Fishermans Bend

Integrated Water Management Infrastructure Plan

December 2022

wave CONSULTING

Traditional Owners

The authors wish to acknowledge the Wurundjeri Woi Wurrung and Bunurong Boon Wurrung peoples of the Eastern Kulin Nation as the traditional custodians of Fishermans Bend.

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Disclaimer

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Cover image

Street trees along River Esplanade (Lorimer precinct). Source: Wave Consulting Australia.

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Glossary

AEP: "Annual Exceedance Probability (AEP) – The probability that a given flooding event will be exceeded in any one year. For example, a flood event with a one per cent Annual Exceedance Probability has a one per cent chance of being exceeded in any one year."

AHD: "Australian Height Datum (AHD) – A measure of height above mean sea level."

ARI: "Average Recurrence Interval (ARI) – A statistical estimate of the average period in years between a flood occurrence of a given magnitude. The ARI of a flood event gives no indication of when a flood of that size will occur next."

CAPEX: "Capital expenditure (CAPEX) – CAPEX is incurred when an organisation spends money, uses collateral, or takes on debt to either buy a new asset or add to the value of an existing asset with the expectation of receiving benefits for longer than a single tax year."

EDD: "Extended detention depth (EDD) – Distance between normal water level or surface level and the overflow weir crest of a water sensitive urban design asset."

IWM: "Integrated water management (IWM) – an approach to managing hydrological cycles and systems in a holistic way to support the development of a water sensitive city. IWM seeks to change the impact of urban development on the natural water cycle, based on the premise that by managing the urban water cycle as a whole, a more efficient use of resources can be achieved, providing not only economic benefits but also improved social and environmental outcomes (Barton, Hine and Pretty, 2009)."

LOS: "Level of service (LOS) – A term in asset management referring to the quality of a given service. For this project, the LOS often relates to flood mitigation for a specific duration and frequency storm event.

MUSIC: "Model for Urban Stormwater Improvement Conceptualisation (MUSIC) – Software developed by the Cooperative Research Centre for Catchment Hydrology to model urban stormwater management schemes."

NEIC: "National Employment and Innovation Cluster (NEIC) – Specifically, the name of one of Fishermans Bends' five Precincts, and more generally, local and regional destinations that also are nationally significant because of the role they play in attracting workers, students and visitors from across Australia and overseas."

OPEX: "Operational expenditure (OPEX) – OPEX is incurred during regular business, such as maintenance or general and administrative expenses."

PIP: "Precinct Implementation Plan (PIP) – Plans to guide new development and implement the long-term vision and underpinning strategies of the Precincts of Fishermans Bend."

Private realm: "Areas that are privately owned such as housing, commercial office, industry and retail uses. Also includes other privately owned spaces that may be publicly accessible either with or without restriction."

Public realm: "Areas that are publicly owned and used generally for civic purposes such as but not limited to community infrastructure, public housing, and road and open space networks."

RORB: "RORB is a computer program that is used to calculate flood hydrographs from rainfall and other channel inputs. It can be used to design retarding basins and to route floods through channel networks."

WSUD: "Water sensitive urban design (WSUD) – WSUD embraces a range of measures that are designed to avoid, or at least minimise, the environmental impacts of urbanisation. WSUD recognises all water streams in the urban water cycle as a resource."

Executive Summary

Fishermans Bend is Australia's largest urban renewal area. It covers over 480 hectares, sits across two local government areas, and is approximately twice the size of the Melbourne CBD. The Fishermans Bend Framework provides the guiding plan to bring to life the vision and for the area to be a:

> *"A thriving place that is a leading example for environmental sustainability, liveability, connectivity, diversity, and innovation"*

This report recommends Integrated Water Management (IWM) infrastructure required in the public realm of the NEIC and Lorimer precincts of Fishermans Bend, within local government area of City of Melbourne. This work focuses on IWM in the public realm and excluded any detailed investigation and analysis of private realm IWM infrastructure.

IWM refers to a holistic approach to managing all water sources and issues within urban environments. IWM infrastructure refers to the assets required to manage rainwater and stormwater, and infrastructure that is used to provide alternative water sources for non-potable water uses. IWM infrastructure refers to the use of raingardens, swales, wetlands, tree pits, infiltration trenches, detention basins, green walls and green facades, rainwater tanks, recycled water networks, and stormwater harvesting assets.

The process to developing this IWM Infrastructure Plan was as follows:

1. Review of past strategies, documents, data, and models.
2. Desktop site analysis.
3. On site review of assets and conditions with DPJR and City of Melbourne representatives
4. Digitisation of proposed roads, green links, and open spaces.
5. Review and development of asset parameters and asset mix.
6. Modelled storage potential by subcatchment.
7. Water quality modelling of proposed WSUD infrastructure by subcatchment.
8. Analysis of infrastructure costs, construction, and maintenance requirements.
9. Consultation and feedback from DPJR, Melbourne Water, and City of Melbourne representatives
10. Reporting

The results from the work are that distributed IWM infrastructure can deliver both flood storage and water quality outcomes across the six primary catchments and support the water sensitive and liveability vision. Within each of the 63 subcatchments, some subcatchments require further storage, and this is discussed in "Appendix F. Subcatchments in need of more storage."

Distributed IWM infrastructure is required across all six precincts, with the volumes required outlined below.

Table 1. Summary of storage targets and storage achieved under IWM infrastructure plan.

Catchment	**5% AEP (20 Year ARI) level of service target**	**1% AEP (100 Year ARI) level of service target**	**Streetscape and green link storage**	**Open space storage required**	**Total distributed storage**
Hall Street	4,198 m³	6,924 m³	5,593 m³	1,332 m³	6,924 m³
River Esplanade	157 m³	2,584 m³	2,584 m³	0 m³	2,584 m³
Sabre Drive	0 m³	2,894 m³	2,894 m³	0 m³	2,894 m³
Salmon Street	2,936 m³	5,048 m³	5,048 m³	0 m³	5,048 m³
Todd Road	620 m³	3,854 m³	3,854 m³	0 m³	3,854 m³
Westgate Lakes	0 m³	0 m³	0 m³	0 m³	0 m³
Total	**13,407 m³**	**21,305 m³**	**19,973 m³**	**1,332 m³**	**21,305 m³**

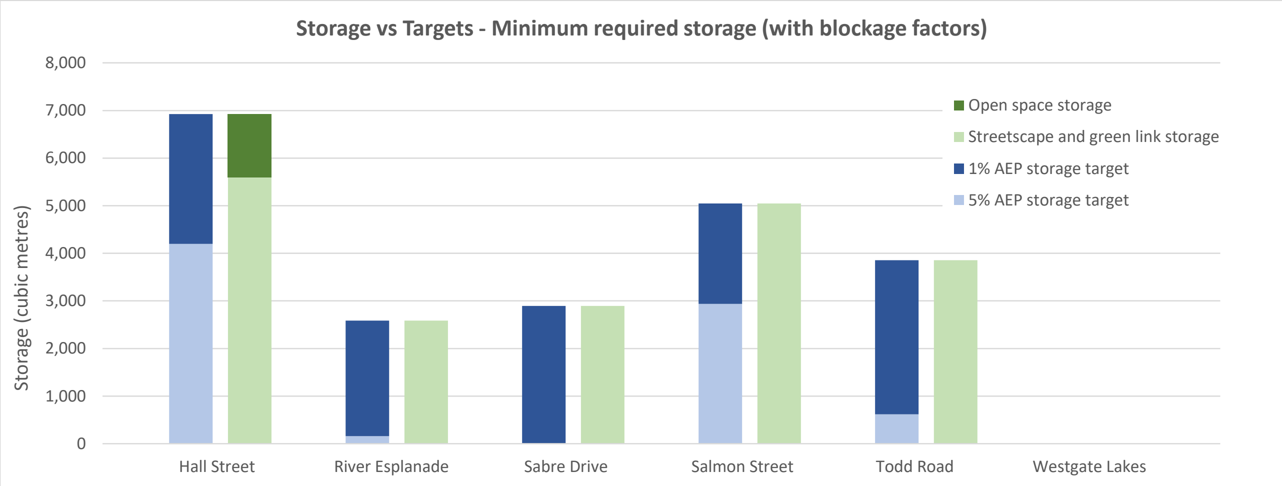


Figure 1. Storage vs Targets summary.

This IWM infrastructure distributed storage scenario requires:

- 1,309 WSUD tree pits,
- 11,785 m of trenches,
- 45,131 m^2 of raingardens (or approximately 2,250 raingardens assuming they are on average 20 m^2 in area),
- 4 hectares of linear parks, and
- A quarter of a hectare of suitable open space detention storage.

A key result from this modelling is an increased awareness of the role of private IWM infrastructure plays in reducing the use and costs of public IWM infrastructure. The vision will be realised, particularly for water quality assets, only if the design, construction and maintenance of IWM infrastructure is met on private and public land.

The indicative cost for IWM infrastructure in the public realm, across the two precincts within the City of Melbourne is $17 million.

It is recommended that City of Melbourne, and stakeholders:

- Consider how to resource and strictly supervise IWM infrastructure on private land
- Monitor and ensure that construction management is closely supervised for all IWM infrastructure on public land, to ensure there are no design defects or rectifications required in the long term.
- Review the governance and ownership of IWM infrastructure, noting that traditionally this infrastructure would be captured in a Melbourne Water Development Services Scheme, but there is limited downstream space for assets at the outlet of catchments.
- Be aware that sea level rise and groundwater constraints require a different approach to business as usual, and that WSUD assets are critical to deliver multiple benefits and need to be incorporated into virtually every subcatchment.
- Share this study with relevant stakeholders to promote catchment and institutional consistency.
- Note the next steps and work together on integrating this work into other planning and infrastructure plans.

1 Introduction & background

Fishermans Bend is Australia's largest urban renewal area. It covers over 480 hectares, sits across two local government areas, is approximately twice the size of the Melbourne CBD. The Fishermans Bend Framework provides the guiding plan to bring to life the vision for the areas to be a: *"A thriving place that is a leading example for environmental sustainability, liveability, connectivity, diversity, and innovation"*

The Framework establishes eight sustainability goals that have in turn informed targets, objectives, and strategies across Fishermans Bend's five precincts.

One of these goals is for Fishermans Bend to be a water sensitive community. A Water Sensitive City Strategy has been collaborative developed by responsible stakeholders to outline how water will be managed and integrated into the urban landscape and focuses on three core pillars:

- flood management,
- a climate resilient water system,
- urban ecology.

The Water Sensitive Strategy has recognised the need for far greater flood storage throughout the precinct while noting the various constraints in Fishermans Bend, such as groundwater, topography, sea level rise, climate change, costs, and maintenance, to determine the optimal strategy to deliver on the Fishermans Bend vision and the framework's goals.

This IWM Infrastructure Plan proposes the location and sizing of integrated water management (IWM) infrastructure that will support the delivery of the Water Sensitive City strategy.

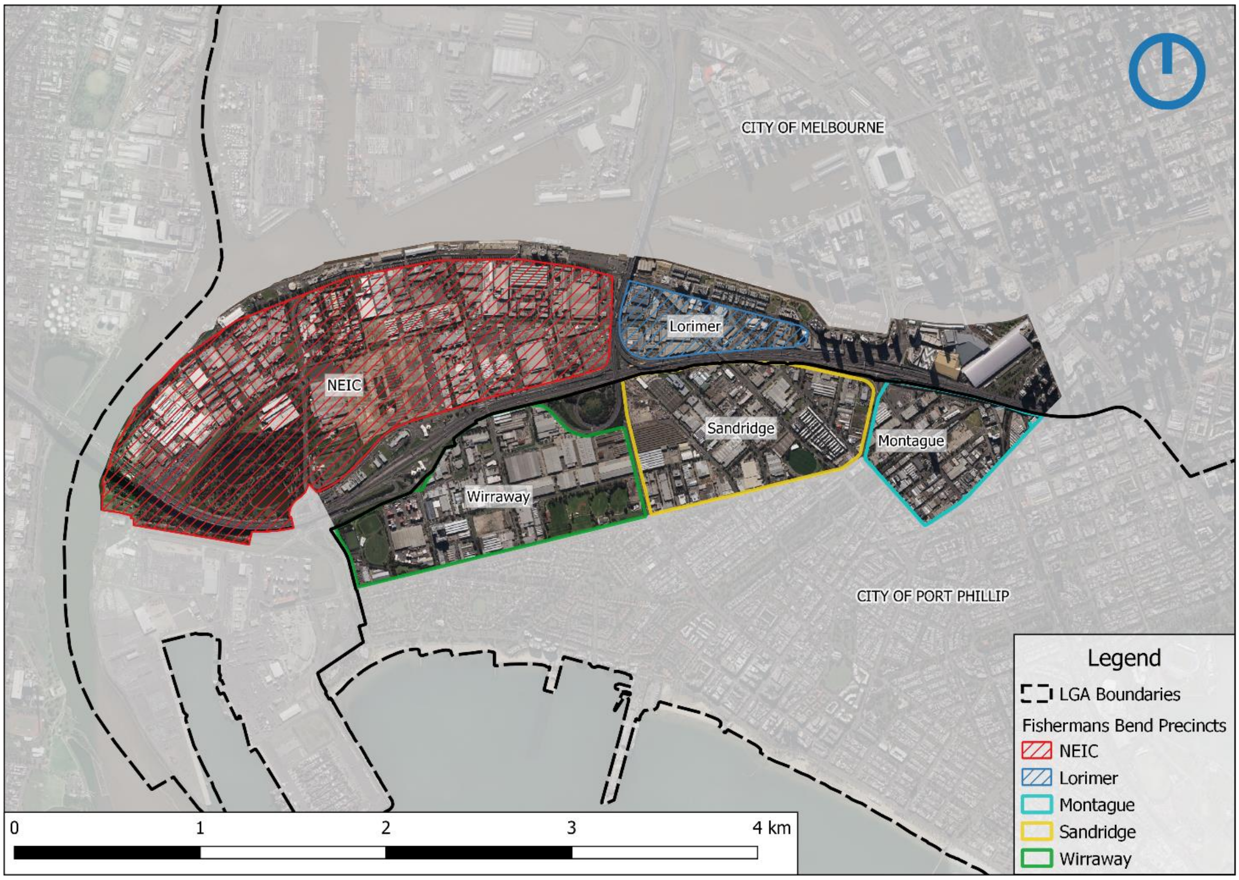


Figure 2. Precincts of Fishermans Bend with City of Melbourne and City of Port Phillip LGA boundaries.

1.1 Integrated Water Management

Integrated Water Management refers to a holistic approach to managing all water sources and issues within urban environments. IWM infrastructure refers to the assets required to manage rainwater and stormwater, and infrastructure that is used to provide alternative water sources for non-potable water uses.

IWM infrastructure refers to the use of raingardens, swales, wetlands, tree pits, infiltration trenches, detention basins, green walls and green facades, rainwater tanks and stormwater harvesting assets.

The design and use of these assets across the NEIC and Lorimer Precincts of Fishermans Bend are primarily to achieve distributed flood storage to maintain the desired level of service with regard to flooding and to achieve best practice water quality performance. The asset mix has been designed to deliver both goals however these assets provide a range of other benefits that directly relate to many of the broader goals within the Fishermans Bend Framework and Water Sensitive Strategy as well as City of Melbourne's broader integrated water management, climate resilience, sustainability, and liveability objectives. These benefits will be reflected via change in the following aspects of the city's infrastructure.

Detention volume

Water sensitive urban design assets provide flood detention at different scales. Larger assets like wetlands can be incorporated into retarding basins, and large rainwater tanks can detain storm events if they are constantly drawn down. Smaller raingardens and swales can increase the capacity of distributed storages in the urban landscape, particularly with subtle design changes to inlets, extended detention and porosity of soils. When deployed across a precinct at scale can provide significant flood mitigation within a catchment.

Water quality

WSUD assets are mostly designed to reduce stormwater pollution and improve downstream water quality flowing into waterways. They do this in a variety of ways, including trapping coarse sediment within the filter media of the asset (which is then periodically removed through standard maintenance), biological treatment, and through evapotranspiration (the removal of water from an area with vegetation through both transpiration and evaporation).

Urban cooling

WSUD provides a mechanism for retaining water in the urban landscape while also reducing urban temperatures through enhanced evapotranspiration and surface cooling. Research suggests that WSUD assets are broadly capable of lowering temperatures and improving human thermal comfort (Coutts et al., 2012).

Increased canopy cover

A passively watered street tree is a tree that is watered by gravity from roads and roofs, through a diversion and infiltration process that retains more water within the landscape and is available to support tree growth and reduces stormwater runoff (including pollution) to local waterways.

Research has shown that passively watered street trees are known to grow at twice the rate of a normal (unwatered) street tree (Grey, Livesley, Fletcher and Szota, 2018).

Liveability

WSUD assets contribute to creating liveable urban spaces not only through all of the aforementioned benefits but also by increase the aesthetics of an urban space by promoting accessible and visible green and blue spaces within a city. Significant increases to property prices adjacent to WSUD assets such as raingardens has been well documented (Polyakov et al., 2017).

1.2 Objectives

The objectives of this IWM Infrastructure Plan are to:

- Advise how much distributed storage could be delivered in public realm of the Lorimer and NEIC precincts (noting that Precinct Planning is not finalised and significant changes to precinct layout will impact the results of this work).
- Review the targets to identify where subcatchments may fail in meeting the 1% AEP (100-year ARI) flood storage targets.
- Consider how the flood storage volumes on private land and public realm will achieve whole of catchment targets.
- Review the influence of maintenance and ownership models on the targets.
- Review costs of the IWM infrastructure.

The subcatchment level distributed storage targets to achieve the 1%AEP level of service are broken down by catchment and shown below in Figure 3. For a detailed methodology of how these were developed see section 2.3 - Determining detention target volumes per subcatchment.

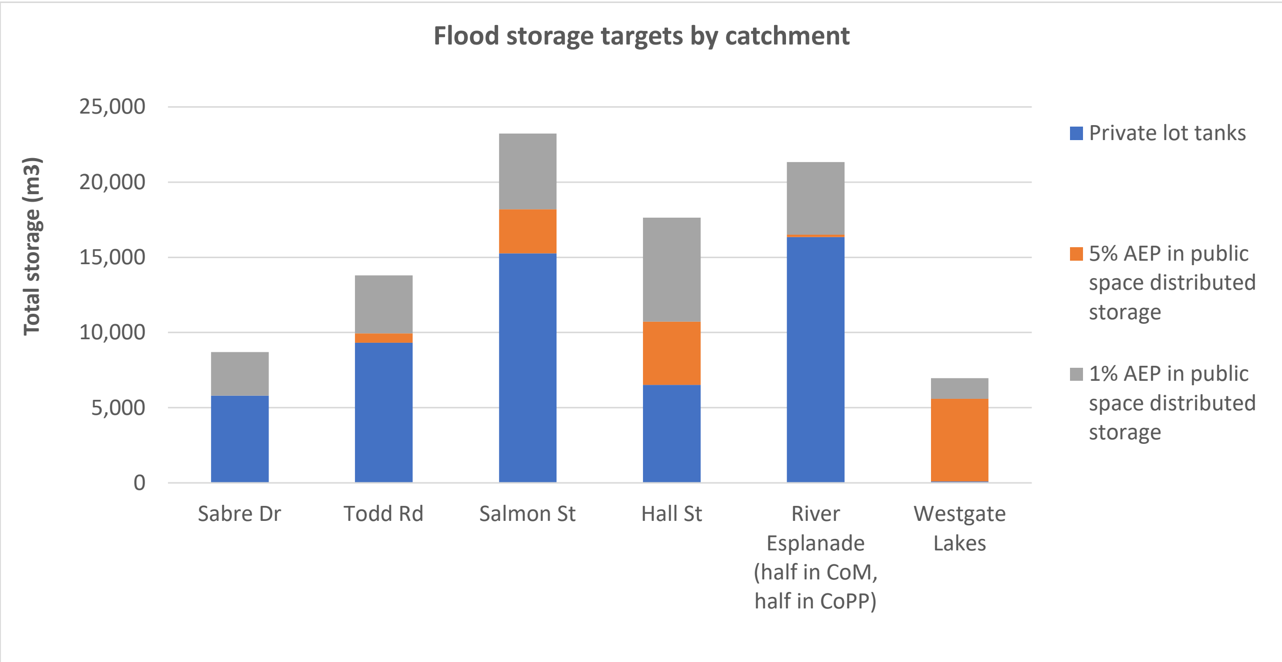


Figure 3. Flood storage targets by catchment.

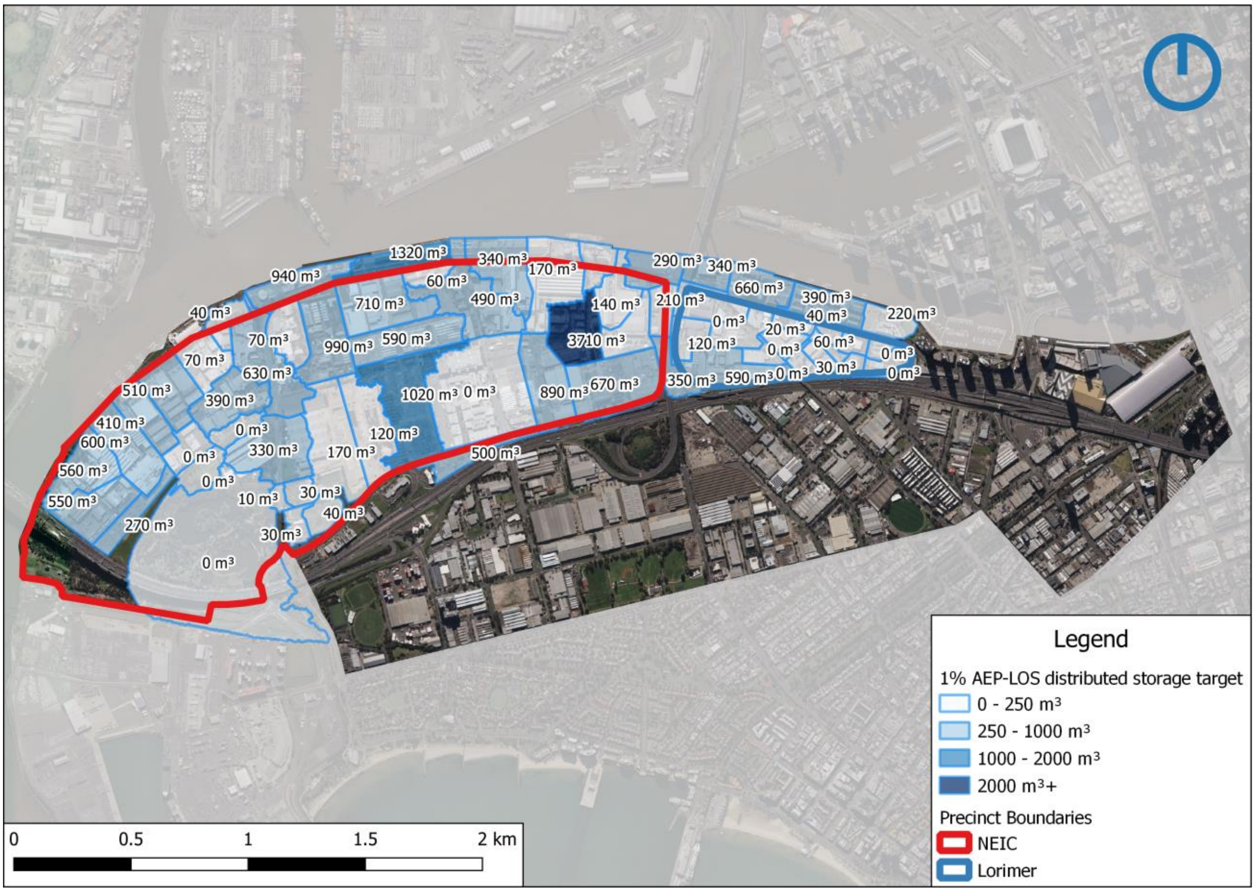


Figure 4. 100-yr level of service (LOS) distributed storage targets by sub catchment (Source: Wave Consulting)

1.3 Fishermans Bend precincts and challenges

There are five precincts in Fishermans Bend. The two precincts that sit within the City of Melbourne's jurisdiction, are the National Employment and Innovation Cluster (NEIC) – formerly known as the Employment Precinct - and Lorimer, these can be seen in Figure 2.

These two precincts have a combined area of 294 hectares. Fifty six percent of this is private land, and 44% is public space (all the roads, open spaces, and Westgate Park). For comparison, the Melbourne CBD Hoddle Street grid is 173 hectares in area.

Fishermans Bend presents many challenges from an urban renewal and water management perspective. These include:

1. The flat grade / topography. With the average elevation of the two precincts of interest being 2.84 m AHD. This provides challenges for drainage and drainage that relies on gravity to flow, throughout the precincts.
2. High groundwater levels. The groundwater levels are expected to be on average across the precincts, 0.8 m AHD in 2100 (compared to the current average of 0.0 m AHD). This constrains the locations of all underground infrastructure including drainage and distributed detention infrastructure.
3. Limited space for downstream and large open space locations for water infrastructure.
4. Infrastructure location. There are a range of constraints within the precinct, due to other services, the location of intersections and other urban form considerations.
5. Maintenance. There is uncertainty as to the level of maintenance and the ability to ensure that the IWM infrastructure are always operational and functional over the long term. Maintaining WSUD assets are an issue for all asset owners, however in the context of Fishermans Bend, where WSUD will play a vital flood management role in low lying and flat terrain, the importance of best practice maintenance is far greater than in most other precincts.

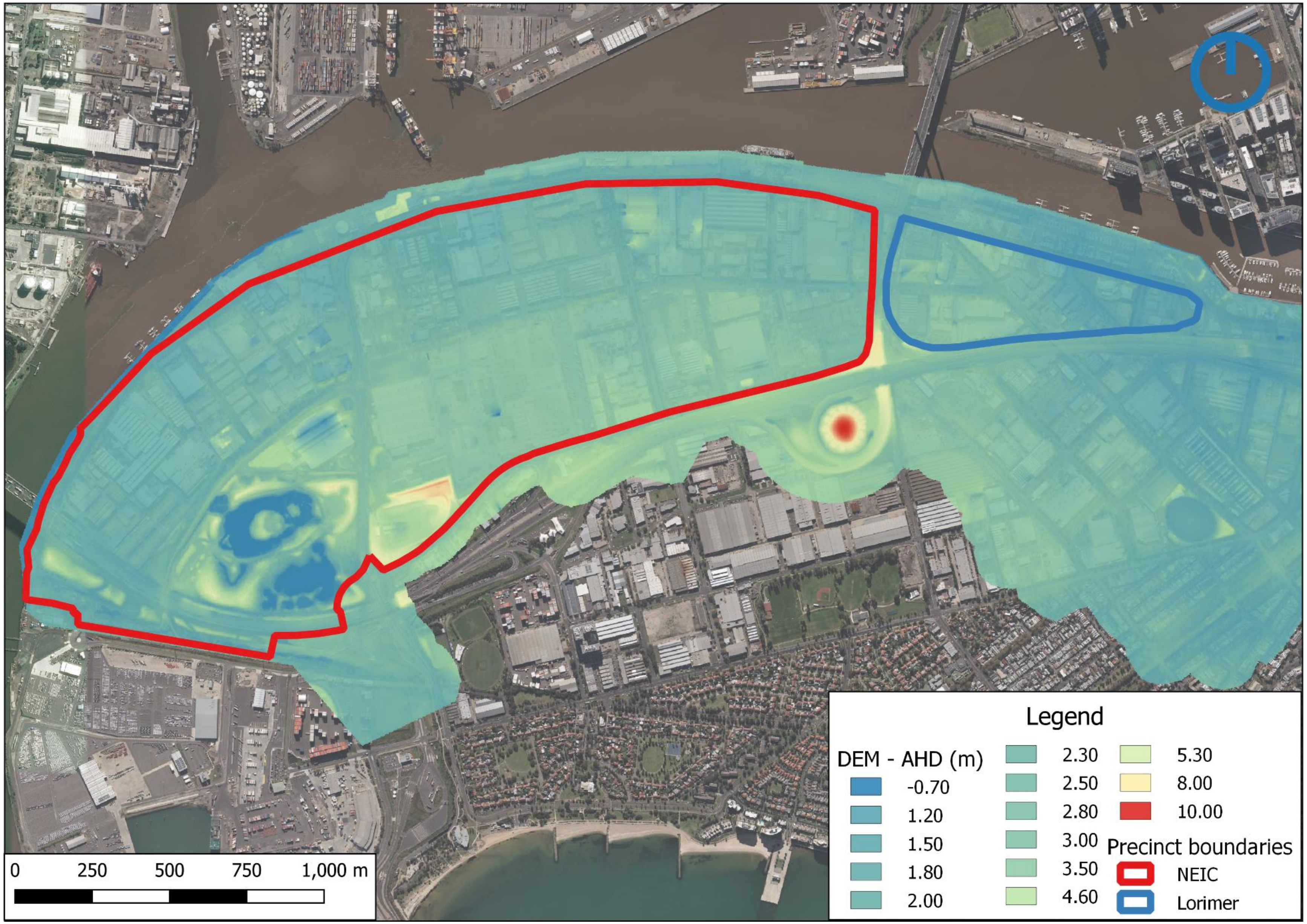


Figure 5. High resolution digital elevation model of NEIC and Lorimer Precincts of Fishermans Bend (DEM Source: GHD).

1.4 Drainage catchments

The topography and the drainage system dictate that across the NEIC and Lorimer precincts there are 6 main catchments, and these can be split into 63 subcatchments.

Catchment boundaries often do not align with municipal boundaries, and for the NEIC and Lorimer precincts the catchments start in the City of Port Phillip, and then flow north towards the Yarra River. The City of Port Phillip and the City of Melbourne will need to continually work closely as ongoing modelling, detailed design, and construction and maintenance these IWM assets are delivered. This report considers stormwater that is generated within the City of Melbourne municipal boundary, the City of Port Phillip will need to take a similar approach for such infrastructure to be suitable. Upstream runoff, which is not filtered or detained, has the potential to over burden City of Melbourne infrastructure.

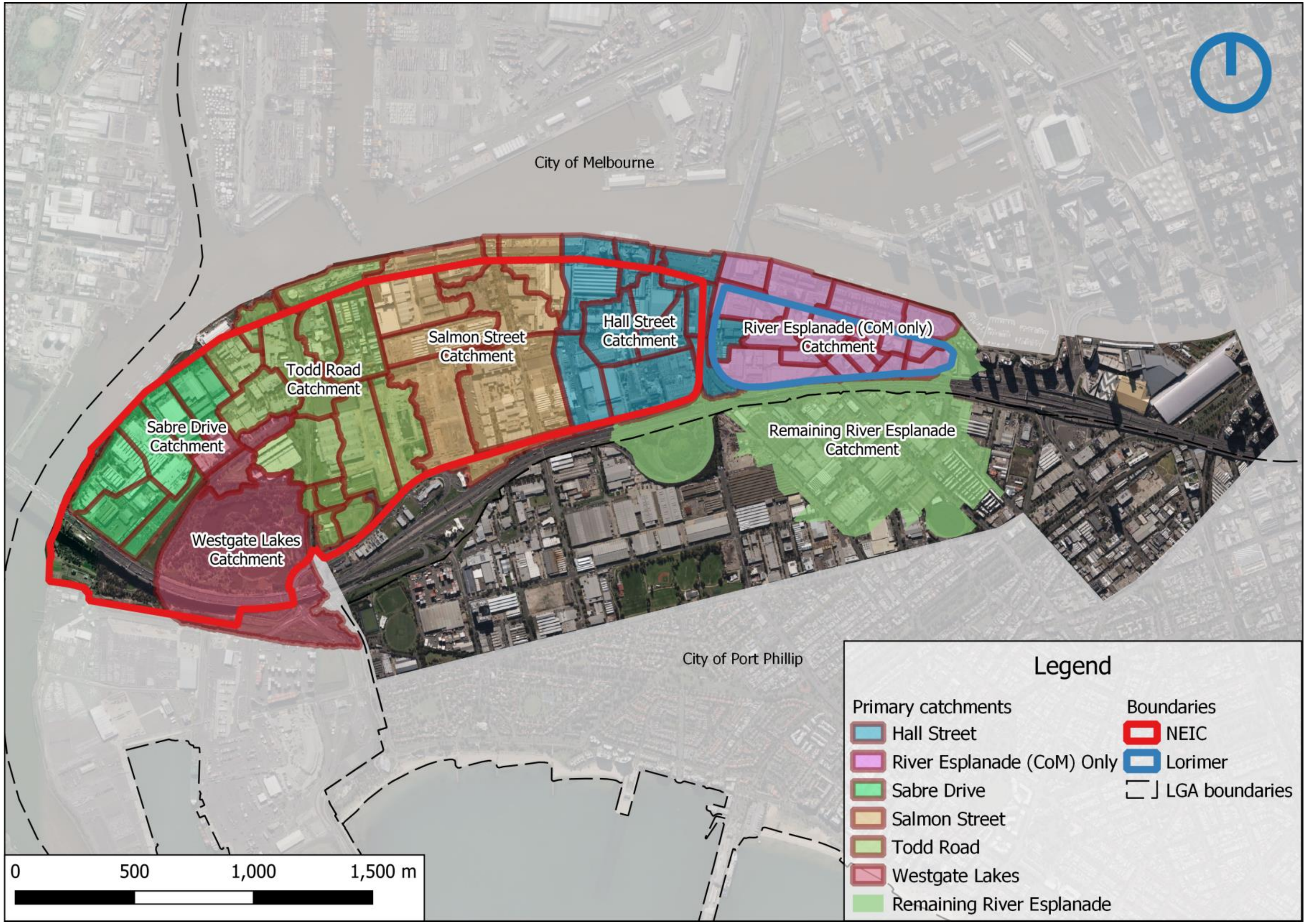


Figure 6. Primary catchments and subcatchments of the NEIC and Lorimer Precincts.

1.5 Previous work

This report follows on from several previous studies, modelling, guidelines, and stakeholder engagement. Some of the key strategic work with a water focus to date are shown below in Figure 7.

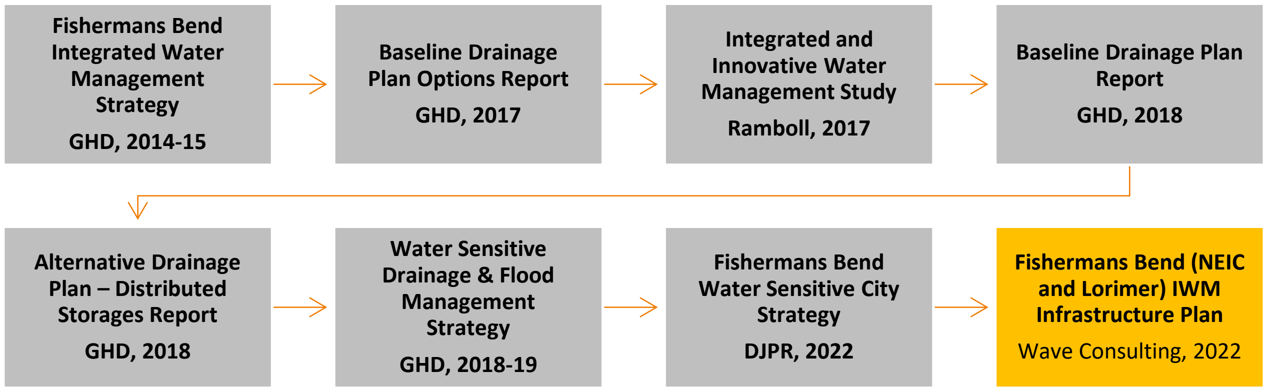


Figure 7. History of IWM strategic investigations within Fishermans Bend regarding drainage, flooding, and water quality work.

Much of the previous work relating to drainage studies within Fishermans Bend has been captured in the Water Sensitive Drainage & Flood Strategy, which specified the desired levels of service this infrastructure needs to deliver and specific targets it needs to meet, with respect to flood management (see Figure 8). The strategy primarily focuses on the use of distributed flood storages alongside the piped drainage network, referred to as the 'hybrid' approach, to mitigate stormwater/pluvial flooding.

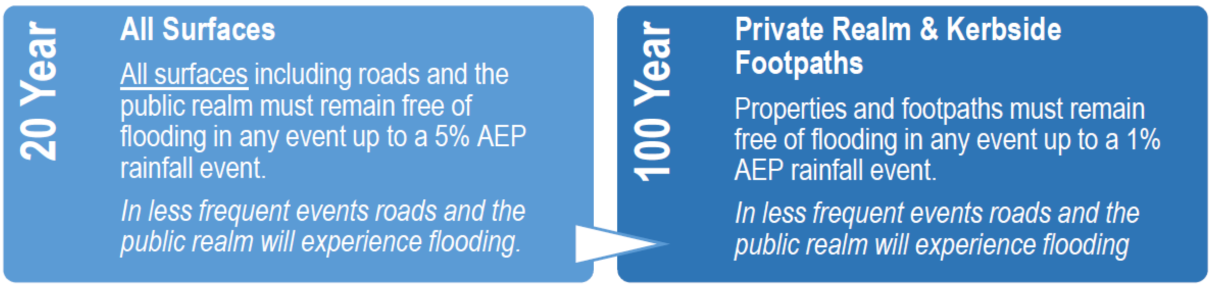


Figure 8. Fishermans Bend's flood performance objectives (Source: GHD, 2019).

This hybrid approach is used to manage stormwater flooding throughout Fishermans Bend and resulted in the following distributed targets within all of Fishermans Bend:

- 90 ML of rainwater tanks, to store and detain roof and podium runoff from all buildings;
- 25 ML of distributed storages designed into streetscapes and open spaces to store and detain stormwater runoff in six subcatchments (rather than pipe upgrades) to meet the storage requirements for the 5% AEP design events;
- Upgrading existing underground pipes in two subcatchments;
- 7 new pump-stations, and new pipes, in seven sub-catchments, to collect the stormwater flows at the end of the catchments and pump to the Yarra River; and
- A levee that will be adapted over time to manage coastal and riverine flooding.

The above solutions stemmed from detailed RORB, and DRAINS modelling completed by GHD for Fishermans Bend: Water Sensitive Drainage and Flood Management Strategy in 2018 and took into account the 20% and 5% AEP storm events under a 2100 climate change scenario, whereby groundwater levels and rainfall intensity are assumed to have increased substantially.

This report focuses on the feasibility and location of IWM infrastructure to achieve 25 ML of distributed storages in streetscapes and open space, and the distribution of IWM infrastructure to reduce stormwater pollution loads to the Yarra River and bay.

This current report looks specifically at the two precincts of Fishermans Bend that are within the City of Melbourne's boundaries

2 Method

This section outlines the methodology to identify the type and scale of IWM infrastructure across the 63 subcatchments within Lorimer and NEIC precincts within Fishermans Bend. For a more detailed modelling methodology see section 2 – Method.

2.1 Overview

The process to developing this IWM Infrastructure Plan was as follows:

1. Review of past strategies, documents, data, and models.
2. Desktop site analysis.
3. On site review of assets and conditions.
4. Digitisation of proposed roads, green links, and open spaces.
5. Review and development of asset parameters and asset mix.
6. Modelled storage potential by subcatchment.
7. Water quality modelling of proposed WSUD infrastructure by subcatchment.
8. Analysis of infrastructure costs, construction, and maintenance requirements.
9. Reporting.

2.2 IWM infrastructure options

A range of assets were considered and when combined with previous work on the Fishermans Bend Water Sensitive City Strategy, the following assets were identified for potential use:

- WUSD Tree pit and trench systems
- Raingardens
- Linear Parks
- Open space storage (detention basins).

These asset types:

- Can be designed to deliver both flood detention and water quality improvement
- Are able to be delivered in different areas of the catchments
- Are more cost effective to be delivered as new urban renewal assets rather than retrofitted later on.

Key design parameters were selected to maximise storage whilst also maintaining a realistic understanding of the nature of WSUD assets (i.e., a raingarden system with a 300 mm designed extended detention depth is often only providing 200 mm of extended detention in practice due to uneven levels and the build-up of material across the filter area).

2.3 Determining detention target volumes per subcatchment

The desired levels of service regarding flood performance refer to the 5% AEP rainfall event (20-year ARI) and 1% AEP rainfall event (100-year ARI).

5% AEP rainfall event (20-year ARI)

Previous modelling work conducted as part of the development of the Fishermans Bend Water Sensitive Drainage and Flood Strategy identified individual subcatchment spill volumes (the amount of excess water to be detained during a rainfall event when drainage infrastructure and private realm storage is at capacity) for the 5 year and 20-year ARI rainfall events.

This provided specific WSUD distributed storage targets for the level of service associated with the 20-year ARI rainfall event but not the 100-year ARI rainfall event.

1% AEP rainfall event (100-year ARI).

Previously developed RORB models did not include drainage infrastructure capacity and so the distributed storage targets for the level of service relating to the 100-year ARI rainfall event were developed as follows:

- Peak flow hydrographs for each sub catchment's critical duration were developed for both the 100-year ARI and 20-year ARI rainfall events.
- The additional volume to be detained (area under said curves) between respective 20-year ARI and 100-year ARI hydrographs were added to the already modelled 20-year spill values, to arrive at a "100-year spill volume" to be detained.

This method assumes that all drainage across both precincts is at capacity during the 20-year ARI rainfall event. This conservative assumption was required without any further knowledge or modelling of the existing or proposed drainage in each subcatchment.

2.4 Water quality modelling

Water quality modelling was completed with MUSIC for the 63 subcatchments.

Due to the large degree of uncertainty around the detailed nature of Fishermans Bend's urban renewal over the next 30 years, some critical assumptions were made, particularly regarding the final urban layout and extent and location of proposed imperviousness. However, where possible, assumptions were made to lean on the 'conservative side' to further provide evidence for the feasibility of this proposed infrastructure. For example, we would suspect the final ratio of public vs private realm catchment sizes to tend towards larger private realm catchments than modelled here.

The size of private realm catchments was determined based on the size of available roof and podium space within the private realm (GHD, 2019), with a further 25% of non-roof/podium private realm imperviousness prescribed to each subcatchment based on the zoning and land use of NEIC and Lorimer. The remaining catchment is then made up of public open space and streetscapes, this is separated using the digitised public open space GIS layer, with the remaining area comprised of the streetscapes within the subcatchment.

The initial scenario model run divided the streetscape catchments into three equal catchments that were to be treated by the respective tree pits/trenches, raingardens, and linear parks within that specific subcatchment, with all open space storage providing bottom of catchment storages only in rarer rainfall events, as such assets are optimally deployed in the upper, middle, and lower parts of the catchment, respectively. This was considered the "untargeted" scenario as it often results in large impervious catchments that are untreated, for example If a particular subcatchment has no linear parks, the bottom third of that catchment is untreated within the model. The "targeted" scenario involved dividing the streetscape catchments by the respective weighting of tree pits/trenches, raingardens, and linear parks within that subcatchment. This results in some form of treatment coverage across the entire streetscape catchment. The final "targeted and maintained" scenario was constructed as the targeted scenario, however, in this run the 'blockage factors' were removed thus increasing the available filter area of the tree pits/trenches and raingardens.

Figure 9 illustrates the MUSIC modelling treatment train for one subcatchment to capture how all areas were broken down and included in the modelling analysis.

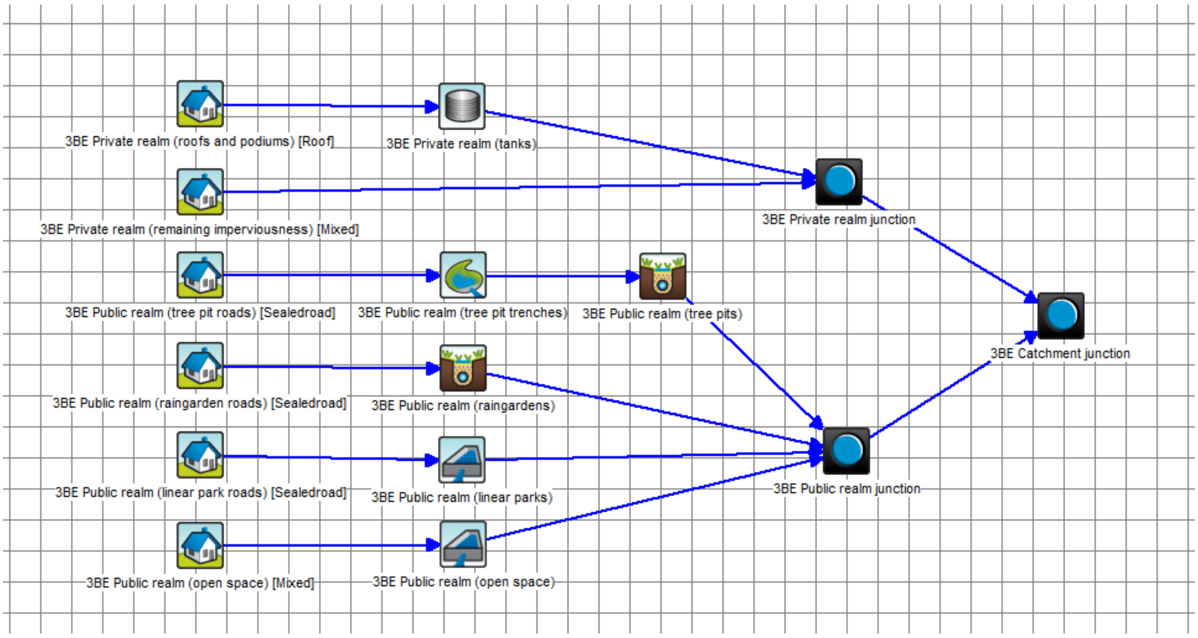


Figure 9. Example MUSIC model structure (Source: Wave Consulting Australia)

Further detail on MUSIC modelling is presented in Appendix A. - Asset allocation and Appendix B. WSUD Asset parameters (for storage and water quality monitoring).

2.5 Opportunities for WSUD storage

Opportunities where distributed storage could be located within the public realm were the main focus of this report. To identify appropriate spaces for WSUD storages, a review of the proposed urban form of the NEIC and Lorimer precincts of Fishermans Bend was completed. This led to the digitisation of three datasets: proposed roads, proposed green links, and proposed open space[1]. These three data sets had a cumulative area of 133.3 hectares across the two precincts. In removing areas deemed unsuitable for WSUD assets, the actual area available to incorporate IWM infrastructure is therefore 56.7 hectares.

Areas deemed unsuitable for WSUD assets are:

1. Areas around all of the existing or proposed intersections.

This removes 9.53% of the available space for distributed storage. Road intersections can be challenging locations to retrofit WSUD infrastructure and present unique operational and maintenance requirements with respect to traffic management. Intersections are still viable and feasible locations, however for the purpose of highlighting the viability and feasibility of delivering large amount of distributed storage across the two precincts, these locations were excluded and assumed to have any IWM infrastructure. The locations of proposed and existing intersections (both signalled and non-signalled) can be seen in Figure 10.

[1] subject to further change and finalisation through the PIP development and finalisation process.

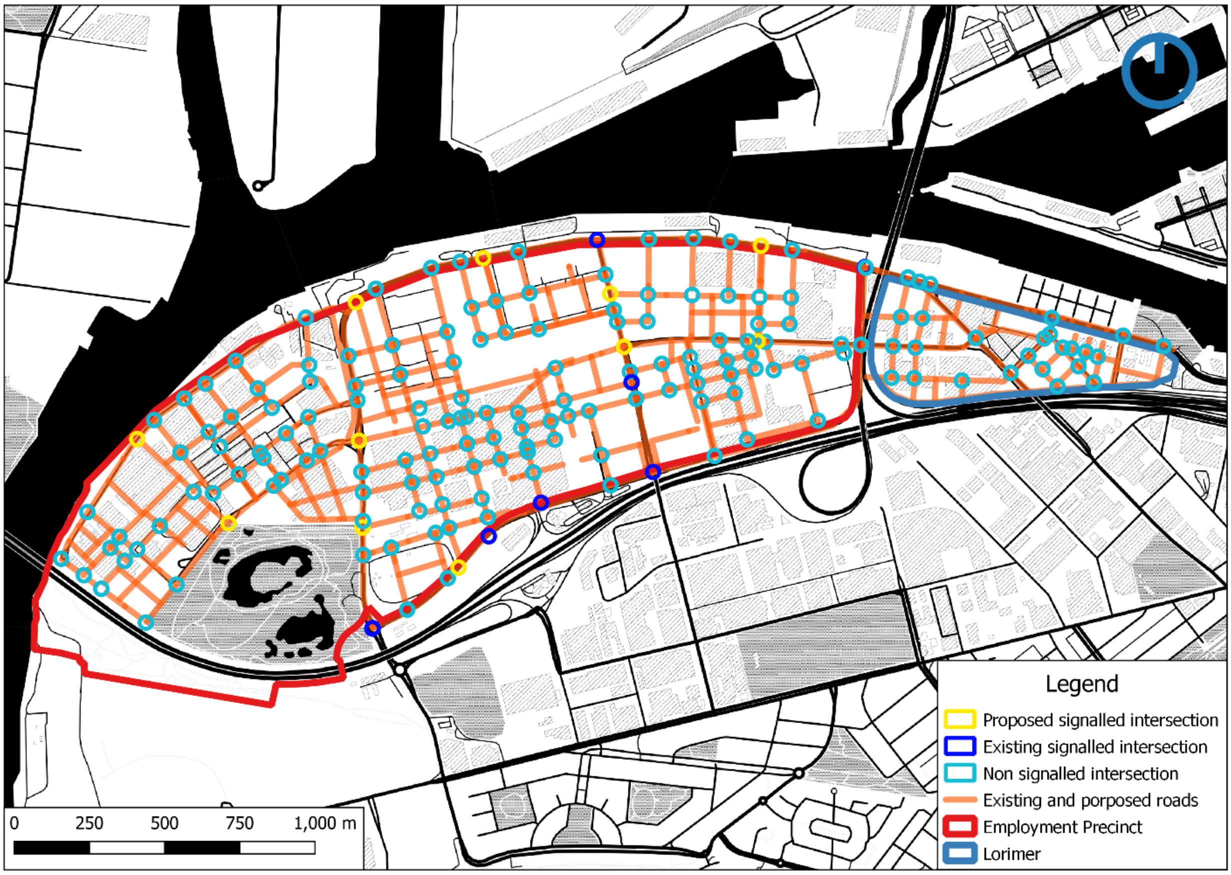


Figure 10. Proposed and existing intersections

2. Areas where groundwater levels are high

Current groundwater levels are approximately 1-3.5 m below surface level and roughly correlates to 0 m AHD. However, due to the impact of climate change this groundwater level, which is closely influenced by sea level, is forecast to increase to 0.8 m AHD by 2100. Initially, the Water Sensitive Drainage and Flood Strategy limited the minimum ground level for excavated storages to 1.8 m AHD, and then with further analysis this was lowered to 1.4 m AHD. By excluding areas where the surface level is near 0.8 m AHD, there is 7.8% less space available for distributed flood storage. One area of groundwater concern is towards the northern end of Salmon Street in the NEIC. Figure 11 shows that the northernmost 200 metres of Salmon Street is unsuitable for underground distributed storage.

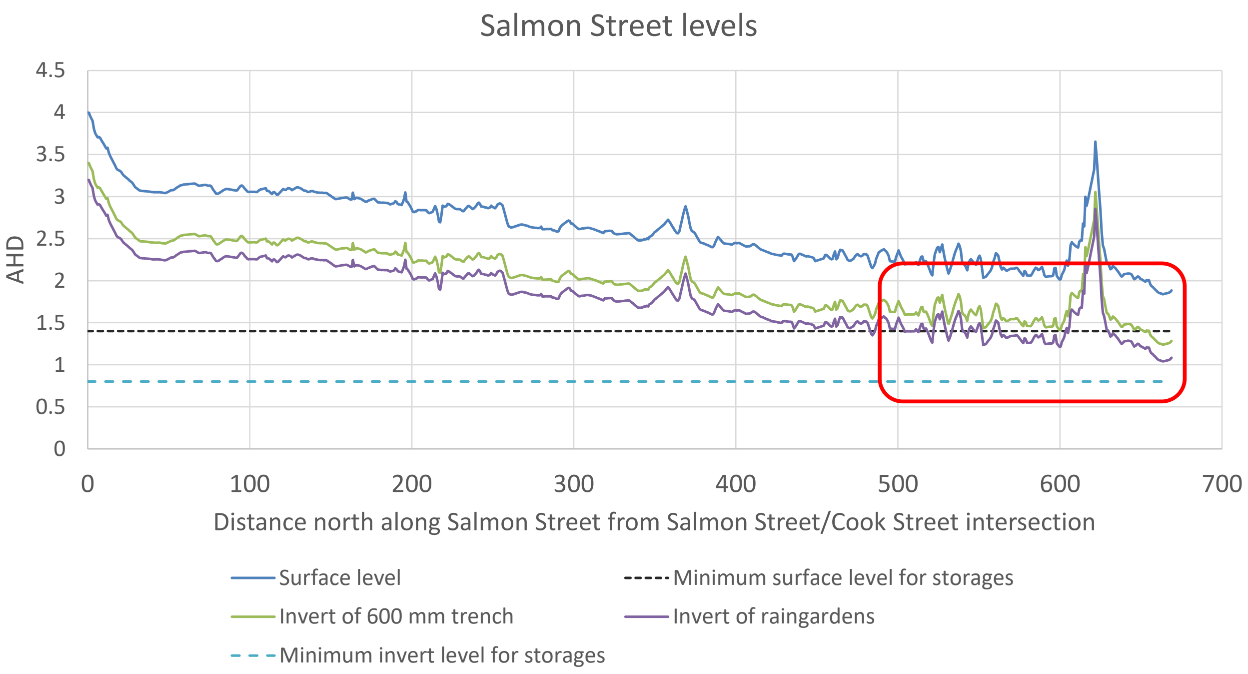


Figure 11. Profile level analysis of Salmon Street running south to north highlighting areas where underground storages are unsuitable.

3. Areas with significant competing demands.

There are some specific roads and laneways that were deemed unsuitable for IWM, by stakeholders, due to the competing demands of these spaces. This removes a further 7.29% of the available space for distributed storage.

Public open space was considered highly valuable for the community and is preferred to not be also used as flood detention. Excluding these spaces removes a further 32.81% of the available space for distributed storage (noting most of this area is within Westgate Park).

The actual area available to incorporate IWM infrastructure is therefore 56.7 hectares.

2.6 Applying IWM to Fishermans Bend

The three cross-sections presented in Figure 13, Figure 14, and Figure 15 show how tree pits and trenches, raingardens, and linear parks are located in the context of local drainage and public open space storage within a nominal streetscape, catchment and/or urban area. These diagrams are modifications of the 'hybrid' approach developed by GHD in the Water Sensitive Drainage and Flood Strategy, as can be seen in Figure 12. The original 'hybrid' approach utilised distributed WSUD storage assets downstream of existing drainage infrastructure at 'spill' locations. This IWM Infrastructure Plan locates WSUD assets upstream of local drainage infrastructure. This was arrangement was chosen as:

- WSUD assets, particularly tree pits and raingardens, need water regularly in order to facilitate the multiple benefits these assets can provide (i.e., cooling, greening, increased canopy cover etc.)
- Will result in greater pollution reduction, as most rain events will be treated.

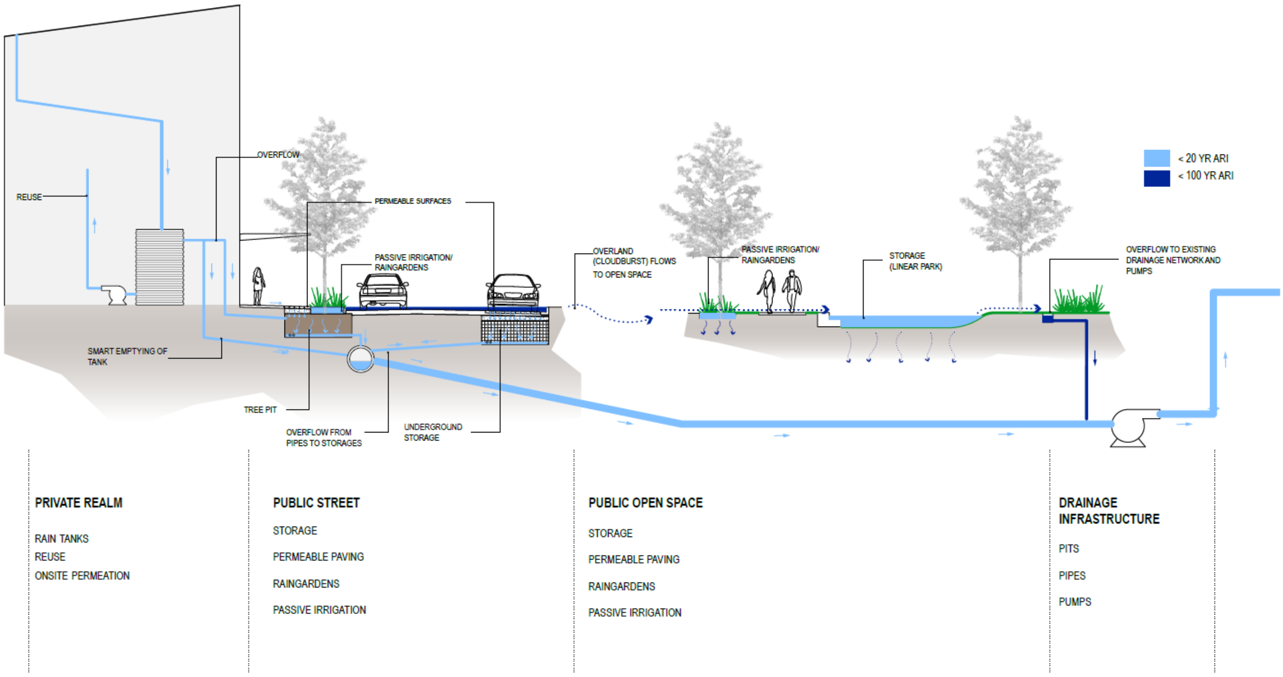
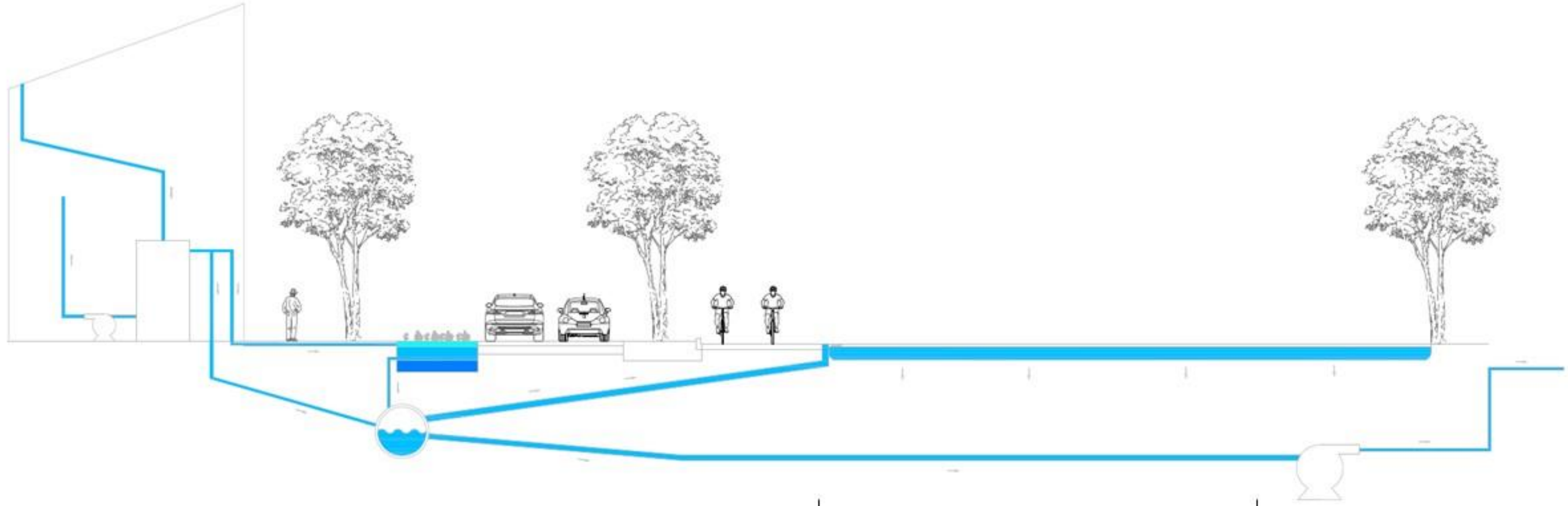


Figure 12. Diagrammatic cross section of the 'hybrid' approach as outlined in the Fishermans Bend: Water Sensitive Drainage and Flood Management Strategy (Source: GHD, 2019).



PRIVATE REALM

- Regular tank overflow to flow to local WSUD infrastructure.
- Smart tank overflows preceding storm event to flow to local drainage.

PUBLIC STREET

- Raingardens to store water through extended detention storage and within soil media.
- Outlets to overflow into downstream raingarden system or to local drainage where appropriate.

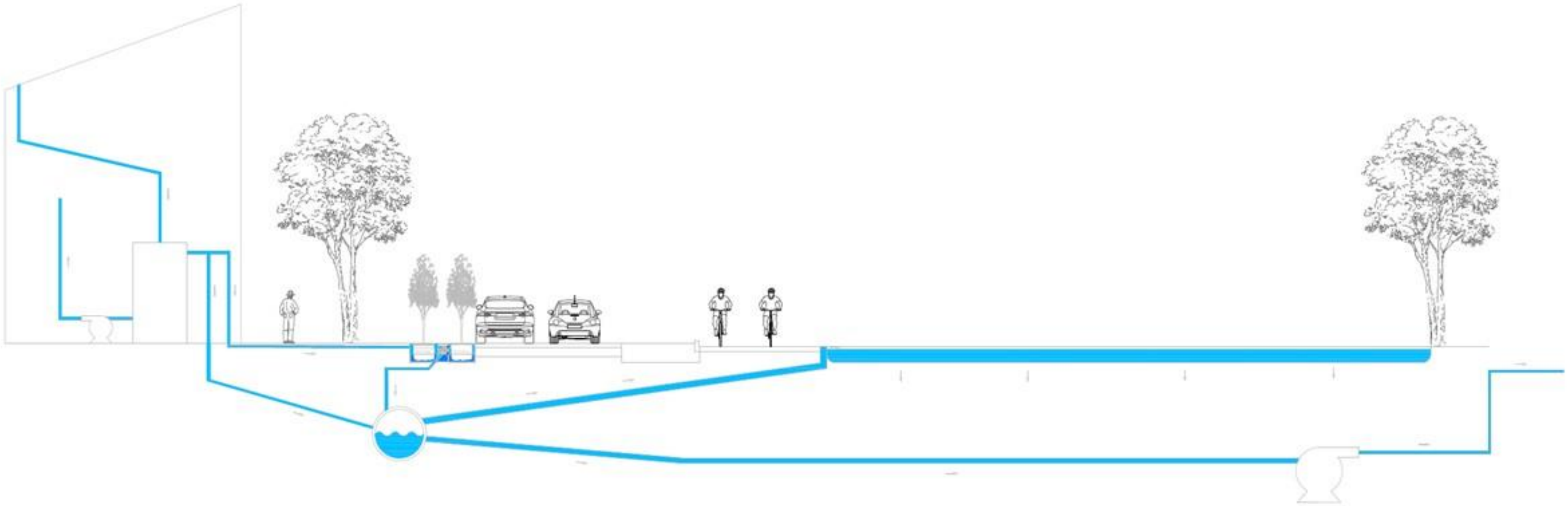
PUBLIC OPEN SPACE

- Public open space to receive overflow from end of catchment drainage infrastructure.
- Will therefore only be engaged extremely infrequently maintaining primary use most of the year.

DRAINAGE INFRASTRUCTURE

- Peak flow burdens on downstream drainage infrastructure reduced by locating WSUD assets upstream of local drainage.

Figure 13. Cross section highlighting raingarden interaction with private realm, typical drainage, and public open space.



PRIVATE REALM

- Regular tank overflow to flow to local WSUD infrastructure.
- Smart tank overflows preceding storm event to flow to local drainage.

PUBLIC STREET

- Tree pits to store water through extended detention storage and within soil media. Trenches to store water only through media storage.
- Outlets to overflow into downstream trench system or to local drainage where appropriate.

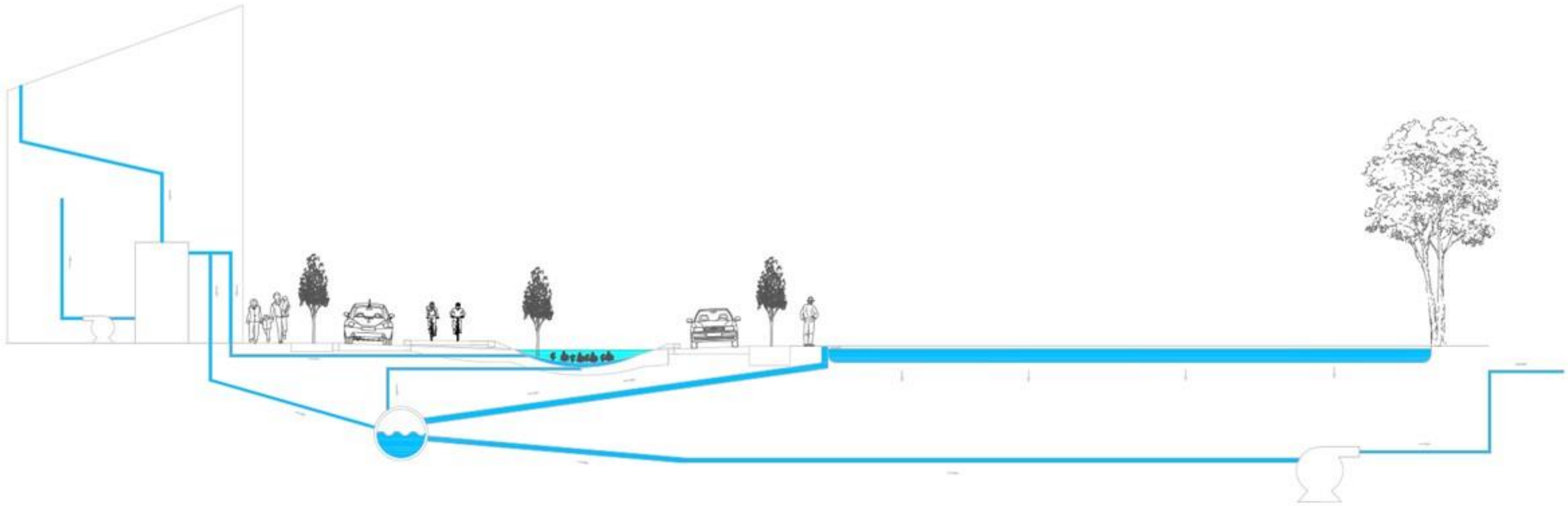
PUBLIC OPEN SPACE

- Public open space to receive overflow from end of catchment drainage infrastructure.
- Will therefore only be engaged extremely infrequently maintaining primary use most of the year.

DRAINAGE INFRASTRUCTURE

- Peak flow burdens on downstream drainage infrastructure reduced by locating WSUD assets upstream of local drainage.

Figure 14. Cross section highlighting tree pit and trench interaction with private realm, typical drainage, and public open space.



PRIVATE REALM

- Regular tank overflow to flow to local WSUD infrastructure.
- Smart tank overflows preceding storm event to flow to local drainage.

PUBLIC STREET

- Linear parks to store water through extended detention storage only.
- Outlets to overflow into downstream linear park system or to local drainage where appropriate.

PUBLIC OPEN SPACE

- Public open space to receive overflow from end of catchment drainage infrastructure.
- Will therefore only be engaged extremely infrequently maintaining primary use most of the year.

DRAINAGE INFRASTRUCTURE

- Peak flow burdens on downstream drainage infrastructure reduced by locating WSUD assets upstream of local drainage.

Figure 15. Cross section highlighting linear park interaction with private realm, typical drainage, and public open space

This infrastructure plan proposes the use of WSUD assets of differing scales and storage potential to be used throughout the respective catchments of the NEIC and Lorimer Precincts. By utilising smaller WSUD assets higher in the catchment, downstream runoff is both reduced and of an improved quality, reducing the scale of large downstream assets (conceptually outlined in Figure 16 below)

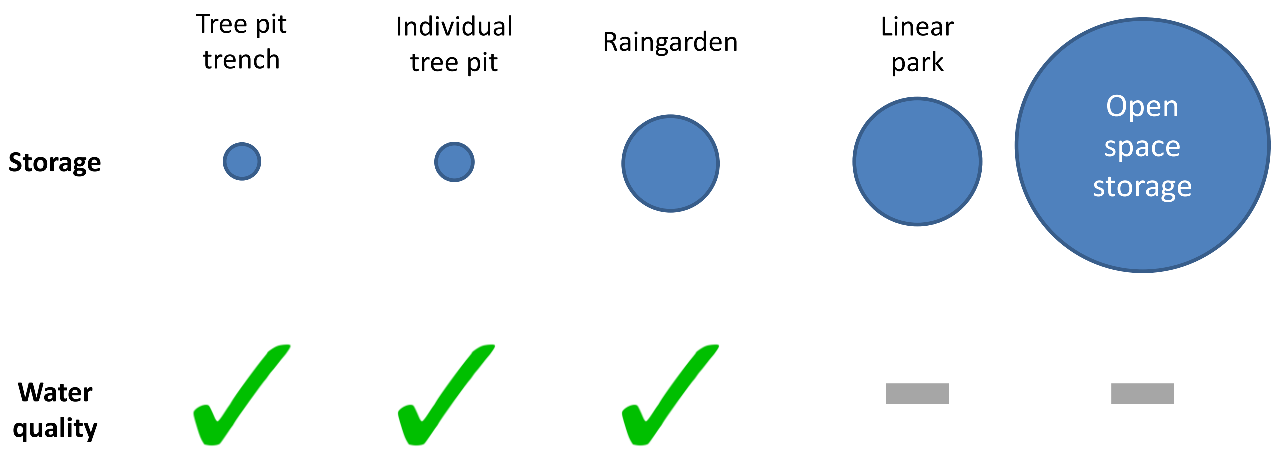


Figure 16. Water quality and flood storage benefits from proposed infrastructure

3 Results

The results of this modelling work for the NEIC and Lorimer Precincts of Fishermans Bend are presented at three levels:

- the whole NEIC and Lorimer precinct scale,
- at a catchment scale for each of the 6 catchments, and

a subcatchment scale for each of the 63 subcatchments (discussed in Appendix F. Subcatchments in need of more storage).

This is important to ensure that the IWM infrastructure is achievable within the 63 individual subcatchments, not just collectively within each of the six catchments .

Storage modelling resulted in three distinct scenarios:

1. **Minimum required storage (with partial asset failures)**. This scenario identifies storage within the street network and doesn't rely heavily on open spaces for storage. Targets are met with 90% of the storage managed upstream of open spaces. Assumes that some of the smaller to medium sized assets (tree pits, trenches, and raingardens) are blocked and therefore providing no storage.
2. **Maximum storage (but assumes partial asset failure)**. This scenario seeks to create additional storage in all parts of the catchment, but then assumes that some of the smaller to medium sized assets (tree pits, trenches, and raingardens) are blocked and therefore providing no storage.
3. **Maximum storage (no asset failures).** This scenario identifies all storage possible and assumes there is no failure of the assets. This scenario represents a situation with ideal best practice maintenance.

This section of the report presents the 'Minimum required storage (with partial asset failures)' scenario. This scenario can provide the 21,305 m^3 of storage across the six primary catchments.

Across the individual 63 subcatchments, some subcatchments require additional storage to meet their respective 1% AEP level of service. However, research on the spatial deployment of detention storages indicates that meeting storage targets at major catchment scale (i.e., within all of the Lorimer precinct) is just as effective compared to having the necessary individual storage capacity within all respective subcatchments (Pezzaniti et al., 2003). Results for the required storage in each individual subcatchment level and relationship to targets is outlined in Appendix F. Subcatchments in need of more storage.

The 'Maximum storage (but assumes partial asset failure)' scenario can provide for a further 23,459 m^3 of storage. However, over 19,000 m^3 of this is by maximising open space storages in parts of the catchment that already have enough storage.

Finally, the 'Maximum storage (no asset failures)' scenario provides for a further 3,505 m^3 by assuming all WSUD assets are optimally maintained and thus have no blockages or diversions. This additional storage is across all catchments where raingardens, tree pits and trenches are utilised.

The modelling results and spatial data has been provided to City of Melbourne for ongoing use and analysis.

3.1 Minimum required storages

The decision to reduce the amount of open space storage in this scenario as opposed to other WSUD asset typologies was based on the high-level of competing demand for public open space in Fishermans Bend and the reduced water quality treatment that such assets provide. By reducing public open space storage and maintaining the same scale of raingardens and tree pits, whilst still meeting detention storage targets, flood mitigation can be delivered alongside other WSUD benefits such as greater biodiversity, cleaner waterways, and cooler and shadier streets.

Table 2. Minimum WSUD distributed storage by catchment.

Catchment	5% AEP (20 Year ARI) level of service target	1% AEP (100 Year ARI) level of service target	Streetscape and green link storage	Open space storage required	Total distributed storage
Hall Street	4,198 m^3	6,924 m^3	5,593 m^3	1,332 m^3	6,924 m^3
River Esplanade	157 m^3	2,584 m^3	2,584 m^3	0 m^3	2,584 m^3
Sabre Drive	0 m^3	2,894 m^3	2,894 m^3	0 m^3	2,894 m^3
Salmon Street	2,936 m^3	5,048 m^3	5,048 m^3	0 m^3	5,048 m^3
Todd Road	620 m^3	3,854 m^3	3,854 m^3	0 m^3	3,854 m^3
Westgate Lakes	0 m^3	0 m^3	0 m^3	0 m^3	0 m^3
Total	**13,407 m^3**	**21,305 m^3**	**19,973 m^3**	**1,332 m^3**	**21,305 m^3**

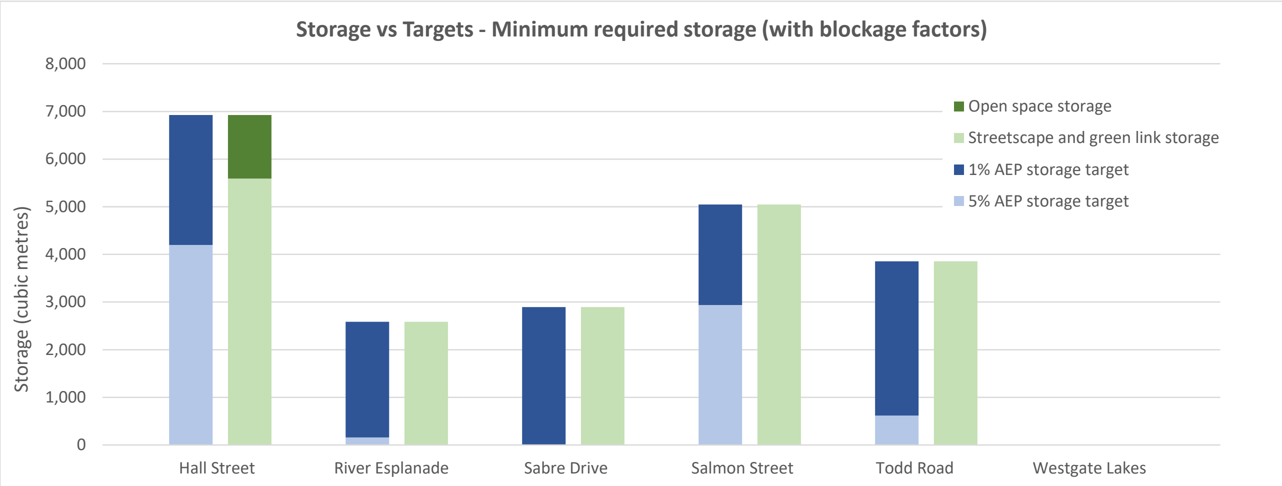


Figure 17. Storage vs targets by catchment for the minimum required storage (with partial asset failures) scenario.

This minimum required storage (with partial asset failures) scenario utilises:

- 1,309 WSUD tree pits,
- 11,785 m of trenches,
- 45,131 m^2 of raingardens (or approximately 2,250 raingardens assuming they are on average 20 m^2 in area),
- 4 hectares of linear parks, and
- A quarter of a hectare of suitable open space detention storage.

The above asset summary is based on combined targets at the level of the six primary subcatchments.

By adopting this scenario (instead of a move toward seeking and planning for maximum flood detention) City of Melbourne and stakeholders would see less open space needing to also deliver IWM outcomes. However, this scenario provides no resilience to flood protection, should upstream detention systems (including private realm rainwater tanks) fail to function as designed.

While this scenario would see 21,305 m^3 of storage within the precincts, other scenarios would see up to 48,269 m^3 of storage by maximising open space storage opportunities and maintaining optimal maintenance regimes. If there is less confidence in the design and operation of this infrastructure, and also more concern about the potential impacts of climate change, then it would be prudent to pursue a scenario that delivers more distributed storage.

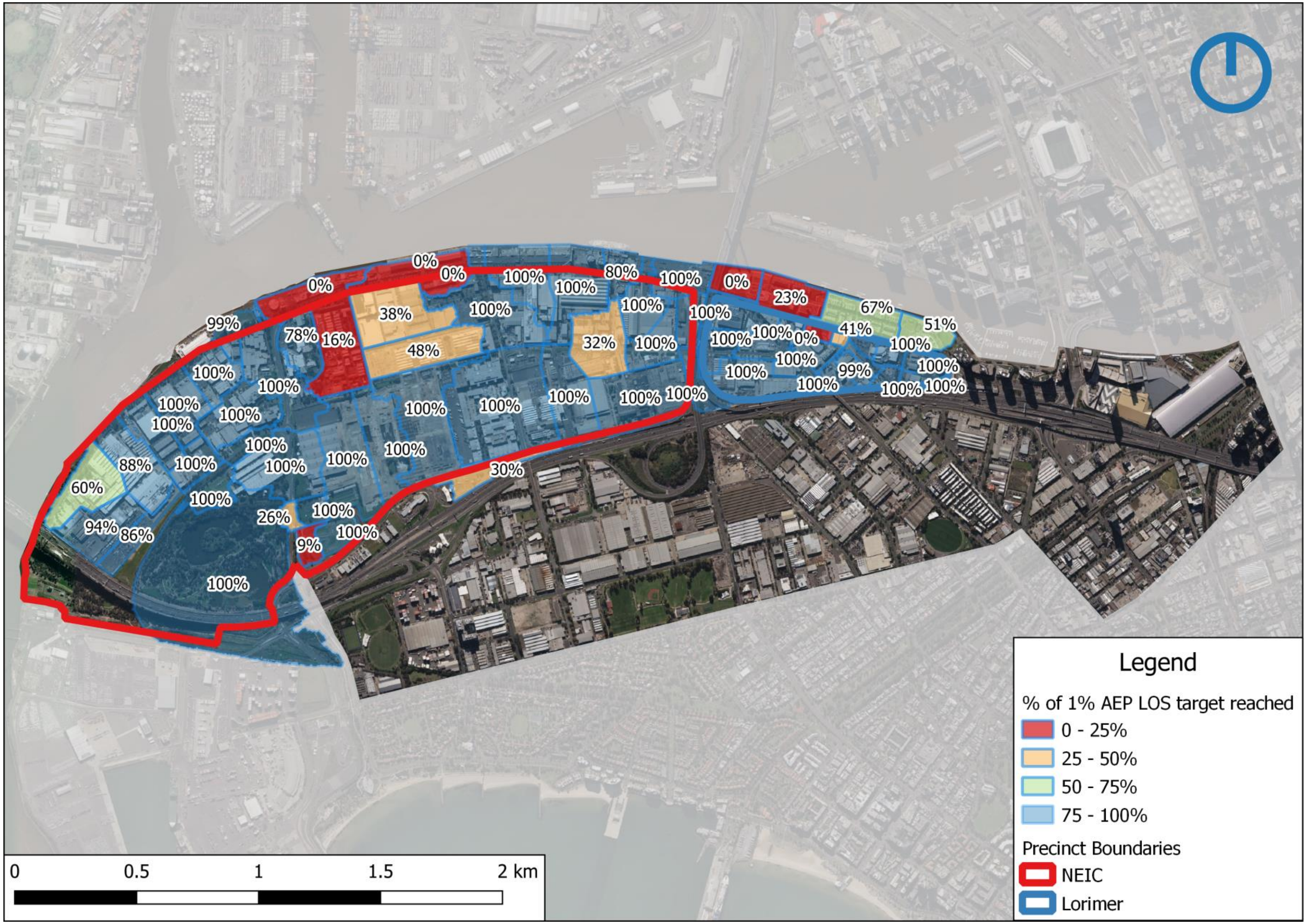


Figure 18. Potential storage available when only meeting individual subcatchment 1% AEP level of service targets

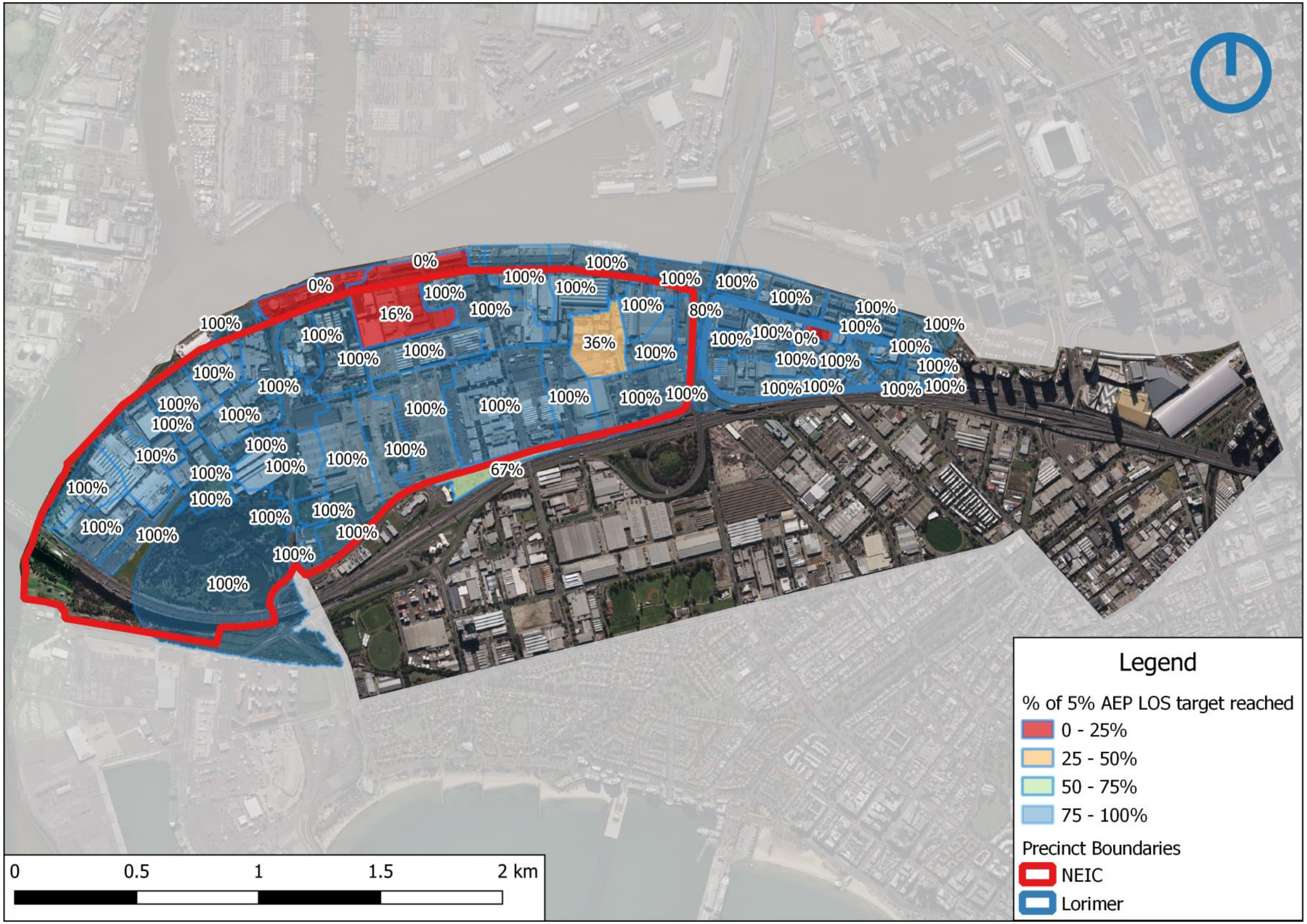


Figure 19. Potential storage available when only meeting individual subcatchment 5% AEP level of service targets

3.2 Critical sub-catchments for flood storage

The combined distributed storage requirement to meet the 100-year level of service across the area of interest (the NEIC and Lorimer precincts of Fishermans Bend, inside the local government area of City of Melbourne) is 21,305 m^3. Under this IWM Infrastructure Plan this high-level target can be met as there is potentially 44,764 m^3 of distributed storage available. However, when this analysis is further broken down in to the 63 subcatchments, not every subcatchment's 1% AEP level of service target can be met with the implementation of this IWM Infrastructure Plan.

In 22 subcatchments (of the 63 modelled), the local area does not have enough capacity to meet the levels of service. There isn't enough space to retain and filter stormwater.

In subcatchments that only require relatively small amounts of additional storage (i.e., less than 25% of the 1% AEP level of service target), minor adjustments to the assets within these subcatchments, such as utilising space around intersections (but allowing for maintenance), or applying more assets along a streetscape than the proposed asset allocation table suggests, will often allow the respective 1% AEP storage targets to be met.

In other subcatchments a larger scale solution will be required. Some potential options in these subcatchments include:

- Structural soils below porous asphalt uncovered parking spaces offer distributed storage opportunities.
    - With a porosity of 0.4 and a depth of 0.5 metres these assets offer 0.2 m^3 of storage per square metre of parking, with a single parallel on-street carpark bay occupying approximately 25 m^2 this could provide up to 5 m^3 per space.
    - A similar approach can be taken to locate storages below porous/permeable road surfaces where loading requirements allow.
    - Both of these strategies decrease the relative level of imperviousness within a subcatchment as well as providing more distributed storage.
- Increasing extended detention depth of raingardens or linear parks (additional extended detention in tree pits offers only minor increases to a subcatchments total distributed storage).
    - Each 100 mm increase in extended detention of these assets provides 0.1 m^3 of storage per square metre of the asset's surface area. This does not require additional surface area for distributed storage as these assets already exist. However, the greater the extended detention on these assets the more critical safety measures become. Additionally, increasing these assets extended detention by 100 mm will also in turn lower their invert level by a corresponding 100 mm and therefore needs to be considered in the context of areas of groundwater level concern.
- Additional or relocated public open space suitable for above ground detention is another option that can be maximised in these subcatchments.
    - As per Appendix B. WSUD Asset parameters (for storage and water quality monitoring), if 25% of the open space is committed to flood detention with a maximum depth of 0.5 metres, each square metres of additional or relocated open space provides 0.125 m^3 of additional storage.

Requiring additional storage within the private realm is not recommended as:

- storage requirements are already significant within the private realm, and it is assumed the modelled tank volumes within the private realm represent an optimised state whereby all tanks are functioning effectively, and

- Monitoring of assets and ensuring compliance with design requirements is often much more challenging in the private realm than in the public realm. Many of these assets will be 'out of sight'.

It is recommended that that mandatory storage requirements (in place for Lorimer) are also applied for the NEIC.

3.3 Open space flood storages

The Water Sensitive Drainage and Flood Strategy states that if in a given catchment or sub-catchment, if the required storage volumes to avoid spills in the 5% AEP event can't be met solely in the streetscape storages, then allowance will need to be made for additional storage in public open spaces or a lower level of service provided.

Subcatchments that are coloured light pink in Figure 20 below are areas where there is less risk and more opportunity to solve that problem with subtle changes to WSUD and/or drainage assets.

The four remaining subcatchments can be seen in red in Figure 20 and lie across the primary catchments of Todd Road, Salmon Street, and Hall Street.

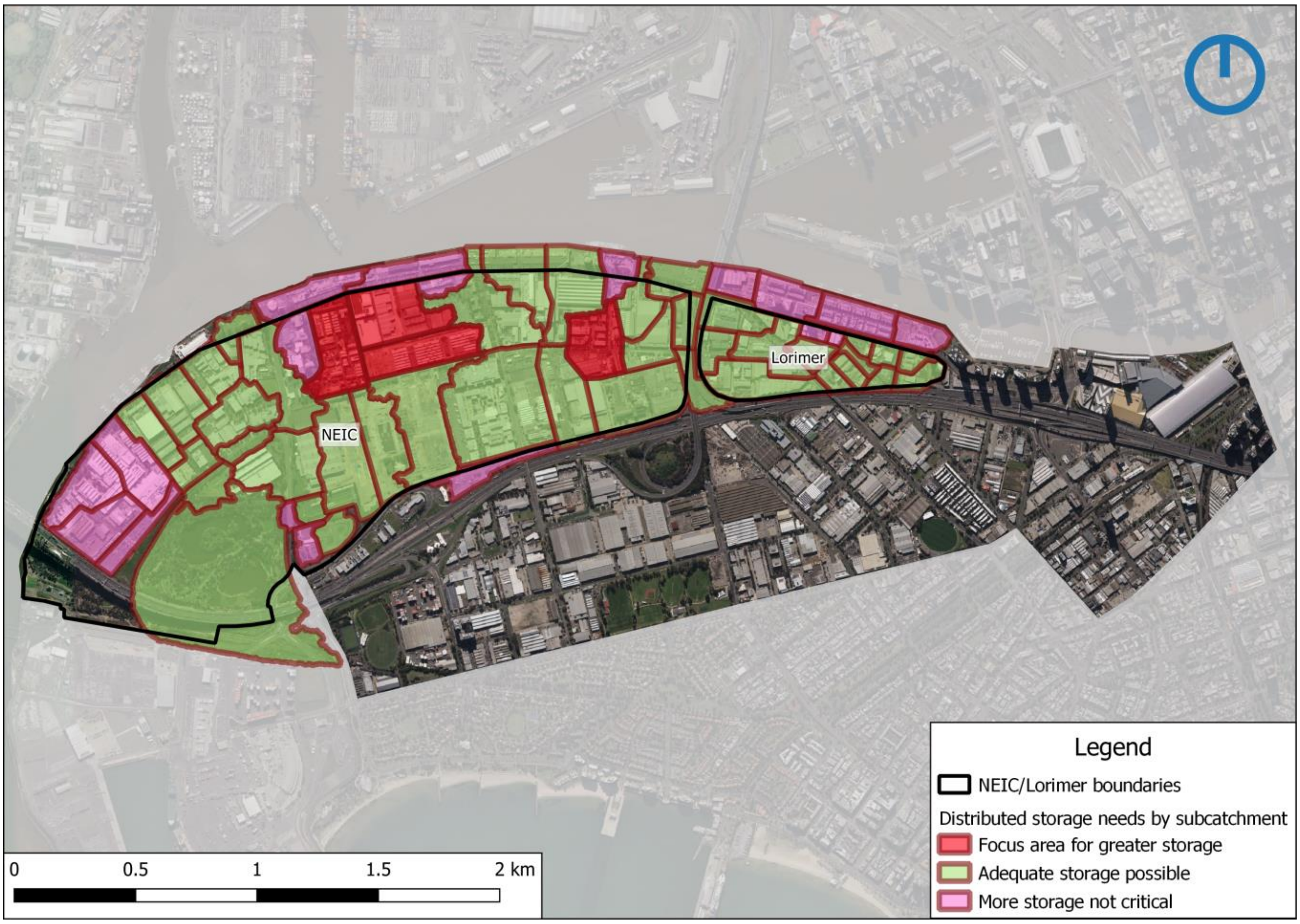


Figure 20. Critical sub catchments for further distributed storage to meet the 1% AEP targets

This analysis shows subcatchments where open space distributed storage is required to meet the 1% AEP level of service minimum storage requirements. When this data is overlayed with proposed open space infrastructure, see Figure 21, it reveals which proposed open space assets will need to be designed to serve a detention function.

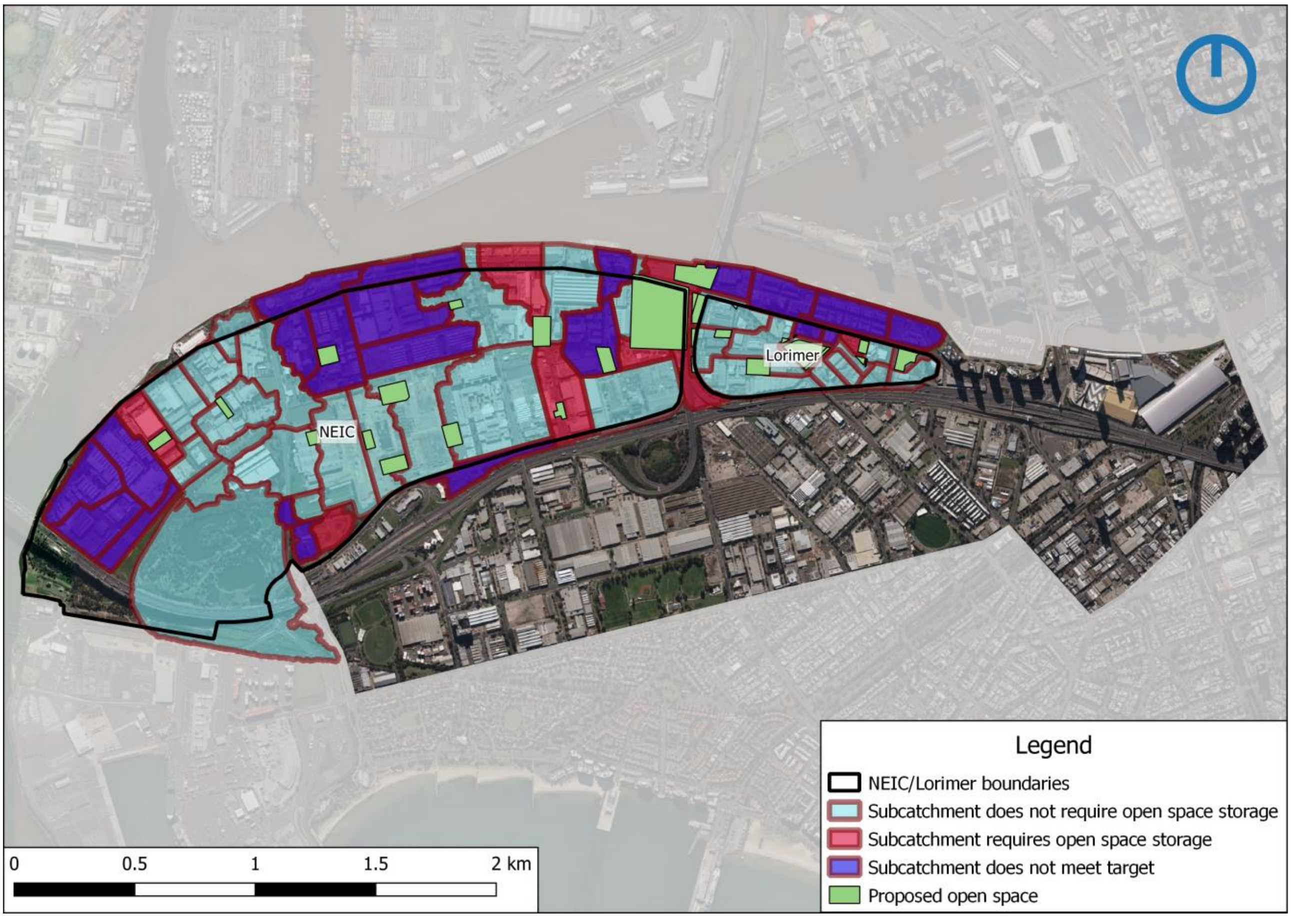


Figure 21. Critical open space storage.

3.4 Advice on open space storage where ground water levels are high

The Fishermans Bend Water Sensitive Drainage and Flood Strategy (2019) states the minimum ground level for excavated storage was set at 1.4 m AHD "*as there is very little area that is below 1.4 m AHD*".

From Figure 22 it can be seen that most of the areas below 1.4 m AHD are in the eastern end of the Lorimer precinct (excluding areas of Westgate Lakes).

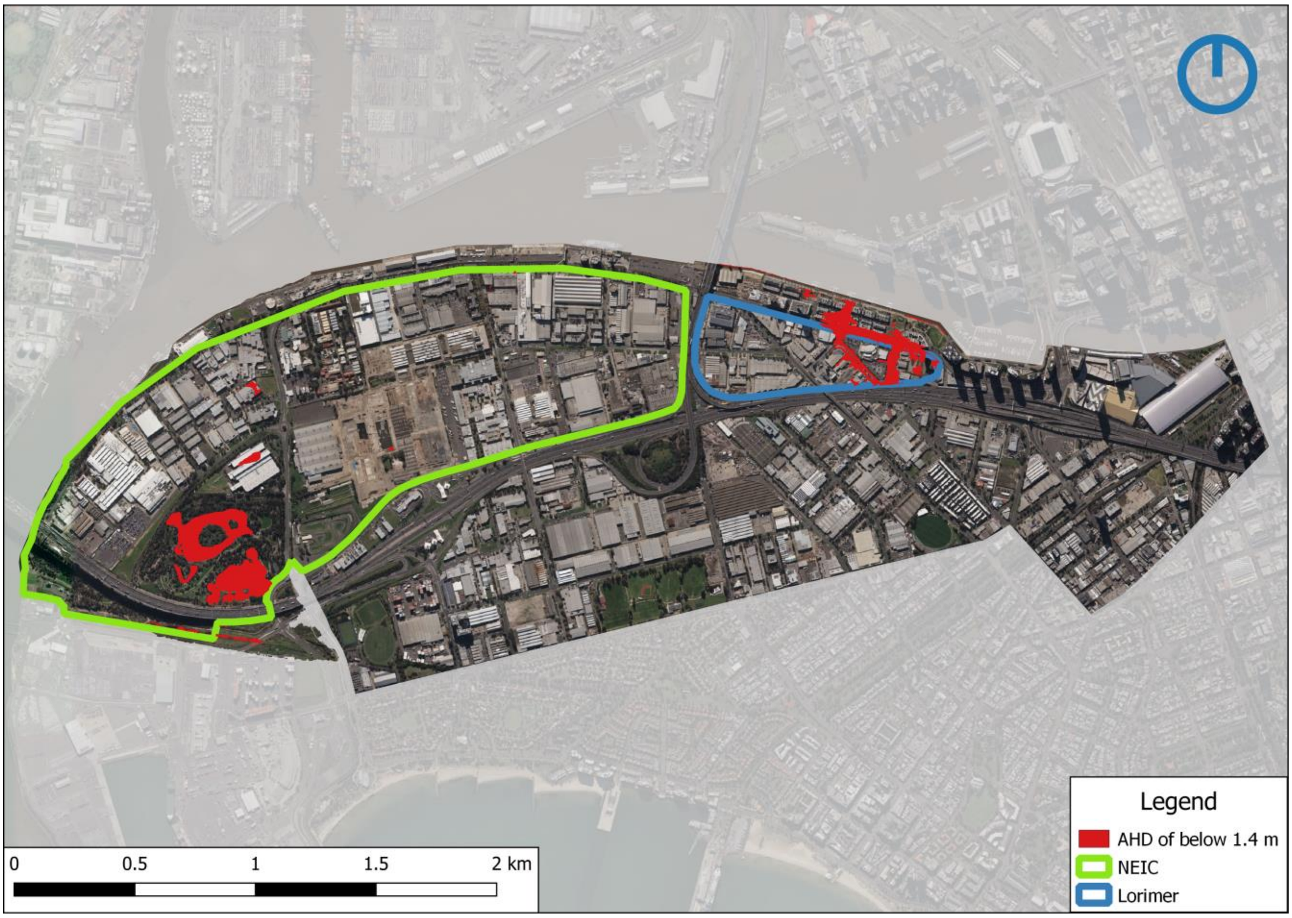


Figure 22. Areas of the NEIC and Lorimer precincts where surface levels are below 1.4 m AHD.

Asset allocation in areas with low surface levels and therefore close proximity to future groundwater levels need to be carefully considered due to the risk of groundwater contamination as well as the impact groundwater levels can have on the infrastructure itself, causing a risk of assets 'floating' in the in-situ soils.

3.5 Alternative asset allocations

The assets recommended in this work all have different relative invert depths as can be seen in Table 3 below.

Table 3. Distributed storage assets with relative invert levels.

Asset type	Preferable location in catchment	Depth of invert relative to surface (mm)	EDD storage ($m^3/m/m$)	Media storage ($m^3/m/m$)	Total storage ($m^3/m/m$)
Tree pits	Top of catchment	650	0.003	0.003	0.006
Trenches	Top of catchment	650	N/A	0.07	0.070
Raingarden	Top/Middle of catchment	1150	0.125	0.109	0.234
Linear parks	Middle/Bottom of catchment	300	0.300	0.000	0.300
Open space storage	Bottom of catchment	500	N/A	N/A	0.125

At a future detailed implementation stage, catchments with areas of groundwater concern need to utilise storage assets with shallow invert levels as much as is practicable. As can also be seen in Table 3 above, utilising linear parks as opposed to raingardens provides 850 mm of additional freeboard with respect to groundwater levels whilst also providing 0.066 m^3 of additional storage per square metre.

3.6 Water quality modelling results

Water quality modelling was performed with MUSIC software (eWater, 2014). The detailed model parameters can be found in Appendix B. WSUD Asset parameters (for storage and water quality monitoring).

The results in Table 2 are for the "targeted and maintained" scenario, which assumes all impervious surfaces are connected to the WSUD assets within that catchment and are well maintained. Subcatchment level results relating to this model scenario can be seen in Figure 23. The modelled WSUD assets will reduce pollution by 80% / 45% / 45% (the industry standard of best practice[2]) across the entire public realm within the NEIC and Lorimer precincts of Fishermans Bend.

Results for the other two modelling scenarios that were conducted, "targeted with partial asset failure (blockages)" and "untargeted with partial asset failure (blockages)" are presents in Table 5 and Table 6 below.

[2] Victorian EPA, 2021. Urban stormwater management guidance. Publication 1739.1. Available at https://www.epa.vic.gov.au/about-epa/publications/1739-1

Table 4. Key water quality modelling results across the NEIC and Lorimer Precincts of Fishermans Bend of the "targeted and maintained" scenario.

	Stormwater pollutant	Stormwater pollution generated (Kg / yr.)	Stormwater pollution that will flow to Port Phillip bay after filtering through WSUD assets (Kg / yr.)	% removed through WSUD infrastructure	Are best practice stormwater pollution reduction targets met?
Public realm (133 ha total)	Total suspended solids (TSS)	150,932	8,497	94.4%	✔
	Total nitrogen (TN)	1,140	345	69.7%	✔
	Total phosphorous (TP)	253	43	83.1%	✔

Table 5. Key water quality modelling results across the NEIC and Lorimer Precincts of Fishermans Bend of the "targeted with partial asset failure (blockages)" scenario.

	Stormwater pollutant	Stormwater pollution generated (Kg / yr.)	Stormwater pollution that will flow to Port Phillip bay after filtering through WSUD assets (Kg / yr.)	% removed through WSUD infrastructure	Are best practice stormwater pollution reduction targets met?
Public realm (133 ha total)	Total suspended solids (TSS)	150,932	31,997	78.8%	✘
	Total nitrogen (TN)	1,140	385	66.2%	✔
	Total phosphorous (TP)	253	68	73.1%	✔

Table 6. Key water quality modelling results across the NEIC and Lorimer Precincts of Fishermans Bend of the "untargeted with partial asset failure (blockages)" scenario.

	Stormwater pollutant	**Stormwater pollution generated (Kg / yr.)**	**Stormwater pollution that will flow to Port Phillip bay after filtering through WSUD assets (Kg / yr.)**	**% removed through WSUD infrastructure**	**Are best practice stormwater pollution reduction targets met?**
Public realm (133 ha total)	**Total suspended solids (TSS)**	150,932	62,335	58.7%	✗
	Total nitrogen (TN)	1,140	943	17.3%	✗
	Total phosphorous (TP)	253	179	29.2%	✗

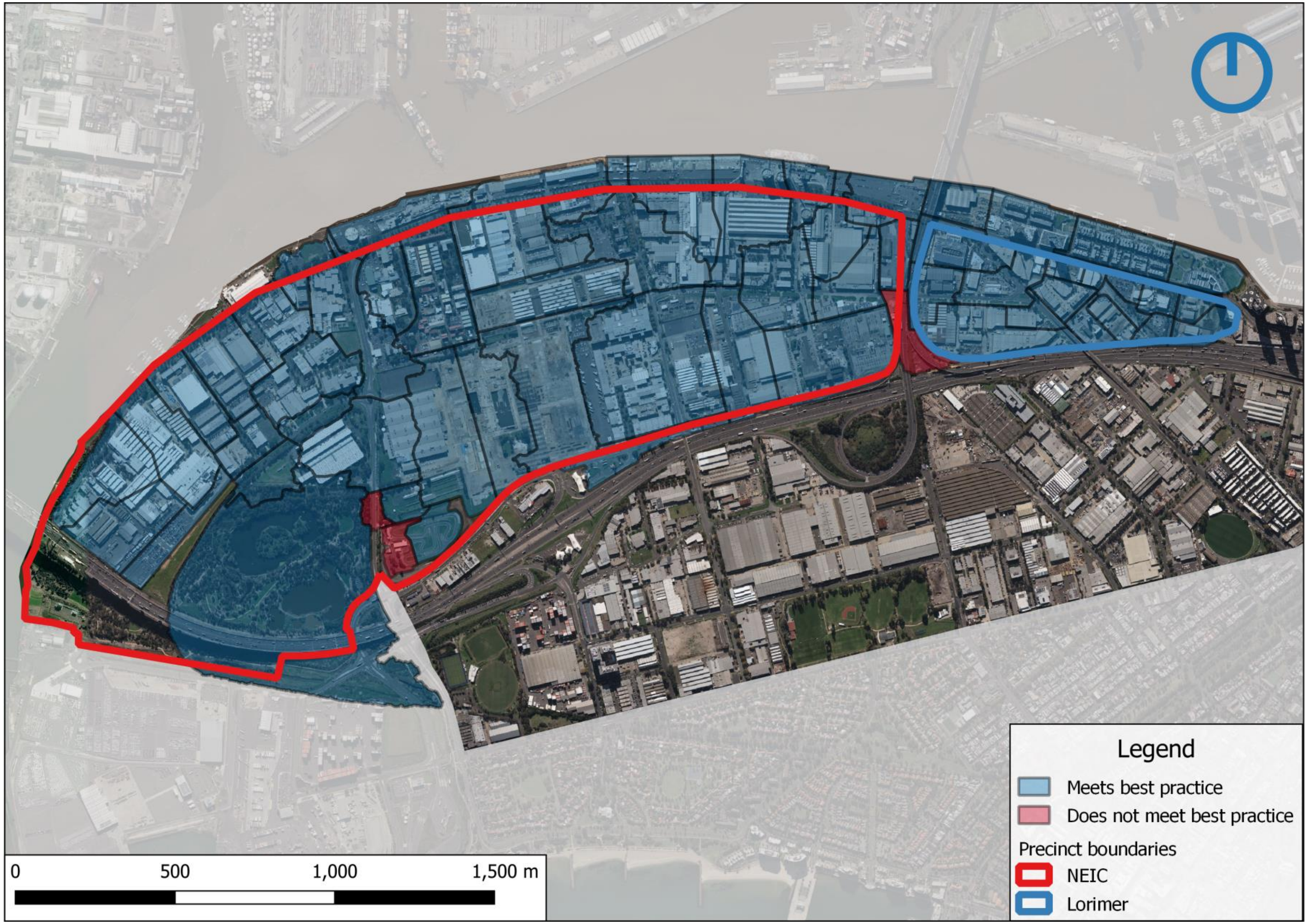


Figure 23. Water quality modelling results for targeted and well maintained WSUD (no blockages).

3.7 Whole of catchment flood targets

Fishermans Bend relies on flood management at multiple scales. Rainwater tanks in the private realm are required to meet flood targets in addition to WSUD measures in streetscapes.

For Lorimer and NEIC precincts, reviewing previous modelling results indicates that from a flood storage perspective, rainwater tanks should contribute 42.6 m^3 of storage. However, this is the maximised amount of storage that can be realised through private lot rainwater tanks, and it is therefore recommended that the public realm maintain additional storage capacity at this stage, any storage capacity that is lost in the private realm due to operational and/or maintenance failures will need to be accounted for within the public realm in order to maintain desired levels of service.

4 Conclusions

Using a combination of IWM asset types, it is possible to meet the vision and objectives of the Water Sensitive City Strategy. A smart and targeted delivery of IWM infrastructure across these precincts would ensure that extreme rainfall events are detained within the catchment, and that small and frequent rainfall events are filtered and significantly less stormwater pollution would flow to the bay. The distributed nature of this infrastructure is crucial in supporting a more climate resilient and cooler and walkable environment for residents and workers.

This infrastructure plan proposes the use of WSUD assets of differing scales and storage potential to be used throughout the respective catchments of the NEIC and Lorimer Precincts. By utilising smaller WSUD assets higher in the catchment, downstream runoff is both reduced and of an improved quality, reducing the scale of large downstream assets

A summary of the recommended scale, extent, and types of assets within this infrastructure plan is outlined below and presented spatially in Figure 24. IWM infrastructure across the precincts includes:

- 1,309 of WSUD tree pits.
- 11,785 m of trenches.
- 45,131 m^2 of raingardens.
- 40,515 m^2 of linear parks.
- 5,237 m^2 of suitable open space storage.
- 20 ML of streetscape distributed storage.
- 1.3 ML of open space distributes storage.

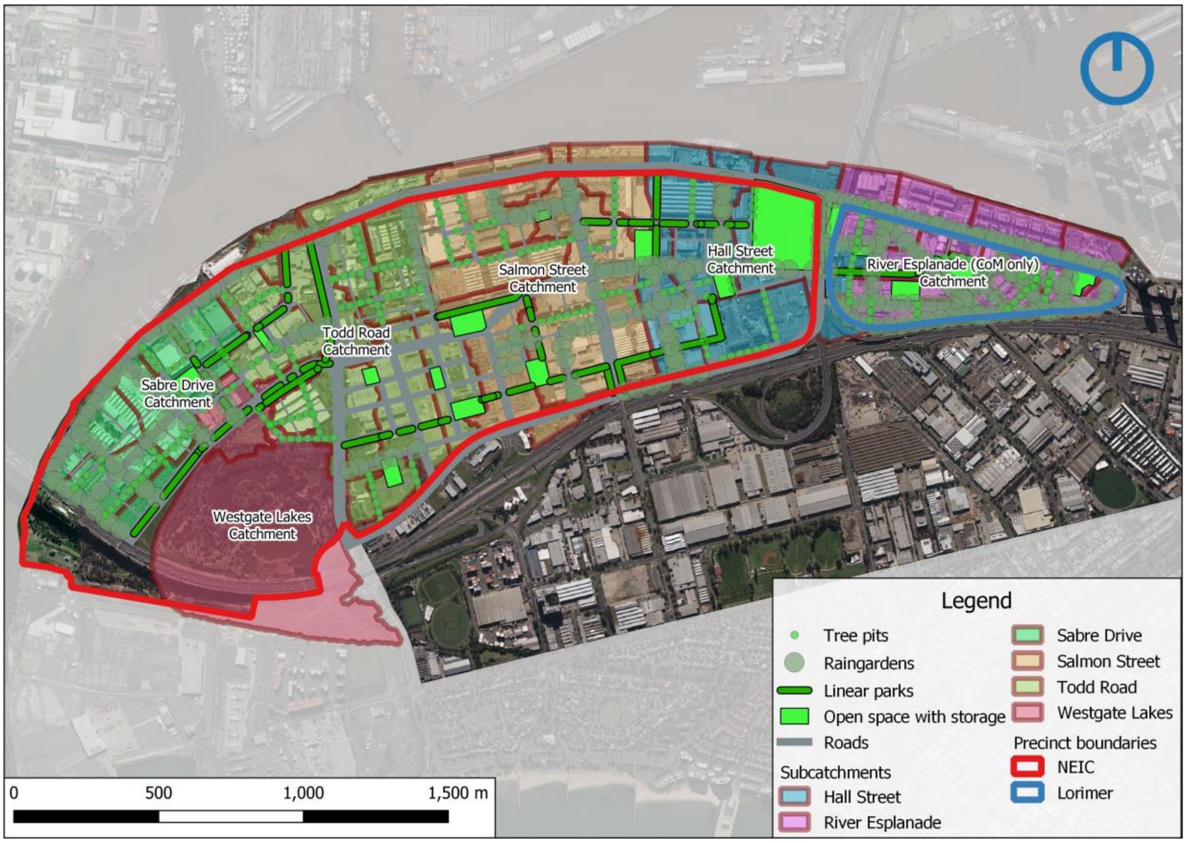


Figure 24. Spatial layout of proposed infrastructure

Water Sensitive Urban Design assets can store water in through

1. **Extended detention (short term flooding whereby surface water pools on the surface)**. This is calculated by the difference in levels between a system's outlet/overflow and either its normal water level or the asset's surface level. In most WSUD designs this volume of water will be visible. This is in keeping with Strategy 5.1.5 of the Fishermans Bend Framework: "Design the public realm to make water visible and part of the Fishermans Bend identity through water sensitive urban design".
2. **Through storage within soil media or structured soil.** The volume of water that can be detained is the volume of the media or structured soil multiplied by the void ratio of the media or structured soil in question. Water being detained within soil media or structured soil provides adjacent vegetation with access to water and is also being actively filtered through the media itself and through the uptake of water by vegetation.
3. **Through a submerged zone.** This is created by elevating the outlet to the desired amount to create an area that cannot drain. However, this isn't a permanent pool as water is evapotranspired, and if the system is unlined, also exfiltrates. The volume doesn't factor into the distributed storage modelling but is essential throughout the tree pits, trenches, and raingardens within this infrastructure plan as it provides many other benefits including maintaining plants' access to water during dry periods, retaining water in the urban landscape, and improves nitrogen and pathogen removal.

Further details of each of these infrastructure types is in Table 7 below and Appendix B. WSUD Asset parameters (for storage and water quality monitoring)

Table 7. WSUD asset types.

Infrastructure Type	Notes
WSUD tree pits	- Provide small amount of 'at source' detention through extended detention and media storage. - Utilise stormwater stored in adjacent trenches for irrigation.
Trenches	- Provide water to adjacent tree pits - 600mm deep with 300 mm submerged zone
Raingardens	- Can provide significant detention volume through large extended detention and significant filter media depth. - Reliable water quality filtration.
Linear Parks	- Can provided detention through extended detention depth. - No losses through infiltration modelled in assumptions so can have lined systems.
Open Space Storages	- Can provide significant volumes of flood detention storage. - Dual purpose open spaces can be achieved through constructed wetlands, lower sections of parks, squares and plazas. - Won't be suitable where groundwater level is high.

5 Costs

Table 3 includes indicative costs for delivering and maintaining IWM infrastructure within the two precincts of interest of Fishermans Bend. Costs do not include any of the existing / traditional infrastructure that will be built irrespective of the Water Sensitive Drainage & Flood Strategy (e.g., stormwater pits, stormwater pipes, kerbs and pumps). IWM infrastructure is site specific but using industry rates and scaling these across all streets and parks, it is possible to estimate the indicative cost of this infrastructure.

Rectification of systems may be required every 5-10 years to reinstate the proper water quality function of the assets if inadequate maintenance is occurring, however a well-maintained system has an expected life span of 15-20 years without the need for rectification.

The table below considers both total CAPEX and OPEX costs of this infrastructure, along with "marginal" CAPEX and OPEX costs of this infrastructure when compared to typical urban infrastructure it would replace (i.e., non WSUD tree pits, garden beds, paved concrete etc.). It should however still be noted that these assets provide multiple benefits along with flood detention and water treatment, for further discussion on these benefits see Section 1.1 above.

It is also important to review regarding the best practice for construction hold points, to avoid rectifications and design defects.

Table 8. Summary of indicative costs.

Asset type	**Forecast life span**	**Typical size**	**Total Capex**	**Marginal IWM Capex**	**Total ongoing maintenance**	**Marginal ongoing maintenance**	**Total Capex of "minimum storage" scenario**	**Marginal IWM Capex of "minimum storage" scenario**	**Total opex/yr. of "minimum storage scenario"**	**Marginal opex/yr. of "minimum storage scenario"**
IWM tree pits	25	< 10 m^2 total	~$4,000/$m^2$	~$3000/$m^2$	$100/$m^2$/yr.	~$20/$m^2$/yr.	$5.24 M	$3.93 M	$0.13 M/yr.	$0.03 M/yr.
Trenches	50	> 50 m^2 total	~$350/$m^2$	~$350/$m^2$	$30/$m^2$/yr.	~$30/$m^2$/yr.	$4.12 M	$4.12 M	$0.35 M/yr.	$0.35 M/yr.
Raingardens	20	> 250 m^2	~$350/$m^2$	~$175/$m^2$	$50/$m^2$/yr.	~$40/$m^2$/yr.	$15.79 M	$7.90 M	$2.26 M/yr.	$1.58 M/yr.
Linear parks	50	> 250 m^2	~$150/$m^2$	~$25/$m^2$	$10/$m^2$/yr.	~$0/$m^2$/yr.	$6.07 M	$1.01 M	$0.41 M/yr.	$0.00 M/yr.
Open space storage	50	> 1,000 m^2	~$25/$m^2$	~$0/$m^2$	$2/$m^2$/yr.	~$0/$m^2$/yr.	$1.02 M	$0.00 M	$0.08 M/yr.	$0.00 M/yr.
Total							**$32.26 M**	**$16.96 M**	**$3.23 M/yr.**	**$1.96 M/yr.**

If this was broken down across the six catchments, then the results are as follows:

Table 9. Capex and IWM Marginal Capex for each catchment

Catchment	Capex	Marginal IWM Capex
Sabre Dr	$4.72 M ($163,000/ha)	$2.68 M ($92,000 /ha)
Todd Rd	$7.15 M ($111,000/ha)	$4.15 ($65,000/ha)
Salmon St	$6.05 M ($92,000/ha)	$2.95 M ($45,000/ha)
Hall St	$6.16 M ($124,000/ha)	$3.02 M ($61,000/ha)
River Esplanade	$5.67 M ($143,000/ha)	$3.16 M ($80,000/ha)
Westgate Lakes	$1.16 M ($25,000/ha)	of $0.67 M ($14,000/ha)

6 Recommendations and considerations

The following recommendations have been developed in relation to the design, construction and maintenance of the proposed IWM infrastructure.

While none of this infrastructure is significantly different from typical WSUD assets and typologies already constructed and currently being maintained in the City of Melbourne, special consideration has been given to these recommendations in light of the critical dual role this infrastructure will play within Fishermans Bend.

Construction and maintenance of WSUD assets has long been a challenge for asset owners, and this challenge must be addressed within Fishermans Bend in order to deliver on the desired flood performance objectives and water quality targets.

6.1 Importance of well-designed and maintained infrastructure on private land

The analysis of flood storage and water quality assets within these two precincts identified that City of Melbourne and stakeholders must be very conscious and focused on ensuring that the appropriate infrastructure is designed, constructed and maintained on private realm. 56% of the precinct is private land, and in most scenarios, if the IWM infrastructure on private land is not delivered as the Water Sensitive City Strategy requires, there will be significant problems in the performance and the maintenance of IWM infrastructure in the public realm.

There would be high value in a dedicated resource to oversee development applications, construction and maintenance of IWM infrastructure in Fishermans Bend.

6.2 Operational and maintenance recommendations

To ensure the ongoing water quality and conveyance function of these assets, regular maintenance is required. The assets proposed within this Infrastructure Plan can be maintained in line with Melbourne Water’s WSUD Maintenance Guidelines.

6.3 Governance and ownership considerations

Although this work is at a subcatchment scale, an understanding of the governance and ownership of these assets is important.

The design, delivery and maintenance of IWM infrastructure must be seen through the lens of asset management, maintenance, depreciation, and developer contributions.

While traditionally precinct scale infrastructure to manage flooding and water quality would be located at the bottom of the catchment, and paid for through a developer services scheme, in this case due to the constraints of the site, there is a larger emphasis on the distributed nature of the infrastructure.

The various options to own, build and maintain this infrastructure are as follows:

- Council owned and operated
- Water retailer owned and operated
- Melbourne Water owned and operated
- Fishermans Bend (underwritten by State Government) Agency owned and operated
- Private provider owned and operated
- Non-for-profit owned and operated
- Hybrid version of the above

The final decision as to who is responsible for what infrastructure is yet to be determined.

6.4 Construction management and supervision recommendations

Almost all WSUD assets are designed to function passively, meaning there are usually no electrical or mechanical parts to be maintained. WSUD assets have very specific elevation levels specified in their design. Industry experience (Pfleiderer, R. and Catchlove. R., 2021) in auditing, maintaining, and rectifying WSUD assets in the field has highlighted how easily an asset can be rendered non-functional due to the slightest of level discrepancies between the detailed design and the works as executed.

Due to the critical role WSUD assets will play in flood management throughout the NEIC and Lorimer precincts, tighter levels of construction management and supervision through the use of appropriate hold points for inspection and approval during construction is recommended. Failure to do so not only risks achieving desired flood management and water quality objectives, but often results in prohibitively costly rectifications.

For more detail around specific construction hold points for the assets utilised in this Infrastructure Plan see section “11.6 Construction hold points”.

6.5 Next steps

Based on this modelling and review of IWM opportunities and benefits, the following next steps for IWM infrastructure in the NEIC and Lorimer Precincts are suggested to be:

- Consider how to ensure WSUD distributed storages (not including public open space storage) are located upstream of local drainage wherever possible. This will allow for more effective irrigation of vegetation, improved water quality, greater urban cooling, and increased canopy cover.
- Consider how to ensure public open space storages be located towards the lower end of catchments/ sub catchments and downstream of local drainage at spill “points”. If considering using sports fields as open space storage, consider the work to date by City of Melbourne and Sport Eng (Sport Eng, 2020).
- Ensure smart tanks can overflow into drainage before a storm event to avoid limiting detention capacity of distributed storage.
- Prioritise WSUD distributed storages from high in the catchment to low in the catchment, and prioritise these assets:
    1. Tree pits/trenches,
    2. raingardens, and
    3. linear parks.
- Closely monitor the delivery of IWM infrastructure on private lots to ensure that the public realm does not become overburdened, particularly from a water quality perspective.
- In subcatchments where detention targets are difficult to achieve, detailed exploration of areas that have been previously deemed as ‘unsuitable’ for distributed storage should be re-assessed to avoid drainage upgrades.
- Consider if there is a need for cost benefit analysis for the proposed IWM infrastructure that would capture the non-market values and benefits.

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8 Appendix A. - Asset allocation

Based on the suitable public space for distributed storage along with feedback and discussions with senior members of the Fishermans Bend taskforce. The following street typology/asset allocation table was developed to be used throughout the storage modelling.

Table 10. Streetscape/asset allocation table.

Typology ID	Description	Streetscape width (m)	Type	Asset	Storage per lineal metre
1	Foundry Ave GMH - Service Road (8000 mm wide raingarden)	22	Road	Raingarden	1.875
2	Laneway - Laneways (all flexible, no assets)	6	Road	None	0.000
3	Other GMH - Service Road (3000 mm wide raingarden)	10	Road	Raingarden	0.703
4	Other GMH - Service Road (3000 mm wide raingarden)	14	Road	Raingarden	0.703
5	Other GMH - Service Road (3000 mm wide raingarden)	15	Road	Raingarden	0.703
6	Other GMH - Service Road (3000 mm wide raingarden)	16	Road	Raingarden	0.703
7	Other GMH - Service Road (3000 mm wide raingarden)	18	Road	Raingarden	0.703
8	Other GMH - Arterial Road (2500 mm raingarden on both sides)	22	Road	Raingarden	1.172
9	Other GMH - Arterial Road (2500 mm raingarden on both sides)	25.7	Road	Raingarden	1.172
10	Other GMH - Arterial Road (2500 mm raingarden on both sides)	29.2	Road	Raingarden	1.172
11	Other GMH - Arterial Road (2500 mm raingarden on both sides)	32	Road	Raingarden	1.172
12	Other GMH - Service Road (3000 mm wide raingarden)	6	Road	Raingarden	1.406
13	Other GMH - Service Road (3000 mm wide raingarden)	9	Road	Raingarden	1.406
14	Road - Service road (tree pits and 1000 mm trenches both sides)	12	Road	Tree pits/trenches	0.153
15	Road - Service road (LHS 1500 mm raingarden)	14	Road	Raingarden	0.352
16	Road - Service road (LHS 1500 mm raingarden)	15	Road	Raingarden	0.352
17	Road - Service road (LHS 1500 mm raingarden)	16	Road	Raingarden	0.352
18	Road - Collector street (3000 mm wide median raingarden)	20	Road	Raingarden	0.703
19	Road - Collector street (3000 mm wide median raingarden)	22	Road	Raingarden	0.703
20	Road - Arterial Road (3000 mm wide median raingarden)	24	Road	Raingarden	0.703

21	Road - Arterial Road (3000 mm wide median raingarden)	27	Road	Raingarden	0.703
22	Road - Arterial Road (3000 mm wide median raingarden)	30	Road	Raingarden	0.703
23	Road - Arterial Road (6000 mm wide median linear park)	32	Road	Linear Park	1.800
24	Road - Arterial Road (12000 mm wide median linear park)	36	Road	Linear Park	3.600
25	Road - Service road (tree pits and 500 mm trenches both sides)	9	Road	Tree pits/trenches	0.083
26	Turner St E GMH - Arterial Road (3000 mm raingarden on both sides, 4000 mm median raingarden)	32	Road	Raingarden	2.344
27	Turner St W GMH - Arterial Road (2500 mm raingarden on both sides)	26.5	Road	Raingarden	1.172
28	Biodiversity corridor - Service Road (4500 mm wide raingarden)	6	Green link	Raingarden	1.055
29	Innovator's trail (20 m) - Green link (6000 mm wide linear park)	20	Green link	Linear park	1.800
30	Innovator's trail (24 m) - Green link (6000 mm wide linear park)	24	Green link	Linear Park	1.800
31	Linear Park - Green link (12000 mm wide linear park)	12	Green link	Linear Park	3.600
32	Setback (10 m) - Green link (6000 mm wide linear park)	10	Green link	Linear Park	1.800
33	Setback (18 m) - Green link (12000 mm wide linear park)	18	Green link	Linear Park	3.600
34	Setback (4 m) - Green link (3000 mm wide raingarden)	4	Green link	Raingarden	0.703
35	Open space storage - (25% of suitable space allocated with 500 mm of EDD)	N/A	Open space	Open space	1250 (per ha)

9 Appendix B. WSUD Asset parameters (for storage and water quality monitoring)

Table 11. Key asset design parameters for storage and water quality modelling

Asset type	Distribution	Width (mm)	Submerged zone depth (mm)	EDD storage depth (mm)	Media storage depth (mm)	Void ratio (mm)	Blocking factor (mm)	EDD storage ($m^3/m/m$)	Media storage ($m^3/m/m$)	Total storage ($m^3/m/m$)
Tree pits	1 m^2 tree pits spaced every 10 m	1000	300	50	300	0.15	33%	0.003	0.003	0.006
Trenches	600 mm deep trenches with a 300 mm submerged zone	Variable	300	0	300	0.35	33%	N/A	0.07	0.070
Raingarden	Spaced to have 2 m breaks for crossovers/pedestrian use every 10 m	Variable	450	200	500	0.35	25%	0.125	0.109	0.234
Linear parks	Continuous storage to be designed with pedestrian footbridges where required	Variable	0	300	0	N/A	0%	0.300	0.000	0.300
Open space storage	Where suitable, 25% of space allocated for open space detention, 500 mm deep	N/A	0	500	0	N/A	0%	N/A	N/A	0.125

10 Appendix C.- Primary documents reviewed and provided

A wealth of relevant previous work was provided to the project team and reviewed, below is a list of the most significant documents that informed this work:

- Fishermans Bend Water Sensitive City Draft Strategy
- GHD Fishermans Bend Water Sensitive Drainage and Flood Strategy Final Report
- GHD Fishermans Bend Water Sensitive Drainage and Flood Strategy – Appendix B
- GHD Fishermans Bend Water Sensitive Drainage and Flood Strategy – Appendix B
- Blue Green Infrastructure Typologies for Streetscapes
- Open Space Strategy
- Fishermans Bend Employment Precinct Connectivity Sprint Output
- Fishermans Bend Employment Precinct Open Space Sprint Output
- HARC Fishermans Bend Flood Risk Assessment - Final Report
- Distributed storages approach for the Employment Precinct - draft estimates.
- GHD Fishermans Bend Water Sensitive Drainage and Flood Strategy GIS data
- Updated work on the flood storage calculation for the Employment Precinct

11 Appendix D. – WSUD Assets for Distributed Storage – Design and Construct notes

This infrastructure plan proposes the use of WSUD assets of differing scales and storage potential to be used throughout the respective catchments of the NEIC and Lorimer Precincts. By utilising smaller WSUD assets higher in the catchment, downstream runoff is both reduced and of an improved quality, reducing the scale of large downstream assets, conceptually outlined in Figure 24.

City of Melbourne has developed a series of design typologies that will assist those planning, designing, constructing, and maintaining blue green infrastructure assets for streetscapes. These are available on www.urbanwater.melbourne.vic.gov.au or by contacting City of Melbourne's Water Sensitive City Lead.

These design typologies are referenced within this appendix, but additional advice is provided to ensure assets are able to provide distributed flood storage.

11.1 WSUD Tree pits

Design and Construct Guidance for WSUD Tree pits

For optimum tree growth soil volumes need to be maximised and for soil moisture to remain close to optimum. This requires close attention to detail of the depth of the pits, for the level of the underdrain to be correct and for the soil mix to be as specified.

To ensure the design is delivered as agreed, the following four hold points are recommended:

1. Excavation and installation of the pit structure. Check depth and dimension of the pit is as per design. Slotted pipe should be installed and connected to the drainage network external to the Pit. Ensure adequate depth from the kerb invert to allow water to flow into pit with the required detention depth. Check inspection risers and overflow points are at the correct height (if required).
2. Placement of filter material or structural soil (inspect prior to backfilling). Ensure filter media/soil is to specification. Ensure drainage and transition layers are to specification and installed at the correct depths.
3. Kerb inlet construction to ensure levels are correct, ensure water can flow in from the kerb invert and there is sufficient extended detention depth above the soil layer. Inlets should be open and easily accessible for cleaning.
4. Practical completion (post planting). Re-inspect levels, underdrain outlet, pits and confirm inspection riser(s) are accessible. Ensure tree is healthy and species is correct. Inspect kerb, tree guards, and other protective infrastructure to ensure they have been installed to specification and will achieve the desired outcome. Pit lids must be easy to lift and not bolted down to allow cleaning of accumulated material above the soil.

Useful resources

City of Melbourne has delivered WSUD tree pits throughout the municipality (refer to Figure 25 below for examples). Design typologies for WSUD tree pits are available at www.urbanwater.melbourne.vic.gov.au

Figure 25. Example City of Melbourne Tree pit.

11.2 Tree Trenches

Design and Construct Guidance

To store the designed volume of water the relative levels of a trench's inlet(s), outlet(s), and invert (base interior level of the trench) are crucial. Provided the inlet and outlet structures can be delivered after the excavation of the trench, completion of this excavation provides an ideal opportunity to assess the invert level of the trench against the designed level. There is an opportunity to either correct the invert level or reassess the respective levels of the yet to be constructed inlet and outlet structures. Often this simply involves changing the designed level of an inlet pipe within a pit.

Tree trenches connect a number of trees and provide greater soil volume for tree roots and therefore greater canopy cover, aiding in delivering on canopy cover targets set out in the City of Melbourne's Urban Ecology and Biodiversity Strategy. This may be compromised by other infrastructure placed across the trench. As far as possible, ensure there is a flow path for the water to move past the obstruction(s), or ensuring other infrastructure crosses perpendicularly at a lower level than the trench. Inspection hold points are similar to tree pits as follows:

1. Excavation for and installation of slotted pipe (Inspect trench prior to pipe install, inspect pipe install). Ensure adequate depth for subsequent layers, liners are in place (as required), underdrain is correct size, laid flat or to grade and connected to the outlet/overflow pit, inspection risers are in place, and ensure overflow pit is installed at correct height (if required).
2. Placement of filter material or structural soil (inspect prior to backfilling). Ensure filter media or structural soil is to specification. Ensure drainage and transition layers (if used) are to specification and installed at the correct depths. Discuss how separation of layers is to be achieved, particularly if a sandy loam mix is to be used around the root ball.

3. Kerb inlet construction to ensure levels are correct, ensure water can flow in from the kerb invert and there is sufficient extended detention depth above the soil layer. A sediment containment device such as a pit or forebay should be used and easily accessible for cleaning. Discuss the placement of pavement above the structural soil.
4. Practical completion (post planting). Ensure finished levels are as per design without trip hazards. Re-inspect levels where possible and ensure underdrain outlet, pits and inspection riser(s) are accessible. Ensure trees are healthy and species is correct. Inspect kerb, tree guards, and other protective infrastructure to ensure they have been installed to specification and will achieve the desired outcome.

Useful resources

City of Melbourne has developed a design typology available at www.urbanwater.melbourne.vic.gov.au. A high-level diagram of this asset's function is presented in Figure 26 below.

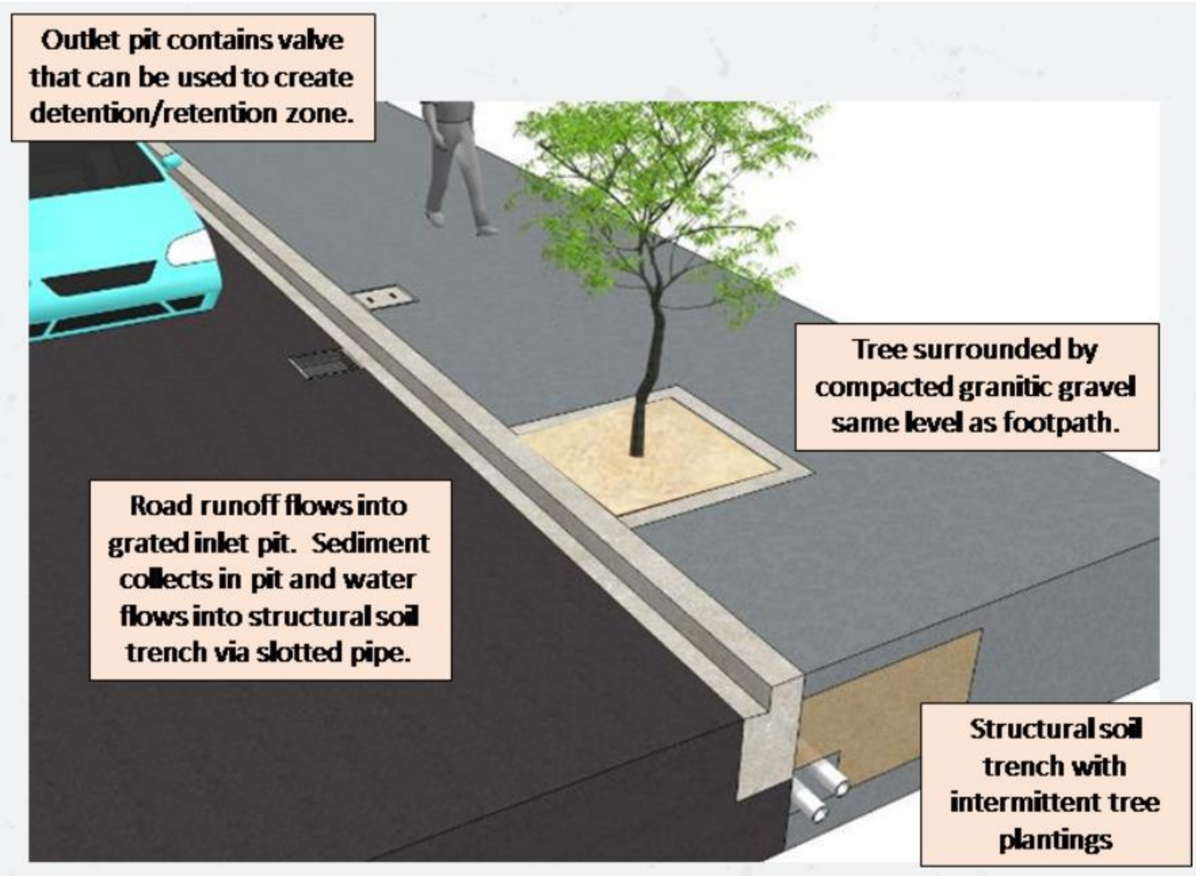

Figure 26. City of Melbourne's Blue Green Infrastructure Design Typology 7: Side of road passive irrigation trench.

11.3 Raingardens

Design and construct guidance

Raingardens filter water through sand (filter media) with specific characteristics, such as the hydraulic conductivity (infiltration rate). They must also have the specified filter media depth, extended detention depth, and plant density to achieve the required water quality improvements.

Again, four inspection points are suggested to ensure the key elements are installed correctly:

1. Excavation of raingarden area and installation of slotted pipe. Ensure adequate depth for subsequent layers, liners are in place (as required), underdrain is correct size, laid flat or with slight fall and connected to the outlet/overflow pit, inspection risers are in place and ensure overflow pit is installed at correct height (if required).

2. Placement of filter material (inspect prior to backfilling). Ensure filter media is to specification. Ensure drainage and transition layers are to specification and installed at the correct depths.
3. Kerb inlet construction to ensure levels are correct, ensure water can flow in from the kerb invert and there is sufficient extended detention depth above the filter media and/or mulch layer. Sediment containment devices such as pits and forebay should be easily accessible for cleaning.
4. Practical completion – or post planting. Re-inspect levels, underdrain outlet, pits and inspection riser(s) are accessible. Ensure plant health, planting density and plant species are correct. Inspect kerb, guards, and other protective infrastructure to ensure they have been installed to specification and will achieve the desired outcome.

Note raingardens have submerged zones.

Useful resources

High level diagrams of raingarden function are available in Figure 27, Figure 28, and Figure 29 below. City of Melbourne has delivered raingardens throughout the municipality (refer to Figure 30 for an example). Design typologies for raingardens are available at www.urbanwater.melbourne.vic.gov.au

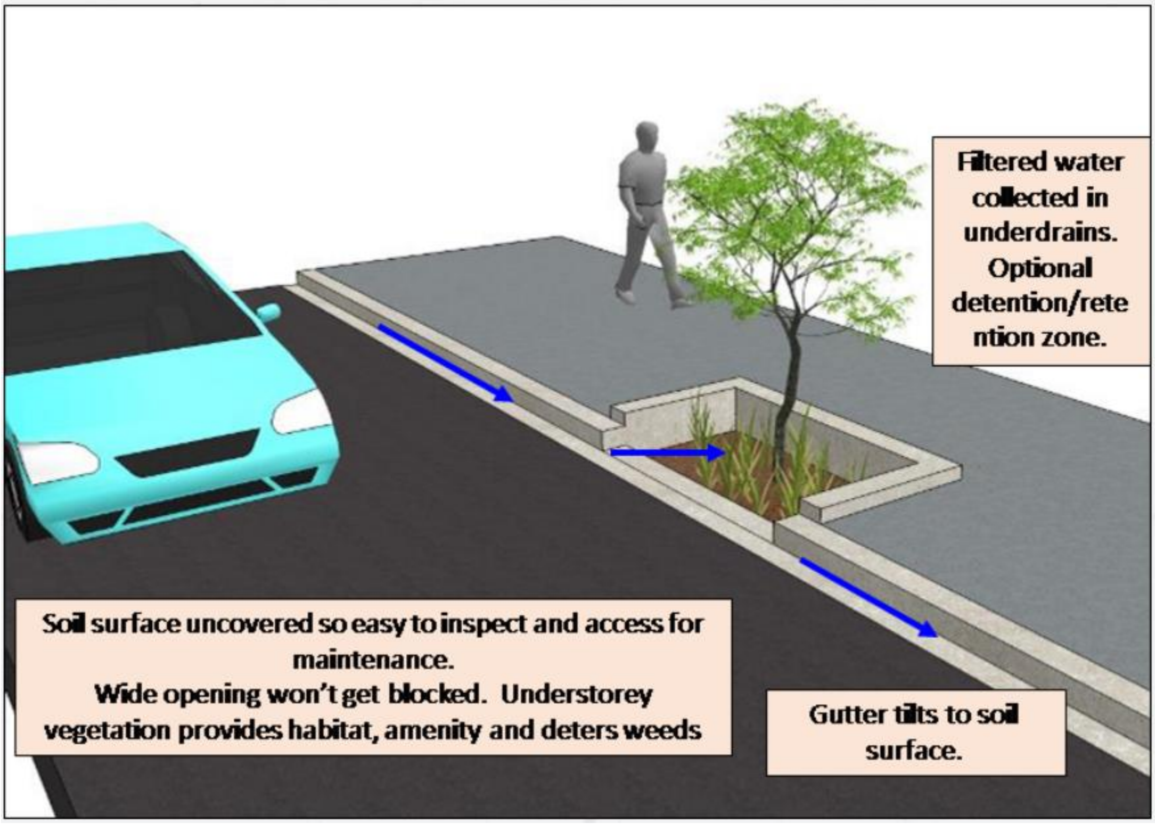

Figure 27. City of Melbourne's Blue Green Infrastructure Design Typology 2: Rectangular back of kerb raingarden.

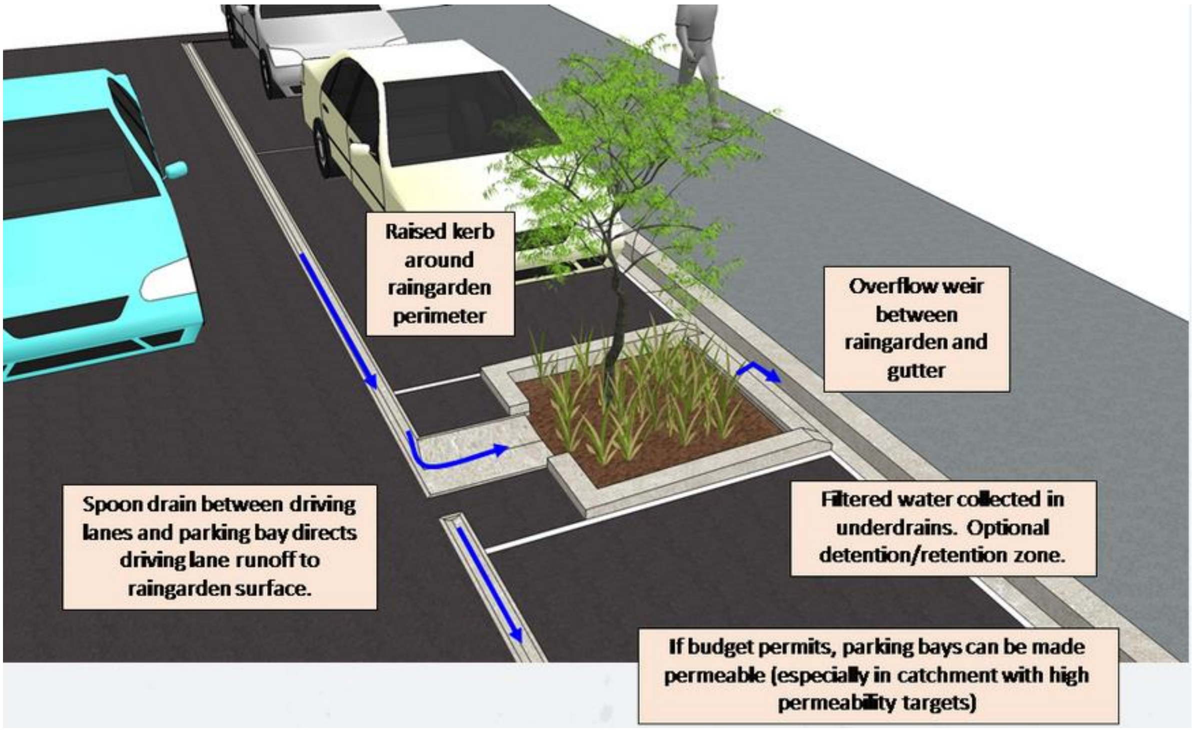

Figure 28. City of Melbourne's Blue Green Infrastructure Design Typology 5: Small outstand raingarden.

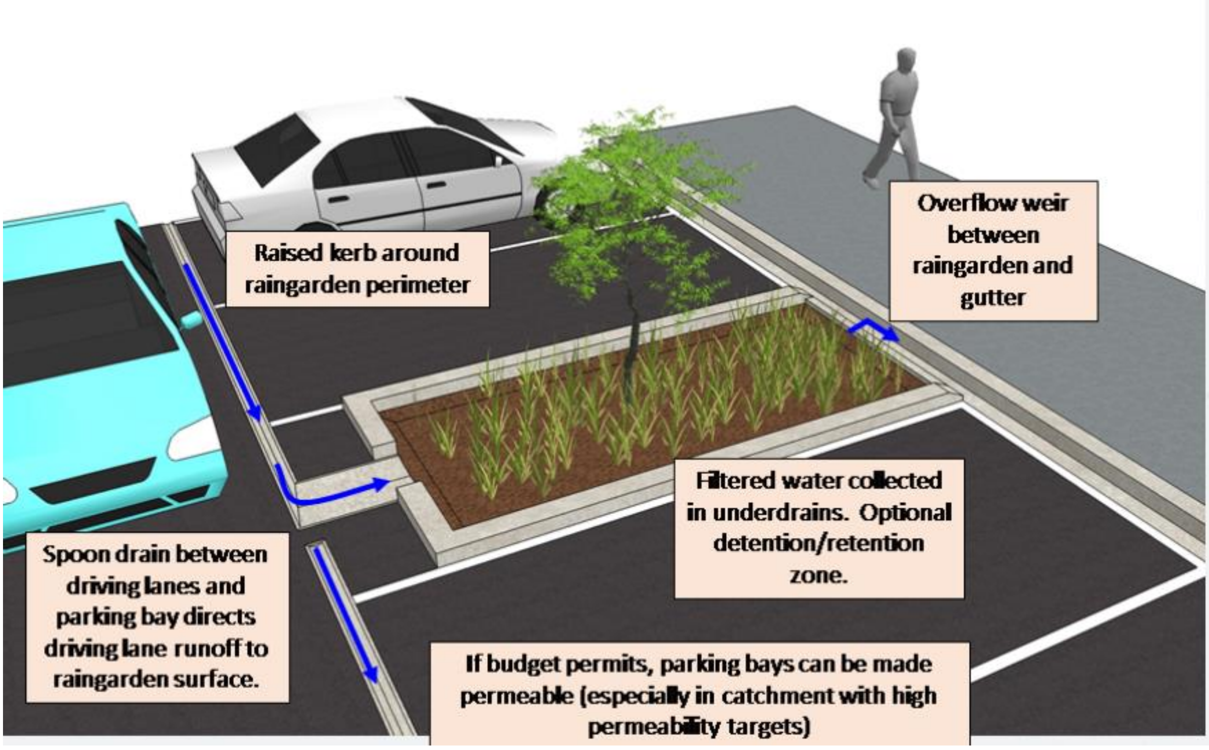

Figure 29. City of Melbourne's Blue Green Infrastructure Design Typology 4: Large outstand raingarden.

Figure 30. Example raingarden in Lorimer.

11.4 Linear parks

Design and construct guidance

Linear parks that serve a conveyance and/or detention function should be inspected to ensure the correct finished levels are achieved, flow paths are established, and unhindered and outlet pits are at the correct height. Filter media may also be used is some instances to assist with draining away water.

On top of landscape inspection points, the following inspection hold points are suggested from a water management perspective:

1. Excavation and installation of drainage infrastructure – ensure correct levels to allow water to flow out and flow into site once top layer is backfilled.
2. Inspection and approval of specified filter media prior to installation (if used).
3. Inspection of final levels prior to planting to ensure correct finished levels allowing for any mulch placement. Ensure inlet kerb and outlet pit/paths are at the specified heights.
4. Practical completion – or post planting. Ensure flow paths have remained clear.
    - Inspections from the Open Space and Urban Forest teams should also be undertaken.

Useful resources

Figure 31 below provides a concept for a linear park system.

Figure 31. Artist's impression of linear park system along Southbank Boulevard (Source: City of Melbourne).

11.5 Open space storages

Design and construct guidance

These areas will infrequently be inundated with flood waters when the drainage and road system is over capacity during heavy rain events. The frequency will be variable, and from a probabilistic perspective each year there is a 1% to 5% chance of the park being inundated with stormwater when all upstream storages are at capacity. The inflow to an open space storage will be relatively calm like a bathtub slowly filling with water. The outflow will take several hours to days depending on the intensity and duration of the rain event. To ensure the correct functioning of the flood detention aspect of the open space storage, the following elements are critical:

- The finished invert level of the open space storage area is correct and flat.
- The surrounding containment (wall, mounds, levies) is at the correct level and waterproof.
- The inlet and outlet points are at the correct level.
- Key infrastructure within the open space that cannot go under water are placed above the top flood level including adequate freeboard.

Inspection hold points are similar to Linear Parks are as follows:

1. Excavation and installation of drainage infrastructure – ensure correct levels to allow water flow out and flow into site once top layer is backfilled.
2. Inspection of final levels prior to turfing/planting to ensure correct finished levels allowing for any turf/mulch placement. Ensure inlet and outlet pit/paths are at the specified heights.
3. Practical completion – or post planting. Ensure flow paths have remained clear.

Design and construction of open space storages are to consider the *AOS (Active Open Space) and Drainage Reserves technical* report completed by Sport Eng in 2020. This report is a feasibility analysis of constructing and maintaining active open space within drainage reserves.

Any changes to the design that has been approved should be noted on the design drawing for Council to record in their systems. Maintenance teams should be invited to the final inspection prior to hand over.

Useful resources

City of Melbourne has delivered open space storage assets throughout the municipality (refer to Figure 32 below for an example).

Figure 32. Lowered section of Victoria Green, Docklands providing flood detention during extreme rainfall events. (Source: Rush Wright Landscape Architects)

11.6 Construction hold points

Inspections have the dual purpose of ensuring the design is built as required, but also to educate and inform the builders of the intent of the design and what are the critical elements that must be built as specified and what can be altered if necessary. Inspections should involve:

- Review of design drawings and specifications prior to inspection.
- Coordination of inspection times with Council representation and/or builders.
- Inspection of the physical assets including photos, measuring and marking out as necessary.
- Discussing the design intent with the builders (training).
- Providing instruction/direction on site for minor alterations to what has been constructed to conform with the design and/or to make the system work to best practice.
- If major errors have occurred, request construction to halt and provide written justification for required change for discussion with the builders and possibly higher levels of management.
- Provide a short post inspection report with photos of each inspection. Where multiple assets have been inspected photos should be taken at each asset, but the report may only include example assets when the condition is similar at each individual asset.
- Discuss timing of next inspection hold point(s) with builder.

Specific hold points for each asset will need to be developed as the assets go through detailed design. The following are key governing principles regarding critical aspects of the construction of each type of asset, and the type and scale of deviations from typical detailed design that can lead to functional issues that are often prohibitively costly to rectify post construction.

12 Appendix E. Storage potential for subcatchments

Figure 33 and Table 12 below summarises key results at the level of the 63 subcatchments.

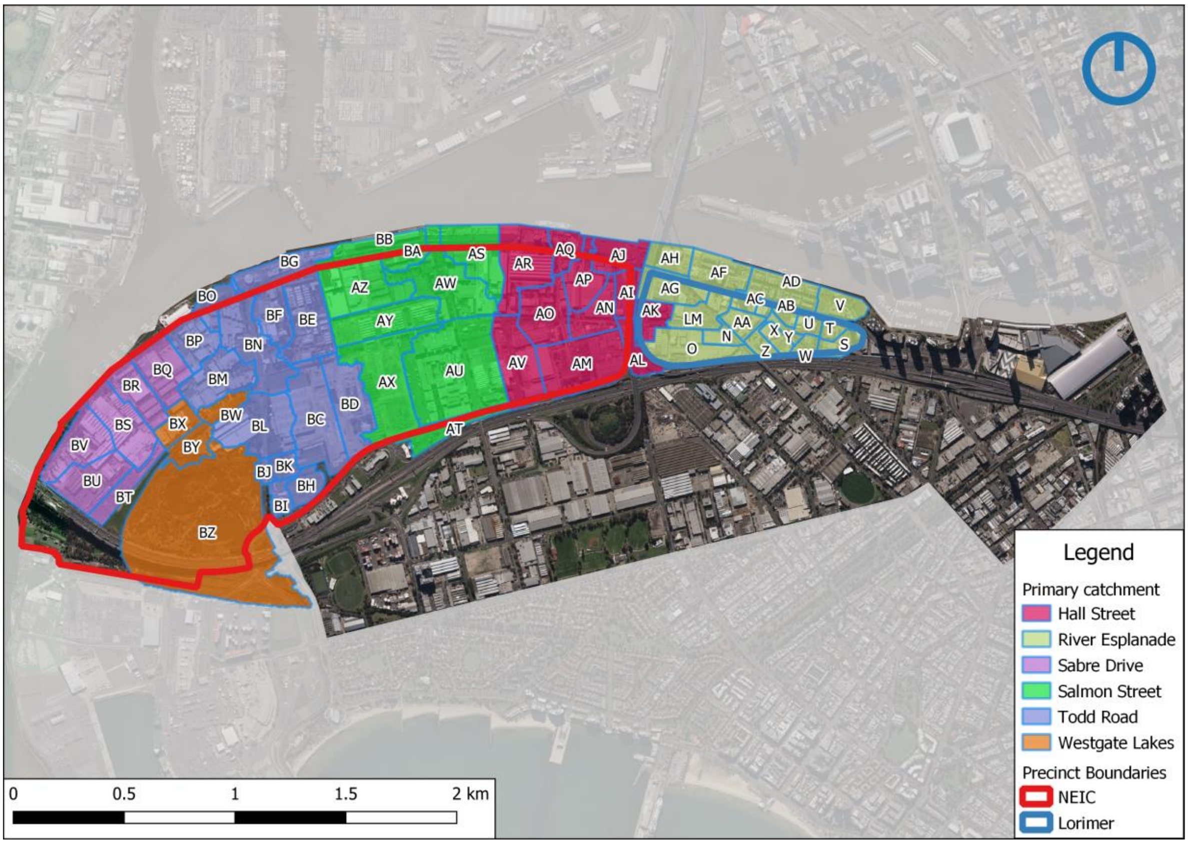

Figure 33. Subcatchment names.

Table 12. Summary of results at the subcatchment level.

Subcatchment	Parent catchment	Area	Impervious fraction	5% AEP (20 Year ARI) level of service target	1% AEP (100 Year ARI) level of service target	Minimum required storage achievable under IWM infrastructure plan	Minimum required achievable asset surface area (not including trenches)
O	River Esplanade	57,000 m²	0.804	0 m³	585 m³	585 m³	2,405 m²
AK	Hall Street	26,000 m²	0.678	0 m³	120 m³	120 m³	398 m²
AH	River Esplanade	25,000 m²	0.877	0 m³	339 m³	0 m³	0 m²
AC	River Esplanade	6,000 m²	0.782	0 m³	36 m³	15 m³	55 m²
AE	River Esplanade	8,000 m²	0.835	2 m³	22 m³	0 m³	0 m²
AF	River Esplanade	40,000 m²	0.886	139 m³	661 m³	155 m³	660 m²
AB	River Esplanade	9,000 m²	0.842	0 m³	50 m³	50 m³	291 m²
U	River Esplanade	13,000 m²	0.781	0 m³	62 m³	62 m³	201 m²
W	River Esplanade	10,000 m²	0.784	0 m³	63 m³	63 m³	256 m²
Z	River Esplanade	13,000 m²	0.835	0 m³	0 m³	0 m³	0 m²
S	River Esplanade	18,000 m²	0.835	0 m³	0 m³	0 m³	0 m²
T	River Esplanade	11,000 m²	0.393	0 m³	0 m³	0 m³	0 m²
V	River Esplanade	25,000 m²	0.671	0 m³	224 m³	113 m³	483 m²
AP	Hall Street	38,000 m²	0.897	0 m³	144 m³	144 m³	448 m²
AL	Hall Street	25,000 m²	0.684	0 m³	351 m³	351 m³	1,257 m²
AM	Hall Street	92,000 m²	0.892	0 m³	668 m³	668 m³	2,133 m²
AW	Salmon Street	89,000 m²	0.873	0 m³	495 m³	495 m³	1,804 m²
BL	Todd Road	80,000 m²	0.881	0 m³	333 m³	333 m³	1,123 m²
BR	Sabre Drive	41,000 m²	0.9	0 m³	409 m³	409 m³	2,736 m²

Subcatchment	Parent catchment	Area	Impervious fraction	5% AEP (20 Year ARI) level of service target	1% AEP (100 Year ARI) level of service target	Minimum required storage achievable under IWM infrastructure plan	Minimum required achievable asset surface area (not including trenches)
BQ	Sabre Drive	51,000 m²	0.9	0 m³	509 m³	509 m³	1,758 m²
BN	Todd Road	79,000 m²	0.865	0 m³	627 m³	627 m³	2,151 m²
BP	Todd Road	38,000 m²	0.9	0 m³	70 m³	70 m³	256 m²
BO	Todd Road	22,000 m²	0.9	0 m³	41 m³	41 m³	174 m²
BW	Westgate Lakes	18,000 m²	0.816	519 m³	0 m³	0 m³	0 m²
BY	Westgate Lakes	27,000 m²	0.603	95 m³	0 m³	0 m³	0 m²
BX	Westgate Lakes	25,000 m²	0.9	603 m³	0 m³	0 m³	0 m²
BB	Salmon Street	40,000 m²	0.841	1,071 m³	1,324 m³	0 m³	0 m²
BK	Todd Road	14,000 m²	0.261	0 m³	26 m³	26 m³	109 m²
BJ	Todd Road	8,000 m²	0.482	0 m³	15 m³	4 m³	17 m²
BZ	Westgate Lakes	392,000 m²	0.265	4,279 m³	0 m³	0 m³	0 m²
BH	Todd Road	21,000 m²	0.496	0 m³	39 m³	39 m³	112 m²
BI	Todd Road	14,000 m²	0.5	0 m³	26 m³	2 m³	3 m²
BG	Todd Road	43,000 m²	0.86	567 m³	938 m³	0 m³	0 m²
BC	Todd Road	93,000 m²	0.8	0 m³	172 m³	172 m³	698 m²
BD	Todd Road	67,000 m²	0.894	0 m³	124 m³	124 m³	513 m²
BF	Todd Road	37,000 m²	0.9	0 m³	69 m³	54 m³	64 m²
AX	Salmon Street	110,000 m²	0.9	0 m³	1,022 m³	1,022 m³	3,747 m²
AY	Salmon Street	64,000 m²	0.896	0 m³	594 m³	285 m³	1,202 m²
AZ	Salmon Street	76,000 m²	0.901	1,643 m³	706 m³	266 m³	981 m²
BA	Salmon Street	14,000 m²	0.884	0 m³	63 m³	0 m³	0 m²
BV	Sabre Drive	56,000 m²	0.9	0 m³	559 m³	336 m³	1,433 m²
BS	Sabre Drive	60,000 m²	0.9	0 m³	599 m³	525 m³	2,163 m²
BU	Sabre Drive	55,000 m²	0.9	0 m³	549 m³	515 m³	2,006 m²
BT	Sabre Drive	27,000 m²	0.9	0 m³	269 m³	231 m³	926 m²
AT	Salmon Street	31,000 m²	0.828	221 m³	502 m³	148 m³	581 m²
AU	Salmon Street	169,000 m²	0.891	0 m³	0 m³	0 m³	0 m²
AV	Hall Street	67,000 m²	0.895	562 m³	888 m³	888 m³	3,484 m²
AS	Salmon Street	62,000 m²	0.887	0 m³	342 m³	342 m³	728 m²
AR	Hall Street	75,000 m²	0.891	0 m³	174 m³	174 m³	573 m²
AQ	Hall Street	24,000 m²	0.873	12 m³	212 m³	169 m³	1,446 m²
AN	Hall Street	35,000 m²	0.89	0 m³	162 m³	162 m³	688 m²
AO	Hall Street	57,000 m²	0.887	3,359 m³	3,711 m³	1,206 m³	7,671 m²
X	River Esplanade	12,000 m²	0.801	0 m³	35 m³	35 m³	115 m²
Y	River Esplanade	7,000 m²	0.348	0 m³	60 m³	60 m³	245 m²
AG	River Esplanade	39,000 m²	0.751	0 m³	0 m³	0 m³	0 m²
AJ	Hall Street	34,000 m²	0.884	6 m³	287 m³	287 m³	1,752 m²
AI	Hall Street	22,000 m²	0.832	259 m³	208 m³	208 m³	1,072 m²
BM	Todd Road	56,000 m²	0.9	53 m³	387 m³	387 m³	1,308 m²
LM	River Esplanade	33,000 m²	0.671	0 m³	0 m³	0 m³	0 m²
N	River Esplanade	12,000 m²	0.816	0 m³	63 m³	63 m³	268 m²
AA	River Esplanade	16,000 m²	0.62	0 m³	0 m³	0 m³	0 m²
AD	River Esplanade	41,000 m²	0.888	15 m³	385 m³	259 m³	1,104 m²
BE	Todd Road	71,000 m²	0.9	0 m³	986 m³	160 m³	515 m²
Total		**2,940,000 m²**	**0.772**	**13,407 m³**	**21,305 m³**	**12,957 m³**	**54,114 m²**

13 Appendix F. Subcatchments in need of more storage

Table 13. Minimum WSUD distributed storage by subcatchment.

Subcatchment	Parent catchment	5% AEP (20 Year ARI) level of service target	1% AEP (100 Year ARI) level of service target	Minimum required streetscape and green link storage achievable	Minimum required open space storage achievable	Minimum required storage achievable under IWM infrastructure plan	Additional storage required
O	River Esplanade	0 m³	585 m³	585 m³	0 m³	585 m³	0 m³
AK	Hall Street	0 m³	120 m³	120 m³	0 m³	120 m³	0 m³
AH	**River Esplanade**	**0 m³**	**339 m³**	**0 m³**	**0 m³**	**0 m³**	**339 m³**
AC	**River Esplanade**	**0 m³**	**36 m³**	**15 m³**	**0 m³**	**15 m³**	**21 m³**
AE	**River Esplanade**	**2 m³**	**22 m³**	**0 m³**	**0 m³**	**0 m³**	**22 m³**
AF	**River Esplanade**	**139 m³**	**661 m³**	**155 m³**	**0 m³**	**155 m³**	**507 m³**
AB	River Esplanade	0 m³	50 m³	24 m³	27 m³	50 m³	0 m³
U	River Esplanade	0 m³	62 m³	62 m³	0 m³	62 m³	0 m³
W	River Esplanade	0 m³	63 m³	63 m³	0 m³	63 m³	0 m³
Z	River Esplanade	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
S	River Esplanade	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
T	River Esplanade	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
V	**River Esplanade**	**0 m³**	**224 m³**	**113 m³**	**0 m³**	**113 m³**	**111 m³**
AP	Hall Street	0 m³	144 m³	144 m³	0 m³	144 m³	0 m³
AL	Hall Street	0 m³	351 m³	337 m³	13 m³	351 m³	0 m³
AM	Hall Street	0 m³	668 m³	668 m³	0 m³	668 m³	0 m³
AW	Salmon Street	0 m³	495 m³	495 m³	0 m³	495 m³	0 m³
BL	Todd Road	0 m³	333 m³	333 m³	0 m³	333 m³	0 m³
BR	Sabre Drive	0 m³	409 m³	106 m³	304 m³	409 m³	0 m³
BQ	Sabre Drive	0 m³	509 m³	509 m³	0 m³	509 m³	0 m³
BN	Todd Road	0 m³	627 m³	627 m³	0 m³	627 m³	0 m³
BP	Todd Road	0 m³	70 m³	70 m³	0 m³	70 m³	0 m³
BO	Todd Road	0 m³	41 m³	41 m³	0 m³	41 m³	0 m³
BW	Westgate Lakes	519 m³	0 m³	0 m³	0 m³	0 m³	0 m³
BY	Westgate Lakes	95 m³	0 m³	0 m³	0 m³	0 m³	0 m³
BX	Westgate Lakes	603 m³	0 m³	0 m³	0 m³	0 m³	0 m³
BB	**Salmon Street**	**1,071 m³**	**1,324 m³**	**0 m³**	**0 m³**	**0 m³**	**1,324 m³**
BK	Todd Road	0 m³	26 m³	26 m³	0 m³	26 m³	0 m³
BJ	**Todd Road**	**0 m³**	**15 m³**	**4 m³**	**0 m³**	**4 m³**	**11 m³**
BZ	Westgate Lakes	4,279 m³	0 m³	0 m³	0 m³	0 m³	0 m³
BH	Todd Road	0 m³	39 m³	29 m³	10 m³	39 m³	0 m³
BI	**Todd Road**	**0 m³**	**26 m³**	**2 m³**	**0 m³**	**2 m³**	**24 m³**
BG	**Todd Road**	**567 m³**	**938 m³**	**0 m³**	**0 m³**	**0 m³**	**938 m³**
BC	Todd Road	0 m³	172 m³	172 m³	0 m³	172 m³	0 m³
BD	Todd Road	0 m³	124 m³	124 m³	0 m³	124 m³	0 m³
BF	**Todd Road**	**0 m³**	**69 m³**	**54 m³**	**0 m³**	**54 m³**	**15 m³**
AX	Salmon Street	0 m³	1,022 m³	1,022 m³	0 m³	1,022 m³	0 m³
AY	**Salmon Street**	**0 m³**	**594 m³**	**285 m³**	**0 m³**	**285 m³**	**309 m³**
AZ	**Salmon Street**	**1,643 m³**	**706 m³**	**266 m³**	**0 m³**	**266 m³**	**440 m³**
BA	**Salmon Street**	**0 m³**	**63 m³**	**0 m³**	**0 m³**	**0 m³**	**63 m³**
BV	**Sabre Drive**	**0 m³**	**559 m³**	**336 m³**	**0 m³**	**336 m³**	**223 m³**
BS	**Sabre Drive**	**0 m³**	**599 m³**	**525 m³**	**0 m³**	**525 m³**	**74 m³**
BU	**Sabre Drive**	**0 m³**	**549 m³**	**515 m³**	**0 m³**	**515 m³**	**34 m³**
BT	**Sabre Drive**	**0 m³**	**269 m³**	**231 m³**	**0 m³**	**231 m³**	**39 m³**
AT	**Salmon Street**	**221 m³**	**502 m³**	**148 m³**	**0 m³**	**148 m³**	**353 m³**
AU	Salmon Street	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
AV	Hall Street	562 m³	888 m³	880 m³	8 m³	888 m³	0 m³
AS	Salmon Street	0 m³	342 m³	254 m³	88 m³	342 m³	0 m³
AR	Hall Street	0 m³	174 m³	174 m³	0 m³	174 m³	0 m³
AQ	**Hall Street**	**12 m³**	**212 m³**	**169 m³**	**0 m³**	**169 m³**	**43 m³**
AN	Hall Street	0 m³	162 m³	152 m³	10 m³	162 m³	0 m³

Subcatchment	Parent catchment	5% AEP (20 Year ARI) level of service target	1% AEP (100 Year ARI) level of service target	Minimum required streetscape and green link storage achievable	Minimum required open space storage achievable	Minimum required storage achievable under IWM infrastructure plan	Additional storage required
AO	**Hall Street**	**3,359 m³**	**3,711 m³**	**463 m³**	**743 m³**	**1,206 m³**	**2,505 m³**
X	River Esplanade	0 m³	35 m³	35 m³	0 m³	35 m³	0 m³
Y	River Esplanade	0 m³	60 m³	60 m³	0 m³	60 m³	0 m³
AG	River Esplanade	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
AJ	Hall Street	6 m³	287 m³	146 m³	141 m³	287 m³	0 m³
AI	Hall Street	259 m³	208 m³	159 m³	49 m³	208 m³	0 m³
BM	Todd Road	53 m³	387 m³	387 m³	0 m³	387 m³	0 m³
LM	River Esplanade	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
N	River Esplanade	0 m³	63 m³	63 m³	0 m³	63 m³	0 m³
AA	River Esplanade	0 m³	0 m³	0 m³	0 m³	0 m³	0 m³
AD	**River Esplanade**	**15 m³**	**385 m³**	**259 m³**	**0 m³**	**259 m³**	**127 m³**
BE	**Todd Road**	**0 m³**	**986 m³**	**160 m³**	**0 m³**	**160 m³**	**827 m³**
Total		**13,407 m³**	**21,305 m³**	**11,564 m³**	**1,393 m³**	**12,957 m³**	**8,347 m³**

It should be noted here once again that to provide robust evidence of the feasibility of utilising distributed storage for flood mitigation, a conservative approach was taken to the modelling work, from the individual asset storage parameters to the approach to asset allocation, as well as the spatial exclusions (i.e., eliminating opportunities for storages around all intersections).

The table below indicates the scale of the above solutions that would be required in each of the 22 subcatchments that require additional storage in order for the 100-year level of service target to be met.

Table 14. Scale of additional storage assets required.

Subcatchment	Parent catchment	5% AEP storage target	1% AEP storage target	Minimum required storage achievable under IWM infrastructure plan	Additional storage required	Area of car parking with porous asphalt and storage to meet additional storage	Approximate number of carparks	Area of relocated or additional open space required
AQ	Hall Street	12 m³	212 m³	169 m³	43 m³	213 m²	9	341 m²
AO	Hall Street	3,359 m³	3,711 m³	1,206 m³	2,505 m³	12,525 m²	501	20,040 m²
AH	River Esplanade	0 m³	339 m³	0 m³	339 m³	1,694 m²	68	2,711 m²
AC	River Esplanade	0 m³	36 m³	15 m³	21 m³	104 m²	4	167 m²
AE	River Esplanade	2 m³	22 m³	0 m³	22 m³	108 m²	4	173 m²
AF	River Esplanade	139 m³	661 m³	155 m³	507 m³	2,533 m²	101	4,054 m²
V	River Esplanade	0 m³	224 m³	113 m³	111 m³	553 m²	22	885 m²
AD	River Esplanade	15 m³	385 m³	259 m³	127 m³	634 m²	25	1,014 m²
BV	Sabre Drive	0 m³	559 m³	336 m³	223 m³	1,115 m²	45	1,785 m²
BS	Sabre Drive	0 m³	599 m³	525 m³	74 m³	370 m²	15	592 m²
BU	Sabre Drive	0 m³	549 m³	515 m³	34 m³	171 m²	7	273 m²
BT	Sabre Drive	0 m³	269 m³	231 m³	39 m³	193 m²	8	309 m²
BB	Salmon Street	1,071 m³	1,324 m³	0 m³	1,324 m³	6,622 m²	265	10,595 m²
AY	Salmon Street	0 m³	594 m³	285 m³	309 m³	1,546 m²	62	2,473 m²
AZ	Salmon Street	1,643 m³	706 m³	266 m³	440 m³	2,200 m²	88	3,520 m²
BA	Salmon Street	0 m³	63 m³	0 m³	63 m³	315 m²	13	504 m²
AT	Salmon Street	221 m³	502 m³	148 m³	353 m³	1,767 m²	71	2,828 m²
BJ	Todd Road	0 m³	15 m³	4 m³	11 m³	55 m²	2	88 m²
BI	Todd Road	0 m³	26 m³	2 m³	24 m³	118 m²	5	188 m²
BG	Todd Road	567 m³	938 m³	0 m³	938 m³	4,692 m²	188	7,507 m²
BF	Todd Road	0 m³	69 m³	54 m³	15 m³	74 m²	3	119 m²
BE	Todd Road	0 m³	986 m³	160 m³	827 m³	4,133 m²	165	6,614 m²

Subcatchment	**Parent catchment**	**5% AEP storage target**	**1% AEP storage target**	**Minimum required storage achievable under IWM infrastructure plan**	**Additional storage required**	**Area of car parking with porous asphalt and storage to meet additional storage**	**Approximate number of carparks**	**Area of relocated or additional open space required**
Total		7,030 m^3	12,789 m^3	4,442 m^3	8,347 m^3	41,737 m^2	1669	66,779 m^2