</i> <i>Galenia pubescens</i> var. <i>pubescens</i> , <i>Lolium perenne</i>
Dominant indigenous species	<i>Austrostipa</i> spp.<1% <i>Eleocharis acuta</i> 1% <i>Rytidosperma duttonianum</i> 1%
Seasonal Herbaceous Wetland observed	No. Insufficient rainfall in the 6 months prior to trigger the growth of plants characteristics SHW.
Potential for Seasonal Herbaceous Wetland	Moderate potential for the expression of SHW. This sight is currently degraded and being grazed however in wet years there is moderate potential of herbaceous species emerging. It is unlikely to reach the threshold of a high quality SHW given the history of grazing and intense management.
Other land management issues	Heavy grazing and direct access to water leading to poor water quality in dams. No adjoining Plains Grassland habitat identified.

Wetland B

This site is approximately 0.9 hectares in area. The site is a treeless grassy area and is almost entirely dominated by Serrated Tussock. A wetland is not present, and it is assumed that this is a mapping/modelling anomaly has incorrectly designated this as a wetland. Review of aerial imagery indicates that it has been heavily grazed or has had a range of weed management activities take place. No indigenous species were identified in the subject area.



Figure 15 Note the high abundance of *Nassella trichotoma*

Table 7 Wetland B characteristics

Approximate size	0.09 hectares
Percentage cover of exotic species	100%
Percentage cover indigenous species	0%
Dominant exotic species	<i>Galenia pubescens</i> var. <i>pubescens</i> , <i>Nassella trichotoma</i> <i>Rosa rubiginosa</i>
Dominant indigenous species	NA
Seasonal Herbaceous Wetland observed	Not observed and not likely
Potential for Seasonal Herbaceous Wetland	None
Other land management issues	Extensive exotic species cover.

Wetland C

This site is approximately 1.6 hectares in area. It is not a natural wetland, our assessment sought to confirm if any indigenous species were present. The site has excavated edges, a clear dam wall and spoil mounds as well as a range of pipes and hoses suggesting that it formed a more permanent water body at some stage in the past. The site is a treeless grassy area with Boxthorn and Briar Rose over an exotic ground-storey dominated by grasses such as Serrated Tussock and exotic herbaceous species including a range of thistle species. The site is within 50 meters of the escarpment and as such would be an inappropriate site for any wetland remediation or stormwater treatment. Further analysis and description of the hydrological issues associated with water management this close to the escarpment is provided in later sections of this document.



Figure 16. Typical overview of degraded dam site, note Boxthorn and Artichoke thistle dominance

Table 8 Wetland C characteristics

Approximate size	1.6 hectares
Percentage cover of exotic species	100%
Percentage cover indigenous species	0%
Dominant exotic species	<i>Cynara cardunculus subsp. flavescent</i> <i>Galenia pubescens var. pubescens</i> , <i>Lycium ferocissimum</i> <i>Nassella trichotoma</i> <i>Rosa rubiginosa</i>
Dominant indigenous species	<i>Juncus sp</i> <i>Rytidosperma sp.</i>
Seasonal Herbaceous Wetland observed	Not observed and not likely
Potential for Seasonal Herbaceous Wetland	None
Other land management issues	Extensive exotic species cover. Rabbit browsing Hydrogeological risk

Wetland D

This site is approximately 0.2 hectares in area. Summary. It is not a natural wetland although modelling suggested it may hence our assessment to confirm features and vegetation values. The site has very steep excavated edges and spoil mounds. The site is a treeless grassy area with Boxthorn and Briar Rose over an exotic ground-storey dominated by grasses such as Serrated Tussock and exotic herbaceous species including a range of thistle species. Note that this site is an appropriate site for the future location of any potential stormwater wetland treatment infrastructure given its poor ecological values and low risk location with regard to hydrogeology. This location is a suitable candidate for a range of treatment scenario combinations.



Figure 17 Typical vegetation composition of the excavated dam (left, the native species *Vittadinia aracilis* was observed (right)

Table 9 Wetland D characteristics

Approximate size	0.2 hectares
Percentage cover of exotic species	>95%
Percentage cover indigenous species	<1%%
Dominant exotic species	<i>Cynara cardunculus subsp. flavescent</i>
	<i>Helminthotheca echioides</i>
	<i>Lycium ferocissimum</i>
	<i>Nassella trichotoma</i>
	<i>Rosa rubiginosa</i>
Dominant indigenous species	<i>Juncus sp</i>
	<i>Rytidosperma sp.</i>
	<i>Senecio sp.</i>
	<i>Vittadinia gracilis</i>
Seasonal Herbaceous Wetland observed	Not observed and not likely
Potential for Seasonal Herbaceous Wetland	None
Other land management issues	The presence of <i>Vittadinia gracilis</i> supports DELWP mapping indicating that this area was formerly Plains Grassland. It can be a colonising species that persists even in highly degraded areas. The dam subject to this assessment did not conform with Plains Grassland.

Wetland E

This site is approximately 0.9 hectares in area. As with many other sites it is not a natural wetland although modelling suggested it may hence our assessment. The site has excavated edges and functions as a temporary storage dam. The site is a treeless grassy area with Olives and planted Eucalypts nearby over an predominantly exotic ground-storey. Note that this site is an appropriate site for the future location of any potential stormwater wetland treatment infrastructure given its poor ecological values and low risk location with regard to hydrogeology. This location is a suitable candidate for a range of treatment scenario combinations.



Figure 18 *Note the relative abundance of woody weeds and a mixture of native and exotic grass.*

Table 10 Wetland E characteristics

Approximate size	0.09 hectares
Percentage cover of exotic species	75%
Percentage cover indigenous species	<20%
Dominant exotic species	<i>Helminthotheca echioides</i>
	<i>Lycium ferocissimum</i>
	<i>Nassella trichotoma</i>
	<i>Rosa rubiginosa</i>
Dominant indigenous species	<i>Austrostipa spp.</i> 10 %
	<i>Rytidosperma sp</i> >1%
	<i>Vittadinia gracilis</i> >1%
Seasonal Herbaceous Wetland observed	Not observed and not likely
Potential for Seasonal Herbaceous Wetland	None
Other land management issues	Extensive exotic species cover.

Wetland F

This site is approximately 0.6 hectares in area. This site is an excavated dam, it is not a natural wetland. It is at the edge of remnant woodland habitat dominated by indigenous species however this constructed dam does not have wetland vegetation or native terrestrial species. The site is within 50 meters of the escarpment and as such would be an inappropriate site for any wetland remediation or stormwater treatment. Further analysis and description of the hydrological issues associated with water management this close to the escarpment is provided in later sections of this document.



Figure 19 Note the proximity to areas of native vegetation and regeneration of Eucalypts.

Table 11 Wetland F characteristics

Approximate size	0.06 hectares
Percentage cover of exotic species	50%, note extensive bare areas
Percentage cover indigenous species	5% ground storey 10% canopy cover
Dominant exotic species	<i>Galenia pubescens</i> var. <i>pubescens</i> , <i>Nassella trichotoma</i>
Dominant indigenous species	<i>Eucalyptus microcarpa</i>
Seasonal Herbaceous Wetland observed	Not observed and not likely
Potential for Seasonal Herbaceous Wetland	None
Other land management issues	Extensive exotic species cover.

Location G

This site is approximately 0.13 hectares in area. Access was not available, so a detailed review was not conducted however review from the adjoining roadside and of aeriels indicates that this is most likely a constructed dam not a natural wetland. Based on our assessment of similar sites it is unlikely to retain significant ecological values. It is an appropriate location to investigate for further stormwater treatment options combinations.

Attachment C Groundwater

CDM Smith groundwater report – see PDF

CDM Smith groundwater report – see PDF

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Attachment D

Water balance modelling

Water balance modelling – methods and assumptions

The purpose of the water balance model is to establish the existing condition water balance and boundaries for stormwater runoff management at the study site. This section describes the assumptions behind the water balance model, the development scenarios that were modelled as well as the stormwater runoff mitigation approaches.

Water balance modelling was used to calculate the annual volume of rainfall across the site, and the fate of that rainfall. The water balance modelling partitions the total annual volume of rainfall into the following hydrological components:

- water lost to the atmosphere via evaporation.
- water that infiltrates the plateau surface to become groundwater and feed the streams that drain the plateau as baseflow
- Water fed to streams as surface flows

Rainfall runoff modelling was undertaken in MUSIC for a 1 ha unit catchment using default rainfall-runoff parameters (it is recommended that calibration of the model rainfall-runoff parameters is undertaken in the future in order to refine the estimation of pre-development surface runoff and baseflow e.g. by utilising stream flow and rainfall data for the catchment or similar depending on data availability). Annual rainfall was partitioned between each of the possible hydrological pathways for three scenarios (the volume of annual rainfall input to the model was held constant). The three scenarios modelled were:

- No development (i.e., current conditions). The no development condition is used as a baseline, that the impact of development can be compared against
- A medium density development scenario (15 lots/Ha)
- A lower density development scenario (8 lots/Ha)

Climate data

The closest BOM station is Merrimu Reservoir which has recorded daily rainfall data between 1974 and 2017. Based on this dataset, the mean annual rainfall at Merrimu reservoir is estimated at 499 mm. The 95th percentile rainfall year is 1995 with an annual rainfall of 698 mm.

Two MUSIC 10-year rainfall templates fall within the Merrimu PSP region – Little River and Melbourne Airport. The “Little River” MUSIC rainfall dataset with a mean annual rainfall of 472 mm is more representative of annual rainfall at Merrimu compared to the Melbourne Airport template with a mean annual rainfall of 575 mm (Figure 16). As a result, the Little River MUSIC rainfall template was used for modelling purposes.

Rainfall is spread across the year (Figure 16) with higher average monthly rainfall in spring (September to November). The highest rainfall recorded at Merrimu Reservoir in any given month show that monthly rainfall can exceed 150 mm in late spring to summer months (Figure 20).

Based on the Little River MUSIC dataset, the annual areal potential evapotranspiration is approximately 1069 mm. This represents evapo-transpiration which would occur over a large area (at least 100 ha) with a never-ending water inflow. Given soil moisture availability, actual annual evapotranspiration is estimated at 705 mm based on SILO data at Laverton RAAF between 1960 and 2020. The SILO data also shows that the Morton shallow lake annual evaporation estimate is 1090 mm which is close to the annual areal potential evapotranspiration (<https://www.longpaddock.qld.gov.au/silo/>). The Morton shallow lake estimate is suitable for lakes less than 30 m deep and more than 300 m wide.

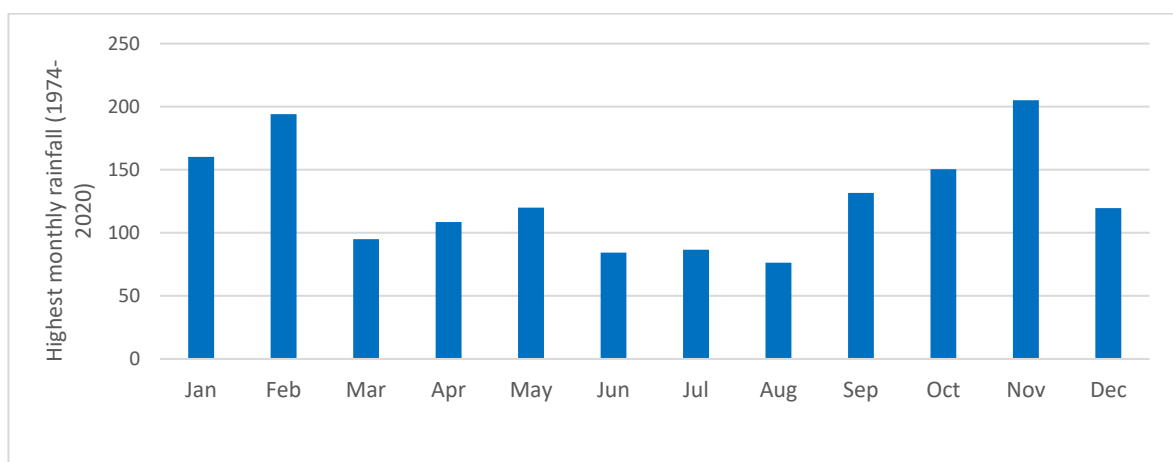
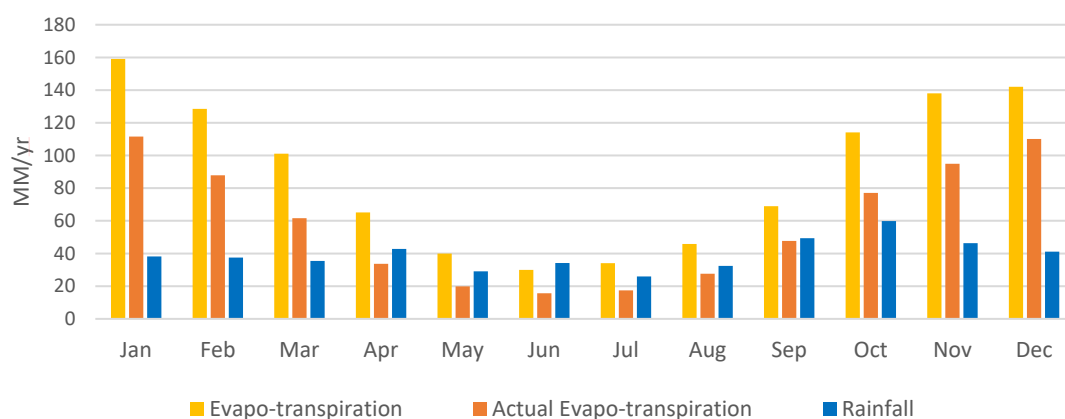
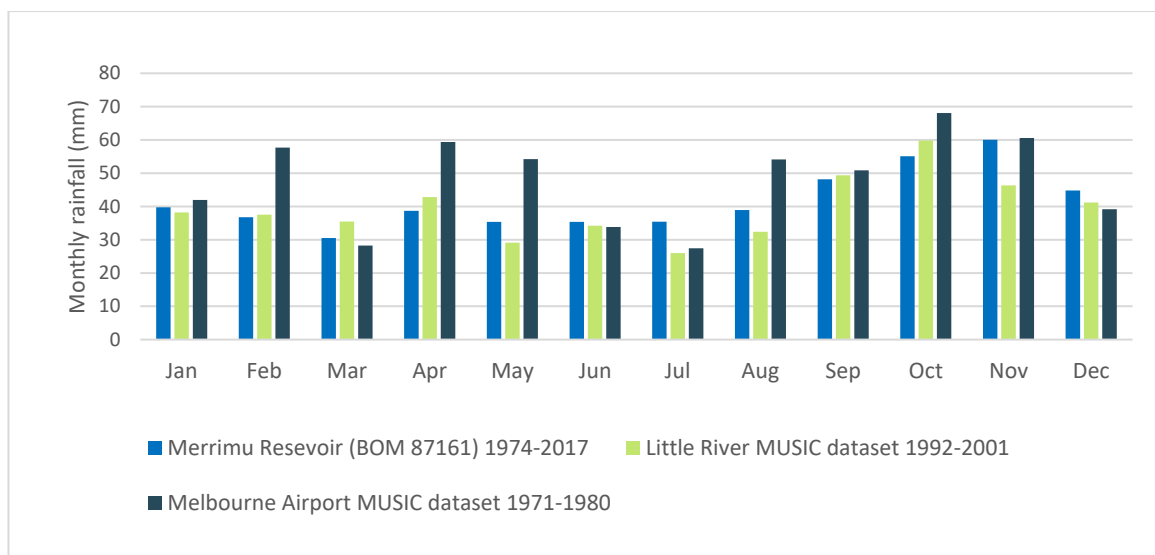


Figure 20 Rainfall dataset comparison (top), monthly potential evapo-transpiration and rainfall (Little River MUSIC dataset) and actual evapo-transpiration (SILO data) (middle), Maximum monthly rainfall (Merrimu Reservoir BOM station 87161) (bottom).

Description of scenarios

Assumptions for the developed scenarios are outlined in Table 12

Table 12 Assumptions for the developed scenario 1 and 2.

	Developed scenario 1 (15 lots/ha)	Developed scenario 2 (8 lots/ha)
Number of lots per ha	15	8
Assumed lot size*	450 m ²	1000 m ²
People per dwelling	2.5	2.5
Lot area per ha of development	6750	8000
% of development area		
Lots	Approx. 70%	80%
Roads	20%	10%
Open space	10%	10%
Assumed fraction imperviousness		
Lots	75%	40%
Roads	90%	90%
Open space	0%	0%
Development overall imperviousness	70%	40%

* Assume roof area for each lot is 200 m²

** Adopted in MUSIC model as fraction imperviousness for developed scenario 1 and 2

Modelled stormwater runoff mitigation approaches

The stormwater runoff mitigation approaches were developed by adapting the 1 ha unit catchment models to understand the general requirements for managing runoff at the study site as opposed to site specific requirements. The following high-level approaches were investigated for developed scenario 1 and 2 to manage the excess runoff:

- No mitigation measures
- Business-as-Usual (BAU) approach – outlet approach with a sediment pond and wetland at the bottom of a large catchment
- Evaporation approach – Evaporation takes place over an open water storage with evaporation rate set at 100 % of areal potential evapo-transpiration e.g. centralised evaporation basins
- Evapo-transpiration approach – Evapo-transpiration takes place over land potentially distributed throughout the catchment with rates set at 80 % of areal potential evapo-transpiration e.g. stormwater harvesting for irrigation of land distributed throughout the catchment. The 80% figure has been used to reflect actual plant evapo-transpiration rates to reflect soil moisture limitations.
- Infiltration approach –Infiltration takes place over a large area at a conservative rate of 0.1 mm/hr (e.g. sub-surface infiltration systems distributed throughout of the catchment)

- Combined evapo-transpiration and infiltration approach (e.g. centralised vegetated infiltration basins and/or distributed measures for passive irrigation/infiltration)
- Combined evapo-transpiration and infiltration approach with lot-scale indoor rainwater use. Lot scale indoor rainwater use is assumed to be for toilet flushing and laundry at a rate of 41 litres/person/day (Smart Water Fund, Melbourne Residential Water Use Studies). To meet the 80 % of this demand, the tank size is expected to be 5 KL per lot.

For modelling the mitigation approaches, we have assumed surface runoff is captured in a hypothetical storage for evaporation, evapo-transpiration, infiltration or combination of the above. The storage can be conceptualised as a large open water body or large land area with the soil profile acting as storage.

For modelling purposes, a storage depth 1.0 m is assumed. The footprint of the storage was determined using a 10-year representative climate dataset – the Little River MUSIC 6-min dataset. The footprint was adjusted to achieve 97% reduction in annual runoff volume in the developed scenario to meet the pre-developed annual surface runoff volume and baseflow volume over the 10-year simulation period. The storage was assumed to be 0.5 m full at the start of the simulation. Once the footprint was determined using the 10-year climate dataset, the depth of the storage was adjusted to determine volume requirement to manage runoff in a wet year. The wet year was chosen to be 1970 with an annual rainfall of 715 mm at Parwan. The modelling was undertaken using 6 min rainfall dataset at Parwan (available from ewater.org.au). The storage was assumed to be 0.5 m full at the start of the simulation.

Attachment E Melbourne Water risk framework

Table 13 Likelihood rating table taken from Melbourne Water Risk Management Framework

Rating	Description	Probability per year
5 Almost Certain	Risk will occur	0.99
4 Likely	Risk is likely to occur	0.98 - 0.50
3 Possible	Risk may occur	0.49 - 0.20
2 Unlikely	Risk not likely to occur	0.19 - 0.05
1 Rare	Risk will only occur in exceptional circumstances	0.04 – 0.00

Table 14 Likelihood of impacts for stormwater management options for the Merrimu plateau

Treatment option	Likelihood of impact			
	Groundwater quality	Waterways		
		Water quality	Geomorphic condition	Riparian flora
Existing (Inherent risk)	1 - Rare	1 - Rare	3 - Possible	2 – Unlikely
Development- BAU (Current risk)	1 - Rare	2 - Unlikely	4 - Likely	3 - Possible
Development - Infiltration	2 - Unlikely	1 - Rare	3 - Possible	2 - Unlikely
Development - Evaporation	2 - Rare	1 - Rare	3 - Possible	2 - Unlikely
Development – piping off plateau	1 - Rare	2 - Unlikely	3 - Possible	2 – Unlikely
Aquifer storage and recovery	3 – Unlikely	1 – Rare	1 - rare	

Table 15 Consequence table for stormwater treatment options for the Merrimu Plateau

Treatment option	Consequences			
	Groundwater quality	Waterways		
		Water quality	Geomorphic condition	Riparian flora
Existing	4 - Major	3 - Moderate	3 - Moderate	3 - Moderate
Development- BAU	4 - Major	3 - Moderate	3 - Moderate	3 - Moderate
Development - Infiltration	4 - Major	3 - Moderate	3 - Moderate	3 - Moderate
Development - Evaporation	4 - Major	3 - Moderate	3 - Moderate	3 - Moderate
Development – piping off plateau	4 - Major	3 - Moderate	3 - Moderate	3 - Moderate
Aquifer storage and recovery	4 - Major	3 - Moderate	3 - Moderate	3 - Moderate

Table 16 Risk rating table for each of the identified risk factors for each stormwater treatment options for the Merrimu Plateau

Treatment option	Consequences			
	Groundwater quality	Waterways		
		Water quality	Geomorphic condition	Riparian flora
Existing	Medium	Low	Medium	Low
Development- BAU	Medium	Medium	High	Medium
Development - Infiltration	Medium	Low	Medium	Low
Development - Evaporation	Medium	Low	Medium	Low
Development – piping off plateau	Medium	Medium	Medium	Low
Aquifer storage and recovery	Medium	Low	Low	Low

Table 17 Consequence rating with additional consequence criteria added to Environmental category, to account for off-site impacts

		CORPORATE <i>Risk Consequences to Melbourne Water</i>							PROJECTS <i>Risk Consequence limited to Project impacts only</i>		
		Public Health and Safety	Environment	MW Safety & Wellbeing	Customer/ Service	Reputational / Political	Regulation	Financial	Financial	Schedule	Outcomes
5	A. Severe	- Single or multiple fatalities to the public - Injury or illness resulting in serious permanent impairment to the public	- Permanent contamination to land, air or water - Permanent loss of species, habitat or community amenity - Impacts are not confined to the Merrimu plateau and materialize over a large area, > 10 km from the boundaries of the Merrimu PSP	- Single or multiple fatalities to staff, contractors or visitors - Injury or illness resulting in serious permanent impairment to staff, contractors or visitors	- Extended total loss of services to a local area - Short term total loss of services to a widespread area	- Serious adverse media coverage at National level over prolonged period - Prolonged loss of trust and confidence of stakeholders and community - Widespread community action or protests	Systemic breach of legislation, regulation, contracts or agreements resulting in one or more of: - criminal prosecution - civil action - licence/permit revocation - public enquiry	>\$100M impact to cash flow	>20% of the last approved business case project budget (P95)	Slippage of project delivery date (not managed within time contingency) and impacting on other projects or external interfaces	Project fails to achieve its outcomes which are irreversible beyond practicability

4	B. Major	- Widespread temporary illness to public resulting in hospitalisation - Major Injury or illness resulting in hospitalisation and ongoing treatment	- Major reversible contamination to land, air or water (Clean-up/recovery >5 years) - Major impact on species, habitat or community amenity - Impacts are not confined to the Merrimu plateau and materialize over a large area between 5 and 10 km from the boundaries of the Merrimu PSP	- Major injury or illness resulting in hospitalisation requiring ongoing treatment - Lost Time Injury > 1 week	- Extended degradation of services to a widespread area - Short term total loss of services to a local area	- Adverse media coverage at a - State level over a prolonged period or: - National level for short period - Short term loss of trust and confidence of stakeholders and community - Community campaign or action	Breach of legislation, regulation, contracts or agreements resulting in one or more of: - prosecution - civil action - major fine/sanction - licence/permit suspension - injunction - enforceable undertaking	\$50-100M impact to cash flow	10-20% of the last approved business case project budget (P95)	Slippage of project delivery date (not managed within time contingency)	Project fails to achieve its outcomes which are irreversible, but has practicable work around
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2	D. Minor	• Localised temporary illness to the public resulting in hospitalisation • Moderate injury or illness requiring treatment	• Moderate contamination to land, air or water (Clean-up / recovery 1-5 years) • Short term impact to species, habitat or community amenity • Impacts are not confined to the Merrimu plateau and materialize within 5 km of the boundaries of the Merrimu PSP	• Moderate injury or illness resulting in hospitalisation requiring treatment • Lost Time Injury < 1 week	• Extended degradation of services to a local area • Short term degradation of services to a widespread area	• Adverse media coverage at a State level for a short period • Expressed Stakeholder concern • Widespread community concern or complaints	Breach of legislation, regulation, contracts or agreements resulting in one or more of: • requirement to notify externally • minor fine/sanction • notice of contravention	• \$10-\$50M impact to cash flow	• 2.5-10% of the last approved business case budget (P95)	• Slippage of project delivery date (managed within time contingency)	• Project outcomes unacceptable but reversible
		• Temporary illness or injury to the public requiring medical treatment	• Minor contamination to land, air or water (Clean-up / recovery less than 1 year) • Minor impact on species, habitat or community amenity • Impacts are confined to the Merrimu PSP area	• Temporary injury or illness resulting medical treatment • Restricted work injury or medical treatment injury	• Short term degradation of services to a local area	• Adverse media coverage at a local level • Local community concern or complaints	Breach of legislation, regulation, contracts or agreements resulting in one or more of: • requirement to notify externally • warning given • internal acknowledgment and review	• \$1-10M impact to cash flow	• 1-2.5% of the last approved business case budget (P95)	• Slippage of the delivery date of a project phase	• Minor impact on project outcomes

1	E. Insignificant	• Symptoms requiring no treatment or first aid treatment only	• No lasting contamination to land, air or water • No lasting impact to species, habitat or community amenity • Cosmetic remediation • Impacts are confined to part of the Merrimu PSP	• Symptoms requiring no treatment or first aid treatment only	• No measurable impact on services provided	• Limited or no media coverage • Low public awareness and isolated community complaints	Breach of legislation, regulation, contracts or agreements resulting in one or more of: • identified internally • resulting in internal acknowledgement and review	• <\$1M impact to cash flow budget	• <1% of the last approved business case budget (P95)	• Negligible impact to project schedule	• No material impact to project outcomes