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STORMWATER MANAGEMENT STRATEGY:

Sunbury South and Lancefield Road

November 2014

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Summary

The Metropolitan Planning Authority (MPA) engaged Alluvium Consulting Australia (Alluvium) to prepare a stormwater management strategy for the Sunbury South and Lancefield Road Precinct Structure Plan (PSP 1074 and PSP 1075). The primary aims of this project are to understand the impact of urban development on waterway condition and health and how alternative management strategies might be applied to lessen that impact. In doing so a key outcome for the MPA is understanding the influence of alternative approaches upon 'land take', or the land set aside for surface water management infrastructure.

The approach taken was to:

Identify objectives: this was done with stakeholders, where the objective of managing erosion potential was identified as a key objective to protect waterway form and values.

Stormwater management framework: the proposed Sunbury WOWCA layout was superimposed over topographic maps and plans showing waterway reaches, their values and management recommendations. A desktop analysis with the team that produced those maps allowed us to complete a preliminary assessment as to the feasibility of that proposal, and whether further investigation might be appropriate.

Some of the key factors influencing feasibility include

- discharge locations above very steep embankments that present both engineering challenges (in terms of conveying the flows from the plateau to the waterway) and challenges to maintaining downstream channel form.
- the exact location of an RB in relation to existing waterways and waterway values and the presence of vegetation or geomorphological values (e.g. chains of ponds) and existing examples of waterway erosion
- the robustness of the downstream waterway and whether it is likely to be capable of accepting additional flows
- whether a constructed waterway is recommended, making it suitable for additional flows.

Case studies: Following this assessment two Case Studies were identified for more detailed analysis.

Case Study 1 addressed an area on the east bank of Jacksons Creek where three waterways discharge from three retarding basins (RB) via steep embankments. The base case (as per the Sunbury WOWCA) and four options underwent hydraulic and hydrologic analysis to understand the implications of reducing the volumes of water from discharge points to eliminating those discharge points.

In addition the potential for stormwater harvesting from wetlands within the RBs was considered to understand the scale of stormwater harvesting that might be required to meet erosion potential objectives.

Case study 2 concerns a tributary catchment on the west bank of Emu Creek. Previous studies have identified waterways here as ranging from 'intact' (the highest classification) to being of moderate condition. Notably, the middle reaches of the main stem are chains of ponds. One chain of ponds was classified in the geomorphic assessment as being the best example in the study area, and one of the best that the authors had observed in the wider Port Phillip and Westernport region.

Two alternative options were investigated to understand the impact of larger and additional RB's, as well as harvesting water from those RBs.

Summary of conclusions

The results from each Case Study indicate that:

- Significantly larger retarding basins are likely to be required to meet an objective of a lower EPI. However, even where a larger RB is assumed and modelled, an EPI of 1 may yet be unachievable.

- Additional retarding basins, upstream of sensitive locations (such as Case Study 2's chain of ponds) may assist in meeting the EPI objective and protecting downstream objectives. This obviously creates additional land take requirements.

- Stormwater harvesting may prove effective in reducing EPI while potentially delivering an alternative water benefit to a WOWC strategy for the area. However, some of the extraction volumes and rates identified are extremely large and are unlikely to be feasible considering capital costs of transfer and treatment and the ongoing maintenance and energy costs associated with that option.

Further investigation of the Case Study sites and other locations might be investigated to understand the costs and benefits of using stormwater harvesting to reduce RB and land take requirements, provide and alternative water source and protect waterway values.

Recommendations

An important outcome is that it is difficult to extrapolate these results across the broader project area given the uniqueness of each subcatchment. What can be proposed is that meeting an EPI objective is likely to increase land take requirements. Rather than extrapolating, it is recommended that analysis similar to that undertaken as part of the Case Study process for locations and discharge points considered 'unlikely to be feasible' or 'feasible with further investigation required': with priority given to those 'unlikely to be feasible'.

Melbourne Water will need to be consulted on these preliminary results and understand how alternative objectives (e.g. EPI) might be adopted to protect unique values, and how adopting those objectives might change or influence the development services scheme (DSS) process.

Western Water will need to consider these results in the context of the Sunbury WOWCA and the options being investigate as part of that study, in particular how a 'stormwater to potable' or other stormwater harvesting option might integrate with a stormwater management strategy that is in part driven by an EPI target.

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1 Introduction

The Metropolitan Planning Authority (MPA) engaged Alluvium Consulting Australia (Alluvium) to prepare a stormwater management strategy for the Sunbury South and Lancefield Road Precinct Structure Plan (PSP 1074 and PSP 1075). The MPA have undertaken this project in recognition of the complexity of surface water management and drainage within the area including the numerous small, often very steep, tributaries that drain the basalt plain to Jacksons and Emu Creek, the major waterways in the study area.

The primary aims of this project are to understand the impact of urban development on waterway condition and health and how alternative management strategies might be applied to lessen that impact. In doing so a key outcome for the MPA will be how these alternative approaches impact upon 'land take' i.e. the area required to house necessary surface water management infrastructure like retarding basins, wetlands and constructed waterways. As well as this, stakeholders including Western Water and Melbourne Water are currently undertaking a whole of water cycle assessment (WOWCA) for the Sunbury region (the Sunbury WOWCA), including the PSP that are the subject of this report. The outcomes from this report will therefore inform elements of that work.

1.1 Project area

The project area encompasses two PSPs to the east and north east of the Sunbury township between Jacksons Creek (that is to the west of the study area) and Emu Creek.

Figure 1 *Project area*

1.2 Background and scope

PSPs 1074 and 1075 are relatively unique in that arguably the key risk associated with urban development is the risk to local waterways and tributaries. The reasons for this include:

- The significant elevation of the plateau (where development will occur) above the floodplains that drain to Emu and Jacksons Creeks. In some locations the plateau and floodplain are linked via steep embankments that present challenges to the transfer of stormwater to the floodplain.
- Soil conditions within parts of the project area are susceptible to erosion such that additional stormwater flows are highly likely to erode waterways with implications for land management and maintenance.
- The existence of unique waterway and vegetation values within some waterway reaches.

The key outcomes for this project are to:

- Review the stormwater management strategy proposed as part of the Sunbury WOWCA.
- Agree objectives with stakeholders that reflect the unique topography and geomorphological conditions that exist within these PSPs.
- Collate information on the values that exist within waterways nominated for stormwater discharge, as well as their sensitivity to additional flows.
- Based on that information, develop a framework that provides commentary and guidance on the likely impact of the proposed flow management strategy on the project area's tributaries.
- Use two case studies to highlight these issues as well as possible alternatives to those proposed under the Sunbury WOWCA strategy.

Limitations

The timelines required for this project meant that case studies that highlighted key issues were required in place of a thorough analysis of each tributary. The case studies were selected to represent unique characteristics of the site and provide an initial understanding of the area's management issues and options.

1.3 Stormwater management objectives

At the commencement of the project stakeholders met to discuss and agree objectives for this project. The stakeholders involved in this discussion were:

- The Metropolitan Planning Authority
- Western Water
- Melbourne Water
- The City of Hume

While traditionally stormwater management strategies are typically concerned with meeting 1 in 100 year flood management and stormwater quality objectives, the unique landscape within the project area called for a different focus: specifically the protection of unique waterways and waterway values.

The table below summarises the parameters and objectives that were discussed and agreed by the stakeholder group. Additional comments are provided to provide additional context. In summary, it was agreed that "channel stability and erosion control" is a key parameter, meaning that aiming for an "erosion potential index" of 1, was agreed to be a key objective.

Table 1. Stormwater management objectives

Water cycle parameter	Objective	Commentary
Channel stability and erosion control	Erosion potential index of 1	It was agreed that this objective may be relaxed to 1.2 depending on the outcomes of the initial analysis. In determining an erosion potential index it will be assumed that the tributaries will ultimately be vegetated and managed to become a healthy, structured native vegetation community Alluvium will review the MUSIC model parameters developed for the WOWC assessment. The assumptions associated with that model are discussed briefly below.
Stormwater quality treatment	Best practice environmental management targets (BPEM) in terms of percentage reduction TSS: 80%, TP: 45%, TN: 45%	Termed "new BPEM", Melbourne Water have defined three levels of service in relation to stormwater management namely: • BAU: existing BPEM • "Baseline": TSS: 85% reduction, TP: 50%, TN: 50% and 60% reduction in mean annual run off • "Aspirational": 90% reduction in mean annual run off Note that the percentage reduction of annual flows proposed within the WOWCA report is 60% for Emu and Kororoit Creeks and 25% for Jacksons Creek (Western Water, 2014)
Alternative water supply	No specific objective	Alluvium is aware that "stormwater to potable" is one of the options being examined as part of Western Water's WOWC assessment. Comment on how proposed changes to the strategy might impact options such as stormwater to potable will be provided where appropriate.
Flood protection and flow retardation	No specific objective	The level of flood protection will be a secondary objective, behind what is required to meet the channel stability and erosion control objective.
Ecological and geomorphic values	Objectives will be based on where flora and geomorphic values need to be protected	We will refer for this to a previous study Alluvium completed entitled *Riparian vegetation and geomorphology in the Sunbury growth area* project for Melbourne Water (Alluvium, 2014)

1.4 Stormwater management framework

Having confirmed our objectives, the next step was to develop a framework for the project area that provided a summary of the condition, unique characteristics or potential sensitivity of receiving waterways to additional flows.

The framework could then overlay the Sunbury WOWCA outcomes, including the location of proposed retarding basins and alignments of constructed waterways with other information including the River Styles[1] stream type classifications and waterway management recommendations that were completed during the *Riparian vegetation and geomorphology in the Sunbury growth area* project for Melbourne Water (Alluvium, 2014).

From this point the feasibility of each proposed retarding basin, waterway alignment and discharge point was qualitatively assessed against these underlying conditions. An assessment was then made according to the following broad descriptions:

- Feasible based on an assessment of the ability of the receiving waterway to manage additional flows.
- Feasible with a caveat that more investigation is likely to be required, and
- Unlikely to be feasible due (primarily) to the steepness from discharge point to receiving waterway.

Whilst these three categories were generally applied across the project area, additional commentary was provided where appropriate to clarify why certain conclusions were reached. The framework is included within the following three figures with additional text provided (where necessary) in Attachment A.

[1] River Styles refers to a “geomorphic approach for examining river character, behaviour, condition and recovery potential, providing a physical template for river management” (http://www.riverstyles.com).

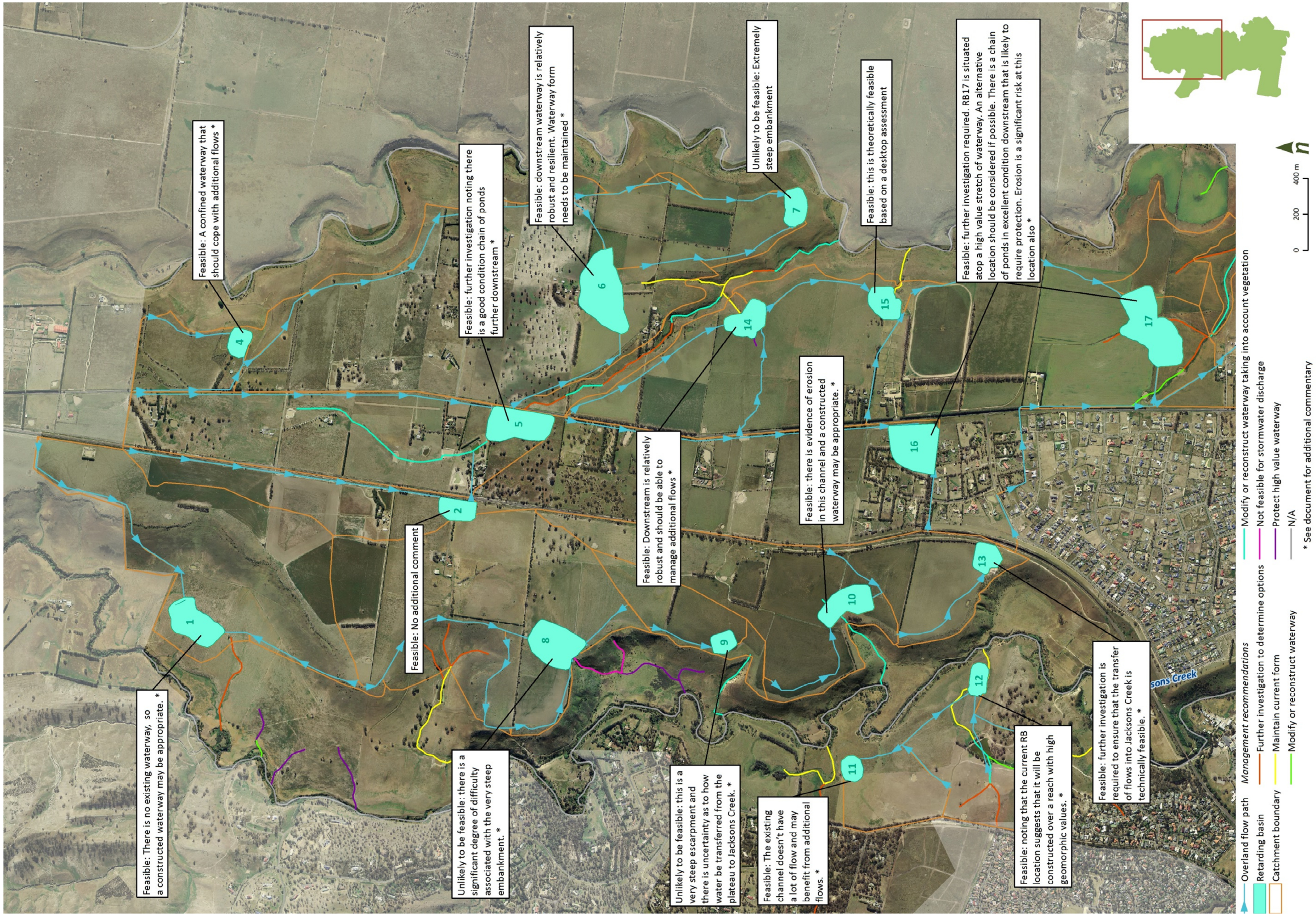


Figure 2 *Feasibility assessment- north of the project area*

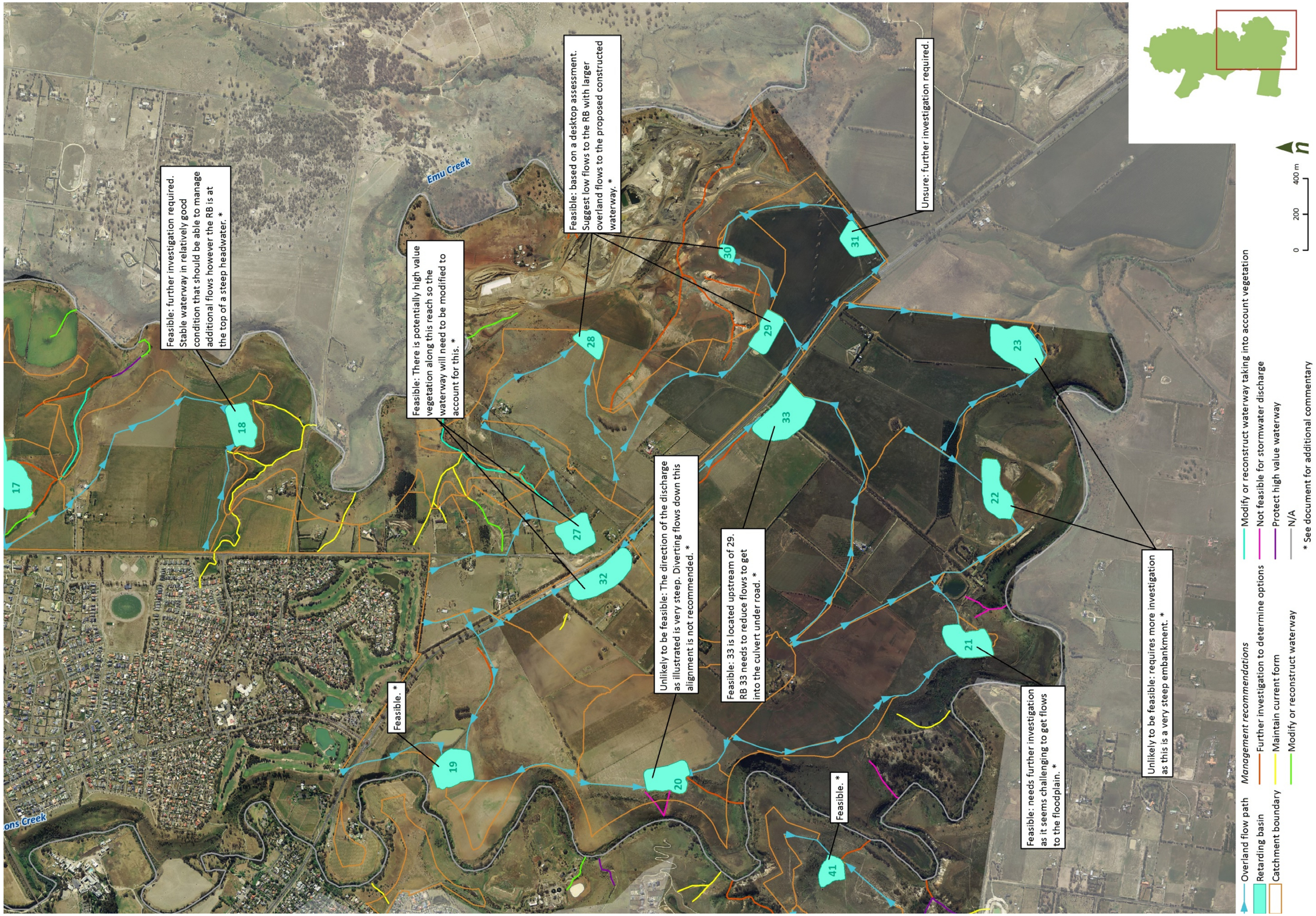


Figure 3 *Feasibility assessment- south of the project area*

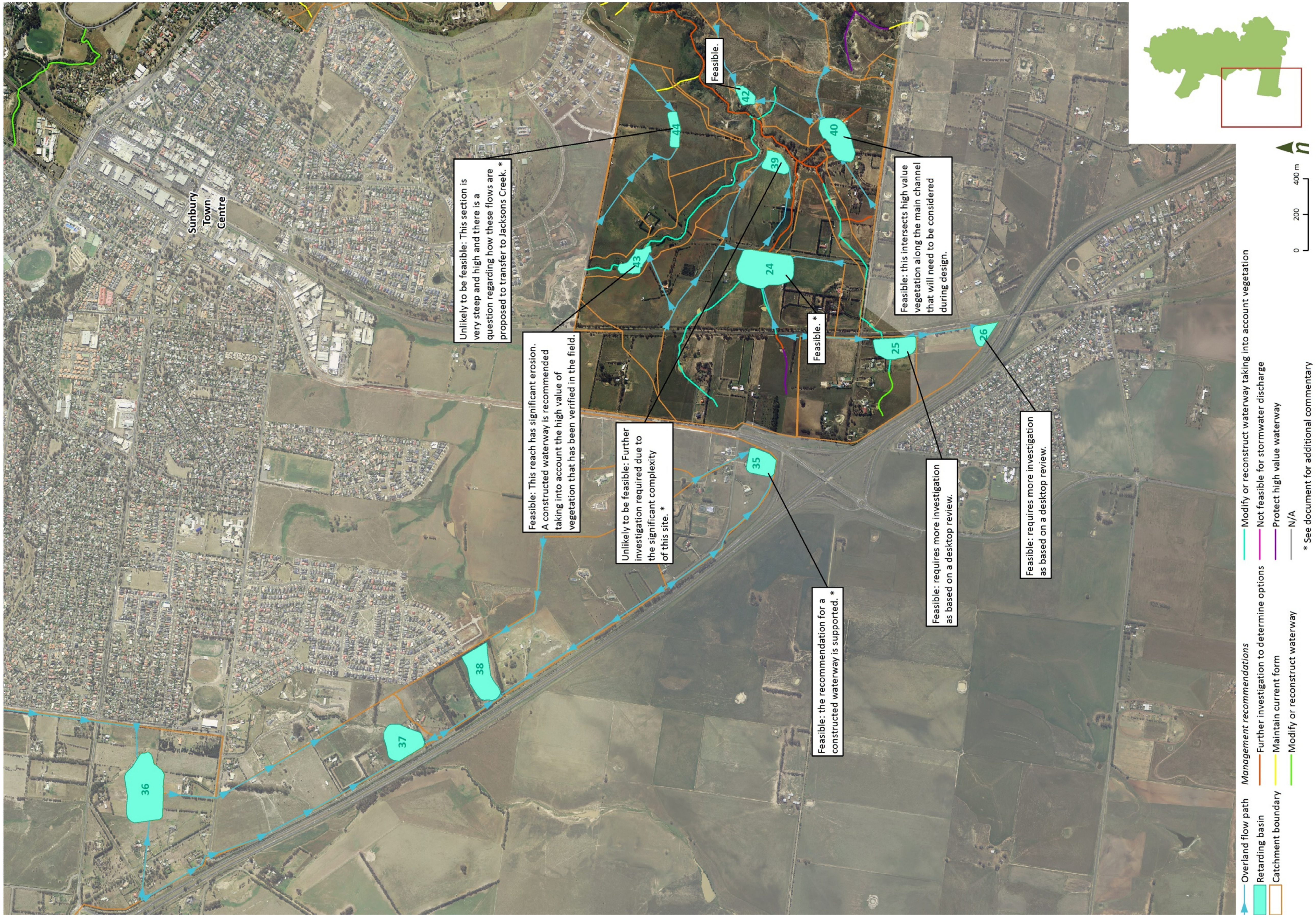


Figure 4 *Feasibility assessment- west of the project area*

Stormwater management framework summary

The summary highlighted typical topographical, geomorphological, erosion and vegetation characteristics that make surface water management complex in this region. A summary of these outcomes is provided in Table 2.

Table 2. Framework outcome summary

Definition	Description	Selected examples
Unlikely to be feasible	Generally refers to discharge locations above very steep embankments that present both engineering challenges (in terms of conveying the flows from the plateau to the waterway) and challenges to maintaining downstream channel form.	Along Jacksons Creek where RBs 8, 9 and 10 are situated RBs 7, 20, 22, 23: extremely steep embankment
Feasible: further investigation required	Applied to locations where the proposal was potentially feasible, however a definitive conclusion could not be reached based on a desktop analysis for reasons including: • Understanding the exact location of an RB in relation to existing waterways and waterway values • Vegetation or geomorphological values (e.g. chains of ponds) • Existing erosion	RB 5 is upstream of a chain of ponds in good condition RB 16 and 17 are upstream of a high value stretch of waterway RB 18 is at the top of a steep headwater RB 32 and 40 intersect high value vegetation
Feasible	Reflected locations where: • the downstream waterway was considered in robust enough condition to accept additional flow • there is limited erosion potential or • a constructed waterway is recommended.	RB1, 10, 35 and 43 constructed waterway recommended RB 4 is a confined waterway that can take additional flows RB 6 robust waterway downstream

2 Case studies

The aim of the stormwater management framework (section 1.4) was to identify site characteristics that present barriers to traditional approaches and would benefit from more detailed analysis. In consultation with stakeholders, and with reference to the framework, case studies were identified that would go into greater detail to:

- Identify alternative stormwater management options in locations where the Sunbury WOWCA approach is deemed 'unlikely to be feasible', and
- Model these alternative approaches to see if the objectives set out in 1.3 can be met.

Whilst hydrologic and stormwater quality modelling for the entire project area was not within the scope of this project, the case studies aim to provide a more detailed insight into the issues that are relatively unique to this project area.

The method we used to undertake the analysis as part of each case study is outlined briefly below, and described in more detail in Attachment A.

2.1 Modelling method and assumptions

Hydrogeomorphic analysis
One of central requirements of the study was to evaluate potential impacts of proposed stormwater management infrastructure on the physical form and process of the tributary waterways into which stormwater will be discharged. The stability of these waterways is related to a number of factors, but an important driver of erosion and sediment transport is the flow regime or hydrology of a particular waterway. If the hydrology changes its possible geomorphic processes will be triggered or accelerated.

The approach used to evaluate suitability of proposed options for each site study had a number of elements which are outlined in Figure 5 and discussed in detail below.

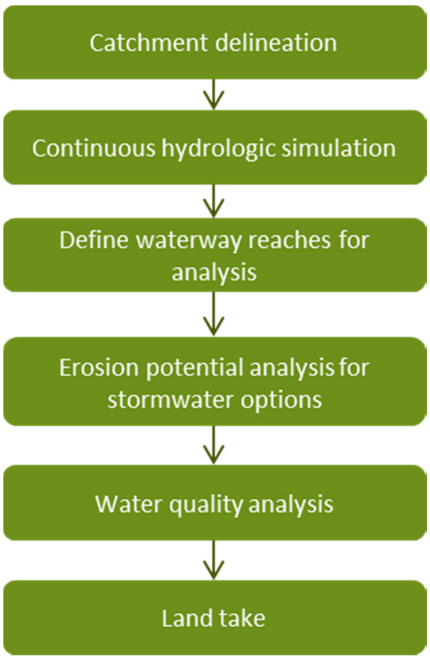


Figure 5 *Applied approach to evaluate suitability of proposed options*

Catchment delineation

An important element in understanding the likely impacts of stormwater management on waterways is the change in catchment areas from current conditions (i.e. undeveloped) to future developed conditions. The method we used to develop the catchment areas is described in detail in Attachment A.

To summarise, we analysed the terrain in the project area using LiDAR processing software to delineate the current catchment boundaries, which are largely a feature of the natural topography, with some modifications for existing urban development and stormwater infrastructure (e.g. culverts under roads). The catchment boundaries for developed conditions were provided in the Sunbury WOWCA report, which we refined where we had specific and detailed knowledge of existing drainage infrastructure and topography. The catchments were used as the basis for the hydrologic and hydro-geomorphic analysis of the stormwater management options.

Continuous hydrologic simulation

A requirement of hydrogeomorphic analysis is an understanding of the likely changes in hydrology following urban development, and the influence of different stormwater management scenarios on that hydrology. We used the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) to generate long-term flow series for current catchment conditions, the base case stormwater arrangements, and alternative stormwater management options. The outputs from the MUSIC models allowed us to test the degree to which the various options met the objectives for the study area.

A detailed description of the hydrologic modelling approach is provided in Attachment A.

Define waterway reaches

The effect of urban stormwater on waterway stability varies with a variety of factors, including the size, shape and bed slope of the waterway, and the composition of its bed and banks. For example, a steep waterway with an erodible sandy bed is more likely to erode than a flatter waterway with a hard clay bed. To realistically assess the effect of the stormwater management options on different waterways in the case studies, we defined waterway reaches with common geomorphic characteristics. To do this, we used the results from the *Riparian vegetation and geomorphology in the Sunbury growth area* (Alluvium, 2014) supplemented with analysis of LiDAR data.

Erosion potential analysis

To understand the likelihood of waterway erosion being triggered by urban stormwater we used the erosion potential index (EPI) approach. EPI is a measure of the change in erosion potential in a waterway following urban development (or other land use changes). By calculate the EPI for different stormwater management options we were able to assess the degree to which each option met the channel stability objective.

The EPI approach combines continuous hydrologic analysis, hydraulic analysis and field observations of channel boundary material. The outputs from the analysis are an index that indicates the likely erosion potential of a proposed urban development/stormwater management option. An EPI of one indicates the channel is likely to remain stable and an EPI of greater than one indicates increased erosion is likely (and an EPI of less than one indicates sediment deposition is likely).

The EPI method followed is also detailed in Attachment A.

Water quality analysis
MUSIC software was also used to ensure that the retarding basin (RB) and wetland combinations modelled as part of the Case Studies undertaken met best practice environmental management (BPEM) targets.

Land take analysis
Understanding the impact the stormwater management strategy on land take will be a high priority for the Metropolitan Planning Authority (MPA) and developers. Land take has been estimated according to a number of factors including:

- The effective area required for a wetland (within the bounds of an RB) to meet BPEM targets
- Additional allowances around that RB / wetland for auxiliary activities including access, sediment drying etc., and
- Area required for constructed waterways.

While effective areas were determined using MUSIC, the Sunbury WOWCA was used as a reference to provide a ratio between effective area and the total area required for an RB / wetland (i.e. the effective area plus an additional area allowance). This resulted in a total area equalling between 1.6 and 2.4 times the effective area of the RB / wetland depending upon the RB.

A width of 40m was assumed for constructed waterways within the project area.

2.2 Case study 1: Steep embankments along Jacksons Creek

Where? The first case study covers an area on the east bank of Jacksons Creek. There are three waterways exiting retarding basins 8, 9 and 10 in Figure 6 below that drain to the east bank of Jacksons Creek. The key issue being addressed here is the feasibility of discharging stormwater to steep embankments.

In the previous geomorphic and vegetation assessment (Alluvium 2014), these waterways were classified as being in moderate to good condition with all draining directly from the basalt escarpment to Jacksons Creek.

***Northern waterway (existing RB 8)**:* this waterway flows down the escarpment directly over fractured basalt bedrock. At the foot of the escarpment the waterway flows over the narrow Jacksons Creek floodplain.

The lower reaches have very high geomorphic values due to the intact condition of the regionally rare alluvial valley fill in this location. The previous management recommendation (Alluvium 2014) was that it was *not feasible to discharge stormwater into this waterway* due to its near vertical bed grade and the risk to significant erosion of the fractured bedrock in the upper section. These characteristics make it essentially unfeasible to design in stream erosion control measures that increase the resistance of the waterway to erosion due to increased flows.

Beyond the feasibility of discharging to this waterway, the lower reaches have the highest classification of geomorphic value and are highly sensitive to changes in hydrology. The management recommendation for these reaches was to *protect high value waterway.* The overall management recommendation for the northern waterway was to ensure no urban excess stormwater was discharged into the waterway.

***Southern waterways (exiting RB 9 and 10)**:* these waterways follows a flatter flow path to Jacksons Creek (especially catchment 10), and do not flow directly over fractured bedrock. The lower reaches of the waterway are eroding through downcutting into the Jacksons Creek floodplain. Downcutting is likely to be driven by historic deepening of the Jacksons Creek channel itself, and has reduced the geomorphic value of the waterway and increased its sensitivity to increased flows. Patches of remnant native vegetation were surveyed along the waterway including Grassy Woodland, Plains Grassland and Escarpment Shrubland ecological vegetation classes (EVCs).

The management recommendation for these waterways was to *modify or construct waterway taking into account vegetation.* In other words, the geomorphic values of the waterways are low enough that significant modification to the channel (up to and including construction of a completely new channel) can be carried out to facilitate stormwater drainage without the loss of significant geomorphic values. By modifying or constructing a waterway there is flexibility to create a significantly more robust waterway. However, the presence of patches of remnant native vegetation means any works avoid the patches of grasses, shrubs and the small number of scattered indigenous trees in the reach. Direct impacts to the riparian vegetation of Jacksons Creek should also be avoided or minimised.

Why? Case study 1 was selected because it represents one of the central challenges in the study area: the feasibility of transferring urban stormwater from the elevated basalt plain to either Jackson or Emu Creeks via the basalt escarpment that is the dominant landscape feature in the overall study area. The height, steepness and highly weathered nature of the escarpment means that business as usual stormwater management may not be feasible, and alternative approaches are likely to be needed.

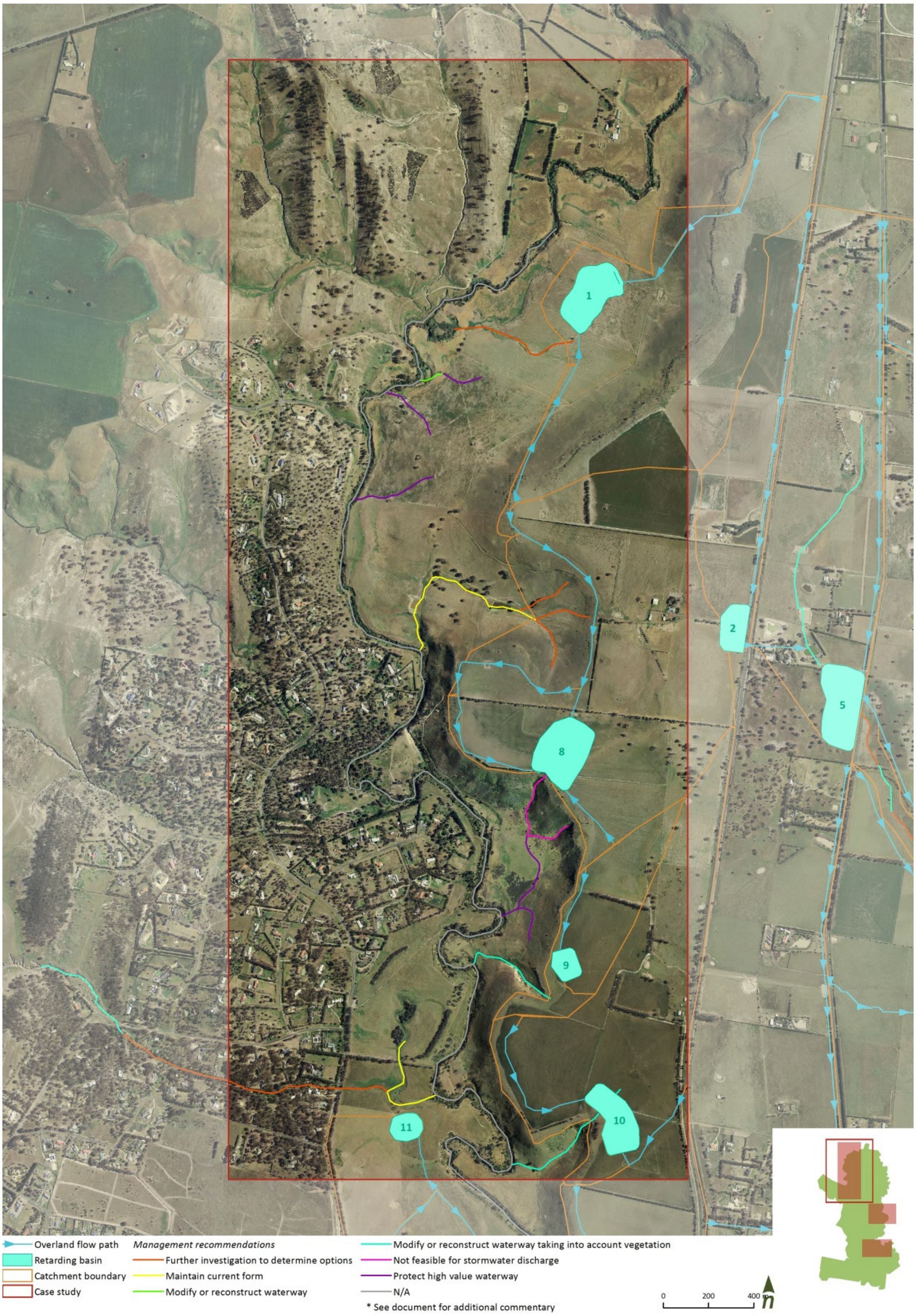


Figure 6 *Case study 1 area*

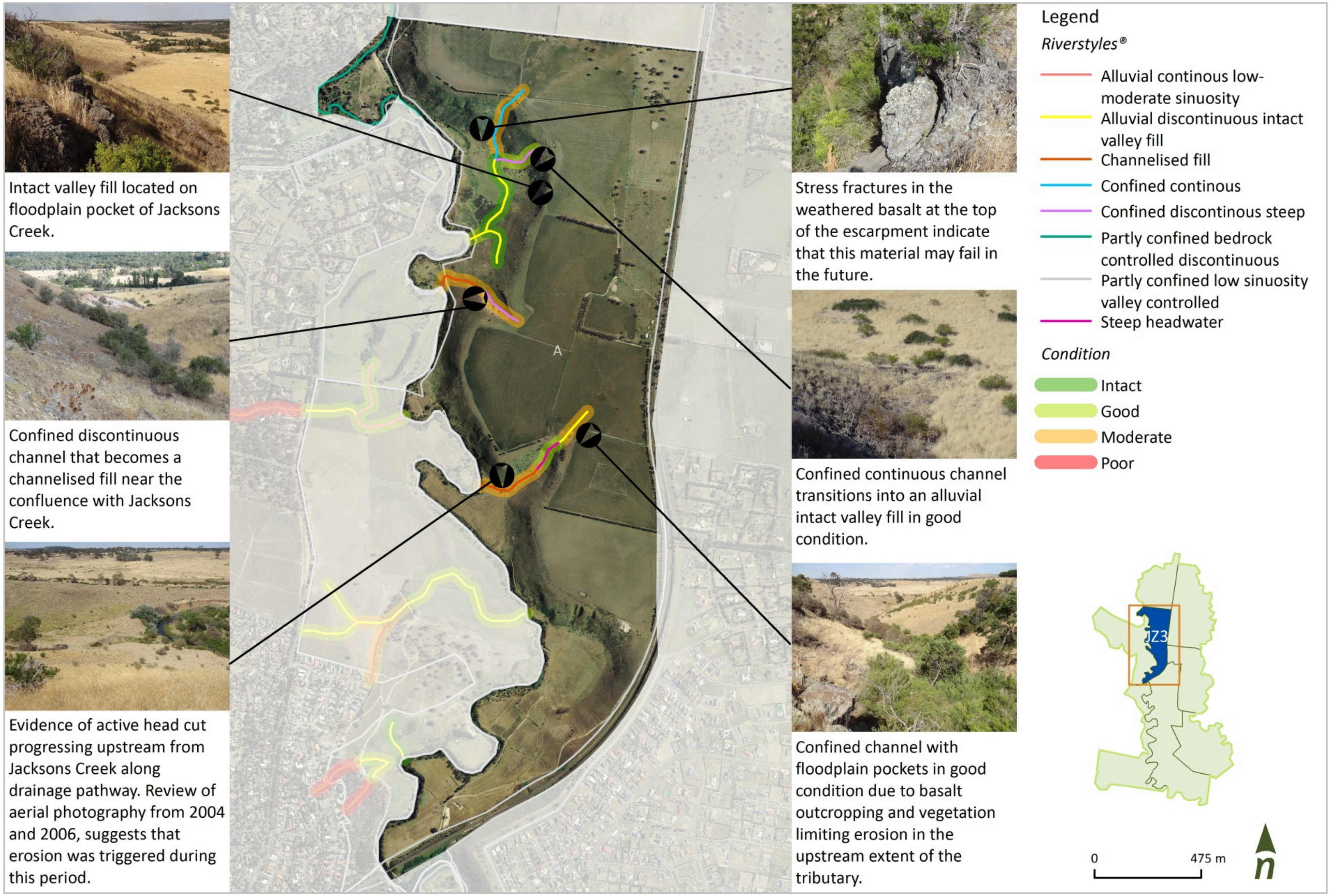


Figure 7. *Case Study 1 geomorphic values of waterways*

Catchment delineation
Catchments for case study 1 were delineated using the method outlined in Section 2 Catchment boundaries for current and developed conditions in Case Study 1 are presented in Figure 8 below.

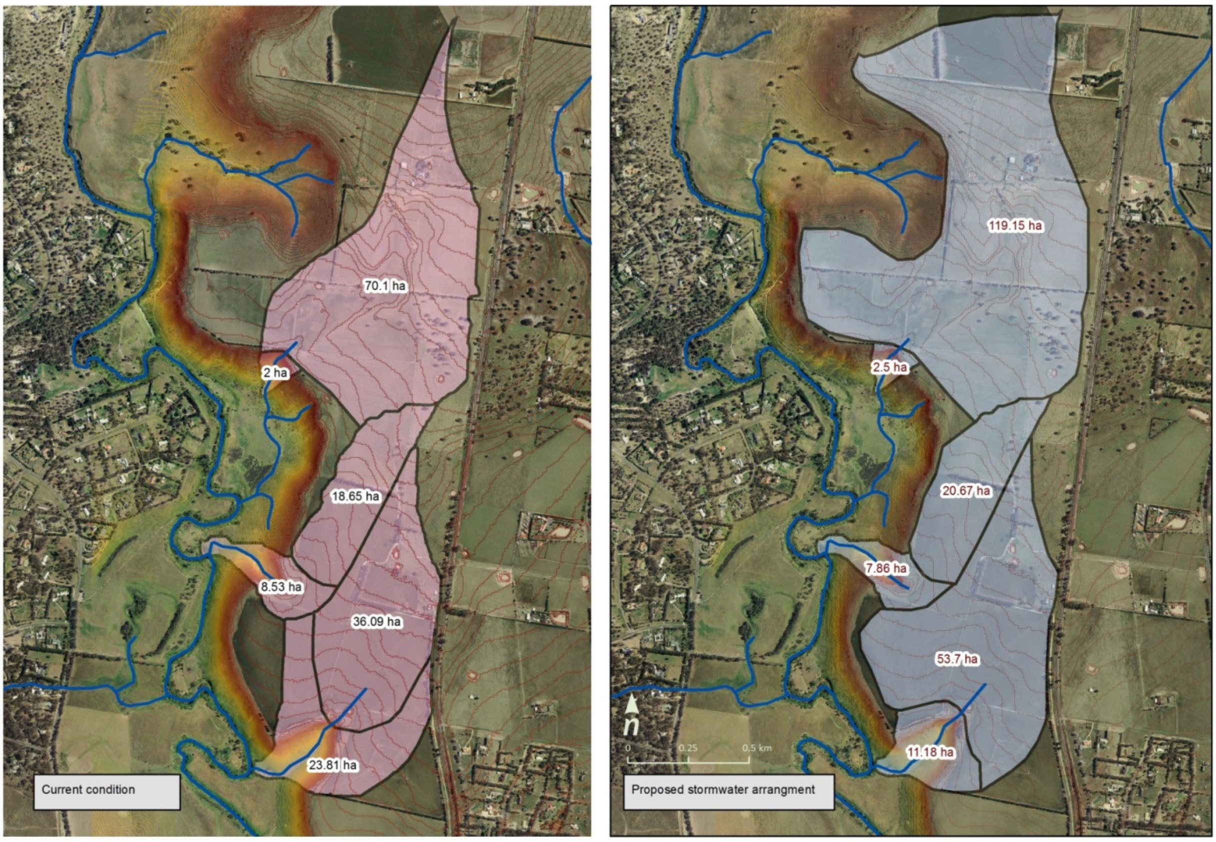


Figure 8. *Case study 1: catchment boundaries for current and developed conditions*

Sunbury WOWCA approach to the Case study 1 area
The baseline parameters adopted within the Sunbury WOWCA are summarised in Table 3. This relates to configuration represented on the right hand side of Figure 9 below.

Table 3. Case study 1: baseline parameters

RB / catchment number	Catchment area (ha)	Fraction impervious	Wetland / RB effective area (ha)	Total land take (ha)*
8	116	0.54	3.5	5.8
9	20.1	0.65	0.6	1.5
10	69.6	0.59	2.1	4.3

Total land take reflects the area accounted for within the WOWCA strategy. It includes an additional allowance for drying area, maintenance access paths etc. that is between 1.6 and 2.4 times the effective area. We have used these factors for each RB to estimate total land take under each of the options below.

These results were based on the objective of retarding both the 2 year ARI flow to maintain waterway health and the 100 year ARI flow to satisfy flood management objectives. As discussed above, the objectives for this current study are focussed on managing erosion and therefore different conclusions are to be expected.

In summary, the Sunbury WOWCA strategy for the Case Study 1 area is for RBs 8, 9 and 10 to discharge to Jacksons Creek via the basalt escarpment discussed above (Figure 9). Discharging from RB 8 is not considered feasible, while discharging from the other RBs requires further investigation.

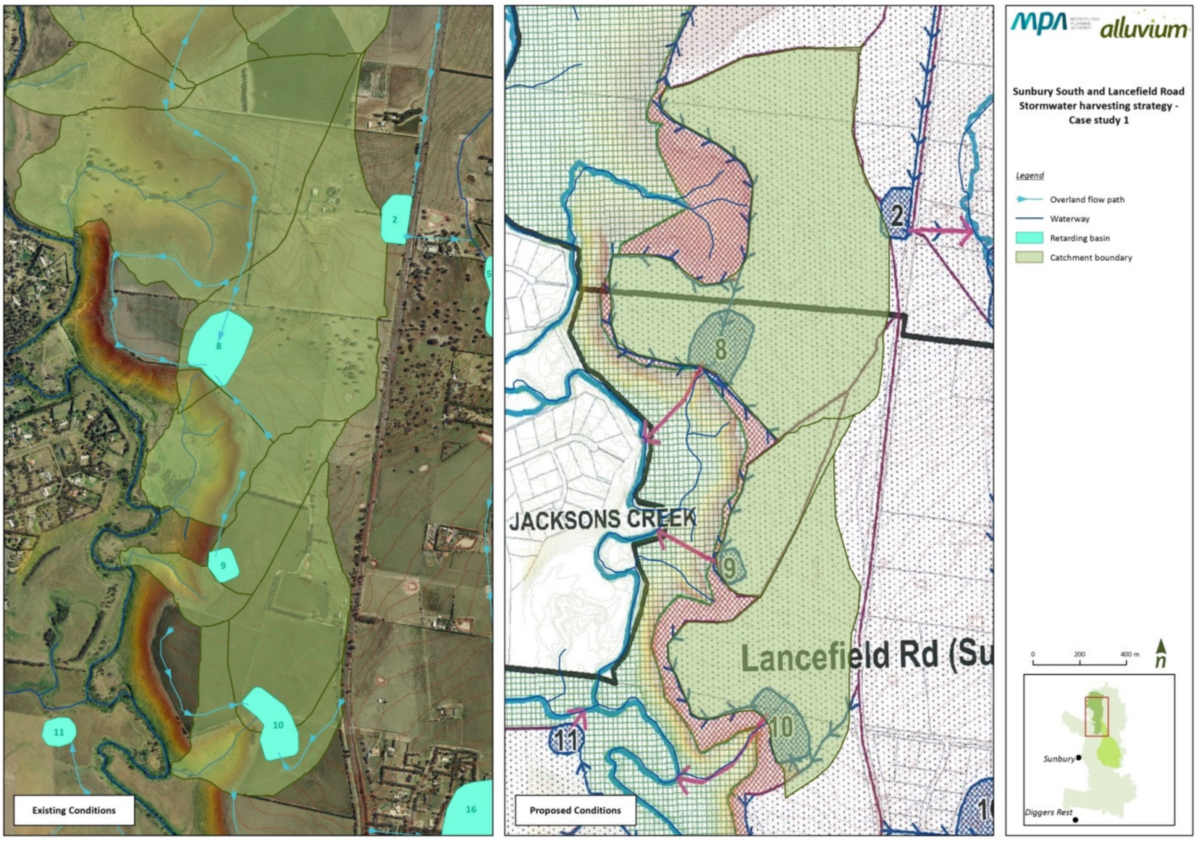


Figure 9. *Case study 1: catchment boundaries for current and developed conditions*

Alternative stormwater drainage options

We developed four alternative drainage strategies in this area that have the objective of protecting downstream waterways. Other than option 1, each option assumes stormwater is harvested and treated as part of a 'stormwater to potable' scheme. For each example we have identified an average daily rate of extraction of stormwater to understand its impact on the erosion potential index target. In doing so we have made the significant assumption that demand for stormwater is unlimited as it is contributing to a potable water supply network.

Each option is described in Table 4 below, with results shown for:

- Erosion potential or channel stability
- Volume of stormwater proposed
- whether constructed waterways are required, and
- effective land take i.e. land take associated with RB / wetlands.

Stormwater quality results for Case Study 1, to illustrate the options meet BPEM requirements, are provided in Attachment D.

Case study 1: Options and results

A number of options were analysed to understand their impact on, primarily, channel stability and land take. Most options considered stormwater harvesting for transfer to a 'stormwater to potable' scheme to illustrate how the option might integrate with broader WOWC management options being investigated by Western Water. Schematic plans for each option are provided in Figure 10, Figure 11, Figure 12 and Figure 13.

Figure 14 provides a summary of the EPI results for the base case and each option.

Table 4. Case study 1 options description and results

Option	Description	RB	Channel stability (EPI)	Stormwater extraction (Average ML/day)	Constructed waterway area in addition to base case (i.e. where EPI >1.2)	Effective area (m^2)
Base case (Sunbury WOWCA)	WOWCA drainage strategy	8	9.2	0	Yes	58,300
		9	0.82	0	No	14,700
		10	1.28	0	Yes	43,400
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor					**116,400**
1	Diversion of flow from catchments 8 and 9 to RB10. Discharge from RB 10 via a constructed waterway. Increase the size of RB 10 to mitigate flows and reduce erosion potential.	8	NA	0	NA	58,300
		9	NA	0	NA	14,700
		10	4.33	0	55,400	320,000
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor					**393,000**
2	Flow diversion to RB 10 and increase in RB 10 area (as per option 1) Plus stormwater reuse from RB 10	8	NA	0	NA	58,300
		9	NA	0	NA	14,700
		10	0.95	20	55,400	160,000
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor					**233,000**
3	Flow paths as per the WOWCA drainage strategy Plus stormwater reuse from wetland/RBs 8 and 10.	8	1.02	3.5	NA	58,300
		9	0.82	0	NA	14,700
		10	1.08	0.3	NA	43,400
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor					**116,400**
4	Flow diversion from catchment 8 to the RB 9. Discharge to Jacksons Creek from RB 9 and 10. Increase RB 9 area plus stormwater reuse from RBs 9 and 10	8	NA	0	NA	58,300
		9	4.42	5	34,200	35,600
		10	1.08	0.3	NA	43,400
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor r					**137,300**

Case study 1: Options plans

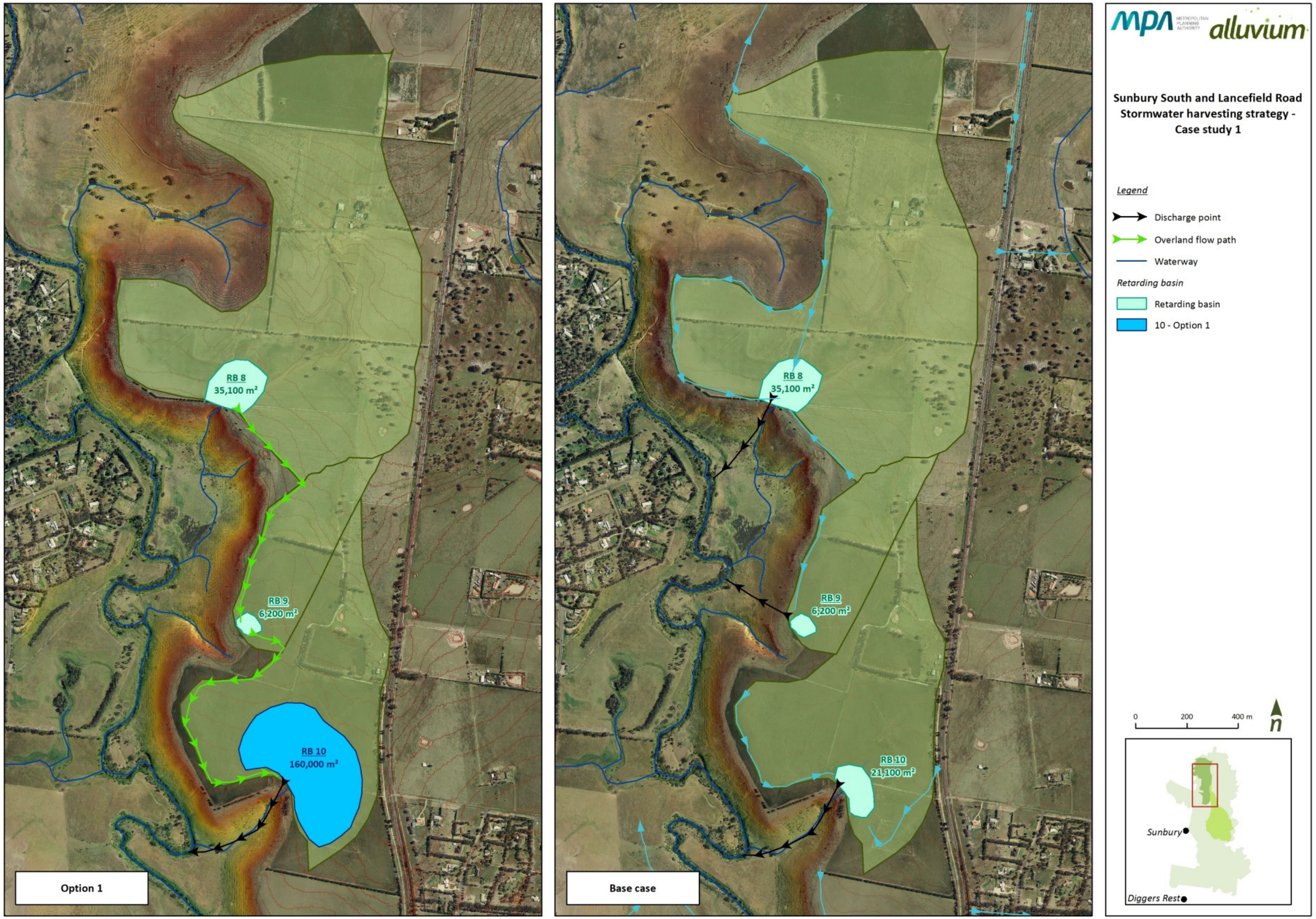


Figure 10. *Case study 1: Option 1*

Figure 11. *Case study 1: Option 2*

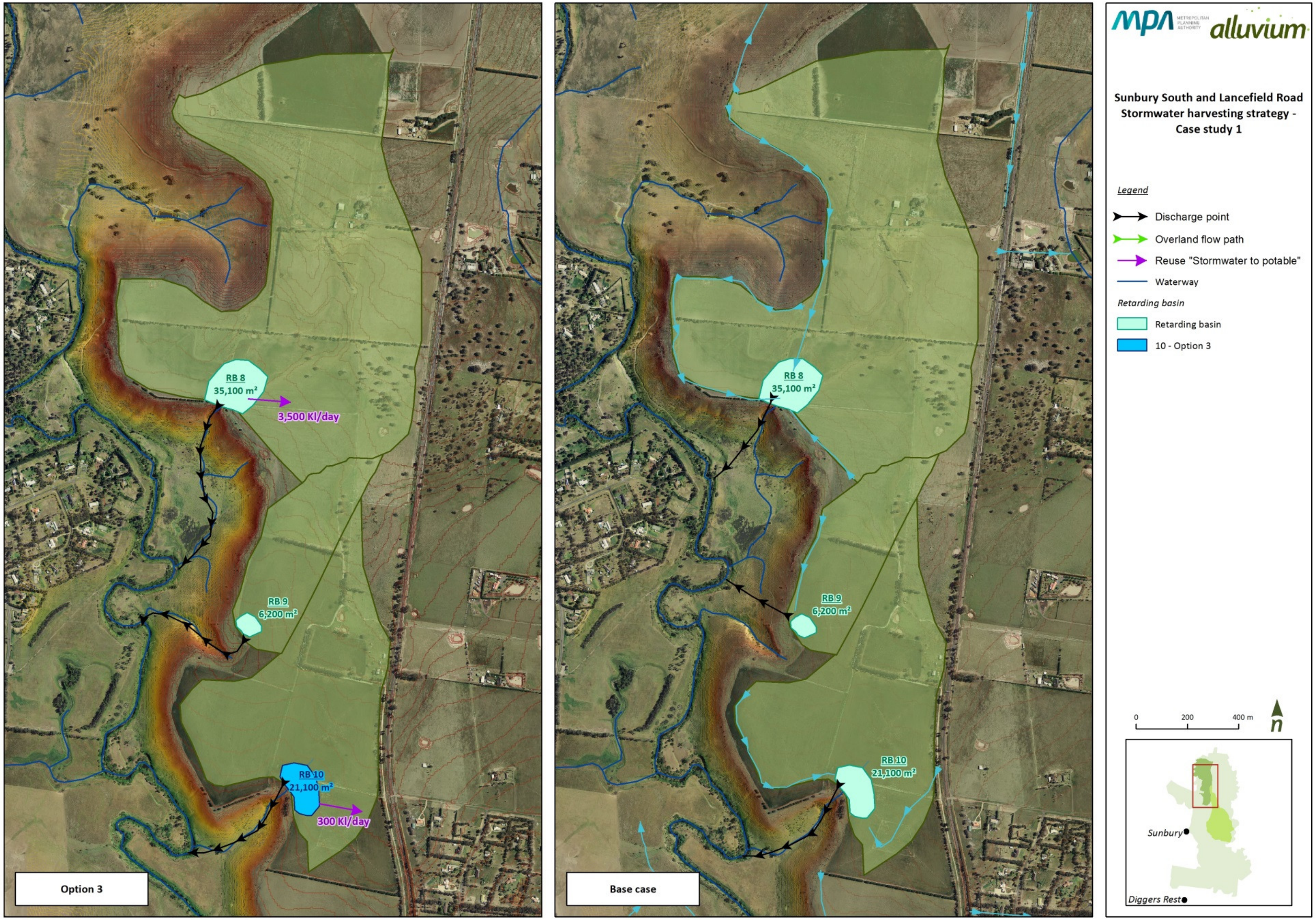


Figure 12. *Case study 1: Option 3*

Figure 13. *Case study 1: Option 4*

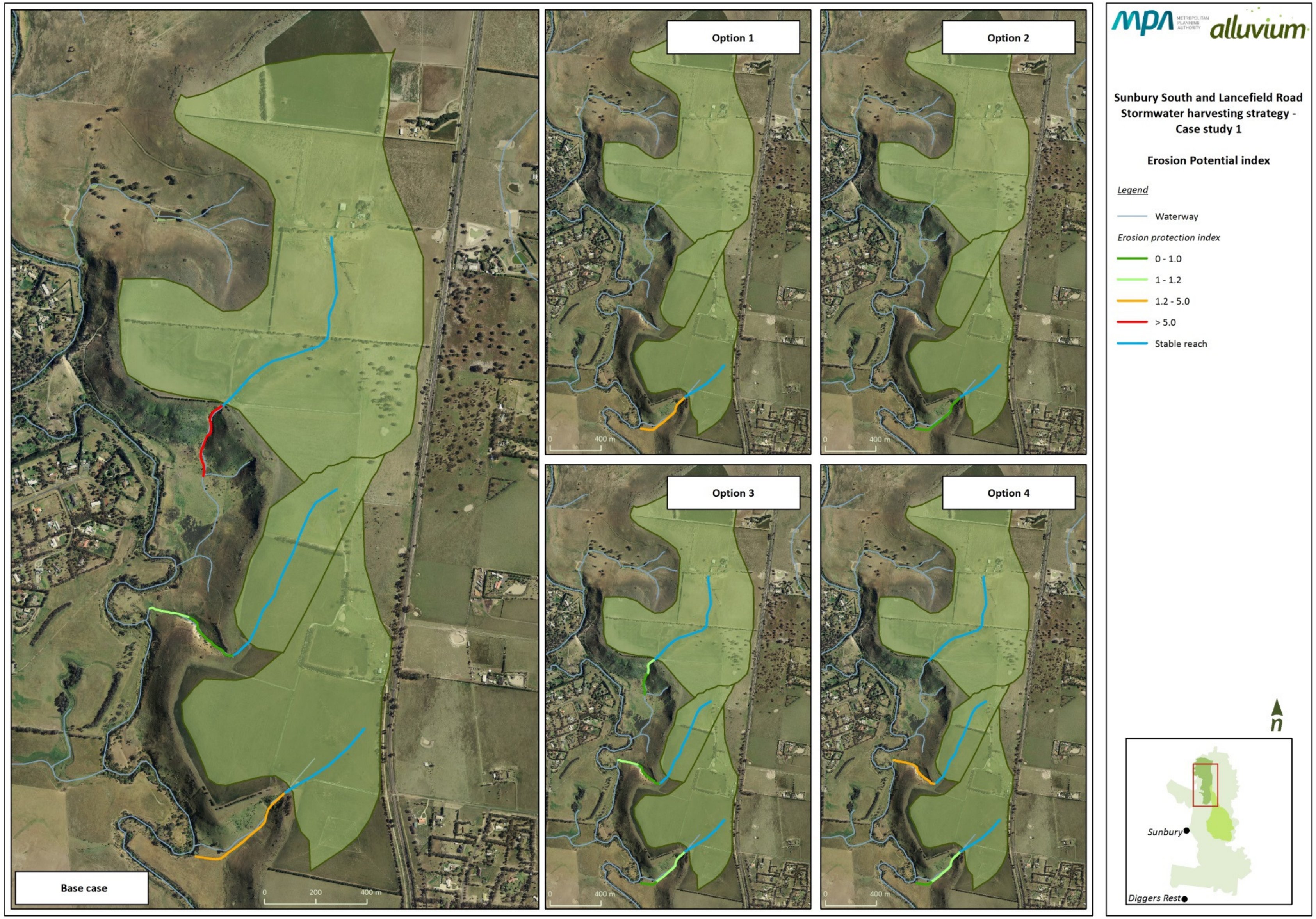


Figure 14. *Case study 1: Erosion potential index summary*

Case Study 1 – Summary

The options investigated highlight challenges associated with transferring stormwater volumes to Jacksons and Emu Creeks. Options to protect receiving waterways include diverting flows from sensitive discharge points requiring significantly larger RBs. Although as Option 1 illustrates, even a significantly larger RB (approximately 3.4 times larger than the base case) is unable to meet the EPI objective specified at the start of the project.

Stormwater harvesting was also considered in a range of configurations from the three RBs. The reasonableness of these assumptions will depend on how they integrate with the options proposed as part of the Sunbury WOWCA project. However, in general terms it does illustrate that stormwater harvesting could play a significant role as part of an integrated solution.

Option 3 strikes a balance by retaining the base case RB area as well as achieving EPIs of below 1.2 with stormwater harvesting of 4 ML/day (when averaged over the whole year). This is not an insignificant volume in terms of transfer and treatment, particularly when we consider that there may be similar examples in this system. Consider also that 4 ML/day reflects an average while the peak extraction rate will determine infrastructure capacity requirements.

2.3 Case study 2: High value and sensitive drainage lines

Where? Case study 2 concerns a tributary catchment on the west bank of Emu Creek, focussing on a small sub-catchment immediately to the east of the intersection between Rolling Meadows Drive and Lancefield Road.

What? In the previous geomorphic and vegetation assessment (Alluvium, 2014), the waterways in the case study area were classified as ranging from intact (the highest classification) to moderate condition. The stream network within the Case Study 2 boundary comprises a main stem with two northern tributaries. The middle reaches of the main stem are chains of ponds, a regionally significant stream type. One chain of ponds was classified in the geomorphic assessment as being the best example in the study area, and one of the best that the authors had observed in the wider Port Phillip and Westernport region (see Figure 16).

The other is threatened by erosion, possibly triggered by increased urban flows from upstream and exacerbated by vegetation removal. These streams are remnant pre-European forms that have survived land use change, increase flows from urban development and direct modification. They provide habitat for a wide range of native plants that are under pressure in the peri-urban landscape. The upstream end of the main stem is steeper, and has been modified to allow flow to be stored in farm dams. The downstream end of the main stem is actively eroding with incision progressing upstream.

The north bank tributaries are ephemeral channels in good geomorphic condition, with no evidence of active erosion. Although they do not have the same regional significance as the chains of ponds, they are remnants of pre-European physical form and as such have high (but not extreme) geomorphic values.

The management recommendations for case study 2 reflect the valuable and fragile nature of the waterways. The chains of ponds and northern tributaries *should be protected* and the eroding or degraded reaches at the upstream and downstream end of the main stem should be stabilised through *modification or construction of a waterway.*

Why? Case study 2 was selected identified because it will allow for the examination of the impact of stormwater drainage on the highest value waterway in the study area. It is likely that the regionally significant waterways in this typology will need to be retained, and this case study will investigate options for achieving this.

Figure 15 shows the case study area, while Figure 16 illustrates the geomorphic values within it.

Figure 15. *Case study 2 area*

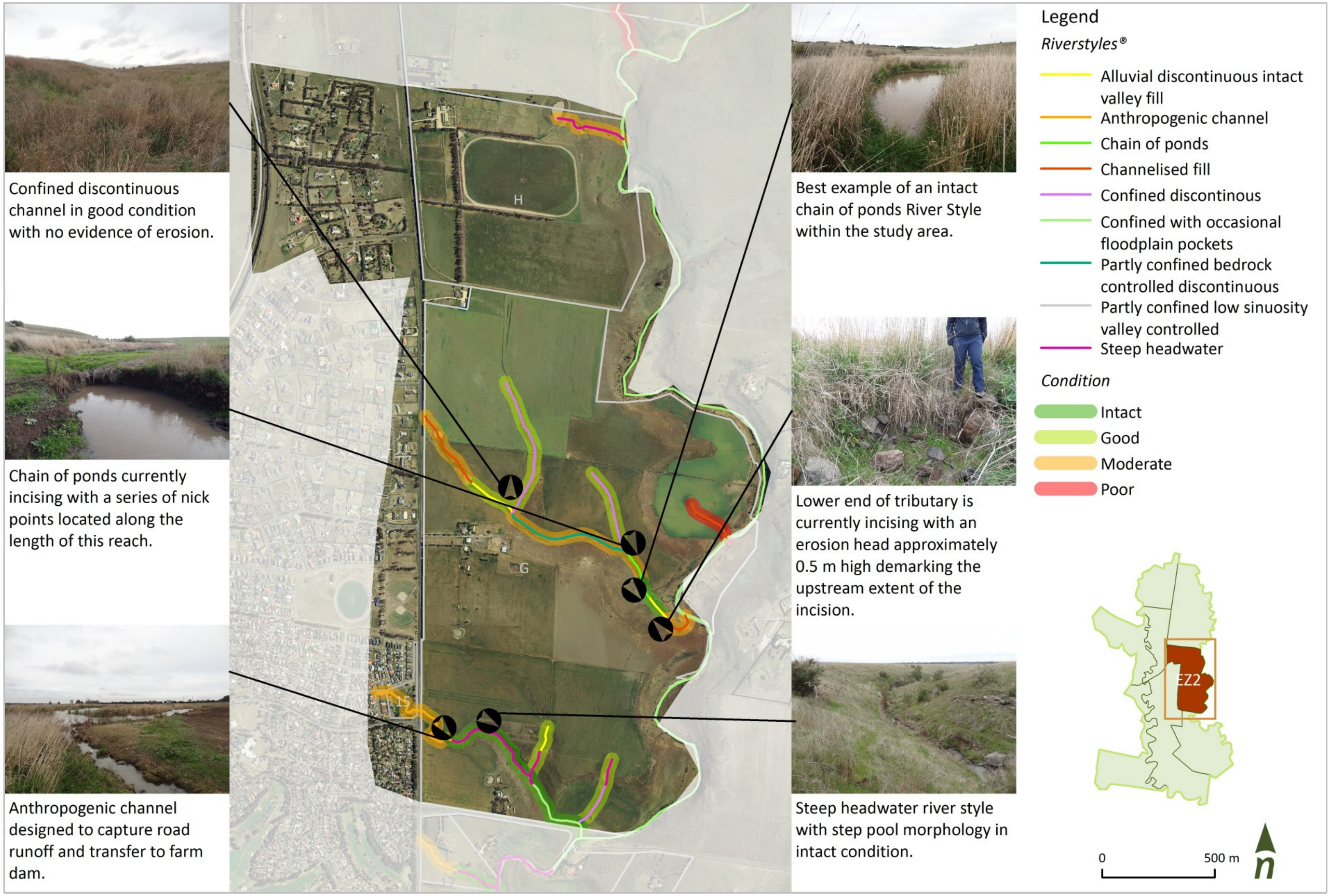


Figure 16. *Geomorphic values of waterways in Case Study 2*

Case study 2 - Catchment delineation

Catchment boundaries were identified for the Case Study 2 waterways using the same approach outlined within Case Study 1, and described in Attachment A and B. The catchments were used as the basis for the hydrologic and hydro-geomorphic analysis of the stormwater management options, and are presented in Figure 17.

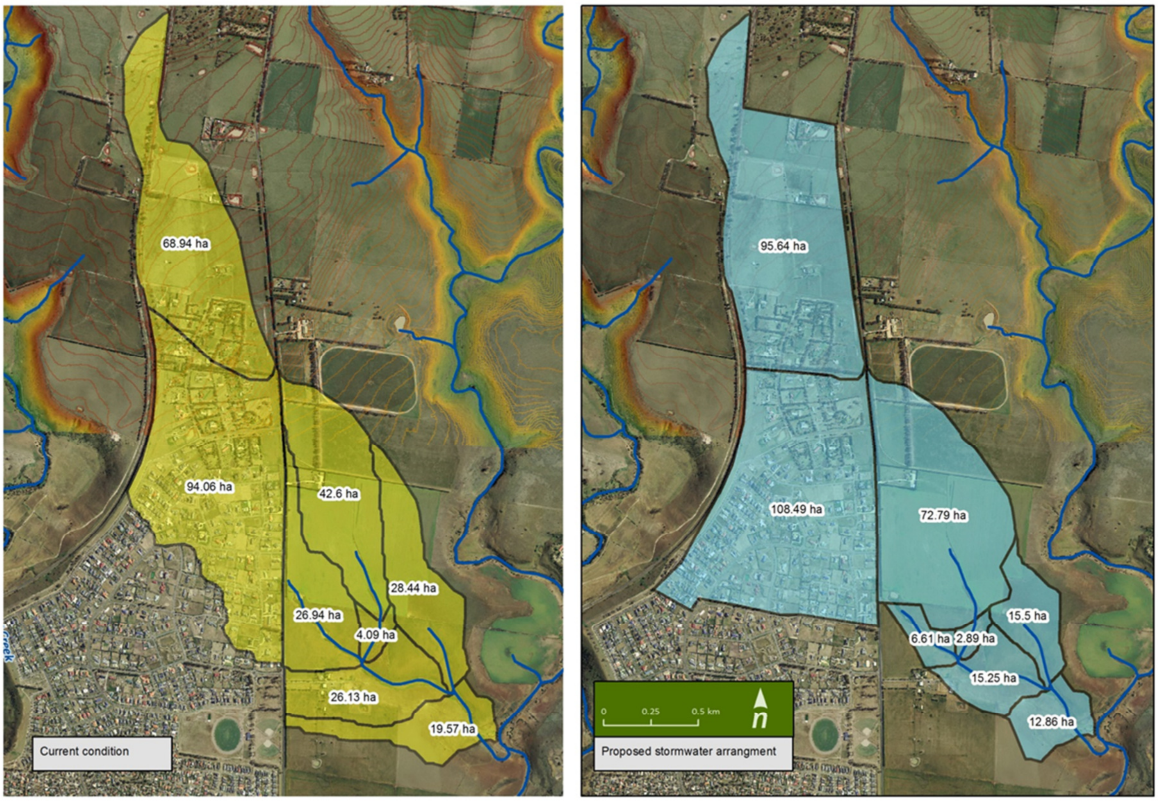


Figure 17. *Catchment delineation*

Sunbury WOWCA strategy approach to Case Study 2

The Sunbury WOWCA sees outflows from RB 16 diverted to RB 17. From there flows are directed to a natural waterway downstream. There is a development area downstream of RB 17 which drains into a natural waterway. Some key baseline parameters are summarised in Table 5 below.

Table 5. Case study 2: baseline parameters

RB / catchment number	Catchment area (ha)	Fraction impervious	Wetland / RB effective area (ha)	Total land take (ha)*
16	137.4	0.5	4.1	6.5
17	151.6	0.65	4.4	9.3

The proposed catchment delineation and a schematic of the Sunbury WOWCA RB locations and waterway alignments are provided in Figure 18.

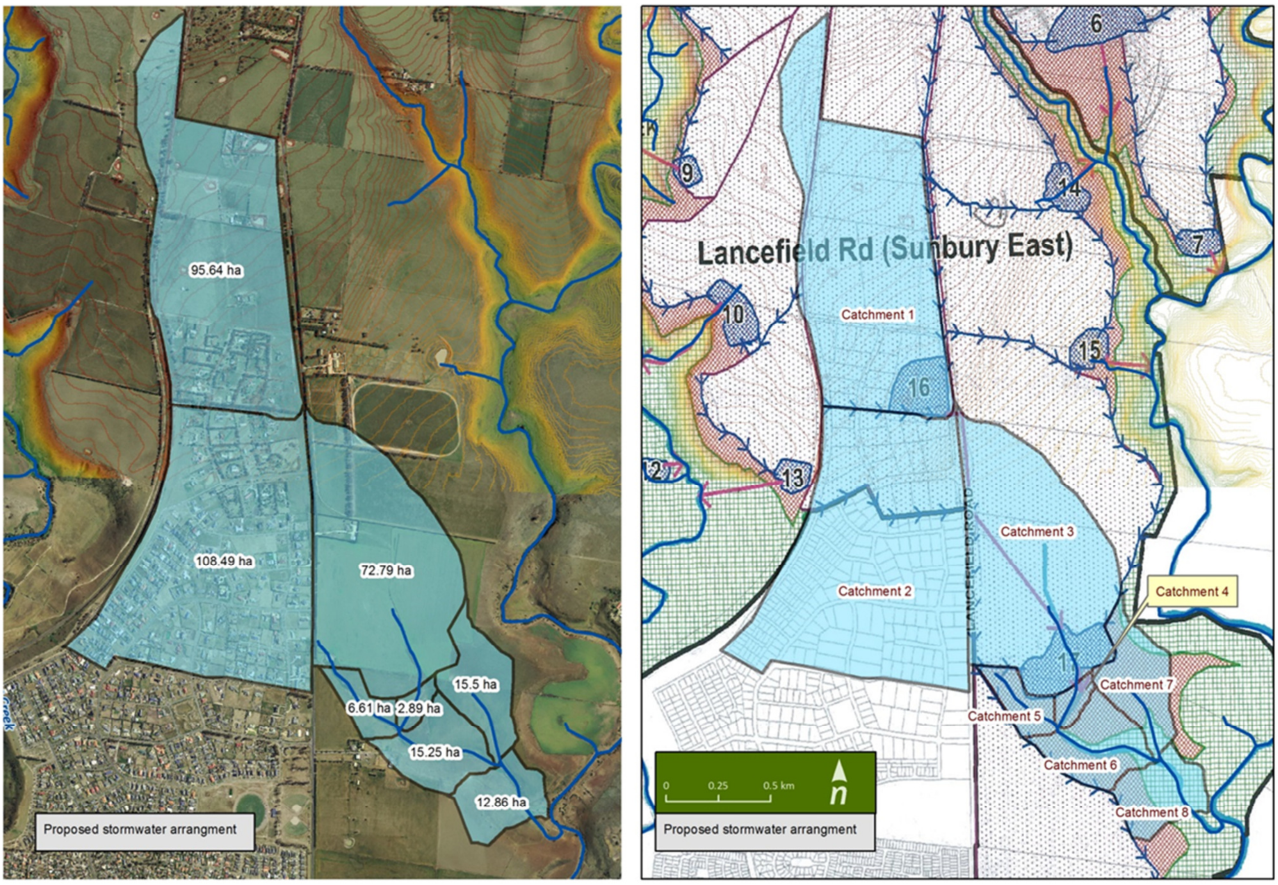


Figure 18. *Case study 2: catchment boundaries for current and developed conditions*

Waterway delineation

The following waterway reaches were defined within the Case Study area.

Table 6. Case study 2: waterway reaches for EPI analysis

Reach name	Catchment	Description
Reach 1	Catchment 1	Upstream of retarding basin 17
Reach 2	Catchment 2	Downstream of retarding basin 17
Reach 3	Catchment 3	
Reach 4	Catchment 4	Where catchment 6 joins the system
Reach 5	Catchment 5	It is assumed that half the flows generated in catchment 7 flow in this reach
Reach 6	Catchment 6	
Reach 7	Catchment 7	Location of chain of ponds
Reach 8	Catchment 8	
Reach 9	Catchment 9	Steep channel bed grade

Figure 19. *Case study 2: defined waterway reaches*

Alternative stormwater drainage options

As discussed above, the Sunbury WOWCA configuration has the potential to risk unique waterway values as additional flows from urbanised catchments are diverted through these channels. The aim of Case Study 2 is to investigate alternatives that have the potential to better preserve those values. In response, the following alternative drainage strategies were developed.

Option 1: Involves increasing the size of RB 17 and adds a wetland and retarding basin just upstream of the reach containing the high value chain of ponds (Figure 20).

Option 2: This option is same as option 1 with the addition of stormwater harvesting from both RB 17 and the additional proposed wetland/retarding basin (Figure 21).

As per Case Study 1, modelling was completed to understand each option's impact on

- channel stability
- stormwater quality and the volume of stormwater extraction required or proposed
- the requirement for constructed waterways, and
- land take i.e. associated with RB / wetlands, auxiliary activities and waterways.

Further detail around the analysis undertaken is provided in Attachment C.

Case study 2: Options and results

The results for the base case and two additional options are provided in Table 7 below. As per Case Study 1, a progressive improvement in channel stability can be observed through the increase in RB area and stormwater extraction from those RBs for reuse. Plans showing each option are provided in Figure 20 and Figure 21. Maps showing the relative EPIs across the Case Study area are provided in Figure 22.

Table 7. Case study 2 options description and results

Option	Description	RB	Channel stability (EPI)	Stormwater quality (pollution reduction %)	Stormwater extraction (Average ML/day)	Constructed waterway area in addition to base case (i.e. where EPI >1.2)	Total area including waterways (m^2)
Base case (WOWCA)	Sunbury WOWCA drainage strategy	17	Waterway 1: 1.88 Waterway 2: 3.6 Waterway 3: 2.04 Waterway 4: 1.5 Waterway 5: stable Waterway 6: 0.46 Waterway 7: 1.7 Waterway 8: 1.04 Waterway 9: 2.26	TSS: 88.2 TP: 76.5 TN: 62.1	NA	Waterway 1: Yes Waterway 2: Yes Waterway 3: Yes Waterway 4: Yes Waterway 5: No Waterway 6: No Waterway 7: Yes Waterway 8: No Waterway 9: Yes	65,000
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor						**65,000**
1	Increasing in the size of RB 17 with an additional wetland and retarding basin just upstream of the reach that contains the high value chain of ponds	17	Waterway 1: 1.88 Waterway 2: 1.44 Waterway 3: 1.48 Waterway 4: 1.08 Waterway 5: stable Waterway 6: 0.46 Waterway 7: 1 Waterway 8: 0.23 Waterway 9: 1.34	TSS: 94.0 TP: 84.8 TN: 72.5	NA	Waterway 1: Yes Waterway 2: Yes Waterway 3: Yes Waterway 4: No Waterway 5: No Waterway 6: No Waterway 7: No Waterway 8: No Waterway 9:Yes	231,000
		New RB		TSS: 69.9 TP: 60.2 TN: 44.7	NA		16,000
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor						**247,000**

Option	Description	RB	Channel stability (EPI)	Stormwater quality (pollution reduction %)	Stormwater extraction (Average ML/day)	Constructed waterway area in addition to base case (i.e. where EPI >1.2)	Effective area (m^2)
2	The same as option 1 plus stormwater harvesting from both RB 17 and the additional proposed wetland/retarding basin	17	Waterway 1: 1.88 Waterway 2: 1.08 Waterway 3: 1.34 Waterway 4: 1.01 Waterway 5: stable Waterway 6: 0.46 Waterway 7: 0.72 Waterway 8: 0.2 Waterway 9: 0.87	TSS: 97.8 TP: 97.1 TN: 95.7	20	Waterway 1: Yes Waterway 2: No Waterway 3: Yes Waterway 4: No Waterway 5: No Waterway 6: No Waterway 7: No Waterway 8: No Waterway 9: No	136,500
		New RB		TSS: 83.8 TP: 82.5 TN: 80.5	5		16,000
	Estimated total land take incl. RB + Waterway/s x WOWCA area factor						**152,500**

Case Study 2 – Summary

The options investigated for Case Study 2 illustrate that a significant increase in the area of RB 17, and an additional RB upstream of reach 7 can bring the EPI of that reach to 1, protecting the chain of ponds it contains. This represents a significant increase in expected land take from 6.5 to 24.7 ha (a nearly four times increase).

Option 2 considers stormwater harvesting, which brings the land take to 15.2 ha (approximately 2.4 times base case). Whilst an improvement, this is based on an average extraction rate of 20 ML/day from RB 17 which is unlikely to be considered feasible. For this option it will be beneficial to understand (from Western Water) the volume of stormwater that may be able to be extracted from the system.

Case study 2: Option plans

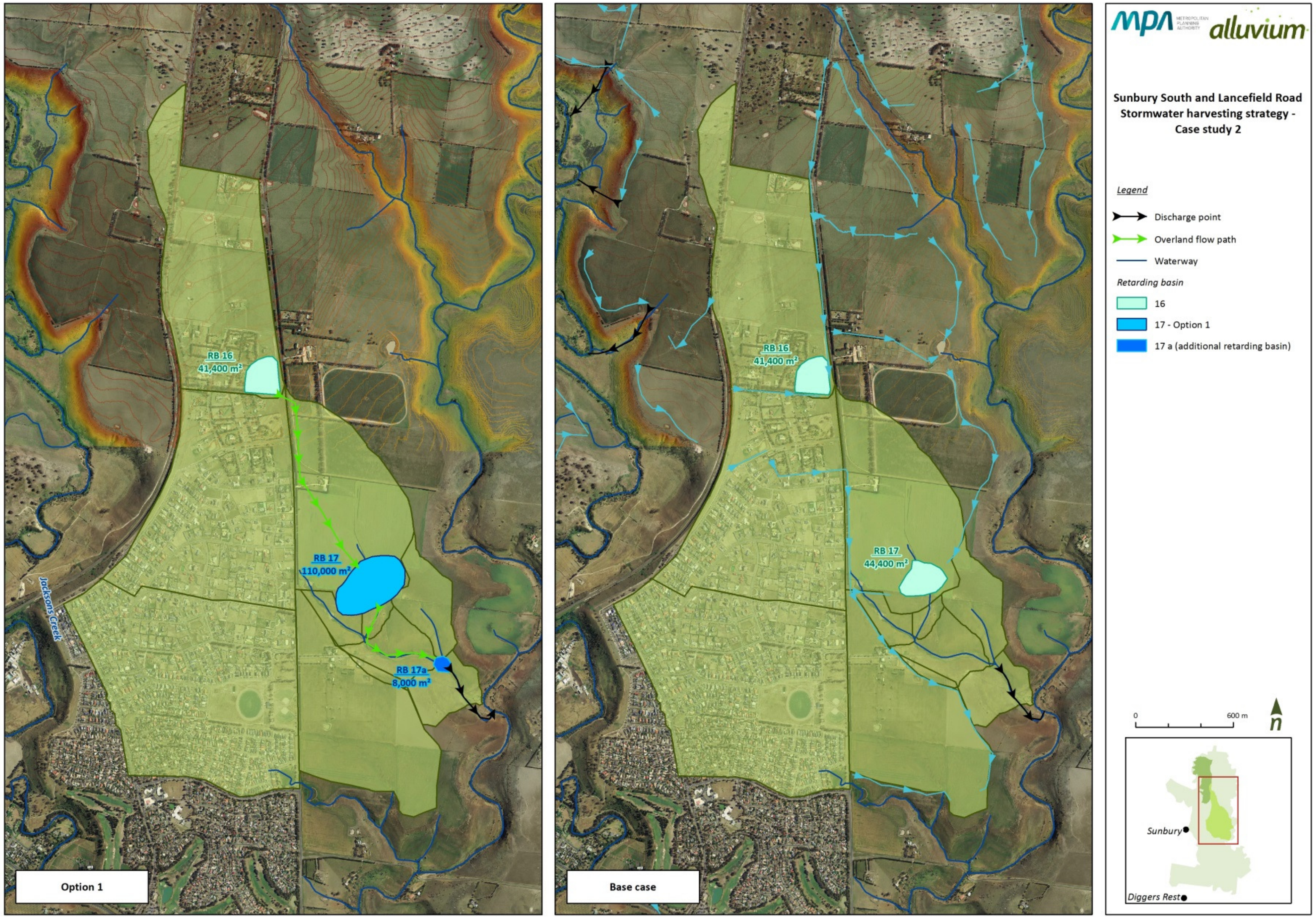


Figure 20. *Case Study 2: option 1*

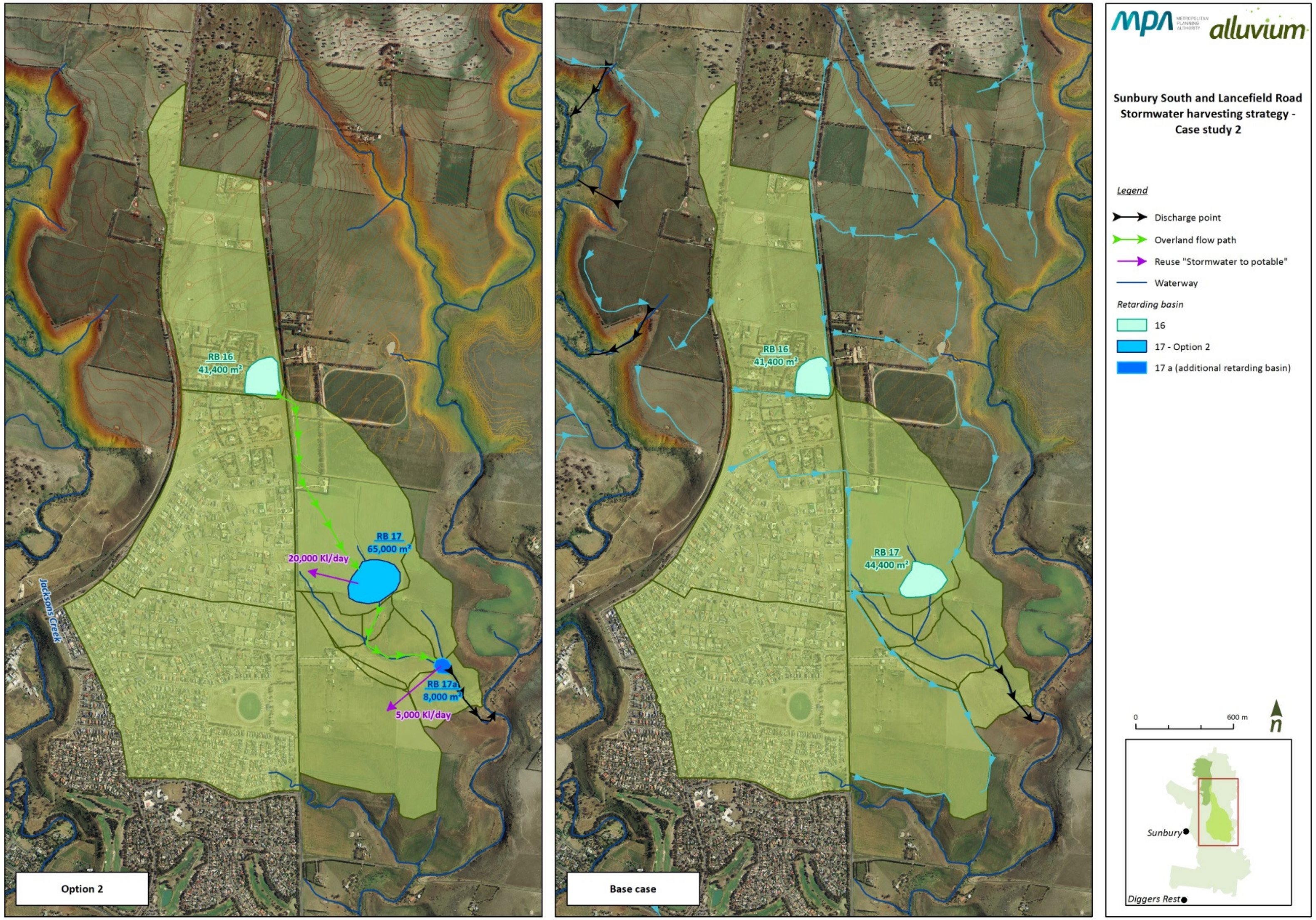


Figure 21. *Case Study 2: option 2*

Figure 22. *Case study 2: Erosion potential index summary*

3 Summary and recommendations

This project highlights the changes in approaches and infrastructure requirements that might occur when different project objectives are adopted. The Sunbury WOWCA reasonably adopted flood mitigation and stormwater quality objectives to define RB locations and areas and constructed waterway alignments. With and understanding of the waterways within Sunbury South and Lancefield Road gained through previous analysis and site visits, it was proposed that other objectives, including erosion potential, might also be appropriate to respond to the regions unique values and topography.

The outcomes from the development of the stormwater management framework indicate that there are a number of locations across the project area that deserve a more detailed degree of analysis to better understand the impact of urbanisation and appropriate or alternative surface water management responses that address flood mitigation and other objectives.

In examining two of these locations in more detail, conclusions include:

- Significantly larger retarding basins – in the order of 2 to 4 times the size of the base case - are required within the two Case Study examples to meet an objective of a lower EPI. However, even where a larger RB is assumed and modelled, an EPI of 1 may yet be unachievable.
- Additional retarding basins, upstream of sensitive locations (such as Case Study 2's chain of ponds) may assist in meeting the EPI objective and protecting downstream objectives, creating additional land take requirements.
- Stormwater harvesting may prove to be effective in reducing EPI while potentially delivering an alternative water benefit to a WOWC strategy for the area. However, some of the volumes identified are extremely large and are unlikely to be considered feasible considering capital costs of transfer and treatment and the ongoing maintenance and energy costs associated with that option.

  Further investigation of the Case Study sites and other locations might be investigated to understand the costs and benefits of using stormwater harvesting to reduce RB and land take requirements, provide and alternative water source and protect waterway values.

3.1 Recommendations

An important outcome is that it is difficult to extrapolate these results across the broader project area given the uniqueness of each subcatchment. It may be appropriate to establish a land allowance of between 2 to 4 times the area for RBs proposed within the Sunbury WOWCA that are defined as being 'unlikely to be feasible' within the stormwater management framework introduced during this project. This may be suitable if there is no more analysis undertaken due to time or other constraints.

Rather than extrapolating however, it would be preferable to complete analysis similar to that undertaken for each Case Study for locations and discharge points considered 'unlikely to be feasible' or 'feasible with further investigation required': with priority given to those 'unlikely to be feasible', to understand with a greater degree of certainty the options available and the implications of those options so that a preferred approach can be pursued.

Melbourne Water will need to be consulted on these preliminary results and understand how alternative objectives (e.g. EPI) might be adopted to protect unique values, and how adopting those objectives might change or influence the development services scheme (DSS) process.

Western Water will need to consider these results in the context of the Sunbury WOWCA and the options being investigate as part of that study, in particular how a 'stormwater to potable' or other stormwater harvesting option might integrate with a stormwater management strategy that is in part driven by an EPI target.

Attachment A
Additional framework comments

Emu Creek

Category	Comment
R/B Wetland	2
Feasible	Feasible: No additional comment

Category	Comment
R/B Wetland	4
Feasible	Feasible: A confined waterway that should cope with additional flows
Comment	Pockets within floodplain indicate erosion potential. Limited vegetation might improve waterway resilience

Category	Comment
R/B Wetland	5
Feasible	Feasible: further investigation noting there is a good condition chain of ponds further downstream
Comment	The chain of ponds is on a declining trajectory and Melbourne Water will need to determine the extent to which these should be protected

Category	Comment
R/B Wetland	6
Feasible	Feasible: downstream waterway is relatively robust and resilient. Waterway form needs to be maintained.
Comment	There will be a risk that additional flows will trigger erosion. Good stormwater harvesting location.

Category	Comment
R/B Wetland	7
Feasible	Unlikely to be feasible: Extremely steep embankment
Comment	

Category	Comment
R/B Wetland	14
Feasible	Feasible: Downstream is relatively robust and should be able to manage additional flows.
Comment	The RB as shown is located over a section of high value waterway that should be protected. Ideally the RB would be moved to discharge downstream from this section. This could allow flows from 14 to be redirected to a confined section of waterway between RB 5 and 14

Category	Comment
R/B Wetland	15
Feasible	Feasible: this is theoretically feasible based on a desktop assessment
Comment	

Category	Comment
R/B Wetland	16 and 17
Feasible	Feasible: further investigation required. RB17 is situated atop a high value stretch of waterway. An alternative location should be considered if possible. There is a chain of ponds in excellent condition downstream that is likely to require protection. Erosion is a significant risk at this location also.
Comment	This section has one of the highest erosion potential index (EPI) within the project area and there is a huge potential for erosion (likely to need large wetland and RB to get EPI down to one). There is also an erosion head moving upstream from Emu Creek

Category	Comment
R/B Wetland	18
Feasible	Feasible: further investigation required. Stable waterway in relatively good condition that should be able to manage additional flows however the RB is at the top of a steep headwater.
Comment	The waterway is an intact valley fill (IVF) at top end, and then becomes a steep headwater (SH). The SH can take a lot more flow, so the proposed RB is likely to be ok. IVF is short and in good condition, so ideally this would be protected, so we need to be sure we happy with constructing a waterway in this location if this is required to make the .solution work. The short length of IVF and its isolated nature mean protection efforts might be better directed elsewhere.

Category	Comment
R/B Wetland	27 and 32
Feasible	Feasible: There is potentially high value vegetation along this reach so the waterway will need to be modified to account for this.
Comment	This is a highly dammed stretch that has low geomorphic value therefore discharging additional stormwater to a constructed waterway is suitable from a geomorphology perspective. Time stamped high value vegetation has been recorded at these sites. Biosis have been to property 7 with no vegetation observed.

Category	Comment
R/B Wetland	28 / 29 / 30
Feasible	Feasible: based on a desktop assessment. Suggest low flows to the RB with larger overland flows to the proposed constructed waterway.
Comment	This area appears to be completely modified due to the quarry. From a geomorphic perspective constructed waterway with flow management is appropriate. High value time stamped vegetation here, but the site was not visited.

Category	Comment
R/B Wetland	31
Feasible	Unsure: further investigation required
Comment	

Category	Comment
R/B Wetland	33
Feasible	Feasible: 33 is located upstream of 29. RB 33 needs to reduce flows to get into the culvert under road.
Comment	Upstream of RB 33 is an intact valley fill, which would ideally be preserved making it a candidate to become a constructed waterway. Melbourne Water will need to confirm this.

Jacksons Creek

Category	Comment
R/B Wetland	1
Feasible	Feasible: There is no existing waterway, so a constructed waterway may be appropriate.
Comment	Need to be mindful to divert flows away from protected waterways to the south west.

Category	Comment
R/B Wetland	8
Feasible	Unlikely to be feasible: there is a significant degree of difficulty associated with the very steep embankment.
Comment	Any additional flows will impact high value reaches that flow into Jacksons Creek. There is significant risk that large sediment loads will be delivered to Jacksons Creek.

Category	Comment
R/B Wetland	9
Feasible	Unlikely to be feasible: this is a a very steep escarpment and there is uncertainty as to how water be transferred from the plateau to Jacksons Creek.
Comment	There are high value reaches in the vicinity also that will need to be avoided. It is recommended to avoid frequent, low flows here, potentially diverting these to 10 (below). Greater, less frequent flows can be transferred to the floodplain.

Category	Comment
R/B Wetland	10
Feasible	Feasible: there is evidence of erosion in this channel and a constructed waterway may be appropriate.
Comment	The waterway is very steep at the top which will require particular design attention.

Category	Comment
R/B Wetland	11
Feasible	Feasible: The existing channel doesn't have a lot of flow and may benefit from additional flows.
Comment	The existing channel should cope with additional flows considering the small RB and catchment associated with the channel.

Category	Comment
R/B Wetland	12
Feasible	Feasible: noting that the current RB location suggests that it will be constructed over a reach with high geomorphic values.
Comment	The waterway will need to be maintained in its current form. This is a swampy reach so standard design may not be appropriate. Design here will need to be sensitive to unique conditions to retain values. Also, there is an existing dam upstream. This could be considered to be modified to perform the role of the RB.

Category	Comment
R/B Wetland	13
Feasible	Feasible: further investigation is required to ensure that the transfer of flows into Jacksons Creek is technically feasible
Comment	There is no existing channel or waterway into Jacksons Creek. Potentially retard the 1 in 100 year flow and transfer this via an existing access track to the floodplain.

Category	Comment
R/B Wetland	19
Feasible	Feasible
Comment	There is an existing dam that currently stores water for a vineyard from an upstream urban catchment. Seems like a suitable location for an RB.

Category	Comment
R/B Wetland	20
Feasible	Unlikely to be feasible: The direction of the discharge as illustrated is very steep. Diverting flows down this alignment is not recommended.
Comment	Option to consider discharging flows into the waterway that exits RB20. This option would require more investigation to understand the erosion potential as this location is also very steep.

Category	Comment
R/B Wetland	21
Feasible	Feasible: needs further investigation as it seems challenging to get flows to the floodplain.
Comment	The proposed alignment may be feasible. From a waterway perspective it is more important that flows are discharged in the direction shown, and not to the waterway to the east. Potentially collect as much stormwater as possible, minimising flows downstream.

Category	Comment
R/B Wetland	22 and 23
Feasible	Unlikely to be feasible: requires more investigation as this is a very steep embankment.
Comment	Potentially maximise stormwater harvested, minimising flows downstream.

Category	Comment
R/B Wetland	24
Feasible	Feasible
Comment	According to timestamp data there are some vegetation values in this location that will need to be considered during design and preferably avoided

Category	Comment
R/B Wetland	25
Feasible	Feasible: requires more investigation as based on a desktop review
Comment	

Category	Comment
R/B Wetland	26
Feasible	Feasible: requires more investigation as based on a desktop review
Comment	

Category	Comment
R/B Wetland	35
Feasible	Feasible: the recommendation for a constructed waterway is supported
Comment	This in Sunbury West and outside the scope of this investigation.

Category	Comment
R/B Wetland	39
Feasible	Unlikely to be feasible: Further investigation required due to the significant complexity of this site
Comment	There are significant erosion issues associated with this reach including existing 'nick' points while the spillway is completely eroded. The footprint and point of entry of what is proposed is also unclear. Potentially consider discharging to the constructed waterway that is proposed to the north of RB 39.

Category	Comment
R/B Wetland	40
Feasible?	Feasible: this intersects high value vegetation along the main channel that will need to be considered during design.
Comment	

Category	Comment
R/B Wetland	41
Feasible?	Feasible
Comment	Based on the plan, it looks like this RB is located at an existing dam. Note also that the existing channel does not join Jacksons Creek and has been filled in.

Category	Comment
R/B Wetland	42
Feasible?	Feasible
Comment	

Category	Comment
R/B Wetland	43
Feasible?	Feasible: This reach has significant erosion. A constructed waterway is recommended taking into account the high value of vegetation that has been verified in the field.
Comment	

Category	Comment
R/B Wetland	44
Feasible?	Unlikely to be feasible: This section is very steep and high and there is a question regarding how these flows are proposed to transfer to Jacksons Creek.
Comment	There is a waterway to the east of RB 44 that may be able to take the intended flows but regardless, this would also be very challenging. It seems there may be some existing flows from an upstream urbanised catchment. There may be an opportunity to connect into that system at some point. It would be beneficial to understand the EPI for the receiving stream.

Attachment B
Case study 1: Additional technical analysis

Case study 1 – additional technical analysis

To understand the changes in hydrology caused by future urban development and proposed stormwater management arrangement, a series of continuous simulation hydrologic models of the study area were developed using MUSIC software. MUSIC was used to simulate catchment hydrology for current or pre-development conditions, the stormwater arrangements proposed in the WOWCA (the base case) and four alternative stormwater management options.

Option	Description
Base case	As per Western Water's WOWCA project
1	Diversion of flow from catchments 8 and 9 to RB10. Discharge from RB 10 via a constructed waterway. Increase the size of RB 10 to mitigate flows and reduce erosion potential.
2	Flow diversion to RB 10 and increase in RB 10 area (as per option 1) Plus stormwater reuse from RB 10
3	Flow paths as per the WOWCA drainage strategy Plus stormwater reuse from wetland/RBs 8 and 10.
4	Flow diversion from catchment 8 to the RB 9. Discharge to Jacksons Creek from RB 9 and 10. Increase RB 9 area plus stormwater reuse from RBs 9 and 10

The MUSIC models for current conditions and the base case stormwater management arrangements are presented schematically in Figure A and Figure B below. The Melbourne Airport rain gauge was selected as the most appropriate rain gauge station with 40 years of 6 minute rainfall data (1970 to 2010) introduced to the model.

Fraction impervious: The other important element of hydrologic modelling in MUSIC is fraction impervious. The entire study area is agricultural in the pre-development scenario so a fraction impervious of zero was adopted. Post-development catchments have been allocated impervious fractions as per the WOWCA study (see Table 1 below). Fraction impervious of 0 was applied to areas that are planned to be retained in natural condition.

Table 1 *Case study 1. Catchment area and fraction impervious assumptions*

Subcatchments	Current conditions		Developed conditions	
	Catchment area (ha)	Fraction impervious	Catchment area (ha)	Fraction impervious
Catchment 8	70.1	0	119.2	54
Catchment 8-1	2.0	0	2.5	0
Catchment 9	18.7	0	20.7	65
Catchment 9-1	8.5	0	3.5 4.34	65 0
Catchment 10	36.1	0	53.7	59
Catchment 10-1	23.8	0	6.3 4.9	59 0

The retarding basins proposed in the WOWCA strategy were modelled as ponds in MUSIC. Table 2 provides the key characteristics of these structures.

Table 2 *Case study 1: RB MUSIC modelling parameters*

Retarding basin	Low flow outlet pipe diameter (mm)	Weir length (m)
RB 8	600	11
RB 9	225	6
RB 10	450	17

Melbourne Water MUSIC model parameters were also adopted (Table 3).

Table3. *MUSIC model parameters adopted in this study*

Parameter	Value
Soil storage capacity (mm)	30
Initial storage (% of capacity)	25
Field capacity (mm)	20
Infiltration capacity coefficient-a	200
Infiltration capacity exponent-b	1
Initial depth (mm)	10
Daily recharge rate (%)	25
Daily baseflow rate (%)	5
Daily deep seepage rate (m%)	0

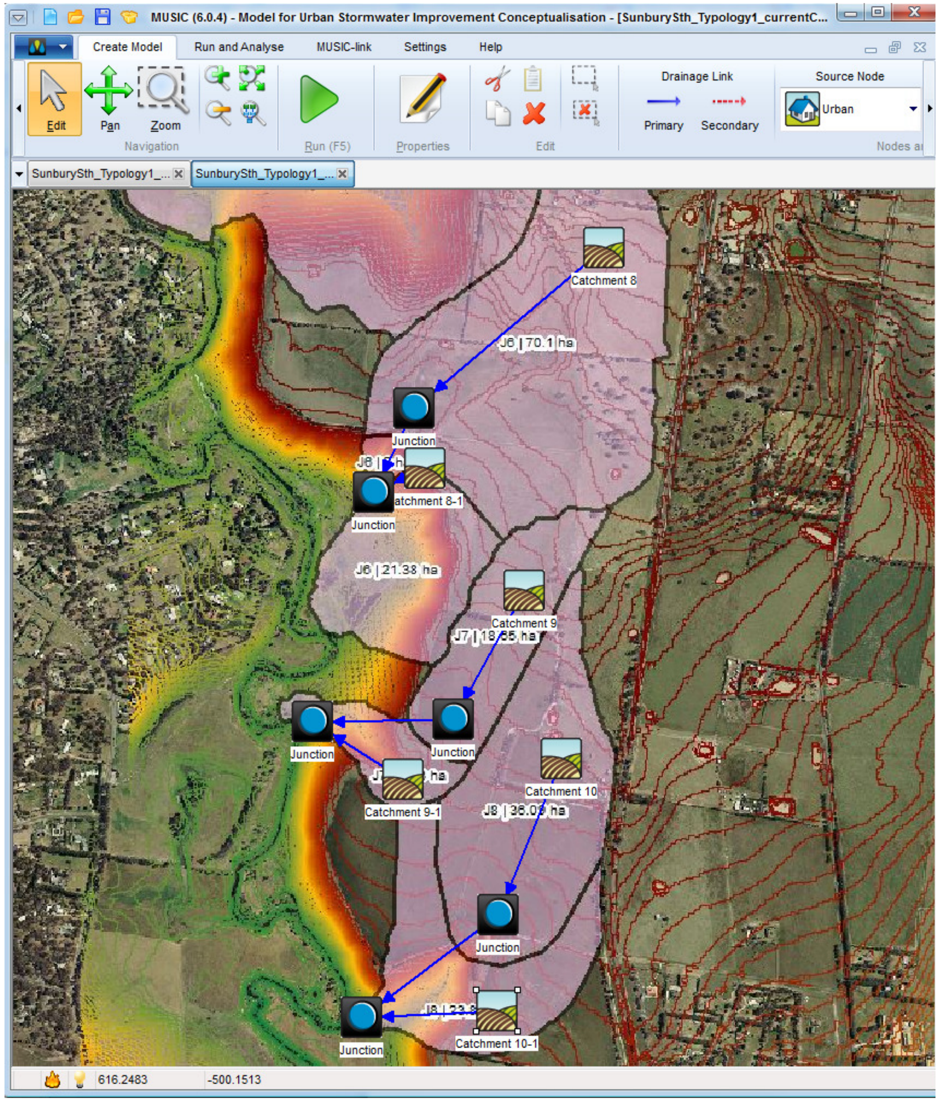


Figure A *Case study 1: MUSIC model layout for current conditions (screenshot)*

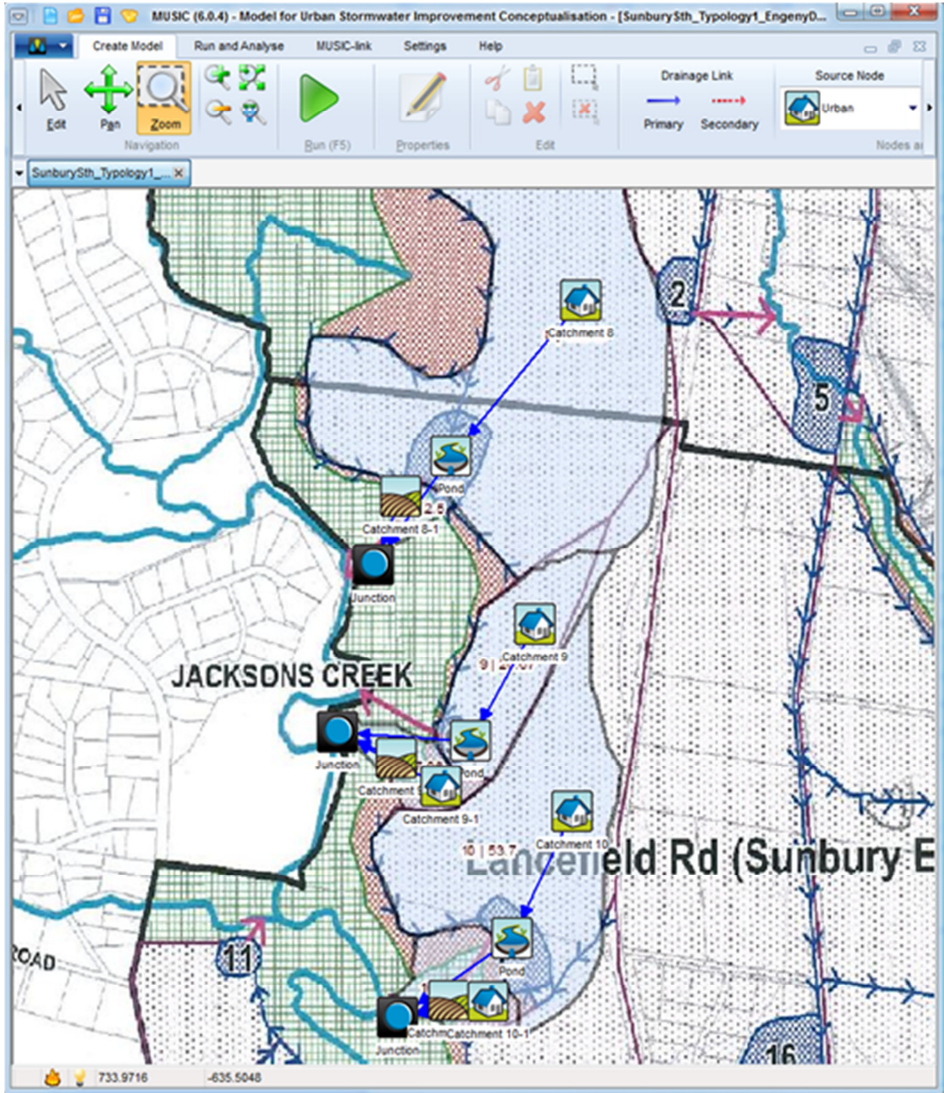


Figure B *Case study 1: MUSIC model layout for base case developed conditions*

Erosion potential analysis

The erosion potential index (EPI) approach was used to assess the geomorphic impacts of the proposed stormwater management options. EPI is a measure of the change in excess shear stress or 'effective work' on a channel as a result of changes in catchment hydrology following (for example) urban development.

The EPI approach requires three main inputs:

- A continuous simulation hydrologic model that provides flow series at locations of interest throughout the study area for current (pre-development) and proposed stormwater condition (post-development).
- A hydraulic model that converts the hydrographs into time series of shear stress for the pre- and post-development scenarios.
- A critical shear stress threshold below which significant sediment transport does not occur.

The long-term shear stress time series are analysed to calculate the time-integrated total effective work for each scenario. Effective work can be illustrated schematically for a single event (Figure C).

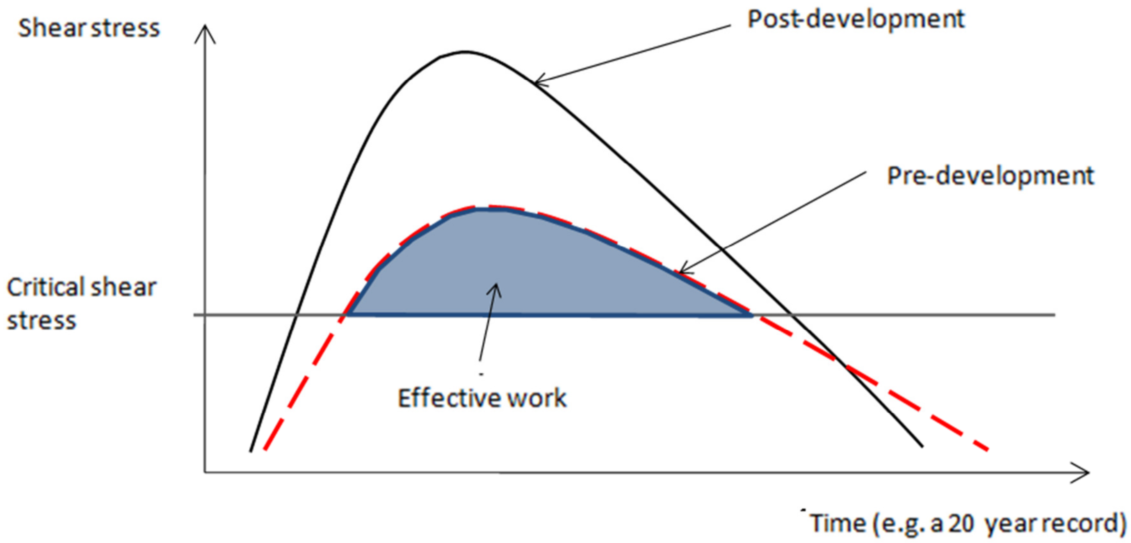


Figure C *Difference in effective work for pre- and post-development scenarios for a single event*

The area under the shear stress curve above the critical shear stress threshold is defined as the *erosion potential* for that flow scenario. The ratio between post- and pre-development erosion potential is the erosion potential index:

$$EPI = \frac{EP_{post-development}}{EP_{pre-development}}$$

Where:

- EPI is erosion potential index
- $EP_{post\text{-}development}$ is erosion potential under post-development conditions
- $EP_{pre\text{-}development}$ is erosion potential under pre-development conditions

An EPI of one indicates the stream will remain in equilibrium over a period of years, although there may be localised erosion and deposition at the flow event time scale. If EPI is greater than one the analysis indicates erosion is likely to occur.

Waterway definition

Different waterway reaches were defined to allow erosion potential to be analysed. The criteria used to define these reaches were the location of changes in hydrology, change in channel bed grade and different River Styles (this information was taken from the *riparian vegetation and geomorphology assessment* undertaken by Alluvium in 2014. Table 4 and Figure D illustrate the location of reaches in catchments 8, 9 and 10.

Table4. Case study 1: waterway reaches for EPI analysis

Catchment	Reach name	Description
Catchment 8	Reach 1	It is assumed that half of flows generated in catchment 8 flow in this reach
	Reach 2	
	Reach 3	
	Reach 4	Different channel bed grade from upstream reach
Catchment 9	Reach 1	It is assumed that half of flows generated in catchment 9 flow in this reach
	Reach 2	
	Reach 3	
	Reach 4	Different channel bed grade from upstream reach
Catchment 10	Reach 1	It is assumed that half of flows generated in catchment 10 flow in this reach
	Reach 2	
	Reach 3	
	Reach 4	Different channel bed grade from upstream reach

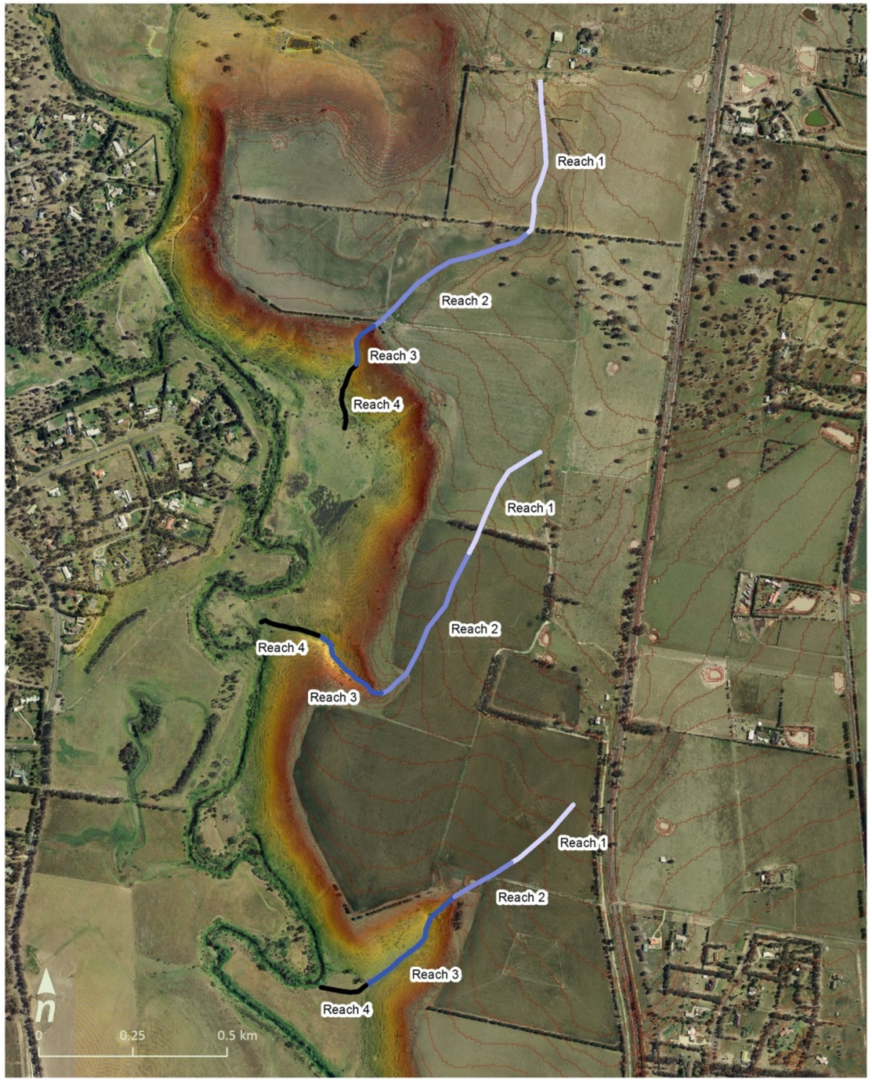


Figure D. *Case study 1: defined waterway reaches*

HEC RAS modelling

To estimate the EPI in waterways in the study area, hydraulic models of the waterways were developed using HEC-RAS: a one-dimensional, steady state hydraulic model (Figure D). The models used LiDAR data of the study area provided by Melbourne Water. A series of cross-sections were extracted from the LiDAR using ArcGIS. Other inputs to the model include the Manning's roughness coefficient (*n*), flow data and model boundary conditions.

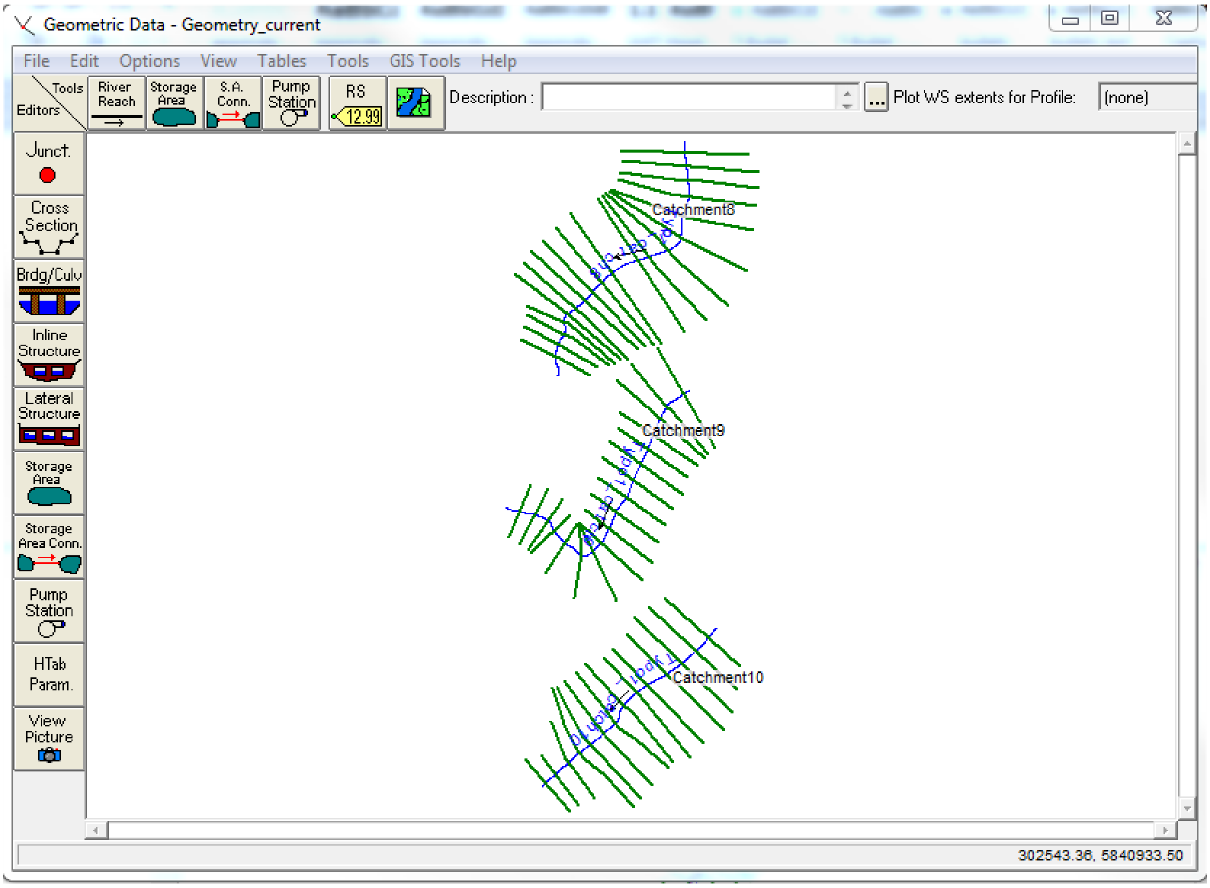


Figure D. *Case study 1: schematic view of HEC-RAS model of waterways*

The Manning's roughness coefficient (*n*) varies between the channel and floodplain and represents the frictional resistance to flow provided by the surface and shape of the bed and banks of the channel and floodplain. Manning's *n* values were identified based on field observations and the values adopted are shown in Table 5.

Table 5. Manning's n values adopted for existing conditions

Location	Manning's *n* Value
Channel	0.03
Floodplain	0.05

Uniform flow characteristics (normal depth) were assumed for upstream and downstream boundary conditions. The HEC-RAS model cross sections were spaced at 30 to 40 m intervals and interpolated at shorter distances where required—for example, where rapid changes in channel size or shape were present.

The key outputs from HEC-RAS was a relationship between shear stress, defined as the frictional force of the water on the bed and bank material that causes erosion, and flow. Initial soil particle motion occurs when the flow power and shear stress around a soil particle exceeds from resisting force of the particle weight. This threshold is called critical shear stress.

Based on channel bed coverage observed during field survey, the critical shear stress were defined and applied for each section. The boundary shear stress was calculated for each cross section using HEC-RAS for a range of flows. This was converted into erosion rates using an excess shear stress equation described by Foster et. al. (1977):

$$\varepsilon = k\,(\tau_0 - \tau_c)^A \qquad \text{Equation 1}$$

Where ε is the shear stress rate, k is an erodibility or detachment coefficient (assigned a value of 1 in this study), τ_0 is the boundary shear stress, τ_c is the critical shear stress and A is an exponent with an average value of 3/2.

Critical shear stress was estimated for each reach using threshold values for different boundary materials published in the literature (Fischenich, 2001). Erosion rate was estimated for each flow at each cross-section by applying estimates of shear stress from HEC-RAS and the critical shear stress for each location to Equation 1 above. The output from this was a relationship between flow and erosion rate for each cross-section. We then derived a relationship between flow and erosion rate for each reach. These relationships were combined with the flow series in each reach, for the pre- and post-development scenarios, to estimate the EPI for each reach.

The calculated EPI value for the base case stormwater system is summarised in table 6.

Table 6. *Case study 1: Calculated EPI value for base case design*

Catchments	Reaches name	EPI value
Catchment 8	Reach 1	Stable reach*
	Reach 2	Stable reach
	Reach 3	9.18
	Reach 4	6.48
Catchment 9	Reach 1	Stable reach
	Reach 2	Stable reach
	Reach 3	0.82
	Reach 4	1.07
Catchment 10	Reach 1	Stable reach
	Reach 2	Stable reach
	Reach 3	1.88
	Reach 4	1.28

*Stable reach condition represents a stable reach condition for both current and designed conditions

The base case retarding basin in catchment 9 reduced EPI and protects the downstream reach (EPIs in the range 0.8 and 1.1). However, in catchment 8 the larger catchment (compared to current conditions) and the insufficient size of the retarding basin generates very large EPI values (between 6.5 and 9.2) in reaches 3 and 4. Increases in erosion potential of this scale indicate significant erosion will result from implementation of the base case strategy. EPIs in the waterways in catchment 10 are higher than the desired objective, but much lower than catchment 8.

It should be noted that the EPI value indicates likely geomorphic changes as a consequence of urban development. It does not take the current geomorphic condition of waterway into account, so it is possible that a waterway with EPI of 1 (i.e. no change in future) is highly unstable due to ongoing active erosion. The waterway in catchment 8 is considered highly unstable, and all waterways in this case study are eroding in their lower reaches.

The EPI results indicate the base case would lead to increased channel erosion in a number of waterways.

In the following sections alternative stormwater options are investigated to reduce EPI and likely channel instability.

Mitigation and water harvesting scenario

In this option diversion of stored stormwater from retarding basin 8 and 9 to retarding basin 10 has been considered. Since retarding basin 10 is not designed for this situation a resizing option has been considered to manage additional stormwater.

Five different wetland areas from 21,000 to 160,000 m^2 with similar characteristics to the base case design were simulated in MUSIC model to find the best solution (Figure E).

Results reveal the EPI value is in lowest condition with a retarding basin of 160,000 m^2. As a consequence of diverting flows from catchment 8 and 9 to catchment 10 the EPI value for reaches downstream of retarding basin 10 are greater than what would be expected from urban development in this catchment (Table 7).

Therefore, to meet the EPI objective downstream for this option, a level of water harvesting was considered to manage stormwater more efficiently and reduce EPI value in downstream reaches.

Table 7 *Calculated EPI values for mitigation option in catchment 10 downstream of retarding basin*

Reaches	Catchments	RB surface area (m^2)	EPI value
Reach 3	Catchment 10	160,000	4.33
		80,000	4.41
		40,000	4.46
		30,000	5.08
		21,000	5.92

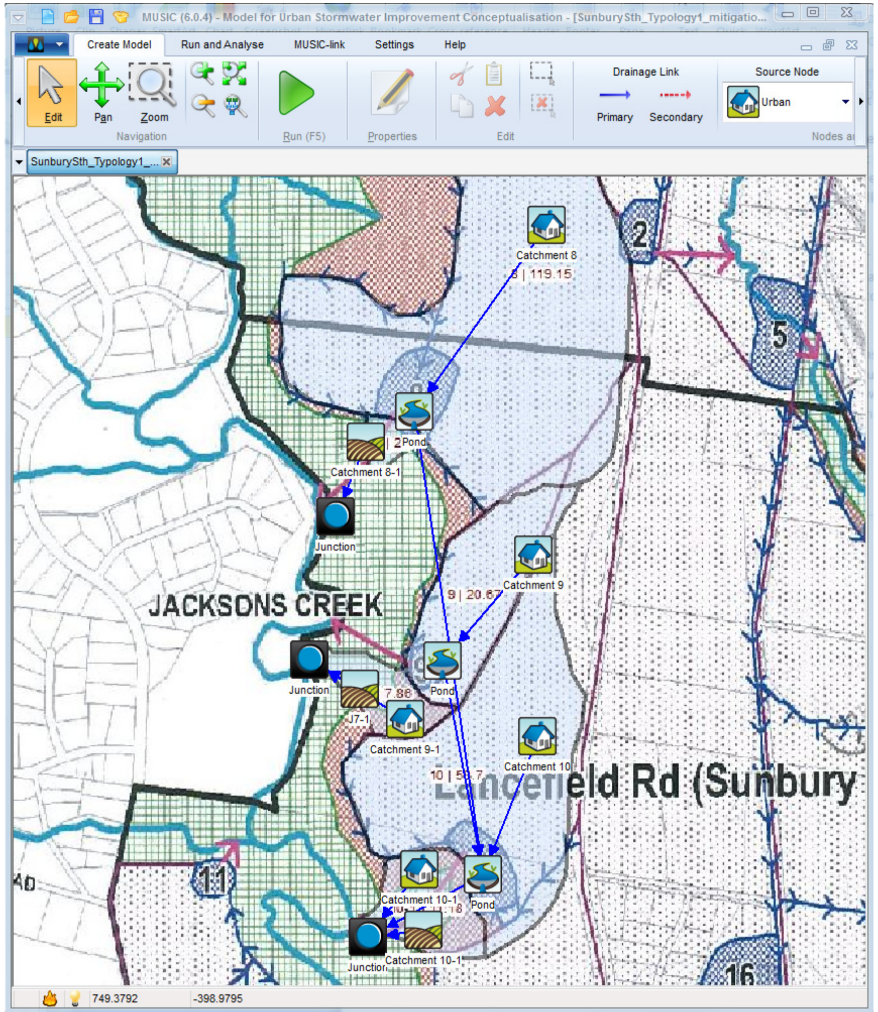


Figure E *Case study 1: MUSIC model layout mitigation option*

Incorporating stormwater harvesting shows that with an RB of 80,000 m^2, an average annual extraction of 20 ML/day of stormwater is required to reduce the EPI to 0.95. This is an unreasonably high volume to be considered feasible.

Table 8 *Case study 1: Calculated EPI values for mitigation and harvesting options downstream of RB 10*

Reaches	Catchments	Top surface area (m^2)	Average stormwater volumes extracted (kL/day)	EPI value
Reach 3	Catchment 10	40,000	10,000	2.72
		40,000	20,000	1.79
		80,000	20,000	0.95

Water harvesting for each retarding basin scenario

Stormwater harvesting from other RBs was investigated, however since the EPI value for catchment 9 (with the base case) is less than 1, this RB has not been considered for stormwater harvesting.

However, in catchments 8 and 10 different levels of stormwater harvesting assuming the same RB areas as per the base case were modelled to understand their impact on EPI. Table 9 summarises the outcomes of this analysis.

Table 9. *Case study 1: Calculated EPI values for catchments 8 and 10*

Reaches	Catchments	Average stormwater volumes extracted (kL/day)	EPI value
Reach 3	Catchment 8	5,000	0.89
		3,500	1.02
		3,000	1.07
Reach 3	Catchment 10	5,000	0.39
		2,000	0.53
		1,000	0.63
		300	1.08

In summary it can be concluded that a significant volume of stormwater is required to be extracted to meet the objective of EPI = 1. Given one of the WOWCA options is ‘stormwater to potable’ then perhaps it is possible to identify a consistent demand in the order of those volumes defined in Table 9.

Attachment C
Case study 2: Additional technical analysis

Case study 2 – additional technical analysis

As per Case study 1,a series of continuous simulation hydrologic models of the study area were developed using MUSIC software, simulating catchment hydrology for current or pre-development conditions, the stormwater arrangements proposed in the WOWCA (the base case) and two alternative stormwater management options.

Option	Description
Base case	As per Western Water's WOWCA project
1	Increasing in the size of RB 17 with an additional wetland and retarding basin just upstream of the reach that contains the high value chain of ponds
2	The same as option 1 plus stormwater harvesting from both RB 17 and the additional proposed wetland/retarding basin

The MUSIC models for current conditions and the base case stormwater management arrangements are presented schematically in Figure A and Figure B below. The Melbourne Airport rain gauge was selected as the most appropriate rain gauge station with 40 years of 6 minute rainfall data (1970 to 2010) introduced to the model.

Figure A and Figure B show the MUSIC models developed to represent current conditions and the Sunbury WOWCA base case design. Table 1 illustrates each catchment' modelled characteristics against current and developed conditions.

The MUSIC parameters adopted were as per Case Study 1.

Table 1. *Case study 2: Catchment areas and associated fraction impervious*

Catchment	Current conditions		Developed conditions	
	Catchment area (ha)	**Fraction impervious**	**Catchment area (ha)**	**Fraction impervious**
Catchment 1	68.9	2%	95.6	50%
Catchment 2	94.1	40%	108.5	65%
Catchment 3	42.6	0%	72.8	65%
Catchment 4	4.1	0%	2.9	65%
Catchment 5	26.9	0%	6.6	65%
Catchment 6	26.1	0%	8.2	65%
			4.7	0%
Catchment 7	28.4	0%	12.2	65%
			3.3	0%
Catchment 8	19.6	0%	4.4	65%
			15.2	0%

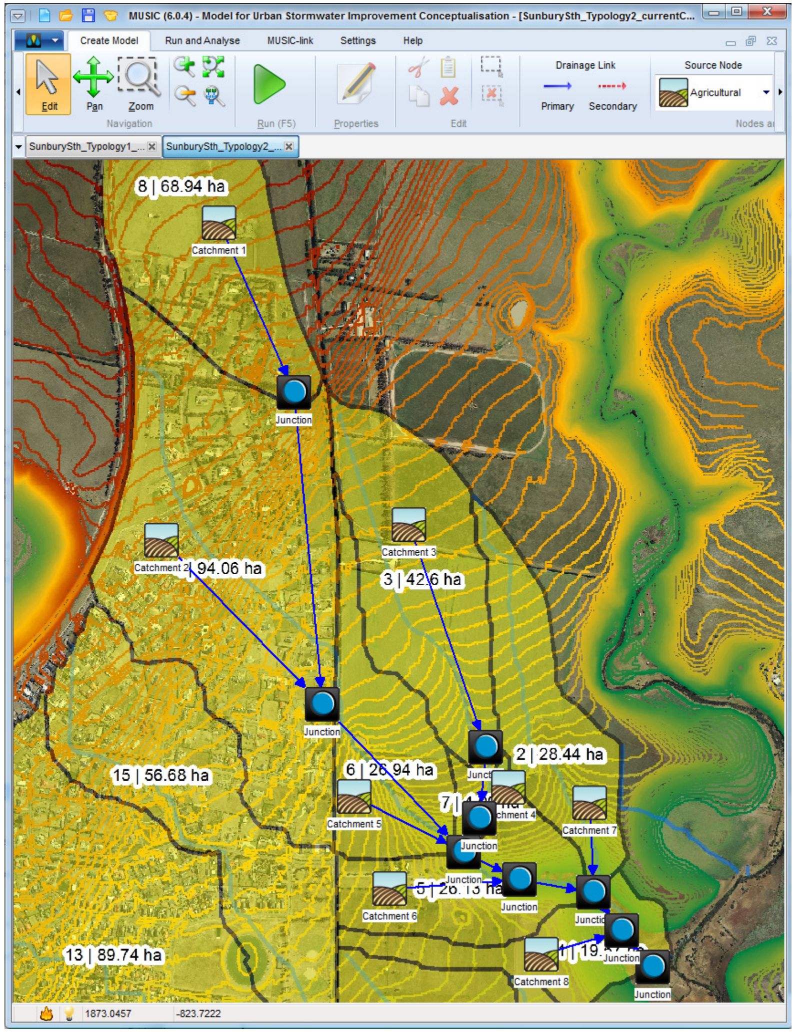


Figure A *Case study 2*: MUSIC model layout for current conditions

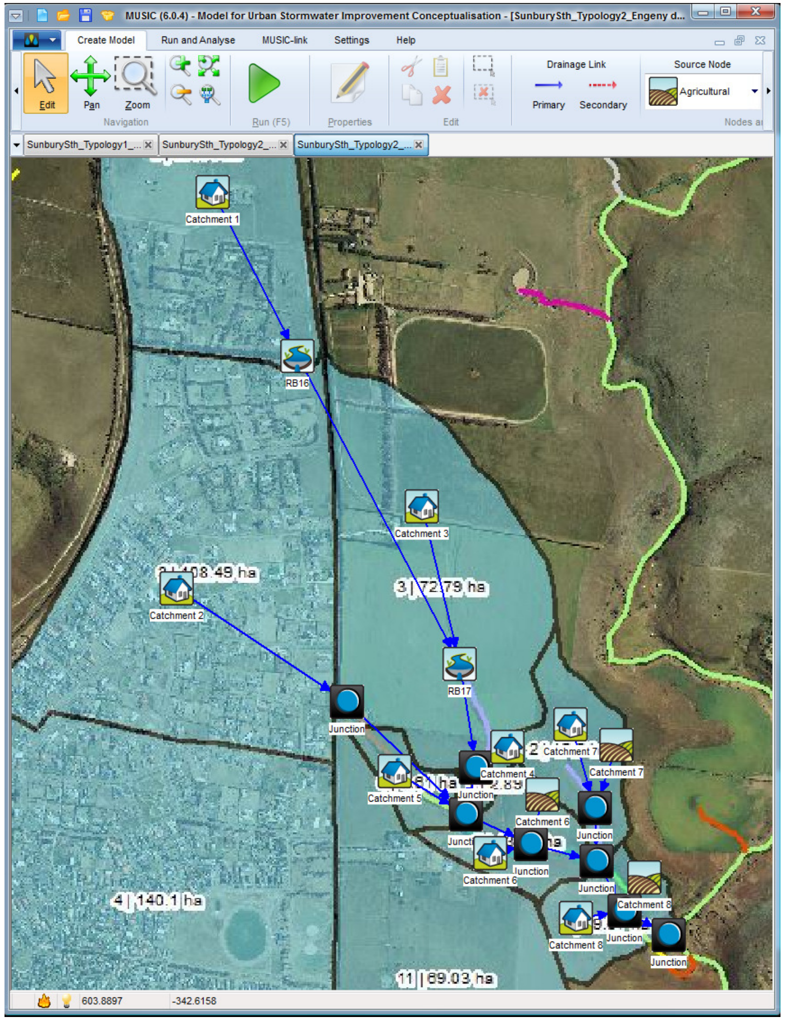


Figure B *Case study 2: MUSIC model layout for base case developed conditions*

Waterway definition

As per Case Study 1, reaches of waterway were defined to allow for EPI analysis (Table 3) and Figure C.

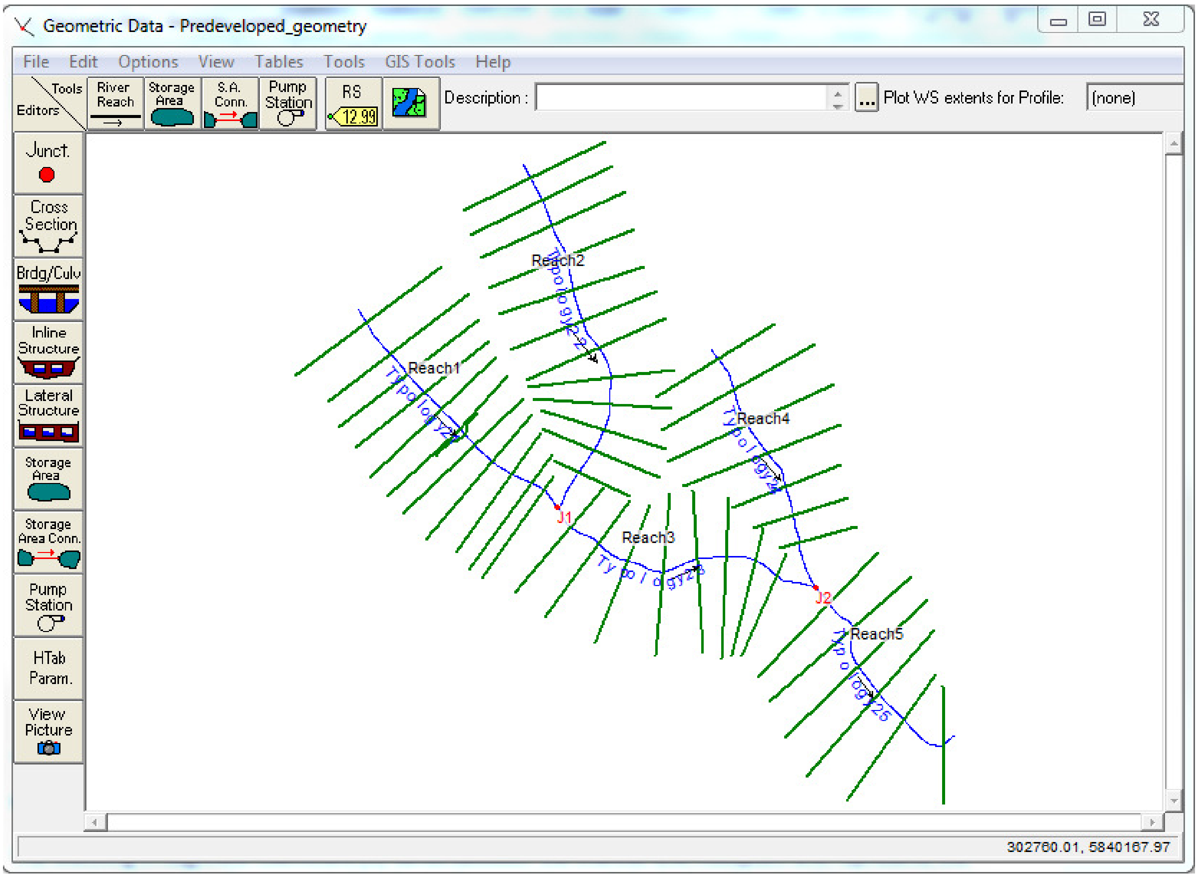
Table3. *Case study 2: waterway reaches for EPI analysis*

Reach name	Catchment	Description
Reach 1	Catchment 1	Upstream of retarding basin 17
Reach 2	Catchment 2	Downstream of retarding basin 17
Reach 3	Catchment 3	
Reach 4	Catchment 4	Where catchment 6 joins the system
Reach 5	Catchment 5	It is assumed that half of flows generated in catchment 7 flow in this reach
Reach 6	Catchment 6	
Reach 7	Catchment 7	Location of chain of ponds
Reach 8	Catchment 8	
Reach 9	Catchment 9	Steep channel bed grade

Figure C. *Case study 2: defined waterway reaches*

Erosion potential analysis

EPI analysis was undertaken using the method described for Case Study 2. The HEC-RAS model used to develop a relationship between shear stress and flow is illustrated in Figure D.



FigureD. *Case study 2: Schematic view of HEC-RAS model of waterways*

The calculated EPI values for the base case are summarised in Table 4.

Table 4 *Calculated EPI value for base case design*

Reach	Catchment	EPI value
Reach 1	Catchment 3	1.88*
Reach 2	Catchment 4	3.6
Reach 3	Catchment 6	2.04
Reach 4	Catchment 6	1.5
Reach 5	Catchment 7	-**
Reach 6	Catchment 7	0.46
Reach 7	Catchment 8	1.7
Reach 8	Catchment 8	1.04
Reach 9	Catchment 8	2.26

* Stable reach condition at current condition and possible erosion in developed situation. In respect to EPI equation value of 0 as diviners give infinitive answer. Therefore the presented value was calculated using ration of generated shear stress.
** Stable reach condition represents a stable reach condition for both current and designed conditions

The EPI results indicate that the base case is likely to lead to increased channel erosion in a number of waterways and refinements are required to reach a stable condition.

Option 1 - Resizing RB 17

This option resizes RB 17 to reduce EPI values of downstream reaches. However, since there was no regulation set to catchment 2 and downstream catchments the impact of this option was not significant. In response, an additional RB with a surface area of 8,000 m^2 was modelled upstream of catchment 8 where the valued chain of ponds exist. Figure E shows the MUSIC model configured for this scenario.

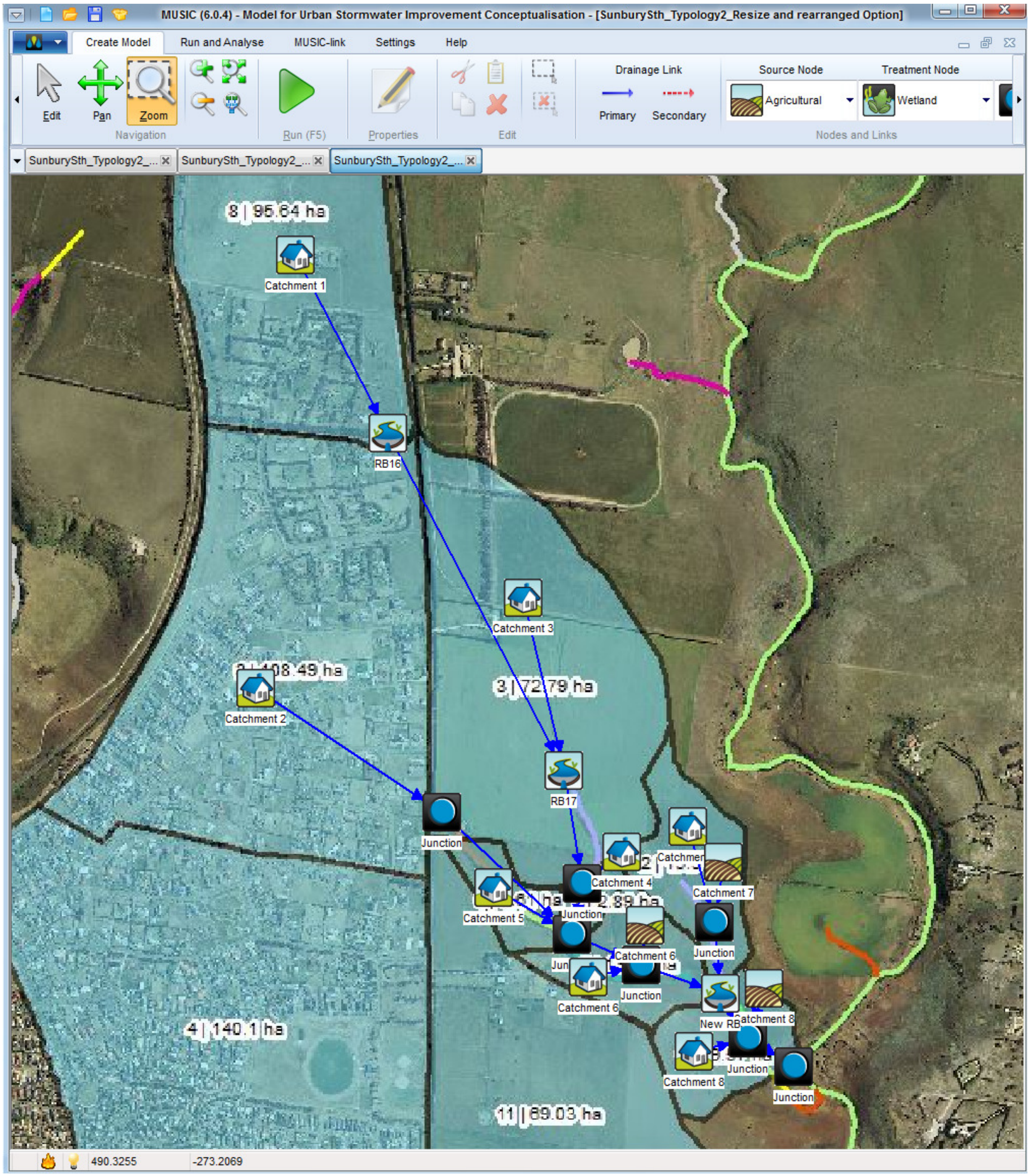


Figure E *Case study 2: MUSIC model layout for resizing option*

The lowest EPI values for this scenario were achieved by increasing the size of RB 17 to 110,000 m^2 in addition to the 8,000 m^2 RB upstream of the chain of ponds. Table 5 shows EPI value calculated for this scenario. It does show a reasonable reduction when compared to the base case, particularly within reaches 2, 3 and 9, however these are still above out target of between 1 and 1.2.

Table 5. *Case study 2: calculated EPI values for resizing scenario*

Reach	Catchments	EPI value
Reach 1	Catchment 3	1.88*
Reach 2	Catchment 4	1.44
Reach 3	Catchment 6	1.48
Reach 4	Catchment 6	1.08
Reach 5	Catchment 7	-**
Reach 6	Catchment 7	0.46
Reach 7	Catchment 8	1
Reach 8	Catchment 8	0.23
Reach 9	Catchment 8	1.34

* Stable reach condition at current condition and possible erosion in developed situation. In respect to EPI equation value of 0 as diviners give infinitive answer. Therefore the presented value was calculated using ration of generated shear stress.
** Stable reach condition represents a stable reach condition for both current and designed conditions

Resize RB 17 and harvest stormwater

This option considers adding stormwater harvesting to option 1. This option results in structures and reduced EPI values. Table 6 summarises the impact of stormwater harvesting on EPI values.

What can be observed is a further reduction in EPI such that only reaches 1 and 3 would be considered beyond our target range.

Table6. *Case study 2: calculated EPI values for resized retarding basin and water harvesting scenario*

Reach	Catchments	EPI value
Reach 1	Catchment 3	1.88*
Reach 2	Catchment 4	1.08
Reach 3	Catchment 6	1.34
Reach 4	Catchment 6	1.01
Reach 5	Catchment 7	-**
Reach 6	Catchment 7	0.46
Reach 7	Catchment 8	0.72
Reach 8	Catchment 8	0.2
Reach 9	Catchment 8	0.87

* Stable reach condition at current condition and possible erosion in developed situation. In respect to EPI equation value of 0 as diviners give infinitive answer. Therefore the presented value was calculated using ration of generated shear stress.
** Stable reach condition represents a stable reach condition for both current and designed conditions

Attachment D
Case study 1 – Stormwater pollution reduction results

Case study 1 – Pollution reduction results

RB	Pollutant	% reduction			
		Option 1	Option 2	Option 3	Option 4
8	TSS	84.8	84.8	92.1	84.8
	TP	71.7	71.7	90.9	71.6
	TN	52.2	52.2	88.9	51.8
9	TSS	84.6	84.6	81.1	94
	TP	71.5	71.5	68.5	92.4
	TN	50.7	50.7	49.9	91.1
10	TSS	98	95.6	91.1	91.1
	TP	97.3	87.4	87.7	78.9
	TN	96.1	76.9	81.6	81.7