urban WaterCycle Solutions
Independent research and consulting

East Werribee Employment Precinct

Analysis of stormwater management

Growth Areas Authority

Final Report

March 2013

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Independent research and consulting

TGM
Engineering | Surveying | Planning

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Executive Summary

During 2009, the Department of Planning and Community Development (DPCD) developed a conceptual integrated water cycle management (IWCM) strategy that incorporated the objectives of a Multi-Agency Working Group and investigated options for use of regional stormwater and local rainwater harvesting, aquifer storage and recovery, wastewater reuse within the Precinct and water efficiency.

The IWCM strategy was dependent on a stormwater management solution that mitigates the significant legacy of flooding and stormwater pollution at the site and incorporates the principles of water sensitive urban design (WSUD). The stormwater management elements of the proposed IWCM strategy were incorporated into a Development Services Scheme (DSS) administered by Melbourne Water Corporation.

The Implementation Plan for the Victorian Government's Living Victoria policy also proposes targets for IWCM throughout the Greater Melbourne region including targets for the Werribee area. The East Werribee Precinct Structure Plan has been prepared by the Growth Areas Authority (GAA) in consultation with the Wyndham City Council, Government agencies, service authorities and major stakeholders.

Dr Peter Coombes from Urban Water Cycle Solutions was commissioned by the GAA to provide advice on integrated water cycle management (IWCM) to progress the preparation of the draft East Werribee Precinct Structure Plan. This analysis was supported by Mark Colegate from TGM.

This investigation has combined the previous investigations and incorporated the latest development profiles proposed by the GAA in additional analysis of flooding and stormwater quality. In addition, the GAA have proposed replacing the retarding basins 1 and 2 with a Lake (named Lake A in this report).

The analysis underpinning this report has also assumed a worst case scenario that does not include water sensitive urban design (WSUD) approaches within the Precinct. This analysis does include the previously proposed strategy to optimise use of the Glen Orden wetland and to install a gross pollutant trap in the upper catchment immediately downstream of the Werribee Plaza shopping precinct. This investigation, therefore, examines the performance of the proposed Lake, restored waterways and retarding basins within the East Werribee Precinct as defined by mitigation of flooding and management of pollutant loads. The following key findings have emerged from this investigation:

1. The proposed integrated system of a Lake, restored waterways and retarding basins will mitigate all flooding generated by all storm events with frequencies from 1 year to 100 years average recurrence intervals (ARI).
    a. Small changes in the inlet conditions, storages volumes and surrounding land fill will be required at Lake A that can be accommodated during the design phase of the project.
    b. The multiple staged outlet conditions, 25% allocation of storage volume for flood mitigation and the integration of storages throughout the Precinct provide substantial reductions in the risk of flooding.

c. Large reductions in the areas inundated by flooding are generated by the proposed strategy.
d. The highly urbanised upstream catchment generates a requirement to utilise the proposed storages for storm events of all ARIs.
e. The integrated nature of the stormwater management strategy provided considerable redundancy that will further reduce risks of flooding.
f. The proposed strategy provides considerable reductions in high frequency runoff events from the East Werribee Precinct that will reduce erosion and sedimentation, and ecological impacts on downstream waterways.

2. The integration of a lake, restored waterways and retarding basins with long detention times provided substantial reductions in pollutant loads discharging from the Precinct. The expected performance of the stormwater management system is in excess of best practice guidelines for stormwater management.
   a. It is noteworthy that the proposed stormwater management systems captures annual loads of sediments (1,645 tonnes), phosphorus (0.63 tonnes), nitrogen (6.92 tonnes) and gross pollutants (66.8 tonnes) originating from the upstream catchments.
   b. The proposed stormwater management strategy is dependent on capturing pollutants in or before storages. Given the cumulative nature of sediments and nutrients it will be important to remove the majority of sediments and nutrients prior to entering each storage.
   c. The capture of substantial annual loads of sediment in the Lake or other storages may increase the risk of climate and ecological generated algae blooms. Installation of a treatment train to capture the majority of sediment discharging from the upper catchments prior to entering the Lake or storages and completion of additional ecological simulations of the proposed Lake A and other storages is recommended.
   d. Implementation of WSUD and source control approaches will further enhance the performance of the proposed stormwater management systems and mitigate any risk of ecological failure of the proposed systems.
   e. The proposed Lake A is subject to drawn down of water levels below the operating water level on 14% of days using the Werribee rainfall record. Maintaining the water levels at the operating level will require an average annual top up volume of 531 ML from an alternative water source. Alternatively, the proposed Lake A system could be allowed to operate as an ephemeral system with various water levels.
   f. It is also recommended that the performance of Lake A be analysed using a rainfall record from a dryer period to further examine the variability of water levels.

Authors

The authors of this report are Dr Peter Coombes from Urban Water Cycle Solutions and Mark Colegate from TGM. Both Peter and Mark are former employees of Bonacci Water.

About the lead author:

Dr Peter Coombes is currently the Chief Scientist at the Office of Living Victoria and the managing director of Urban Water Cycle Solutions that operates as an independent research and consulting think tank.

Peter was formerly the Managing Director of Bonacci Water, a conjoint Associate Professor of Integrated Water Cycle Management at the University of Newcastle, an Associate Professor of Chemistry and Biomolecular Engineering at Melbourne University and former chairman of the Stormwater Industry Association.

He was one of the architects of the new Victorian government water policy Living Melbourne, Living Victoria; the recent report on water reform in the Greater Sydney region and led the restoration of Al Asfar Lake system in the historical city of Al Hasa.

Peter has served as a member of advisory group to the Prime Ministers Science, Engineering and Innovation Council, a member the advisory council on alternative water sources for the Victoria Government's Our Water Our Future policy, a member of the advisory panel on urban water resources to the National Water Commission, an advisor on alternative water policy to the United Nations and a research leader of innovative WSUD strategies in the eWater CRC.

His research interests include Integrated Water Cycle Management, Water Sensitive Urban design, hydrology, analysis of complex systems and molecular sciences including water quality. He has generated over 150 scientific publications and designed more than 120 sustainable projects including settlements that generate all of their water resources. Dr. Coombes was also a co-author of Australian Runoff Quality.

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1 Introduction

The East Werribee Employment Precinct (formerly known as the Werribee Employment Precinct) is located near Werribee, 25 km south-west of Melbourne's central business district (CBD) (see Figure 1.1). It is the largest undeveloped parcel of publicly owned land in metropolitan Melbourne and is located in one of the fastest growing urban areas in Australia.

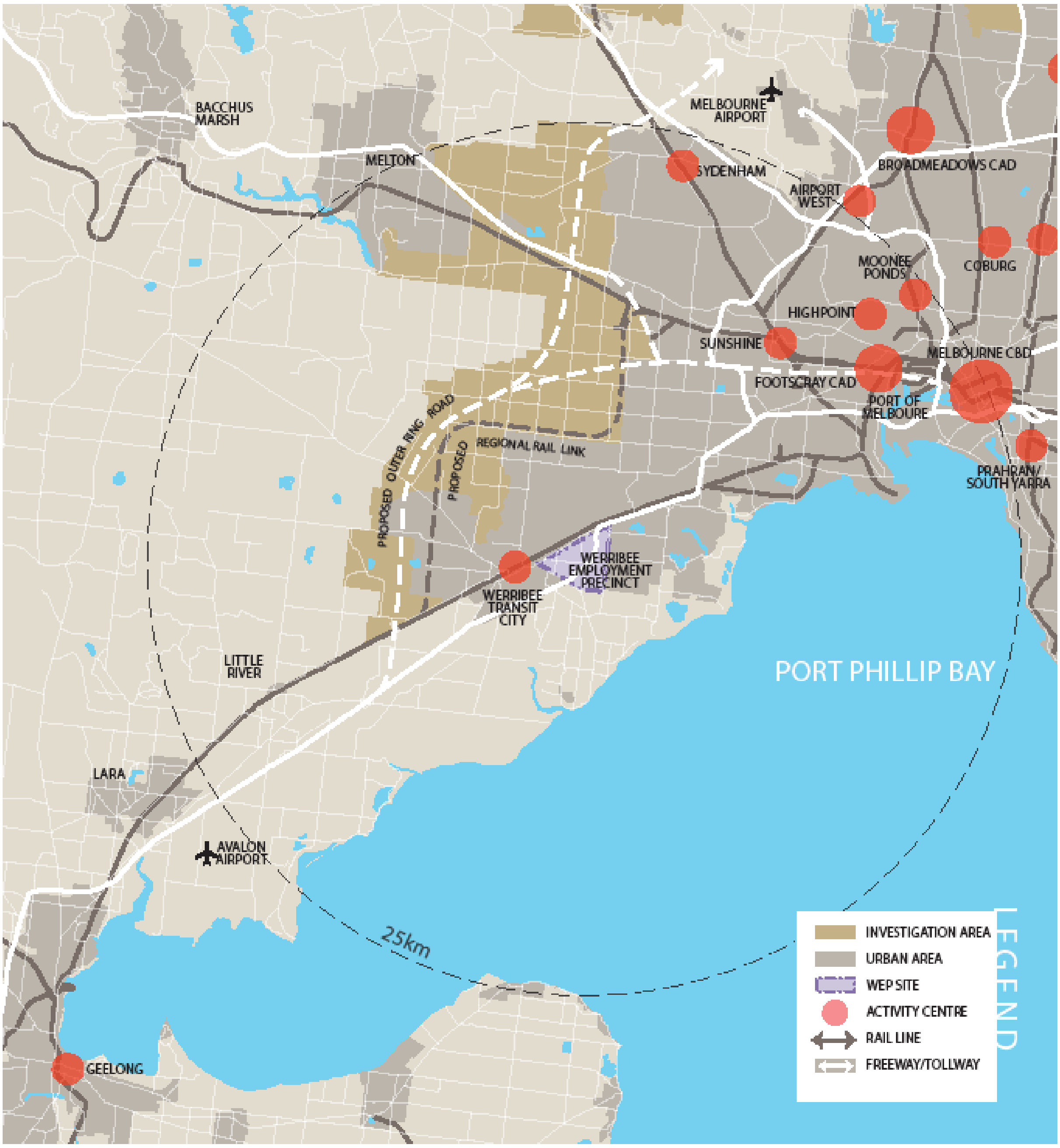


Figure 1.1: Location of the East Werribee Employment Precinct.

During 2009, the Department of Planning and Community Development (DPCD) commissioned detailed investigations and preparation of a preliminary Development Strategy involving input from 20 organisations. Twelve background technical studies were undertaken, including preliminary contamination and heritage assessments, and the preparation of transport, stormwater and economic studies.

The investigations highlighted the potential to provide a new 'mixed use' city with a range of civic, educational, employment, recreational and residential uses that coexist in the one area. An Independent Expert Review Panel supported this view.

The Department of Planning and Community Development commissioned Dr Peter Coombes (Urban Water Cycle Solutions) – formerly Bonacci Water to develop a conceptual integrated water cycle management (IWCM) strategy that incorporated the objectives of a Multi-Agency Working Group and investigated the options for intelligent use of regional stormwater and local rainwater harvesting, district scale aquifer storage and recovery, wastewater reuse within the Precinct and water efficiency approaches.

The East Werribee Precinct Structure Plan (the "PSP") has been prepared by the Growth Areas Authority in consultation with the Wyndham City Council, Government agencies, service authorities and major stakeholders. The Growth Areas Authority (GAA) adopted the scheme in its current master planning for urban development of the Precinct. The master plan is presented in Figure 1.2.

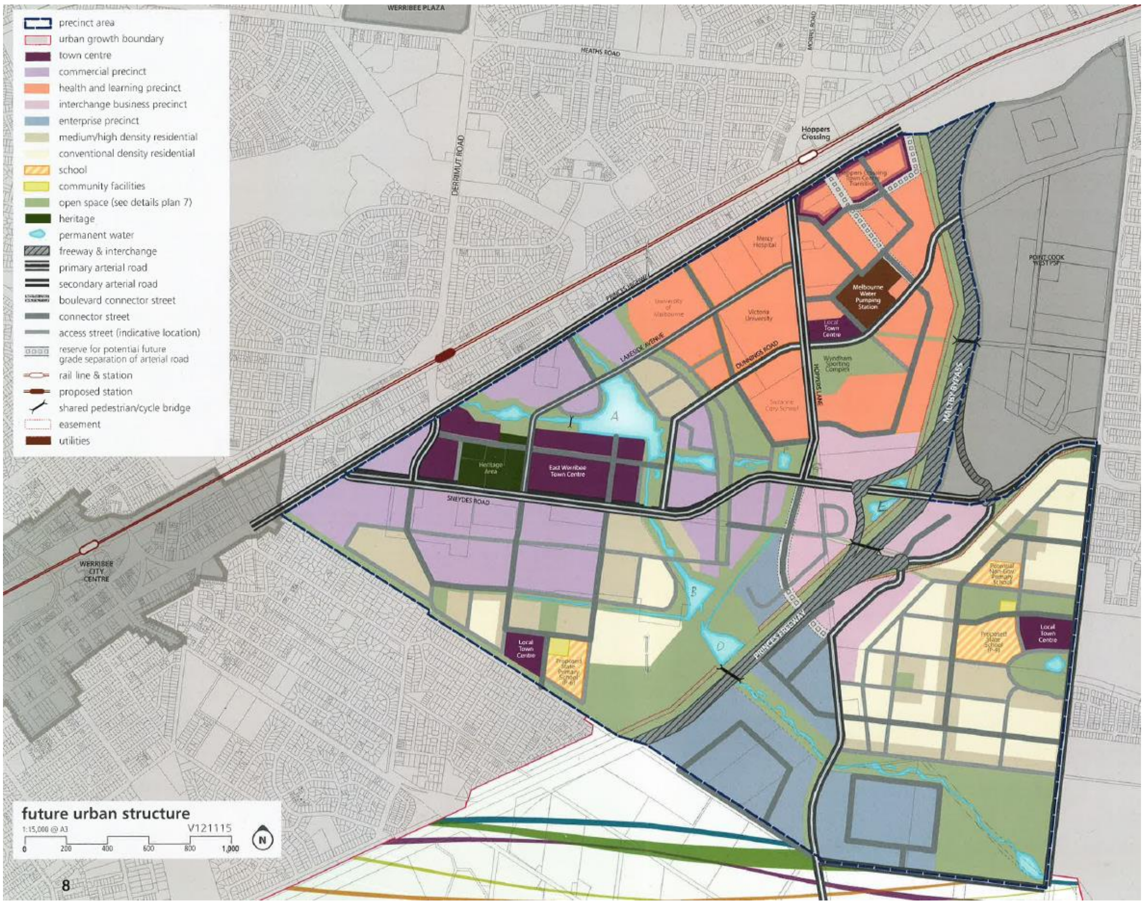


Figure 1.2: Proposed master plan for the East Werribee Precinct.

Figure 1.2 highlights that the proposed master plan is significantly different from the previous planning overlays created by DPCD. The Growth Areas Authority (GAA) commissioned Dr Peter Coombes from Urban Water Cycle Solutions to provide advice on integrated water cycle management (IWCM) to progress the preparation of the draft East Werribee Precinct Structure Plan.

The key integrated water strategies prepared by Dr Coombes at Bonacci Water were included in this investigation, namely the draft Development Services Scheme produced for Melbourne Water (February 2011) and the draft Integrated Water Cycle Management strategy produced for DPCD (January 2010).

The aim of this project is to identify key implementation and staging issues and opportunities to deliver integrated water for the site while achieving the objectives of the master planning for East Werribee. Investigation and advice was provided on the following issues:

1. The drainage and stormwater network based on the current draft precinct structure plan for East Werribee:
    a. Proposed location of waterways and retarding basins and their integration into the road and development layout, particularly to the north of Sneydes Road.
    b. Establishment of a permanent lake feature approximately in the location of the proposed RB2, including options for maintaining suitable water quality, hard and soft landscaping, incorporation of flood retardation, and limiting variations to normal water levels due to prevailing weather or climatic affects.
    c. Incorporating additional flood retardation capacity downstream of the permanent lake feature.
    d. Provision of a waterway in the proposed residential precinct generally West South West of RB3, whether this would be a permanent waterway and how this should be delivered. This advice should consider the possibility that the profile of the existing Melbourne Water trunk sewer cannot be altered.
    e. Extents of the 100 year ARI flood levels and flood storage capacity details throughout the site.
    f. Delivery of aquifer storage and recovery in the precinct, including preferred locations of storage, treatment and injection infrastructure.
2. Implications for the drainage and stormwater network if all or part of the recommended integrated water cycle management solution (aquifer storage and recovery, precinct scale and wastewater reuse) are not delivered.
3. Advice on the way forward to investigate local and precinct scale waste water treatment and reuse.
4. Confirmation of off-site works necessary to deliver the drainage strategy for the precinct.

2 Background

The Department of Planning and Community Development (DPCD), in 2009, facilitated detailed investigations and preparation of a preliminary development strategy involving input from twenty organisations. A wide range of technical investigations were undertaken, including preliminary contamination and heritage assessments, and the preparation of transport, stormwater and economic studies. These investigations highlighted the potential to provide a new 'mixed use' city with civic, educational, employment, recreational and residential uses that coexist in the one area. An Independent Expert Review Panel supported this view.

Dr Peter Coombes and Bonacci Water were commissioned to develop a conceptual integrated water cycle management (IWCM) strategy that incorporated the objectives of the Multi-Agency Working Group and investigated the options for intelligent use of regional stormwater and local rainwater harvesting, district scale aquifer storage and recovery, wastewater reuse within the Precinct and water efficiency.

The IWCM strategy was dependent on a stormwater management solution that mitigates the significant legacy of flooding and stormwater pollution at the site and incorporates the principles of water sensitive urban design (WSUD). The stormwater management elements of the proposed IWCM strategy therefore needed to be incorporated into a Development Services Scheme (DSS) administered by Melbourne Water Corporation.

As a consequence, Dr Peter Coombes and Bonacci Water were commissioned by Department of Planning and Community Development and Melbourne Water Corporation to prepare an innovative integrated stormwater management strategy for the site based on rigorous scientific and economic analysis.

In addition, the Implementation Plan for the Living Victoria policy also proposes targets for IWCM throughout the Greater Melbourne region. These recommendations include targets for the Werribee area. This Chapter outlines the key elements of the investigations of IWCM, stormwater management strategies and the Living Victoria policies.

2.1 IWCM strategy

The DPCD and VicUrban prepared a development strategy for the proposed Werribee Employment Precinct. This report outlined the investigations into setting objectives for integrated water cycle management (IWCM) including stormwater management at the site.

Objectives

The development of an IWCM strategy and a vision for sustainable development of the Werribee Employment Precinct allowed the setting of objectives and targets for water management. These objectives represent current best practice for source control, protection of the health and amenity of waterway ecosystems, mitigation of flooding and minimising the impacts on the water cycle (Table 2.1). The targets aim to mitigate water cycle impacts to pre-European levels where possible.

Table 2.1: Objectives or targets for water cycle management at the Werribee Employment Precinct

Criteria	Objectives or targets
Effective Impervious areas	Not greater than 5%
Building form	Greenstar 6 or equivalent
Suspended solids	80% reduction in average annual urban loads
Total phosphorus	60% reduction in average annual urban loads
Total nitrogen	45% reduction in average annual urban loads
Litter	No litter discharging to waterways
Peak stormwater discharges	Maintain all peak discharges at pre-European levels
Stormwater runoff days	Average annual days maintained at Pre-European levels
Water demands	Net self sufficiency
Sewage discharges	Net self sufficiency
Salinity	Return the salinity of waterways and soils to pre-European levels
Energy	No increase in energy demands in comparison to BAU
Carbon	Carbon neutral
Climate change	All water cycle systems resilient when subject to the high emissions scenario for 2070

The objectives in Table 2.1 include targets for stormwater flow regimes that utilise average annual runoff days and average annual runoff volumes. Targets for stormwater quality include total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN) and litter. The target for total nitrogen, in particular, is important for managing impacts on Port Philip Bay whilst stormwater quality and flow regime targets aim to protect waterways. Maintenance of 1.5 year average recurrence interval (ARI) storm events at pre-European levels will protect waterways from erosion and sedimentation.

Objectives for managing building form and limiting effective impervious areas are important for managing stormwater impacts and demands for water at source. Reductions in the effective impervious areas at the allotment or sub-precinct scale will mitigate impacts on waterway health[1]. Effective impervious area is defined as the impervious area that is directly connected to waterways via stormwater drainage systems.

It is proposed that flooding can be managed by limiting peak stormwater discharges to pre-European conditions. The ultimate objective for water demands and sewerage discharges is net self-sufficiency assessed over a 10 year period. Thus net self-sufficiency is attained when mains water demands of the site are balanced by water savings generated by the site.

A salinity target is included to mitigate the increasing salinity of groundwater, soils and waterways in the Werribee region (similar to many other parts of Australia). In particular, urban soil salinity has the potential to limit the amenity of urban areas and cause significant damage to

[1] Walsh C.J. (2004). Protection of instream biota from urban impacts: minimize catchment imperviousness or improve drainage design? Marine and Freshwater Research. 55, 317-326.

infrastructure. The salinity target also includes the aim to restore the quality of water in the aquifer and to preference use of treated wastewater from local catchments with lower salt content.

Targets for energy and carbon aim for no net increases in comparison to 2006 levels to mitigate the impact of urban development on future climate. The ultimate aim for a carbon neutral development with no increase in net energy demands embraces the challenge of minimising impacts of climate change. This action will set an example for urban development.

Options

The study examined a range of alternative options for water cycle management at the East Werribee Employment Precinct.

- Option A is the base case (BAU) which assumes that mains water will be the sole source of water supply to the Precinct. The BAU case assumes that potable water will be freed up in the Greater Melbourne water supply system by construction of the Wonthaggi desalination plant and the Food Bowl Modernisation project. All sewerage generated by the Precinct will discharge to the Western Trunk Sewer and the site will utilise the existing stormwater management infrastructure with traditional drainage strategies.
- Options B – J consider the use of water efficient appliances and gardens, stormwater and rainwater harvesting, Water Sensitive Urban Design (WSUD), wastewater reuse from local and Precinct scale treatment plants.
- Option K is an integrated water cycle management strategy incorporating most of the above elements. This strategy meets the objectives of the Interagency Working Group and includes treated effluent from a wastewater treatment plant located within the Precinct used for toilet flushing, garden watering and open space irrigation. Class A+ treated effluent will be distributed to households and commercial users via a third pipe distribution network. Rainwater harvested from roofs and treated to appropriate standards will supply laundry, bathroom and hot water demands. All other water demands will be supplied from stormwater stored in the aquifer that is extracted and treated to drinking water standards as required by the development.

Results

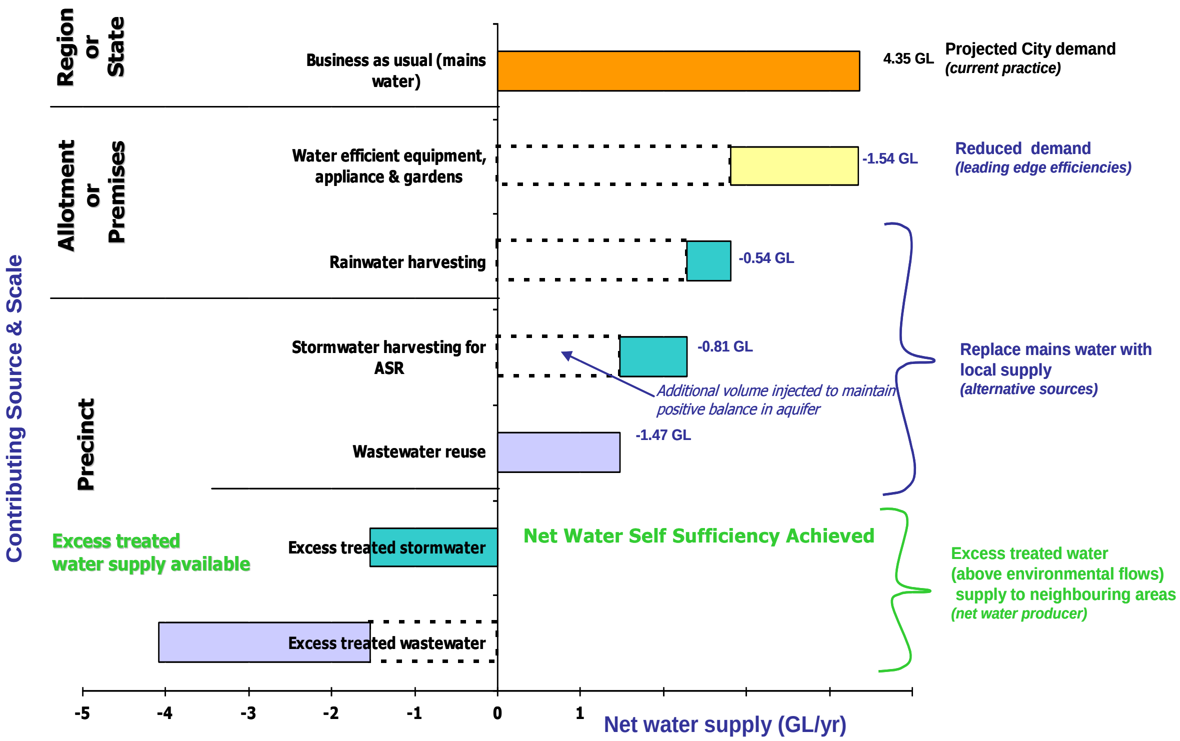
The best options reduce demand on regional mains water supplies, minimise sewerage discharges and have a positive net present value, while reducing greenhouse gas emissions in comparison to the Business As Usual (BAU) Option. Option K (Table 2.2 and Figure 2.1) provided an optimum response to these multiple objectives.

The selected Option included the integrated use of regional stormwater and local rainwater harvesting, district scale aquifer storage and recovery, wastewater reuse from treatment plants within the Precinct and water efficiency as shown in Table 2.2.

Table 2.2: Summary of the Integrated Water Cycle Management strategy (IWCM)

Scale	Strategy	Concept
Precinct *Efficiency*	**Productive reuse of treated water** - storm water and treated wastewater provide a secure local supply of quality water for the new city, with excess exported to neighbouring areas	1) **Establish secure supply of reuse water** by integrating amenity enhancing infrastructure into the urban form: (a) Reuse of regional storm water entering the site from upstream: • Replacing the concrete D1 drain and 150 hectare retarding basin with amenity enhancing waterways • Using aquifer storage and retrieval (ASR) with treatment to potable water standards (b) Retrieval, treatment and reuse of local wastewater with timely installation of modular wastewater treatment plants 2) **Reticulated supply of reuse water** to all allotments with excess exported for supply to neighbouring areas 3) **Open space network with overland flow paths** to increase resilience to the impacts of severe storm events that are projected to occur under a high emissions climate change scenario
Sub-Precincts Flexibility	**Flexible** development of sub-precincts	Provide developers with maximum flexibility in sub-precinct structure planning to adopt the latest technologies and approaches providing they meet the predetermined objectives and associated standards
Allotments *Effectiveness*	Developer delivers to Precinct standards	Reduced upfront Precinct Services Scheme charges based on developer delivery of more effective, source based, infrastructure: • Rainwater plumbed into internal laundry, bathroom and non-food preparatory areas • Reticulated wastewater reuse for external purposes • Smart streetscapes that clean rainwater where it falls and integrate with neighbourhood open space and stormwater management systems • Water sensitive urban designed neighbourhoods • Installation of water efficient equipment, processes and appliances

Table 2.2 shows that the IWCM strategy incorporates solutions that operate across multiple scales that also contribute to the water balance at the site as presented in Figure 2.2.



Notes:
* Excess stormwater is volumes above environmental flows
* DCPD ultimate land use scenario with 50,000 Jobs and 30,000 residents
* Average values shown - Variances due to climate and seasonal variability in demand and supply
• Locally sourced water treated to potable standards for business use
• Each year inject stormwater in excess of that required to build a reservoir as a future buffer/resource

Source: Werribee City Infrastructure Planning - Integrated Water Cycle Management Strategy, Bonacci Water - 2010

Figure 2.2: Water balance from the IWCM strategy – opportunities for the new city to be water positive, generating more water than it uses (local water supply to neighbouring areas)

Figure 2.2 demonstrates that the IWCM strategy was found to be independent of regional mains water supplies; decrease sewerage discharges from the Precinct; supply surplus treated wastewater to surrounding areas, contribute to restoring the aquifer under the site; and substantially reduce the requirement for water and sewerage infrastructure. This strategy also provided significant reductions in greenhouse gas emissions.

2.2 Stormwater management

The IWCM strategy is dependent on a stormwater management solution that mitigates the significant legacy of flooding and stormwater pollution at the site and incorporates the principles of water sensitive urban design (WSUD). The stormwater management elements of the proposed IWCM strategy therefore needed to be incorporated into a Development Services Scheme (DSS) administered by Melbourne Water Corporation.

Dr Coombes and Bonacci Water were commissioned by Department of Planning and Community Development and Melbourne Water Corporation to prepare an innovative integrated stormwater management strategy. The strategy outlined the essential stormwater management facilities required to achieve the stormwater flow and quality objectives throughout the Precinct. The intent of the report was to form the basis of a new Development Services Scheme for the East Werribee

Employment Precinct and an addition to the existing schemes for the Skeleton Creek and Upper Point Cook catchments.

The Werribee Employment Precinct is predominantly crown land used historically for various agricultural and animal research purposes. It is traversed by significant infrastructure including the Maltby Bypass, several minor roads, Melbourne Water's Western Trunk Sewer, and the historical Western Trunk Sewer (Figure 2.3).

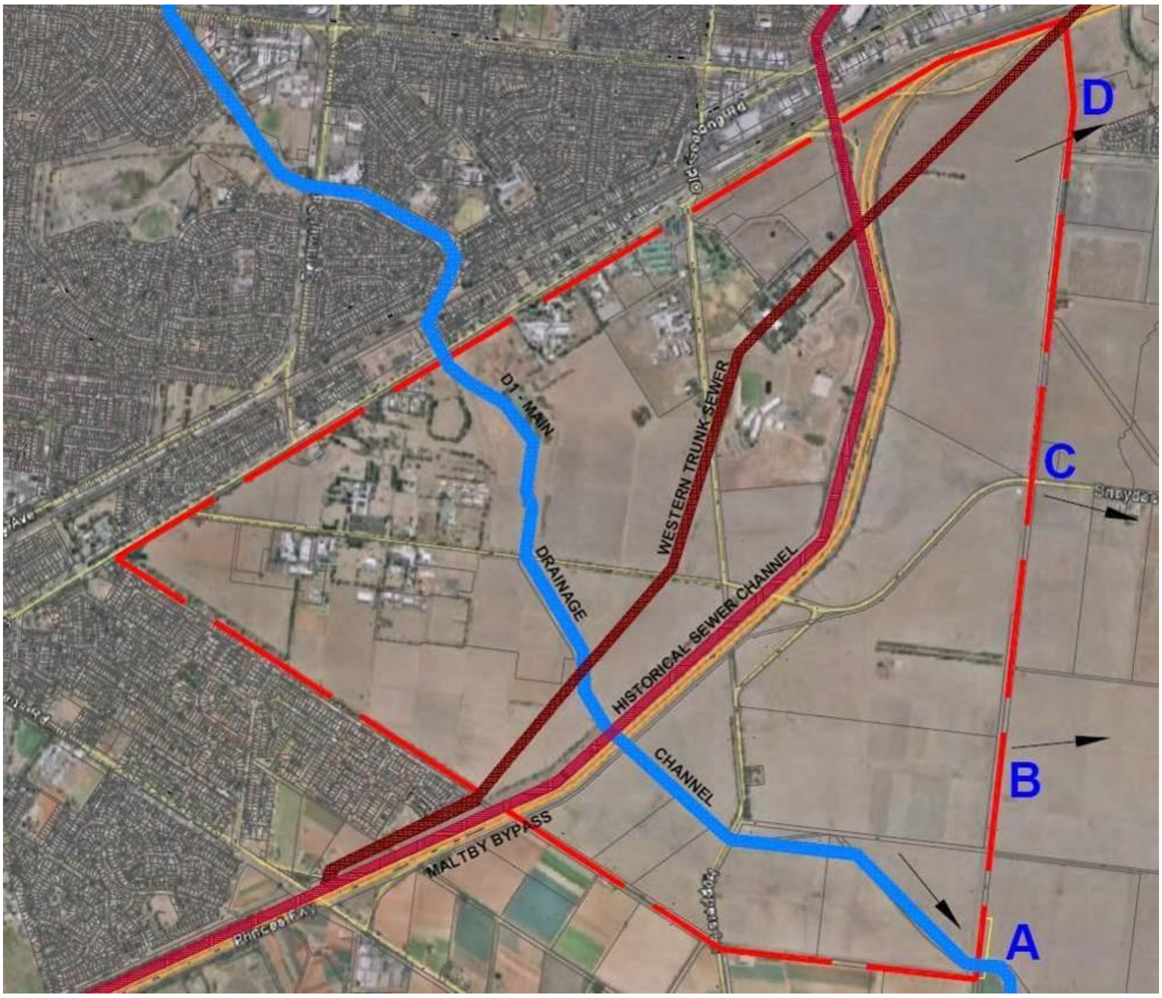


Figure 2.3: Existing development, major infrastructure and natural drainage flowpaths.

Figure 2.3 shows the main drainage alignment, the major above ground infrastructure and the existing urban development. It also shows that stormwater flows out of the Precinct at the main drainage outlet (A) and three other locations (B, C and D). The Princes Highway forms the north-west boundary of the Precinct. The adjoining areas north of the Maltby Bypass are mostly urbanised and area to the south includes mostly irrigated agriculture. Land uses to the east and north-east of the site are dry land farming transitioning into new urban developments (out of view in Figure 2.3).

The urbanised catchments that drain into the Precinct from north-west of the Princes Highway are shown in Figure 2.4. These catchments incorporate an area of greater than 1,097 ha which is slightly larger than the area of the precinct. The topography across the entire site is relatively flat with a fall of less than 20 m in the 9 km downstream of Sayers Road to exit point A in Figure 2.4.

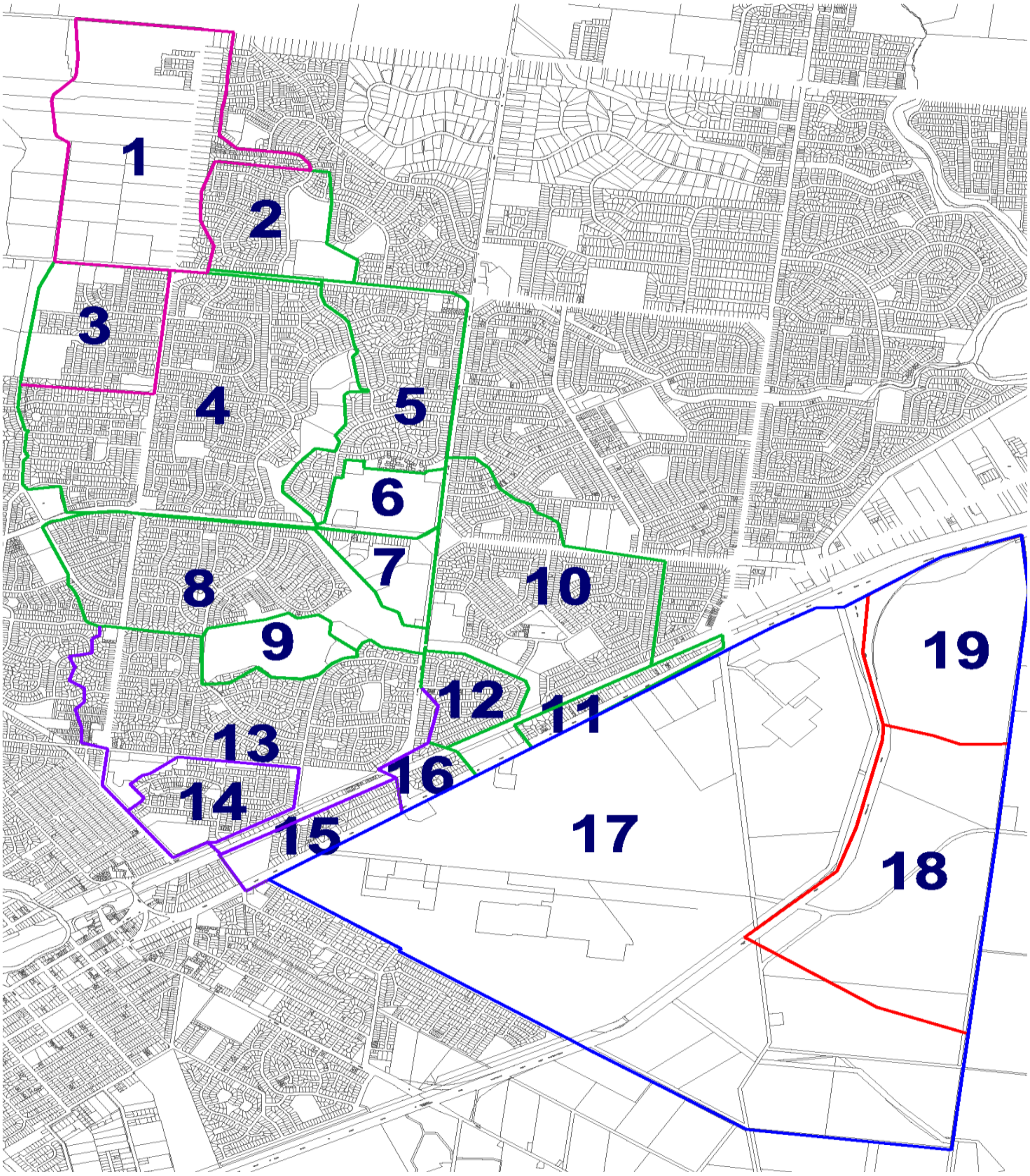


Figure 2.4: Existing stormwater sub-catchments impacting on the East Werribee site

Land uses in the upstream sub-catchments include residential housing, shopping centres, schools and road networks within the suburb of Werribee. The characteristics of these sub-catchments were identified by field inspections, from the Wyndham Planning Scheme and aerial photography as shown in Table 2.3.

Table 2.3: Characteristics of upstream stormwater catchments

Sub-catchment	Area (ha)	Impervious area (%)	Dominant land use
1	110	20	Mostly rural
2	52	57	Residential with schools
3	70	60	Residential
4	163	55	Residential
5	90	60	Residential
6	24	95	Werribee Plaza Shopping Centre
7	22	55	Mixed use development and school
8	102	60	Residential and detention basin
9	28	10	Glen Orden constructed wetland
10	157	57	Residential
11	8	60	Residential
12	25	60	Residential
13	166	60	Residential
14	41	60	Residential
15	26	57	Residential
16	13	70	Residential

Table 2.3 shows the areas, proportion of impervious areas and dominant land uses of the sub-catchments as agreed with MWC. The upstream catchment includes shopping centres, mixed use development and schools that can generate significant pollutant loads that include litter and debris during rain events.[2] In addition, the upstream catchment includes a detention basin located in the D1 Drain, an off-line constructed wetland at Glen Orden and a rural area that will soon be developed as low density urban settlement.

Methods

Objectives for stormwater management and protection of waterways were agreed with the Multi-agency working group. Analysis of the stormwater infrastructure required to support the overall IWCM strategy relied on detailed forensic inspection of the existing drainage infrastructure and facilities, and checking of the physical dimensions of all culverts, spillways and other flow controls.

This study included historical rainfall data from representative nearby locations sourced from the Bureau of Meteorology and design rainfall from the national guideline, Australian Rainfall and Runoff. Estimates of the impacts of climate change on rainfall intensity by CSIRO and IPCC were also incorporated in the analysis.

[2] Engineers Australia (2006). Australian Runoff Quality.

High resolution digital terrain models were generated by the investigation that represented pre-European, current and future conditions. The hydrological analysis utilised design storms and a state-of-the-art model called WUFS that can compare traditional drainage solutions to water sensitive urban design (WSUD) solutions or analyse combinations of both. A parallel model of the hydrology was also created using the RORB software package to confirm the results of the hydrological analysis. As no stream gages were present at the site, the pre-European hydrology was calibrated to rational method calculations.

The hydraulic analysis utilised the digital terrain model and inputs from the hydrology model in the hydraulic model TUFLOW that produces one and two dimensional simulation. The MapInfo geographic information system was used to analyse and present the hydraulic results. Simulation of stormwater quality was undertaken using the MUSIC model and local rainfall from the Werribee area. All data sets were rigorously inspected for any inconsistencies.

Stormwater Management Objectives

Objectives and targets for stormwater management were developed in accordance with the vision for sustainable development of the Werribee Employment Precinct to include:

- source controls and rainwater harvesting
- trapping of gross pollutants
- removal of suspended solids and nutrients from stormwater runoff
- achieving current best practice targets for reduction in pollutants below typical urban levels
- enhancing health and amenity of waterway ecosystems
- mitigation of flooding
- optimising opportunities to harvest water for aquifer storage and retrieval

Analysis of pre-European conditions included research into the likely historical stormwater flow paths and catchments to establish natural stormwater runoff regimes. These results were used to inform the targets for stormwater management.

Existing Conditions

Information from a range of sources was combined with site inspections and detailed analysis to identify the urban stormwater sub-catchments discharging to the Precinct. This was a critical aspect and outcome of the study, as this task had not been accurately undertaken before.

The site of the Werribee Employment Precinct is subject to stormwater runoff from a large urbanised catchment (1,097 ha) upstream of the site. Land uses in the upstream sub-catchments include residential housing, shopping centres, schools and road networks within the Local Government area of Werribee.

Two different urbanised catchments (D1 Drain and P1 Pipe) discharge to the Werribee Employment Precinct from the upstream area. The D1 catchment includes a drainage corridor that discharges to a detention basin located below Werribee Plaza that discharges under Derrimut Road towards the Precinct. This catchment also includes the offline constructed wetland known as Glen Orden that is not directly connected to any of the stormwater sub-catchments.

Existing stormwater management facilities in the upper catchments pre-date current design guidelines and do not achieve required standards for stormwater management. They include nine small detention basins and two large storages identified as the D1 reserve retarding basin and the Glen Orden constructed wetland. Areas of the upper catchment and substantial parts of the Precinct are subject to flooding to depths of 50 mm or greater during severe rainfall events (Figure 2.5).

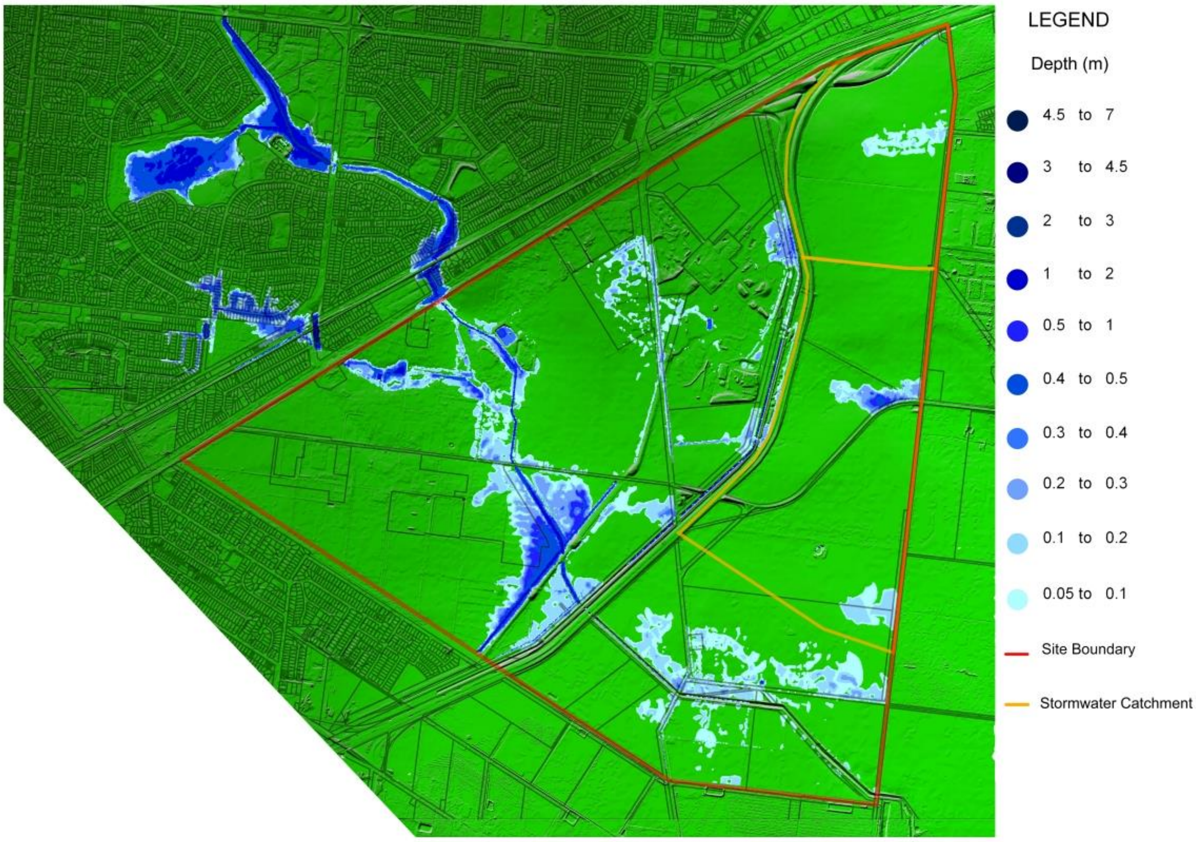


Figure 2.5: Extent of flooding from 100 year ARI storm events under existing conditions

It is expected that inundation from flooding in the Precinct would increase substantially under the proposed development scenarios because of the additional runoff generated by urban development.

Proposed stormwater infrastructure

The investigation proposed stormwater management infrastructure to achieve best possible results for:

- Flood mitigation
- Stormwater quality improvement and
- Waterway health and stability

An important underlying objective for the Precinct is that domestic and commercial developments will adopt on-site harvesting and indoor utilisation of roof runoff, and local scale best management practices for water sensitive urban design.

The principal elements of the major infrastructure incorporate retarding basins, wetlands, gross pollutant traps, culverts, weirs, spillways and re-aligned or re-formed waterways. The predominant features in the upper catchment are shown in Figure 2.6.

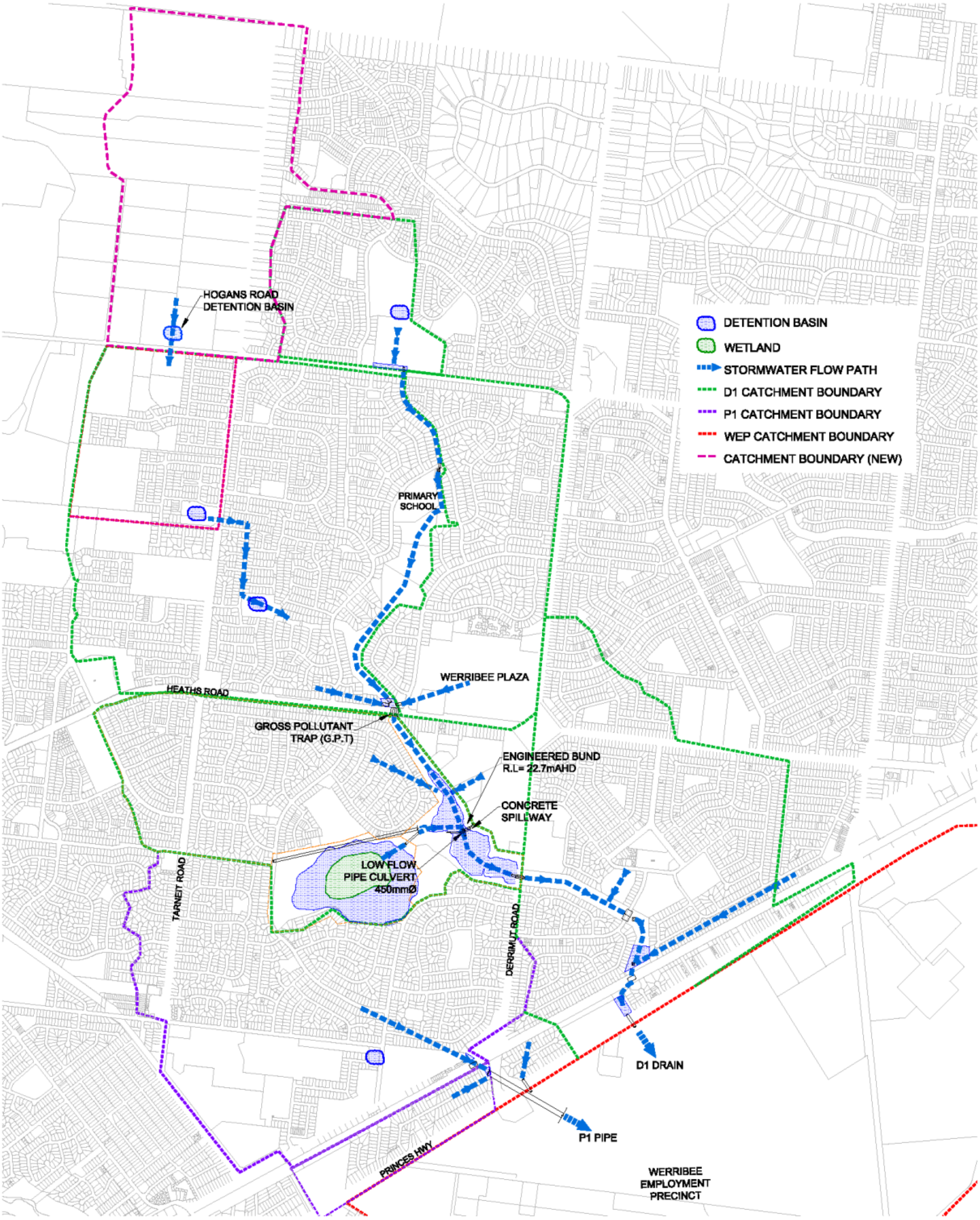


Figure 2.6: Designed stormwater infrastructure in upper catchment

Figure 2.6 highlights the key changes in the upper catchment include a gross pollution trap just upstream of Heaths Road, a new weir and other modifications to better link the retarding basin in the D1 Drain Reserve to the Glen Orden constructed wetland. This will achieve higher utilisation of the storage capacity in Glen Orden at lower flows with significant stormwater quality and flood mitigation benefits. Key elements of the infrastructure proposed to be used, modified or constructed within the Precinct are set out in Figure 2.7.

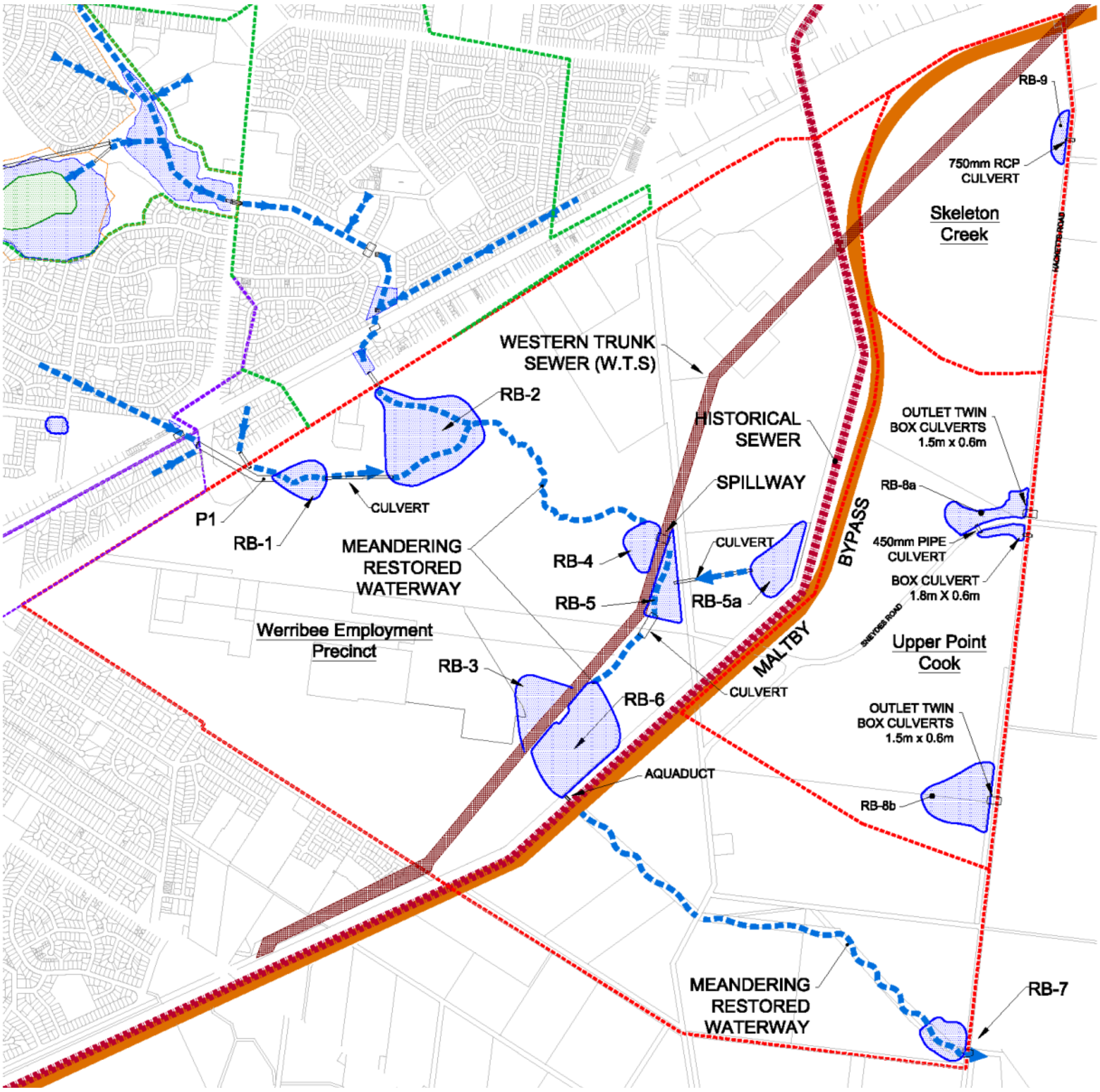


Figure 2.7: Overview of stormwater management infrastructure within the Werribee Employment Precinct

Figure 2.7 outlines the initiatives developed for the D1 drainage system within the Precinct that includes:

- A gross pollutant trap and retarding basin RB1 at the P1 entry to the Precinct;
- A re-formed meandering waterway through the base of RB1 and on to RB2;
- A gross pollution trap and retarding basin RB2 at the entry of the main D1 drain to the Precinct.
- Re-formed meandering waterways through the base of RB2 which also contains a small permanent wetland pond to assist in harvesting water for aquifer storage and recovery;
- A new meandering waterway from RB2 to the new retarding basin RB4. The new alignment meets the Western Trunk Sewer further north than the current D1 drain alignment where the sewer is set lower in the ground permitting easier passage of stormwater flows;

- Filling and stabilising the old alignment of the D1 drain through this portion of the area;
- A permanent pond in the new RB4 for habitat and aquifer storage and recovery;
- A spillway from new RB4 over the Western Trunk Sewer into new RB5 retarding basin;
- A new retarding basin RB5a collects stormwater from the isolated catchment further north between the two sewer alignments;
- A low flow culvert and high flow overland pathway linking retarding basin RB5a to the new RB5;
- High flow spillway and low flow outlet directing flows from new retarding basin RB5 through box culverts under Sneydes Road. A bund to prevent inundation of Sneydes Road at this location during high flow events;
- A new meandering waterway from Sneydes Road south to new retsrding basin RB6 located between the new and old sewers;
- Inclusion of a pond for habitat and aquifer storage extractions in existing retarding basin RB3 which outlets to new retarding basin RB6 via an existing siphon under the Western Trunk Sewer and a high flow spillway over the sewer;
- Modification of the existing twin siphon to increase flows under the Historical Sewer channel from the RB6 retarding basin;
- Construction of an aqueduct from the RB6 retarding basin over the Historical Sewer to carry high flows across the sewer. Stormwater currently spills into the sewer;
- Re-construction of a meandering waterway along the D1 drain alignment between the Maltby Bypass and the south-east limit of the Precinct,
- Construction of a new retarding basin RB7 just inside the Precinct at the outflow location.

Upper Point Cook drainage system works

Works associated with the stormwater catchment that falls towards the Point Cook drainage system include:

- New RB8a retarding basin which includes an existing reeded billabong likely to have high ecological value. The existing outlets under Sneydes and Hackets Roads will meet outflow requirements, and
- New RB8b retarding basin that utilises the existing twin culverts to pass flows under hackets Road towards Point Cook

Skeleton Creek drainage system works

A small retarding basin RB9 is proposed for the very north-east corner of the Precinct where the stormwater catchment discharges to the north into the Skeleton Creek system through an existing urban development.

Results

Flooding

The areas subject to inundation from flooding at depths of 50 mm or greater depth generated by 100 year ARI storm events are shown in Figure 2.8. This result shows the effect of the proposed stormwater management infrastructure and the eventual full development of the Precinct. It is clear that the surface area has been significantly reduced compared to existing conditions that are shown in Figure 2.5.

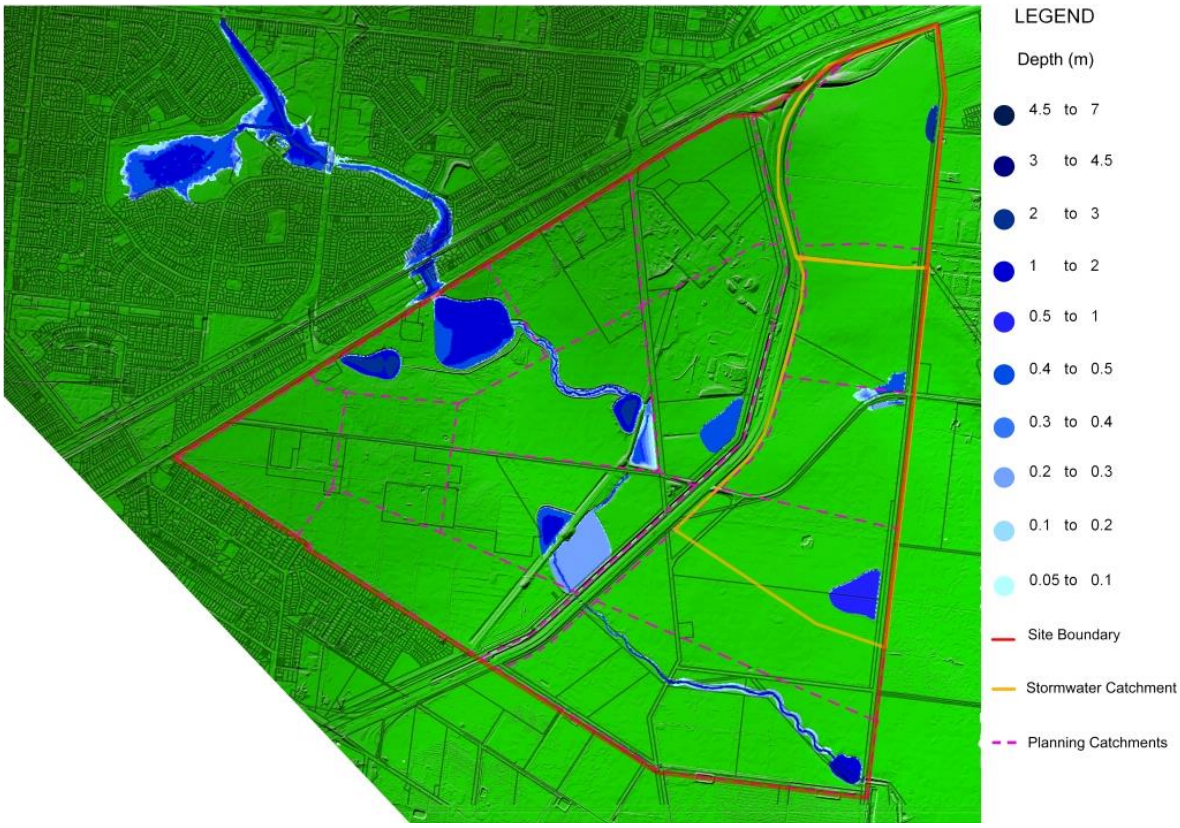


Figure 2.8: Extent of flooding from 100 year ARI storm events in the developed catchments

Stormwater Quality

The characteristics of stormwater leaving the Precinct towards the downstream D1 drainage system are shown in Table 2.4. The Table can be interpreted using the following definitions:

- SOURCE represents the cumulative contributions from all areas in the upstream catchments in the fully developed state
- RESIDUAL represents the pollutant that have not been eliminated, removed or otherwise ameliorated by the cumulative action of all the stormwater management measures in the upstream catchments

The reductions in pollutant loads achieved by the stormwater management strategy are considerable and exceed the best practice objectives identified for the study.

Table 2.4: Stormwater quality discharging from the Precinct outfall to the lower D1 drain

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	4,010	1,740	56.6
Total Suspended Solids (kg/yr)	690,000	36,100	94.8
Total Phosphorus (kg/yr)	1,440	235	83.7
Total Nitrogen (kg/yr)	10,500	2,990	71.6
Gross Pollutants (kg/yr)	105,000	0	100.0

The improvements in stormwater quality for the upper Point Cook and Upper Skeleton Creek sections of the Precinct were similarly effective.

Riparian Habitat

The wetland ponds in most of the retarding basins and the newly formed waterways arranged as meandering low-flow channels between high flow levees or bunds will underpin significant long term improvements in riparian habitat. Careful attention to design, construction and revegetation of these areas will be important.

Climate Change

The areas estimated to be affected by flooding under current design conditions and with the impacts of climate change are shown in Table 2.5. The high emissions climate change scenario (17% increase in rainfall intensity) would increase the extent of flooding. However, these increases are contained in the stormwater infrastructure designed for the site.

Table 2.5: Land areas affected by flooding generated by current design conditions and with the impacts of climate change

Inundation at indicated depth	Area of flood (ha)	
	Design	Climate Change
Full extent	57	79
> 50 mm	55	57
> 100 mm	54	56

Land Yield

The area of land available for development across the Precinct is approximately 670 ha. This discounts the areas required for current permanent uses and infrastructure, the heritage reservation at the old research station and the areas required for waterways, retarding basins and other stormwater facilities as shown in Table 2.6.

Table 2.6: Land area available for development

Land Category	Area (Ha)	Balance (Ha)
Total Precinct		915
Existing Permanent Uses and infrastructure easements	171.8	743.2
Cultural heritage reservation at old research station	5	738.2
Waterways, retarding basins and other stormwater reserves	69	669.8

Rigorous and detailed analysis of stormwater processes in the Precinct and its upstream catchments has provided a sound understanding of the dynamics of stormwater runoff. Existing conditions in the upstream catchments do not meet current stormwater quality or quantity objectives, creating a challenge for stormwater management within the Werribee Employment Precinct.

However, the works proposed are capable of achieving exemplar stormwater objectives for the Precinct and its upstream catchments at a considerable economic benefit. The proposed works will also significantly enhance riparian habitat values, improve amenity and are resilient to potential increases in rainfall intensity associated with climate change.

Development of the Precinct as currently proposed will not be unduly constrained by stormwater requirements. The gross cost of the proposed stormwater management strategy is $45,917/ha and the net benefits are $117,165/ha when the value of land is considered. The gross costs of Precinct scale stormwater infrastructure in the three catchments within the Precinct as shown in Table 2.7.

Table 2.7: Gross cost of Precinct scale stormwater infrastructure

Location	Developable area (ha)	Cost ($/ha)
Remainder of Werribee Employment Precinct	449	59,997
Upper Point Cook	140.1	16,404
Upper Skeleton Creek	80.7	10,772

Inclusion of the net land values in the analysis provides the net costs of the Precinct scale infrastructure as shown in Table 2.8.

Table 2.8: Net costs of Precinct scale stormwater infrastructure

Location	Net costs ($)	Cost ($/ha)
Remainder of Werribee Employment Precinct	78,294,267 (benefit)	174,365 (benefit)
Upper Point Cook	646,501	4,615
Upper Skeleton Creek	3,018,513 (benefit)	37,402 (benefit)

Table 2.8 shows that the value of the land that is made available as a result of the reduced flood inundation generated by the stormwater management strategy has mitigated the costs of the stormwater infrastructure. Although the developers of the land will have to make the contributions

listed in Table 2.7, the value of the increased developable land area reduces the net cost of the stormwater management strategy to the values shown in Table 2.8.

Note that the net benefit of the proposed stormwater management scheme for the entire Werribee Employment Precinct is $117,165/ha when the value of the increased developable area is included. The stormwater management strategy has produced sufficient increases in developable land to fund both the proposed stormwater management and the IWCM strategies, and provide considerable surplus in value.

2.3 Living Victoria policy

The Living Victoria policy[3] included objectives for water cycle management that include minimum annual reductions in demand for mains water, wastewater discharges and stormwater runoff as shown in Table 2.9. These objectives include spatially relevant building and precinct scale targets.

Table 2.9: Targets for the "West Greenfield Growth" region from the Living Victoria policy

Criteria	Reduction (%)	
	Building	Precinct
Water demand	39	81
Wastewater discharge	26	85
Stormwater runoff	27	27
Greenhouse gas emissions	25	40

The MIWCS includes the ***water cycle shadow cost*** that is the sum of the full cumulative costs of providing water, wastewater and stormwater services to different locations throughout Greater Melbourne. This value is divided by the accumulative volume of water supply, wastewater discharges and stormwater runoff at each location. This results in *water cycle shadow cost* that is presented as a value for each megalitre (ML) of water cycle service. Note that the *water cycle shadow costs* include all cumulative costs and the costs of alternative strategies but do not include the costs of traditional "street scale" reticulation infrastructure normally provided by developers.

This approach undertakes complete systems analysis to aid the calculation of water cycle benefits across the entire Greater Melbourne region. This work shows that cumulative costs of delivering water cycle services vary throughout the Greater Melbourne region. As consequence the relative benefits of IWCM projects will also vary widely across the region.

The following maps (Figures 2.9) presents a *"shadow cost for water services"* that captures the full "whole of system" accumulative costs of providing water services across the region that includes casts of desalination, taxes and dividends. This overlay of *shadow costs for water* is a component of the ***water cycle shadow costs*** can be used to determine the relative value of an IWCM project. Similarly, the shadow cost for wastewater services, shadow costs for stormwater management and the water cycle shadow costs are presented in Figures 2.10, 2.11 and 2.12 respectively.

[3] Coombes P.J., S. Want, M Colegate and J. McBride (2012). Living Melbourne, Living Victoria. Greater Melbourne systems model – modelling in support of the Living Victoria Ministerial Advisory Council.

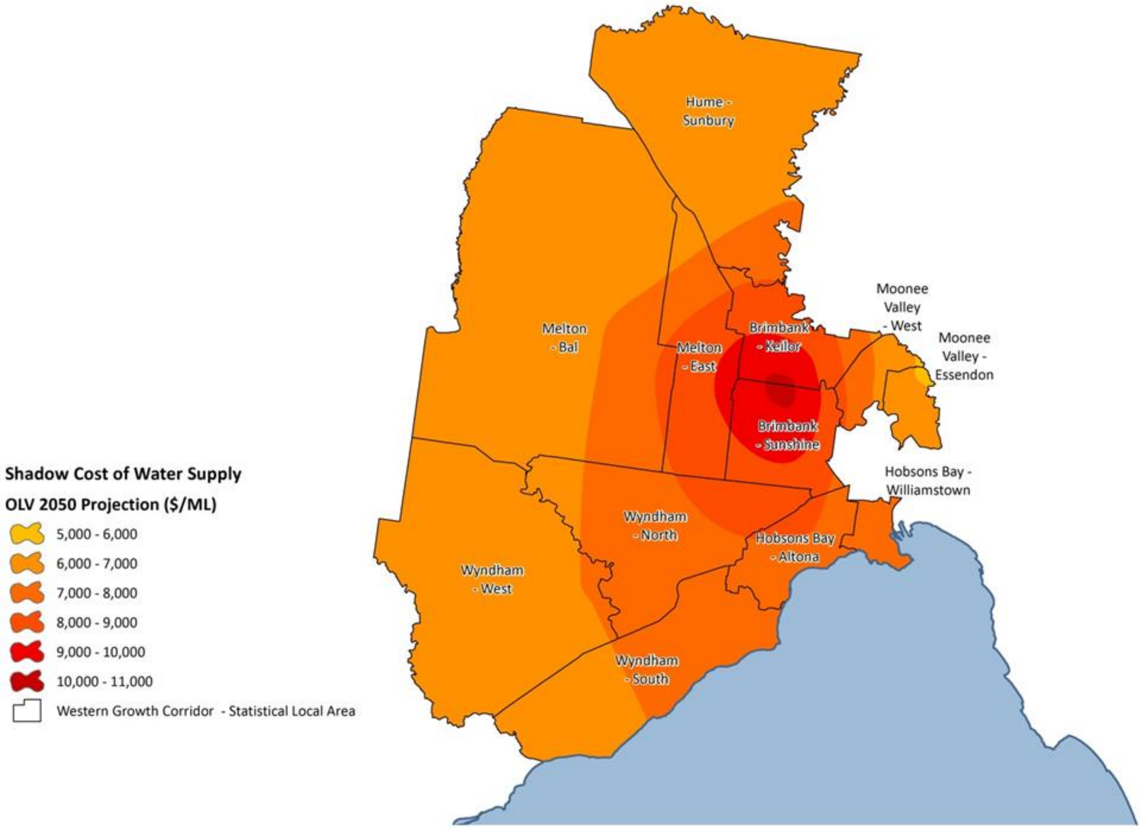


Figure 2.9: Shadow costs of water services

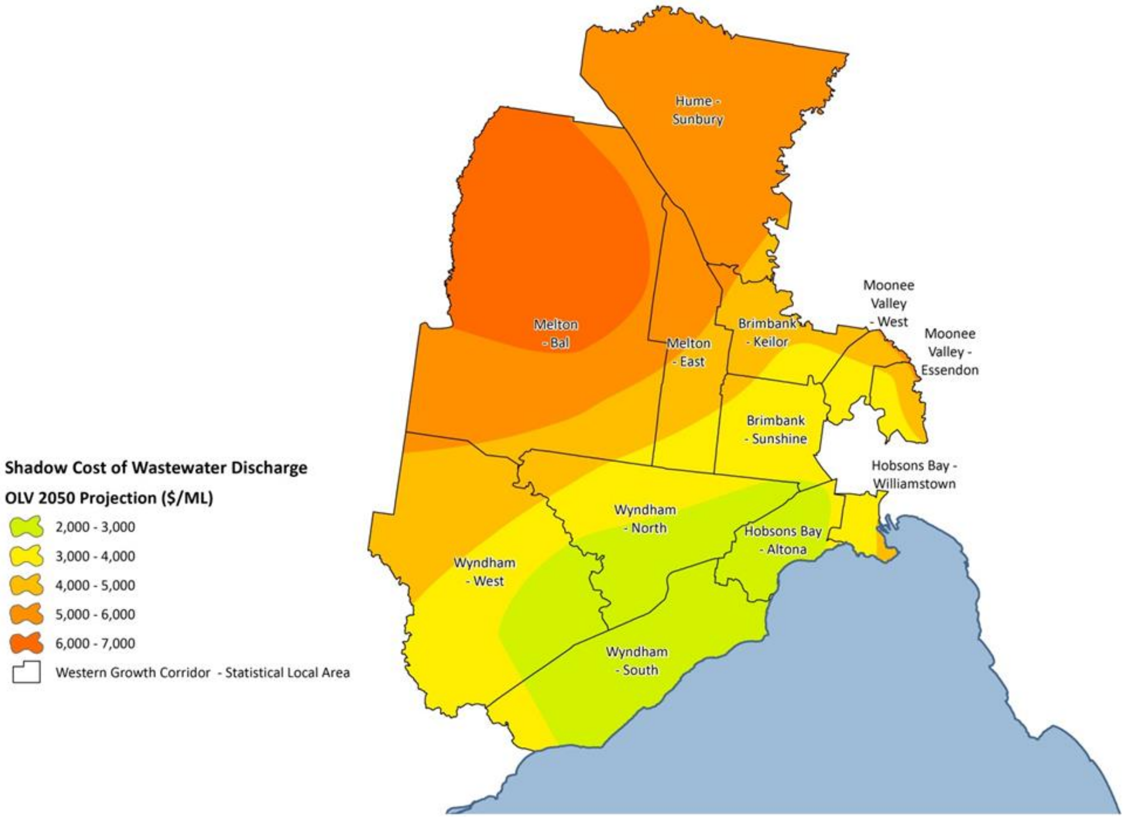


Figure 2.10: Shadow costs of wastewater services

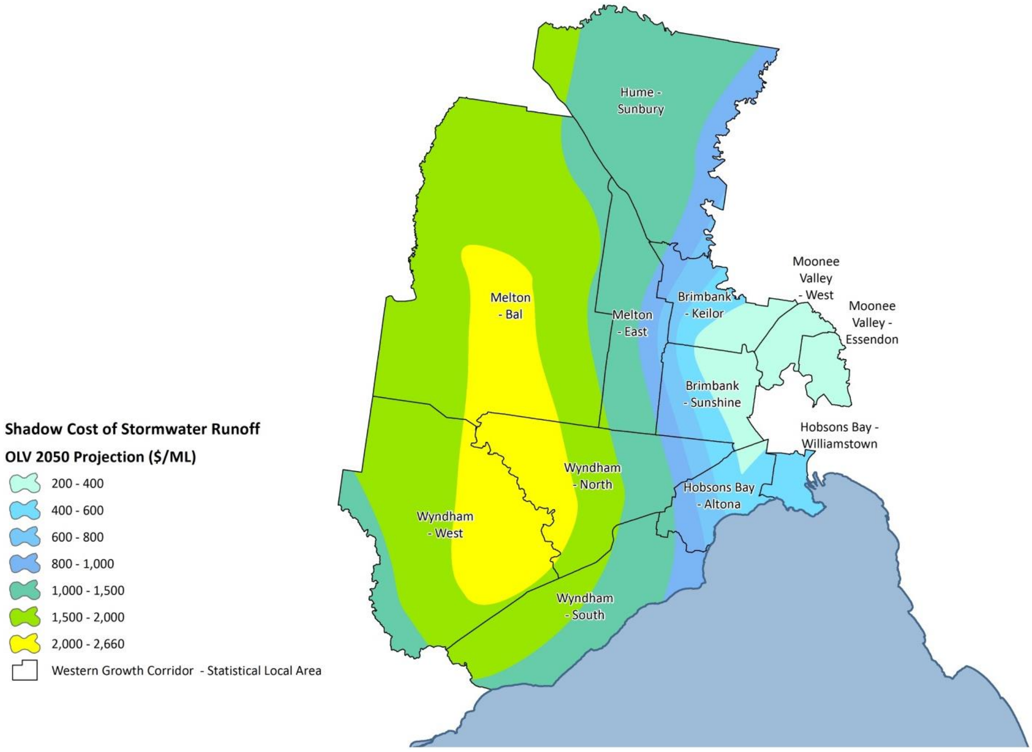


Figure 2.11: Shadow costs of stormwater management

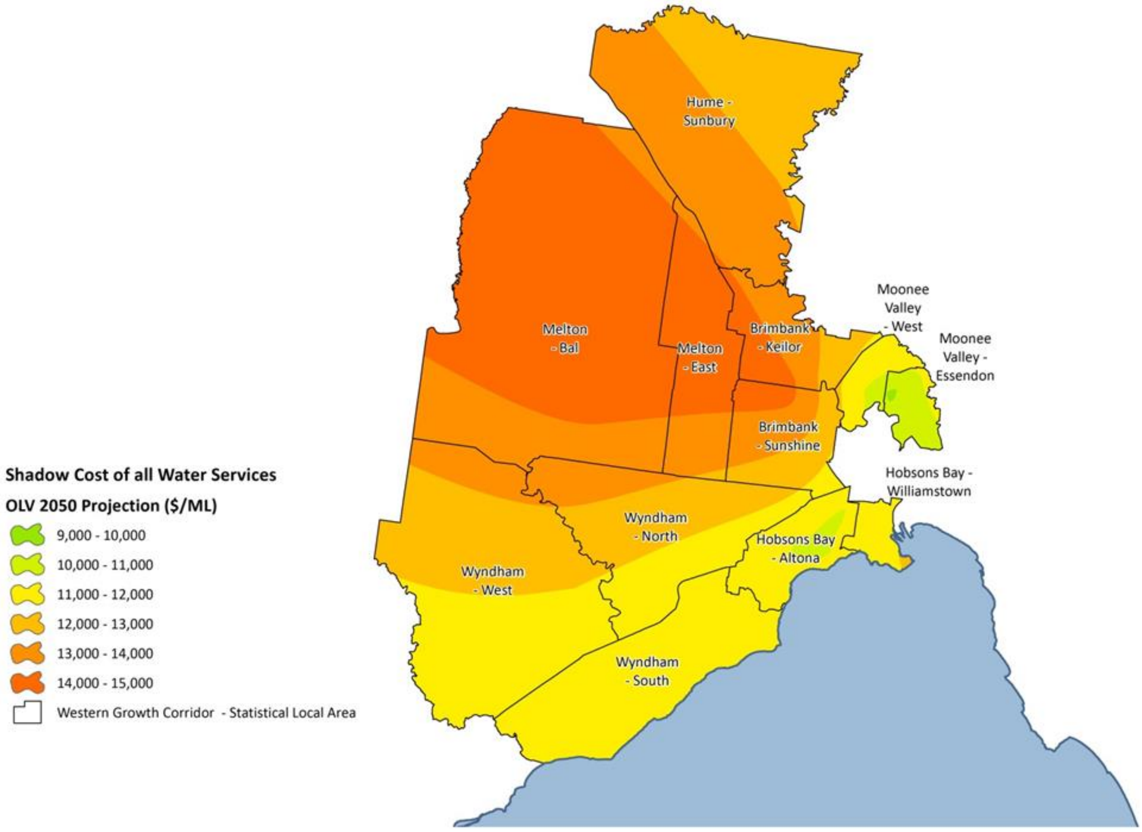


Figure 2.12: Water cycle shadow costs

Figure 2.12 reveals that the water cycle shadow costs range from $12,000/ML to $12,000/ML at location of the East Werribee Precinct. These results indicate that there is substantial value in local management of the water cycle in this region to offset the whole of Melbourne costs of providing services.

3 Methods

This study utilised the integrated systems approach detailed in previous IWCM report by Coombes and Bonacci Water to analyse the performance of the proposed stormwater treatment train for the East Werribee Employment Precinct. The analysis is dependent on detailed inputs including topography, climate, hydrology and hydraulics, and integrated systems analysis methods.

The topography of the Werribee area was derived from photogrammetry and LiDar data provided by the Department of Sustainability and Environment, Melbourne Water and augmented with field survey data. The layout, topography and geology of the catchments were incorporated into a digital terrain model (DTM). Information about existing conditions at the site and in the upstream catchments was sourced from Wyndham City Council and Melbourne Water, and verified by field inspections and surveys.

A preliminary master plan for urban development in the Precinct was provided by the Growth Areas Authority (GAA). This allowed assessment of the density of development and proportions of impervious surface. It is important to have an interactive process between urban planners and the designers of water cycle systems to identify the often hidden benefits of integrated water cycle management (IWCM) and water sensitive urban design (WSUD).

This study used a hydrological model (WUFS) from the University of Newcastle and a two-dimensional hydraulic model (TUFLOW) to analyse the stormwater runoff and the extent of flooding generated by different options. The WUFS model is a variant of ILSAX that utilises the accepted methods and design storm events published in Australian Rainfall and Runoff by Engineers Australia. This model was chosen because it is the only software package that has the capability for robust analysis of integrated stormwater design strategies such as combinations of WSUD and traditional drainage methods.

Analysis of the extent of flooding generated by 1 to 100 year average recurrence interval (ARI) storm events was conducted using TUFLOW that utilised the digital terrain model (DTM) and stormwater runoff hydrographs for each catchment generated by the WUFS model. The results from the analysis of flooding were mapped using the vertical mapping functionality provided with the geographical information systems (GIS) software Mapinfo.

3.1 Stormwater Quality

A comparative analysis of stormwater quality at key locations within the Werribee Employment Precinct was integrated with the hydrological simulations. Four key reference locations at Upper Skeleton Creek (D), Upper Point Cook (B and C) and Werribee Employment precinct (A) were nominated for assessment of stormwater quality targets (see Figure 2.1). Analysis of the impacts of urban development on waterways was conducted using the continuous simulation model MUSIC (Version 5) from eWater CRC and the hydrological model. The MUSIC model was used to analyse the efficiency of the proposed stormwater system for:

- Stormwater quality,
    - Total Suspended Solids
    - Total Phosphorus
    - Total Nitrogen

- Gross Pollutants

- Average annual runoff volumes, and
- Frequency of stormwater runoff as indicated by average annual runoff days.

Stormwater quality measures were designed using MUSIC to meet "best practice" targets described earlier in this report. The hydrological model was used to determine a no worsening of stormwater peak discharges for 1 and 2 year ARI storm events to protect waterways from erosion and sedimentation. These design parameters serve the dual purpose of protecting waterway health and improving the amenity of waterways. Details of the rainfall record utilised in the analysis of stormwater quality are shown in Table 3.1.

Table 3.1: Rainfall record used in the analysis of stormwater quality and flows

Record	Start date	End date	Annual rainfall (mm/yr)	Length (years)
Werribee	7/05/1968	29/06/1980	586	12

Information from the survey of geological and soil profiles for the Wyndham area is presented in Table 3.2.

Table 3.2: Extent of inundation within the Werribee Employment Precinct

Soil depth (m)	Soil type
0 – 0.1	Clayey silt
0.1 – 0.6	Heavy clay
0.6 – 0.9	Medium clay
0.9 – 1.0	Regolith basalt

Table 3.2 shows that the soil profile for Wyndham primarily consists of clay composites over basalt bedrock. The resultant assumptions about soils in Wyndham for use in the MUSIC model are listed in Table 3.3.

Table 3.3: Extent of inundation within the Werribee Employment Precinct

Criteria	Value
Soil storage capacity (mm)	30
Initial storage (% of capacity)	30
Field capacity (mm)	20
Infiltration capacity coefficient - a	100
Infiltration capacity exponent	1

The schematics from the MUSIC model of the East Werribee site is presented in Figure 3.1.

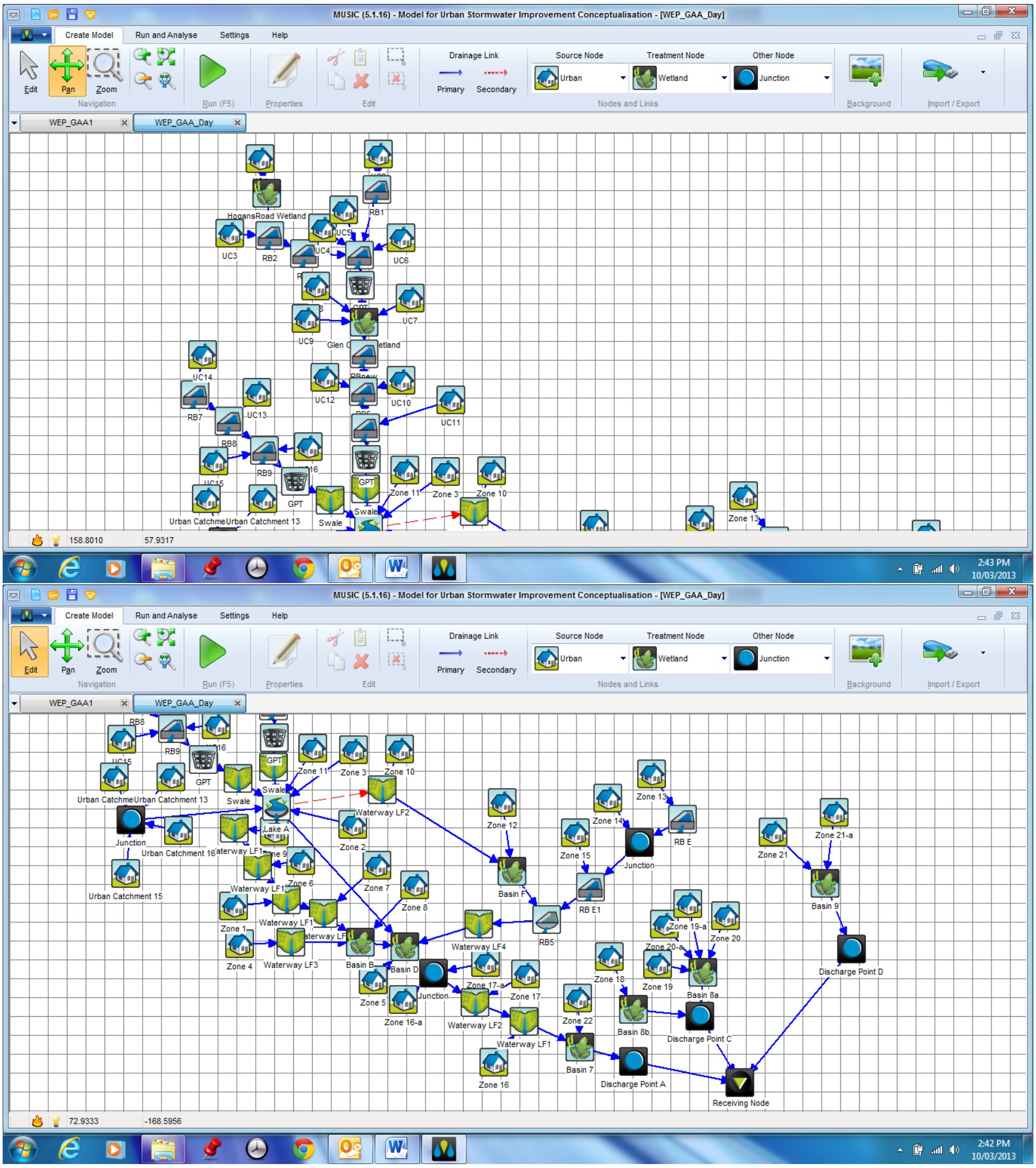


Figure 3.1: Schematic from the MUSIC model used in this investigation

3.2 Topography and existing infrastructure

The topography of the Werribee area was derived from photogrammetry and LiDar data provided by the Department of Sustainability and Environment, Melbourne Water and augmented with field survey data. The topography, geology and catchments of the area were combined in a digital terrain model (DTM).

This information was analysed using the 12D civil design package and Mapinfo Vertical Mapper to create a DTM with 3 metre grid spacing for the site. A fine grid of topographical information was required to adequately capture the variable terrain and low lying areas. Continuous elevation strings were included in the model to account for significant features including road structures, channels and embankments.

Details of existing stormwater infrastructure (including culverts, wetlands and detention basins) in the Werribee Employment Precinct and in the surrounding Werribee catchments were sourced from Wyndham City Council, the Department of Sustainability and Environment, Melbourne Water and from the infrastructure report prepared by ARUP. Additional information to complete the understanding of existing infrastructure and conditions was obtained from field inspections. The digital terrain model of the Werribee Employment Precinct is shown in Figure 3.2.

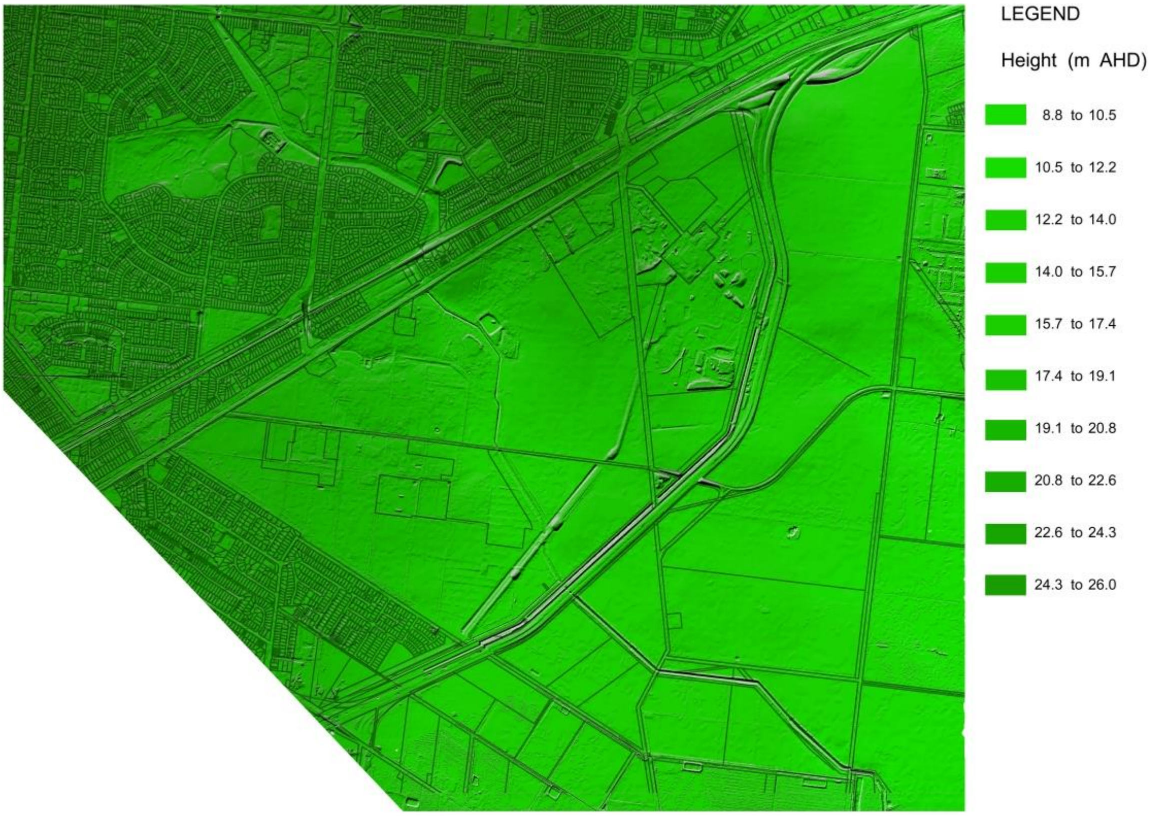


Figure 3.2: Digital terrain model and the cadastre at the East Werribee Employment Precinct and surrounding area

3.3 Hydrology

The assessment of the stormwater runoff characteristics of the site in the existing and developed states was undertaken using WUFS (Water Urban Flow Simulator) developed at the University of Newcastle.[4]

The WUFS program is the only reliable analysis tool available to industry that can compare traditional drainage solutions to water sensitive urban design solutions or analyse combinations of both. The WUFS software was until recently freely available to industry from the website www.eng.newcastle.edu.au/~cegak in a similar mode to the availability of ILSAX. Note that both ILSAX and WUFS are freeware that are recommended for research and investigation purposes.

[4] Kuczera, G., Williams, B., Binning, P. and Lambert, M., (2000). An education web site for free water engineering software. 3rd International Hydrology and Water Resources Symposium. Institution of Engineers Australia. Perth. Western Australia. 1048 – 1053.

WUFS has been developed from the ILSAX algorithms. The more simplistic Rational Method calculations were not employed in this study (other than for calibration purposes) because this type of method does not account for the volumes of rainfall in storm events and the range of initial conditions that impact on stormwater runoff.

The defined stormwater sub-catchments and design storm parameters from Australian Rainfall and Runoff [5] were used in the WUFS model to analyse the performance of the stormwater sub-catchments. The intensity frequency duration (IFD) data used in the hydrology model to simulate the performance is shown in Table 3.4.

Table 3.4: IFD data for the Werribee Employment Precinct

ARI (years)	Rainfall intensity (mm/hour) for a given duration (hours)		
	1	12	72
2	18	3.5	0.9
50	38	7	2

The WUFS model was calibrated to peak discharges in the pre-European option derived using the Rational Method at key locations within the Werribee Employment Precinct. The expected changes in rainfall intensity due to climate change have also been included in this analysis. Design storms were generated for all storm durations using a skew of 0.38 and temporal pattern region 1 as defined from Australian Rainfall and Runoff.

3.4 Design Surface

The proposed design surface reflecting the GAA master plan was created using the 12D civil design package and civil design standards to input the stormwater infrastructure consisting of a Lake, wetlands, waterways, weirs, aqueducts and retarding basins; into the existing digital terrain model (DTM) as shown in Figure 3.3. The treatment train was created by applying the volume required to successfully mitigate the peak discharges to the available land take footprint defined in the concept master plan.

[5] IEAust., (2001). Australian rainfall and runoff: a guide to flood estimation. Vols. 1 and 2. The Institution of Engineers, Australia.

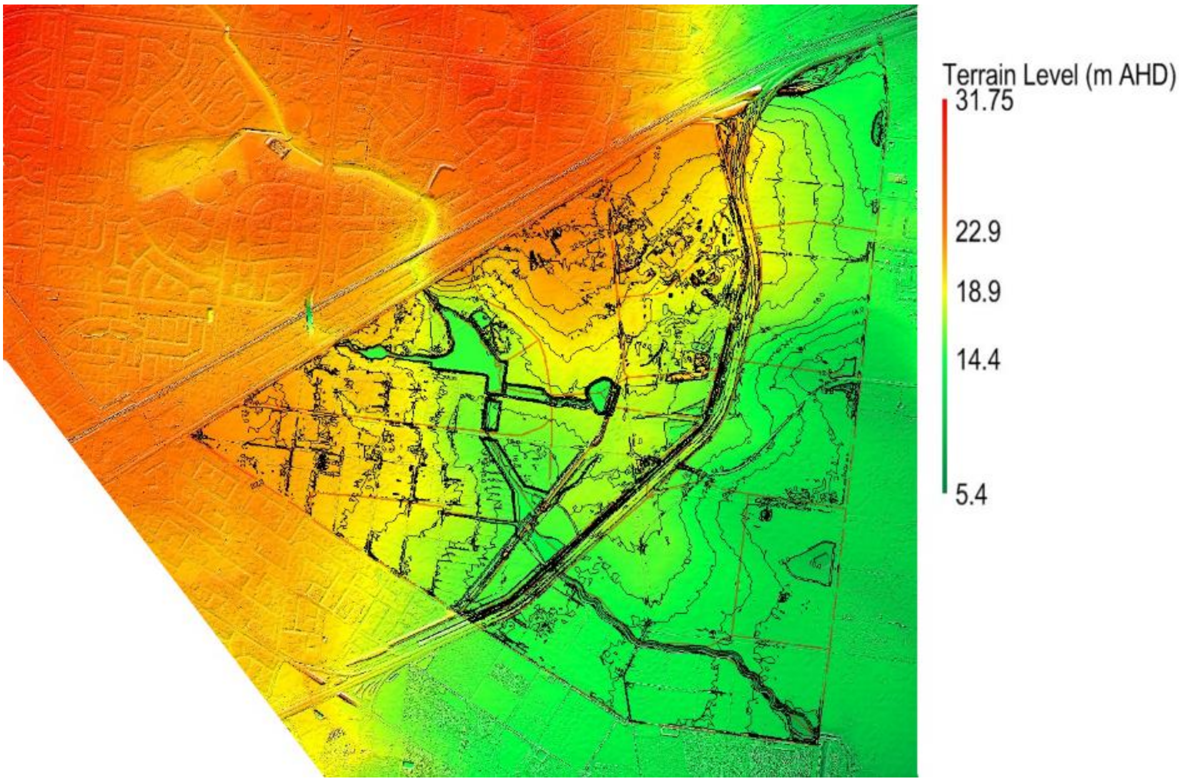


Figure 3.3: Design digital terrain model East Werribee Employment Precinct and surrounding area

3.5 New inputs for the East Werribee Precinct

The preliminary urban structure Master Plan for East Werribee Employment Precinct addresses current growth area planning, land uses and government objectives for the site. Outcomes from the preplanning studies were adopted in the investigation. The preliminary structure plan was used in this study to develop zones or developed stormwater catchments as shown in Figure 3.4.

Figure 3.4: The stormwater catchments and development zones derived from the preliminary structure plan

The areas of each development zone are shown in Table 3.5.

Table 3.5: Catchment areas derived from the preliminary structure plan

Catchment	Area (ha)	Catchment	Area (ha)
1	84.67	15	13.7
2	42.99	16	78.69
3	14.76	17	71.79
4	47.69	18	48.79
5	10.1	19	64.52
6	11.43	20	57.5
7	13.22	21	20.05
8	32.63	21	72.82
9	8.99	16-a	3.5
10	6.6	17-a	5.31
11	14.05	19-a	7.2
12	69.24	20-a	6.51
13	52.41	21-a	9.48
14	40.43	Lake	11.23

The proportions of impervious surfaces for each land use shown in Table 3.6 were adopted for this study.

Table 3.6: Proportions of impervious surfaces versus land use

Land Use	Impervious (%)	Land Use	Impervious (%)
Arterial Roads	85	Open Space	25
Commercial Mixed Use	80	Reserve For Future Growth	80
Enterprise	60	Retarding Basin	10
Freeway	80	School	60
Community Centre	65	Town Centre	85
Green Corridor	10	Historical Sewer Easement	40
Heritage	40	Water Body	100
Local Roads	80	Education and Health	50
Medium Density Housing	80	Sewer Pump Station	75
New Community Residential	70	Indoor Centre	90

Analysis using the zones shown in Figure 3.4 and details outlined in Table 3.5 and 3.6 provides a reasonable indication of potential land uses that allows evaluation of various water cycle management strategies.

The new Master Plan for the site has required the conceptual design of the stormwater storages shown in Figure 5.3 and Table 3.7.

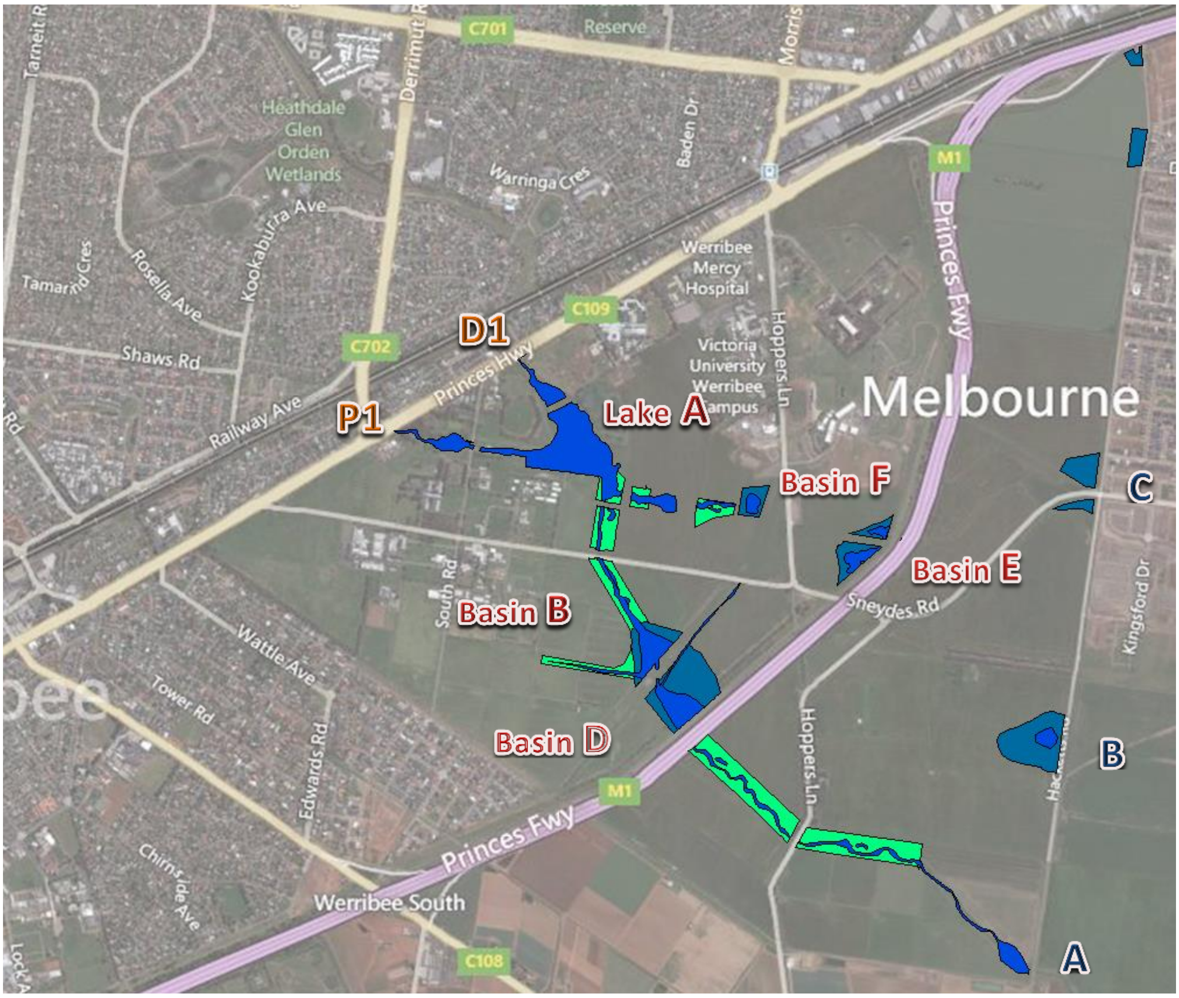


Figure 3.5: Overview of redesigned stormwater treatment train within the East Werribee Precinct

Table 3.7: Summary of retarding basins within the East Werribee precinct

Retarding basin	Surface area (m^2)	Storage volume (m^3)	Permanent Pool (m^3)	Invert (m AHD)	Top (m AHD)
Lake A	182,863	307,477	263,930	15.3	19
Basin B	80,171	59,251	7,134	14.7	19
Basin D	144,692	174,136	14,538	14	17
Basin E	27,144	45,455	-	15.2	17.2
Basin F	66,174	88,909	107,689	14.7	19

The details of Lake A are provided in Figure 3.6 and Table 3.8.

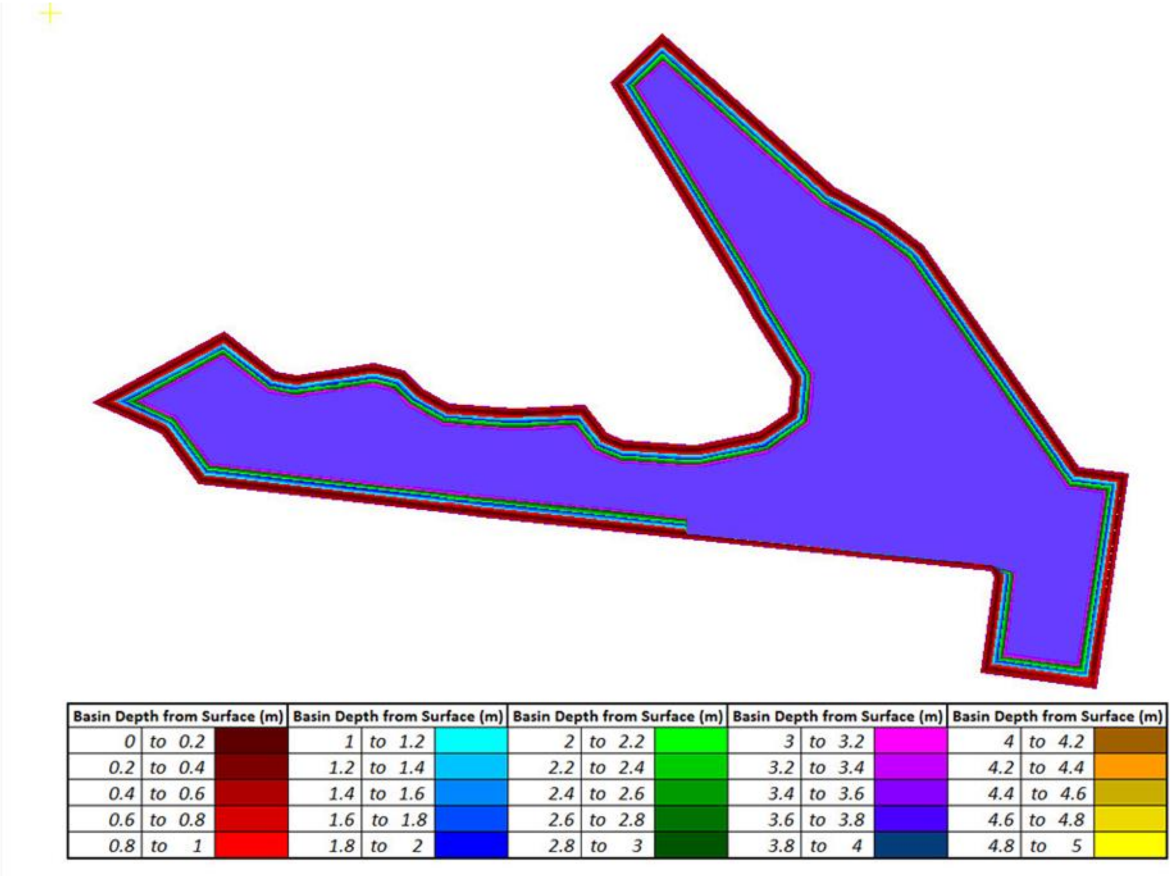


Figure 3.6: Extent of storage for Lake A

Table 3.8: Details of the Lake A system

Comments	Elevation (m AHD)	Storage (m³)
IL Basin	15.3	0
	15.5	28,949
IL of 600mm dia. Low Flow pipe	16	103,758
	16.5	182,014
IL of 1800mm dia. siphon	17	263,930
IL of weir (30m wide)	17.5	349,360
	18	438,401
100 year TWL	18.33	499,227
300mm Freeboard; IL of weir (20m wide)	18.7	571,407
Basin Top of Bank	19	633,972

The details of Basin F are provided in Figure 3.7 and Table 3.9.

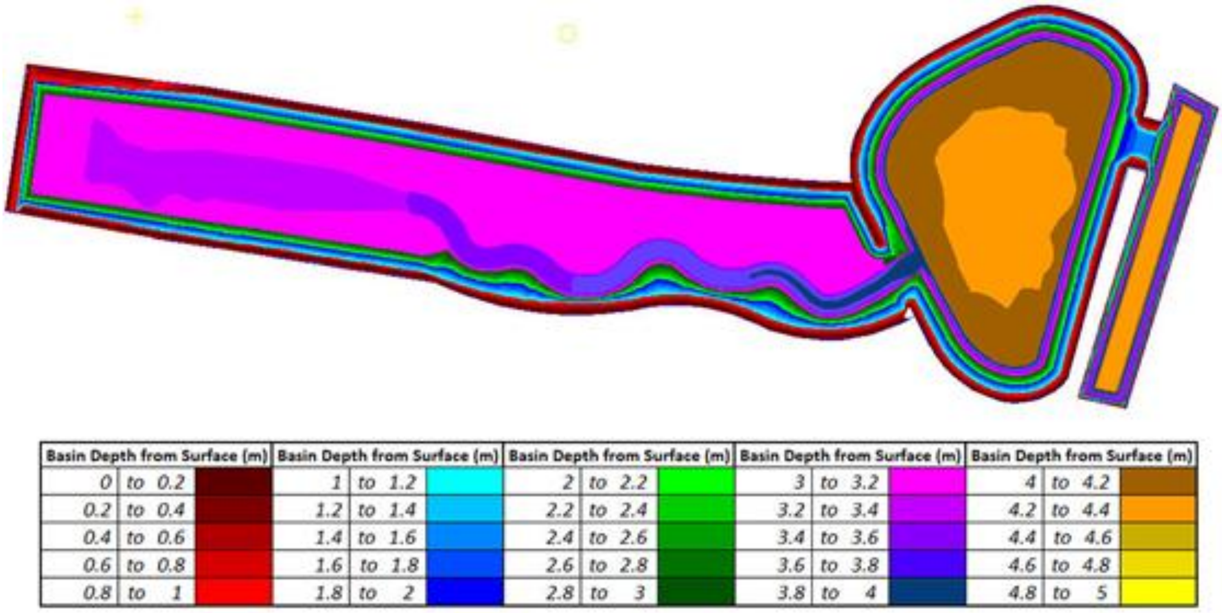
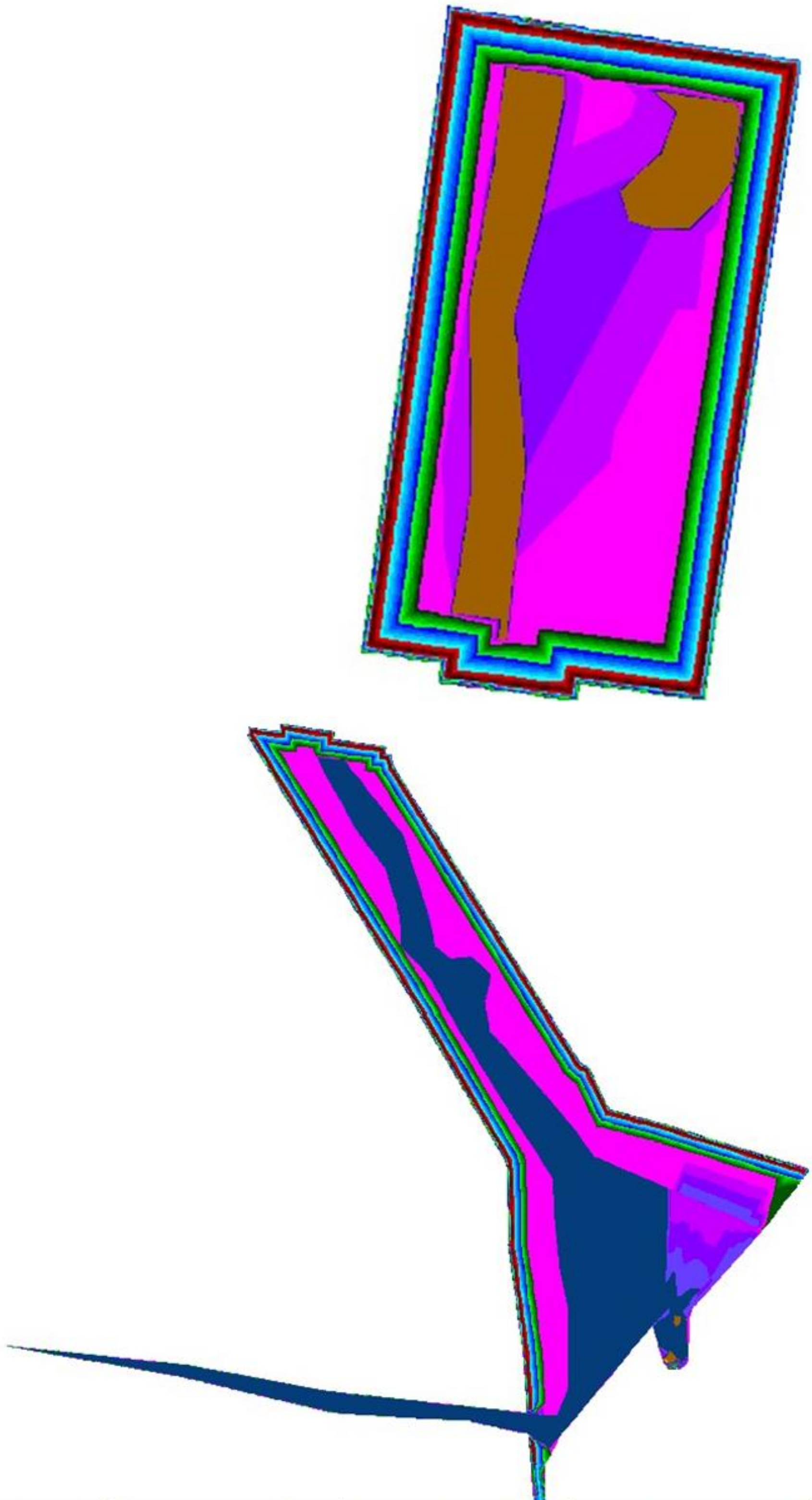


Figure 3.7: Extent of storage for Basin F

Table 3.9: Details of the Basin F

Comments	Elevation (m AHD)	Storage (m^3)
IL Basin	14.7	0
	15	3,244
IL 2 No. 2400mm x 2100mm box culvert	15.5	13,385
	16	23,148
	16.5	54,627
	17	83,213
IL of weir (30m wide)	17.4	107,689
	17.5	114,039
100 year TWL	18.16	158,084
300mm Freeboard	18.70	196,598
Basin Top of Bank	19	219,202

The details of Basin B are provided in Figure 3.8 and Table 3.10.



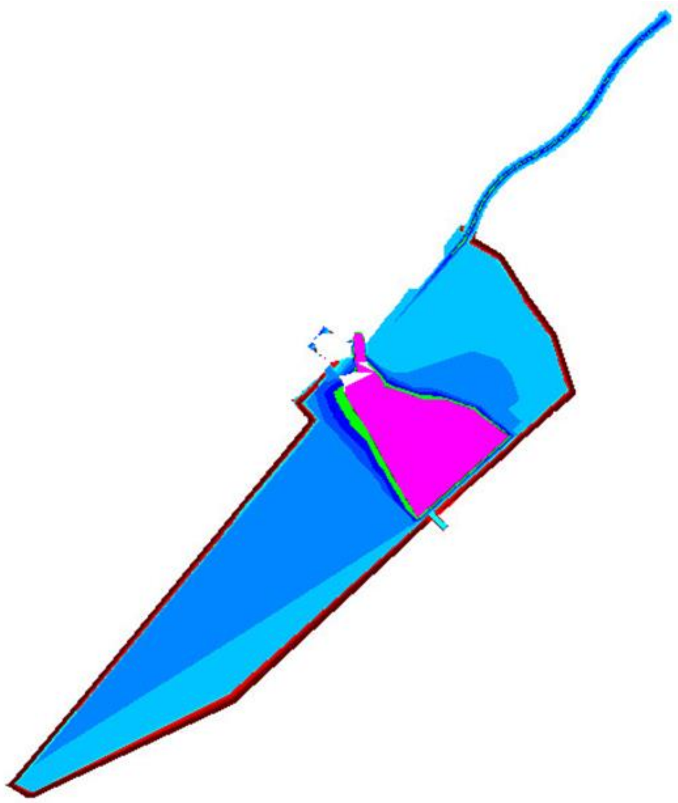
Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)	
0 to 0.2		1 to 1.2		2 to 2.2		3 to 3.2		4 to 4.2	
0.2 to 0.4		1.2 to 1.4		2.2 to 2.4		3.2 to 3.4		4.2 to 4.4	
0.4 to 0.6		1.4 to 1.6		2.4 to 2.6		3.4 to 3.6		4.4 to 4.6	
0.6 to 0.8		1.6 to 1.8		2.6 to 2.8		3.6 to 3.8		4.6 to 4.8	
0.8 to 1		1.8 to 2		2.8 to 3		3.8 to 4		4.8 to 5	

Figure 3.8: Extent of storage for Basin B

Table 3.10: Details of the Basin B

Comments	Elevation (m AHD)	Storage (m^3)
IL of basin	14.7	0
	15.5	5,600
IL of 1200mm diam. Culvert	15.05	7,133
	15.5	22,330
100 Year TWL	15.98	47,931
	16	49,113
IL of weir (30m wide)	16.5	80,430
300mm Freeboard	18.3	211,641
Basin top of bank	18.6	235,799

The details of Basin D are provided in Figure 3.9 and Table 3.11.



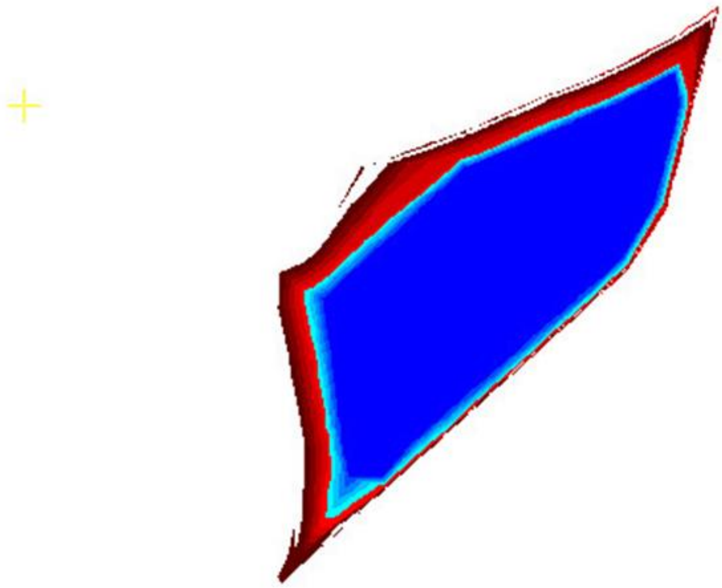
Basin Depth from Surface (m)	Basin Depth from Surface (m)	Basin Depth from Surface (m)	Basin Depth from Surface (m)	Basin Depth from Surface (m)
0 to 0.2	1 to 1.2	2 to 2.2	3 to 3.2	4 to 4.2
0.2 to 0.4	1.2 to 1.4	2.2 to 2.4	3.2 to 3.4	4.2 to 4.4
0.4 to 0.6	1.4 to 1.6	2.4 to 2.6	3.4 to 3.6	4.4 to 4.6
0.6 to 0.8	1.6 to 1.8	2.6 to 2.8	3.6 to 3.8	4.6 to 4.8
0.8 to 1	1.8 to 2	2.8 to 3	3.8 to 4	4.8 to 5

Figure 3.9: Extent of storage for Basin D

Table 3.11: Details of the Basin D

Comments	Elevation (m AHD)	Storage (m^3)
IL Basin	14	0
	14.5	9,039
IL of siphon 1200mm dia.	14.8	14,538
	15	18,475
	15.5	32,229
IL aqueduct	16	89,299
	16.5	159,849
300mm Freeboard; 100 year TWL	16.7	188,674
Basin Top of Bank	17	233,172

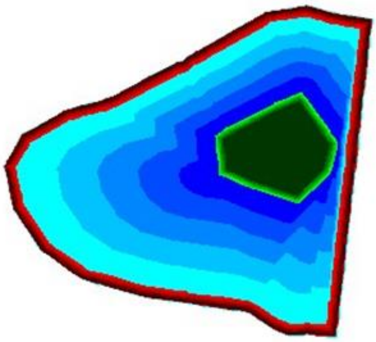
The details of Basin E are provided in Figure 3.10.



Basin Depth from Surface (m)	Basin Depth from Surface (m)	Basin Depth from Surface (m)	Basin Depth from Surface (m)	Basin Depth from Surface (m)
0 to 0.2	1 to 1.2	2 to 2.2	3 to 3.2	4 to 4.2
0.2 to 0.4	1.2 to 1.4	2.2 to 2.4	3.2 to 3.4	4.2 to 4.4
0.4 to 0.6	1.4 to 1.6	2.4 to 2.6	3.4 to 3.6	4.4 to 4.6
0.6 to 0.8	1.6 to 1.8	2.6 to 2.8	3.6 to 3.8	4.6 to 4.8
0.8 to 1	1.8 to 2	2.8 to 3	3.8 to 4	4.8 to 5

Figure 3.10: Extent of storage for Basin E

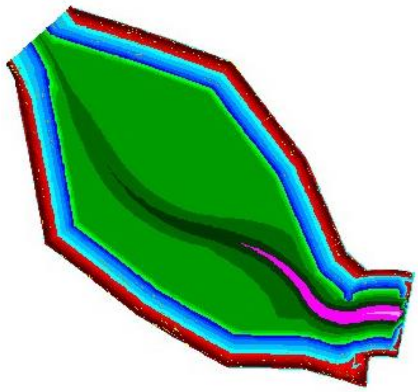
The details of the retarding basin in the upper Point Cook Catchment at discharge point B are provided in Figure 3.11.



Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)	
0 to 0.2		1 to 1.2		2 to 2.2		3 to 3.2		4 to 4.2	
0.2 to 0.4		1.2 to 1.4		2.2 to 2.4		3.2 to 3.4		4.2 to 4.4	
0.4 to 0.6		1.4 to 1.6		2.4 to 2.6		3.4 to 3.6		4.4 to 4.6	
0.6 to 0.8		1.6 to 1.8		2.6 to 2.8		3.6 to 3.8		4.6 to 4.8	
0.8 to 1		1.8 to 2		2.8 to 3		3.8 to 4		4.8 to 5	

Figure 3.11: Extent of storage for the retarding basin in the upper Point Cook Catchment at discharge point B

The details of the retarding basin in the upper Point Cook Catchment at discharge point B are provided in Figure 3.12.



Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)		Basin Depth from Surface (m)	
0 to 0.2		1 to 1.2		2 to 2.2		3 to 3.2		4 to 4.2	
0.2 to 0.4		1.2 to 1.4		2.2 to 2.4		3.2 to 3.4		4.2 to 4.4	
0.4 to 0.6		1.4 to 1.6		2.4 to 2.6		3.4 to 3.6		4.4 to 4.6	
0.6 to 0.8		1.6 to 1.8		2.6 to 2.8		3.6 to 3.8		4.6 to 4.8	
0.8 to 1		1.8 to 2		2.8 to 3		3.8 to 4		4.8 to 5	

Figure 3.12: Extent of storage for the retarding basin at discharge point A

The details of the Lake and Basins from this Section were used in the systems analysis of the East Werribee site.

4 Results

The purpose of this investigation was to complete supplementary analysis of the performance of the East Werribee site to incorporate the changes in the planning strategy and new stormwater management strategies proposed by the Growth Areas Authority (GAA). This Chapter presents impacts of the changes on the hydraulic, water balance and stormwater quality performance of the site.

4.1 Hydraulics

The extent of flooding generated by stormwater runoff from 100 year average recurrence interval (ARI) storm events is shown in Figure 4.1.

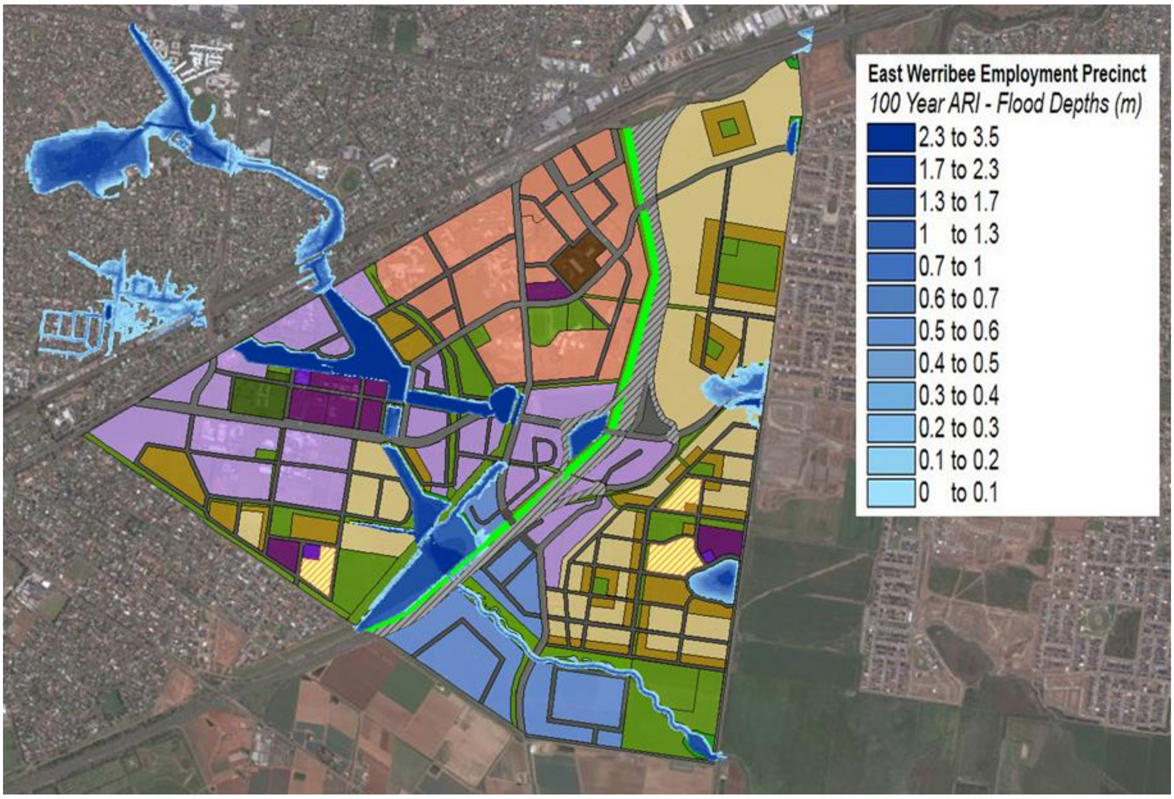


Figure 4.1: Extent of flooding from 100 year ARI storm events in the developed catchments

Figure 4.1 reveals that the amended retarding basin and constructed wetland in the upper catchment, and the restored waterways and new retarding basins within Werribee Employment Precinct provides significant mitigation of flooding in the D1 Drain catchment.

Note that the strategy generates small overtopping of the inlet to Lake A from the D1 drain catchment and at Basin E that can be addressed during the design phase for the infrastructure. It is expected that slight alterations of inlet conditions, storage volumes and areas of fill. The extent of inundation from flooding is shown in Table 4.1.

Table 4.1: Extent of inundation within the Werribee Employment Precinct for 100 year ARI storm events

Inundation at depth	Area of flood (ha)	
	Design	Existing
Full extent	69.7	391
> 50 mm	66.5	230
> 100 mm	65.2	172

Table 4.1 demonstrates that the proposed stormwater management strategy will provide substantial reductions in the extent of flooding at the site in comparison to existing flooding. The extent of flooding generated 50 year ARI storm events is shown in Figure 4.2.

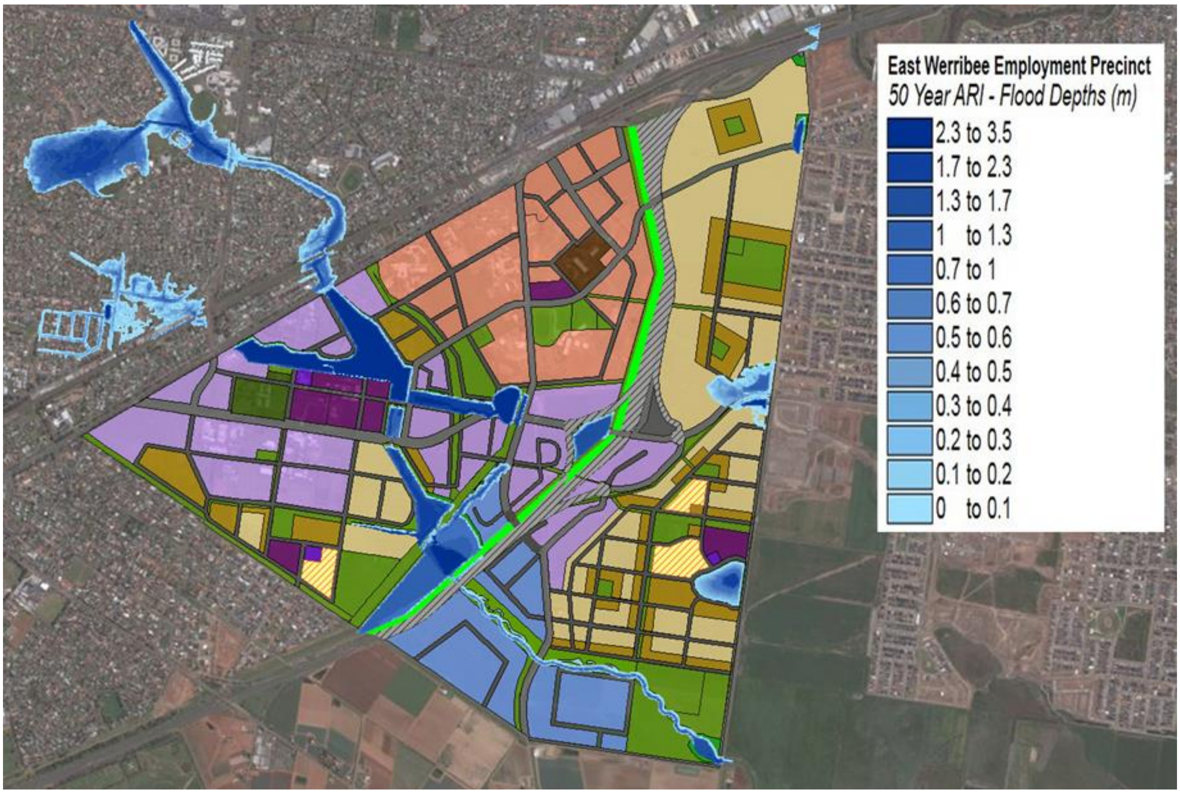


Figure 4.2: Flood overlays generated by 50 year ARI storm events

Figures 4.1 and 4.2 reveal that the stormwater management strategy distributes stormwater between the various storages upstream of the Maltby Bypass to maximise protection from flooding throughout the surrounding areas. The extent of flooding generated 20 and 10 year ARI storm events is shown in Figures 4.3 and 4.4.

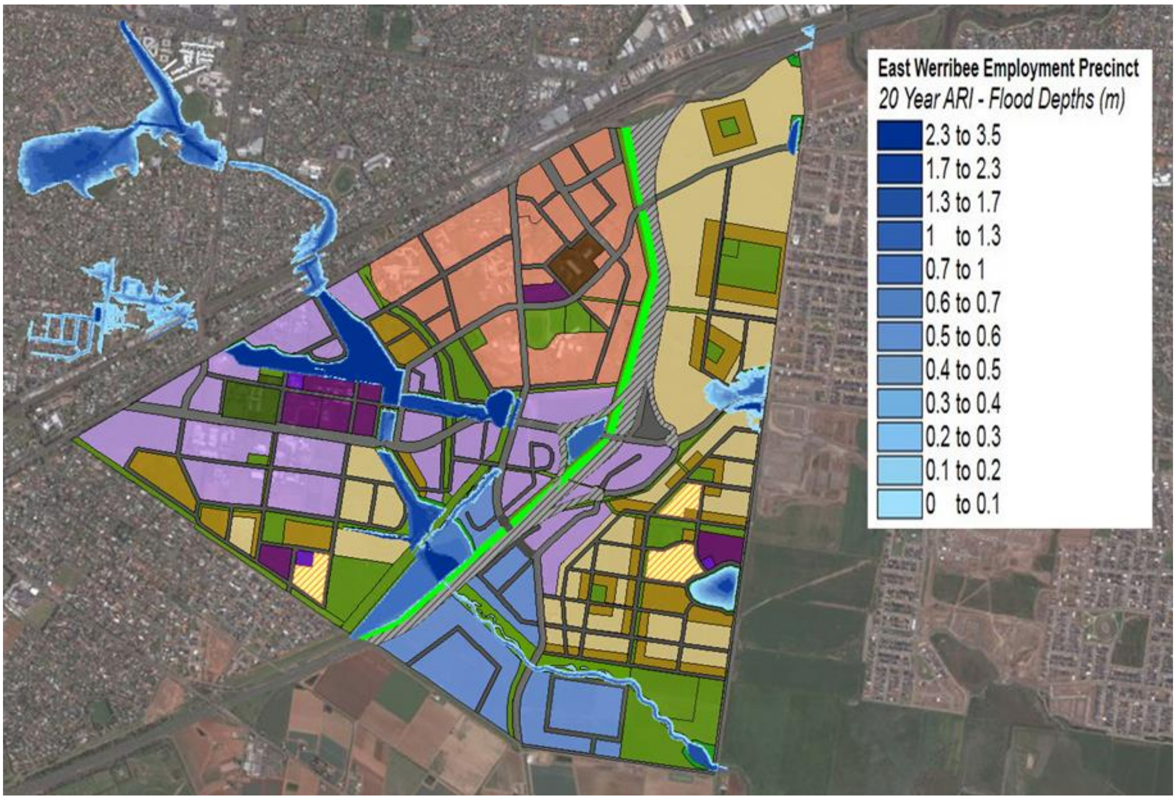


Figure 4.3: Flood overlays generated by 20 year ARI storm events

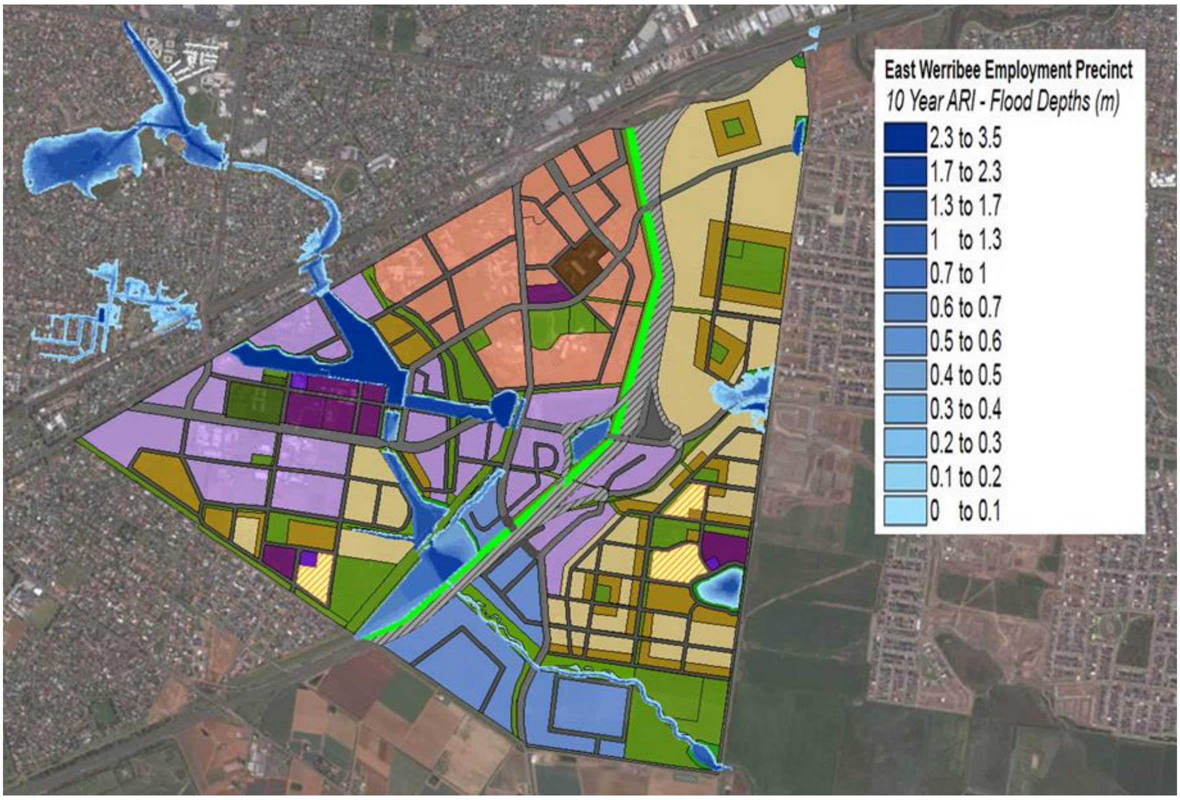


Figure 4.4: Flood overlays for generated by 10 year ARI storm events

The extent of flooding generated 5 and 2 year ARI storm events is shown in Figures 4.5 and 4.6.

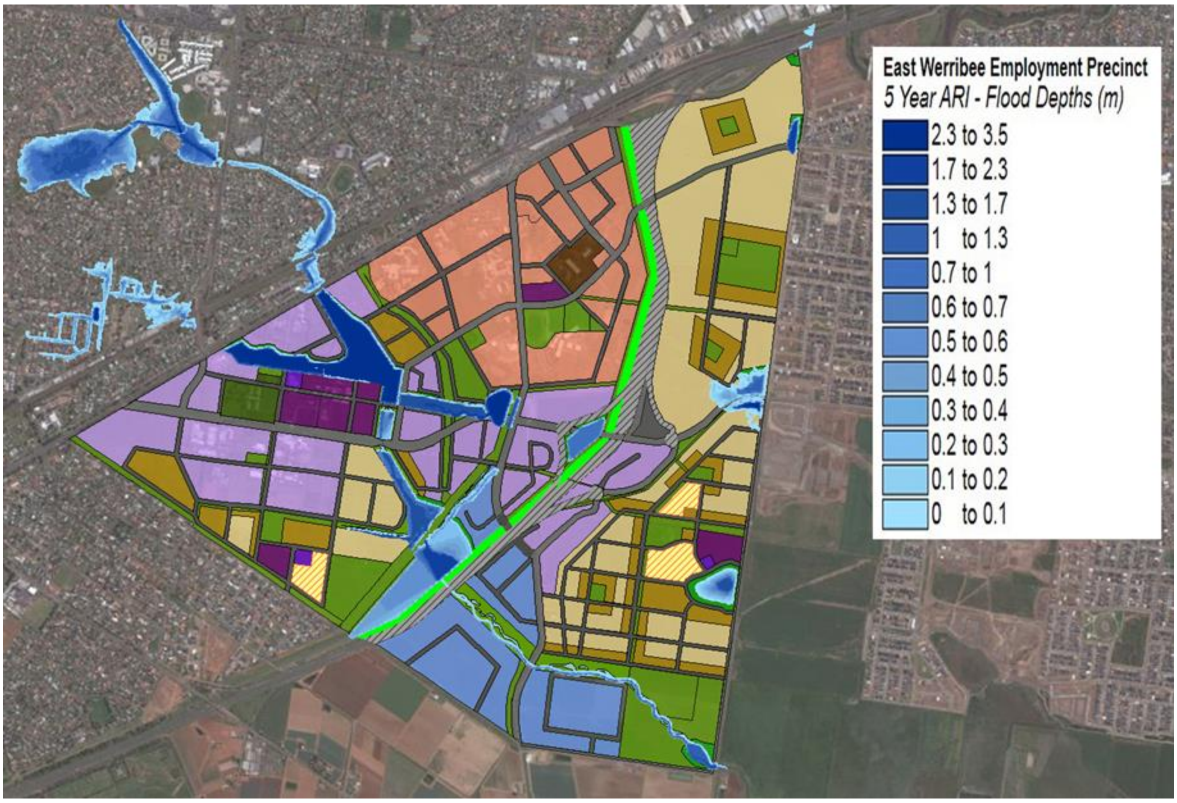


Figure 4.5: Flood overlays for generated by 5 year ARI storm events

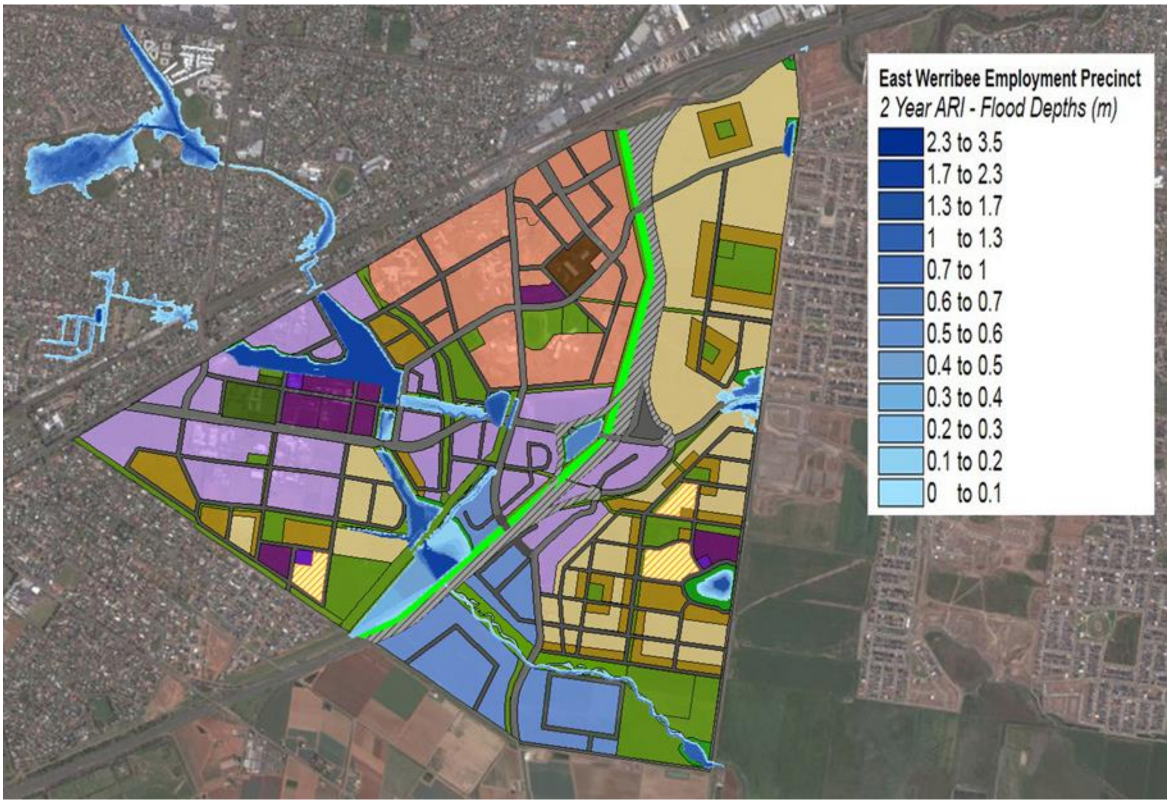


Figure 4.6: Flood overlays for generated by 2 year ARI storm events

Figures 4.3 to 4.6 demonstrate that the proposed stormwater management strategy will provide mitigation of the substantial inflows from upstream catchments generated by more frequent storm events. The extent of flooding generated 1 year ARI storm events is shown in Figure 4.7.

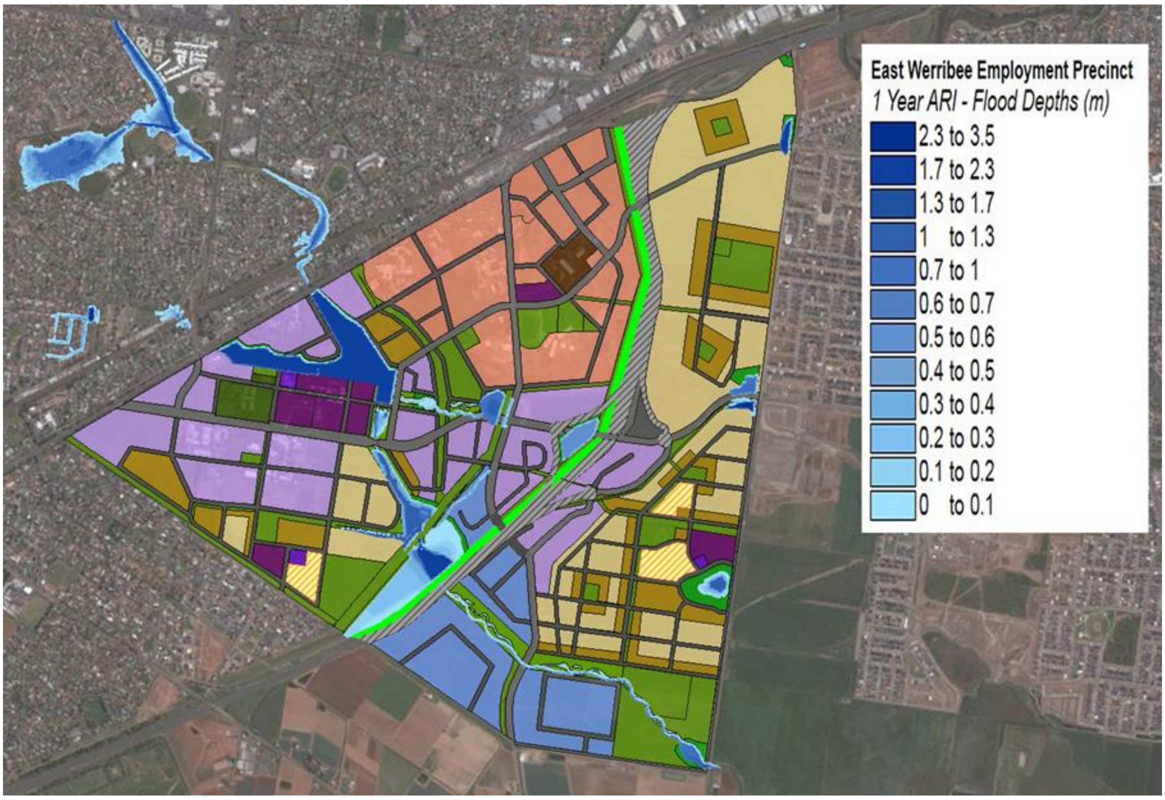


Figure 4.7: Flood overlays for generated by 1 year ARI storm events

Figure 4.7 highlights that the proposed stormwater management strategy will also act to manage high frequency stormwater discharges. The strategy also provides management of erosion and sedimentation, and the quality of stormwater discharging to downstream waterways. The extent of flooding generated by storm events of different ARIs is provided in Table 4.2.

Table 4.2: Extent of flooding generated by storm events of different ARI (years)

ARI (years)	Extent of flooding (Ha)		
	Full Extent	Depth >50mm	Depth >100mm
1	46.1	42.7	40.9
2	52.8	50.4	49.6
5	57.7	54.8	53.7
10	60.2	57.3	56.1
20	53.1	60.2	58.9
50	69.7	63.4	62.4
100	69.7	66.5	65.2

Table 4.2 reveals that the storages in the proposed stormwater management strategy are required for all storm events with frequencies between 1 and 100 years. This result is a consequence of the large stormwater catchments discharging into the Precinct and a characteristic of the integrated nature of the strategy.

4.2 Stormwater Quality

The land uses in the Master Plan from the Growth Areas Authority and infrastructure within the catchments were analysed in the analysis of stormwater quality. The MUSIC (Version 5) model was utilised to analyse the performance of the catchments.

The treatment train for the proposed Lake A includes 100 metres of vegetated waterway and a Gross Pollutant Trap (GPT) at the entry of each catchment to the Lake. The quality of stormwater entering the proposed Lake A, via the treatment train, from the P1 catchment and from the D1 catchment is presented in Table 4.3 and 4.4 respectively.

Table 4.3: Stormwater quality discharging from the P1 catchment via treatment train

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	817	817	0
Total Suspended Solids (kg/yr)	85,500	11,700	86.3
Total Phosphorus (kg/yr)	227	189	16.7
Total Nitrogen (kg/yr)	2,250	304	86.5
Gross Pollutants (kg/yr)	29,210	1,461	95

Table 4.4: Stormwater quality discharging from the D1 catchment via treatment train

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	2,570	2,570	0
Total Suspended Solids (kg/yr)	79,000	32,500	58.9
Total Phosphorus (kg/yr)	402	374	7
Total Nitrogen (kg/yr)	4,660	4,210	9.7
Gross Pollutants (kg/yr)	37,566	1,878	95

Tables 4.3 and 4.4 reveal that substantial loads of suspended solids and nutrients are generated in the upper catchments. These pollutant loads discharge via the treatment train into the proposed Lake A. Note that the proposed treatment train removes substantial masses of pollutants prior to discharge into the Lake.

The water balance from simulation of the performance of Lake A is presented in Figure 4.8.

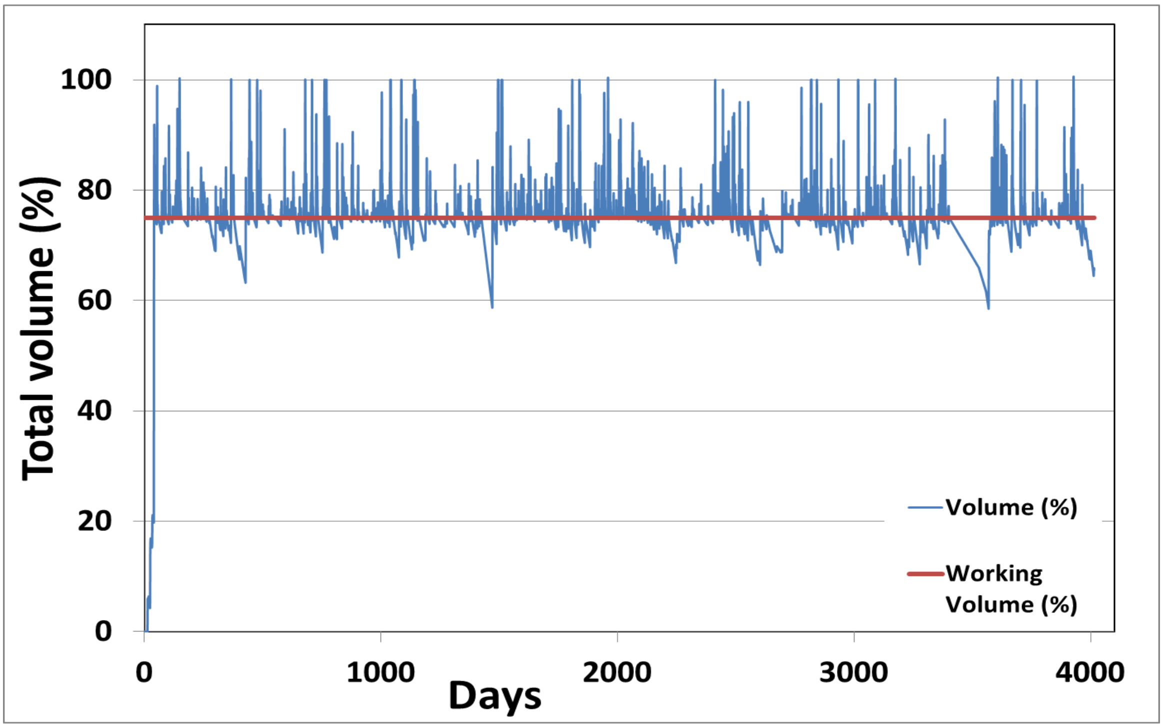


Figure 4.8: Water balance for the proposed Lake A

Figure 4.8 reveals that on 14% of days the water level in the proposed Lake A will be less that the assumed working level of the Lake. Note that the upper 25% of the Lake volume is assigned to flood management. Maintenance of the proposed working water level in the Lake will require an average annual top up volume of 531 ML from alternative water sources as shown in Figure 4.9.

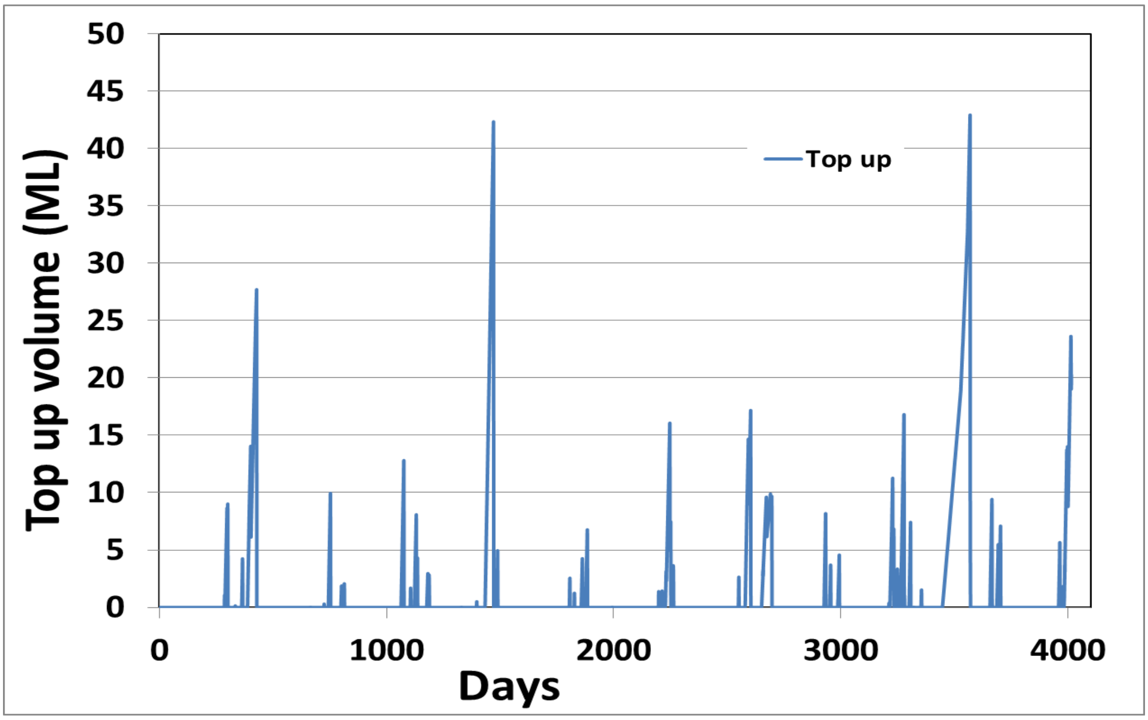


Figure 4.9: The required top up volumes to maintain the water balance of the proposed Lake A

Figure 4.9 highlights that the management of water levels in the Lake will require water from alternative sources at infrequent intervals to maintain a consistent water level. Alternatively, a strategy to allow natural variations in water levels of the proposed Lake A could be adopted. It is expected that such a strategy should consider Lake A as semi ephemeral system that includes an appropriate landscaping strategy.

The quality of stormwater discharging from Lake A is provided in Table 4.5.

Table 4.5: Stormwater quality discharging from Lake A

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	4,480	967	78.4
Total Suspended Solids (kg/yr)	268,000	44,800	83.4
Total Phosphorus (kg/yr)	1,010	225	77.4
Total Nitrogen (kg/yr)	9,380	2,260	75.9
Gross Pollutants (kg/yr)	1,461	0	100

Table 4.5 demonstrates that the proposed Lake A captures significant annual loads of sediments (203 tonnes), nutrients (6 tonnes) and gross pollutants (1.5 tonnes) whilst discharging diminished loads of pollutants to the remainder of the stormwater management system. Indeed, the conceptual treatment effectiveness of Lake A is consistent with best practice stormwater management.

However, the capture of substantial annual loads of sediment in the Lake may increase the risk of climate and ecological generated algae blooms. Installation of a treatment train to capture the majority of sediment discharging from the upper catchments prior to entering the Lake and completion of additional ecological simulations of the proposed Lake A is recommended.

The quality of stormwater entering Basin B (formerly RB 3) is provided in Table 4.6. Note that the catchments downstream of Lake A discharge into Basin B via 800 metres of vegetated waterway and the Basin also accepts high level overflows from Lake A.

Table 4.6: Stormwater quality discharging from Basin B

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	612	279	54.3
Total Suspended Solids (kg/yr)	57,400	7,670	86.6
Total Phosphorus (kg/yr)	157	33.6	78.7
Total Nitrogen (kg/yr)	1,610	626	61.2
Gross Pollutants (kg/yr)	16,120	0	100

Table 4.6 shows that Basin B provides substantial reductions in stormwater flows and pollutant loads that result from the long detention times in the basin prior to slow discharge to Basin D via a syphon.

The quality of stormwater discharging from Basin F is presented in Table 4.7. Note stormwater discharges from catchments downstream of Lake A into Basin F via 750 metres of vegetated waterway and from overflows via a weir in Lake A.

Table 4.7: Stormwater quality discharging from Basin F

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	635	352	44.6
Total Suspended Solids (kg/yr)	71,300	21,900	69.3
Total Phosphorus (kg/yr)	209	103	50.7
Total Nitrogen (kg/yr)	1,680	891	47
Gross Pollutants (kg/yr)	9,940	0	100

Table 4.7 reveals that Basin F captures considerable loads of sediments and nutrients from the developed catchments within the Precinct and overflows from Lake A.

The characteristics of stormwater discharging from Basin D are shown in Table 4.8. Note that Basin D receives stormwater discharging from Lake A via a 1.8 metre diameter pipe, via a syphon from Basin B and from surrounding catchments.

Table 4.8: Stormwater quality discharging from Basin D

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	1,390	1,110	20.4
Total Suspended Solids (kg/yr)	55,200	27,500	50.2
Total Phosphorus (kg/yr)	266	168	37.1
Total Nitrogen (kg/yr)	3,130	2,410	23.1
Gross Pollutants (kg/yr)	624	0	100

Table 4.8 reveals that Basin D also captures substantial loads of sediments and nutrients as a result of the long detention time in the basin prior to discharge via a syphon. The quality of stormwater discharging from Basin 7 (discharge point A) at the Precinct boundary is provided in Table 4.9.

Table 4.9: Stormwater quality discharging from Basin 7 (discharge point A)

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	1,550	1,460	5.3
Total Suspended Solids (kg/yr)	58,600	43,200	26.4
Total Phosphorus (kg/yr)	273	224	17.9
Total Nitrogen (kg/yr)	3,470	3,180	8.2
Gross Pollutants (kg/yr)	650	0	100

The effectiveness of the treatment train that includes the entire D1 drain catchment to the exit point from the Precinct at Basin 7 is presented in Table 4.10.

Table 4.10: Effectiveness of treatment train for the D1 catchment discharging from the East Werribee Precinct

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	6,620	1,460	77.9
Total Suspended Solids (kg/yr)	1,330,000	43,200	96.7
Total Phosphorus (kg/yr)	2,710	224	91.7
Total Nitrogen (kg/yr)	19,000	3,180	83.3
Gross Pollutants (kg/yr)	238,000	0	100

Table 4.10 demonstrates that the proposed stormwater management strategy for the East Werribee Precinct provides substantial reductions in pollutant loads discharging from the entire D1 Drain catchment. The strategy mitigates stormwater pollutant loads in excess of best practice guidelines. The characteristics of stormwater discharging at point C from the Precinct are provided in Tables 4.11 and 4.12.

Table 4.11: Stormwater quality discharging from Basin 8b (discharge point C)

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	165	141	14.8
Total Suspended Solids (kg/yr)	32,900	3,070	90.7
Total Phosphorus (kg/yr)	67.6	14.8	78.1
Total Nitrogen (kg/yr)	476	265	44.3
Gross Pollutants (kg/yr)	6,030	0	100

Table 4.12: Stormwater quality discharging from Basin 8a (discharge point C)

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	455	233	48.6
Total Suspended Solids (kg/yr)	91,500	15,200	83.4
Total Phosphorus (kg/yr)	187	46.2	75.2
Total Nitrogen (kg/yr)	1,310	569	56.6
Gross Pollutants (kg/yr)	16,500	0	100

Tables 4.11 and 4.12 show that the pollutant loads discharging at point C from the East Werribee site will reduce pollutant loads by the proportions required by best practice guidelines. The characteristics of stormwater discharging at point D from the Precinct are presented in Table 4.13.

Table 4.13: Stormwater quality discharging from Basin 9 (discharge point D)

Criteria	Source	Residual	Reduction (%)
Flow (ML/yr)	290	196	32.3
Total Suspended Solids (kg/yr)	58,800	16,100	72.7
Total Phosphorus (kg/yr)	120	44.6	62.9
Total Nitrogen (kg/yr)	843	477	43.4
Gross Pollutants (kg/yr)	10,600	0	0

Table 4.13 reveals that the current design for the retarding basin (Upper Skeleton Creek) will provide reductions in pollutant loads that are slightly less than the requirements of best practice guidelines. Small changes to the existing concept design or implementation of water sensitive urban design (WSUD) approaches will ensure compliance with objectives for stormwater management.

5 Conclusions

This investigation has combined the previous investigations and incorporated the latest development profiles proposed by the GAA in additional analysis of flooding and stormwater quality. In addition, the GAA have proposed replacing the retarding basins 1 and 2 with a Lake (named Lake A in this report).

The analysis underpinning this report has also assumed a worst case scenario that does not include water sensitive urban design (WSUD) approaches within the Precinct. This analysis does include the previously proposed strategy to optimise use of the Glen Orden wetland and to install a gross pollutant trap in the upper catchment immediately downstream of the Werribee Plaza shopping precinct. This investigation, therefore, examines the performance of the proposed Lake, restored waterways and retarding basins within the East Werribee Precinct as defined by mitigation of flooding and management of pollutant loads. The following key findings have emerged from this investigation:

3. The proposed integrated system of a Lake, restored waterways and retarding basins will mitigate all flooding generated by all storm events with frequencies from 1 year to 100 years average recurrence intervals (ARI).
    a. Small changes in the inlet conditions, storages volumes and surrounding land fill will be required at Lake A that can be accommodated during the design phase of the project.
    b. The multiple staged outlet conditions, 25% allocation of storage volume for flood mitigation and the integration of storages throughout the Precinct provide substantial reductions in the risk of flooding.
    c. Large reductions in the areas inundated by flooding are generated by the proposed strategy.
    d. The highly urbanised upstream catchment generates a requirement to utilise the proposed storages for storm events of all ARIs.
    e. The integrated nature of the stormwater management strategy provided considerable redundancy that will further reduce risks of flooding.
    f. The proposed strategy provides considerable reductions in high frequency runoff events from the East Werribee Precinct that will reduce erosion and sedimentation, and ecological impacts on downstream waterways.
4. The integration of a lake, restored waterways and retarding basins with long detention times provided substantial reductions in pollutant loads discharging from the Precinct. The expected performance of the stormwater management system is in excess of best practice guidelines for stormwater management.
    a. It is noteworthy that the proposed stormwater management systems captures annual loads of sediments (1,645 tonnes), phosphorus (0.63 tonnes), nitrogen (6.92 tonnes) and gross pollutants (66.8 tonnes) originating from the upstream catchments.
    b. The proposed stormwater management strategy is dependent on capturing pollutants in or before storages. Given the cumulative nature of sediments and nutrients it will be important to remove the majority of sediments and nutrients prior to entering each storage.

c. The capture of substantial annual loads of sediment in the Lake or other storages may increase the risk of climate and ecological generated algae blooms. Installation of a treatment train to capture the majority of sediment discharging from the upper catchments prior to entering the Lake or storages and completion of additional ecological simulations of the proposed Lake A and other storages is recommended.
d. Implementation of WSUD and source control approaches will further enhance the performance of the proposed stormwater management systems and mitigate any risk of ecological failure of the proposed systems.
e. The proposed Lake A is subject to drawn down of water levels below the operating water level on 14% of days using the Werribee rainfall record. Maintaining the water levels at the operating level will require an average annual top up volume of 531 ML from an alternative water source. Alternatively, the proposed Lake A system could be allowed to operate as an ephemeral system with various water levels.
f. It is also recommended that the performance of Lake A be analysed using a rainfall record from a dryer period to further examine the variability of water levels.